# A Simulation Approach for Internet QoS Market Analysis

SeungJae Shin and Martin B.H. Weiss
Dept. of Inf. Science and Telecommunications
School of Information Science
University of Pittsburgh
Pittsburgh, PA, 15260
{sjshin, mweiss} @ mail.sis.pitt.edu

Abstract

One of the major areas for research and investment related to the Internet is the provision of quality of service (QoS). In this paper, study the equilibrium outcomes when two Internet Access Providers (IAPs) interact. These IAPs are assumed to be rural dialup providers (as data shows that duopolies often exist in such markets), using empirically based demand functions. To determine the equilibria, we construct duopoly game model and solve it by simulation and computational methods. For the demand function, we use data from the U.S. General Accounting Office (GAO) survey for Internet usage.

In our game model, each IAP has three factors it can control: pricing strategy, investment level, and technology choice (best effort (BE) or QoS). We study the case in which one IAP chooses flat rate QoS pricing and the other chooses a two-part tariff, and both IAPs choose the investment level to maximize their profitability. Investment level is equivalent to the maximum number of users they can support. Finally, they can determine their product mix (BE vs QoS), depending on their capacity level and pricing scheme for optimal profits.

Based on the results of the model, we conclude that QoS-IAP with the two-part tariff has a better market position in the future QoS Internet. The two-part tariff is constructed such that the flat portion of the tariff (the access rate) is for BE service, and the variable portion (usage rate) is for QoS. Thus, the IAP using a two-part tariff is able to differentiate BE and QoS users, which is essentially a form of price discrimination.

Topic Words: Internet QoS, Pricing, Game Theory, and Simulation

## 1. Introduction

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

(DiffServ). The CoS consists of four classes according to the priority level: Platinum, Gold, Silver, and Bronze. For example, voice or video applications can get the highest priority, while other traffic, such as e-mail or HTTP, can be given the lowest priority, which is the same class as the current Internet. Since QoS interconnection policies have yet to be established, this CoS capability is limited to traffic that is contained completely in the provider's own network.

To address this limitation, BellSouth Florida Multimedia Internet Exchange (FMIX) announced plans in 2001 to be the first NAP[1] (Network Access Point) to support MPLS interconnection. Some of the challenges (that were not in the announcement) will be exactly how class matching between providers will be achieved, and how to disclose needed network information for end-to-end quality guarantees without compromising the competitive position of the interconnecting parties.

Despite these difficulties, we remain confident that in the not-to-distant future, QoS will be introduced not only in private networks but in the whole Internet. We take the backbone market leaders' movement toward QoS and the emergence of QoS enabled NAP as strong signs of this shift. Other features of this new network include:

(1) *Product diversification* Before QoS, there was only one available service level (BE) in which traffic delay and traffic dropping are possible. With QoS, there are two products in the Internet market: a BE product and a QoS product. Since QoS includes BE service as its lowest class of service, the new markets will feature vertical product differentiation.

(2) *Operational transition* Traditionally, IAPs in the US provided flat rate access plans, and later performed a limited amount of usage metering. Previous research indicates that, in the absence of price-based differentiation, users will choose the highest quality level regardless of traffic type. [4] Thus, it is reasonable to expect a change in pricing and billing practices toward usage-sensitive pricing with metering.

IAPs (and ISPs) are competitors and cooperators simultaneously: competitors for market share and cooperators for global connectivity. Thus, one IAP's decision has an influence on other IAP's decisions. Thus, they have a strong dependence on each beyond just competitive factors. These characteristics make the Internet provision industry suitable for game theoretic analysis, i.e., each player in the game model is a

[1] A NAP is where Internet interconnection among different providers occurs.

competitor in a market and there are interactions according to their strategic variables, such as production or price level.

In our model, there are two IAPs that produce both BE product and QoS products (which has BE as one of its classes). Their production level is limited by their investment on their network capacity. The product with same quality is assumed to be homogeneous.

This scenario is a reasonable one to analyze even in a highly competitive Internet industry. According to Greenstein, 2069 counties (66%) out of 3139 in the U.S. had two or fewer ISPs in the fall of 1998; 87% of these 2069 counties are rural. While national ISPs usually concentrate in major urban areas and moderate density suburban areas, low density rural areas are usually served by local providers. In these low density areas, the national ISPs do not have local POPs[2] so their customers would be forced to use measured service via a toll free number[3]. Thus, users of national ISPs have to pay a usage-based data communication fee in addition to the ISP's subscription fee. An important competitive advantage of local ISPs is the lower cost of access for the local population.[3]

Based upon the above scenario, we construct a Cournot model calibrated to data from rural IAPs. We assume that subscribers in the rural area generally use dial-up modems to access their IAP for the time being, so our analysis will be restricted to 56 Kbps dial-up modem technology. Thus, the QoS services that subscribers might use are most likely audio-oriented, such as Internet radio, VoIP or audio conferencing, and possibly also low bit rate video.

In this paper, we will study the market behavior of these IAPs in the QoS Internet market. Each IAP has a different set of business and technical strategies:

- ❖ It can choose flat rate pricing or usage-sensitive pricing;
- ❖ It can choose its investment level (i.e, network capacity) at 1000, 2000 or 3000 users[4]; and
- ❖ It can choose the production ratio between BE and QoS services

For the purpose of our model, IAP1 is assumed to choose unlimited access flat rate QoS pricing and IAP2 is assumed to choose two-part tariff for its QoS pricing. The details of the pricing strategy will be introduced in Section 2.

---

[2] Any site where networks interconnect is may be referred to as a POP.

[3] For example, AOL's usage price for 1-800 number (28.8Kbps) is 10 cents / minute.

[4] The maximum number of users in the market is 5000.

This paper is part of an ongoing project in which we are analyzing the behavior of IAPs. The overall goal of the project is to model IAP behavior in the presence of QoS choices as well as peering/transit choices in this relatively simple market. We anticipate that some general ideas from this work may be applicable to more complex urban markets as well.

## 2. QoS Demand Function

We will conduct a simulation with a RNG (random number generator). The simulation method is apt when departures from theoretical models are used and for sensitivity analysis. We will use real statistical distribution data for the Internet usage. Thus, the outcome of the analysis should be close to what we would expect in markets, which is an overall goal for this research.

### 2.1 Two stage RNG Simulation for Utility

In its 2001 survey, the U.S. GAO report [6] asked respondents: "*About how much do you pay per month to access the Internet from your home?*" The responses are summarized in Table 1. While this is not an exact measure of utility for Internet access, we can use this data as a proxy for customer's utility of a BE Internet access product.

**[Table 1: Expenditure for Internet Access per month]**

| | $0 | ~$5 | ~$10 | ~$15 | ~$20 | ~$30 | ~$40 | ~$50 | $50~ |
|---|---|---|---|---|---|---|---|---|---|
| % | 8.9 | 1.4 | 3.8 | 8.3 | 21.0 | 31.7 | 11.1 | 8.7 | 5.1 |

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

We modified the above table into the equal sub-ranges [$0-$10], [$10-$20], [$20-$30], [$30-$40], and [$40-$50] to derive the following table that we will use in our analysis.

**[Table 2: Modified Distribution]**

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

To generate an empirical demand distribution, we will use two-stage RNG. The first RNG will produce a random number based on the above empirical distribution table to find a sub-range and the second will produce another random number from a uniform distribution for the specific utility value within the sub-range. For example, if the first RNG produces a number between 0 and 0.141, then this customer's utility value is determined by the second random number produced by the function of uniform [0, 10]. Table 3 summarizes this two-stage RNG method.

**[Table 3: Two-Stage RNG]**

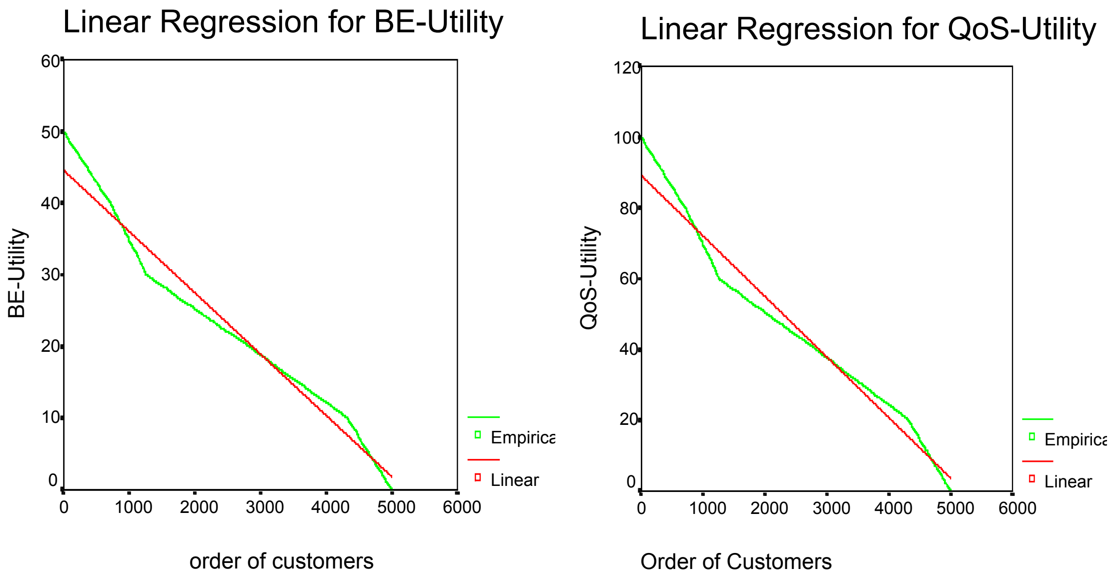
| RNG-1 | Sub-Range | RNG-2 |
|---|---|---|
| $0.0 \leqq$ RNG-1 $\leqq 0.1410$ | \$0 - \$10 | RNG-2 = Uniform [0,10] |
| $0.1411 \leqq$ RNG-1 $\leqq 0.4340$ | \$10 - \$20 | RNG-2 = Uniform [10,20] |
| $0.4341 \leqq$ RNG-1 $\leqq 0.7510$ | \$20 - \$30 | RNG-2 = Uniform [20,30] |
| $0.7511 \leqq$ RNG-1 $\leqq 0.8620$ | \$30 - \$40 | RNG-2 = Uniform [30,40] |
| $0.8621 \leqq$ RNG-1 $\leqq 1.0$ | \$40 - \$50 | RNG-2 = Uniform [40,50] |

### 2.2 Demand for QoS Product

According Gal-Or [2], the utility is a function of the quality of the product and the taste factor when the product is differentiated, i.e., U[X, M] = M*(a+bX), a > 0, b > 0, where M = level of quality, and X = taste factor. The utility generated by the two stage RNG is the (a+bX) part, and we let M be the number of classes that each product has, i.e., $M_{BE}$ = '1' and $M_{QoS}$ = '2', because BE is one of the QoS classes. Therefore, the utility value of QoS is twice of that of BE, or U[X, 2]= 2*U[X, 1]. Figure 1 shows the BE and QoS demand curves based on the empirical distribution using the two RNG method. The kinked lines are the real demand curve and the straight lines are from a linear regression of these functions[5] and are given analytically by the following two inverse demand functions:

[Eq-1] (BE Inverse Demand Function) $P_{BE} = 44.550 - 0.00855 * Q_{BE}$
[Eq-2] (QoS Inverse Demand Function) $P_{QoS} = 89.093 - 0.0171 * Q_{QoS}$
where $Q_{BE} = q1_{BE} + q2_{BE}$ and $Q_{QoS} = q1_{BE} + q2_{BE}$

[5] To generate data for the linear regression, we conducted 30 trials.




**[Figure-1] Demand Functions of BE and QoS**

### 2.3 Demand Function with Two-Part Tariff

One of the traditional pricing schemes in the US Internet access market is flat rate, eg, unlimited Internet access for a fixed amount of money per month.regardless of use[6]. The reasons to use flat rate pricing are: (1) IAPs 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 do not worry about additional expense for usage, which boost's IAP's advertising revenues. However, this kind of flat rate pricing can cause a 'tragedy of commons' phenomenon, i.e., the congestion of the Internet. After introducing QoS, it may be necessary to introduce a usage-sensitive pricing, because the value of QoS traffic is higher than that of BE traffic, as is the cost of supporting it. To reduce customers' resistance to pure usage-sensitive pricing, we anticipate that a flat rate pricing regime will remain in place for BE service and a new pricing scheme will be introduced for the new QoS product. Generally speaking, when firms do not know consumers' willingness to pay, an alternative might be to use two part-tariff, which charges a lump-sum fee for access (or the right to purchase QoS service) plus a per-unit charge for consumption. In the Internet industry, two-part tariffs may not be fully efficient because the added fixed

[6] Many of the large ISPs now offer a range of pricing options, which include a number of unbilled hours. When the users exceed this budget, they are charged for additional hours on a measured usage basis.

charges may deter some users who, at marginal cost prices, would be willing to join the network and consume. [1] The two-part tariff in our model has the same form as the normal one but its meaning is little different. The fixed part lump-sum fee is the right to use the lowest class of QoS product (BE) and the variable part is for the consumption of the premium class (i.e., QoS) product. Thus, someone who only wants to use the BE product pays only fixed part of the tariff.

To estimate the value of usage demand function, we use long distance telephone prices as a proxy for VoIP tariffs, which we anticipate to be an important application of QoS service in the rural dialup market that we are studying. We assume that 5 cents per minute (i.e., $3 per hour) is a typical competitive long distance rate in the United States. From the GAO report on Internet usage [3], we can derive an estimate the average number of connection hours[7] as shown in Table 5.

**[Table 5] Internet Usage**

| Answer | ~ 1 hr | ~ 4 hrs | ~ 10 hrs | ~15 hrs | ~25 hrs | ~ 40 hrs | ~60 hrs | 60 hrs ~ |
|---|---|---|---|---|---|---|---|---|
| **Percent** | 0.0 | 6.3 | 12.1 | 19.4 | 29.3 | 19.8 | 6.3 | 6.9 |

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

Based on this table, we can use 100 hours per month[8] as the average monthly Internet connection time. Users of flat rate QoS pricing will use 100% QoS connection but users of two-part tariff will not make a QoS connect all the time. Our assumptions for the relationship between hourly QoS rate '*r*' and QoS connection hours '*h(r)*' are:

The higher the rate *r*, the lower the QoS usage percentage,

A range of rate '*r*' is from $0 to $3 per hour.

For example, if *r* = $0, all users use 100% QoS connection, i.e., 0 hour for BE connection and 100 hours for QoS connection. If *r* = $3, no one use QoS connection. Instead users will use long distance telephone service, i.e. 100 hours for BE connection and 0 hour for QoS connection. In the absence of market data, we assume the linearity for simplicity between these endpoints, resulting in Table 6.

[7] One of the survey questions was "On average, how many hours per week do you and all your members of your household spend on the Internet from your home?"

[8] {(2 hrs* 0.063) +(7 hrs*0.121)+(12.5 hrs*0.194)+(20 hrs*0.293)+(32.5 hrs*0.198)+(50 hrs* 0.063)+ (75 hrs*0.069)}*4.3 = 103.2774 hours per month

**[Table 6] Relationship between Usage Rate *r* and QoS Connection**

| ***r*** | $0 | $1 | $2 | $3 |
|---|---|---|---|---|
| **% of QoS** | 100% | 66.7% | 33.3% | 0% |
| **% of BE** | 0% | 33.3% | 66.7% | 100% |
| **Hours of QoS Connection** | 100 | 66.7 | 33.3 | 0 |
| **Hours of BE Connection** | 0 | 33.3 | 66.7 | 100 |

We assume that rate *r* could influence both access demand functions of BE and QoS, because in our model every QoS user is also a BE user. Considering scaling effect, we assume the coefficient of rate '*r*' is 5, i.e. $1 increase of usage rate means $5 decrease access price, with which we modify the two demand functions, [Eq-1] and [Eq-2] into [Eq-3] and [Eq-4]:

[Eq-3] $P_{BE} = 44.550 – 0.00855*Q_{BE} –5*r$

[Eq-4] $P_{QoS} = 89.093 – 0.0171*Q_{QoS} –5*r$

where $Q_{BE} = q1_{BE} + q2_{BE}$ and $Q_{QoS} = q1_{BE} + q2_{BE}$

**3. Profit Functions**

The followings are the profit functions of QoS-IAP1 with flat rate pricing (*f1*) and QoS-IAP2 with two-part tariff(*f2)*:

$f1[q1_{BE,}, q2_{BE,} q1_{QoS,}, q2_{QoS}] = q1_{BE}*(P_{BE}+8) + q2_{QoS}*(P_{QoS} +8) - (q1_{QoS}\text{^}1.5 +10{,}000 + n_1*8000) – q1_{BE,}$

$0 \leqq (q1_{BE} + q1_{QoS}) < n_1*1{,}000$

$f2[q1_{BE}, q2_{BE,} q1_{QoS}, q2_{QoS}] = q2_{BE}*(P_{BE}+8) + q2_{QoS}*(P_{BE} +8)+ h*r* q2_{QoS} - (q2_{QoS}\text{^}1.6 +10{,}000 + n_2*8000) – q2_{BE,}$

$0 \leqq (q2_{BE} + q2_{QoS}) < n_1*1{,}000$

The revenue part consists of subscription revenue and advertisement revenue[9] and the cost part consists of capital ($C_c$), transit ($C_t$) and operation ($C_o$) costs. Table 7 shows the coefficient value of each cost parameter.

[9] $8 per subscriber which comes from the AOL's 2000 Annual Report. We chose this year because it preceded the merger with Time Warner, which could obscure the reporting of these revenues.

**[Table 7] Coefficients of Cost Parameters**

| Category | Parameter | QoS-IAP with flat rate | QoS-IAP with two-part tariff |
|---|---|---|---|
| **Capital**[10] | $c_c$ / 1,000 subscribers | 10,000+ $n_1$*6,000 | 10,000+ $n_2$*6,000 |
| **Transit** | $c_t$ / 1,000 subscribers | $n_1$*$2,000 | $n_2$*2,000 |
| **Operation** | $c_o$ / subscriber | $1*$q1_{BE}$ +($q1_{QoS}$)^1.5 | $1*$q2_{BE}$ +($q2_{QoS}$)^1.6 |

The capital costs consist predominantly of the equipment that an IAP needs to provide its services, that is, mail-server, router, and modem pool. The transit costs are payments by an IAP to an IBP for the right to use the IBP's facilities to transmit the communications of the IAP's subscribers. Although the price of bandwidth is decreasing substantially and the demand for T-3 lines[11] and optical links are increasing, T-1 service still dominates in the market[12]. We assume that the IBP sells only T-1 connections to the two IAPs, which is reasonable given that these are small IAPs serving a rural area. The current average T-1 transit price is assumed to $1000 per month. The QoS transit price for T-1 capacity is assumed to $2,000 per month.

The operating cost includes the set-up cost for network connectivity such as login account, allocation of storage, user registration, etc., and maintenance costs. These types of costs increase as the number of users increase. There is a difference operation costs for QoS user between flat rate IAP (($q1_{QoS}$)^1.5) and two-part tariff IAP (($q2_{QoS}$)^1.6) because usage-sensitive pricing has more complicated (and therefore more costly) measurement and billing functions than flat rate pricing. We assume $1 operation cost for BE user.

## 4. Computational Method for Finding an Equilibrium Point

To find the Nash equilibrium of this game, we optimize profits of each QoS-IAP under the assumption that the other QoS-IAP's strategic values are unchanged. Then compare best response values of QoS-IAP1 and QoS-IAP2 to find an intersection point, which is the equilibrium point in this game model. We use a two-stage method:

---

[10] $10,000 for a distribution layer router and $6000 for a server and modem pool
[11] The bandwidth of T-3 line is 45.736 Mbps, which equals to that of 28 T-1 lines.
[12] In 2000, T-1:1.2 million, T-3:58,000, Ocx:14,000, Source: Gartner/Dataquest

first we find an equilibrium (q1*, q2*) then at the second stage, with the values of q1* and q2*, we will try to find an equilibrium ratio between BE and QoS, i.e., ($q1^*_{BE}$, $q1^*_{QoS}$) and ($q2^*_{BE}$, $q2^*_{QoS}$).

For ($0 \leqq q1 < n_1*1000$, and $0 \leqq q2 < n_2*1000$), i.e., a capacity limit of [$n_1$K, $n_2$K], we use the following procedure:

Stage one:

fix *q1* from *0* to ($n_1*1000-1$) and find the best response of *f2* for each fixed *q1*,

do the same thing for *q2*, i.e. fix *q2* value from *0* to ($n_2*1000-1$) and find the best response value of *f1* for each fixed *q2*,

find an intersection point where the best response functions meet,

Stage two, with the values of *q1** and *q2** from the stage one:

fix $q1_{BE}$ from *0* to (*q1**) and at the same time $q1_{QoS}$ will be fixed from ($q1^*- q1_{BE}$) and *0*, and find the best response value of *f2* with an optimal combination of ($q2_{BE}$ and $q2_{QoS}$), do the same thing for IAP1 and find the best response value of *f1,*

find an intersection point where the best response functions meet.

For example, when *r* = $1.0 and *h* = 67 QoS hours, and IAP1's maximal profit with the capacity limit [1K, 1K] is obtained at

[q2 = 990, $q2_{BE}$=990, $q2_{QoS}$=0, q1=990, $q1_{BE}$=420, $q1_{QoS}$=570, f1*=20,918, f2*=11,324]

Similarly, IAP2's maximal profit is obtained at

[q1=990, $q1_{BE}$ =990, $q1_{QoS}$ =0, q2=990, $q2_{BE}$ =0, $q2_{QoS}$ =990, f2*=47,198, f1*=11,795].

Even if (q1*, q2*) = (990, 990)[13] is an equilibrium point, there is an inconsistency of the ratio of BE and QoS, {(990, 0), (420, 570)} and {(990, 0), (0, 990)} and the IAPs' profits.

At the stage two, with the information of (q1*, q2*) = (990, 990), we try to search again for the equilibrium point with perfect matching. We calculate every possible combination of ($q1_{BE}$, $q1_{QoS}$, $q2_{BE}$, $q2_{QoS}$) for optimal profits of IAP1 and IAP2. And we get equilibrium points like the following:

| qi*: | $qi_{BE}$: | $qi_{QoS}$: | qj*: | $qj_{BE}$: | $qj_{QoS}$: | fi*/fj*: | fj*/fi* |
|---|---|---|---|---|---|---|---|
| 990: | 480: | 510: | 990: | 510: | 480: | 18633: | 21818 |

[13] For the efficiency of computing, we use increment of 10 instead of 1.

990: 510: 480: 990: 480: 510: 21818: 18633

The final equilibrium point is ($q1^*$, $q1^*_{BE}$, $q1^*_{QoS}$, $f1^*$) = (990, 510, 480, 18633) and ($q2^*$, $q2^*_{BE}$, $q2^*_{QoS}$, $f2^*$) = (990, 480, 510, 21818)

**5. Equilibrium Analysis**

Proceeding using the above method for each investment level, we compute the data contained in Table 8 with QoS usage rate *r* = $1 per hour. The dominant strategy of IAP2 is an investment level to support 2000 users (2K) and its best response of IAP1 is 1K, so [1K, 2K] is the final equilibrium investment strategy when two IAPs use the pricing strategies described in Section 2. If we examine Table 8 in more detail, we see that, whichever investment strategies both IAPs choose, the equilibrium QoS product is always ($q1^*_{QoS}$, $q2^*_{QoS}$) = (480, 510). This result is caused in part by the exponential form of the operating cost ($qi_{QoS}^{1.5}$ for flat rate and $qi_{QoS}^{1.6}$ for two part tariffs), which rapidly decreases profits to both IAPs as the number of QoS customers increase.

**[Table 8] Equilibrium Strategy for IAP1 and IAP2**

| IAP2 / IAP1 | | **1K** | **2K** | 3K | **Best Response of QoS-IAP2** |
|---|---|---|---|---|---|
| **1K** | [q1*, q2*] | [990, 990] | **[990, 1990]** | [990, 2230] | 2K |
| | ($q1_{BE}$, $q1_{QoS}$)<br>($q2_{BE}$, $q2_{QoS}$) | (510, 480)<br>(480, 510) | **(510, 480)**<br>**(1480, 510)** | (510,480)<br>(1720, 510) | |
| | (f1*, f2*) | [18633, 21818] | **[10169, 26424]** | [8137, 18906] | |
| **2K** | [q1*, q2*] | [1990, 990] | [1750, 1940] | [1750, 1940] | 2K |
| | ($q1_{BE}$, $q1_{QoS}$)<br>($q2_{BE}$, $q2_{QoS}$) | (1510, 480)<br>(480, 510) | (1270, 480)<br>(1430, 510) | (1270, 480)<br>(1430, 510) | |
| | (f1*, f2*) | [23240, 13353] | [7559, 16144] | [7559, 5594] | |
| **3K** | [q1*, q2*] | [2230, 990] | [1750, 1940] | [1750, 1940] | 2K |
| | ($q1_{BE}$, $q1_{QoS}$)<br>($q2_{BE}$, $q2_{QoS}$) | (1750, 480)<br>(480, 510) | (1270, 480)<br>(1430, 510) | (1270, 480)<br>(1430, 510) | |
| | (f1*, f2*) | [15721, 13872] | [-441, 16144] | [-441, 5594] | |
| **Best Response of QoS-IAP1** | | 2K | 1K | 1K | |

## 6. Conclusion

In the current Internet, pricing has not been an issue outside of the research community because many of Internet users select flat rate pricing for their usage level. We anticipate that pricing strategy will be more important for IAPs than it is today. To some extent, the variations in pricing strategies that are being used by the US wireless carriers for their 3G services[14] can be seen as foreshadowing the kinds of experimentation that might go on as QoS support becomes more commonplace in the wireline Internet market. Our results indicate that the IAP with usage-sensitive pricing will be a better position in the QoS market. The rationale for this outcome is that the two-part tariff allows the IAP to price discriminate among BE and QoS uses on an application-by-application basis (as well as a user-by-user basis, of course). In contrast, the flat rate IAP offers less flexibility in this regard, even if they offer both BE and QoS service, since users must choose one or the other.

The change of pricing scheme will have an impact on settlements for exchanging traffic as well. The peering,arrangements in place among many carriers today work because the product is uniform (i.e., BE). Interconnection among QoS enabled ISPs (whether IAPs or IBPs) will be more difficult, as the quality parameters provided by one ISP must be mapped correctly into the parameters of the other so that the end-to-end performance guarantee needed by the user can be provided. This will most likely require complex pricing rules for reservations as well as for usage to ensure efficiency among the interconnecting firms. [5] Such payments would alter the cost structure of ISPs, so we anticipate that this equilibrium analysis will change with the introduction of paid peering. In future work, we will consider peering as another strategic choice of QoS-IAPs.

[14] Verizon Wireless is offering high speed service at a flat rate of $99/month in the Pittsburgh market, whereas AT&T Wireless is offering a two part tariff with a fixed monthly rate for a given number of Kbytes of usage (eg. $19/month for 500kbytes) plus $0.05/kbyte beyond that usage level. Despite this parallel, we do not believe that the results of this paper translate well into the market for wireless data because the modeling parameters would be quite different.

References

[1] Cawley, Richard A., . “Interconnection, Pricing, and Settlements: Some Healthy Jostling in the Growth of the Internet,” in Kahin, Brian and Keller, James H., . Coordinating the Internet. MA. MIT Press, pp346-76, 1997.

[2] Gal-Or, Esther, “Differentiated Industries without Entry Barriers.” Journal of Economic Theory, Vol. 37, Issue 2, pp 310-339, 1985

[3] Greenstein, S., “Understanding the evolving structure of commercial Internet markets,” Draft. http://www.kellogg.nwu.edu/faculty/greenstein/images/research.html, 1999

[4] MacKie-Mason and Varian Hal R., “Pricing Congestible Network Resources”, 1994

[5] Q. Wang, J. M. Peha, and M. Sirbu, ``Optimal Pricing for Integrated-Services Networks,'' Internet Economics, MIT Press, 1997, pp. 353-76.

[6] USGAO, Characteristics and Choice of Internet Users, GAO-01-345, 2001