Proposed congestion control method for all-IP networks including NGN

Kenichi HATAKEYAMA† and Shin-ichi KURIBAYASHI†
† Faculty of Science and Technology, Seikei University, Tokyo, JAPAN

Abstract *– All-IP networks, including next generation networks (NGNs), in which IP technology is used to integrate all services, are being studied or introduced in earnest worldwide. To support any services in all-IP networks, it is necessary to allocate both the computing resource (processing ability) and the network resource (bandwidth) simultaneously.*

This paper discusses congestion control schemes for all-IP based networks, based on the joint allocation of multiple types of resources. This paper first analyzes congestion control schemes used in existing services and networks, and proposes basic principles on congestion control for all-IP networks, assuming the joint allocation of multiple types of resources. Next, two schemes are proposed to materialized a part of basic principles. First scheme is a flexible resource reallocation scheme in which a part of network resources not fully used in one center are reallocated to other center. Second scheme is a smart request restriction scheme to ease the congestion, which does not restrict all requests uniformly but restricts only those requests that require a large amount of resource of the congested resource type. Finally, we demonstrate the effectiveness of the proposed schemes by numerical computation and simulation evaluations.

key words- *Congestion control, all-IP network, resource reallocation*

1. Introduction

Recently, all-IP networks including next generation networks (NGNs) [1], in which IP technology is used to integrate all services, are being studied or introduced in earnest worldwide. An all-IP network adopts IP technology to provide not only those services that have traditionally been provided in the Internet, such as email, Web access, blogs and video delivery services, but also fixed-line telephone, mobile phone, TV [2], and sensor data delivery services. It not only provides these existing services but also is expected to allow collaboration between different services and creation of entirely new services. Today, traditional so-called network providers have begun to provide computation capabilities in addition to providing networks [3].

The provision of all services on a network similar to the Internet raises a concern that problems typical of the Internet, such as viruses, unauthorized access and DoS/DDoS attacks, will spread to services that have traditionally been free from such problems. Such new threats include spam over Internet telephony (SPIT), which is a voice spam using VoIP.

Another concern is that the co-existence of multiple services on a single network may increase chances of interference between user traffic flows and between different services, causing an overload or congestion of one service to affect other services. For example, the restriction of call origination in the event of an earthquake has traditionally not been an important issue in a data communication network, but will surely affect data communication in an all-IP network because all services share the same network resources. In other words, in an all-IP network, an occurrence of congestion, which has been confined to a specific service in a traditional network, may induce congestion of other services, or abnormal traffic, such as spams or DDoS attack packets. A specific service may degrade the quality of other services.

It is of great importance to establish adequate measures to deal with these problems before all-IP networks, including NGNs, are introduced extensively and become a part of social infrastructure. This paper concentrates on 'congestion control' for all-IP network. This paper supposes the joint allocation of multiple types of resources because it is necessary to allocate both the computing resource (processing ability) and the network resource (bandwidth) simultaneously to support any services in all-IP networks.

This paper first analyzes congestion control schemes for existing services and networks to provide a wide perspective on basic principles applicable to congestion control for all-IP networks. Next, this paper proposes two new congestion control schemes to materialize a part of basic principles, assuming joint allocation of multiple types of resources. Then, this paper demonstrates the effectiveness of the proposed schemes by numerical computation and simulation evaluations.

2. Basic principles of congestion control of all-IP networks

A variety of measures to deal with congestion have been adopted in a variety of existing networks, such as telephone networks, packet-switched networks, mobile phone networks, FR networks, ISDN networks, ATM networks, advanced IN networks, Internet, and VoIP networks [4],[5]. Many of these measures are expected to be applicable to all-IP networks. Building on these existing measures, we have identified the following principles for congestion control of all-IP networks. These are only typical ones and are not meant to be exhaustive. It is not necessary to implement all these principles. Rather, only the ones appropriate for a specific system should be implemented selectively.

<1> The overload, congestion, or DoS/DDoS attacks in one service on other services should be prevented from affecting or interfering other services, or the influence or

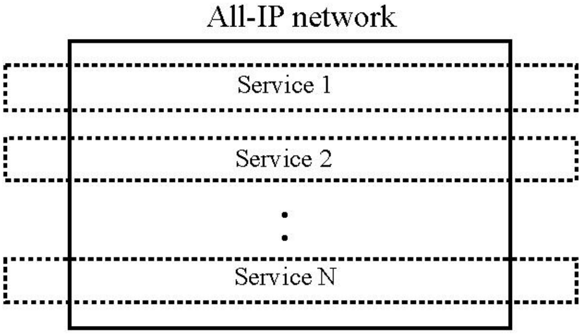


Fig. 1 Multiple types of resources in all-IP network are treated as virtual resources so that virtual resources are allocated to each service.

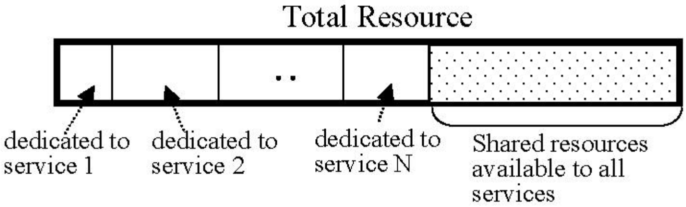


Fig. 2 Possible image of resource allocation to multiple services

interference should be minimized as much as possible. To achieve this, various resources distributed geographically, such as servers, network bandwidths and firewall devices, including session border controllers (SBCs) for SIP, should be treated as virtual resources so that virtual resources are allocated to each service (Fig. 1).

<2> Some resources should be dedicated to each service to ensure the maintenance of minimal quality of service, and shared resources should be made available to all services as impartially as possible (Fig. 2). The amount of resource dedicated to each service should be readjusted from time to time depending on how the service is used. If a specific service becomes congested, the shared resource may be allocated to that service with high priority to relieve the congestion.

<3> To control traffic in the event a specific service has become overloaded or congested, both a priority level and a non-priority level should be provided for each service.

<4> To provide a service in an all-IP network, it is necessary to provide joint multiple resources, such as computing resources (processing abilities) and network resources (bandwidths) [6],[7]. If we assume this "joint allocation" of multiple types of resources to a service, it may be possible to flexibly reallocate resources. For example, if one type of resource allocated to a service becomes congested, the same type of resource allocated to other services may be reallocated to the congested service. Or, if congestion continues unabated, only those services that demand a large quantity of the congested type of resource may be restricted rather than all services. These measures will reduce degradation in

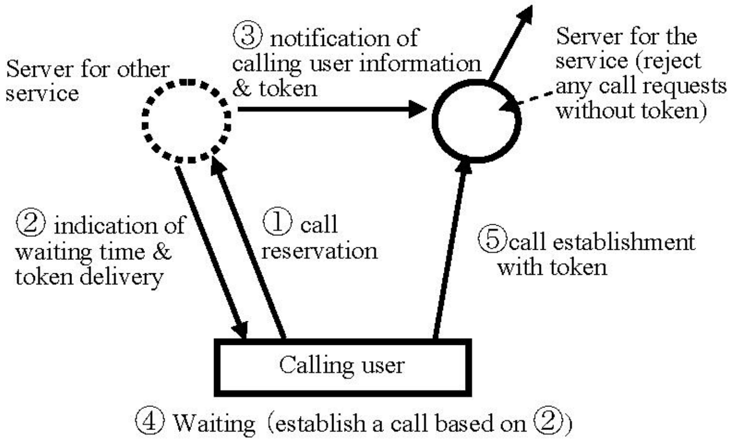


Fig. 3 Possible scheme to materialize basic principle <5>

service quality and allow effective use of resources. Details of these measures are discussed in Section 3.

<5> In order to ensure communication of urgent calls and to ensure impartial treatment of ordinary calls or requests (i.e., to provide connections in the sequence in which calls originate), the resources that are otherwise allocated to other uncongested services should be used to notify the state of congestion, or to support call establishment control (Fig. 3). However, the amount of resource reallocated to the congested service should be limited to a certain level so that the uncongested services whose resources are reallocated would not become congested as a result of the reallocation.

<6> In selecting measures to be taken to control congestion for each service, it is necessary not to base the judgment on the states of individual elements, such as servers, network bandwidths and terminals, but to identify the "real cause of congestion" from the overall network perspective. For example, when a server is congested, the real cause of the congestion may be that the bandwidth allocated to that server is too wide (which is really a network engineering problem). In such a case, it is necessary to reduce that bandwidth rather than taking measures in the server itself.

<7> There should be adequate collaboration between different parts of the network. For example, when the transport part of the network is congested, this news should be communicated to the resource/admission control part and the service control part, in order to restrict requests for new connections.

<8> In preparation for congestion that may result from a disaster, it is necessary to provide services that enable users to confirm the safety of their acquaintances, similar to 171 (NTT's service for leaving messages in case of a disaster in Japan) or the IAA (I am alive) system, and to provide congestion announcement for terminal devices normally used by users.

3. Congestion control that assumes joint allocation of multiple types of resources

3.1 Overview

This section proposes a specific congestion control scheme that implements Principle <4> in Section 2. There have been reports of congestion control schemes that monitor multiple indicators, such as the CPU usage rates and the buffer usage rates of network devices, and initiate traffic restriction when one or more of these indicators exceed their thresholds. However, there are few reports that assume a joint allocation of multiple types of resources.

When joint allocation of multiple types of resource is assumed, a problem with the conventional approach is that even when only one type of resource is congested, the use of all types of resource required for the affected service is restricted to maintain its service quality. This may result in a significant reduction in the efficiency at which these resources are used. This paper proposes a method to avoid such a reduction in the efficiency of resource usage for the case where two types of resource are in use: computing resources (processing abilities) and network resources (bandwidth).

3.2 Flexible resource reallocation scheme focusing on a specific resource type

3.2.1 Overview

We suppose that a part of network resources (bandwidths) not fully used in one center are reallocated to other centers. This is done on condition that the request discard rate of the center that releases a part of its resources will not be degraded (i.e., the center's service quality will not be degraded even when the center releases a part of its resources to other centers).

3.2.2 Proposed bandwidth reallocation

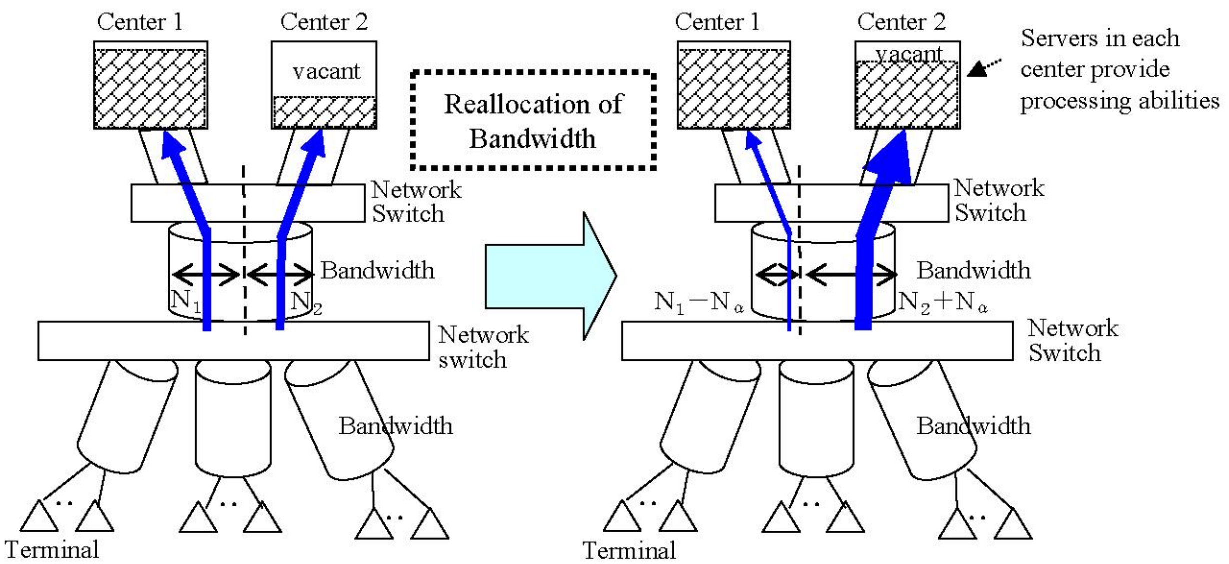
Fig. 4 illustrates network model and explains how bandwidths are reallocated in this scheme. Centers 1 and 2 are located at separate sites. , Servers in each center provide processing abilities. A network switch in the network divides the bandwidth available and allocates a part of it to each server. In the example of Fig. 4, Bandwidth N_2 allocated to center 2 is almost fully used, and thus center 2 is unable to accept new requests in spite of the fact that its servers still have sufficient processing abilities available. If Bandwidth N_1 allocated to center 1 has a spare capacity, a part (N_α) of Bandwidth N_1 can be reallocated to center 2 to the extent that the service quality of center 1 is not degraded. This reallocation would enable center 2 to handle more requests, and thus increase the overall capacity of the system.

3.2.3 Calculation of the maximum bandwidth that could be reallocated

Table 1 summarizes the equations used for calculating

Table 1. Calculation of maximum amount of bandwidth that could be reallocated

Patterns	Conditions	Maximum amount of bandwidth that could be reallocated
I	Vn2＝Vn2max Vc2＜Vc2max Vn1＜Vn1max	$\min\{W_{aI}, W_{bI}\}$ $W_{aI}=\{(Vc2max-Vc2)\times Vn2/Vc2\}\times N_2$ $W_{bI}=\{Vn1max-Vn1\}\times N_1$
II	Vn1＝Vn1max Vc1＜Vc1max Vn2＜Vn2max	$\min\{W_{aII}, W_{bII}\}$ $W_{aII}=\{(Vc1max-Vc1)\times Vn1/Vc1\}\times N_1$ $W_{bII}=\{Vn2max-Vn2\}\times N_2$



C_1: Maximum size of computing power of center 1, C_2: Maximum size of computing power of center 2
N_1[bps]:Maximum size of bandwidth allocated for server 1, N_2[bps] Maximum size of bandwidth allocated for server 2
N_α[bps] Bandwidth reallocated from center 1 to center 2
Vc1: Usage rate of processing ability of center 1, Vc2: Usage rate of processing ability of center 2
Vn1: Usage rate for bandwidth allocated for center 1, Vn2: Usage rate for bandwidth allocated for center 2
Vc1max : Permitted maximum usage rate of processing ability at center 1
Vc2max: Permitted maximum usage rate of processing ability at center 2
Vn1max: Permitted maximum usage rate for bandwidth allocated for center 1
Vn2max: Permitted maximum usage rate for bandwidth allocated for center 2

Fig. 4 Network model and image of bandwidth reallocation (pattern I in Table 1) the amount of bandwidth that could be reallocated for the model shown in Fig. 4. If neither Pattern I nor II in Table 1 is applicable, no reallocation of bandwidth will be made. In pattern I, W_{aI} is a bandwidth that enables Server 2 to use up its CPU and W_{bI} is the still available bandwidth of Server 1. The bandwidth that can be allocated is the smaller of W_{aI} and W_{bI}.

Fig. 5 shows an example of the specific amount of bandwidth reallocated for the case of Pattern I in Table 1. The shaded part in Fig. 5 is the reallocated bandwidth. Fig. 5 also shows the total number of resources normalized with those processed before bandwidth reallocation. The following points are clear from Fig. 5:

1) Until the usage rate of processing abilities of center 2, Vc2, reaches a certain level, W_{bI} is smaller than W_{aI}, and thus the amount of reallocated bandwidth is constant. If Vc2 exceeds that level, the amount of reallocated bandwidth is reduced, and reaches 0 at Vc2max. This is because, as the spare processing abilities of center 2 becomes smaller, it is more difficult for center 2 to increase its capability to accept new requests even when a wider bandwidth is allocated to it.

2) When an equal amount of bandwidth is allocated to each center (N_1=N_2=N), and if Vn1 is 0.0, all the bandwidth, N, allocated to center 1 can be reallocated to center 2, which would double the capability of the system to handle requests.

3.2.4 Dynamic reallocation of resources

When the amount of requests applied to each center is constant and known, it is possible to statically determine whether or not reallocation is possible and the amount of resources that could be reallocated. However, in a real system, the amount of requests applied changes over time, and consequently it is necessary to dynamically determine whether or not reallocation is possible and the amount of resources that could be reallocated. This dynamic determination is described below. As in Section 3.2.3, we focus on the reallocation of bandwidth here.

(1) First, it is necessary to determine how much of each resource is being used. A possible solution to this is central management of all resources, but this would require a large processing power and incur delay in collecting resource usage information. Therefore, we assume that each network switch, which is in a position to be able to measure bandwidth usages and actually implement bandwidth reallocation, keeps track of resource usages, and determines the amount of bandwidth that could be reallocated.

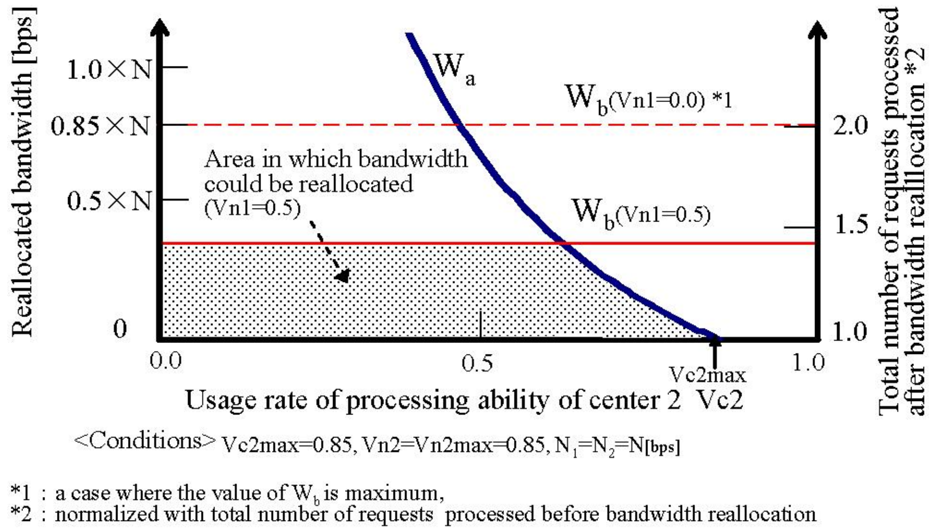
(2) Each network switch monitors bandwidth usages, and when the usage rate of any bandwidth reaches the maximum permissible level, the network switch sends a message to each server inquiring about its usage rate of processing abilities. Based on the collected information, the network switch calculates the amount of bandwidth that could be reallocated with Table 1. In an MPLS network, this "resource usage inquiry message" (message type:ox0600)can be implemented by expanding an LDP message [8].

3.3 Smart request restriction scheme to ease the congestion

3.3.1 Overview of the scheme

When a specific type of resource is so congested that it is difficult to admit new requests, this scheme does not restrict all requests uniformly but restricts only those requests that require a large amount of resource of the type that is congested.

Fig. 6 shows an example of the operation of this scheme, in which the computing resource is congested. Conventional schemes would restrict all requests uniformly irrespective of the types of resource required by individual requests (including cases where not all requests but only some requests are restricted). In contrast, our proposed scheme restricts only those types of requests ① that require a large amount of computing resource (congested resource), thus leaving room for



<Conditions> Vc2max=0.85, Vn2=Vn2max=0.85, N_1=N_2=N[bps]

*1 : a case where the value of W_b is maximum,
*2 : normalized with total number of requests processed before bandwidth reallocation

Fig. 5 Example of calculating the amount of bandwidth that could be reallocated (based on Table 1)

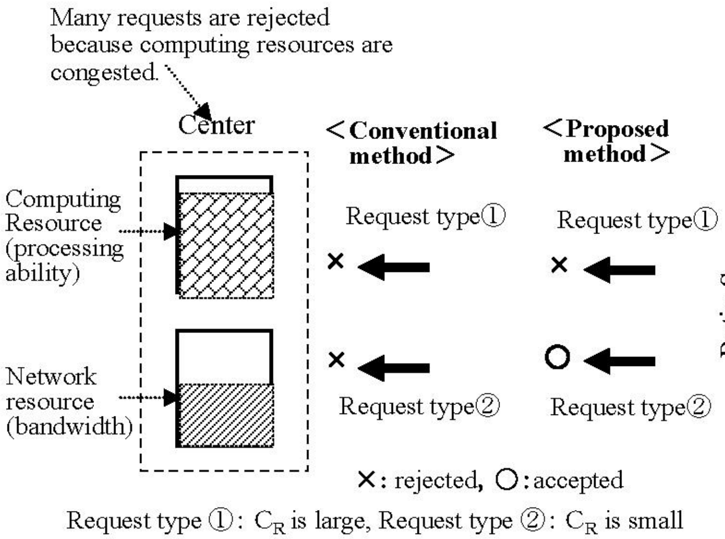


Fig. 6 Proposed scheme which eases the congestion

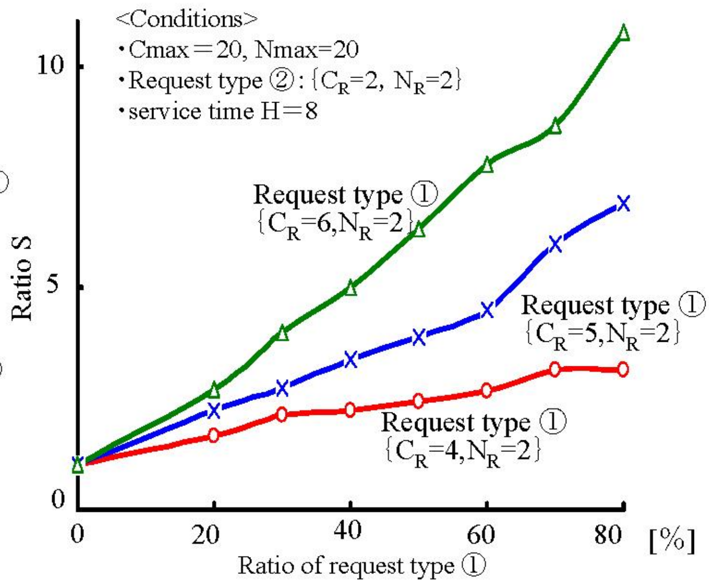


Fig. 7 Simulation result

processing more requests of other types.

3.3.2 Simulation evaluations

(1) Simulation conditions

- The evaluation is performed by a computer simulation using the C language.

-It is supposed that there is one center. The maximum size of computing resource (processing abilities) and that of network resource (bandwidth) in the center is given by Cmax and Nmax respectively.

-The size of required processing abilities and bandwidth follow a Gaussian distribution, and average values are given by C_R and N_R respectively.

-The request generation pattern is shown by {C_R=a, N_R=b}, which means that the request with C_R=a and N_R=b will be generated repeatedly.

- The generation interval of requests follows an exponential distribution. The service time H, which is the total time from a generation of the request to a completion of the service, is assumed to be constant. Each request occupies the allocated resources until its service time passes.

- In order to create a situation in which the processing abilities of the center is congested, it is assumed that a separate load of T% is constantly applied to the center besides the requests we are focusing on.

- The request loss probability, which is the probability that either the computing resource or network resource is not available, is evaluated.

(2) Simulation results and analysis

In Fig. 7, it is assumed that Request ①, {C_R=x,N_R=2}(x=4, 5, 6), and Request ②, {C_R=2,N_R=2}, are processed at Center 1. T is supposed to be 25% in Fig. 7. The request origination rate that satisfies the condition that the request discard rate is 1% or lower is calculated for two cases: a case where there is a mix of Requests ① and ② (percentage of each is varied), and a case where there is only Request ②. Then, the ratio, S, of the originating rate for the case of Request ② only to the originating rate for the case of a mix of Requests ① and ② is calculated. This ratio corresponds to the rate at which requests are restricted in actual congestion control so that the request discard rate will become 1% or less. The following points are clear from Fig. 7:

1) The larger the ratio of Request ①, which requires a large amount of processing abilities, the ratio, S, increases. In other words, by restricting Request ①, it is possible to process more requests than when no restriction is made.

2) The larger the size C_R of Request ①, the large the degree of effectiveness of the restriction.

4. Conclusions

This paper has analyzed congestion control schemes used in existing services and networks, and has proposed basic principles on congestion control for all-IP networks, assuming the joint allocation of multiple types of resources. Next, we have proposed two schemes to materialize a part of basic principles. First scheme is a flexible resource reallocation scheme in which a part of network resources not fully used in one center are reallocated to other center. Second scheme is a smart request restriction scheme to ease the congestion, which does not restrict all requests uniformly but restricts only those requests that require a large amount of resource of the congested resource type. Finally, we has demonstrated the effectiveness of the proposed schemes by numerical computation and simulation evaluations.

<References>

[1] N.Morita and H.Imanaka, "Introduction to the Functional Architecture of NGN," Proc. IEICE, Vol.E90-B, No.5, pp.1022-1031, May 2007.

[2] M. Montpetit and S.Ganesan, "IPTV architectures and deployments", CCNC2007 Tutorial.

[3] ULTINA On Demand Platform http://www.japan-telecom.co.jp/english/newsrelease/2006/feb/0209/0209.html

[4] R.Jain, "Congestion Control and Traffic Management in ATM Networks: Recent Advances and A Survey," Computer Networks and ISDN Systems, Vol.28, No. 13, October 1996, pp. 1723-1738.

[5] Go HASEGAWA, Masayuki MURATA,"Survey on Fairness Issues in TCP Congestion Control Mechanisms IEICE Trans. on Commun. Vol.E84-B No.6 pp.1461-1472 (2001.6)

[6] S.Tsumura and S.Kuribayashi, "Simultaneous allocation of multiple resources for computer communications networks", APCC2006, 2F-4 (2006.8)

[7] S.Tsumura and S.Kuribayashi, "Delayed resource allocation method for a joint multiple resource management system", APCC2007 TPM2-3 (2006.10)

[8] F.M.Holness,"Congestion Control Mechanisms within MPLS Networks", Doctor paper, Queen Mary and Westfield College University of London, September 2000