Maximizing Throughput & Minimizing Packet Loss Ratio by Traffic Shaping Technique in Wireless Mesh Network

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Dated: 05/03/2011

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Dedication

-TO ***ALLAH almighty*** *and his prophet* ***Muhammad (P.B.U.H)*** *who made me aware of the mysterious things.*

-To my beloved **parents** *who encouraged, supported and* gave me unconditional love and prayers *until the end of their lives.*

-To ever loving **Rizwana** *who* is both my sister and my best friend, who kept my spirits up when the muses failed me.

A dissertation Submitted To

Department of Computer Science,

Faculty of Basic and Applied Sciences,

International Islamic University, Islamabad

As a Partial Fulfillment of the Requirement for the Award of the

Degree of Master of Science in Computer Science

Declaration

I hereby declare that this thesis ***"Maximizing throughput & minimizing packet loss ratio by traffic shaping technique in wireless mesh network"*** neither as a whole nor as a part has been copied out from any source. It is further declared that we have done this research with the accompanied report entirely on the basis of our personal efforts, under the proficient guidance of our teachers especially our supervisor ***Muneera Bano*** and ***Khalid Hussain***. If any part of the system is proved to be copied out from any source or found to be reproduction of any project from any of the training institute or educational institutions, I shall stand by the consequences.

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Acknowledgement

First of all I am obliged to Allah Almighty the Gracious, the Beneficent and the source of all Knowledge, for granting me the courage and knowledge to complete my project. I was totally unable to present if Allah Almighty was not there with me.

After that I am thankful to The Holy prophet (peace be upon him) the messenger of Allah Almighty who became a source to help us while understanding the mysterious things in this world and the worlds after this.

I cordially thank to my teachers especially my supervisors "Miss Muneera Bano" and "Sir Khalid Hussain who helped me a lot at each stage for the successful completion of my thesis. Their kind guidance, perceptive criticisms, and support helped me a lot in write up of this thesis. Here, especially I say thanks to my teacher "Sir Atif Naseer" whose persistent support and encouragement greatly helped me to complete my project.

Finally I genially regard the motivation, pray and support of my brothers, sisters and all my family for their immense support and motivation in each stage of my studies, hence to complete this research work also. Without their indefatigable help and guideline I was not capable to present this project.

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Project In Brief

Project Title:

Maximizing Throughput & Minimizing Packet Loss Ratio by Traffic Shaping Technique in Wireless Mesh Network

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Start Date: **01-01-2010**

Completion Date: **05-03-2011**

Tools & Technologies

OMNeT++

Documentation Tools

Microsoft Word
Microsoft Visio
Microsoft Excel
Microsoft Power Point

Operating System:

Windows Vista Home Edition

System Used:

Pentium 4
Intel core 2 Duo CPU
Memory 3062 MB
32 bit Operating System

Abstract:

Wireless networks are commonly used now a day and mostly preferred so, the end users expect the same degree of performance from wireless networks as they have from wired networks. End users expect more instead of simply sending or receiving text or graphics. Because multimedia traffic is delay sensitive and required more bandwidth as compared to other traffic so while delivering real time traffic Quality of Service is a main issue which should be seriously tackled by the service providers. Multimedia traffic contains packet loss and delay constraints and in some cases it requires no delay and needs to deliver exactly at the time it is send. So, here we make an attempt to meet with such big issue and propose an architecture which results in low packet loss ratio and an acceptable delay which results to enhance throughput.

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Chapter 1
Introduction

1: Introduction

A communication network is a mean for sending or receiving data i.e. text, graphics, audio or video across the networks. The nodes in such type of communication network may directly associate with each other or with the help of intermediary nodes. Connection maintained between such type of nodes is double sided and mechanism followed by nodes is that each and every node in network holds a buffer which is used in case of heavy flow when communication of some traffic is not possible for the particular node due to the bandwidth limitation, so traffic temporarily stored in the buffers unless the link have adequate bandwidth. Networks are increasingly used between end nodes for reliable and high data transmission rate across wide area networks. This thing demands high quality of services and outstanding infrastructure design.

As wireless networks are commonly used now a day and mostly preferred so end users expect the same degree of performance from wireless networks as they have from wired networks. End users expect more instead of simply sending or receiving text or graphics. Multimedia traffic becomes a very common part in wireless networks and end users expect same effectiveness for real time traffic as they get from non real time traffic. As multimedia traffic is delay sensitive and require more bandwidth as compare to other data traffic so while delivering real time traffic Quality of Service is main issue which should be seriously tackled by the service providers. Multimedia traffic utilizes more bandwidth and contains delay constraints and in some cases it requires no delay and needs to deliver exactly at the time when it is sent.

Providing multimedia traffic service in wireless mesh network is somewhat complex task which have strict conditions to be considered while delivering such type of traffic. Like other wireless networks, wireless mesh network have the ability to efficiently handle the multimedia traffic, so that we get the same type of performance as in wired network. Providing quality of service in wireless mesh network is most fundamental and complex task which should be handled efficiently. Quality of service in terms of bandwidth utilization, mean delay, packet loss ratio and congestion control are main point which should be tackled efficiently for multimedia traffic within or across the networks.

Various mechanisms have been proposed to control and scrutinize the network traffic. These techniques may be implemented on the points where traffic enters or from where it leaves within the network, this decision is dependent upon the particular situation requirements.

Three types of techniques have been established i.e. policing, shaping and scheduling. Traffic policing is a mechanism to control and regulate the accepted connections. If the arriving data rate not fulfils the committed rate for data transmission the policer may drop that or assign as low priority traffic which may be dropped later in case of congestion encountered between the linked nodes . So traffic policing may guarantee to fulfil the agreement. It is an over conservative regulating technique. In contrast of traffic policing, traffic shaping is a technique in which buffers are used to store the traffic for the purpose of traffic normalization. Hence shaping performs the task of traffic smoothing. Without doing this task the network may face performance degradation or it have to be able to possess resources to maintain variable size bursts of traffic. So traffic shaping reduce packet loss ratio as it buffers the coming streams of data although non-confirming and list them to send them later when they became confirming.

1.1 Introduction to traffic shaping

Traffic shaping is a way to organize the network traffic in such a way so that it provide best network performance for delay sensitive traffic. Traffic shaping takes the charge of traffic classification, queuing discipline, managing congestion and providing quality of service (QoS). Hence it means to control the degree of traffic sent towards the network and the rate by which it will be sent. Reduced packet loss, low latency and less jitter are the key benefits which it will provide in case of high data traffic flow.

Traffic management is a way to utilize available bandwidth on a given network by reducing delay in real time traffic and congestion control by means of quality of service. The term traffic management also recommended as traffic shaping and traffic engineering is a mean to provide best effort quality of service for real time traffic. It is away to assure the performance increment for traffic which is time sensitive by utilizing bandwidth currently available and in some cases delaying some data traffic and giving priority to other classes of data traffic according to some predefined mechanism. This mechanism applied to control the randomly generated traffic in a way so that it can be efficiently transferred to end nodes with no or minimum delay and without packet loss.

1.1.1 Purpose of implementing traffic shaping technique

Main motive to implement traffic shaping technique is to assure the performance issue across the networks. Traffic shaping permits us to:

- Utilize and manage the bandwidth and regulate the traffic by avoiding congestion.
- Implement the policies for traffic smoothing or implement policies where no pre-policies exist.

1.1.2 Domain of traffic shaping

Traffic shaping is an element of traffic conditioner which basically consists on four elements. But it is not necessary that traffic conditioner use all four elements. Traffic conditioners usually lie on the entering or leaving edges of a network or between the intermediate nodes lie in particular network. A traffic conditioner consist of

- Traffic Meter
- Traffic Marker
- Traffic Shaper
- Traffic Dropper

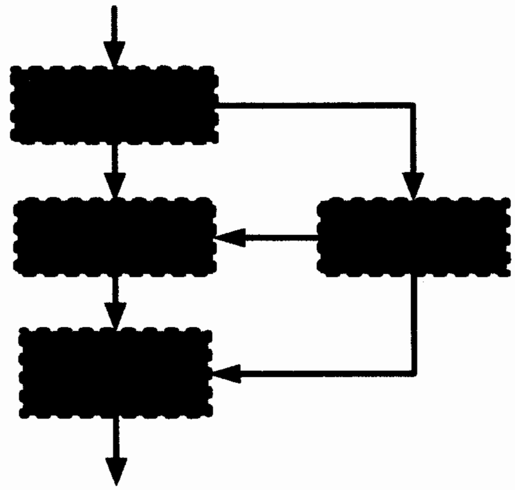


Fig 1.1: Logical view of Traffic Conditioner [5]

1.1.2.1 Traffic Meter

Traffic meter used to measure the streams of packets against the profile of traffic. Its results may effect the actions undertaken by a marker, shaper or dropper. It is used to inform other elements of traffic conditioner about state of packets.

1.1.2.2 Traffic Marker

Traffic marker organized for the purpose of marking all the packets which are entered into marker for a single code point or for the organization of packets for a set of code points.

1.1.2.3 Traffic Shaper

Shaper is used to shape the traffic which finally brings the traffic towards the network. It may delay some of the packets to meet the required demand defined in profiles. If the range of delayed packets exceeds from the buffer size it may discard packets [5]

1.1.2.4 Traffic Dropper

Often it happens that a coming stream of traffic even didn't match the already defined category of rules. In this case traffic dropper is used which drop either some or whole packets in such type of situation. Dropper also named as a process of traffic policing. Traffic dropper may also be organized in the form of shaper in such a case its buffer size either set as zero or a small amount of packets.

1.1.3 Rules of implementing traffic shaping technique

Although the rule of implementing traffic shaping is that we apply this technique on the edge nodes of network, however we can also apply this technique in the midway nodes. Three types of rules are followed while implementing traffic shaping. [29]

- By Application
- By User
- Priority Management

1.1.3.1 Application

In the first one a specific share is allowed by all data traffic over network. Each class of data is restricted not to use more then the defined limit of bandwidth. Here each category of traffic uses a specific defined share of bandwidth.

1.1.3.2 User

In user rule case all users get equal share i.e. here each user get a fair share of bandwidth. According to users point of view network traffic is distributed. Rule may be followed when a pre-assured range of bandwidth used to assign for particular user.

1.1.3.3 Priority Management

Third one is priority management in which data to be travelled over the network is divided into different classes according to their priority level they needed. For example in multimedia transmission, the rule can be set that highest priority will be given to multimedia traffic and low priority will be given to best effort traffic.

1.2 What is Wireless Mesh Network

In the era of wireless networks Wireless Mesh Network (WMN) is an approaching technology. WMN are made up of radio nodes organized in mesh topology. Easily deployment, self-configuration and self-organization are some of the key advantages introduced by WMN. This is because mesh nodes maintain automatic establishment of connection with each other. So WMN becomes a preferable network due to its easily deployment, cheap up-front cost, robustness and reliability in coverage of service. WMN are the pioneer which provide high bandwidth in there coverage area. They have point to point wireless connection with end nodes so if a link fails alternate path exist to send data towards the destination.

One main reason which makes wireless mesh networks unstable is infrequent nodes or adding up of new nodes. The data traffic of diverse nature is collected from many users on a network. In case of infrastructure mesh network traffic flow to or from gateways. As compared to that in ad hoc networks or in client based mesh networks traffic flow between nodes.

Currently, wireless technology enables a lot of multimedia applications which demand seamless real time delivery. Multimedia applications get a major portion of internet traffic and require stringent quality of service requirements. WMN has drawn the attention of researchers due to its low deployment cost ease of use and reliable data transmission. Besides providing other traditional services it can mitigate the challenges of providing real time services of VoIP, video meeting and video telephone etc.

1.2.1 Architecture of WMN

WMNS architecture can be distributed into following forms.

- **Infrastructure WMN**
- **Client WMN**
- **Hybrid WMN**

1.2.1.1 Infrastructure WMN

In infrastructure WMN, routers are used which make connection between clients. In spite of using IEEE 802.11 technologies a variety of radio technologies are used to build up this type. The main architecture in this is made by mesh routers. Mesh routers among themselves perform the function of self healing, and self configuration. Gateways are used to connect mesh routers with the internet.

Infrastructure meshing is another name of this type as it provides backbone for conventional clients. Due to the gateway/bridge functionalities it permits WMN to make conversation with other networks. Clients either make connection with mesh routers by using Ethernet cable or they may use radio techniques. In the later case mesh routers. Infrastructure/Backbone WMN is one of the most common types of WMN.

Two types of radio communications are used in the routers. One type is used for backbone communication and other is used for user communication. Directional antennas may be included for the establishment of mesh backbone communication in long-range communication techniques.

1.2.1.2 Client WMN

In client WMN clients can also directly send data towards destination. In this type of mesh networks mesh routers are not required. Clients itself perform the additional functions of mesh routers. Hence client or end user devices requirements obviously increased as compared to infrastructure meshing. Here the flow of traffic is in between arbitrary pairs of nodes instead of mesh nodes.

1.2.1.3 Hybrid WMN

Hybrid WMN is mixture of both types. Data traffic either directly flows between two mesh clients or it may be forwarded to and from mesh routers. As it is combination of both above discussed techniques so it possesses the plus points of two techniques. Like Infrastructure WMN it offers connectivity with Internet, WiMAX, cellular and sensor networks. Client WMN offers efficient connection routing capabilities and exposure inside the WMN. Hence provide greater flexibility and advantage from both discussed above.

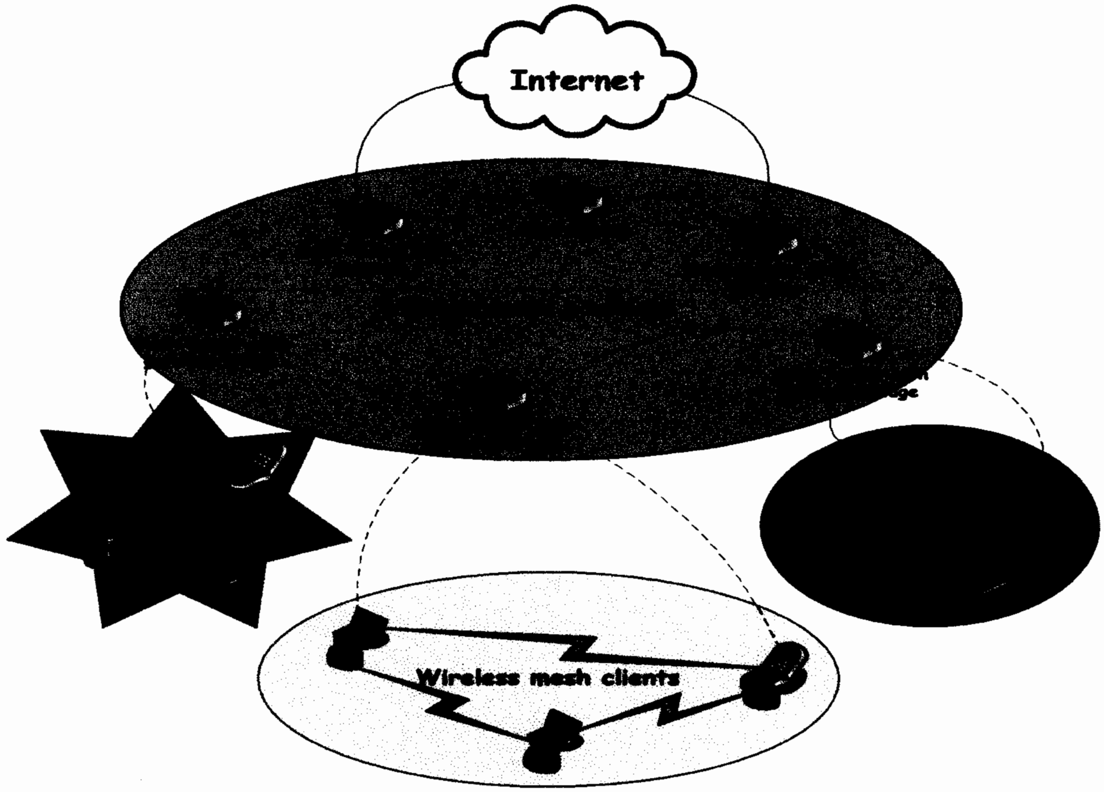


Fig 1.2: Hybrid WMN [7]

1.2.2 Types of WMN

WMN are of two types ***fully meshed*** and ***partially meshed***. In the first case all nodes are directly connected to every other node that lie in that network. In second case some nodes are directly connected to other nodes as in fully meshed type while others are indirectly connected to some of the nodes in the network.

1.2.3 Types of nodes in WMN

WMN contain two types of nodes ***mesh routers*** and ***mesh clients***. In mesh routers, router maintains the functionality of sending data from source node to destination node. Other then the functionality of simple router's capabilities of gateways or repeaters, mesh routers has additional routing functionalities to support mesh networking. Mesh clients possesses extra functions of mesh routers. Except the functionalities of gateways or bridges mesh clients have all the functionalities of mesh routers. Besides all this mesh clients possess unique wireless interface. So the hardware and software platform of mesh clients is extremely simpler than that of the mesh routers. As compared to mesh routers mesh clients have greater number of device these include laptop/desktop PC, PDA, IP phone, BACnet (building automation and control networks) controller etc.

1.2.4 Characteristics of WMN

WMN equipped with the following qualities.

1) Multi hop wireless network:

Increasing coverage area is from one of the main purposes of establishing WMN.

2) Maintain for ad hoc networking, and capability of self-forming, self-healing, and self-organization:

WMN increase the network performance so provide flexible network architecture. They provide multipoint to multipoint connection in network so they are growing up gradually.

3) Mobility dependence:

In this network mobility depends on the type of end nodes. A mesh router has minimum or no mobility whereas mesh clients can be stationary or mobile nodes.

4) Limitations of power expenditure depend on mesh nodes type:

Mesh routers are not strict to power consumption where as the mesh client require power efficient protocol. Usually power consumption is not a serious issue for mesh routers but as far as mesh clients are concerned power consumption is a critical issue.

5) Compatible with existing networks:

As WMN is based on 802.11 standards so it should be compatible with all other 802.11 technologies. Hence it should be compatible with mesh as well as other Wi-Fi networks

1.2.5 Comparison of ad hoc networks with WMN

WMN by some means measured as form of ad hoc networks. This is due to the common features which both the networks possess. Like both the networks are wireless butt more refined algorithms are required when ad hoc network techniques are used in WMN. So in spite of saying it as type of ad hoc networks we can say that WMN enhance the capabilities of ad hoc networks.

1) WMN when used as wireless backbone offers high area coverage, robustness and connectivity. Ad hoc networks in contrast to that depended on end users involvement which may not provide reliability.

2) As in WMN mesh routers are equipped with functions of connectivity and routing functionalities so the traffic can be classified in wireless domains but in case of ad hoc network, single channel perform all the functionalities so performance may decrease.

3) Functionality of routing and mobility are provided by end users in ad hoc networks so it become a complex task of routing protocols and network deployment.

Often it is considered that wireless mesh network is same as wireless ad hoc network. It is also supposed that WMN possess such type of nodes which are stationary and can't experience mobility. Actually WMN contains end nodes which can be stationary or have mobility in them. However routers in WMN may work as stationary nodes or they may possess inadequate mobility. Mesh routers contain more resources then that of mesh clients hence they can perform more functionality. So mesh routers perform more typical complex functions as compared to mesh clients. Hence a WMN network differs than that of ad hoc network. In ad hoc network resources are forced on all nodes.

1.2.6 Factors have effect on the efficiency of WMN

Till the time a large number of radio techniques have been developed to increase the capacity and flexibility of wireless networks. Commonly known examples are smart and directional antenna, and MIMO systems etc. In order to get additional control over wireless era further enhancement in radio technologies are introduced. These enhancements include reconfigurable radios and yet usage of software radios.

Scalability is another issue in WMN as multi hop concept came here so the issue of scalability arises. Still a problem exists that existing routing protocols may not possess the efficiency up to that extent which search out trustworthy routing path. Transport protocols may suffer links loss. MAC protocols may incident major reduce in throughput. So when a network becomes wider the issue of reliability can occur frequently, this needs proper solution.

Mesh connectivity is a special issue which brings many advantages in WMN hence it also a critical requirement in protocol design particularly in MAC layer and routing protocols. Topology aware MAC and routing protocols improve the performance of WMN.

Compatibility and inter-operability are also the factors which can influence the efficiency of WMN. The task of incorporation needs such sort of mesh routers which contain the ability to interoperate between heterogeneous wireless networks. It's expected that WMN resolve many shortcomings and improve the performance of ad hoc networks, WLAN, WPAN, and WMAN. Exciting numerous deployments and undergoing rapid progress there.

As basic components which we need for deployment of WMN already exist in the form of ad hoc routing protocols so implementing WMN is not complex issue. Companies also aware about the power of this technology and they recommend products which are based on wireless mesh networking.

1.3 What is Quality of Service (QoS)

Quality of Service (QoS) vast area which describes the overall experience which a user or application got over the network. QoS includes a wide range of protocols, architecture and technologies. It is a mean of providing best service for targeted network traffic over diverse technologies. Such type of diverse technologies includes frame relay, Asynchronous Transfer Mode (ATM), Ethernet and 802.1 networks and IP-routed networks etc. The main motive of QoS is to offer high bandwidth controlled jitter and latency (case sensitive for real time traffic) and packet loss features. Often this happens that if one requirement fulfils other may suffer but QoS also guarantee that while providing efficiency in one factor the remaining factors will not suffer. Basically QoS facilitate to provide better services to some flows. This mechanism can be achieved by increasing or decreasing the priority level of some of the flows. In case if congestion management is the main focus so priority is managed by maintaining queues in various ways. The scheme of overseeing queue used to avoid jam. According to previous schemes high priority traffic is buffered and or lower priority traffic is dropped in some cases. On the other side policing and shaping restrict throughput for some flows while providing high priority to other flows.

1.3.1: Fundamental concepts about QoS

Fundamental architecture for quality of service consist on three type of implementations

- Technique include recognition and staining
- QoS within a single network element
- Policy, administration, and accounting functions

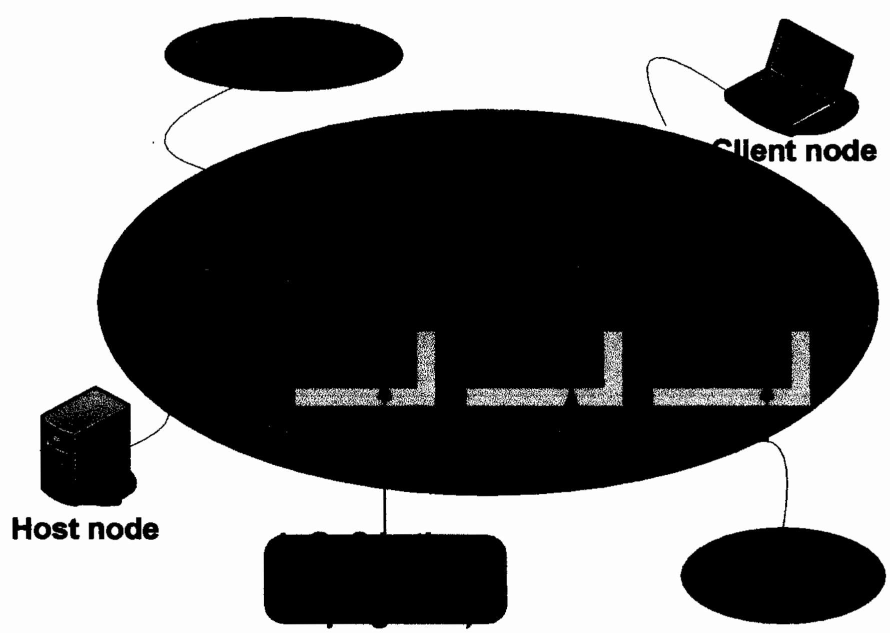


Fig 1.3: Basic Components for QoS Implementation [5]

1.3.1.1 Identification and marking techniques

Such techniques manage QoS from sending node towards the receiving node in particular network. The mechanism of classification and reserving is used for this purpose.

For the purpose of providing different services for different type of traffic, process of identification performs on it. Secondly the packet may not be marked. The classification mechanism based on these two types of processes [5].

Commonly used identification methods include access control lists (ACLs), policy-based committed access rate (CAR) etc.

1.3.1.2 QoS within a single network element

This aspect of QoS is applied over a single element of network like applying queuing mechanism, congestion management, scheduling and traffic shaping tools etc. as the nature of different type of data traffic is bursty so the speed at which data transfer on a link exceeds the rate of arrival of data traffic so in that case what decision the router will perform is task to tackle i.e. will the router buffer all the traffic in single queue and transmit that according to first in first out method? Or will it put traffic in different queues and prefer some of the queues more then others? Such type of questions is handled in congestion control. Tools include priority Queuing, Weighted Fair Queuing and Class-Based Weighted Fair Queuing etc.

The mechanism of queue management uses buffers. Nodes possess buffers which have certain limit to store the data. When this limit exceeds then the packets which come after that limit will be dropped. Some of those packets may belong to high priority level. For this reason there should be some way out that assures even if the buffer is full there is some way to accommodate at least the high priority data. Tool used for this is Weighted Early Random Detect (WRED)

Traffic Shaping and Policing: Arrangement of slight and smooth traffic is handled by the process of shaping. Often it is used to mitigate the problem of overflow. Traffic shaping is an ideal means to speed traffic and to control loss or excess of end nodes. Data traffic which comes after limit exceeds will be temporarily stored by some way and retransmit after some time. Policing is somewhat same like shaping. The main difference between the two is policing normally discard the packets that exceed the configured rate.

1.3.1.3 Policy, management, and accounting functions

QoS policy, management, and accounting functions used to be in charge to govern end-to-end traffic across a network.

1.3.2 QoS parameters

Parameters are used for the measurement of whether the level of service being offered is achieved or not. From the aspect of QoS following parameters are measured.

- Network availability
- Bandwidth
- Delay
- jitter
- loss

Some other parameters also exist which can not be measured but they effect on the performance of QoS. These parameters especially used for traffic management of routers and switches. These are

- Emission priority
- Discard priority

1.3.2.1 Network availability

This has a considerable affect on QoS as for efficient performances of any service it should be easily accessible. If network is occupied yet for a small time period the user or the application both suffers uncomfortable and undesirable performance. Network availability is dependent on many factors which coordinate to build up whole network. These factors include network devices, processor cards, power supplies, switches or hubs, multiple physical connections, backup power sources etc. Operators of a particular network can enhance their network availability by implementing varying level of above mentioned elements.

1.3.2.1 Bandwidth

Bandwidth is considered as second major parameter which affect on the performance of QoS. The mechanism of bandwidth allocation can be divided as

- Vacant bandwidth
- Assured bandwidth

The mechanism of **vacant bandwidth** insists network operators to oversubscribe the bandwidth on their network. In this type of division the users which subscribe the portion of bandwidth may not always get that portion so users may have to compete for the vacant bandwidth. Users can get high level or low level of bandwidth depending on the traffic rate of that network. On the other hand in **assured bandwidth** the users get an assured share of bandwidth. As the bandwidth is assured this service is preferred as compared to vacant bandwidth. The network operators make this thing sure that the subscribers of assured bandwidth will be preferred over those who subscribed for vacant bandwidth.

1.3.2.2 Delay

Delay is the transfer time which an application experience while entering into a network and until leaving that network. Delay is a parameter which can cause serious QoS issues for the application like audio or video traffic. Some applications can tolerate a small amount of delay but when this ratio continuously increases then QoS is compromised.

Delay can be either fixed or variable. Paradigms including fixed delay are:

- Application based delay.
- Delay due to queuing on physical network media.
- If end nodes are far away then broadcast delay occur.

Paradigms including variable delay are:

- Delay which occur when traffic enter in queue within a network.

- Within a network clash other traffic at each node of the network.
- Egress queuing delay for traffic going away from the network.

1.3.2.3 Jitter

Jitter is a means of measurement for the variation in the delay between two successive packets for observed flow of traffic. Jitter has an evident effect on the performance of delay sensitive traffic like audio and video traffic etc. Real time traffic expects the smooth delivery of packets at stable rate with fixed delay between successive packets. With the variation of packet arrival the jitter influence the performance of particular application. If this variation is small it may be acceptable but in case of increment the application may be useless. All kind of networks bring in some sort of jitter due to the variability in delay introduced by each network node as packets are queued at each node. However up to the time jitter is restricted QoS is sustained.

1.3.2.4 Loss

Loss can be defined as failure of data packets due to some problem which can occur on either physical or communication medium. When we talk about physical medium then this loss ratio is relatively low. However if we talk about wireless networks like satellite , mobile or fixed wireless networks then such types of networks have to deal a lot with problem of loss rate. The reason of this can be environmental conditions such as rain, fog and other impediments such as walls, trees, buildings and mountains etc. Due to high data rate packets are also dropped in wireless networks.

It can occur in case of congestion when encountered the node drop packets. TCP (Transmission Control Protocol) provide a solution of this as it resends packets which are loosed. But in case of high congestion ratio of congestion will be high, also retransmission will be high so if congestion continuously increases the QoS may be compromised as a lot of bandwidth used to retransmit the dropped packets. Congestion has direct impact on packet loss ratio so mechanism should be adopt to control congestion. One such type of mechanism is known as Random Early Detection (RED). In RED when a predefined level achieved then packets will be dropped [21].

1.3.2.5 Emission priorities

Emission priorities demonstrate the order how the traffic forwarded to the network when it leaves a network node. High emission priority traffic forwarded before the low emission priority traffic it also demonstrate the latency of a network which occur due to the queuing mechanism.

1.3.2.6 Discard priorities

It is the opposite of emission priority mechanism. It shows the order by which network traffic discarded. The traffic may be discarded due to the reason of congestion. Under situation of congestion the traffic with high discard priority is discarded before discarding the low discard priority traffic.

1.4 Problem Domain

Currently wireless technology enables a lot of multimedia applications which demand seamless real time delivery. Multimedia applications get a major portion of internet traffic and require stringent quality of service requirements. WMN has drawn the attention of researchers due to its low deployment cost, ease of use and reliable data transmission. Besides providing other traditional services it can mitigate the challenges of providing real time services of VoIP, video meeting and video telephone etc.

QoS is a critical factor which influences the performance of data traffic in wireless mesh networks. When we compare WMN with other ad hoc networks we observe that it possess diverse nature of broadband services which require diverse levels of quality of services for data transmission. So in order to achieve this goal in spite of providing end to end data delivery and fairness, the communication protocols must also take into consideration the issues like delay jitter, per node throughput, packet loss ratio etc.

Providing multimedia traffic in wireless mesh network is very complex task which have strict conditions to be considered while delivering such type of traffic. Like other wireless networks, wireless mesh network have the ability to efficiently handle the multimedia traffic, so that we get the same type of performance as in wired network. Providing quality of service in wireless mesh network is most fundamental and complex task which should be handled efficiently. Quality of service in terms of bandwidth utilization, mean delay, packet loss ratio and congestion control are main point which should be tackled efficiently for multimedia traffic within or across the networks.

The traffic shaping techniques are used as an attempt which organizes the network traffic so that the given network assures performance and high bandwidth etc. Traffic shaping takes the charge of traffic classification, queuing discipline, managing congestion and providing quality of service (QoS). Hence it means to control the degree of traffic sent towards the network and the rate by which it will be sent. Reduced packet loss, low latency and less jitter are the key benefits which it will provide in case of high data traffic flow.

Multimedia applications capture a wide of internet traffic in recent years. Most of the multimedia traffic is delay sensitive and need high service quality with no or minimum delay. Providing QoS for real time traffic is a key requirement in wireless mesh networks. End users expect delivery of multiple online service availability on their end devices (which include online video communication, online video gaming and video conferencing etc) very smoothly with minimum or no loss of data.

From chapter 2 we come to know that a variety of traffic shaping techniques have been proposed in literature. The problem to meet the challenging factors in the field of quality of service (QoS) is still a hot issue. So efficiency could be brought by maximizing throughput with no or minimum loss of data packets. Some of the researcher's focal point is separately on these key points. Somchai Lekcharoen et al. [11] provide a means to enhance the quality of service for real time delivery of multimedia traffic but packet loss ratio not discussed. YAN Wei REN et al. [16] concentrates on quality of service for VoIP traffic in wireless mesh networks. The main concentration is to enhance quality of service for voice users over the network. The given framework is not applicable for multimedia traffic. Firat Birlik et al. [14] studied two types of features, mesh topologies and multimedia communication. Centralized resource allocation scheme used here which enforce the central management of resources within the network so deficiency comes in case of central management failure. Maazen Alsabaan et al. [20] use leaky buckets to analyze its effect for enhancing outage probability and the capacity for voice users. The main focus of the paper is only one type of data traffic that is voice users.

Others don't mention the priority classification methods for different classes of data traffic or ignore the best effort traffic while enhancing the QoS for real time traffic [21].

1.5 Proposed Approach

In order to achieve a solution for above stated problem, there should be such a mechanism to provide end users a very smooth traffic delivery without delay and with no or minimum packet loss. In this regard our main target is multimedia traffic so we provide a way of efficient service for multimedia traffic we meet the challenge to increase the throughput and reduce flow of packet loss meanwhile we also take into consideration best effort traffic as well.

Various algorithms are proposed for the traffic shaping technique like token bucket and leaky bucket etc. To meet such challenges of delivering multimedia traffic in wireless mesh network traffic shaping technique with dual bucket proposed which gave highest priority to multimedia traffic then for best effort traffic while maximizing throughput meanwhile with no or minimum packet loss.

In a partially connected mesh network with decentralized management traffic shaping technique will be implemented which will utilize available bandwidth for multimedia traffic with minimum delay meanwhile which provides a mechanism which will reduce packet loss probability. We also take into consideration best effort traffic in our scenario.

1.6 Thesis Outline

In chapter 2 describes the related work of research area. Shortcomings are also mentioned in this chapter which exist in literature study and a brief summary of literature. In chapter 3, Main focused on requirement analysis of the proposed solution and mentions the problem area in detail. Chapter 4 is about the detailed study of proposed scheme. Focus of chapter 5 is on implementation and deployment environment. In Chapter 6 testing and performance evaluation is done. Chapter 7 includes the achievements and improvements of research work.

Chapter 2

Literature Survey

2.1: Introduction

Multimedia applications capture a wide range of internet now a day. So in order to provide better quality of service to the end users the wireless network services should be able to meet up challenges of high data transfer rate, low packet loss and with minimum delay. Current chapter is about the existing literature related to the research topic. Limitations exist in the literature is also the focus of this chapter.

This chapter divided into three parts. Part 1 is about the literature study related to the research topic while part 2 is related to the limitations of the literature and part 3 is conclusion of whole literature study.

2.2 Related Research/Technologies

In this part of the chapter a critical review of existing work done which includes survey in particular field and then it contain the problems encountered in the existing work.

Ian F. Akyildiz et al. [7] and IAN F. AKYILDIZ *et al.* [2] in a survey on wireless mesh networks said that WMN are different from ad hoc networks so they have different QoS requirements. For source to destination efficient data transmission per node throughput, typical time of delay and ratio by which packets loose should be focused by protocols of transmission. In this survey the author argues that for real time delivery solutions of ad hoc networks is not applicable in WMN. So while considering characteristics of WMN exclusively new protocols should be developed. In this survey it was mentioned that although some of the protocols used in ad hoc networks may be implemented in WMN but for providing end to end delivery of data in WMN specific communication mechanisms needed for quality assurance.

Yuan Sun et al. [8] performs tentative reading on efficiency of real time traffic in WMNs. They estimate overall efficiency of real time traffic over multilevel hop wireless network. Specifically they evaluate performance of video and voice data. UDP video and voice stream recorded with RTP and transmitted to destination.

RTS/CTS standard use for large packet sizes. Matrix evaluates the performance of packet loss rate, packet latency, packet jitter. For normal traffic less than 1% loss of video data acceptable so resilient coding scheme used to tolerate high loss. RTS/CTS are used to overcome hidden terminals problem. For larger packet it is beneficial for collision avoidance but not provide sufficient performance for packet loss or latency so it is suggested not to be used for multimedia traffic. When traffic is bursty auto rate adoption is not efficient. Moreover they summarize in their results that solution still needed to reduce the variations in the multimedia traffic delivery.

Luís Felipe M. de Moraes et al. [9] proposed a new QoS architecture against 802.16 standards. They used traffic conditioner which is basically an idea of fair maker which introduces the traffic classification methods and priority based packet scheduling mechanism. This is an enhancement in 802.16 standards by including QoS functionalities. The author focus on channel utilization and assigned priorities to different stations but the mechanism adopted for assigning priorities and which type of data will get priority are not mentioned here also the any mechanism against packet loss is not focused.

Wang Jian-ming et al. [10] focus on issue of QoS in wireless LAN. For this purpose two main algorithms used here queue management algorithm and polling list management. QoS is more complex task in wireless LAN as compared to wired LAN. DCF, PCF, PQ and black burst scheme are four possible VoWLAN schemes which exist. Some of researchers focused on QoS but still some areas remain undefined. Polling scheme defined in 802.11 standard doesn't define method of management of polling list also not have good performance. Hence round robin's slight modification is used. In queue, a comparison of deficit counter (Dci) to next packet is made. If it is greater than the next packet then that will be send and same process followed. If Dci is last in queue then its length checked if it's greater than defined range then control passed to next station. In policy list management a list maintained this made upon the capability information, association and reassociation response etc of receiving stations. Here a policy list proposed which allocate the free bandwidth to those stations which are active at that time so performance increases, while simulation assumption made for voice traffic that it is modeled as talk state and silent state. For video traffic constant bit rate frames are used. Asynchronous traffic may result in the transmission of data in contention period so delay may occur. During contention free period stations are polled according policy list for video and voice data. For downlink deficit RR algorithm and for uplink remote deficit RR algorithm implemented. The result of this scheme is better than original RR algorithm. It's demonstrated from simulation results that transmission and throughput increases while mean delay decreases. The video traffic model is constant bit rate. Further, more variable bit rate video traffic model should design to make efficient transmission of video data.

Somchai Lekcharoen et al. [11] describe a traffic shaping scheme for wireless networks. This scheme primarily fulfills the congestion problem by using leaky bucket. In this paper the data traffic is of fixed type i.e. the data traffic is either busty or silent. Moreover they didn't discuss about the different traffic types and which one get priority like delay sensitive traffic. Here if the buffer of the receiving node is full a message from the receiving node to sending node will be triggered to make its transmission half. Message may be lost or not reach at destination due to heavy load or packet loss due to congestion. So a mechanism should provide which efficiently handle the receiving traffic in such a way that minimum packet loss occur in case of heavy load.

Samrat Ganguly et al. [12] in his paper concentrates on quality of service for VoIP traffic in wireless mesh networks. In this article the author considered quality of service for voice users which have mobility with them. The main focus is to improve quality of service for voice users on the network. In a mobile environment this framework is applicable for voice users only.

Spyros Xergias et al. [13] suggested two types of features here i.e. mesh topologies and multimedia communication. The task is how 802.16 mesh networks provide QoS in distributed multimedia environment. E-FRTS (enhanced frame registry tree scheduler) used here which provide QoS resource allocation and reduce time frame processing requirements in start. Primary focus of the scheduler is to describe the efficiency while handling multimedia traffic in IEEE 802.16 mesh network.

The ongoing discussion describes only stationary subscribers in which E-FRTS scheduler discusses centralized aspect of 802.16. In advance it prepares every time frame in order to avoid the complex processing in short time period between two frames. Moreover the communication is about point to multipoint traffic load. Centralized Resource Allocation (CRA) scheme used here which enforce the central management of resources within the network so deficiency comes in case of central management failure.

Firat Birlik et al. [14] implemented wireless mesh implementation and a video prioritization algorithm which provide high quality video traffic meanwhile other mesh nodes in that cloud not suffer from bandwidth difficulties. Priority scheme is to give high priority to video traffic while H.264 latest video encoding standard is used which provide prioritization to different packets according to their priority level with less utilization of bandwidth. H.264 encoder consists of Video Coding Layer (VCL). It has the responsibility to encode video data. Network Abstraction Layer (NAL) is responsible for packetization for transformation across the network. An expansion of NAL is Classification, which generates packets with different priorities. Here the data traffic will get a fair share of bandwidth while providing a high priority to video traffic. According to the given scheme from source to destination each sending node must know the priority level of the packets this goal can be achieved by including priority level in the video packet by the source node.

Frank Yong Li et al. [15] proposed a framework for traffic policing and traffic shaping is presented for wireless networks. Traffic conditioner is used for the QoS in the universal mobile telecommunication systems. Traffic conditioner is used within each UE here token bucket algorithm is used for traffic conditioning while traffic policing strategy deployed at each RNC. A token bucket shaper confirms either packets are according to the parameters or if the packets size larger than the bucket size they will be seen as non- compliant. Non-compliant will be acknowledged if there is no congestion. In case load increased then non-compliant packets will be dropped first. Simulation results show that for both classes discarded probability is lower than without traffic shaping. With the increase in load this difference also increased. Paper focuses on two types of traffic classes' video and www. Moreover mobility is not considered in this framework. Also efficient only in lightweight traffic load as it can't provide help with packet discarding probability so they suggest not to use traffic shaping in case of heavy traffic load.

YAN Wei REN Maosheng Tong Zhao LI Xiaoming et al. [16] considered in this paper infrastructure wireless mesh network in order to provide QoS while providing bandwidth utilization for real time traffic. The scheme named as SRAM proposed to meet the challenges of admission control for load balancing at judge router, a rate control module for best effort traffic, estimation of available bandwidth for calculating rate control and admission control and reserving bandwidth for mobile users. This paper mainly focuses on IWMN. The results of SRAM implemented on NS2. It can support real time applications for moving users. This scheme ensures that accepted traffic will never effect on coming real time traffic. However up to what extent bandwidth should be reserved is still a question to be solved further.

Somchai Lekcharoen et al. [17] claim that telecommunication traffic suffers from fluctuation. Traditional schemes are insufficient to provide high quality of service requirements so they propose the artificial intelligence techniques mainly in fuzzy system suggested as a solution. From the simulation results they compare and show that the fuzzy system techniques when compared with the conventional techniques gave high throughput and dropped frame rate also it improves quality of service when the source have high data rate. It was observed that all fuzzy control schemes make all the frames wait in queue longer than the other conventional schemes. With fixed type of traffic the performance of fuzzy control schemes is evaluated.

S. Radhakrishnan et al. [18] gives an idea of flexible traffic shaper to avoid traffic congestion for high speed networks. He also makes comparison of that with leaky bucket. For purpose of traffic shaping at source end this scheme named as SRTS (Shift Register Traffic Shaper) is combined with sliding window. More than one window combinely used in this scheme overcome the issue of burstiness. The basic idea is taken from leaky bucket but with some modification. The discussion mainly focus on three of the five multimedia sources i.e. data, voice and video. The main focus was to provide high performance for short term bursty traffic and second is to reduce access delays in short term burstiness. For this purpose window based shaping scheme with SRTS used to achieve the goals. By simulation comparison of two windows showed that the SRTS performed better then the leaky bucket policer. However for the efficient results it should work with the source and network switched schemes. Emphasis of the study is only on the traffic shaping at source end.

Amir Seyfi et al. [19] the author used suggested leaky buckets to analyze its effect for enhancing outage probability and the capacity for voice users. The main focus of the paper is upon only one type of data traffic that is voice users. The work revolves around two contradictions. First is that variations lessons when traffic is smooth and second is that it increases user's capacity. So main concentration of paper is for voice user's capacity improved and for data users delay deployment made. After comparing results of leaky bucket compared with simple traffic smoothing technique it observed that mean and variance efficiently managed. Although the delay is same as without leaky bucket but the capacity for voice users improved 10% with leaky bucket.

Maazen Alsabaan, et al. [20] provides an efficient mean for QoS from multimedia traffic point of view. In this paper they not only consider the priority level for the delay sensitive traffic but also focus on each node priority classification for different types of applications of data traffic. They gave an idea of priority schemes for MAC layer in WMN which is decentralized. They also consider best effort traffic in their proposed system. Hence it overcome some of the flows exist in previous research but still some points need to refine. The proposed system model considering assumption fixed network topology in which all nodes are stationary and have the information about all the nodes lie in that network.

Iffat Ahmed [21] proposed a general framework for wireless networks which is based on two types of queuing disciplines. The main target of the researcher is to enhance the quality of service for multimedia traffic applications in wireless networks. To efficiently regulate the traffic she integrates two types of queuing disciplines i.e. Priority Queue and RIO (RED with In/Out). First one is used to make priority classification among different types of traffic which is going to transmit across the network, the second one is used to mark or identify the low and high priority traffic. Simulation results show that it provides stable bandwidth with no or minimum loss for to multimedia traffic. In case of congestion or heavy load the proposed solution is permitted to drop low priority or best effort traffic.

2.3: Limitations

From the literature survey it is clear that a variety of traffic shaping techniques have been proposed. But unfortunately most of them are insufficient to mitigate required challenges in terms of maximizing throughput with no or minimum loss of data packets and with minimum delay for real time traffic. Somchai Lekcharoen et al. [17] provide a mechanism to enhance the quality of service real time delivery of multimedia traffic but packet loss ratio not discussed while YAN Wei REN et al. [16] concentrates on VoIP traffic in terms of quality of service for WMN. The main focus of study is to improve quality of service for voice users over the network. The given framework is not applicable for multimedia traffic. Firat Birlik et al. [14] studied two types of features, mesh topologies and multimedia communication. The ongoing discussion describes only stationary subscribers. Centralized resource allocation scheme used here which enforce the central management of resources within the network so deficiency comes in case of central management failure. Maazen Alsabaan et al. [20] used leaky buckets to analyze its effect for enhancing outage probability and the capacity for voice users. The main focus of the paper is only one type of data traffic that is voice users.

2.4 Summary

Multimedia applications capture a wide of internet traffic in recent years. Most of the multimedia traffic is delay sensitive and need high service quality with no or minimum delay. Providing QoS for real time traffic is a key requirement in wireless mesh networks. End users expect availability of multiple online services on their end devices (which include online video communication, online video gaming and video conferencing etc) very smoothly with no or minimum loss of data.

Chapter 3

Requirement Analysis

3.1: Introduction

Recently it became a general trend that people choose such type of applications which can be used as multipurpose applications. Along with this they prefer the services which high bandwidth and gave ease of access to the Internet. For the purpose of conversion from mobile ad hoc network into a commodity there must be some way to build more realistic network. It is sort of network in which multi hop ad hoc networks not only take the form of self configured networks but also regarded as flexible and an extendable low cost wired communications networks. Here comes as a new class concept in networks from this view: known as wireless mesh network (WMN).

Now a day's mobility is a very common demand which is required in networks. Due to this requirement of QoS in such networks also rise. Providing multimedia services in wireless networks is still a complex job. This complexity is because of different type of QoS requirements. It may also because of the dynamic and static natures of wireless networks and may be because some multimedia applications often claim high bandwidth, flow synchronization and contain sensitive data. In order to meet guaranteed performance requirement for different network applications MANET can be used for multiple QoS requests of applications [22].

In this chapter I will demonstrate the requirement analysis of my research work. Section 3.2 will demonstrate the application scenario. I will talk about the different problem scenarios in section 3.3 and focus of my research will be described in section 3.4. In the last section 3.5 of chapter I will concludes the summary of whole chapter.

3.2: Application scenarios

Several applications play a vital role in the research and development of WMN. It demonstrates that remaining networks like cellular networks, ad hoc networks, wireless sensor networks etc cannot maintain such applications directly. Some of these applications summarized below.

3.2.1: Broad band home networks

Although multiple access point is expensive as Ethernet wiring is used. Mesh routers take the place of access points in WMN. More robust and flexible to network faults and link failure.

3.2.2: Community and neighborhood networking

Usually in community the cable or DSL is used for network access. This thing has some drawbacks.

(i) Reduce network resource utilization.

(ii) Expensive and setup cost.

(iii) One single path for one home to access to internet or neighbors WMN's enables much application such as distributed file storage, distributed file access and video streaming.

3.2.3: Enterprise networking

Usually wired Ethernet is used to connect offices which exist on more than one building. It increase the network cost. These types of networks are not robust to link failure. Here access points are replaced by mesh routers which reduced Ethernet wiring.

3.2.4: Metropolitan area networks

In WMN's rate of data transmission are much longer than that of cellular networks.

3.2.5: Transportation systems

Mesh network technology is so common today that it extends even to buses, ferries and trains. It also utilized for passenger information services, mobile management of in-vehicle security video etc can be supported.

3.2.6: structured computerization

Standard wired network are used to build up electrical devices for users such as light, elevator, air conditioner. Such types of devices are usually expensive, complex in deployment and maintenance. In WMN's mesh routers take the place of access points due to which its cost reduced significantly. Mesh routers are also simpler in connectivity.

3.2.7: Health and medical system

Patient data transmitted to one room contain images and various predictably monitoring functions this type of information produce large volume of data. However, these issues do not exist in WMN's.

3.2.8: Security surveillance system

WMN's are much more viable solution for connecting the security device than wired networks.

3.2.9: Emergency response

User connecting to WMN's inform about the emergency response using Laptop or PDA'. WMN's are the superset of ad-hoc networks.

3.3: Problem Scenarios

In order to plan a network its deployment and operation, there are some factors that influence a network's performance which should be considered seriously. For WMN, detail of each scenario discussed below.

3.3.1: Radio Technique

Directional and smart antennas and MIMO (Multiple inputs and multiple outputs) systems are typical examples of radio technique. Many advanced technologies like reconfigurable radio, frequency agile/ cognitive radio and software radio are still in their infancy. Above stated technologies have the ability to dynamically control the radio waves. It is needed at higher layer protocols level to design such type of radio techniques.

3.3.2: Scalability

WMN's uses multi-ho communication that is suffering from scalability issues. Whenever there is an increment in range of network performance automatically decreases. As WMN's possess ad-hoc nature so it utilizes centralized TDMA and CDMA technique. Such types of mechanisms are complex from implementation point of view and due to time synchronization. Time synchronization is relatively complex to attain in global network especially in distributed multi-hop network. For multi-hop networks CSMA/CA scheme is used. CSMA/CA along with TDMA or CDMA is also a exigent research issue.

Protocols which may have number of nodes or number of hopes existing in the network can't mitigate the scalability requirement [22]. Such type of approaches either uses several channels/ radios on one node or come forward with wireless radios having elevated rate of data diffusion. Unfortunately this issue of scalability didn't actually improved by such schemes. So in WMN scalability issue still needs concentration. So it is necessary to build up new MAC, routing, and transport protocols.

3.3.3: Mesh connectivity

MAC protocol and routing protocol is needed to redesign for achieving the advantage of WMN'S.

3.3.4: Broadband and QoS

Ad hoc networks and WMNs possess slight differences. WMN have to deal with various QoS issues in order to provide broad band services. For such purpose communication protocols should focus on issues like end to end transmission delay, performance and throughput and packet loss ratio.

Delay in traffic from sending to receiving node, performance matrices and ratio by which packets loose, these are the points which should be carefully considered.

From the aspect of QoS following parameters are measured. These parameters are used to measure whether the level of service being offered is achieved or not. These parameters include

- Network availability
- Bandwidth
- Delay
- jitter
- loss

❖ Network availability

Network availability has a considerable affect on QoS. If the network is unavailable even for a short time period the user or the application both suffers uncomfortable and undesirable performance. Network availability is dependent on many factors which include network devices, processor cards, power supplies, switches or hubs, multiple physical connections, backup power sources etc. Operators of a particular network can enhance there network availability by implementing varying level of above mentioned elements.

❖ Bandwidth

Bandwidth is considered as second major parameter which affect on the performance of QoS. This allocation mechanism split into

- Vacant bandwidth
- Assured bandwidth

The mechanism of vacant **bandwidth** insists network operators to oversubscribe the bandwidth on their network. In this type of division the users which subscribe the portion of bandwidth may not always get that portion so users may have to compete for the vacant bandwidth. In **assured bandwidth** the users get an assured share of bandwidth. As the bandwidth is assured this service is preferred as compared to vacant bandwidth. The network operators make this thing sure that the subscribers of assured bandwidth will be preferred over those who subscribed for vacant bandwidth.

❖ Delay

Delay is the transfer time which an application experience while entering into a network and until leaving that network. For sensitive traffic like audio or video traffic delay is considered as a serious issue. Although up to some extent some application bear delay but if this ratio increases continuously then QoS compromised. Paradigms including variable delay are:

- Delay which occur when traffic enter in queue within a network.
- Within a network clash other traffic at each node of the network.
- Egress queuing delay for traffic going away from the network.

❖ Jitter

Jitter is a means of measurement for the variation in the delay between two successive packets for observed flow of traffic. Jitter has an evident effect on the performance of delay sensitive traffic like audio and video traffic etc. For the sensitive traffic it is assumed that data packets will be delivered smoothly at a constant rate. If this constant rate varies then arrival of data packets effected which further affects the performance of specific application. If this variation is small it may be acceptable but in case of increment the application may be useless. In almost all networks some sort of jitter occurs. This is due to the variable delay introduced by each network node because packets queued at every node of the network. However if we restrict jitter QoS will remain persistent.

❖ Loss

Loss can be defined as failure of data packets due to some problem which can occur on either physical or communication medium. When we talk about physical medium then this loss ratio is relatively low. However if we talk about wireless networks like satellite , mobile or fixed wireless networks then such types of networks have to deal a lot with problem of loss rate. The reason of this can be environmental conditions such as rain, fog and other impediments such as walls, trees, buildings and mountains etc. Due to high data rate packets are also dropped in wireless networks.

It can occur in case of congestion when encountered the node drop packets. TCP (Transmission Control Protocol) provide a solution of this as it resends packets which are loosed. But in case of high congestion ratio of congestion will be high, also retransmission will be high so if congestion continuously increases the QoS may be compromised as a lot of bandwidth used to retransmit the dropped packets. Congestion has direct effect on packet loss ration so mechanism should be adopted to control congestion. One such type of mechanism is known as Random Early Detection (RED). In RED when a predefined level achieved then packets will be dropped.

3.3.5: Compatibility and interoperability

WMN's needs to be backward compatible with mesh clients. This one is the preferred feature which WMN must support otherwise the efficiency and the goal of WMN deployment will be compromised. For the purpose of compatibility and interoperability in WMN mesh router should have the capability to interoperate between diverse networks.

3.3.6: Security

WMN's consists on scattered system architecture. Hence it possesses no unique authority which distributes a public key. Security techniques still in their infancy and needs further concentration [22].

3.3.7: Ease of use

Network management tool needed to be developed efficiently together with the protocol stack.

3.3: Focus of Research

Wireless Mesh Network (WMN) currently capture the attentions of majority of users because of attractive features which it offers which includes cheap cost, ease of deployment, increased coverage etc. WMN is different from other network services. It make possible to deliver real-time services such as Voice over IP (VoIP), video telephone and video meeting. It is also considered as an aggressive substitute of cellular network.

Multimedia technologies capture a wide range of internet traffic now a day. Providing enough quality is important for multimedia, real-time services in wireless communication systems [23]. Providing quality of service for real time applications in wireless mesh network is still a question needs to be solved further. As described above there are certain parameters which exist in quality of service in terms of WMN. The focus of my research work revolves around the following parameters among all.

- **Increase Throughput**
- **Minimize Packet loss ratio**
- **Minimize Delay in Multimedia Traffic**

3.4: Summary

In WMN, there are a number of challenges which have to face in the deployment of real time services. Real-time applications like audio video data also exist along with best effort application. So in case of shared medium of transmission delay sensitive traffic which is real time traffic has to battle with delay-insensitive "best-effort" data traffic in case of using 802.11 DCF MAC. Even though 802.11e MAC protocol has been developed to enhance the effectiveness of 802.11 DCF MAC protocol for WLAN. But in case of multi-hop wireless transmission environment this is not enough to provide efficient service intolerance for real-time applications [16].

In this chapter of requirement analysis I have discussed existing problems in WMN. Application scenarios and then the problem scenarios are discussed. Hence main focus of my research work is to minimize packet loss ratio and to maximize the throughput in terms of multimedia applications.

Chapter 4

System Design

4.1: Introduction

System design phase concentrates on the detailed study of whole research work in terms of its design. It gives a sketch before its implementation that how architecture will be designed against the requirements which were focused in requirement analysis chapter and also that how it will work. Generally, in system design a scenario shown that how the system which is designed will look like after its finalization and that will finally become architecture when that sketch is implemented in pre-defined scenario/environment.

The basic design requirements of this research work will be discussed in section 4.2. Section 4.3 encloses the reference architecture and proposed detail solution of the focused problem will be discussed in chapter 4.4. A brief summary of the system design phase will be given in section 4.5.

4.2: Design Requirements

The researchers are still finding ways to develop such mechanisms which can control traffic and manage that in order to provide QoS control. Such types of objectives are really very complex because of the diverse nature of data traffic and the complexity of internet. In spite of all this it is very hard to manage heterogeneous traffic with single architecture which have the capability to be effective and at the same time an easy one to deploy traffic control mechanisms. The issues attached with traffic modeling should be encouraged as internet traffic dynamically changes by nature [25].

In order to provide solution for proposed architecture we need a set of different kinds of data traffic. Incoming traffic possess video, audio and text data which will entered into the network. A classifier will be used which will classify the incoming data traffic into different queues. This function of classification will be performed to enable priority mechanism for different classes of data traffic. In proposed architecture highest priority will be assigned to the video and audio traffic which is recognized by classifier as "multimedia traffic". After that best effort traffic will be treated, this will be recognized by the classifier as "text traffic."

Bucket concept will used to reduce packet loss ratio for multimedia traffic. In simple environment it works as it is but in case of heavy traffic entry it will be modified slightly. In such an environment of heavy traffic packets from primary bucket will be buffered in the additional bucket instead of dropping them so that the goal of minimizing packet loss ratio we can be achieved.

4.3 Reference Architecture

A flourishing network should have the capability to support different types of requests. Every application may generate different request which needs different type of QoS. In case of real time applications delay should not be too long and in case of non real time applications packet loss ratio should be considered [25].

For the purpose of managing different types of data traffic we have to maintain classes of incoming traffic. To accomplish such a task we use priority mechanism in which highest priority will be given to the multimedia traffic after that text traffic will be served. We have assigned multilevel priorities to these classes of data traffic hence to achieve a minimized packet loss ratio and less delay for multimedia traffic. For proposed solution we will use additional bucket concept which will be used in case of congestion i.e. when traffic load increases then best effort traffic will be queued in the additional bucket while the real time traffic will be queued in the primary bucket and after the congestion reduces the traffic from additional bucket will move towards the primary bucket.

The architecture of proposed solution is as given below.

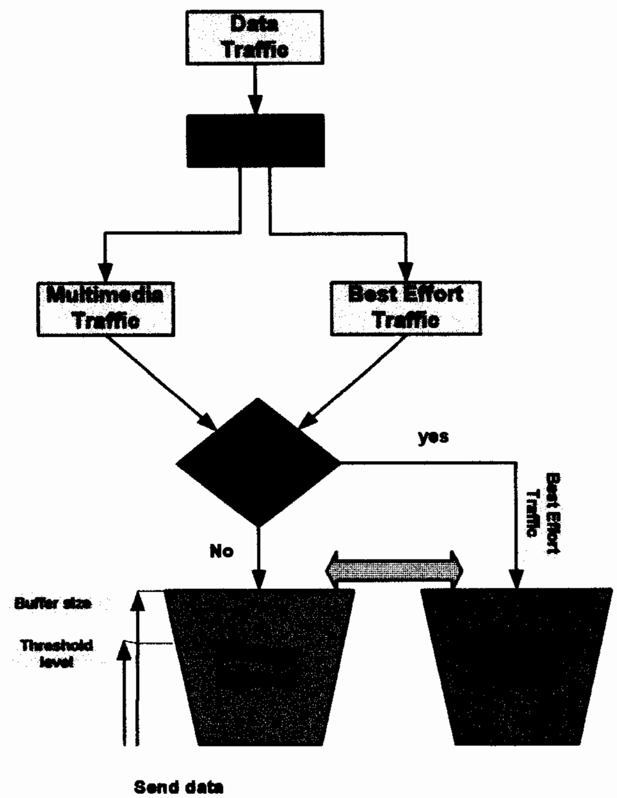


Fig 4.1: Proposed Architecture for Multimedia Traffic Shaping in WMN

Reference architecture of the given solution is subdivided into following sections.

- **Data traffic**
- **Classifier**
- **Congestion check mechanism**
- **Threshold level**
- **Primary bucket**
- **Additional bucket**

4.3.1 Data traffic

In this phase data traffic will be generated which contains multimedia as well as best effort traffic. The traffic will be generated randomly. Indiscriminate number of messages will be generated and passed to the classifier.

4.3.2: Classifier

This is the second phase through which traffic will be passed. In this phase we will classify the randomly generated traffic in different types i.e. either multimedia traffic which holds both audio and video traffic or best effort traffic which is text traffic. According to their type we will assign different priority levels. The criteria of classification of data traffic will be that multimedia traffic will get priority over best effort traffic. The functionality of classifier is maintained on each node level.

4.3.3: Congestion checking mechanism

In this phase a mechanism is implemented which will check the load of coming traffic over a node. This phase basically covers two tasks. It firstly checks the congestion either it exists or not.

- If congestion exists a pre-alarm will be generated for the particular node that chances of heavy traffic load may occur on the underlying node.
- When congestion becomes false the classified best effort traffic will be moved from additional bucket towards the primary bucket in order to pass it towards the destination node. It will show that primary bucket is capable to pass the best effort traffic so the best effort traffic stored in additional bucket will move from the additional bucket towards the primary bucket.

4.3.4: Threshold level

In order to follow the process by which best effort traffic will be passed to additional bucket instead of passing towards the primary bucket, there should be some mechanism which demonstrates that the buffer size is almost full and the incoming packets must move towards the additional bucket. For this purpose threshold level will be set which will perform the following function.

- It will check the primary bucket threshold level and if it is achieved classified best effort traffic forwarded towards the additional bucket.

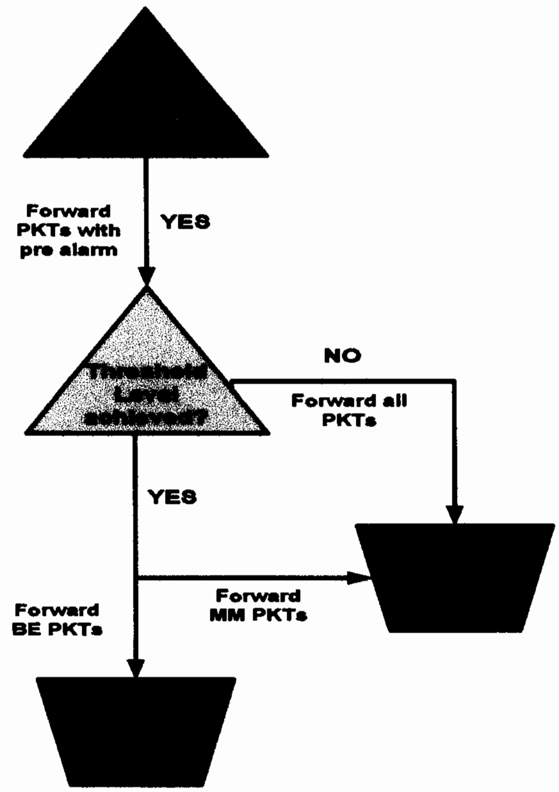


Fig 4.2: Mechanism for Threshold and Congestion check

4.3.5: Primary bucket

The work of primary bucket is to smoothly pass away the data traffic towards the network. When the traffic comes into the primary bucket it will pass it towards the next node in the network. Here multimedia packets will be passed before the best effort traffic due to delay constraints.

4.3.6: Additional bucket

If the situation of congestion and threshold level both becomes yes in case of heavy traffic load then classified best effort traffic will be passed towards the additional bucket. The purpose of using additional bucket is to minimize packet loss ratio. Normally in primary bucket case when traffic exceeds from the buffer size it will start dropping packets which decreases the efficiency as well as QoS compromised. Hence in our architecture we use additional bucket concept which will store the classified best effort packets when threshold level achieved.

4.4: Methodology / Algorithm

To achieve some goal certain criteria must be followed which leads towards the solution of problem. For the solution of our proposed architecture we will do simulation in order to achieve the results. The environment we will use for simulation is OMNeT++.

4.5: Summary

In this chapter we have proposed a traffic shaping technique for the wireless mesh networks. The proposed technique deals with the most challenging features of QoS i.e. minimizing packet loss ratio for all type of data traffic and delay for multimedia traffic hence to improve the throughput for multimedia applications. To achieve this goal we propose additional bucket concept which will store packets in case of heavy traffic so that packet loss ratio for all type of data traffic and delay for multimedia traffic could be minimized.

Chapter 5

Implementation

5.1: Introduction

In the implementation phase we implement the proposed solution in order to examine whether the corresponding results meet the criteria which was established as the final outcome under some terms and conditions. Environment in which we deploy our research work is foremost important thing which should be able to deploy work from all the aspects.

This chapter will focus on the environment which is used to implement the research work in order to achieve the results, flow charts which show the flow of our algorithm and last phase contain summary of whole chapter.

5.2 Deployment/Environment

Environment in which we deploy the research work should be capable to model all the work. For the deployment of this research work a network simulator used named as OMNeT++. It contains discrete event simulation environment. OMNeT++ is used in a number of fields i.e. queuing network simulation, wireless ad hoc network simulation, optical switch and storage area network simulations [26].

5.2.1: OMNeT++

OMNeT++ is based on C++. It is a discrete event simulation environment. Its model basically contains nested modules hierarchically which have not ending limit as for as its depth is concerned. The simulator possesses an easy and friendly environment due to its graphical user interface. OMNeT_++ used for many purposes of simulation. Most commonly it is used in the fields of network traffic modeling and validating hardware architecture etc [26] [27].

OMNeT++ is an easy user interface simulator which helps the initial users a user friendly environment. It helps to debug, demonstrate and batch execution etc. transparent interaction with inside processes. So that users run the interface and make interfere by doing changes inside the modules. Due to its ease of access it can be easily demonstrated by users that how they simulated there model.

5.2.1.1: modeling concept

OMNeT++ is an efficient tool which can be used to demonstrate the organization of architecture. It basically contains following features.

- Step by step arrangement of modules
- Messages are used as source of interaction between two modules
- Parameter assignment is easy
- Consist on self demonstrated language

5.2.1.2: Programming the algorithms

Two types of modules exist in OMNeT++ i.e. simple and compound modules. Simple modules possess algorithms as c++ functions. It provides full programming support. A simulation class library also maintained here. The user can choose relevant class from library and can use the concept in their own.

Simulation objects are also in the form of c++ classes. They have the ability to work together in order to create a dominant simulation.

5.2.1.3: Using OMNeT++

In this phase overall network buildup, mechanism and the procedure described that how to run that network with the OMNeT++.

5.2.1.3.1: Building and running simulations

This phase provide the actual interaction with the OMNeT++. Model of OMNeT++ basically consist of following parts.

- **NED topology description:** it consist of complete organization of model with defined are set parameters

- **Message definitions:** the kind of a message that it is of what type for example multimedia message or text message etc also data fields are added to them.

  The simulation system offers the given mechanism.

  - **Simulation kernel:** It possesses code which maintains the simulation and simulation class library
  - **User interfaces:** OMNeT++ provides user friendly environment. Here we can make changes in front end and can change the simulation execution.

5.2.1.4: Simulation and Execution along with the output

OMNeT++ posses the ability that here executable simulation can also be run on some else machine which may not possess model files which are being processed. In the very first phase of program execution configuration files which are also called omnetpp.ini will be read. Data files are maintained for results. These data files possess simulation output vector files, output scalar files, and possibly the result files of consumer.

A graphical user interface tool named as Plove exist in OMNeT++ which provide a look on output vector files it can also help to plot its contents. Nobody can process the output files alone with OMNeT++. The format of output files can be readable into math packages like Matlab or bring into spreadsheets like excel etc.

5.3: Flow Chart

A flow chart is a step by step sequential description of any given problem. We use flow charts to analyze and document the sequence of overall process by which we will perform our research work.

According to the proposed solution our architecture broadly divided into four phases. In the first phase we use a classifier which divides the incoming traffic into two type's i.e. multimedia traffic and best effort traffic.

In our case we will give priority to the multimedia traffic and our aim is to minimize packet loss ratio and delay in order to maximize overall throughput.

In the second phase after the classification we will check the congestion situation that either it exists or not. If it exists then a pre alarm will be triggered as a caution for the particular node. This step didn't change the direction of data flow. Its purpose is to make the node aware about heavy load which may be occurring on that node.

Third phase will occur when threshold level meets. In this situation we will move classified best effort traffic towards the additional bucket and those packets will remain in additional bucket until the congestion situation becomes normal.

In the fourth phase when congestion becomes normal, packets in the additional bucket will move to the primary bucket and send towards the next node in order to reach on destination node.

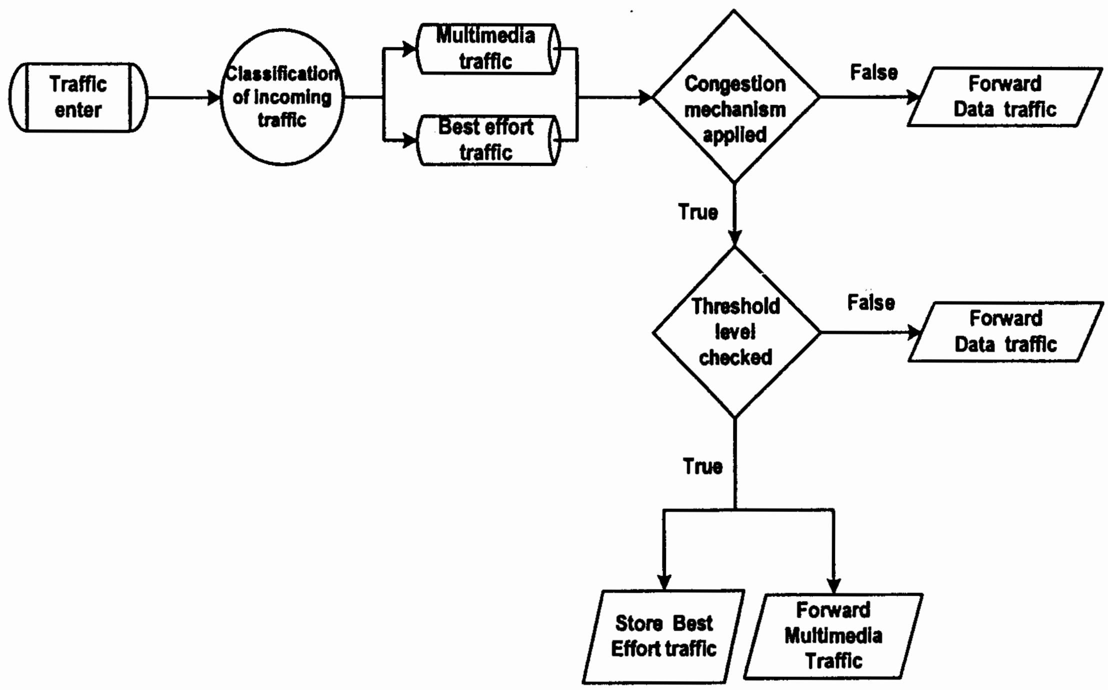


Fig 5.1: Complete Flow Chart of the Proposed Architecture

The above flow chart describes the process which will be followed to organize the incoming traffic and how to forward that traffic. The decision that either traffic forward or it will be queued depends upon the load of traffic on that particular time in which congestion checked. On the basis of congestion and threshold level situation further two types of traffic handling decisions will be taken. In the first case

(Fig#5.2) when congestion occurs and threshold not exist, we will move all data traffic towards the next node. In the later case (Fig# 5.3) when congestion occurs and threshold level achieved, in this case we will queue up best effort traffic and it will wait until the congestion situation becomes false after heavy traffic load. After that when congestion ends stored traffic from additional bucket will be moved towards the primary bucket (Fig#5.4).

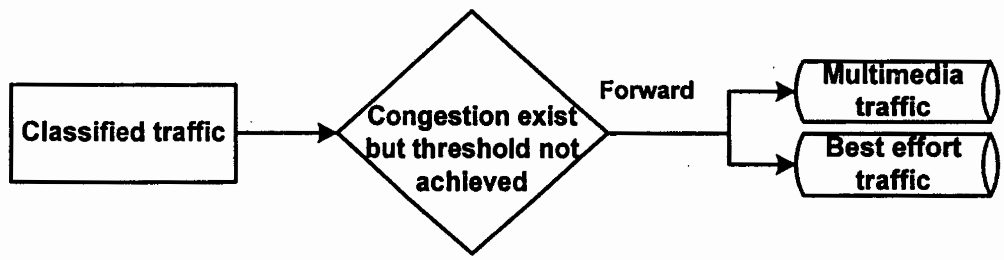


Fig 5.2: In Case Congestion occur but Threshold not Achieved

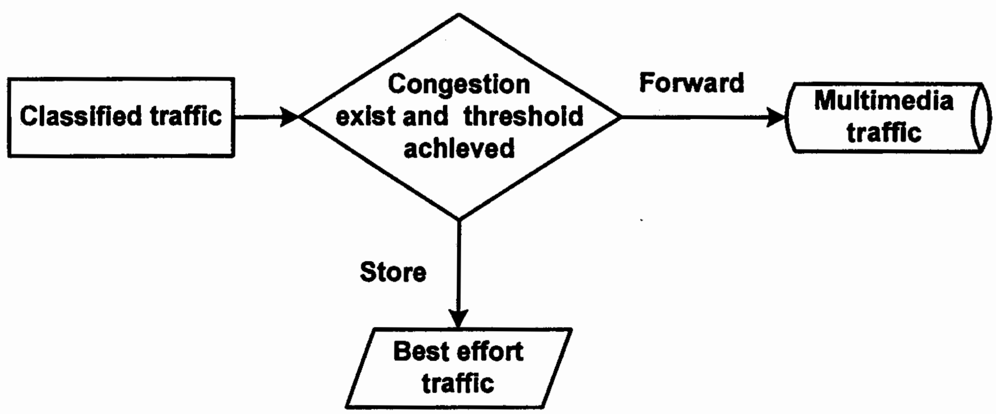


Fig 5.3: In Case of Congestion occurs and Threshold level Reaches

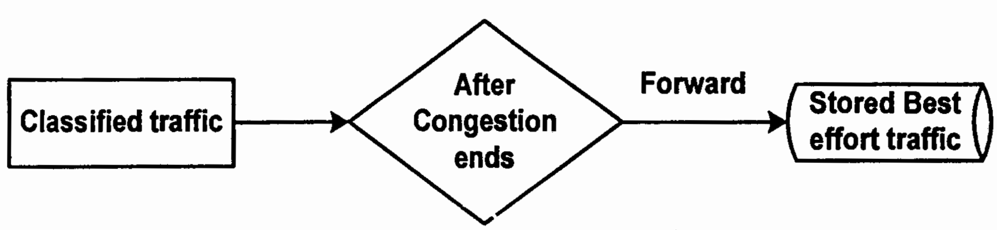


Fig 5.4: After Congestion ends

5.4 Pseudo code

This phase will note down the pseudo code of proposed traffic shaping technique according to the flowchart given above. The pseudo code will give the detailed report for the execution of the algorithm in order to meet the desired criteria.

Abbreviations:

Wireless mesh network → WMN

Traffic shaping → TS

Data traffic → DT

Classifier → CLF

Multimedia traffic→MMT

Best effort traffic →BET

Congestion →CON

Primary bucket→PB

Additional bucket→ ADD B

Buffer size→BS

Threshold→THLD

Pseudo code:

DT enters into the WMN

CLF captures the DT

CLF classify DT into two types:

- MMT
- BET

Check CON mechanism

If no CON occurs:

Then Move all MMT immediately towards the PB

Forward all MMT before BET

Send BET

End if

If CON occurs & THLD not achieved:

Generate a pre-alarm for current node

Move MMT immediately towards the PB

Send all BET after MMT pass away

Move all DP towards the PB until THLD level reaches

End if

Else If

CON exists & PB reaches THLD level:

Pass all MMT immediately towards the PB

Move all BET towards the ADD B

Move all BET towards the ADDB until the CON situation becomes NO

End if

After CON situation ends:

Pass all MMT immediately towards the PB

Move stored BET from ADDB towards the PB

End if

....

5.5 Summary

This chapter mainly focused on the deployment environment of simulated research work. Then it describes the sequence of the algorithm implemented in the form of flow charts. After that the working of the algorithm is described in the form of pseudo code in which the step by step execution method of the algorithm in captured.

Chapter 6

Testing and Performance Evaluation

Introduction

This chapter will enclose the details about the implementation work, test scenarios, results and comparison with previous techniques. With different number of parameters proposed architecture run which leads to different type of results.

6.1: Implementation work

In order to implement proposed idea network simulator i.e. OMNeT++ is used which have been discussed in previous chapter. The proposed idea consists on mesh of 75 nodes which are partially connected with each other. While implementing proposed architecture other than the nodes two other modules also lie in the network which is "enter" and "classifier" modules. Function of enter module is to simply pass the data traffic. While a classifier module used to split data traffic towards the mesh network from where working of implemented work starts.

In this context priority is given to the multimedia traffic which can either hold video or audio traffic after that best effort traffic will be treated respectively. Proposed idea initially gives a sketch that how it will treat with different types of traffic. Two types of phases will be shown in implemented scenario. Front end diagram of implemented work is shown in diagram#6.1

First phase:

In first phase of simulation normal traffic will flow from the first node towards the destination node lie in the network. In this phase all nodes forward the traffic either multimedia or text.

Second phase:

Second phase is the actual phase in which we have implemented our proposed algorithm. Major steps are given below.

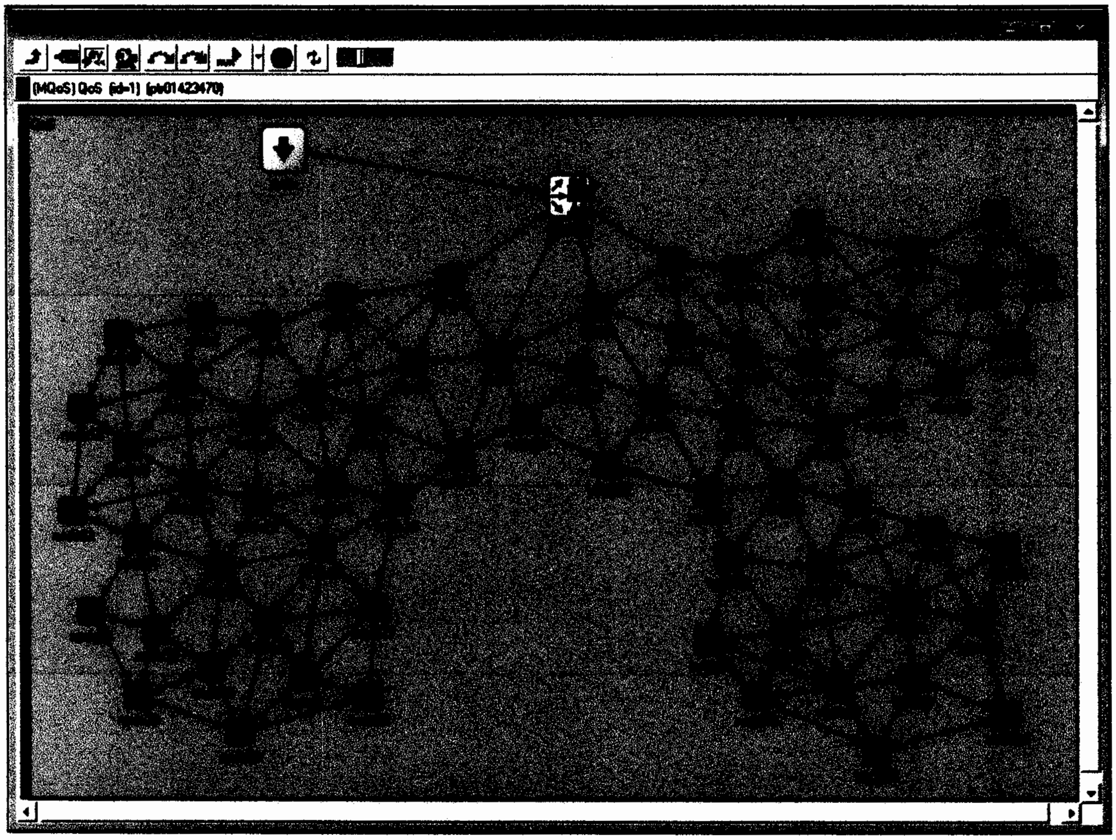


Fig 6.1: Front-end of Architecture Implemented

1: When the given level of congestion will take place. This congestion situation will be shown as it changes the color of that particular node as green. Even after this condition all traffic either that is text or multimedia traffic that will be forwarded smoothly towards the next node in order to deliver that traffic on destination node but the change in the previous phase and current phase is that after congestion situation achieved we will check the threshold level of particular node which generates pre alarm of congestion. And if the buffer size is below the threshold level all data traffic will be passed from that node as we pass it in previous step before congestion situation mitigate.

2: The next step will be to check the primary bucket threshold level if both congestion level and after that threshold level of primary bucket achieved we will stop the classified best effort packets to go in primary buckets but meanwhile we will forward the multimedia packets without any delay.

3: Additional bucket will let the text packets to wait for the situation of no congestion i.e. when congestion situation normalized then we will forward the delayed text packets towards the primary bucket in order to send them towards the destination node. This situation of no congestion will be shown as the color of particular node will be changed. After simulation runs our network will look like shown in following diagram#6.2

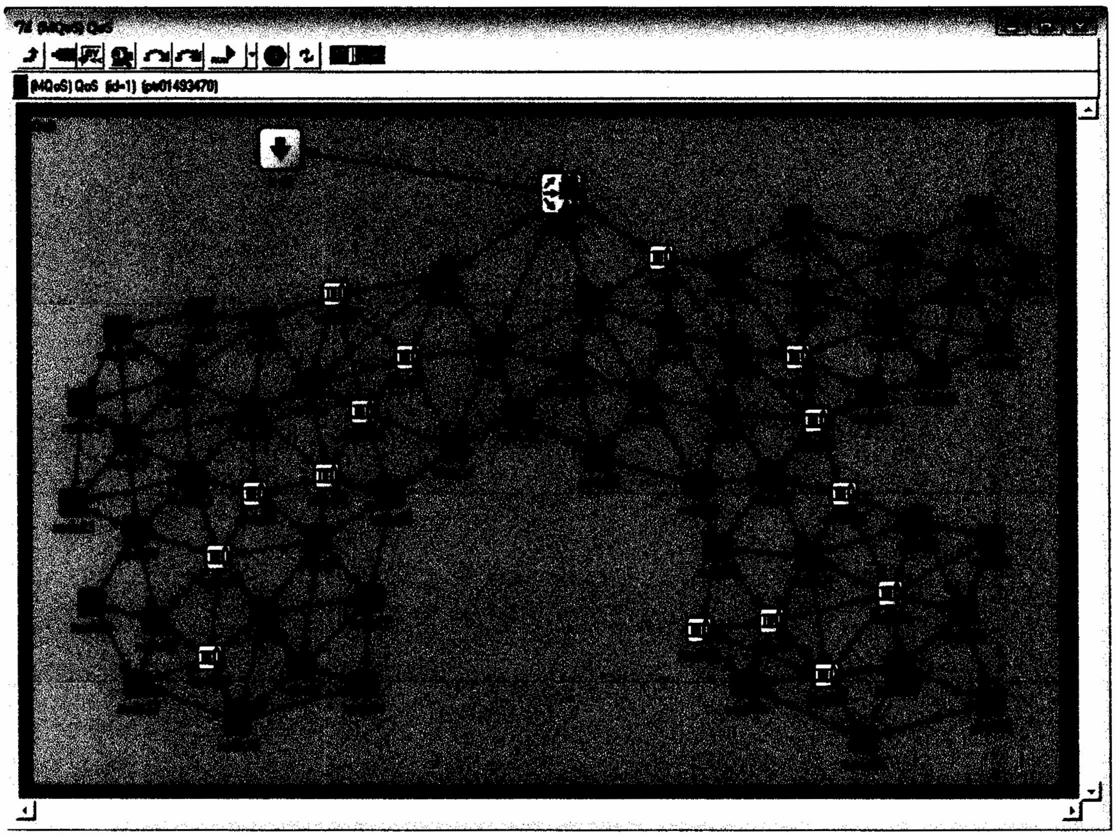


Fig 6.2: Proposed Architecture after Simulation Runs

While implementing the proposed solution in OMNeT++ both simple and compound modules are used. Each node further contains two types of simple modules. Which are used for the purpose of either check the mechanism under given circumstances and either send or let the traffic to wait i.e. best effort traffic. Nodes in the network are connected with each other via in or out gates. A single node has multiple in and multiple out gates which are used to connect it with its neighbor nodes. A detailed view of the modules and in or out gates of these modules is given in following diagram#6.3

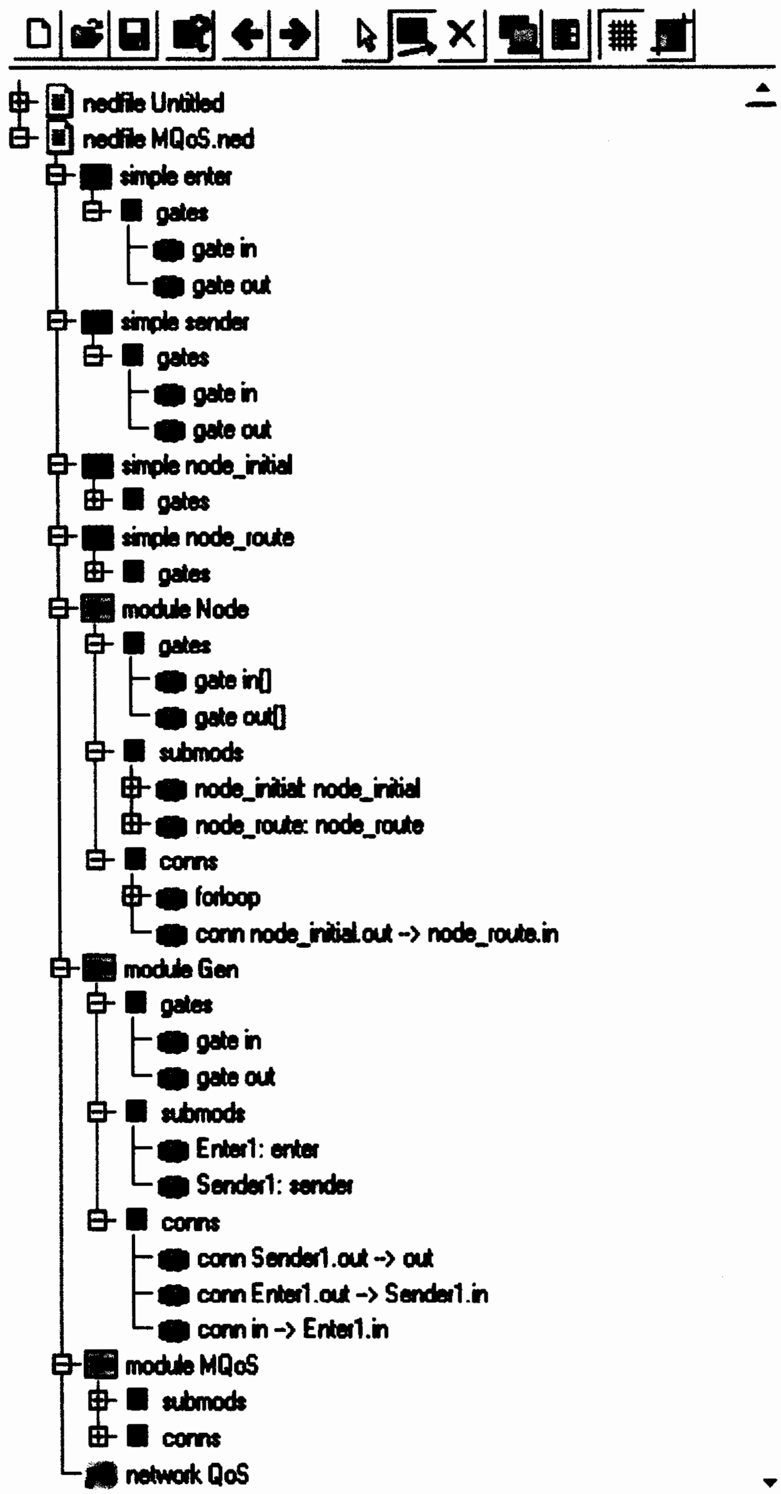


Fig 6.3: Diagram of Simple and Compound Modules and Gates

6.2: Test Scenarios

Certain experiments have been performed on the designed architecture and results have been concluded in order to observe either it fulfill the requirements and demands for which it is designed. As we know it's almost impossible to achieve an ideal situation for given environment but it is possible to achieve a near to an ideal situation. Here an attempt is made to build up an architecture which is near to ideal situation and it is shown by the results which attained during the test experiments of designed architecture.

In order to achieve the results simulation run on different number of conditions and gathers results which are shown in the form of tables and graphs.

The simulation scenario consists of 75 nodes; three of them are destination nodes. And in order to achieve the best analysis maximum nodes indulged so that the architecture could be bitterly observed and sort out either it works efficiently and fulfill the objective for which it is developed.

In test scenario some terms are used like congestion level, maximum threshold level etc. Where **Congestion level**: means a situation in which traffic from a particular node passed away more than the normal situation. If such condition meets it will make congestion level true in our simulation.

Maximum threshold level: It is level of buffer in primary bucket which every node holds in the network. It demonstrates the length of bucket which is used to pass the traffic even if congestion level meets. When threshold level reaches a trigger generate and classified best effort will be hold on in additional bucket. When congestion ends up best effort traffic will be passed from additional bucket to primary bucket from where it will be send towards destination node.

6.2.1: Results of packet loss ratio

Firstly simulation executed to check the ratio of packet loss in proposed architecture. For such purpose this simulation will be executed with variable number of packets.

Different numbers of packets are passed out and on the basis of number of packets; variable values of congestion level and maximum threshold level etc are established.

The results which are gathered are shown below in the form of tables and graphs. As the terms used like multimedia and text traffic so data traffic generated randomly with different kinds of data packets. In this section the results for the packet loss ratio while running the developed architecture on a different quantity of data packets i.e. 40, 80, 150, 300, 500 are measured respectively. Results obtained by running the simulation on a number of randomly generated data packets are shown in the form of tables and graphs as given below.

Three type of scenarios will be followed which are described first.

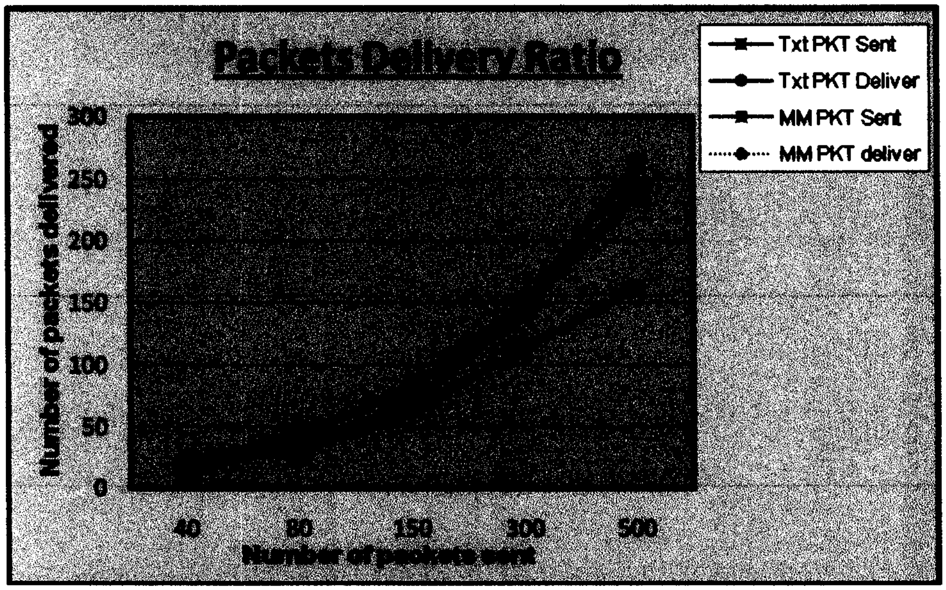
Parameters Description	Test scenarios		
	(1)	(2)	(3)
Congestion level	4	6	9
Maximum Threshold level	8	9	12

Table 1: Description of Test Scenaiors

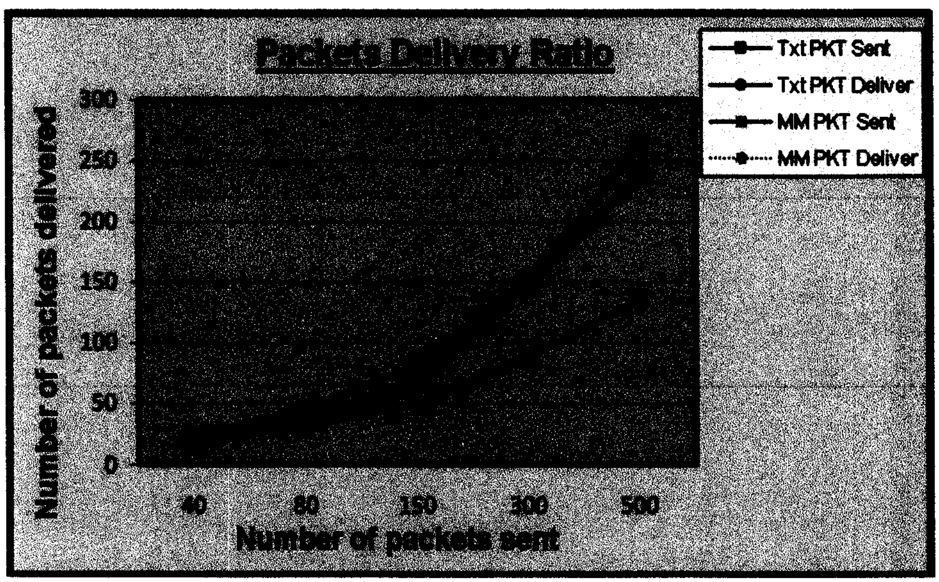
Deliver Ratio:

Total number of PKT	Total text PKT delivered			Total mm PKT delivered		
	(1)	(2)	(3)	(1)	(2)	(3)
40	20	18	22	17	17	17
80	32	33	39	36	36	36
150	49	64	60	68	68	68
300	88	113	112	148	148	148
500	136	163	180	238	238	238

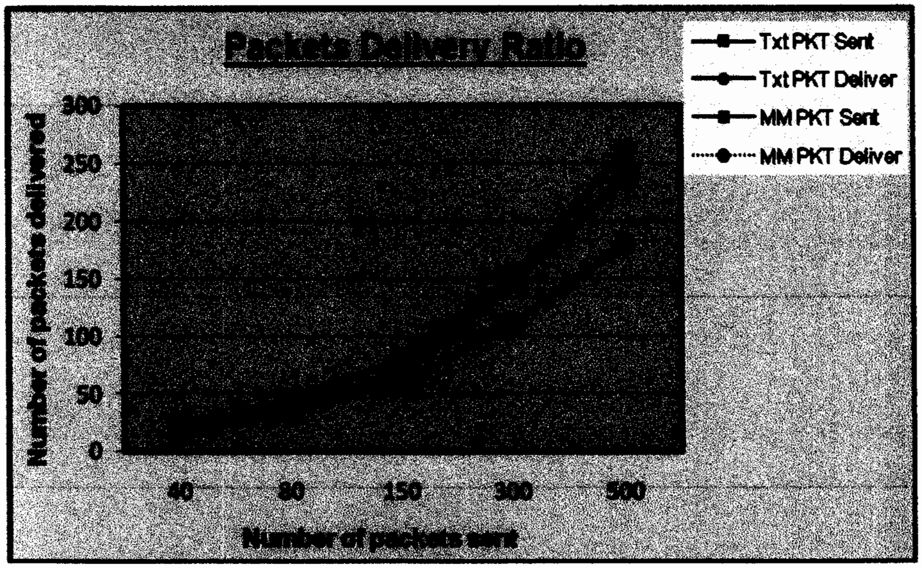
Table 2: Result of Delivered Packets in form of Table


Packets Delivery Ratio
Txt PKT Sent
Txt PKT Deliver
MM PKT Sent
MM PKT deliver
Number of packets delivered
300
250
200
150
100
50
0
40
80
150
300
500
Number of packets sent

(1)


Packets Delivery Ratio
Txt PKT Sent
Txt PKT Deliver
MM PKT Sent
MM PKT Deliver
Number of packets delivered
300
250
200
150
100
50
0
40
80
150
300
500
Number of packets sent

(2)



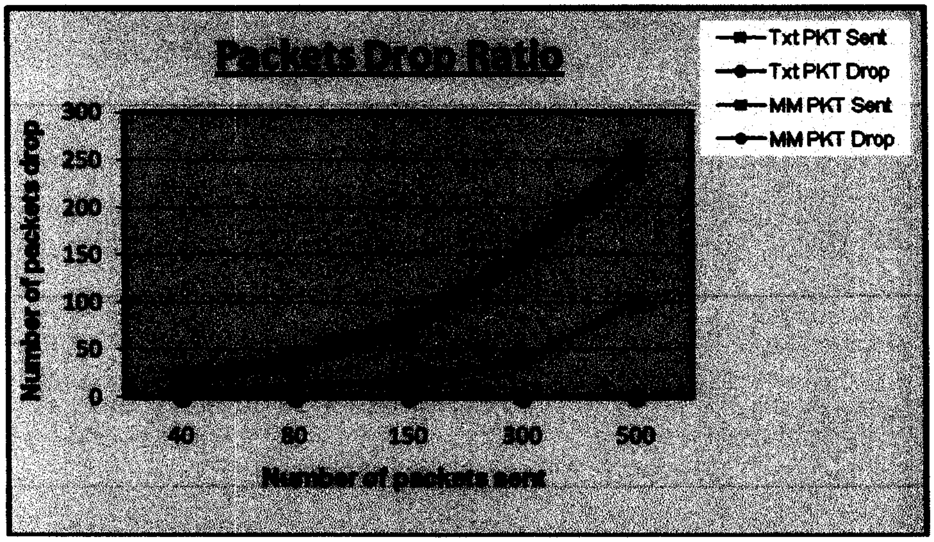
(3)

Fig 6.4: Results of packet's delivered ratio in the form of graphs..(1),(2),(3)

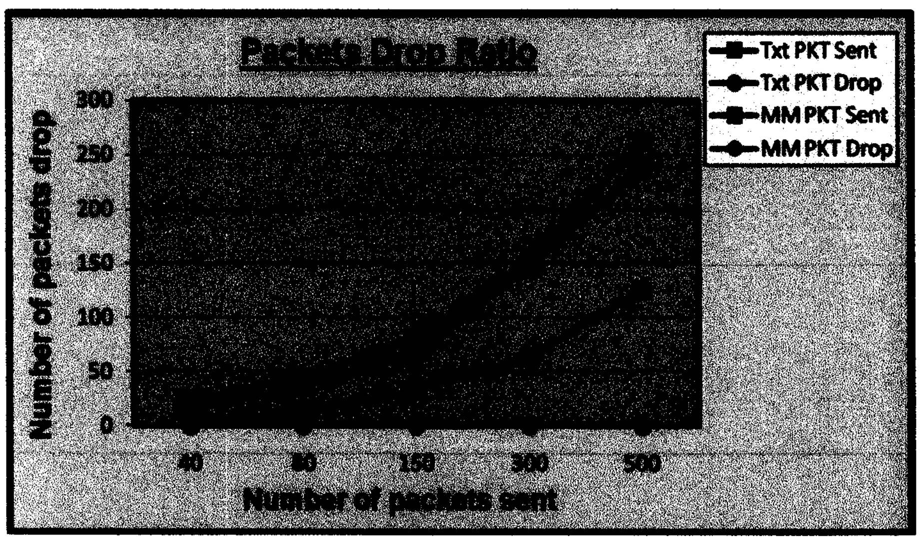
Drop Ratio:

Total number of PKT	Total text PKT drop			Total mm PKT drop		
	(1)	(2)	(3)	(1)	(2)	(3)
40	3	5	1	0	0	0
80	12	11	5	0	0	0
150	33	18	22	0	0	0
300	64	39	40	0	0	0
500	126	99	82	0	0	0

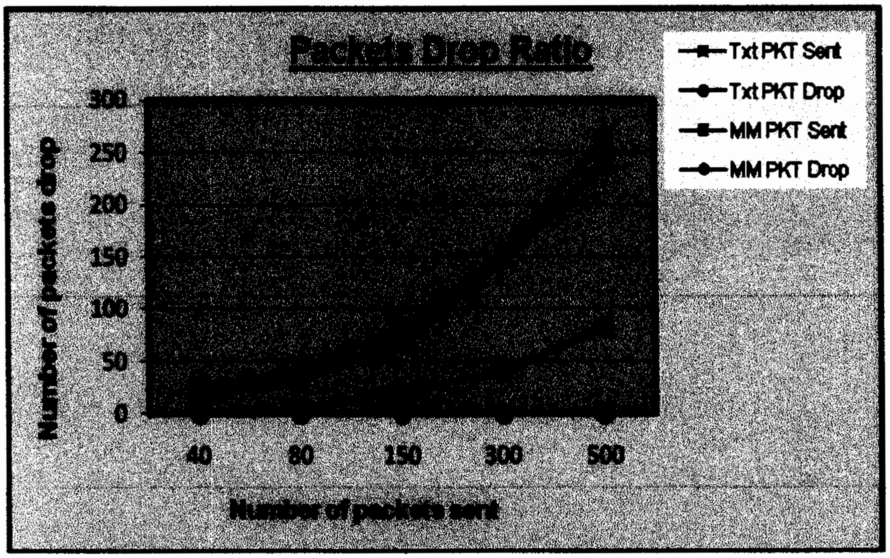
Table 3: Result of Droped Packets in form of Table


Packets Drop Ratio
Txt PKT Sent
Txt PKT Drop
MM PKT Sent
MM PKT Drop
Number of packets drop
300
250
200
150
100
50
0
40
80
150
300
500
Number of packets sent

(1)


Packets Drop Ratio
Txt PKT Sent
Txt PKT Drop
MM PKT Sent
MM PKT Drop
Number of packets drop
300
250
200
150
100
50
0
40
80
150
300
500
Number of packets sent

(2)



(3)

Fig 6.5: Results of Packet's drop ratio in the form of Graphs..(1),(2),(3)

In this scenario experiment are performed to calculate the delay time for multimedia traffic in order to provide QoS for real time traffic.

6.2.2: Results of delay

Previous section encloses three types of experiments to evaluate the performance of our proposed architecture. These three experiments show the less packet drop ratio in a network of 75 nodes which have 3 destination nodes.

In second section delay time is calculated for multimedia packets which is our secondary objective in terms of providing QoS in WMNs. For this purpose the simulation will be run on different number of packets and delay for multimedia traffic calculated. Tabular form of the results is given below.

Total number of PKT	Total Delay in MM PKT
40	170.01us
80	360.01us
150	680.01us
300	1.48ms
500	2.38ms

Table 4: Total Delay in MM PKTs

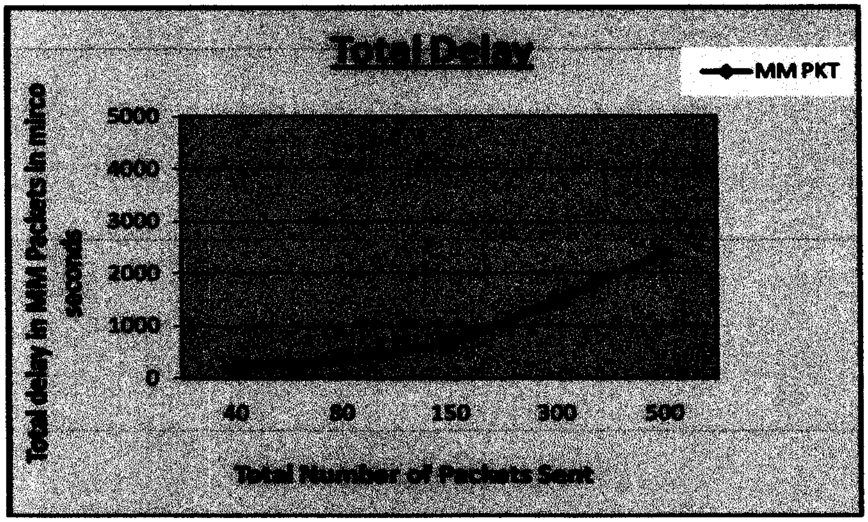


Fig 6.6: Delay in MM PKTs in form of Graph

6.3: Performance and Evaluation

As it is mentioned in the literature review that quality of service is a serious issue in wireless mesh network which should be tackled efficiently. So the main contribution in this framework is to provide quality of service in terms of very low packet loss ratio as well as minimum delay for the multimedia traffic. In order to compare the efficiency of proposed framework it is compared with previously given technique [21]. In this technique after classification when load increase they drop packets after a certain range achieved in the buffer. Which create packet loss of data traffic in the situation of heavy load instead of packet drop while in current scheme case; it is suggested in the situation of heavy load to hold data packets instead of dropping them and send them when the situation of heavy load normalized.

In order to check the efficiency of proposed scheme, the results of this technique have been compared with one of the previous technique and it is concluded that proposed scheme gives more promising results than previous one. For the reason of comparing the two techniques average of results of both previous technique and proposed scheme has been taken which are shown in the form of graph.

6.3.1: Packet loss comparison

This part will cover the graphical results and comparison with previous technique [21]. Here average of both multimedia and text packets from the previous technique taken and compared with the average of proposed scheme and following graph concluded from that.

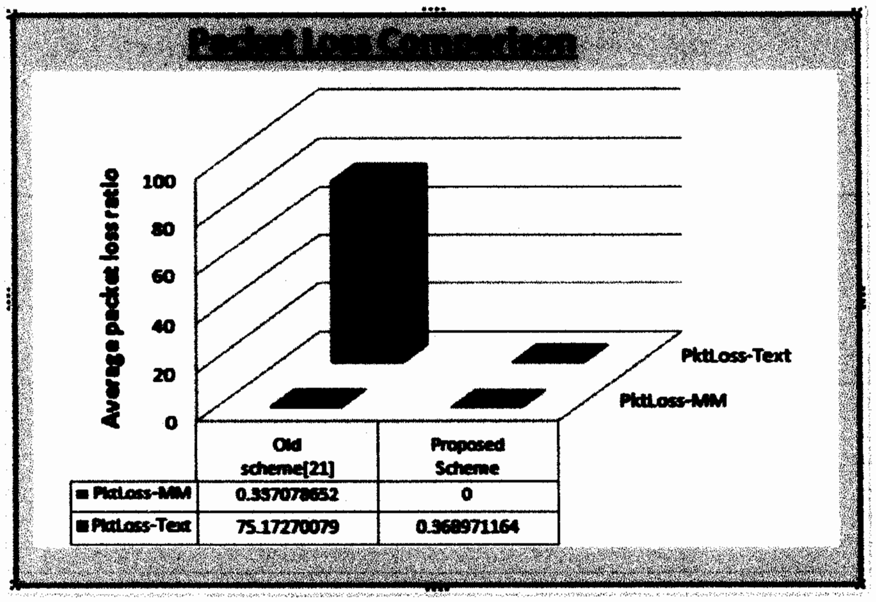


Fig 6.7: Packet Loss Comparison in form of Graph

As it is shown from the graph and table of graph that packet loss ratio for multimedia is low in previous technique but in proposed technique its zero which means our proposed scheme provides no loss of multimedia packets which was main motive of research. Text packets which have less priority then multimedia traffic are also considered in current technique that is an effort makes to reduce the loss of text packets.

6.3.1: Delay comparison

Delay minimization is the secondary aim of this scheme to achieve. For this purpose best effort traffic queued up but multimedia traffic forwarded towards the destination nodes without any delay. Hence the delay comparison of both techniques proves that proposed technique provide low delay than previous scheme which is acceptable in wireless networks. A graph of comparison of both techniques is given below.

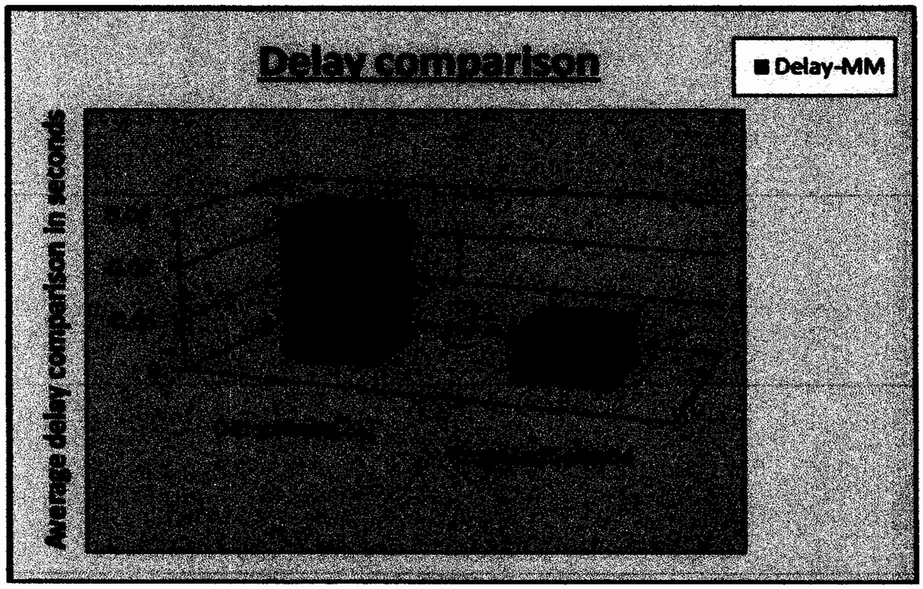


Fig 6.8: Delay Comparison in form of Graph

6.4: Summary

This chapter consists on the detail of implementation work. Detailed framework of architecture discussed in this part and after that the results are gathered after running simulation on a number of data packets. After that a brief summary of performance evaluation is given.

Chapter 7

Conclusion and Outlook

7.1: Introduction

WMNs are visualized as a key resolution to the increasing claim on multimedia networking and providing broadband access. The lower cost and easier installation of the WMNs than the wire line counterpart pushes industry and academia to pay more attention to this promising technology. Most of the work done focused on increasing the network capacity for best effort traffic. Few works have been done for satisfying the QoS and many research areas are still open in all the network stack layers.

7.2: Achievements and improvements

We focus on providing quality of service in terms of minimum packet loss ratio also the lower delay in multimedia traffic. For this purpose we propose a mechanism which will classify different type of data traffic. We prioritize the multimedia traffic (which contains video and audio traffic) over the best effort traffic. In case of heavy load on network we gave priority to multimedia traffic and simultaneously we consider the best effort traffic also. As we don't let over mechanism to drop best effort traffic as previous techniques did [21]. We store the best effort traffic and send them towards destination when the situation of heavy load becomes normal.

Our results show that we gave such a mechanism which not only provides minimum packet loss ratio for all type of data traffic but minimizes delay for multimedia traffic as well.

7.3: Future Recommendations

Some future work may be extended from our research work. In our implementation, we use an algorithm which reduce packet loss ratio of both multimedia and best effort traffic and minimize delay in multimedia traffic. Under different number of parameters we check the results of our simulation and find out our results near to the required solutions.

However there are certain points which could be further resolved and some points require further research work. In our implementation work we have considered the four nodes as first nodes which receive data traffic from other networks and pass it towards remaining nodes in the mesh network. A mechanism may be applied over the entire network that all nodes have the ability to receive the data traffic from outer source.

Moreover nodes lie in our network are stationary so mobility can be added as a future enhancement of our work.

7.4: Summary

In order to provide wireless broad band services WMN is considered as a cost-effectively sufficient model. However lots of work still needs serious consideration in it. Providing quality of service in WMNs is still a big issue which needs further improvements. Quality of service itself contains many areas in it which include bandwidth, throughput, packet loss, jitter etc.

Main focus of this research work is to minimize packet loss ratio and maximize throughput in order to provide QoS in WMNs. For such purpose a mechanism proposed which firstly classify the data traffic then pas it towards the corresponding nodes lie in that network. In case of heavy load best effort traffic will be stored meanwhile it let the multimedia traffic to pass away. And after that when congestion ends, stored best effort traffic will be forwarded. In such a way proposed scheme tried to minimize packet loss ratio and maximize the throughput for multimedia traffic.

For implementation purpose OMNeT++ is used which is most recent network simulator. It's easy to use and provide user friendly environment. Proposed scheme implemented on a network of 75 nodes. Each node in the network is either fully or partially connected towards other node lie in that network. Every node contains an additional bucket in it which stores best effort traffic data in case of heavy load situation occurred. This scenario contains three destination nodes in the network. The results have been gathered under different scenarios and shown in the form of tables and graphs in chapter 6.

This research work has got promising results in terms of packet loss and delay. However the provision of enhancement is there. So some future work may extend from the given research work.

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Acronyms:

WMNs	Wireless Mesh Networks
QoS	Quality of Service
MMT	Multimedia Traffic
DT	Data traffic
PB	Primary bucket
ADD B	Additional bucket
BET	Best Effort Traffic
VoIP	Voice over IP
PQ	Priority Queuing
CQ	Custom Queuing
WEP	Wired Equivalent Privacy
WiMAX	Worldwide Interoperability for Microwave Access
MIMO	Multiple input and multiple output
MAC	Media Access Protocol
WFQ	Weighted Fair Queuing
CBWFQ	Class-Based Weighted Fair Queuing
RED	Random Early Detection
WRED	Weighted random early detection
UDP	User Datagram Protocol
RTP	Real-Time Transport Protocol
RTS/CTS	Request to Send/Clear to Send
DCF	Distributed Coordination Function
PCF	Point Coordination Function
RR	Round Robin
CRA	Centralized Resource Allocation
SRAM	Support Real-time Application in wireless Mesh network
SRTS	Shift Register Traffic Shaper
MANET	Mobile Adhoc NETwork
BAC net	Building automation and control network

CSMA/CA	Carrier Sense Multiple Access/Collision Avoidance
NED	Network Description
OMNeT++	Objective Modular Network Testbed in