AN ENHANCED DYNAMIC CONGESTION DETECTION AND CONTROL ROUTING IN MOBILE AD-HOC NETWORK

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Abstract— **Mobile ad-hoc network (MANET) is a collection of independent nodes which forms a temporary network without any fixed infrastructure or central controller. Due to the dynamic topology, the field of MANET is rapidly growing and changing and there are number of issues such as medium access control, routing, resource management, congestion control and power control which affect the reliability of secured communication in MANET. Congestion control is an important issue in MANET which can occur in any intermediate node often due to limitation in resources, when data packets are being transmitted from the source to the destination nodes. Network congestion can cause many problems such as packet loss, long delay and reduce network throughput. Hence detecting and controlling congestion at router level is an important research work in MANET and this research paper proposes an enhanced dynamic congestion detection and control routing (EDCDCR) technique for congestion detection and control routing on MAC layer. The proposed EDCDCR technique uses the node thresholds to detect the congestion nodes in the routing path and construct the congestion free route for data transmission in MANET.**

Keywords: MANET, routing, congestion, MAC layer, congestion detection, congestion control.

1. INTRODUCTION

A mobile ad-hoc network (MANET) is a temporary network that can change locations and configure itself on the fly [3]. MANETs use wireless connections to connect various networks and is different from other network since it provides various characteristics such as dynamic topology, node mobility and self-organizing capability. MANET provides several advantages which includes low cost, easy network maintenance and convenient service coverage. MANET is used in various applications such as military, virtual classroom, conference, emergency operations, business applications and vehicular ad-hoc network (VANET). Network congestion is the major problem in MANET and it takes place at intermediate nodes when data packets are being transmitted from source to destination node.

Congestion may occur in a network, if the load on the network is greater than the capacity of the network [7]. Network congestion can cause many problems such as packet loss, long delay and reduce network throughput. To preserve the packet loss among the nodes from congestion, a congestion control is required which satisfy certain sort of requirements to ensure proper functioning of network capacity and link stability for data transmission from source to destination nodes. The goal of congestion control is to minimize the delay for packet delivery, packet loss and maximize network throughput. Hence detecting and controlling congestion at router level is an important research work in MANET.

In this research work, an enhanced dynamic congestion detection and control routing (EDCDCR) technique has been proposed for detecting congestion based on the parameters such as link stability, residual battery power and residual bandwidth and controlling congestion by constructing the congestion free route discovery process. The proposed system uses the node thresholds to detect the congestion nodes in the routing path and control congestion for non-congested neighbor among the path for data transmission in MANET.

The remaining structure of this paper is organized as follows. Section 2 describes the literature review. Section 3 presents the proposed methodology. Section 4 describes the simulation results. Section 5 concludes this research paper and further research.

2. LITERATURE REVIEW

Congestion takes place at router level causes many problems and thus the development of congestion detection and control is an important research work in MANET. The development of a congestion control technique can be either rate based or buffer based congestion control at router level. The various proposed congestion control techniques at router level in the literature are described as follows:

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Senthilkumaran and Sankaranarayanan [8] proposed an early congestion detection and adaptive routing in MANET called as EDAPR. Initially EDAPR constructs a non-congested neighbors (NHN) neighbors list and finds a route to a destination through an NHN node. All the primary path nodes periodically calculate its queue_status at node level. While using early congestion detection technique, node detects congestion that is likely to happen and sends warning message to NHN nodes. The ancestor NHN node is aware of this situation and finds an alternate path to a destination immediately by applying adaptive path mechanism. Thus, EDAPR improves performance in terms of reducing delay, routing overhead and increases packet delivery ratio without incurring any significant additional cost.

Senthilkumaran and Sankaranarayanan [7] have proposed dynamic congestion detection and control routing algorithm (DCDR) to detect and control routing in ad-hoc networks. This algorithm detects congestion based on the estimation of the average queue length at the node level. By the assessment of average queue length, a node detects the probability of congestion and sends a warning message to its neighbors. When neighbors received the warning message they try to search the alternative congestion free path to the destination. If the path is available, then predecessor node starts further communication through alternative path. DCDR uses a non-congested path discovery mechanism to prevent network congestion, hence packet loss rate is decreased and by which end-to-end delay is reduced. The advantages of this technique are reduction of delay and improvement in packet delivery ratio. The disadvantages of this technique are: packet losses and route failure.

Chen et al. [2] have proposed EXACT to control congestion with standard TCP compatibility for MANET environment. EXACT adopts rate based approach and in this technique all the intermediate nodes dedicate itself for monitoring the packet flow through them. These intermediate nodes determine and share the current bandwidth information with their neighbours. When a packet arrives at intermediate node, it checks for the rate information, if the rate is lower than the rate specified, the rate information in the header of the packet is modified before forwarding it. This helps the destination node in updating about the bottleneck rate. This technique is implemented using two different header fields, one field contains the current rate of the sender and the other is the rate requested by the sending application. This technique also helps in managing the flow rate at router and also informs the sender probable increase/decrease its transmission rate. In case of route failure, a safety window prevents the sender from overloading the network. In EXACT there are no retransmission timers, instead it uses SACK scheme. When a packet is not acknowledged by the receiver or if the received acknowledgement sequence number is too apart from the highest acknowledged packet then it is retransmitted.

Su and Gross [11] have proposed WXCP to detect and control congestion for Wireless Multi-hop Network. This technique is a window based approach involving rate based element in it. This technique uses multiple congestion metric and explicit feedback within the network. These values are computed at each intermediate node. The three metrics, the local available bandwidth, length of the queue and average number of retransmissions are computed at WXCP enabled intermediate node. The average number of retransmissions is computed to avoid the disturbance caused within the flow. The feedback is a function of relative influence of these three metrics. In this technique separate decisions are taken for congestion fairness control. Fairness controller achieves time fairness among flows rather than throughput fairness.

Kazuya Nishimura and Kazuko Takahashi [4] have proposed a multi-agent routing protocol to reduce network congestion for MANET. This research work uses two kinds of agents such as routing agents and message agents. These agents are used to store the routing table at each node data and move the data between nodes. In this work, a route is evaluated based on the evaluation function. The limitations of this work are: the identification of positional relationships between source and destination nodes, time frequency for sending packets.

Soundararajan and Bhuvaneswaran [9] have proposed a multipath load balancing and rate based congestion control for mobile ad-hoc network. Multipath routing can balance the load better than single path routing in ad-hoc networks, thereby reducing the congestion dividing the traffic in several paths. This work presents an approach for multipath load balancing and rate based congestion control [MCBRBCC] based on rate control mechanism for avoiding congestion in network. This work uses an adaptive rate control based technique in which the destination node copies the estimated rate from the intermediate node and the feedback is forward to the sender through an acknowledgement packet. Since the sending rate is adjusted based on the estimate rate, this proposed technique has better performance like high packet delivery ratio and improved throughput. However this work does not consider the power and processing ability.

Makoto Ikeda et al., [5] have proposed a congestion control mechanism for multi-flow traffic in wireless mobile ad-hoc network. Optimized link state routing (OLSR) protocol is applied for congestion control. OLSR is a proactive routing protocol which builds up a route for data transmission and also maintains a routing table for each node in the network. OLSR use HELLO message to find its one hop and two hop neighbors. Every node computes the path towards a destination using a shortest path algorithm. The source destination pairs are fixed over the network.CBR flow is transported over TCP and UDP from source to destination. CBR interval is the ratio of packet size to throughput.

M. Ali et al., [1] have proposed a congestion adaptive multipath routing for load balancing in mobile ad-hoc network. In this work multipath routing technique is used to increase the throughput and avoid congestion. This algorithm is based on scalable multipath ondemand routing (SMORT) which computes fail-safe multiple paths. The fail-safe multiple paths are the nodes with least load, more bandwidth and residual energy. When the average loads of an existing link, increase beyond a threshold, traffic is distributed over multipath routes to reduce the load in a etwork. This mechanism achieves better throughput and packet delivery ratio.

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Thilagavathe and Duraisamy [12] have proposed a cross layer based congestion control techniques for reliable and energy aware routing in MANET. This mechanism is applied over a ad-hoc ondemand multipath reliable and energy aware QoS routing protocol (AOMP-REQR). In this technique a congestion free route has established for transmission without performing any rate control. If the congestion happens at the time of routing, it is detected and handled by congestion control and an alternative route is established for transmission.

Vishnu Kumar Sharma and Sarita Singh Bhadauria [13] have proposed a mobile agent based congestion control using AODV routing protocol for mobile ad-hoc network. In this mechanism, the entire congestion information about a network is collected and distributed by mobile agents. When mobile nodes move through the network, they can select a less loaded neighbor node as its next hop and then update the routing table. In this work mobile agent starts from every node and moves to an adjacent node. Traffic belongs to background, best effort, video or voice AC. Average queue length is estimated of the various traffic classes and the channel contention of each path. The total congestion metric is applied to the routing protocol to select the minimum congested route in the network.

Reeta Bourasi and Sandeep Sahu [6] have proposed detection and removal of packet dropper nodes for congestion control over the MANET. This work focus on the data packet dropping in MANET in both dense and a few node counts. The packet dropper nodes are eliminated using a new algorithm by adding a reliability factor of each node which is increased when the node receives the acknowledgement of the forwarded packet to assure that the node has actually forwarded the packet and have not dropped it. This proposed technique dynamically detects packet dropper nodes and eliminates the packet dropper nodes during the packet transfer.

Srinivasa Rao et al., [10] have proposed an energy efficient and reliable congestion control (EERCC) protocol for multicasting in MANETs. In this work the energy efficient and reliable congestion control protocol for multicasting is implemented in three phases: In the first phase of EERCC protocol, a multicast tree routed at the source is build by including the nodes with higher residual energy towards the receivers. In the second phase an admission control scheme is proposed in which a multicast flow is admitted or rejected depending upon on the output queue size. In the third phase a scheme which adjusts the multicast traffic rate at each bottleneck of a multicast tree is proposed. Because of the on-the-spot information collection and rate control, this scheme has very limited control traffic overhead and delay.

Xiaoqin Chen et al., [14] have proposed a congestion-aware routing protocol for mobile ad-hoc networks (CARM) which uses a metric incorporating data-rate, channel delay, buffer delay, and retransmission count to combat congestion and improve network utilization. This metric is used, together with the avoidance of mismatched link data-rate routes, to make ad-hoc networks robust and adaptive to congestion. Routing protocol adaptive to mobile ad-hoc networks congestion status can greatly improve network performance.

Most of the congestion control techniques reviewed in this section control congestion based on the issues related to packet loss, link efficiency and throughput degradation. MANET has limited bandwidth and are more prone to error and also impose limits the amount of data that can be sent between nodes. The limited bandwidth of MANET can cause traffic overload related problems because of unfairness in traffic flow control in router. If the incoming traffic is heavy, the reviewed research works still suffers from router failure, channel error-induced packet losses and long delay. The limitations of the existing congestion control algorithms may serve as directions to extend the area of congestion control mechanism further. Hence the focus of this research work is to improve the detection and controlling of congestion control by developing a dynamic congestion control technique at routing level on MAC layer in MANET.

3. PROPOSED METHODOLOGY

3.1 SYSTEM DESIGN

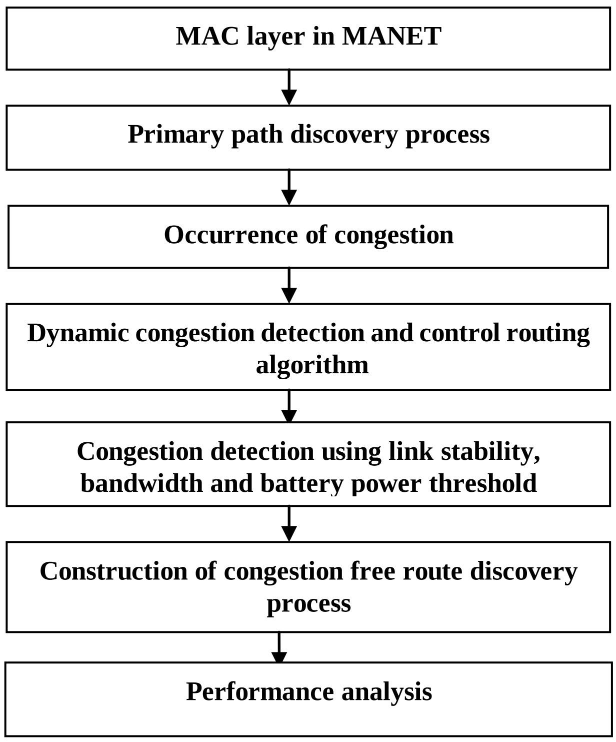

Figure 3.1 System design

The proposed EDCDCR algorithm is used to detect and control the congestion along a primary path. The number of packets is given as input for primary route discovery process from source to destination. If congestion is occur at any intermediate node in primary path, then send warning message to its neighboring node. The proposed EDCDCR algorithm is used to find the congestion free alternative path for data transmission. Finally, the performance is analyzed using the metrics such as end-to-end delay, packet delivery ratio and throughput. The proposed system design is shown in Figure 3.1.

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3.2 DYNAMIC CONGESTION CONTROL ROUTING ALGORITHM

In MANETs, congestion can occur in any intermediate node, often due to limitation in resources when data packets are being transmitted from the source to the destination. The proposed algorithm controls network congestion by ways of reducing the unnecessary flooding of packets and finding a congestion-free path between the source and the destination. In this research work the EDCDCR technique first detect the congestion, then constructs a congestion free set (CFS) to connect both one-hop and two-hop neighbors and the source initiates the route discovery procedure using the CFS to identify a congestion-free path to the destination.

The EDCDCR algorithm has been proposed to find a congestion-free route between the source and the destination nodes and is shown in Figure 3.2. The proposed algorithm consists of three components to detect and control congestion on MAC layer in MANET includes: (i) dynamic congestion detection (ii) congestion-free set (CFS) construction (iii) congestion-free route discovery.

Step 1: Initialize number of N, S, D.
// N-Number of nodes, S-Source node, D-destination node

// Congestion detection

Step 2: Compute link stability, residual bandwidth and residual battery power between source to destination nodes.
// LSD-link stability degree, BR- bandwidth, PR-battery power, LSDth-
link stability degree threshold

Step 3: If (LSD< LSDth) | | (BR < BRth) | | (PR < PRth)
then congestion occurs
else congestion free nodes, go to Step 10.

Step 4: Compute congestion free set using congestion status packet.

Step 5: Each node update the congestion status information in its routing table.

// Construction of congestion free route discovery process

Step 6: Source node generate route request to the destination node.

Step 7: If the destination node is two-hop list, then the packet directly transmitted by routing table
else route request send to congestion free set.

Step 8: Congestion free set directly forward the route request to destination node.

Step 9: The destination node send route reply packet to source node.

Step 10: Source node find outs the non-congested path for data transmission.

Figure 3.2 Dynamic congestion detection and control routing algorithm

- **Dynamic congestion detection**

In this work detecting congestion is based on estimation of the link stability (LS), residual bandwidth (RB), and residual battery power (RP).

- **Link stability**

The link stability (LSD) is used to define link's connection strength. In MANET, to improve QoS LSD is essential and is defined as:

LSD = Mobility factor / Energy factor

LSD defines the degree of the link stability. The higher value of LSD, higher is the stability of the link and greater is the duration of its existence. Thus a route having the entire link with LSD> LSD_{thr} is feasible.

- **Estimation of residual bandwidth**

The residual bandwidth defines the remaining bandwidth available in each node after the transmission. Every node within the interference range holds the sufficient bandwidth for transmitting the data without congestion. Thus it is necessary to familiarize with the local and neighboring nodes within the interference range. Any node that has necessity to transmit the data must consider local bandwidth and interference range mutually. The process of predicting the bandwidth of local and neighboring nodes is explained below.

Since the bandwidth is shared among neighboring nodes, by taking channel into consideration, the nodes calculates bandwidth based on the ratio of idle and busy times projected for pre-defined interval of time (t)

The local bandwidth (Bl) is estimated as follows:

$$B_l = C_{ch} * \left(\frac{t_i}{t}\right)$$

Where C_{ch} − channel capacity and t_i - idle time in t

As the information regarding the neighboring nodes is gathered previously, the minimum bandwidth (B min) of all nodes within the transmission range can be recognized. Thus the residual bandwidth (BR) is defined as the difference between B min and B_l and is stored in the residual bandwidth register.

- **Estimation of residual battery power**

The residual battery power defines the remaining energy available in each node after the transmission.

After time t, the power consumed by the node (P (t)) is computed as follows.

$$P(t) = DP_{tx} * \lambda + DP * \eta$$

Where

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

DP = Number of data packets received by the node after time t.

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λ, η -constants in the range of [0, 1].

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

$$PR = Pi - P(t)$$

The node threshold is a constant value which is used to detect the congestion nodes in the routing path. The link stability, bandwidth, battery power parameters are node thresholds to present the current status of the queue. The performance of proposed system depends on these node thresholds. If the node thresholds are small, then link utilization will be very low. If the node thresholds are set too high, then congestion might occur even before the nodes are notified.

If the link stability, bandwidth and battery power are less than normal node thresholds and instantaneous queue is less than warn line, then the node is in congestion free node. If the link stability, bandwidth and batter power are greater than normal node thresholds, then the node is likely to be in congestion node and congestion-free set is initiated for non-congested neighbor among the path.

- **Congestion-free set (CFS) construction**

The CFS is used to identify a congestion free path to the destination during packet transmission. Each mobile node selects its CFS from among its non-congested one-hop neighbors in such a way that it covers all two-hop nodes. The CFS of source host S, denoted by CFS(S), is then an arbitrary subset of the non-congested one-hop neighborhood of S that satisfies the following condition: every node in the strict two-hop neighborhood of S must have a link toward CFS(S), and it should not fall in the congested zone. The CFS setup is an initialization procedure in which each mobile node calculates its congestion status every second by using the dynamic congestion detection technique. Every mobile node broadcasts its congestion status by using a congestion status packet (CSP) to its one-hop neighboring node on the network.

The CSP interval time is one second, and the maximum interval time is 1.25*CSP interval. Now, each mobile host learns about its one-hop non-congested neighbor nodes and records the information into its non-congested one-hop list. After that, each mobile host exchanges its one-hop non-congested neighbor information so as to learn about its two-hop non-congested neighbor nodes. At this point, each mobile node constructs its CFS by selecting a subset of its one-hop non-congested neighbor nodes. So that the mobile node in the subset can forward its broadcast traffic to the two-hop neighbor nodes and minimize the flooding traffic. Each mobile host updates the information in its routing table.

The format of each entry in the routing table is <src_addr, dst_addr, hop_cnt, CFS_Node, CFSSET, congest_ status>, where src_addr is the source address, dst_addr is the destination address, hop_cnt is the hop count, CFS_ Node is the non-congested node address, CFSSET is the list of non congested neighbors, and congest status is neighbor's congestion status.

- **Congestion-free route discovery**

After congestion-free set construction, congestion-free route discovery is initiated for finds a non-congested path to the destination node. In order to send a data packet to a destination, the source host generates the route request (RREQ) packet for communication using the CFS nodes. The source node first checks its two-hop list. If the destination node is in its two-hop list, then the datagram is transmitted by following the path in routing table. Otherwise, the source node broadcasts the RREQ to the CFS on the network. When the CFS receives this RREQ packet, it also checks its two-hop list. If the destination node is in its two-hop list, then the CFS forwards the RREQ directly to the destination node. The destination responds to the first received RREQ and sends back an RREP packet. The RREP will travel back in the same path and add a new entry in its routing table. This path now becomes the primary route between the source and the destination. In case the destination node is not in its two hop list, then it modifies the sequence number and hop count and rebroadcasts this RREQ to the network. The process is repeated until the destination host is found. Finally, the source finds a non-congested path to the destination. The congestion free path is discovered to achieve efficient packet transmission.

4. SIMULATION RESULTS

The various parameters have been used for testing the proposed EDCDCR technique has been described and is shown in table 4.1. The network consists of 30 nodes in a 1000 X 1000 meter terrain size. The radio range is 250 meter with bandwidth 2 Mbps. The MAC layer is based on IEEE 802.11 distributed coordination function. The channel propagation model used was the 2-ray ground reflection model. An interface queue at the MAC layer could hold 50 packets before they were sent out to the physical link. Link breakage was detected as feedback from the MAC layer. A routing buffer at the network layer could store up to 64 data packets. This buffer keeps in waiting the data packets for which the route discovery had started but no reply had arrived yet. The routing protocols, this work used EDCDCR. The data flow used constant bit rate (CBR), which varies from 4 packets to 40 packets, and the flow varies from 10 to 50. The maximum speed of the node is 10 milli second and the simulation time is 900 sec.

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Table 4.1 Simulation parameters

Routing protocol	EDCDCR
MAC	802.11
Bandwidth	2 Mbps
Area size	1000 X 1000
No. of. Nodes	30
Antenna	Omni Antenna
Node placement	Uniform
Data traffic	CBR
Simulation time	900 second
MAC queue size	50 packets
Routing queue	54 packets
Load (Flows)	10-50 Flows
Load (Pkts/Seconds)	4-16 Packets/Second
Max Speed (m/s)	0-10 mill sec−1
Pause Time(s)	30 second

4.1. Performance metrics and results

The performance of the proposed EDCDCR technique has been compared with the existing DCDR technique using the metrics such as end-to-end delay, packet delivery ratio, and throughput. The simulation results are based on number of nodes and time.

- **End-to-end delay**

End-to-end delay refers to the time taken for a packet to be transmitted across a network from source to destination. The end-to-end delay of the network is shown in Figure 4.1. In the X-axis number of nodes is taken and in the Y-axis time is taken in milli seconds. The graph shows that if the number of nodes increases then the end-to-end delay of the network has also been increased.

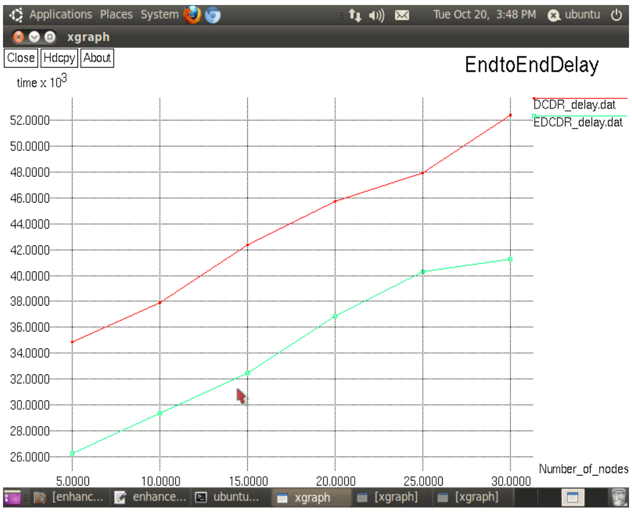

Figure 4.1 Comparison of end-to-end delay

- **Packet delivery ratio**

Packet delivery ratio is defined as the ratio of the number of delivered data packet to the destination. The packet delivery ratio of the network is shown in Figure 4.7. In the X-axis number of nodes is taken and in the Y-axis packet delivery ratio of the network is taken. Figure 4.2 shows if the number of nodes increases then packet delivery ratio is also increased.

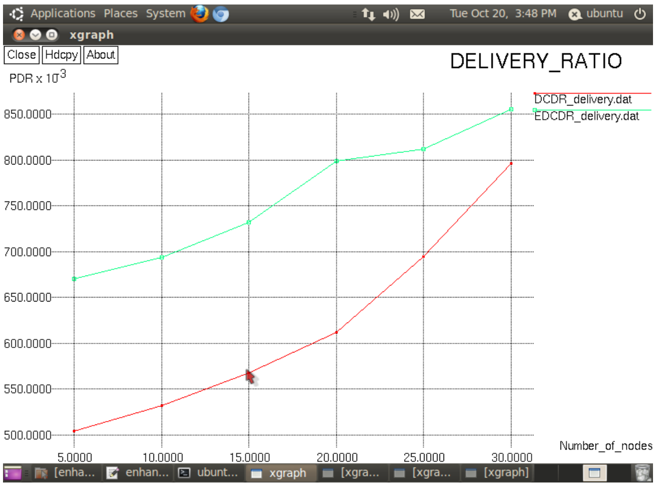

Figure 4.2 Comparison of packet delivery ratio

- **System throughput**

The system throughput is the sum of the data rates that are delivered to all terminals in a network. Throughput of the network is shown in this Figure 4.3. In the X-axis number of nodes is taken and in the Y-axis throughput of the network is taken. The graph shows that if the number of nodes increases then throughput of the network is decreased. The proposed EDCDCR achieves better result compared with existing DCDR technique.

Figure 4.3 Comparison of system throughput

5. Conclusion

Network characteristics like congestion and route failure need to be detected and controlled for establishing a reliable communication in MANET. To solve the congestion

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problem, this research paper has been proposed an enhanced dynamic congestion detection and control routing (EDCDCR) technique that could analyze the traffic fluctuation and detect congestion and control routing on MAC layer in MANET. The congestion has been detected by using the link stability, residual battery power and residual bandwidth threshold measurement. After estimating the congestion status at the node level along a path, the proposed algorithm controls the congestion by constructing a congestion free path. The simulation results shows that the proposed EDCDCR technique provides better performance than the existing dynamic congestion detection and control routing technique, in terms of end-to-end delay, packet delivery ratio and system throughput.

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