A Universal Pricing Scheme for the WiMAX Services

Seung-Hak Suk* ***Regular Member***, Hoon Lee** ***Lifelong Member***
Kwang-Hui Lee*** ***Regular Member***

ABSTRACT

In this work we propose a universal pricing machine, which incorporates a universal pricing framework for the future IEEE802.16 WiMAX service with multiple classes of service. A multimedia service is provided by a QoS provisioning scheme in the WiMAX network and universal pricing means that it can compute the price for any type of service in a unified framework. In the proposed pricing framework we incorporate multiple types of services such as the real time and nonreal time services that are supposed to be provided in the WiMAX network. To that purpose, let us first carry out an analysis on the current pricing scheme of Korean WiMAX service which incorporates only the data size. From that analysis we propose a new pricing scheme for the future WiMAX service that provides different service classes in the network. Via numerical experiment, we verify the implication of the work.

Key Words : WiMAX service, Universal pricing machine, Price calculation

Ⅰ. Introduction

Recently, a movement toward the reduction of the price of the telecommunication services such as the voice and Internet services is active in Korea. A foremost runner in this action is the mobile phone companies as well as the VoIP (Voice over IP protocol) and ADSL (Asymmetric digital subscriber line) access companies. ISPs (Internet service providers) in Korea present users with discount of price in the unit of time or volume for the voice, data or video services.

There exists lots of literature in the field of Internet pricing. To name a few, one can find works from [1] to [11]. If we summarize the type of current and future Internet pricing we argue that pricing for the best effort network is aimed at preventing or avoiding the network congestion. When it comes to the DiffServ (Differentiated service) network, pricing is aimed at the provision of QoS for the traffic, while also preventing or avoiding the network congestion as well.

From this fact we argue that a rule of thumb for the Internet pricing is prerequisite. When the bandwidth is demanded by a connection in an inelastic manner, the most ideal pricing scheme is to charge by a flat rate pricing. When the bandwidth is demanded by a connection in an elastic manner, the connection is charged by a new pricing scheme other than the flat rate pricing[12]. Another scheme is a sustained bandwidth pricing or volume pricing about which we propose in this work.

When it comes to a price for the bandwidth demand only, different prices have to be charged to different bandwidth demands. That is, a bandwidth demand of X is charged higher price than a bandwidth demand of Y if X>Y.

On the other hand, WiMAX (Worldwide interoperability for microwave access) service is recognized as one of the complementary solutions that can replace an ADSL in dense urban area by offering broadband bandwidth connectivity to users

* KT Network Technology Laboratories (shsuk1@paran.com),
** Changwon National University (hoony@cwnu.ac.kr, khlee@cwnu.ac.kr)
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that require the broadband wireless access networks. WiMAX service is based on an IP-based IEEE802.16 standard, and it will provide the users with a high-quality multimedia service by using QoS (quality of service) technologies and mobility management. WiMAX service, which is also called a WIBRO™ (Wireless+Broadband) service that is proposed by Korea, will prevail in the near future as it is determined as an international standard by ITU-T in the October 2007 meeting.

Contrary to the proliferation of discussion about WiMAX service itself, little work is done about the pricing scheme of this service[13]. Inspired by those trends in the real field, let us propose a framework for the universal pricing scheme (UPS) for the WiMAX service. To the best of authors' knowledge, this is the first attempt to establish a framework for the universal price of the WiMAX service.

This work is composed as follows: In Chapter Ⅱ we review a pricing architecture for the current WiMAX service, and propose a new pricing architecture for the future WiMAX service that incorporates multiple service classes. In Chapter Ⅲ we propose a new pricing function for the WiMAX service. In Chapter Ⅳ we present numerical results. Finally, in Chapter Ⅴ, we summarize our work.

Ⅱ. Framework of the WiMAX service prices

Let us review the state of the current pricing scheme for the WiMAX service of Korea, and after that we propose a new pricing scheme for the future WiMAX service where there exist multiple types of service scheme.

2.1 Current pricing for WiMAX service

Currently in Korea, a commercial WiMAX service is provided in the name of WIBRO. At the time of the service subscription, an SLA (Service level agreement) is contracted between the ISP and customers by the name of the service. There are four kinds of service name in the current WIBRO service: Slim, Basic, Special, and Premium. The service menu is classified by the allowed amount of data transfer in the unit of Gigabytes. Note that this service name is categorized by the allowed volume of data that can be sent over the basic flat charge.

When it comes to the price, WIBRO service is priced by a hybrid of flat and volume pricing (HFVP) scheme. For each service the allowed amount of data transfer is defined and users can transfer the predefined amount of data for a fixed price, say 20 Dollars/2GB (Gigabytes) for a month when a user is subscribed to a basic service. When a user uses more bytes than the subscribed amount, he/she has to pay extra price: for example, 2.5Cents/MB(Megabytes) for a basic service.

Table 1 summarizes the price of the current WIBRO service announced by one of the ISPs in Korea[14]. As we can find from the Table 1, there exist different price structures in the service: the basic price is charged by a unit of GB, whereas the extra price is charged by a unit of MB. One can find that the extra price is very expensive compared with the basic rate. For example, a user who is subscribed to a basic service, pays 20$ if his/her usage of the network does not exceeds 2 Gbytes. When he/she uses the network in excess of 2G bytes, he/she has to pay an extra charge of 2.5C per extra mega byte.

Now let us compare the price for each service

Table 1. Price of WIBRO service (January 2008)

Service name	Basic price per allowed amount of data transfer	Extra price per extra bytes
Slim	10$/0.5GB*	5C/MB*
Basic	20$/2GB	2.5C/MB
Special	30$/4GB	1C/MB
Premium	40$/6GB	0.7C/MB

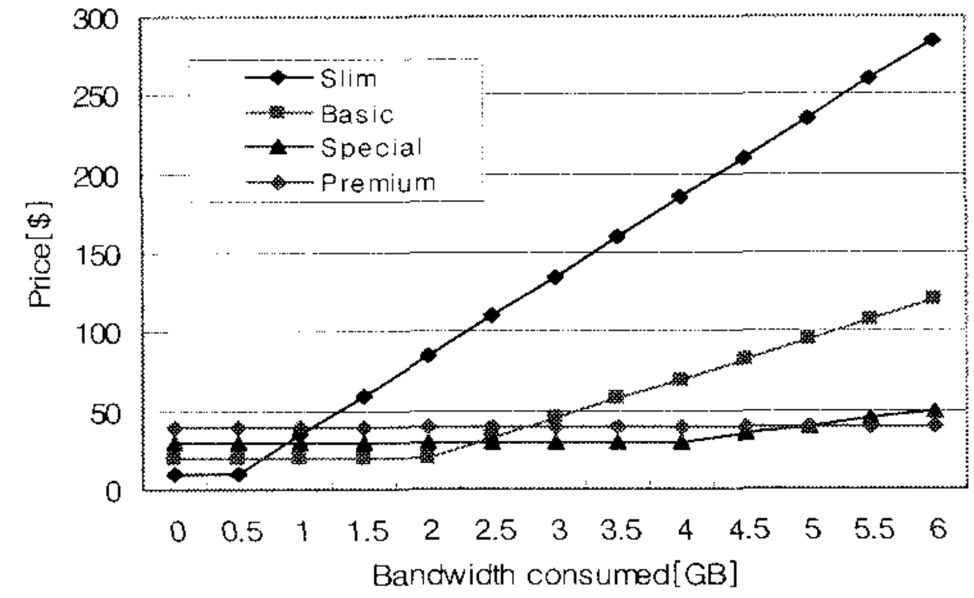

Fig.1. Total price for each service

name as a function of the consumed bandwidth, which is illustrated in Fig.1.

As one can find from the figure, there exist cross points in the price with respect to the consumed bandwidth, which results in an unfairness in the price between the services when users consume bandwidth greater than the contracted bandwidth. This enforces the users for his/her refraining from the overuse of bandwidth in excess from the contracted value. Therefore, this kind of pricing scheme acts as a means to prevent excess use of the limited bandwidth in the Internet.

2.2 Nature of WiMAX service

Now let us investigate the problem inherent in the current HFVP scheme from the philosophy of the WiMAX service. In the generic WiMAX service that is defined by IEEE 802.6 standard, the guarantee of the different services is assumed and there are three service classes, which is defined by the packet transfer scheme over the MAC layer: UGS (unsolicited granted service), PS (polling service), and BE (best effort service)[15].

UGS is defined to require absolute and strict guarantee of a certain amount of bandwidth to a connection so that strict delay requirement of real-time service is guaranteed. VoIP (Voice over IP) application without silence suppression belongs to this class. This class is analogous to a constant bit rate (CBR) service of the ATM network.

PS includes traffic generated from bursty applications with soft QoS requirements. There exist two kinds of service for this class: PS for real-time service (rt-PS) and that for nonreal-time service (nrt-PS). Real-time service requires strict delay guarantee, and example for this class includes video streaming such as MPEG video or interactive real-time game service. Nonreal-time service can tolerate a certain amount of delay for the packet, but the tolerance for the packet loss has to be kept to a certain level. Therefore, a minimum amount of bandwidth has to be provided to this service. Web browsing and e-commerce belong to this service class. This class is analogous to a variable bit rate (VBR) service of the ATM network.

Finally, BE requires no QoS guarantee, and file transfer and e-mail belong to this service class. This class is analogous to an unspecified bit rate (UBR) service of the ATM network.

As one can find from this classification of the service class of the WiMAX service, each class of service requires a different treatment of the packet, so that the pricing scheme has to reflect the differences in the service. Note also that this categorization of service class is different from the current service name. So, there is little relationship between them.

However, the intrinsic problem behind the current HFVP pricing scheme lies in the ignorance of service class and incentives accompanied by the support of QoS for different service classes to a user such as the voice, data and video services. The current HFVP pricing scheme ignores the WiMAX service class, and all the packets from different class of applications are levied at the same rate.

Therefore, our argument is that different classes of service have to be treated in different manners by way of the service scheme introduced in the WiMAX service, so that the price has to be levied according to the differences in the QoS. This motivated our proposition of a new pricing scheme for the WiMAX service.

2.3 Universal Pricing Machine

Bearing in mind the basic philosophy of the WiMAX service and its service classes, let us argue that we have to prepare multiple types of pricing scheme for the WiMAX service other than the current HFVP. To that purpose, let us think about the desire of the ordinary users. Some users prefer a pure volume pricing (VP) rather than the flat pricing (FP), because they neither consume large bandwidth nor require QoS guarantee. This scheme may be preferred by light users who use small amount of bandwidth. On the other hand, some users may want a flat pricing because they do not want to mind about the price every time when they send the packets to the network. There may be users who want a pricing scheme in the middle of these two schemes.

From this conjecture, let us propose a new pricing scheme for the packet transfer service of the WiMAX service that takes into account a different service classes, which is called the universal pricing machine (UPM). The basic principle behind the universal pricing scheme lies in the provision of the freedom to the users in the selection of the pricing alternatives, which is dependent on the service class provided by ISP. As such, users can select the type of the payment for the Internet services such as the voice, data, and video at the phase of the service initiation.

UPM is sketched as shown in Fig.2, where pricing machine is deployed at the forefront of an access network, which we call an access gateway. This kind of pricing architecture is usually called as an edge pricing. A user is connected to an access network of the WiMAX for the transfer of packet through the Internet. Before the transfer of the packet to the network a user contracts an access service by selecting the type of payment to the ISP via service contractor (SC) of an access node.

The details of user's subscription are transferred to a pricing engine (PE), where each type of pricing scheme is implemented. When a user sends packets to the network the PE computes the price of transferring the packet to the network from the user information such as the byte count, connection holding time, etc.

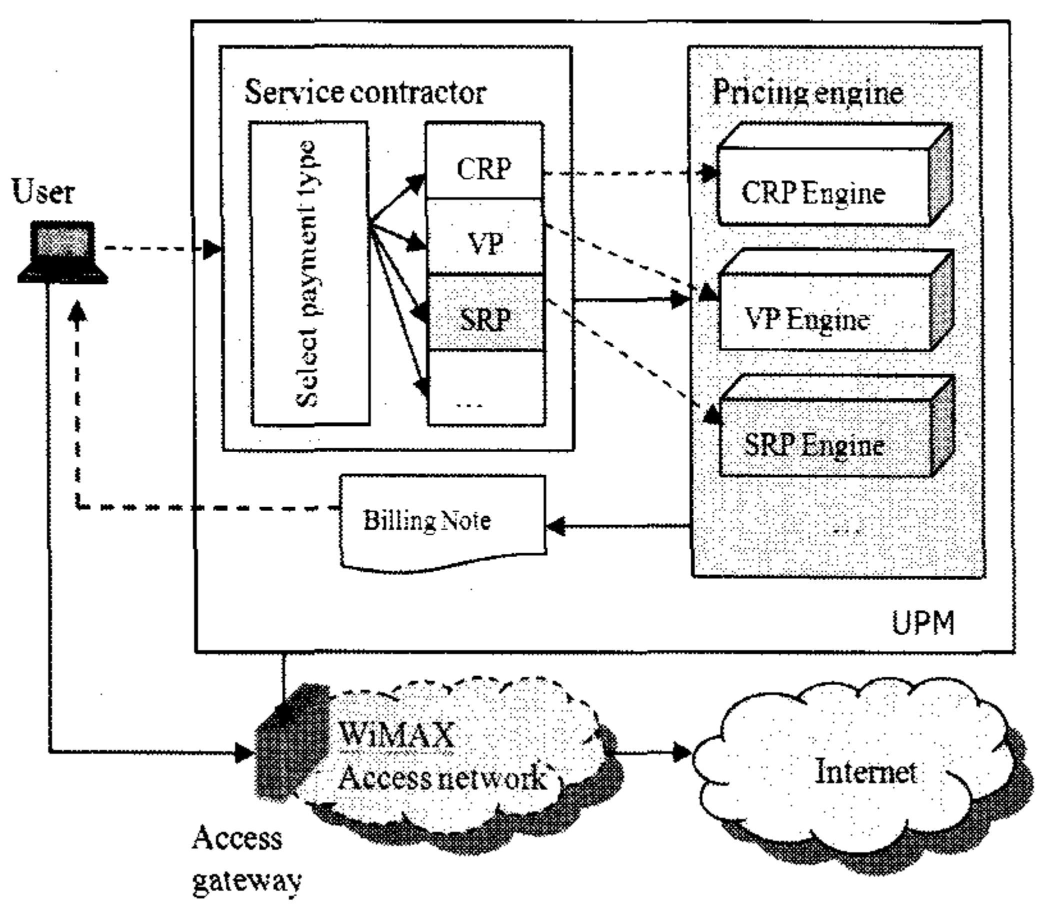

Fig. 2. Universal pricing machine

There may exist lots of payment types for the WiMAX service, typical of which includes fixed monthly price, volume price, and a compromise between the two schemes. However, to the best of our knowledge, we could find no explicit scheme for the WiMAX service that incorporate the service type of the WiMAX service itself, yet.

On the other hand, in the world of IP network, there exist lots of pricing scheme for the Internet service: few of which includes volume pricing (VP), committed rate pricing (CRP) and sustained rate pricing (SRP). Let us introduce these pricing schemes into a WiMAX service network, and let us call it a UPS as a package for packet pricing.

2.3.1 Committed rate pricing

The basic principle behind the CRP is its simplicity in the pricing architecture by reserving peak bandwidth to the connection and levies a fixed amount of price to the connection. In CRP, users can use a bandwidth resource up to the preset limit, e.g., 2Gbps of transfer speed, during the contraction period. ISP does not mind whether the user is actually using the bandwidth up to its limit, so that no metering is committed to the user except the duration of a connection. This scheme is analogous to the current flat pricing scheme for the xDLS access service except that CRP measures the duration of a connection.

The main advantage of this scheme is that it is simple to the users as well as to the network operators. However, when a user does not use the allocated bandwidth up to the limit, the user utility and network utilization are low.

2.3.2 Volume pricing

When it comes to VP, ISP measures the total amount of bytes that has been sent by a connection, based upon which the price is levied. The main advantage of this scheme is the fairness of the price to the users: the heavy users pay high price compared with the light users. On the other hand, the drawback of VP is the overhead in the network operator in that the network operator has to collect the user's total usage history for his/her entire connection time. There exist many varieties for the VP scheme, which can be found in [16,17,18].

2.3.3 Sustained rate pricjng

A compromise between CRP and VP is SRP. In SRP the network operator maintains a trace for the user's usage by a sampled measurement of the usage history. Let us assume that the sampling frequency and interval are determined appropriately by a network operator. When ISP finds that a certain amount of bandwidth, say at most 2Gbps of bandwidth, is used by a connection for the ϕ (e.g., 95) per cent of the connection time, the network operator charges a fixed amount of money, say P$ per Gbps per second, from the user.

On the other hand, user may transmit bursty traffic during the connection time without being charged at his peak rate. This implies that 2Gbps of bandwidth is sustained to the connection with probability 95%, and ISP understands that his/her bandwidth resource of 2Gbps is allocated to the connection during the connection holding time. Note that this is analogous to the percentile pricing scheme proposed by [19], where the 95 percentile of bandwidth used, measured over the 5-minute time periods, is billed to the user over the length of the connection time.

Ⅲ. Pricing functions

3.1 Pricing functions

Let us define the pricing function for each service type. In order to compute the price for the flow, let us define a flow and the method to measure parameters from the flow. Flow is identified by generic flow identifiers such as the source/destination IP address, source/destination port number, and protocol field. The flow duration is measured by the flow start time and end time for each flow, which can be computed by observing the time stamps between the packets with SYN and FIN flags. The flow size is calculated by summing up the packet length field in the packet. Price is charged to a flow by the following alternatives for the pricing scheme.

3.1.1 Committed rate pricing

Following the basic principle for the CRP, price is determined as follows: ISP levies the price by a function of the committed amount of bandwidth (CAB) to the connection, which is given by f(y) $ per y Gbps, where y is the amount of bandwidth reserved to the connection. A description on the function f(y) is defined later. When we translate this price as a unit price of per Gbps, we have

$$\Psi_{UB}^{CRP} = \frac{f(y)}{y} \quad \$ \text{ per Gbps}, \qquad (1)$$

where the subscript UB indicates 'unit bandwidth'. When the duration of a connection with committed rate of C Giga bps is T, the price for a connection is given as follows:

$$\Psi^{CRP} = f(C) \times T \quad [\text{unit: Dollars}] \qquad (2)$$

Price is levied to a connection even though the connection does not use the reserved bandwidth. Fig.3 illustrates the concept of CRP, where the basis for the pricing is indicated as a bold dotted line.

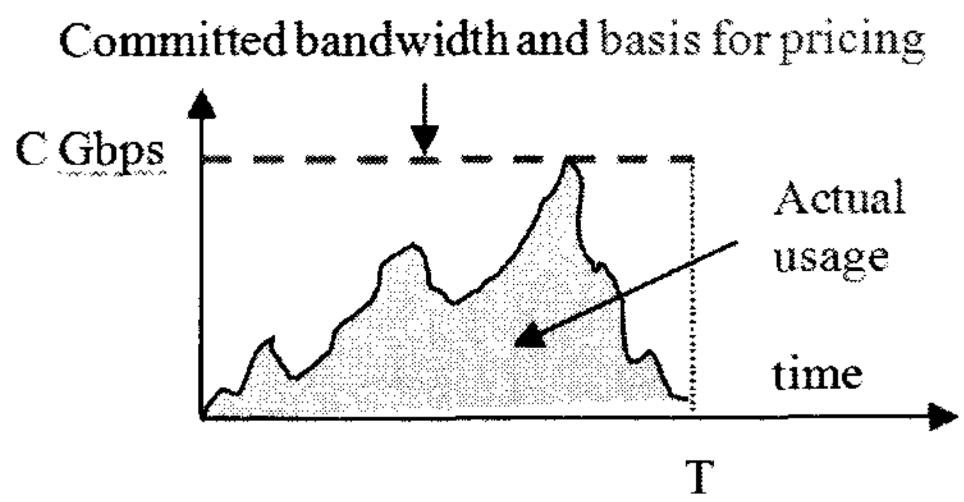

Fig. 3. Committed bandwidth and actual usage

3.1.2 Volume pricing

Following the basic principle for VP, price is determined as follows: ISP levies the price in the unit of bytes the connection has sent to the network, which is represented as a function of f(x) $ per x Gigabyte. Therefore, the price for a connection that has sent L Gigabytes is given as follows:

$$\Psi^{VP} = f(L) \quad [\text{unit: Dollars}] \qquad (3)$$

A description on the function f(x) is defined later. Note that the price in VP is based on the used

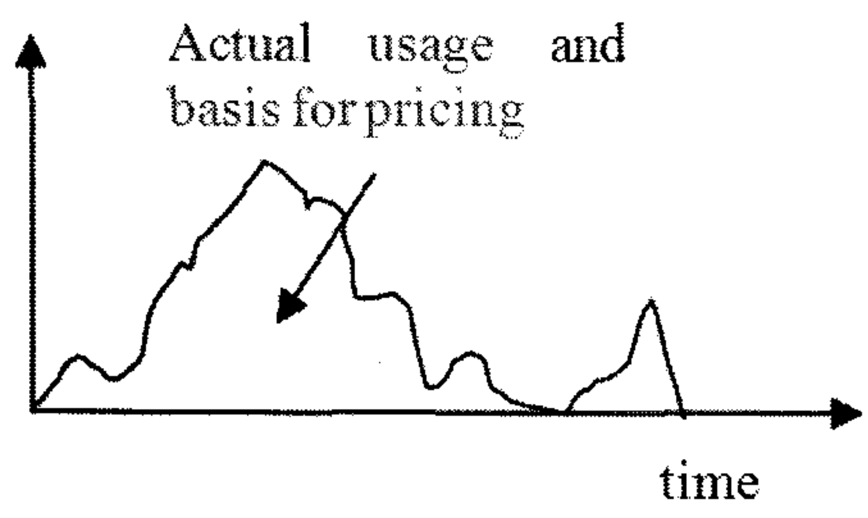

Fig. 4. Actual usage and VP

volume, so that no subscript is needed per se. Fig.4 illustrates the concept of VP, where the basis for the pricing is pure volume of packets.

3.1.3 Sustained rate pricing

Following the basic principle for SRP, the price is determined as follows: ISP levies the price by a function of the sustained bandwidth to the connection, which is given by f(z) $ per z Gbps, where z is the amount of bandwidth sustained to the connection during its connection duration.

When the instantaneous rate of a flow is a(t), and if the duration of a flow with sustained rate of S Gbps is T, the price [unit: Dollars] for a flow is given as follows:

$$\Psi^{SRP} = \begin{cases} f(S)\times T, if\_percentile\_of\_a(t) > S\_is\_less\_than\_\phi \\ f(C)\times T, else \end{cases} \quad (4)$$

where C is the maximum link speed and ϕ is the performance objective that is defined above.

Fig.5 illustrates the concept of SRP, where the basis for the pricing is the sustained bandwidth (SB) of S Gbps to a flow throughout the connection time. Note that a fixed price is levied to a flow even

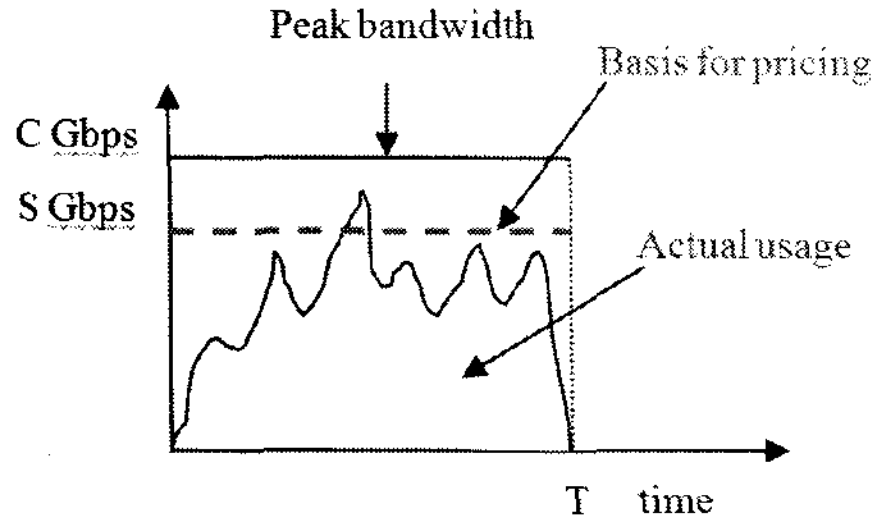

Fig. 5. Sustained bandwidth and actual usage

though the flow does not send packets to the network during its connection time, and instead no extra price is charged to a connection for the excess use of the bandwidth up to the limit of S Gbps if the percentile of a(t) that exceeds S Gbps is less than 0.05. The basis for the price is indicated by the dotted line in the graph.

3.2 Incentive and penalty in the price

It would be natural to give an incentive and/or penalty to the users when their behavior is harmful to the welfare of the network society. Now let us propose a method to give an incentive and penalty for the users.

Incentive is given to the users when they consume a moderate amount of bandwidth but up to a certain limit, whereas penalty is given to the users when they consume bandwidth excess to a certain limit. Former encourages moderate use of the unused bandwidth, whereas latter discourages excess use of the limited bandwidth. To illustrate this concept in the context of pricing, let us define a term called the consumed bandwidth (CB), which is given as follows: When it comes to CRP, CB is defined by an amount of bandwidth that is allocated to a flow. When it comes to a VP, CB is defined by the amount of bytes that is sent by a flow. Finally, when it comes to an SRP, CB is defined by an amount of bandwidth that is sustained by a flow.

Now let us first consider the incentive and penalty in the price for the CB. To that purpose we have to take into account the following facts: First, the price has to be concave under a certain threshold. This means that high price is levied to a small volume of CB, whereas price is discounted for the large volume of CB, which is in line with the discount scheme for the customary users who habitually transfers a large volume of traffic to the network by contracting a high bandwidth. This corresponds to the whole sale price for a box of apples as compared with the retail price for each piece of apple in the market. This is called the discount price, because an incentive is given to customary users. Discount price is applied to CB which is near the upper threshold.

When the volume of consumed bandwidth exceeds a certain threshold U, which is called the contracted volume, users have to pay higher price for the extra amount of traffic that they have sent to the network. This corresponds to penalty price for the unexpected heavy users. Note that it would be natural for the extra price to be a convex function of the volume size. This means that high penalty is given to a high level of unexpected usage of bandwidth, which prevents the network from unstable fluctuation of the usage of the bandwidth in the link. Fig.6 illustrates our argument where x is the volume of CB and p(x) is the price.

There exist lots of functions which fit the above mentioned principle for the pricing. Among them let us suggest the following heuristic function, where x is the consumed bandwidth and p(x) is the price of bandwidth usage x.

In Fig.6, we set the following criteria for the pricing:

if $x \le aU$, then

$$p(x) = \frac{\alpha Q}{aU} x$$

if $aU < x \le bU$, then

$$p(x) = \frac{(\beta - \alpha)Q}{(b-a)U}(x - aU) + \alpha Q$$

if $bU < x \le U$, then

$$p(x) = \frac{(1-\beta)Q}{(1-b)U}(x - bU) + \beta Q$$

else, $$p(x) = Qe^{x-U} \qquad (5)$$

Note in Fig.6 that the contracted volume U can be interpreted in a variety of ways: U can be allowed amount of data transfer (AADT) for VP, as we have witnessed in Table 1. On the other hand, U can be mapped to CAB for CRP or SB for SRP. Determination of U for VP is straightforward. We can use the current billing policy in this case. When it comes to CRP or SRP, we have to be a little bit cautious. On the other hand, when it comes to the determination of the thresholds in the pricing function p(x), ISPs can determine the values of a, b, α, and β in their own policies, and it is not the focus of this work.

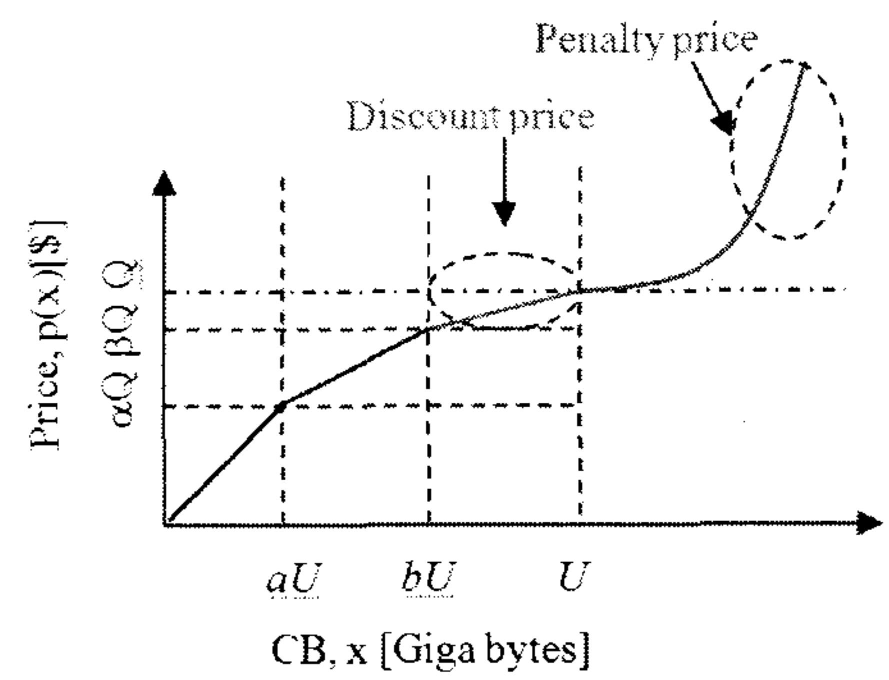

Fig. 6. Pricing function for the UPS

Note that one can relate the function f(x) to p(x) if one has information about the usage of bandwidth and time duration of a flow, which is given below.

Now let us argue that there has to be an adjustment parameter that reflects the difference of the guaranteed QoS for the WiMAX service. At present, we could find no result in this problem. On the other hand, we had already proposed a differentiated packet price scheme for the two-class DiffServ service over IP network [20]. The proposed scheme aims at the maximization of the revenue from the ISP's point of view by differentiation of the unit price for the strict priority packet scheduling scheme.

Note that determination of the differentiation factor for the three-class WiMAX service is not a simple problem to be solved. Therefore, our current work assumes a simple adjustment rule for the CRP, SRP, and VP scheme, which is as follows: Unit price of SRP is γ times that of VP, and unit price of CRP is η times that of VP. At present, ISPs provide no QoS differentiation scheme for the services, so that we can assume that $\gamma = \eta = 1$.

Ⅳ. Numerical Experiments

Let us illustrate a simple but typical example for the proposed scheme. To that purpose, let us assume the followings:

First, let us assume a single per-packet price, which is different from the current scheme which classifies the service name for different volumes. Instead, we assume the generic service class for the

WiMAX standard. Second, let us assume that users abide by the contraction carried out before receiving the services, so that overcharge due to excess use of the bandwidth is not considered in the experiment. We assumed like this because a single flow does not generate such a large amount of data. Therefore, let us assume that price is levied by the consumed volume within the upper threshold of contracted volume. The pricing rate is determined by a pricing function that is depicted in Fig.6, where the following parameters are assumed: $a=0.3$, $b=0.6$, $\alpha=0.6$, $\beta=0.9$, $Q=20$, $U=2$.

4.1 Price for the data service

Let us assume that a customer is subscribed to a basic service that is defined at Table 1, so that the threshold for the moderate usage is U=2gigabytes and upper limit on the price is Q=20$. Now let us assume that data service is subscribed as a best effort service, so that it is charged by VP. A data flow is assumed to have a file size of 750Megabytes, which is assumed to be a file size of a CD-ROM. Then, the amount of data used belongs to the area of $aU < x \leq bU$ in Fig.6.

From these parameters we can compute the price for the data service, which is given as follows:

$$\Psi^{VP} = 13.5 \quad \text{[Dollars]}$$

4.2 Price for the voice service

Now let us assume that phone service is subscribed as a committed rate service, so that it is charged by CRP. Let us assume that phone service has the following traffic parameters: Voice call uses ITU-T G.729 voice encoder, which is used as a coding scheme for the cellular phone. The packet length is 76bytes with packet generation period of 20msec. This corresponds to 30.4Kbps of link speed. Therefore, C=30.4Kbps of link capacity is allocated to a flow as a committed bandwidth. The flow duration T is assumed to be 3 minutes. Then, the consumed volume of the network resource is 684Kbytes.

Let us assume that a customer is subscribed to a basic service, so that the threshold for the moderate usage is U=2gigabytes and upper limit on the price is Q=20$. Then, the amount of data used belongs to the area of $x \leq aU$ in Fig.6.

From these parameters we can compute the price for the voice service, which is given as follows:

$$\Psi^{CRP} = 1.37 \quad \text{[Cents]}$$

Note that, the current volume pricing scheme, users have to pay about 1.37 Cents to WiMAX service provider for their 3 minutes voice conversation over a reserved bandwidth of 30.4Kbps of link speed.

4.3 Price for the video service

Now let us assume that video service is subscribed as a sustained rate service, so that it is charged by SRP. Now let us assume a music video with the following traffic parameters: Video file is in the form of MPEG-1 with pixel size given by 320 ×240. The bit rate of the video file is as follows: peak and mean rate of 3.0 and 2.5Mbps, respectively, and the standard deviation of the bit rate is 0.2Mbps. The duration of a music video is assumed to be 90minutes.

From these parameters let us compute the sustained rate as follows: Sustained rate = mean rate + 2×standard deviation = 2.9 Mbps. Then, the amount of consumed network resource is computed as follows: Amount of consumed network resource = 1.9575giga bytes.

Let us assume that a customer is subscribed to a basic service, so that the threshold for the moderate usage is U=2gigabytes and upper limit on the price is Q=20$. This amount of data usage belongs to the area of discount price, where $bU < x \leq U$ in Fig.6.

From these parameters we can compute the price for the voice service, which is given as follows:

$$\Psi^{SRP} = 19.89 \quad \text{[Dollars]}$$

In this case users have to pay about 19.9 Dollars to WiMAX service provider for their 90minutes of music video clip over an almost-reserved but statistical bandwidth of 2.9Mbps of link speed.

4.4 Findings from the experiment

From these results we can find the followings: First, we find that the proposed UPS can compute the price of each class of the WiMAX service in a unified manner. Second, the price of each type of service can be reduced by the proposed UPS as compared with the current HFVP scheme.

Therefore, we can conclude that the proposed UPS can contribute to the following field: Users can save the money from UPS by selecting an appropriate price menu to their service. Network operators can save the limited bandwidth resource since users do not abuse the bandwidth, otherwise they have to pay much money for their abuse of the bandwidth.

V. Conclusions

In this work, we proposed a pricing scheme called a UPS for the WiMAX service. To that purpose we proposed a UPM as a functional framework for the pricing of the WiMAX service. After that we proposed a new pricing scheme for the WiMAX service by way of a hybrid of VP, CRP and the SRP for each type of WiMAX service such as the UGS, PS, and BE. By carrying out numerical experiments we could show the practicality and possibility of the use of the proposed pricing scheme to the real WiMAX network environment.

This work is our first step toward the systematic pricing scheme of the WiMAX service. Therefore, lots of work has to be done after this work. Our future research work includes the proposition of the pricing scheme by taking into account the flow-level grade of service such as the flow blocking probability in of the WiMAX service by carrying out the flow-level performance analysis of the WiMAX system. Also, we are also thinking about the implementation aspect of the UPS over the NS.2 simulation environment.

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Seung-Hak Suk Regular Member

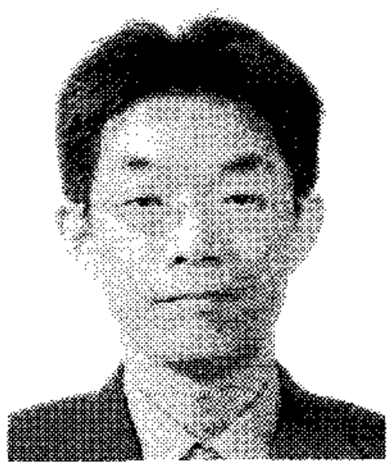
Feb.1984 B.E. from Kyungpook National University

Feb.1986 M.E. from Kyungpook National University

Feb.1986~Current KT Network Technology Laboratories

<Research fields> Network management, Service control for BcN

Hoon Lee Lifelong Member



Feb.1984 B.E. from Kyungpook National University

Feb.1986 M.E. from Kyungpook National University

Mar. 1996 Ph.D. from Tohoku University, Japan.

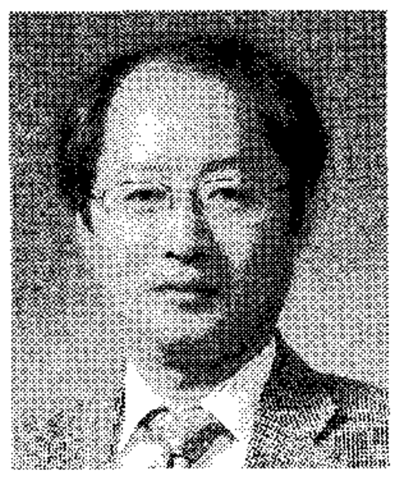
Feb. 1986~Feb.2001 KT Network Laboratories

Feb. 2001~Current Changwon National University

Mar.2005~Aug.2006 Visiting Scholar, University of Missouri-Kansas city, USA.

<Research fields> Network design, Performance evaluation, Internet QoS and charging,

Kwang-Hui Lee Regular Member



Feb.1983 B.E. from Korea University

Feb.1985 M.E. from Korea University

Feb.1989 Ph.D. from Korea University

Mar.1988~Current Changwon National University

1991~1992 Researcher, New Bridge Networks, UK

1991~1993 Visiting Scientist, Univ. of Reading, UK

1997~1998 Researcher, Univ. of Wales Swansea, UK

1999~2006 Researcher, Nortel Networks, UK

<Research fields> Mobile ad-hoc network, USN, Network management