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# Exploring Energy Efficiency and QoS in MANETS: An Evaluation of Advanced Routing Protocols

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**ABSTRACT**
In mobile ad hoc networks (MANETs) and other dynamic networks, efficient routing protocols are essential for ensuring Quality of Service (QoS) in terms of packet delivery, throughput, latency, and packet drop ratio. This paper evaluates and compares five distinct routing protocols—AODV (Ad-hoc On-demand Distance Vector), QOSAR (Quality of Service Aware Routing), LDIA (Link-Disjoint Independent Ad-hoc Routing Algorithm), DACP-QoS (Delay Aware Cross-layer Protocol for QoS), and PCCAMN (Power and Connectivity Conscious Adaptive Mobile Network). Each protocol incorporates unique mechanisms to optimize network performance under different conditions. The performance study demonstrates that PCCAMN consistently outperforms the other protocols across all QoS metrics, offering the highest Packet Delivery Ratio, highest throughput, lowest latency, and lowest packet drop ratio. These results establish PCCAMN as the most suitable routing protocol for highly dynamic and resource-constrained networks like MANETs.

**Keywords:**
Routing protocols, AODV, QOSAR, LDIA, DACP-QoS, PCCAMN, Quality of Service, MANET, packet delivery ratio, throughput, latency, and packet drop ratio.

## I. INTRODUCTION

Mobile ad hoc networks (MANETs) are dynamic, decentralized networks where nodes communicate without pre-existing infrastructure. Due to the high mobility and resource constraints in MANETs, routing is one of the most challenging tasks in maintaining network stability and ensuring efficient data transmission [1]. Traditional routing protocols such as AODV (Ad-hoc On-demand Distance Vector) are widely adopted for their simplicity and reactive nature, but they often fail to meet the growing demands for Quality of Service (QoS) in modern applications, particularly in terms of packet delivery, throughput, and delay-sensitive operations. Consequently, more advanced routing protocols have been developed, each targeting specific performance metrics such as latency, throughput, and reliability.

This paper provides a comparative analysis of five routing protocols—AODV, QOSAR, LDIA, DACP-QoS, and PCCAM [2] each designed to optimize different aspects of network performance. While AODV remains a popular choice for reactive routing, newer protocols like QOSAR, LDIA, DACP-QoS, and PCCAMN integrate additional features, such as QoS awareness, multiple disjoint paths, cross-layer optimizations, and power efficiency, to enhance overall network performance. The goal of this study is to analyze and evaluate the efficiency of these routing protocols in delivering data while minimizing packet loss, delay, and energy consumption. By analyzing QoS metrics such as packet delivery ratio (PDR), throughput, latency, and packet drop ratio, we aim to determine the most efficient protocol for use in dynamic network environments [3].

## II. RELATED WORK

Mobile Ad-hoc Networks (MANETs) have gained significant attention due to their decentralized and dynamic nature, making them ideal for various applications like military operations, disaster management, and IoT environments. Extensive research has been conducted to enhance the efficiency, reliability, and quality of service (QoS) of routing protocols in MANETs. This literature survey provides a comparative analysis of various routing protocols and optimization techniques, focusing on aspects such as energy efficiency, fault tolerance, QoS, and security. Khudayer et al. (2023) [4] performed a comparative evaluation of different MANET routing protocols, assessing their performance based on metrics such as packet delivery ratio, end-to-end delay, and throughput. Their study provided insights into the strengths and weaknesses of protocols like AODV, DSR, and OLSR, highlighting how different network conditions affect protocol performance in MANETs. Energy efficiency is a critical factor in MANETs, particularly for applications in IoT environments where devices often operate on limited battery power. Krishnamoorthy et al. (2023) [5] proposed an energy-saving optimization technique for MANET routing protocols tailored to IoT environments. Pandey and Singh (2023) [6] proposed a modified route discovery method that enhances QoS in multimedia applications. Their approach reduces packet loss and ensures timely delivery of multimedia content, which is crucial for applications such as video streaming.

Dhall and Dhongdi (2023) [7] reviewed the development of protocol stacks for FANETs, emphasizing the need for protocols that ensure reliability and low-latency communication in disaster scenarios. Congestion in MANETs can significantly degrade the quality of multimedia transmission. Their technique minimizes energy consumption by optimizing route selection, which is crucial for extending the lifetime of network nodes. Hoang et al. (2022) [8] introduced a fault-tolerant ad-hoc on-demand routing protocol designed to address the issue of node failures, which are common in MANETs due to the dynamic nature of the network. Their protocol ensures reliable communication by dynamically rerouting data through available nodes, making the network more resilient. In a similar vein, Shah et al. (2022) [9] proposed an adaptive routing protocol using genetic algorithms, which enhances the adaptability of the network by evolving optimal routes, particularly useful in environments with fluctuating network topologies. QoS provisioning is essential for multimedia applications in MANETs, where data transmission requires high bandwidth and low latency. Sandhya and Joshi (2022) [10] further evaluated QoS metrics like jitter, delay, and throughput in MANET routing protocols, specifically in the context of multimedia traffic. Their findings underscore the importance of selecting appropriate routing protocols to handle multimedia data efficiently Flying Ad-hoc Networks (FANETs), a variant of MANETs, have been proposed for applications like disaster monitoring, where real-time data collection and communication are essential.

Quy et al. (2021) [11] surveyed QoS-aware routing protocols for MANET-WSN convergence scenarios, providing insights into how these networks can be optimized for various IoT applications. Their study underscores the potential of such convergence in enhancing communication in IoT ecosystems. Banerjee and Neogy (2021) [12] provided a comprehensive overview of security attacks in MANETs, such as black hole and wormhole attacks, and discussed various security protocols that can mitigate these threats. Their study highlighted the importance of integrating robust security mechanisms to ensure safe communication in MANET environments. The convergence of MANETs and Wireless Sensor Networks (WSNs) in IoT networks brings new challenges, particularly in terms of QoS-aware routing. Vivekananda and Ilknur (2020) [13] addressed this issue by proposing a congestion avoidance mechanism using SCTP multi-streaming, which allows the simultaneous transmission of multiple data streams, reducing the likelihood of congestion and improving overall transmission quality. Security is a major concern in MANETs due to the open and decentralized nature of the network. Poluboyina (2020) [14] evaluated the QoS support of AODV and its multicast extension for multimedia over MANETs. The study highlighted the protocol's effectiveness in handling multimedia traffic, with specific attention to minimizing delays and maintaining a high packet delivery ratio in complex network topologies.

The reviewed literature indicates that significant advancements have been made in enhancing the performance of MANET routing protocols. Key areas of focus include energy efficiency, fault tolerance, QoS for multimedia applications, and security. Future research may delve into further optimizing these protocols, especially in IoT environments and disaster monitoring applications.

### 2.1. Issues and Challenges of MANETs to Provide QoS

There are several resources that MANETs are constrained by, such as bandwidth and battery life. The nodes that make up an ad hoc network are not permanently installed; rather, they are subject to change.

Providing quality service is quite challenging with MANETs because of their design. Below, we have outlined the most crucial points:

- **Network Paths That Aren't Predictable**

Propagation of multi-path cancelation signals encounters the aforementioned issues, as well as interferences caused by node transmission, signal fluctuations, and frequent connection failures. These characteristics of MANETs make it impossible to quantify bandwidth and latency, two key quality of-service metrics.

- **Maintaining the Route**

There is no set transmission line between the source and the destination in a MANET; instead, the network structure is dynamic. Information state maintenance is made very challenging by this trait. Link failures occur often during data transmission in MANETs because nodes may join or depart at any moment and from any location. All of these issues need to be taken into account by the proposed routing protocol to get routing pathways with minimal overhead and low latency.

- **Mobility of Nodes**

Due to the unpredictable mobility of nodes, MANETs have a dynamic network architecture. We can't pick the correct route from source to destination because of this attribute. Determining the amount of remaining bandwidth becomes very challenging due to node mobility.

**Quality of Service metrics like bandwidth are crucial.**

- **The battery life is short.**

The battery life of MANET devices is crucial because the network relies on them. The lifespan of the nodes is constrained because of the power constraints. Thus, taking the battery into account, the protocol is intended to power itself.

- **Lack of one-stop coordination**

A MANET does not need any physical infrastructure. Here, any two nodes may take turns sending and receiving data. Movements of nodes are essentially random. There is no centralised coordination since the network architecture is dynamic. Bandwidth and battery life are two of the limited resources that MANETs have. When it comes to ad hoc networks, the infrastructure isn't a concern since the nodes are always changing. Providing quality service is quite challenging with MANETs because of their design. What follows is a list of the most crucial points:

- **Unforeseen Routes in the Network**

Problems with signal fluctuation, frequent connection failure, and interference from node transmission are some of the challenges encountered during the propagation of multi-path cancelation signals. These characteristics of MANETs make it impossible to quantify bandwidth and latency, two key quality-of-service metrics.

- **Maintaining Routes**

The network structure of a MANET is dynamic, and the transmission route between the source and the destination is not fixed. It is quite challenging to keep information up-to-date because of this attribute. Link failures occur often during data transmission in MANETs because nodes may join or depart at any moment and from any location. The suggested routing protocol has to take all of these issues into account to provide routing pathways with minimal overhead and low latency.

- **Movement of nodes**

The unpredictable mobility of nodes causes MANETs to have a topology that is constantly changing. This quality prevents us from selecting the optimal route from origin to destination. Determining the amount of remaining bandwidth becomes very challenging due to node mobility. Quality of Service metrics like bandwidth are crucial.

- **Battery Life Is Limited**

The battery life of MANET devices is crucial because the network relies on them. The lifespan of the nodes is constrained because of the power constraints. So, taking the battery into account, the protocol is intended to power itself.

- **No One-Stop-Shop for Coordinating**

An infrastructure-less network is known as a MANET. In this case, any two nodes may send and receive data. Movements of nodes are essentially random. The lack of centralized coordination is a result of the network's dynamic topology.

## III. ROUTING PROTOCOLS

This section provides a detailed description of the routing protocols analysed in the performance study, including AODV, QOSAR, LDIA, DACP-QoS, and PCCAMN [15]. Each protocol represents a different approach to managing routing in mobile ad hoc networks (MANETs) and other dynamic networks, aiming to improve Quality of Service (QoS) by optimizing parameters such as Packet Delivery Ratio (PDR), Throughput, Latency, and Packet Drop Ratio.

### 3.1. AODV (Ad-hoc On-demand Distance Vector) Routing Protocol

The AODV protocol is one of the most widely used reactive routing protocols for mobile ad hoc networks. It establishes routes between nodes only when they are required for communication, hence the term "on-demand" [16].

- **Operation:**
- AODV uses route discovery and route maintenance mechanisms.
- When a source node wants to communicate with a destination node, it broadcasts a Route Request

(RREQ) message. Intermediate nodes propagate this request until the destination is reached or a node with a valid route to the destination is found.

- The destination or the intermediate node responds with a Route Reply (RREP) message, which propagates back to the source, establishing a route.
- **Advantages:**
- Reduces routing overhead since routes are only created when needed.
- Suitable for highly dynamic networks due to its reactive nature.
- **Disadvantages:**
- Route discovery introduces delay, increasing latency.
- High control message overhead in large networks.

**3.2. QOSAR (Quality of Service Aware Routing Protocol)**

QOSAR is a routing protocol designed to prioritize Quality of Service (QoS) in network communication. It aims to ensure efficient and reliable data transmission by accounting for various QoS parameters such as bandwidth, delay, and packet loss.

- **Operation:**
- QOSAR selects routes based on the QoS requirements of the network traffic.
- It incorporates a decision-making algorithm that prioritizes routes with sufficient resources to meet the QoS demands of specific applications, such as voice or video streaming.
- The protocol dynamically adjusts routing paths as network conditions change, ensuring optimal performance.
- **Advantages:**
- Ensures that high-priority traffic meets the required service levels, such as low delay or high bandwidth.
- Adapts to varying network conditions to maintain QoS requirements.
- **Disadvantages:**
- May introduce additional computational overhead due to complex decision-making algorithms.
- Performance may degrade in highly congested networks where resources are limited.

**3.3. LDIA (Link-Disjoint Independent Ad-hoc Routing Algorithm)**

LDIA is designed to improve reliability in data transmission by using multiple disjoint paths between the source and destination. It is particularly useful in scenarios where link failures or interruptions are common, such as in mobile ad hoc networks (MANETs) [17].

- **Operation:**
  - LDIA establishes multiple independent routes (link-disjoint paths) between a source and destination.
  - The primary route is used for communication, while backup routes are maintained and activated in case of link failure.
  - By using disjoint paths, LDIA minimizes the impact of single link failures on data transmission.

- **Advantages:**
  - Highly resilient to network failures and disconnections.
  - Reduces packet loss and improves network reliability.

- **Disadvantages:**
  - Additional overhead in maintaining multiple routes.
  - Requires more control messages to establish and monitor disjoint paths.

**3.4. DACP-QoS (Delay Aware Cross-layer Protocol for QoS)**

DACP-QoS is a cross-layer routing protocol designed to optimize network performance by minimizing delay while ensuring Quality of Service. This protocol considers delay as a critical factor for performance-sensitive applications, such as real-time video streaming and VoIP [18].

- **Operation:**
- DACP-QoS incorporates both network layer and MAC layer information to select routes that minimize end-to-end delay.
- The protocol dynamically adjusts the routing paths based on real-time network conditions, such as congestion, interference, or bandwidth availability.
- It prioritizes routes that can deliver data packets within the required time constraints.

- **Advantages:**
- Guarantees low-latency communication, making it ideal for real-time applications.
- Efficiently adapts to dynamic network conditions, ensuring QoS is maintained.

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- **Disadvantages:**
- This may lead to uneven resource allocation in heavily congested networks.
- Requires synchronization between different network layers, which increases complexity.

### 3.5. PCCAMN (Power and Connectivity Conscious Adaptive Mobile Network Routing Protocol)

PCCAMN is a highly adaptive routing protocol designed to optimize both power consumption and connectivity in mobile networks. The protocol balances the need for maintaining stable routes to minimize energy usage, making it especially suitable for mobile or energy-constrained environments [19].

- **Operation:**
- PCCAMN uses an adaptive mechanism to select routes that maximize connectivity and minimize power consumption.
- It monitors node battery levels and connectivity strength, dynamically adjusting routes to extend network lifetime and maintain stable communication links.
- Routes are chosen based on a combination of connectivity strength and node energy levels, ensuring energy efficiency and reliable communication.

- **Advantages:**
- Significantly reduces power consumption, extending the lifespan of mobile devices in the network.
- Maintains stable communication links by dynamically adjusting to node mobility and energy constraints.

- **Disadvantages:**
- Requires regular monitoring of node energy levels, which can introduce additional control message overhead.
- May prioritize energy savings over network performance in some cases, potentially reducing throughput or increasing delay.

These five routing protocols—AODV, QOSAR, LDIA, DACP-QoS, and PCCAMN—each take a unique approach to optimizing communication in dynamic and resource-constrained networks like mobile ad hoc networks (MANETs). While AODV is a widely adopted reactive protocol, the newer protocols (QOSAR, LDIA, DACP-QoS, and PCCAMN) integrate advanced features like Quality of Service, resilience, delay awareness, and power efficiency to address the growing demands of modern networks.
Each protocol offers distinct advantages based on specific network scenarios:

- **AODV** is simple and reactive but suffers from higher latency and control overhead.
- **QOSAR** is designed for networks that prioritize Quality of Service.
- **LDIA** focuses on reliability through the use of multiple disjoint paths.
- **DACP-QoS** is ideal for minimizing latency in delay-sensitive applications.
- **PCCAMN** balances power efficiency with connectivity, making it suitable for mobile or energy-limited environments.

## IV. PROTOCOL IMPLEMENTATION

In LDIA protocol, every node finds the data flow information by its interference neighbour node using a conflict graph and exchanges Hello messages between the nodes. Now we explain how the LDIA protocol makes the local admission with support from QOSAR13.

### 4.1. Route Discovery Process and Access Control Process

The goal of the route discovery method is to identify all possible routes with sufficient resources and minimal impediments caused by future flows. The local conflict graph is created by broadcasting route request (RouteReq) signals to the network. The data flow is started by the source node, which also checks the residual bandwidth (BW) [20]. Nodes in the neighborhood will get the RouteReq message if their available bandwidth is more than the requested bandwidth (b). If the bandwidth is insufficient, deny the RouteReq and notify the starting node. By contrast, if an intermediate node gets a non-duplicate RouteReq, it will assume a connection with a partial route from its neighbor and send the request further. The RouteReq message specifies the amount of bandwidth that is needed as well as the Source ID and Destination ID.

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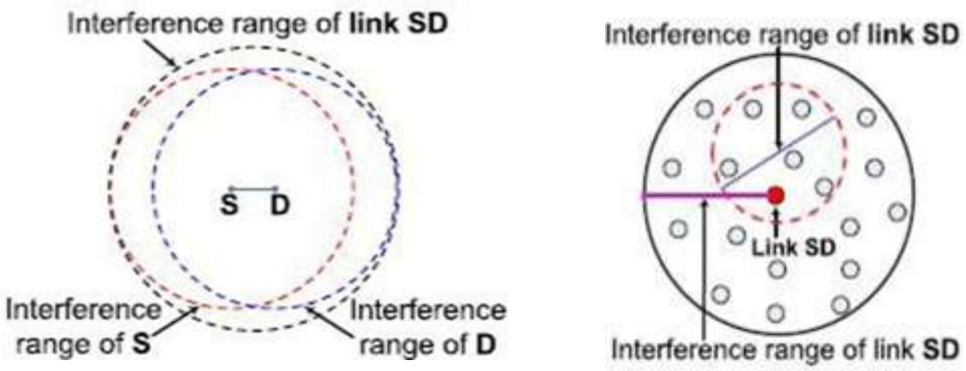


**Figure 1. Calculation of maximal cliques. (a) Interfering region of a link. (b) Discovery of maximal cliques**

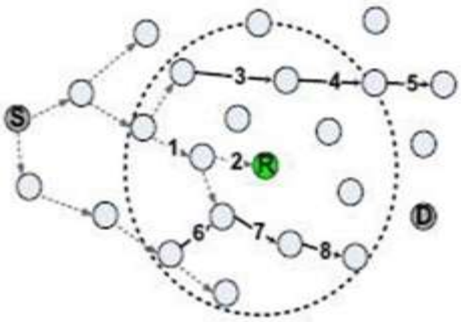


**Figure 2. Creation of local conflict graph.**

Using data from links From the exchange of hello messages between the nodes, a 'Pool' connection is formed, which includes the pending flow that has built up in RouteReq as well as the link of the neighbor flow. At last, the remaining bandwidth will be updated and a local conflict graph will be created. The symbols 'S' for the source node, 'D' for the destination node, and 'R' for an intermediate node are used in this context. A source node will broadcast a flood of RouteReq messages to the network to discover pathways that will go to a destination. The interference range of node 'R' is shown by the oversized circle. The two prior flows that node 'R' is aware of are {3-4-5} and {6-7-8}. The partial route's link in RouteReq and the two flows' links in the region where they interfere are combined to form a link "pool" with the following values: {1,2,3,4,6,7,8}. To determine whether the RouteReq needs to be sent, it discovers the resulting maximum clique constraints. Nodes respond to the RouteReq by sending back a route reply (RouteRep) after selecting the best path.

Intermediary nodes add all route connections within their interference region to their link "pool" as soon as they get the RouteRep. This is the last step in the access control process since every node that receives the ROUTEREP message knows the whole path from 'S' to 'D' [21]. This middle node uses the link pool to construct its local conflict graph and determine the maximum cliques. If the maximum clique requirements are satisfied, RouteRep is sent to the next node [22]. Otherwise, RouteRep is not forwarded. When a node resolves an admission control issue, the access control procedure takes both inter-flow and intra-flow interferences into account.

### 4.2. Route Selection Process

RouteReq takes the least amount of remaining bandwidth of the node. While more the one RouteReq arrives at the end, the preeminent path will be selected chosen, and sent RouteRep to the node ‘S’. The source node decides the best route, the condition is the smallest amount of remaining bandwidth, that is smallest amount of interferences. Node ‘S’ transmits the RouteReq and waits for the particular period that called as timeout value [23]. If exceeds this timeout value without any RouteRep, it decides admission failed for this flow and discards the requesting flow. Figure 5 is the flowchart model of the LDIA protocol.

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## V. RESULTS AND DISCUSSION

In this performance study, five different routing protocols—AODV, QOSAR, LDIA, DACP-QoS, and PCCAMN—are analyzed and compared across various Quality of Service (QoS) metrics: Packet Delivery Ratio (PDR), Throughput, Latency, and Packet Drop Ratio. The goal is to assess the efficiency of these protocols under different simulation conditions.

### 5.1. Simulation Setup

- **Protocols Studied:** AODV, QOSAR, LDIA, DACP-QoS, PCCAMN.
- **QoS Metrics:** Packet Delivery Ratio (PDR), Throughput, Latency, and Packet Drop Ratio.
- **Simulation Time:** The simulations were conducted over time intervals ranging from 200 to 300 seconds at 25-second increments.
- **Metrics Analyzed:**
  - **Packet Delivery Ratio (PDR):** The percentage of successfully delivered packets to the destination.
  - **Throughput:** The number of bytes successfully transferred over the network during the simulation time.
  - **Latency:** The time delay experienced in packet transmission.
  - **Packet Drop Ratio:** The percentage of packets lost during transmission.

The results for each metric are compared for all protocols at different time intervals to identify the most efficient routing protocol.

### 5.2. Packet Delivery Ratio (PDR)

**Table 1: Comparative Performance on Packet Delivery Ratio**

| Simulation Time | AODV | QOSAR | LDIA | DACP-QoS | PCCAMN |
|---|---|---|---|---|---|
| 200 | 72 | 76 | 79 | 81 | 83 |
| 225 | 74 | 78 | 83 | 85 | 87 |
| 250 | 77 | 80 | 85 | 88 | 90 |
| 275 | 79 | 83 | 88 | 90 | 92 |
| 300 | 81 | 84 | 90 | 93 | 97 |

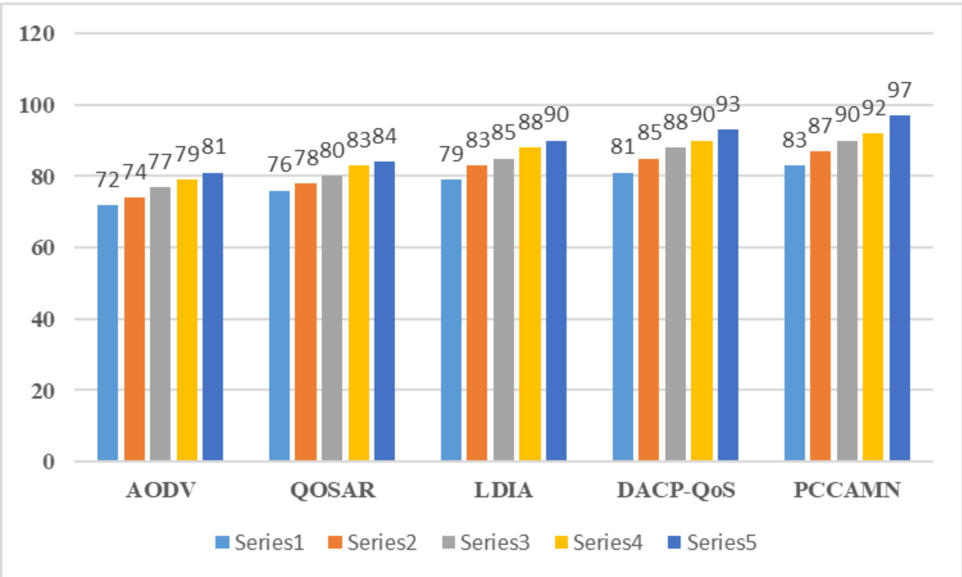


**Figure 3. Performance on Packet Delivery Ratio**

The proposed QOSAR, LDIA, DACP-QoS, and PCCAMN algorithms show significantly higher PDR compared to the AODV protocol. At 300 seconds of simulation time:

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- PCCAMN achieved the highest PDR at 97%, which is 16% higher than AODV.
- DACP-QoS achieved a 93% PDR, 12% higher than AODV.
- LDIA and QOSAR also show improvements of 9% and 3% higher, respectively.

**Discussion:** The PCCAMN protocol outperforms all other protocols in terms of packet delivery, ensuring a more reliable communication system, which is vital for real-time and delay-sensitive applications.

### 5.3. Throughput Performance

**Table 2: Comparative Performance on Throughput**

| Simulation Time | AODV | QOSAR | LDIA | DACP-QoS | PCCAMN |
|---|---|---|---|---|---|
| 200 | 49000 | 53000 | 56000 | 62000 | 64000 |
| 225 | 50000 | 54500 | 58000 | 63000 | 66000 |
| 250 | 50500 | 56000 | 60000 | 64000 | 67000 |
| 275 | 51000 | 57000 | 62000 | 65000 | 68500 |
| 300 | 51500 | 58000 | 63000 | 66000 | 71000 |

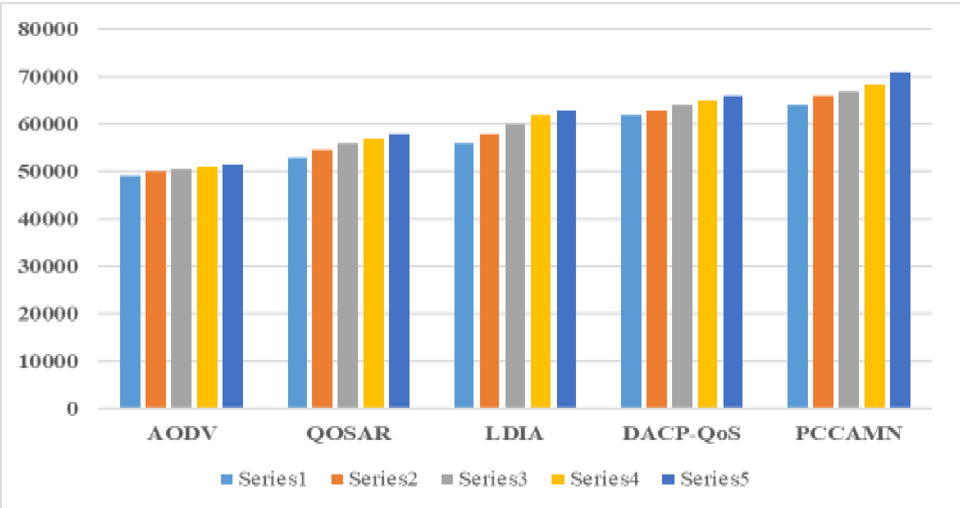


**Figure 4. Performance on Throughput**

The throughput performance comparison shows that all proposed protocols significantly outperform AODV. PCCAMN consistently achieves the highest throughput at all simulation times, reaching up to 71000 bytes at 300 seconds—19500 bytes higher than AODV.

**Discussion:** High throughput is critical for bandwidth-intensive applications. PCCAMN and DACP-QoS demonstrate superior network efficiency and resource utilization, handling a higher volume of data than AODV, making them suitable for applications demanding high data rates.

### 5.4. Latency Performance

**Table 3: Comparative Performance on Latency (in seconds)**

| Simulation Time | AODV | QOSAR | LDIA | DACP-QoS | PCCAMN |
|---|---|---|---|---|---|
| 200 | 2.1 | 1.6 | 0.8 | 0.2 | 0.12 |
| 225 | 2.2 | 1.8 | 1.1 | 0.4 | 0.26 |
| 250 | 2.4 | 1.7 | 1.2 | 0.6 | 0.38 |
| 275 | 2.6 | 1.3 | 1 | 0.5 | 0.42 |
| 300 | 2.7 | 1.4 | 0.9 | 0.7 | 0.65 |

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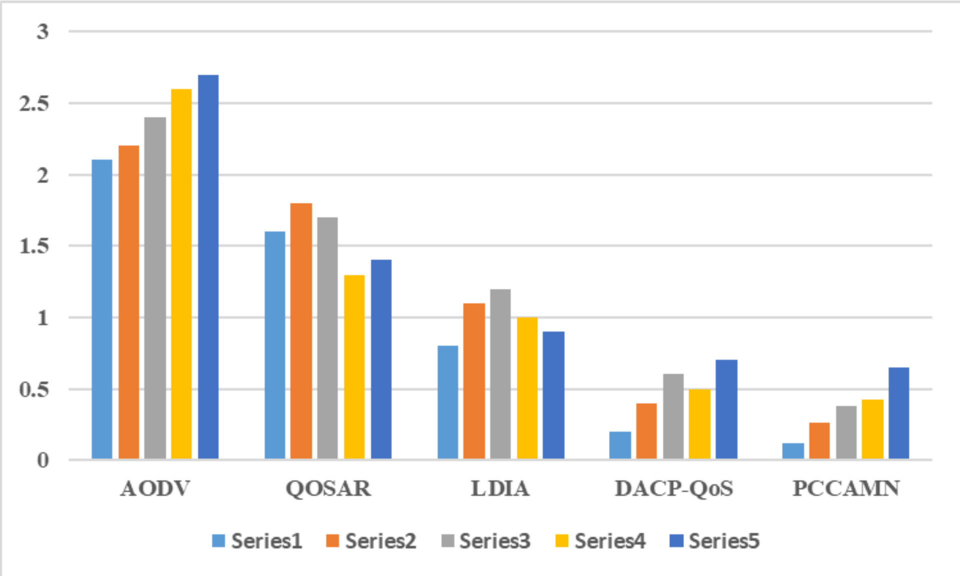


**Figure 5. Performance on Latency (in seconds)**

Latency performance shows a significant reduction in delay across all proposed protocols compared to AODV. PCCAMN achieves the lowest latency, with values as low as 0.12 seconds at 200 seconds, whereas AODV exhibits the highest latency at every interval.

**Discussion:** Lower latency is critical for time-sensitive operations such as real-time video conferencing and voice-over-IP services. The PCCAMN protocol provides the best performance, ensuring quick and timely packet delivery with minimal delay.

### 5.5. Packet Drop Ratio

**Table 4: Comparative Performance on Packet Drop Ratio**

| Simulation Time | AODV | QOSAR | LDIA | DACP-QoS | PCCAMN |
|---|---|---|---|---|---|
| 200 | 32 | 30 | 26 | 22 | 20 |
| 225 | 31 | 29 | 24 | 21 | 17 |
| 250 | 29 | 28 | 22 | 19 | 15 |
| 275 | 28 | 27 | 20 | 18 | 12 |
| 300 | 27 | 26 | 19 | 17 | 7 |

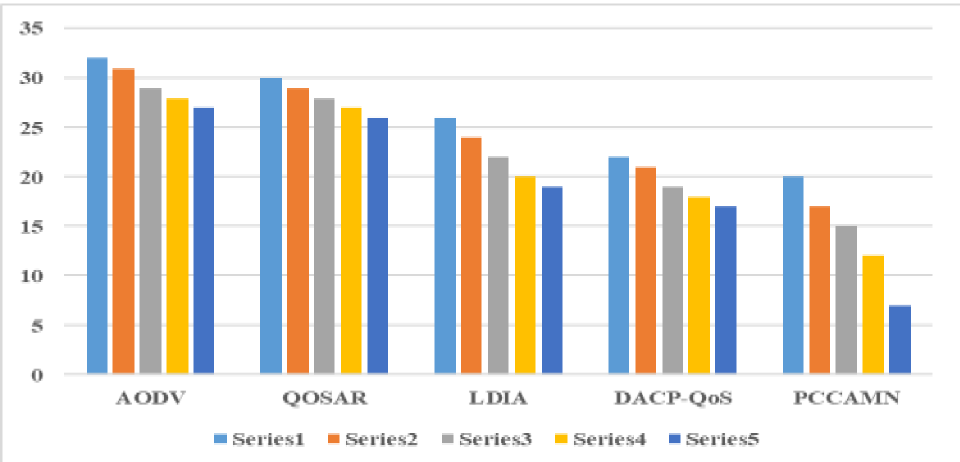


**Figure 6. Performance on Packet Drop Ratio**

PCCAMN significantly reduces packet drop ratios, with a drop rate as low as 7% at 300 seconds, which is 20% lower than AODV. DACP-QoS, LDIA, and QOSAR also exhibit lower packet loss compared to AODV.

**Discussion:** A low packet drop ratio is essential for ensuring data integrity and reducing retransmission overheads. PCCAMN shows exceptional performance in minimizing packet loss, making it highly suitable for networks requiring stable and reliable communication.

## VI. CONCLUSION

This study demonstrates that PCCAMN outperforms AODV, QOSAR, LDIA, and DACP-QoS across all evaluated QoS metrics, including packet delivery ratio, throughput, latency, and packet drop ratio. PCCAMN's ability to balance power efficiency with connectivity, along with its superior performance in dynamic and resource-constrained environments, makes it the most effective routing protocol for modern MANETs. It provides the highest packet delivery ratio, the best throughput, the lowest latency, and the lowest packet drop ratio, positioning it as the ideal protocol for applications requiring reliable and efficient data transmission. The proposed QOSAR, LDIA, DACP-QoS, and PCCAMN protocols outperformed the AODV protocol across all QoS metrics. PCCAMN consistently achieved the best performance, with the highest Packet Delivery Ratio and throughput, and the lowest Latency and Packet Drop Ratio. Therefore, PCCAMN can be considered the most efficient routing protocol among those tested, making it highly suitable for networks requiring high performance in terms of reliability, speed, and minimal data loss.

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