Cross Layer based Congestion Control Technique for Reliable and Energy Aware Routing in MANET

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ABSTRACT
Since the congestion problem is prevalent in transport, data link and network layer in Mobile Ad hoc networks, a cross layer based congestion control technique is necessary to overcome the congestion problem. In this paper, we propose a cross-layer based technique to overcome congestion that occurs in MAC and transport layer in MANET. The proposed technique is applied over a Ad hoc On demand Multipath Reliable and Energy Aware QoS Routing Protocol (AOMP-REQR). The technique of additive increase and multiplicative decrease (AIMD) is applied for rate based congestion control of transport layer protocol. If source receives congestion status information from both MAC and transport layer simultaneously for the same route, then congestion free route will be established for transmission, without performing rate control. By simulation results, we show that the proposed technique attains more packet delivery ratio with less packet drop and reduced delay.

Keywords
AIMD, Congestion, Cross layer, Energy, Reliable, Routing

1. INTRODUCTION
A Mobile Ad-Hoc Network (MANET) is a self-configuring network of mobile nodes connected by wireless links, to form an arbitrary topology. The nodes are free to move arbitrarily. Thus, the network's wireless topology may be random and may change quickly. Such a network may operate in a standalone fashion, or may be linked to the larger Internet. An ad Hoc network is formed by sensor networks consisting of sensing, data processing, and communication components. Due to its deficiency in infrastructure support, each node acts as a router, forwarding data packets for other nodes [1]. Its application area includes Tactical Networks, Emergency Services, Commercial Environments Educational Applications and Entertainment.

Routing is the process of selecting paths in a network along which to send network traffic. Routing is performed for many kinds of networks, including the telephone network (Circuit switching), electronic data networks (such as the Internet), and transportation networks. Nodes in traditional wired networks do not route packets, while in MANET every node is a router. Nodes transmit and receive their own packets and also forward packets for other nodes. Due to mobile nodes, topologies are dynamic in MANET, but are relatively static in traditional networks. Connectivity and interference are indicated by link layer information. A traditional router has an interface for each network to which it connects, while a MANET “router” has a single interface. Routed packet sent forward during transmission also gets transmitted to the previous transmitter.

In mobile wireless ad hoc networks the key issue is network congestion and traffic blocking. The congestion occurs in mobile ad hoc networks due to limited availability of resources. The packet transmission in these networks experience interference and fading owing to shared wireless channel and dynamic topology. The network is loaded because of transmission errors. The multimedia communication in MANET is developing with increased demand in recent times. Real time traffic lead to high bandwidth and it results in congestion. Further, congestion causes packet losses and bandwidth degradation and hence can waste time and energy on congestion recovery. [2]

The existing adhoc routing protocols do not aware about congestion. In this paper, we propose routing protocol Cross layer Congestion Aware Reliable and Energy Aware QoS Routing Protocol. The motivation is to reduce the packet loss in MANETs, typically which involves congestion control technique running on top of a routing protocol at the network layer. If congestion happens at the time of routing, it is detected and handled by congestion control. Normally the routing protocols in MANETs which does not aware congestion may lead to the following problems:

a) Long delay: It delays the process of detecting congestion. If the congestion is severe, it is best way to choose a new route. The main drawback of existing on-demand routing protocol is that it delays the process of searching the new route.

b) High overhead: The processing and communication effort is required to discover a new route. In spite of alternate route availability, if multipath routing is used, more effort is required to maintain multiple paths.

c) Many packet losses: Within the time the congestion is detected, many packets might have lost. The congestion control techniques reduces the traffic load either by decrementing the sending rate at the sender or by dropping packets at the intermediate nodes or by performing the both and this results in high packet loss rate or reduced throughput at the receiver section. [3]

d) The routes are predefined for any source-destination pair without including the traffic demand and there exists interference among link. These will result in congestion problem [4].

e) Those transport layer flows which do not share a wireless link can compete when they are close, which leads to congestion. For all these phenomena, a MAC protocol that defines rules for orderly or random access to the physical shared medium plays significant role and need to be optimized with congestion control to make sure about efficient utilization and sharing of network resources [3].

Congestion control technique is the method by which the network bandwidth is distributed across multiple end to end connections. Limiting the delay and buffer overflow due to network congestion is the main aim of congestion control technique and it offers tradeoff between efficient and fair resource allocation. The leading cause for packet loss in MANET is congestion. The reduction of packet loss involves congestion control which is operating on top of mobility and failure adaptive routing protocol at the network layer [5].

In previous work [8], we have developed a Adhoc Ondemand Multipath Reliable and Energy Aware QoS Routing Protocol (AOMP-REQR) for MANETs to provide a combined solution for both energy consumption and reliability. In this protocol, multiple disjoint paths are determined for a source and destination and the routes are selected based on Route availability (RA) which is estimated from link availability (LA) and total energy consumed (TE) during the transmission of packets.

In this paper, Cross layer Congestion Aware REQR is proposed as an extension work of [8] to overcome the congestion problem encountered in transport, data link and network layers. In transport layer, if the rate of packet delivered through the route exceeds the predefined threshold, it will lead to congestion problem. In MAC layer the congestion occurs due to the signal interference. If the congestion problem occurs in both the layers at the same time, a node formulates a list containing affected route entries and this information is broadcasted to the corresponding nodes. The nodes upon receiving the message send the congestion information to source so that data packet rate of the source is reduced or another congestion free route is selected.

The remainder of this paper is organized as follows. Section 2 gives the previous related works. The detail of proposed protocol is described in Section 3. The simulation results of our performance study are given in Section 4. Section 5 concludes the paper.

2. RELATED WORK

Every host maintains a routing table containing the distances from it to possible destinations in a distance vector routing protocol. The delay of sending a packet is positively correlated with congestion. In Congestion Aware Distance Vector Protocol (CADV) [11], each entry is associated with an expected delay, which measures congestion at the next hop. Every host estimates the expected delay based on the mean of delay for all data packets sent in a past short period of time. Currently, the length of the period is equal to the interval between two periodical updates.

CRP (congestion-adaptive routing protocol) [3] tried to prevent the congestion from occurring in the first place, rather than dealing with it reactively. A key in CRP design is the bypass concept. A bypass is a sub-path connecting a node and the next non-congested node. If a node is aware of a potential congestion ahead, it finds a bypass that will be used in case the congestion actually occurs or is about to. Part of the incoming traffic will be sent on the bypass, making the traffic coming to the potentially congested node less. The congestion may be avoided as a result. Because a bypass is removed when the congestion is totally resolved, CRP does not incur heavy overhead due to maintaining bypass paths. The bypass maintenance cost is further reduced because a bypass is typically short and a primary node can only create at most one bypass.

[2] proposed a hop-by-hop congestion aware routing protocol which employs a combined weight value as a routing metric, based on the data rate, queuing delay, link quality and MAC overhead. Among the discovered routes, the route with minimum cost index is selected, which is based on the node weight of all the in-network nodes

DLAR (Dynamic Load-Aware Routing) [12] considers the load of intermediate nodes as the main route selection metrics and monitors the congestion status of active routes to reconstruct the path when nodes of the route have their interface queue overloaded. DLAR uses the number of packets buffered in the interface as the primary route selection criteria and DLAR builds routes on-demand.

Cross layer hop by hop congestion control scheme [6] is proposed to improve TCP performance in multihop wireless networks which coordinates the congestion response across the transport, network, and transport layer protocols. The proposed scheme attempts to determine the actual cause of a packet loss and then coordinates the appropriate congestion control response among the MAC network, and transport protocols. The congestion control efforts are invoke at all intermediate and source node along the upstream paths directed from the wireless link experiencing the congestion induced packet drop.

A multi agent routing protocol [7] is proposed to reduce network congestion for MANET. They use two kinds of agents: Routing Agents to collect information about congestion and to update the routing table at each node, and Message Agents to move using this information. In the future, they will investigate a better evaluation function and discuss the limits of its effectiveness. The evaluation function itself may change depending on the environment. Incorporating learning into the function is also an interesting issue.

3. CROSS LAYER BASED CONGESTION CONTROL TECHNIQUE

The proposed technique is applied over a reliable and energy aware routing protocol. In transport layer, if the received packet rate exceeds the predefined threshold, then source decrements the sending rate. In MAC layer, if the estimated received power at current time is beyond an exponential average power of received signal, signal interference will be indicated and the link is assumed to be congested. If the congested route entries exceed, then a new alternative route is established for transmission. If source receives congestion status information from both MAC and transport layer simultaneously for the same route, then congestion free route will be established for transmission, without performing rate control.

3.1 AIMD mechanism of TCP

The additive increase/multiplicative-decrease (AIMD) algorithm is the congestion control algorithm used in TCP. AIMD combines linear growth of the congestion window with an exponential reduction when congestion takes place. The approach taken is to increase the transmission rate (window size), probing for usable bandwidth, until loss occurs. The policy of additive increase (Figure 1) may, for instance, increase the congestion window by 1 MSS (Maximum segment size) every RTT (Round Trip Time) until a loss is detected. When loss is detected, the policy is changed to be one of multiplicative decrease, which may, for instance, cut the congestion window in half after loss.

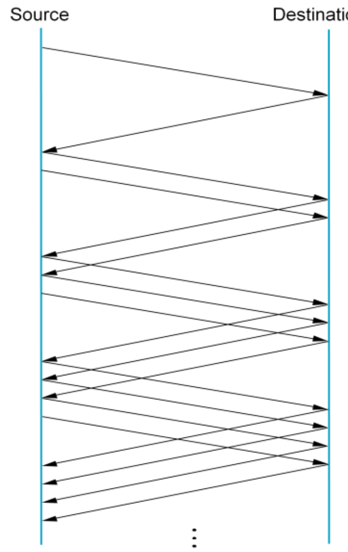

Figure1. Packets in transmit during additive increase, with one packet being added each RTT.

3.2 Congestion Detection in Transport Layer

The additive increase and multiplicative decrease (AIMD) is applied for rate based congestion control of transport layer protocol. Rate based congestion control is worked as follows. Source measures the T_{oack} and T_{nack} time values when ACK packets are created at the receiver, as indicated in the ACK packets. ACK packet informs the source regarding the amount and time interval at which the data was received at the destination. A rate adjustment algorithm is used at the source to adjust the sending rate using this ACK information. Source estimates values of D_{oap} and D_{nap} as indicated in the ACK packets.

where T_{oack} - Old ACK time, T_{nack} - New ACK time,
D_{oap} - Number packets received at T_{oack},
D_{nap} - Number of packets received at T_{nack}.

The timer and a received data counter are equipped in the destination node. Both will be initiated, whenever the first packet arrives. According to timer and counters preset values, receiver feedback collective acknowledgment (ACK) packet which informs the source about total number of packets which has been received and the time between this group of ACK packet and the last collective ACK packet and reset the timer. The source calculates the actual receiving packet rate (RPR) of the destination using the formula,

$$RPR = \frac{D_{nap} - D_{oap}}{T_{nack} - T_{oack}} \qquad (1)$$

The sending rate can be adjusted using following condition:

If (RPR ≥ Threshold $_{predefined}$)
SR = SR/2;
Else
SR = SR + 1;

where, RPR - Received packet rate
SR - Sending rate

3.3 Congestion Detection in MAC layer

If packet drop is experienced or data is not delivered along a wireless link which is not subject to failures, then it can be identified that it is because of signal interference from nearby transmission. In other words, if a wireless link undergoes a packet loss at the MAC layer due to signal interference, it indicates the presence of congestion at the contention area of the link. We now develop a congestion detection technique based on the current received signal.

Let P_l - Power of latest signal received measured in db
T - Predefined window
t - Time period from the last received to till now
P_r - Exponential average power of received signal in T
P_c - Estimated received power at current time
P_{thr} - Threshold value of Pr in db
δ - slope of P_r

The power of current signal received which is estimated during the packet drop is given as

$$P_c = P_r + \delta_t \qquad (2)$$

If (P_c < (P_{thr}) then
MAC layer will report a link failure to the routing protocol.
Else
MAC layer indicates signal interference to routing protocol and the link is assumed to be congested.

The routing table is updated with the congested route entries. This information is forwarded to source using routing protocol.

3.3 Congestion Control Technique

Case 1: Congestion detected in Transport layer
If (RPR > Threshold $_{predefined}$) then
The source decrements the sending rate.

Case 2: Congestion detected in MAC layer

If a wireless link experiences a packet loss at the MAC layer due to signal interference, it indicates the presence of congestion at the contention area of the link. If the congested route entries found, then new alternative route is established for transmission.

Case 3: Congestion detected in both Transport and MAC layer at the same time.

If source receives congestion status information from both MAC and transport layer simultaneously for the same route, then congestion free route will be established for transmission, without performing rate control.

4. SIMULATION RESULTS

4.1. Simulation Model and Parameters

We use NS2 [9] to simulate our proposed protocol; the channel capacity of mobile hosts is set to the same value: 2 Mbps. We use the distributed coordination function (DCF) of IEEE 802.11 for wireless LANs as the MAC layer protocol. It has the functionality to notify the network layer about link breakage. In our simulation, mobile nodes move in a 1000 meter x 1000 meter region for 100 seconds simulation time. We assume each node moves independently with the same average speed. All nodes have the same transmission range of 250 meters. The network size is fixed as 100 nodes and the pause time of the mobile node is 10 seconds. The speed of the mobile node is set as 10 m/s. The simulated traffic is Constant Bit Rate (CBR). We apply our cross-layer based congestion control technique (CBCCT) over our previous work AOMP-REQR [9] and AOMDV [15] protocol. Our simulation settings and parameters are summarized in Table 1

TABLE 1 Simulation Settings

No. of Nodes	100
Area Size	1000 X 1000
MAC	802.11
Routing Protocol	AOMP-REQR
Transmission range	250m
Simulation Time	100 sec
Traffic Source	CBR
Packet Size	512 Bytes
Mobility Model	Random Way Point
Speed	10 m/s
Rate	50,100,150,200 and 250 kb
No. of Flows	1 to 5

4.2 Performance Metrics

We compare our CBCCT with the Adhoc Ondemand Multipath Reliable and Energy Aware QoS Routing Protocol (AOMP-REQR) [8] and AOMDV [13]. We evaluate mainly the performance according to the following metrics.

Average end-to-end delay: The end-to-end-delay is averaged over all surviving data packets from the sources to the destinations.

Average Packet Delivery Ratio: It is the ratio of the number of packets received successfully and the total number of packets sent.

Drop: It is the number of packets dropped.

4.3. Results and Discussion

Initially, we vary the number of CBR flows as 1,2,3,4 and 5 with rate as 250kb.

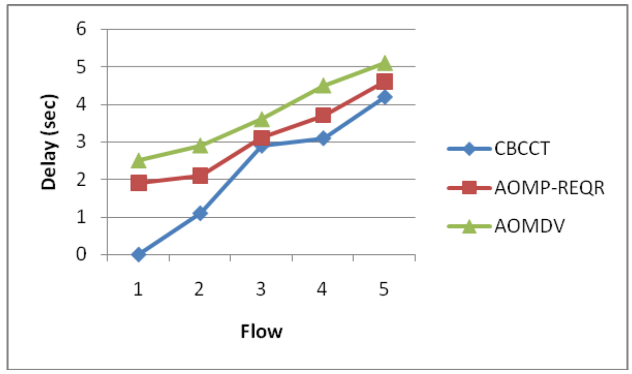

Fig 2: Flow Vs Delay

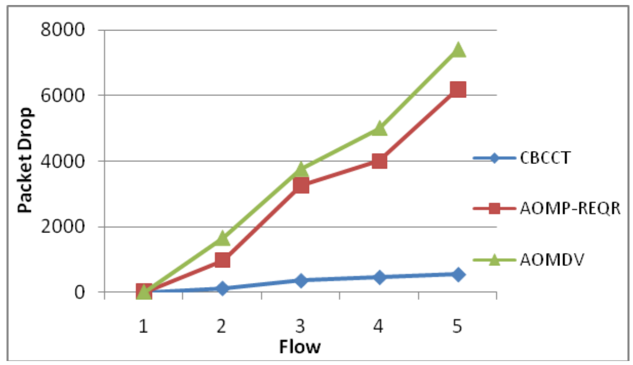

Fig 3: Flow Vs Packet Drop

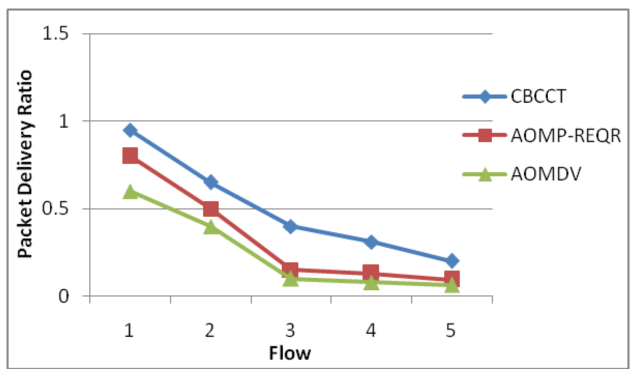

Fig 4: Flow Vs Packet Delivery Ratio

When the number of flows increases, it results in interference at MAC layer and overloaded traffic rate at the transport layer. As a result, the number packet drops and delay increase while the packet delivery ratio decreases. From Figure 2, we can see that the average end-to-end delay of the proposed CBCCT protocol is less when compared to the AOMP-REQR and AOMDV protocol. From Figure 3, we can ensure that the drop is less for CBCCT when compared to AOMP-REQR and AOMDV. Figure 4 presents the packet delivery ratio of both the schemes. Since the packet drop is less, CBCCT achieves good packet delivery ratio, compared to AOMP-REQR and AOMDV.

In the second experiment, we vary CBR traffic rate as 50,100,150,200 and 250kb for the five flows.

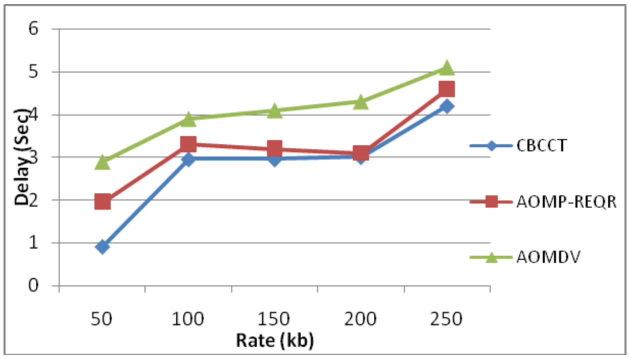

Fig 5: Rate Vs Delay

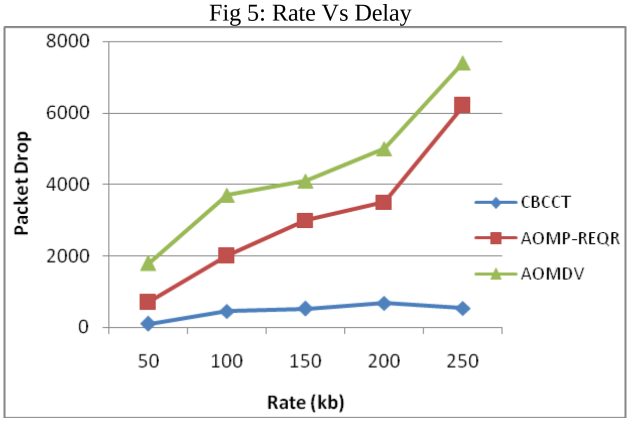

Fig 6: Rate Vs Drop

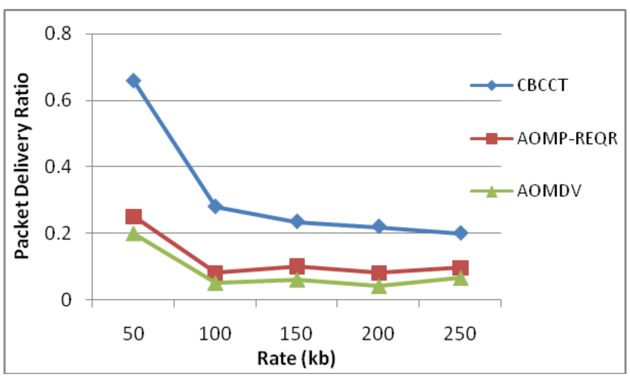

Fig 7: Rate Vs Delivery Ratio

When the traffic rate increases, it results overloaded traffic rate at the transport layer. As a result, the number packet drops and delay increase while the packet delivery ratio decreases. From Figure 5, we can see that the average end-to-end delay of the proposed CBCCT protocol is decreased when compared to the AOMP-REQR and AOMDV protocol. From Figures 6, we can ensure that the drop is less for CBCCT when compared to AOMP-REQR and AOMDV protocol. Figure 7 presents the packet delivery ratio of all the protocols. Since the packet drop is less, CBCCT achieves good delivery ratio, compared to AOMP-REQR and AOMDV.

5. CONCLUSION

The congestion problem is prevalent in transport, MAC and network layer. Congestion causes packet losses and bandwidth degradation and also wastes time and energy on congestion recovery. In this paper, we have proposed a combined technique to overcome congestion in MAC and Transport layer in MANET. The proposed technique is applied over a Adhoc Ondemand Multipath Reliable and Energy aware Quality of Service Routing Protocol. The technique of additive increase and multiplicative decrease (AIMD) is applied for rate based congestion control of transport layer protocol. In transport layer, if the received packet rate exceeds the predefined threshold, then source decrements the sending rate. In MAC layer, if the estimated received power at current time is beyond an exponential average power of received signal, signal interference will be indicated and the link is assumed to be congested. If the congested route entries exceeds, then a new alternative route is established for transmission. If source receives congestion status information from both MAC and transport layer simultaneously for the same route, then congestion free route will be established for transmission, without performing rate control. By simulation results, we have shown that the proposed technique attains less packet drop with reduced delay.

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