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A Strategic Pricing for Quality of Service (QoS) Network Business

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ABSTRACT

In order to support emerging network businesses, such as Voice-over-IP (VoIP), virtual learning, video conferencing, and telemedicine, the Internet has to provide classes of service that are better than traditional 'best-effort' service. In computer networks, Quality of Service (QoS) is defined as the mechanisms that allow differentiation of network services based on their unique service requirements. To provide QoS over the current Internet, the Internet Engineering Task Force (IETF) and others have proposed a number of architectures, including Integrated Service (IntServ) and Differentiated Service (DiffServ).

This research examines the basic issue of designing pricing models for Internet services at various quality levels. By formulating a pricing formula that is based on price-quality schema drawn from marketing theory, this research provides a unique approach to understand the pricing of Internet services. The pricing model in this research provides a flexible and dynamic capability to develop Internet pricing for upcoming digital economy.

Keywords

Quality of Service (QoS), Communication Network, Network Service Pricing, Dynamic Pricing

INTRODUCTION

When the digital economy is defined as the economy that is based on the creation and exchange of digitized information (Zimmermann 2000), communication networks, especially the Internet, have important roles in this new economic model. Network service providers should develop new services to improve the exchange of information and create value through existing infrastructures. By providing different levels of service (QoS), network service providers can develop new sources of profit for themselves, and the companies who are using these new structures can develop new digital products and services that were not possible with the previous best-effort networks.

We observed that the technical solutions are there, but the network service providers (NSP) are reluctant to provide these new services, partially because of the lack of proper pricing mechanisms. By proper pricing mechanism we mean that the pricing strategies should be logical and persuasive for customers, economical to compensate the service costs of the network services, and profitable to allow competition in the market and bring competitive advantages to the companies.

Pricing a product or a service is a difficult but important task for an organization. With the right pricing, a company can acquire customers, retain them, and make profits. Therefore, a pricing strategy provides a "bottom line" for the business and maintains customer "goodwill" (Lewis and Shoemaker 1997). Pricing has been considered to be "difficult to imitate and a source of sustainable competitive advantage" (Dutta, Bergen, Levy, Ritson, and Zbaracki 2002).

Traditional pricing of Internet service is has focused on recovering costs or maximizing profits (MacKie-Mason and Varian 1995). The pricing theories that are based on economics assume rational behavior and utility maximization of the participants in the ' perfect' market (Monroe 2003). The price is supposed to be changed according to the demand and supply functions of the market (Pindyck and Rubinfeld 2001; Monroe 2003). However, after the privatization of communication networks and remarkable technical developments, network service providers have suffered from the lack of adequate and practical pricing model for their services (Odlyzko 2001).

Compared to the previous decade's communication network that is data centric, the current Internet users often transmit voice and video along with data. Voice and video communications are more stringent in their quality requirements than data. They are more sensitive to delays and require reliable transmission of the packets. Because the characteristics of traffic have changed, we need some reconsideration of the implications of architecture, service classes, and design principles on the pricing models of Internet service providers (Blumenthal and Clark 2001).

QUALITY OF SERVICE NETWORK

In earlier days, Quality of Service (QoS) meant delivering packets from the source to the destination without any transmission errors. As the Internet has become commercialized, however, QoS has started to become an important strategic tool for market competition (Ferguson and Huston 1998).

Current Internet provides 'best-effort' service for packet transmissions. Although, the last mile connection speed from Internet Service Provider (ISP) to customer could be different, the core network provides same quality of service for all packets regardless of the characteristics of the packets.

To support QoS network, two improvements to the level of service have been proposed. Integrated Services (IntServ) uses a resource reservation mechanism and provides connection-oriented services as do traditional telephone networks (Ferrari and Verma 1990; Braden, Clark and Shenker 1994).

Differentiated Service (DiffServ) marks each incoming packet based on the service requirement of the packet (Bernet, Binder, Blake, Carlson, Davies, Ohlman, Verma, Wang, and Weiss 1998). Intermediate routers interpret the marking information and provide a predefined service that is known as Per-Hop-Behavior (PHB) (Striegel and Manimaran 2002). Table 1 shows the differences between different QoS architectures that are compared with the traditional best effort service network.

Approach	QoS Specification	Strength	Weakness
Best Effort	TCP/IP Overprovision of the network resource Error checking and retransmission	Simple De facto Standard	Service quality is not guaranteed Network resources are overused.
IntServ/ RSVP1	Reserve network resources per call Connection oriented and refresh regularly	Guaranteed performance Stable communication	Lack of scalability Complex management
DiffServ/ BB2	DiffServ Code Point (DSCP) Per-Hop-Behavior (PHB) Connectionless management	Scalable and flexible	Lack of performance guarantee

Table 1. Summary of the Quality of Service Architecture

INTERNET SERVICE PRICING FOR QOS NETWORK

Current Internet pricing has two forms, flat rate pricing and usage-based pricing. Flat rate pricing is simple to understand and easy to implement (Wiseman 2000). All customers are charged equally by some criterion such as connection speed, connection time, or connected location. There is empirical evidence that consumers prefer a simple flat price, even if they have to pay a higher price (Altmann and Chu 2001; Odlyzko 2001). This phenomenon explains the importance of the certainty or price predictability. In addition, network service providers can save costs for accounting and management with flat rate pricing mechanism. Since simple pricing promotes the overall network usage, network service providers can make more profit (Wiseman 2000).

However, flat rate pricing does not reflect the current congestion level, and cannot solve the network congestion problem. All packets are treated equally in this mechanism and there is no chance to select a different service class. The classic problem of the "tragedy of the commons" cannot be prevented in the flat rate pricing mechanism (Odlyzko 2001).

With a usage based pricing scheme, customers would pay for what they actually use. Although usage based pricing is beneficial to customers and network service providers, they do not welcome this pricing scheme (DaSilva 2000). Customers want to have simple and predictable pricing plans rather than complex and possibly more expensive ones. A reasonable and understandable approach to pricing based on quality and service demand is needed.

[1] RSVP: Resource reSerVation Protocol
[2] BB: Bandwidth Broker

Adapting consumer perception theory from marketing literature (Lewis and Shoemaker 1997; Monroe 2003), this research proposes a reasonable and scalable pricing model for Quality of Service (QoS) network service providers. To maximize the profit, network service providers should design pricing strategy to reflect the willingness to pay of their customers.

RESEARCH QUESTION

Although QoS mechanisms are available in technical documentations, there are few practical QoS network. It is partially because of the lack of proper pricing (Crowcroft, Hand, Mortier, Roscoe, and Warfield 2003). QoS pricing is difficult to develop since QoS network is dynamic and the service performance of QoS network is unpredictable in advance. This research has the questions that how to design effective QoS pricing mechanism. While other researches on Internet pricing focused on one side of pricing, this research tried to include both sides of network congestion control and profit maximization.

THEORETICAL FOUNDATION: QOS PRICING WITH PRICE-QUALITY SCHEMA

In marketing, price has been determined to be an important cue for perceived product quality (Monroe 1990; Lewis and Shoemaker 1997; Rao, Qu and Ruekert, 1999; Brouthers, Werner and Matulich, 2000; Kirmani and Rao 2000; Varki and Colgate 2001). Consumers assume a positive relationship between quality and cost, although the quality and cost relationship was not always true for certain products in past years. For example, luxury automobiles such as Rolls Royce and Bentley are sold at a higher price but the actual quality may not justify this price.

When the market price is high it changes the consumers' perceptions about the quality of the product (Monroe 2003). A different pricing strategy provides an "imaginary effect" on perceptions of quality and leads to a willingness to buy (Naipaul and Parsa 2001). Most network pricing researchers assume that when the price is high the arrival rate or demand for that service class is low (Keon and Anandalingam 2003). However, this assumption may not be always true. Some customers value high quality services more than lower-class services. Therefore, some people buy more expensive services because they believe that they can get better quality of service by paying more.

In many cases, price signals the quality of product and services that the user can expect to receive. When there is a strong relationship between price and quality perception, some people would buy more products and services even the price is relatively high. Therefore, network service providers can increase profit by charging higher prices for premium services. However, they can't improve the service quality infinitely because the network bandwidth or the network resources are limited. Therefore, the pricing question should address how to maximize the profit within the limited capacity of the service network.

RESEARCH MODEL

We assume that when the quality of network services is known, we can determine prices for those services based on observed network parameters, actual service quality delivered, and market perceptions of the price. In other words, when we know the service quality, we can set the price through a certain formula of market indices and quality indicators. Figure 1 shows the simulated network model for this research.

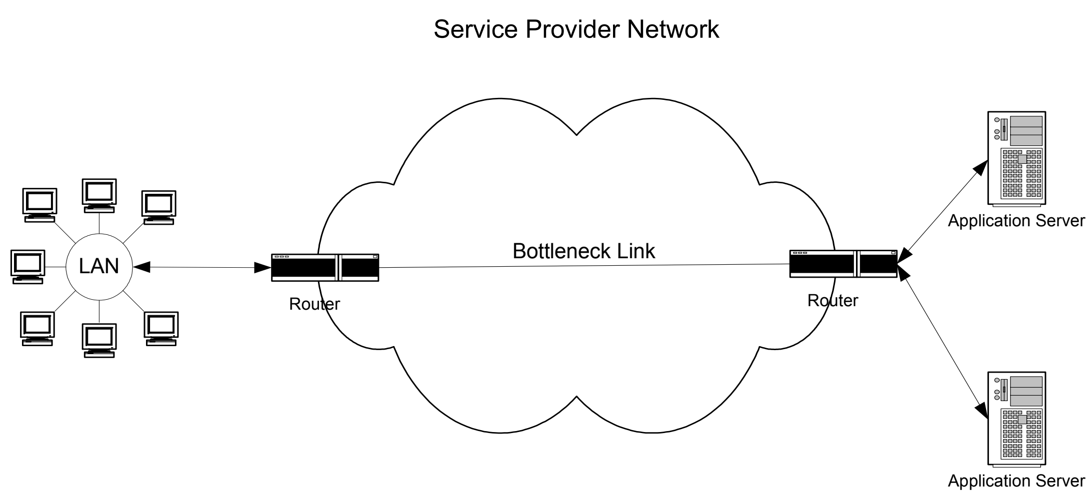

Figure 1. Simulated Network Service Model

Assumptions

We assume there is a single network that has only one path from the source to the destination. The reason for this assumption is partially because this research is not related to the network routing problem but network service pricing. Therefore, the number of links or the complexity of the network architectures is not directly related to the research domain.

We assume that there are m independent traffic flows in n network service classes. The j_{th} traffic flow in the i_{th} service class has unique service requirements that can be represented by average bandwidth requirement d_i^j bits per second.

Let k_i represent the number of flows in i_{th} service class, then demand of i_{th} service class u_i can be defined as follows:

$$u_i = \sum_{j=1}^{k_i} d_i^j \text{, where } i = 1, \dots, n \text{ and } j = 1, \dots, m \quad (1)$$

$$\sum_{i=1}^{n} k_i = m \quad (2)$$

Proposition 1

The *service quality* of j_{th} flow in i_{th} class, Q_i^j, is defined as the ratio of the served or fulfilled bandwidth, d_i^{j*}, to requested bandwidth, d_i^j, of the flow.

$$Q_i^j = \frac{d_i^{j*}}{d_i^j} \text{, where } i = 1, \dots, n \text{ and } j = 1, \dots, m \quad (3)$$

$$0 \leq Q_i^j \leq 1 \quad (4)$$

When the network is over-provisioned, we can set the service quality to 1, which means 100% service quality. The rationale for this definition is that once the service quality is 100%, more capacity does not lead to any performance improvement for the traffic. The actual bandwidth, d_i^{j*}, is obtained in real time. In our case, we use simulation to obtain values for d_i^{j*}.

$$Q_i^j = 1, \text{ when } d_i^{j*} \geq d_i^j \quad (5)$$

Proposition 2

The summation of the fulfilled bandwidth makes the total bandwidth consumption of i_{th} service class, u_i*. The unit of u_i* is bits per second (bps).

$$u_i^* = \sum_{j=1}^{k_i} d_i^{j*} \text{, where } I = 1, \dots, n \text{ and } j = 1, \dots, m \quad (6)$$

Also it should be noted that the u_i* must be less than the bottleneck capacity $C_{bottleneck}$ since the network can't transmit more than its bottleneck link capacity at any time.

$$\sum_{i=1}^{n} u_i^* \leq C_{bottlenecklink} \quad (7)$$

Proposition 3

The *quality index* I_q^i of the i_{th} service class is defined as the average of service quality Q_i^j.

$$I_q^i = \frac{\sum_{j=1}^{k_i} Q_i^j}{k_i} \quad (8)$$

$$0 \leq I_q^i \leq 1 \quad (9)$$

For example, when we have 3 service classes, there are I_q^1, I_q^2, and I_q^3 respectively. I_q^i represents the average QoS level of the i_{th} service class.

Proposition 4

We propose that the price of i_{th} service class is based on the service quality of the class. In the equation, P_i is the price for bits per second of the i_{th} service class.

$$P_i = \alpha + \beta_i * I_q^i \qquad (10)$$

α is the base price for a bit transmission (or any unit for quality) when there is no service guarantee ($I_q^i = 0$; i.e. best effort service). It provides the lower bound price of the unreliable service. β_i is the quality premium for service class i when the service has quality difference ($I_q^i > 0$). Therefore, $\alpha + \beta_i$ is the upper bound price for perfect service of $I_q^i = 1$.

The total revenue R_i of i_{th} service class is defined as the product of the price and the total number of transmitted bits in i_{th} service class.

$$R_i = P_i * u_i^* \qquad (11)$$

$$R = \sum_{i=1}^{n} R_i \qquad (12)$$

RESEARCH MODEL

The proposed goal of a network service provider is to maximize the revenue function R in equation (12) with different level of prices and quality indices. The network service providers can develop different sets of α and β according to the QoS level of their networks.

$$\begin{aligned} \text{Maximize } R &= \sum_{i=1}^{n} R_i \qquad (13) \\ &= \sum_{i=1}^{n} P_i * u_i^* \\ &= \sum_{i=1}^{n} (\alpha + \beta_i * I_q^i) * u_i^* \end{aligned}$$

Subject to

$$\sum_{i=1}^{n} u_i^* \leq C_{bottlenecklink}$$

$$0 \leq I_q^i \leq 1 \text{ for } \forall i$$

$$P_i \geq P_{i-1} \text{ for } i > 1$$

$$I_q^i \geq I_q^{i-1} \text{ for } i > 1$$

The last two constraints explain one might charge premium price for high quality service. A network service provider may find the solution for this maximization function with various constraints such as network resource limitations, customer price sensitivity, and different network performance level. Although the entire model is an optimization problem, we are not solving this problem by using integer programming. Instead we will consider the various combinations of α and β according to the different service quality.

About α

We define α as the base or floor price of a network service. When service quality level equals to zero ($I_q^i = 0$) or can't be guaranteed, the price for that service equals α, which is greater than zero. Since the current Internet can't guarantee a specified level of service quality, α should be equivalent to the price of best-effort (BE) service in the current Internet architecture.

To profitably provide communication services, the total revenue should be greater than the total cost of services. Therefore, α should be greater than the production cost of the service. The following equation shows the unit production cost of the service and α should be greater than the unit production cost.

$$\alpha \geq \frac{\text{Total Cost}}{\text{Network Capacity}} \qquad (14)$$

Since the network capacity is bounded by the bottleneck link of the entire path from the source to the destination, α should be equivalent to the following equation.

$$\alpha \geq \frac{\text{Total Cost}}{\text{Bottleneck Link Capacity}} \qquad (15)$$

α is the minimum price of service class i when $I_q^i = 0$. In a short run, α couldn't be changed flexibly since the network capacity can't be changed so fast to fulfill the demand fluctuations. Therefore, α should be fixed and used for production cost recovery and providing reasonable service margin.

About β

β_i denotes the quality premium of service class i that have I_q^i service performance. β_i can be fixed for all service classes.

$$\beta_i = K \ (i = 1 \sim n) \text{ where } K \text{ is constant.} \qquad (16)$$

In this case, the different service class will be charged uniformly according to its service quality level.

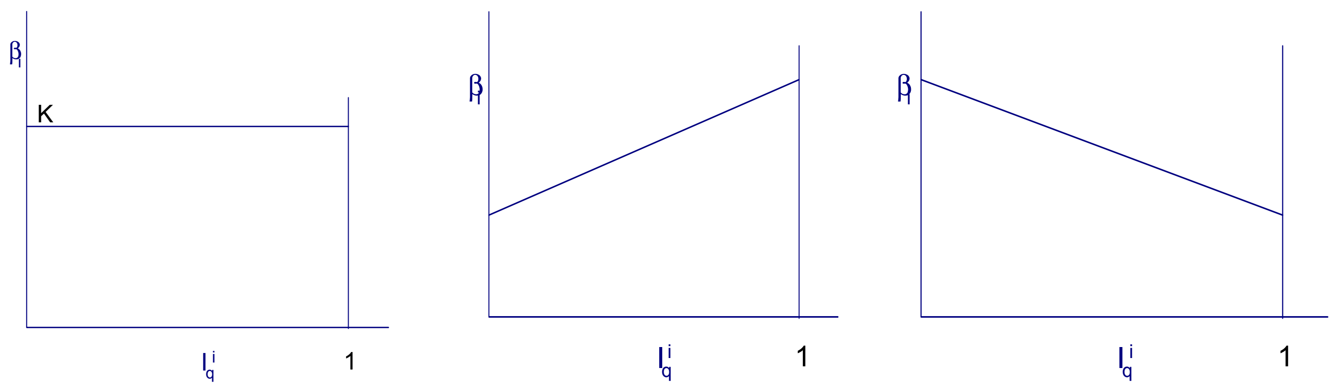

Figure 2. Various β_i by service quality

Sometimes, we need to differentiate β_i in accordance with corporate strategies. When a service provider wants to encourage or discourage the usage level of certain service classes, β_i can be adjusted. There are two cases to consider. The first case is when we need to reserve the high quality service and make the performance better in that class, we can charge a significantly higher price for the service. In this case the high quality service users are charged exponentially, since the equation of (10) shows the price is the sum of α and the product of β and I_q^i. When the β is increasing according to I_q^i, the price P is increased as a product of the two.

The other extreme case that decreasing β_i with increasing I_q^i could not happen in real situation because soon customers will prefer the higher I_q^i with lower β_i.

β_i can be determined by setting total revenue in advance. In this case, the service provider defines its profit goal with cost and appropriate profit margin.

$$When\ R = R_{fixed} = \sum_{i=1}^{n} P_i * u_i^* \qquad (17)$$

$$= \sum_{i=1}^{n} (\alpha + \beta_i * I_q^{\,i}) * u_i^*$$

In the above equation, α is equal to the total cost / u_i*. $I_q^{\,i}$ and u_i* are obtainable with network simulation, and therefore we can specify the β_i. R_{fixed} is a constant pre-defined profit goal by the network service provider.

About Price *(P)*

We conducted simulation experiments to obtain specific results. Table 2 shows example pricing strategies for a network service provider. The service provider can specify α and β as fixed or variable. α could be fixed when the network service provider wants to recover its cost of service. However, when there is market competition the network service provider may differentiate α to compete in the market. It means the network service provider might provide its service with the price below the production costs, i.e., at a loss. In the long run a company can't survive without cost recovery.

When β is fixed, a user can select a QoS class according to his preferences and budget constraints. Each service class has a different price that is proportional to the service quality. Each service class has the same marginal cost of service quality.

The network service provider can make β vary to promote specific service classes. If the β is increasing with $I_q^{\,i}$, the unit price of high quality class services is more expensive than the unit price of lower class. If the β is decreasing with higher $I_q^{\,i}$, the network service provider promotes the usage of higher QoS class service.

		α		
		fixed	variable	
β	fixed	$\alpha + \beta * I_q^{\,i}$	$\alpha_i + \beta * I_q^{\,i}$	User can select the class
	variable	$\alpha + \beta_i * I_q^{\,i}$	$\alpha_i + \beta_i * I_q^{\,i}$	Promote certain service
		Recover cost	Market competition	

Table 2. Pricing Strategies Examples

SIMULATION RESULTS

We used the OPNET program as the simulation tool. OPNET software is a network simulation program, which is used by various service providers and network research institutions (OPNET 2002).

There are six common applications such as e-mail, database, file transfer (FTP), web browsing, voice-over-IP, and video conferencing that originate from workstations in a local area network (LAN). Each application has specific requirements such as bandwidth, delay, jitter, and data loss. These configurations are similar to the statistical characteristics of real world applications (OPNET 2002). All applications share limited network links and are competing for network resources such as bandwidth, processors, and buffer. Therefore, a link between network routers is congested as a bottleneck always.

The LAN is connected to a switch that is connected to an ingress router of the network service provider. There are two core routers in the service network and an egress router that are connected to the servers. The Ethernet server serves four applications that are not so sensitive to the delay and jitter. The video station and voice station provide the client level video conferencing application and voice over IP service respectively.

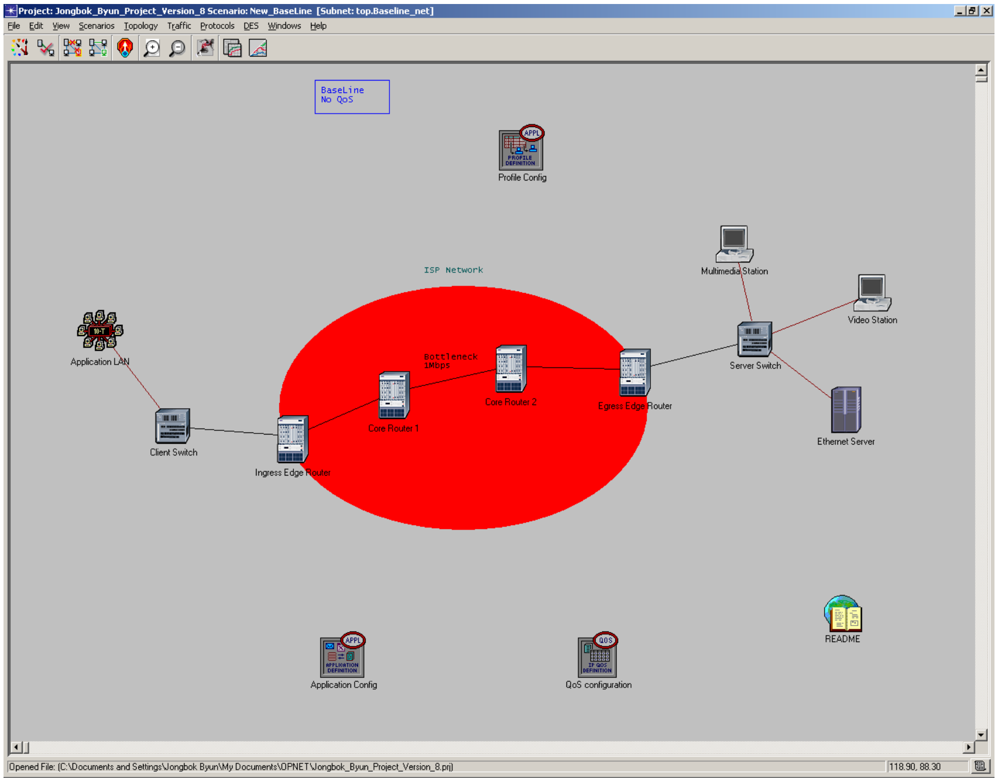

Figure 3. Network Model Configuration with OPNET

For the simulation experiment, we set up two different network models; one for best effort (BE) and the other one for a DiffServ-based QoS network. The model doesn't include the IntServ QoS model since the IntServ architecture has scalability problems in practice and this study is intended to be applicable to any network architecture that provides different level of QoS.

Theoretically, BE networks do not need any QoS mechanisms that could support different users. In reality, however, the actual network router has limited buffer size that can hold only limited numbers of packet at any moment. FIFO (First In First Out) rule is applied to BE network and the last packet in the queue that exceeds the limited buffer size will be dropped.

Compared to BE networks, the DiffServ network could have various QoS mechanisms such as queuing, packet classification, and packet dropping rule per each hop. Queuing mechanism provides the transmission rules of packet. Each packet is queued according to specifically predefined rules such as arrival order (FIFO), priority (PQ: Priority Queue), packet class (CQ: Class Queue), and others (WFQ: Weight Fair Queue).

As another QoS tool, we used Committed Access Rate (CAR). CAR limits the incoming and outgoing traffic by using various criteria such as the interface, QoS group, and IP precedence information. When the traffic is in the predefined agreed or committed rate range, CAR transmits the conformed traffics into the network. If the traffic exceeds the rate range, CAR will drop or change the priority of the traffic and send it as low priority traffics.

We applied Random Early Detection (RED) as a mechanism to prevent TCP synchronization failure by dropping packets randomly in advance (Floyd and Jacobson 1993). Once certain threshold is reached, the router starts to randomly drop some of the packets in its queue. The TCP applications in the end nodes notice this dropping and reduce their transmission rate.

We developed 17 scenarios with different QoS settings (Table 3). Each scenario has unique QoS mechanisms such as queuing, random early detection, and committed access rate.

No	Scenario Name	Queuing	CAR	WRED	Category
1	Baseline	-	-	-	No QoS
2	FQ_NC_NW	FIFO	No CAR	No WRED	Queuing
3	PQ_NC_NW	Priority Queue	No CAR	No WRED	
4	CQ_NC_NW	Custom Queue	No CAR	No WRED	
5	WQ_NC_NW	Weighted Queue	No CAR	No WRED	
6	FQ_C_NW	FIFO	CAR	No WRED	Queuing & CAR
7	PQ_C_NW	Priority Queue	CAR	No WRED	
8	CQ_C_NW	Custom Queue	CAR	No WRED	
9	WQ_C_NW	Weighted Queue	CAR	No WRED	
10	FQ_NC_W	FIFO	No CAR	WRED	Queuing & WRED
11	PQ_NC_W	Priority Queue	No CAR	WRED	
12	CQ_NC_W	Custom Queue	No CAR	WRED	
13	WQ_NC_W	Weighted Queue	No CAR	WRED	
14	FQ_C_W	FIFO	CAR	WRED	Queuing CAR WRED
15	PQ_C_W	Priority Queue	CAR	WRED	
16	CQ_C_W	Custom Queue	CAR	WRED	
17	WQ_C_W	Weighted Queue	CAR	WRED	

Table 3. Network Simulation Scenarios

Table 4 shows a sample performance metrics of e-mail application for each scenario. To calculate the adequate pricing strategy the results of Table 5 are compared with the results of Table 4.

Application	Scenario	Traffic (bytes/sec)		Response Time (sec)
		Sent	Received	
E-Mail	Baseline (d_i^j)	6.10	6.10	2.234838439
	FQ_NC_NW	8.32	4.72	0.208857893
	PQ_NC_NW	89.43	106.81	9.420833711
	CQ_NC_NW	85.93	90.01	9.034450505
	WQ_NC_NW	102.44	89.54	29.242994717
	FQ_C_NW	127.53	120.46	10.978689566
	PQ_C_NW	106.69	99.83	9.290626928
	CQ_C_NW	114.38	126.33	11.825723516
	WQ_C_NW	105.74	86.29	29.806137322
	FQ_NC_W	41.65	14.66	7.922248958
	PQ_NC_W	100.97	107.21	7.875902969
	CQ_NC_W	29.95	23.42	1.796027971
	WQ_NC_W	11.66	5.29	-
	FQ_C_W	20.86	20.90	3.156187046
	PQ_C_W	19.19	16.23	3.798155261
	CQ_C_W	22.53	24.17	1.333995885
	WQ_C_W	8.37	5.55	-

Table 4. E-Mail Application Performance

Table 5 shows the performance percentage of e-mail application. The performance of e-mail application is averaged of sent and received traffic.

Scenario	Q_i^j		[3]*Adjusted* Q_i^j		Average Q_i^j
	Sent	Received	Sent	Received	
BaseLine	36.67%	45.62%	36.67%	45.62%	41.15%
FQ_NC_NW	50.00%	35.28%	50.00%	35.28%	42.64%
PQ_NC_NW	537.35%	798.44%	100.00%	100.00%	100.00%
CQ_NC_NW	516.35%	672.83%	100.00%	100.00%	100.00%
WQ_NC_NW	615.56%	669.33%	100.00%	100.00%	100.00%
FQ_C_NW	766.30%	900.49%	100.00%	100.00%	100.00%
PQ_C_NW	641.09%	746.30%	100.00%	100.00%	100.00%
CQ_C_NW	687.30%	944.33%	100.00%	100.00%	100.00%
WQ_C_NW	635.34%	645.05%	100.00%	100.00%	100.00%
FQ_NC_W	250.26%	109.56%	100.00%	100.00%	100.00%
PQ_NC_W	606.70%	801.41%	100.00%	100.00%	100.00%
CQ_NC_W	179.96%	175.07%	100.00%	100.00%	100.00%
WQ_NC_W	70.04%	39.52%	70.04%	39.52%	54.78%
FQ_C_W	125.32%	156.25%	100.00%	100.00%	100.00%
PQ_C_W	115.30%	121.30%	100.00%	100.00%	100.00%
CQ_C_W	135.39%	180.64%	100.00%	100.00%	100.00%
WQ_C_W	50.26%	41.51%	50.26%	41.51%	45.89%

Table 5. Application Performance (Q_i^j) for E-Mail

After we calculate performance for each application by scenario, we created the following table 6 for the QoS class service performance for each scenario.

Scenario	Class	Application	Average Q_i^j	I_q^i	u_i*
FQ_NC_NW	BE	E-Mail	42.64%	42.99%	6.52
		FTP	43.33%		4.87
	AF	DB	31.40%	18.80%	18.04
		Web Browsing	6.20%		10.04
	EF	VoIP	0.00%	50.00%	920.18
		Video Conferencing	100.00%		401978.61

Table 6. FQ_NC_NW Scenario Simulation Results

Finally, Table 7 shows the pricing comparisons between traditional best effort network and QoS network. Both pricing scheme is usage based. However, in QoS pricing mechanism, network service provider could have more revenue.

[3] Adjusted Q_i^j is calculated by the equation (5).

Traditional usage based pricing (FQ_NC_NW)				QoS pricing (α = \$ 0.1/bps and β = \$ 0.05)			
Class	Usage (bps)	Price	Revenue	Revenue	Price	Usage (bps)	Class
BE	402938.26	\$0.12	\$48,352.59	\$1.38	\$0.12	11.39	BE
				\$3.07	\$0.11	28.08	AF
				\$50,362.35	\$0.13	402898.79	EF

[Table 7] BE pricing and QoS pricing (FQ_NC_NW)

In the previous comparison tables we changed the QoS pricing based on the service quality differences of the class. The important point of this simulation study is that the service provider has a valid set of pricing rules that enable its pricing changes according to the service quality difference. Another strength of this pricing mechanism is its flexibility. When there is any change of service level, network service providers can adjust their service pricing promptly. If a network service provider has a service level agreement (SLA) with its customers, the network service providers can adjust the price without notifying customers. Therefore, this pricing mechanism is dynamic and usage based that could control the network congestion promptly.

CONCLUSION

In this research we proposed a simple but robust pricing scheme for the QoS mechanism over the current Internet architecture. Since the Internet is very unpredictable in its performance and service quality, the designing of proper pricing schemes can be complex and challenging. We adapted the quality index into the pricing formula directly instead of using a complex mathematical formula. Therefore, our model is simple and dynamic in nature. When there are any changes in the quality of Internet service, our pricing model can reflect the fluctuation of the service quality.

Our model provides dynamic pricing with a price-quality schema. Therefore, it can provide a better solution for the current QoS pricing scenarios. We simulated the model communication network with OPNET program that is the widely used simulation program for network performance simulation. The results show the possible changes in service pricing and the associated total revenue changes.

Future research may address multiple routes from the source applications since such a scenario is a more realistic situation and practical environment. When there is significant complexity of a network routing problem, the service performance will be changed and therefore, the pricing could be also affected.

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