The CATI Project: Charging and Accounting Technology for the Internet

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Abstract

The objectives of the CATI project (Charging and Accounting Technology for the Internet) include the design, implementation, and evaluation of charging and accounting mechanisms for Internet services and Virtual Private Networks (VPN). They include the enabling technology support for open, Internet-based Electronic Commerce platforms in terms of usage-based transport service charging as well as high-quality Internet transport services and its advanced and flexible configurations for VPNs. In addition, security-relevant and trust-related issues in charging, accounting, and billing processes are investigated. Important application scenarios, such as an Internet telephony application as well as an Electronic Commerce shopping network, demonstrate the applicability and efficiency of the developed approaches. This work is complemented by an appropriate cost model for Internet communication services, including investigations of suitable usage-sensitive pricing models.

1 Introduction and Motivation

The CATI project covers the design and implementation of charging and accounting mechanisms based on currently available protocols of the Internet protocol suite. Efficient protocol support for collecting and handling accounting and charging information is developed to deliver a solution to communication services capable of handling cost-related information. This is extended by a design and implementation of a Virtual Private Network (VPN) management and configuration system, where charging mechanisms form the basis for the cost recovery in VPNs. The implemented network charging and accounting system is used within a test-bed (Internet and VPN) to evaluate its real-life behavior.

The Internet is known as an open and heterogeneous networking infrastructure. To support open Electronic Commerce, a myriad of service providers, users, and networking equipment has to be integrated. However, besides the technical provision of services, charging and accounting issues have never been solved in the Internet. This is due to a very strong component of public funding of Internet infrastructure and operation and the presence of many non-commercial services on the Internet (*e.g.*, Universities, Libraries). However, commercially operated IP (Internet Protocol) networks, *e.g.*, the one connecting Swiss universities and research centers are running out of central funding. Therefore, operating cost has to be fully recovered by usage fees. In the past, mostly volume-based pricing schemes for IP services have proven to be somewhat beneficial, but they have caused suboptimal usage of the network. The advent of new IP service classes will require more fine-grained accounting and control.

From a commercial point of view charging and accounting must take place where most of Electronic Commerce traffic can be accounted for to allow service providers to receive feedback about the usage of their services and to recover communication costs. Two pre-studies [15], [17] have determined that such traffic will be based on the Internet and that Internet customers constitute the fastest growing and largest community in Electronic Commerce. Therefore, research focuses on the well-known hour-glass-model (cf. Figure 1) which describes the relationship between network technology, Internet protocols, and value added services.

On one hand, a huge variety of network technology, such as Frame Relay, Sonet, ATM (Asynchronous Transfer Mode) technology, is available. On the other hand, value added services as offered from providers show a broad range as well, such as with video, interactive television (TV), or entertainment. The questions to be answered is now: How can these services be supported over the range of network technology? The Internet Protocol (IP) suite serves as a common interface. In particular, the Internet Protocol (IP) serves as a robust, connectionless network protocol. It is completed with the User Datagram Protocol (UDP) or the Transmission Control Protocol (TCP) for different degrees of required reliabilities and traffic management control functionality. Depending on the overall network model, the Resource Reservation Protocol (RSVP) allows for the network-wide reservation of resources required for guaranteed services in the Integrated Services (IntServ) approach. The hourglass now is due to the fact that purely a very limited set of protocols forms the common denominator for applications and network technology.

The integration of resource reservation protocols and their employment for charging and accounting information as well as flow aggregation approaches are required to offer a future-safe Internet being prepared for commercialization within open Electronic Commerce platforms and limited funding for operating public networks.

Commercial Internet users require integrated services [2] and differentiated services [1] Internet technology for advanced applications, *e.g.*, based on the Internet Protocol Next Generation [3], [4]. While products for both enhanced service concepts are appearing, provisioning of enhanced services is currently unsupported, due to lack of appropriate charging, accounting, and billing mechanisms. Users must be ensured that accounting and charging data is secured. Managing accounting data in the Internet involves two groups of applied security. This covers the (1) secure collection and transmission of data related to accounting and charging and (2) a secure payment system allowing for transferring funds allocated for paying communication and information services. Furthermore, Internet charging protocols must support flexible payment modes (sender/receiver) to accommodate for applications such as reverse charging, advertising, or emerging push technologies.

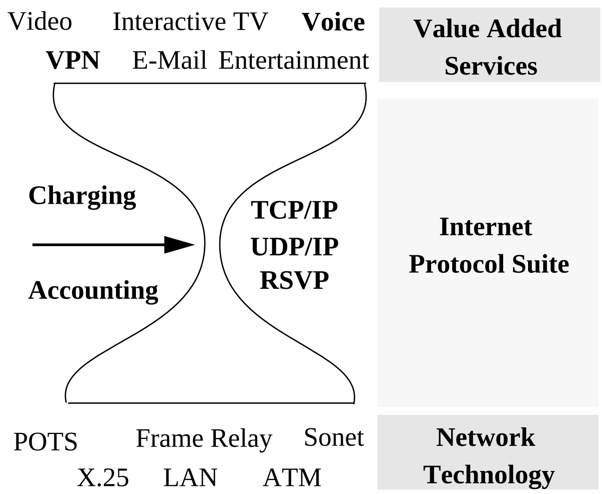

Figure 1. Hour-glass Model of the Internet

In the highly competitive Internet Service Provider (ISP) market it is mandatory that a provider is able to respond quickly to changing market conditions. One important difference can be a flexible customer management and billing system that allows the quick and easy deployment of new service bundles and aggressive pricing plans. Besides today's traditional Web access and e-mail services it is foreseeable that new services like Internet Telephony will become part of ISPs' service offering. This trend is incompatible with today's undifferentiated pricing schemes and will require fine-grained accounting information from the network infrastructure.

The ISP connecting Swiss universities and research centers currently applies a simple volume-based charging scheme to recover costs from connected organizations. While this has proven mostly beneficial, it has caused suboptimal usage of the network. As the connected sites have expressed a need for better cost attribution within their respective organization and the advent of new service classes will require even more fine-grained accounting and control, cost and pricing models for IP-based networks and the Internet in particular are required.

Networks for electronic commerce are required to support secure and flexible communication within a dynamic set of users originating from different companies. In addition, the communication technology must be widely available such that it provides a common basis for as many people as possible in order to support as many business processes as possible. Internet technology is currently the only networking technology which fulfills this requirement of being widely available. In addition, there is currently a tremendous growth of Internet technology usage in order to establish intra- and inter-company networks such as Intranets and Extranets. The technological basis for Intranets and Extranets are Virtual Private Networks (VPN). VPNs are used to build temporary or permanent networks for distributed inter-/intra-company working groups and virtual companies/enterprises. Appropriate concepts must cover several issues, not only data transfer volumes, but also other factors such as costs for server access or VPN management.

Therefore, the emerging need for providing a basis for accounting and charging schemes in today's and tomorrow's Internet requires protocols and mechanisms capable of defining, collecting, charging and accounting information being utilized to determine resource and service usage. In addition to the reservation-based approach, the target scenario for the proposed project is based on a best-effort Internet. Customers decide to establish a VPN, *e.g.*, in order to run secure business applications. Currently, VPNs are established by manual configuration of IP tunnels. Dynamic reconfigurations for adding or deleting tunnels and the support for Quality-of-Service (QoS) are not possible today. Routers provide features in order to support QoS, such as sophisticated filtering and scheduling mechanisms, allowing to provide bandwidth reservations for aggregated flows through an IP router network. However, since filtering and scheduling parameters must be configured manually, dynamic and flexible QoS support is hard to achieve in larger networks.

This paper is organized as follows. Section 2 determines the detailed project objectives. In addition, Section 3 discusses the work in progress on charging and accounting protocols, the VPN configuration and management design, the development of a demonstrator, and evaluation principles. Finally, in Section 4 currently available results are summarized and preliminary conclusions are drawn.

2 Project Objectives

The feasibility and customer acceptance of such new charging protocols/schemes can be best verified with Internet Telephony, for several reasons. Firstly, users are already accustomed to pay for such a service in a usage dependent way, *e.g.*, per-minute. Secondly, desktop based telephony is an elementary service recurring in many envisaged Internet and Electronic Commerce scenarios. IP Telephony charging can be viewed as an important initial step in establishing pricing in the Internet. Expanding Internet usage scenarios should more easily follow, given Telephony as a well understood crystallization point.

Within the CATI project, a demonstrator will be established implementing a basic Electronic Commerce scenario. It will allow the use of the WWW to make a product offer and include Internet Telephony as a means for interested parties to contact the supplier for clarifying aspects of a possible product purchase. While the focus will be on pricing issues relating to Telephony itself, considering a whole usage scenario shall help to understand how a solution can fit into an overall approach regarding pricing.

Based on the introductory motivation of the CATI project, its working goals include the following ones:

- Design and implementation of charging and accounting mechanisms based on currently available protocols of the Internet protocol suite, focussing on secured, reservation-based approaches.
- Design and implementation of a VPN configuration service including charging and accounting functions, best-effort and differentiated services, fairness and congestion control mechanisms to ensure that customer traffic is handled fairly and securely.
- Development of generic support functionality in terms of Application Programming Interfaces (API) for Internet-based open Electronic Commerce.
- Development and demonstration of an IP Phone, which employs the implemented charging and accounting functionality and makes use of QoS-support in existing Internet protocols.
- Investigation and definition of business models for Internet services for the Internet, which include Internet Service Provider network costs and pricing schemes with respect to traditional, best-effort IP services and the integrated/differentiated services Internet architecture.
- Evaluation of developed Internet charging and accounting mechanisms based on Internet services business models for the Internet, which include Internet Service Provider network costs and pricing schemes, the demonstrator application as well as regular traffic.

3 Work in Progress

The work undertaken in CATI concentrates on charging and accounting protocols which are based on the current IP technology and Integrated Services (IntServ) architecture to allow for the implementation of a demonstrator. Recent developments in the Differentiated Services (DiffServ) architecture are closely considered in the design process as well. In addition, the design and implementation of a flexible and efficient VPN configuration and management architecture for IP-VPNs is considered essential. Based on a demonstrator application, which will be an IP telephony, the progress made for usage-based charging of transport services can be shown in the open Internet as well as the VPN environment. A set of closely related evaluations in terms of technical and economic performance metrics complements the work.

3.1 Charging and Accounting Protocols

The design of a family of protocols will complement existing ones used on the Internet by adding charging and accounting mechanisms. The Internet protocol suite is easy to implement using existing network protocols, such as TCP/IP, and it results in the smallest possible overhead. This defines naturally an initial demonstrator to be assessed. Other desired features are that the extended protocols work with local control, make efficient use of existing resources, and scale naturally as the network grows. Thus, enabling the enlargement of the initial demonstrator to support more realistic scenarios, where non-uniform communication costs, among others, are taken into account. Furthermore, the development of such a demonstrator within the project on “Management, Evaluation, Demonstrator, and Business – MEDeB” delivers a tool of broader applicability; in particular for applications, where the control of the distribution of information and the avoidance of duplication may help in saving resources.

The implementation of project tasks covers as basic end-system protocol mechanisms consumer interface and feedback aspects, network-internal monitoring, resource reservation, admission control techniques, and protocol support for the pricing model. In particular, this includes the implementation of protocols for accounting, charging, and controlling. Assuming a distributed, unfair, insecure, and unfriendly (=commercial) environment, the implemented solution includes wide-spread protocols and environments as far as required features for fair charging and accounting can be solved. Mechanisms to provide fairness are important in addition to charging methods. Identifying these mechanisms which act locally to restrict aggressive flows, need to perform without an overall view of the network. Assuming a minimum of information about the network (obtained indirectly) approximate global fairness in these places have to be warranted. In this sense, fairness determines the basis for fair charging. Charging for a service makes fair customer handling necessary. In all networks, *e.g.*, the Internet, the traffic in congested points (bottlenecks) should receive fair treatment as in the future, available bandwidth in the Internet will grow, but the demand of bandwidth will increase even faster according to several reasons: (1) The amount of users will continue to grow. (2) Applications, such as multimedia applications need more and more bandwidth to satisfy acceptable information transfer quality,*e.g.*, for pictures or movies. There will never be too much bandwidth. Congestion will not disappear. However, QoS is essential for business applications, since business users cannot tolerate service degradation as occurring in the Internet today. In addition, in contrast to home users, business users are willing to pay for better services. Therefore, there is an urgent need for chargeable Internet services providing better QoS than today.

In the Internet, the Transport Control Protocol (TCP) runs on top of the Internet Protocol (IP). Conform TCP traffic is defined as a well-behaving traffic, if it slows down, when congestion occurs. During congestion packets are dropped. Missing acknowledgments provide to the protocol TCP this information which acts by reducing the amount of unacknowledged data, it allows in the network. In addition, misbehaving traffic (aggressive flows) already exists. Applications like Web-browsers start with several parallel connections for Web-page downloading as opposed to one because they can steal more resources from others. Other applications, such as real time radio, do not slow down in the face of congestion, i.e. they will continue to send at the same rate. Various applications increase their rate to try to ensure their required rate is obtained. All these applications use network resources at the expense of well-behaving traffic. Well-behaved charged traffic needs protection, and thus misbehaving traffic needs restriction and control at bottleneck points, i.e. where congestion occurs. Fair treatment/fairness can be considered at many different levels, two of which are fundamental - local and global fairness. For local fairness, allocation and control is restricted to information at this point. Parameters and, in the case of networks, congestion information from other places are not available or considered. This can lead to wasted network resources. The achievement of global fairness is more difficult, but more important, since it suppresses the waste of network resources. New mechanisms have to be found to warrant approximate global fairness.

Based on the availability of protocols and systems in support of IntServ, the Crossbow toolkit [8] provides a suitable design environment. IntServ mechanisms such as a packet classifier or packet filtering and scheduling on the host's and router's implementation platform are available, as well as an preliminary version of the Resource Reservation Protocol RSVP. Figure 2 depicts the simple IntServ architecture enhanced with a charging interface where applications are able to access reservation services and they will be offered with additional accounting and pricing information on the return.

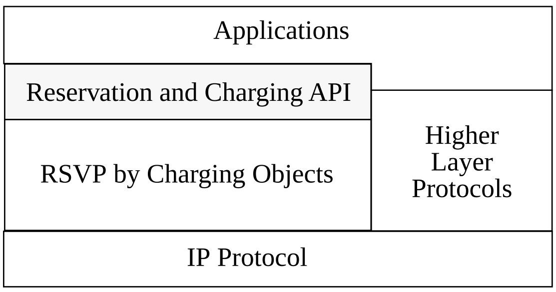

Figure 2. IntServ Protocol Architecture

Since current RSVP implementations do not support the exchange of charging or accounting information, standard RSVP objects have been extended by appropriate pricing and payment objects. Figure 3 depicts necessary objects. The price object allows for the exchange of market prices between senders and receivers. The payer object delivers the possibility to implement split payments between sender and receiver within a single connection. The bid object carries information for highly dynamic pricing models, such as the bid for the currently requested service.

3.2 Virtual Private Networks for the Internet

VPNs emerge from the need to securely interconnect private networks. The Internet is a promising platform for that task, because of its global reach and cost effectiveness. However the Internet is intrinsically insecure. Internet VPN technologies (IP-VPN) therefore add access control and privacy mechanisms to ensure the desired level of privacy.

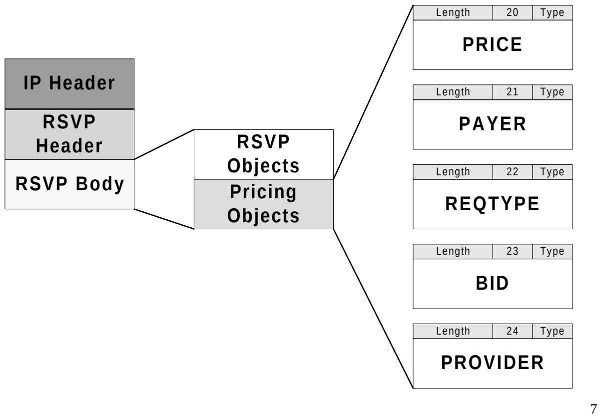

Figure 3. RSVP Object Extensions

3.2.1 VPN State of the Art

IP-VPNs use tunnelling to decouple the internal addressing scheme and the routing mechanisms from the ones used in the underlying Internet. Access control, authenticity and confidentiality of the VPN traffic is typically ensured by cryptography. The Internet Engineering Task Force (IETF) proposes a variety of Protocols capable of supporting VPNs for the Internet, some of which are specialized for different types of VPNs. IPSec is a transparent security architecture that handles tunneling and cryptography on a per packet basis, while PPTP and L2TP support remote users connecting to a VPN. These protocols enable the setup of logical and secured networks over the public Internet and thus form the basis for new applications namely in the area of e-commerce. E.g. a VPN can consist of computers of a company offering a service over the Internet such as soft products (software, electronic newspapers, digitized audio and video) and the customers using the service. An upcoming application of VPNs is the support of virtual organizations or virtual companies. Virtual companies consist of single specialists residing at different real companies. The different specialists shall complement each other in order to collaborate in a common project which duration is limited. Thus the involved companies must securely open parts of their private networks for collaboration. This scenario is often called an Extranet.

However, today’s VPN solutions suffer from several drawbacks. On one hand, VPNs are a significant management burden, they require additional network equipment and trained staff. If VPNs are not managed properly either the connectivity or the security of the VPN will be affected. On the other hand, VPNs using the Internet suffer from the inherent lack of quality-of-service (QoS) of the Internet. These problems can be addressed by outsourcing the VPNs to Internet Service Providers (ISP), since they have the knowledge and the resources to manage VPNs and may use QoS ensuring technology. Furthermore the ISPs are eager to offer new value added services such as VPNs to survive in the ever increasing competitiveness of the data forwarding market. The CATI project designs an architecture to deploy such services, and to account and charge for them. It focuses on the on-line configuration of VPN services and automatic price calculations, since the automation of the service installation, configuration and management is crucial for a successful service offering.

3.2.2 QoS Enabled VPNs as a Value-Added Service: Using IPSec with DiffServ

A major competitor of IP-VPNs are private leased lines (Frame Relay, ISDN). While the leased lines are more expensive because the user has to pay even when not using the line, they usually come with guaranteed QoS. Enhancing todays VPN solutions with QoS will eliminate the VPN’s only real disadvantage compared to the leased line solutions.

An Internet Service Provider (ISP) has control over a part of the Internet. Using emerging traffic forwarding technologies such ATM, MPLS or RSVP it can offer QoS guarantees for traffic in its own domain. However, a customer wants to be able to purchase a VPN spanning more than just one ISP. Therefore the ISPs need an automated way to link their individual QoS solutions together to form one supply chain.

Differentiated Services (DiffServ) seem to be the technology that is simple enough to enhance VPNs without restricting the global reach of the Internet. Thus the most promising technologies for a service bundle combining VPN with QoS are DiffServ and IPSec. DiffServ and VPNs have various concepts in common:

- VPNs are traffic aggregations with known traffic destination points. DiffServ also operates on traffic aggregations. The known destination points can furthermore ease the specification of necessary service level agreements.
- DiffServ and VPNs both need enhanced functionality of border routers of the ISP but not of intermediate routers. Both share some similar functionality in the border routers, e.g. the traffic classification.

It was pointed out before that in order to bundle services spanning multiple ISPs such as a QoS VPN the ISPs must use an automated and flexible mechanism to collaborate and sell services to each other, allowing them to partially configure the peer's network. Since this does not exist up to date, the CATI project proposes a generic architecture for that purpose.

3.2.3 An Architecture for Configurable Internet Services

Todays Internet is made of the interconnection of multiple autonomous networks (domains). Some of these networks are driven by business companies such as ISPs. We can assume that the future ISPs and their services will have the following features:

- A network which is fully remotely controllable (configurable) by the ISP and whose hardware is able to support the new service.
- Intra-domain resource management that is able to provide service guarantees. This can be a fine grained mechanism (e.g. per flow) if the domain is small.
- Application level interfaces for service requests by customers.

In order to produce the complete revenue of these investments, the ISPs need to collaborate. Today the collaboration is done by human network administrators communicating with each other by phone or fax. However, with automatically configurable networks and appropriate communication protocols, an automated approach is much more favorable. We envision the following requirements:

- Between each adjacent ISP there are electronic service level agreements (SLAs), describing the service delivered and its duration and price.
- Also, there is an inter domain resource management procedure which allows the new services to span multiple ISPs. In order to be scalable to large backbone networks, this management must handle aggregations of the intra domain resource management entities; it must be coarse grained.

The following goals for an architecture allow the automatic provision of new services spanning multiple ISPs based on the mentioned assumptions.

- The architecture shall consist of generic components that are specialized for the given purpose.
- It shall not limit the ISP to a given business model.
- The architecture shall be open and interoperable in the sense that component interfaces are declared.
- The architecture shall focus on security issues (robustness and prevention of abuse).
- The new services we are focussing on are the support of QoS based on DiffServ and VPNs. However, the architecture shall be service independent.

Service Brokers as Basic Components

A service broker accepts service specifications for the specific service it sells. It can query the cost of the service and negotiate its price with a customer. Upon agreement, the broker can setup the service. The broker keeps the knowledge about the services provided in the form of electronic service level agreements (SLA). It can thus accept requests to change the service specifications for a given customer. Note that the service broker may synchronize and coordinate multiple service requests. Furthermore, a service broker is an autonomous entity. It can pro-actively change an SLA. For such decisions, it needs access to various policy databases.

In general, services can be classified regarding two criteria:

(1) The *range* of the service: local to a single machine, local to ISP or affecting multiple ISPs.

(2) The service can be implemented by hardware configuration *orthogonally* to other services or it must be coordinated with configuration of other services.

For each orthogonal service we propose a component hierarchy following criterion (1). This situation is depicted in Figure 4: The machine-dependent configuration local to a network equipment is handled by a configuration daemon (CD). An Internal Service Broker (ISB) is used to manage an ISP's service that is solely supported local to the ISP. The ISB can configure the ISP's network via secured connections to configuration daemons of each relevant network equipment (e.g. border routers). The ISB manifests the fine grained resource management. Its implementation is in the responsibility of the ISP and does not need standardization. If the service needs the collaboration of other ISPs we propose the External Service Broker component (ESB). The ESB has knowledge of the adjacent ISPs and can negotiate the necessary services of the adjacent ISP through its peer ESB broker. The

ESB controls the corresponding local ISB in order to trigger local service configuration.The ESB manifests the coarse grained resource management mentioned before.

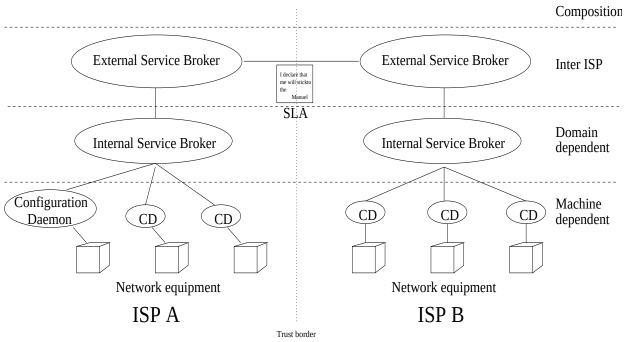

Figure 4. Broker Hierarchy

The bandwidth broker (BB) for differentiated services [13] is an example for an external service broker. It is often neglected how the BB interacts with its network. In our case, the BB would not only interact with BBs of other domains but also with an ISB that could for example match DiffServ to ATM configurations. Note that ESB and ISB represent a two class hierarchy which allows for a scalable solution. The separation matches the topology found in todays Internet. The case of non-orthogonal services (see previous classification) must be handled by servers that are specially designed to offer a service combination. Such composite service servers (CoSS) can use and coordinate several ISBs and ESBs (of the different services influenced by this special service). Note that the management of such services is very complex. In general such a service can only be automated if the different ‘sub’-services interfere in very few specific areas.

An example of such a service combination is the provision of VPNs with QoS guarantees with DiffServ. Such a service is very useful for the branch office scenario: the headquarter of a company is connected to its trusted ISP, the branch office to another ISP. The headquarter requests a VPN with QoS from its ISP using the QoS -VPN composite service server of the ISP. The QoS-VPN server (Composite Service Server) negotiates with the local ESBs (VPN ESB and DiffServ ESB) that they negotiate with the next domain and so forth. Finally, the ISBs on the route between the headquarter and the branch office will configure their network to support the requested QoS, and the ISBs of the border ISPs will configure their border routers for the VPN tunnel.

Conceptionally, there are only external service brokers interacting between two ISPs. At least in the case of a customer network it is desirable, that also a human can interact with a foreign service broker. We propose a simple GUI supporting service server to translate between a human and an ESB.

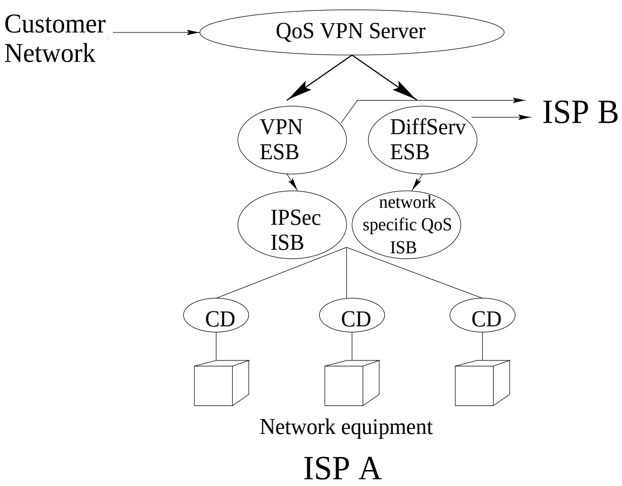

Figure 5. Combined Services

Charging and Accounting between Brokers

The electronic SLAs established between ESBs describe how the use of services is charged between ISPs. The same mechanism can be used to charge customers of ISPs. The SLAs are negotiated using a signalling protocol between the brokers, which is a topic of current research.

The service price is dependent of three basic components: (1) The one time charge, which has to be paid upon service establishment, (2) the reservation based fee, which is dependent of the amount of reservation needed for a given service and (3) a usage based fee. Given that brokers calculate these prices semi-autonomous this opens an interesting field for simulation and optimization of business strategies.

3.3 Demonstrator

As a demonstrator for CATI Internet telephony is being developed. It determines an emerging service based on packet–based delivery of voice data. Today's IP Phone products neglect real-time network transport issues and charging for such voice calls. Being currently positioned as a low–end service with these deficiencies, pricing is intermixed with the ISPs pricing policy or specialized voice carriers offer the service via gateways and charge per minute. However, if these services are going to be as dominant as described in [16] solving the problem of usage–based charging is of utmost importance. Models being developed and studied at MIT predict that voice and data traffic will share equal bandwidth in 1999. Due to the traffic networks higher growth rate, a significant transition will happen in the following years (cf. Figure 6).

At the same time, and related to this, the Internet is expected to evolve from a best-effort network service to one that offers a range of service qualities in order to support more applications and to allow for more differentiation in the market. Besides the technical problems that have to be solved, this will involve an adaptation of the commercial interrelations between customers and service providers as well as among service providers. Internet telephony is considered an interesting test case for such an architecture: it poses significant quality requirements on the underlying network service, and the economics of the traditional, while complex, are reasonably well understood. Charging models for an Internet telephony will probably look very different from those for traditional telephony, but many of the concepts will be common to both.

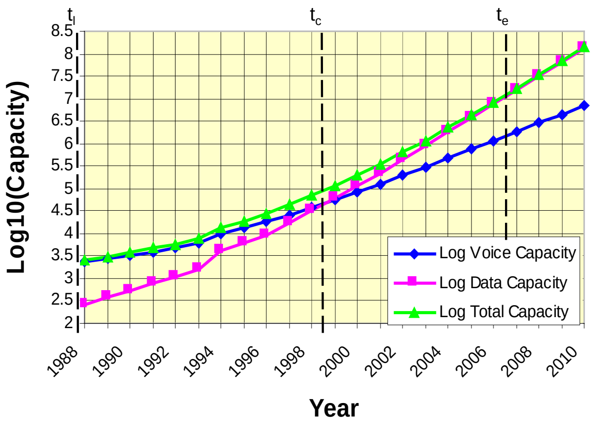

Figure 6. Transition to Multiservice Integrated Networks

Within this project an IP Phone will be utilized to facilitate and demonstrate the various aspects of charging and accounting in the Internet. The IP phone determines in this case a basic and Internet-integrated application in an Electronic Commerce environment, since on-line support during a shopping transaction or a pre-sales advertisement activity supports one-to-one marketing and facilitates business transactions in general. On one hand the IP Phone will make use of the (reservation-based) network service used to set up connections for real-time data transfer between telephony end users. Also, it will provide for the required signaling (*e.g.*, ringing, busy phone signaling) between end-systems. In addition, it will make use of the charging and accounting functions offered to applications which form an integrated part of the Electronic Commerce platform. In a first step, the IP Phone will be provided as a stand-alone application making charging and accounting information directly available at the user interface. In a second step, the IP Phone will be integrated into a basic Electronic Commerce scenario, where electronic offers are made to allow users to contact the party making an offer. This setting shall allow to take into account requirements regarding pricing and accounting which emerge from various forms of Telephony usage, for instance for allowing for charging the sender or receivers for calls, including telephony charging into an overall Electronic Commerce service scheme, for instance by considering the content of the offer to be a pricing factor. This basic scenario will also be a basis for the development of various business models for charging IP telephony.

The basic infrastructure for the demonstrator to be developed, the newly established SWITCHng forms an excellent basis. With SWITCHng, each Swiss university can get two kinds of services: either an IP service or an ATM service. For the network that will interconnect the project partners, the ATM service will be used. The various routers and end systems of the partners will be interconnected via direct ATM connections. This allows to control the bandwidth available for the experiments.

3.4 Evaluations

The economic and technical performances are measured for different ranges of environments. This will validate decisions and show their practical usability made in other projects and work packages of the compound-project proposal. The performance analysis is likely to be used for tuning the implemented solution and reach an attractive trade-off, economically acceptable for Internet Service Providers (ISPs) and clients and technically sound to be incorporated harmless in the Internet. Besides the tuning of the solution, the analysis should give birth to a rating system guiding ISPs to define their pricing policies and helping ISPs' customers in their search for the optimal service adapted to their needs. In addition, VPN configuration and management systems are rated in terms of configuration overhead, performance, and seamless integration of charging and accounting mechanisms. Flow aggregation and Quality-of-Service support in routers for VPNs and their provision are investigated in detail.

The preparation of a performance analysis, *e.g.*, in terms of natural metrics of Internet distance, in this particular framework is itself a challenging task, because it will encompass both the pricing model and the communication aspects of networking. Therefore, performances must be expressed in terms of:

- Economic metrics, such as the kind of service the most requested, the average connection time, the average duration of the client's subscription to an ISP, the kind of payment, *e.g.*, totally electronic payment with banks on the Internet, fund-transfer orders processed by a back-end office.
- Usual computing metrics, such as net latency, response time, or bandwidth consumption.

Moreover, these metrics and the resulting analysis are also likely to be exploited in the commercial context of ISPs in order to determine marketing and pricing policies for their own product line, particularly Internet services. Henceforth, testbed and metrics have to be as meaningful as possible to suit the real market requirements. The performance analysis needs to be designed also in order to measure the overhead introduced by accounting at application level in terms of the number of exchanged messages, logging records, or account management.

To add the perspective of an Internet Service Provider (ISP), insight into technical and commercial interrelations of the networks that form the Internet is essential. The different accounting and charging mechanisms developed are being used. The participation in the definition and evaluation of new charging schemes and in the support of accounting and charging protocols for the Internet will lead to significant improvements in current schemes. In particular, this is a refinement of the cost sharing model to optimize resource usage for Internet services. It devises methods to provide customers with sufficient accounting information for cost distribution within their local organization. Finally, it develops pricing models aware of integrated and differentiated Internet services and for multicast traffic.

3.5 Related Work

Related work with respect to the CATI objectives corresponds to the technical area as well as the economic area and their interoperation. Therefore, pricing models and their application to service integrated networks are important. This subsection briefly sketches a small number or other related approaches. Refer to the book [11] for a good overview of related work approximately until 1997.

A priority-based multiple service class network architecture with separate fixed prices set for each class is proposed in [5] and [7]. Another model has been developed that calculates prices by conducting second price auctions for packets arriving at a congested router [12]. The goods available are the time and processing slots in the queue of the output interface. This model has been made technically efficient by applying auctions to reservation requests for reservation periods [10]. An additional pricing model as proposed in [6] is based on a contract between user and provider for a specified bandwidth, the expected capacity. Some of those ideas were revisited for a new proposal termed Edge Pricing [14].

4 Results and Conclusions

Concerning the status of the work in progress the results achieved so far are of an intermediate nature. Therefore, the following details will be extended further and elaborated with respect to a number of metrics that are being developed currently. With respect to the charging and accounting protocol the flow of relevant information and their messages between senders and receivers are defined for reservation-based charging methods. In addition, the employment of electronic payment systems for a full electronic handling of payments for Internet flows is being investigated. Furthermore, basic issues of a trust model for participating players in an Electronic Commerce environment have been discussed including the definition of suitable assumptions of trusted or untrusted relations between the roles of Internet-hosts, routers or Internet Service Providers, banks, and public certification infrastructures. An Internet telephony scenario has been designed to act as a demonstrator. The description of a business model for Internet service provisioning and service differentiation has been initiated.

A number of VPN concepts has been evaluated in terms of configuration approaches, charging mechanisms, and QoS-support. Basic mechanisms, such as IP tunneling or Class-of-Service mechanisms, are provided by many hardware vendors. However, pure hardware solutions for VPN management are inflexible and lacking Application Programming Interfaces (API) do not facilitate VPN management tasks. Therefore, the CATI project aims to support a highly efficient and flexible system for charging and accounting of Internet services as well as a feature-rich VPN configuration service.

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