Managing Usage-Based Pricing in a Future Telecommunication Market[1]

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Abstract

We describe one scenario of a future telecommunication market in which Internet Service Providers and Internet users sell and buy services. ISPs specialize in niche markets offering certain telecommunication services under different usage-based pricing schemes. Users choose between those services on the basis of their current needs and QoS-price preferences. Since the service choice is a complicated task in a competitive environment we propose a software agent which purchases services on behalf of the user. The user agent is also supported by an agent for evaluating delivered services. At the ISP site, a flexible billing and accounting system exists. The design and implementation of this multi-agent system is investigated within the framework of the INternet Demand EXperiment project (INDEX), a testbed for analyzing the user's demand and willingness to pay for different qualities of services.

1 INTRODUCTION

Internet's success is founded on the huge number of diverse applications that people may choose for their preferred way of communication, ranging from programs for sending electronic mail to high bandwidth consuming tele-conference systems. Since these applications are running at the same priority on today's Internet, the applications may strongly interfere with each other. Consequently, high performance applications requiring a certain network quality (e.g. delay and bandwidth) cannot perform their task effectively.

A solution to this problem is the introduction of *differentiated services* on the Internet [5][9]. Differentiated services means that services are distinguished by basic quality metrics for the network layer such as delay, jitter, bandwidth, and reliability. Although differentiated services may not provide any guarantees, they allow Internet Service Providers (ISP) to adapt their services to the needs of certain customer groups. Therefore, ISPs can specialize in niche markets, and customers get more tailored services. Since different services will have different costs, more sophisticated pricing schemes are necessary for those services. Flat rate pricing would not be appropriate for each user and service. Instead, customers would be charged by the ISP according to their usage within a pricing scheme of their choice [15]. For example, customers who only read electronic email once in a while would pay much less than customers who transmit tele-seminars.

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While some articles about agent systems in the telecommunication market [4][11][16] concentrate on methods that offer services and prices to users, we focus on the mechanism to find the best service for users' needs and to charge users for consumed services. The selection of the best service depends on the user's application running, the destination address of communication, the budget of the user, as well as the pricing schemes offered by ISPs. Therefore, it might occur that users, which face usage-based pricing, might be overwhelmed by the amount of possible service choices.

A system is necessary which supports the user in his decision to select the best fitting service for his needs. It must also be able to deal with changing needs of users and a variety of similar services under different pricing schemes. Such a system is currently developed in the INternet Demand EXperiment project [15]. INDEX is a field trial for investigating users' willingness to pay for a certain service quality. INDEX users select the quality of their Internet access from a menu of price-quality combinations.

The article is organized as follows: In the next section, a model of a future Internet telecommunication market is introduced, describing the structure of the Internet, quality of service (QoS) issues, and possible pricing schemes. A scenario of the interaction between agents of users and ISPs is discussed in Section 3. Based on that, Section 4 focuses on the implementation of the multi-agent system. Finally, we present some preliminary results and describe our future research topics regarding the multi-agent system within the INDEX project.

2 MODEL OF A FUTURE TELECOMMUNICATION MARKET

2.1 Structure of the Internet

The Internet is a dynamic network whose topology is steadily changing. This change is intensified by the continuing privatization of the Internet which began in 1995. The topology changes for the most part when business relationships between ISPs change. When ISPs become dissatisfied with the price and quality of service received from their business partners, they cut connections and build up new to other ISPs.

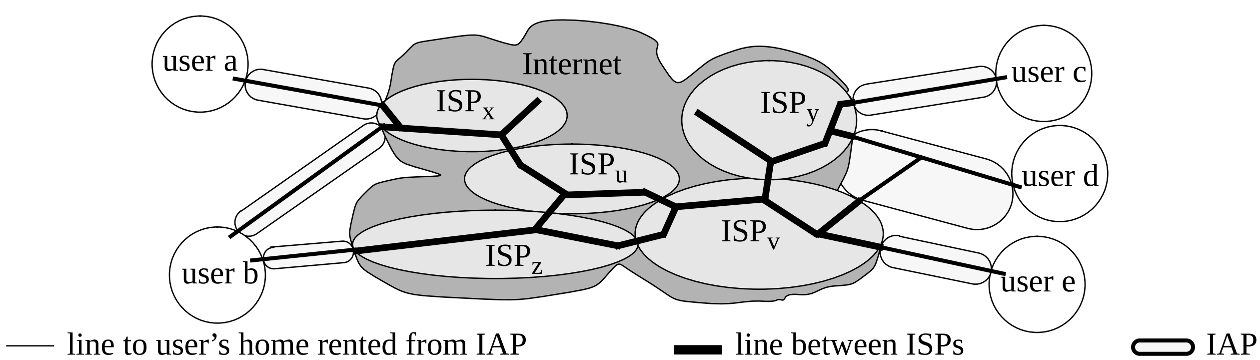

Figure 1: Structure of the Internet

The topology of the Internet (see Figure 1) is also determined by the interconnection between ISPs and users. As depicted in Figure 1, users might have one or more lines to the Internet provided by Internet Access Providers (IAP). The user's IAP might be the local telephone carrier, the cable TV provider, or a wireless service provider.

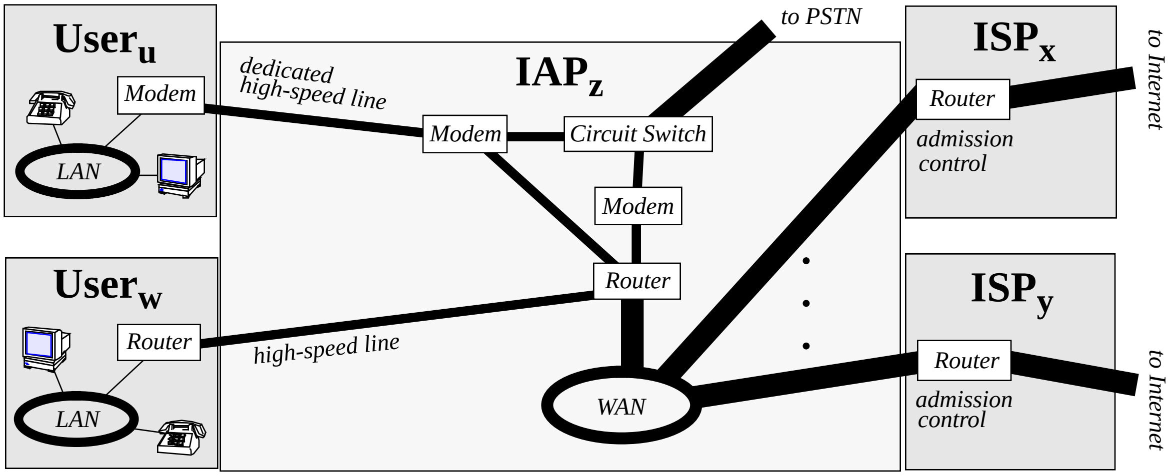

Figure 2: Model of the network interconnection between user and ISP

In the future, the user's Internet access line might have a bandwidth capacity of several megabits per second. The line might be used for either voice and data communication (see line of $user_u$ in Figure 2) or only for data communication (see line of $user_w$). In order to indicate the user's preferred ISP, each IP packet is marked with the IP address of the ISP's router (i.e. source routing [7]). When such a IP packet arrives at the IAP's router, the router forwards it to the corresponding ISP router.

As this scenario shows, it might become a difficult task for the user to choose the IAP. The user's choice of IAPs depends on the service rates, Internet access speed, and the connectivity to ISPs.

2.2 Quality of service

It is essential to meet the QoS requirements of applications in order to get good application performance. The user's computer has to have an operating system that performs admission control of the network resource for all running applications. This operating system also tags and sorts outgoing IP packets according to their Quality of Service Level (QoSL) affiliation. Incoming IP packets are delivered to the corresponding application without violating QoSL requirements (Figure 3).

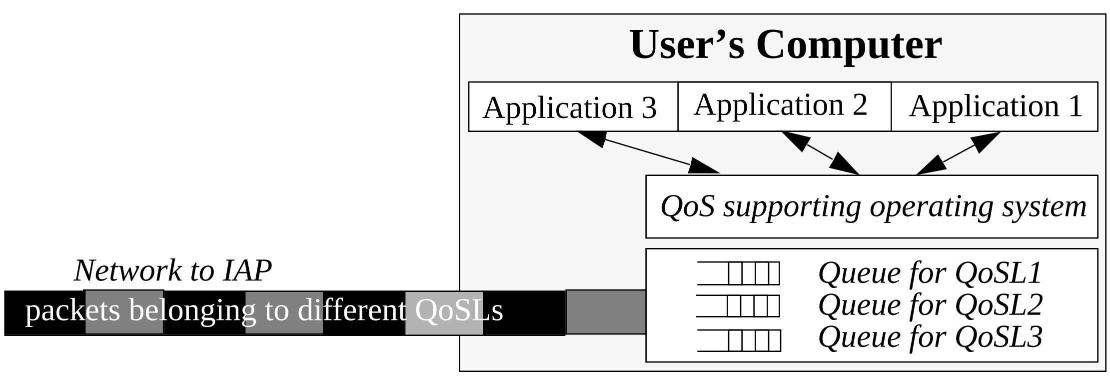

Figure 3: QoS supporting operating system

However, since quality of service is subjective and different QoSLs will have different prices, users have to choose the appropriate QoS for their applications. Even more, users also have to react to performance changes of delivered QoS which might require to switch to another QoSL during a ongoing communication in order to keep the performance level up.

Another aspect of QoS is the evaluation of received services. The evaluation of a communication can be used for the next service choice. For example, if the service received from a certain ISP was poor, the user could conclude that he should request a service of a different service provider the next time.

Considering those aspects, it is obvious that the user needs support for choosing the QoS-price selection.

2.3 Pricing Schemes

Many pricing schemes might be used in the future telecommunication market [14]. Since ISPs will have to focus on niche markets, they will design certain pricing schemes to attract certain customer groups. Pricing schemes will range from simple pricing schemes such as per-byte pricing and per-minute pricing to more complicated pricing schemes such as *smart market pricing schemes* [12]. Therefore, it is necessary to find a way to represent different pricing schemes which allows users to compare pricing schemes. The following formula can be used for calculating the usage-based costs:

$$C = \sum_j (t_j \cdot p'_j(b_j) + v_j \cdot p''_j(b_j))$$

The cost C is the sum of the costs caused at each QoSL j. The cost per QoSL, in turn, is the sum of two values. The first 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 second is the fee for the actual used capacity of the network (i.e. the transmitted bytes) v and price p'' at bandwidth b.

Using this formula it is possible to compare pricing schemes like:

- per-minute pricing (i.e. user chooses between different bandwidths),
- per-byte pricing (i.e. user is charged according to the number of transmitted bytes),
- priority pricing (i.e. user can choose between different QoS levels (QoSL).

3 MULTI-AGENT SYSTEM FOR A TELECOMMUNICATION MARKET

In a highly dynamical telecommunication market, the user has to select not only the sufficient bandwidth at a certain QoSL for his applications but also the appropriate pricing scheme of an ISP. As described in the previous section, this is a complicated task. Therefore, a tool supporting the user in the selection process might be helpful. The tool we propose is a software agent (*user agent*) running on the user's computer, analyzing user's QoS-price preferences and QoS requirements of applications currently running. If the user agent has to buy a service, it requests prices for services from different ISPs, chooses the best one according to the users preferences, and purchases the service.

The agent running at the ISP site (*ISP agent*) is the counterpart of the user agent. It handles request 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. Furthermore, the ISP agent will also react to complaints about poor service sent by the user agent. In order to improve customer service, the ISP agent initiates measurements for localizing the cause of a received complaint.

Beside those agents, there are *service evaluation agents* providing performance data about services delivered by ISPs. In order to improve its purchase decision, user agents contact the service evaluation agent. On request, a user agent gets information about the quality of routes in the Internet, delivered QoS by ISPs (i.e. an assessment of ISPs), or price comparison. The service evaluation agent gathers data from participating user agents (e.g. as proposed in [1]). The interaction between all those agents in the future telecommunication market is illustrated in Figure 4.

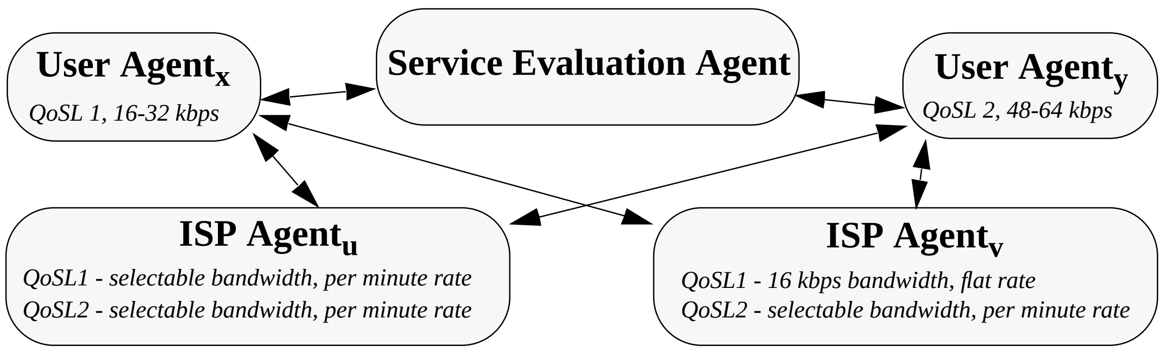

Figure 4: Example of a multi-agent system for a telecommunication market

Figure 4 shows an example of the interaction between the agents of the multi-agent system. The example illustrates the process of finding the best service offer according to the user's requirements. The user agent starts out with calculating the *required QoS* by analyzing the QoS requirements of the application (i.e. the bandwidth of the lowest QoSL needed by the application to run smoothly) and comparing these results with the user's performance preferences (i.e. considering the minimum bandwidth the user wants to have at least for a certain application). If the user agent doesn't have detailed information about the network quality delivered in previous communications from different ISPs in the past, it can ask the service evaluation agent for this kind of information. Then, the user agent incorporates the information about the network quality into the calculation process for determining the *maximum QoS* (Maximum QoS is defined as the required QoS adapted to the network situation). In the example of Figure 4, *user agent*$_y$ came up with a calculation result of *QoSL 2*, required bandwidth *48kbps*, and maximum bandwidth *64kbps*. *User agent*$_x$ came up with *QoSL 1* and a bandwidth range of *16-32kbps*. Finally, the user agents have to purchase a service form ISP agents. After gathering price information from different ISP agents, the user agent compares the prices with the user's QoS-price preferences. The result is the *preferred QoS*. In example of Figure 4, the decision of *user agent*$_y$ only depends on the per minute rate offered by both ISPs while the decision of the *user agent*$_x$ might also be influenced by the fact that the user's profile predicts a low bandwidth-consuming work (so that the user agent prefers the flat rated *16kbps* service offered by *ISP agent*$_v$).

4 IMPLEMENTATION

4.1 Environment

The test bed for the multi-agent system is the INDEX network capable of providing quality differentiated services [2][6]. The structure of the INDEX system comprises four main components: the billing gateway, the accounting component, the database, and the ISP agent (see Figure 5). The interaction between these components is based on RPCs. Whenever the ISP agent receives a request for availability checks, prices, or admission, it initiates a request to the accounting process. The accounting process is the central unit which has access to secure data of customers in the database and can invoke the billing gateway to record all communication of a user for billing purposes. Besides, the billing gateway also restricts the bandwidth for a certain QoSL according to user's choice of bandwidth.

Figure 5: Structure of the ISP's accounting and billing system

In order to provide access to a user, the user agent must be authenticated. This authentication is based on pre-existing accounts. Our INDEX subjects had to subscribe in advance. However, prepaid accounts would also be a way to do accounting. Thus, whenever a user agent requests access the ISP agent asks the accounting process to validate access. The accounting process queries the database for the user and returns the result to the ISP agent. Then, the user agent can request service plans and prices from the ISP agent.

When the ISP agent gets a valid request for a certain bandwidth of a specified QoSL, it forwards the request to the billing gateway via the accounting process. The billing gateway checks if the request can be met with available network resources. Information about service availability would be obtained by aggregating over network performance data. The request is rejected if it cannot be met. Otherwise, the billing gateway opens the requested service, and polices user traffic to ensure that it conforms to the requested bandwidth. Within INDEX, the billing gateway does the policing by configuring various leaky buckets.

4.2 Architecture of the User Agent

An important aspect of the user agent is its connection to the QoS management system on the user's computer [3]. The QoS management system provides the user agent with information such as which application is going to be started, what are the application's QoS requirements, and what is the network situation. Furthermore, the user agent, as part of the QoS mapping component within the QoS management system, provides results about availability to the QoS management system (see Figure 6).

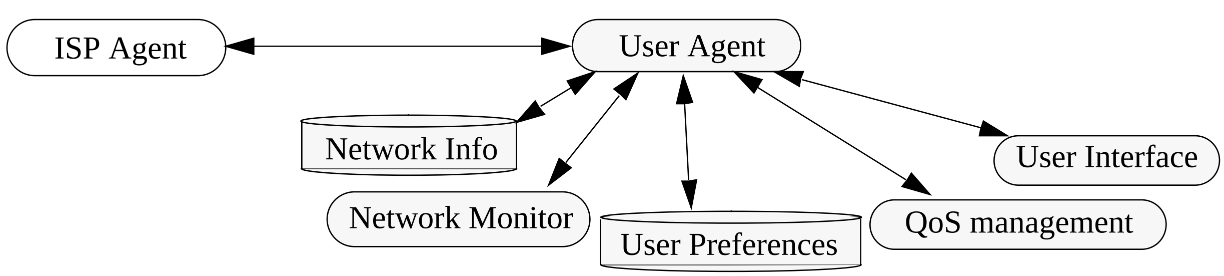

Figure 6: Interaction between user agent and its environment

Figure 6 also shows the connection between the user agent and the network monitor. The monitor provides detailed information about the network status at network layer level. This information enables the agent to react quickly to performance changes. Besides, performance data is also used to evaluate the received service. The evaluation result is stored in the *Network Information Database*. The network monitor used is *tcpdump*. The remaining part of the implementation is written in *Java* including the interface to the *Mini SQL* database management system.

The user interface is an important part of the user agent. On the one hand, the user interface has to be as simple as possible. On the other hand, the user interface has to provide sufficient information for the user to check the software agent's purchasing decisions.

Since we want to provide the user agent as an additional help for our INDEX subjects to make service purchases, we must offer our subjects the choice to activate or deactivate the user agent. Deactivate means the subjects has to make the service purchase decision manually on the *Choice* panel (see Figure 7). Nevertheless, the user agent monitors the user's choices in order to improve model of the user's QoS-price preferences. We are applying methods of microeconomic analysis to determine QoS-price preferences by modeling the user's utility function.

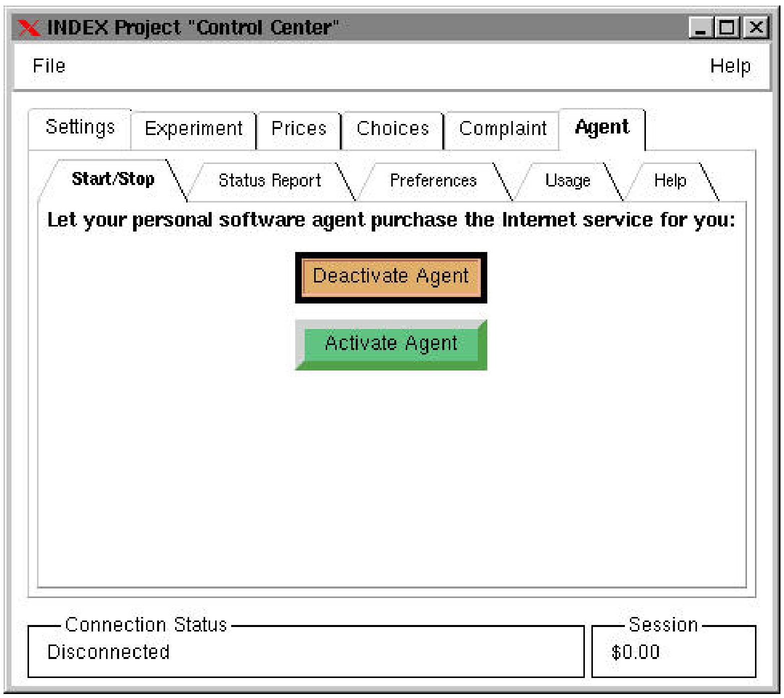

Figure 7: UI of the user agent - *Start* Panel

To check the purchase choices of the user agent, the user has to go to the *Status* panel (see Figure 8). The upper half of the *Status* panel provides information about the currently chosen QoS by the user agent. For additional information, the user can click on either the *Text* button for getting a textual explanation of the agent's choice or the *Graph* button to view a graph about user agent's expenditures. If the user is not content with the agent's choice he can give feedback to the software agent by clicking on the button at the lower half of the panel. This feedback will be used for adapting the user's QoS-price preferences in the same way as if the user made a manual service choice.

Beside those panels, there is a *Preference* panel. The user can specify on this panel certain parameters as, for example, how much money he wants to spend per month or which applications have to get high-priority service. Each change on this panel will be stored in the *User Preference Database*. The *Usage* panel can display and print records of all service purchases. This is a simple way for a user to check the expenditure. The *Help* panel provides users with information dealing with the agent technology and should help to increase the confidence in software agents.

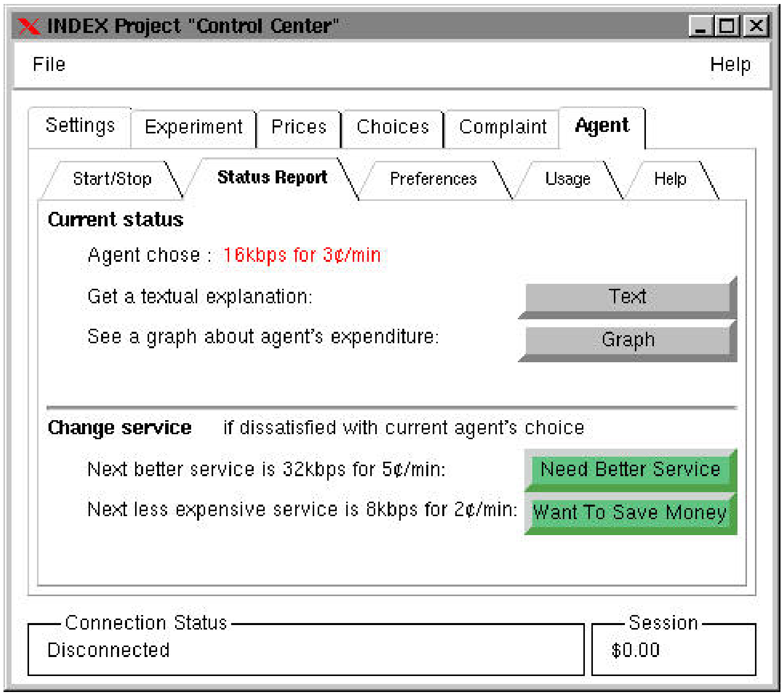

Figure 8: UI of the user agent - *Status* panel

4.3 User Agent's Decision Making Process

The mechanism to calculate the preferred QoS is initiated whenever one of the three events occurs: the network monitor notices a change in the network status, an application requiring the Internet is started or terminated, or the user gives feedback to the current agent's choice. The exact steps performed depend on the event. If an application is started the agent performs the following steps:

1. get *required QoS* (i.e. QoSL and bandwidth) of new application;
2. add *required QoS* of new application to the *required QoS* of running applications;
3. look up database for information about new application regarding received quality of services (i.e. Internet path, delay, jitter, throughput) in the past;
4. calculate *maximum QoS* for all running applications based on the results of the previous step;
5. check for availability, price, and service plan of required QoS with several ISPs;
6. calculate *preferred QoS* by comparing user's QoS-price preferences with *required QoS/maximum QoS*;
7. purchase QoS (i.e. QoSL and bandwidth) according to the *preferred QoS*.

If the user isn't satisfied with the user agent's purchase decision, he can give feedback via the user interface. Afterwards, step 6 and 7 of the algorithm above are executed considering the modification of the user's QoS-price preferences. In case the network monitor detects a modification in network performance on a certain QoSL the user agent adapts the required QoS to the current situation and proceeds with step 5 and 6 of the algorithm above.

In addition to the steps performed in each case, the user agent stores all significant performance changes in the corresponding database so that these information can be used in the next execution cycle.

Availability and price checks of services prerequisites that the user agent can obtain addresses of ISP agents. There are two approaches. The first approach requires a directory look-up service. For example, the user agent gets the address of ISP agents by contacting a service evaluation agent proposing one or more ISPs [13]. The second approach which we implemented is looking up the user agent's own database containing a list of ISPs to which the user has already subscribed.

During the purchasing step it might occur that the service request is not admitted by the ISP. If this happens the next best ISP has to be contacted and the algorithm starting at step 5 has to be re-executed.

4.4 Experimental Results

To demonstrate the way the user agent works, the user agent was applied in the *variable bandwidth experiment* to determine the best-fitting bandwidth at best-effort QoSL. This experiment offers INDEX subjects a selection between different bandwidths of best-effort QoSL (i.e. between 0, 8, 16, 32, 64, 96, and 128 kbps) at different prices. The analysis of user behavior in this experiment showed (see [2]), the average connection utilization is quite low, about 7.5%. The connection utilization is the percentage of purchased connection capacity that is actually used. Connection capacity is the amount of bytes possible that can be sent by a user utilizing all purchased bandwidths. Therefore, the low connection utilization leaves a substantial margin for the user agent to reduce costs.

Test data is the traffic caused by downloading dummy web-pages over a 10mbps connection, without any interference with other traffic. We assume a required QoS of 8kbps at best-effort QoSL, the lowest available bandwidth in this experiment. Since we have a 10mbps connection we set the maximum QoS to 10mbps at best-effort QoSL. The preferred QoS of the user is assumed to be 32kbps.

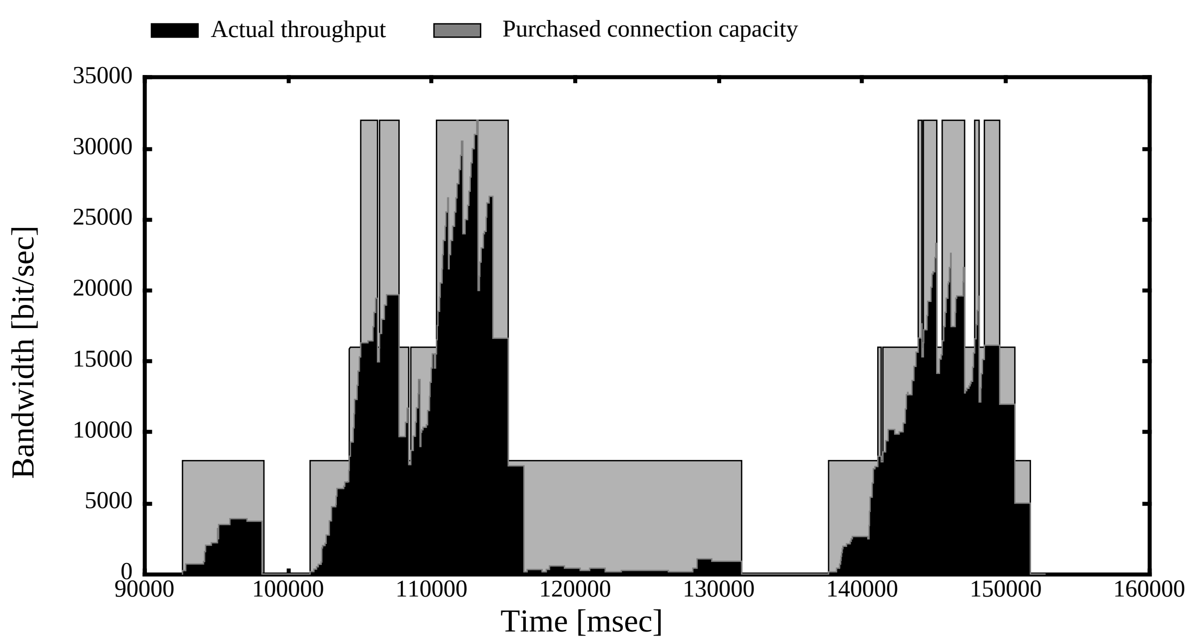

Figure 9: Optimization of connection utilization by the user agent

Figure 9 illustrates the increased connection utilization in the variable bandwidth experiment performed by the user agent. The actual throughput generated by browsing the WWW over a time period of 1 minute is marked black in Figure 9. The connection capacity purchased by the user agent is the gray marked area framing the actual throughput. The quality of the framing depends on the strategy. If the framing is too close to the actual throughput, it might influence the traffic. If it is too wide, connection utilization might be too low. However, Figure 9 shows that the connection utilization can be increased significantly by using the user agent for choosing the bandwidth. The connection utilization is 79.3%.

5 CONCLUSION

We sketched one possible future telecommunication market on the Internet, and showed that today's technology provides all the features to implement such a market. This market would enable ISPs as well as users to act according to their specific ideas. In order to deal with such a highly dynamic market we suggested to implement the market as a multi-agent system. The user agent running on the user's computer supports the user in finding the best service offer for his current needs while the ISP agent manages the accounting and billing of its resource-consuming customers.

Our future work will focus on improving the capabilities of the agents. An important QoS management issue is the strategy of how the user agent should react to performance loss. This performance loss endangers ongoing communication flows. In addition, we are planning stage of starting a field trial within INDEX offering our subjects the option of utilizing the user agent to make service choices, in lieu of manual selection.

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