# An Efficient Priority Based Adaptive QoS Traffic Control Scheme for Wireless Access Networks

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## ABSTRACT

In this paper, an efficient Adaptive quality-of-service (QoS) traffic control scheme with priority scheduling is proposed for the multimedia traffic transmission over wireless access networks. The objective of the proposed adaptive QoS control (AQC) scheme is to realize end-to-end QoS, to be scalable without the excess signaling process, and to adapt dynamically to the network traffic state according to traffic flow characteristics. Here, the reservation scheme can be used over the wireless access network in order to get the per-flow guarantees necessary for implementation of some kinds of multimedia applications. The AQC model is based on both differentiated service model with different per hop behaviors and priority scheduling one. It consists of several various routers, access points, and bandwidth broker and adopts the IEEE 802.11e wireless radio technique for wireless access interface. The AQC scheme includes queue management and packet scheduler to transmit class-based packets with different per hop behaviors (PHBs). Simulation results demonstrate effectiveness of the proposed AQC scheme.

**Key Words** : Quality of service, Adaptive QoS control, Priority Scheduling, Differentiated Service model, Wireless access network

## I. Introduction

The development of efficient wireless transmission systems is a challenge for modern communication engineering toward the realization of universal personal telecommunication, which will offer access to all kinds of information services at a reasonable cost at any place and time. In the past few years, there have been great demand for mobile communication services and tremendous improvements in wireless technology. With the diversity applications, the Internet has changed from the original experiment research project to a commercial network. It can be predicted that Internet will evolve to become the principal communication medium of the future. As Internet has become one part of our daily lives, people want to have it ready to use not only on the desktop PC but also in their mobile devices. There is increasing pressure to seamlessly integrate emerging wireless systems with the Internet, which is a broad, multidimensional, and challenging problem. Although IP (Internet Protocol) obtained great success in designing Internet architectures, two restrictive elements such as both mobility and QoS still exist[1][2] due to its hierarchy, scalability and simplicity. In order to solve the problem of mobility, mobile IP provides a good solution, because it makes it easy for the fixed IP address configure and allows nodes to continue to receive packets, independently of their connection point to the Internet. One of the 3rd generation systems, CDMA 2000, has been utilizing the enhanced mobile IP in its core network architecture[3]. Meanwhile, QoS is a general term which means that the service user receives a predefined, but not necessarily a constant amount of resources from the network, guaranteeing that the

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논문번호 : KICS2005-04-159, 접수일자 : 2005년 4월 14일
※ This work was supported by Kangnung National University under the 2004 research abroad program

user's traffic is delivered to the destination within the set parameters and performance bounds. The QoS provision is necessary especially when the wireless and mobile network (WMN) providers have to commit a certain level of service to their users including bandwidth and delay[1][4]. There are no guarantees for relative or absolute QoS in traditional Internet, but only CoS may be provided with all network traffic competing for the network resource. The best-effort (BE) model can be used for the service, of which model may induce some impairments. One visible problem is network congestion that causes packets getting dropped and leads to the degradation for real time traffic. Furthermore, real-time applications may be treated unfairly on the congested links by taking excessive resources compared with the self-adjusting data applications.

To solve these QoS problem, many solutions have been proposed by both extending the BE service model and providing guarantees for the selected emerging multimedia applications. Integrated Service (IS) and Differentiated Service (DS) are good examples of technologies that are currently standardized and available in commercial products[5][6]. These technologies can be used successfully for deploying QoS in corporate networks and small portions of the Internet. IS model can provide the dynamic resource allocation and the per flow QoS guarantees[1]. It also provides BE service class as traditional Internet and represents a major advance based on the concept that only end systems maintain flow-related information. However, this model needs to hold state information and hence may fail to scale in the large public domain. Instead of maintaining state information, DS model applies different PHBs specified by DSCP (DS Code Point) in the ToS (Type of Service) field of IP header. DS model[6] has an architecture for implementing scalable service differentiation and can provide scalability by aggregating traffic classification state.

Therefore, we have been devoted to the research of adaptive QoS traffic transmission and control mechanism in WMN environment. In this paper, we propose an AQC service model under consideration of efficiency, fairness and scalability. One solution is to classify all the traffics into different types and then accordingly treat them differently as performed in DS model[6][9]. Scalability is aimed at providing QoS-based services in an Internet-wide scope with neglecting of the real user numbers. Thus it can carry out QoS guarantees including small and large network scales. In order to realize the efficiency the proposed AQC model can use reservation scheme by negotiating QoS requirements between mobile users and the network. Also, it adopts the behavior aggregation (BA) model for achieving fairness.

## II. The QoS service models and wireless access

The primary goal of QoS is to provide priority including dedicated bandwidth, controlled jitter and latency (required by some real-time and interactive traffic), and improved loss characteristics. Also it is important to make sure that providing priority for one or more flows does not make other flows fail. Fundamentally, QoS enables us to provide better service to certain flows. This is done by either raising the priority of a flow or limiting the priority of another flow.

### 2.1 Differentiated Service model

As mentioned before, IS model needs to maintain state information and hence may be unsuccessful to scale in the large public domain. DS model was introduced to alleviate this problem[6][8]. Instead of maintaining state information, DS treats different PHBs specified by DSCP in the ToS field of IP header. It achieves scalability by aggregating traffic classification state for the IP-layer packets in DS network. The aggregation functions are implemented only at network boundaries or hosts: either the user explicitly (or the network implicitly) chooses the appropriate service class for the flow without actually reservation of resources to the individual flows. Because of this aggregation function the core routers in DS network only maintain minimum state information for providing the required QoS. The DS region refers to a set of DS domains. Differentiated services can be offered over paths across those DS domains. The PHB refers to the externally observable forwarding behavior applied at a DS-compliant node to a DS behavior aggregate. According to different kinds of applications, two types of PHB behaviors are defined in DS model[7]: AF (Assured Forward) PHB behavior and EF (Expedited Forward) PHB. The routers in DS domain perform different functions. There are two kinds of routers: boundary router and interior router. The boundary routers are responsible for connecting DS domain to a node either in another DS domain or in a non-DS domain. SLAs (Service Level Agreements) are kinds of contract between a customer and a service provider, which typically cover the issues of QoS service specifications that are to be met by the service provider[9]. TCA (Traffic Conditioning Agreement) is a part of DS SLA. The TCA represents a filter to which the specific SLA is bound. This filter is a classifier separating the traffic stream for processing. In DS region, SLA is mapped to a conceptual network model, which is then applicable to the configuration of individual elements within the network. This requires translation from SLA to a more detailed SLS (Service Level Specification). SLS is defined to be a set of parameters and their values, which together define the service offered to a traffic stream by the DS domain. Also as a part of SLA, the TCA is translated into a DS specific conditioning specification Traffic Conditioning Specification (TCS). The TCS is defined as a set of parameters specifying the traffic profile.

Two kinds of classifiers are defined in DS model. The classifiers may be located in the ingress nodes or interior nodes in DS domain. The classifier located at the ingress node is generally a MF (Multi-field) classifier. The other is BA (Behavior Aggregate) classifier located at the Interior routers: this classifier is performed based on DSCP value. DSCP is a reformatted ToS field of the IP header, which is used to define the class of the packet. This class specifies both forwarding treatment (scheduling) and path selection (routing). Forwarding treatment is a set of nodes defining importance of a class compared with the other classes. Rules characterize the relative amount of resources, which should be dedicated for a particular class in the scheduler, and the packet dropping order during the congestion. Traffic conditioner is used to verify that the offered traffic is in compliance to the agreed profile (subscribed information). The main components of traffic conditioner include: meter, marker, and shaper/Dropper. The meter is used to measure the temporal properties of the traffic flowing and its comparison against those specified in a TCA. A packet in agreement with the TCS (in profile) is treated differently from those that are out of profile. The Marker is used to perform the DSCP marking of the packets. The DSCP value is defined by the SLA between the host and the service provider, and PHB behaviors are decided according to the DSCP value. The shaper is used to delay the packets at nodes where they are active: the dropper is used to discard them. MF classifier will classify traffic from multiple sources, and after this classification process, an appropriate TCS will be assigned to each source traffic. Then, BA classifier is performed based on DSCP[9]. A meter then compares the marked traffic with the traffic profile in the TCS. The conformance status of the packet is decided and as a result, the non-conforming packets are re-marked for lower service-level, or shaped to conform to the TCS, otherwise they are dropped. The policing process is used to delay some or all of the packets in a traffic stream in order to bring the stream into compliance with a traffic profile. A policer usually has finite-size buffer, and packets may be discarded if there is not sufficient buffer space to hold the delayed packets.

The EF PHB is intended to provide a building block for low delay, low jitter and low loss, assured bandwidth, end-to-end service through DS domain. To minimize delay and jitter, the packet serving capacity at the routers should be greater than their arrival rates. The AF PHB is applied to those applications that the traffic out of profile will be delivered with less probability compared with the traffic in profile. It is a mean for a provider DS domain to offer different levels of forwarding assurances for IP packets. Also four AF classes have been defined in each node with allocating a certain portion of the forwarding resources. The packets for the assured forwarding are marked with a code point by mapping them to one of these classes. The packets within the classes can be assigned to one of three-drop precedence.

### 2.2 Wireless access part

The wireless access network is designed to meet some requirements. One of them is to be as independent as possible of what type of packets are being transported with the assumption that packets are forwarded according to their IP header. It is considered to minimize the number of special functions provided in the access network. The access network should limit its functionality for providing IP packet forwarding, independent of upper layer applications. The network layer within the access network should have a generic interface toward the link layer so that the new (and old) link layers may be exploited without wholesale network infrastructure redesign. When the particular applications require the optimized support, they should be invoked and made available in a generic way typically via some sort of QoS aware service interface. All specific features in link layer should be hidden as much as possible from the upper layers. It is desirable for any network to minimize any barriers to technology evolution. This applies equally to upper layer services, link layer technologies, and the components of the access network. The components within the access network should be modular so that different parts may be evolved and upgraded independently.

Our proposed scheme use the air interface technique based on IEEE 802.11e standard. The 802.11e network works by optimizing the existing protocol so that it may support the priority access according to different types of traffic[11]. It has two new schemes for wireless access: Enhanced Distributed Co-ordination Function (EDCF) and Hybrid Co-ordination Function (HCF). The wireless access network may be subdivided into cells (called Basic Service Set or BSS) controlled by a Access Point. These cells are connected through Ethernet to extend the coverage area. The whole interconnected wireless LAN with different cells can be seen as a single wireless access network. The 802.11e draft standard[11] proposed some interesting schemes and there are still some unaddressed issues. These issues are likely to be addressed before the draft becomes a standard. The MAC layer functions include organization of the access to the transmission of data on the radio link, fragmentation, and packet re-transmission.

## Ⅲ. The proposed AQC scheme

The proposed AQC scheme is designed to realize the scalable end-to-end QoS by supporting dynamic resource allocation without excess signaling process. The reservation scheme (i.e. RSVP) can be used for the wireless access in order to get the per-flow guarantees necessary for implementation of some kinds of multimedia applications. Meanwhile, the individual flow signaling and state maintenance will not cause serious scalable problems in relatively small networks. Also, the DS technique is used in core network to provide the service differentiation according to traffic aggregations. It may be a low overhead scalable solution with the simple forwarding treatment. The AQC domain is divided in to three parts: two access parts and one transmission one. Some mapping mechanisms are needed in the borders among them to maintain end-to-end QoS guarantees. In order to cooperate with DS technologies the reservation processing needs to be modified somewhat. Within DS core network, reservation messages are processed only on border routers, which enables to map the access network service classes to proper PHBs. Only when they reach the receiver's access network, the reservation messages will be processed again. Thus, this configuration maintains the flow based end-to-end feature with supporting the scalability from DS model.

### 3.1 Network model and architecture for QoS

The main components of the AQC scheme are mobile terminals (MT), Access Points (AP), Bandwidth Broker (BB), Wireless Access Router (WAR), and Gateway Router (GR). It is assumed that all APs are interconnected to each other with the wireless packet network using IEEE 802.11e wireless radio techniques. Also, mobile terminals are assumed to be reservation-enabled so they can communicate the QoS requirements of the applications to the network by using the reservation requests. The mobile terminals or the routers are assumed to make DSCP marking value. To make the wireless access look like "normal" access through wired infrastructure, the AQC scheme allows a mobile terminal to get an IP address with routing packets to and from this address in a way that looks like any other IP networks. This can be realized by using DHCP (Dynamic Host Configuration Protocol). It can be operated by some extended functions of link layer. This address should be unique instead of being shared, thus packets can be routed to the mobile terminal based purely on an assigned local IP address. Figure 3.1 shows the overall structure and the main components of AQC network model.The wireless access network is designed to meet some requirements as described previous section. Our scheme adopts IEEE 802.11e[12] standard resulted from some modifications to the MAC Layer protocol of the IEEE 802.11 standard.

It works by the way that the priority access can be given to the medium according to different traffic types. The WAR is actually an upgraded DS border router with the functions of supporting reservation signaling and Service Level Agreement(SLA) management. The DS border router is in charge of admission control, QoS negotiation, and marking DSCP for the proper PHBs. To map these service classes to DS networks, SLA negotiations are working between the mobile terminal and the network. The WAR gets the information for the SLAs from the BB using Common Open Policy Service(COPS) protocol.

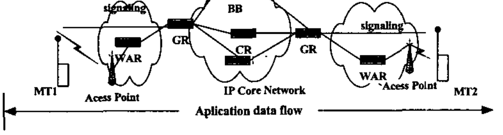


Figure 3.1. Adaptive QoS control network architecture and main components

## 3.2 QoS negotiation and Bandwidth Broker function

The reservation signaling[7] is used to reserve bandwidth before data transmission takes place for the QoS negotiation between the mobile terminals. The reservation takes into account different traffic characteristics. Our system is designed to handle out three different service classes such as GS, CLS, and BE[5]. The GS is used for data flows with strict constraints both in terms of delay and reliability, of which applications don't tolerate QoS variations. The CLS is used for data flows with the conformed streams. The BE offer no QoS guarantees. Reservation messages will then be transferred to the Bandwidth Broker in DS region and data flows will be transferred to the border routers.

The bandwidth broker as an QoS controller can operate so as to propagate the policing and admission control messages to BR. It is used for accurate resources utilization and better provision of end-to-end QoS[12]. The BB stores and propagates to the Border Router some informations related to the network policy and admission control. Depending on the usage model, the SLA management can be handled by periodic broadcasts of the available SLAs. Bandwidth Broker can ask for the admission control decisions each time the incoming explicit QoS request happens. SLA management can be very dynamic. BB is designed as an overlay network for resource management. The overlay network means a "virtual" network created on top of existing network. It creates architecture of a higher level of abstraction to resolve a variety of problems that are very difficult to deal with at the IP-layer.

## 3.3 Design of QoS mapping process

The service request in AQC mode is in the form of a flowspec. When this request is transferred from the access region to the DS region, this flow-based form has to be mapped onto the underlying capabilities of the DS region. Some corresponding functions are needed to perform such kind of mapping: admission control and traffic conditioning scheme before entering DS region. It can select an appropriate PHB in DS region according to the traffic parameters. The BB can perform admission control function purely on the base of SLA, with specifying QoS parameters such as bandwidth delay and jitter. The SLA can work as various policies for the preferential treatment of certain traffic streams. To map the incoming traffics at BB with the appropriate PHB in DS region, we use the cooperation components in the following.

The EF PHBs is used for mapping the GS traffics from the necessary shaping and policing functions, which determine whether they are in profile. The non-conformed packets will be dropped after shaping process, meanwhile the conformed packets will be marked with the appropriate DSCP value. For CLS mapping, when the conformed traffic is received the access network will forward it with a queuing delay smaller than the burst time. Here, the burst time is derived from the TSpec. A single class can then be divided into several sub-classes according to the burst-time and the conforming traffic can be queued into them for the desired QoS. Non-conformed traffic can be treated as BE without affecting the already existing BE traffic. The CLS can be implemented using AF PHB in DS region. At the border router, after the shaping process, the incoming traffic is classified into four delay classes according to their burst time. Each of them is treated by a separate AF PHB. Maintaining an aggregate TSpec corresponding to each class will be used for admission control.

For each AF class, the shaping process performs to determine if they are in profile or not. All conforming packets are marked with the DSCP value corresponding to the mapped AF class with the lowest Dropping Precedence (DP). Non-conformed packets are marked with the DSCP value corresponding to the mapped AF class with the highest DP. Thus, the conformed CLS can be carried out according to the flowspec, meanwhile the non-conformed CLS can be treated as BE packet in access network with highest DP value. These mapping implementation is shown in Figure 3.2.

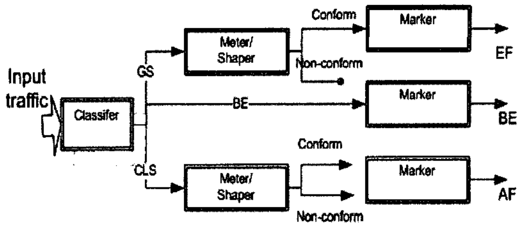


Figure 3.2. QoS mapping implementation framework

### 3.4 Packet Scheduling and Congestion control in AQC model

According to the DSCP values marked, the BA classifier will classify the packets into three classes and maintain them in different queues. So different PHBs will be performed to different classes. Here, some traffic control mechanisms can be used to obtain better QoS with the efficient network resource usages, queue management, and packet scheduling. Also, buffer management and packet scheduling mechanism are implemented here to organize the order of transmission packets. Based on the analysis of various scheduling schemes, the adaptive scheduling with both PQ and WFQ is implemented in the proposed AQC as shown in Figure 3.3. As this figure shows, a priority scheduler treats EF PHB (GS) packets while a weighted fair queueing handles out BE PHBs and AF PHB (CLS). PQ scheduler can add the smallest delay to the packet forwarding and it thus can satisfy the delay-sensitive characteristic. Therefore, the proposed AQC scheme can operate adaptively according to the three types of traffic flows.

The congestion control of the AQC scheme is performed as the following: First, GS packets do not need congestion control as they benefit from a PQ ensuring router. Associated with a drop of out of profile packets, this guarantees without congestion will occur in routers of GS queues. Second, CLS packets need congestion control function. As the opportunistic traffic is admitted to the network and the amount of CLS packets cannot be known as a priori, the congestion will occur. Here, the Leaky-Bucket Token Buffer (LBTB) is selected as the component to allow drop of opportunistic packets.

The CLS packets will enter a leaky bucket (LB) for the regulation of the opportunistic packets. The LB is like a FIFO buffer where CLS packets can wait the token to begin the standard LBTB operations. The CLS packets can be stored in the

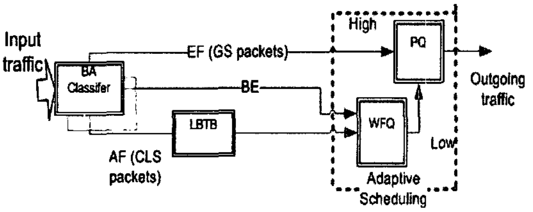


Figure 3.3. Adaptive scheduling implementation

LB only if this buffer is not full. The LBTB parameters can be set consistently with the profile so that the packets admitted by the LB can be only conformed. The conformed packets are stored in high priority queues of the scheduler, while those overflowed packets are not discarded and will be stored in low priority queue instead.

## Ⅳ. Performance Evaluation

### 4.1 Simulation model and scenario

In order to analyze the performance of the AQC model, two aspects such as fairness and efficiency are considered. Fairness is measured by the received bandwidth and efficiency is measured by the average delay and throughput. The average delay is the queuing delay that a packet encounters in the router. Though there also exists the delay jitter defined as the difference between the packet delays of two consecutive packets we assume that this factor has little influence to performance evaluation in this simulation. The throughput is measured by the ratio of the packets number of the outgoing traffic and the incoming traffic. In order to evaluate the performance of proposed scheme, we have carried out our simulation with AweSim simulation package (version 3.0 by Symix systems, Inc.).

The network model for simulation is shown in Figure 4.1. The interior(core) routers perform the DS functions in the AQC model. The traffic flows with different QoS requirements are classified into GS, CLS, and BE after the QoS negotiation. Before entering the core DS network, the border routers(BR) of DS network prepare to perform admission control, traffic conditioning and QoS mapping. After the traffic conditioning process, the non-conformed packets will be dropped. But the conformed packets will be marked with appropriate DSCP values, i.e., EF for GS flows. As mentioned in previous section, the GS packets will be forwarded by EF PHB, while the CLS packets will be implemented by AF PHB. Then the proposed packet scheduling scheme will perform at router 1(R1) in order to control the packet order and the usage of the buffer space without congestion. Here, the priority scheduler decides the order of outgoing traffic. We will investigate this impact on traffic QoS parameters.

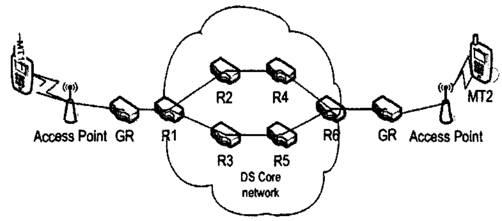


Figure 4.1. Simulation network model

It is assumed that both the arrival pattern and the connection duration have exponential distributions. The session transmission rate is set to 4 Mbps and the maximum packet length of each session and the whole network are set to 1000 bytes. Also, we use some values of parameters as follows. Hop number is 6, the number of the maximum connections is 8, each link has bandwidth of 10Mbps, and the average packet generation intervals are 0.3, 0.5, 1.2, 2, and 5 respectively.

### 4.2 Simulation Results and discussion

First, we will evaluate the fairness of the AQC model for the bandwidth allocation. It is mapped to the link utilization defined as the ratio between the sum of all the reserved bandwidth and the sum of bandwidth along all the links. The link average utilization is shown in Figure 4.2. Here, the link_GS means the link for transmit GS packets and similarly the link_CLS means the link for CLS packets. The analysis of the difference between link_GS and link_CLS gives notice that the minimum difference is 16.5% while the largest one is 29.5%. Therefore, the results show that the link utilization increases with the arrival time for the short, while the link utilization decreases for relatively long arrival time.

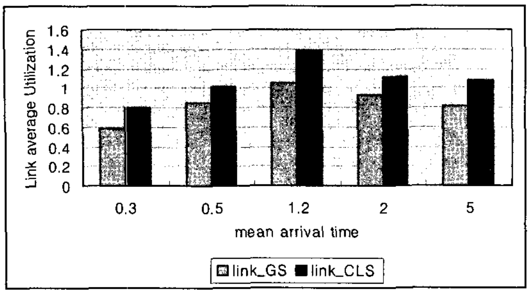


Figure 4.2. Link average utilization

Next, we'll examine the efficiency of AQC model measured by the delay performance and throughput. First, we will examine the average delay of each node for GS packets and CLS packets respectively. Two packet scheduling schemes are implemented by using both the priority scheduling and the fair scheduling. Then the average delay of the AQC scheme with priority queuing is examined by classifying as two priority classes: class I and class II. Also, the end-to-end delays resulted from the AQC with priority queuing are compared with the values for the case with fair scheduling. Packets are assumed to arrive at the corresponding queues according to independent Poisson process with various rates. The service times of class i packets are independent, identically distributed, and stochastic variables. In the simulation work, AQC and FQ functions are implemented respectively at router 1 (R1). The QoS parameters are compared between two kinds of routers such as the router with PQ scheduling and the other router. Figure 4.3 shows the average delay of each router for CLS packets. This results show the difference between AQC and FQ for CLS packets implemented by AF PHB. The end-to-end delays with AQC and FQ are showed in Figure 4.4. When the arrival duration is very short and the traffic density is heightened, AQC performance is much greater than FQ performance. With increasing the arrival time and the traffic density is lightened, the AQC performance may degrade.

Figure 4.5 shows the throughput comparison of AQC and FQ. These simulation results make clear that the throughput performance of AQC is better than FQ. When the arrival duration is very short and the traffic density is heightened, the packet loss of

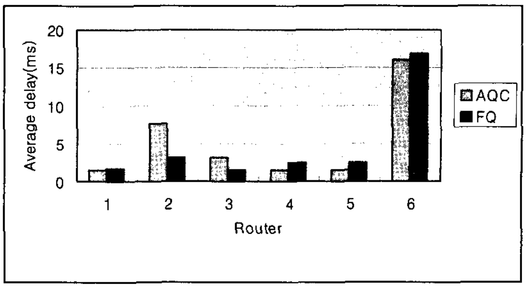


Figure 4.3. The average delay of each router for CLS packets

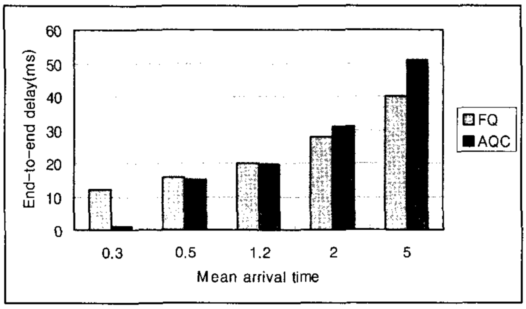


Figure 4.4. End-to-end Delay according to mean arrival time

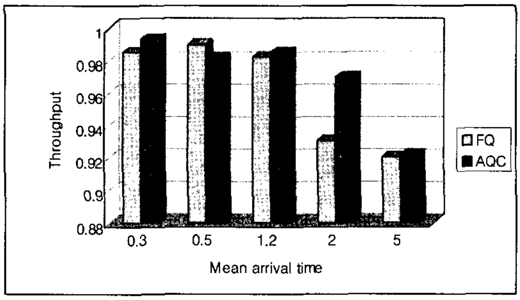


Figure 4.5. Throughput comparisons between AQC and FQ

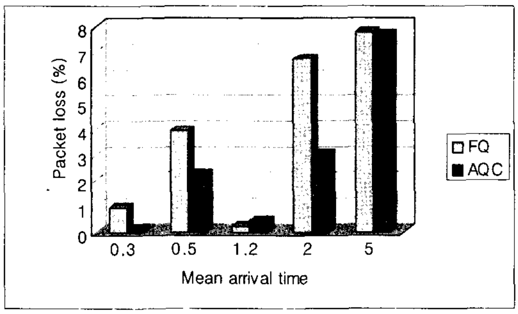


Figure 4.6. Packet Loss comparisons between AQC and FQ

AQC performance approximate close to zero, thus for real-time traffic, AQC scheduling can meet the near-zero packet loss probability. Figure 4.6 shows total packet loss of AQC and FQ respectively. These simulation results show that AQC scheduling performs very well for real time traffic on two aspects: the delay performance and the packet loss performance. Thus the efficiency characteristics of AQC model has been validated. Therefore, it may be considered as design idea that FQ may be used for a scheduler for CLS packets. However, after this scheduling process, GS packets must be scheduled by a priority scheduling. This design idea considers that GS packets requires absolute bounded delay and zero packet loss, meanwhile CLS and BE packets are not so sensitive to delay but required low packet loss.

## V. Conclusion

The major characteristics of the next generation networks can be described as the open IP enabled services and applications, the single consistent multimedia network infrastructure, the multimedia service with high quality of service, and finally the access technology independence. Such kinds of system will have to incorporate a wide range of radio access technologies to provide seamless service for users with high mobility and support high throughput. This paper has focused on the QoS provision problem in wireless access network. Here, an AQC model was proposed under consideration of efficiency, fairness and scalability. Also, the efficient queue management scheme was introduced for QoS provision. The proposed AQC scheme is to classify all the traffics into different types and then accordingly treat them differently as performed in DS model. To realize the efficiency in AQC model, the reservation scheme can be used to negotiate QoS requirements between mobile users. Also, the behavior aggregation based scheme is used for the purpose of fairness. The simulation results show that the proposed AQC model with priority scheduling scheme can perform very well by providing the short delay and near-zero packet loss. Thus it can meet the QoS requirements of GS packets. For CLS packets and Background packets, the AQC scheme can provide high throughput, but the delay performance may be a little less than the FQ performance. Therefore, GS packets are scheduled by a priority scheduling from the idea that GS packets require absolute bounded delay and zero packet loss, while CLS and Background packets are not so sensitive to delay but required low packet loss.

For the further study, we will devote to the research of more efficient traffic management mechanisms to cooperate with next generation networks including the extension of the service coverage area.

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<Current research interests> Design and analysis of high-sped high-performance networks, QoS provisioning in wireless networks