CHAPTER 1: INTRODUCTION

1.1: Study Background

Wireless network is the any kind of network which does not need the wire for transmission. The concept of the wireless communication begins up when the equations of the Maxwell illustrates possibility to transfer information without need of wire [1].The high amount of research was accomplished in the twentieth century on wireless communication technology. As a result of which large number of new wireless technologies can be seen today. Introduction of wireless technology were one of new and huge evolution in human society. With the growth of wireless network technologies, its demand is also increasing. Users want more sophisticated wireless technology with better quality. The revolution of wireless was started by GSM system (Voice transmission). In today's scenario, it means voice, VoIP, online gaming, video etc. The wireless technology does not stop here as it also raises the matter and point of availability, reliability and most importantly better Quality of Service with very high speed network.

Over the last decade, not only residential users but also global economy had been greatly impacted. Meanwhile both commercial as well as residential users have become familiar with the devices like laptop devices, mobile devices etc. [7]. Many new multimedia based applications like VoIP, video conferencing was implemented also. Broadband access was proposed by International Telecommunication Union (ITU) to meet up the demand of growing wireless communication. IEEE 802 project working group 16 developed Broadband Wireless Access (BWA) [8]. And WiMax (Commercial name of IEEE 802.16 standard) was then proposed. WiMax guarantee a better QoS by the potential and efficient use of bandwidth.

Fast expansion of wireless communication with the rising number of wireless users should provide better QoS to distinct service applications as well as retain the high speed. In a wireless communication system management of resources with better Quality of Service (QoS) is a huge challenging task as it has become the basic necessities for good communication. Besides, obstruction causes by the simultaneous users communicating, there is also chance of initiating race among the user's devices for limited resources of wireless communication [9]. To overcome such problem of limited resources and requirement of user group, the wireless network with the inadequate availability of resources might have to decline new connections to maintain the better Quality of Service (QoS).

Connection Admission Control (CAC) is one of the solutions for managing wireless resources in order to maintain the better QoS [3]. This paper proposes CAC as solution for IEEE 802.16 standard that maintains the higher QoS and supports the real time applications. In wireless networking, generally resources are limited so proper utilization of the resources is necessary to provide the better services to existing users. Here, CAC algorithms can play vital role because they decides whether a new connection will be admitted or rejected on the bases of availability of resources [3].

The wireless network is gaining popularity because of high coverage area and mobility features at low cost. It is also seen as the alternative of the wired networks. To replace the wired and other wireless technology, WiMax has to deliver the desired level of QoS. This thesis report will present detail overview on the QoS supports provided by WiMax technology and also present existing literature survey on WiMax and Connection Control Admission Control (CAC). The main focus will be Admission algorithm and lastly, this report will conclude with actual challenges of research, directing and detailing the most promising and efficient way to pursue further search in the field.

In 1990's the Internet Engineering Task Force (IETF) started the Integrated Service working group to standardize a new resource allocation architecture and service models which is based on resource reservation of per flow. In order to get assurance of resource, resource reservation is compulsory process for a new connection before it starts transferring traffic on the network. While reserving the resources, there are a number of steps involved. First step is to define & characterize traffic source and resources requirements after that network applies a routing protocol & a path based on the resources requested. Next step is reservation, where reservation protocol is applies for installation of reservation state along with the path. Meanwhile at each hop an admission control module checks resources to confirm the availability in order to accept the new connections. Here available resource means bandwidth and buffer space. If the new connections are admitted by the admission control module, Exclusive resources are set up for new connection. The main work of the admission control module is to ensure guarantees of QoS for the existing flow and make sure that existing flows are not hampered by addition of new flow otherwise admission control must reject the new request for the connection.

CAC is an algorithm which is used to maintain the desired level of QoS by limiting the number of ongoing connection in the network, Furthermore it also accepts and rejects the new connection according to the status of the network. So it is known as the Radio Resource

Management (RRM) technique. The CAC in a WiMax network comes in the scene whenever new request arrives for connection; the decision of the CAC mainly relies on the availability of resource in the network. In this case the resource availability means available bandwidth of the network. There are some questions need to answer while taking any decision. They are:

- How much bandwidth is requiring for new connection?
- What is the available bandwidth in network for new connection?
- Will the currently running connections face any disturbance by introduction of new connection?

After getting the feedback of above question the CAC takes the decision if there is enough resource available in a network for new connection without any interference to the existing connection then new connection is accepted if not, then simply it is rejected. Although there are some more challenges left. The wireless communication connection needs to conscious about other factors like path delay propagation, handoff, and multiple channel interference besides bandwidth limitation.

Admission Control

A well designed Admission Control Algorithm has significant impact on the performance of network, as ineffective algorithm may needlessly declines admittance to flows that could have been easily admitted [7]. Similarly, an algorithm that unacceptably allows many flows will make Quality of Service contravention. According to the principle guarantees of QoS are hard bound on transport performance as an example bounded packet transfer delay. Such kinds of bound are comparatively easy to maintain end to end base, especially in this case packet delay evaluates. Different from deterministic services, a soft real time service or statistical service associates a minimum violation probability with the delay and throughput bounds, as required to utilization gain over a purely worst case approach [7].

1.2: Motivations and objectives

The main aim of this thesis is to do the research on the connection admission control that helps to maintain the QoS (Quality of service) for various applications in WiMax network and evaluate and analyze the two distinct approaches towards the CAC.

The following are the objectives:

1. To identify and understand the problem in order to maintain desired and control Quality of Service (QoS) in WiMax.

2. To present and understand the importance of Connection Admission Control (CAC) and CAC algorithm in WiMax Network.

3. To Categorize and identify the distinct approaches done towards Connection Admission Control in order to achieve better Quality of Service.

4. To understand, analyze and identify the two different approaches based on adapting connection admission control, measurement-based admission control.

5. Critical analysis and evaluation of the two approaches collectively that are related to maintain QoS in WiMax.

6. To suggest further possible methods towards the solution in order to obtain better Quality of Service in WiMax Network.

1.3: Approach & Methodology

This dissertation project will be based on the logical analysis and evaluation of the problem area. It will also analyze different research approaches towards Connection Admission Control (CAC) to maintain the required level of Quality of Service in WiMax. This thesis report presents the basic structure of WiMax. A fair approach will be made to understand the Connection Admission Control (CAC) algorithm and need and importance of Connection Admission Control (CAC) algorithm in WiMax network by identifying a specific problem area. The thesis report briefly will discuss two different approaches by presenting their approaches and methodology. The project will also present and validate the outcome achieved by the research approaches present in this report.

CHAPTER 2: BACKGROUND AND IDENTIFICATION OF PROBLEM

This chapter produces an executive summary of WiMax Networks, also provides the IEEE 802.16 group activities and relationship with WiMax. Some technical features and characteristics of the Physical and MAC layer of the WiMax are been described. It also presents the simplified version of QoS in WiMax network and second half of this chapter discusses about the problem area.

2.1: Introduction

IEEE 802.16 Standard provides broadband wireless access technology. It offers high speed networking with better Quality of service. Besides that IEEE 802.16 standard is popular for its cost effectiveness at high data rates in area where DSL and cable are not possible to reach. The main aims of IEEE 802.16 standards to provide the required QoS for various kinds of traffic along with high speed broadband wireless connectivity, especially for real time applications. To support Quality provisioning Connection Admission Control is one of the very effective methods in IEEE 802.16. However, it is not specified any Connection Admission Control (CAC) techniques in IEEE802.16 Wireless MAN, although MAC signalling and Physical specifications are defined in the IEEE 802.16 standard. Designing Connection Admission Control (CAC) algorithm has been left to vendors. This chapter provides the overview of IEEE802.16 standard and requirement of CAC technique in WiMax network.

2.2: Overview of IEEE802.16 WiMax

The full form of WiMax is 'Worldwide interoperability for Microwave Access', which is defined as IEEE 'Institute of Electrical and Electronics Engineers' telecommunication standard. 802.16-2004 standards were designated for fixed wireless application and amendment 802.16e-2005 for mobile wireless application. A forum for WiMax was formed in 2001. This same forum gave the name WiMax for this new WiMax technology. WiMax has emerged as a promising technology from its beginning to till now. The first IEEE 802.16 standard was published in 2001 that was operating in 10 GHz - 66 GHz frequency band. IEEE 802.16a standard was developed in 2003 with some addition of Physical level application features and was operating in 2GHz frequency band. In 2004 these two standards 802.16 and 802.16a was revised and combined as the IEEE 802.16 - 2004 for fixed wireless application. In 2005 new version of WiMax was published which was known as IEEE802.16e-2005 with mobility features .IEEE802.16e-2005 was an amendment of IEEE 802.16-2004.IEEE 802.16e-2005 can work on both NLOS (Non Lines Of Sight) and LOS (Lines Of Sight) situation. It has the following features because of that it has the ability to complete and replace the current infrastructure of telecommunication.

Characteristic	**Fixed WiMax**	**Mobile WiMax**
Industry Standard	802.16-2004	802.16e-2005
Access Type	Fixed	Fixed, Portable and Mobility
Modulation	OFDM	OFDMA
Duplexing	TDD, FDD	TDD, FDD Optional
Handoff	No	Yes
Types of Service Providers	DSL, Cable Modems and Competitive Access Providers (CAPs)	Mobile Operators, DSL, Cable Modems, Wireless and Wired ISPs
Subscriber Units	High Performance Outdoor and Indoor CPE	Low cost Consumer Electronic CPE and Embedding Modules
Preferred Frequency Bands	2.5 GHz, 3.4-3.6 GHz 5.8 GHz	2.3-2.4 GHz, 2.5-2.7 GHz, 3.3-3.4 GHz,3.4-3.8 GHz

Table 2-1: Comparative features of both version of WiMax (Fixed and Mobile)

2.2.1: WiMax Topologies

Normally, two types of possible topologies used in the WiMax network according to IEEE802.16 standard. They are Point to Multipoint and Mesh topology.

2.2.1.1:Point to Multipoint topology: It is a centralized topology where the Base Station (BS) acts as the center system of the whole system and all the SSs are located in the transmission range of Base station (BS), where traffic flows only between the Base Station(BS) and SSs station.

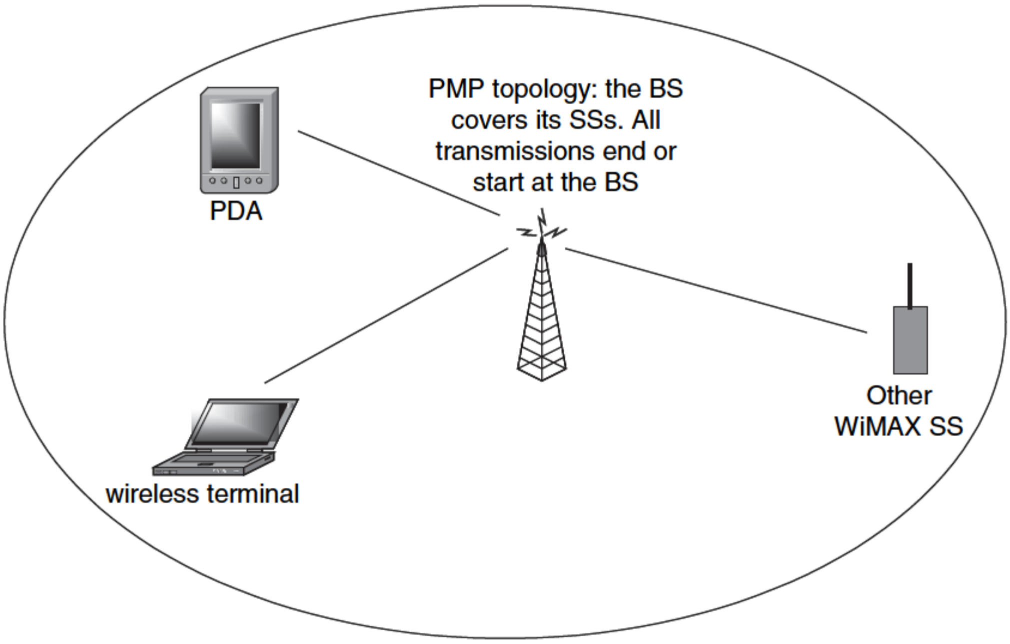

Fig 2-1: PMP topology [3]

2.2.1.2: Mesh topology: In the mesh topology there is not centralized system. All the SSs can communicate with each other via Base Station (BS) or without the Base Station. Delivery of traffic can be performed by using hop by hop. It has the several advantages compare to the Point to Multipoint (PMP) mode. Some of them are:

- Direct traffic flow between the nodes.
- Traffic can flow on the base of relay among the nodes to reach the destination.
- Throughput and transmission range can be improved.
- Mesh topology provides the scalability and flexibility.

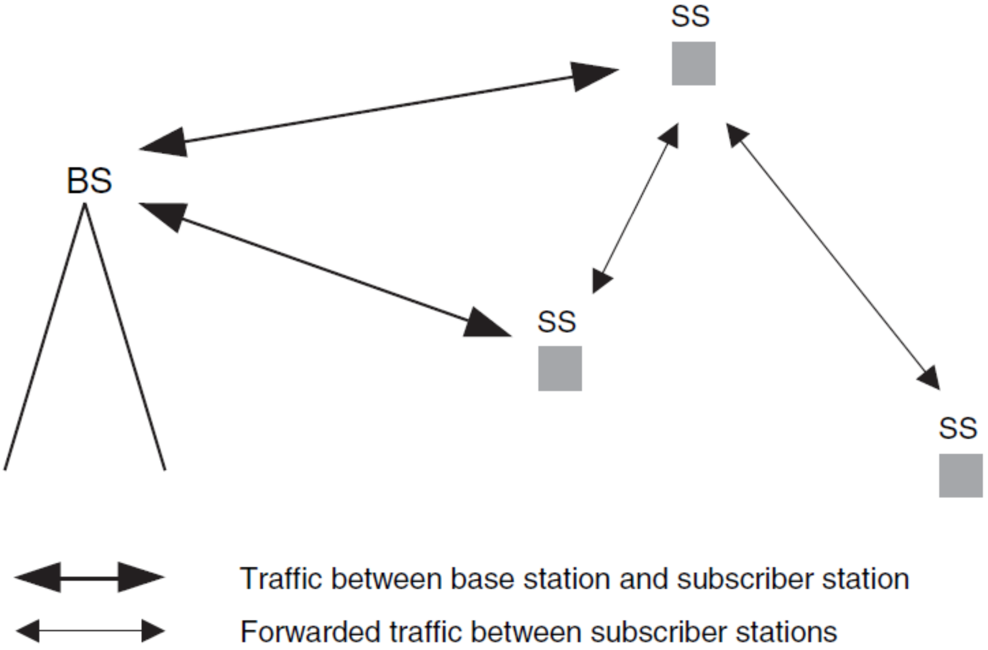

Fig 2-2: Mesh topology [3]

2.2.2WiMax Protocols Layer

The IEEE 802.16 BWA standard is known as WiMax, it applies Open System Interconnection (OSI) model. It is reference as seven layer model and used to explain the various aspects of network technology. Application layer lies at the top of the OSI model, where last two layers are applied by the IEEE 802.16 standard as the Physical (PHY) and Medium Access Control (MAC) layer. In the WiMax network data link layer is been divided into two layer MAC layer and Logical control layer by the IEEE802.16 standard.

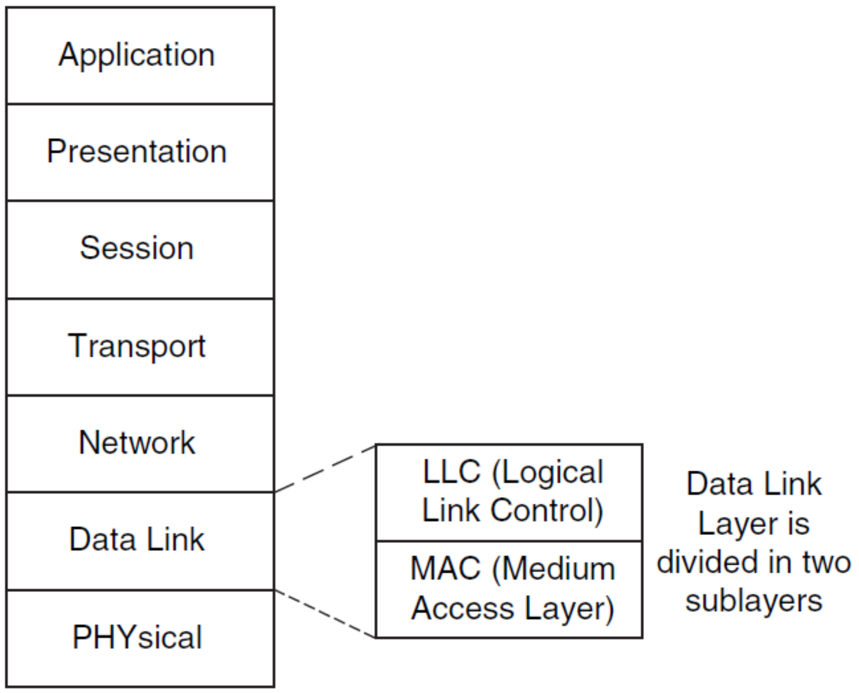

Fig 2-3: Seven layers OSI reference model, In WiMax only the two first layers are defined [2]

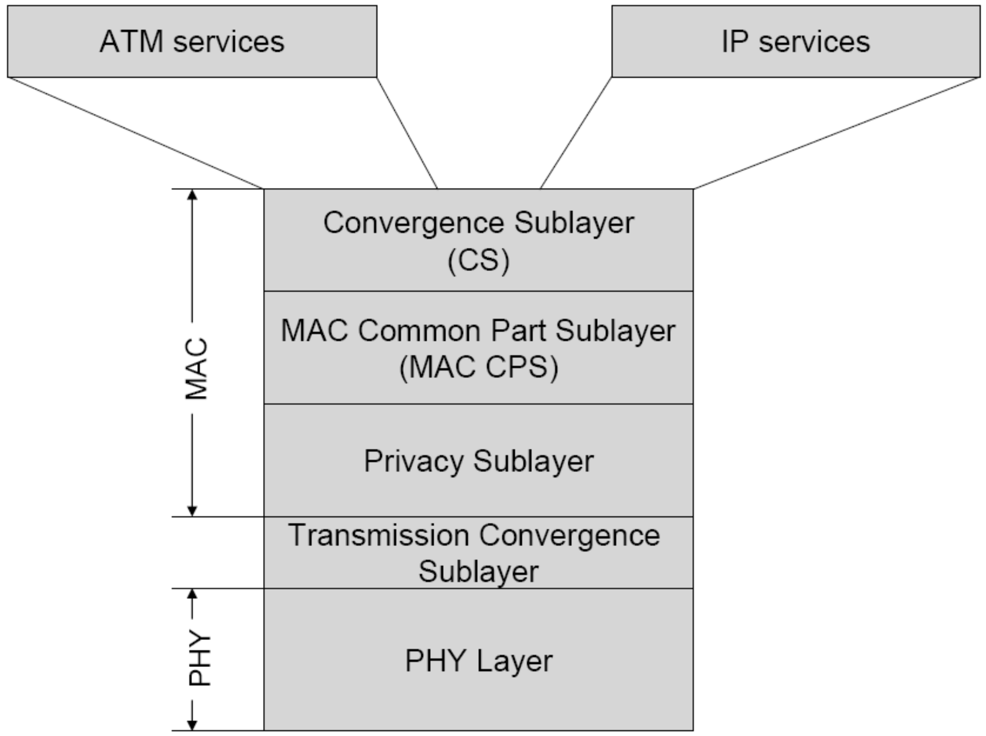

Fig 2-4: IEEE 802.16 protocol architecture [9]

2.2.2.1: WiMax Physical Layer

WiMax Physical layer is use to establish physical connection between the peering sides for the both direction downlink and uplink. The Physical layer also takes the responsibility of bit transmission in a sequence order [2]. It also describes the types of modulation, demodulation signal used, physical interface and transmission power. There are five physical interfaces which are defined in the IEEE 802.16 standard. The frequency range of each interface is different on the base that they were proposed for that duplex method is used. They also have the distinct section and MAC option in IEEE 802.16 standard.

2.2.2.2WiMax MAC Layer

The MAC layer of WiMax is used to manage the radio resources in the effective and efficient manner. MAC layer establish the link communication between physical layer and higher transport layer [11]. MAC layer of WiMax collects the data packets from the upper layer and organize the packets in MPDU (MAC Protocol Data Unit) in order to transmit on the air. These packets which are collected from higher layer known as MAC Service Data Unit (MSDU).The Physical layer receives MPDU as a Physical Service Data Unit (PSDU) [2]. The MAC protocol is centralized and connection oriented [9].

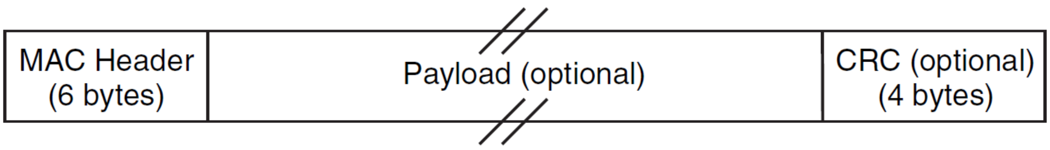

Fig 2-5: General format of MAC PDU [2]

<u>Convergence Sub layer (CS)</u>

Convergence sub layer is the service specific layer, called as the CS; it lies above the MAC CPS sub layer, In MAC design of both versions IEEE 802.16-2004 and IEEE 802.16e-2005 standard, convergence sub layer was included [11] in order to provide the accommodation for a various high layer protocols like TDM voice, ATM, IP, Ethernet etc. CS uses the services that are offered by the MAC CPS, via the MAC SAP (MAC s Services Access Point).The function of the CS are:

- Receiving CS PDUs from the peer entity, delivering Convergence Sub layer (CS) PDUs to the appropriate MAC SAP.

- An optional function of the convergence sub layer (CS) is Payload Header Suppression (PHS).

- It processes the higher layer PDUs on the basis of the classification, if required.

- Mapping and Classifying the MSDUs into appropriate Connection Identifier (CIDs).

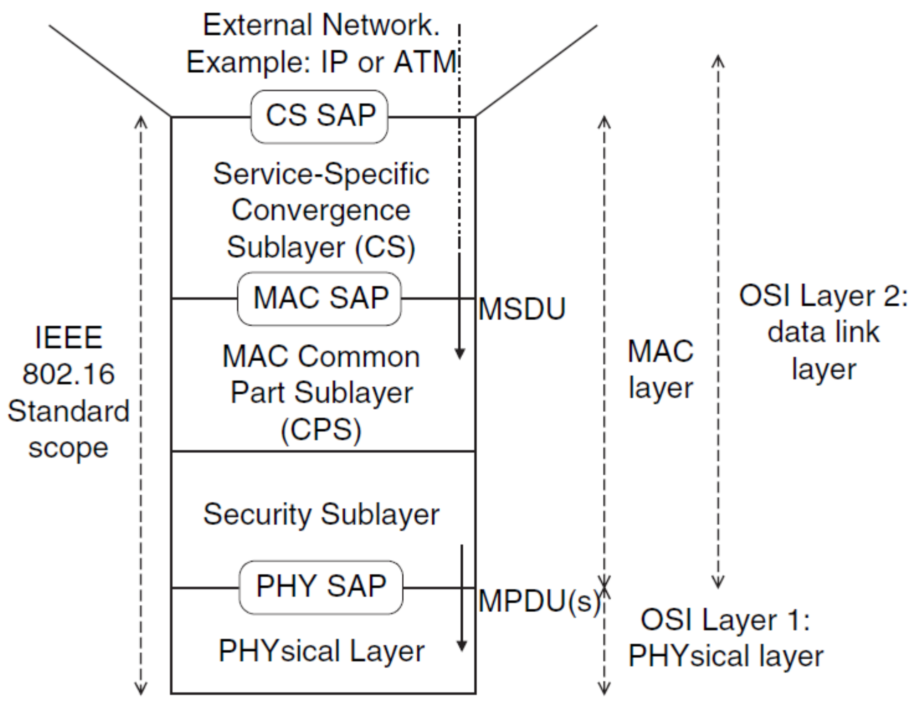

Figure 2-6: Protocol layers of IEEE 802.16 [2]

<u>Medium Access Control Common Part Sub layer (MAC CPS)</u>

The Common Part Sub layer (CPS) is the core of the whole MAC protocol. It is the middle part of the MAC layer. It performs following activities

- Bandwidth allocation

- Connection establishment

- Maintenance of the connection between two sides

When MAC CPS gets request from the Subscriber stations (SS) where each SS has to fulfil the requirement.

Security Sub layer

Main responsibility of security sub layer is towards security control across the BWA system. For this it uses the authentication, encryption, secure key exchange mechanism. Security sub layer includes two types of protocols in order to provide security. They are Privacy and Key management protocol and encapsulation protocol.

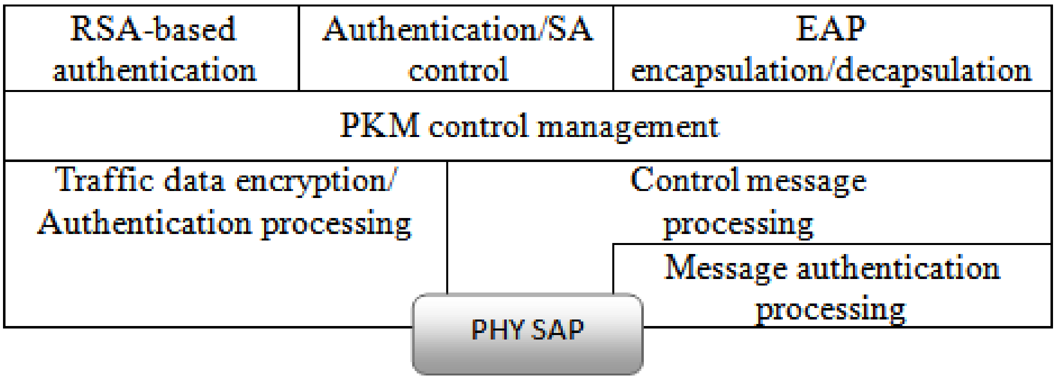

Fig 2-7: Security Sub layer [2]

2.2.3QoS Framework and Service Types in WiMax Networks

QoS framework and different kinds of service flows are defined by the WiMax standards. The MAC layer of WiMax is responsible to provide distinguishes QoS in order to support various classes of services. For voice, video, data and other kinds of traffic WiMax standards provide accommodation by applying the suitable features in the MAC layer.

2.2.3.1 Service Flows

One of the fundamental mechanisms for better Quality of Service (QoS) in WiMax is to relate data packets application with a flow of service. A MAC layer transport service is known as Service flow which offers the unidirectional transmission of packets in both downlink and uplink directions. In WiMax network, base station assigns 32-bit SFID (service flow identifier) and 16-bit unique connection ID (CID) for all service flows. Quality of Service (QoS) depends on the set of Quality of service parameters which are defined for the service flow. Set parameters of Quality of service (QoS) describes the require Quality of Service (QoS) metrics like bandwidth guarantee, jitter, delay and priority of traffic for the applications being delivered.

There are two kinds of service flow which are static and dynamic. As the name suggests dynamic flows may be deleted, created or changed, which can be carried out through MAC management message series. The series of MAC management messages are:

- Dynamic Service Addition (DSA): It is used to create a new service flow.
- Dynamic Service Change (DSC): It is used to change the existing service flow.
- Dynamic Service Deletion (DSD): It is used to delete the existing service flow.

In the WiMax network base station issues SFIDs and maps with SFIDs to unique CIDs. To enable end-to-end IP based Quality of service (QoS) service flows can also be mapped with multiprotocol label switching (MPLS) flow labels or distinguishes Services code points. The standard also defines the process of authorization via which the both subscriber and base station identify each other. The change in the QoS parameter of service flow like DSA, DSD, DSC message, must be approved by an authorization module. These types of changes include service flow reduction requests, requesting a CAC decision, or service flow activation.

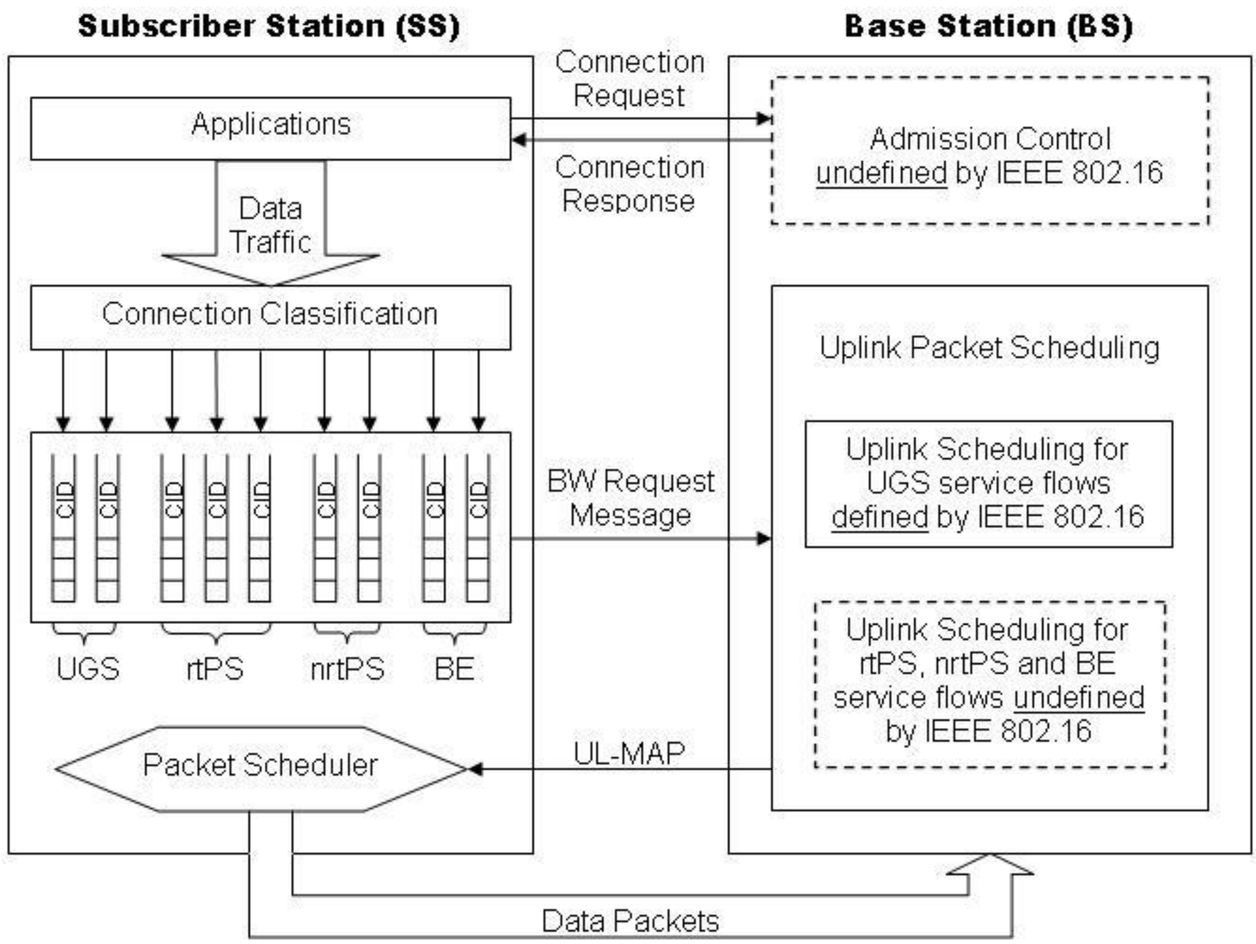

Fig 2-8: QoS Architecture in WiMax Network [21].

2.2.3.2 Scheduling Services

The data handling mechanisms are called as the Scheduling Services. These services are supported by the MAC scheduler for transmission of data on a connection; there are four scheduling services defined in WiMax standards for uplink flows whereas QoS requirements of each scheduling service are different.

Classes	Applications	QoS parameters
UGS	VoIP without silence suppression.	Max. Sustained Traffic Rate; Max. Latency; Jitter;
rtPS	Video Streaming.	Max. Sustained Traffic Rate; Min. Reserved Traffic Rate; Max. Latency;
ertPS	VoIP with silence suppression.	Max. Sustained Traffic Rate; Min. Reserved Traffic Rate; Max. Latency; Jitter;
nrtPS	FTP.	Max. Sustained Traffic Rate; Min. Reserved Traffic Rate;
BE	Web browsing, e-mail.	Max. Sustained Traffic Rate;

Table 2-2: IEEE803.16E Classes, Applications and QOS Parameters [2]

- Unsolicited grant service (UGS): It is designed for real time service flows that create fixed size packets of data periodically such as VoIP (voice over IP).In the UGS case the allocation of bandwidth for each connection is fixed in a static manner due to which minimizes jitter and delay. It is appropriate for traffic with very strict QoS constraints.

- Real-time polling service (rtPS): It is designed for real time service flows that create different size of data packets periodically such as MPEG. This service provides real time, unicast and periodic request which meet the need of real time flows and offers the facility to subscriber stations in order to specify the size of data packets according to their desire. rtPS needs more request overhead than Unsolicited grant service (UGS)

- Extended real time polling service (ertPS): It is defined only 802.16e-2005 standard not in the 802.16-2004 standard and designed for variable data rate real-time traffic like VoIP. This scheduling mechanism builds on the efficiency of rtPS and UGS.

- Non-real time polling service (nrtPS): This type of scheduling mechanism is designed for non-real time service flows that need different size of data grants regularly like high bandwidth file transfer. nrtPS provides unicast polls regularly which make sure that the flow gets request opportunities even during congestions of network.

- Best effort service (BE): This type of scheduling mechanism is designed to support email traffic and web surfing traffic. The bandwidth allocation relies on the bandwidth allocation policies of other types of service. In the BE service generally no guarantees for delay and throughput.

Typical Applications/Services	Data Rate (bps)	Delay Bound (ms)	Packet Loss Rate
Voice	32 k - 2 M	30-60	10^{-2}
Video streaming	1-10 M	Large	10^{-6}
Videoconference	128 k - 6 M	40-90	10^{-3}
File transfer	1-10 M	Large	10^{-8}
Web browsing	1-10 M	Large	10^{-8}

Table 2-3: QoS requirements for different applications [2]

2.3: Problem Statement

Because of high popularity, the numbers of wireless users are increasing day by day and wireless technologies are countering each problem to maintain level of Quality of service for higher number of users. Wireless network is more & more concerned about its reliability, quality, security, availability and capability due to high demand. Wireless network need to overcome its obstructions in order to offer good quality of service (QoS) to its user. These day people are depended on the wireless network to perform daily work. It is necessary to wireless networks to be more concerned about the full effective and complete utilization of available network resources. It is challenging task to providing better QoS in high speed network. Therefore high speed network is still a big challenge for researchers. The main motto behind this thesis is to purpose the new effective thing in order to maintain Quality of Service for WiMax (Wireless) network.

CHAPTER 3: LITERATURE REVIEW

3.1 Connection Admission Control (CAC):

Unlike wired network wireless network has the limited resources. Therefore effective utilization of the resources is vital in the wireless networking in order to obtain the desired level of the QoS. Resource limitation necessitate the CAC along with the scheduling algorithms that makes possible to support non real-time and real-time traffic in the WiMax[9].The main functionality and objectives of the CAC algorithm's is to maintain the QoS level in the WiMax network by managing resources and limiting the number of ongoing connections. The operation of the CAC begins when the new request for new connection arrives. The IEEE 802.16 standard defines scheduling classes but it doesn't define any CAC and scheduling algorithm's to provide the better QoS and are left to the vendors [22].

3.1.1: The Need of CAC in WiMax:

These days, there is rapid growth in wireless communication systems, with growth the numbers of its user are consequently in increasing order. Therefore, wireless network need to provide guarantee QoS for various services whilst maintaining high utilization of network. In order to provide the good balance between these two competing requirements (Quality of Service and Network Utilization) necessitate an efficient algorithm [9] that should be understood when designing wireless networks. Moreover the concurrent transmission by users of network causes the interference that may initiate race between the users for limited resources of the wireless network. To overcome with these types of challenges, effective management of available radio resources is very necessary in such a heterogeneous wireless network supporting different kinds of applications with distinct Quality of Service requirements. It may possible that wireless network have to refuse new connection due to the lack of available resources or this new connection would disobey the promises of network. The process which is necessary to take such decision is called Connection Admission Control (CAC).

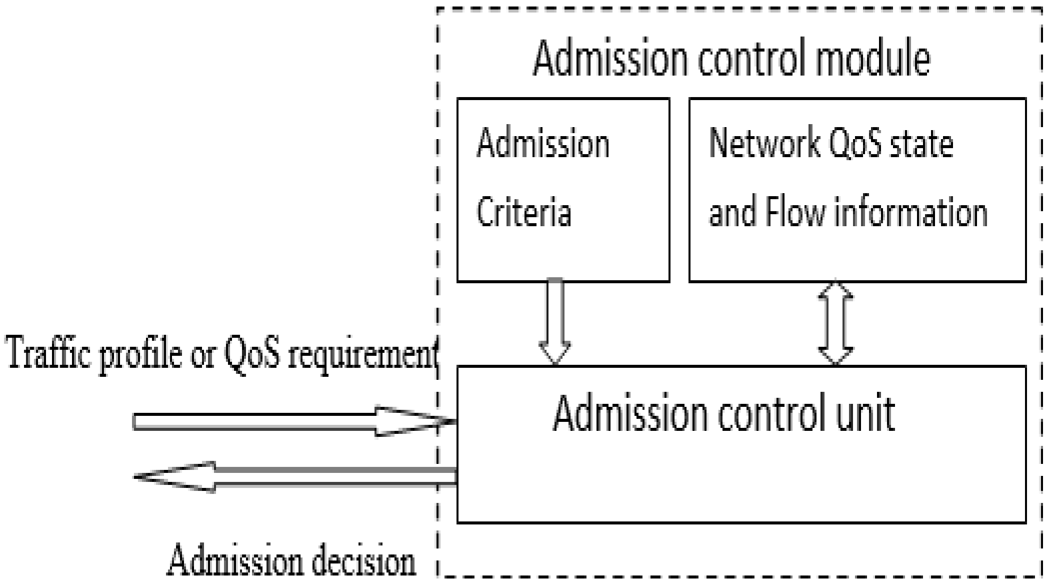

Fig 3-1: Basic Architecture of Admission Control [16]

Purpose of connection Admission Control in WiMax:

CAC plays a very important role in WiMax network. How and why CAC is important in WiMax network can be seen from below:

- CAC manages the radio resources of WiMax as it is shared network.
- CAC regulates the new connections in order to ensure the highest level of QoS
- CAC ensures the minimum data transmission rate
- CAC guarantee the minimum requirements for quality of the connection

3.1.2: Basic components of Connection Admission control (CAC):

It is necessary to consider some challenges like managing concurrent calls while designing the CAC mechanisms. Soft handoff of continuing connections and upcoming new connections have to be faced as the first challenges of connection admission mechanism. In the quality assurance scenario blocking the new connection instead of terminating the existing connection is more preferred.

The decision of CAC relies on the three basic components [13].They are:

1. Traffic descriptor
2. Admission criteria and
3. Network Quality of Service (QoS) and flow information

CAC mechanism decides whether to deny the flow or to admit the flow based on the input where QoS requirements and traffic descriptor are taken as an input for admission control module .In order to admit the flow the QoS state has to meet otherwise the flow is rejected. Traffic descriptor performs on the base of parameter and it takes source traffic parameters as its decision making components. Admission criteria are a setup of rules, proposed by the Connection Admission Control algorithm [13].

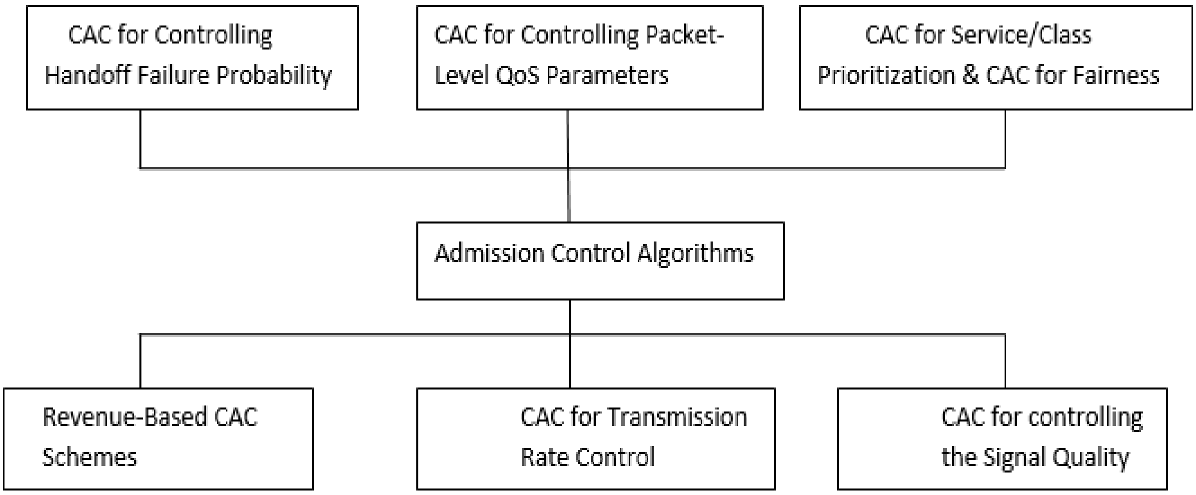

Fig 3-2: Traditional CAC Algorithms in WiMax Networks [13]

3.1.3 Parameter based and Measurement based Admission Control:

Parameter based admission control is a primary admission control scheme; it computes packet loss or worst case delay and uses traffic profile of the new and existing flows for the information, on the base of that makes decision. It follows the explicit traffic descriptors approach where token bucket acts as a typical descriptor and limits the traffic level over any period. In the high traffic condition, parameter based admission control is not sufficient to cope with the situation where it is not possible to describe the characteristics of traffic and reduce the utilization of network [15]. Due to insufficiency to handle high traffic of parameter based admission control leads the requirement of Measurement based admission control. In 1995, S.Jamin, P.B dazing, S.Shenker and L.Zhang had proposed the Measurement based algorithm (A Measurement based Admission Control algorithm for Integrated Services Packet Networks).This algorithm is divided into two parts:

- Measurement that estimate the current network load and
- Admission Control based on estimated load [15].

3.2: Adaptive admission control

Researchers Chiapin Wang, Hsin-Chi Lin and Hao-Kai Lo has proposed CAC scheme in their paper [16]. In general the adaptive scheme is based on the priority where real time traffic gets more priority over non real time traffic. In the paper [16] the authors assumed the equal possibility of occurrences of all service classes. The proposed CAC scheme dynamically adjusts the amount of reserve bandwidth for handoff and new coming connections.

In [16] the authors propose a CAC scheme that differentiates the connections by its service class. It has three modules: traffic classifier, dispatcher and the CAC Decision Maker. The Decision Maker module is based on the maximum rate for UGS and ertPS connections, the average rate for rtPS, the minimum rate for nrtPS and the average rate divided by 2 for BE connections. A connection will be accepted if: *[(Total bandwidth) – (bandwidth allocated to the current connections) – (requested bandwidth)] > 0.* The proposed algorithm also differentiates the connections by its service classes and uses bandwidth reserves for attending the connections according to service class to which they belong.

The CAC scheme proposed in [16] is based on bandwidth reserves with fixed thresholds. These thresholds split the bandwidth into reserves for the connections belonging to the different service classes. In our proposal, the algorithm also uses bandwidth reserves with thresholds, but their values are not fixed, these are dynamically adjusted based on admissions of the connections.

It is proposed in [23] a CAC scheme with a dynamic bandwidth reserve for handoff connections. This reserve varies according to the admission of new handoff connections and the ending of handoffs already admitted. In our work, the variations of the thresholds are caused by admissions of handoffs as well as new connections.

In [23] the authors propose an adaptive CAC algorithm named AACA - Adaptive Admission Control Algorithm, which dynamically determines the reserved bandwidth for handoff connections according to the arrival distributions of both handoff and new connections. When a handoff connection is accepted, the reserve is extended and when a new connection is admitted, the reserve is reduced. In our proposal, besides the reservation for handoff connections, there are also reserves for new connections of real-time, non-real-time and BE traffic. These reserves allow the differentiation in the treatment of each traffic type, in terms of the amount of bandwidth that is destined for each one. Furthermore, these reserves will change only if their occupation reaches a predetermined threshold value. As a result, more connections can be admitted in the network.

3.3: Measurement based admission control (MBAC)

One of the mechanisms to maintain QoS in WiMax networks is Measurement based admission control algorithm. There are different measurement based schemes which are proposed by the different researcher. In their paper [17] method proposed by authors R.Guuerin, H.Ahmadi, and M.Naghshineh is based on delay factor and measured on equivalent capacity process is distinct from the one proposed by author Randa Ibrahim Aljohani in [13]. In papers [19] and [18] where researchers have proposed admission algorithm based on estimation of network load. In paper [19] the CAC is defined in two various ways, one is based tuning the network load and another is based on estimation average number of free slots.

<u>Components of measurement-based admission control:</u>

Signaling Protocol is necessary to establish the flow. In wireless network signaling protocol acts as the medium between the source node and destination node in order to perform the requests for the resource reservation where request originate from source node and pass to destination node. While sending the request from source node the request must be characterized due to distinct traffic nature in the network. Most of the case token bucket parameters are used to characterize the flow. In order to be an admission control unit all admission control mechanism is controlled centrally. The admission decision algorithm uses the traffic estimator and resources estimators to collect the information about the existing traffic and estimated available resources. The admission decision algorithm collects the information frequently from the network system. The main function of the traffic estimator is to keep the record of the total traffic, traffic characteristic and provide to the admission decision algorithm. The resource estimator frequently provides the information about the available resources [13].

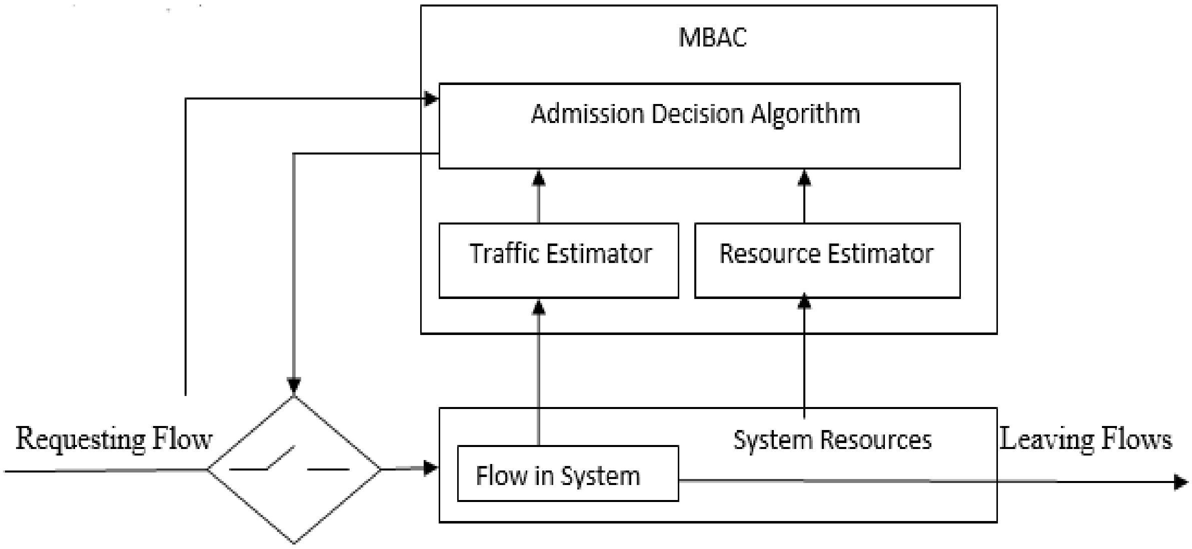

Fig 3-3: Components of Measurement based admission control

“MBAC is an attractive mechanism to concurrently offer QoS to users without requiring a priori traffic specification and online policing" [13]. Comparing MBAC mechanism to support real time traffic and traditional real-time methods, the traditional real-time service provides a hard bound on the delay of every packet in which admission control algorithm uses worst-case analytical bounds as its basis. Because of the bursty nature of network traffic, these types of admission control schemes normally suffer from low network utilization. MBAC; however, can achieve potentially better network utilization. Real-time applications are delay and loss sensitive, yet they can bear some loss and delay; therefore, they are tolerant of occasional QoS violations. Consequently, efficiency in achieving high network utilization can be granted by using the MBAC. MBAC uses actual traffic load measurements and QoS performance to make admission control decisions in which a new call will be rejected if there is no available bandwidth to accommodate it; otherwise, accepting the new call will violate the QoS of the existing calls. MBAC provides a good network utilization and predicted QoS where the network will attempt to assure the requested QoS; nevertheless, it will not provide any guarantee [13]. Real-time applications mostly have adequate adaptability to actual packet delays and are tolerant of occasional delay bound violations; consequently, they do not necessitate a hard reliable bound.

Therefore, real-time applications should utilize the MBAC advantages for their benefit. It was reported in [13] that in a basic structure, a MBAC consists of three components: (1) admission decision algorithm; (2) traffic estimator; (3) resource estimator as shown in figure 3-1 [13]. MBAC extracts its decision based on the collaboration of these three basic components. Each one of these components has its specific function. The admission algorithm obtains frequent measurements from the system such as the estimated available resources and the ongoing traffic information. Basically, the traffic estimator is responsible to provide the admission algorithm with the needed information about the ongoing traffic such as its characterizations and capacity. On the other hand, the resource estimator updates the admission algorithm with the remaining recourses in the system. Upon the arrival of a new request, the admission decision algorithm is operated to take a decision regarding the admission of the new request. The admission decision algorithm uses the inputs from the traffic and the recourse estimator as well as it uses some information from the requesting flow such as its quality of service requirement and its traffic description.

CHAPTER 4: METHODOLOGY

4.1: Approaches and methodology used in Adaptive CAC & Measurement based admission control

4.1.1: Methodologies

<u>Adaptive CAC:</u>

In order to identify the problem area more detail existing architecture of the QoS is used and new adaptive CAC scheme is compared with the previous conventional schemes of adaptive by the authors in paper [16] so that better solution for QoS can be provided. The proposed algorithm in [16] paper is based on the adjustment dynamically the amount of reserved bandwidth for handoffs as regards to the arrival connections of new and handoff connections. The motto behind the scheme is to provide the admission opportunities for new connections and provide the guarantee of QoS for existing & handoff connections. In general the incoming rate of the new connections may be much higher than the handoff. Therefore to minimize & avoid the wastage of the network bandwidth in the form of reservation the allocation of the bandwidth should be adaptive according to behavior of arrival of new and handoff connections.

<u>Measurement based admission control:</u>

According to [13] the connection admission decision depends on the two factors, they are total number of ongoing connection and availability of bandwidth. According to the scheme presented in paper[13] new connection is only accepted if there is require amount of bandwidth available to perform new connection or the new connection within the limit of maximum amount of connection permitted in the network. In wireless network measurement of QoS for the real time traffic is based on the packet delay.

4.1.2: A specific methods & algorithms used by Adaptive CAC& Measurement based admission control

Adaptive CAC process:

In the network, distinct kinds of flow need distinct bandwidth .The algorithm which is proposed in the paper [16] has considered two thresholds values (th_{min} and th_{max}) for the reservations of bandwidth to avoid low priority starvation. Minimum threshold value represents by th_{min}

and maximum represents by th_{max}. Although this novel adaptive CAC scheme considers the guard channel policy but deployment of that policy is bit difference from the conventional adaptive scheme based on the fixed thresholds value. According to the relevant paper [16] this adaptive CAC scheme adapts the adaptive threshold for reservation bandwidth which is represented as th_{ad} that adjust within the range th_{min} and th_{max} depending on the incoming behaviour handoff and new connections. But it is initially set as $(th_{min} + th_{max})/2$ which mean minimum value added with maximum value of threshold and result is divided by two. The acceptance of handoff connection depends on availability of bandwidth in the network. In this scheme minimum bandwidth for handoffs are reserved.

As stated earlier for each connection it defines the minimum (th_{min}) and maximum (th_{max}) where total bandwidth (B) is high than maximum (th_{min}) and minimum value (th_{max}). Termination requests for existing connection and arriving requests for new handoff connection effect the dynamic adaption of th_{max} and th_{min}. In fact the dynamic adaption relies on these two factors. In terms of new connection establishment new connections beyond few specific guard channels are blocked. The handoff connections are admitted as long as there is available of capacity in the system. The maximum and minimum threshold values have been defined for handoff in the guard channel.

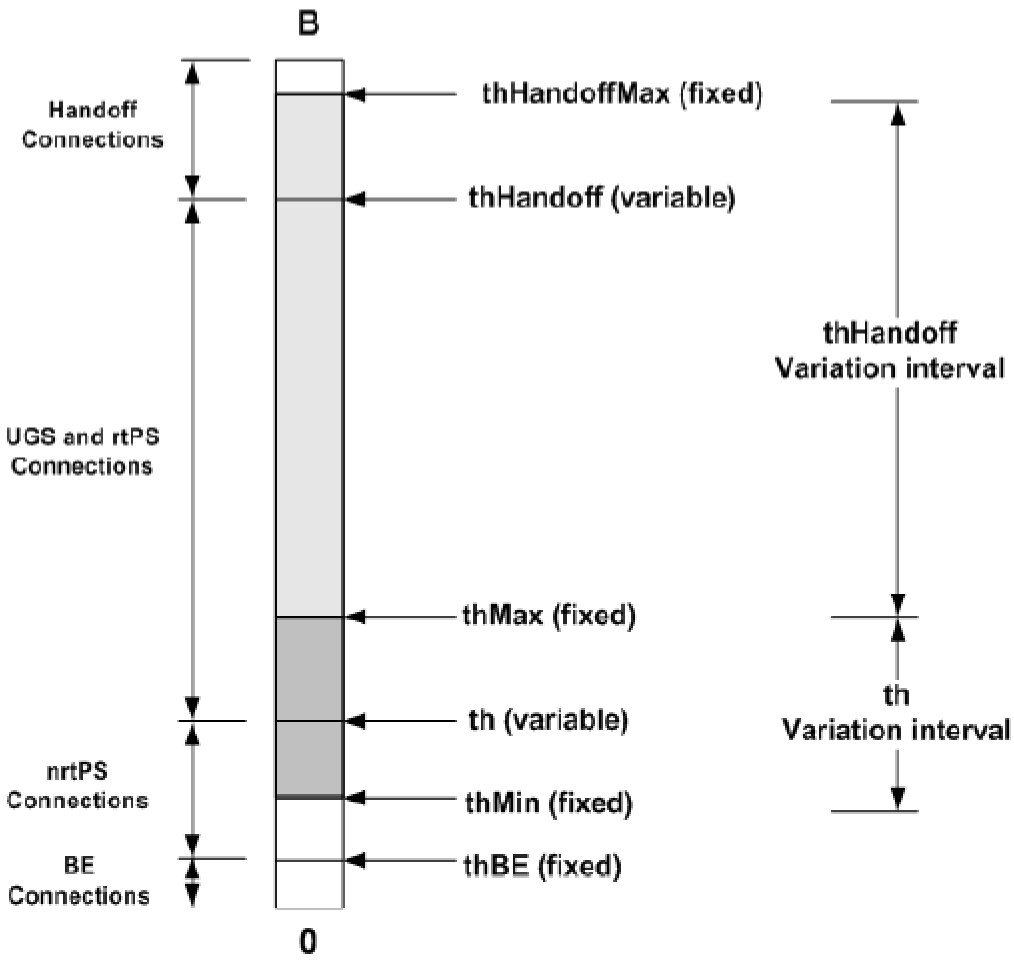

Fig 4-1: Proposed Bandwidth Reservation Scheme [23]

th_{min} = minimum threshold value for handoff
th_{max} = maximum threshold value for handoff
Where, Total bandwidth B is more than th_{min} and th_{max}.

Intially th_{ad} is set as $th_{ad} = (th_{min} + th_{max})/2$

Where, th_{ad} is adaptive threshold of bandwidth reservation that adjusted dynamically inside the range of th_{min} and th_{max} .Handoff and new connections also impacts the adjustment of th_{ad}.

According to this approach the handoff connections are admitted in the network if there is require amount of bandwidth in the network and that satisfies the minimum requirement criteria. The acceptance criteria for handoff are given below in equation form.

$(b_i,h_o+b_n+b_h)<=B$

Where

bi,ho = required bandwidth for handoff connection i
bn= allocated bandwidth for new connections
bh= allocated bandwidth for existing connections

If the above condition is satisfied, the adaptive threshold (th_{ad}) reduces along with the amount of allocated resources of handoff connection. It means

$th_{ad} = th_{ad}-b_i,h_o$

New connection acceptance criteria is

New= $((b_{i,new}+b_n)<=th_{ad}) \cap((b_{i,new}+b_n+b_h)<=th_{max})$ Where,

bi,new = requirement of bandwidth for new connection.

To ensure the minimum bandwidth reservation for handoffs when the new connection criteria are satisfied, th_{ad} increases with bandwidth allocated new connection.

That means

$th_{ad} = th_{ad} +b_{i,new}$

The algorithm which is presented in the paper [16] as follows:

$th_{ad} = (th_{max} +th_{min})/2$

At time epoch t,

forall (pending connections c & service flow i of c) is (UGS, ertPS,rtPS,nrtPS,BE) do if(type is handover and service class is i) then

if($b_i+b_n+b_h<=B$) then

Accept handover

if ($b_i + b_n+ b_h<=th_{max}$) then
$th_{ad}=max(th_{min}(th_{ad}-b_i))$
endif

else //no more capacity in B

reject handover

else //it is new condition

if($b_i+b_n<=th_{ad}$ *and* $b_i+b_n+b_h<=th_{max}$)*then*

accept new

else

reject new

if ($b_i+b_n,<=th_{ad}$)*then*

$th_{ad} = min(th_{max},(th_{ad} +b_i))$

endif

endif

endforall

MBAC process:

In order to make sure the feasibility of QoS provision in WiMax network the author used CAC scheme with the M-LWDF (Modified Largest Weighted Delay First) scheduling algorithm which doesn't allow exceeding the delay level of each flow above threshold value and maintain below it. If delay level of new connection is higher than the predefined delay or closer to predefined delay in that case the request of new connection is denied.

<u>M-LDF scheduling algorithm</u>

In terms of throughput and delay, the M-LWDF algorithm offers two distinct kinds of QoS according to paper [13]. For the real time applications packet delay must be under the predefined value by vendors.

Defined condition

$P_r(W_i>T_i)<= \xi_i$

Where,

W_i=packet delay for individual user

T_i=delay bound

ξ_i= maximum probability of violating delay bound.

Another way to achieve QoS,

$R_i >= r_i$

Where,

R_i =average throughput for each user.

r_i=specified value

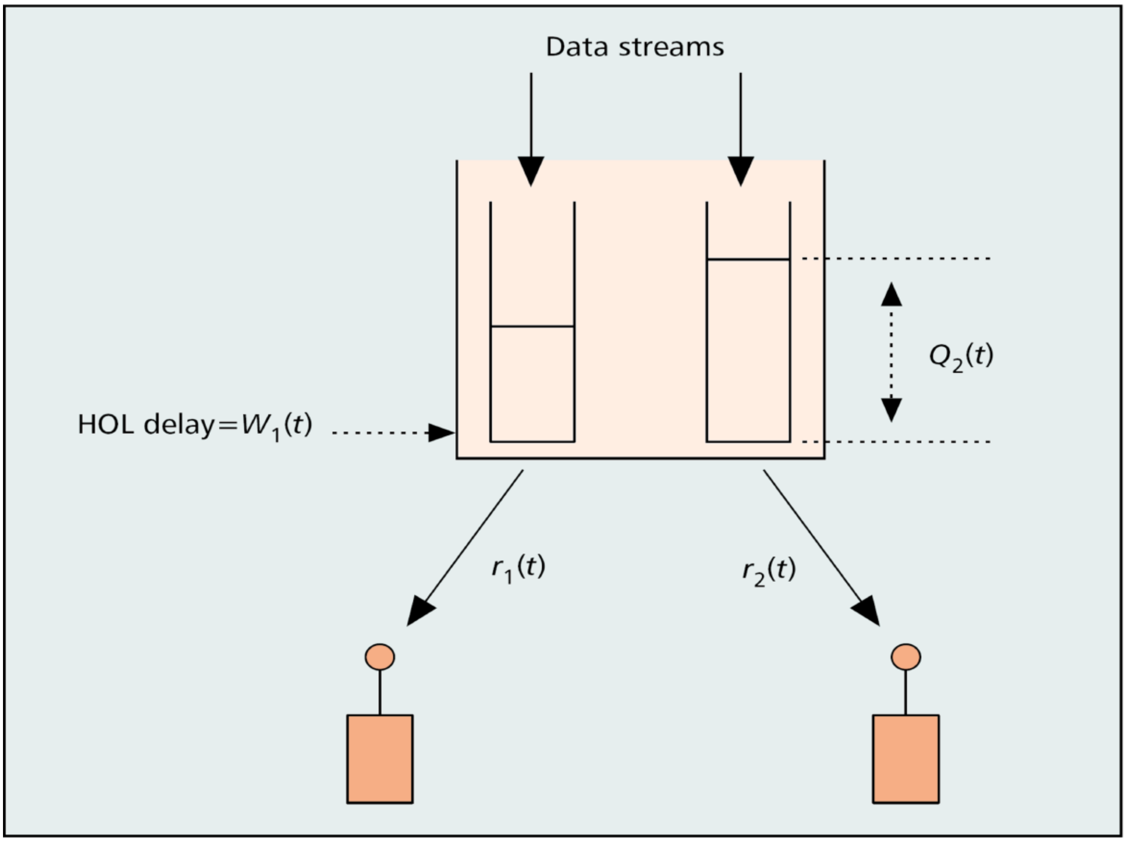

Fig 4-2: M-LWDF scheduler [13]

Suppose that, total number of user in the system=N and data flow can be received by each individual user. Moreover delay requirements of each flow should be steady to maintain the Quality of Service. According to the M-LWDF select user i at a time t. and adds maximum of delay value bound $\gamma_i W_i(t) r_i(t)$.

- $W_i(t)$= packet delay for i user

- $r_i(t)$= the capacity of the channel
- γ_i =arbitrary positive constant, can be distinct for individual user[13]

In the measurement based admission algorithm, the vendors can set the value γ_i according to the requirements of delay for distinct traffic flow. In order to scale the time of arrival packets of data for individual user, the scheduler M-LWDF is used. The M-LDF monitors the present condition of the queue length.

Proposed Algorithm and Simulation Parameters

The measurement based admission control algorithm which is proposed in [13] by the author works with M-LWDF scheduling algorithm and follows the M-LWDF scheduling policy. In this case, author has considered the measurement based CAC scheme for the real time traffic flow like voice. The scheme which is provided in measurement based admission control in [13] can be applied for any kinds of traffic flow. The algorithm which has proposed in the paper is applied to provide the measurement of packet delay for real time existing user in the system.

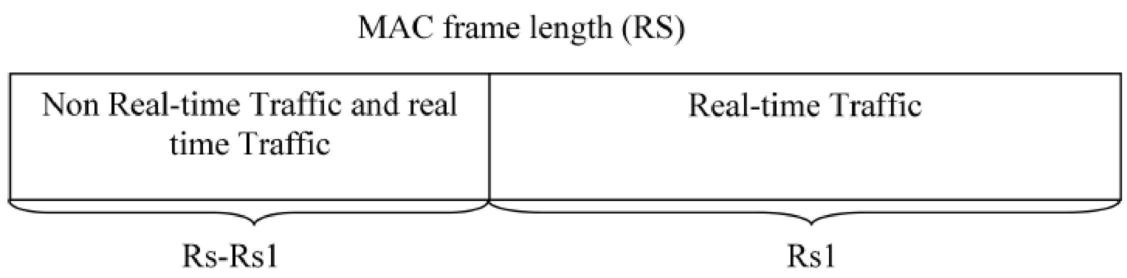

Fig 4-3: MAC frame partitioning

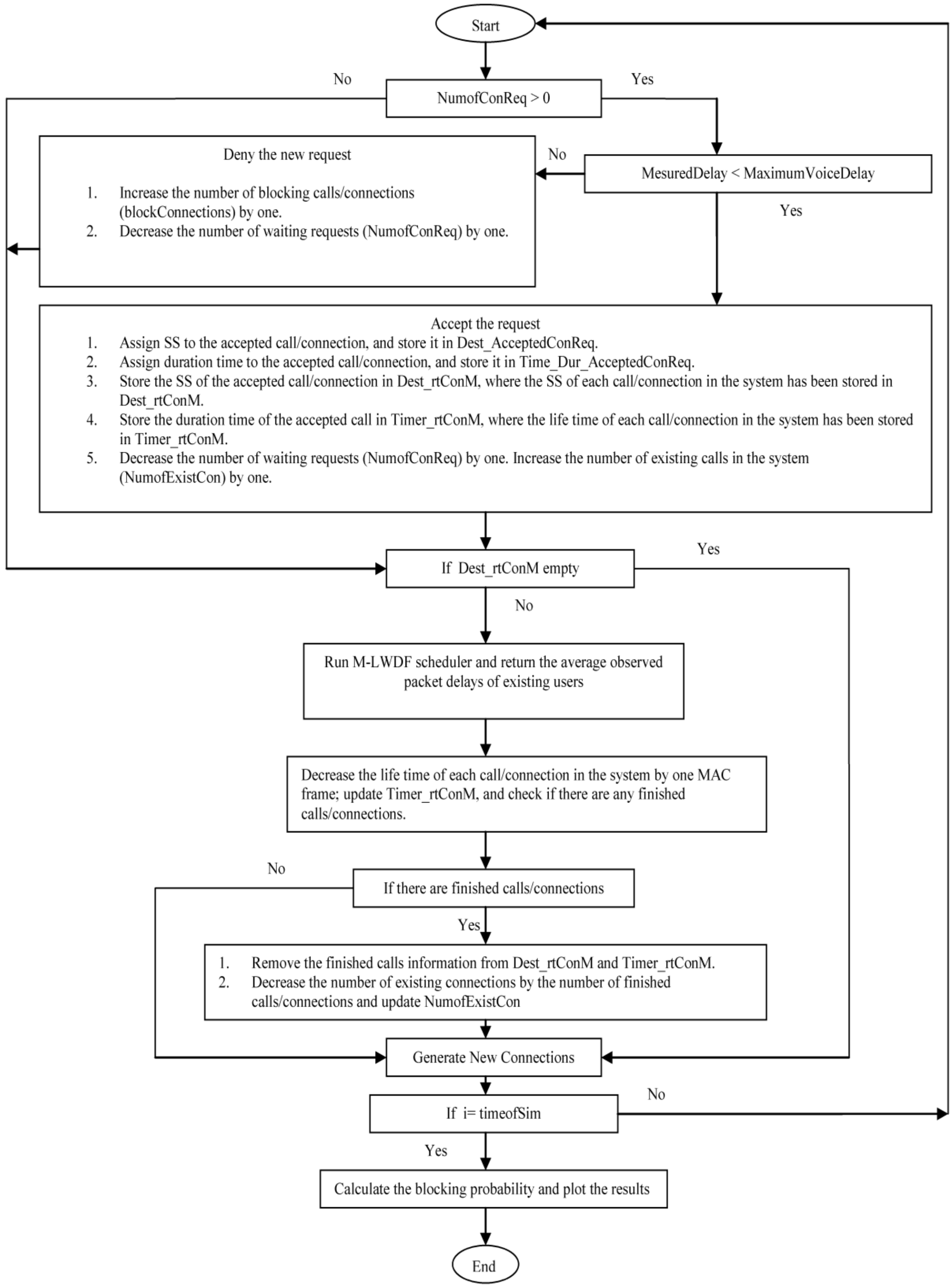

Fig 4-4: CAC algorithms for real time traffic [13].

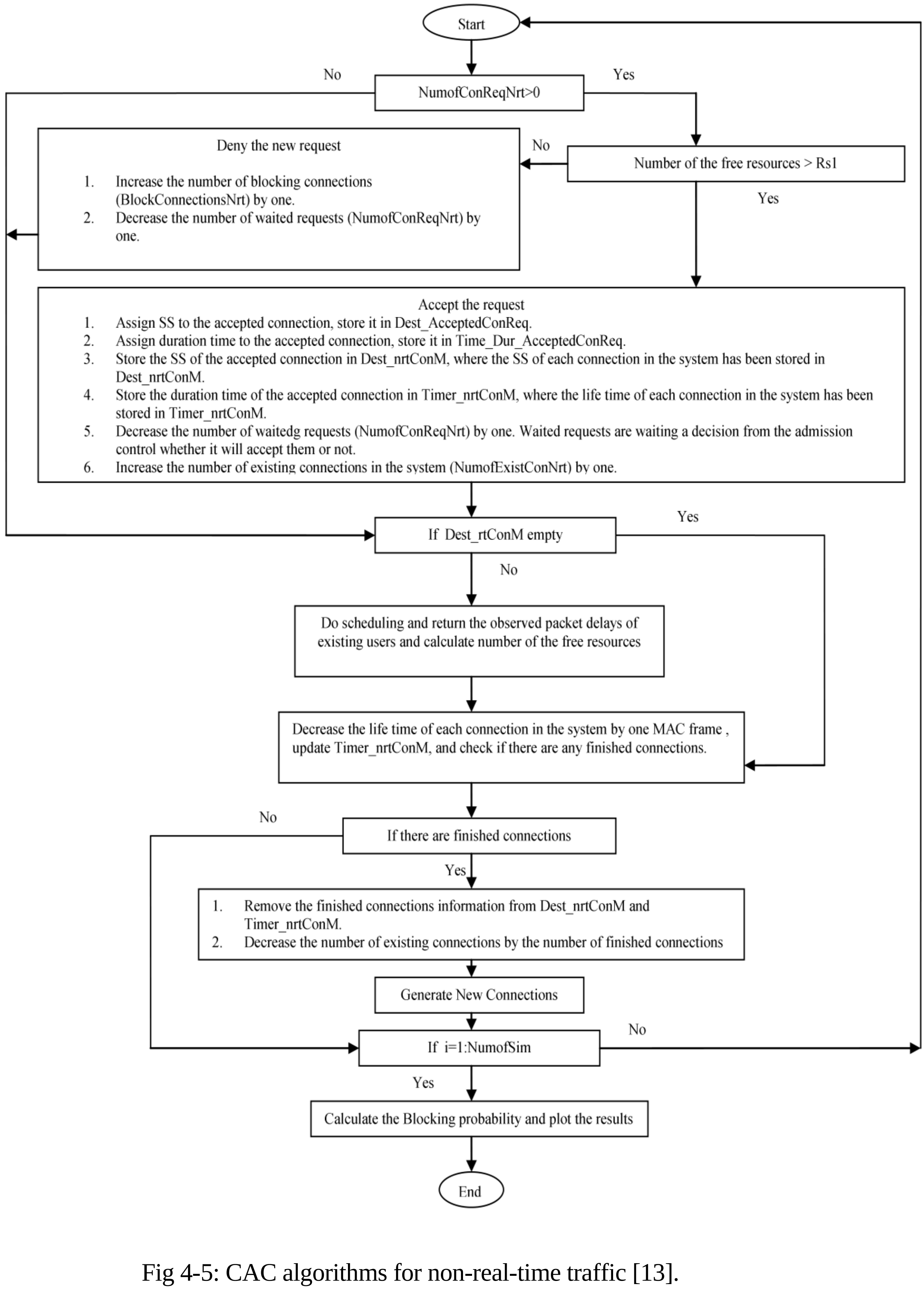

Fig 4-5: CAC algorithms for non-real-time traffic [13].

The above figure shows the measurement of delay for the real time traffic flow. According to the diagram new connection request is rejected by the admission control algorithm when it doesn't match the predefined bound. In this algorithm real time applications get more priority over the non-real time.

The proposed algorithm uses reservation scheme to reduce the rejection or blocking provability for real time traffic .That indicates the exclusively reservation plan for the real time traffic.

The proposed algorithm in the paper [13] by the author is follows:

```
if NumofConReq > 0 then
if (MeasuredDelay < MaximumVoiceDelay) then Accept the request
NumofConReq = NumofConReq - 1;
NumofExistCon = NumofExistCon + 1;
else
Deny the request
NumofConReq = NumofConReq - 1;
Blockconnections = Blockconnections + 1;
endif
endif
if NumofConReqnrt > 0 then
if (number of the free resources > Rs1) then Accept the request
NumofConReqnrt = NumofConReqnrt - 1;
NumofExistConnrt = NumofExistConnrt + 1;
else
Deny the request
NumofConReqnrt = NumofConReqnrt - 1;
Blockconnectionsnrt = Blockconnectionsnrt + 1;
endif
endif
```

“Where variable declare by the author for the algorithm

- NumofConReq = the number of waiting real-time requests.
- MeasuredDelay = the observed average packet delay of existing real-time users.
- MaximumVoiceDelay = the delay bound.
- NumofExistCon = the number of existing calls in the system.
- BlockConnections = the number of blocking calls in the system.
- NumofConReqNrt = the number of waiting non real-time requests.
- NumofExistConNrt = the number of existing non real-time connections in the system.
- BlockConnectionsNrt = the number of blocking non real-time connections in the system.”[13]

Above algorithm mainly focus on the call blocking and packet delay. In order to evaluate the algorithm MATLAB R2013a and OPNET Modeler 14.5 is used.

CHAPTER 5: RESULT AND ANALYSIS

This chapter presents the simulation obtained of the two approaches and evaluates the two approaches based on the relevant papers are presented in this thesis report.

5.1: Result obtained:

5.1.1: Adaptive CAC:

Simulation Parameters

Parameter	Value
Uplink Transmission Rate	10 Mbps;
UGS traffic	CBR Traffic Rate = 96 Kbps;
rtPS traffic	Video Streaming MPEG; Average rate = 480 Kbps;
nrtPS traffic	FTP (Min. rate = 160 Kbps; Max. rate = 800 Kbps);
BE traffic	HTTP traffic (Average rate = 64 Kbps);
Handoff connections	CBR Traffic Rate = 96 Kbps;

Table 5-1: Simulation Parameters for Adaptive CAC

Connection blocking rate:

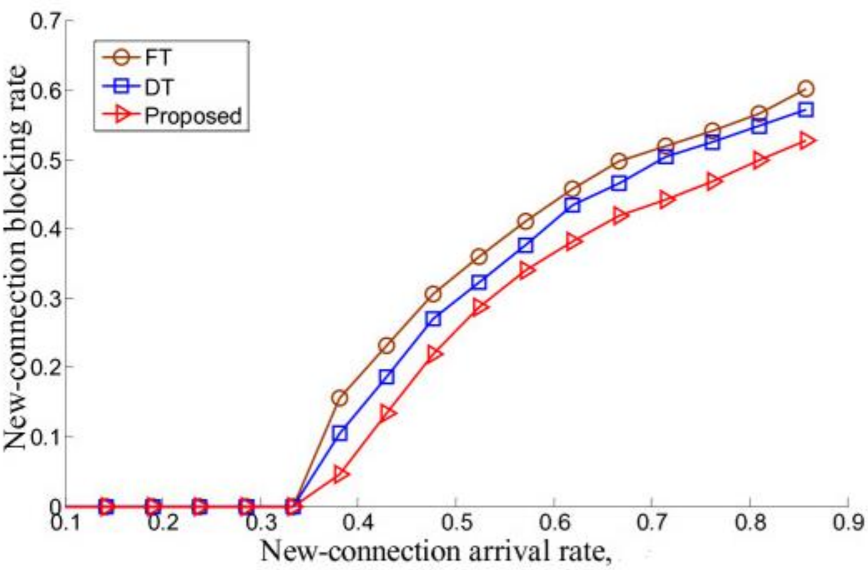

Fig 5-1: the blocking rates of new connections [18]

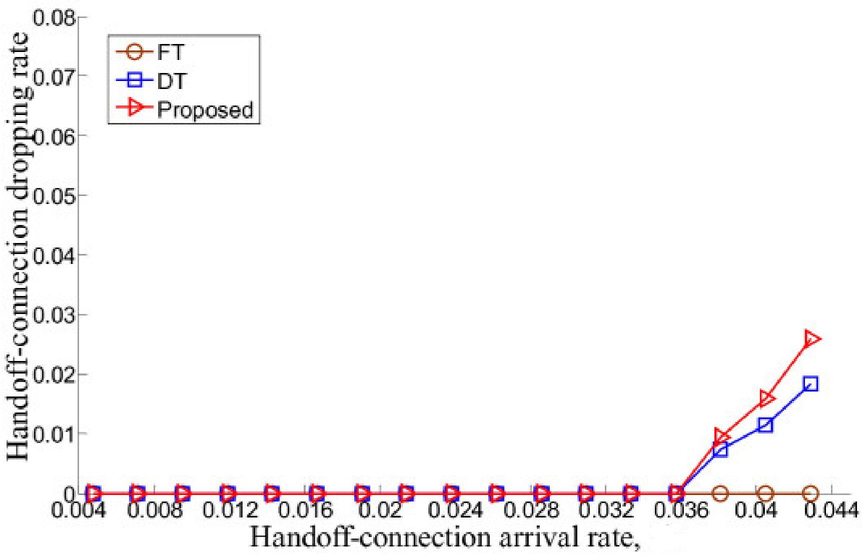

Fig 5-2: the dropping rates of handoff connections [18]

This adaptive scheme proposed on the paper [18] where the simulation time taken as the network load. According to the figure 5-1, 5-2 above in the adaptive CAC scheme the network load is depend on the blocking of connection. At the initial period when the simulation time (network load) is low the blocking is also low but after increase the simulation time or increase load the blocking on the both case has increased.

Figure 5-1, 5-2 shows the new connection blocking rate and handoff dropping rate respectively, when the ratio of handoff arrival rates to new connection arrival rates is 1:20. We can observe that our proposed scheme provides a much lower blocking probability and a slightly higher handoff dropping rate than the fixed threshold (FT) and dynamic threshold (DT) schemes. Regarding this transmission scenario in which the occurrences of new connections are much more frequent than those of handoff connections, the proposed scheme can significantly outperform the two schemes in terms of the amount of admitted connections.

The blocking rate with FT, DT, and the proposed scheme is about 0.54, 0.53, and 0.47,respectively, while the dropping rate with the three schemes is about 0, 0.007, and 0.009, respectively. Consequently, the total number of admitted new and handoff connections with FT, DT, and the proposed scheme is 387, 399, and 442, respectively. The DT scheme grants 12 connections more than the FT scheme, providing a slight increase of network efficiency by 3.20% over the FT scheme. It is shown that the DT scheme provides a rather marginal improvement over the FT scheme when the occurrences of handoff connections are relatively sparse. In this situation, the DT scheme may cause a waste of network resources as much as the FT scheme does. With the proposed scheme, the number of granted handoff connections is almost equal to that of the FT and DT schemes since a bandwidth guard is used in our scheme to ensure a minimum BR for handoff users. On the other hand, the number of admitted new connections with the proposed scheme is much more than that with the FT and DT schemes. Totally, our scheme can grant 55 and 43 connections more than the FT and DT schemes, providing a significant improvement of network efficiency by as large as 14.15 and 10.61% over the FT and DT schemes, respectively. In general when the arrival rates λ ($\lambda = \lambda_h + \lambda_n$) (where λ_n = new connection and λ_h = handoff connection) varies from 0.4 to 0.9, our proposed scheme averagely can increase the network efficiency by 13.09 and 7.93% in comparison with the FT and DT schemes, respectively. The simulations demonstrate that our adaptive bandwidth reservation (BR) scheme can simultaneously grant more new connections to improve utilization efficiency of network resources and also guarantee BRs for handoff users.

5.1.2: Measurement Based admission control:

The result based on the mathematical analysis and used the MATLAB R2013a for simulation.

Simulation Parameters	
Parameter	Value
BS power budget	20 Watt
System bandwidth	$5MHz$
Queue size	10^6 bits
Voice packet size	$66 * 8$ bits
preamble	2 OFDM symbol
FCH	1 OFDM symbol
TTG	2 OFDM symbol
MPDU header	6 byte
MPDU CRC	4 byte
DL-MAP	$9 + 4 * n$ byte
n	Number of transmitted bursts in each DL subframe
OFDM symbol duration	13.891μ sec
Rs1	6 ms
Rs-Rs1	4 ms

Table 5-2: Simulation Parameter for Measurement Based admission control

Packet Delay

Admission control scheme decides to accept or reject a new call based on the measured average delay of exiting calls in the network. The scheduler operates to allocate the resources to the admitted calls. Measured delay is obtained from the scheduler. The measured delay must be less than the threshold of maximum average packet delay to accept a new request. Otherwise the call will be denied.

Figure 5-3 shows packet delay versus arrival rate of calls. Note that the packet delay increases as the number of accepted calls increases. At low system load (arrival rate of calls < 8 calls/ms), the packet delay is low while the delay increases rapidly at medium system load (arrival rate of calls is equal or greater than 8 calls/ms and less than 12 calls/ms). In the heavy load case (arrival rate of calls >12 calls/ms), the packet delay increases sharply; consequently, the CAC scheme attempt to maintain the delay requirement by blocking new calls.

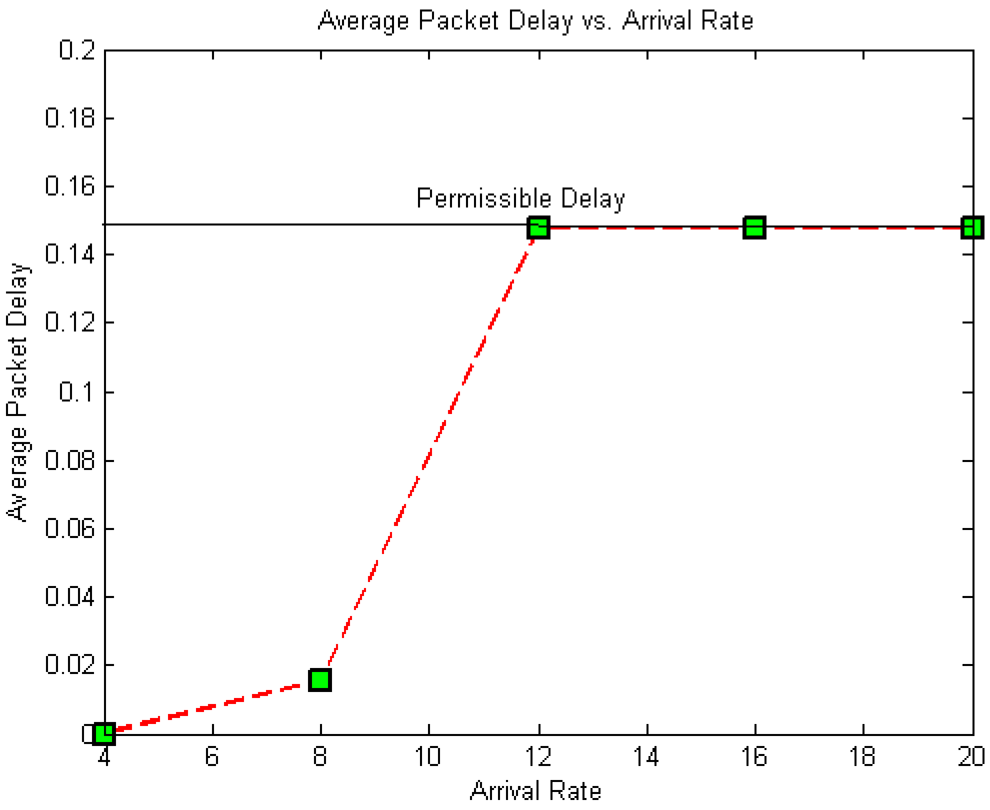

Fig 5-3: Average packet delay Vs Average rate [13].

In this case the scheduler was used to receive the measurement delay where predefined delay must be greater than the measured delay. In figure 5-3 it can be seen the dependency of the packet delay on the number of accepted connection where packet delay rises if the number accepted connection rises. In case of high load the Connection Admission Control algorithm maintains the requirement of packet delay low by refusing connections.

Connection blocking probability

Figure 5-4 depicts the call blocking probability with different arrival rates of calls. Note that the call blocking probability for real time traffic is zero at low and medium system load (arrival rate of calls < 12 calls/ms), which indicates that no new call has been blocked and the existing calls enjoy their requested service. However, in the heavy load case (arrival rate of calls > 12 calls/ms), the packet delay increases sharply in a way that accepting a new call may violate the network promises in term of the delay requirement. Consequently, CAC scheme attempts to maintain QoS by blocking new calls.

For non-real-time traffic, the call blocking probability is zero at low system load, which indicates that no new request is blocked and the existing connections enjoy their requested service. However, in the medium and heavy load case, CAC scheme starts to block non-real time requests to maintain the promised QoS for all the admitted users.

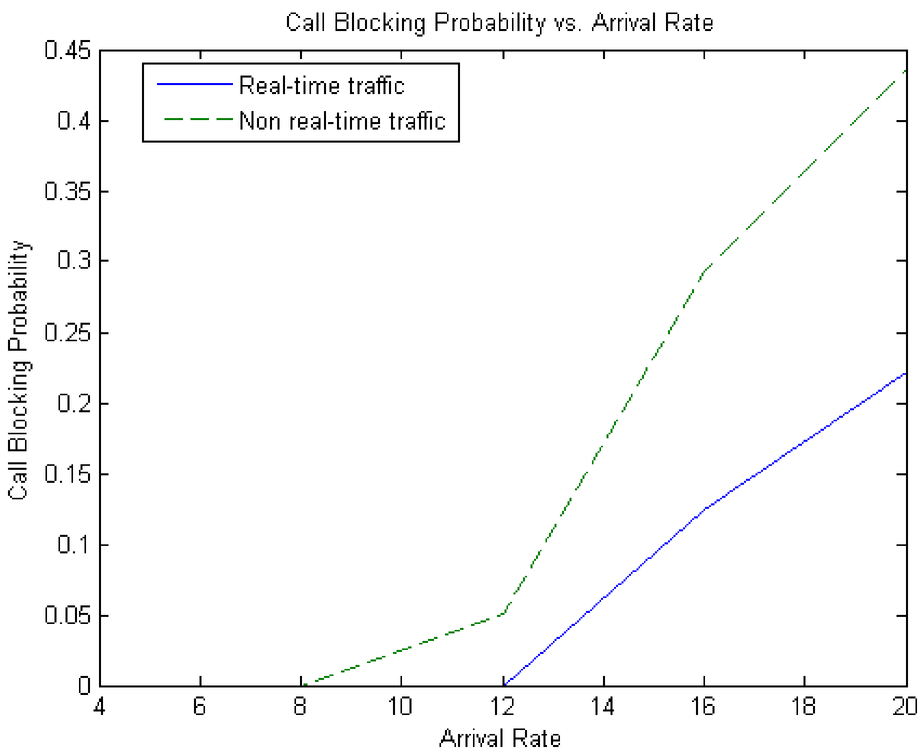

Fig 5-4: Call blocking probability Vs Arrival rate [13].

The blocking probability of connection also depends on the arrival rate of the connection in the real time flow. In the figure it can see that there is low blocking probability for the real time connection when the network has low load. Therefore the probability of blocking new connection in the case of low load is very low.

5.2: Discussion of results

While comparing the simulation result obtained the measurement based admission control has the less blocking rate than the all the adaptive scheme. But the utility of adaptive scheme supports the handoff connections and gives the more priority than the new connections. Furthermore blocking probability of both scheme measurement admission control and adaptive novel scheme depend on the load of the network. (i.e. blocking probability increases with the network load).

.5.3: Analysis

In this project report chapter 3 discuss the two approaches towards the CAC which are proposed by the different researchers. The main focuses of all researchers are based on the two common areas, they are utilization of resources and QoS guarantee but their paths to achieve that are different. The issue is been raised in this dissertation project is to ensure better QoS in WiMax networks, where two groups of researchers are provided their approach for the solution, first group proposed the adaptive admission control algorithm and second group of researchers proposed the scheme based on the Measurement admission control.

Although, adaptive admission control algorithm supports the mobility and handover but it has the issue of proper resource utilization. In the paper [18] the authors tried to solve that issue with their new novel adaptive scheme which is little bit difference in the case of bandwidth allocation from conventional approaches of adaptive scheme. It is somehow better than the conventional scheme in terms of resource utilization according to the result obtained by the authors it is not fully utilize the resources. Therefore there is still issue of utilization of resources remains there. The working pattern of the conventional adaptive admission control algorithm is similar as the measurement based except that the novel scheme which has been presented in [18] supports the handoff process.

The new novel adaptive CAC scheme is little bit difference than the conventional scheme in terms of prioritization and allocation of bandwidth where every data flow has given the equal opportunity to establish the connection. Moreover this scheme is focused on the proper utilization of the resources than the priority. Because of that, there are issues rise in the case of handoff and real time scenario. These two connections should get the higher priority rather than other flows to maintain the QoS in the WiMax. Although the authors of the relevant paper stated that this scheme is vital for real time and emergency situation but there is not any description about the how.

After analyzing overall simulation result of this paper, adaptive CAC algorithm has the higher blocking possibility than the measurement based algorithm. The decision of measurement based admission control always relies on the current traffic status and parameters of QoS. This approach is efficient to adopt because of no need of prior knowledge about the traffic specification. When the new request arrives for connection measurement based algorithm first checks existing or reserved uplink and downlink bandwidth and also checks the minimum require reserve rate of traffic for new connection if require rate is below than the corresponding limit in that case request is accepted. Measurement based scheme has the simple logic but it has some bottleneck problem. This logic bears the risk of resource requirements prediction for next request and it doesn't have any proper solution for the handover issue.

CHAPTER 6: CONCLUSION

This is the final chapter of thesis. It concludes the whole thesis by directing the possible future work of the two approaches and recommends for improvement.

6.1: Conclusions

WiMax is one of the emerging technologies. According to its initial deployment it has promised a lot in the field of wireless networking filed. It is also viewed as the alternative solution for the wired networking because of mobility and large coverage area at low cost. But it has one drawback of limited resources as the other wireless technologies that necessitates the proper management of the resources and QoS guarantee for different applications.

In IEEE802 /WiMax standard there only flow classes are defined there is not any scheme as regards to the managing the resources (limited) and maintaining the QoS that is left to the vendors. Guarantee of QoS in WiMax is open issues on the base that lots of researches have been conducting. According to different research and QoS supports in the WiMax can be maintain the use of effective CAC scheme and scheduling algorithm together. CAC provision in the WiMax is in initial face before that the use of CAC can be seen ATM technology.

Indeed CAC scheme works on two main policies accepting a request and rejecting a request depending on the condition. New request is accepted only when QoS parameter is met otherwise it is declined.

This thesis report has presented Adaptive & Measurement approaches of the CAC based on the base of two papers which has been proposed by the different researchers. The focus of the Adaptive CAC is on the handoff issue and another Measurement is on the proper utilization of bandwidth, delay & throughput. Finally those two approaches are analysed and logically evaluated on the based characteristics of the algorithm and result obtained by the authors.

Although, evaluation and analysis procedure should be based on the simulation result this thesis report is only based on the theoretical analysis.

6.2: Recommendations

Although both approaches towards the QoS provision in WiMax have their own strong point, yet there are lots of scopes remain in both algorithms for future work in order to guarantee the QoS in all circumstances. The CAC schemes for better QoS which has been presented in this project based on two idea blocking and prioritization in the case of lack of enough bandwidth to serve the all requested connection.

In the adaptive CAC algorithm the issue of the handoff is been addressed and to provide the required level of QoS. The main drawback of adaptive CAC is issue of proper network utilization although in the novel algorithm dynamical bandwidth is proposed in order to utilize the more network resource than the fixed allocation. Therefore the future work can be done on that issue So that the entire network can be utilized.

Each individual connection is admitted if there is enough bandwidth and all the requirements of QoS is been met. The presented algorithm which is been discussed in this report on the base of measurement admission control make sure QoS as regards to throughput and delay where delay of packet remains below the certain predefined value. Main drawback of this presented scheme is there is no any provision for the issue like mobility and handoff. Therefore the researcher has to do research on the base of these two very essential issues in this measurement based admission control approach for wireless network (WiMax).

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