HOP-by-HOP Packet Forwarding Mechanism in Wireless Mesh Network

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ABSTRACT

A Wireless Mesh Network is infrastructure-less, "Self organizing & Self configured" network where participating node automatically establish & maintain connectivity amongst themselves. Such type of networks difficult to provide internet access and connection in remote areas. In literature lot of methods are proposed in order to handle problem in this network but in recent year we found expected transmission count metric and composite available bandwidth hop-by-hop routing mechanism. In this paper we compare these two methods i.e. expected transmission count metric (ETX) and new path weight called composite available bandwidth (CAB) method which captures the available path bandwidth information. Composite available bandwidth has good performance in terms of high throughput path and low packet delay. The simulation experiment shows that composite available bandwidth method is better in terms of delay, packet delivery ratio, throughput of flows.

Keywords

Wireless Mesh Network, Routing metrics i.e. ETX, CAB, Routing protocol.

1. INTRODUCTION

Wireless Mesh Networks (WMNs) is a promising technology to provide flexible and low-cost broadband network services. In wireless mesh network each node provide a multiple possible connection path ways to every other node to reach to the destination [1]. A mesh network delivers a numbers of advantages over a direct client connection and a point-to-multipoint wireless network i.e. reduced infrastructure costs, improved wireless coverage, reliability and scalability. WMN are not built on a fixed infrastructure; hosts relay on each other to keep the connection. Mesh network provide low cost broadband internet access. The reason of preferring WMNs is easy, fast and deployment of technology [2]. WMNs send a packet over multiple nodes, so packet loss rate can be minimized.

A routing protocol optimized for WMN that provides accurate Quality-of-Service properties by correctly estimating delay and loss characteristic of data traffic. In addition to support from the medium access control (MAC) layer and the forwarding engine, selecting the "best" routes for different traffic classes is an essential ingredient for QoS support[3]-[4]. In WMNs, a routing protocol provides one or more network paths over which packets can be delivered or routed to the destination. The routing metric ensure such paths to meet criteria that is minimum delay, maximum data rate, minimum path length etc. A Routing protocol for self organized networks are expected to provide functions like detecting and responding to changes in network service, providing management, constructing and selecting routes maximizing the capacity of the network and minimizing the packet delivery delay.

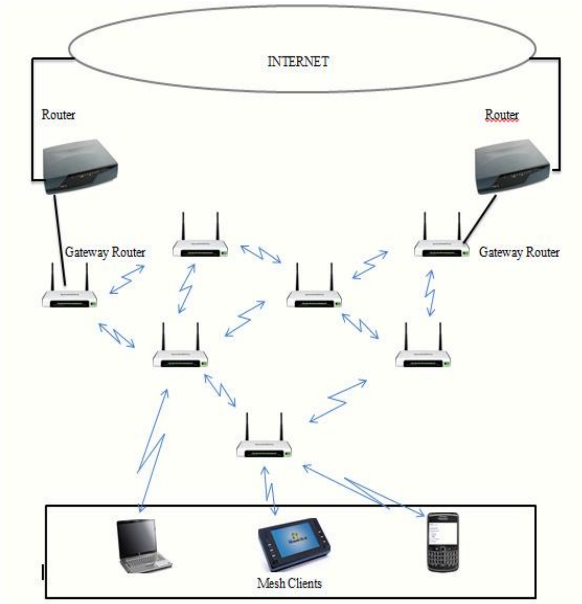

Figure 1 Wireless Mesh Structure[1]

Bandwidth estimation is a basic function that is required to provide QoS. Identifying the maximum available bandwidth path from source to destination, where every node in this path find its own widest path is one of the parameter for supporting QoS[4]. Finding maximum available bandwidth path is not an easy task due to interference among links in wireless networks [6]. For an efficient data transfer in the wireless mesh networks, desire to obtain the path with the maximum available bandwidth is one of the fundamental problem. Intra-flow interference increases bandwidth consumption of the flow at each node along the path and causes the throughput of the flow such intra-flow interference must be considered when designing a routing metric for mesh networks [7].

The bandwidth guaranteed packet forwarding mechanism identifying the maximum available bandwidth path, where every node in this path find its own widest path. Then this new path weight called composite available bandwidth path and this hop-by-hop routing protocol implementation based on destination sequenced distance vector routing (DSDV) protocol and it satisfy the consistency and loop freeness requirements.

The rest of the paper is organized as follows: Section 2 describes the related work, we explain expected transmission count metric method and bandwidth guaranteed packet forwarding mechanism which captures available path bandwidth information in Section 3, and Section 4 presents our simulation results.

2. LITERATURE REVIEW

In this section we overlook an existing work for finding a path with higher bandwidth; many researches develop a link metrics such as Expected transmission count, Expected transmission time, etc.

- The expected transmission count (ETX) metric is proposed by Couto et al. [8]-[9] , is defined as the number of transmissions required to successfully deliver a packet over a wireless link.
- The Expected transmission time (ETT) routing metric proposed by Draves et al. [10], is expected time to successfully transmit a packet at the MAC layer and is defined for a single link as

$$ETT = ETX * \frac{S}{B} \quad (1)$$

  S denotes the average size of packet and B denotes current link bandwidth.ETT path metric is obtained by adding up all the ETT values of individual links in the path. The ETT of link *l* if defined as the expected MAC layer duration for a successful transmission of a packet at link *l*. The drawback of ETT is that it does not fully capture the intra-flow and inter-flow interference[10]. ETT does not consider link load explicitly due to which it cannot avoid routing traffic through already heavily loaded nodes and links.

- The link metric expected transmission time is used for designing the path metrics weighted cumulative expected transmission time (WCETT) [10]. WCETT is simply to considers the number of links operating on the same channel and their respective ETTs but does not consider the relative location of these links. It assumes all links of a path operating on same channel interfere which can lead to selection of non-optimal paths. It does not explicitly consider the effect of interflow interference. Due to this, it may establish routes which suffer from high levels of interference.

- Another routing metrics such as Interference Aware metric (iAWARE) is proposed by Subramanian et al. [11] is the expected transmission time metrics adjusted based on the number of interference links and the existing traffic load on the interference links. This metric captures interference in terms of the level of the power that a node receives from all other nodes. However, it does not captures interference at the MAC layer.

All these work do not consider the problem of providing bandwidth guarantees. ETX is packet loss based metric and its extension do not always provide correct information for identifying high throughput path.

3. ROUTING MECHANISM

In this section we explain the expected transmission count metric and new path weight.

3.1 Expected Transmission Count

The expected transmission count (ETX) metric is which computes the average no. of transmission attempts required to send successfully a packet over the link [8]-[9]. ETX of a wireless link is the estimated average number of transmission of data frames and ACK frames necessary for the successful transmission of packets [9]. A node derives ETX by estimating the frame loss ratio at the link *l* to each of its neighbors in the forward direction as P_{lf} , and in the reverse direction as P_{lr} transmitting broadcast probe packets(which are not retransmitted) at the link layer once every second as :

$$ETX_l = \frac{1}{(1 - P_{lf})(1 - P_{lr})} \quad (2)$$

To find the widest path, many researches develop new path weights and the path with the maximum / minimum weight is understood to be the maximum available bandwidth path of the network. ETX characterizes the link loss ratio using the expected number of MAC retransmission needed to successfully transmit a packet from sender to the receiver. Lesser the ETX metrics for a link, better is the link. ETX does not consider the data rate at which the packets are transmitted over each link [8]. ETX vary when there is very high load due to 802.11 MAC unfairness or when there is loss of the broadcast packets due to collision with packets from hidden terminals [9]. ETX is defined as the expected number of MAC layer transmission i.e. needed for successfully delivering a packet through a wireless link. The drawback of ETX is that it does not consider the fact that different links may have different transmission rates and also it does not consider load of the link, it will route through heavily loaded nodes leading to unbalanced resource usage. Expected transmission count are made to suffer routes with more hops, which have lower throughput due to interference between different hops of the same path .

3.2 Bandwidth Guaranteed Packet forwarding Mechanism

Given a source and destination node a routing protocol provides one or more network paths over which packets can be routed to the destination, the routing protocol computes such path to meet criteria such as minimum delay, maximum data rate, minimum path length etc [11]. We show that the routing protocol based on this new path weight satisfies the optimality requirement. Afterward our hop-by-hop packet forwarding mechanism which satisfies the consistency requirement. Bandwidth is defined as achieved throughput i.e. average rate of data transfer through a path. It is always preferable to choose a path with higher throughput between a pair of source / destination node to provide high speed data transfer [12]-[13]. Hop-by-Hop packet forwarding techniques identifying maximum available bandwidth path where every node in this path find its own widest path. It proposes a new isotonic path weight called composite available bandwidth (CAB) and captures the available path bandwidth information. “ Isotonicity is a sufficient and necessary condition to find minimum weight path” [12]. The isotonic property of a routing metric means that a metric should ensure that the order of weights of two paths is preserved if they are prefixed by a common third path. Isotonicity does not only determine whether minimum weight path can be calculated efficiently, it may also be needed to ensure loop free routing [12]-[14]. Hop-by-Hop routing means forwarding decision made independently at each node based only on the destination addresses of incoming packets but not on its source. Each packet contains the address of its destination and every node maintains a forwarding table that maps each destination address into the out-neighbor to which packets addressed to the destination should be forwarded [14].

In hop-by-hop routing every nodes maintains a routing table that indicates next hops for the routes to all other nodes in the network. For a packet to reach to the destination ,it only needs to carry the destination address after that intermediate nodes forward the packet along its path based only on the destination address [16]. Due to its simple forwarding scheme and low message overhead, hop-by-hop routing is the most preferable for mesh network. This hop-by-hop routing protocol based on the new path weight and it satisfies consistency and loop freeness requirement. Consistency property satisfies that each node take a proper packet forwarding decision, thus packet traverses over the estimated best path to the destination and also ensures loop free routing.

Available bandwidth of path P is estimated as follows:

$$B(e) = \min_{q \in Q} C_q \quad \text{where Cq is}$$

$$C_q = \frac{1}{\sum_{l \in q} \frac{1}{B(l)}} \qquad (3)$$

Given a path P=<V_1 ; V_2 ; ---------; V_h > based on the current flows on each link in the network. B(e) as the available bandwidth of link e. It means that if a new connection only needs to go through link e, e can send at most B(e) k bits amount of information in a sec. without affecting existing flows. Cq is the set of maximal cliques containing only the links on q [13]-[15].

Composite available bandwidth of a path is a quadruplet (w_1(p) ,w_2(p) , w_3(p) ,w_4(p)): where w_1(p) is the whole bandwidth of path 'p' , w_2(p) is the bandwidth of first three link of path p , w_3(p) is the bandwidth of first two link of path p, w_4(p) is the bandwidth of first link of path p. By using this formula we calculate the minimum weight path, we choose minimum weight path selected by routing protocol must have good performance in terms of higher throughput and low packet delay , longer the path usually increases the end-to-end delay and reduces the throughput of a flow.[17]

Steps of performing a hop-by-hop proactive routing protocol with bandwidth guarantees:

- Compute the available bandwidth of a given path.
- Select the best path to be advertised i.e new path weight is composite available bandwidth path.
- Hop-by-Hop routing protocol based on the new weight path implements based on DSDV routing protocol and it satisfies consistency and loop freeness requirement.

4. SIMULATION RESULTS

The simulation focuses the comparison between the existing method and proposed method based on DSDV routing protocol. We are comparing on some of the network properties such as:

- Throughput of flow
- Delay
- Packet delivery ratio

The Table 1.below shows the required parameter values during experimental evaluation.

Table 1. Simulation Parameter

Channel type	Channel/Wireless channel
Radio-propagation model	Propagation
Network interface type	Phy/WirelessPhy
MAC Type	Mac/802.11
Link layer type	LL
No. of nodes	50
Area	1000*1000
Routing protocol	DSDV

The main objective of this work is to find the better throughput path from source to destination. The key advantage of DSDV over traditional distance vector protocol is that it uses sequence numbers to guarantees the protocol to be loop free by indicating the freshness of a route. The routing protocol maintains the best path instead of maintaining multiple paths to every destination. It guarantees the loop free path and count to infinity problem is also reduced.

4.1 Throughput

Throughput is the amount of data received by the destination. It refers to how much data can be transferred from one location to another in a given amount of time. Throughput defined as the number of successfully received packets in a particular unit of time and it is represented in bps. This performance metric shows the total numbers of packets that have been successfully delivered from source node to destination node.

$$Throughput = \frac{\mathrm{Re}ceived\_Packet\_Size}{Time\_to\_Send}$$

Figure 4.1-a shows that the simulation result of the flows which are sorted according to the throughput. As in the graph bandwidth is not constant, bandwidth is changes because we have to check the effect on the throughput. If bandwidth is increases throughput is also increases.

Figure 4.1-b here in this graph we give the comparison between CAB method and ETX method. Here throughput is consider only with the same bandwidth that is bandwidth is constant for composite available bandwidth and expected transmission count method. We observe that expected transmission count metrics do not work well in some cases, ETX prefer the shorter path to the longer path, such that ETX may select a low available bandwidth path. Hence CAB is relatively more efficient for finding the high throughput path.

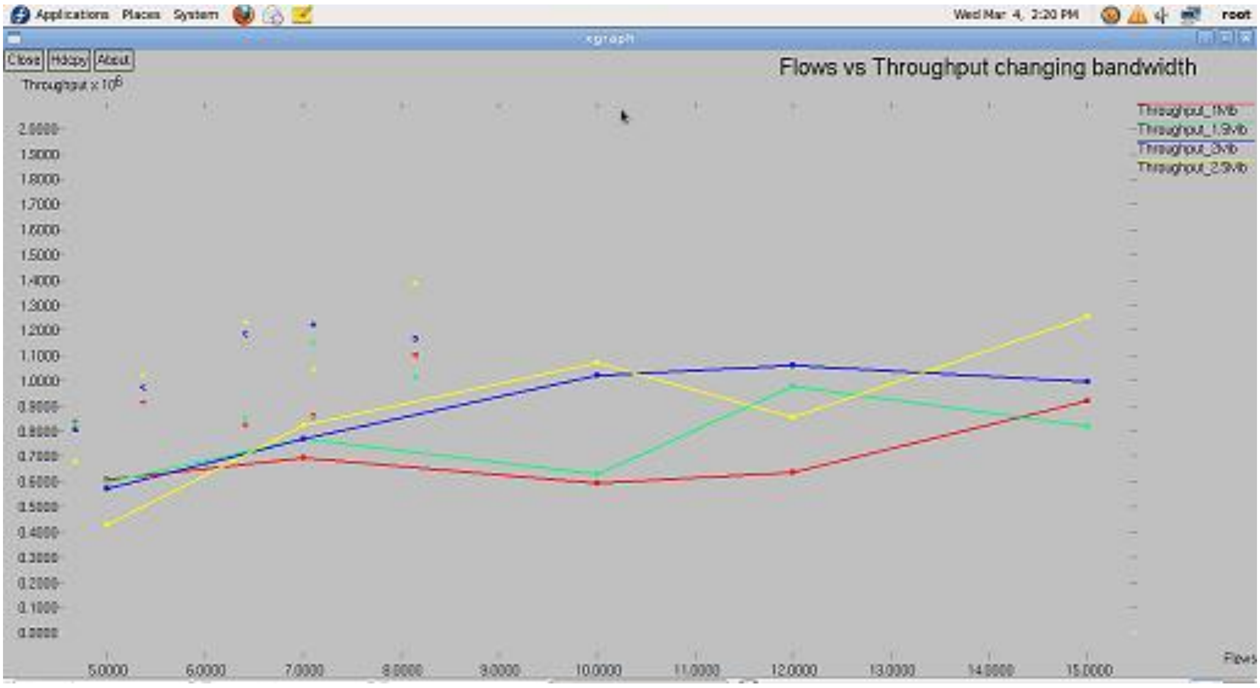

Figure 4.1-a Throughput Vs. flows

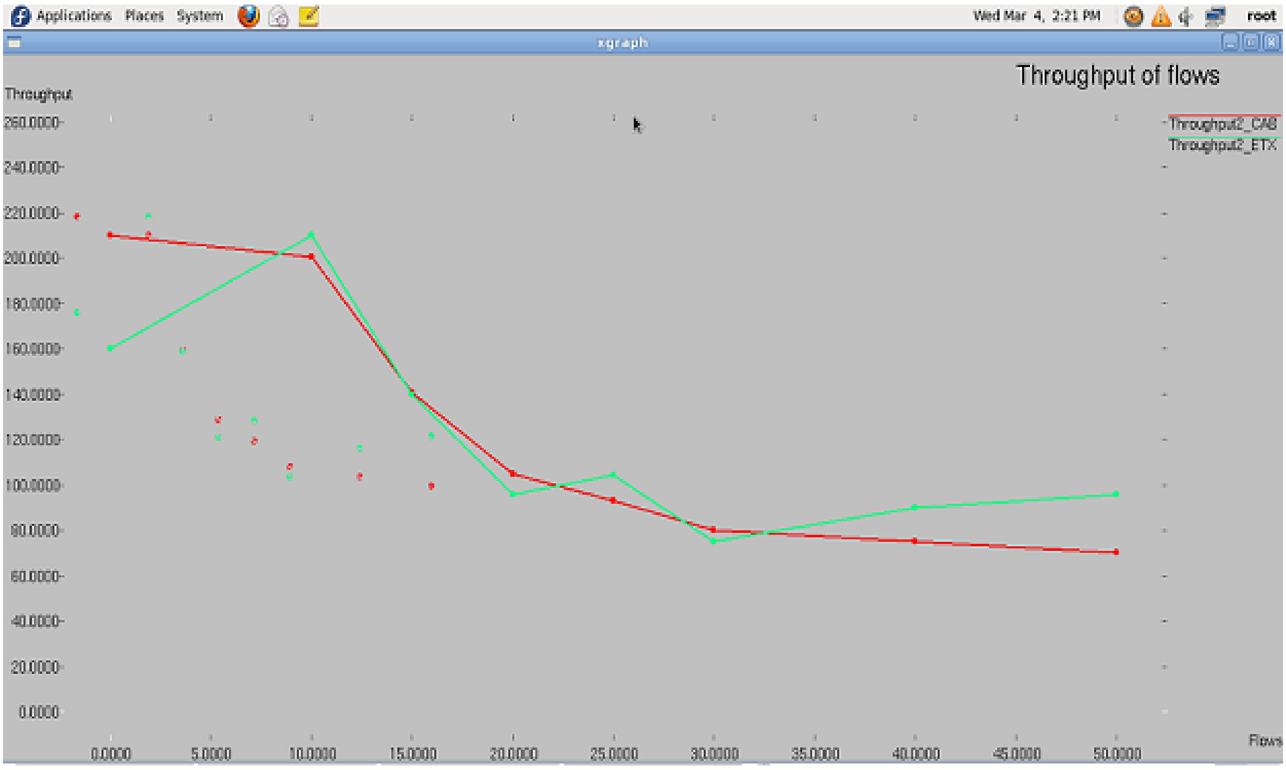

Figure 4.1-b Throughput of flows with bandwidth constant

4.2 Delay

Delay means information send as early as possible in any case within the time , if information to send required more time than normal then delay occur. Delay refers to the time taken for a packet to be transmitted across a network from source to destination. A specific packet is transmitting form source to destination node and calculates the difference between send times and received times. Delay is calculated for different number of nodes. Figure 4.2 graph shows that the delay is compared with CAB and ETX which shows that the delay is less for the composite available bandwidth method i.e we observe that CAB has better performance than ETX.

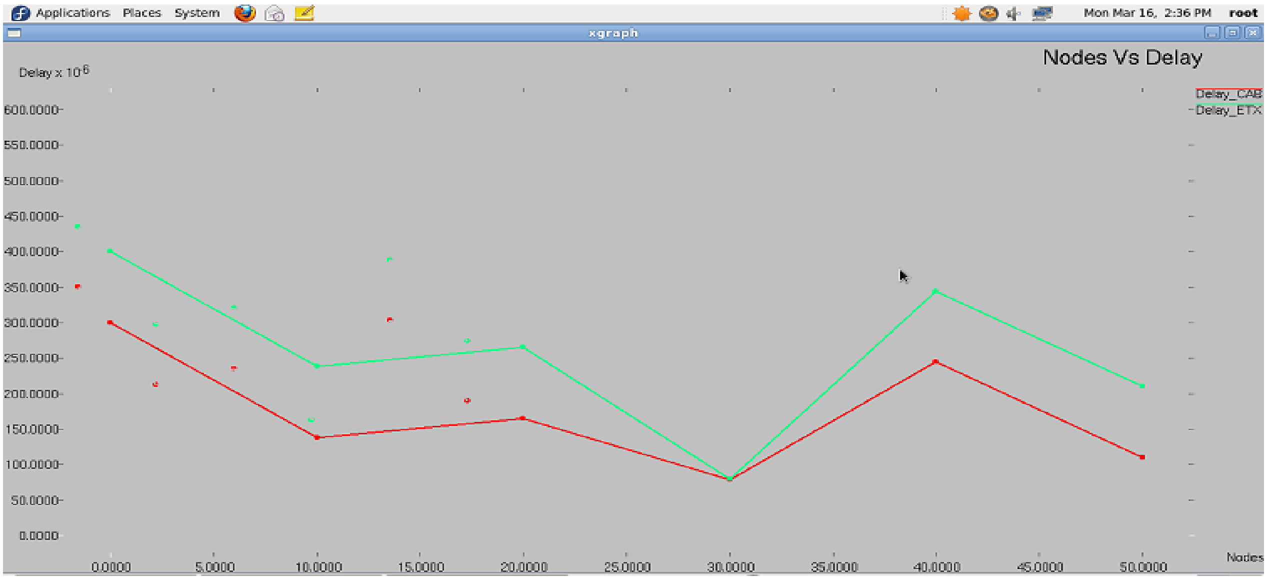

Figure 4.2 Delay Vs. No. of nodes

4.3 Packet Delivery Ratio

Packet delivery ratio is defined as the ratio of data packet received by the destination to those generated by the source that is packet successfully sent from source to destination. The ratio of packets that are successfully delivered to a destination compared to the number of packets that have been sent out by the sender.

$$PDR = \frac{packet\_received\_by\_destination\_node}{packet\_received + packet\_dropped}$$

In Figure 4.3-a packet delivery ratio is plotted against time interval. The packet delivery ratio is compared with the composite available bandwidth method and expected transmission count method. According to our simulation result packet delivery ratio is better for the composite available bandwidth method. As the time interval is increases PDR is also increase that is PDR is increases with time.

In Figure 4.3-b packet delivery ratio is plotted against number of nodes. Packet delivery ratio is compared with proposed method and existing method. According to our simulation result packet delivery ratio is better for the composite available bandwidth method.

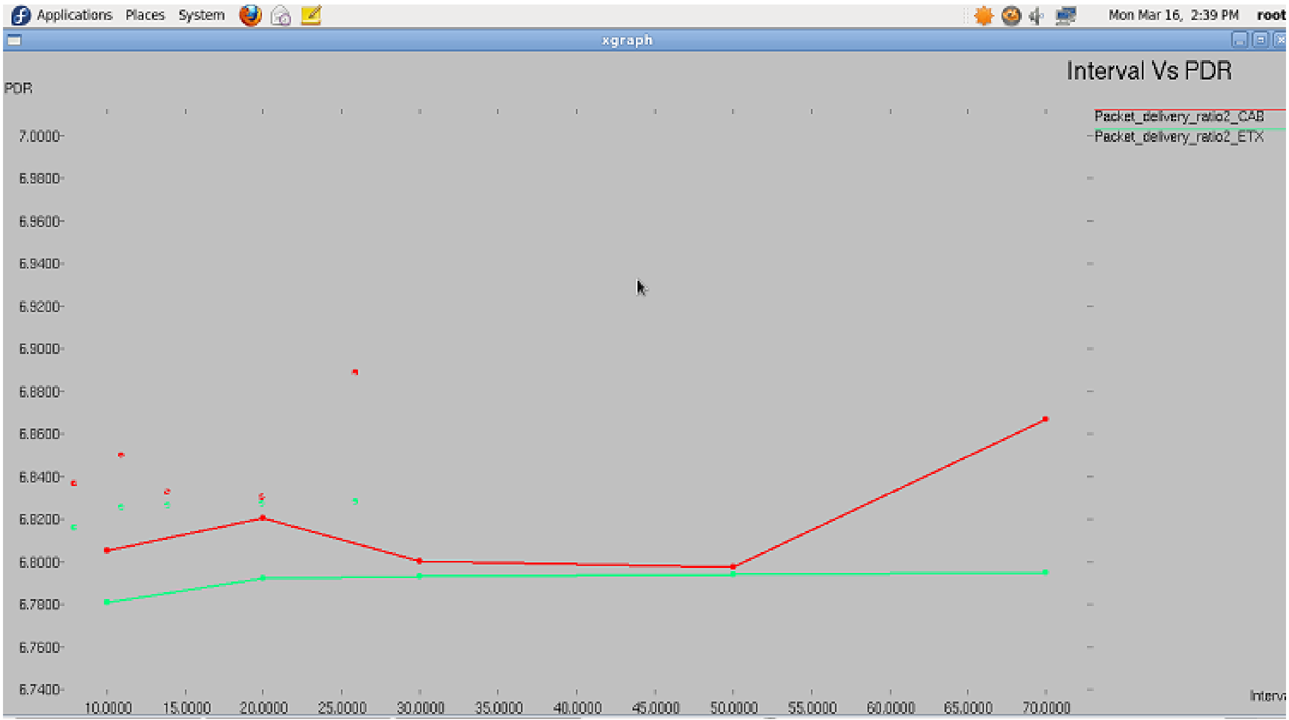

Figure 4.3-a packet delivery ratio Vs. Time interval

Fig.4.3-a Packet delivery ratio Vs. No. of nodes

5. CONCLUSION

A wireless mesh network is always preferable to choose a path with higher throughput between a pair of source to destination nodes. Our hop-by-hop routing protocol based on the new path weight which provides the consistency and loop freeness to the network. The main advantage of this work is a new path weight which captures the available path bandwidth information and every node in this path can make a consistent packet forwarding mechanism and also conclude that CAB has better performance for finding the widest path as compared to ETX. The hop by hop packet forwarding mechanism in CAB is the only bandwidth guaranteed routing method that can route through the maximum available bandwidth path from source to destination. We choose the minimum weight path selected by routing protocol must have good performance in terms of high throughput and low packet delay because longer path usually increases the end to end delay and reduces throughput of a flow. Future plan is to extend the performance of our protocol under different scenarios.

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