Congestion Aware Multi-Path Routing Protocol for Mobile Ad-Hoc Networks

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[□] *Abstract*—A congestion based extension to existing multipath routing protocol AOMDV (CA-AOMDV) is proposed in this work. AOMDV is based on minimum number of hops count between source and destination nodes and is not suitable for real time applications because of its high end to end delay, jitter and packet loss. CA-AOMDV selects a least congested path instead of minimum number of hops between source and destination nodes. CA-AOMDV performs well under high load and varying mobility conditions. In CA-AOMDV, End to End delay is improved by 20%-80%, jitter is reduced by 25-47%, routing overheads is reduced by 40-70%. The proposed protocol has been tested for node mobility under high load condition.

Keywords— Congestion Level, MANETs, Multipath, Routing Protocol, , Quality of Service (QoS).

I. INTRODUCTION

MOBILE ad-hoc networks (MANET) are infrastructure less highly dynamic communication networks used to transmit data among the communicating nodes in absence of any central co-ordination device. Because of its different architecture, various communication issues like admission control, channel accessing, routing mechanism are dealt differently in MANET and require more attention.

In MANETs, data transmission is affected due to channel sharing and its dynamic topology. In recent years, there has been increasing demand in multimedia communication in such networks. The large amount of real-time traffic tends to be in bursts, is bandwidth intensive and liable to congestion. Congestion leads to packet losses, bandwidth degradation, increased end-to-end delay, jitter and loss of energy. There is a need of a different routing protocol that can either manage congestion or locate a better route to improve the QoS parameters.

Broadly, the existing routing protocols can be classified in two categories: Single path routing protocols and Multipath routing protocols. Single path routing protocols do not perform well in highly dynamic networks. In a single path protocol a new route is to be discovered whenever the only path from the source to the destination fails and results in unnecessary flow of control packets and retransmission of data that adds congestion in the network. Multipath protocols discover multiple paths between the source and the destination nodes in a single route discovery. In these protocols, a new route discovery is needed, which avoids additional control packets and retransmission of data.

By applying congestion control mechanism network bandwidth gets distributed across multiple end-to-end connections. The mechanism is used mainly to limit the delay and buffer overflow caused by network congestion and provide tradeoffs between efficient and fair resource allocation

The existing congestion aware multipath routing protocols designed for other wireless networks are not suitable for MANETs because of its infrastructure less and highly dynamic nature. Most of them select a route depending on the minimum number of hop counts between source and destination nodes. This route (shortest path) may be highly congested as compared to other existing longer paths and may cause high time delay, transmission delay and packet drop rate which results in poor QoS.

In this paper, we propose a Congestion Aware Ad-hoc Ondemand Multipath (CA-AOMDV) routing protocol, which opts a path with minimum congestion but not necessarily with minimum number of hops. The proposed protocol is designed to provide loop-free redundant routes to quickly maintain transmission in case of route break caused due to mobility. CA-AOMDV is implemented using NS-2.35 network simulator and results are compared with AOMDV protocol.

The rest of the paper is organized as follows: Literature Survey is presented in Section II. Section III contains details of the proposed Method. In section IV performance is evaluated results are analyzed and conclusions are given in section V

II. LITERATURE SURVEY

The routing protocols for MANET proposed by different researchers can be categorized as follows on the basis of temporal routing information: (a) table-driven routing (b) ondemand routing (c) single path routing (d) multipath routing (e) flat routing and (f) hierarchical routing protocols. In tabledriven routing protocols, given in [2], [3] and [4], every node maintains a route table which contains information of existing paths between a node and every other neighboring node even when transmission is not required between them. The table information is updated periodically. These protocols generate heavy control packets during high mobility conditions [1]. Ondemand protocols [5], [6] and [7] perform better than tabledriven protocols in which a route is discovered only at the time of transmission and released on its completion.

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A link failure or packet loss due to congestion causes delay and overhead in the network and degrades the performance of the network. The single path routing protocols are not suitable in MANET due to high congestion, high link failure and node mobility. To address this situation, multiple path routing algorithms are considered better. Multipath routing protocols as in [7], [8], [9], [10] and [11] locate various multiple paths from source node to destination node. In case of path break, an alternate path is used to continue the transmission. All these routing protocols are based on hop count between the source and destination nodes.

AOMDV routing protocol is the most popular multi path routing protocol. In AOMDV, a source node locates more than one path and selects one of them having minimum number of hops between them [12], [13]. Though shortest path routing has been proven better than the other protocols discussed earlier for static networks but for a dynamic network, like, MANET shortest path may not give satisfactory QoS due to frequent link breaks which causes retransmission of packet and results in congestion.

To overcome the congestion related problems [14], [15], [16] and [17] have proposed shortest route protocols with effective congestion control schemes. For transmission of real time data, an Adaptive Wavelet and Probability-based scheme (AWP) is proposed in [14]. AWP adopts the Extended Multi Fractal Wavelet Model (EMWM) for analyzing estimated traffic volume across multiple time scales. In [15], authors have compared rate base and queue base congestion control models. In the queue-based model, the queue length at the router is explicitly a part of the model. In [16] and [17], authors have proposed a k-out-of-n congestion system to overcome a single point of failure. In this system, a connection is successfully established between source and destination if none of the intermediate nodes is congested.



Fig.1 Mechanism of a CA-AOMDV

III. PROPOSED METHOD

The proposed CA-AOMDV protocol uses congestion as a parameter to decide a path between source and destination

nodes. It discovers all available transmission routes based on congestion level and number of hops between source and destination nodes. If congestion levels of two paths between source and destination nodes are same then the path with less number of intermediate nodes is be chosen. A path with minimum congestion level is selected as primary path. On failure of primary path CA-AOMDV selects other available path in increasing order of their congestion levels.

Figure 1 shows two paths, path1 ($S \rightarrow A \rightarrow B$ R) and path2 ($S \rightarrow D \rightarrow E \rightarrow F \rightarrow R$) with 2 and 3 hops, respectively. Each node is equipped with a First Come First Serve (FCFS) queue, which stores the data packets in order of their arrival and forwards them to the next node in the path. It may be observed from the figure 1 that path1 with two hops is more congested compared to the path2 with three hops. The CA-AOMDV would select the less congested but longer path path2 and is expected to give better QoS. For a network of 100 nodes within the range of 1000m×1000m, the difference between the path is not greater than two hops and hence the time taken to cross two hops in a less congested path may be less than waiting time in a high congested path.

CA-AOMDV follows following steps for data ommunication:

TABLE I	
CA-AOMDV STEPS	

Step1: Route Discovery Process
Step2: Calculate Path congestion level
Step3: Select a route with minimum avg. congestion level
as primary route and other as secondary in order of
increasing congestion level
Step4: Start Data Transmission
Step5: if current route breaks
Select a new route with next higher congestion
level from the route table
Step 6: repeat step 5 until all routes break
<i>Step 7</i> : If all routes are broken
Go to Step 1.

A. Route Discovery Process

A source node starts route discovery process by generating RREQ packet, and initiating its flooding throughout the network. On receiving RREQ packet, an intermediate node compares destination sequence number available with it with destination sequence number available with RREQ packet. If destination sequence number available with RREQ packet is greater than destination sequence number available with intermediate node then intermediate node calculates its congestion level and forwards the RREQ packet with its congestion level to its neighboring nodes, if there is no direct forward path from it to the destination node. An intermediate node can receive multiple copies of RREQ packet and are examined to form alternate reverse paths. These reverse paths are formed only for those copies of RREQ packets which follow loop freedom and disjoint path conditions. When an intermediate node finds a reverse path to source node, it checks for the one or more forward paths to the destination node. If there exists a forward path, it generates a RREP

packet and sends it to the source node through reverse path. If an intermediate node does not have forward path, it further rebroadcasts the RREQ packet. On receiving a RREQ packet, destination node generates a RREP in response to every RREQ copy that arrives through a loop-free path to the source node. The destination node forms reverse paths using only RREQ copies that arrive through loop-free and disjoint alternate paths to the source node.

B. Path Congestion Level Calculation

CA-AOMDV calculates congestion level for all paths available between source and destination nodes. For calculating congestion level of a path, CA-AOMDV, takes average of congestion levels of all intermediate nodes. If the congestion level at any intermediate node is 1 then the packet loss rate at that node maximum and calculation of congestion level for other intermediate node is aborted. This process is repeated for all available paths.

(i) Congestion Level of a Node

Let n be the size of the buffer at a node (say ith) and m be the number of packets waiting for processing in the buffer at any instant of time t. The congestion level (CL_t^i) at any intermediate node *i* and time *t* can be given as:

$$CL_t^i = \frac{m}{n} \tag{1}$$

The value of CL_t^i lies between zero and one. is zero for empty buffer (m = 0) and one for full buffer (m = n), respectively. We have considered three levels of congestion level: (i) low (ii) medium and (iii) high. A node is low congested, if its congestion level (CL_t^i) is ≤ 0.50 , medium if $0.50 < CL_t^i \leq 0.75$ and high if $CL_t^i > 0.75$.

(ii) Average Congestion level of a Path

Let *k be* the number of intermediate nodes between source and destination nodes then the average congestion level for a path can be calculated as follows:

$$ACL_t^p = \frac{\sum_{i=1}^{k} CL_t^i}{k}$$
(2)

Proposed method is based on finding out the least congested path among available multipath. The source node executes the proposed congestion adaptive routing algorithm to find out all available paths between itself and the destination node. The algorithm calculates the congestion level at each intermediate node and obtains average congestion level of the path. These calculations are repeated for every discovered path. The average congestion levels are compared and the path with minimum congestion level is chosen as primary path and rest of the paths are saved in the routing table for later use in increasing order of their congestion level.

C. Primary Route Selection

CA-AOMDV starts with exchanging RREQ and RREP packets and selects a route with minimum congestion level for data transmission and continues data transmission until link break occurs. If two or more routes are having same congestion level then a path with least number of hops is selected as primary path.

D. Secondary Route Selection

Routes other than primary routes are assumed as secondary routes in CA-AOMDV. On failure of primary path, the path with next higher congestion level is selected as current (secondary) path for continuing data transmission and this condition follows for all available routes between source and destination node.

E. Avoiding Loop Formation

One of the major problems with multipath routing protocol is loop formation. To avoid loop formation while processing multi paths, following two issues arises:

(i) Which one of the available paths should a node advertise to other nodes? Since each of these paths may have different congestion levels.

(ii) Which of the advertised paths should a neighboring node accept?

These problems are demonstrated using figure 2. In figure 2a, node S is the source node and node R is the destination node. Node S has two paths from S to R: path1 and path2.



Fig. 2(a) Routing Loop Scenario I



Fig. 2(b) Routing Loop Scenario II

Let Node S, advertises path1 to node F and path2 to node G, each of them have path to R through S but with different congestion levels. Later if S has a new path via E and F to R through S with lesser congestion level than path1, there are chances of forming a loop. Because S cannot determine whether F is upstream or downstream node to itself as only congestion level is used to advertise route. Figure 2b shows another loop formation situation. Node A and node D have same congestion level to a destination node R. Let D obtain another path to R via A with more congestion level. In this case, D cannot decide whether node A is an upstream node or downstream node. A path with higher congestion level may cause loop in the path. To provide solution to this loop formation problem, we use highest sequence number as solution. Entries of new routes are made into routing table (Table II).

(*i*) For Highest Destination Sequence Number: Routes are maintained for highest sequence number only. We can avoid a loop with a restriction that a node with multiple paths will have same destination sequence number.

(ii) For Same Destination Sequence Number: A source node never advertises a route having a lesser congestion level and the neighbor node never accepts a route having higher congestion level than advertised.

F. Route Maintenance

On failure of current route, CA-AOMDV looks into the routing table for next low congested available route and sends the data via this new route. The lost packets due to link break are resend through this new alternate route. In case of failure of all routes, the node generates and forwards RERR packets towards destination node to restart route establishment process. In MANET, a route may not be active for longer time and for a very short duration may lose the benefit of multipath routing. CA-AOMDV uses a moderate setting to timeout value of a route and uses HELLO packets to proactively remove the old routes.

CA-AOMDV uses source sequence number and destination sequence number for updating the information about latest route between source and destination node. Source and destination sequence numbers are time stamps which allow a node to compare how fresh their information on other node is. The structure used in the algorithm is shown in figure 4. Parameter (advertised_cng_level) is used to advertise the maximum value of path congestion level to avoid loop formation. Route list contains the (next hop, last hop, hop count, path congestion level, time to live) informations about each alternate path. An intermediate node i compares its destination sequence number $(seq_num_i^d)$ with the destination sequence number of RREP packet $((seq_num_i^d))$. If $(seq_num_i^d <$ then node i update the route list with latest $seq_num_i^d$) sequence number (figure 4b) and initialize corresponding advertized congestion level as follows:



advertised_cng_level=max(cng_level_...cng_level_n)

= 0, otherwise.

(3)





Fig 3b Node Disjoint Path

IV. III. DATA PACKET FORWARDING

A source node with real time data in CA-AOMDV, initiates with route establishment process, selects a route with minimum congestion level and forwards data packets to the destination node. On failure of current path CA-AOMDV switches to next available path with minimum congestion level available in routing table and continue data packet forwarding.

TABLE II ROUTING TABLE STRUCTURE

Destination	Sequence Number	Advertised Hop Count	Advertised Cong. Level	Route List				
				Next hop1 Next hop2 :	Last hop1 Last hop2 :	Hop count 1 Hop count2 : :	Cng_level1 Cng_level2 :	TTL1 TTL2 :

if $(seq _num_i^d < seq _num_i^d)$ then $seq _num_i^d := seq _num_i^d;$ advertised $_hop_count = \infty$ *advertised* _*cng* _*level* = 1; // maximum congestion level =1 *route* $_{list_i^d} = NULL;$ if (j=d) then insert (j,i,1,0) into route $_list_i^d$; // Neighbor is the destination else insert (j, last _ hop $_{ik}^d$, advertised _ hop _ count $_i^d$ +1, advertised _ cng _ level $_i^d$ + cng _ level $_i$) into route _ list $_i^d$; end if else if $((seq_num_i^d = seq_num_j^d)$ and $(advertised_cng_level_i^d > advertised_cng_level_j^d))$ then //Apply route maintenance rule if (j=d) then if $((next _hop_{ik1}^d = j)$ and $(last _hop_{ik2}^d = i))$ then //uniqueness of next hop and last hop is insert (j,i,1,0) into route $_list_i^d$; // checked for path k1 and k2 respectively. end if else if $((next _hop_{ik3}^d = j)$ and $(last _hop_{ik4}^d = last _hop_{ik}^d)$ then insert (j, last $_{hop}^{d}$, advertised $_{hop}_{count}^{d}$ +1, advertised $_{cng}_{level}^{d}$ + cng $_{level}_{i}$) into route $list_i^d$: //uniqueness of next hop and last hop is established end if end if

end if

end if

Fig. 4 Route updating process in CA-AOMDV, invoked by a node i on receiving a route advertisement for a destination d from a neighbor j.

V. PERFORMANCE EVALUATION

NS-2.35 simulator is used to test the performance of the network. Observations are taken for End to End Delay, Jitter and Routing Overhead for different mobility and congestion levels. The nodes are free to move in all directions and create link breaks at unknown intervals. Simulation parameters are given in table III and congestion level are defined in table IV.

SIMULATION PARAMETERS					
S.	Network Components	Value			
No.	_				
1	Number of Nodes	100			
2	Number of CBR/UDP	50			
	Connections				
3	Bandwidth	200 Kbps			
4	MAC Layer	802.11			
5	Simulation Area	1000m×1000m			
6	Node Mobility	1-15 m/s step 5			
7	Packet Rate	1-50 packets/s step			
		10			
8	Queue Buffer Size	50			

TABLE III

I ABLE IV					
CONGESTION LEVELS					
S. No.	Packet Rate	Congestion Level			
1	1-10 packets/s	low			
2	20 - 30 packets/s	medium			
3.	40-50 packet/s	high			

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A. End to End Delay (E2E Delay)

Figure 5 shows the effect of packet rate on end to end delay when nodes moves at 1 m/s. 5 m/s 10 m/s and 15 m/s. For both CA-AOMDV and AOMDV E2E delay increases with increasing packet rate but CA-AOMDV provides low (80% of AOMDV) end to end delay in comparison to AOMDV at high congestion level (packet rate 50 packet/s). The improvement in this QoS parameter may be attributed to congestion aware nature of the protocol.

At 1m/s average speed, average end to end delay is reduced by 80% as compared to AOMDV (figure 5a). But as speed increases to 5 m/s (figure 5b), 10 m/s (figure 5c) and 15 m/s (figure 5d), it is reduced to 50%. High speed likely to cause link breaks and create a reduction of 30% in average end to end delay at 5 m/s,10 m/s and 15 m/s . CA-AOMDV gives good results under all congestion levels at avg. speed of 1 m/s, 5 m/s and 10 m/s. At 15 m/s (figure 5d), the results are obtained suitable for packet rate up to 30 packets/s.



(a) End to End Delay at 1m/s







(c) End to End Delay at 10 m/s



(d) End to End Delay at 15m/s Fig. 5 End to End delay in CA-AOMDV

B. Jitter

Jitter is an important QoS parameter for real time applications. Growth in jitter is reduced by a factor of 2 for all packet rates in CA-AOMDV than AOMDV.

In AOMDV, for medium and high congestion levels, jitter is increased in the range of 150%-210% and 300%-350% than low congestion level. In CA-AOMDV this growth is less and lies in the range of 110%-125% and 155%-170%.

In CA-AOMDV, as congestion level increases jitter increases but give much better results than AOMDV. Packet loss and delay is low in CA-AOMDV because of less congestion in the route which results in better jitter performance. At 1 m/s (Fig. 6a) and 5 m/s (Fig. 6b) speed, congestion level do not have much effect in CA-AOMDV but at avg. speed of 10m/s (Fig. 6c) and 15m/s (Fig. 6d) and packet rate 40 packets/s jitter increases with very high rate (100%-300%) because of link breaks and retransmission of lost packets. Real time applications can bear a maximum jitter of 30 ms. CA-AOMDV is a better option for real time data transmission at high load of 20 mbps up to 10m/s avg. speed of the nodes and 80 kbps at 15 m/s.



(a) Jitter at 1 m/s



(b) Jitter at 5 m/s



(c) Jitter at 10 m/s



Fig. 6 Jitter in CA-AOMDv

C. Routing Overheads

CA-AOMDV calculates congestion level at the time of route discovery so initial Routing overheads in CA-AOMDV are more than AOMDV. But as congestion level grow from low to medium and high routing overheads are improved by 70%-80%. For medium and high congestion level routing overheads are almost constant at 1m/s and 5m/s.

In AOMDV, routing overheads increase by 150%-300% due to high packet drop rate caused by congestion.

Initial routing overheads are increased by more than 100% with mobility of nodes from 1m/s to 15 m/s both in AOMDV and CA-AOMDV. High speed causes more link breaks and adds additional overheads in the network. Later routing overheads are increased in the range of 10%-300% for both the protocols

VI. CONCLUSION

Multipath protocols based on minimum hop counts do not fulfill QoS requirements of real time data transmission in MANET. In this paper we propose a congestion aware multipath routing protocol (CA-AOMDV) for MANET to transmit the data under heavy load conditions. CA-AOMDV detects all paths between source and destination node which are less congested. In CA-AOMDV, End to End delay is improved by 20%-80%, jitter is reduced by 25-47%, and even though initial routing overhead is increased by 10% but overall routing overhead is reduced by 40-70% and packet delivery ratio. This work can be extended in future for simultaneous transmission of higher priority video packet (I packets) on less congested path and low priority video(P and B) packets on higher congested path.

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