Adaptive Bandwidth Control System with Incoming Traffic in Home Network

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Abstract:

QoS is a subject of high interest for successful deployment of various services in a home gateway and the gateway is possible to support QoS by installing existing queuing disciplines, which control the outgoing traffic to guarantee only QoS of the traffic. But in the home gateway it is also important to guarantee QoS of the incoming traffic. This paper proposes an adaptive control of the traffic to guarantee QoS of incoming traffic into the home gateway. In the proposed method, the upper limit of the available bandwidth of sending rate varies with receiving rate. And the proposed method makes the gap between the allocated rate and the actual service rate of the traffic narrow. Some experiments on a test bed show that the proposed method is valid.

Keywords: Home gateway, Incoming traffic guarantee, QoS, CBQ

1. INTRODUCTION

Home network interconnects among various electronic devices within a home such as a home gateway (HG), PC and AV set. The home gateway is located at between the home network and the Internet. A homeowner might control the devices and flow of information from within the home or remotely from somewhere outside the home [1]. The home gateway is very important device for home network. It connects various devices (PC, Cellular phone, Digital TV, PDA, Game station, and so on) in a home area network to Internet Service Provider (ISP) networks. HG has been evolved from just a simple gateway into an intelligent gateway enabling various services to provide to the devices in home and arbitrating bandwidth between them.

As shown in Fig. 1, HG has two kinds of traffic: Incoming traffic and Outgoing traffic. Incoming traffic is traffic set whose final destination is HG, but outgoing traffic is traffic set, which is forwarding or source one of HG. So the former contains traffic running from ISP network to HG and from home network to HG. The latter contains traffic from ISP network to home network, from home network to ISP network, and from HG to home network and ISP network. Many companies introduce HGs operating home server for audio and video media, where most traffic heading to HG is multimedia data traffic requiring guarantee of QoS such as bandwidth and delay. Moreover, because HG traffic includes signaling traffic for management of home network, if the traffic is not guaranteed, then it may not be able to meet QoS for data services required by users. Note that the multimedia data traffic and the signaling traffic are types of the incoming traffic. So methods for guarantee of incoming traffic have to be proposed. In the case where HG offers QoS, the process for QoS should not affect correct services in the home network. So its processing time should be short as soon as possible.

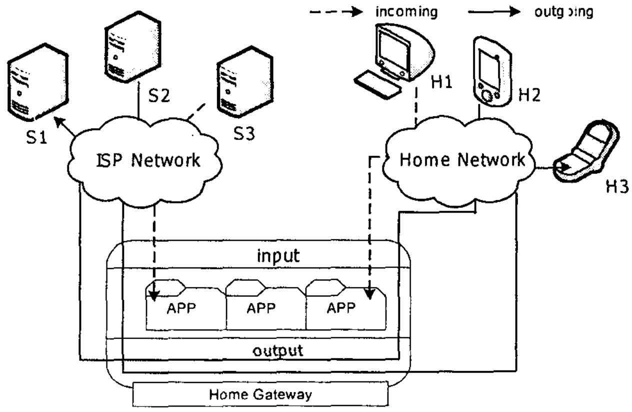

Fig. 1. Traffic identification traversing through the HG

QoS-aware HG is possible by installing existing queuing disciplines. Many researches have been studied various queuing discipline algorithms to provide more effective traffic management [2-7]. First-in, first-out (FIFO) queuing is the most basic queue scheduling discipline. In FIFO queuing, all packets are treated equally by placing them into a single queue, and then servicing them in the same order that they were placed into the queue. To provide different service, Priority Queuing (PQ) [2] is proposed. PQ is the most effective scheduler from low delay service standpoint but it can lead to complete resource starvation for lower-priority traffic. To solve the starvation of PQ and to provide the fair bandwidth, Fair scheduler [4] such as Weighted Fair Queuing (WFQ) [5] or Weighted Round Robin (WRR) are proposed as an excellent discipline for the guaranteed bandwidth service because of their ability to guarantee a predetermined amount of bandwidth to each session. But, in fair queuing, delay and bandwidth are coupled. Currently, Class Based Queuing (CBQ) [6] is considered as the most appealing advanced scheduler available today. CBQ is based on several mechanisms that basically merge PQ and fail capabilities to provide different kinds of service to data traffic [7].

Hierarchical Token Bucket (HTB) [8] is proposed to solve the CBQ drawbacks such as low accuracy and high complexities. But it is slower than CBQ.

Unfortunately, all the previous queuing disciplines are able to control only an output link [9], via which the outgoing traffic is transmitted. In other words, it means that the system implementing queuing discipline can control the transmission rate but cannot control the receiving rate. For this reason, HG can support QoS guarantee for forwarding or outgoing traffic, but cannot do it for incoming traffic taking the gateway as a final destination.

For instance, let's imagine that traffic, which rate is 120Mbps (an incoming traffic rate and an outgoing traffic rate are 40Mbps and 80Mbps, respectively), want to be serviced to the gateway installing two network interface cards of 100 Mbps. Note that the existing queuing discipline cannot control the incoming traffic. In general it allocates to the traffic the service time according to portion of types of traffic. So the amount of the traffic into a network interface card exceeds its processing capacity, some packets should be discarded. To cope with the problem, the existing queuing discipline can provide following two methods: to give higher priority to incoming traffic heading to HG and to allocate 40Mbps bandwidth to incoming traffic to guarantee QoS. But both of them cannot guarantee the QoS because traffic control rules are generally applied only to the output link. Practically there can't be any queuing policy applied to the input link. That is, QoS of incoming traffic cannot be guaranteed.

Some traffic control algorithms of HG have been proposed for the efficient service management [10-11]. In [10], traffic control algorithm reassigning priority according to traffic usage variation is proposed. In [11], the algorithm taking into consideration the priority value and the amount of memory occupied by each service is proposed. But these researches do not consider incoming traffic and only outgoing traffic. To author's knowledge there hasn't been experimented any research about guarantee of incoming traffic.

This paper proposes the adaptive control method of incoming traffic in HG. An incoming traffic can be guaranteed by decreasing the CPU processing rate of transmission and by increasing receiving rate. In the proposed method, the upper limit of the available bandwidth for sending is dynamically varied according to the receiving rate. And this paper proposes a viable feedback control mechanism using PID controller. Our feedback algorithm makes narrow the difference from the allocated rate and actual rate of the traffic. Also we study how to reduce the processing rate of HG using the proposed traffic controller.

The paper is organized as follows. Section 2 briefly explains HG. The adaptive control method of incoming traffic in HG is introduced in Section 3. The experiment results of our system and discussion about the results are presented in Section 4, and followed by concluding remarks in Section 5.

2. HOME GATEWAY

HG plays a role of hub connecting and managing PCs and information devices in home and a role of gateway connecting home network to external Internet network. Fig. 2 shows the of HG architecture. A general HG should have the following basic functional features. First of all, as data are service between different kinds of external networks and home networks, HG can interface to them. The examples of an external network standard are cable modem, ISDN, xDSL, etc. and of a home area network standard are Bluetooth, RF, IEEE1394, etc. [12]. This is basic function and for this function, several groups are processing gateway standardization. TIA TR-41.5 and WG1 are focusing on physical transmission between access network and home network and CableHome is for home networking using cable network as access network. And, in middleware area, UPnP, Jini and HAVi are studied. Particularly, OSGi provide framework and API for service from external network to home. Because configuration of HG complete and function definition is hard, there are different kinds of HG standard.

As shown in Fig. 2, all traffic flowing in or flowing out home network have to pass though this. It means that HG is located the best position to provide QoS according to traffic characteristics. Then second function of HG is traffic management. By providing differentiated service according to service characteristic to which a traffic belong or traffic direction, HG can provide efficient data service. In this paper, we are focusing on QoS-aware and will be pointed out in the next Section

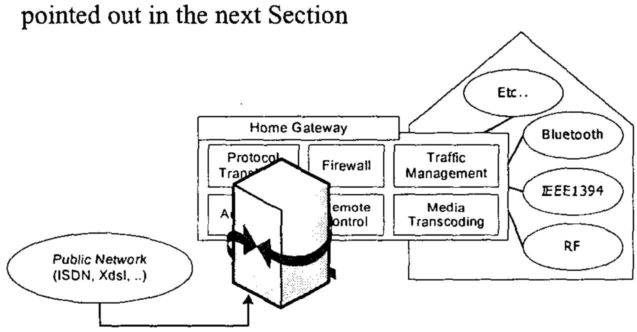

Fig. 2.Home Gateway Architecture

3. ADAPTIVE CONTROL SYSTEM

As shown in Fig. 3, our architecture of control system is broken down into three components: the network QoS manager, the traffic controller and the traffic monitor. The network QoS manager receives the QoS request of incoming traffic through external interface and determines whether the request is accepted according to bandwidth allocation algorithm. If the requested bandwidth is available, it notices the limited share of outgoing to traffic controller component. Also, this asks traffic monitor component for the real service rate of incoming and compensates for the gap between requested rate and serviced rate. In this section, we address details of implements of the proposed schemes.

3.1. Network QoS Manager

If requested bandwidth of incoming traffic is available, Network QoS Manager allows the connection. We assume that incoming traffic and outgoing traffic have portion of bandwidth PB_I and PB_O respectively, Total bandwidth is BW_T, available bandwidth is BW_A, and requested bandwidth is BW_R. BW_A is obtained by the equation (1).

$$BW_A = BW_T - PB_I \qquad (1)$$

It is noteworthy that we control traffic of outgoing traffic for guaranteeing of incoming traffic's share. Because existing solutions such as some portion or higher priority assignment can't affect the QoS guarantee. BW_A is obtained by equation (1) is allocated to PB_O and network QoS Manager delivers this value to traffic controller. At this time, the total bandwidth has to be measured before in that the value is dependent upon system capability and network environment.

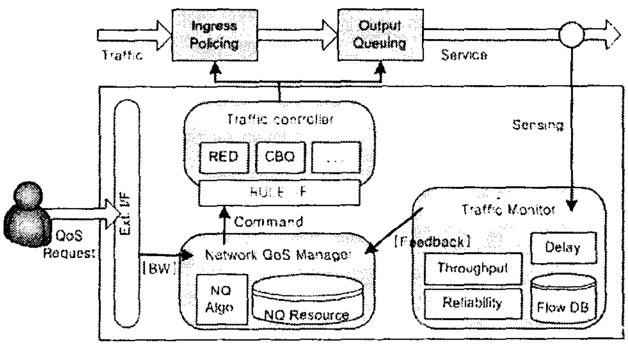

Fig. 3. System Architecture

CBQ is considered the most appealing advanced scheduler available today. So, in this paper, we use CBQ discipline as traffic controller. But the system implemented CBQ as a queuing discipline is not guaranteed accurate bandwidth even when the traffic control algorithm is very strong because CBQ has many drawbacks such as low accuracy and high complexities. Accordingly, to solve this problem, we use a viable feedback control mechanism using PID controller. Our feedback algorithm makes narrow the difference from the allocated rate and actual service rate of the traffic. Fig. 4 depicts the Bandwidth control algorithm of network QoS manager using feedback.

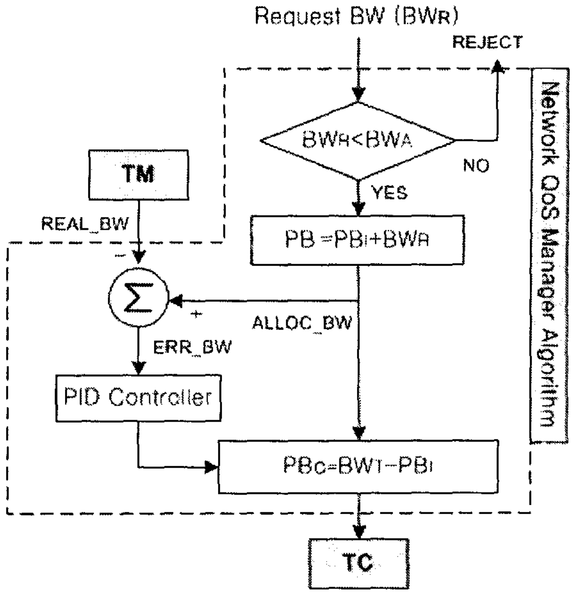

Fig. 4. Network QoS Manager with feedback

3.2. Traffic Controller

Traffic controller gets the value that has to be allocated to each class from the Network QoS Manager and performs traffic shaping of incoming and outgoing traffic. We can use existing queuing discipline as traffic controller and propose a default setup of CBQ discipline. This component can be implemented not only HG but also home devices in home network. If this function installed in home devices, because each device adjusts a sending rate determined by network QoS manager, total load in home network and processing rate of HG would reduce.

3.3. Traffic Monitor

Traffic monitor component captures packet on home network and calculates throughput, delay and reliability per flow and then store such QoS metrics in flow DB. At this time, incoming and outgoing traffic to which a flow belong information updated. When receiving a request for current service state of a incoming from network QoS manager, Traffic monitor component searches flow DB and returns the value of QoS Metrics.

4. EXPERIMENT RESULTS

We accomplish experiment to evaluate the performance of proposed control method and examine the bandwidth of incoming traffic as a result. We assume that outgoing traffic is fixed at 80Mbps and incoming traffic requesting 20Mbps flows in HG ever 20sec.

Fig. 5 shows the bandwidth usage of incoming traffic when we use only CBQ. QoS of requested traffic isn't guaranteed because CBQ rules are applied output link.

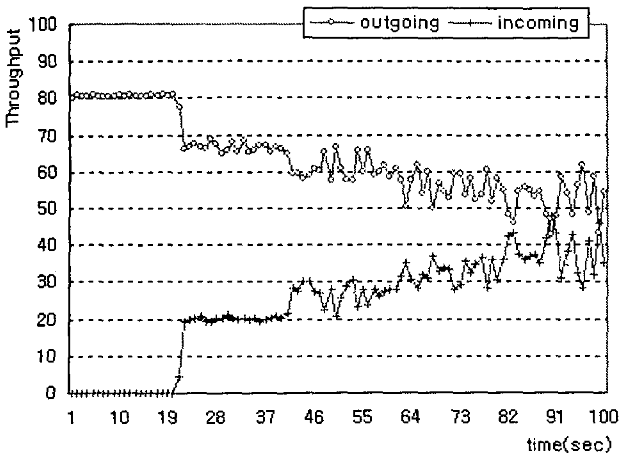

Fig. 5. Bandwidth of incoming traffic using CBQ

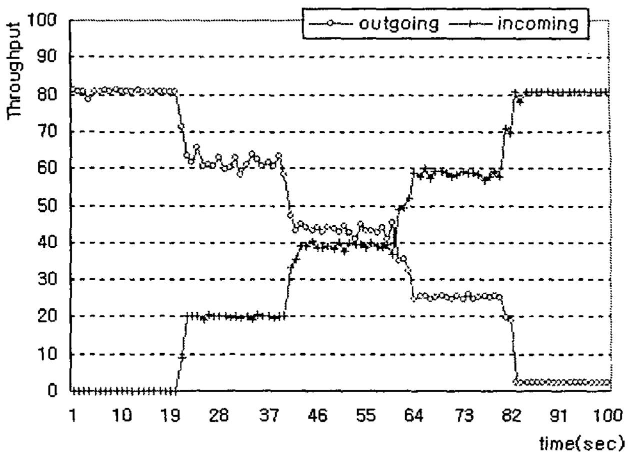

Fig. 7. Bandwidth of incoming traffic using adaptive control with feedback

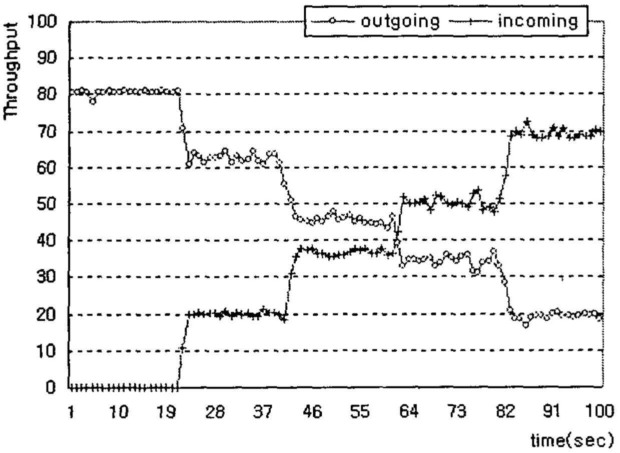

Fig. 6. Bandwidth of incoming traffic using adaptive control without feedback

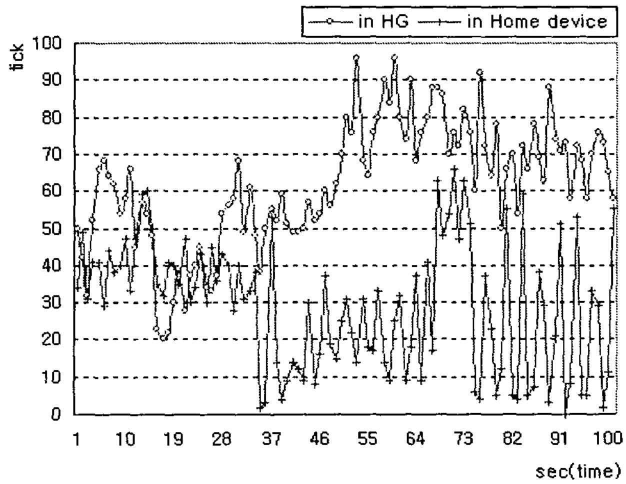

Fig. 8. Traffic control in HG vs. in home device

Fig. 6 and Fig. 7 show the result of incoming traffic service using adaptive control without feedback and with feedback respectively. In Fig. 6, QoS of incoming traffic is enhanced but the difference between requested rate and actual service rate is large. Because CBQ is largely imprecise and each session has several problems in getting the exact share assigned to it. While, as shown in Fig. 7, we can confirm proposed control system guarantee accurately the bandwidth of incoming traffic.

Fig. 8 shows the CPU utilization of HG when HG performs the outgoing traffic shaping and when home device performs the traffic shaping. In the case of latter, processing time of HG is reduced considerably.

5. CONCLUSION

This paper presented an adaptive control of traffic to guarantee QoS of incoming traffic into in HG. In the proposed method, the upper limit of the available bandwidth for transmission of HG is dynamically varied according to the receiving rate. Also, we used a PID controller to solve the drawbacks of CBQ, which is not to be accurate in control of bandwidth. We showed how to reduce the processing rate of HG by distributing traffic control function. Some experiments on the test bed show that the proposed method is an efficient method to guarantee QoS of traffic. For future works, how to integrate QoS manager into the task manager will be studied.

ACKNOLEGEMENT

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