RICE

Edward W. Knightly
ECE Department
Rice University
6100 S. Main Street, MS 380
Houston, TX 77005
Phone: (713) 348-5748

My name is Edward W. Knightly. I am a Professor of Electrical and Computer Engineering and Computer Science at Rice University, 6100 South Main, Houston, Texas. I make this declaration of my own personal knowledge and state as follows:

1. I was program co-chair and organizer of the 6th IEEE International Workshop on Quality of Service, a conference sponsored by the IEEE Communications Society that took place in Napa, California from May 18-20, 1998. I also attended the conference. My recollection, based on my personal knowledge as a program co-chair, organizer, and attendee of the conference, is the following:

2. The 6th IEEE International Workshop on Quality of Service was a conference for academics and others in the computer industry interested in networks and communications. Its objective was to bring together researchers, developers, and practitioners working in all facets of network QoS (Quality of Service) research addressing distributed systems, Internet services, multimedia, operating systems, networking, and middleware. The conference had over 100 participants.

3. In advance of the conference, the program committee collected technical papers from the individuals who were selected to present on the various topics for the workshop. Once collected, the papers were combined and included in the workshop published program materials. Those materials were handed out and distributed to the attendees of the conference on the first day of the conference, May 18, 1998. The attendees were allowed to keep their copies of the workshop published materials.

4. One of the technical papers that was part of the workshop published materials, and that was handed out to the attendees of the conference, was titled "INDEX: A Platform for Determining how People Value the Quality of their Internet Access" by Bjoern Rupp et al. I have attached a copy of that paper in the form that it was submitted to the conference committee, and handed out to attendees on the first day of the workshop, as Attachment 1. Attachment 1 was included as pages 85-90 of the workshop published program materials that were handed out to the attendees on the first day of the conference.

5. I declare, under penalty of perjury, that all statements herein made of my knowledge are true and that all statements made on information and belief are believed to be true. Also, all statements made herein were made with the knowledge that willful false statements and the

like are punishable by fine or imprisonment or both under Section 1001 of Title 18 of the United States Code.

Signed on this 8th day of November 2019, in Houston, Texas.

Edward W. Knightly

ATTACHMENT 1

INDEX: A Platform for Determining how People Value the Quality of their Internet Access

Björn Rupp* Richard Edell* Harish Chand† Pravin Varaiya*

*Department of Electrical Engineering & Computer Sciences †Department of Economics
University of California at Berkeley

Abstract

The continuing exponential growth of the Internet and the emergence of new time-critical applications have led to the integration of a large number of different services on the Internet. In the process, the question of how to efficiently allocate bandwidth as a scarce resource has become a crucial issue for the continued proliferation of these new services. Future growth depends on the division of services into quality-differentiated market segments and the pricing structure of each segment. Successful growth requires service providers to offer combinations of quality and price that match user need. But to do this providers must understand the structure of user demand. Such understanding is lacking at present.

This paper describes a platform designed to obtain a basic understanding of how individuals value Internet usage when offered different Quality of Service choices. The Internet Demand Experiment (INDEX) has two main objectives: (a) Measurement of user demand for Internet access as a function of Quality of Service (QoS), pricing structure, and application; and (b) Demonstration of an end-to-end system that provides access to a diverse group of users at attractive price-quality combinations. The data being collected is expected to reveal the correlation between user application and service demand, how demand varies with user experience, and up to what extent users form discrete market segments. This paper gives an overview of both the technology employed at INDEX and the goals of the experimental design.

1 Motivation

In recent years, the Internet has undergone a dramatic transformation from a computer network dominated by traditional, mostly text-based applications and a comparatively small, coherent user community to a universal platform for ever more users and services. This was not without its consequences. While traditional applications like electronic mail or file transfers can react in an elastic fashion to deviations in available bandwidth, new time-critical applications like Internet telephony and video conferencing cannot, thereby causing their employment to be severely limited as soon as network congestion leads to high packet delays and packet drops. With the explosion of demand for Internet services, higher speed access, and new applications, this situation continues to worsen. A single "best effort" service quality seems to become increasingly inappropriate for a network serving a wide variety of users and applications. Currently, users who occasionally need high bandwidth are either forced to lease over-provisioned dedicated lines, risk the vagaries of the performance of "best effort"-quality shared resources, or forego the desired application altogether. When demand for Internet access varies among the population (as indicated by population-projectable data as in [CommerceNet/Nielsen 1997]), quality differentiation, along with proper economic incentives, can increase the overall value of the network by making available resources when needed for high value applications. The division of services into quality-differentiated market segments and the design of appropriate pricing structures for each segment is crucial for further proliferation of Internet services. Successful growth requires service providers to offer combinations of quality and price that match user need. But to do this providers must understand the structure of user demand. While there have been many pricing proposals in recent literature (for a short overview of different approaches, see [Shenker et al. 1996]), such understanding of user demand is lacking at present.

INDEX — the Internet Demand Experiment — is a real-world market trial seeking to provide this information and measure how individuals value Internet usage when they are offered different Quality of Service choices. INDEX has two main objectives: (a) Measurement of user demand for Internet access as a function of quality of service (QoS), pricing structure, and application; and (b) Demonstration of an end-to-end system that provides access to a diverse group of users at attractive price-quality combinations. The experiment will provide Internet access over ISDN lines to a group of about 150 users from the Berkeley campus community for a two-year period. Users select network services from a menu of QoS-price offerings and pay for their usage. It is important to stress that while the subjects' basic Internet access (in particular, the ISDN line and access equipment) is greatly subsidized, each choice on these QoS menus has a real economic cost which the subjects pay out of their own pockets. This is necessary in order to achieve incentive compatibility, i.e. given the incentive schedule as represented by their active menu, users pick the option that corresponds to their true valuation of the network resources in question. The menu changes in certain intervals in order to measure demand for a wide range of combinations of QoS, price and user characteristics. The data being collected is expected to reveal the correlation between user application and service demand, how demand varies with user experience, and up to what extent users form discrete market segments. The data will also allow to test hypotheses about the structure of the market for variable-quality ATM services. In addition, the experiment demonstrates a single system that offers variable service quality-price combinations that meet the needs of a diverse user population, an automated billing system that also gives the user control over service selection, and

a remotely operated network monitoring and management system.

This paper gives an overview of the INDEX Project's scope and describes both the technology employed and the goals, timing and structural details of the experimental design.

2 Experimental Setup

2.1 INDEX Access Network Provision

The INDEX access network provides IP service over dedicated, 128kbps ISDN lines in order to establish a predictable and stable QoS between the subjects' homes and the INDEX Project Network Operations Center[1]. For this purpose, INDEX loans a preconfigured Cisco 762 ISDN router to each subject participating in the experiment and installs an ISDN phone line at their home. The 128kbps basic rate interface lines coming from the subjects' homes are then multiplexed over ISDN primary rate lines at the Pacific Bell central office before they reach the INDEX Project Network Operations Center. In contrast to common industry practice, the overall available bandwidth is not reduced in the multiplexing process and the whole network is heavily overprovisioned to make sure that none of the subjects experience deteriorations of their selected quality level due to potential bottlenecks at the INDEX access network.

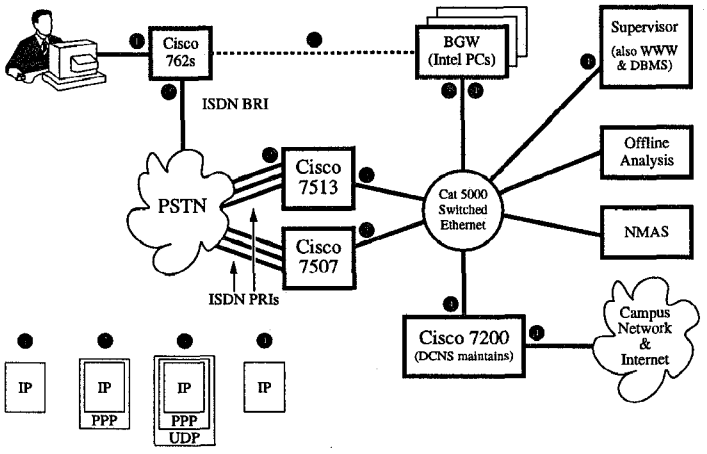

Figure 1: INDEX Network – Transport Layer

At the INDEX NOC, all connections are through either a Cisco 7507 or 7513 Internet router. These routers distribute all user traffic over a set of Billing Gateways specifically designed to meter usage and selectively adjust the service quality of individual connections. The user may select a service quality from the currently active menu of choices at any time. Connections are aggregated by user so that the quality for this bundle can then be controlled accordingly. All outbound packets are forwarded to a Cisco 7200 router that is directly connected to the UC Berkeley 100Mbps FDDI backbone.

[1]It should be noted that although the current experimental setup is oriented towards providing service over ISDN lines, the INDEX network architecture is flexible enough to allow us to expand the experiment to demonstrate ADSL or CATV access using cable modems at a later stage.

2.2 User Interaction, Accounting and Billing

INDEX uses a locally developed system for user interaction and metering individual subject usage. The user interacts with this system by means of the "Control Center", a Java application running on the user's computer. For the subjects, this is the central application enabling them to select different Qualities of Service and control their usage of network resources. Apart from functions for login and authentication, it consists of a small window informing the user about the current experiment, the price schedule currently in effect and the actual choices. The subjects can choose a service quality by the click of a button and change their Quality of Service even during the active session. The Control Center also provides usage feedback by displaying a summary of charges for either the current session, the current day or the current month.

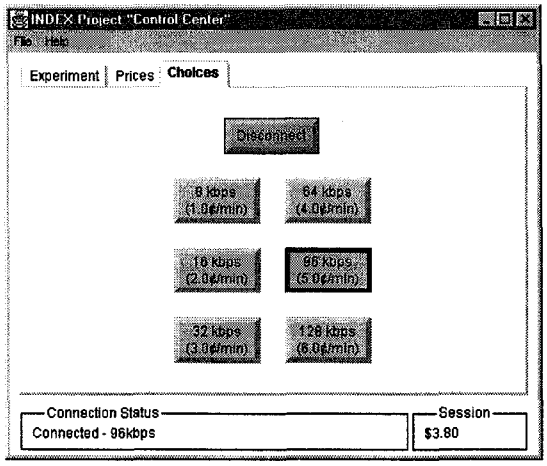

Figure 2: INDEX User Interface ("Control Center")

The Control Center application communicates user choices and selected quality levels as control data going through a Billing Gateway to a "supervisor" process. This supervisor process then orders the Billing Gateway to treat this user's connections according to the selected quality level. The Billing Gateway in turn meters the traffic and reports back to the supervisor process.

User traffic is monitored and recorded at a fairly detailed level for both billing purposes and subsequent offline analysis. The database contains records for each TCP connection. Apart from an anonymized user ID, time stamp, selected QoS/price information and a variety of TCP control data types, they include information about connection length, the amount of inbound and outbound traffic for the connection, source and destination IP addresses, port numbers, and other data describing the type of user activity. It is important to collect data at this level of detail in order to not only record at what time users change their QoS choices, but also to infer what parameters influence these decisions and what the reasons for these changes are. Such detailed records are able to reveal, for instance, what applications are running at the time of a QoS change and what types of hosts and network services are involved.

DOCKET ALARM

Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts

Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research

With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips

Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

LAW FIRMS
Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS
Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS
Sync your system to PACER to automate legal marketing.