Australian Telecommunications Networks & Applications Conference 2003 (ATNAC2003), Melbourne, Australia, December 2003

Pricing the Internet - A visual 3-Dimensional Evaluation Model

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Abstract –We develop a novel visual approach to evaluating an Internet pricing scheme using a 3D-metric model, which encompasses the dimensions of technical complexity, economic efficiency and social impact. We review the history of Internet pricing research over the last decade, summarizing the key features of the most significant models, and analyzing and evaluating them using our 3D model. Based on the analysis results, we address and discuss important factors that have inhibited the deployment of the reviewed models and suggest what might be future Internet pricing solutions.

I. Introduction

The Internet has grown exponentially over the last decade, not only in the number of its users, hosts and servers, networks and autonomous systems, but also the volume and types of traffic. Traditional Internet applications (such as electronic mail, file transfer, and static-content web surfing) are being joined by newer services that have far more demanding Quality of Service (QoS) requirements (such as real-time interactive audio or video conferencing, streaming of multimedia content, online games, and electronic commerce).

With these changes in the use of the Internet, current Internet pricing schemes have become inappropriate. Flat rate pricing does not make users take into account, and be accountable for, the resources that they consume. As a result network congestion is exacerbated through user's acting primarily in their own self-interest. Flat rate pricing also does not support the non-uniformity of Internet traffic with different QoS requirements, and even inhibits such development. In addition, there is no flexibility of sharing costs between diverse groups of receivers and senders [3][4].

Finding a more efficient charging scheme has attracted much research effort over the last decade. Many pricing models have been proposed, most of which could be classified into two broad categories: Pricing for Best Effort Services and Pricing with Quality of Service guaranteed. However, significant questions still exist regarding how to analyze and evaluate these schemes, and how practical they are to deploy and operate.

We present a novel visual approach to comparing and evaluating such schemes using a 3D-metric model, which encompasses the dimensions of technical complexity, economic efficiency and social impact. In section III we review the history of Internet pricing over the last ten years, summarizing the key features of the most significant schemes, analyzing and evaluating them using our 3D model. We then address and discuss important factors that have inhibited the deployment of those reviewed models in section IV and suggest what might be short-term and long-term Internet pricing solutions in section V before the final conclusion in section VI.

II. Our Visual 3-Dimensional Evaluation Model

A viable Internet pricing scheme needs support of both economic tools (including accounting, charging, billing, and pricing strategies in resource allocation) and technology support (for example congestion control, QoS technologies, authentication and system security). Figure1 shows broadly how Internet pricing research sits in relation to supported research areas.

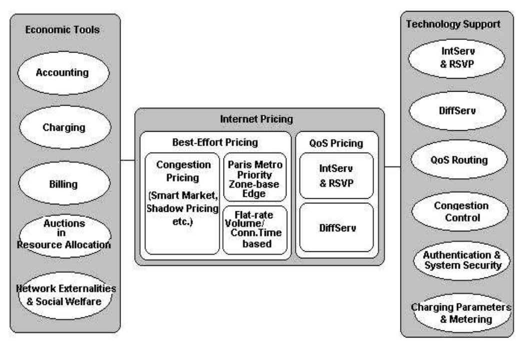

Figure 1 – An overview of Internet Pricing research

Implementation effort is of great importance to the practicality of the proposed pricing schemes. In order to evaluate a pricing scheme we examine both economic and technical aspects in a three-dimension metric (3D) model. The model encompasses the dimensions of technical complexity, economic efficiency and social impact.

Technical complexity refers to the implementation cost of a model. It contains the cost of applying new technologies, upgrading equipment, overhead costs of accounting, charging and billing system and labor cost (the cost of training and employing qualified technical personnel in order to operate the new upgraded equipment and software).

Economic efficiency includes the efficiency of

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network utilities and optimization of service provider's revenue. This dimension reflects the ability to handle additional customers without upgrading links, the possibility of attracting new customers due to cheaper traffic options and/or improved QoS, the capability of accommodating new Internet services and valued customers, and the maximization of marginal costs in charging customers' traffic.

Social impact concerns the fairness among network users. The users with more valuable traffic will be given more network resources and better quality of services if they have greater willingness to pay than the others. Also the price these users have to pay bears in itself the marginal social cost of extra traffic that their traffic creates for others.

Economic efficiency, social impact and technical complexity are tightly inter-related. The more granular the charging unit and the dynamic of a pricing system, the fairer allocation between users will be, and so will the maximization of service providers' revenue and network utility. However these come with the cost of technical complexity. The smaller the charging unit, the greater accounting overhead and processing cost. The better adaptability of a pricing scheme with the network status such as network congestion comes with the higher cost of communication overhead transmitted between senders, network nodes and receivers.

One might think of an optimal pricing model, which maximizes the economic efficiency and social impact, and minimizes its implementation cost. However, since there is always a trade-off between those aspects, a practical model should be a compromise among them. Figure 2 below illustrates the differences between an Optimal Pricing model and a Practical Pricing model.

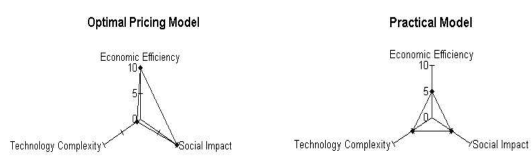

Figure 2 – Optimal pricing model vs. Practical pricing model

The following section provides an overview of important Internet pricing schemes that have been investigated over the last 10 years and have turned out to be of special importance from a practical and economic point of view. It concludes with a comparison of those schemes based on the 3D evaluation model.

III. Research on Internet Pricing- Scanning the History for the Last Decade

Proposed Internet Pricing models over the last decade can be classified into two broad categories:

- Pricing for Best Effort Service including congestion pricing, priority pricing, Paris Metro, zone-based pricing and edge pricing, and
- Pricing with Quality of Service guaranteed, including charging scheme for Integrated Services (IntServ) [5] and Differentiated Services (DiffServ) [6].

A. Significant Pricing and Charging Models

1. Pricing for Best-Effort Service

Congestion pricing has drawn considerable attention and efforts from Internet pricing research. The use of the network by one user exhibits negative externalities for others in that his/her traffic imposing on the network might cause extra delay or even result in congestion and loss to others' traffic. The user, therefore, should pay the social costs of delaying other users' traffic when the network is congested. On the other hand, the marginal cost of transporting additional packets is essentially zero when the network has spare capacity. The only time requiring a pricing mechanism, therefore, is when congestion occurs [3].

The first proposed congestion-pricing scheme was the *Smart Market* [11]. Each packet has a "bid" field in its header to indicate how much its sender is willing to pay for sending it. The packet will be admitted if the bid exceeds the current marginal cost of transportation in each router. Users pay the market-clearing price (the bid of the lowest-priority admitted packet) rather than their own bid. Though considered to achieve optimal capacity distribution and network efficiency, this mechanism guarantees only relative priority rather than absolute quality of service. A packet with a high bid gains access sooner than the one with lower bid, but delivery time cannot be guaranteed.

The *Shadow pricing scheme* (Proportional Fair pricing) [12] is applied to model a network in which a resource has the capacity to cope with a given number of equal sized packets in each time slot. Each packet arriving in overloaded slots is marked, charged a fixed small amount – called "shadow price", and the mark is sent to the users. Congestion causes the shadow price to increase, and end users adjust their traffic load based on this feedback.

Edge Pricing- As contended by Shenker et al [13], true congestion pricing is complicated, requiring knowledge of utilities all other users who might be affected by the extra traffic along the entire path. It is also unfair to charge different users different amounts because of internal routing decisions that are beyond their control [3]. Edge Pricing charges based on the *expected* congestion (depending on time of day, short-term congestion history and so on) along the packet's *expected* path. The price can be determined and charged at ingress (the network's edge) rather than computed in a distributed fashion along the entire path.

Congestion Discount (Keon and Anandalingam [17]) uses price as an incentive to shift traffic from congested periods to non-peak periods. Customers may accept a congestion discount rate and return during a subsequent non-peak period, or reject the discount offer and obtaining services immediately with a higher price.

Clark addresses the problem of sharing payment

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between senders and receivers in the *Zone-based cost sharing* pricing model [18]. Depending on the service, senders and receivers might wish to share the costs. An additional field is proposed in the IP header to indicate whether the sender, or receiver, or neither of them is willing to pay for better than best-effort quality of service. The Internet is divided into regions (zones) in which service is provided at a uniform, distance insensitive way. Users specify the zones for which they are willing to pay.

Odlyzko proposed *Paris Metro Pricing* [19], based the old Paris Metro system where two classes of otherwise identical cars where offered, with the first class car charged twice as much as the second class. First class customers paid more knowing that the first class cars would be less crowded. Odlyzko suggests applying this model to Internet pricing by splitting the network into different channels, each with a fixed fraction of the network capacity. Charge a higher price for one channel, and it will exhibit lower utilization (and better QoS) to users willing to pay the price.

Cocchi et al introduced *Priority pricing* [20] for multiple services over best effort networks. Users flag their traffic as "service priority" or "no-drop". When two packets arrive at the router the higher priority packet will be processed first (lowering delay during congestion). However, the fixed price means users might pay a premium even when the network has spare capacity, or receive best-effort service when the paid-for priority class is congested. Gupta et al [21] present a variant where prices are updated at intervals, according to the network's load and congestion level.

2. Pricing with QoS guarantees

2.1 Charging for Integrated Services using RSVP

Karsten et al [10] propose a charging model that can be embedded in the RSVP architecture [22] for Integrated Services (IntServ) [5] network. RSVP's PATH and RESV messages are used to transmit pricing information and building a contract among senders, receivers and the network. PATH messages carry price information including the sender's willingness to pay, the maximum share of costs and the duration of price validity [10]. At each hop of an outgoing link, the current market price for the sender's requested QoS is added to the price field. An ISP's portion of an end-to-end service price depends on each ISP's local pricing scheme, valid for a dedicated section of the end-to-end connection only. However, the final price may still vary in case of dynamic pricing schemes. RESV messages are returned to reserve resources (as normal) if the receivers agree with pricing information in a PATH message. The RESV also carries the calculated price to the sender..

2.2 Charging for Differentiated Services

The Differentiated Services (DiffServ) architecture defines a set of per-hop building blocks and a language with which to express per-hop forwarding behaviors, rather than a complete solution for end to end QoS.

2.2.1 DiffServ Bandwidth Brokers as Mini-Markets

Fankhauser and Plattner [24] proposed a Service Level Agreement Trader (SLA Trader, a form of advanced Bandwidth Broker). Trading SLAs is performed between an ISP and its neighbors. An ISP offers to its peers network 'resources' that consist of both directly owned resources and resources purchased from other providers. ISPs charge other providers for the service through their network including the outgoing link from its egress nodes to the next anonymous system (AS). Centralized SLA traders at each AS make local decisions about what services are provided to which peers at a medium time scale (several minutes to hours).

2.2.2 Resource Negotiation And Pricing (RNAP) scheme-

Wang and Schulzrinne [25] proposed a resource negotiation and pricing framework, RNAP, in which customers are able to negotiate and contract with the service provider about several QoS parameters, such as peak rate, loss rate and maximum delay. Both centralised and distributed ways of implementing RNAP are introduced in this model.

B. Analysing and Evaluating of the reviewed models

Congestion pricing and Flat rate pricing are two ends of the 3D metric. Congestion pricing maximizes the economic efficiency and social welfare (charging at packet-level and taking into account the social cost of delivering a packet). Smart Market is an extreme of this pricing category. However, the implementation costs of congestion pricing schemes are quite high. Flat-rate pricing incurs no special implementation costs, but provides very low economic efficiency and social welfare. Figure 3 illustrates differences between Congestion pricing and Flat-rate pricing using our 3D method:

Figure 3 - Congestion Pricing vs. Flat-Rate pricing

For most proposed pricing models with QoS guarantees, the economic efficiency and social welfare goals are achieved to some extent. The technical complexity, however, is also a concern. Those models are constrained by the supporting QoS technologies, and most require upgrading of all routers to support both the QoS technologies and the charging system.

Self-regulating schemes such as Paris Metro Pricing and Congestion Discount might not work under competition with the nature of the current Internet. Service providers might lower their prices in response to competition, and economic efficiency and social impact dimensions are hardly achieved.

Figure 4 compares different categories of pricing models based on the 3D-metric evaluation model.

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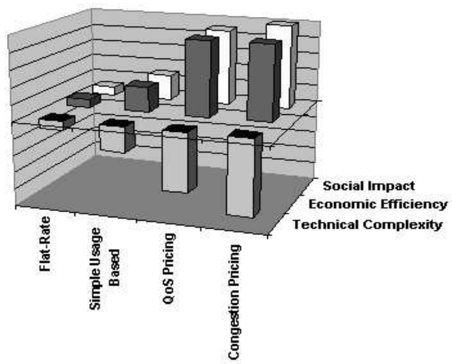

Figure 4 – Technical-Economic-Social Impact Metric

IV. Factors Inhibiting Those Proposed Pricing Schemes' Deployment

Implementation cost is one of the major factors hindering deployment of proposed pricing schemes. This section discusses a number of other important inhibiting factors and returns to the implementation factor in a Cost Benefit Analysis from an ISP's point of view.

Firstly, we examines the schemes from the consumers' perspectives. Both INDEX [26][27] and CATI project [28] show that the most important requirements and expectations from the users are transparency and predictivity of a pricing scheme - proividing the users' detailed charging information (such as per flow of traffic, per sessions or per different services); and enabling users to predict or estimate the costs of using the network service [10][23]. Charging schemes that adapt according to internal network status rarely meet this criteria (except the highest bidding values in auction-based charging schemes). Prices can be updated in a short time-scale if the user-provider negotiation is done automatically, while negotiation requiring human intervention might prefer a longer and more stable time-scale.

Another critical user requirement is stability - the assurance of QoS provided to users. In congestion pricing users only pay more to gain a higher priority for their traffic, without any QoS assurance. Pricing for IntServ using RSVP provides hard QoS guarantees. However, users would be irritated when dynamic price changes result in the tear-down of their reservationd mid-session. In terms of charging parameters, such as delay, jitter and loss, we also need an exact definition of "quality assurance is met". Users must be able to estimate the impact of such quality goals on their applications and see evidence that QoS targets have been met.

Pricing schemes should also be flexible and user friendly. Zone-based cost sharing and IntServ pricing with RSVP provide the ability of sharing cost between senders and receivers. However, IntServ pricing with RSVP is inflexible when it forces receivers to compete for resources along a common, and potentially congested, shortest path back to the source. The ability to switch between competitive ISPs is also still an open issue.

Secondly, we will look at the schemes from the ISPs' perspectives. Clearly implementation costs are critical, and must not exceed revenues likely to be gained by deploying any new scheme.

On the other hand, the benefits come from the network utilities and marginal revenues from value customers. The Cost Benefit Analysis can be illustrated in Figure 5 as below:

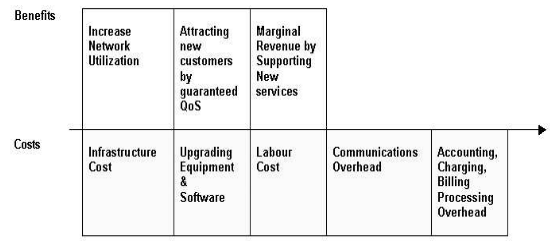

Figure 5 – Cost Benefit Analysis from ISP's perspective

Note: The size of each component does not represent the value

An effective solution maximizes the consequences of implementation cost and benefits (of which additional revenue is just one).

Network stability and reliability must also be considered. ISPs resist deploying complex technology if there are questions as to its reliability and operational effort. In this context "throwing bandwidth at the problem" is attractively simple and reliable. Pricing schemes that require equipment upgrades must work around the reality of incremental upgrades end-to-end. They must consider backward compatibility with older parts of the network and different service domains.

The settlement processes between ISPs is also not addressed well in the previous proposals. For example, DiffServ is claimed to solve the scaling problem of IntServ technology, however, it lacks standardized service classes between ISPs – making settlement between ISPs more difficult. Fraud Protection and Legal Security are also important in charging for end-to-end QoS. In multi-ISPs environment, in case of a failure, there should be enough information to determine who has the liability for the failure.

V. Future Internet Pricing Scheme

We suggest short-term and long-term Internet pricing solutions, due to the constraint of the supporting QoS technologies, time for technology standardization and the current Internet context. Currently, there is a limited deployment of QoS technologies, such as Intserv and DiffServ – which discourages research into QoS pricing schemes. On the other hand, a lack of supporting pricing schemes inhibits deployment of new QoS technologies. So the most appropriate short-term solution would be pricing models proposed for Best-Effort traffic. However, in the long-term additional demand for 'hard' QoS will make efficient QoS pricing schemes more desirable.

An example Short-term Internet pricing solution would combine Flat-Rate pricing, Usage pricing and congestion pricing with a compromise of implementation costs and benefits. Flat-Rate pricing covers the fixed cost of services while usage and congestion pricing controls congestion, differentiates service by different charging levels, increase social welfare and fairness among Internet users and produce improved marginal revenues for service providers.

Long-term Internet pricing schemes must allow predictable establishment of QoS tied closely with measurable charging parameters (such as bandwidth, delay, jitter and loss) and overall financial consequences for users. There are no clear solutions at this stage that account for user control of routing, cost sharing between senders and receivers, and standardized settlements between ISPs. Authentication and legal security issues also need to be solved in this settlement.

VI. Conclusions

This paper has presented a novel 3D model for analyzing and evaluating Internet pricing schemes based on technical complexity, economic efficiency and social impact aspects. It has reviewed Internet pricing research over the last ten years, compared and evaluated reviewed models using the 3D evaluation model. It has also highlighted the possible factors that have inhibited the deployment of the discussed models and proposed short-term and long-term Internet pricing solutions.

A viable pricing scheme will be a trade-off between technical efficiency, economic efficiency and social impact aspects. A simple, low cost and easy to explain scheme with an acceptable economic efficiency might be preferred to an optimal solution of economic efficiency, but is complex and costly in implementation.

Also, most of the models reviewed here have been theoretical or speculative rather than experimental in nature, so it is difficult to make clear and strong assessments to their worth. Although the 3D-metric evaluating model addressed critical aspects of a pricing model, it needs to be supported by a strong experimental-based support. Future research, therefore, should include the detailed evaluation of the technology implemented for the proposed pricing schemes.

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