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An Efficient Routing Metric in Wireless Mesh Networks (WMNs)

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Abstract*— Wireless Mesh Networks (WMNs) being an emerging technology has in recent years received research focus. Considered to be the next step in the evolution of wireless networks, WMNs promises greater flexibility, reliability and performance.In wireless mesh networks, there are multiple potential paths exist between any pair of mesh stations; as each route uses a different set of links with varying link quality, these routes may have different throughputs. Routing protocol selects the route with the best possible throughput. Routing metrics used by routing protocols decides which route to use between pair of nodes. A routing metric is a transaction that provides a number assigned to each route then the routing protocol selects the route with the best one. Our prime concern to design routing metric referred AETT: Advanced Expected Transmission Time. Our proposed metric can be able to estimate the end-to-end delay experienced by packet for the available paths to enable the routing protocol to select the best path. AETT considers the link rate, number of retransmissions, control overhead, number of neighboring node, intensity of interference etc. We consider the control overhead of sending a data packet that includes the time to send a RTS, CTS, DIFS, SIFS. So, the metric show the exact transmission time of a packet from one node to another. It modified the ETTand MIC routing metric and represents a new way to calculate expected transmission time.

Keywords*— Wireless Mesh Network, Routing, WMN Routing Metric, Best Path Selection in WMNs, Wireless Routing Strategy.

I. INTRODUCTION

Communication traffic over wireless devices has been increasing enormously, handling a wide range of collective communication based applications. The Internet, in future world, be everywhere, and will be a vastly deeper and more powerful environment than we know today. The information society will be a networked society, with individuals and enterprises always linked locally and to the Internet. Even today, the Internet has a significant influence as a requisite part in individuals' life. Many Internet access devices are used nowadays, including portable devices such as mobile phone, PDA, laptop PC, PlayStation Portable [1], etc. and non-portable devices such as desktop PC, PlayStation 3 [2], and digital TV etc. At the service provider side, they try to offer services within different features, from webpage browsing to video browsing in wide areas in order to meet various demands. However, such services cannot be afforded by applying traditional networking technology owing to two points: bandwidth and construction cost. In the bandwidth side, the bandwidth of 2.5G GPRS cellular network is up to 48 kbps, and even 3G cellular network provides data rates at 384 kbps. In fact, this speed is only enough for the web browsing and emailing applications, but not adequate to support neither high quality video streaming nor Internet gaming. It is worth indicating that only the cable broadband such as DSL and Wi-Fi can offer high speed Internet access. On the other hand, as for the construction cost, it is needed to set up base stations for cellular networks (2G, 2.5G, 3G and for 4G) which are costly. In addition, the installation of the cable broadband is also expensive.Therefore, Wireless Mesh Networks (WMNs) [3] is an ideal candidate to construct scalable high-bandwidth broadband network with low deployment cost. Thus, the main focus of this study is on the WMN technology in order to investigate community mesh networks. WMNs have shown a great potential locally and globally to deploy wireless networks. Due to its high quality and cost effective performance, WMN has been attractive to different Internet service providers, aiming to fill the UK's broadband black spots. For instance, in Scotland, Speed net Scotland [4] uses a mesh network to provide wireless broadband access to the area surrounding Troon, Ayreshire, where many telephone exchanges were unable to support broadband until recent time. Locust World [5] is a pioneer within this growing market, offering a range of broadband access services to business and residential customers in different areas in the UK and worldwide. In addition, the Southampton Open Wireless Network (SOWN) [6] is a project that uses WMN to build non-profit WCNs in Southampton. Globally, many zones and cities have been equipped with WMNs to facilitate wireless broadband access services to urban and rural communities.

II. WIRELESSMESH NETWORKS

Wireless Mesh Networks (WMNs) being an emerging technology has in recent years received research focus. Considered to be the next step in the evolution of wireless networks, WMNs promises greater flexibility, reliability and performance.

A wireless mesh network (WMN) is a communications network made up of radio nodes organized in a mesh topology. Wirelessmesh networks often consist of mesh clients, mesh routers and gateways. The mesh clients are often laptops, cell phones and other wireless devices while the mesh routers forward traffic to and from the gateways which may but need not connect to the Internet. When one node can no longer operate, the rest of the nodes can still communicate with each other, directly or through one or more intermediate nodes.

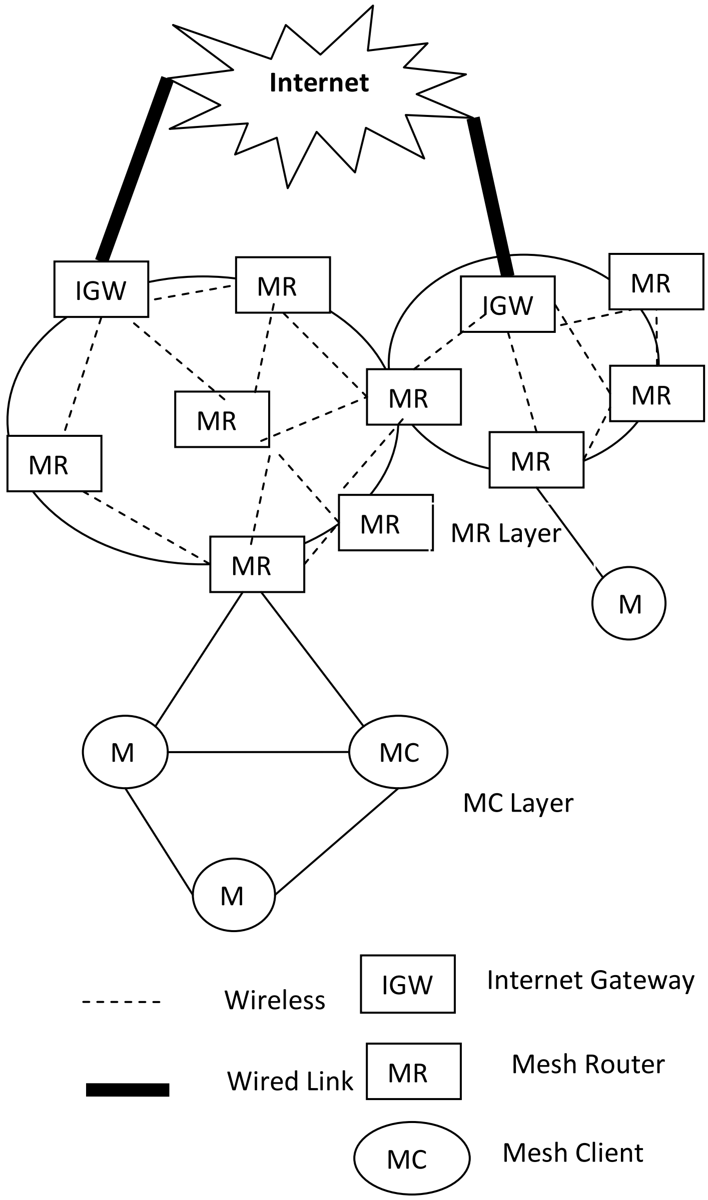

Fig-1: A typical Wireless Mesh Network

WMN architecture employs multi-hop communication among network nodes, i.e., mesh nodes and mesh clients, to forward packets from source to destination through intermediate nodes which not only boost the signal, but cooperatively make forwarding decisions based on their knowledge of the network. The peculiar characteristics of dynamic self-organization, auto configuration and self-healing in WMNs offer many benefits such as low upfront investment, increased reliability and scalability.

The wireless routers in WMNs have minimal or no mobility and form the backbone for mesh clients. They contain additional routing functions to support mesh networking other than the routing capability for gateway/bridge functions as in the conventional wireless routers. To further improve the flexibility of mesh networking, a mesh router is usually equipped with multiple wireless interfaces built on the same or different wireless access technologies. However, mesh and conventional wireless routers are usually built based on a similar hardware platform. Although mesh clients can also work as routers for mesh networking, they can be much simpler in the hardware platform and software.This simplicity can be reflected: in the communication protocol which can be light-weighted, the inexistence of gateway or bridge functions, availability of only a single wireless inter-face, etc. So conventional nodes, such as, desktop, laptops, PDAs, pocket PCs, phones, etc, equipped with wireless network interface cards(NICs) can connect directly to wire-less mesh routers, otherwise, customers without wireless NICs can also be always-on-line anywhere anytime by connecting the wireless mesh routers through Ethernet for example. The integration of WMNs with other already existing wireless networks such as wireless sensor, wireless-fidelity (Wi-Fi), cellular, worldwide inter-operability for microwaves access (WiMAX) and media networks is enabled by the gateway/bridge functionalities in the mesh routers.

Most application scenarios of WMNs are broadband services with various QoS requirements. Other applications include community and neighborhood net-works, enterprise networking, building automation, etc. Since a WMN is dynamically self-organized, self-configured and provides self-healing, i.e., every node has a link to every other node, alternative links can be used in case of a node failure or traffic congestion in a direction. The network can be deployed incrementally one node at a time as need be. Increase in new installed nodes increases accordingly the reliability and connectivity for the users. But despite the admirable present day achievements in the area of WMNs, considerable research efforts are still required.

In this regard, we focus in the network layer, more specifically in routing, wherein considerable research has been going on in recent years. The performance of the WMN routing protocol relies on the routing metrics to perform efficient routing decisions. The performance routing metrics must capture critical design features such as end-to-end delay, throughput, bandwidth, etc. The research target in this thesis is to increase the overall network throughput (i.e., the amount of data received by the destinations in unit time) of IEEE 802.11 based WMNs. To develop the overall network performance, we propose for high throughput path selection routing metric.

III. MAZOR CHALLENGES AND MOTIVATION

There are lots of challenging issues in the area of IEEE 802.11s wireless mesh networks, such as medium access control (MAC), routing metric design, topology control, mesh security, mesh connectivity control, congestion control etc. [7]. In a WMN, asthe wireless medium is shared among neighboring mesh node and data frames need to be transferred over multi-hop wireless paths; the wireless mesh networks act as wireless infrastructure or backbone network and therefore, volume of traffic in a WMN is much high. With multiple channels, each radio interface on adjacent links can be assigned a different channel such that the interference among links can be eliminated and the network capacity can be improved. In general with proper design, leveraging multiple links has several benefits, including increasing system throughput, decreasing end-to-end delay, achieving better load balancing and preventing the starvation problem in single channel WMNs.WMNs exhibit a topology that does not have a device dedicated for central coordination which can guarantee QoS. On the other hand, WMNs are expected to provide quality-of-service (QoS) to meet the increasing demands of multimedia applications (such as VOIP, video).

In wireless mesh networks, there are multiple potential paths exist between any pair of mesh stations; as each route uses a different set of links with varying link quality, these routes may have different throughputs. Routing protocol selects the route with the best possible throughput. Routing metrics used by routing protocols decides which route to use between pair of nodes. A routing metric is a transaction that provides a number assigned to each route then the routing protocol selects the route with the best one.

Designing a routing metric for WMNs requires consideration of the unique architecture and the associated wireless networking environment of WMNs. Therefore, we need to consider other factors such as data rate, transmission time of the contending nodes, packet size, control overhead etc., while designing a routing metric. All these requirements make the design of a routing metric a challenging issue. Therefore, our second challenge in this context is to design a routing metric to select a path the path where a packet experiences minimum end-to-end transmission delay among the available paths for a specific link.

IV. ROUTINGMETRRICS FORWMNs

Routing in multi-rate multi-hop wireless networks has been an active area of research for many years. Efficient data transfers over multi-hop networks require an appropriate routing metric that is critical in selecting a path with the highest achievable throughput. The design of such a routing metric is much more difficult on wireless networks than on wired networks, due to the conflicting and dynamic characteristics of multi-hop wireless network with shared unreliable links. Currently, various routing metrics have been proposed.

Shortest Path Metric

The shortest path metric is one of the most popular routing metrics in multi-hop networks. Many multi-hop routing protocols select paths based on this lowest hop count metric [8] [9] [10]. The primary strengths of this metric reside in its simplicity and low computing overhead. However, it has been shown that a path based on minimal hop count does not necessarily yield a high throughput performance [11]. The shortest path metric selects the path with the smallest hop count, but that may suffer from higher loss rate (as shown in Section I). A wireless link with higher loss rate requires on average more transmissions for one successful packet delivery, and hence leads to lower throughput. Therefore, considering the link quality is important to design a good routing metric in wireless networks.

Drawbacks of Shortest Path Metric

The shortest path metric, which is used to find routes by most multi-hop routing protocols, has been proved to be flawed. It tends to choose paths with more physically distant nodes that result in higher loss rates. As shown in Figure 1, the path A − D − E has only two hops, but the distance is longer between nodes A, D and E than for the three hop path A −reliable, the throughput with path A − B − C − E may be higher than with path A−D−E. This simple example shows that it is crucial to consider the quality of each wireless link when designing a routing metric.

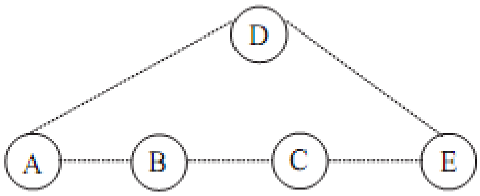

Fig-2: Simple example of Shortest Path Metric

Hop count (HC)

Hop count is the simplest of routing metrics, because it only needs to know if a link exists or not. However, because of this feature, the hop count cannot provide helpful information about a link, such as packet loss, link quality, etc.Thus, routing protocols based on hop-count only consider one performance parameter, i.e., the minimum hop count of each routing path. In very few cases the minimum hop-count is a reasonable metric to find a good routing path. However, in most cases the minimum hop-count is not enough for a routing protocol to achieve a good performance. Nevertheless, the hop-count is used in some existing routing protocols for WMNs, mainly because of its simplicity. In some application scenarios, if reachability instead of optimized performance is the main concern, the hop-count is a useful routing metric.

Drawbacks of HC

The Hop count routing metric fails to account for the specifics of wireless environments (links may have different transmission rates, loss ratios, etc.) and it doesn't consider the congestion level resulting from the shared use of the transmission medium. Many prior researches [12-16] have recognized the shortcomings of shortest path-routing in multi-hop wireless networks. Hop count tends to select long distance links with low quality, which typically already operate at the lowest possible rate, due the link layers auto rate mechanism. This can lead the hop count metric to choose paths with low throughput and cause poor medium utilization, as slower links will take more time to send packets.

Expected Transmission Count (ETX)

The Expected Transmission Count (ETX) metric was introduced by De Couto et al. ETX is the number of expected transmissions for a successful transmission over a hop. ETX is derived from the measured hop packet loss rate. The quality of a path is characterized by the sum of ETX's.

Let, P_f and P_r be the hop forward and reverse direction loss rates respectively. The probability of unsuccessful delivery rate P for this link is:

$$P = 1 - (1 - P_f) \times (1 - P_r)$$

Thus the expected number of transmissions of a packet on this hop is:

ETX = 1/1-p

The weight of a path with n links is the sum of all link's ETX:

$$ETX = \sum_{i=1}^{n} ETX_i$$

ETX captures the effect of both the path length and each link's loss rate. Draves et al. reported that the ETX metric performs better than the shortest path and RTT metrics.

Drawback of ETX

The weakness of ETX is that ETX ignores that links may have very different data transmission rates in multi-rate radio networks. Since ETX is measured using periodic broadcast packets which are sent at a very slow interval (usually1 sec), they do not reflect how busy a link is. ETX might vary when there is very high load due to 802.11 MAC unfair-nesses [17] or when there is loss of the broadcast packets due to collision with packets from hidden terminals. However, whether sender of the ETX broadcast packet can hear (or sense) the neighboring transmissions, collision does not happen and ETX is not affected. Thus, ETX does not capture the interference experienced by the links completely. ETX was designed for net-works using a single channel, so it cannot exploit the presence of multiple channels and find paths that have better channel diversity.

Expected Transmission Time (ETT)

Modern wireless radios utilize multiple data transmission in order to accommodate variable channel conditions. This multi-
rate strategy has been shown to greatly improve wireless multi-hop networks performance [18]. Currently, the IEEE802.11g [19] standard offers data rates of 6, 9, 12, 18, 24, 36,48 and 54 Mbps while the earlier IEEE 802.11b [20] standard supports 1, 2 , 5.5 and 11Mbps data rates. Thus, a wide range of data transmission rates may exist simultaneously within one single network scenario.

In a heterogeneous data rate network, the ETX metric does not accurately capture link quality of a path. Draves et al. addressed this problem and improved the ETX metric into the Expected Transmission Time (ETT) metric [13] by considering the data rate. ETT depends on the packet size S, the data rate B, and the loss rate. It is the expected time required for one successful data packet delivery. Let S be the packet size, B the data rate, and ETX the expected transmission count on a given hop, ETT is defined as:

$$ETT_i = ETX_i \times \frac{S}{B_i}$$

Where, B_i is the data rate of i^{th} link.

Drawbacks of ETT

Though, ETT has been considered as the most widely used metric for routing in WMN, it still has some limitations, which do not allow ETT to always select high throughput paths. ETT do not consider the presence of multiple channels and therefore, find paths with less channel diversity. Also ETT characterizes the expected transmission time in the absence of interference in the network.

Metric of Interference and Channel-Switching (MIC)

In [36], the authors propose MIC which improves upon WCETT by considering inter-flow interference. MIC for a path p is defined as follows:

$$MIC(q) = \frac{1}{N \times \min(ETT)} \sum_{linkl \in p} IRU$$

where N is the set of neighbors that interfere with the trans-missions on link l. CH(i)represents the channel assigned for node i's transmission and prev(i) represents the previous hop of node i along the path p. MIC is also non-isotonic because of the second component (CSC) and the authors in [24], demonstrate somewhat complex ways to form virtual nodes and make the metric isotonic.

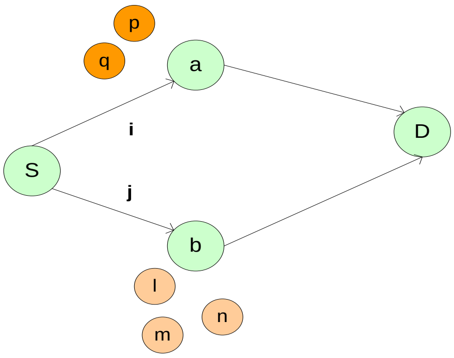

Figure 3.2: Understanding of Interference

Drawbacks of MIC

MIC metric poses some advantages over ETX, ETT and Airtime metric, by considering the impact of interference caused by contending nodes. However, it assumes that all the nodes located in the collision domain of a particular link contribute to the level of interference, irrespective of whether those nodes are actually generating interfering traffic or not. More specifically, it considers the number of contending nodes but not the load of the contending nodes. Note that a neighbor's queue might be empty and such node will not interfere with the link. Therefore, MIC prefers links with less number of contending neighbors irrespective of whether the neighbors causes any interference or not. For example, consider the two links i and j in Fig. 3.2, with ETTi > ETTj . Link i has two neighbors which are close to node 2and caused high degree of interference.On the other hand, link j has three neighbors but caused no interference. In this case, MIC prefers link i over j, resulting in choosing the link with higher ETT and poor throughput. Because of preferring paths with less number of interfering neighbors, MIC may result in finding paths along the edges of the network where nodes have less number of neighbors and thereby, find longer paths [80-81]. Moreover, MIC requires upto-date information regarding the ETT of each link to measure the minimum ETT of the network - this requires significant overhead and degrades the overall network performance.

V. PROPOSEDMETRICS

In wireless mesh networks (WMNs) route selection is an important issue due to existing lot of wireless path among the nodes. Designing of a routing metric is very important issue in the telecommunication era. In congestion and for dynamic network topology route selecting issue is the most measure issue. For selecting efficient route for best throughput an efficient routing metric is most important. We have tried to design a routing metric that is the almost perfect to select a route as it consider the very effective parameters. We consider mainly on focusing the control overhead data rate of that link that make the metric strategic and efficient. For performance analysis analytical proof and explanation of the metric working process given below with related graph and chart.

Problem Statement and Motivation

In wireless mesh network (WMNs) transmission of packet efficiently from one node to another is an important issue. There may be lot of links for a source to send a packet to destination. The end to end delay of packet transmission is different due to shared nature of wireless link. To choice a link for sending a packet is depends upon the less time taken by to transmit the packet to the destination. Our goal is to design a routing metric that will be able to estimate the end-to-end delay experienced by packet for the available paths to enable the routing protocol to select the best path. If all the packets can be delivered within minimum delays, the overall network throughput will be increased. In the following we discuss the issues that are related to a packet forwarding from a node to another node.

Transmission Rate

In telecommunications, effective transmission rate (average rate of transmission, effective speed of transmission) is the rate at which information is processed by a transmission facility. The effective transmission rate is calculated as (a) the measured number of units of data, such as bits, characters, blocks, or frames, transmitted during a significant measurement time interval divided by (b) the measurement time interval. The effective transmission rate is usually expressed as a number of units of data per unit time, such as bits per second or characters per second.

Size of the Packet

Size of the packet is most important issue in wireless mesh networks (WMNs). If the size of the packet is larger, the impact of control overhead: RTS, CTS, ACK is such that the throughput is better than that of being the packet size smaller. Again, being the packet size very much larger packet loss ratio is high, so there should be a standard size for packet that is for higher throughput and also less packet loss ratio.

Success Rate

Success rate is the rate of successful transmission of packet. If the transmission attempt for successful transmission is high then it is considered as poor success rate. When a sender received an acknowledgement of a message from the destination then it is said that the transmission attempt is successful. Success rate depends upon network congestion, and success rate affects the total network throughput. So, for best performance and for higher throughput the success rate is an important issue.

Contending Neighboring Node and Their Load

The nodes those are around the source node is called neighboring node, nodes that are ready to send a packet is called contending node. In wireless mesh networks (WMNs) contending neighboring node play a vital role for the case of efficient routing and the networks throughput. Contending nodes affect the source node very much if the contending nodes are highly loaded.When the load of the nodes is higher, the packet loss rate will increase that makes the network throughput lower. On the view for lightly weighted node the source or the sender node experience lower queuing delay and also lower MAC delay.

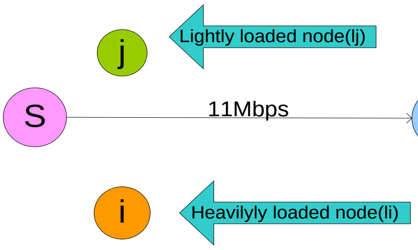

Figure 4.1: Contending nodes and their loads

In the above figure we see that sender S node belongs to send data packet to destination node D. node i, j are contending node for sender node S so the consideration of node i, j is required to estimate for getting the channel to send data nod j is lightly loaded and node is heavily loaded. So, we see that consideration of contending nodes and their loads is a major issue to design a routing metric for wireless mesh networks (WMNs).

Considering Issues

To design an efficient routing metric in wireless mesh networks (WMNs) there are lot of issues considered by lot of articulate, but we tried to consider more and much imported and impacted issues. We also tried to design the metric contributing the better decision from these issues.The issues we consider to design and analyze the metric are as follows:

Link rate and number of retransmissions
Control overhead
Interfering intensity
Queuing delay

Link Rate and Number of Retransmissions

We consider the link rate of a link to count the Advanced Expected Transmission Time (AETT). Number of retransmissions of a packet to make the attempt successful is one kind of issue that is fully determined by the matric Expected Transmission Count (ETX). Basically link rate of network control the network throughput. Data rate of a link is always different than that of the basic rate of the link. So, there is a vast variation with the data rate of the link to the basic rate of the link. Both of them depends upon the link rate, and link rate is relates the number of retransmissions for successful attempts. Modern wireless radios utilize multiple data transmission in order to accommodate variable channel conditions. This multi-rate strategy has been shown to greatly improve wireless multi-hop networks performance [7].

Currently, the IEEE 802.11g standard offers data rates of 6, 9, 12, 18, 24, 36,48 and 54 Mbps while the earlier IEEE 802.11b standard supports 1, 2 , 5.5 and 11Mbps data rates. Thus, a wide range of data transmission rates may exist simultaneously within one single network scenario.

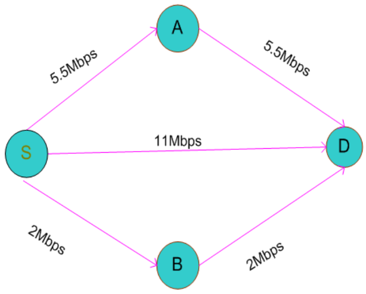

Fig-3: WMNs with various link rate

In the above network S and D are the source and destination nodes, A and B are the intermediary nodes there are paths of different data rate. For the better data rate the number of retransmission is lower, but for the lower data rate link the number of retransmission is higher.

Control Overhead

In wireless mesh network (WMNs) for sending data there is an data channel and for sending control information there is a control channel. All the metric always considers various issues such as link rate, transmission delay, number of retransmission, number of interfering nodes, MAC delay but never consider the control channel rate i.e. basic rate for control information. This control channel rate makes delay that is called control overhead delay time for control overhead may have great impact to the network throughput. When source send a packet data to a destination, it exchanges control messages are RTS, CTS, ACK and SIFS, DIFS etc. This Control Over head time will be must delayed to get the channel for sending data. So, if we don't consider this issue there will be big wrong measurement to the counting the transmission time. The following figure represents the control overhead delay slot for exchanging control information.

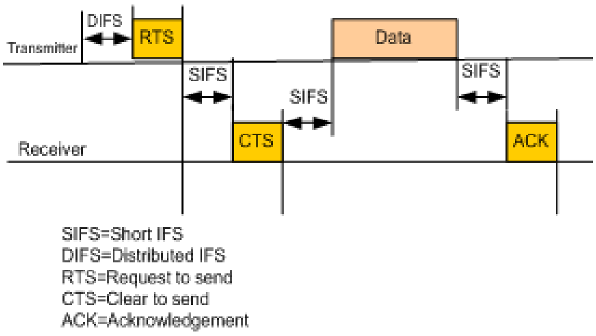

Fig-4: Exchange of control frame between sender and receiver

The exchanging of control frames is major issue and it have huge impact on routing in wireless networking. According to the above figure we can calculate it and have the impact of it in route selecting through our proposed metric.

Interfering Intensity

For selecting a link in wireless mesh networks (WMNs) interference is another major issue that can impact on the best route selecting decision. Less interference oriented link is better than that of the high interference oriented. As we see that for data transmitting from sender to receiver is highly affected by interference, consideration of interference to design a new routing metric greatly make efficient metric. It can be caught the interference respect to the link through which data may be sent by counting the number of interfering nodes or the total intensity of interference. To design a best routing metric, to get high throughput of the network and exact estimation of interference we considered the interference intensity. According to the following wireless mesh networks (WMNs) node p, q, r are the interfering node and lp, lq, lr are the respected loads.

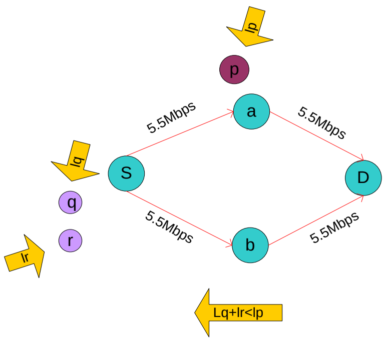

Figure 4.4: Interfering node with different load in WMNs

Node p is the highly loaded interfering node, and node q, r are the lightly loaded interfering node. Though the number of node along with the link A to b is more than that of the link A to a, the load of interfering node along with A to b is less than that of node p along with the link A to a. Interfering intensity comes from the load of interfering nodes along with the link.

Queuing Delay

In wireless mesh networks (WMNs) each data packet experience a delay when the packet is ready to be transmitted in the transmitting queue is called queuing delay[86]. Queuing is defined by the volume of load of a node if a node is lightly loaded the queuing delay will be very low. But being the node is loaded the queuing delay will be more and more. So, considering the queuing delay is very important issue and it make the metric very much efficient. So, we see that if nodes are highly loaded then the major portion of transmission delay may be come from the queuing delay. if a packet is scheduled through a node that already has enough packets in the transmission queue then it will have to wait until the other packets in the queue finish their transmission successfully.

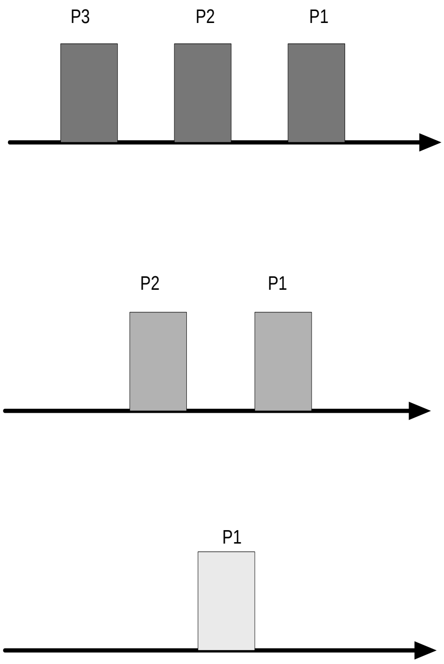

Figure 4.5: Packets in the queue with various queuing delay

According to the above figure 4.5 we see that in the first queue there are 3 packets with same size and in the 2nd queue there are only two packets in the queue, finally in the last queue there is only one packet. For the first queue the packet P1 will experience lowest queuing delay and P3 will experience the highest queuing delay. In the same way the packets in the 2nd queue will experience less queuing delay than that of the 1st queue. The packet in the last queue will experience no delay.

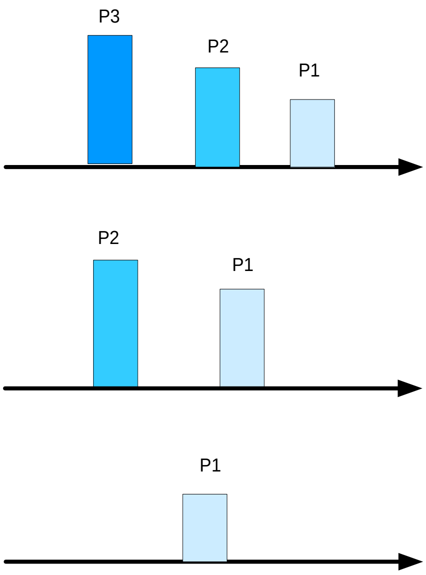

Figure 4.6: Queuing with different packet size

In the above figure each queue is with various sized data packet that is represent the various queuing delay. So, for queuing delay this scenario is different than that of the figure 4.6 scenario.

Advanced Expected Transmission Time (AETT)

For wireless mesh network there are a lot of metric for routing a packet, each of these consider various issues. We also tried to consider those issues for efficient routing a packet from source node to destination. Finally we have designed a metric for wireless mesh networks (WMNs) as stated below.

Our proposed metric

AETT = $T_{delay} + \sum_{i=1}^{N} CuT_i + Q_{delay}$ -----------(i)

Where,

T_{delay} = Transmission delay

$\sum_{i=1}^{N} CuT_i$ =Channel use time by interfering nodes

N = Number of interfering node along with the lin

Q_{delay} = Queuing delay of a packet

Advanced Expected Transmission Time (AETT) calculate total transmission time based on the terms of the equation (i) such as transmission delay that is the consideration of Expected Transmission Count (ETX), bandwidth, packet size, control overhead, channel use time is to measure the interference intensity of nodes along with a link, queuing delay that a packet has to wait in the queue to be transmitted.Advanced Expected Transmission Time (AETT) considers the transmission delay that is the delay of a packet only to be transmitted. To calculate transmission delay we consider Expected Transmission Count (ETX), packet size, control overhead, bandwidth of the link. Impact of Control Overhead on the total network throughput is very much high. The Advanced Expected Transmission Time (AETT) metric is designed to take into account the Control Overhead with packet size and bandwidth, queuing delay, level of interference when computing the transmission delay that is composition Number of retransmission, bandwidth packet size.Expected Transmission Time (ETT) depends on packet size, the data rate and the loss rate. It is the expected time required for on successful data packet delivery.

Let,

S = Packet size

B = Data rate or bandwidth of the link and

ETX = Expected transmission count on a given hop

ETT is defined as

ETT = ETX × $\frac{S}{B}$ ……………………………………………………….....(ii)

The ETT metric for a path is the sum of all links ETT over the path. The ETT metric uses equation (ii) considering loss rate, packet size and data transmission rate. But ETT does not consider the transmission time which is not only the transmission rate and lose rate but also the control frames which are sent at basic data rate of 1 Mbps such as RTS, CTS, DIFS, SIFS and ACK of IEEE802.11 networks.

This paper assumes a full control packet exchange before a data packet transmission. Thus the overhead of sending a data packet includes the time to send a RTS, CTS, DIFS, SIFS and ACK.

Now, T_{delay} = ETX ×$\left(\frac{S}{B} + \frac{C_o}{B_{br}} \right)$ …………………… (iii)

Hence,

The considering control frame size is constant but the impact of control overhead in transmission time is depends on different transmission rate. The basic rate of control overhead is 1 Mbps and control overhead is 48B. Consideration of control overhead in the transmission delay calculates exact delay that protects deviation between expected throughput and practical throughput. Interference intensity that is measured from the term $\sum_{i=1}^{N} CuT_i$ of the equation 4(i).This term in interfering intensity of neighboring nodes along with the link through which the source node may send packet data to the destination node. This term is also can be said as channel use time of neighboring nodes. In this case we always calculate the intensity of interference of each considering link. This interference intensity keeps the channel busy of the packet sender node. So, in Advanced Expected Transmission Time (AETT) we consider the delay to get the channel by the sender node to transmit data packet. In this case we calculate the sum total interference of total number of interfering nodes along with each considering link. This intensity of interference depends upon the link rate the load of a node, queuing delay. If the data link rate is too much low then the interference will be high. Again being the load is higher of node, the intensity of interference is high. So, to the interfering intensity bandwidth has great impact.

Queuing delay is the amount of time, when a packet is waiting in the transmitter’s queue before it gets the chance of transmission. So if a packet is scheduled through a node that already has enough packets in the transmission queue then it will have to wait until the other packets in the queue finish their transmission successfully.If a packet is transmitted through a lightly loaded node then the packet will experience a less queuing delay and the end-to-end delay will be decreased.

VI. PERFORMANCEANALYSIS

The Revised Expected Transmission Time (RETT) metric is designed to take into account the Control Overhead with packet size and bandwidth when computing Revised Expected Transmission Time (RETT). The proposed metric that affects the performance of itself in routing can be as the impact of control overhead on the network throughput.

Impact of Control Overhead

Expected Transmission Time (ETT) depends on packet size, the data rate and the loss rate. It is the expected time required for on successful data packet delivery.

Let,

S = Packet size

B = Data rate or bandwidth of the link and

ETX = Expected transmission count on a given hop

ETT is defined as:

$$ETT = ETX \times \frac{S}{B}$$

The ETT metric for a path is the sum of all links ETT over the path. The ETT metric uses equation 4(iii) considering loss rate, packet size and data transmission rate. The transmission delay not only considers loss rate, packet size, data transmission rate but also the control frames which are sent at basic rate.This paper assumes a full control packet exchange before a data packet transmission. Thus the overhead of sending a data packet includes the time to send a RTS, CTS, DIFS, SIFS and ACK.

Now,

$$RETT = ETX \times (\frac{S}{B} + \frac{C_o}{B_{br}})$$

Hence, the considering control frame size is constant but the impact of control overhead in transmission time is depends on different transmission rate of data packet. The IEEE802.11g standard offers Data rate of 6, 9, 12, 18, 24, 36, 48, and 54Mbps. 6Mbps is the basic rate for transmission of control frame where the control overhead is 48B. Consideration of control overhead in the transmission delay calculates exact delay that protects deviation between expected throughput and practical throughput.

We can calculate the time need to transmit the control frames and time need to transmit the data frame.

Time need to transmit the control overhead

$$= \frac{48 \times 8byte}{6 \times 1024 \times 1024 byte/\sec} = 61.033\ \mu s$$

For the data packet size =256KB, according to the IEEE802.11g standard data rate 54Mbps we have following

Time need to transmit data packet

$$= \frac{256 \times 8byte}{54 \times 1024 \times 1024 byte/\sec} = 36.17\ \mu s$$

Now,

The total time required to transmit a packet = 61.03 µs+ 36.17 µs =97.20 µs

The earlier IEEE 802.11b standard supports 1, 2, 5.5 and 11Mbps data rates to which we can have the accounts of impact of control overhead.

Time need to transmit the control overhead

$$= \frac{48 \times 8byte}{1 \times 1024 \times 1024 byte/\sec} = 366.20\ \mu s$$

For the data packet size =256B, according to the IEEE802.11g standard data rate 11Mbps we have following

Time need to transmit data packet

$$= \frac{256 \times 8byte}{11 \times 1024 \times 1024 byte/\sec} = 17.26\ \mu s$$

Now, the total time required to transmit a packet

= 366.20 µs+ 17.26 µs =383.46µs

On the change in packet size and data rate there is change in the impact of control overhead on the data volume.

Measuring Interference

Our proposed metric first of all consider the intensity of interference in route selecting by routing metric in wireless mesh networks (WMNs). Some other routing metric consider the interference but not the level of interference. If we look at the MIC metric that measure the interference by a term IRU_l of a link that is on the basis of number of interfering node along with the link that cannot select the lower interference link always. We can have the explanation of this improvement ofrouting metric from others to our proposed metric through the following network scenario.

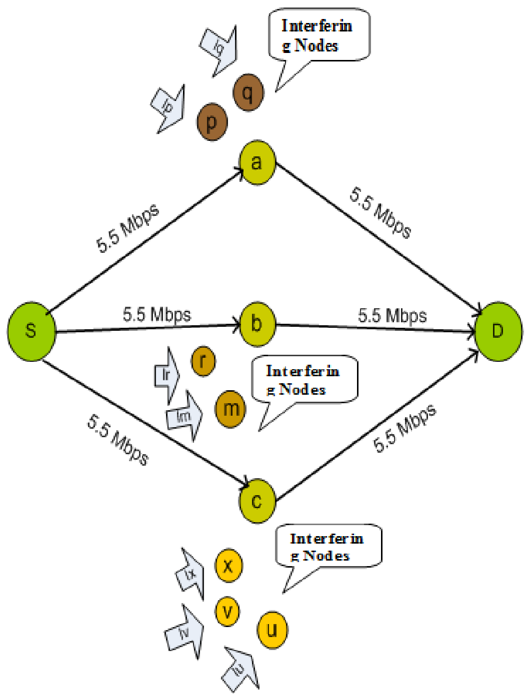

Figure 4.7: Network with interfering nodes for same link rate

In the above networks diagram there are 11 nodes from which
S = Source node
D = Destination node
p, q, r, m, u, v, x = Interfering node
a, b, c = intermediate node

Now source node S is to send a packet to the destination node D. For selecting the path there are three paths for node S are as follows:

$S \to a$
$S \to b$
$S \to c$

Each of the above link is of link rate 5.5 Mbps offered by the standard IEEE8011.b [81]. Along with each link there are interfering nodes.

$S \to a$: with this link node p, q are interfering nodes and l_p , l_q are their loads

$S \to b$: with this link node r, m are interfering nodes and l_r , l_m are their loads

$S \to c$: with this link node u, v, x are interfering nodes and l_u , l_v , l_x are their loads

Let,

l_p = 1024B l_q =1024B

l_r = 512B l_m = 1024B

l_u = 256B l_v =256B l_x =512B

Now, we can calculate the channel use time (interference intensity) for each link: $S \to a$, $S \to b$, $S \to c$ to select the best path from the existing path from source node to destination node in the given wireless mesh networks (WMNs).

Channel use time along with $S \to a$ is:

$$Cut_{S\to a} = Cut_p + Cut_q = \frac{1024 \times 8bit}{5.5 \times 1024 \times 1024bit/\sec} + \frac{1024 \times 8bit}{5.5 \times 1024 \times 1024bit/\sec} = 2.84\text{ms}$$

Channel use time along with $S \to b$ is:

$$Cut_{S\to b} = Cut_r + Cut_m = \frac{512 \times 8bit}{5.5 \times 1024 \times 1024bit/\sec} + \frac{1024 \times 8bit}{5.5 \times 1024 \times 1024bit/\sec} = 2.13\text{ms}$$

Channel use time along with $S \to c$ is:

$$Cut_{S\to c} = Cut_u + Cut_v + Cut_x$$

$$= \frac{256 \times 8bit}{5.5 \times 1024 \times 1024bit/\sec} + \frac{512 \times 8bit}{5.5 \times 1024 \times 1024bit/\sec} + \frac{256 \times 8bit}{5.5 \times 1024 \times 1024bit/\sec}$$

= 0.71ms + 0.36ms + 0.36ms
=1.43ms

So, we see that for link S $\rightarrow$ a, the channel use time is 2.84ms,
link S $\rightarrow$ b the channel use time is 2.13ms and
link S $\rightarrow$ c the channel use time is 1.43ms.
As much as the channel use time is increase the intensity of interference will increase.

So, the highest interfere oriented path is the high channel use time path. In this networks scenario we see that the S $\rightarrow$ c path is less interference path and path S $\rightarrow$ a is high interference path though there are more interfering node with path S $\rightarrow$ c than that of with path S $\rightarrow$ a.

In this case if we look at the interference measure by MIC [81] we see that IRU_l is calculated from ETT of the respected path and number of interfering node along with the path.

For same ETT from the above wireless mesh network (WMNs) the MIC will select the path S $\rightarrow$ a or S $\rightarrow$ b but never S $\rightarrow$ c because of more number of interfering node with along with path S $\rightarrow$ c.

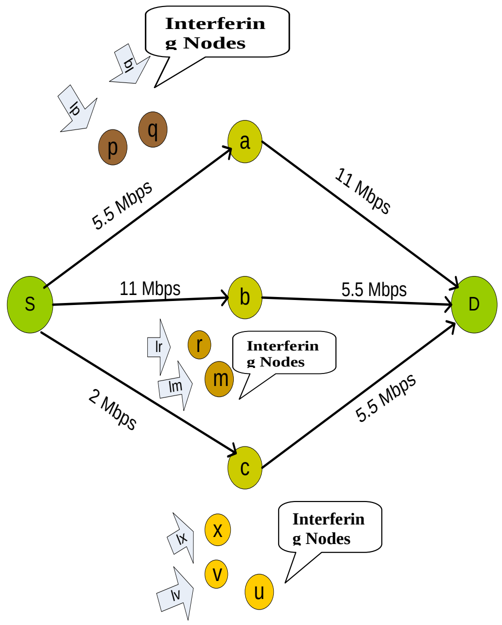

Figure 4.8 Network with interfering nodes with different link rate

Now, we can calculate the channel use time (interference intensity) for each link: S $\rightarrow$ a, S $\rightarrow$ b, S $\rightarrow$ c to select the best path from the existing path from source node to destination node in the given wireless mesh networks (WMNs) for different link rate according to the figure 4.8

Channel use time along with S $\rightarrow$ a is:

$$Cut_{S\rightarrow a} = Cut_p + Cut_q = \frac{1024\times 8bit}{5.5\times 1024\times 1024bit/\sec} + \frac{1024\times 8bit}{5.5\times 1024\times 1024bit/\sec} = 2.84\text{ms}$$

Channel use time along with S $\rightarrow$ b is:

$$Cut_{S\rightarrow b} = Cut_r + Cut_m = \frac{512\times 8bit}{11\times 1024\times 1024bit/\sec} + \frac{1024\times 8bit}{11\times 1024\times 1024bit/\sec} = 1.06\text{ms}$$

Channel use time along with S $\rightarrow$ c is:

$$Cut_{S\rightarrow c} = Cut_u + Cut_v + Cut_x$$

$$= \frac{256\times 8bit}{(2\times 1024\times 1024)bit/\sec} + \frac{512\times 8bit}{(2\times 1024\times 1024)bit/\sec} + \frac{256\times 8bit}{2\times 1024\times 1024bit/\sec}$$

= 0.98ms + 1.96ms + 0.98ms
=3.92ms

So, we see that for link S $\rightarrow$ a the channel use time is 2.84ms,
link S $\rightarrow$ b the channel use time is 1.06ms and
link S $\rightarrow$ c the channel use time is 3.92ms.

As much as the channel use time is increase the intensity of interference will increase.

So, the highest interference oriented path is the high channel use time path. In this networks scenario figure 4.8 we see that the S $\rightarrow$ b path is less interference path and path S $\rightarrow$ c is high interference path.

In this case if we look at the interference measure by MIC [82] we see that IRU_l is calculated from ETT of the respected path and number of interfering node along with the path. So, the S $\rightarrow$ b is the high throughput path due to high link rate.

For same ETT from the above wireless mesh network (WMNs) the MIC will select the path S $\rightarrow$ a or S $\rightarrow$ b but never S $\rightarrow$ c because of more number of interfering node with along with path S $\rightarrow$ c

Graphical Analysis

Impact of Control Overhead

When a node transmits a data packet, it transmits also control frames that affect the data packet transmission time. Control packet sent at the basic rate of the link and the time need to send control overhead is constant. The following figure 4.9 represents the impact of control overhead over data packet size. As the packet size increase the impact of constant control overhead on transmission time is decreases.

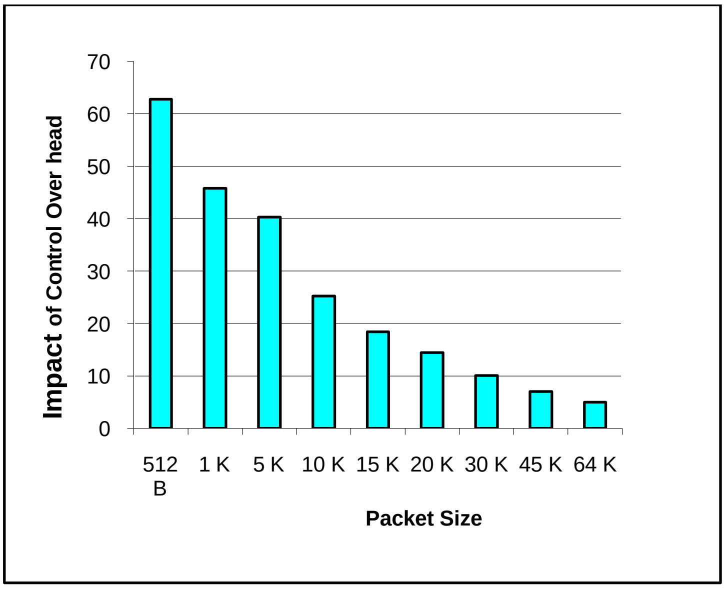

Fig-5: Impact of control overhead over packet size

In the following figure 4.10 shown that time need to send control overhead is constant and the time to send packet data is varying with respect to data packet size. We see that when the packet data size is near about to the control frame size the time needed to transmit data and time needed to transmit the control overhead is almost same. Being the high variation between data packet and the control data the time variation between control overhead and data is high.

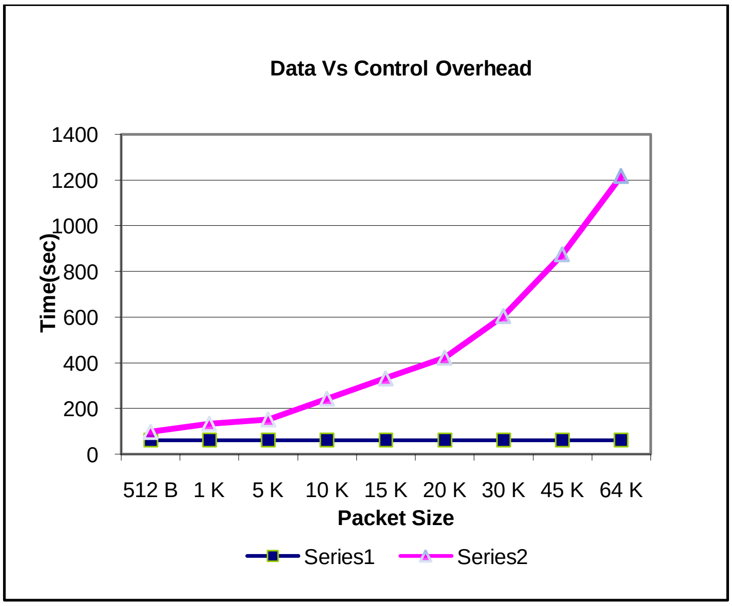

Fig-6: Transmission timed for control overhead and data packet

Computing Advanced Expected Transmission Time

In the routing metric Expected Transmission Time (ETT) control overhead is not considered that makes the metric time estimation is different than that of exact transmission time. In our proposed metric Revised Expected Transmission Time (AETT)control overheadis considered with data packet transmission time that represents exact Transmission time. The following fig-7 and fig-8 represents the transmission delay by ETT and our proposed metric RETT respect to two aspects i.e. dynamic in data packet size and link rate.

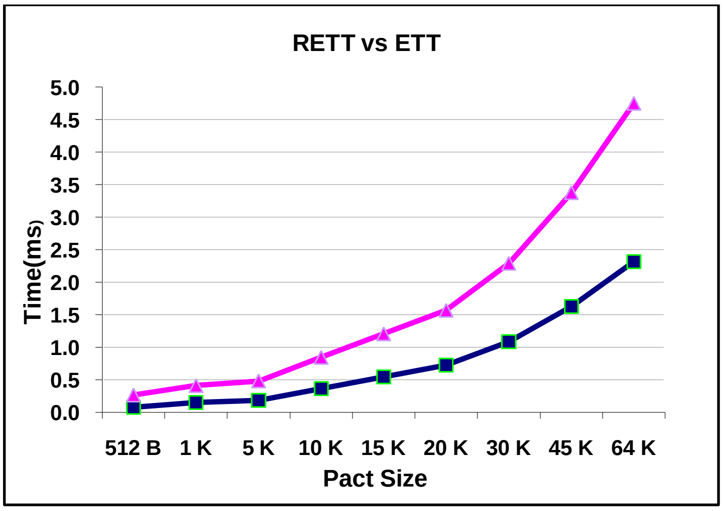

Fig-7: Exact transmission time (varying data packet)

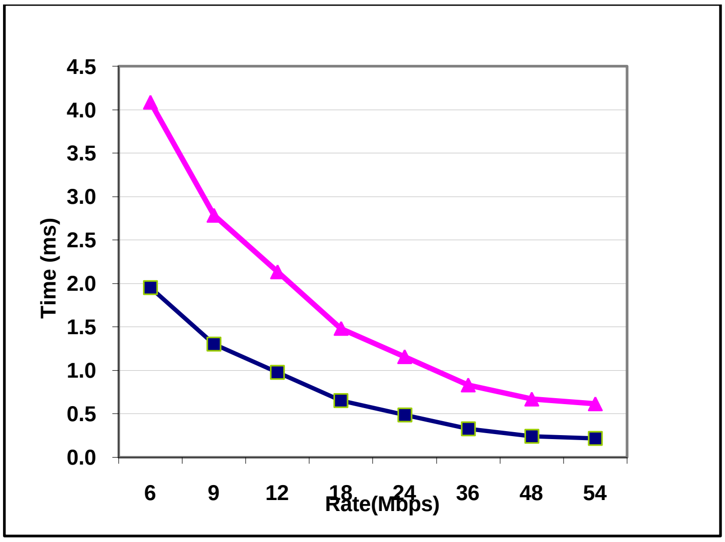

Fig-8: Exact transmission time (varying data link rate)

Estimation of Interference

According to MIC metric the measurment of interference is depends on the number of nodes along with the considered link..

The count of $IRU_l = ETT_l \times N_l$

By ploting the IRU respect to the number of nodes we have the following straight line that will linearly increasing

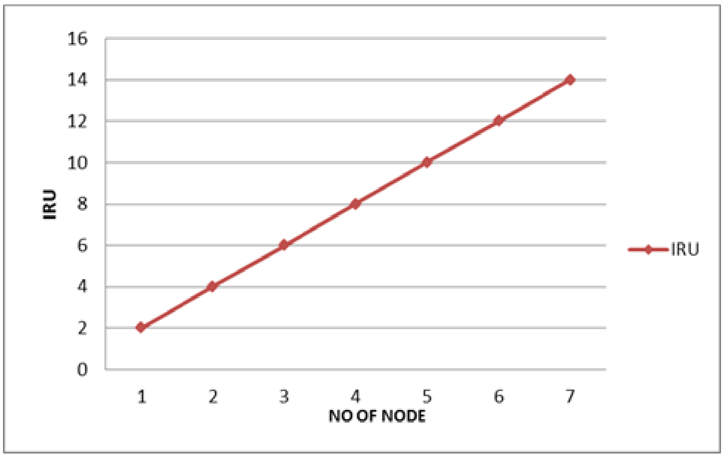

Figure 4.13: Interference according to MIC metric

On the other hand in our metric the measurement of interference is done by Channel Use Time(CUT) that is related to the loads of interfering node along with the respected link. In the following table the all explanation of computing the interference intensity given below.

Table 4.1: computing interference intensity

No. of Node	Load(B)	Link Rate (Mbps)	Time (μs)	CUT
1	1024	11	710.23	710.23
2	512	5.5	710.23	1686.79
	256	2	976.56	
3	1024	11	710.23	3639.91
	256	2	976.56	
	512	2	1953.13	
4	512	5.5	710.23	2530.18
	256	5.5	355.11	
	128	2	488.28	
	256	2	976.56	
5	256	11	177.56	3773.08
	512	2	1953.13	
	128	5.5	177.56	
	256	2	976.56	
	128	2	488.28	
6	256	5.5	355.11	3107.24
	512	5.5	710.23	
	128	2	488.28	
	256	2	976.56	
	128	11	88.78	
	128	2	488.28	
7	1024	11	710.23	5193.54
	256	5.5	355.11	
	512	2	1953.13	
	512	11	355.11	
	256	2	976.56	
	128	2	488.28	
	256	5.5	355.11	

According to our metric AETT we see that the level of interference is not linear depending on the number of node. Advanced Estimation of Transmission Time (AETT) computes the exact interference from the loads of each interfering node of the respected link.

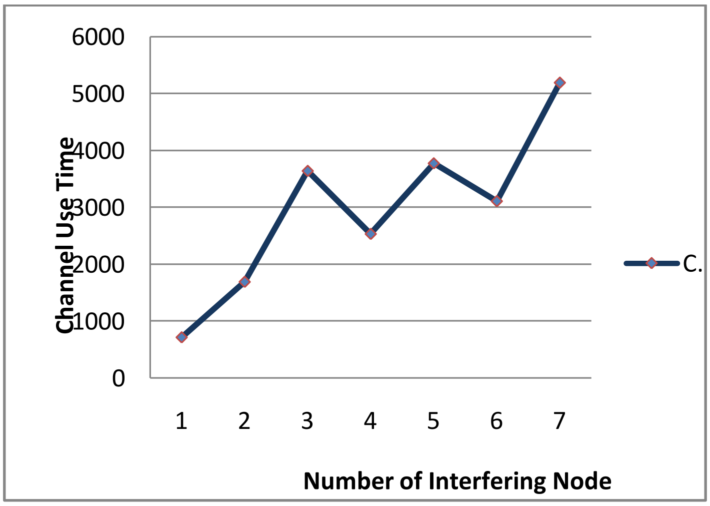

Figure 4.14: Interference intensity according to AETT

VII. CONCLUSION

In this work we have tried to overcome interferences problem, control overhead calculation, queuing delay, and propagation delay. We have big research plan on this topic more to contribute lot in wireless mesh network. We next try to experiment on real mesh stations gathering as the real interfering and analytical interfering may differ. We make the virtual calculation in straight computing for routing. Our metric will be then fully successful to count the routing load and decide to proper route on that moment for that packet. So, our next concern on real simulation and noting the impact of this metric to facilitate routing.

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