Multipath Load Balanced Congestion Control Routing Techniques in Mobile Ad Hoc Networks

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Abstract— In Mobile Ad Hoc Networks (MANET), the network congestion can severely reduce the network throughput. Also the network congestion results in the packet losses, bandwidth degradation and energy expenditure. Hence a load balancing scheme is required to prevent the network from congestion and exhaustion of resources of congested node. In this paper, we propose a congestion adaptive multi-path routing protocol for load balancing in MANET. When the source node wants to forward the data packet to the destination, it utilizes the reactive route discovery technique where the multiple paths are established using multi-path Dijkstra algorithm. By simulation results, a show that the proposed approach alleviates the multipath network congestion.

Key words: Multipath routing, Congestion Control, Load Balancing, Dijkstra algorithm, Routing Protocols

I. INTRODUCTION

In Ad hoc networks, it is essential to use efficient routing protocols that provide high quality communication. To maintain portability, size and weight of the device this network has lot of resource constrain. The nodes in MANET have limited bandwidth, buffer space, battery power etc. So it is required to distribute the traffic among the mobile host. A routing protocol in MANET should fairly distribute the routing tasks among the mobile host. An unbalanced traffic/load distribution leads to performance degradation of the network[1]. Due to this unbalancing nature, few nodes in the network are highly loaded with routing duties which causes the large queue size, high packet delay, high packet loss ratio and high power consumption. Now we provide a solution of load balancing routing algorithm for MANET. The advantages of load balancing can be optimal resource utilization, increased throughput, and lesser routing overload. The load can also be unequally distributed over multiple links by manipulating the path cost involved.

II. RELATED WORKS

Shruti Sangwan et al [2] have proposed adaptive and efficient load balancing schemes to achieve fair routing in mobile ad hoc networks (MANETs). They described various load balancing mechanisms that controls congestion.

Valarmathi et al [3] have proposed a congestion aware and adaptive DSR algorithm with load balancing for MANET. Their protocol after supervising the congestion status informs the routing process of congestion and invokes multi-path routing. They also estimated the effects of various traffic load model on routing protocol. Their approach of multi-pathrouting and load-balancing at the time of congestion enhances the QoS in MANETs for constant bit rate (CBR) multimedia applications.

Duc A. Tran et al [4] have proposed a congestion adaptive routing protocol (CRP) for MANETs. Their protocol assists in avoiding the congestion from occurring in the first place before dealing it reactively. CRP utilized bypass concept where part of the incoming traffic will be sent on the bypass, making the traffic coming to the potentially congested node less. This protocol further reduces the queuing delay and minimal packet loss rate.

Zhijing Xu et al [5] have proposed adaptive threshold routing algorithm with load balancing for ad hoc networks. Their scheme can distribute the traffic load evenly among nodes in ad hoc networks which is applied over an on-demand routing protocols. During route discovery, they judge the overloaded condition of the node by the threshold value and if the node is overloaded then the route request packet is dropped. Or else request packet will be broadcast again. The threshold value dynamically changes as per the interface queue occupancy (IQO) of nodes on and around the backward path.

R. Vinod Kumar et al [6] have proposed an effective scheme to balance the load in ad hoc network. They used ad hoc on demand multi-path distance vector (AOMDV) for selecting a path with a lower hop count and discarding the routes with higher hop count. They used a threshold value to judge whether the intermediate node is overloaded where the threshold value is changing along with the nodes' interface queue occupancy around the backward path.

P. P. Tandon et al [7] have proposed a novel congestion avoidance based load balanced routing with optimal flooding in MANET. Their approach attempts to avoid the congestion of a node by selecting the disjoint paths. This is achieved by setting a flag bit with the time limit TTL, at the node. On exceeding of this value, the flag bit is reset. Their approach limits the flooding and congestion of the node along with effective balancing of the traffic load. They did not take traffic load and hop count metric into consideration for selecting the route that reduces the network performance.

Rajbhupinder Kaur et al [8] have proposed a load balancing of ant based algorithm in MANET. Their algorithm is based on balancing the load among the routes by calculating threshold value of each routing table & ants' helps to effectively balance the loads as it find a pair of under loaded and over loaded nests. Their proposed algorithm can control the overhead generated by ants, while achieving faster end-toend delay and improved packet delivery ratio.

Vishnu Kumar Sharma et al [9] have proposed a congestion and power control technique based on agent in MANET. They utilized mobile agent for transmitting the data packets through the path containing minimum cost and congestion. After composing the status of every node, it is delivered to the target node. Their power control technique classifies the nodes based on the power level as listening and non-listening nodes. During the packet transmission, when the node is listening, the packet is transmitted or else node checks for the adjacent listening for transmitting the packet.

III. LOAD BALANCING IN MANET

For improved utility of the resources of the MANET and also to enhance the performance of the MANET, load balancing technique is employed which is the significant tool. Using the load balancing technique, the network can reduce the traffic congestion and imbalance of the load. This is possible because the technique reduces the end-to-end delay, increase the nodes lifetime and optimizes the energy expenditure [10].

The main problem with existing routing protocols is concerned with consideration of minimum hop paths as best path for transmitting the data towards destination. But the mentioned approach is short of communicating the load and path quality while creating the route. The reduced number of innermost nodes turns out to be strength for entire traffic which further causes congestion in medium access control layer (MAC). Consequently it results in increased packet delays as some nodes possess more loads. There is a possibility that heavily loaded nodes acquire more power utilization which declines the batter power. Thus the load imbalance occurs on various routes depreciating the performance causing issues such as congestion, power exhaustion and queuing delay [11]. Therefore, the importance of effective load balancing scheme is to reduce the variation among overloaded and under-loaded nodes based on workload. The load balancing scheme allocates the traffic among the mobile hosts preventing congestion and exhaustion of resources of congested nodes [12]. On the whole, load balancing scheme is required to perform following actions: For choosing non-congested paths or to distribute excessive load of a node to its neighbor Stabilizing the energy expenditure of the network Guaranteeing the energy efficiency and robustness. To minimize the end-to-end delay and packet losses caused by queue overflow. Improving the resource usage Enhancing the network performance and minimizes collision by the distribution of load.

Multi-path routing can balance the load better than the single path routing in ad hoc networks, where the first selective shortest paths are used for routing. This is possible only for the networks having a huge number of nodes (i.e., a large fraction of the total number of nodes in the network) between any source-destination pair of nodes. It is infeasible to build such a system it is economical for discovering and maintaining a large number of paths. Load balance is not improved by using multiple shortest path routes instead of a single path. So, for a better load balanced network distributed multi-path load splitting strategies need to be carefully designed.

IV. CONGESTION IN MANETS

In mobile ad hoc network, congestion is a global issue, involving the behavior of all the hosts, all the routers, the store-and-forward processing within the routers, and so forth, which occurs with limited sources. Congestion is a situation in which too many packets are present in (a part of) the subnet and performance degrades. Congestion results from applications sending more packets than the network devices (i.e., router and switches) can accommodate, thus causing the buffers on such devices to fill up and possibly overflow. Traditionally, congestion occurs when the total volume of traffic offered to the network or part of the network exceeds the resource availability.

Congestion typically manifests itself in excessive end-to-end delay and packet drops due to buffer overflow. There are a variety of conditions that can contribute to congestion and they include but are not limited to traffic volume, the underlying network architecture, and the specification of devices in the network (e.g., buffer space, transmission rate, processing power, etc.). Network congestion can severely deteriorate network throughput. Congestion not only leads to packet losses and bandwidth degradation but also wastes time and energy on congestion recovery. If no appropriate congestion control is performed this can lead to a congestion collapse of the network, where almost no data is successfully delivered[13].

Congestion control is necessary in avoiding congestion and/or improving performance after congestion. Congestion control schemes are usually composed of three components: congestion detection, congestion feedback, and sending-rate control. Practically, congestion detection can be processed in intermediate nodes or receivers. The criteria for congestion detection vary with protocols. Congestion can be determined by checking queues length. It can also be indirectly detected by monitoring the trend of throughput or response time. Chief metrics for monitoring the congestion are the percentage of all packets discarded for lack of buffer space, the average queues lengths, and the number of packets that timed out and are retransmitted, the average packet delay, and the standard deviation of packet delay[14]. Congestion control is a method used for monitoring the process of regulating the total amount of data entering the network so as to keep traffic levels at an acceptable value.

Congestion Control Mechanisms:

1) End-system flow control: This is not a congestion control mechanism scheme, but it is a way to prevent the sender in network from overflow the buffers of the receiver.
2) Network congestion control: In this scheme, end systems choke back in order to avoid congesting the network. The mechanism is similar to end-to-end flow controls, but the main intention is to reduce congestion in the network, not the receiver.
3) Network-based congestion avoidance: In this scheme, a router detects that congestion may occur and attempts to slow down senders before queues become full.
4) Resource allocation: This technique involves scheduling the use of physical circuits or other resources, for a specific time period. A virtual circuit, built across a series switches with a guaranteed bandwidth is a form of resource allocation. This technique is difficult, but can eliminate network congestion by blocking traffic that is in excess of the network capacity.

V. MULTIPATH ROUTING IN MANET

Multipath routing has been explored in several different contexts. Traditional circuit switched telephone networks used a type of multipath routing called alternate path routing. In alternate path routing, each source node and destination node have a set of paths (or multi-paths) which consist of a primary path and one or more alternate paths. Alternate path routing was reposed in order to decrease the call blocking probability and increase overall network utilization. In alternate path routing, the shortest path between exchanges is typically one hop across the backbone network; the network core consists of a fully connected set of switches. When the shortest path for a particular source destination pair becomes unavailable (due to either link failure or full capacity), rather than blocking a connection, an alternate path, which is typically two hops, is used. Well known alternate path routing schemes such as Dynamic Non-hierarchical Routing and Dynamic Alternative Routing are proposed and evaluated in [15] [16].

Multipath routing has also been addressed in data networks which are intended to support connection-oriented service with QoS. For instance, Asynchronous Transfer Mode (ATM) networks use a signaling protocol, PNNI, to set up multiple paths between a source node and a destination node. The primary (or optimal) path is used until it either fails or becomes over-utilized, and then alternate paths are tried. Using a crank-back process, the alternate routes are attempted until a connection is completed. Alternate or multipath routing has typically lent itself to be of more obvious use to connection-oriented networks; call blocking probability is only relevant to connection oriented networks. However, in packet-oriented networks, like the Internet, multipath routing could be used to alleviate congestion by routing packets from highly utilized links to links which are less highly utilized. The drawback of this approach is that the cost of storing extra routes at each router usually precludes the use of multipath routing. However, multipath routing techniques have been proposed for OSPF [17], a widely used Internet routing protocol.

VI. PROPOSED MULTIPATH LOAD BALANCED CONGESTION CONTROL ROUTING PROTOCOL

The proposed congestion control algorithm is capable of avoid congestion in the network and is referred to as multipath load balanced congestion control routing (MLCR) algorithm. In this protocol each node maintains a record of the most recent traffic load estimations at each of its neighbors in a table. This table is used to maintain the load information of local neighbors at each node. Neighbors that receive this packet update the corresponding neighbor's load information in their neighborhood tables. MLCR is a new load balanced congestion control technique proposed to reduce congestion and to maximize the network operational lifetime. The metric traffic load density is used to determine the congestion status of the route and link cost is used to determine the lifetime of the route. The route with low traffic load intensity and maximum lifetime is selected for packet transmission and this algorithm practically limits the idealized maximum number of packets transmit table through the route having weakest node with minimum lifetime and high traffic load intensity.

A. *Estimation of Route Metrics:*

1) Estimation of Residual Battery Power After time t, the power consumed by the node (P (t)) is computed as follows.

$$P_{(t)} = DP_{tx} * + DP_{re} * \quad (1)$$

Where DP_{tx} = Number of data packets transmitted by the node after time t

DP_{re} = Number of data packets received by the node after time t

ƛ and η are constants in the range of [0, 1].

If Pi denotes the initial power of a node, the residual power PR of a node at time t, can be calculated as:

$P_R = P_i – P_{(t)}$

B. *Algorithm Steps:*

1) Compute the weight W_i on the basis of the above parameters and this computed value determines whether a node will act as a cluster head or as a normal node.
2) Compute Δi , which determines the practical degree of a node i. As Δi = [Ni – M], where Ni is the current degree and M is the maximum degree of the node.
3) The distance summation, represented as Di for i^{th} node determines the distance of the given node from its neighbor nodes. Compute the distance summation, the smaller the value of D_i , less power will be consumed to communicate with the normal nodes, thus the cost will be smaller.
4) According to the random waypoint mobility model, set the velocity V_i of a node.
5) The energy parameter E_i is set to zero initially i.e. the maximum energy level of a node, increase the value according to the energy consuming model. Algorithm terminates when some E_i reaches a value above 1.
6) The parameters computed above will determine the value of W_i . Calculate W_i .
7) Select the node with minimum W_i as the first cluster head and choose nodes with next less values of W_i as its member nodes, keeping optimal node degree into consideration. This supports the formation of an optimal cluster. This process continues until all nodes act as either cluster head or normal nodes.
8) To facilitate the communication between two clusters or nodes, select a node having compatibility with both the clusters in terms of its W_i value, as a gateway node.
9) After some unit of time all the nodes move randomly and algorithm repeats from step 1 again. Terminates, until a maximum no. of time is reached or some node's E_i exceeds 1.

VII. SIMULATION SETUP

Simulation Parameters	**Value**
Simulation time	15M
Seed	1
Terrain range	500x500
No. of nodes	100

Node placement	Random
Propagation path-loss model	Free space
Radio type	Radio accumulated noise
Transmission power	20dBm
Mobility model	Gauss Markov
Pause time	600sec
Minimum speed	0 m/sec
Maximum speed	35 m/sec
Packet size	512 Bytes
Routing protocol	AODV,MLCR
Application traffic	CBR

1) Control overhead: The control overhead is defined as the total number of routing control packets normalized by the total number of received data packets.
2) Average end-to-end delay: The end-to-end-delay is averaged over all surviving data packets from the sources to the destinations.
3) Average packet delivery ratio: It is the ratio of the number of packets received successfully and the total number of packets transmitted.

VIII. RESULTS AND DISCUSSION

Nodes	**Delay**		**Overhead**		**Throughput**	
	AODV	**MLCR**	**AODV**	**MLCR**	**AODV**	**MLCR**
25	0.5	0.3	6000	5400	14500	14750
50	0.7	0.4	7200	5900	15500	15900
75	0.9	0.6	7800	6400	15900	16650
100	1.5	0.9	8200	7600	16200	17250
125	1.8	1.3	9400	8100	16900	17875
150	2.4	1.6	10500	8650	17450	18700
175	2.8	1.9	11200	9250	18000	19350
200	3.4	2.2	11850	9900	18700	19900

Table 1: Comparison between AODV and MLCR

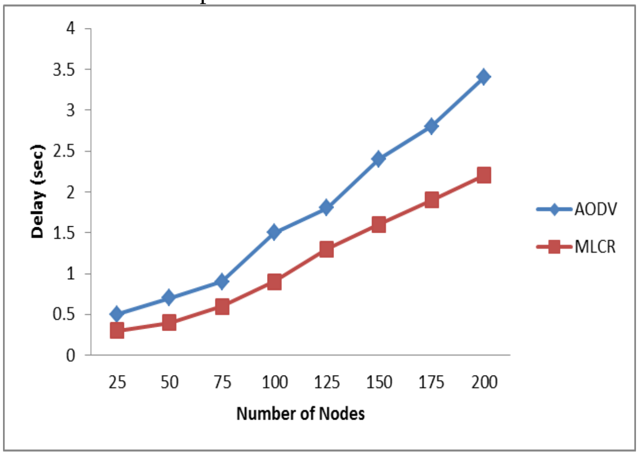

Fig. 2: Delay Vs Number of Nodes

Figure 2 shows the results of average end-to-end delay for the increasing number of nodes. From the results, we can see that MLCR scheme has 56% of lower delay than the AODV scheme.

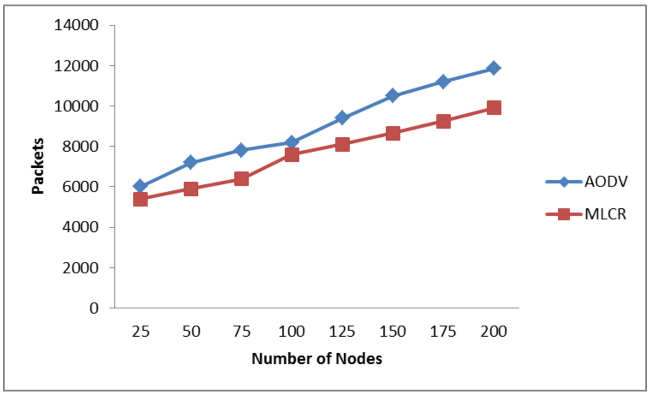

Fig. 3: Routing Overhead

Figure 3 shows the results of routing overhead versus number of nodes. From the results, we can see that MLCR scheme produces 5% less routing overhead than the AODV scheme since it does not involve frequent route re-discovery routines.

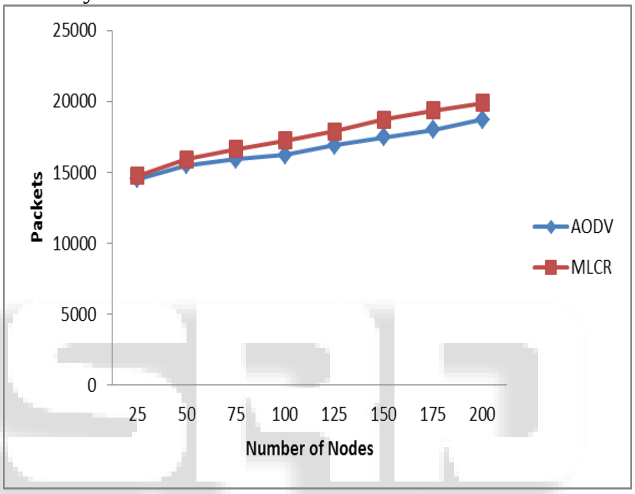

Fig. 3: Nodes Vs Throughput

Figure 4 shows the results of throughput obtained in both the schemes for various numbers of nodes. From the results we can see that our MLCR scheme has 20% high throughput when compared with the AODV scheme.

IX. CONCLUSION

The principle of congestion control technique is to control the traffic and buffer overflow caused by congestion and provide better performance of the network. The proposed approach is very efficient load balancing technique that improves network performance. The proposed a multipath load balanced congestion control routing protocol scheme to achieve load balance and avoid congestion in Mobile Ad Hoc Networks. The algorithm for finding multi-path routes computes fail-safe multiple paths, which provide all the intermediate nodes on the primary path with multiple routes to destination. The fail-safe multiple paths include the nodes with least load and more bandwidth and residual energy. When the normal load of an existing link increases beyond a threshold or the available bandwidth and residual battery power of a node decreases below a threshold, it distributes the traffic over disjoint multi-path routes to reduce the traffic load on a congested link. By simulation results, results shows that the proposed approach alleviates the network congestion.

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