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TO STUDY THE ADAPTIVE MULTIPATH CONGESTION CONTROL SCHEMES FOR MOBILE AD HOC NETWORKS

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ABSTRACT

This study provides an overview of congestion management methodologies in mobile ad hoc networks (MANETs), taking into account several lines of congestion control research in the field. Taking a comprehensive approach to congestion control challenges in mobile ad-hoc networks and studying several ways together is a viable notion. The main goal of this paper is to outline recent research in this field, identify important issues and obstacles in traffic control, and encourage more research on this topic.

Keywords: Congestion Management, Challenges, Obstacles, Mobile Ad-Hoc

1.1 INTRODUCTION

A mobile ad-hoc network (MANET) is made up of a set of mobile nodes that communicate through wireless. This type of network is simple to set up and maintain in areas where network infrastructure is difficult to come by. MANETs are adaptable, resource-light, and versatile, but they can be difficult to discover pathways that provide optimal communication between their component nodes. Wireless mobile nodes in such networks may dynamically enter and/or depart the network. Multiple hops are frequently required for a node to share information with any other node in the network due to the restricted transmission range of wireless network nodes. As a result, routing is a critical aspect of MANET design. Appropriate routing protocols that are robust, dependable, efficient, and as simple as feasible are necessary to complete this task **(Bhavyesh Divecha et al 2007).**

MANETs are a plug-and-play type of networking that requires no infrastructure. Due to the lack of infrastructure, the cost of establishing the network **(Ahmed Al- Maashri and Mohamed Ould-Khaoua 2006)** is reduced. Furthermore, where there is inadequate time or resources to construct and configure an infrastructure, this type of network might be useful in failure recovery. Because these networks do not require centralized management, they are used in military operations. In military operations, units move about the battlefield and cannot be managed using a single unit. They require discovering paths that permit communication between their component nodes, despite being flexible **(Iliya Enchev 2011),** adaptive, and requiring a small quantity of resources. Robust, reliable, efficient, and simple routing protocols are required to execute path discovery.

1.2 CHARACTERISTICS OF MANETS

MANETs have a number of qualities that make them useful in a wide range of situations. The first is that because ad-hoc networks have no infrastructure, they may be built as needed, making them highly adaptable to any context. As the benefits stack up, there are several downsides that make implementing a Mobile Ad-hoc network problematic. The following are their key characteristics:

The communication channel is broadcast, and the connections between the network nodes are wireless. The wireless connection allows the nodes to roam about freely, allowing them to come together as needed and build a network without relying on the cable connections.

There is no fixed infrastructure in mobile ad hoc networks. They are nothing more than a collection of self-organized mobile nodes connected by links of varying quality. As a result, the network topology is constantly changing.

The movable nodes are free to go wherever they want, leave whenever they want, and new nodes might appear at any time. There is no mechanism in place to regulate or monitor membership. The execution environment is untrustworthy and hostile. Malicious nodes have a higher probability of mounting assaults due to the lack of a set infrastructure and administration. Furthermore, nodes may act selfishly, resulting in a decrease in performance or possibly the loss of functionality.

1.3 CONGESTION CONTROL

Congestion control aims to reduce network latency and buffer overflow while maintaining network performance. Congestion is the primary cause of packet loss in MANETs, and it may be decreased by employing congestion control at the mobility layer and the failure adaptive routing protocol at the network layer **(Senthil Kumaran and Sankaranarayanan 2011).**

The restricted supply of resources causes congestion in mobile ad hoc networks. Up/downlink congestion is caused by an increase in the number of customers and higher connection prices. That example, network congestion occurs when the current load on a channel exceeds its bandwidth. Due to transmission faults, the network is overburdened (Nan Jiang et al 2012).

Due to a shared wireless channel and dynamic topology, packet transmission in the MANET is hampered by interference and fading. Multimedia communication in MANETs is becoming increasingly popular these days. Real-time traffic necessitates more bandwidth, which causes congestion. Additionally, congestion causes packet losses and bandwidth degradation, wasting time and energy on congestion recovery **(Thilagavathe and Duraiswamy 2011).**

There are two types of congestion: node-level congestion and link-level congestion. Node-level congestion, which is frequent in networks, is produced by a node's buffer overflow, which results in packet loss and increased queuing delay. When a packet is lost, the missing packet is resent. Additional energy is required due to packet retransmission. In a MANET, all nodes use protocols to share wireless channels, and congestion arises when a large number of nodes try to seize the channel at the same time. Link-level congestion is the term for this type of congestion. Congestion at the connection level results in long packet delivery times, low link usage, and low total throughput **(Wang et al 2007).**

1.4 LOAD BALANCING

Network performance is degraded by heavily and lightly loaded nodes, and this is more important than other downsides, such as the effects of congestion on network traffic. If routes with low bandwidth receive the fewest packets and routes with high bandwidth receive more packets, the network's end-to-end delay and stability can be enhanced. End-to-end delay, packet loss, uneven energy consumption, and inefficiency are all symptoms of an imbalanced load in a MANET. By distributing the load in the network, load balancing systems prevent the network from becoming congested and the resources of the congested node from being depleted. When the shortest path routing algorithm is employed for path discovery in the network, traffic imbalance problems arise. This type of routing method is ineffective since it does not fully leverage the system's capabilities.

Multi-path routing can provide higher bandwidth and a better packet delivery ratio for multimedia applications than typical shortest path routing protocols because it uses numerous concurrent paths to send data. Multi-path routing reduces excessive load by dispersing traffic burden on network links in a uniform or non-uniform manner (Shruti Sangwan et al 2011).

1.5 MOTIVATION

Congestion is a serious issue with MANETs, lowering overall network performance. At the network layer, it causes packet loss, which can be mitigated by applying congestion management via a mobility and failure adaptive routing protocol. Congestion control seeks to reduce latency and buffer overflow while also improving QoS metrics such as packet delivery ratio, end-to-end delay, and throughput. Packet loss in MANETs is mostly caused by congestion, which can be decreased by employing congestion control at the network layer via a mobility and failure adaptive routing protocol **(Senthil kumaran and Sankaranarayanan 2011).**

Improper load distribution or load imbalance can cause congestion in mobile ad hoc networks. In ad hoc networks, multipath routing can balance the load better than single path routing, minimizing congestion. The solutions to load balancing, congestion, and fault-tolerance are offered individually in most existing protocols. Additionally, packet loss in multipath routing must be recovered due to congestion or other factors like as noise, external interference, and buffer overflow. The information flow and throughput of the loss recovery technique must be maximized.

2.1 REVIEW OF LITERATURE

The routing protocol created by **Peter Pham and Sylvie Perreau (2020)** boosts network throughput A multi-path routing protocol with a load balancing policy was suggested in this scheme. The theoretical analysis of reactive single-path and multi-path routing with load balance mechanisms in ad hoc networks in terms of overheads, traffic distribution, and connection throughput is a key contribution of this work. Multi-path routing (with a load balance policy) outperforms reactive single-path routing in terms of congestion and connection throughput, as long as the average route length is less than certain upper limitations computed from network parameters. These upper boundaries are critical because they can be used as constraints in the route discovery mechanism, ensuring that the multi-path routing protocol outperforms a single-path routing protocol.

In the context of ad hoc wireless networks, two difficulties have been addressed, and it has been demonstrated that the success of multipath routing is dependent on the impacts of route coupling **(Siuli Roy et al 2020)** during path selection. In a wireless medium, route coupling occurs when two routes are physically close enough to interfere with each other during data transmission. They employed the concept of zone-disjoint routes to reduce the influence of interference between routes in a wireless medium.

Victor Carrascal Frias (2020) suggested a QoS-aware multipath DSR-based (Dynamic Source Routing) routing protocol that helps to increase connection dependability while balancing load and reducing end-to-end delay. Several multipath routing designs have been tested in order to improve the network's overall performance. A cross-layer approach in which a network layer scheduler controls different priority traffics and operates according to the IEEE 802.11e MAC (Medium Access Control) layer was also presented as part of this scheme.

The load-balancing method suggested by **Oussama Souihli et al. (2020)** sends traffic away from the network's hub. They also provided a routing metric for proactive and reactive routing protocols that takes into account the degree of centrality of the nodes. The authors' proposed mechanism improves load distribution while also improving network performance in terms of average delay and dependability. However, it only uses single path routing, which adds to the overhead.

Gabriel Ioan Ivascu et al. (2019) suggested a method for supporting Quality of Service (QoS) in MANETs based on a mobile routing backbone. They wanted to find nodes with the capabilities and features that would allow them to participate in the mobile routing backbone and participate in the routing process efficiently. Furthermore, the route discovery system they created for the mobile routing backbone dynamically distributes traffic within the network based on current network traffic levels and the processing loads of the nodes. They've demonstrated that their method enhances network performance and packet delivery ratio by routing traffic through less crowded, resource-rich areas of the network. Furthermore, when looking for routes in the network, their approach has lower communication overheads than the AODV (ad hoc on-demand distance vector routing protocol).

The topic of combining scheduling and congestion control in mobile Adhoc networks **(Umut Akyol et al 2019)** has been investigated, with the goal of keeping network queues restricted and ensuring that flow rates satisfy an associated network utility maximization problem. They proposed a special network utility maximization problem and claimed that their solution was suitable for mobile Adhoc networks. They also described a Wireless Greedy Primal Dual (WGPD) algorithm for wireless ad-hoc network congestion control and scheduling.

According to **Zhijing Xu et al. (2019)**, a routing measure can indicate not just the path's load, but also the load distribution along it. They demonstrated a multi-path load balancing technique. It's a basic yet effective algorithm for balancing the load and reducing network congestion. The program starts by analyzing the queuing model and then proposes two formulas for evaluating the partial and complete functions for ad hoc networks. The utilization condition of each connection and function index can be computed using the connective matrix and traffic matrix. Finally, they established a threshold value to prohibit excessive link consumption, lowering the risk of congestion.

Fujian Qin and Youyuan Liu (2019) devised a multipath source routing technique with guaranteed bandwidth and reliability. Their protocol selects numerous different alternative paths that match the QoS requirements during the route discovery phase, and the optimal number of multipath routing is accomplished to balance load balancing and network overhead. It can successfully deal with route failures in the route maintenance phase, comparable to DSR. In addition, in the traffic allocation step, per-packet granularity is used. Multiple pathways are built in this case based on bandwidth availability and reliability. Furthermore, congestion is not taken into account in their research.

Su Jin Kim et al. (2018) presented Traffic Prediction Multi-path Energy-aware Source Routing (TP-MESR), which use a multi-path routing technique combined with a traffic prediction function to expand the number of pathways to more than two. Their suggested TP-MESR solved the existing multi-path routing problem caused by overhead, radio interference, and packet reassembly, as well as confirming its contribution to energy efficiency in ad hoc networks. For traffic distribution and expanding the number of pathways, it employs a prediction function. It will not be successful if the prediction is not exact or if the prediction error is big.

3.1 RESEARCH METHODOLOGY

The simulation settings and parameters are listed in Table

Parameters	Values
No. of Nodes	30, 50, 70, 90 & 110
Area	1250 * 1250
MAC	802.11

Radio Range	250m
Simulation Time	100 sec
Traffic Source	CBR
Rate	250kb/s
Packet Size	512 B
Mobility Model	Random Way Point
Speed	10, 20, 30 & 40 m/s
Pause time	10 seconds

3.2 PERFORMANCE PARAMETERS

The protocol's performance is assessed primarily using the following criteria:

- Routing Overhead is defined as the ratio of the size of the routing messages created by a routing protocol to the size of the data packets received at the destination.
- End-to-end delay: The average time it takes to send a data packet from a source to a destination is referred to as end-to-end delay.
- The ratio of the number of data packets received at the destination to the number of data packets generated by the source is known as the packet delivery ratio.
- The quantity of data packets received by the destination over a given time period is known as throughput.

4.1 RESULTS AND ANALYSIS

Using multipath routing techniques, the proposed AMRCC protocol is compared against the QoS Mobile Routing Backbone (QMRB) (Gabriel Ivascu et al 2009).

TABLE 1.2 PERFORMANCE METRICS COMPARISON BASED ON NODES

No. of Nodes	Delay (Seconds)		Packet Delivery Ratio		Overhead (Packets)		Throughput (Packets)	
	AMRCC	QMRB	AMRCC	QMRB	AMRCC	QMRB	AMRCC	QMRB
30	1.4549	1.5389	0.9424	0.9220	13645	13857	13635	13340
50	0.8425	1.2103	0.9813	0.9409	14201	14468	14198	11193
70	0.9383	1.9309	0.8330	0.6541	14245	14636	12052	9464
90	1.2838	2.5629	0.9335	0.6056	14325	14442	13506	8763
110	1.7302	3.1894	0.9203	0.7668	14150	14468	13315	11095

The number of data packets received by the destination node over the simulation's duration is the network throughput. The AMRCC and QMRB's average network throughput as a function of the number of mobile nodes, respectively. These simulation runs have a 10-second stop time. In most circumstances, this protocol gives a greater average network throughput than QMRB. When the number of mobile nodes is set to 30, both the AMRCC and the QMRB work equally well when the number of mobile nodes is increased, however, the AMRCC protocol outperforms the QMRB protocol. When the number of mobile nodes in the simulated environment reaches 90, the AMRCC scheme outperforms the QMRB scheme in terms of throughput. The suggested protocol outperforms the QMRB by 2.21 percent while the number of mobile nodes is kept at 30. When the number of mobile nodes is increased to 90, the QMRB improves by 35.11 percent. The proposed protocol has been observed to improve QMRB throughput performance by 23.60 percent on average when the number of mobile nodes is varied from 30 to 150. In general, scalability refers to a network's ability to manage an increasing amount of work in order to accommodate that growth. It refers to the possibility of increasing overall throughput under higher load when the number of nodes is increased in this suggested protocol. In a scalable setting, the proposed protocol works well. At 70 nodes, there is a decrease in AMRCC throughput, which subsequently begins to increase at 90 nodes. Similarly, the throughput of QMRB begins to decline at 30 nodes and then begins to improve around 110 nodes. However, at 110, AMRCC's throughput begins to climb again, whilst QMRB's remains constant.

4.2 EFFECTS BASED ON THE SPEED

For the simulation environment, the node speed is changed between 10 and 40 m/s. The findings obtained for the variable node speed scenario are shown in Table.

TABLE 1.2 PERFORMANCE METRICS COMPARISON BASED ON SPEED

Speed (m/s)	Delay (Seconds)		Packet Delivery Ratio		Overhead (Packets)		Throughput (Packets)	
	AMRCC	QMRB	AMRCC	QMRB	AMRCC	QMRB	AMRCC	QMRB
10	5.8315	7.4702	0.9813	0.9409	14201	14468	14198	10193
20	8.7752	11.1785	0.7350	0.4664	13595	14110	10634	6748
30	8.6838	12.5089	0.8746	0.4789	14262	14467	12654	6930
40	10.2823	16.9563	0.6744	0.3830	13274	13975	9758	5542

For ad hoc networks of 50 nodes, the average network throughput for the AMRCC and QMRB as a function of mobile node speed. When mobile nodes move at speeds greater than 10 m/s, the AMRCC has a better average network throughput than the QMRB. When the data is studied, it can be seen that the AMRCC's throughput is somewhat reduced for maximum mobile node speeds less than 20 m/s, and then gradually increases until it reaches around 12654 packets/s at 30 m/s. As a result, the decreased throughput at 20 m/s is largely offset by the higher throughput at 30 m/s. Indeed, the AMRCC protocol outperforms the QMRB protocol by 45.23 percent at 30 m/s. Figure 3.10 shows that the AMRCC performs better than the QMRB. When compared to the QMRB, this protocol enhances throughput performance by 38.29% over the 10 to 40 m/s range. The suggested protocol's route optimization and congestion control mechanisms are responsible for the improved performance.

This presents an adaptive multi-path congestion management approach for controlling congestion in Mobile Ad Hoc Networks (MANETs). The nodes with the least load, more bandwidth, and residual energy were used to achieve load balancing and congestion control. The overloaded part of the traffic is dispersed among the optimal multi-path routes to minimize the load on the congested path when the average load of a node in the path grows or the residual battery power of a node falls. The simulation results demonstrate that the suggested technique effectively solves the load balancing and network congestion problems.

5.1 CONCLUSION

The purpose of this study is to look into efficient multipath routing algorithms for use in mobile ad hoc networks as congestion management mechanisms. Congestion and load balancing were two critical features that these proposed multi path routing methods had to meet. Fault tolerance, loss recovery, congestion monitoring, and rate control techniques are some of the key variables that drove the suggested solutions.

In MANETs, an unbalanced load causes packet loss and end-to-end delay. Load balancing techniques reduce network congestion by dispersing loads across several channels in the network. The chosen path must be both dependable and discontinuous.

An adaptive congestion control strategy is offered as a solution to the congestion problems. The algorithm for identifying multi-path routes computes various pathways that provide multiple routes to destination for all intermediate nodes on the principal path. The nodes with the least load, more bandwidth, and residual energy are among the many pathways. It distributes traffic along discontinuous multi-path routes to minimize traffic load on a congested link when the average load of an existing link exceeds a threshold, or when the available bandwidth and remaining battery power of a node falls below a threshold.

Congestion control requires not only load balancing but also effective congestion detection and rate control solutions. A rate-based congestion control technique is employed, which effectively minimizes congestion. To identify and alter the rate, the system employs rate estimation and rate control techniques. The destination node can get the estimation rate from the intermediate nodes, and then forward this information to the source. This technique outperforms the classic MANET congestion control technique since the transmitting rate is modified based on the estimated rate from intermediate nodes.

5.2 FUTURE ENHANCEMENTS

The proposed methods are tested in the MANET under various settings. It would be interesting to examine how the proposed protocol performs when different parameters are considered, such as average density, average number of link change routes, average length of paths, variable energy capacity nodes, nodes with diverse processing capabilities, and so on.

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