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Advanced QoS Management in MANETs: Insights from the DACP-QoS Protocol

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Abstract

Mobile Adhoc Networks (MANETs) encounter significant challenges, including fluctuating connectivity and broadcast contention, which degrade network performance and compromise Quality of Service (QoS). While existing protocols like QoS Aware Routing (QOSAR) and Link Disjoint Interference Aware (LDIA) address some QoS issues, they lack a robust admission control mechanism, essential for maintaining high network performance. This paper introduces the Distributed Admission Control Protocol with Quality of Service (DACP-QoS), a novel protocol designed to enhance QoS in MANETs by using a flow-based, per-hop admission control approach. DACP-QoS not only supports multimedia applications with minimal overhead but also significantly outperforms existing QOSAR and LDIA protocols in terms of key QoS metrics such as Packet Delivery Ratio (PDR), throughput, and latency. Simulation results demonstrate that DACP-QoS can achieve a PDR improvement of up to 96%, an increase in throughput by 66k bytes, and a reduction in packet drop ratio by 17%, making it a superior choice for MANET environments.

Keywords: *Admission Control, Adhoc On-demand Distance Vector (AODV), DACP-QoS, MANET, Multimedia applications*

1. INTRODUCTION

Mobile Adhoc Networks (MANETs) represent a dynamic and decentralized network structure where each node functions as both a router and a host, facilitating the seamless transmission of data without relying on a fixed infrastructure. While MANETs offer significant advantages in scenarios where traditional network infrastructure is impractical, they also face unique challenges, particularly related to fluctuating connectivity and broadcast contention [1]. These challenges can lead to significant degradation in network performance, impacting the Quality of Service (QoS).

Quality of Service (QoS) is a critical metric in MANETs, especially given the increasing demand for reliable and high-performance networks capable of supporting multimedia and real-time applications. Existing protocols, such as the QoS Aware Routing (QOSAR) protocol and the Link Disjoint Interference Aware (LDIA) protocol, have been developed to address some of these issues by discovering backup routes and interference-free paths, respectively [2]. However, these protocols lack a robust admission control mechanism, which is essential for ensuring QoS across the network.

To address this gap, this paper proposes a novel Distributed Admission Control Protocol with Quality of Service (DACP-QoS). The proposed DACP-QoS protocol is designed to improve the QoS in MANET environments by employing a flow-based approach on a per-hop basis

[3]. This protocol not only enhances network performance but also supports multimedia applications with minimal overhead, offering a significant improvement over existing protocols.

2. LITERATUR REVIEW

The challenges associated with MANETs, particularly in terms of fluctuating connectivity and broadcast contention, have been extensively studied in the literature. Various QoS routing protocols have been proposed to mitigate these challenges [5]. The QoS Aware Routing (QOSAR) protocol is one such example, where backup routes for active sessions are discovered to maintain service continuity. Another significant contribution is the Link Disjoint Interference Aware (LDIA) QoS routing protocol, which utilizes the MARIA framework to identify multiple interference-free paths, thereby enhancing the reliability of the network [6].

Despite these advancements, a major limitation of both QOSAR and LDIA protocols is their lack of an effective admission control mechanism. Admission control is crucial in ensuring that new flows do not degrade the QoS of existing sessions, particularly in networks with high traffic loads. Various admission control mechanisms have been proposed in the past, but many are centralized and hence not well-suited for the decentralized nature of MANETs.

Recent studies have highlighted the need for a distributed approach to admission control that can operate effectively in MANET environments. Such an approach would be more adaptable to the dynamic nature of MANETs, allowing for better resource allocation and improved QoS [7]. However, existing distributed admission control mechanisms often suffer from high overhead, limiting their practicality in real-world scenarios [9].

Quy et al. (2022) [10] conducted a comprehensive survey of routing algorithms tailored for MANET-IoT networks, reflecting the growing convergence between MANETs and IoT technologies. Their work categorizes various routing protocols based on their design principles, such as energy efficiency, scalability, and QoS support. This survey provides a critical evaluation of existing protocols, highlighting the need for new algorithms that can better address the challenges of IoT integration in MANET environments.

Singh et al. (2022) [11]explored the use of cryptographic techniques to enhance QoS in MANETs, particularly in the context of sustainable smart cities. Their research focused on preventing network incursions and ensuring secure data transmission, which is essential for maintaining high QoS levels in smart city applications. The proposed cryptographic approach was demonstrated to effectively mitigate security threats, thereby enhancing the reliability and performance of MANETs in urban environments.

Vivekananda et al. (2021) [12] proposed the Dynamic Link Management (DLM) technique for improving QoS in MANETs. The DLM technique dynamically adjusts link parameters based on real-time network conditions, enabling better resource allocation and reducing the likelihood of link failures. This technique was shown to significantly improve QoS metrics such as throughput and PDR, especially in high-density networks.

Hamdi et al. (2020) [13] analyzed the performance of QoS in MANETs based on the IEEE 802.11b standard. Their study focused on the impact of various network parameters, including node mobility and traffic load, on QoS metrics such as delay, jitter, and throughput. The results of their analysis underscored the importance of adapting routing protocols and QoS mechanisms to the specific characteristics of the underlying communication standard .
Hassan et al. (2018) [14] proposed a hybrid algorithm aimed at improving QoS in MANETs. Their approach combines features from both reactive and proactive routing protocols to optimize the trade-off between route discovery latency and control overhead. The hybrid algorithm was shown to enhance QoS by reducing end-to-end delay and improving packet delivery in scenarios with high mobility and dynamic topologies.
Ahmed et al. (2018) [15] introduced a Distributed Admission Control-QoS (DACP-QoS) algorithm to enhance network performance in MANET environments. Their algorithm emphasizes admission control to manage network resources effectively, thus improving the overall QoS by reducing packet loss and managing network congestion. This approach was validated through simulations, demonstrating its ability to outperform existing protocols in terms of packet delivery ratio (PDR) and throughput.

3. METRICS OF QoS

Different applications have varying Quality of Service (QoS) requirements. For instance, multimedia applications prioritize bandwidth, jitter, and delay as key QoS metrics. Military applications, on the other hand, have stringent security needs, while emergency search and rescue operations focus on network availability. In scenarios like group communication within a conference hall, minimizing energy consumption is crucial, making battery life a critical QoS parameter. Other important QoS metrics include the Probability of Packet Loss (PDR), overhead, delay, jitter, packet dropping ratio, and network throughput or capacity.
In the proposed DACP-QoS protocol, each node that receives a Route Request (RREQ) packet first checks whether the destination node of the Route Reply (RREP) packet falls within an interference zone. The hop count in the RREQ packet is used to estimate the total hop count for the end-to-end route. Admission control is integrated into the route discovery process by DACP-QoS. To estimate the end-to-end hop count, the protocol requires information about the first and second neighbor nodes, which can be obtained through the HELLO messages used in the QOSAR protocol. This approach reduces the number of RREQ packets during the route discovery process, thereby minimizing overhead and enhancing the network's QoS.

Table 1: Transmitted Packet Format

Source address	Packet size	Required Bandwidth	Data sequence no.	Next hop address	Sink address

Each node in the network collects information about its first and second neighbor nodes, storing this data in a connectivity table, as illustrated in Figures 1 and 2. The purpose of this is to check whether any conflicting links within the network could disrupt the intra-flow communication. When a node makes an admission control decision, it needs to assess the number of conflicting links within its interference area. First neighbor nodes are identified directly through the propagation of HELLO messages while identifying second neighbor nodes requires higher broadcast power. In this protocol, HELLO messages are also used to convey information about second neighbor nodes.

To maintain connectivity, all nodes periodically broadcast HELLO messages containing details about their first neighbor nodes, which in turn helps identify the next set of neighbor nodes. This information is regularly updated in the subsequent neighbor table. The interference and transmission ranges of nodes differ, as depicted in Figures 1 and 2. The outer circle represents node A's interference range, while the inner dotted circles show the transmission ranges of all nodes. Notably, even though node J does not fall within node A's second neighborhood, it does not cause any performance issues in the network. This is because node J does not participate in the path when node A makes an admission control decision. By checking the timestamps of the HELLO messages, nodes can update this information accordingly.

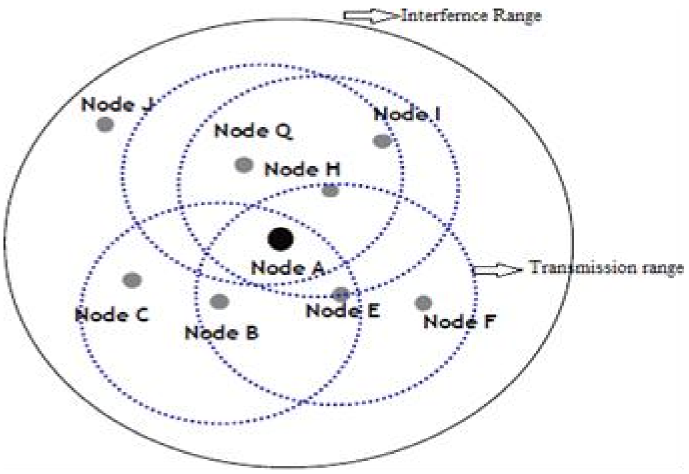

Figure 1. **Connectivity nodes**

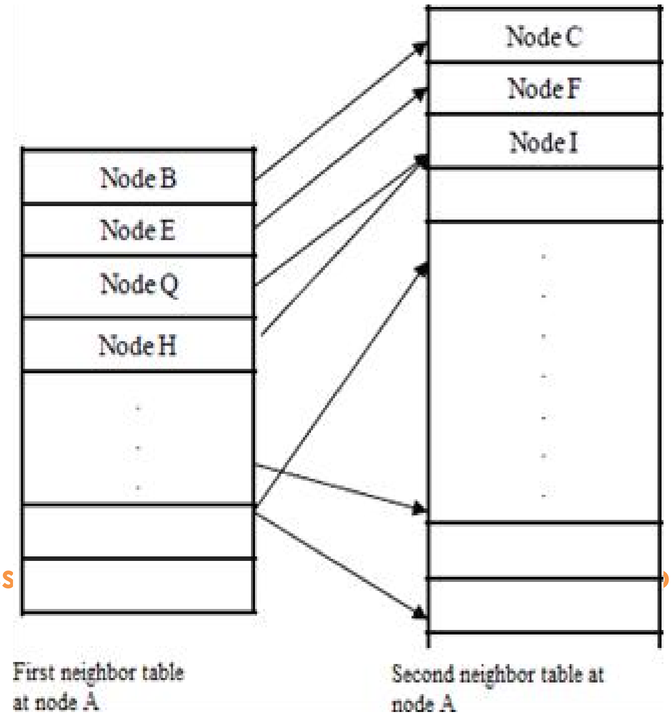

Figure 2. Connectivity tables of the first and second neighbour tables of node A

Admission Control Algorithm for DACP-QoS in MANETs

To initiate the route discovery in a MANET environment, the source node broadcasts a Route Request (RREQ) message along with the required bandwidth (Breq). Using the destination IP (DestIP) from the neighborhood table, the end-to-end hop count is determined [15].

Admission Control Algorithm for the Source Node:

- Step 1: Begin the route discovery process with Breq and DestIP, and initialize the hop count to 0.
- Step 2: Check if DestIP is present in the First Neighbor Table (FnT).
- Step 3: If DestIP is found in FnT with a hop count of 0, verify whether the average available bandwidth (Bava) is greater than Breq. If Bava > Breq, broadcast the RREQ with an incremented hop count. Otherwise, discard the RREQ packet.
- Step 4: If DestIP is in the Second Neighbor Table (SnT), proceed to the next step.
- Step 5: If DestIP is found in SnT and Bava > 2Breq, broadcast the RREQ with an incremented hop count. Otherwise, discard the RREQ packet.
- Step 6: If Bava is greater than 3Breq, broadcast the RREQ with an incremented hop count. Otherwise, discard the RREQ packet.

Admission Control Algorithm for Intermediate Nodes:

- Step 1: Begin the admission control process for data with Breq and DestIP, initializing the hop count to 0.
- Step 2: Verify if DestIP is in the FnT.
- Step 3: If DestIP is found in FnT with a hop count of 1, check if Bava > 2Breq. If true, broadcast the RREQ with an incremented hop count. Otherwise, discard the RREQ packet.

- Step 4: If DestIP is present in SnT with a hop count of 1, check if Bava > 3Breq. If true, broadcast the RREQ with an incremented hop count. Otherwise, discard the RREQ packet.
- Step 5: If DestIP is in FnT with a hop count greater than 1, ensure Bava > 3Breq. If true, broadcast the RREQ with an incremented hop count. Otherwise, discard the RREQ packet.
- Step 6: If Bava > 4Breq, broadcast the RREQ with an incremented hop count. Otherwise, discard the RREQ packet.

Admission Control Algorithm for the Destination Node:

- Step 1: Initiate the admission control process with Breq, DestIP, and a hop count set to 0.
- Step 2: If the hop count equals 1, verify at the destination node if Bava > Breq. If true, update the information in the table; otherwise, discard the RREQ packet.
- Step 3: If Bava at the destination node is greater than 2Breq, update the table accordingly; otherwise, discard the RREQ packet.

4. PERFORMANCE ANALYSIS

To assess the realistic performance of the proposed DACP-QoS protocol, simulations were conducted within a MANET environment. In these simulations, between 50 to 200 dynamic nodes were randomly distributed across an area measuring 1000m × 1000m. The packet sizes varied between 1500 and 2000 bytes, and the source-destination pairs were selected randomly. Each simulation was run for 200 seconds. The performance of the DACP-QoS protocol was evaluated using several metrics, including Packet Delivery Ratio (PDR), jitter, delay, overhead, and throughput. The parameters used in the simulation are listed in Table 2.

Figure 3 illustrates the variation in PDR for the proposed DACP-QoS protocol compared to the existing QOSAR [6] and LDIA protocols [7] as the number of nodes increases. The results show that the PDR of the DACP-QoS protocol is higher than that of the existing protocols, indicating an improvement in network performance.

Table 2: Simulation Parameters

Parameters	Values
Number of nodes	50-200
Area	1000x1000
Node movement	Random
Routing	DACP-QoS, MARIA, QOSAR
Node configuration	Adhoc routing
Propagation model	Two-ray ground model
Packet size	1500-2000
Traffic model	CBR

Simulation time	200s

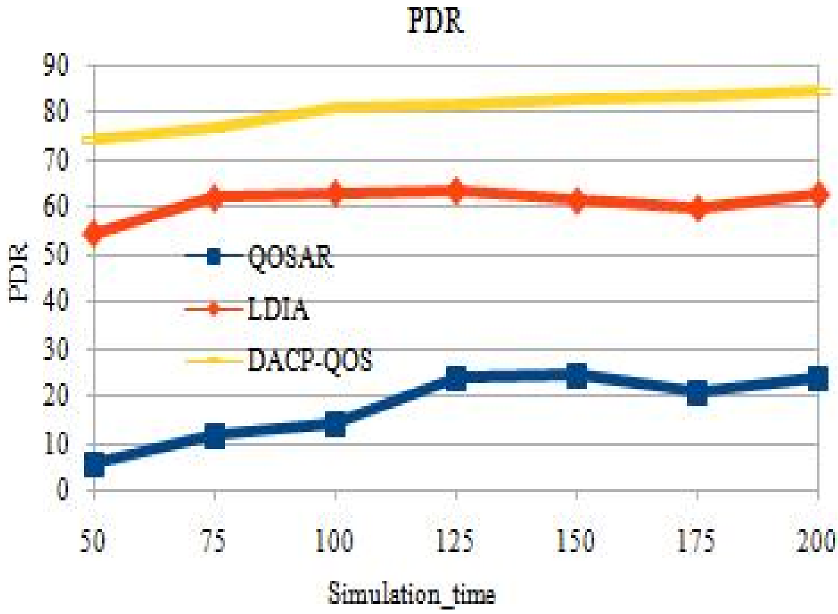

Figure 3. Comparisons on Packet Delivery Ratio (PDR)

Figure 3. illustrates the comparisons of the Packet Delivery Ratio and the performance of the Packet Delivery Ratio for various protocols at different simulation times. A comparative analysis of the outcomes generated by different methods has been conducted and shown. The DACP-QoS algorithm has yielded a greater Packet Delivery Ratio (PDR) compared to other approaches. The Packet Delivery Ratio has been enhanced by a maximum of 96%.

Table 3 displays the correlation between the packet size and the performance of QoS factors. In contrast to existing protocols, the proposed one minimizes latency, control overhead, and normalized overhead while increasing goodput, throughput, and Packet Delivery Ratio (PDR). The DACP-QoS protocol greatly improves the efficiency of the network as shown in Figure 4.

Table 3. Performance analysis by varying packet size

QoS Parameters	Packet Size	QOSAR	LDIA	DACP-QoS
PDR	1500	21.1667	79.7005	86.3561
	1600	23.3333	76.8719	79.3677
	1700	24.8333	76.5391	85.5241
	1800	24.1667	77.8702	79.5341
	1900	22.1667	74.376	82.6955
	2000	20.3333	78.7022	82.6955
Delay	1500	4.61623	2.41108	1.73852
	1600	5.03102	2.42976	2.03396

	1700	5.07025	2.46813	2.04754
	1800	4.90802	2.59647	2.22207
	1900	4.64768	2.60126	1.93163
	2000	4.76812	2.53966	2.0089
Control Overhead	1500	11098	10217	10071
	1600	11057	10259	10150
	1700	11125	10259	10075
	1800	10978	10271	10081
	1900	11164	10289	10056
	2000	11172	10274	10063
Normalized Overhead	1500	87.3858	21.3299	19.4046
	1600	78.9786	22.2056	21.2788
	1700	74.6644	22.3022	19.6012
	1800	75.7103	21.9466	21.09
	1900	83.9398	23.0179	20.2334
	2000	91.5738	21.7209	20.2475
Dropping Ratio	1500	78.8333	20.2995	13.6439
	1600	76.6667	23.1281	20.6323
	1700	75.1667	23.4609	14.4759
	1800	75.8333	22.1298	20.4659
	1900	77.8333	25.624	17.3045
	2000	79.6667	21.2978	17.3045
Jitter	1500	1.3779	0.37209	0.345617
	1600	1.24903	0.38585	0.377433
	1700	1.17305	0.38753	0.349593
	1800	1.20566	0.38135	0.375349
	1900	1.31521	0.39997	0.362212
	2000	1.43476	0.37793	0.361573
Throughput	1500	8593.88	31933.3	34600
	1600	10096.8	32853.3	33920
	1700	11409.2	34755.6	38835.6
	1800	11748.5	37440	38240
	1900	11368.3	37746.7	41968.9
	2000	10971.2	42044.4	44177.8
Goodput	1500	2559.83	4366.49	7175.34
	1600	2442.32	4826	7977.5
	1700	2935.74	5339.53	7272.85

	1800	3017.66	5488.96	8147.38
	1900	3049.73	5894.11	9007.28
	2000	3349.53	6091.54	10316.7

Figure 4. Comparison of efficiency of networks

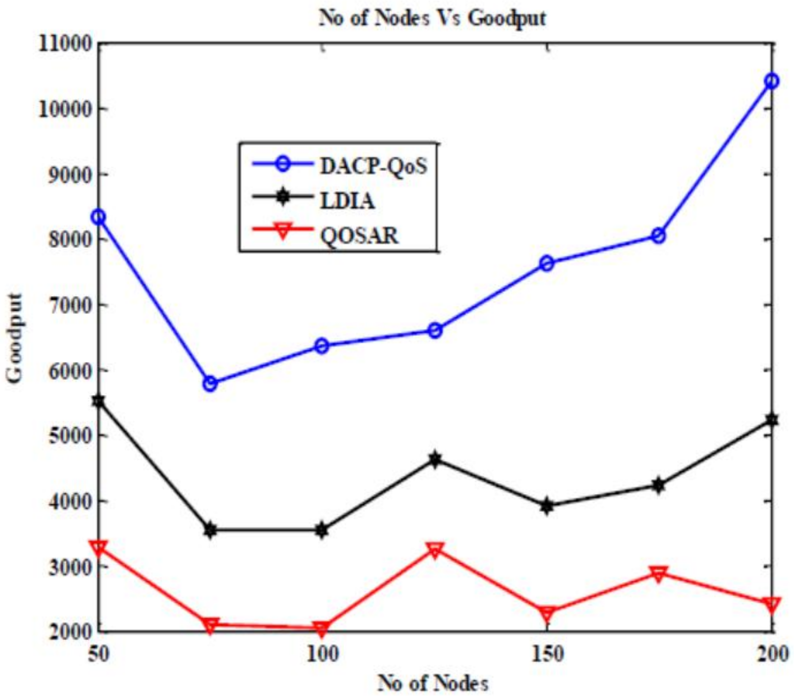

Figure 5. The Correlation between node density and goodput

The term "goodput" describes the speed with which important data may be transferred to a specific node in a network. There is a graph in Figure 5. that shows the goodput variation of the DACP-QoS protocol, the currently used QOSAR protocol, and the LDIA protocol. In terms of goodput, the proposed DACP-QoS protocol surpasses the existing QOSAR and LDIA protocols.

4. Conclusion

The proposed DACP-QoS protocol effectively addresses the challenges of fluctuating connectivity and broadcast contention in Mobile Adhoc Networks (MANETs) by introducing a robust distributed admission control mechanism. Through a flow-based, per-hop approach integrated into the route discovery process, DACP-QoS significantly enhances Quality of Service (QoS) metrics, including Packet Delivery Ratio (PDR), throughput, and latency, compared to existing protocols like QOSAR and LDIA. The protocol's ability to support multimedia applications with minimal overhead further underscores its practical applicability in real-world MANET environments. Simulation results demonstrate that DACP-QoS consistently outperforms existing solutions, achieving higher network efficiency, lower packet drop ratios, and improved overall performance. This makes DACP-QoS a promising candidate for deployment in dynamic and decentralized network scenarios, where maintaining high QoS is essential. Future work may explore further optimizations of the protocol to adapt to increasingly complex network conditions and the integration of additional QoS parameters tailored to specific application needs.

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