ABSTRACT

The Internet develops toward an integrated services network by offering differentiated network services for all kinds of applications. This variety of services and the fact that different service providers will offer the same service at different prices overwhelms the user. It will become difficult for users to find the best service offer, meeting their specific requirements. In this paper[1], we present a software agent system that supports the user in making service purchase decisions. After describing the environment, the architecture, and the implementation of the software agent system, we present a format for formulating pricing schemes. This format enables software agents to compare pricing schemes of different service providers.

1 INTRODUCTION

Since the success of the Internet depends greatly on user satisfaction, fair pricing schemes are becoming increasingly necessary. Usage-based pricing is overcoming limitations of flat-rate pricing, the predominant pricing scheme. In the future, users will be charged according to their usage within a pricing scheme of their choice [2]. Users consuming high bandwidth at higher quality will pay more than users consuming less. For example, customers who only read electronic e-mail once in a while would pay much less than customers who transmit tele-seminars.

Based on usage-based pricing schemes, each Internet Service Provider (ISP) can specialize in niche markets. ISPs can adapt services to the needs of various customer groups and provide customers with more tailored services.

The greater flexibility of usage-based pricing creates more complications for the user. They have to find the best-fitting service for their needs among a huge number of offers. Furthermore, the QoS-price negotiation between ISPs and users is becoming more sophisticated. In order to deal with this appropriately, the interaction between ISPs and users must be defined clearly. In such an environment, a possible solution would be a software agent system where users and ISPs are represented by agents. Those agents would trade services autonomously. Although some articles describe the general architecture of an agent-based telecommunication market [7][11], the discussion of a framework for specifying service plans (pricing schemes) has been neglected. A possible way to go is definition of basic pricing components. Based on those components, more sophisticated pricing schemes can also be described.

Usage-based pricing and the comparison of different pricing schemes is currently investigated in the *IN*ternet *D*emand *EX*periment project [2]. INDEX is a field trial investigating users' willingness to pay for a specific service quality. INDEX users are provided with tools to select the quality of their Internet access according to their current needs and QoS requirements of the applications.

The remainder of this paper is subdivided in 4 sections. In the next section, the future network service market is introduced, describing the service model of the Internet and possible pricing schemes. The user agent, acting in such an environment, is presented in Section 3. Section 4 illustrates the framework for specifying service plans. Section 5 concludes the paper with remarks about our future work.

2 FUTURE NETWORK SERVICE MARKET

2.1 SERVICE MODEL

In the future, the connection between the user's computer and the ISP's network might be a line with a bandwidth

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capacity of several megabits per second. As shown in Fig. 1 the connection between the user's home and the Internet Access Provider's (IAP) facilities might be utilized either for voice and data communication (see line of $user_u$) or only for data communication (see line of $user_v$). Both types of connections are provided by the IAP. The service of the IAPs, much like the service of the local telephone carriers, provides the interconnection between the user and his preferred ISPs. ISPs distinguish themselves by offering different services, accessible via fast connections to backbone provider.

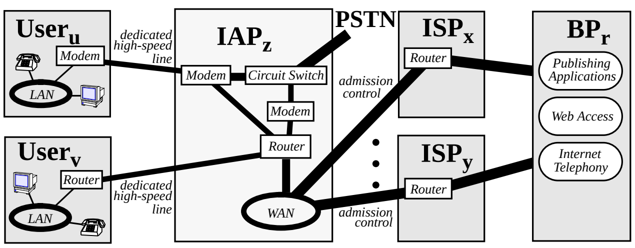

Fig. 1: Model of the future service network

2.2 SERVICE PLANS

Since there will be strong competition on the ISP market in the future, many service plans will be used in the future telecommunication market [10]. Different service plans enable ISPs to focus on certain niche markets, since they can customize their services. Even more, ISP will design pricing schemes to attract certain customer groups. In addition, users will have a broader selection of ISPs, service plans, and network service qualities (QoS) to choose from. In order to find the best offer (regarding QoS and price) the user has to know the QoS requirements (i.e. QoS level and bandwidth) of his applications as well as how his personal price-quality preferences can be best met. In order to compare prices, the user has to request the prices for those services from several ISPs, and then choose the ISP, the service plan, and the service.

The following examples show the variety of pricing schemes that will be found in a future market. A more detailed description of those pricing schemes can be found in [2].

Variable Bandwidth Pricing

This pricing scheme allows users to choose between different bandwidths (e.g. 16 kbps, 32 kbps, 48 kbps, 64 kbps, 80 kbps, 96 kbps). Users can alter the selection during an on-going communication. Charges are calculated on basis of a per-minute rate and the chosen connection speed. Prices increase with bandwidth.

Asymmetric Bandwidth Pricing

Asymmetric bandwidth pricing enables the user to choose different bandwidths for in-bound and out-bound traffic in the same way as discribed in the symmetric bandwidth pricing.

Byte Volume Pricing

Users face per-byte charges under this pricing scheme. That means, users have to pay a fixed rate for each byte transmitted at a certain bandwidth. The rate might vary depending on the chosen bandwidth.

Variable Bandwidth And Byte Volume Pricing

This pricing scheme is a combination of the byte volume pricing and the bandwidth pricing. The total charge is the sum of the per-byte charges and the per-minute charges. For instance, if the file download of size 1.83 mbyte (15 cents/mbyte) took 4 minutes at bandwidth 64 kbps (2 cent/sec), the user has to pay 27.5 + 8 cents.

Flat-Rate And Peak Performance Pricing

Here, users pay a flat-rate for a basic bandwidth (e.g. 32 kbps), but pay a per-minute rate if they request higher bandwidths (as in the symmetric bandwidth experiment and the asymmetric bandwidth experiment).

Priority Pricing

The priority pricing scheme offers users premium service for a higher rate than the usual best-effort service. Each service is specified by guaranteeing a lower bandwidth. For example, the premium service could be a maximum bandwidth of 96 kbps and a guaranteed minimum bandwidth of 64 kbps. The best-effort service, on the other hand, is 96 kbps with no guaranteed minimum bandwidth (i.e. 0 kbps).

Congestion Pricing

Charges for using a network increase when the network is congested. As a consequence, only users remain connected who value the network service most. This kind of pricing is a mechanism to reduce congestion on networks.

3 SOFTWARE AGENT FOR PURCHASING NETWORK SERVICES

The necessity for supporting the user in his purchasing decision was demonstrated in the previous section. INDEX provides a software agent purchasing Internet services on behalf of the user. Such a software agent (*User Agent*) runs on the user's computer. In order to make good decisions, the software agent has to perform such tasks as gathering information about:

- user QoS-price preferences,
- user usage profile,
- application's QoS requirements,
- network performance,
- prices of offered services,
- ISPs' past performance,

and, finally, after calculating the optimal service that meets the user's need, purchases the corresponding service from one of the ISPs.

3.1 ENVIRONMENT

The interaction of the *user agent* with other software agents (e.g. *ISP agents* and *Service Evaluation Agents*) in the future telecommunication market is illustrated in Fig. 2.

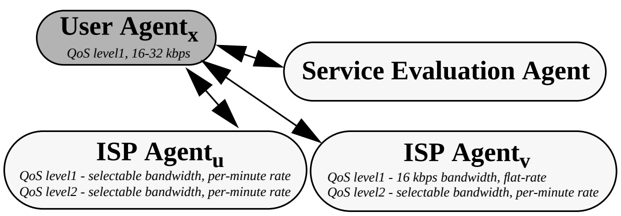

Fig. 2: Interaction of the user agent

The ISP agent is the counterpart to the user agent and runs at the ISP site. It handles requests for prices, verifies user identity, and manages price negotiations for services with the user agent. In case the service has been purchased by the user agent, the ISP agent provides the user agent with usage and billing information.

In the future network service market, there might also be *service evaluation agents* providing performance data about services delivered by ISPs. This data could be either the quality of a certain path in the Internet, or an assessment of ISPs with regard to their delivered services. The service evaluation agent might gather those data by actively probing the Internet or by requesting experienced performance data from all participating user agents [3]. If the user agent gets this kind of information, it will improve the calculation of the most useful QoS level and bandwidth.

3.2 ARCHITECTURE OF THE USER AGENT IN THE INDEX PROJECT

The user agent is connected to the QoS management system on the user's computer [5][9]. The QoS management system provides the user agent with information regarding which application is going to be started, and on are the application's QoS requirements (see *QoS Specification Interface* in Fig. 3). The user agent, as part of the QoS mapping component within the QoS management system, provides results about availability and admission tests to the QoS management system.

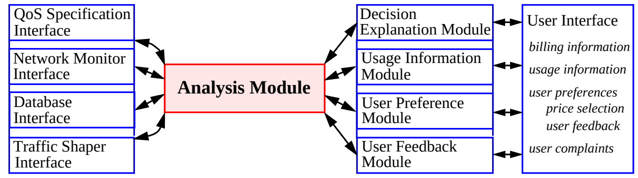

Fig. 3: Architecture of the user agent

Fig. 3 shows the interface between the user agent and the network monitor. The monitor provides detailed performance data about the network status at network layer level. This information enables the agent to react quickly to performance changes. The network monitor used is *tcpdump*. Performance data is also used to evaluate the received service. The evaluation result is stored in the *Database* which is managed by the *Mini SQL* database management system. The user agent's interface to the Traffic Shaper is necessary to inform the Traffic Shaper about the capacity currently available.

The user interface is an important part of the user agent. The user interface has to be as simple as possible while providing sufficient information for the user to check the software agent's purchasing decisions.

To check the agent's purchase decision, the user interface displays the QoS currently chosen by the user agent. The user is also provided with a textual explanation for the agent's choice and with graphs about the software agent's expenditures. Whenever the user is not satisfied with the purchase decision of the software agent, s/he can modify the QoS selection (i.e requesting better service or lowering the expenditure). The user can also specify at the user interface how much money s/he wants to spend per month, or which applications have to get high-priority service.

3.3 IMPLEMENTATION

The INDEX project [2][4] provides 80 subjects (affiliates of the University of California at Berkeley) a permanent connection to the Internet via an ISDN line without any monthly fee. The subjects are only charged according to their Internet usage. Since all pricing schemes require the selection of QoS choice for accessing the Internet, the subjects have to run the *INDEX Control Center* where they can manually enter their service choice (Fig. 4). Alternatively, the user can activate the user agent. Whenever the user agent is activated, the user is relieved from making purchasing decisions.

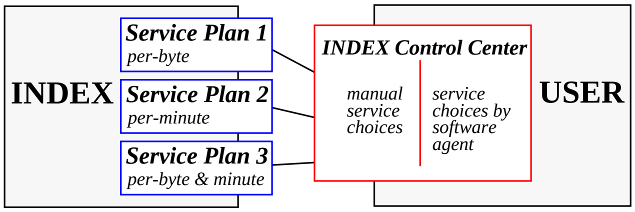

Fig. 4: Service choices in INDEX

Whether or not the user activated the user agent, the user agent monitors the user's decision in order to improve the model of the user's QoS-price preferences. We are applying methods of microeconomic analysis to determine QoS-price preferences. To model the user's utility function regarding QoS and price, we examine the user's demand for services.

3.4 QoS-PRICE ANALYSIS

The decision making process of the INDEX user agent for purchasing services is composed of 6 steps: When an application (e.g. e-mail) is started the user agent gets the application's QoS requirement from the QoS management system and adds it to the sum of required services for all running Internet applications. The next step is a database lookup for information about performance received in the past for this application to the current destination IP address. Then, the applications' QoS requirements are adapted with regard to this data. The 4th step consists of requesting service plans, prices, and availability from several ISPs. Afterwards, this data and the model of the user's QoS-price preferences are compared. Finally, the user agent makes the purchasing decision.

4 SERVICE PLAN FRAMEWORK

An essential prerequisite for an automated QoS-price analysis is a standardized format to describe service plans. It would not be possible to compare service plans without such a framework. The definition of atomic pricing components, which are the basis of more sophisticated service plans, will help to define the format for exchanging QoS-price information between ISPs and users. The format we are proposing uses the following atomic pricing components:

- per-minute pricing (i.e. user is charged for the number of minutes being connected to the network at a certain bandwidth),
- per-byte pricing (i.e. user is charged for the amount of transmitted bytes),
- priority pricing (i.e. user is charged for the QoS level chosen),
- date pricing (i.e. user faces different prices for the same service depending on the date and the time of day),
- congestion pricing (i.e. user charges are dependent on the congestion of the network [6][8]).

The following formula unifies all those atomic pricing components. It can be used to calculate the usage-based charges of all the pricing schemes presented in section 2:

$$C = \sum_i C_i$$

$$C_i = \sum_j (T_{ij} + V_{ij} + F_j)$$

$$T_{ij} = t_j \cdot p'_{ij}(b_{ij}, l_{ij}, t_j, v_j)$$

$$V_{ij} = v_j \cdot p''_{ij}(b_{ij}, l_{ij}, t_j, v_j)$$

$$F_j = f_j$$

The user's cost C is the sum of the costs C_i generated in a certain time period i (date pricing). C_i is the sum of costs caused at each QoS level j. The cost per QoS level, in turn, is the sum of three variables (T_{ij}, V_{ij}, F_{ij}). The first variable (T_{ij}) is the fee for being connected to the network for a time period t at bandwidth b (i.e. peak rate) and price p'. The variable V_{ij} defines the fee for the actual used capacity of the network (i.e. the transmitted bytes) v (byte volume) at price p''. The third term F_{ij} is a flat-rate charge f. In order to consider congestion pricing, the prices p' and p'' depend not only depents on the bandwidth but also on the load of the network l. For describing cost caps, prices have to depend on the actual usage (time t and bytes v)

We use an object-oriented approach for the implementation. The four objects, that we propose to describe service plans, are illustrated in Fig. 5. Beside the information mentioned in the formula, we also need the ISP name and the expiration date of the service plan offer.

The *ServicePlan* object contains an array of *IntervalPriceSet* objects, a *String* object, and a *Date* object. The *Date* object defines the expiration date of the service plan offered by ISP *isp_name* (*String* object). The *IntervalPriceSet* object represents the price in a certain time period *time_period* (*Interval* object) for a specific QoS level (*Interval* object). The price itself is defined by two arrays of *IntervalPrice* objects and an *int* object. While the *int* object just defines a minimum charge (i.e. flat-rate) for the service, the *IntervalPrice* objects define the price functions (*priceFct()*) for a certain bandwidth (*Interval* object), network load, and usage (time and byte volume). The price function can be any simple function.

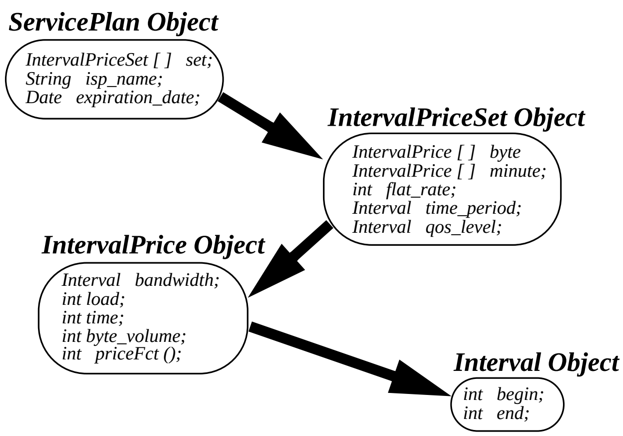

Fig. 5: Objects representing a pricing scheme

5 CONCLUSION

We illustrated a model of the future service network market. The analysis of the future Internet and different pricing schemes showed that it will become a difficult task to find the best-fitting service with regard to users' needs and preferences. As a solution we proposed a user agent that purchases services on behalf of the user. We described the software agent's environment, architecture, and some part of the user agent's implementation within the INDEX project. In more detail, we examined different kind of service plans. Based on those results, we proposed a general formula and a set of objects to describe service plans. Both will help to automate the exchange of QoS-price information between ISPs and customers.

Our future work will focus on the protocol for exchanging information between ISPs and customers.

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