An Adaptive Congestion Control Mechanism for Streaming Multimedia in Mobile Ad-hoc Networks

B. Ramesh[1], D. Manjula[2]

[1]Department of Computer Science and Engineering, College of Engineering, Anna University, Chennai, India
[2]Department of Computer Science and Engineering, College of Engineering, Anna University, Chennai, India

Abstract

In mobile ad hoc networks, most of the present routing protocols are designed to have congestion aware, but not congestion adaptive. The way in which the congestion is handled results in longer delay and more packets to be lost for streaming multimedia. When a new route is needed, the routing protocols require a significant overhead in finding it. Mobile Ad hoc Networks shows unexpected behavior with multiple data streams under heavy traffic load such as multimedia data when it is sent to common destination. The main reason for more delay and packet loss in mobile ad hoc networks is due to congestion. The system adapts adaptive congestion control aware to existing routing protocols in mobile ad hoc networks. In this paper we propose an adaptive congestion control method, in which perform well even during constrained situation. We have considered four popular routing protocols such as AODV, DSR, DSDV and TORA to analyzing the performance of the system. The proposed congestion control routing protocol will perform well for all the other routing protocols during heavy traffic loads. We can suggest here that routing protocols should not have only be aware of but also be adaptive to network congestion.

I INTRODUCTION

The mobile ad hoc networks is a consisting of a collection of mobile nodes, dynamically create a wireless network among themselves without using any infrastructure or administrative support as shown in figure 1. Ad hoc wireless networks are self-creating, self-organizing, and self-administering. They come into being solely by interactions among their constituent mobile nodes, and only such interactions are used to provide the necessary control and administration functions supporting such networks. The ad hoc wireless networks offer unique benefits and versatility for certain environments and certain applications. The preexisting fixed infrastructure and base stations are not being prerequisite. They can be created and used any time, anywhere. Such networks could be intrinsically fault-resilient, for they do not operate under the limitations of a fixed topology. Indeed, since all nodes are allowed to be mobile, the composition of such networks is necessarily time varying. Addition and deletion of nodes occur only by interactions with other nodes; no other agency is involved. Such perceived advantages elicited immediate interest in the early days among military, police, and rescue agencies in the use of such networks, especially under disorganized or hostile environments, including isolated scenes of natural disaster and armed conflict. In recent days, home or small office networking and collaborative computing with laptop computers in a small area (e.g., a conference or classroom, single building, convention center) have emerged as other major areas of potential application. In addition, people also recognize that ad hoc networking has obvious potential application in all the traditional areas of interest for mobile computing.

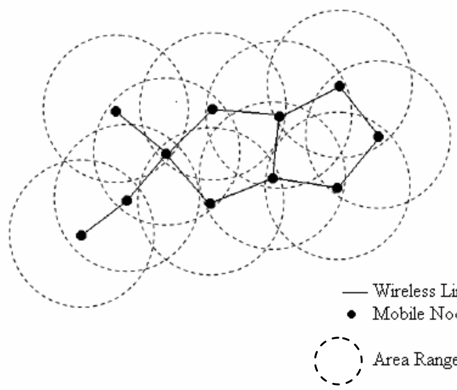

Figure 1 A Schematic diagram of Mobile Ad Hoc Network

In mobile ad hoc networks, a message sent by a mobile node may be received simultaneously by all of its neighboring nodes**.** Messages directed to mobile nodes not within the sender's transmission range must be forwarded by neighbors, which thus act as *routers***.** Due to mobility it is

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not possible to establish fixed paths for message delivery through the network. Mobile Ad hoc networks are composed of mobile stations communicating solely through wireless links [1]. Routing protocols are classified as *proactive or reactive*, depending on whether they keep routes continuously updated, or whether they react on demand.

The routing protocols [2] can also be categorized based on congestion-adaptive versus congestion-un adaptive routing. The congestion unawareness in routing in MANETs may lead to the following issues.

Maximum delay to find a new route: Traditional routing protocol takes maximum time for congestion to be detected by the congestion control mechanism. In severe congestion situations, it may be better to use a new route. The problem with an on-demand routing protocol is the delay it takes to search for the new route.

Huge routing overhead: In case a new route is needed, it takes processing and communication effort to discover it. If multi-path routing is used, though an alternate route is readily found, it takes effort to maintain multiple paths.

Heavy packet loss: Many packets may have already been lost by the time congestion is detected. A typical congestion control solution will try to reduce the traffic load, either by decreasing the sending rate at the sender or dropping packets at the intermediate nodes or doing both. The consequence is a high packet loss rate or a small throughput at the receiver.

The above problems become more visible in large-scale transmission of traffic intensive data such as multimedia data, where congestion is more probable and the negative impact of packet loss on the service quality is more of significance. We have proposed A Novel Congestion Adaptive Routing Protocol which tries to prevent congestion from occurring in the first place and be adaptive should a congestion occur. The ns-2 simulation results show that our protocol significantly improves the packet loss rate and end-to-end delay while enjoying small protocol overhead and high-energy efficiency as compared to AODV [6], DSR [16], DSDV [7] and TORA [20]. Our proposed Novel Adaptive Congestion Control Routing Algorithm protocol tries to prevent congestion from occurring in the first place and be adaptive should a congestion occur.

The remainder of the paper is organized as follows: Review of all four routing protocols is presented in Section II. The detail observation on constraint environment is discussed in Section III. The proposed congestion control protocol is presented in Section IV. In Section V we investigate simulation results and analysis of obtained results. Finally, Section VI concludes this paper and defines topics for further research.

II REVIEW OF ROUTING PROTOCOLS

A AODV (Ad hoc On-Demand Distance Vector)

AODV (Ad hoc On-demand Distance Vector) is a dynamic, self-starting, multi-hop on-demand routing protocol for mobile wireless ad hoc networks. AODV discovers paths without source routing and maintains table instance of route cache. This is loop free and uses destination sequence numbers. The mobile nodes to respond to link breakages, changes in network topology in a timely manner. AODV also maintains active routes only while they are in use and delete the stale (unused) route. AODV performs Route Discovery using control messages Route Request (RREQ) and Route Reply (RREP) whenever node wishes to send packet to destination. The source node in network broadcasts RREQs to neighbors and uses an expanding ring search technique. The forward path sets up in intermediate nodes in its routing table with a lifetime association using RREP. When route is broken, destination or intermediate node moves RERR to the source node. When RERR is received, source node reinitiate discovery is still needed.

B Dynamic Source Routing

DSR (Dynamic Source Routing) is reactive, simple and efficient routing protocol for multi-hop wireless ad hoc networks of mobile nodes. DSR uses source routing and protocol is composed of two main mechanisms: Route Discovery and Route Maintenance, which works together entirely, on-loop-free routing, rapid discovery when routes in the network change, designed for mobile ad hoc networks of up to about two hundred nodes and to work well even with high rates of mobility. The source route is needed when some nodes originate a new packet destined for some node by searching its route cache or initiating route discovery using RREQ and RREP messages. On detecting the break, DSR sends RERR message to source for new route.

C DSDV (Destination Sequenced Distance Vector)

The Destination-Sequenced Distance-Vector (DSDV) Routing Algorithm is based on the idea of the classical Bellman-Ford Routing Algorithm with certain improvements. Every mobile station maintains a routing table that lists all available destinations, the number of hops to reach the destination and the sequence number assigned by the destination node. The sequence number is used to distinguish stale routes from new ones and thus avoid the formation of loops. The stations periodically transmit their routing tables to their immediate neighbors. A station also transmits its routing table if a significant change has occurred in its table from the last update sent. So, the update is both time-driven and event-driven.

The routing table updates can be sent in two ways: - a "full dump" or an incremental update. A full dump sends the full routing table to the neighbors and could span many packets whereas in an incremental update only those entries from the routing table are sent that has a metric change since the last update and it must fit in a packet. If there is space in the incremental update packet then those entries may be included whose sequence number has changed. When the network is relatively stable, incremental updates are sent to avoid extra traffic and full dump are relatively infrequent. In a fast-changing network, incremental packets can grow big so full dumps will be more frequent.

D TORA (Temporally Ordered Routing Algorithm)

The Temporally-Ordered Routing Algorithm (TORA) is "an adaptive routing protocol for multi-hop networks". TORA is a distributed algorithm so that routers only need to maintain knowledge about their neighbors. TORA also maintains states on a per destination basis like other distance-vector algorithms. It uses a mix of reactive and proactive routing. Sources initiate route requests in a reactive mode. At the same time, selected destinations may start proactive operations to build traditional routing tables. Usually, routes to these destinations may be consistently or frequently required, such as routes to gateways or servers. TORA supports multiple path routing. It is said that TORA minimizes the communication overhead associated with adapting to network topology changes. The reason is that TORA keeps multiple paths and it does not need to discover a new route when the network topology changes unless all routes in the local route cache fail. Hence, the trade off is that since multiple paths are used, routes may not always be the shortest ones.

TORA uses the concept of *height* associated with a certain destination to describe the routing metric used by routers. Like water flows in pipes, routers with higher heights may forward packet flows to neighbors with lower heights. Note that since heights for routers are associated with particular destinations, the paths to forward packets are also associated with the corresponding destinations. In networks using TORA, an independent copy of TORA runs for each possible destination. So for different destinations, routers may have different heights and links can have different directions.

III OBSERVED PROBLEM IN CONSTRAINED SITUATION

The experiments are conducted with six CBR traffic sources sessions between common destination using AODV, DSR, DSDV and TORA. We have considered three performance metrics such as Packet Delivery Ratio, Average End-to-End Delay and Routing Overhead. In normal case AODV outperforms better than routing protocols. The TORA performs better than DSDV.

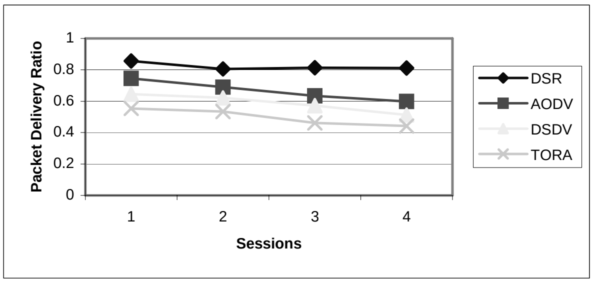

Figure 1 Performance of Routing Protocols in Constraint Situation

But under constraint situation the same routing protocols behaves differently. With the six CBR traffic sources to a common destination, AODV suffers degradation up to 35% whereas DSR suffers only 10% compared to normal situation. TORA suffers degradation of 45% whereas DSDV suffers only 15%. On comparing their performances, it was observed that DSR performs better than other three routing protocols. The main reason for performance degradation in packet delivery ratio is due to packet drops by the routing algorithm after being failed to transfer the data in the active routes. There are several reasons for packet drops such as network partitioning, link break, collision and congestion in the ad hoc networks. The main important property of routing algorithm is quick link recovery through efficient route maintenance. Therefore the DSR routing protocol has fast reaction for link recovery and finds alternative path (during congestion) in compared with AODV and other routing protocols in the given situation. This is shown in the Figure 1.

IV PROPOSED NOVEL ADAPTIVE CONGESTION CONTROL ALGORITHM

The Algorithm is designed to ensure the high availability of alternative routes and reduce the rate of stale route.

A Protocol Design

Every node appearing on a route warns its previous node when there is congestion. The previous node uses "non congested" route to the node on the main route.

The congestion may result in any of the following reasons:

- Lack of buffer space
- Link load exceeds the carrying capacity
- Redundant broadcasting packets
- Number of packets timeout and retransmitted
- Average Packet Delay/ Standard Deviation of Packet delay
- Number of nodes increases

B Congestion Status Indicator:

By checking the occupancy of link layer buffer of node periodically the congestion status C_s can be estimated.

C_s = Number of packet buffered in Buffer / Buffer Size.

Congestion can be indicated by three statuses "Go", "Careful" and "Stop"

- *"Go"* indicates there is no congestion with $C_s \le ½$
- *"Careful"* indicates the status likely to be congested with $½ \le C_s \le ¾$ and
- *"Stop"* indicates the status already congested, $¾ \le C_s \le 1$.

C Novel Adaptive Congestion Control Algorithm

Every entry in the table is unique to a destination. *MainTable [N, D]* specify the entry for destination D in the routing table of node N and *MainTable [N, D].attr* specify the value for the attribute attr. The traffic can be reduce by dropping RREQ packets when congestion status is "stop" and also stop broadcasting RREQ packets.

Step 1: [Set the Main Routing table metric attribute.]

MainTable [N, D].nc_metric = 1.

Step 2: [Set the Destination node and Its congestion status as "Go"]

Set *MainTable [N, D].nc_hop* = D

Set *MainTable [N, D].hop_status* = "Go"

Step 3: [for every other node, Set Main Table has no congested node]

MainTable [N, D].nc_hop = -1

Step 4: [Node N receives a Update packet from its next main node N_{next}]

If MainTable [N_{next}, D].nc_status = "stop" and MainTable [N_{next}, D].nc_status = "careful" then node *N* initiate non congested route discovery process toward node of *N* obtained from the update packet.

Step 5: [Non congested route search]

(i) Non congested request packets set TTL to 2 x k. where k is distance between Node N and non-congested Node P on the main route.

(ii) Drop non-congested request if arriving at a node already present on the Main route.

Step 6: Remove the entries in the Non-congested Table if timeout occurs after certain period.

Step 7: [Traffic splitting effectively reduces the congestion status at the next main node.]

(i) If next Main node *MainTable [N, D].hop = "stop"* the incoming packets will follow Main Link

N → MainTable [N, D].hop and

with probability *p = MainTable [N, D].prob = 0.5*

(ii) Non congested link *N → MainTable [N, D].nc_hop* will have equal chance *(1-p = 0.5)*

V PERFORMANCE EVALUATION AND RESULTS ANALYSIS

We have implemented proposed protocol using Network Simulator NS-2 [15] version 2.28. We compared e-CARA to DSR, AODV, DSDV and TORA the most popular MANET routing protocols. In following sections observations are discussed.

A Simulation Parameters

The network consists of 25 nodes in a 1500m x 800m rectangular field. The MAC layer was based on IEEE 802.11 CSMA and interface queue at MAC layer could hold 50 packets. The nominal bit rate is 2 Mbps and transmission range is 250 m. The routing buffer at the network layer could store up to 128 data packets. The random waypoint model [19] was used with maximum node speed of 4m/s as suggested in [18]. The traffic loads can be illustrated either varying the number of connections with fixed packet rate or varying the packet rate with fixed number of connections. The simulations were run for 900 seconds with 25 connections generated. For each connection, the source generated 512-byte data packets at a constant bit rate (CBR).

B Performance Metrics

We have considered three important metrics for the analysis of the results obtained. 1) The *packet delivery ratio* (PDR) which is defined as the ratio between payload packets delivered to the destination and those generated by the source nodes; 2) The average packet delay which can be defined as the delay for sending packets from source node to the destination node. This metrics includes all the possible delays caused by buffering during the route discovery latency, queuing at the interface queue, retransmission delays at the MAC layer, and propagation and transfer times; 3) The *routing overhead* defined as the number of packets carrying control messages for route discovery and routing to the number of packets carrying payload.

C Simulation Result Analysis

The results were collected as average values over 15 runs of each simulation setting. We kept the fixed of connections to 20 and varied the packet rate. The improvement of protocol with Packet Delivery Ratio over other routing protocols is shown in Figure 2.

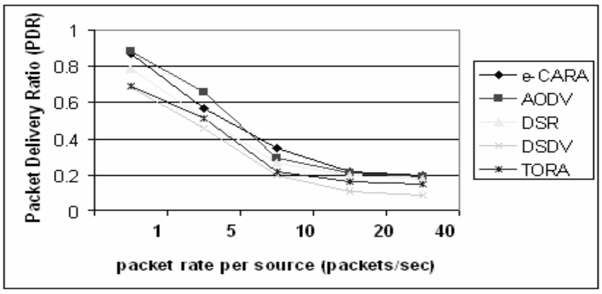

Figure 2 Packet Delivery Ratio Vs Packet Rate

In regard of Packet Delivery Ratio, both AODV and e-CARA outperforms DSR, DSDV and TORA. This is because packets are lost due to congestion in DSR were more than in the other routing protocols. When packets rate was small, AODV delivered more packets than congestion control algorithm. This is due to less network load. With increase in the traffic of packet rate 20 packets/sec, 30 packets/sec and 40 packets/sec, proposed protocol successfully delivered packets more than AODV and other routing protocols. Similarly, for end-to-end delay we have computed worse case, which is shown in Figure 3. The proposed protocol improved over AODV by 63.76%, DSR even better by 77.42%, DSDV by 79.12% and TORA by 80.67% in worst case. The delay variation less than that of AODV and DSR which makes our protocol more suitable for multimedia kind of applications as shown in Figure 3.

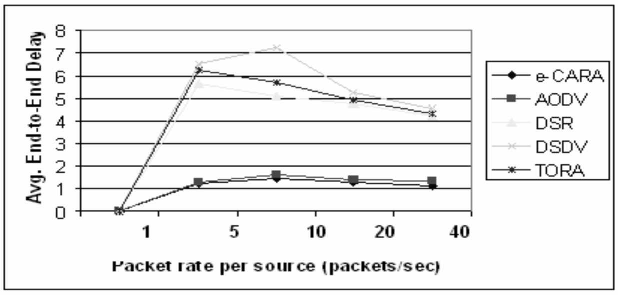

Figure 3 Average End-to-End Delay Vs Packet Rate.

The routing overhead incurred by e-CARA is very less when compared to other routing protocol. This is shown in Figure 4.

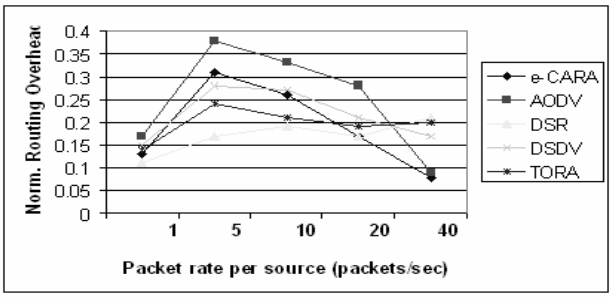

Figure 4 Normalized Routing Overhead Vs Packet Rate.

When packet rate was 50 packets/sec the proposed protocol incurred less routing head and delivered 21.34% more data than AODV. This because, upon link breakage, AODV tried to establish a new route to the destination by broadcasting RREQ and RREP packets, congestion control protocol tried to make use of non congested available route and uses route request packets very often. The overhead to maintain non-congested paths in proposed algorithm is kept small by minimizing the use of multiple paths.

VI CONCLUSION

Most of the MANET protocols are not adaptive to congestion and cannot handle the heavy traffic load while offering services to multimedia applications. The proposed novel adaptive congestion control protocol enjoys fewer packet losses than routing protocols in a constraint situation. The non-congested route concept in the algorithm help next node that may go congested. If a node is aware of congestion ahead, it finds a non-congested route that will be used in case congestion is about to occur. The part of incoming traffic is split and sent on the non-congested route, making the traffic coming to the congested node less. Thus congestion can be avoided. Proposed Algorithm does not incur heavy overhead due to maintaining of non-congested paths. It also offers high Packet Delivery Ratio when the traffic in heavy. The delay incurred while establishing is low because of using existing non-congested paths. Thus the proposed algorithm in mobile ad hoc networks is especially designed for multimedia applications.

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Ramesh B received the B.E. degree in Computer science and engineering from Mysore University, Karnataka, India, in 1991 and the M.Tech. degree in Computer Science from DAVV,Indore, MadhyaPradesh, India, in 1995. He is currently working towards the Ph.D. degree in Computer Science & Engineering at Anna University, Chennai.His current research interests lie in the areas of Congestion Control and QoS-aware Routing Algorithms in ad hoc networks.

D. Manjula received M.E. in Computer Science & Engineering from Anna University, Chennai, in 1987 and Ph.D. from Anna University, Chennai, in 2004. She is an Assistant Professor in the Department of Computer Science & Engineering, Anna University, Chennai. Her current research interests lie in the areas of wireless communications and networking, mobile computing, and multimedia communication.