

Simulation Analysis of QoS Enabled Internet Pricing Strategies: Flat Rate Vs. Two-Part Tariff

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Abstract

In this paper, we study the influence of QoS pricing strategy in the future QoS Internet market. We create a Bertrand duopoly game model with different pricing schemes: One ISP with flat rate pricing for its QoS service and the other ISP with two part tariff, a combined pricing scheme with flat rate and usage-sensitive pricing. Based on industry survey data, we conduct a simulation of a random number generation method for consumer demand and Internet access hours. Then, we find an equilibrium point of pricing strategy where an ISP with flat rate pricing has higher profit than an ISP with a two-part tariff. Finally, we present an analytical framework for the future QoS Internet pricing strategy.

1. Introduction

After the commercialization of the Internet, the demand for various Internet services diversified. Real-time and business-critical data applications require improved levels of services, or 'QoS (Quality of Service).' However, in the current Internet, most traffic is treated indifferently; i.e., there is no discrimination among different Internet traffic streams. There is only one class of service to which all traffics belong, no delivery confirmation, no guarantee for timely delivery, and a possibility for traffic loss. This kind of Internet service is called 'Best Effort (BE).' Compared to BE, QoS has various classes: a class for guaranteed timely delivery, a class for no traffic loss, and a class for delivery confirmation.

In the summer of 2001, large service providers like AT&T and WorldCom announced that they would provide Internet "Class of Service" (CoS) to their customers using Multi-Protocol Label Switching (MPLS) and Differentiated Services (DiffServ). This CoS-based service consisted of

four classes according to priority level: Platinum, Gold, Silver, and Bronze. For example, voice or video applications would probably choose the highest priority (Platinum class) service, while other traffic, such as e-mail or HTTP, might choose the lowest priority (Bronze class) service (i.e., best effort). Business critical data applications might use an intermediate priority level. These announced service levels were limited to connections completely contained in the carriers' networks. In early 2001, the Florida Multimedia Internet Exchange (FMIX), managed by Bell South, announced plans to be the first NAP¹ (Network Access Point) to use MPLS interconnection. In doing this, FMIX faced many new challenges with QoS interconnection, such as class matching between providers and managing the disclosure of network information for end-to-end quality guarantees. We believe that these developments are harbingers of the future as follows:

- (1) First, the product will be diversified. Before QoS, there was only one service level, BE, in which traffic delay and traffic dropping are possible. After QoS, there will be at least two services in the Internet market: BE and QoS. Since QoS includes BE service as its lowest class of service, QoS is superior to BE resulting in vertical product differentiation.
- (2) Some of the traditional characteristics of Internet industry in U.S. are (i) 'non metered' Internet usage and (ii) 'flat rate' unlimited access user pricing. We believe that it is reasonable to expect a change in the pricing paradigm to usage-sensitive pricing with metering given the higher value of QoS service.

¹ A NAP is where Internet interconnection among different providers occurs. The detailed will be explained in later section, chapter 2 Internet Industry.

ISPs in this industry are competitors and cooperators simultaneously: On one hand they are competitors for market share but on the other they are cooperators that provide universal, global connectivity. Thus, one ISP's decision has an influence on other ISP's decisions and ISPs in the Internet industry have a strong dependence on each other. This characteristic suggests game theoretic modelling, i.e., each player in the game model is a competitor in a market and there are interactions according to their strategic decisions. Furthermore, the end-to-end QoS could not be established without a strong cooperation among ISPs.

Under current Internet pricing (unlimited access flat rate monthly payment), users want to take as much bandwidth as they can within their access capacity, which causes a 'tragedy of the commons' phenomenon. This can be overcome through appropriate pricing. Introducing Internet QoS is a good opportunity to consider usage-sensitive pricing. In this paper, we will demonstrate ISPs' equilibrium behavior in an Internet QoS market with the different pricing schemes: one ISP with a traditional unlimited access flat rate pricing and the other ISP with two part tariff, i.e., a combined pricing strategy with fixed rate plus a usage sensitive pricing. We will construct a Bertrand price competition model and conduct a simulation² with the industry survey data for user's demand and Internet usage patterns.

The paper is structured as follows. Section 2 explains the assumptions and background for the simulation model. Section 3 describes the simulation procedure. Section 4 analyzes behaviors of ISPs at the equilibrium point. Finally, we conclude in the Section 5 with an explanation of the limitations of this research.

2. Background and Assumptions

2.1 Bertrand Duopoly Game Model

A duopoly game model is a useful first approximation for the analysis of an industry with limited competition. In this model it is assumed that there are two duopolists in the Internet Access market without the possibility of new entrants³. For Internet industry analysis, some papers [1,5,6] use a Cournot game model, which is reasonable under the assumption of homogeneous BE service and capacity limitations. In this paper, we use a game model based on the Bertrand model. Since over-provisioning itself is not enough to provide a guaranteed QoS service,

there is a strong possibility that both ISPs will wage a price war.

The ISPs are competing each other for their market shares so they are trying to maximize their own profits based on the belief that the other ISP's price is fixed. While ISP1 uses the same pricing scheme as it used for BE, the other ISP uses two-part tariff, which includes usage-sensitive pricing. We assume there is no quality difference in the each ISP's class of traffic, which means customers feel indifferent whether they consume QoS service from ISP1 or ISP2. In our simulation, each ISP is trying to change its price for a higher profit, which is consistent with a Bertrand game model: firms set prices rather than output and they produce identical products; Each firm believes its rival's price is fixed; by a slight price cut, the firm is able to capture its rival's business. [2]

2.2 Pricing Strategy

An ISP's service is access to the Internet, which includes login authorization, e-mail services, some storage space, and possibly personal web pages. There are several Internet access technologies including dial-up, cable-modem, DSL, and wireless. According to the U.S.GAO (United States General Accounting Office) report [8], the dominant technology is dial-up access (87.5%) in 2000⁴; so we restrict our analysis to that technology. Dial-up access using PSTN (Public Switched Telephone Network) is also the most universal form of Internet access. The switching system in the Local Exchange Carrier's Central Office connects calls between the Internet user's computer and the ISP's modem pool, so the LECs' facilities support dial-up Internet communications. In the U.S., the local telephone services are provided under flat-rate billing; that is, a telephone user can originate local calls as many times and as long as he wishes with only a fixed monthly charge. This type of billing system has been a great influence on the growth of Internet access market in the US.

The main pricing scheme in the current Internet access market is flat rate pricing, similar to telephone access; for example, unlimited Internet access for a fixed amount of money per month. The reasons to use flat rate pricing are: (1) ISPs do not have to meter their customer's traffic for billing, (2) customers prefer flat rating pricing to usage-sensitive pricing, and (3) flat-rate pricing encourages Internet usage because users are not concerned about additional cost for usage. However, this kind of flat rate pricing causes the congestion of the Internet. For major national ISPs, the price ranges generally from \$0 to \$25 per month⁵. Some ISPs provide Internet access service

² This simulation is conducted by the CSIM Simulation Package based on the Visual C++ 6.0 platform.

³ In rural markets, a duopoly is common for internet service provision. See [6] and [7] for a further discussion of this.

⁴ Dial-up (87.5%), Cable modem (8.9%), DSL telephone (3.2%), and Wireless (0.4%)

⁵ Telecommunications International Inc.'s Quarterly Online Census at March 31, 2000

with zero monthly subscription fees to their customers⁶; their revenues depend completely on advertising income. According to Zigmont [9], the cost of startup ISP is roughly \$12 per subscriber including \$7 for management/maintenance cost plus \$5 for marketing. For this paper, we assume the price of dial-up Internet access to be \$20 per month, which can be the lower bound for the QoS price.

After introducing QoS, it may be possible or even necessary to introduce a usage-sensitive pricing, because the value of QoS traffic is higher than BE traffic. To reduce customers' resistance to pure usage-sensitive pricing, we assume that flat rate pricing will remain for BE and a new pricing scheme will be introduced for QoS.

Generally speaking, when firms do not exactly know consumers' willingness to pay, a way to price would be to use a two part-tariff, which charges a lump-sum fee for the right to purchase plus a per-unit charge for each unit consumed. In the Internet industry, two-part tariff is not fully efficient because the added fixed charges may deter some users who at marginal cost prices would be willing to join the network and consume. [3]

The two-part tariff in our model has the same form as described above, but its meaning is a little bit different. The fixed part lump-sum fee is the right to use the lowest class of QoS service (BE) and the variable part is for the consumption of the premium classes of QoS service. Someone who only wants to use the BE service pays only fixed part lump-sum fee.

2.3 QoS Demand

According to Gal-Or [4,5], when a product is differentiated on the basis of quality and each consumer is assumed to purchase only one unit of the product, the consumers' willingness to pay is assumed to be dependent upon their taste factor (X) and a quality level (M) for the product, i.e., (1) $U(X, M) = f(X)*M$. According to her theory, the price of high quality product is the price of low product plus a function of quality difference. In our model, QoS is a high quality service and BE is a low quality service. The price of QoS is assumed to be the price of BE plus a function of quality difference between QoS and BE, i.e., (2) $P_{BE} = f(X)*M_{BE}$ and (3) $P_{QoS} = P_{BE} + f(X)*(M_{QoS} - M_{BE})$. We assume the number of classes in the service that each ISP can provide as a quality level of that service. The QoS service has two classes: BE class and premium class. Therefore we can say that the quantitative quality level of BE is '1', i.e., $M_{BE} = 1$ and that of QoS is '2', i.e., $M_{QoS} = 2$. If we put these numbers into the above

equations (2) and (3), we can rewrite them as (4) $P_{BE} = f(X)$ and (5) $P_{QoS} = P_{BE} + f(X)$. Therefore, (6) $P_{QoS} = 2*P_{BE}$.

In a U.S. GAO report [8], there is a survey question: "About how much do you pay per month to access the Internet from your home?" Although this question does not provide willingness to pay for Internet access but we can use this answer as a proxy for customer's demand. The following is the distribution from this question.

[Table 1] Distribution of Household Expenditure for Internet Access (per Month)

	\$0	~\$5	~\$10	~\$15	~\$20
%	8.9	1.4	3.8	8.3	21.0

	~\$30	~\$40	~\$50	\$50~
%	31.7	11.1	8.7	5.1

* Source: GAO-01-345, Characteristics and Choices of Internet Users, p46.

We modified the above table into an equal sub-range: [\$0-\$10], [\$10-\$20], [\$20-\$30], [\$30-\$40], and [\$40-\$50]. We assume the price range for BE is from \$0 to \$50 and the data within a sub-range is uniformly distributed. The following is the modified table according to the above assumption.

[Table 2] Piecewise Uniform Distribution

\$0-\$10	\$10-\$20	\$20-\$30	\$30-\$40	\$40-\$50
14.1%	29.3%	31.7%	11.1%	13.8%

We use two-stage RNG (Random Number Generator): (1) first, we use the above empirical distribution table to match a sub-range and (2) then we use the piecewise uniform distribution for the specific utility value. For example, if the random number generated from the empirical distribution is between 0 and 0.141, then this customer's utility value is determined by the function of uniform [\$0, \$10]. The following table shows this two-stage RNG method.

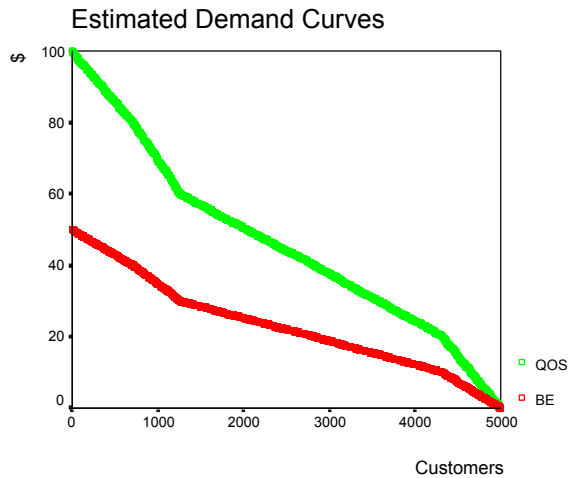
[Table 3] Two-Stage RNG

Result from First RNG	Second RNG Function
0.0 ~ 0.1410	Uniform [\$0, \$10]
0.1411~0.4340	Uniform [\$10, \$20]
0.4341~0.7510	Uniform [\$20, \$30]
0.7511~0.8620	Uniform [\$30, \$40]
0.8621~1.0	Uniform [\$40, \$50]

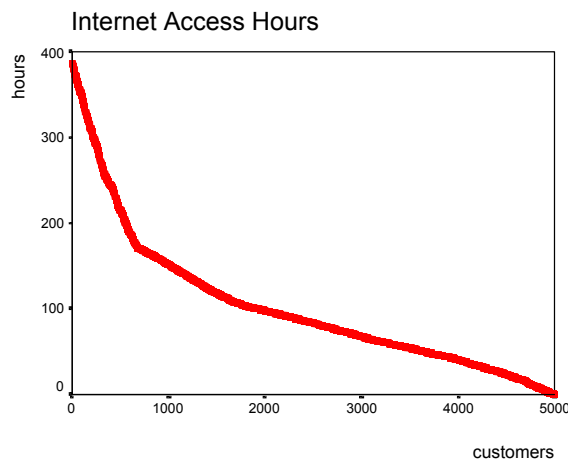
Based on these assumptions and methods, the demand functions for BE and QoS are presented in Figure 1. The average willingness to pay of BE and QoS are \$23.19 and \$46.39.

⁶ AltaVista, FreeInternet.com, NetZero, FreeLane, Source: www.ispworld.com/introduction.htm.

[Figure 1] Demand for BE and QoS



[Figure 2] Internet Usage Hours



2.4 Internet Usage Pattern

The main assumption for Internet usage in this simulation depends on the Internet usage pattern, which comes from the USGAO report [8]. One of the survey questions is “On average, how many hours per week do you and all your members of your household spend on the Internet from your home?” The following table comes from that survey question.

[Table 4] Internet Usage Distribution (Per Week)

Answer	~ 1 hr	~ 4 hrs	~ 10 hrs	~15 hrs
Percent	0.0	6.3	12.1	19.4

Answer	~25 hrs	~40 hrs	~60 hrs	60 hrs ~
Percent	29.3	19.8	6.3	6.9

* Source: GAO-01-345, Characteristics and Choices of Internet Users, p44.

We modify the above table into the one shown in Table 5. We define the practical maximum number of hours for the Internet usage to be 90 hours per week⁷, which is equivalent to 387 hours per month. We use the same two-stage RNG method: (1) a RNG based on empirical distribution for the selection of sub-range and (2) another RNG based on uniform distribution for the exact consumer’s usage hours. We multiply the random numbers generated by the above RNGs by 4.3 to transform weekly to monthly data. This monthly Internet usage data determine users’ monthly payment under the usage sensitive two-part tariff. Figure 2 shows the sorted Internet access hours. The average Internet access hour per month is 102.40 hours (/month), which is calculated by $\Sigma(\text{random number for Internet usage} * 4.3 (\text{week/month})) / 5000$ (users).

[Table 5] Piecewise Uniform Internet Usage Distribution (Per Week)

Sub-Range	0 ~4	4 ~ 10	10~15
Percent	6.3%	12.1%	19.4%

Sub-Range	15~25	25~40	40~60	60 ~90
Percent	29.3%	19.8%	6.3%	6.9%

2.5 QoS-Time Matrix

The traffic class can be determined either by the provider or by the user. The source and destination IP addresses and port numbers can be used by the provider’s edge router to assign a class to traffic flow. For example, e-mail and HTTP traffic may belong to a lowest class and VoIP and videoconference traffic may belong to the highest class. Alternatively, a user can assign a class to each application. For example, even e-mail users can assign the highest class if they consider their e-mails critical to their business. For example, a QoS time matrix can be built by users, i.e., for business users a platinum class for all traffic from 9 A.M. to 5 P.M in the weekdays, a gold class for the rest of the weekdays, and a silver class for weekend and holidays.

2.6 Profit Functions

In our simulation, consumers can compare the prices of the two ISPs and their willingness to pay for the QoS service⁸. Therefore, if one ISP cuts its price, it may not capture the market because the two ISPs have different price structures.

⁷ Practically, maximum number of hours per week is 168 hours (7 * 24).

⁸ That is, we assume that everyone has perfect information.

The number of potential customers in the market is assumed to be 5,000, which means sum of q_1 and q_2 cannot go over 5,000. We assume that the cost of each ISP is zero. As long as costs of both ISPs are symmetric, the fixed costs have no influence on the outcome at the equilibrium point of the simulation model (except for the profits). Therefore, we can say that two ISPs are identical except for the QoS pricing strategy: (1) ISP1 chooses flat price for unlimited Internet QoS access, and (2) ISP2 chooses two-part tariff, which is combined pricing strategy with flat price plus usage-sensitive price. The followings are the profit functions: The profit1 is the profit function of ISP1 and the Profit2 is that of ISP2.

- $Profit1[p1] = p1 * q1$,
 - where $q1$ ($0 < q1 < 5000$) is the number of ISP1's subscribers and
 - $p1$ ($\$20 < p1 < \100) is unlimited QoS connection flat rate,
- $Profit2[p2] = F * q2 + \Sigma(h_{QoS} * r)$,
 - where F ($\$20, \$25, \$30, \$35, \text{ or } \$40$) is fixed rate for unlimited BE connection,
 - $q2$ ($0 < q2 < 5000$) is the number of ISP2's customers,
 - h_{QoS} ($0 < h < 387$) is the number of QoS connection hours per user, and
 - r ($\$0.0 < r < \1.5) is the QoS connection rate per hour.

For example, while subscribers of ISP1 pay \$40 per month regardless of number of hours of QoS Internet connection, subscribers of ISP2 pay \$20 per month for BE Internet connection plus \$1 per hour for their QoS Internet connection. The range of QoS price ($p1$) should be over \$20 and F must be equal or higher than \$20, which is assumed to be the current unlimited access BE price. In the two-part tariff case, we assume the range of rate (r) is from \$0.1 to \$1.4, which comes from the following idea:

- (1) The average hours of Internet access per month is 102 hours (/month) in our model.
- (2) We assume the average customer use 50% of his Internet connection hours as a QoS connection, i.e., 51 hours of BE connection and 51 hours of QoS connection.
- (3) We assume his willingness to pay for the QoS service is the average of all customers (\$46.39).
- (4) We assume the customer with an average willing to pay will consume 51 hours of BE and 51 hours of QoS, which means he will pay \$20 ($=F$) for BE connection and \$26.39 ($=\$46.39 - \20) for QoS connection. Therefore, using the QoS connection hours and the payment for QoS connection, the rate (r) should be \$0.5 per hour of

QoS connection ($\$0.5 * 51 \text{ hours} = \$25.5 \approx \$26.39$).

- (5) We make a 'rate and QoS connection percent' relationship based on the following:
 - ($r, \% \text{ of QoS}$) = ($\$0.5, 50\%$) will be a base point,
 - From this point, increasing \$0.1 of r causes decreasing 5% of QoS connection hours,
 - Decreasing \$0.1 of r causes increasing 5% of QoS connection hours.
 - The following table shows the overall relationship between rate (r) and percentage of QoS connection hours.

[Table 6] Rate (r) and QoS Connection Hours Percentage

Rate	\$0.1	\$0.2	\$0.3	\$0.4	\$0.5
QoS	70%	65%	60%	55%	50%

Rate	\$0.6	\$0.7	\$0.8	\$0.9	\$1.0
QoS	45%	40%	35%	30%	25%

Rate	\$1.1	\$1.2	\$1.3	\$1.4
QoS	20%	15%	10%	5%

The following table summarizes values and ranges of various parameters assumed in our simulation model. W_{BE} and W_{QoS} mean willingness to pay for BE and QoS.

[Table 7] Parameter Values

Parameters		Range
W_{BE}		\$0 ~ \$50
W_{QoS}		\$0 ~ \$100
$p1$		\$21, \$22, ~ \$100
$p2$	F	\$20, \$25, \$30, \$35, \$40
	r	\$0.1, \$0.2, ~ \$1.4
	h_{QoS}	0 ~ 387 hours

3. Simulation Procedure

The followings are the simulation procedure:

- (1) Each user will be assigned by willingness to pay (W) and number of Internet usage hours (h), which are generated by the RNGs explained in the previous section.
- (2) Then, each user can calculate the difference between willingness to pay for QoS and price of the Internet connection service for each ISP. For example, $Net1 = W_{QoS} - p1$ comes from consuming ISP1's QoS service and $Net2 = W_{QoS} - p2 = W_{QoS} - (F + h_{QoS} * r)$ comes from consuming ISP2's QoS service. If both $Net1$ and $Net2$ are below zero, a user will not buy either service. If $Net1$ or $Net2$ is greater than zero, the user will choose the ISP that will give him a

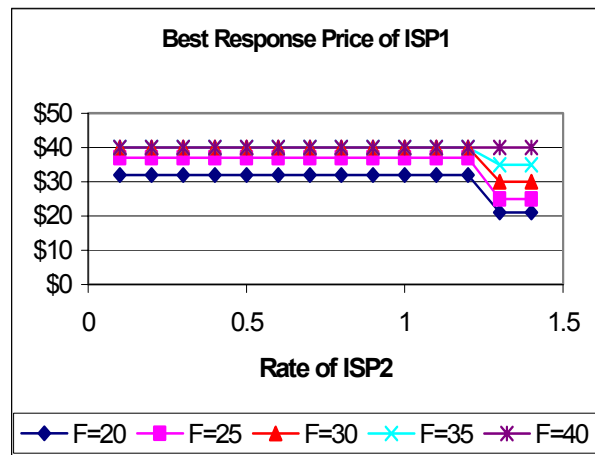
higher value for QoS connection, i.e., if ($Net1 > Net2$), a user chooses ISP1, otherwise a user chooses ISP2.

- (3) According to the Bertrand Duopoly model, ISP1 will choose a price for its optimal profit assuming that ISP2's price is unchangeable. ISP2 will also choose a price, F and r , for its optimal profit of ISP2 under the assumption that ISP1's price is unchangeable. We calculate all the possible profits of ISP1 and ISP2, and by the definition of the Nash equilibrium, choose the best response profit for each ISP.
- (4) To find equilibrium prices of ISP1 and ISP2, we follow these steps:
 - First we need to set a value of F among three control variables, $p1$, and $p2(r, F)$. We set $F = \$20$,
 - We calculate response profits with the change of $p1$ and r , i.e., $f1[p1, p2(r, F=\$20)]$ and $f2[p1, p2(r, F=\$20)]$,
 - Choose the maximum profit, $f1^*$ and $f2^*$, as a best response profit comparing all possible $f1s$ and $f2s$ respectively. For example, when $r = \$0.1$, find a $p1^*$, which gives a maximum $f1^*[p1^*, p2(r = \$0.1, F = \$20)]$, do the same thing with a change of r until $r = \$1.4$.
 - Do the same thing for the ISP2 as we did for ISP1. When $p1 = \$21$ ($p1 > (\$20 = \text{the price for BE})$), find a r^* , which gives a maximum $f2^*[p1 = \$21, p2(r^*, F = \$20)]$, do the same thing with a change of $p1$ until $p1 = \$100$.
 - Since an equilibrium point is the intersection point of each ISP's best response functions, by comparing $f1^*$ and $f2^*$ we can find the equilibrium point at $F = \$20$,
 - Do the above procedure when $F = \$25, \$30, \$35$, and $\$40$, and
 - Now we have 5 equilibrium points with 5 different F values. Choose an optimal equilibrium profit for ISP2 among these 5 points because the F is the part of ISP2's price structure.

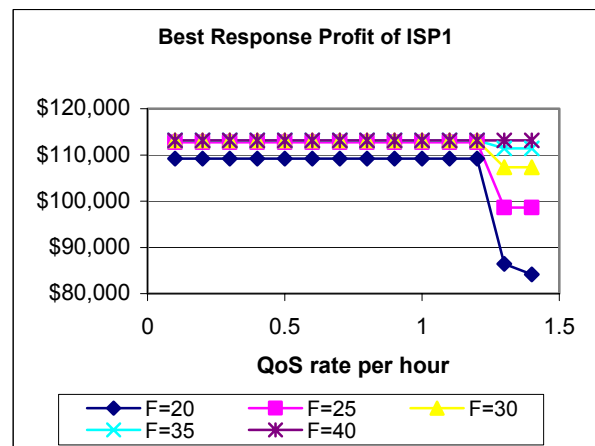
4. Equilibrium Analysis

The following graphs show the best response prices and profits of ISP1 and ISP2 when the ISP2's fixed part is \$20, \$25, \$30, \$35, or \$40. Selected cases of response prices and profits are in the appendix. Best response prices of ISP1 and ISP2 are also in the appendix.

[Figure 3] Best Response P1



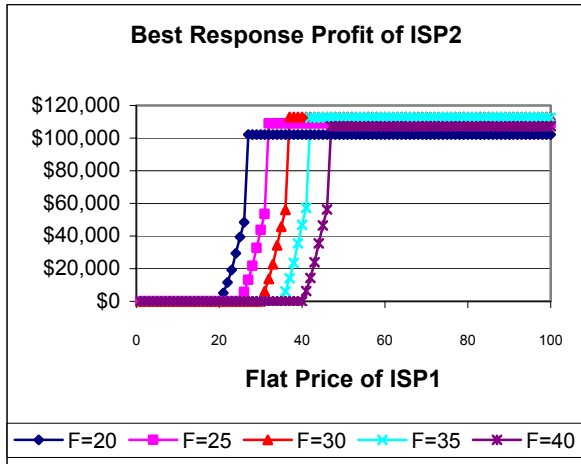
[Figure 4] Best Response f1



[Figure 5] Best Response r of ISP2



[Figure 6: Best Response f2]



The following table shows the intersection points of the best response profit functions of ISP1 and ISP2 when F is given \$20, \$25, \$30, \$35, and \$40.

[Table 8] Best Responses of ISP1 and ISP2

F	Best Response of ISP1 (q2: r: f2:q1*:p1*:f1*)
\$20	(245:1.40:5018:4007: 21: <u>84147</u>)
\$25	(0:1.40: 0:3945: 25: 98625)
\$30	(0:1.30: 0:3578: 30:107340)
\$35	(0:1.40: 0:3184: 35:111440)
\$40	(0:*.**: 0:2828: 40:113120)

F	Best Response of ISP2 (q1: p1: f2: q2*:r*:f2*)
\$20	(4007: 21: 84147: 245:1.40: <u>5018</u>)
\$25	(3945: 25: 98625: 0:*.**: 0)
\$30	(3578: 30:107340: 0:*.**: 0)
\$35	(3184: 35:111440: 0:*.**: 0)
\$40	(2828: 40:113120: 0:*.**: 0)

*,**: any rate can match, i.e., there are 14 rates from 0.1 to 1.4 are possible.

According to Table 8, for each value of F , ISP1 always has a higher profit than ISP2 ($f1^* > f2^*$), because ISP1 can set its price close to the F value of ISP2, i.e., when F is \$25, optimal $p1$ is \$25 and when F is \$30, the optimal $p1$ is \$30, and so on. Customers choose ISP1 when there is not a significant difference between the unlimited QoS price and fixed part of two-part tariff. Among the above five equilibrium points, for all values of F , the equilibrium point of this model is $\{p1^*=\$21, (F^*=\$20, r^*=1.40)\}$ with $f1^*=\$84,147$ and $f2^*=\$5,018$, because ISP2 will not choose a price that results in zero profit.

In Bertrand games, firms make zero profits at equilibrium and the prices of both firms converge to marginal cost, where is equivalent to the social optimum. [2] At the equilibrium of our model, \$20 is the lowest F value of ISP2 and \$21 is also the lowest $p1$ of ISP1, which implies that ISP1 and ISP2 will try to set their price at the lowest level.

However, in reality, the prices for unlimited BE Internet access at \$20 and for unlimited QoS Internet access at \$21 are not reasonable. This result obtains because we ignored the cost part of the profit function. Only \$1 difference between BE production and QoS production is not acceptable because QoS service needs (1) QoS enabled router (2) QoS enabled IP protocol like IntServ, DiffServ, or MPLS, (3) traffic engineering for guaranteeing QoS and (4) especially, QoS billing with several dimensions like class matching, time for delaying, packet loss ratio, and destination (on-net and off-net). The billing cost of the unlimited QoS Internet access pricing is definitely lower than that of the two-part tariff QoS pricing. Therefore, we put another restriction to the simulation model: $p1$, unlimited QoS Internet access price, should be at least \$10 higher than F , i.e., $p1 \geq F + \$10$. For example, if $F = \$20$, $p1 \geq \$30$, if $F = \$25$, $p1 \geq \$35$, and so on. The following table is the result of the simulation with the new restriction.

[Table 9] Best Responses of ISP & ISP2 with $p1 \geq F + \$10$

F	Best Response of ISP1 (q2: r: f2:q1*:p1*:f1*)
\$20	(3052:1.40:75111:831:30:24930)
\$25	(2772:1.40:82053:739:35:25865)
\$30	(2463:1.40:85239:648:40:25920)
\$35	(2176:1.40:86127:560:45: <u>25200</u>)
\$40	(1878:1.40:83618:472:50:23600)

F	Best Response of ISP2 (q1: p1: f2: q2*:r*:f2*)
\$20	(831:30:24930:3052:1.40:75111)
\$25	(739:35:25865:2772:1.40:82053)
\$30	(648:40:25920:2463:1.40:85239)
\$35	(560:45:25200:2176:1.40: <u>86127</u>)
\$40	(472:50:23600:1878:1.40:83618)

In this case, ISP2 will choose \$35 as the value for F , because $f2^*$ is higher than any other case. The final equilibrium point is $\{(p1^*=\$45), (F^*=\$35, r^*=\$1.4)\}$ with the profit of $f1^*=\$25,200$ and $f2^*=\$86,127$. In this case, the price of ISP1, $p1$, also converges at its lowest price ($F+\$10$), i.e., $p1$ is \$30 when $F=\$20$, $p1$ is \$35 when $F=\$25$, and so on. This phenomenon is the same when we use a constraint like ($p1 \geq F + \$5$) instead of ($p1 \geq F + \10).

The following table summarizes the equilibrium results of the two cases, one without the constraint and the other with it. While ISP1 has more subscribers and a higher profit in the case of no constraint, ISP2 has more subscribers and a higher profit when the constraint is present.

[Table 10] Comparison of Equilibrium Points

	(p1*, p2*)	(q1*, q2*)
Without Constraint	(\$21, \$20+\$1.4*h)	(4007, 245)
With Constraint	(\$45, \$35+\$1.5*h)	(560, 2176)

	(f1*, f2*)
Without Constraint	(\$84147, \$5018)
With Constraint	(\$25200, \$86127)

5. Research Limitations and Conclusion

The two-part tariff with usage-sensitive pricing generally gives higher consumer welfare to the customers. However, when an ISP with unlimited QoS access pricing sets its price close to the fixed part of the other ISPs' price, that ISP could get a higher profit at the equilibrium point than the ISP with the two-part tariff. If we add the additional cost constraint, that unlimited flat price should be higher than fixed part of the two-part tariff. Thus, the ISP with two-part tariff will obtain a higher profit at the equilibrium point. Many scholars and industry experts say that over-provisioning and traffic engineering methods cannot successfully provide a guaranteed QoS service without an appropriate pricing scheme. Therefore, the problem of introducing usage-sensitive pricing into the Internet industry accustomed to flat rate prices is a problem that has yet to be solved for the QoS Internet.

We would like to point out that there are limitations of this simulation model, which should be considered in the future research: (1) The mechanism to decide the quality level is arbitrary, ($M_{BE} = '1'$ and $M_{QoS} = '2'$), and we need to study sensitivity analysis of quality level, and (2) we ignore the cost issues of flat rate pricing. Under flat rate QoS pricing users will have a tendency to classify all of their traffic as premium class, whose opportunity cost is higher than that of BE class. In spite of these limitations, the result of this simulation suggests which pricing strategies in the future QoS Internet market will be more successful.

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[Appendix]

[1] Response of ISP1 when F=\$20

F = \$20					
q1	Given p1	f1	q2*	p2*	Best f2*
0	100	0	3810	1.3	102178
0	99	0	3810	1.3	102178
0	98	0	3810	1.3	102178
0	97	0	3810	1.3	102178
0	96	0	3810	1.3	102178
0	95	0	3810	1.3	102178
0	94	0	3810	1.3	102178
0	93	0	3810	1.3	102178
0	92	0	3810	1.3	102178
0	91	0	3810	1.3	102178
0	90	0	3810	1.3	102178
0	89	0	3810	1.3	102178
0	88	0	3810	1.3	102178
0	87	0	3810	1.3	102178
0	86	0	3810	1.3	102178
0	85	0	3810	1.3	102178
0	84	0	3810	1.3	102178
0	83	0	3810	1.3	102178
0	82	0	3810	1.3	102178
0	81	0	3810	1.3	102178
0	80	0	3810	1.3	102178
0	79	0	3810	1.3	102178
0	78	0	3810	1.3	102178
0	77	0	3810	1.3	102178
0	76	0	3810	1.3	102178

0	75	0	3810	1.3	102178
0	74	0	3810	1.3	102178
0	73	0	3810	1.3	102178
0	72	0	3810	1.3	102178
0	71	0	3810	1.3	102178
0	70	0	3810	1.3	102178
0	69	0	3810	1.3	102178
0	68	0	3810	1.3	102178
0	67	0	3810	1.3	102178
0	66	0	3810	1.3	102178
0	65	0	3810	1.3	102178
0	64	0	3810	1.3	102178
0	63	0	3810	1.3	102178
0	62	0	3810	1.3	102178
0	61	0	3810	1.3	102178
0	60	0	3810	1.3	102178
0	59	0	3810	1.3	102178
0	58	0	3810	1.3	102178
0	57	0	3810	1.3	102178
0	56	0	3810	1.3	102178
0	55	0	3810	1.3	102178
0	54	0	3810	1.3	102178
0	53	0	3810	1.3	102178
0	52	0	3810	1.3	102178
0	51	0	3810	1.3	102178
0	50	0	3810	1.3	102178
0	49	0	3810	1.3	102178
0	48	0	3810	1.3	102178
0	47	0	3810	1.3	102178
0	46	0	3810	1.3	102178
0	45	0	3810	1.3	102178
0	44	0	3810	1.3	102178
0	43	0	3810	1.3	102178
0	42	0	3810	1.3	102178
0	41	0	3810	1.3	102178
0	40	0	3810	1.3	102178
0	39	0	3810	1.3	102178
0	38	0	3810	1.3	102178
0	37	0	3810	1.3	102178
0	36	0	3810	1.3	102178
0	35	0	3810	1.3	102178
0	34	0	3810	1.3	102178
0	33	0	3810	1.3	102178
0	32	0	3810	1.3	102178
0	31	0	3810	1.3	102178
0	30	0	3810	1.3	102178
0	29	0	3810	1.3	102178

0	28	0	3810	1.3	102178
0	27	0	3810	1.3	102178
1897	26	49322	2087	1.4	48464
2288	25	57200	1729	1.4	39338
2748	24	65952	1320	1.4	29333
3243	23	74589	889	1.4	19214
3636	22	79992	553	1.4	11653
4007	21	84147	245	1.4	5018
4323	20	86460	0	0	0
4352	19	82688	0	0	0
4381	18	78858	0	0	0
4424	17	75208	0	0	0
4463	16	71408	0	0	0
4487	15	67305	0	0	0
4516	14	63224	0	0	0
4547	13	59111	0	0	0
4586	12	55032	0	0	0
4627	11	50897	0	0	0
4655	10	46550	0	0	0
4693	9	42237	0	0	0
4721	8	37768	0	0	0
4759	7	33313	0	0	0
4788	6	28728	0	0	0
4830	5	24150	0	0	0
4865	4	19460	0	0	0
4898	3	14694	0	0	0
4931	2	9862	0	0	0
4973	1	4973	0	0	0

[2] Response of ISP2 when F=\$20, \$30, and \$40

F = \$20						
q2	given	p2	f2	q1*	p1*	best f1*
245		1.4	5017.9	4007	21	84147
136		1.3	2786.5	4116	21	86436
0		1.2	0	3412	32	109184
0		1.1	0	3412	32	109184
0		1	0	3412	32	109184
0		0.9	0	3412	32	109184
0		0.8	0	3412	32	109184
0		0.7	0	3412	32	109184
0		0.6	0	3412	32	109184
0		0.5	0	3412	32	109184
0		0.4	0	3412	32	109184
0		0.3	0	3412	32	109184
0		0.2	0	3412	32	109184
0		0.1	0	3412	32	109184

F = \$30

q2 given p2	f2	q1	p1	best fl	
0	1.4	0	3578	30	107340
0	1.3	0	3578	30	107340
0	1.2	0	2828	40	113120
0	1.1	0	2828	40	113120
0	1	0	2828	40	113120
0	0.9	0	2828	40	113120
0	0.8	0	2828	40	113120
0	0.7	0	2828	40	113120
0	0.6	0	2828	40	113120
0	0.5	0	2828	40	113120
0	0.4	0	2828	40	113120
0	0.3	0	2828	40	113120
0	0.2	0	2828	40	113120
0	0.1	0	2828	40	113120

F = \$40

q2 given p2	f2	q1	p1	best fl	
0	1.4	0	2828	40	113120
0	1.3	0	2828	40	113120
0	1.2	0	2828	40	113120
0	1.1	0	2828	40	113120
0	1	0	2828	40	113120
0	0.9	0	2828	40	113120
0	0.8	0	2828	40	113120
0	0.7	0	2828	40	113120
0	0.6	0	2828	40	113120
0	0.5	0	2828	40	113120
0	0.4	0	2828	40	113120
0	0.3	0	2828	40	113120
0	0.2	0	2828	40	113120
0	0.1	0	2828	40	113120

[3] Best Response Price of ISP1

r	F=20	F=25	F=30	F=35	F=40
1.4	21	25	30	35	40
1.3	21	25	30	35	40
1.2	32	37	40	40	40
1.1	32	37	40	40	40
1	32	37	40	40	40
0.9	32	37	40	40	40
0.8	32	37	40	40	40
0.7	32	37	40	40	40
0.6	32	37	40	40	40
0.5	32	37	40	40	40
0.4	32	37	40	40	40
0.3	32	37	40	40	40
0.2	32	37	40	40	40
0.1	32	37	40	40	40

[4] Best Response Rate of ISP2

p1	F=20	F=25	F=30	F=35	F=40
100~50	1.2	1.2	1.2	1.4	1.4
49	1.2	1.2	1.2	1.4	1.4
48	1.2	1.2	1.2	1.4	1.4
47	1.2	1.2	1.4	1.4	1.4
46	1.2	1.2	1.4	1.4	1.4
45	1.2	1.2	1.4	1.4	1.4
44	1.2	1.2	1.4	1.4	1.4
43	1.2	1.2	1.4	1.4	1.4
42	1.2	1.2	1.4	1.4	1.4
41	1.2	1.2	1.4	1.4	1.4
40	1.2	1.2	1.4	1.4	
39	1.2	1.2	1.4	1.4	
38	1.2	1.2	1.4	1.4	
37	1.2	1.4	1.4	1.4	
36	1.2	1.4	1.4	1.4	
35	1.2	1.4	1.4		
34	1.2	1.4	1.4		
33	1.2	1.4	1.4		
32	1.4	1.4	1.4		
31	1.4	1.4	1.4		
30	1.4	1.4			
29	1.4	1.4			
28	1.4	1.4			
27	1.4	1.4			
26	1.4	1.4			
25	1.4				
24	1.4				
23	1.4				
22	1.4				
21	1.4				