논문 2004-41TC-3-4

최저대역보장형 서비스에 대한 과금

(Charging the Assured-Bandwidth Service)

석 승 학*, 이 훈**, 이 광 휘**

(Seung-Hak Seok, Hoon Lee, and Kwang-Hui Lee)

요 약

가까운 미래에 우리는 기존의 정액제 요금에서 종량제가 첨가되는 것과 같은 인터넷서비스의 요금체계에 변화를 맞이할 것이다. 본 논문은 이와 같은 움직임에 대비하여 차세대 네트워크에서 서비스품질이 보장되는 인터넷 서비스에 대한 사용량기반의 과금체계를 제안하고자 한다. 먼저, IP네트워크에서 가장 주류를 이룰 Assured service에 의해서 발생되는 적응성이 있는 트래픽의 특성을 살펴보고, 이어서 네트워크 대역의 사용량에 기반한 과금방안을 제안한다. 그리고, 어떤 형태의 Assured service에도 적용 가능한 과금함수를 제안하고, 간단한 수치계산을 통하여 제안하는 방법의 유효성에 대하여 기술한다.

Abstract

In the near future we can expect a change in charging the Internet service. The flat charging maybe replaced with a usage-based charging. In line with this movement, we propose a method of charging the assured-quality Internet services for the next generation network by introducing a UBC (usage-based charging) scheme over the conventional flat charging platform. First, we investigate the attribute of elastic traffic generated by assured services in IP network. Next, we propose a new method to relate the bandwidth usage with the pricing for the elastic traffic, which is based partially on the usage rate of the network bandwidth. Next, we propose a charging function for elastic traffic, which is applicable to any type of assured Internet services. Finally, we discuss the implication of the work via simple numerical experiments.

Keywords : NGN, Assured services, QoS, Internet pricing, UBC

I. Introduction

At present almost all the Internet services such as web browsing, file transfer as well as the exchange of e-mails are paid by a fixed charge irrespective of the amount of data transferred over the commercial Internet.

IP-VPN and ADSL services adopt this charging scheme. A customer only pay an access charge to the Internet irrespective of the usage of the network resources. Thus, this is called a flat charging, and it is a kind of a subscription-charge.

The flat charging scheme has been adopted in a shared network with best effort service architecture, because there exists no classes or priorities in service. So, there exists a high probability that greedy users can monopolize the network resources, especially the bandwidth, so that non-greedy users experience high delays upon their visit to the network when the network is congested with packets generated from the heavy users.

Recently, we could find new applications which require timely delivery of data such as the Internet phone or applications which favor guarantee of minimum amount of bandwidth during data transfer such as web browsing or Intra/Extranet via VPN (Virtual Private Network). To cope with these differences in the requirements for the network performance, differentiated service policy such as DiffServ (differentiated service) architecture has been proposed by IETF (Internet Engineering Task

* 정회원, KT 운용시스템 연구소
(KT Operations Support System Lab.)
** 정회원, 창원대학교
(Changwon National University)
접수일자:2003년9월27일, 수정완료일: 2004년3월5일

Forces)[18]. In line with these approaches, the concepts of charging in the current Internet services are undergoing changes toward the UBC (usage-based charging) [1,11,14,16].

We could find a lot of literature for UBC. Firdman advocated the necessity of the usage-sensitive pricing, priority-based pricing, and value-added pricing [5]. McKnight gave a qualitative overview on pricing the next generation Internet services after flat rate scheme [14]. Blot et al. reported a functional framework called NetCounter on charging the individual connection in IP commercial network [2]. Karsten proposed a scheme for a linear price calculation in IETF integrated service architecture advocating that the internal price calculation should be linear and has to be based on the resource usage in the network, where he assumed a reservation-based service differentiation scheme [6]. Kelly devised the concept of pricing by effective bandwidth, which is evolved into usage based charging [7]. Lee presented a discussion on bandwidth sharing and its impact on user utility and pricing for IP network in [9], where he argued that the network service provider has to levy charge based on the usage of the network bandwidth by illustrating the quantitative numerical results for elastic traffic with best effort service architecture. In [10,11], Lee extended the concept of usage-based charging to more specific applications, the VPN services, where usage rate charging is also advocated by showing some numerical results. Recently, Park proposed a two-part tariff scheme from the pure economic point of view [15], which is very similar to Lee's work. Lee also advocated the two-part scheme even for the current best effort Internet services [12].

Recently, two leading mobile ISPs (Internet Service Providers) in Korea announced that they would change the charging scheme for the mobile Internet toward a combined flat & UBC [17]. They levy a fixed charge of 20$ for 124,000 packets (packet size is assumed to be 512bytes) transfers during a month. If the amount of packet transfer exceeds the predetermined amount, they levy a charge of 0.02Cents per packet. Note that the telecommunication companies began to move toward a mix of flat & UBC pricing for the Internet services.

This paper is an extension of those works of [10,11,12]. We argue that the usage-based charging has to be tuned to the value of the network resources. That is, if the bandwidth is allocated to a connection in the form of reservation the charge can be fixed, otherwise the charging scheme can take the usage-based charging. This work devises a realistic approach that mixes the flat charging and the usage-based charging for the assured-bandwidth services of next generation Internet.

This paper is composed as follows: In Section II we describe the attributes of assured services and the limit of conventional flat charging. In Section III we propose a method to determine the price curve under the flat & residual pricing scheme for elastic traffic. Section IV gives the results for numerical experiments, where the implication of the proposed methods is shown with graphs. In Section V we summarize the paper and give some comments on further research areas.

II. Assured Service and Flat Pricing

In this work, assured service (AS) is defined to be applications that require a QoS (Quality of Service) defined by minimum amount of bandwidth under any network condition. Each arriving packet is classified by an edge router from DSCP (Differentiated service code point) of a packet header, and treated as an AF PHB (assured forwarding per hop behavior) in DiffServ architecture of IETF. Examples of AS are transfer of streaming files and web browsing, and it can cope with variable throughput, from which the traffic of AS is called elastic traffic (ET). ET can tolerate packet delays gracefully and it would rather wait for reception of traffic in the correct order, almost without losses. Therefore, traffic of AS needs an elastic bandwidth allocation mechanism like TCP, and it is treated next to EF (expedited forwarding) services in IP network.

As to AS, the specification for QoS is usually expressed in terms of minimum throughput. Throughput is represented by the mean value of the file size divided by transfer time[13]. Minimum throughput of AS is synonymous with the minimum bandwidth the network has to provide to a connection, which is contracted with the customer in the phase of SLA (service level agreement) before traffic is transferred. The contracted minimum bandwidth (CMB), which is denoted by μ, can be allocated (in the form of reservation) a priori or statistically guaranteed by a scheduler in a DiffServ router, and an additional bandwidth (call it "plus-α") is provided by network if there is any available bandwidth unused by other connections in the network.

Even though CMB is contracted between ISP and a customer, a customer may generate traffic less than or greater than the CMB at any instant, because CMB is based on the average value computed over some time interval (we will describe this aspect in more detail in Section IV). If there exists sufficient bandwidth in the link, the network can carry out all the traffic in excess of the contracted value μ, otherwise some packets are forced to wait in the queue for later transmission. Because the variation of the traffic volume generated from a connection for Internet access is very harsh[3], there may happen a case in which a connection can or can't use the contracted bandwidth μ. So, the traffic curve goes up and down across the CMB. Of course, the traffic rate of a connection should not exceed the maximum link capacity M.

Flat pricing levies a fixed charge to a connection irrespective of the connection's actual usage. For example, a network can provide a connection with at most M bits per second (e.g., 1.5 Mega bps for the standard ADSL service), and it levies a fixed amount of a charge to a connection whether a connection uses it or not. The flat pricing scheme is not suited to AS services from the following reasons. First, FP (Flat pricing) results in unfairness between heavy users and light users. Second, moral hazard exists between users, because the charging is not sensitive to the actual usage. Moral hazard results in an excessive use of network bandwidth, which in turn results in network congestion. Under the network congestion, heavy users impose a damage to light users with delayed packet transfer, which results in negative network externality.[15] Finally, FP gives no incentive to ISP's effort for the differentiation and/or upgrade of the quality of services. The flat pricing is best suited to the VPN type services in which a customer can use the bandwidth up to a full capacity at any time. From this discussion, one can find that a new pricing scheme that is suited to the elastic traffic has to be developed.

III. Pricing the Elastic Traffic from Assured Service

The discussion in Section II implies that a new pricing scheme that takes into account the additional usage exceeding the CMB has to be devised in any manner. To that purpose, we have to devise a method to translate the value of bandwidth used by the elastic traffic into a price.

1. Flat & Residual Price for Elastic Traffic

For AS, the CMR, denoted by μ in the previous section, can be looked upon as a kind of reserved bandwidth within which a customer can use at one's own will, whereas the additional bandwidth, called plus-α, is an excess bandwidth that can be used by a customer if there exists additional bandwidth the network operator can provide to the customer. Let us levy a charge in a fixed and residual way such that a fixed amount of charge for a unit time is levied unless the usage exceeds CMR. If the usage exceeds CMR, additional charge is levied in proportion to the excess usage in addition to the fixed charge. Let us define this scheme as a flat & residual pricing (FRP). The basic assumption behind FRP is that a customer pays a fixed amount of charge for the minimum bandwidth whether he/she uses it or not during a connection to the network, whereas the assumption on the provision of additional bandwidth is that the customer is ready to pay additional price for the additional bandwidth provided by the network. Let us call the price of residual bandwidth to be the residual price. The concept of FRP is illustrated in Fig.1.

As one can find from Fig.1, a customer pays a fixed amount of charge per unit time during a connection irrespective of the usage of the network bandwidth so far as the usage rate does not exceed the predefined minimum bandwidth μ. So, computation for pricing is not carried out by the network operator. However, a customer has to pay additional charge for the usage of the bandwidth in an amount he/she used in addition to when the bandwidth usage is greater than μ.

There may exist various ways for levying prices differently to the usage of the bandwidth (see [9,10]). The typical curve for the residual price is a linear function connecting the two points of (μ, γ) and (M, Λ). The slope of residual price is determined by the pricing policy of the network company.

Let us assume that maximum price that can be levied is Λ per unit time for the usage of maximum allowed bandwidth of M. Then, σ is given by

$$\sigma = \frac{\Delta P}{\Delta u} = \frac{\Lambda - \gamma}{M - \mu} \quad (1)$$

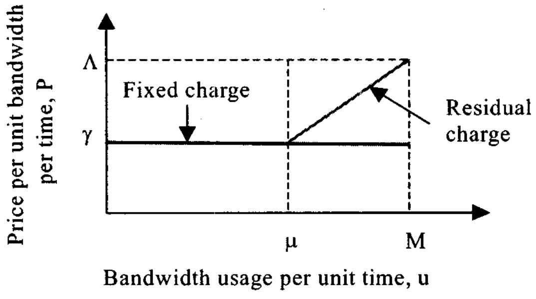


그림 1. FRP의 개념
Fig. 1. Concept of FRP.

In order to compute the unit prices γ and Λ, we have to know the relationship between the available bandwidth and the unit price. The price for a packet transfer over the current IP network in Korea is based on the fixed rate and the only metric for charging is the speed of an access link of ADSL or Leased-line [11]. In order to compute the unit charge with respect to the use of the unit bandwidth for IP network, we use the average of current charges for Korea's standard ADSL services with maximum speed of down link to be 1.5Mbps, which is a fixed monthly price of about 25$ [8].

Recently (from September 2002), MIC (Ministry of Information & Communication) of Korean government announced a recommendation for the contraction of SLA for the high-speed Internet services of Korea [4]. SLA is defined in terms of the minimum bandwidth of 0.5Mbps for the standard ADSL services. SLA monitoring is carried out by 10 measurements during a busy hour (the average connection time of Internet services of Korea is about an hour). If at least 60% of the measured data violates the SLA, ISP has to refund one-day's charge to a customer.

Even though an SLA is introduced to an Internet service, the charging principle is not changed, yet. That is, if an SLA is defined to be 0.5Mbps from the maximum available link speed of 1.5Mbps, the charge has to be lowered in accordance with it.

Now let us devise a method to determine γ and Λ in Fig.1. A fixed charge of γ per unit time is levied to a user whose usage is not greater than a minimum service rate of μ, which is contracted as an SLA between ISP and a user. A maximum of Λ is levied to a user whose usage is M. In between (μ, M), a proportional charge is levied.

To the best of author's knowledge, there does not exist a concrete way to determine γ and Λ, which may be determined by the network company's pricing policy or from the market forces. In general, it is known that the flat monthly charge is determined by adding appropriate profit margin to the cost of service provisioning with regard to a customer with "average usage" [15]. This is one of the main reasons of the cheap charges for the current high-speed Internet services. However, ISPs can confront severe economic problems if usages of customers increase far above the average usage, because the network resources have to be reinforced in order to maintain good quality of services.

Based on this general principle of economics, let us propose a new approach for determining the values γ and Λ by adopting the usage and price graph as shown in Fig.2.

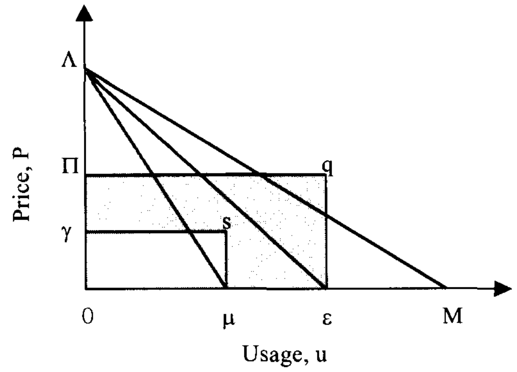


그림 2. 네트워크의 대역사용량과 과금과의 관계
Fig. 2. Usage and price curve for network bandwidth.

The usage and price curve illustrated in Fig.2, which is similar to demand and supply graph in standard Economics, implies that a user uses no bandwidth if the price is greater than Λ, whereas a user tempts to use M amount of bandwidth if the price is zero. In between the values $[0,\Lambda]$ a user uses the bandwidth between [0,M] in reverse-proportion to the price shown in Fig.2. Ideally, the utility is equal to the product of the available bandwidth and the charge a customer pays. The area formed by a triangle $0\Lambda M$ is the maximum utility that a customer can obtain by consuming M amount of bandwidth for a monthly price Λ. Even though a customer can use M amount of bandwidth at any time instant, a customer can't always use the whole amount of allocated bandwidth. Let us assume that a customer uses ϵ amount of bandwidth on average.

In general ISP levies a charge Π under the flat charging scheme, where Π is determined from the average usage ϵ of customers. In order to estimate a unit price for a bandwidth provided from the ADSL service, let us assume that on average a user connects to the Internet service 50 minutes per connection and once per day. The average amount of bandwidth a user consumes is assumed to be ϵ =0.75Mbps during a connection. If we assume an activity factor of 25days per month, the amount of data a customer sends to the network is 56.25Gbits per month(0.75Mbps×3000sec×25days/month). Since the charge for the service is 25$ per month, the unit price will be 0.044Cents per Megabits, from which we can compute Π in Fig.1. Table 1 summarizes the result.

표 1. 대역량과 가격
Table 1. Bandwidth and price

Bandwidth type	Price
Maximum Speed, M (Mbps)	1.5
Minimum Speed, μ (Mbps)	0.5
Maximum usage (Gbits/Month)	56.25
Price under the current fixed pricing scheme (US$/month)	25
Unit price, Π (Cents per Mbits)	0.044

The utility under the current pricing scheme is the area of a rectangle $o\Pi q\epsilon$, which is equal to $\Pi\epsilon$. If we levy a maximum charge of Λ and a customer can use M amount of bandwidth, the utility of a user is equal to an area determined by a triangle $0\Lambda M$.

Therefore, Λ can be obtained by proportioning the two areas made from triangle $o\Lambda M$ and the rectangle $o\Pi q\epsilon$. From this, we obtain the following result:

$$\Lambda = \frac{M}{\varepsilon}\Pi. \tag{2}$$

On the other hand, the utility of a user who consumes M and μ amount of bandwidth on average is equal to an area determined by a triangle $0\Lambda M$ and $0\Lambda\mu$, respectively. From this, we can easily notice that there exists subsidy of cost between heavy users and light users if ISP levies the same charge for all customers irrespective of the actual usage. In order to eliminate this kind of subsidies, charges have to be levied in proportion to the usage of the bandwidth. That is, when an average usage of a customer is equal to M, where the utility of that customer is $\Lambda M/2$, he/she has to pay Λ. In the same manner, we can find that the utility a customer can obtain from using μ amount of bandwidth is equal to $\Lambda\mu/2$. Therefore, the charge levied to a user who used μ amount of bandwidth is given as follows:

$$\gamma = \frac{\mu}{M}\Lambda. \tag{3}$$

Note that the price for using bandwidth not greater than μ is the same as that of using bandwidth of μ. That is, the amount of charge levied to a customer is γ irrespective of the actual usage unless the usage does not exceed the threshold μ, the minimum bandwidththat is guaranteed at any time. This implies that the network can provide the customer with a minimum bandwidth μ at any time at the price of a fixed charge of γ. Then, from Table 1 one can find that γ=0.029Cents. Finally, from eq.(1) and Table 1, one can obtain the slope of the residual pricing function, which is given by σ =0.059Cents/Mbits. Note that the residual price is much higher than the fixed price, so that the pricing scheme can be used as a controller of the traffic inflow to the network.

2. Pricing Function

As we have described in the above discussion, a detailed collection of data for the usage of bandwidth is carried out if the instantaneous usage exceeds the threshold μ. Fig.3 illustrates the period of measurement in pricing the residual charging.

Let us define some variables and parameters for the calculation of the charge levied to a connection. Let v(t) be the traffic volume (unit: bits) which is generated by a customer at time t. Then, the usage of the network bandwidth (unit; bits per second) is divided into two distinct intervals: one for monitoring only, the other for price computation.

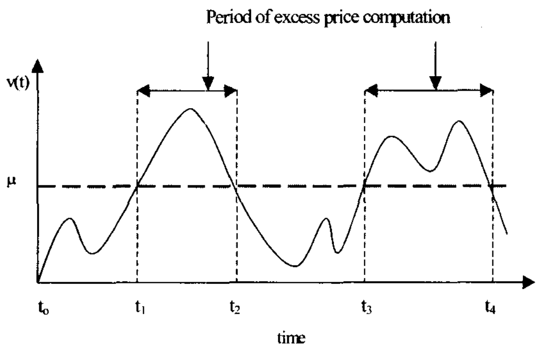


그림 3. 대역사용량과 과금 구간
Fig. 3. Usage profile and pricing period.

Referring to Fig.3, t_{ij}, where i=0,2,... and j=1,3,..., corresponds to the former, and t_{ij}, where i=1,3, ... and j=2,4,..., corresponds to the latter. In order to collect data for pricing, the monitoring device carries out the following functions:

(A) Monitor the bandwidth usage v(t) of the link. If v(t)is greater than the threshold μ, then compute the amount of traffic in excess of μ, which is represented by v(t)-μ, until v(t) down-crosses the threshold μ, Otherwise, do not compute the amount of traffic.

(B) Repeat "step (A)" until a connection is finished.

(C) Compute e_{ij}, for all i=1,3,... and j=2,4,..., which is defined by the amount of excess bits transmitted in the network during t_i and t_j, and it is given by

$$e_{ij} = \int_{t_i}^{t_j} (v(t) - \mu)dt \tag{4}$$

(D) Finally, take the sum of e_{ij}, i=1,3,... and j=2,4,..., which is given as follows:

$$e = \sum_{ij} e_{ij} \text{, i=1,3,... and j=2,4,...} \tag{5}$$

Now let us assume that the holding time of a connection is T, and let us define a time period w_{ij} as follows:

$$w_{ij} = [t_j - t_i | usage \le \mu] \text{, i=0,2,... and j=1,3,....} \tag{6}$$

Let us define the total time period w during which bandwidth usage is less than the threshold μ as follows:

$$w = \sum_{ij} w_{ij} = (t_1 - t_0) + (t_3 - t_2) + \cdots = \sum_i (-1)^{i+1} t_i \tag{7}$$

Note that we can obtain the total period of time during which the usage is greater than the threshold μ if the time stamp t_i, i=0,1,..., is identified. Note also that w in eq.(7) is the total time during which the usage of a connection is not greater than CMR. On the other hand, T-w is the total time during which the usage of a connection is greater than CMR. If we have real data for the usage rate of network bandwidth, we can relate the usage rate into charging functions F(T) and R(e), which are summarized in Table2.

표 2. 연결당 단위가격과 사용요금
Table 2. Price and charge per connection per day

Pricing	Flat	Residual	Total
Price function	F(T)=$\gamma \times$T	R(e)=$\sigma \times$e	P(T,e)= F(T)+R(e)
Condition	v(t)$\le \mu$	v(t) > μ	x
Note	Time charge	Volume charge	Time+Volume charge

Note that the flat price is determined by time duration of a connection, whereas the residual price is determined by volume of the excess data. Note also that the charge as a whole is based on the usage of a network bandwidth even though the price is a mixture of flat and UBC. F(T) is proportional to the connection time, which is based on the time-usage. R(e) is proportional to volume, which is based on the volume-usage. Therefore, the proposed scheme is a usage-based charging as a whole. One point we have to notice is that the above result considers only one-way traffic. The usage rate of both-way traffic for the asymmetric link can be obtained in the same way [11].

IV. Numerical Results and Discussion

In order to apply the proposed scheme into the estimation of monthly charge, let us assume some parameters. Let us assume the mean holding time of a connection is 50 minutes. Then we can compute the time portion of a charge from eq.(8). In order to compute the volume portion of a charge that is represented in eq.(9), we have to know the amount of excess bandwidth used by a connection, which is assumed to be an input in this numerical experiment. Finally, we can compute an estimation of monthly charge for a customer from Table 2.

Fig.4 illustrates the result of the estimated total monthly charge as a function of usage for a customer with usage behavior of T=50minutes per day and activity factor of 25days per month. Note that the charge contributed by a fixed price is 22$ when the network usage is 0.5Mbps in the figure, which is the minimum charge a customer has to pay per month for the Internet service. The maximum charge is 66.25$ when a customer uses the link up to the limit (1.5Mbps in Fig.4) during his/her connection to the network.

An implication of the result illustrated in Fig.4 can be as follows: An ISP provides a customer with information about the network usage profile (cumulative one) of Internet services on daily or monthly basis. Then, the customer can estimate his daily or monthly charge from that information. If he is an economic person, he may be sensitive to the charges, and if he looks at his usage profile every time he connects to the network, and if it exceeds the CMR he will refrain from unnecessary transfer of data into the network. This might be one of a few effective means for the congestion avoidance for the future Internet services.

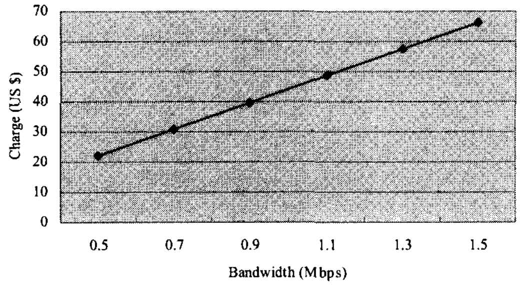


그림 4. 대역사용량에 대한 과금 예측치
Fig. 4. Usage of bandwidth and estimated charge.

V. Conclusions

In this paper we proposed a method of estimating the charges for the assured service in IP network. We argued that the conventional flat charging scheme has to be replaced with the proposed flat & residual charging due to several reasons described in the paper. Regarding the flat & residual charging scheme, we proposed a systematic procedure for the determination of the unit price for the contracted minimum bandwidth of assured services and the maximum price, the measurement method, and the charging functions. Via simple numerical experiments we could provide an intuition for the estimation of monthly charges from the average amount of traffic transferred over IP network.

This work might be one of a few works that deal with quantitative discussion for charging the Internet services with SLA of better than Best Effort based on the residual usage of the bandwidth. Thus, there remain lots of problems to be solved. To name a few, more work has to be done in the determination of the optimal price for the use of links with different speeds, time granularity for metering specific applications such as a voice or video, implementation to the billing system in NGN OSS (Operation support system), etc. Our next research will be concentrated on these areas.

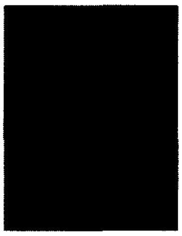
참 고 문 헌

[1] A. Pras et al., "Internet accounting", IEEE

Communications Magazine May 2001.
[2] S.M. Blot, et al., "User-level billing and accounting in IP networks", Bell Labs Technical Journal, Oct-Dec. 1999.
[3] J. Charzinski, "Problems of elastic traffic admission control in an HTTP scenario", Proceedings of IWQoS2001.
[4] "On the quality regulation of high-speed Internet services of Korea", http://www/chosun.com/
[5] E. Firdman, "Rx for the Internet: usage-based pricing", Data Communications on the web, http://www.data.com/business_case/rx_internet.html
[6] M. Karsten et al., "Provider-oriented linear price calculation for Integrated services", Proceedings of IWQoS'99, 1999.
[7] F.P. Kelly, "Charging and accounting for bursty connections", Internet Economics, ed. L.W. McKnight and J.P. Bailey (eds) MIT Press, 1996.
[8] The price for Megapass services for the KT, http://www.kt.co.kr, as of July 10, 2002.
[9] H. Lee, "Bandwidth sharing, utility and pricing for the best effort Internet services", Proceedings of the 3rd Int'l conference on advanced communication technology (ICACT2001), February 8-10, 2001, Muju, Korea.
[10] H. Lee, "A usage based charging in IP-VPN", NCS2000, December 4-6, 2000.
[11] H. Lee and J.-H. Eom, "A usage-rate based charging for QoS-free traffic in IP-VPN", Proceedings of the ICC2001, June 11-15, 2001, Helsinki, Finland.
[12] H. Lee et al., "Differentiated charging for elastic traffic", Journal of KICS, Vol.26, No.12, December 2001.
[13] K. Lindberger, "Balancing Quality of Service, pricing and utilization in multi-service networks with Stream and Elastic Traffic", ITC 16, Edinburgh, June 1999.
[14] Lee W. McKnight and J. Boroumand, "Pricing Internet services: after flat rate", Telecommunications Policy 24 (2000).
[15] J.S. Park and J.H. Lee, "A study on problems of the high-speed Internet pricing inKorea and its optimal solution", Summer Conference of KICS 2002, July 11-13, 2002, Muju, Korea.
[16] A. Pras, et al., "Internet accounting", IEEE Communications Magazine, May 2001.
[17] Y.S. Kim, "A change toward Flat & UBC for mobile Internet services in Korea", The Electronics Times (Korea), June 4, 2003.
[18] http://www.ietf.org.

저 자 소 개

석 승 학(정회원)
1984년 2월 경북대학교 전자공학과 (공학사)
1986년 2월 경북대학교 대학원 전자공학과 (공학석사)
1986년 2월~현재: KT 기술본부 운용시스템연구소 선임연구원/실장
<주관심분야: BcN 네트워크 / 서비스 관리, BcN QoS 제어 및 관리>



이 광 휘(정회원)
1983년 2월 고려대학교 전자공학과 (공학사)
1985년 2월 고려대학교 대학원 전자공학과 (공학석사)
1989년 2월 고려대학교 대학원 전자공학과 (공학박사)
1988년 3월~현재 창원대학교 컴퓨터공학과 교수
<주관심분야: 네트워크/QoS 관리, 정책기반 네트워킹, 멀티캐스팅 프로토콜, 모바일 컴퓨팅>

이 훈(정회원)
1984년 2월 경북대학교 전자공학과 (공학사)
1986년 2월 경북대학교 대학원 전자공학과 (공학석사)
1996년 3월 일본 토호쿠대학 대학원 공학연구과 (공학박사)
1986년 2월~2001년 2월 KT 연구개발본부 선임연구원
2001년 3월~현재 창원대학교 정보통신공학과 조교수
<주관심분야: 인터넷트래픽엔지니어링, 네트워크 성능분석 및 설계, QoS 보장 및 과금>