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PROACTIVE ROUTING WITH EARLY CONGESTION DETECTION IN MANET

[1]A. MOHAMMED MUNAWAR HUSSAIN, [2]Dr. P. SHEIK ABDUL KHADER, [3]Dr.A.MOHAMED ABBAS

[1]Research Scholar, Bharathiar University, Coimbatore, India.
[2]Professor & Head, Department of Computer Applications, B.S.Abdur Rahman Univeristy, Chennai, India.
[3]Assistant Professor, Department of Computer Applications, B.S.Abdur Rahman University, Chennai, India.

E-mail: [1]munawar.munna@gmail.com, [2]hodca@bsauniv.ac.in, [3]abbasasfaq@gmail.com

ABSTRACT

Ad hoc mobile networks are composed of mobile nodes communicating through wireless medium, without any fixed backbone infrastructure. In these networks, congestion occurs in any intermediate node, when data packets travel from the source to the destination, and they incur high packet loss and long delay, which cause the performance degradation of a network. This paper proposes Proactive Routing with Early Congestion Detection (PRECD) in MANET. Initially PRECD constructs a non-congested neighbors' list, and finds a route to a destination. All the primary path nodes periodically calculate their queue_status at the node level. While using the early congestion detection technique, the node detects the congestion that is likely to happen, and sends a warning message to the nodes. The ancestor node is aware of this situation, and finds an alternative path to the destination immediately, by applying adaptive path mechanism. Thus, PRECD improves the performance, in terms of reducing the delay, routing overhead, and increases the packet delivery ratio without incurring any significant additional cost. The performance of PRECD was compared with that of Early Congestion Detection and Adaptive Routing (EDAPR) and Early Detection Congestion and Control Routing (EDAODV), using the NS-2 simulator. The result reveals significant improvement over the EDAPR and EDAODV routing schemes.

Keywords: *MANET, Proactive Routing, Congestion, EDAPR, EDAODV.*

1. INTRODUCTION

A Mobile ad hoc network is a dynamic network formed by a large number of nodes. An Ad hoc network is an autonomous network, which works without the aid of any centralizing authority. Due to the mobility of the nodes, routing is quite a challenging task. One of the fundamental tasks that an ad hoc network should perform is congestion control. The main objective of congestion control is to limit the delay and buffer overflow caused by network congestion, and to provide better performance of the network [2].

Routing is the key functionality for directing communication over large networks. The primary task of any routing protocol is to discover and maintain the routes to reach the network destinations. The routing protocols for ad hoc networks can be divided into two groups, proactive and reactive. Proactive routing refers to the condition, in which whenever a node has some data for a particular destination it can be transmitted immediately. On the other hand, reactive routing protocol determines the routes as and when required by a node in the network [1]. This paper focuses on MANETs using the proactive routing protocol.

There is another dimension for categorizing routing protocols: congestion-adaptive routing versus congestion un-adaptive routing. We note that the existing routing protocols are congestion un-adaptive [5-7]. When establishing a new route, it remains the same until mobility or failure results in disconnection. During packet transfer

between the source and the destination, congestion may happen; this is not handled by the existing routing protocol. It may also lead to the following problems: (i) long delay, (ii) many packet losses and (iii) low throughput. The above problems become more visible in large-scale transmission of traffic intensive data, such as multimedia data probable, and the negative impact of packet loss on the service quality is of great significance [2]. Unlike well-established networks, such as the Internet, in a dynamic network like a MANET, it is expensive, in terms of time and overhead, to recover from congestion [2].

The main aim of congestion control is to lower the end to end delay, and reduce the packet loss caused by network congestion, and offer better performance of the network [3]. In wire line networks, congestion control is employed at the transport layer, and it is independent of the functionality of other layers. However, these congestion control techniques do not apply directly to ad hoc networks, because the ad hoc network is challenged by a limited wireless bandwidth, power constraints and route failures, due to node mobility and limited buffer size. The final result is a high packet-loss rate, re-routing instability, loss of energy, bandwidth and retransmission of lost packets, which implies that more packets are transmitted in the network. These delays and packet losses are not originated by network congestion, but this can be misinterpreted as congestion losses [4].

Our motivation is to clear that congestion which is a dominant cause for packet loss in MANETs. Typically, reducing packet loss involves congestion control running on top of a mobility and failure adaptive routing protocol, at the network layer. A new perspective of this problem might be to realize congestion control in the MAC or network layer. After all, it might make sense to tackle the problem from where it emerges. An exceedingly high network load is a problem closely associated with medium access and packet forwarding [2, 8].

The rest of the paper is structured in the following way. First, Section 2 provides the various related works. Proactive Routing is discussed in Section 3 along with the early congestion detection technique and route discovery. A detailed performance study is presented in Section 4 where the simulation configuration is listed, and the metrics used to measure the performance of PRECD are given. Simulation results and performance comparison charts with EDAPR and EDAODV are provided in Section 5. It also presents the way in which performance is tuned by increasing the CBR load and the number of connections. The work is concluded in Section 6.

2. RELATED WORK

This paper is a follow up of [17], where an analysis of MANET routing protocols and metrics was performed. It was identified that rerouting time is a vital performance metric. The Queue length of a node is directly proportional to rerouting time; i.e., an increase in the queue length would increase the rerouting time. For a good routing protocol, the rerouting time should be less. Queue stagnation is a problem of stale packets being stayed in the queue. This would lead to an increase in the rerouting time. Hence, this has to be reduced. The investigation of the queuing problem was performed by [15] and [16] along with solutions to reduce queue stagnation.

Congestion is another problem which has a direct impact on the rerouting time. So this has also to be mitigated. Congestion is a dominant reason for packet drops in ad hoc networks [13]. Lu et al. [13] found that the AODV is ineffective under stressful network traffic conditions. They proposed a modified version of the AODV (called CADV), which favors nodes with short queuing delays adding to the route to the destination. While this modification may improve the route quality, the issues of long delay and high overhead when a new route needs to be discovered, remain unsolved. Furthermore, the CADV is not congestion adaptive. It offers no remedy when an existing route becomes heavily congested. A Dynamic Load Aware Routing protocol (DLAR) was proposed in [12]. DLAR is similar to CADV, the difference being that a node with a low routing load is favored to be included in the routing path during the route discovery phase.

In our previous work, reactive methods of reducing the rerouting time in MANETs were proposed. [14] Proposes an enhanced approach to reduce the rerouting time, whereas, this paper focuses on a proactive way of reducing rerouting time. [14] Extends the buffer zone routing algorithm with the introduction of virtual zones. In Early Congestion Detection and Optimal Control Routing (EDOCR), the network is divided in to sparse and dense regions, by using average neighbors, to find a non-congested alternative path with the help of dense nodes. EDAODV [9] techniques have been proposed to detect the congestion well in advance and find a non congested alternative path bi-directionally. A technique for self curing the congestion was proposed in [10], and is called the Early Detection

Congestion and Self Cure Routing (EDCSCAODV). EDAPR was proposed in [11]. In EDAPR, techniques have been proposed for preventing congestion by using the NHN (Non-congested 2 hop neighbors list).

To utilize the concepts of EDAODV and EDAPR, we propose the PRECD routing protocol for mobile ad hoc networks. PRECD detects congestion by using early congestion detection techniques, and it can easily choose a non-congested alternative node from the two hop lists and establish a route to the destination immediately. The new protocol can reduce broadcast packets and find a non-congested path.

3. PROACTIVE ROUTING

3.1 Early Congestion Detection

Congestion in a network may occur at any time; when the number of packets coming to a node exceeds its buffer capacity, the node becomes congested and starts losing packets. We can use a variety of metrics at a node to monitor the congestion status. For instance, we can be based on the percentage of all packets discarded for lack of buffer space and the average queue length. We use an early congestion detection technique at a node to detect the congestion well in advance. An early congestion detection technique is a queue management algorithm with an optimization of the Random Early Detection (RED) model, which makes use of direct measurement congestion status well in advance in a network.

Equations (1) and (2) are used to set the Minimum and Maximum threshold values for the queue length.

$$\text{Minth} = 25\%\text{buffer\_size} \quad (1)$$

$$\text{Maxth} = 3 * \text{Minth} \quad (2)$$

If the queue length is less than the Minth, then the node can be classified to be in Zone I (safe zone); greater than Minth but lesser than Maxth is classified as Zone-II (likely to be a congested zone), and if it is greater than Maxth it is classified as Zone-III (congested zone).

To detect the congestion well in advance, compute the average queue size as

$$\text{Avgque} = (1 - w_q) * \text{Avgque} + \text{Inst\_Que} * w_q \quad (3)$$

Where w_q, the queue weight is a constant parameter (w_q =0.002 from RED queue experimental result), and Inst_Que is an instantaneous queue size.

The Congestion detection model proposed in [11] introduced the Queue_status over the average queue size given by equation (4), which reflects the heaviness of the incoming traffic. Based on the Queue_status, the mobile node can get useful information about the incoming traffic. If the Queue_status value is large, the incoming traffic becomes bursty. The continuous growth of the Queue_status indicates that the incoming heavy traffic is beyond the mobile node's buffer capacity and buffer overflow is imminent.

$$\text{Queue\_status} = \text{Inst que} - \text{Avgque} \quad (4)$$

If the Queue_status is <minimum threshold, the incoming traffic is low, and the queue is in the safe zone. If the Queue_status is >minimum threshold and Inst_Que is < the maximum threshold, the incoming traffic is normal, and the queue is likely to be in the congested zone. If the Inst_Que is > maximum threshold, the incoming traffic is heavy and the queue is in the congested zone, as shown in Figure 1.

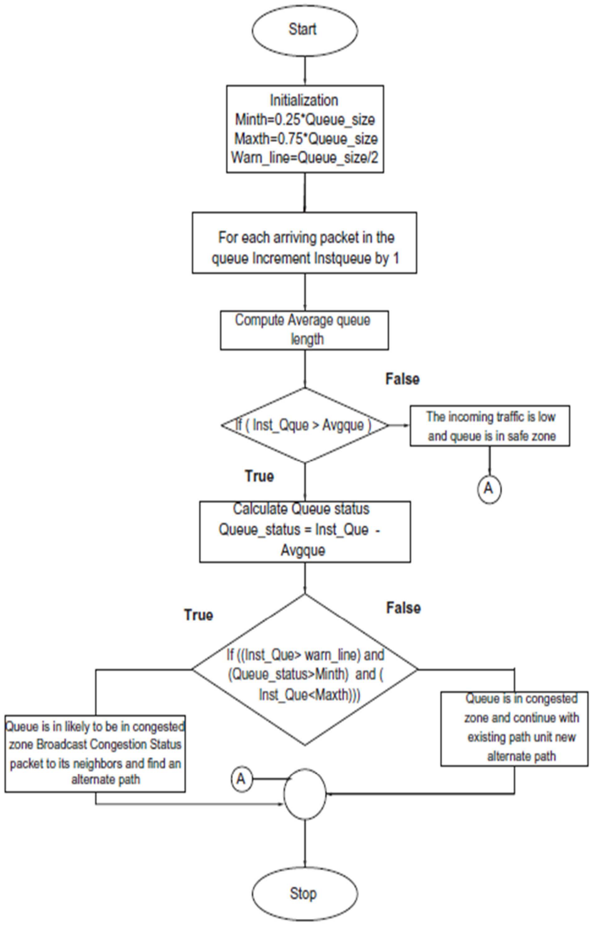


Figure 1.Early Congestion Detection.

3.2 Route Discovery

Each mobile node chooses its Congestion Free Set (CFS) [18, 19] from its non-congested 1-hop neighbors. The CFS is chosen in such a method that it wraps all 2-hop nodes.

The Congestion Free Set of source host S, represented by CFS(S), then a random subset of the non-congested 1- hop region of S which convinces condition: Every node in the exacting 2-hops zone of S must have a link towards CFS(S) and it should not fall in the congested zone. The CFS setup is an initialization procedure, where each mobile host every second calculates its congestion status by using the dynamic congestion estimation technique. Every mobile host broadcasts its congestion status by using a Congestion Status Packet (CSP) to its one hop neighbors on the network. Now, each mobile node discovers its 1-hop non-congested neighbor nodes, and gathers information about its 1-congested one-hop list. At this point, each mobile node builds its CFS-set by selecting a subset of its 1-hop non-congested neighbor nodes, so that the mobile node in the subset can send its broadcast packet to the 2-hop neighbor nodes, to decrease the overflow traffic. Each mobile node updates all the information in its routing table.

When the source node desires to communicate a data packet to a destination, the source node creates the RREQ packet for broadcasting using the CFS-set nodes towards the destination. The source node initially verifies its 2-hop list. If the destination host is present within the 2-hop list, then the RREQ is transmitted by the routing table's path. If the destination node is not within the 2-hop list, the source host broadcasts the RREQ to the CFS-set in a network.

When the CFS-set obtains the RREQ packet, it checks its 2-hop list. If the destination is within its 2- hop list, then the CFS node delivers the RREQ to the destination node. The destination answered the first received RREQ and replied an RREP packet to the source node, and adds a new entry in its routing table.

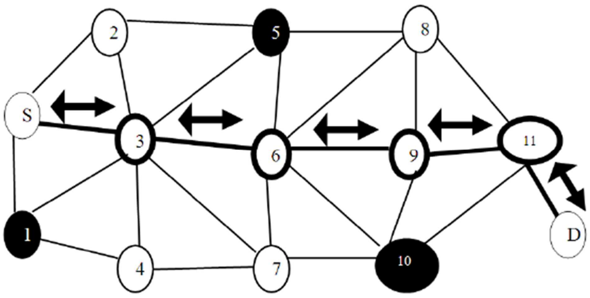


Figure 2.Route discovery process
⬌ *Route Request, Replay*

Figure 2 shows the route discovery subsequent to the CFS-set selection. The source node S has a non-congested 1-hop lists are {2, 3, 4} and a non-congested 2-hop lists are {4, 6, 7}. The source has chosen node 3 as a CFS and added it to the CFS list. The first node S verifies its 2-hop list to check whether it contains the destination node D. If the destination node D is not within the list, the source node S broadcasts the RREQ packet to the next CFS node 3. Then, node 3 would verify the 2-hop list. If the destination is not inside, the CFS node 3 broadcasts the RREQ to the next CFS node 6; The CFS node 6 would verify the 2-hop list. If the destination is not present, then the CFS node 6 broadcasts the RREQ to the next CFS node 9; now, node 9 discovers that the destination node D is in the 2-hop list; so node 9 forwards the RREQ packet by the CFS node 11 to the destination node D. Destination node D gets the RREQ packet, and then sends the RREP packet to the source. A route S ->3 -> 6 ->9->11> D is found between source S and destination D. This path becomes a non-congested path between the source and the destination. After the route discovery, the data packet is sent between the source and the destination. This route became the core route from S to D.

3.3 Alternate Path Routing

The core path of a node predicts its congestion status periodically and updates its congestion status by broadcasting a CSP packet with the Time to Live (TTL) = 1. When the precursor node receives a CSP packet from its core path node of say A regarding destination D, the precursor node will alert the congestion information of A, Non - congested node in the core path and its hop count.

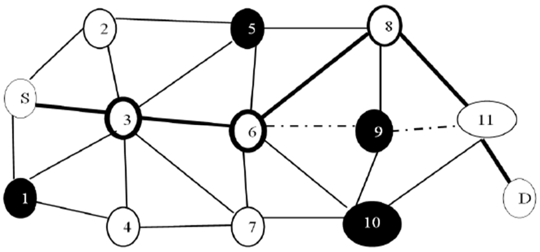


Figure 3.Alternate path finding process.
● *Congested node* -·-·- *Primary path* —— *Alternate path*

When the descendant node receives a CSP packet from its core path node of A regarding Source S, the descendant node will be awake of the congestion information of A, previous Non-congested node in the core path and its hop count. The routing table of the ancestor and its nodes are kept informed accordingly. This information is a step forward to find the bidirectional non-congested alternative path:

Figure 3 shows how the CFS node 9 notices that congestion is likely to occur, and sends a warning to its neighbor CFS nodes 6 and 11; they are aware of this situation and update their non-congested neighbor list in their routing table. In response, the processor CFS node 6 chooses a new CFS node 8 from its non-congested neighbor list, because node 8 is a common node for node 6 and node 8, and it finds the route to the destination using the CFS node 8, as shown in Figure 3. The traffic coming to 6 will be routed through the new route s ->3 ->6 ->8 ->11 -> D respectively. It is possible that if no CFS nodes are found, it continues using the primary route S ->3 ->6 ->9->11>D. The new path is a non-congested path, but not necessarily the shortest path.

4. PERFORMANCE STUDY

4.1 Performance Metrics

PRECD, EDAPR and EDAODV are implemented using the Network Simulator (NS-2.34) [20]. A comparison of PRECD‘s performance and those of the EDAODV and EDAPR routing protocols in MANETs, is made. The observation is presented below as:

We considered the following important metrics for the evaluation:

1. *Packet Delivery Ratio (PDR):* The ratio between the number of packets received by the destination and the number of packets sent by the source.
2. *End-to-End Delay*: The delay a packet suffers from leaving the sender till arriving at the receiver.
3. *Routing overhead:* The total number of Control packets transmitted during the simulation time. For packets sent over multiple hops, each transmission over one hop is counted as one transmission.

4.2 Simulation Configuration

The network consists of 100 nodes in a 1400, 1400 m terrine size. The radio range is 250 m with 2 Mbps bandwidth. The MAC layer was based on IEEE 802.11 Distributed Coordination Function (DCF). A 2-ray ground reflection model was used as the channel propagation 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 from the MAC layer feedbacks. A routing buffer at the network layer could store up to 64 data packets. This buffer keeps data packets waiting for a route, such as packets for which route discovery had started, but no reply had arrived yet. The routing protocols we used are PRECD, EDAPR and EDAODV. The data flow used CBR, which varies from 4 packets to 16 packets and the flows vary from 10 to 50. The Maximum speed of the node is 10 m/s and simulation time is 900 s. Table 1 provides the simulator parameter settings used during the simulations.

Table 1.Simulation Parameter Settings

Parameters	Values
Routing	CFR, AODV
MAC	802.11
Bandwidth	2 Mbps
Terrain	1400, 1400 m
Nodes	100
Antenna	2 ray ground
Node placement	Uniform
Data traffic	CBR
Simulation time	900 sec
MAC queue size	50 packets
Routing queue	54 packets
Load (Flows)	10-50 Flows
Load (Pkts/Seconds)	4-16 Pkts/S
Max Speed (m/s)	0-10 m sec^{-1}
Pause Time (s)	30 sec

5. SIMULATION RESULTS

In this section, the simulation setup is presented, and then the results are documented. Comparison charts are provided between the standard PRECD, EDAPR and EDAODV.

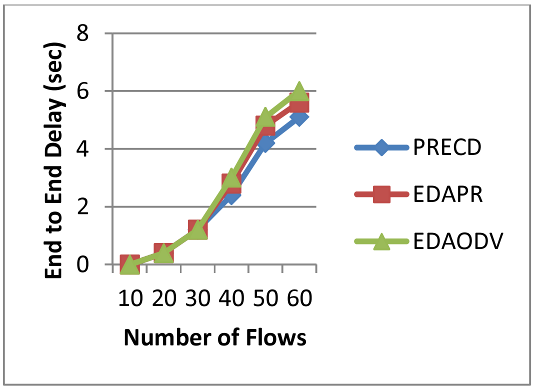
5.1 Varying number of connections

In this simulation, the number of connections (source to destination) is varied from 10 to 50; CBR sending rate is 4 packets/s, maximum node speed 10 m/s and pause time 30 s.

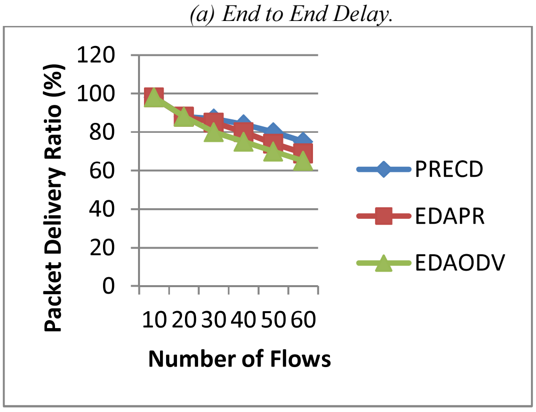
Figures 4 (a), (b) and (c) show the end-to-end delay, packet delivery ratio and routing overhead for PRECD, EDAPR and EDAODV respectively. The results in Figure 4 (a) show that the delays incurred by the three protocols (PRECD, EDAPR, and EDAODV) are similar, when set to 10 flows. This is because at a low offered load, the network congestion level falls in the safe zone, as the outcome of the end-to end delay being minimum, by incurring data packets on route to their destinations. In the case of high offered load (e.g. 20 flows), the network congestion level falls in the likely to be congestion zone; the end to end delay incurred by the three protocols increases almost linearly with an increased offered load. However, at 30 flows, the PRECD routing protocols demonstrate a 4% reduction of the delay over the EDAPR and 10% reduction over EDAODV. The reasons are as follows: when the network falls in the likely to be congested zone (Zone II level), all three protocols try to find a non-congested alternative path. While finding an alternative path, in EDAODV, the non-congested primary path predecessor and successor node tried to find an alternative path explicitly, whereas the PRECD has a two hop non congested neighbors set, so that it can easily choose a non-congested alternative node from its two hop list and establish a route to the destination immediately. This is due to the fact that the numbers of forwarding nodes are minimal; this leads to decreased network congestion. When the PRECD is compared with EDAPR and EDAODV, at high offered loads (between 40 and 50 flows), the delay is reduced by around 12% over EDAPR, and by 20% over EDAODV.

Figure 4 (b) shows the achieved packet delivery ratio of the three protocols, which is similar when the offered load is below 20 flows. This is because when the number of flows is less, the number of nodes initiating the route discovery operation is also less. When the numbers of flows increases from 30 to 50, as an outcome, more RREQ packets are generated and transmitted, this leads to a high consumption of the node's buffer which causes network congestion. This, in fact, leads to a fewer number of data packets being delivered at the destinations, thereby degrading the network's performance. But, it can be noticed from Figure 4 (b) that initially the PRECD constructed two hop non congested neighbors. It knows all such neighbors, both one hop and two hops, so that it takes the minimum number of control packets to find an alternative path than EDAPR and EDAODV. At the offered load of 30–50 flows, the packet delivery ratio is increased from 6% to13%, when compared against the EDAPR, whereas compared with EDAODV; it increases from 10% to 21%. The difference in the achieved packet delivery ratio is due to the reduction of the number of nodes involved in the broadcasting of RREQ packets in congested networks, leading to a reduction of the node's buffer occupancy. As a result more communication bandwidth is available for data transmission.

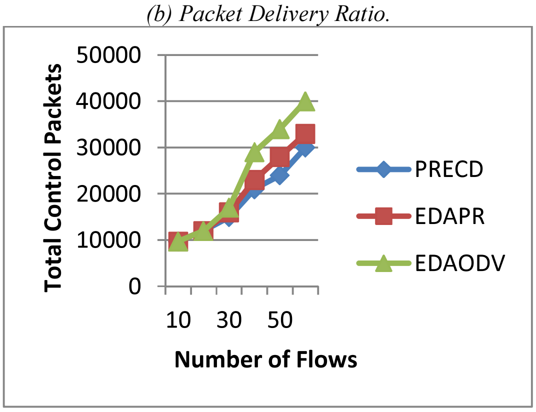
With regard to the routing overhead, Figure 4 (c) shows, that when the offer load is low (e.g. 20 flows) the PRECD did not yield a better performance than the EDAODV and EDAPR. This is because at low offered load, the network congestion level falls in the safe zone. When the offer load is increased from 30 to 50 flows, the EDAODV incurred a heavy routing overhead, and consumed the heaviest control packets to find an alternative path. The EDAPR consumed more control packets to find an alternative path, whereas the PRECD required the least control packers from 16% to 9% of the overhead of EDAPR, and 33% to 16% over that of EDAODV. The PRECD seemed unaffected by increasing traffic because; it resolves congestion by using non congested neighbors, which is implicitly distributed over the alternative paths. This was the reason for the routing overhead of the PRECD to be less than that of the EDAODV and EDAPR.



(a) End to End Delay.



(b) Packet Delivery Ratio.



(C) Routing Overhead.

Figure 4 .Performance When Number Of Connections (Source And Destination) Change.

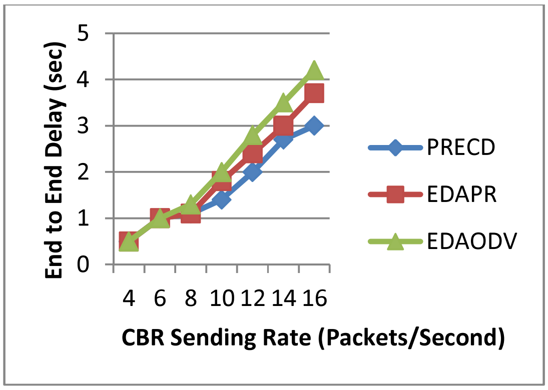
5.2 Varying CBR load

In this simulation, the number of connections (different source and different destination) is kept at 20. The CBR sources send data packets to the destinations at different rates, varying from 4 packets/s to 16 packets/s. Figures 5 (a), (b) and (c) show the End-to-End delay, packet delivery ratio and Routing overhead for PRECD, EDAPR and EDAODV respectively.

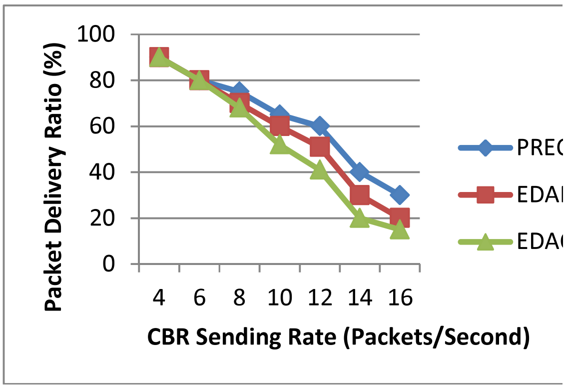
One observes the End-to-End delay in PRECD, EDAPR, and EDAODV, as shown in Figure 5 (a). When the data packet-sending rate is low (less than 8 packets/s), the delay incurred by the three protocols increases almost linearly with the increase in the offered load, and the delay variation between PRECD, EDAPR and EDAODV seem unchanged. When the packet rate is high (more than 8 packets/s), the network is in zone II level congestion; EDAODV used a bidirectional path discovery mechanism to find an alternative path, but the PRECD uses non congested neighbors; it takes all two hops non-congested nodes, so that it can find an alternative path with minimum cost. The PRECD demonstrates a reduction in the delay over the EDAODV and EDAPR. This is because the number of forwarding nodes is reduced; leading to unnecessary broadcast and network congestion. Compared with both EDAODV and EDAPR, at a high packet rate (10–16 packets/s), the delay is reduced from 14% to 12% over EDAPR, and from 20% to 15% over EDAODV respectively.

With regard to the packet delivery ratio Figure 5 (b), shows that when the packet rate was small (less than 8 packets/s), the PRECD, EDAPR and EDAODV delivered similar loads of packets. This was because the network traffic was not yet heavy. But, when the packet rate is high (10–16 packets/s), the network comes in the zone II level congestion; the EDAODV uses the bidirectional path discovery mechanism to find an alternative path but the PRECD uses non congested neighbors, so that it finds an alternative path immediately. The PRECD seems to have improved the packet delivery ratio at least by 13-15% over the EDAPR, and an improvement of 19–22% over EDAODV.

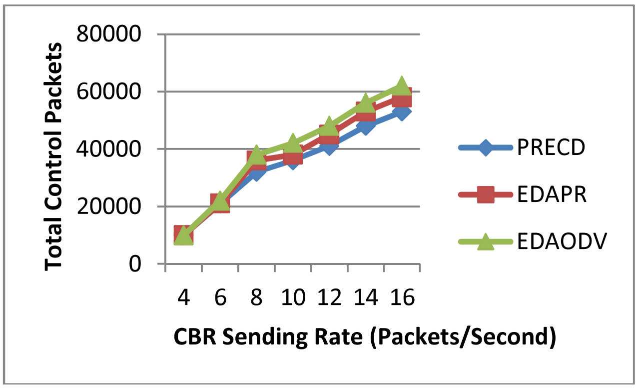
Figure 5 (c) shows the routing overhead between PRECD, EDAODV and EDAPR. When the traffic load was small (4–8 packets/s), the routing overhead of the PRECD, EDAODV and EDAPR was similar. More impressively, when the traffic was heavier (10–16 packets/s), the routing overhead of PRECD was reduced from 15% to 13% than the routing overhead of EDAPR, and from 30% to 22% than that of EDAODV. The reason is as follows: when the traffic was heavier, while EDAODV tried to find an alternative path to the destination by broadcasting a more route request, the PRECD initially found a set of non congested neighbors, which consists of one hop and two hop neighbors, so that it can easily find an alternative path than EDAPR and EDAODV. Therefore, less number of route request packets was consumed than in EDAPR and EDAODV. The difference between PRECD, EDAODV and EDAPR is in terms of delay, delivery ratio and routing overhead; PRECD seems better than both.



(A) End To End Delay.



(B) Packet Delivery Ratio.



(C) Total Control Packets.

Figure 5.Performance when CBR load changes.

6. CONCLUSION

MANET network characteristics, like congestion, and route failure, need to be detected and remedied with a reliable mechanism. In this paper, we have proposed a novel way of accomplishing congestion control in wireless multihop networks: Proactive Routing with Early Congestion Detection in MANET (PRECD). PRECD works with fewer packet losses than other techniques that are not adaptive to congestion. This is because, the PRECD tries to prevent congestion from occurring in the first place, rather than dealing with it reactively.

In this technique, the nodes are aware of a potential congestion ahead. They find a non-congested route between the source and the destination, so that the congestion is controlled. The PRECD does not incur a heavy overhead to find non-congested paths, because this intelligence is delegated to the nodes, which forward the broadcast control packets during the flooding process. The technique substantially reduces the overhead as compared to the existing flooding mechanism. It also monitors the congestion status during data transmission. If any congestion is likely to happen, it adapts the congestion to find an alternative route.

Rerouting time is an important performance measure in MANETs, where the network topology is dynamic, and connectivity between nodes is disrupted frequently. The PRECD also provides a shorter end-to-end delay compared to the other techniques. Our NS-2-based simulation has confirmed the advantages of PRECD and demonstrated the reduction of End-to-End delay, routing over head and improvement of packet delivery ratio over EDAPR and EDAODV.

REFERENCES

[1] Siva Ram Murthy C, Manoj BS. Ad hoc wireless networks – architectures and protocols. Pearson Edu 2007.

[2] Duc A, Tran, Harish Raghavendra. Congestion adaptive routing in mobile ad hoc networks. IEEE Trans Parallel Distrib Syst 2006;17(11):16–28.

[3] Corson S, Macker J. Mobile ad hoc networking (MANET): routing protocol performance issues and evaluation considerations. RFC 1999;2501.

[4] Johnson, Maltz D. Ad hoc networking. Addison-Wesley; 2001.

[5] Li VOK, Lu Zhenxin. Ad hoc network routing 2004. In: IEEE international conference on networking, sensing and control, vol. 1; 2004. p. 100–5.

[6] Ramanathan R, Redi J. A brief overview of ad hoc networks: challenges and directions. Commun Mag IEEE 2002;40(5):20–2.

[7] Royer E, Toh CK. A review of current routing protocols for ad hoc mobile wireless networks. IEEE Pers Commun1999;6(4):46–55.

[8] Christian Lochert, Bjo¨ rn Scheuermann, Martin Mauve. A survey on congestion control for mobile ad-hoc networks. Wiley Wireless Commun Mobile Comput 2007;7(5):655–76.

[9] Senthil Kumaran T, Sankaranarayanan V. Early detection congestion and control routing in MANET. In: Proceedings of the seventh IEEE and IFIP international conference on wireless and optical communications networks (WOCN 2010); 2010. p. 1–5.

[10] Senthil Kumaran T, Sankaranarayanan V. Early detection congestion and self cure routing in MANET. In: Proceedings of Springer LNCS computer and information science, vol. 142 (Pt.3); 2011. p. 562–7. E.

[11] Senthil Kumaran, T. and Sankaranarayanan V, 2011b. Early congestion detection and adaptive routing in MANET. Egyptian Inform. J., 12: 165-175. DOI:10.1016/j.eij.2011.09001.

[12] Lee SJ, Gerla M. Dynamic load-aware routing in ad hoc networks. Proc IEEE Intl Conf Commun 2001:3206–10.

[13] Lu Y, Wang W, Zhong Y, Bhargava B. Study of distance vector routing protocols for mobile ad hoc networks. Proc IEEE Intl Conf Pervasive Comput Commun (PerCom) 2003:187–94.

[14] A. Mohammed Munawar and Dr.P.Sheik Abdul Khader, "An Enhanced Approach to Reduce Rerouting Time in MANETs" in proceedings of the IEEE International Conference on Emerging Trends in Computing, Communication and Nano Technology(ICE-CCN'13), March 25-26 2013, ISBN: 978-1-4673-5036-5.

[15] A. Mohammed Munawar and Dr.P.Sheik Abdul Khader, "Elimination of Queue Stagnation in MANETs" in proceedings of National Conference on Recent Trends in Web Technologies (RTWT'13) October 4-5 2013, ISSN: 2347 - 7806 .

[16] A.Mohammed Munawar and Dr.P.Sheik Abdul Khader, "Asynchronous Invocation method to Eliminate Queueing in MANETs" in proceedings of Second International Conference on Design and Applications of Structures, Drives, Communicational and Computing Systems (ICDASDC'13) November 29 & 30, 2013, ISBN: 978-93-80686-92-9.

[17] A. Mohammed Munawar and Dr.P.Sheik Abdul Khader. "A Comprehensive Analysis on MANET Routing Metrics, Protocols and Simulators" in proceedings of National Conference on Advances in Computer Applications, 28 March 2012, ISBN:978-93-80769-16-5.

[18] Wu, J., W. Lou and F. Dai, 2006. Extended multipoint relays to determine connected dominating sets in MANETs. IEEE Trans. Comput., 55: 334-347.DOI: 10.1109/TC.2006.40

[19] Yen, Y.S., H.C. Chang, R.S. Chang and H.C. Chao, 2010. Routing with adaptivepath and limitedflooding for mobile ad hoc networks. Comput. Elect. Eng., 36: 280-290. DOI: 10.1016/j.compeleceng.2009.03.002

[20] Network Simulator ns-2 , http://www.isi.edu/nsnam/ns/