Providing Internet Access: What we learn from the INDEX Trial*

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*We thank Jörn Altmann, Karyen Chu and Hal Varian for use of their unpublished results. A version of this paper was presented as the keynote talk at Infocom '99.

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Abstract

The Internet Demand Experiment or INDEX is a market and technology trial. Its objective is to determine how much users value different qualities of service for Interent access. Findings from the trial imply that today's system of flat-rate pricing by ISPs is very inefficient. Flat-rate pricing wastes resources, requires light users to subsidize heavy users, and hinders deployment of broadband access. INDEX is a prototype of an alternative ISP model that offers differentiated-quality service on demand, with prices that reflect resource cost. In this alternative ISP consumers pay less, suppliers increase profits, and the deployment of broadband access is facilitated.

1 The unavailability of differentiated quality service

A major contribution of network engineering is the development of techniques (signalling protocols and associated algorithms) for using the same set of network resources (links and switches or routers) to simultaneously provide different services to end users. This is sometimes called an integrated services model to emphasize network support of different applications such as real-time voice and video and non-real time data transfer. One may also say that these techniques allow provisioning of differentiated quality service. The latter characterization emphasizes the flexible transport capabilities of the network and frees users to select the best way to match service quality to the demands of their application, time, and budget.

Although it is possible to provide it, differentiated quality service is not sold in the marketplace. There may be for two reasons for this, one economic, the other technical. To offer differentiated quality requires the design and testing of economically viable alternatives to the flat-rate pricing model adopted by virtually all Internet Service Providers (ISPs). It also requires a technology to package such a service in forms that users can purchase, provide the means for users to express their demand, signal the network to provision the requested quality, and generate accounting and billing records. The INDEX trial tests alternative pricing models and a technology to implement those models.

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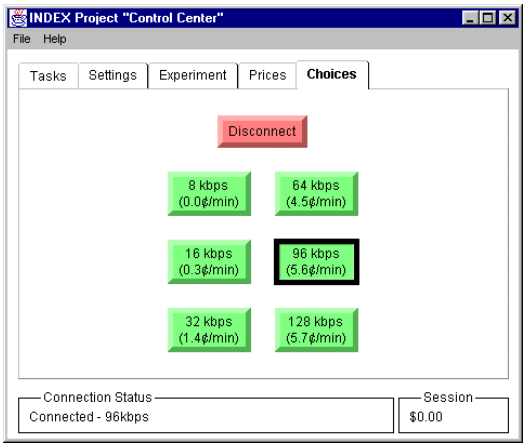

Figure 1: In the first experiment a user instantaneously selects her access speed and pays per minute of connect time. The control panel also shows the accumulated charges. Prices are selected randomly.

2 The INDEX trial

INDEX offers its subjects (customers) differentiated quality Internet access at home. The ongoing trial started in April 1998, and this paper reports findings based on data from the trial. The 70+ customers are students, faculty and staff of the University of California at Berkeley. There has been some turnover among customers due to changes in residence.

Every customer participates in a sequence of *service plans* or *experiments*, each lasting six to ten weeks. A service plan is characterized by a menu of service quality/price combinations. So each service plan implements a particular pricing model, parametrized by quality choices and prices. Customers pay by credit card. The value to a customer of a particular service quality is measured by how much money and time she spends consuming it.

INDEX collects detailed statistics on customer behavior. The basic data include byte counts in each direction, quality choice, accounting, and connection information. The time granularity is the minimum of one minute and change in quality choice. These data, with adequate protection of customer privacy, are available for study by researchers. The website: www.INDEX.Berkeley.EDU gives the details.

Figure 1 is a snapshot of the 'Choices' panel of the INDEX 'Control Center' or CC for the first experiment. The CC is the interface running on the desktop through which a customer controls access to the Internet. In this particular service plan a customer can select one of six different speeds (8, 16, 32, 64, 96, 128 Kbps) at a cost ranging from 0 cents for 8 Kbps to 5.7 cents per minute for 128 Kbps. The selected service quality (speed in this case) is provisioned virtually instantaneously.[1] The lower left corner of the CC indicates the current status of the connection—"connected at 96 Kbps" in this snapshot.

[1]The highest quality service that INDEX provides is a permanent 128 Kbps ISDN channel to the UC Berkeley campus network. There are plans to provide broadband service over ADSL.

The lower right corner of the CC shows a 'spending meter' that can be toggled to reveal the cost incurred until now during the current session, day, or month. (The figure shows the cost of the session to be $0.00, indicating the session has just started.) The spending meter is updated each minute, so customers can, if they wish, be aware of the cost of the resources they are consuming. Flat-rate charges, by contrast, deny users all information about their resource consumption. As a result, ISPs have to place inefficient restrictions on subscribers to limit resource consumption.

Another distinguishing feature is that an INDEX customer can *instantaneously* shift between different service qualities with no effort (beyond a mouse click). The quality may be changed during a session, if the user wishes. By contrast, when an ISP does offer different access speeds, the service is segmented into tiers: users must pick a single speed, and it is not possible to change that speed.

How much an INDEX customer values different speeds is measured directly by her purchase of the different speed options. The prices that are seen in Figure 1 are randomly selected and varied each week. Different customers face different prices. The price variation is large so that the demand estimates are robust.

Service quality has many dimensions besides speed, and INDEX service plans are designed to explore these dimensions. Furthermore, how a service is packaged into a commodity and priced makes a difference in demand, and some plans are designed to explore those differences.

By March 1999 the earliest subscribers participated in six experiments: (1) Symmetric bandwidth, (2) Asymmetric bandwidth, (3) Volume pricing, (4) Volume plus capacity charge, (5) Self-selecting tariff, (6) Enhanced flat-rate tariff. Figure 1 illustrates the choices in experiment (1), but it must be remembered that the prices are randomly selected for each customer and for each week. The aim is to determine sensitivity of demand for a certain speed to the prices of that speed and its substitutes. From INDEX data we learn that the price sensitivity is very high.

Experiment (2) is similar except that customers separately choose and pay for bandwidth in the upstream and downstream directions. The experiment is motivated by cable TV and DSL access, both of which have asymmetric speeds. The objective is to find out if users are aware of the asymmetry in their traffic pattern and make use of this asymmetry to reduce their bill. The answer is most are aware, and they do reduce their bill.

In experiment (3) users can select 128 Kbps and pay so many cents per megabyte of upstream and downstream traffic, or select free 8 Kbps service. We can compare user behavior when the commodity is megabytes of data transfer versus minutes of connect time. It turns out that the connect time goes up dramatically under volume pricing compared with connect time charges.

In experiment (4) a user incurs a volume or per megabyte charge plus a per minute connect time charge. This form of charge can reflect the bandwidth and buffer resources needed to support the user's traffic. (See [1, Chapter 8].)

In experiment (1) the plan offers a per minute connect time price, and in experiment (3) the plan offers a per MB price (at 128 Kbps). In experiment (5) users are allowed to pick a convex combination of an offered per minute connect time price for 128 Kbps and an offered per MB price. The user must choose the combination at the beginning of each week and the combination is then fixed for the rest of the week. If the traffic to be generated during the week can be predicted, the least

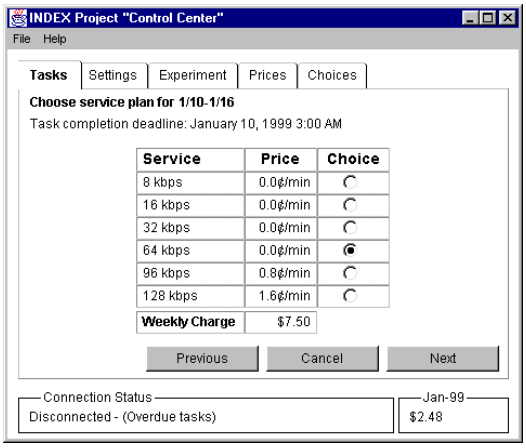

Figure 2: Customer choice panel for Flat Rate experiment. This customer is choosing to pay $7.50 for one week of unlimited 64 Kbps access. This choice is made once per week. During the week, the customer may select higher speeds at an additional per minute charge. The experiment combines flat rate and usage-based charges.

experiment is to find out how well users can predict their traffic pattern.

Experiment (6) is designed to test how much users value flat-rate pricing. At the beginning of each week consumers purchase unlimited usage for one week at a particular speed. They may connect at a higher speed for an extra cost per minute. Figure 2 shows the CC for a user who was offered one week of unlimited usage at a charge ranging from $0 for 8 Kbps to $15.00 for 128 Kbps and chose to pay $7.50 for 64 Kbps, while retaining the option of selecting 96 Kbps at 0.8 cents and 128 Kbps at 1.6 cents per minute.

Future experiments are aimed at estimating how much users value reduced blocking in modem pools, reduced congestion, as well as how much users shift their demand over time in response to time-of-use pricing.

The different INDEX service plans are alternatives to the prevailing dominant ISP model of flat-rate pricing.

3 Today's ISP

Figure 3 depicts an ISP network. Subscriber traffic, generated over dial-up 28 Kbps or higher speed DSL and cable TV modems, is aggregated at the ISP's point of presence or PoP. The ISP directs user datagrams over the Internet backbone through a Network Access Provider or NAP. Subscribers may connect to ISP servers that provide e-mail, news, web caching.

Users are charged a monthly flat rate of $20 for 28 Kbps dial-up access, $50 - $200 for access over dedicated 128 Kbps–1.5 Mbps DSL lines, and $40 for shared access over cable TV. More than 90 percent of residential subscribers use 28 Kbps dial-up modems, and in addition pay $15 per month

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