# Charging and Accounting for Integrated Internet Services
# – State of the Art, Problems, and Trends –

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## Abstract

*Today's information society bears a stringent need for advanced communication services and content. Although solutions for methods of charging and accounting of single service class networks exist and are applied successfully, Integrated Services Networks require a completely different approach. Charging and accounting for the future Internet remain unsolved problems at the time being. This is due to a variety of service characterizations by Quality-of-Service (QoS) and the fact that the shape of the Integrated Services Internet is still not fully defined. In addition, a highly competitive telecommunication service provider market requires dynamic pricing schemes for integrated multiservice networks in order to deal with basic bandwidth allocation and advanced QoS services. Based on basic terminology and general economic models an investigation of best-effort and integrated services Internet characteristics in terms of suitable, applicable, or existent solutions and approaches for charging and accounting methods is provided. Using these ideas being developed in research trends are sketched for the upcoming third and fourth phase of Internet development which will be strongly influenced by economic elements.*

## 1 Introduction

Today's basic Internet service offerings and future advanced services on the Internet lack a crucial component for businesses: adequate pricing and charging methods. Funding transport services with revenue from related services, such as content and entertainment offerings, and advertising is used to help cover network cost. However, cross-financing transport services is not transparent to businesses and does not scale to high-bandwidth offerings.

Although solutions for methods of charging and accounting single service class networks, such as the telephone network or Virtual Private Networks, exist and are applied successfully, Integrated Services Networks [RFC1633] require a completely different approach. Charging and accounting for integrated services remain unsolved problems at the time being which is due to a variety of service characterizations by Quality-of-Service (QoS), advanced networking technologies, such as ATM (Asynchronous Transfer Mode), and an emerging Integrated Services Internet. In addition, new telecommunication services impose another degree of complexity to existing billing systems, including the demand to bill separately for content. This determines the need to integrate concepts for interoperable and standardized billing solutions between providers for inter-operator agreements which include content and transport services.

Besides its popularity, the Internet offers the important possibility to access usage information for many services at a single network layer, since most services will be transported by IP, independently of the underlying network technology. For commercial applications, this allows for very interesting product offerings, such as service bundling. Figure 1 shows the hour-glass-model which describes the relationship between network technology, Internet protocols, and value added services.

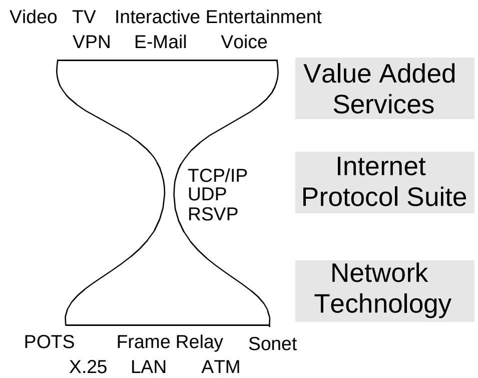


**Figure 1: Hourglass-model of the Internet**

Aside from communication protocol relevant issues, a particular problem area arises with electronic payments for various kinds of transport services, determining the clear necessity of pico- or micro-payments. As existing traditional and electronic payment systems are not well suited for this task, solutions have to be researched, including cryptographic protocols for secure transmission of payments. In addition, due to the highly competitive telecommunication service provider market, dynamic pricing schemes for integrated multiservice networks are required as well.

This paper is structured as follows. Section 2 covers the sate of the art in charging and accounting in the Internet. Based on an introduction into basic terminology and pricing models, the best-effort and Integrated Services Internet is evaluated in terms of charging and accounting concepts. This is completed by some thoughts on billing and payment systems. While Section 3 briefly elaborates on related areas in ATM networks, Section 4 discusses current problems and trends and draws conclusions.

# 2 Generating Revenue for Internet Services

The support of accounting and charging in the best-effort Internet and the Integrated Services Internet of the future are discussed in the following subsections. Since networking in general provides the requested connectivity for a variety of traditional applications, advanced multimedia systems, Electronic Commerce platforms, marketplaces, and applications, the provision and usage of this connectivity has to be accounted and charged for.

In the beginning, the terminology for accounting and charging is determined around existing definitions and descriptions. Even though no consensus on a common and unique definition is accepted today, a computing service center-based and telecommunication system-oriented terminology is utilized within the remainder of this paper. Further approaches and definition drafts may be obtained from [Bell95], [ETSI95], [ETSI97], [FSPl98a], and [McBa97].

## 2.1 Terminology

The terminology applied shows a diffuse and sometimes contradictory semantics. Mainly, this is due to the new dimension of charging and accounting for packet-based networks which is in contrast to traditionally connection-oriented or virtual connection-oriented networks.

### 2.1.1 Accounting

Accounting determines the collection of information in relation to a customer's service utilization being expressed in resource usage or consumption. Thus, accounting defines a functions from a particular resource usage into technical values. The information to be collected is determined by a parameter set included within an *accounting record*. This record depends on (1) the network infrastructure, which supports the service, *e.g.*, Internet, N-ISDN, ATM, or Frame Relay, and (2) the service provided. The content of an accounting record is of technical nature, such as the duration of a phone call, the distance of a high-speed network link utilized, or the number of market transactions done. This accounting record forms the basis for charging and billing.

### 2.1.2 Charging

Charging determines the process of calculating the cost of a resource by using the a price for a given accounting record which determines a particular resource consumption. Thus, charging defines a function which translates technical values into monetary units. The monetary charging information is included in charging records. Prices already may be available for particular resources in the accounting record or any suitable resource combination depending on the network technology or the application.

### 2.1.3 Pricing

Pricing is the process of setting a price on a service, a product, or on content. This process is an integral and critical part of businesses and closely related to marketing. Prices can be calculated on a cost/profit basis or on the current market situation. In businesses selling telecommunication services, prices are set on predefined services, where the quantity used is measured, *e.g.*, in units, time, distance, bandwidth, volume, or any combination thereof. These basic quantities to be priced are obtained from accounting devices and depend on the network type (cf. Paragraph 2.1.1 above).

Tariffing is a special case of pricing, normally regulated by governmental and political economic impacts. It has been applied to the traditional telephone network.

### 2.1.4 Billing

Billing denotes the process of transforming the collected charging information for a customer to his bill. It includes the process of listing for a customer all charging information being contained in charging records which were collected over a time period, i.e., one month. The bill summarizes all charges and indicates the amount to be payed. It may identify the method of payment chosen or selected, and it is transferred electronically or on paper to customers.

The method of payment defines a well-defined scheme, how money between participants is exchanged, *e.g.*, customers and retailers or service users and providers. In general, electronic payment systems or traditional systems as utilized for traditional payment transactions are applicable.

### 2.1.5 Example

A typical scenario encompasses an accounting applied to the number of outgoing data on a special link or on content included in a file. The accounting record contains, *e.g.*, the duration of a data transfer, the obtained Quality-of-Service (QoS) characteristics (such as bandwidth consumed, delay encountered, and error rates experienced), and additional resource and device usage (such as a video camera). The content may be indicated by different video clips sent. These accounting records are fed into the charging which happens, *e.g.*, in an administrative domain of the video clip provider. Pricing has been defined by the network operator, based on QoS characteristics of the particular communication service, and it has been defined by the content provider of video clips. All charges are calculated and collected in charging records from the centralized billing system of the video clip provider. A number of charging records for a certain period of time are accumulated and billed to the customer. Finally, he may decide at this point in time or in a pre-defined manner, how the bill gets payed for, applying traditional or electronic systems, *e.g.*, by credit card payments applying Secure Electronic Transactions (SET).

## 2.2 Pricing and Economic Models

In this subsection the terminology pricing and tariffing is used interchangeably. This is based on the assumption of increasing deregulation of the telecommunications market and the emerging business orientation of players in this field. Traditional and widely accepted pricing models on networks offering a single network service, *e.g.*, telephony or X.25, are provider-centric, i.e. they are set to fixed values and re-issued whenever provider cost or regulations change. However, in an increasingly competitive environment, this approach is too slow and often too costly.

Although projects covering charging and accounting functionality on the network level try to achieve a high independence from pricing models, it has been found that pricing in general and usage-based pricing in particular can impose a high overhead on telecommunication systems [MaVa95], [SCEH96]. Usage-based pricing for telecommunication services is especially interesting, because underlying resources used (satellites, spectrum, cables, routers/switches, and most notable operating personnel) are scarce and very costly. The often heard argument that scarcity of bandwidth can be solved by installing more fibers or multiplexing on an existing fiber, holds for certain links only. Operation of the whole network and providing high quality end-to-end service is still an expensive venture. The strict flat-fee pricing (comparable to an all-you-can-eat offer) has proven to be difficult in practice. For example, AOL (America On-line) and other ISPs (Internet Service Providers) turned to this pricing scheme which led to blocked dial-up phone lines at the Regional Bell Operating Companies which do not charge for local calls. From a customers point of view there is no more incentive to hang up a dial-up Internet connection, when there is no charge per time or volume. European ISPs followed a more differentiated pricing model with free-hours and a charge for additional hours using the on-line service. Additionally, local phone calls have a significant price in Europe.

A fundamental problem with usage-based pricing, however, is the type and precision (granularity) of the collected accounting information which is used as a basis for pricing. For example, collecting connection time information of connection time to an ISP rounded to 10 seconds means much less overhead than counting IP packets at each interconnection point. With current pricing models in *single service networks* there is also implicit information which can be used in the pricing process by exploiting an implicit traffic specification. However, if one aims for a more efficiently working *multiple services network* for applications with varying requirements [Shen95], this implicit knowledge is lost and must be recovered from the information made available by the protocols employed.

Using networks providing multiple service classes, such as the integrated services Internet, the precision used in pricing models depends much on the way of how communication is handled. On the Internet, new protocols like RSVP [ZDES93] can provide the basis for collecting usage-based accounting data.

Applying a differentiated pricing model for typical Internet services gives network operators a substantial gain in efficiency. It has been shown theoretically and by simulation that this increase in efficiency depends on the traffic characteristics of the applications [Shen95], [CESZ93]. Another important factor is the degree of competition allowed by regulators. Global Internet services usually cross many different provider networks and more and more providers overlap each other geographically. This development increases not only competition, but increases also the choice of service offerings and efficiency of network operation.

### 2.2.1 Revenue and Network Efficiency

The above mentioned efficiency gain which is achieved in competitive markets has a theoretical foundation, the Pareto efficiency, where no player can be better off without hurting any other [Vari96]. In a globally distributed system, however, such competitive markets can be approximated only. Nevertheless, a gain in efficiency in the telecommunications service market means a surplus which will be distributed. Of course there are two views:

- **Customer View:** Budget constraints and spending strategies are used to get as much service for as little money as possible. The underlying economic principle could be formulated as “users buy the best bundle they can afford”. With software agents and brokers, automated, optimal spending strategies for finding telecommunication service bundles could be used to achieve this goal. Target services include, *e.g.*, phone, fax, Internet access, enhanced services, TV/VoD (Video-on-Demand). They could be chosen by software agents working on behalf of customers in markets becoming more and more competitive. Users only need to express their preference and budget.
- **Provider View:** From a business point of view cost for providing telecommunication services must be recovered to guarantee a stable long-term existence of a provider. While pricing for traditional telecommunication services is well understood by companies, large as well as small ISPs still struggle to make a profit [McLe97]. Furthermore, providers want to maximize revenues.

Assuming higher market efficiency and the above described views of users and providers, *fairness* defines to what extent which party profits from the improved efficiency. Furthermore, fairness requires that customers pay the same price for the same telecommunication services at the same time. In networks that do not charge for usage, i.e. the currently used Internet, fairness is defined in technical terms. For example, TCP/IP (Transmission Control Protocol/Internet Protocol) tries to serve all connections with the same throughput. Unfortunately, this works only for regional access without high delay variations between competing connections [ClFa97].

### 2.2.2 Pricing Models

Components of Internet pricing include three basic elements (cf. Figure 2). Firstly, an *access-fee* is collected which is usually a monthly charge for using an access link to the network. The price depends on the capacity of that link. Secondly, a *per-call* or *connection/reservation-setup-fee* may be charged. In connection-oriented networks or connectionless networks with reservation mechanisms setting up connections or reservations can be charged separately. Finally, a *usage-fee* can be used to charge services on time-, volume-, or QoS-basis. This fee determines the actual resource usage customers consume based on economic principles of marginal cost and market mechanisms. For Internet services network externalities play an important role. Independently of the basic transport service a content-fee can be introduced. Depending on the application content this fee may be omitted (*e.g.*, telephony, fax, e-mail services where the "content" is provided by the customer herself), billed separately (*e.g.*, Wall Street Journal on-line edition), or integrated into the telecommunication charging system (*e.g.*, 1-900 numbers, cf. Subsection 2.5).

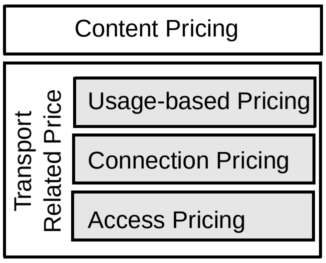


**Figure 2: Components of Internet Pricing**

These price components are reflected in pricing schemes fully or partially. For example, voice services have all three transport components, but an ISP usually charges only for access and optionally for usage on a connect-time basis. Different combinations of the components and approaches to pricing of telecommunication services are classified in [Gade97]. For Internet services, the most important methods include flat-fee, usage-based, reservation-based, volume-based, service class-based, and connect time-based methods. These methods may be combined, such as class-based and volume-based.

## 2.3 Traditional Best-effort Internet

Traditional Internet transport services are usually priced and charged on a flat-fee basis. Different Internet Service Providers may provide services at different price levels in a single geographic region, but the service quality is more or less similar (best-effort). Due to currently used pricing models, neither seller nor customer have a direct control over the actual service, *e.g.*, in terms of parameter determining volume, connection time, and quality. However, large corporations, small and medium sized enterprises, or universities have a stringent incentive to control their spending on Internet traffic, and they also require to control their particular spending on their departments and institutes.

State-of-the-art solutions to support such accounting is based on mechanisms offered by commercially available routers and switches. The most often used approach employs packet filtering and statistical sampling which gives a coarse picture of the usage of such services within an organization. However, it is difficult to account usage-based traffic for small units or even single users, since the granularity of these methods is too coarse and the measurement overhead significant. For volume measurements the IETF rtfm (Real-time Traffic Flow Measurement) working group has proposed standards to meter flows and to distribute this accounting information via SNMP (Simple Network Management Protocol) [RFC2064]. Some research performed applies dedicated, but standard hardware and open management interfaces to obtain flow-based traffic measurements [LCLo97].

At the edge of IP networks the Remote Authentication Dial-In User Service (RADIUS) serves as a proposed IETF standard to help for managing Internet access networks, in particular large modem pools at IAPs [RFC2138]. Since these links are sensitive to security and accounting, a protocol is provided to authenticate dial-in users and negotiate configuration data. RADIUS servers are implemented by most router manufacturers. Accounting data can be collected on a time-, packet-, or octet-basis for a particular service [RFC2139].

Besides these edge- or customer-centered measurements, IAPs use peering agreements (contracts) amongst themselves to achieve interconnection. These contracts usually are not based on in- and outbound traffic (as telecommunication service providers do this), they just state the interconnection agreement per se and are supposed to locate revenue neutral points in the network [Clar96]. The advantage is that there is no need for traffic flow measurements at these points. But recently, this scheme led to problems, since larger, especially backbone providers said they lost money by agreeing to transport packets across their backbones for smaller IAPs [UUNE97].

The traditional Internet pricing model has been critiqued constantly in the past years for its economic draw-backs of not being incentive-compatible [SCEH96], [Clar96], and [GSWh94]. Furthermore, it is inflexible — for example, it does not allow for combined sender/receiver payments — and does not provide economic signals which are needed for network planning and expansion. But most importantly, the current model is based on the assumption of a single service best-effort network that provides a similar service to all customers. With all emerging enhancements being built into the future Internet, most notably the integrated services architecture [RFC1633] (cf. Subsection 2.4 below), it is very likely that technical achievements (reservations, quality of service, and real-time traffic support) will fail, because of shortcomings in economic and business models for the network, providers, and customers [FSPl98a]. Moreover, it is not known how current pricing models can guarantee fairness in a network offering service discrimination. Economic models are also described as a way of providing adaptive congestion control in packet networks [MaVa95].

In the framework of charging best-effort Internet it is also necessary to consider mechanisms allowing for the observation and control of aggressive flows to enforce fairness. These mechanisms have to be placed, like bandwidth brokers, at points experiencing high congestion. There have been mentioned three possible approaches [FlFa97] for sharing scarce bandwidth amongst best effort flows and in curtailing abusive flows. Note that they can be complementary and various combinations are possible. (1) Routers are given the responsibility to isolate each flow as much as possible and they regulate each flow's bandwidth. (2) The primary mechanism is still the end-to-end congestion control, but additional mechanisms are deployed to restrict the bandwidth of flows which use a disproportionate share of the existing bandwidth at times of congestion. They additionally propose to rely on the drop history in routers to identify and restrict the bandwidth for these flows. (3) The last approach leads back to charging. Appropriate pricing structures fast enough to keep up with the growth of best effort traffic in the Internet and the ability to provision additional bandwidth on the provider side could be mechanisms to control the sharing of the bandwidth. Congestion control is necessary for fair charging, but charging can also be a mechanism to control bandwidth allocation during times of congestion.

Originally, the Internet was subsidized as a research network by governments and non-commercial third parties. Pricing models for the traditional Internet service is based on the fact that there is only one service class. Moreover, the lack of accounting information led to very simple models. Most ISPs charge only a monthly flat-fee, while Some ISPs charge additionally a time-based fee in the range of a few dollars per hour if a base amount of "free hours" is exceeded. As many economists predicted [McLe97] and [Stah97], the flat-fee model did not work for most smaller ISPs and recently also for AOL. The worlds largest ISP was forced to raise its flat-fee by $2 to $21.95 [Macl98]. Due to this provider-centric and static pricing approach such companies have to adjust pricing in a repetitive and costly process.

A retrospective analysis for the funding of the Internet during the last few years has been performed in [Noll97]. *E.g.*, based on the amount of Internet traffic carried in the NSFNET (in December 1995: 16,000 billion Byte) and the reported spending of approximately $25 million, a low-estimate cost of 1.6µ¢/bit can be calculated. These considerations allow for preliminary conclusions that billing in the Internet "would commence at a rate of 2µ¢/bit", however, which should be discounted for high volume traffic. Due to its emerging behavior into an integrated services Internet (cf. Subsection 2.4 below) suitable pricing schemes need to be researched.

## 2.4 Integrated Services Internet

This section discusses state of the art in research in the area of charging and accounting for the Integrated Services Internet model [RFC1633]. The integrated services architecture is currently adopted by major telecommunications equipment manufacturers [Bay97], [Cisc98] and is expected to be deployed in the next years in most developed countries. Proposed charging and accounting approaches are divided into three categories:

- Best-effort charging and accounting, usually a measurement-based approach,
- Flow- or reservation based charging and accounting in integrated services (intserv), including flow aggregation, and
- Charging and accounting of differentiated services (diffserv).

Since the integrated services approach still maintains the traditional best-effort service class, it is discussed here with respect to charging and accounting. Accounting for datagrams in a connection-less network imposes a high processing overhead on Internet routers. To measure volumes and account them to address-port pairs was studied in the rtfm working group and practical experience was collected in New Zealand where the only Internet link is a satellite connection and usage based accounting was necessary [Brow94]. The seminal work of Varian and MacKie first mentioned the application of economic pricing models to Internet traffic [MaVa95]. Their first auction-based approach was never implemented and is still considered as too costly. Nevertheless, a recent proposal for an experimental high-speed router based on multiple processors aims at integrating auctions on packet level [Suez98]. Other approaches use hardware to speed up accounting [EMVa95]

The integrated services model is based on service class discrimination. New services encompass controlled-load and guaranteed services which are signalled by a newly introduced Resource Reservation Protocol (RSVP) [ZDES93]. With this new integrated services description, it was time to review charging and accounting issues [SCEH96]. With bandwidth reservation and support for QoS new models and architectures for charging and accounting surfaced. The auction-based approach was revisited by MacKie and applied to flows on the integrated services architecture [MacK97]. MacKie gives a solution for network optimization based on economic principles (Generalized Vickrey Auctions). This work is still in progress and its feasibility has yet to be proved. Another recent proposal for a flexible architecture supporting different charging and accounting methods is described in [FSPl98a] and first implementation results based on the intserv model and resource reservations are presented in [FSPl98b]. Using a high-speed integrated services test-platform, this work shows the feasibility of measuring large numbers of flows in real-time. Since the granularity is no longer a packet but a flow-state, less overhead is generated and the burden of charging and accounting can be put on recent router hardware. Recent work on flow aggregation promise to solve the backbone scaling problem associated with a purely reservation-based approach [BeVi98]. Such an approach allows to keep protocols like RSVP at the end-systems and eliminates the need for per-flow state at high-speed routers. This approach could be combined with the reservation based charging scheme described in [FSPl98b] using zone-based charging for each provider at ingress and egress routers.

Work on differentiated services is performed within the integrated services working group of the IETF. It is primarily based on the observation that per-flow state in routers as it is needed for reservation protocols such as RSVP can become a bottleneck in the Internet. Therefore, proposals have been made to provide light-weight reservations or priority schemes [ClWr97], [Wroc98]. No agreement on a possible introduction or standardization has been reached and work on charging and accounting options for such protocols is only starting slowly. For example, a proposal by Clark and Fang [ClFa97] describes a zone-based charging scheme that is based on packet tagging and dropping (in/out profile tagging). The proposal supports different service classes and has the nice property that charging is performed at the edge and at interconnection points of the network only. In this context, other proposals introduced assured and premium service for prioritized service classes [NJZh97]. However, such proposals do not describe concrete methods how money is collected and they do not study economic implications of charging for integrated network services. Early work in this direction outside the Internet community, however, can be found in [Pau96] and [MacK97].

The recently initiated differentiated services models [Wroc98] did not spawn much work in the field of pricing models yet. [ClFa97] focuses on diffserv mechanisms and experimental approaches to zone and QoS-based pricing schemes, while SIMA [RuKi98] focuses on charging and accounting at the edge of the network.

## 2.5 Integrated Billing and Payment

Integrated billing aspires to send only one bill to customers. Services include basic Internet access as well as content oriented ones. Extending this billing and service integration to content is difficult, because new interfaces to content providers must be offered which increase the complexity of billing systems. Furthermore, the usual flat-fee approach is not viable for content services.

A tight billing integration as practiced for telephone service is not appropriate for ISPs**.** In this approach, charges for content or enhanced services are converted to transport charges, *e.g.*, a support hotline using a 1-900 number. First, the Internet does not provide a time-based charging mechanism that can be accessed by other service providers. Second, this solution is not very transparent to customers, since time is not always a natural metric for enhanced services.

For ISPs a loose billing integration is more suitable, but needs an elaborate interface between content/enhanced service providers and the ISP’s billing facilities. For example, AOL as an ISP charges for playing games which are additionally listed on the monthly bill. Such an integration is suitable and already practice for database services, information retrieval, multimedia services, or retail of electronic products and services, *e.g.*, software or support by e-mail. The content service provider can choose freely the amount and time to charge for the service. In addition, bills can be presented transparently to customers.

### 2.5.1 Payment Systems and Security Issues

To implement a billing system successfully, legal contracts are needed which are based today mostly on verification of customers’ identity by letter or telephone. This is due to the absence of proper electronic authentication mechanisms and certification authorities. Once a contract has been established, traditional invoicing or credit card billing is the most popular way to collect money.

Electronic payment systems that provide anonymity [Chau97] and/or small amounts [MaWh96] are still not accepted with ISPs. It is not clear at the moment, whether micro-payments or anonymous e-cash provide a real advantage to service providers offering usage-based pricing for their services.

# 3 Charging and Accounting in ATM Networks

As charging and accounting is per se no completely new area, related issues are of significance. This is due to, *e.g.*, a long lasting experience in the telephone network. However, the main difference compared to the Internet is visible in the set of fixed QoS characteristics per telephone connection. Therefore, the style of packet-based networks shows major technical differences and requires different handling of charging and accounting tasks. In addition, recently started work on charging and accounting in the ATM environment shows some commonalities, but is still significantly different due to at least the virtual connection principle applied.

For ATM-based B-ISDN (Broadband Integrated Services Networks) the tasks of accounting, charging, and billing are required to complete the offer of integrated services. ATM accounting may be expected to serve as an embracing network functionality capable of supporting the needs of service providers, retail customers, value added service providers, and other businesses. Virtual Private Networks (VPN) offer a possibility to satisfy special enterprise needs on closed networking environment, where an ATM-based solution is highly qualified to obtain high bandwidths and guaranteed QoS. The “Broadband Network Infrastructure for the Swiss Federal Administration” (KOMBV) determines a Swiss example for a VPN based on the Swisscom ATM network [BFI97]. It guarantees a maximum flexibility for a variety of different applications requiring multimedia services, it eases management overhead, and it reduces costs to operate the VPN. However, ATM-based intranets are only affordable for medium and larger enterprises, because tariffing structures slightly favor high-volume customers.

The telecommunications view of the terms accounting, charging, and billing has been preliminarily defined in [ETSI97]. The basic charging for ATM is called “three tier charging” [Kuip97], where the set-up fee, the total of all duration fees, and the total of volume fees are included. In contrast, two basic components of ATM tariffs are commonly identified [ETSI95]. The charges of an *access component* are typically fixed per installation and they are constant over billing periods. This charging does not require any on-line measurements. However, it should allow for compensating providers for required facilities for a service subscriber to access a service or services, *e.g.*, those facilities specifically provided to that service subscriber. In addition, they are independent of the utilization and related mainly to the type of access, such as capacity provided, maintenance, or redundancy. Charges of the *utilization component* should be in accordance with the service requested by the service subscriber. In principle, these charges should be determined on the basis of network resources and additional functions required, providing the service to the service subscriber. The measurement of the utilization component usually has to be carried out on-line. Most current utilization charging schemes are based on saving parameters received through the ATM signalling, *e.g.*, including traffic contract, source and destination addresses, counting ATM cells during the ongoing call, and saving the set-up time and duration of the call. Current research is being done by several ACTS projects, such as CA$HMAN (Charging and Accounting Schemes in Multi-Service ATM Networks) [WKSo97] and CANCAN (Contract Negotiation and Charging in ATM Networks) [Kuip97] as well as a small Swiss project.

As ATM technology in the WAN environment used to be controlled by PTTs (Post Telephone Telegraph) formerly, tariffing schemes defined initial approaches for public ATM networks. This changes today due to private companies offering ATM services and pricing schemes. However, legacy ATM networks still rely on conventional tariff models as applied to telephone services. Current implementations on ATM pricing models are based either on a flat rate, as for legacy leased line tariffs, or on a two-part pricing scheme which is monthly an access and usage-based fee, as for legacy switched circuits tariffs. However, new proposals in recent research suggest different ATM pricing models to take into account various services classes offered by ATM. However, as ATM provides different service classes, it is not appropriate, *e.g.*, to charge for a constant bit rate traffic a volume charge. As the result obtained shows, various traffic types require different pricing approaches to make their special characteristics visible in economic incentives.

## 4 Conclusions and Trends

Looking back at the historical development of the Internet, two major phases can be distinguished, where economic principles have not been regarded as the major driving force. In the initial **first phase**, provider networks were run by universities, backbones were subsidized, and commercial use was actually not endorsed. With very few exceptions, pricing of the services was hidden from the academic users of Internet services and private use was almost unknown.

The **second phase** is characterized by the inclusion of commercial and private users, the global deployment of the network, and its continuous extension and enhancement. Very simple pricing models were implemented in order to support the cost recovery process of ISPs who started businesses in order to provide commercial Internet services. Not only limited by technical means of the Internet protocols, but also driven by the run for market-share of large ISPs, simple flat-rate pricing schemes dominate this phase. Although economists warned that an all-you-can-eat mentality is a rather inefficient way to price the Internet, ISPs are still adjusting monthly rates and provision service on grounds of traffic statistics that are still limited by the rather slow access speed of voice-band modems. All-you-can-eat offer sounds great, but in reality it happens to be an offer for a very modest buffet. We expect to see the end of this phase in the very near future due to driving technological developments, such as xDSL modems for access speeds in the Mbit/s range, new Internet protocols offering QoS guarantees, and extended backbone capacity. This technology development itself is driven by new service offerings and requirements, such as voice, video, and other time-sensitive multimedia applications.

This transition marks the beginning of the **third phase**. Many factors (*e.g.*, technology, services) play important roles to establish this phase, but the most fundamental one is the shift from a single service class, best-effort network to an Integrated Services Internet providing multiple service classes. This type of network is required as the range of services emerges, in particular Internet services that provide quality service (*e.g.*, IP telephony, IP faxing, TV and radio over IP) cannot cover costs using today's pricing models. The trends we sketch here for the future phases of Internet development are based on the simple, but often accurate observation that today's research labs work on systems that have been deployed a decade later. As we have discussed in Section 2, on one hand, economic researchers are working on models that fit new differentiated network services. On the other hand, network people have shown increasing interest to support such efforts by implementing efficient accounting methods and new integrated protocols supporting the secure transfer of charging data and payments. Judging from today's state-of-the-art research in this field, a truly integrated solution will not survive in the third phase. The optimal balance between economic and engineering efficiency has to be found yet. It is to be expected that we will see a great variety of new pricing schemes and offerings. Due to enhanced networking capabilities, however, these pricing plans have to be more and more usage-based. Building charging and accounting methods into the Internet protocols makes the hour-glass model even more attractive for Electronic Commerce on the Internet and an overall service convergence. It enables service-oriented and usage-based charging for end-to-end connections between the customer and service provider. On the technology side resource reservation protocols combined with charging capabilities will fill in the high-end of the service palette (*e.g.*, multimedia applications), while priority-based network protocols establish mid-range services, such as fast Web surfing. More expensive services probably will require a finer charging granularity than others. Whether best-effort services will be charged differently than today, however, is still an open question.

Looking at future work of today's research allows us to prepare some assumptions on a **fourth phase** in Internet development. While technological development continues (i.e. mostly in quantitative terms), the established economic and network models will be consolidated and enhanced. For example, simple charging mechanisms for resource reservation protocols will be extended with least-cost routing functions or intelligent agents will act as bandwidth brokers. Trading resources on spot-markets has limitations and will most likely be extended by trading in-advance reservations. Since we expect increasingly competitive markets, a trend towards dynamic pricing models can be anticipated. Full deployment of multicast services with built-in cost sharing functionality could be the final reason to converge broadcast media into the Internet and make them globally available.

Predicting the outcome of some smaller technological battles might prove difficult and inaccurate, but the major trend of Internet development from a technically focused network to an economically controlled, efficient global information system seems inevitable. Charging and accounting mechanisms provide the technical fundament to make it happen, and new economic models will ensure an efficient and fair allocation of network resources.

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