Design and Deployment of QoS Enabled Network for Contents Businesses

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Abstract

Major contents businesses like TV broadcasting and commercial (CM) production can use the Internet if quality of service (QoS) is guaranteed. For providing guarantee of QoS on the Internet, the differentiated services (DiffServ in short) architecture is preferred due to its advantage of scalability. Especially for mission critical applications like real-time video stream, the absolute guarantee of QoS like a virtual leased line (called Premium service) is necessary and gives an affordable solution.

In this paper, we show a new design of QoS enabled network and its deployment which can provide Premium service to contents businesses. We set focus on two typical contents businesses, TV broadcasting and CM production which deal with multimedia contents. First, we introduce a contents business model in case of using the Internet for its contents transmission, and clarify the requirements from the network to provide guarantee of QoS. Based on these, we design a QoS enabled network to provide Premium service by introducing DiffServ compliant routers and a resource management system (a bandwidth broker). A bandwidth broker centrally manages all resources (primarily bandwidth) in a DS (DiffServ) domain by performing admission control.

We deploy the designed QoS enabled functions to the testbed network which connects some real broadcast stations, production companies, and end users through ATM network. On this network, we plan several experiments to check the guarantee of QoS required by the applications for the real business cases.

The main advantage of our design is that, it provides scalable centrally controlled management of network resources on the Internet. This project is the first step in order to find an appropriate and affordable solution of QoS mechanism on the Internet for the contents businesses and also to promote new businesses on the next generation Internet.

Keywords QoS, bandwidth broker, policy, differentiated services, premium service, multimedia contents business
1 Introduction

A contents business dealing with the production, distribution and delivery of multimedia contents is one of the most promising businesses of the next generation Internet (NGI). For example, a broadcasting company may deliver its programs including audio and video via the Internet as well as via TV/radio broadcasting, satellite or cable TV. However, the best-effort service provided by the current Internet will not yet satisfy the requirement from contents businesses with mission critical applications. Therefore, some new mechanism for guaranteeing quality of service (QoS) will be required for these specific communications over the Internet.

The discussion of provisioning of QoS in the Internet is just underway. There are two proposed mechanisms in IETF for provisioning QoS on the Internet, the integrated services (IntServ) [1] and the differentiated services (DiffServ) [2]. DiffServ architecture which provides QoS on hop by hop basis is being paid rapid growing attention in the Internet community. DiffServ architecture has advantage of its scalability because it deals with not per-flow but aggregated traffic, and it is suitable for the structure of the Internet. In order to apply this architecture to contents businesses, there is a need of some additional mechanism that must accomplish a low loss, low latency, low jitter, assured bandwidth, end-to-end service through network domains. Such a service appears to the endpoints like a point-to-point connection or a virtual leased line. This service has also been described as Premium service [3].

On the other hand, since most of the research and discussion about the DiffServ based QoS model is mainly going on in the academia, it is still unclear whether it is an affordable solution for the real businesses. And it is also unclear how absolutely the QoS must be guaranteed or what kind of problems may occur during actual QoS management. To investigate these problems and then solve them, we introduce a new design of a QoS mechanism for the real contents businesses, perform its deployment to an actual network, and do experiments which cover QoS from the network level up to the application level. Our design is based on the DiffServ architecture and provides Premium service with a guarantee of assured end-to-end bandwidth and corresponds well with the major contents businesses like TV broadcasting and CM production. Through experiments on our designed QoS enabled network, we also investigate the feasibility of the DiffServ architecture for contents businesses. The project mentioned in this paper is to be achieved by the NGI-WG in the Cyber Kansai Project (CKP) 1.

The rest of this paper is structured as follows. In Chapter 2, we explain the target model by first describing contents business model and then the DiffServ based QoS model. In this chapter, we describe how the DiffServ based QoS model can be used by the contents businesses to get guarantee of QoS. In Chapter 3, we explain our proposed design of a QoS enabled network and in Chapter 4, we evaluate this design through discussion. In Chapter 5, we state the deployment of QoS enabling modules to an actual network. In Chapter 6, we conclude our paper.

2 Target Model

In section 2.1, we introduce the contents business model and its contents exchange mechanism. Based on this model we clarify the requirements of contents businesses from the network regarding guarantee of QoS and therefore design a QoS enabled network. We show in section 2.2, that the DiffServ architecture is suitable for this purpose, however, it needs a supporting resource management mechanism to accomplish the Premium service.

2.1 Contents Business Model

We define contents business in this paper as the one that sells contents and provides various other services using contents. A TV broadcasting company is one typical example of doing such business by broadcasting high value contents as TV programs, commercials (CM), etc. These businesses have much in common, for example, they provide high value contents with multimedia features. Obviously, if these businesses use the Internet to exchange their multimedia contents, they can substantially bring down costs and become easily affordable for common users.

Let us now analyze the contents businesses. Contents businesses need to exchange contents at various stages of contents development, for example, during co-production or co-editing among producers, contents distribution to the contents providers, and delivery/ broadcasting to end users. The content flows among different players in the contents businesses can be broadly categorized as follows;

1. Contents producers and contents providers exchange source data or content products with each other during production phase, and
2. Contents provider sells, delivers or shows (broadcasts) contents to end users in the final delivery phase.

In addition to the players and business transaction stated above, the network service provider also plays an important role in the contents business over the Internet.

From the above analysis, we here propose a model consisting of these factors for contents business over the Internet as shown in Fig. 2.1. It shows that the network has to satisfy various demands from players of contents businesses. These demands originally represent the required level of service during transfer of contents based

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1 CKP is an independent initiative which consists of business, government and academic people. Its twin aims are; to further the development of advanced Internet utilization, and to transfer its benefits to broad segments of society.
on agreement between business players, which means a service level agreement (SLA) on network services. Such SLAs on real business should be mapped to the SLAs between each player and the network service provider in the NGI. Each SLA may result in demands for various levels of services on the network, therefore, the network service provider should be able to support these services by providing guarantee of QoS.

**2.2 DiffServ based QoS Model**

DiffServ architecture is based on a simple model where traffic entering a network is classified and possibly conditioned at the boundaries of the network, and assigned to different behavior aggregates. DiffServ provides classification of packets at the router by marking the DS field (DS codepoint) in each IP packet [4]. Each packet receives a specified forwarding behavior by its marking called per hop behavior (PHB). Until now, two PHB are proposed, one is Assured forwarding (AF in short) and the other is Expedited forwarding (EF in short). The EF PHB can be used to build a low loss, low latency, low jitter, assured bandwidth, end-to-end service, that is a Premium service, through DS domains [2].

However, DiffServ does not define the mechanism to realize Premium service. It leaves the design and implementation of this mechanism to the service providers. Therefore, we attempt to design and implement a support mechanism to provide Premium service (see Fig. 2.2). In section 2.2.1 and 2.2.2, we explain the basic functions of this support mechanism.

2.2.1 Bandwidth Management

The management of bandwidth in a DS domain is necessary for Premium service. Note that the loss, latency, and jitter all directly depend on the available bandwidth. The bandwidth management can be achieved by performing bandwidth reservation in a DS domain. The reservation is performed for each flow according to the required amount of bandwidth and time to actually use it: time to start using it and quit it. This successfully provides continuous stream communication with bandwidth required while the communication is active. Note that this allows users to reserve the bandwidth for future use as well as to use it immediately after their request. A renegotiation of reservation in terms of the amount of bandwidth and the time period of the reservation is also necessary. A contents service provider must be able to cancel a reservation at any time he desires, that is, before actual utilization or during usage of reserved bandwidth.

2.2.2 Policy Management

A policy describes the overall business functions to be accomplished, while a set of policy rules defines how those business functions will be met. A policy rule defines a sequence of actions to be initiated when a corresponding set of conditions is satisfied. Policies are considered to be a link between a high-level business specification (e.g., SLA) of desired services and low-level device configurations which provide those services [5].

The Premium service can be used by the contents businesses, if it can realize the implementation of different service level agreements (SLA) or policy as shown in Fig.2.1. The bandwidth management and policy management are implemented here as separate modules, which enables contents business companies to use both or only one of them depending upon their requirement.
We see from Fig. 2.2 that this system receives a request on a per flow basis but manages the network on an aggregate basis. Since it has been shown that scalability of a design is the main concern, our design must scale well besides fulfilling the above stated requirements.

3 Design of QoS Enabled Network

In this section, we show our fundamental design of a QoS enabled Network.

3.1 Overall Architecture

As stated in Chapter 2, bandwidth is a primary resource in the network for the contents businesses. The guarantee of QoS in terms of bandwidth can be provided if we use Premium service and manage bandwidth in the whole network using a bandwidth broker [6]. To provide guarantee of bandwidth in Premium service, we propose a bandwidth brokering mechanism which controls the total bandwidth used by each flow (See Fig. 3.1). The Bandwidth Broker (BB) in our proposed system further controls the total bandwidth that can be used by the Premium service users so that traffic from other service (for example, best effort) users may not get bogged down. To use Premium service, an application must consult with BB every time it wants to send data.

3.2 Bandwidth Broker

A BB manages all network resources (primarily bandwidth) in a DS domain. BB is responsible to:

1. Manage bandwidth resources available in a domain, and
2. Maintain and implement policies within the domain.

To provide the above stated and other supporting functions, we divide BB into the following modules:

1. Application Control
2. Policy Control
3. Bandwidth Calculation
4. Router Control

A typical request goes through the above modules in that order. We now describe each module in detail (See Fig. 3.2).

3.2.1 Application Control

When an application needs to send contents to an “End User”, it sends a bandwidth reservation request to BB. In BB, first of all authentication is performed by the Application Manager (Fig. 3.2). It checks whether a user and/or an application is allowed to make a reservation request.

3.2.2 Policy Control

After performing application control, Application Manager through Simple Policy Manager validates SLA of “End User” and/or application. Then Application Manager reserves the bandwidth if bandwidth is available.

3.2.3 Bandwidth Calculation

The Bandwidth Calculator (BC) is responsible for calculating bandwidth available in the domain. BC can handle the following requests concerning bandwidth.
1. Perform reservation
2. Cancel reservation
3. Change reservation (bandwidth and time period).

Besides handling above stated requests, BC can explicitly state the maximum amount of bandwidth that is available during a specified time period. This function is necessary for applications to negotiate the amount of bandwidth to be reserved.

The main idea behind BC is that it keeps a record of bandwidth reservation of all links in a domain. When a request arrives in real time or for future reservation, BC handles these requests in the following steps:

1. Find out route (links) from a source to a destination.
2. If all links in the route have sufficient amount of bandwidth available during the requested time period, the reservation is done, otherwise the request is rejected.
3. For cancellation or change, simply update reservation information of each link in the route.

BC creates and maintains a virtual network where an application can enjoy guaranteed service. However, the accuracy of guarantee of service depends on the behavior of individual applications. For the current implementation, we assume that all applications are well behaved that is they do not break their contract with the BB.

3.2.4 Router Control

The next step is to perform corresponding router configuration. The router configuration is performed using three modules namely; Scheduler, RCC (Route Configuration Controller), and RT (Router Translator) which are shown in Fig. 3.2. A router configuration request for a source to destination path is at first broken down by the RCC into router configurations for all nodes lying in that path. These atomic router configuration requests are then registered with the Scheduler. Just before the time of actual bandwidth utilization, Scheduler sends these router configuration requests back to RCC and which in turn sends each to a proper RT module.

A large overhead of router configuration may occur due to slow routers in the path. To solve this problem a record of router configurations is maintained by the RCC. A new configuration is performed only if it does not lie in the existing configurations.

A Router Translator (RT) is responsible to translate a logical configuration request received from RCC into physical configuration for different types routers in the domain.

4. Design Evaluation

In this section we evaluate our system design through discussions.

4.1 Precise Brokering

BB performs Precise brokering of the bandwidth in the network. By Precise brokering we mean that the requesting application must know in advance the exact amount of bandwidth required. Furthermore, BB can provide the exact amount of bandwidth that can be reserved for a particular time period.

It is not necessary for an application to know in advance the exact time period it needs to use the network. An application may request an extension of the time period. The BB answers in positive if resources are available.

4.2 Central Management

The central management of a domain approach is necessary to efficiently utilize the network resources. Also, the central management of network resources is necessary to provide a robust guarantee of quality of service. Without the central management of network resources by a BB, guarantee of Premium service can not provided mainly due to the reason that atomic units in a network do not know the availability of resources in other units in the network and thus can not provide overall guarantee. It is the BB which maintains the resource allocation information of all of the units in a network and thus can provide a guarantee of resource allocation for a path if sufficient resources are available. The other approaches like that of RSVP produces large overhead and may not scale well.

4.3 Scalability

Regarding the scalability of our BB, one can argue that it may not be scalable due to its central management concept. BB can handle a large domain, however, in case if a domain becomes extraordinarily large, network administrators can conveniently divide very large networks into manageable domains.

In this concern, we performed a simulation of bandwidth calculation and admission control by the BB and the results are as under.

Simulation Environment & Assumptions:

Nodes: two
Links: one
Platform: Java2
Machine: UltraSPARC-II 400MHz
Memory: 512 MB

The graph in Fig. 4.1 shows the performance of our BB against mainly two types of requests, i.e., doReseration and getAllocableBw. The doReservation API is used to reserve a certain amount of bandwidth for a particular time period. The getAllocableBw API is used to find out the amount of bandwidth that may be available for a particular time period and particular user.

The x-axis in the graph represents the number of requests in million and the y-axis the time in micro seconds consumed by the bandwidth broker to handle these requests. We can see that the simulation results for doReservation almost coincide with a curve plotted for
2.0*(log N)² and for getAllocableBw with 1.5*(log N)². Here N is the number of requests. We can see from the graph that our BB can handle reservation requests in time which is an order of square of the log number of requests or O((log N)²).

4.4 Heterogeneous Routers

A large network infrastructure already exists which deploys different types of routers. Any system which attempts to provide a guarantee of QoS and requires a homogeneous network (same routers) is not desirable because it will require a new infrastructure. In our system, a BB can support heterogeneous routers by introducing a router translator module for each type of router. Each router translator is responsible for translating a logical policy into some policy rules which are router dependent physical policy and convey it to the router. The function of this protocol is similar to that of router translator module in our system that is to change the logical policy into a router dependent physical policy and convey it to the router. We plan to use COPS in the next implementation of BB.

4.5 Future Work

In this section we state the features which are planned to be included in our BB but are not available in the current implementation.

Network Feedback:

To support security and handle misbehaving users, we plan to introduce a module in our BB which would get the traffic information from routers in the network using currently available protocols like SNMP, MIB etc. BB will compare this traffic information with the statistics hold by it and find out the misbehaving and illegal users.

Topology Detection:

The domain topology at present is stored by the network administrator in some storage media (actually an LDAP Directory). Our BB, loads the topology information stored in the Directory and then uses it for the calculation of path determined by a source and destination pair. This is not desirable because if there is some error in the topology information stored in the Directory, the whole system will not work as desired. Therefore, to make our system more robust and reliable, in future, we plan to enable BB to sniff the topology information from the network directly.

QoS Routing:

The QoS routing is not considered in this version of our BB. Currently, we are conducting research on this topic and we plan to take into consideration the QoS routing in future. Another assumption of our BB design regarding routing is that there is only a single path from a source to a destination.

Inter-Domain SLA:

Another main feature which we want to include in our BB is to support inter-domain SLA. For this a BB must be able to communicate and resolve SLA with its neighboring domains. Many other themes may be considered and researched before Inter-domain SLA support can be achieved, for example, request aggregation, parameter definition for Inter-domain SLA definition, etc.

4.6 Comparison with Related Work

The related work being done in this field is that of QBone project. Its primary target is to provide guarantee of QoS to the multimedia applications using DiffServ architecture [6]. Their approach basically attempts to do bandwidth management on the boundary of a domain.

The BB designed by us, as a first step, focuses on the intra-domain bandwidth management. The reason is that our target model is that of contents businesses. As already defined in previous sections, the main requirement of contents businesses is the precise control of bandwidth resource in a domain so that mission critical applications...
like CM production etc may be given an end-to-end guarantee of QoS.

5 Deployment to the Testbed Network

We deploy the our designed QoS support mechanism to a testbed network which includes TV broadcasting stations, an advertising agency, a video production company, and a server center. In this section, we explain in some detail the testbed network as well as the contents and objectives of the planned experiments to be performed after deployment of QoS support mechanism.

5.1 The Testbed Network

5.1.1 Network Topology

The testbed network is an ATM based WAN (Wide Area Network) including Kansai and Tokyo regions (Fig.5.1). The link connecting Kansai and Tokyo is provided by JGN (Japan Gigabit Network) and the Kansai area network is provided by BBCC (association of Broadband-network Business chance & Culture Creation). It consists of QoS compliant routers, CSR and GR, and most links connecting the routers are OC-3 (155Mbps).

![Network Topology](image_url)

A bandwidth broker and contents servers are deployed at the server center which is supposed to be a future contents service provider. The bandwidth broker manages the QoS policy and the bandwidth of the entire network while contents servers store multimedia contents and send them to the clients.

On this testbed network, we verify the implementation of our proposed system as well as check the effectiveness of the DiffServ QoS model for contents businesses.

5.1.2 DiffServ Compliant Routers

Our experimental network is equipped with two types of DiffServ compliant routers, one is a silicon router (GR2000) and the other is a MPLS based router (CSR).

Silicon Router (Hitachi GR2000) :

To the best of our knowledge, GR2000 is the first DiffServ compliant router. The GR2000 is a very high-speed router which can forward up to 30 million packets per second. Its features that enable it to produce high speed are: distributed layer-3 switching architecture and hardware assisted route table lookup. The above stated capabilities of GR2000 router makes it suitable for high bandwidth networking applications, like TV programs and CM production. The GR2000 also possesses hardware based QoS controls and features that enable administrating and managing network traffic.

GR2000's following QoS functions are provided based on per IP flow: DiffServ, 8 levels outgoing priority control, outgoing bandwidth control, 4 classes discard control and incoming bandwidth. Due to the above stated features of GR2000 we decided to use this router in our testbed network.

MPLS based Router (Toshiba CSR) :

A CSR (Cell Switch Router) [9] is one of implementations using the label switching technology , which is currently discussed by the IETF MPLS (Multi-Protocol Label Switching) WG [10]. The CSR has a label switching engine, such as ATM switch, as well as a conventional IP packet forwarding engine. A packet can be forwarded using the label, e.g., VPI/VCI, without analyzing the IP address. This means that a particular packet stream is mapped to the label. The mapping is performed by a label distribution protocol.

In the experimental network, we deal with a high priority packet in addition to a best effort packet. The CSR maps each packet stream to a label with a different policy. The label switching engine, which is an ATM switch, in the CSR forwards packets based on this policy. For example, the high priority packet is mapped to a label with a high priority, and the best effort packet is mapped to a label with a low priority. This means that the CSR performs QoS packet forwarding using the label switch function without the conventional IP forwarding engine. Using the routers, we make a QoS capable network and evaluate them.

5.2 Planned Experiments

Three experiments dealing with two kinds of business contents, CMs and TV programs, will be done on the testbed network from June through the end of 1999. Media companies such as broadcasting stations, video contents production companies, advertising agencies, and a contents server center are connected by the network. The common subject of the experiments is to distribute or produce digital contents realizing cooperative work among remote sites and to inspect controlling the QoS policy for various contents. There are two classes of service defined and they are applied to different communications according to the type of their applications.

Through these experiments, we are going to evaluate our system by measurement of traffic state that shows attained level of QoS or policy control. Besides, we are aiming to obtain know-how about QoS management by administration of the actual QoS enabled network.
(1) Broadcasting Japanese High School Baseball Games

In this experiment we broadcast High School Baseball Championship, which is very popular in Japan, on the network in live streaming MPEG2, applying Premium service.

The live pictures are also adapted into multimedia contents by the addition of some information such as batting order, score and pitches. They are broadcast on the Internet as live streaming video in low bit rate encoding.

(2) Cooperative CM Production

CM materials are checked as a draft by the advertising agencies (or sponsors) and transmitted to broadcasting station as a final production. Owing to high unit cost and quality of CM pictures, cooperative production of CMs among remote sites requires Premium service which is free from network congestion. The following are supposed processes in the experiment:

1. Checking materials by real-time streaming in MPEG2 format placed at remote sites as a draft, and
2. Transmitting pictures in D1 format from a production to a broadcasting station as a final production.

Material stored in a contents server is encoded to MPEG2 and is broadcasted using the Internet at the same time.

(3) Non Linear Editing and Live Transmission

Video materials to be edited are in DV (Digital Video) format and stored at the broadcasting stations or contents servers. They are transmitted over the network as required for non-linear editing that needs high quality network service such as Premium service.

The edited pictures of TV program are relayed from a local broadcasting station to some other stations over the network with IP Multicast by real-time streaming in DV format. DV sets equipped with DV player/recorder are placed at each station. In this experiment we verify validity of QoS control on IP Multicast communications.

6 Conclusion

In this paper, we show a new design of QoS enabled network and its deployment which can provide Premium service to contents businesses. The Premium service based on the DiffServ model is achieved by introducing a Bandwidth Broker and DiffServ compliant routers in a network domain. We show that our design scales well. Three experiments on testbed wide area network to evaluate our model and check feasibility of future business model for contents provider are underway.

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