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Drop Reduction with Controlled Flow Rate for Reliable Delivery in MANET

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***Abstract* - To support reliable delivery in Mobile Ad hoc Networks (MANETs), there are many challenges in supporting quality of service for MANETs. One of the significant challenge in ad hoc networks is coping with the unpredictable motion and the unreliable behavior of mobile nodes. We have proposed a new routing protocol, Drop Reduction with Controlled Flow (DRCF) to reduce the drop rate by controlling the flow rate based on the number of hops to the destination. The proposed routing protocol is highly adaptive to rapid movements of mobile nodes to control the flow rate. The performance of DRCF was studied using NS2 simulation environment. Analysis of the simulation results indicates an increased delivery ratio and reduced drop rate, average end-to-end delay compared to Ad Hoc On Demand Distance Vector Routing (AODV) and Destination Sequenced Distance Vector Routing (DSDV).**

***Index Terms* - Delivery ratio, Drop rate, End-to-end delay, Flow control, Mobile Ad Hoc Networks.**

I. INTRODUCTION

MOBILE Ad hoc Network is an autonomous system of mobile hosts, which moves randomly and organize themselves randomly. The random movement of the devices and the absence of central infrastructure give rise to various problems such as the design of communication and networking protocols for routing and security. Hence, all the nodes of these networks behave as hosts as well as routers, forwarding packets to other mobile nodes in the network taking part in discovery and maintenance of routes to other nodes in the network. Due to the limited transmission range of wireless network interfaces, multiple network hops may be needed for one node to exchange data with another node across the network through the router nodes that lies between the source and the destination.

Some examples of the possible uses of ad hoc networking include students using laptop computers to participate in an interactive lecture, business associates sharing information during a meeting, soldiers relaying information for situational awareness on the battle field, and emergency disaster relief personnel coordinating after a hurricane or earthquake.

The wireless devices have limited bandwidth and the network provides unreliable service resulting in high packet loss and throughput. These networks are not scalable. The nodes of the ad hoc network do not have any access points , they communicate without any centralized control and cooperate in the process of delivering the packets of data.

MANETs are highly dependent on the sending rate and the route length from the source node to the destination. Sending packets at the optimal rate for a given route length maximizes throughput in the network, whereas slightly increasing the sending rate over the optimal value may decrease throughput by up to 55%. Packet loss in wireless network is due to bit error rate and disconnections due to mobility. Due to the limited transmission range of wireless network interfaces, multiple network *hops* may be needed for one node to exchange data with another across the network.

Motivation: As the links are highly error-prone and go down frequently, providing reliability is difficult in wireless networks because of unreliable transmissions. Thus paths may become frequently invalid during connections. The wireless channel is prone to bit errors due to interference from other transmissions, thermal noise, shadowing and multi-path fading effects. This makes it impossible to provide high reliability, packet delivery ratio or link longevity guarantees. If the packets are sent at a rate which a node can not process, more packets are dropped. The maximum data rate effects the number of packets in the network and hence the network load, which in turn affects the performance significantly. The drop rate can be reduced by controlling the flow rate.

Contribution: Majority of solutions proposed on providing QOS in MANETs is based on two metrics, throughput and delay. We have proposed a new protocol that adopts a strategy that a node should send a data with a rate depending on the number of hops to the destination. We have proposed a new proactive routing protocol, Drop Reduction with Controlled Flow Rate (DRCF) which reduces the end- to-end delay and drop rate. The proposed protocol relatively reduces the rate at which it sends data with respect to number of hops. As the number of hops to destination increases, the sending rate is decreased.

Organization: The remainder of this paper is organized as follows: Section II presents related work; Section III gives the overview of the routing methods; Section IV presents a network model and problem definition; Section V explains the

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proposed DRCF protocol; Performance Analysis and Conclusions are presented in Section VI and VII respectively.

II. RELATED WORK

Chi-Sheng Chiu et al., [1] have presented a Reliable Multipath Routing protocol to improve routing performance for ad hoc networks. The protocol uses a new loop-free route update scheme to accept backup paths that are longer-lived by considering the power information also. They also proposed a dynamic route maintenance mechanism to erase invalid backup routes preemptively and to reduce energy consumption, hosts adjust the transmission power to send packets adaptively based on the mobility prediction.

Yow-Yiong Edwin Tan et al., [2] have proposed a multi-rate network model to deliver differentiated service in an ad hoc network with varying physical-layer link speed. They have used a multi-dimensional Markov chain to support both real-time and non-real-time applications. Various types of data arrival process is modeled by a Markov Modulated Arrival Process. They have employed numerical methods to estimate the packet drop probability, effective throughput and packet queuing delay. They have compared the analytical and simulation results to determine the accuracy of the presented methods. The proposed method achieves increased Quality-of-Service performance for high priority traffic.

Kuang Ching Wang et al., [3] have addressed the various challenges in concurrently providing a wide range of end-to-end throughput and delay assurances in ad hoc networks. The proposed solution in the paper is based on the Neighborhood Proportional Delay Differentiation service model. An end-to-end QoS is achieved using Dynamic Class Selection algorithm. In a highly mobile multi hop network, the model provides a set of classes with per hop delays proportional to the predefined ratios and this proportionality holds across all nodes independent of network dynamics. The proposed class selection mechanism achieve diverse end-to-end throughput and delay assurances in ad hoc networks with random arrivals of mobile nodes.

Anelise et al., [4] have proposed an Optimized Link State Routing protocol which introduces a more appropriate metric than the hop distance. The protocol reduces the size of control messages and minimizes the overhead from the flooding of control traffic. This approach makes available detailed information about the connectivity and conditions found in the network. It is proactive in nature hence the routes are immediately available when needed and Dijkstra routing algorithm with number of hops metric is used to route the packet.

In [5], authors have presented a cross-layer technique that improves throughput and delivery ratio in lightly-loaded ad hoc networks. The technique allows applications to send packets at the rate that maximizes throughput for a given route length. In this technique the routing layer notices interested applications about routing changes, and the applications adaptively modify their sending rates based on the new route length to the destination. In static and mobile networks, this technique outperforms UDP-based flows with a fixed sending rate and doubles the throughput of TCP for networks.

Gharavi et al., [6] have presented a cross-layer feedback control scheme for video communications over unstructured mobile networks for tactical operations considering a peer-to-peer mobile ad-hoc network for the experimental testbed. They have developed a rate control as well as a packet recovery scheme based on the network characteristics derived from the underlying ad-hoc routing protocol. To enhance the quality of service, a redundant packet transmission scheme is presented for lossy recovery of the missing packets. R. Pandian et al., [7] have implemented an Enhanced On-Demand Routing protocol for transmitting video over mobile ad hoc network. It determines more stable routes by including the signal power received from all other neighboring nodes as an association stability factor along with the conventional route identifying parameters and shows better performance for various mobility models.

R. Khalaf et al., [8] have presented a performance comparison between two routing algorithms, AODV, from the reactive family and DSDV, from the proactive family in terms of average throughput, packet loss ratio, and routing overhead, while varying number of nodes, speed and pause time. Through simulation results they have revealed that DSDV perfectly scales to small networks with low node speeds and AODV is more preferred due to its more efficient use of bandwidth. Jack W. Tsai and Tim Moors [9] have investigated the problem of selecting multiple routing paths to provide better reliability in multi-radio, multi-channel mesh networks with stationary nodes. They have proposed a path weight function based on the Expected Transmission Time (ETT) metric and interference minimization to provide higher packet delivery ratio and lower end-to-end delay when compared to the single path Weighted Cumulated ETT metric, a maximally disjoint path selection metric, and the Channel Aware Multipath metric.

III. OVERVIEW OF ROUTING METHODS

AODV [10] routing protocol is a reactive routing algorithm that maintains the established routes as long as they are needed by the sources. The algorithm uses sequence numbers to ensure the freshness of routes. Route discovery and route maintenance stages of the algorithm are described below.

Route discovery process is initiated whenever a traffic source needs a route to a destination. Route discovery typically involves a network wide flood of route request packets targeting the destination and waiting for a route reply. An intermediate node receiving a request packet, first sets up a reverse path to the source using the previous hop of the message as the next hop on the reverse path. If a valid route to the destination is available, then the intermediate node generates a reply message, else the request is rebroadcast.

Duplicate copies of the request packet received at any node are discarded. When the destination receives a request, it also generates a reply. The reply is routed back to the source, a forward path to the destination is established. Route Maintenance is done using route error packets. When a link failure is detected, an error packet is sent back via separately maintained predecessor links to all sources using that failed link. Routes are erased by the error packet along its way. When the traffic source receives an error packet, it initiates a new route discovery if the route is still needed. Unused routes in the routing table are expired using a timer-based technique.

DSDV [11] routing protocol is a proactive routing algorithm that transmits the packets between the nodes of the network using route tables that are stored at every node of the network. DSDV protocol requires each mobile node to advertise, to each of its current neighbors, its own routing table. The entries in the list may change fairly dynamically over time, so the advertisement of the routing table is done often to ensure that every node can always locate every other node in the network. The routing table contains a sequence number created by the transmitter. Routes with more recent sequence number is always preferred for making forwarding decisions. The broken links are either detected by the layer-2 protocol, or it may be inferred if no broadcasts have been received for a while from a former neighbor.

IV. NETWORK MODEL

A. Architecture

The nodes of the network are randomly distributed with uniform density over a specified two dimensional region in a wireless medium. The links between nodes are symmetrical. We have considered a mobile wireless network, where all mobile nodes are equipped with identical communication devices such that each node may act as a transmitter or a receiver as needed and the nodes co-operate on the packets' delivery. Let *N* denote the set of nodes in the network, that are labeled *1, . . . , N*. In order to study the performance of the proposed protocol, the following performance metrics are used:

1. *Number of Packets Dropped* : Total number of packets sent which is not received by the transport or higher layer agent at the packets final destination node.
2. *Average end-to-end Delay* : It is the average of time differences between the data packets generated at the source and arrival at the destination.
3. *Packet Delivery Ratio* : Corresponds to the ratio of received packets to the amount of packets sent.

B. Mobility Model

Random Walk (RW) Mobility Model is chosen in which a node movement is determined by the following rules. First, each node decides the direction in which to move. Once it starts moving, it goes on for a pre defined movetime, at the end of which it selects a new direction. At every random decision of movement direction, the speed is also randomly chosen from an interval (speedmin, speedmax). When a node reaches the system boundary, it bounces off the border with an angle equal to the incoming angle, and continues until movetime expires. Table I lists the notations used in this paper.

C. Problem Definition

Given an Ad Hoc wireless network with finite number of nodes and finite number of links and if the two nodes *n1*, *n2* are within the transmission range of each other and the data flow rate is controlled based on the principle that, as the number of hops to destination increases the data rate at which the source sends the data should decrease, then the objectives are to:

TABLE I
NOTATION

Symbols	Definitions
s	source node
d	destination node
P_t	packet type
P_r	DRCF packet
P_d	data packet
R_{nr}	number of entries in the routing table of DRCFpacket
R_n	number of entries in the routing table of a processing node
H_n	next pop
N_{hr}	number of hops to *d* in the received DRCF packet
N_h	number of hops to *d* in processing node's routing table
t_c	current simulation time
t_r	updated time of a routing table entry in received DRCF packet

1. Reduce the drop rate using varying sending data rate based on number hops between the source and destination.
2. Decrease the average end to end delay.

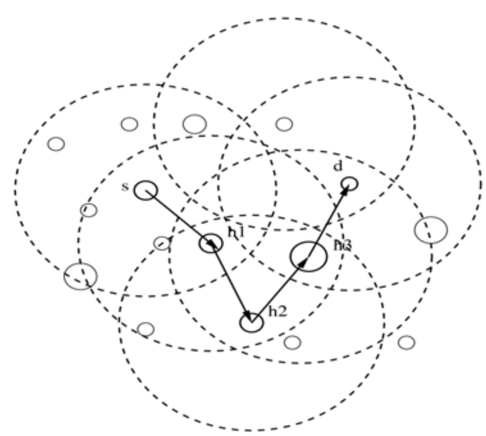

Fig. 1. Network showing the path from node *s* to node *d*

Fig. 2. Network showing the path from node *s* to node *d1*

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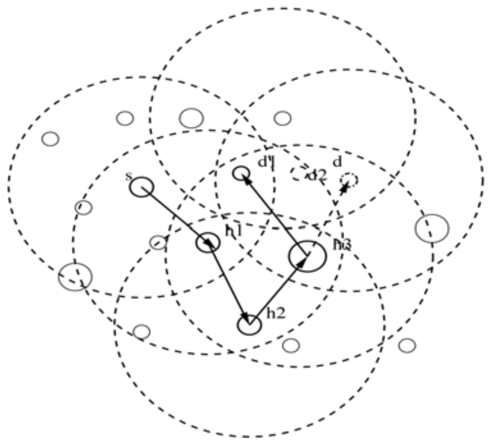

One of the problem with AODV can be explained with the help of a network shown in Fig. 1. Let the node denoted as s be the source and d be the destination. Let us assume that the route discovery process of AODV finds the path to d as s→h1→h2→h3→d. There are 4 hops to reach the destination from the source. When the node moves to its new location say d2 or d1 as shown in Fig. 2, the path from s to d1 remains same as the new position is still the neighbor of node h3 i.e., the new position is within the transmission range of the node h3. Though the node is within the transmission range of s, the path to destination will not change as long as there is link failure or any node in the path moves out of transmission range of the previous or next node in the path. Though the node d is reachable with 1 hop, the data from s moves with the existing route with 4 hops. This is because of the fact that as long as the node d is within the transmission range of the node h3, the link from h3 to d will not break and thus the error packet is not generated and the route table entry of s does not get updated.

This situation is taken care in the proposed protocol DRCF, as such, once the *d* moves to new location *d1*, *s* updates its routing table and the data flows directly with one hop thereby decreasing the average end-to-end delay and increasing the delivery ratio. Next section describes the working of the proposed DRCF protocol.

V. DRCF PROTOCOL

DRCF is a proactive protocol which minimizes the drop rate by varying sending data rate based on the number hops to destination. Route tables are created with the help of DRCF packets. A node broadcasts DRCF packets at an interval of few seconds say every second. The DRCF packet has the following information: Address of the node generating the DRCF packet, its routing table information, number of entries in its routing table. The routing table contains destination address, next hop and number of hops required to reach the destination. DRCF protocol has two phases: Route Setup Phase and Route Maintenance Phase. As frequent updates of routing table leads to network congestion, the proposed protocol is used in applications such as in seminar hall or shopping complex where there is less mobility and more nodes are communicating simultaneously.

A. Route Setup Phase

All the nodes interoperating to create data paths between themselves broadcast the DRCF packet periodically, say every second. DRCF protocol requires each mobile node to advertise, its own routing table, to each of its current neighbors. The entries in the list may change fairly dynamically over time, so the advertisement has to be made often to ensure that every mobile node can always locate each other mobile node in the network. Initially, a node generates a DRCF packet with no route table entries. After route table setup, each node contains an entry to every other node in the network. Setup time depends on the maximum number of hops between any two nodes in the network. If there are multiple paths from a node to a destination, the one with least number of hops is retained. When a node receives a DRCF packet, a node compares each and every entry of the received route table with its routing table. If there exist no entry for a specified destination, a new entry for that destination is made in its routing table. If an entry exists for a specified destination, it updates its entry only if the number of hops to reach the destination in its routing table is greater or equal or if it is an old entry that is, if the difference of current time and the last updated time is more than 2 seconds. Table II gives the pseudocode of the functionality in intermediate node.

TABLE II
PSEUDOCODE : FUNCTIONALITY IN INTERMEDIATE NODE

Intermediate Node:
if (P_t==P_r)
  for *i*=0 to R_{nr}
    search for an entry in R_n
    if (found)
      if ((N_h >= N_{hr}) && (t_c - t_r > 2))
        update route table entry
    else
      add routing table information of R_{nr} in R_n
else if (P_t== P_d)
    look for a route to *d* in R_n
    if ((found) && (H_n != ∞))
      Forward the data packet
    else
      Drop the data packet

B. Route Maintenance Phase

To maintain the consistency of routing tables in a dynamically varying topology, each node periodically transmits updates. Mobile hosts cause broken links as they move from one place to another place. This can be taken care by monitoring the route table information. The link failures are taken care by refreshing the routing table every few seconds. The updated time of the route table entries is compared with the current simulation time and if the difference exceeds a certain limit then replace the next hop with ∞. When the node broadcasts this information route table of the neighboring nodes gets updated. When the data packet finds that the next hop is ∞, it drops the packet as the node can not be reached.

Data packets are transmitted between the nodes of the network by using routing tables which are stored at every node of the network. Routing table at each node contains a list of all the available destinations, next hop and number of hops required to reach the destination. When a node has data to send it looks for an entry to the destination in its routing table, if not found packet is dropped else it forwards the packet to the next hop. The rate at which the data has to be sent is decided based on the number of hops to reach the destination and is calculated based on the following equation :

$$S_{rt} = N_{rt} - (H_{cnt} * P_{tm}) \quad (1)$$

where S_{rt} is the rate at which data has to be sent by the source, N_{rt} is the sending rate at which there are no drops for one hop, H_{cnt} is the number of hops to destination and P_{tm} is the time required to process the packet at a node. When a node receives a data packet, if it is not destined for it, node looks for next hop to reach the specified destination and forwards the packet. If next hop information is ∞, assuming that there is no path to the destination, the data packet is dropped. Sending rate is set to a constant value after certain number of hops depending on the values of N_{rt} and P_{tm}.

VI. PERFORMANCE EVALUATION

In this section, we discuss our Simulation studies to compare the performance of AODV and DSDV routing protocols with the proposed DRCF routing protocol with respect to its drop rate, average end-to-end delay and delivery ratio. Simulations have been carried out using the *NS 2* simulator [12]. Nodes in the simulation are placed randomly in a 500 X 500 m^2 terrain and move in random walk mobility patterns. Table III summarizes simulation settings. For simulation, we have considered two scenarios. One with a single node having data to send and the other with five nodes having data to send.

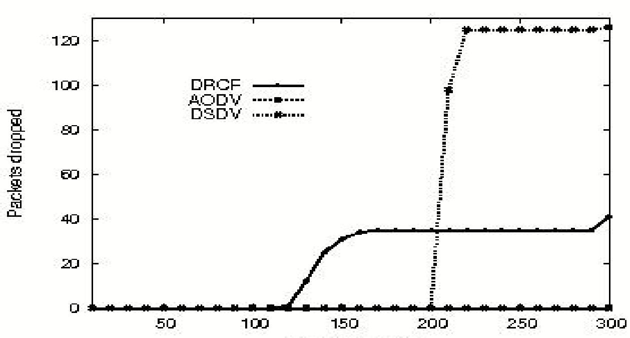

Fig. 3 Number of Drops and Pause Time (1 Active node)

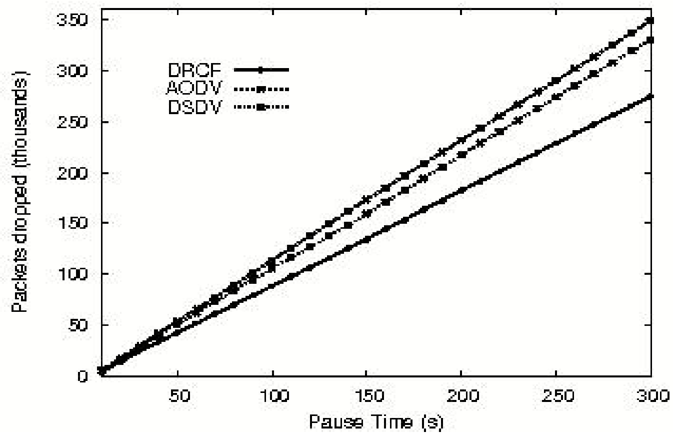

Fig. 4 Number of Drops and Pause Time (5 Active nodes)

Fig. 3 is a graph of packets dropped and pause time when only one node has data to send. Graph clearly indicates that when only one node has data, the number of packets dropped is zero with the AODV protocol. When there is only one node is active, there is no collision and the data packets are sent from source to destination, thereby packets dropped is zero. The number of packets dropped for other protocols is zero up to 100 seconds and increases later due to link failure resulting due to random movement of the nodes. The graph also indicates that the drop rate of the proposed protocol is less than that of the other proactive protocol, DSDV.

TABLE III
SIMULATION SETTINGS

Parameter	***Value***
Simulation Area	500 X 500 m
Number of Nodes	50
Node Mobility	10 m/s
Pause Time	10s
Mobility Model	Random
Number of Data Sendimg Nodes(active)	1 or 5
Simulation Time	300s

Fig. 4 is a plot of packets dropped and pause time when five nodes have data to send. Drop rate of AODV and DSDV is significantly more as compared to the proposed protocol DRCF. When more nodes has data to send, more requests are generated, that may lead to congestion and packet drop at the interfacing queue or at the router. As the sending rate of all five active nodes is same in AODV and DSDV there are chances that packets being accumulated at a particular forwarding node during transmission resulting in queue overflow and thereby dropping of packets. Whereas in DRCF the sending rate of all five active nodes may be different based on the number of hops to its respective destinations, so chances of packets accumulating at a particular node during its transmission is minimized, decreasing the drop rate.

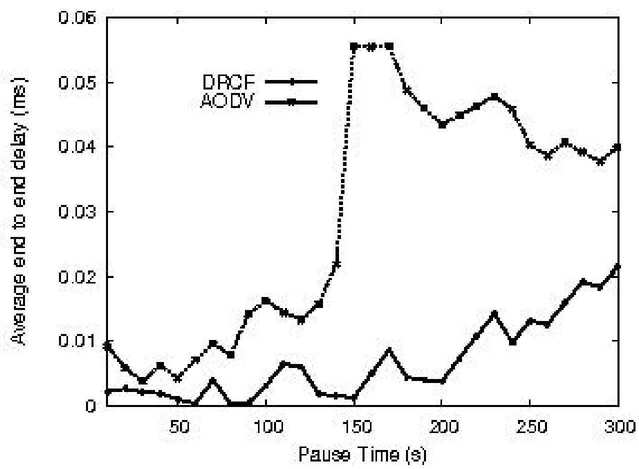

Fig. 5 Average end-to-end Delay and Pause Time (5 Active nodes)

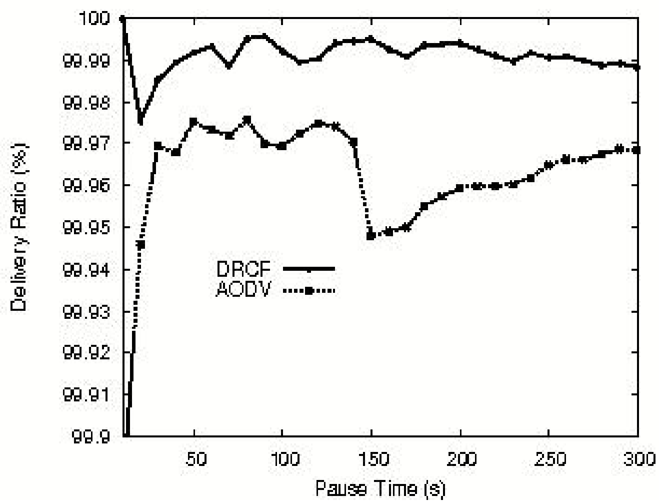

Fig. 6 Delivery Ratio and Pause Time (5 Active nodes)

Fig. 5 shows the plot of average end-to-end delay and pause time. The average end-to-end delay of the proposed protocol is less compared to AODV. This is basically due to the problem defined in section IV. As the destination node moves towards the source, reducing the number of hops, the data rate at which the data sent in the proposed protocol is increased and thereby delay is reduced whereas in AODV, packet takes longer route and increases the average delay. Fig. 6 is a plot of delivery ratio and pause time. The graph clearly shows that there is not much differences in the delivery ratios of the proposed protocol DRCF and AODV. It is also observed that the delivery ratio of AODV is less at times compared to DRCF. This is due to random movement of node which may cause the situation as explained in section IV leading to more drops.

VII. CONCLUSIONS

Reliable delivery is challenging due to the changes in the topology, that results in a relatively short lifetime of the network paths, high transmission bit error rates during fading periods. In this paper, we have proposed a new protocol to reduce the drop rate and average end-to-end delay. The DRCF protocol as compared to AODV and DSDV routing protocols shows a reduced drop rate, average end-to-end delay and increased delivery ratio. Analysis of the simulation results indicate a reduced drop rate with increase in number of communicating nodes. With DRCF protocol, as the number of hops between the communicating node changes, there is a change in delivery ratio. As frequent updates of routing table leads to network congestion, the proposed protocol is used in applications such as in seminar hall or shopping complex where there is less mobility and more nodes are communicating simultaneously. In future, we can reduce the number of DRCF packet broadcast by sending the DRCF packets only when the node changes its location rather than sending every second or every few seconds. Further, we can control the flow rate based on the distance rather than number of hops.

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IX. BIOGRAPHY

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