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NOVEL BUFFER MANAGEMENT FOR CONGESTION CONTROL IN MOBILE AD-HOC NETWORKS

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ABSTRACT

In order to keep the buffer size in Mobile Ad-Hoc Networks (MANETs) within a 50% to 90% range of its overall capacity, this study presents a new buffer management technique (NBM). Efficiently managing congestion while minimizing packet loss is the aim of the suggested approach. The NBM is tested in two scenarios, one with and one without congestion, by simulating it in the Network Simulator (NS2) under different packet flow and arrival rates. Three popular methods—Drop Tail, Random Early Detection (RED), and TCP congestion control—are pitted against the NBM. In cases when there is no congestion, NBM proves to be the best packet loss manager by attaining the lowest packet loss ratio (PLR) at all flow rates that were evaluated. Even in very crowded situations, NBM maintains the lowest packet loss rate (PLR), edging out TCP congestion, RED, and Drop Tail—which exhibits the worst packet loss rate, particularly at higher flow rates. In light of these results, the NBM seems to be a viable option for enhancing MANET network performance by reducing packet loss, regardless of whether congestion is present or not.

Keywords: Congestion Control, Buffer, Packet loss, Algorithm

I. INTRODUCTION

Congestion control is an important problem in contemporary communication networks, especially in wireless settings and Mobile Ad-Hoc Networks (MANETs). It has a direct effect on QoS and overall network performance. Delays, dropped packets, or even the complete breakdown of the network can result from congestion, which happens when the demand for network resources like processing power, buffer space, or bandwidth surpasses the available capacity. Modifying transmission speeds, rerouting packets, or decreasing the volume delivered via the network are common approaches to traditional congestion control. Congestion control in MANETs, which are dynamic and have limited resources, calls for more sophisticated strategies, especially with regard to buffer management.

Data transmission in packet-switched networks is accomplished by briefly storing each unit of data in a buffer before sending them on to their next destination. In these networks, buffer management is particularly important for reducing congestion. Congestion in router or intermediary node buffers causes packet loss and wasteful use of network resources in networks with heavy traffic or unreliable connections. Congestion control relies heavily on the storage, queuing, and discarding of packets as well as other data management techniques employed by these buffers. The requirements of contemporary high-performance networks, particularly those pertaining to low latency, high throughput, and reliability, are frequently not satisfied by the traditional approaches to buffer management, such as Priority Queuing (PQ), Random Early Detection (RED), and First In First Out (FIFO).

In today's complicated networking settings, new buffer management algorithms are becoming an essential part of congestion control systems. By incorporating novel ideas and methods that are more in line with the unique needs of contemporary networks, these solutions hope to enhance the efficiency of conventional buffer management approaches. The primary goal of new buffer management strategies is to make efficient use of buffer capacity while reducing packet loss and congestion. In mobile environments, where devices frequently use battery power, the challenge is to design strategies that are both energy efficient and adaptive to changing network conditions, such as fluctuating topologies, limited network resources, and varying traffic loads.

A growing number of factors, including the complexity of network traffic in contemporary communication systems, necessitate new approaches to buffer management. Due to the proliferation of latency-sensitive applications like online gaming, real-time video streaming, and voice over IP (VoIP), networks must now prioritize the timely transmission of data in order to accommodate the more unpredictable and inconsistent traffic patterns. Instead of handling packets according to their arrival time, researchers have begun to investigate more complex buffering methods that consider variables like packet significance, time sensitivity, and flow management. For example, Adaptive Queue Management (AQM) has demonstrated potential in lowering congestion and increasing network efficiency by dynamically adjusting buffer size in response to real-time network circumstances.

Using machine learning and artificial intelligence (AI) approaches is becoming more popular in buffer management for congestion reduction. Congestion prediction and optimal buffer management choices may be accomplished through the training of machine learning algorithms, especially those based on reinforcement learning. By analyzing historical network data, these algorithms may foretell which nodes would be most impacted by congestion and alter buffer management tactics appropriately. By combining AI-based techniques with conventional congestion management algorithms, we may build smarter, more self-adaptive systems that can change their buffer size, packet scheduling, and flow control in response to the changing network conditions. These systems can increase network speed and avoid congestion by using real-time data to make better judgments.

Developing innovative buffer management strategies while keeping energy consumption to a minimum is crucial for mobile networks like MANETs, where nodes often run on batteries. In such energy-constrained settings, conventional congestion control methods that rely on the continual transmission of feedback signals or the frequent modification of buffer designs could not work. To solve this issue, new approaches to buffer management minimize state updates and optimize buffer widths, which helps to conserve energy without sacrificing congestion control effectiveness. The entire stability and dependability of the network depends on mobile nodes being able to function for longer periods of time without draining their battery resources. Energy-efficient buffer management makes this possible.

When creating new methods for managing buffers, scalability is also quite important. Managing buffers becomes more challenging as the network size increases. Highly scalable congestion management systems are essential for networks with numerous nodes, high mobility, and variable traffic loads. These systems must be able to adapt to these growing demands without compromising performance. To keep up with the expanding network and more complicated traffic patterns, innovative buffer management systems are built to be scalable. To keep the network from becoming even more congested or causing bottlenecks, these solutions must also make optimal use of memory and processing resources.

When coming up with new methods of buffer management, it's important to think about how to balance performance with fairness. A important aspect in various congestion management techniques is ensuring that no flow dominates the network resources while others starve. This is done to prevent unfairness between flows. Nevertheless, in extremely crowded situations, promoting justice could result in inefficiency. In order to strike a balance between performance and fairness, new buffer management algorithms dynamically alter the distribution of buffer space according to the significance, time sensitivity, and congestion contribution of the traffic. The network's optimal operation, including the provision of high-quality service to both non-real-time and real-time applications, depends on this balance.

II. REVIEW OF LITERATURE

Alattas, Khalid. (2021) Constraints on available resources are the primary source of congestion in mobile ad hoc network systems. But the main features of the shared wireless channel system are outside the control and handling capabilities of the standardized TCP-based congestion management method. As a result of finally understanding the mechanics of congestion, it influences the design of appropriate protocols and protocol stacks. Not only that, but mobile ad hoc networks are often considered to have a more troublesome environment when compared to traditional TCP systems. In contrast, in order to circumvent congestion in any form inside ad hoc network systems, an agent-based mobile congestion strategy is created and optimized.

NS, Kavitha. (2016) An essential problem that may develop with MANETs is congestion control. When there are an excessive number of packets in one area, the performance of communication networks suffers. This problem arises when the amount of data packets supplied to the network exceeds its capacity, or when the demand on the network is increasing. Traffic occurs when several users compete for limited resources like bandwidth, buffers, and queues. If there is a lot of traffic, the buffers will fill up, the next packet will not arrive, and the delay will be too great. Methods including end-system flow control, network-based congestion monitoring and allocation, and resource allocation are the foundational tools for congestion management. Both multipath routing and the load-aware approach are highlighted in this survey; they both offer more dependable performance and take into account the load on each node. Therefore, all of the provided methods employ routing-based congestion control in order to reduce data drop. In this survey, we found that dynamic queue management is a good strategy for controlling congestion. We also provided a problem statement on the dynamic queue base approach to congestion control and the parameters for the simulation.

Firdous, Ul et al., (2013) Most networks employ Transmission Control Protocol (TCP) because of how effectively it functions over wires. It is imperative that TCP be updated to support both wired and wireless networks in light of the rapid deployment of wireless networks. Unless you're using a wired network, TCP won't be able to tell whether a packet loss isn't due to congestion. TCP In order to maintain a stable Internet and allocate bandwidth fairly and efficiently, congestion control is crucial. Congestion control is thus a hot topic among network researchers and practitioners right now. In an effort to alleviate congestion, researchers have created and improved a plethora of congestion control technologies. A number of methods for bettering TCP congestion control have been suggested within the past ten years. Using the AODV routing protocol, this study will examine and contrast three distinct TCP variants: Reno, New Reno, and Vegas. The fact that retransmissions guarantee dependability and that TCP reacts to congestion make it resilient.

Antonopoulos, Christos & Koubias, Prof. Stavros. (2010) The need for advanced methods of controlling bandwidth and traffic control has grown in recent years as major concerns in ad hoc wireless networks. Also, these problems are only going to get worse in the future since there are so many different kinds of applications, each with its own unique requirement for bandwidth control. Complexity and the necessity for efficient handling are heightened by the fact that major properties of MANETs, such as enabling dynamically shifting topologies and multi-hop communication, can change quickly and unpredictablely or stay static over lengthy periods of time. In an effort to get around these issues, a lot of academics are looking into cross-layer design as a way to make a flexible, lightweight substrate for the demanding ad hoc wireless networks. The essential qualities required by ad hoc wireless networks are met by this method of architecture. A new cross-layer architecture for controlling congestion in wireless ad hoc networks is proposed in this research. It is lightweight, efficient, and innovative. In both static and mobile network topologies, this framework's performance is tested using popular ad hoc routing protocols like AODV and DSR in the renowned NS2 simulator.

Lochert, Christian et al., (2007) One of the main challenges of mobile ad hoc networks is managing congestion. Due to its unique characteristics, a shared wireless multihop channel is difficult for the conventional TCP congestion management technique to manage. Specifically, there are a lot of obstacles due to the shared wireless channel and the frequent changes in the network topology. To get past these obstacles, several different strategies have been suggested. This document provides a synopsis of previous proposals, outlining their main points and illustrating how they relate to one another.

III. SIMULATION SETUP

An innovative algorithm is introduced that oversees buffer capacity and implements the approach when the buffer reaches fifty percent fullness. The suggested method consistently sustains the buffer capacity within the range of 50% to 90%. The purpose of maintaining the buffer size range is to regulate congestion control in the MANET.

The proposed Novel Buffer Management approach is evaluated using the Network Simulator (NS2) with packet flow arrival rates varying from 20 Mbps to 25 Mbps, 30 Mbps to 40 Mbps, and a total of 100 nodes. Drop Tail, RED, and TCP congestion are compared with the NBM's active, passive, and proactive buffer management strategies. When the flow arrival rate is first established at 20Mbps and then escalates, the increased packet flow and transmission result in congestion inside the MANET. Two simulation testing scenarios are established: a. packet arrival rate in the absence of congestion and b. packet arrival rate in the presence of congestion.

IV. RESULTS AND DISCUSSION

Tables 1 and 2 present a comparative analysis of the Packet Loss Ratio of the Novel Buffer Management (NBM) methodology against the Drop Tail, RED, and TCP congestion solutions, respectively.

Table 1 Comparison of Packet Loss Ratio without congestion

Packet Flow Rate	Novel Buffer Management Algorithm	Random Early Detection	TCP	Drop Tail
20	0.05	0.07	0.10	0.10
25	0.07	0.10	0.11	0.15
30	0.08	0.14	0.14	0.17
35	0.09	0.15	0.10	0.19
40	0.10	0.18	0.12	0.20

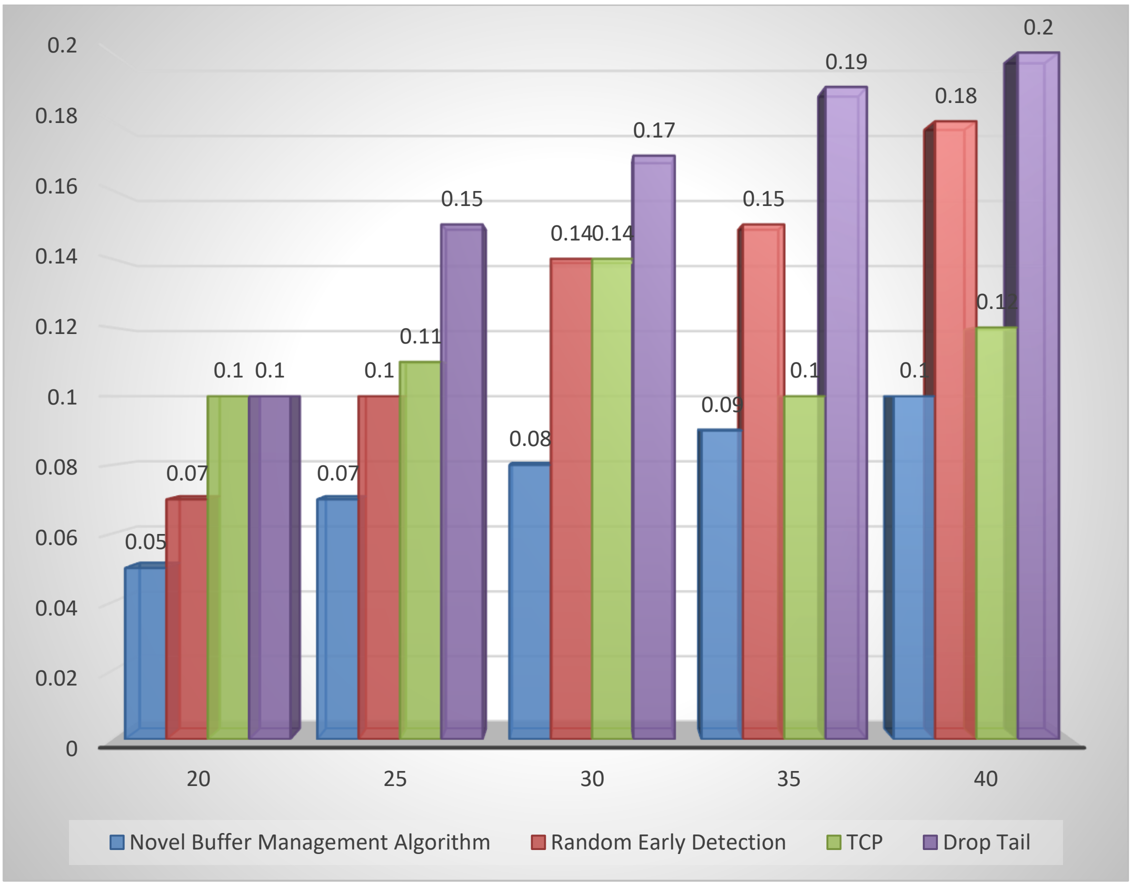

Figure 1: Comparison of Packet Loss Ratio without congestion

The table compares the Packet Loss Ratio (PLR) of various algorithms and approaches across varying packet flow rates, with the network operating without congestion. At a packet flow rate of 20, the Novel

Buffer Management Algorithm demonstrates the minimal packet loss ratio of 0.05, succeeded by RED, TCP, and Drop Tail, which provide greater loss ratios of 0.07, 0.10, and 0.10, respectively. As the packet flow rate escalates, the packet loss ratio for all methods concurrently increases. At a packet flow rate of 25, the loss ratio of the Novel Buffer Management Algorithm rises to 0.07, whereas RED, TCP, and Drop Tail exhibit greater loss ratios of 0.10, 0.11, and 0.15, respectively.

The Novel Buffer Management Algorithm consistently exhibits the lowest packet loss ratios across all flow rates, signifying its better efficacy in mitigating packet loss relative to RED, TCP, and Drop Tail. The Drop Tail algorithm has the largest packet loss ratios, especially at elevated flow rates, with the loss ratio increasing markedly from 0.10 at a flow rate of 20 to 0.20 at 40. This indicates that Drop Tail may have difficulty managing elevated traffic levels, resulting in greater packet loss. Conversely, RED and TCP exhibit more uniform behavior, with minor increases in packet loss as the flow rate escalates.

Table 2 Comparison of Packet Loss Ratio with congestion

Packet Arrival (Mbps)	Novel Buffer Management Algorithm	Random Early Detection	TCP Congestion	Drop Tail
20	0.07	0.09	0.07	0.13
25	0.09	0.10	0.13	0.15
30	0.09	0.14	0.17	0.17
35	0.10	0.15	0.10	0.21
40	0.12	0.18	0.15	0.22

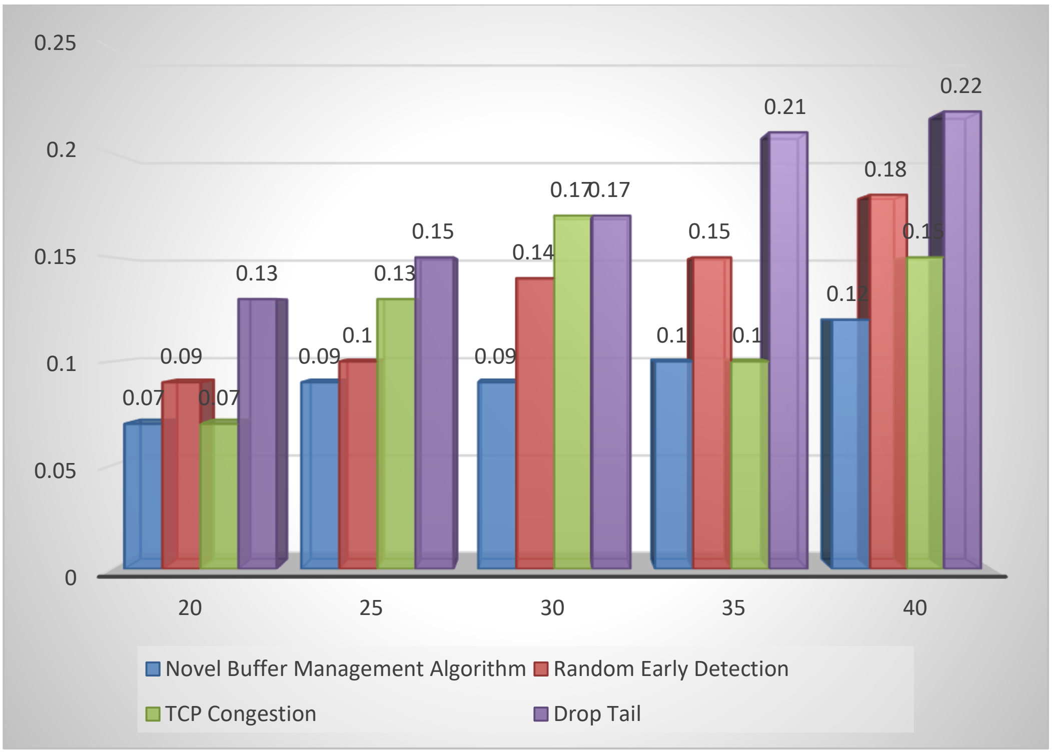

Figure 2 Comparison of Packet Loss Ratio with congestion

In this case, we have network congestion, and the table shows the Packet Loss Ratio (PLR) for various methods when packet arrival rates are varied. While RED's packet loss ratio is 0.09 at a slightly higher rate of 20 Mbps, Drop Tail's is 0.13, and the Novel Buffer Management Algorithm and TCP Congestion both show the lowest packet loss ratio at 0.07. The Novel Buffer Management Algorithm maintains its superior performance in minimizing packet loss, even as the packet arrival rate increases. All methods exhibit an increasing packet loss ratio. As an example, its loss ratio at 25 Mbps is 0.09, which is lower than RED's 0.10, TCP Congestion's 0.13, and Drop Tail's 0.15. The loss ratio for the Novel Buffer Management Algorithm rises to 0.12 when the packet arrival rate approaches 40 Mbps, which is still lower than RED's 0.18, TCP Congestion's 0.15, and Drop Tail's 0.22. The results show that the Novel Buffer Management Algorithm is still the best at dealing with packet loss caused by congestion, regardless of the flow rate.

V. CONCLUSION

When compared to more conventional algorithms like Drop Tail, Random Early Detection (RED), and TCP congestion control, the suggested Novel Buffer Management (NBM) algorithm significantly reduces packet loss in Mobile Ad-Hoc Networks (MANETs). The simulation results demonstrate that regardless of the packet flow rate or the presence or absence of congestion, NBM always attains the lowest Packet Loss Ratio (PLR). When there is no congestion, NBM is the best option since it keeps the buffer capacity consistent and reduces packet loss to a minimum. Even when faced with heavy traffic, the algorithm maintains its superior performance, guaranteeing faster and more efficient data transfer. To regulate congestion and reduce packet loss, it is necessary to be able to maintain buffer capacity between 50% and 90%.

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