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Efficient Bandwidth Utilization with Congestion Control for Wireless Mesh Networks

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Abstract

In recent years, Multi hop wireless networks have caught wide attention in the areas of high speed traffic and applications with high bandwidth requirement such as video and audio transmissions. Congestion is one of the major factors which degrade the system performance while we are working with high speed multi hop networks. Congestion control plays a vital role to improve the bandwidth utilization and system performance. In this project, an accurate measurement of the Available Bandwidth in a network is calculated and an enhanced congestion control mechanism for such paths in wireless mesh networks is proposed. The performance evaluation of the proposed model is simulated in NS-2 simulator and the results were compared with existing model.

Keywords: Multi Hop Networks, Congestion Control, Available Bandwidth, ECN Introduction

1. Introduction

Wired networks are infrastructure networks wherein there will be a centralized system monitoring. There are several benefits of wired networks such as security, speed, reliability and easy maintainability. Yet, people prefer using wireless networks due to its advantages like portability, ease of deployment and its high usage comes into act when there is a need to set up a network for a temporary purpose wherein the need for a base station will not be needed. Wireless networks implies to a technology wherein communication between two or more computers is enabled without the usage of any cables. Wireless Mesh networks (WMN) falls under a type of wireless network called as Mobile Ad-hoc Networks (MANETs) but the difference between MANETs and WMNs is that the clients rely on an infrastructure in WMNs whereas MANETs is truly infrastructure-less. Though TCP is known for its reliability and error-handling techniques in wired networks, its usage in wireless networks is not up to par. To make TCP more reliable, it is important to address the way TCP handles congestion.

Congestion is the instability of the network which results in packet drops leading to retransmission of packets which in turn leads to the bottleneck stage. Congestion occurs mainly due to the over-loading of the network because of not knowing the network stage at that particular moment of time. Though there are certain active queue management techniques like RED, Fast Retransmit and Recovery for handling congestion, which is the marking up of packets instead of dropping them, ECN had evolved, due to the delay constraints imposed by these techniques making them not so suitable when it comes to their usage in larger scaled networks.

ECN is Explicit Congestion Notification Technique which notifies whenever congestion occurs unlike the discussed active queue management techniques. Hence, knowing the state of the network before hand will indeed result in avoiding congestion if not fully, at least to an extent. The proposed model provides solutions to the above mentioned problems so that it will result in reduced effect of congestion in a network thereby increasing the performance of a network with regards to the performance metrics such as end-to-end delay, throughput, enhanced packet delivery ratio etc. The simulation results will be compared with the existing model proving the proposed model to be efficient.

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2. Related Works

Krishnamurthy S V et al. devised a framework to address the problem of increasing traffic due to interferences and rate requirements as minimal. The solution was to allocate channel to many different communication links[1] by enabling each individual nodes transmission power. The cross-decomposition technique was used along with the schedule of each channel's allocation thereby resulting in an effective solution. Kang G Shin K G et al. developed a new protocol CHORUS[2] which was designed for MAC/PHY resulting in collision. The same data packets were being detected and with comparable signal strengths made to overcome collision using the symbol-level cancellation technique. The simulation results showed that CHORUS was more reliable, scalable than the existing protocols.

Nishanthini C et al. identified the shortest path using hop count. If the number of hops and the number of packets were found to be lesser than the default value, then transmission took place. If either of these were found to be greater than the default value, then Carman Algorithm[3] will be called. The simulator used was NS 2 which resulted in increased Quality of Service in MANETs. Gupta H et al. performed Multipath Routing by using queues. It was witnessed that using queues had lead to a drastic reduction in overhead, end to end delay and maximized packet delivery ratio[4]. The simulator used was NS 2 which had given a quicker and easier understanding of the algorithms used and also identified the behavior of the networks.

Yu Cheng et al, had made a theoretical analysis of achieving maximized throughput[5] in CSMA/CA in a wireless blackhaul network. This network connects the multihop wireless network to the internet backbone. A conflict graph was plotted to notify the interference between the various links which indeed guarantees that this method must in turn be highly reliable for which maximum throughput is indeed necessary. Ikeda M et al. calculated the traffic in multiple routes, congestion state, capacity and the latency by using two reactive protocols suitable for MANETs such as AODV and OLSR. OLSR protocol identified the shortest path using Fish Eye Algorithm[6]. NS 3 was used to measure the performance metrics such as throughput, round-trip time and packet loss during simulation.

Soundararajan S et al. had efficiently performed load balancing by dividing the traffic to multiple paths[7]. Here, the intermediate nodes calculated the traffic rate in a path and this information was passed to the destination node depending on which sender receives feedback through acknowledgement packets. Finally, congestion was controlled effectively due to the traffic rate obtained at a priori. Disadvantage of this method would be it incurs overhead due to communication. Nandgave-Usturge S et al. had used cross-layer approach to overcome the difficulties like mobility, interference and congestion in MANETs. A periodic HELLO message is being sent by AODV using which congestion is identified. Considering the signal strength and link failure notification from neighbors[8], performance of the network was increased.

Al Islam A B M A et al. had taken two problems namely lossy nature of wireless medium and high congestion effect into consideration. Solution is obtained through simulation in NS 2, Wireline TCP and Wireless TCP. Since, no optimal results could be found in any literature for MABCC[9]. Staehle B et al. solved the intra-mesh packet loss by turning it into local packet loss to reduce the impact of the former. Intra-mesh packet loss thrusts greater impact on the network throughput and the amount of payload that couldn't be done in successful transmissions. The following were three mechanisms used TCC, LSCC, PSCC[10] to increase the network throughput and reliability on the network during simulation.

Masri A E et al. proposed a congestion control protocol based on neighborhood and overhead free[11] without the usage of any resource. The main issues bandwidth scarcity and starvation were addressed by using multi-bit feedback and neighborhood management respectively in NICC. Rangwala S et al. had made a wireless control protocol for recognizing congestion on the neighborhood nodes[12]. Congestion can in turn be avoided once a clear estimation of the capacity and the bandwidth available is calculated in a network. Simulation results have proven this to be more fair and efficient then the existing ones.

Lindemann C et al. designed a congestion control algorithm[13] to overcome the flaws in TCP as in 802.11. Dynamically changing the transmission rates has indeed resulted in 10 times more goodput than TCP NewReno. Aziz A et al. provided a mechanism for understanding the root causes for the instability of wireless mesh networks[14]. There were two parameters which were considered important for maintaining the stability of the network: network size, stealing effect the consequence of hidden node problem. The mechanism was to maintain a distributed flow – control when there is finite number of relay nodes.

Baretto L et al. used two protocols: XCP and RCP which were useful in determining available bandwidth and link capacity[15] of a network using Cross layer approach. XCP-winf and RCP-winf was a new technique with the base rt-winf as in[16]. Res B et al. devised rt-winf[16] which was similar to idle gap mechanism[17] wherein calculation of available bandwidth is done passively. Difference between IdleGap and rt-winf was that, available bandwidth and link capacity were calculated using RTS/CTS packets information. In their absence, only small amount of probe packets will be needed to determine them. There were two simulators used to show a detailed comparison in the results obtained: CMU and NS2. Both proved the accuracy of the obtained measurements.

Kumaran T S et al. used two measures: queue status and congestion status[18]. Depending on the latter, a bi-directional route discovery (say) a non-congested alternate path along the congested node was identified using which routing was performed resulting in minimal packet loss. Since this was done prior to routing, there was optimality in the early congestion control mechanism. Tiejun Chen at al. devised an algorithm for congestion control in WMN. It performs random routing algorithm based on path weight[19].Firstly, Identify the shortest path from the Dijktras algorithm which maintains a routing table. Secondly, find the candidate paths. Now, for each candidate paths, identify the weights with distance vectors and select a path randomly from the candidates and use that path for routing. The simulation results proved better with reduced average wait time and successful rate of service requests.

Rashidi S et al. had used trust based routing protocols which have embedded cryptographic algorithm and trust agents[20].The Congestion Control agent distributed the load to the trusted nodes. Packets are being routed through these trusted nodes only. The protocol used was AODV as the routes were being identified on demand and yet only the trusted nodes were used for routing. Limitation would be, a small miscalculation of trust of a node will lead to huge loss. Giovandinis A et al. addressed the issue of hop by hop packet loss and retransmissions[21] by providing an expression for network capacity region. The power allocation problem was also addressed using the brute force technique. The simulated result showed that the applied technique had optimal results.

Yerajana R et al. had time stamped every node and the nodes with minimum time stamped value was considered to be the optimal path for routing packets[22]. The simulation results in Glomosim Network Simulator showed that the method proved to produce increased packet delivery ratio, decreased end to end delay and number of collisions. Gang feng et al. first devised an end to end algorithm. Later, based on this algorithm, hop by hop congestion control information feedback[23] was developed and its convergence was proven. At simulation in NS 2 it was seen that hop by hop congestion information algorithm outperforms end to end algorithm.

Wei sun et al. overcame the basic problem of TCP (any problem-means congestion). The disadvantage of this mechanism is that, it has low-throughput than TCP flows. On the event of any congestion, TCP will react to it by adapting the end systems sending rate to avoid congestion collapse and increase network utilization[24]. Giannoulis A et al. solved two issues jointly such as Congestion Control and Channel Allocation. Congestion Control sub-problem were approached by distributing the traffic to a poorly loaded network and Channel Allocation was done by using the Congestion control information[25] which in turn shapes the congestion control problem of the next iteration. This scheme was proven to be highly efficient.

Nascimento V et al. presented a new technique to improve TCP performance in wireless mesh networks using a cross layer approach known as vertical calibration across layer[26]. This technique was simulated in NS 2 and the performance metrics Expected Transmission Count and Minimum Delay were considered. Depending on the information from CLM –TCP which comes from OLSR combined with ETX and MD, manipulation of congestion window size and congestion threshold values were done. Wen Tsuen Chen et al. proposed a multichannel MAC protocol[27] using multichannel congestion control thereby overcoming the hidden terminal problem. The proposed scheme was simulated and the results proved to be very efficient than traditional MAC protocol.

Tan kun et al. addressed various TCP problems which occur due to wireless media, lack of congestion indication and efficient allocation of resources. The devised dynamic algorithm was called as EWCCP[28] which uses CSMA with collision avoidance in MAC with optimal window size, robustness and was proven to be highly efficient during simulation.

3. Proposed Model

A mesh network is to be set-up using the AODV routing protocol. This protocol is a reactive protocol. Meaning, it will create a network only on demand. Since wireless mesh networks is a type of MANETs, it is in fact clear that there will be no centralized monitoring of the network.

3.1 AODV Module

The setting up of path in AODV takes place in Route Discovery phase. Route Discovery consists of two phases: Join_Request and Join_Reply. A multicast source broadcasts Join_request packets to all the nodes in a network. This Join_Request packet, is a member advertizing node meaning, it will become a member of the Forwarding Group if their ID matches. A multicast receiver broadcasts Join_Reply packets on obtaining the Join_Request packet. It updates the member table and if there are duplicate Join_Request packets it will discard the old one and update the routing table. Now, the Join Table will be broadcasted to all the nodes. The intermediate nodes check if there is an ID match or not, if yes, then it becomes a member of the FG thus setting FG flag to 1. Mesh network is better than tree because the latter requires frequent path reconfigurations whereas in former, there is constant broadcasting of packets thus resulting in avoiding channel fading and node displacements.

In Figure 1, it can be seen that there are 10 nodes out of which some become the member of the FG nodes who are indulged in the transmission of the data packets. After the setting up of the mesh network, the bandwidth available will be calculated as described below in Algorithm1. The calculation of the bandwidth available will be done using active measurement technique such as probing. Probing is the continuous transmission of control packet throughout the network which monitors the state of the network and returns the traffic, throughput, probe return time, train length and all the other required measures. Though there are passive measurement techniques like pathload, pathchirp tools, active measurement is done to get a reliable and accurate value of the available bandwidth in a network as in[29].

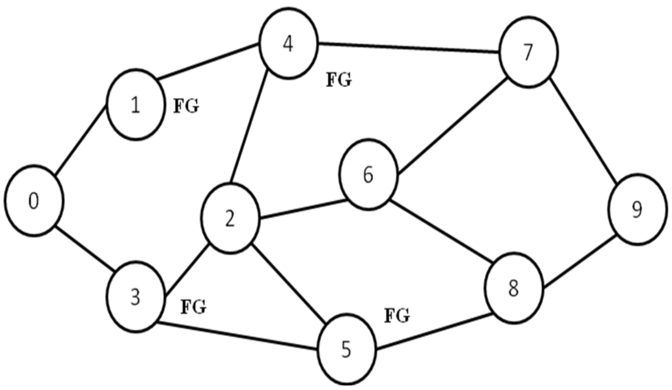

Figure 1. Mesh Network

Algorithm 1: Calculation of Available Bandwidth

The probe packets are transmitted in a train-like fashion. The probe gap is the intermediate gap between the probe packets. This value will be noted down along with the packet train length. The average return time of the probe packets is indeed identified and noted down.

$$probeGap = \frac{probeSize}{(2 * \text{capacity})}$$

$$beta = \frac{probeGap}{4}$$

$$alpha = 0.01$$

$$err = \frac{(avg(probe\,\text{Re}\,turnTime) - probeGap)}{probeGap}$$

$$probeGap = probeGap + beta$$

$$availBandwidth = \frac{(probeSize * (trainLength - 1))}{sum(probe\,\text{ReturnTime})}$$

Thus, the required Available Bandwidth is obtained with accuracy. Hence, the transmission of data packets will be done, depending on the bandwidth available. The amount of data packet transmission will indeed be dependent on the AB value obtained. This ensures that, the bandwidth is neither over – utilized, nor under – utilized resulting in efficient utilization of it. Now that AB is calculated, it is essential to check if there is any congestion in a network because the same nodes in the mesh might be in the middle of another data packet transmission. If congestion does exist, then ECN will notify about it. Now that congestion occurrence is notified, it is important to check if the congestion value obtained is lesser than the C_{thresh} value. If yes, then queue and transmit the packets. Otherwise, the proposed congestion control mechanism as in **Algorithm 2** will be called.

Algorithm 2: Proposed Congestion Control Mechanism

if

$rtt\_new = (rtt_{current+1} < rtt_{current} < rtt_{current-1})$

$\text{new\_winsz} = \text{winsz} + 2$

else-if

$\text{rtt\_new} = (\text{rtt}_{current} < \text{rtt}_{current+1} < \text{rtt}_{current+2})$

$\text{new\_winsz} = \text{win\_sz} - 1$

else

$\text{new\_winsz} = \text{winsz}$

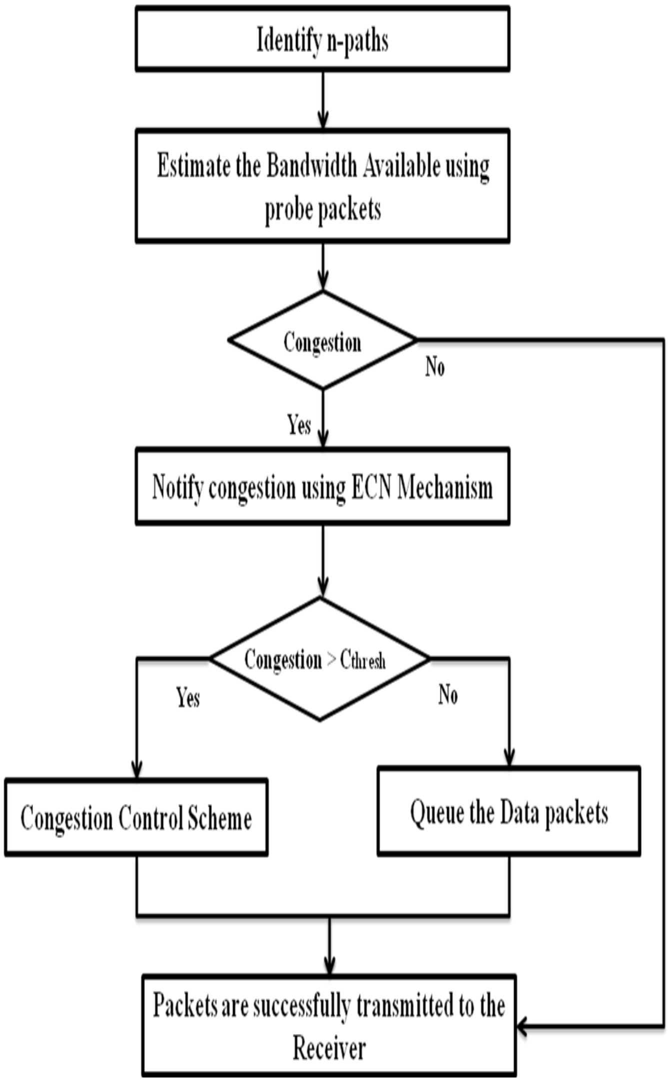

Figure 2. Proposed System Architecture

We are all aware of the basic nature of TCP which is to drop packets during congestion occurrence. Now that we have been notified of its occurrence using ECN, we can handle it by using the congestion window size (winsz) as a parameter. The last 3 round trip times (rtt) of the transmitted packets will be considered. If the most recent rtt value is lesser than the previous ones, we understand that there has been a successful transmission of packets hence we increase the window size by 2. If the most recent rtt value is greater than the previous ones, we identify that there is a possibility of congestion occurrence and hence we decrease the window size by 1 for transmitting limited amount of packets thereby avoiding bottleneck issue or over utilization of the bandwidth leading to poor throughput. Otherwise, there will be no change in the congestion window size.

4. Results and Analysis

4.1 Simulation Environment

The proposed model is implemented in Network Simulator-2 (NS 2) environment. The basic use of network simulators is that, it is very costly to create a real - world network and embed networking algorithms in it. Network Simulators provide wide range of networking scenarios with large number of in-built protocols using which it is possible to experiment and obtain certain statistical results. Changes can be made in these protocols in a controlled environment thereby making the code reusable to the current needs by analyzing the modified code.

The routing protocol considered in this paper is AODV (Ad-hoc On Demand Vector) which will create a network on demand basis. A routing table will be maintained to store all the related information like Source ID, Destination ID, number of hops, neighbor node ID, TTL flag etc.

We have considered a grid of area 750 x 500 and the routing protocol taken is AODV with drop tail as the queuing mechanisms wherein the maximum queue size is 300. The number of nodes in the mesh test – bed has been increased gradually from 6 to 10 nodes to give us an idea of the network state for the performance metrics considered below.

4.2 Performance Metrics

End-to-End Delay:

It is the overall time taken by the packet to travel from the source to the destination.

Table 1. Simulation Parameters

Parameters	Values
Area	750 × 500
Channel	Wireless Channel
Propagation	Two ray ground
Physical Medium	Wireless/Physical
MAC	802.11
Queue	DropTail, PriQueue
Antenna	Omni Antenna
Maximum Queue Size	300
Routing Protocol	AODV
Transport Protocol	TCP
Number of Nodes	6,10
Application Type	FTP
Simulation Time	1.0

Packet Delivery Ratio:
It is the ratio of the number of packets received to the number of packets sent. (The time lapse between the sending of the packets from the source till the receiving of the packets at the destination)

Throughput:
It refers to the amount of data transferrable at a given point of time. It can also be said that it is the measure of number of delivered packets.

4.3 Simulation Results and Analysis

The below table has the values from the simulation experimented for the performance metrics considered above. For the sake of understanding, there has been a gradual increase in the number of hops so that we can get a clear idea of the nature of the network and its impact on the performance scales considered.

The number of hops is compared against the three parameters to enable us to witness the state of the network as the number of hops is increased gradually. From Table 2 it can be seen that, Average end to end delay is relative to packet drops leading to more delay due to the need for retransmission of the packets (node 8, 10). Packet delivery ratio increases with increase in the number of hops. As there is an increase in the number of nodes, it can be seen that throughput decreases gradually.

4.4 Graphical Representation

From Figure2, we can infer that there has been a packet loss due to high delay rate for nodes 8 and 10. Simulation results have shown that the enhanced model has lesser end-to-end delay as compared to the existing model due to the fact that detection of congestion takes place at an earlier stage as in contrary to the existing model.

The more the number of intermediate nodes, the more is the assurance that the packet will be delivered rather than having some nodes scattered around and resulting in packet loss and retransmission overhead. From Figure 3, it can be inferred that the delivery ratio in the proposed model is better than the existing method because, we combine the bandwidth available with ECN scheme and only after controlling congestion effectively, packets are transmitted, hence, the reliability.

Table 2. Performance Results

Number of Hops	Average End to End Delay	Packet Delivery Ratio	Throughput
5	46.5899	71.7949	169.11
6	39.5937	70.8333	162.30
7	106.658	71.4286	147.07
8	60.4678	63.6364	138.85
9	70.1355	73.913	100.37

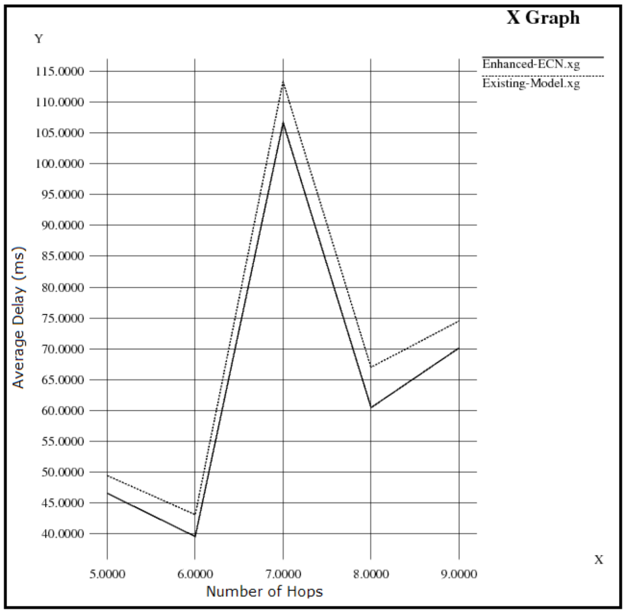

Figure 3. Number of Hops vs. End to End Delay

The values obtained for the enhanced model and the existing model for (say) in node 10 is (100.37, 99.81). Even these minute differences prove enhanced model to be a better one. From figure 4, we can infer that, for achieving

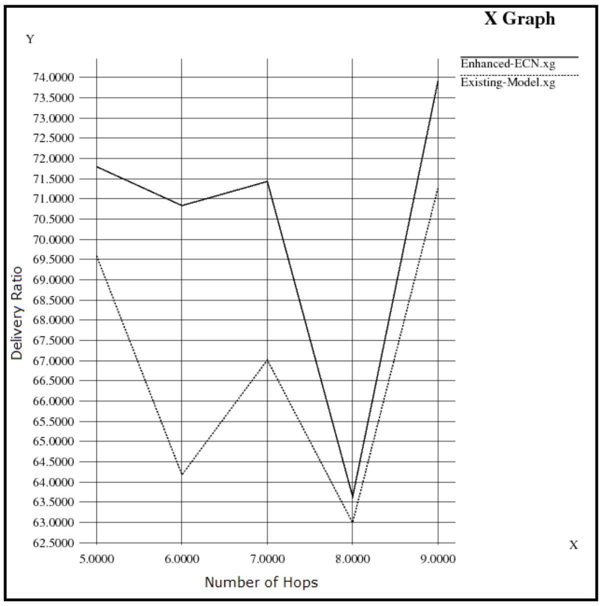

Figure 4. Number of Hops vs. Packet Delivery Ratio

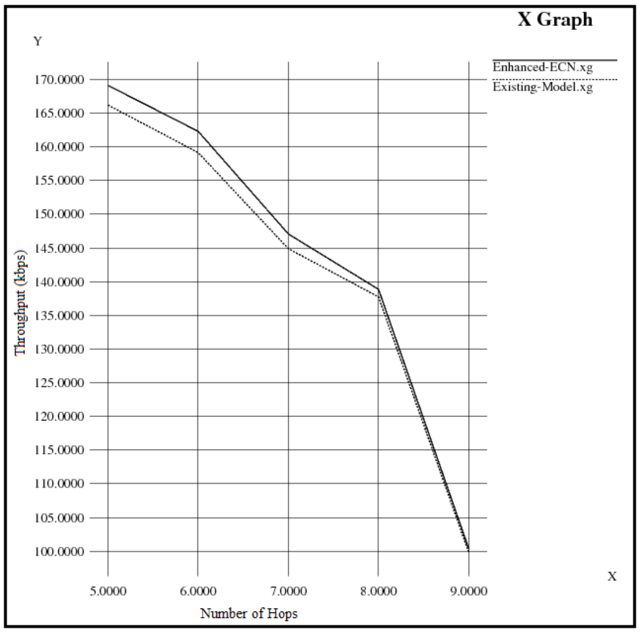

Figure 5. Number of Hops vs. Throughput

higher throughput, it is essential that the shortest path be chosen for the data transmission so that the number of hops will be less resulting in better throughput.

5. Conclusion

The main goal of the proposed model is the efficient utilization of the bandwidth available so that it will result in reduced congestion in a network. Moreover, instead of noticing congestion occurrence due to packet drop, enabling ECN mechanism has in turn provided a sight of the actual state of the network. Witnessing the network state before hand, has indeed proven to be highly helpful. From the above graphs, it can be inferred that the proposed model is better in performance than the existing model by taking delay, throughput and packet delivery ratio as the target metrics.

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