PAYING FOR HIGH SPEED NETWORKING SERVICES

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Statement

I declare that PAYING FOR HIGH SPEED NETWORKING SERVICES is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

A. Nie

(A van Niekerk)

Abstract

The idea of a free network is a myth of the past. Networking costs are expected to remain a burden to future IT budgets, no doubt raising questions regarding the payment of such services.

Users do not normally pay to use local area networks, as companies tend to own their LANs. However, when wide area or international networks are considered, the situation is different.

It is argued that in these cases the invoicing and payment system should be integral to the network's communication protocol. This implies changes to the networking protocol (to handle invoicing) as well as a new look at customary ideas of representing currency (to handle payment).

In this dissertation, an invoicing and payment scheme that uses electronic cash and is implemented as part of the basic ATM protocols is discussed. The main advantages of this scheme can be summarized as a low administrative overhead and user privacy.

Key Terms

Overview of High Speed Protocols; High Speed Networking; ATM Signaling; ATM Connection Setup; ATM Protocols; Electronic Cash; Electronic Payment; Anonymous Payment; Network Integrated Invoicing and Payment System; Evaluation of modified ATM Setup methods.

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Terminology and Abbreviations

Terminology:

- **Asynchronous**
  Signals that are sourced from independent clocks.

- **Asynchronous Transfer Mode**
  A data transmission method based on fixed-length packets, called cells, that can carry data, voice, and video at high speeds.

- **ATM Adaptation Layer**
  One of the layers of the ATM reference model, which acts as an interface between the ATM layer and higher layer functions.

- **AAL 1**
  ATM Adaption Layer 1, which supports ATM connection-oriented services with constant bit rates and specific timing and delay requirements.

- **AAL 2**
  ATM Adaption Layer 2, which supports ATM connection-oriented services with variable bit rates such as video.

- **AAL 3/4**
  ATM Adaption Layer 3/4, rendering support for both ATM connectionless and connection-oriented variable rate services.

- **AAL 5**
  ATM Adaption Layer 5, which supports connection-oriented variable bit rate ATM data services such as the typical bursty data traffic found in LANs.

- **ATM endpoint**
  That point in an ATM network where an ATM connection is terminated.

- **Billing**
  A Transactional process during which the user receives an invoices for services rendered by the service provider.

- **Blinding**
  A method of hiding a note number during bank signing to prevent tracking.

- **Cell**
  A fixed-length transmission unit used by high speed protocols. For ATM each cell is 53 bytes long with a 5-byte header and 48 byte data section.

- **Cell Loss Priority**
  A one-bit field in ATM cell headers, indicating the relative importance of a cell. If set to 1, the cell may be discarded if necessary.

- **Connection Admission Control**
  Actions by the network during connection setup in order to determine whether a requested QoS should be accepted or rejected.

- **Connection-oriented**
  Communication for which a connection must be provided between a sender and receiver before transmission can start.

- **Costing**
  A Transactional process by which the cost of providing a service is determined.

- **Data Exchange Interface**
  The local interface between a packet-based router and an ATM capable DSU.

- **Generic Flow Control**
  The first 4 bits of the ATM UNI cell header.

- **Header Error Control**
  The HEC field is an 8-bit Cyclic Redundancy Code (CRC) computed on all fields in an ATM Header.

- **IP Address**
  An identifier for a node, expressed as four one-byte fields separated by decimal points. Example: 155.237.91.1

- **LAN Emulation**
  A method used by an ATM network to emulate the MAC protocol from an existing LAN technology, such as Ethernet.

- **Link**
  Any connection on a network that links two separate devices such as an ATM Switch and an endpoint.

- **Network Synchronization**
  Consistent timing within a network, provided by a single selected clock used throughout the network. I.e. Novell's time synchronization used to keep NDS transactions and replicas in sync.

- **Network-to-Network Interface**
  Interface between ATM switches or an ATM switch and an entire switching system.

- **Paying**
  A Transactional process during which funds are transferred from (in this case) the user to the service provider.

- **Payload Type Identifier**
  Three bit field in ATM headers, indicating the type of payload the cell contains.

- **Permanent Virtual Circuit**
  A logical connection between endpoints which stays intact until manually broken.

- **Physical Layer**
  The layer that passes cells from the media to the ATM Layer and vice versa. Also OSI Layer 1.

- **Private Network-to-Network Interface**
  Interface between two ATM switches or between an ATM switch and an entire switching system in a private network.

- **Protocol Data Unit**
  Unit of data consisting of control and user information exchanged between peer layers.

- **Recording**
  A Transactional process during which the service provider keeps track of the user's network usage in order to enable him to bill the user.

- **Switched Virtual Circuit**
  A logical connection between endpoints in the network after receiving a connection request.

- **Traffic Policing**
  Methods used to detect and discard cells that violate Quality of Service contract agreed to at connection setup.

- **Traffic Shaping**
  Methods used to modify traffic characteristics in order to match a desired Quality of Service contract.

- **Usage Parameter Control**
  Those actions used by the network to monitor and control traffic. Its purpose is to protect network resources from both malicious and unintentional misbehavior.

- **User-to-Network Interface.**
  A connection that directly links a user's device to an ATM network, through an ATM switch.

- **Virtual Channel Connection**
  A concatenation of virtual channel links between two end points.

- **Virtual Channel Identifier**
  An Identifying field (together with VPI) in the header of each ATM cell.

- **Virtual Local Area Network**
  A logical LAN formed by emulating a single network MAC address between a number of nodes connected to a switch.

- **Virtual Path Connection**
  A concatenation of virtual path links between two points.

- **Virtual Path Identifier**
  An identifying field in the ATM header.

Abbreviations:

♦ **AAL**	ATM Adaptation Layer
♦ **ANSI**	American National Standards Institute
♦ **ARP**	Address Resolution Protocol
♦ **ATM**	Asynchronous Transfer Mode
♦ **B-ISDN**	Broadband Integrated Services Digital Network
♦ **CAC**	Connection Admission Control
♦ **CBR**	Constant Bit Rate
♦ **CCITT**	Consultative Committee on International Telephone and Telegraph (now ITU)
♦ **CLP**	Cell Loss Priority
♦ **CS**	Convergence Sublayer
♦ **CRC**	Cyclic Redundancy Code
♦ **ECash**	Electronic Cash
♦ **FCS**	Frame Check Sequence
♦ **FDDI**	Fiber Distributed Data Interface
♦ **GFC**	Generic Flow Control
♦ **HEC**	Header Error Control
♦ **HSNP**	High Speed Networking Protocol
♦ **IEEE**	Institute of Electrical and Electronics Engineers
♦ **IP**	Internet Protocol
♦ **IPX**	Internet Packet Exchange
♦ **IPS**	Invoice and Payment System
♦ **ISDN**	Integrated Services Digital Network
♦ **ISO**	International Standards Organization
♦ **ITU**	International Telecommunications Union (formerly CCITT)
♦ **LAN**	Local Area Network

♦ **DSU**	Digital Service Unit
♦ **MAC**	Media Access Control
♦ **MAN**	Metropolitan Area Network
♦ **MIB**	Management Information Base
♦ **NDIS**	Network Driver Interface Specification
♦ **NNI**	Network-to-Network Interface
♦ **OC-n**	Optical Carrier-n
♦ **ODI**	Open Datalink Interface
♦ **OSI**	Open Systems Interconnect
♦ **PDU**	Protocol Data Unit
♦ **P-NNI**	Private Network-to-Network Interface
♦ **PTI**	Payload Type Identifier
♦ **PVC**	Permanent Virtual Circuit
♦ **QoS**	Quality of Service
♦ **RIP**	Routing Information Protocol
♦ **SAAL**	Signaling ATM Adaptation Layer
♦ **SAR**	Segmentation And Reassembly
♦ **SDH**	Synchronous Digital Hierarchy
♦ **SEAL**	Simple and Efficient Adaptation Layer
♦ **SNMP**	Simple Network Management Protocol
♦ **SONET**	Synchronous Optical Network
♦ **SS**	Switching System
♦ **STM**	Synchronous Transfer Mode
♦ **SVC**	Switched Virtual Circuit
♦ **TCP**	Transmission Control Protocol
♦ **TCP/IP**	Transmission Control Protocol/Internet Protocol
♦ **TDM**	Time Division Multiplexing
♦ **UNI**	User-to-Network Interface
♦ **VC**	Virtual Channel

VCC	Virtual Channel Connection
VCI	Virtual Channel Identifier
VLAN	Virtual Local Area Network
VP	Virtual Path
VPC	Virtual Path Connection
VPI	Virtual Path Identifier
WAN	Wide Area Network

Chapter 1

Introduction

1.1. Background

The idea of a free network is no doubt a myth. The cost of modern day networking equipment and services will certainly remain a substantial portion of the average IT budget for years to come. This is bound to raise questions regarding the payment of such services.

In most cases, users do not pay for the use of local area networks, as companies normally own their LANs. Although these systems still cost money to install and maintain their costs can simply be seen as an overhead internal cost (similar to an internal telephone system). This is however not the case when wide area or international networks are considered. These networks often are owned and used by more than one company or division, who must then share the responsibility of installing, maintaining and upgrading these systems.

Paying for the use of such a network should therefore not be a controversial idea. In fact, users may even be in favor of such a scheme, provided that it will guarantee a better, more comprehensive or faster service.

If users of a LAN want to share the cost of installing and maintaining their network, an affordable and fair cost sharing scheme should be relatively easy to define. Quite often an accounting system in the form of departmental budgets will be sufficient. Such a system could be run on a spreadsheet (or even paper) and does not necessarily need built in LAN accounting (although this capability is available in network operating systems like Novell [Nov94]). This situation does however change drastically when wide area or international networks are considered.

Once again the services on these networks can not be considered to be free. Somewhere someone pays for the infrastructure. Comparison with the normal methods of paying for LAN services could reveal that the conventional approach (i.e. departmental budget / auditing systems run in parallel with the LAN) may not be able to cope with the task in hand. The fact that these systems may be more expensive to maintain than the network itself being but one of the problems at hand.

The data communication and telecommunication fields have often in the past found each other's solutions to common problems beneficial. However, prevailing methods of dealing with these problems in the telecommunication community also seem to be overly expensive and cumbersome.

Thus Dai Davies [Dav94] might have indicated the correct solution to the problem when stating that the answer is not free use but "*a creative approach to pricing*". In fact it may be worth while to also investigate new methods of gathering usage information, billing and payment as part of a network accounting system as illustrated in Fig 1-1.

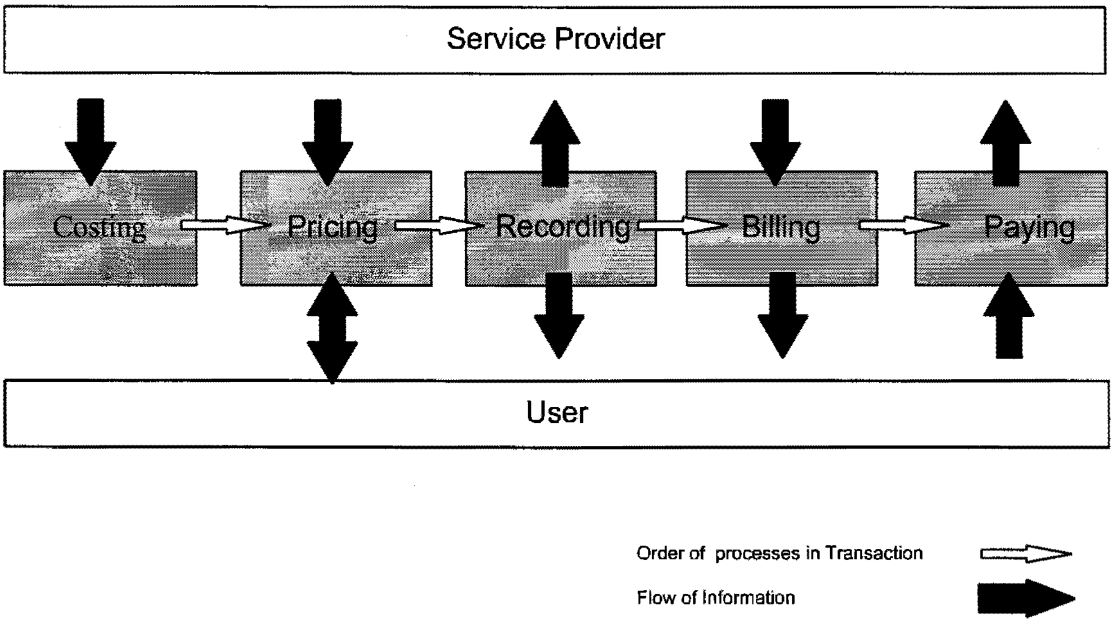


Figure 1-1: Processes forming a Transaction

Throughout in this dissertation a transaction will be seen as a sequence of processes consisting of, costing (determining the cost of providing a service), pricing (determining the rate a user should pay), recording (gathering the usage information per user), billing (sending out invoices) and payment (the transfer of funds). Pricing and Costing are financial issues, which may benefit more from a financial rather than technological approach. However, recording, billing and payment can be investigated from a scientific angle in order to discover the above mentioned creative approach.

1.2. Problem Statement

Conventional accounting systems are not well suited for dealing with billing and paying for wide area and inter-networking services due to the high cost of implementing and running these systems.

1.3. Hypothesis

The hypothesis is made that it is possible to implement a cost effective accounting system by using a form of electronic cash and incorporating recording, billing and payment as an integral part of the High Speed Networking Protocol.

1.4. Assumptions

In order to limit the scope of this dissertation, as well as to maintain the relevance of the research done here, the following assumptions are made:

- On future wide area and internetworks, bandwidth will still be a restricted and (to a certain extent) scarce commodity.
- The availability of video on demand, client server, voice-mail and fast processors will increase the demand for bandwidth on future networks.
- With the availability of the Internet and other information services it can be assumed that traffic on future networks will no longer abide by the 80/20 rule stating that 80% of traffic will stay local [Ser94].
- It is preferable to handle the cost of a connection as just another characteristic of that connection (to be controlled in a similar fashion as time delay is controlled).

1.5. Objectives of this research

The objectives of this research include:

- To understand ATM;
- To understand electronic billing and ecash;
- To propose an ATM-embedded billing and payment method;
- To evaluate this method by means of computations.

1.6. Scope

In order to reach the above mentioned objectives, this study includes an overview of transaction recording, billing and ecash payment techniques. The high speed networking environment and current ATM protocols are also examined, after which an extension to ATM, that includes billing and payment, is proposed and evaluated.

As Costing and Pricing are seen as processes that should rather be approached from a financial point of view, they are specifically not included as part of this research. Regarding the high speed networking protocols, the emphasis falls on ATM. The extension of electronic billing and payment techniques to protocols like Fast Ethernet and Frame Relay are not considered to fall inside the scope of this research and as such, these protocols are not discussed in depth.

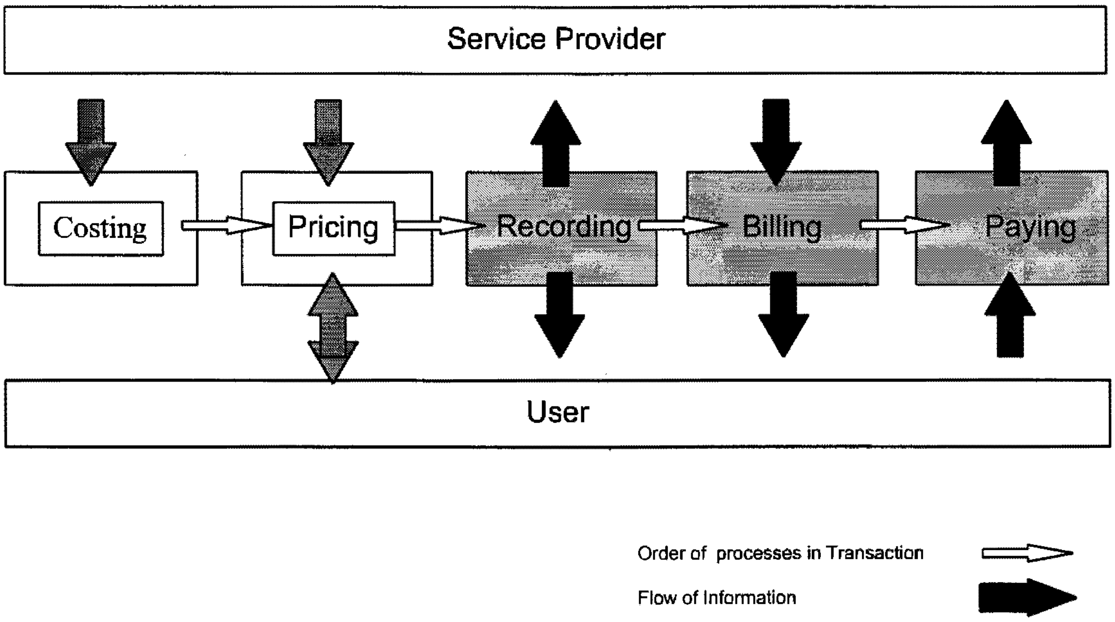


Figure 1-2: Transaction Processes included in scope

With reference to Figure 1.1 the discussion can thus be seen to focus on implementing the indicated processes (shaded parts in Figure 1.2) as an integral part of the ATM protocol.

1.7. Methodology

In order to cover the above mentioned scope, this dissertation is approached as a theoretic study of the fields mentioned above. To evaluate the proposed extension to the ATM protocol a computational approach is used rather than simulation or a full implementation.

1.8. Relevance of Research

Dai Davies [Dav94] has pointed out that "*There is no such thing as a free Internet*". As stated before, providing networking services currently costs money and in future it can be expected that they will still do so. This means that someone will be paying for these networking services and infrastructure.

Serjak [Ser94] points out that in an age where telecommuting is becoming a reality, companies expect that their employees should be able to use network resources regardless of the user's and the resource's location. This contributes to the breaking of what he calls the

80/20 rule of networking. Yet, as stated in section 1.1, current methods of handling network costs are much better suited to LAN's than to international/global networks.

Studies done by Parris, show that the Qualities of Service (QoS) available on high speed networks are complex enough to justify a new look at pricing in integrated networks. He also mentions that the correct approach to pricing may help to equalize the demand on networks with definitive peaks in traffic. [PF92]

In an article by Smuts [Smu95], it is pointed out that free networks with the ability to reserve certain services, coupled with a service guarantee and limited bandwidth (as assumed in 1.1), may change the *free-for-all* principle to a *free-for-a-few* approach. Obviously the same goes for a relative low fixed rate.

From the above it can be seen that:

- Networking costs money and will still do so in future;
- The current approaches (including built in LAN accounting systems) are not suited to control increased WAN and inter-network traffic;
- The use of a free-for-all, or a fixed rate accounting method is not suited to a high speed networking protocol that provides reservation and service guarantees.

Thus, it can be concluded that it may be necessary to pay for certain types of network use in future and that research regarding new methods of doing so is no doubt relevant.

1.9. Summary and Organization of this Document

This dissertation includes a theoretic overview, a proposal and an evaluation. It is organized around three main topics, dealing with:

- ATM;
- billing and ecash and
- the proposed combination of these two fields.

In chapter two the high speed networking environment is described, touching on subjects like service guarantees and the motivation behind reservation and payment.

Chapter three gives a theoretical overview of ATM and chapter four a theoretical overview of ecash. These chapters can be skipped by a reader who is familiar with these topics.

Chapter five discusses a proposed extension to the ATM protocol to include billing and payment by ecash as part of the basic ATM protocol. Chapter six evaluates this scheme by means of computation, with chapter seven summarizing the research and drawing certain conclusions regarding the viability of the proposed ATM extension based on this evaluation.

Chapter 2

The High Speed Networking Environment

2.1. Introduction

Shortly after the development of the 8086 PC, it was deemed that an average network speed of 10 Mb/s is more than sufficient. As a matter of fact it was the author's experience that some users preferred to keep their data on the LAN, because access to the server was much faster than to their own PC's hard drive. This is, however, no longer the case, in fact, chances are that with the advent of PC's like the 160Mhz Pentium, the 10 Mb/s Ethernet LAN has become the bottleneck in the system.

Serjack [Ser94], points out that just about everything in the computing environment has changed - except the network. He continues to indicate that it is necessary to move to different LAN / WAN and Internet technologies, in order to render a worth while network service. These and other problems in the networking environment lead to the development of several high speed protocols and devices.

This chapter indicates, why high speed networking services should be considered necessary, rather than preferable in the future IT industry. In section 2.3 a short overview of the current technologies in various sizes of networks is given. The different protocols and devices available for use in these networks are discussed in section 2.5 and 2.6. Finally it is shown why ATM is considered to be the best technology on which to implement the accounting system proposed in chapter six.

2.2. Leaving the low speed comfort zone

The current low speed networking technologies, having been matured during a number of years of development can be seen as reasonably stable. On average the modern day equipment using these protocols are quite advanced and reliable. No doubt the question can then be asked, why change? The answer can be found in the following [Ser94] :

2.2.1. Downsizing

The IT industry is moving away from large mainframes towards client server computing. This means that subroutine calls become network transactions. Figure 2-

1 indicates the difference between a terminal and a client/server type of transaction. In both cases a 40 byte user query receives a 1,000 byte response. However, the client/server instance needs significantly more bandwidth than the terminal/host case, due to distributed processing and different protocols.

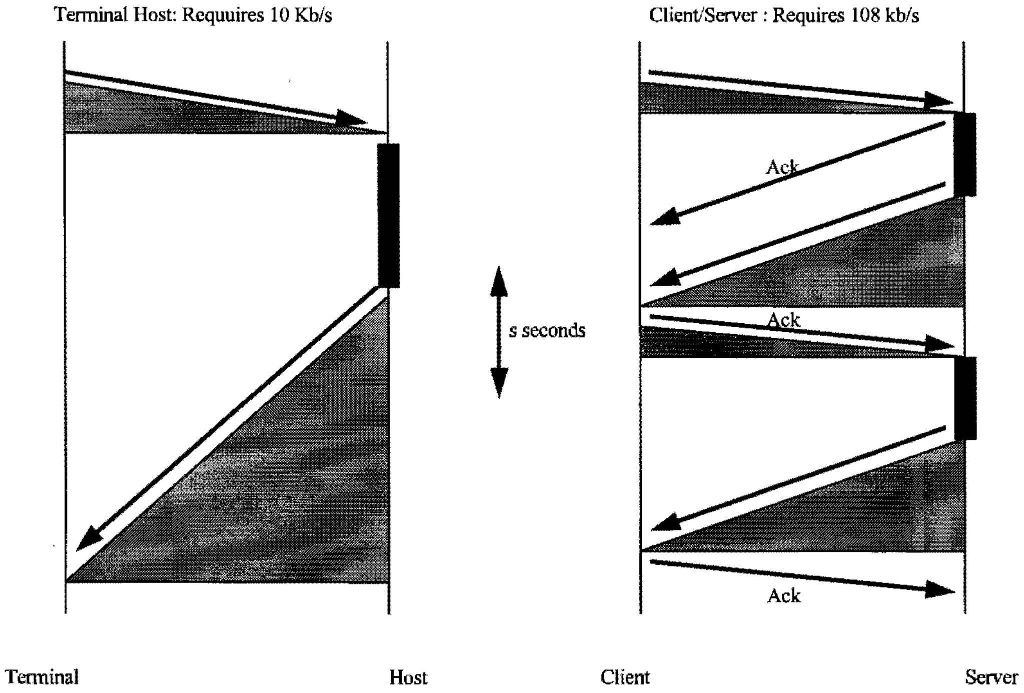

Terminal Host: Requuires 10 Kb/s
Client/Server : Requires 108 kb/s
s seconds
Ack
Ack
Ack
Terminal
Host
Client
Server

Figure 2-1: The effect of client server technology on bandwidth [Ser94]

This difference in required bandwidth motivates the move to a higher speed on the network side. As such, downsizing the computing equipment often means upsizing the network.

2.2.2. Server Centralization

As client/server networks begin to support mission critical applications, issues such as security, reliability, disaster recovery and control become increasingly important. According to Serjack [Ser94 p4], these servers are normally afforded the same protection as is granted to mainframes, by installing them centrally in the same room where the mainframe used to be.

This tendency however, moves these servers away from the work groups who are using them. When running a standard benchmarking program on different servers in the network, Serjack [Ser94 p3] shows the following number of elapsed seconds before receiving results:

- on a workgroup server : 1.1 seconds
- on a server centralized in a data center on the same LAN : 1.6 seconds
- on a server in a data center across the WAN : 8.6 seconds

Once again this means an increased required bandwidth due to an increase in latency. Thus, this is another factor motivating the move towards high speed networks.

2.2.3. What the user expects

Due to perceived speed of their new generation workstations, users have grown accustomed to a certain reaction time from their PCs. However, at the same time the nature of the average type of application run across the network is changing. Applications like voice-mail, video conferencing and multimedia presentations are all bandwidth hungry due to their size and time restrictions. Partridge [Par94 p226] points out that some of today's networking protocols may be adapted to sustain Gigabit/sec speeds but that these protocols do not support performance guarantees regarding delay and bandwidth, which are no doubt necessary in such an environment. It should therefore be clear that the 10 Mb/s Ethernet or the 16 Mb/s Token-Ring may not be sufficient any longer. No doubt the question will then arise, what next?

2.3. High speed networking in various environments

2.3.1. LAN

In the LAN environment, the answer to *what comes after 10 Mb/s Ethernet?* at one stage seemed to have varied between, *Fast Ethernet* and *ATM.* Advocates of both points of view appeared to be smugly self assured that their point of view is correct. However, the recent opinion seem to be more biased towards ATM, or an ATM / Ethernet combination. (See [Lind93], [Axn93], [Ben94].)

The main advantage pointed out by those who prefer Fast Ethernet is that it will run on a company's existing Ethernet technology (if they are already using CAT 5 UTP). Due to its cost implications, this factor can therefore not be ignored. However, as is pointed out by [Lind93], Ethernet has the disadvantage of still providing a limited bandwidth.

Except for it's scaleable bandwidth, ATM also does have another big point in it's favor; it can run on both the LAN and the WAN environment. With the help of LAN Emulation it can also, like Fast Ethernet, be tied into an existing Ethernet LAN. (I.e.

using switches with both ATM and Ethernet ports in order to replace only the hart of an existing Ethernet LAN with ATM.)

2.3.2. WAN

With the above mentioned in mind, it may appear that that the future choice in the WAN environment should also fall on ATM. In this case, Fast Ethernet is not really a contender, but, FDDI and TCP/IP has already got a large share of the market. However, the IT industry does seem to be getting ready for a move towards ATM. (See [LAN96 p14] for a case study regarding migration from FDDI to ATM.)

In order to justify why we will consider ATM as the network protocol on which to implement our proposed accounting system, it may be necessary to briefly examine some of the other protocols in the high speed networking environment. As our accounting system should be optimal in the WAN environment rather than for LANs (see par 1.1) Fast Ethernet will not be discussed in more detail.

2.3.3. Intranet

Intranets can be seen as a relative new term developed by the industry. However it refers to an idea that has been around for some time, that of using Internet (specifically TCP/IP) technology on a LAN, or private WAN. Companies like Novell and Microsoft seems to be aiming at this market. Novell with NetWare 4.11 and IntraNetWare and Microsoft with Windows NT, add on products. When taking a look at the marketing effort going into Intranet technologies it is bound to increase the popularity and use of TCP/IP. Novell has already included TCP/IP clients as part of it's freely available client software, while Microsoft has built native support for TCP/IP into Windows NT 4.11

2.3.4. Internet

As in the case of the Intranet, the popularity of the Internet seems to be increasing in leaps and bounds. Popular software manufacturers in the PC arena, like Microsoft, Novell and Netscape are flooding the market with software aimed at Internet use, once again of course all running on TCP/IP.

For obvious reasons, the choice of a protocol on which to implement the proposed accounting scheme should not be based on popularity. However the increased use of TCP/IP in the Internet and Intranet environments should be kept in mind, if such a scheme is to be usable in practice.

2.4. Networking protocols

In order to choose a protocol and to develop the proposed accounting scheme as an extension to that protocol, a closer look must be taken at the available protocols in the network environment. In the subsequent sections a brief overview of these protocols is given, attention is also paid to the position of these protocols to the OSI network model as well as the extendibility of some of these protocols. As our accounting system must be optimal in the WAN environment rather than for LANs (see par 1.1) LAN and MAN based protocols like Fast Ethernet are not discussed in more detail.

2.5. TCP/IP

Overview

The TCP/IP protocol suite was developed in the late 1970s and is the protocol that is currently in use on the Internet and the World Wide Web extension thereof. Due to the exponential growth rate of the Internet, this protocol is already widely in use and seems to be moving into the LAN environment as well with the establishment of Intranet technologies.

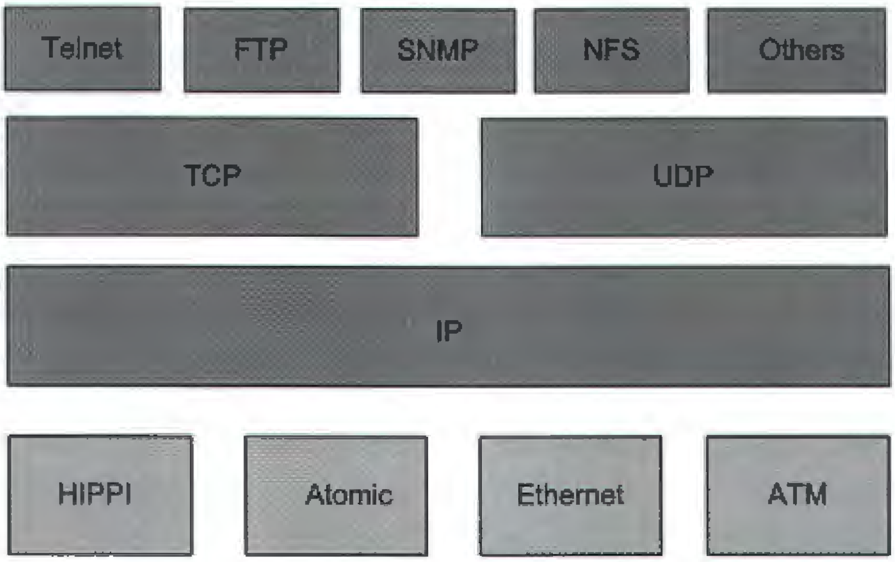


Figure 2-2: TCP/IP Protocol Architecture [adapted from TCP94, p 1-8]

At the core of the TCP/IP suite lies the Internet Protocol (IP) which offers a best effort delivery service between hosts connected to a TCP/IP inernetwork. On top of IP two well known (and a number of less well known) protocols called User Datagram Protocol (UDP) and Transmission Control Protocol (TCP) are implemented. These protocols provide reliable (TCP) and unreliable (UDP) data transfer services on top of IP [Par94, P 227].

IP hosts are identified by a 4 byte IP-address that is typically written as four separate decimal numbers separated by dots (i.e. 155.237.91.1). This address is normally split into a network, subnetwork and host identifier. IP makes use of a special address in order to support multicasting. As TCP does not support reliable multicasting this function is implemented by means of UDP.

In order to support a reliable service (described by [Par94] as *the in order delivery of a stream of bytes*), TCP requires that the TCP module at the host confirms correct reception of each segment of a message. If confirmation is not received before a certain time-out limit, the segment is resent. Flow control is done by means of a sliding window, with the window size indicating the amount of segments that may be outstanding during a particular time. Segments are also numbered in order to uniquely identify them. To ensure correct delivery each segment also caries a checksum.

Mapping TCP/IP to the OSI Model

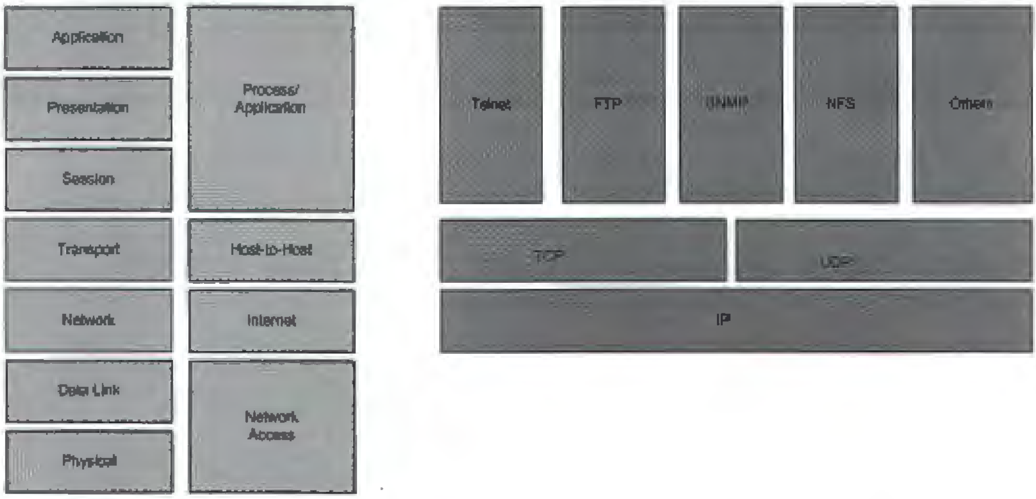


Figure 2-3: TCP/IP and the OSI model

The TCP/IP suite was developed about a decade before the OSI model, as such it maps better to it's own four layered model, however it can be roughly mapped to the OSI model as indicated in Fig 2-3..

Scalability to higher transmission speeds

Jacobson has indicated that TCP/IP can be adapted to run at Gigabit speeds, [Par94] mentions that Cray's standard TCP/IP has been measured at 790 MB/s. These adaptations should include:

- Better lookup techniques: the idea is to use lookup techniques with fast running times and use caches wherever possible.

- Reduced Checksum costs: faster checksums can be made by using a native word size, by using trailing checksums or even leaving the checksum out.
- Prediction: As TCP behavior is highly predictable, the TCP codepath can be optimized accordingly rendering better performance for the average case
- Increasing the data in flight: By increasing the window size to correspond to the product of a networks delay and bandwidth (with a corresponding increase in the sequence number size), bandwidth can be used optimally.

Given these possible extensions, TCP/IP should be fast enough last into future network environments. However, it still does not supply performance guarantees regarding delay or bandwidth. A problem when implementing an accounting scheme on top of this protocol, is that it would be difficult to implement in non routing network devices (i.e. switches that does not perform level 3 switching).

2.5.2. FDDI

Overview

Fiber Distributed Data Interface (FDDI), is a set of standards that was developed by Task Group X329.5 of the ANSI Accredited Standards Committee [Jai94]. FDDI uses a timed token access method to access a dual ring topology at 100 Mb/s. (Although a logical ring is used, the physical topology can be a star, or a ring.) This kind of network makes provision for up to 500 stations connected no more than 2 km apart to fiber that can be up to 200 km in total length for a single ring. FDDI uses a point to point connection type with baseband signaling.

The FDDI protocol makes use of packets called frames. The maximum length per packet is 4500 bytes, ignoring headers and trailers, the available space for data is in the order of 4096 (4k) bytes. These frames can be transmitted by means of synchronous or asynchronous traffic schemes. Normally synchronous traffic will be used for delay sensitive packets, i.e. video and asynchronous for traffic that is less sensitive in this regard i.e. data.

In order to make provision for high priority traffic during asynchronous communication up to eight priority levels have been defined. Due to a scheme based on token rotation time, only higher priority traffic will be transmitted during periods of high load.

FDDI uses fully distributed algorithms for fault recovery, clock synchronization and topology control. Due to this factor, the rest of the network will detect if a certain station has failed, and will attempt to continue operation without it. One method that

FDDI uses to increase fault tolerance is by unfolding the dual ring topology, into a logical bus in case of an error on the ring. This is done by using a dual attached station (DAS) to redirect the traffic around the problem. DASs can also be used to supply load balancing between the two bi-directional rings.

Mapping FDDI to the OSI model

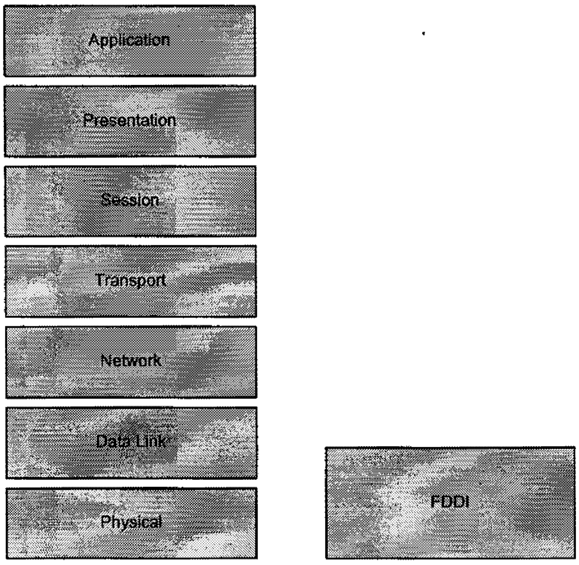


Figure 2- 4: FDDI and the OSI Model [NT94, P 13-61]

FDDI is normally considered to be a WAN protocol although it is usable in the MAN and even LAN environments.

This protocol includes Physical and Data Link-MAC specifications. This makes it similar to Ethernet, Token-Bus and Token Ring in it's relationship to the OSI model. As in the case of these protocols it assumes that it's services will principally be used by IEEE 802.2 (LLC), although it does not exclude the use of other upper-layer protocols.

Scalability

In [Jai94] Jain point out that the ring topology of FDDI allows it to be scaleable to even higher speeds than 100 Mb/s. He points out that increasing the speed in an Ethernet environment form 10 to 100 Mb/s will have a serious detrimental effect on the network's efficiency (because the collision window increase from 64 to 640 bytes) while the effect on a ring topology will be much less noticeable. Another advantage in the case of FDDI is that the access delay is bounded, as such it should be possible to extend the protocol to provide service guarantees.

2.5.3. X.25

Overview

The X.25 protocol stack was defined by the CCITT (now ITU) in 1974. This protocol is designed specifically for attaching computers to packet switched networks. The X.25 Datagram protocol was dropped in 1984 making end to end error control mandatory for X.25 applications.

X.25 makes use of a point-to-point connection type to send synchronous traffic over a Mesh/Hybrid topology. It uses packet switching over virtual circuits with LLC and network layer flow control. Addressing is done on a channel basis with addresses maintained per connection [NT94 p 13-64].

The protocol makes provision for both permanent and switched virtual circuits. Data Terminal Equipment (DTE) on X.25 can handle multiple virtual circuits simultaneously. The also provide end to end flow and error control.

The X.25 architecture defines three layers. Layer one gives physical connectivity over X.21, V.32, etc., while level two gives the methods for providing the connection orientated data path. This is done over Link Access Procedures-Balanced protocol (LAPB). Level three defines the interface between the data terminal equipment (i.e. computers) and the data circuit terminating equipment (the network). X.25 does not make provision for the definition of routing algorithms, but instead leaves that to the vendors to implement [NT94 p 13-64].

In South Africa national X.25 connections are available from Telcom at various transmission speeds.

Mapping X.25 to the OSI Model

X.25 and its supporting protocols can be mapped to the lower three layers of the OSI model. X.25 itself can be seen to fit into the Network layer and upper part of the Data Link layer.

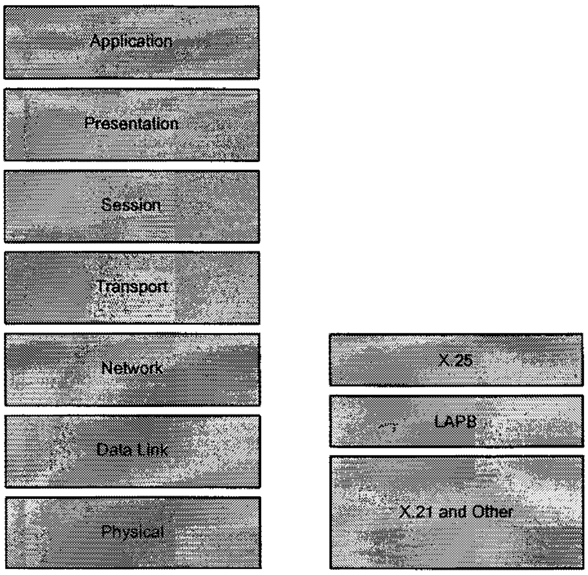


Figure 2-5: X.25 and the OSI model [NT94 P 13-63]

2.5.4. Frame Relay

Overview

Frame relay is defined by ANSI and the ITU. Frame relay is a type of public data network service, as well as a protocol. It provides data link functions on switched or permanent virtual circuits. Frame relay falls into the same family as X.25, and is also (like X.25) aimed at the WAN environment.

Frame relay uses a point to point connection type on a mesh / hybrid topology. Switching is done on packets using virtual circuits. LLC-level flow control is used with Error detection (not recovery) also supported. Normal bit rates vary from 56 Kb/s to 1.544 Mb/s.

An interesting feature of Frame relay is that it offers a crude type of performance guarantee in the form of a committed information rate (CIR). A CIR indicates the minimum capacity that a user will receive from the vendor for a particular virtual channel. As such a user leasing a 64 Kb/s CIR from a vendor is guaranteed of at least 64 Kb/s, but may be able to get a better transfer rate at times when the network is less congested [NT94 p 13-66].

Mapping Frame Relay to the OSI model

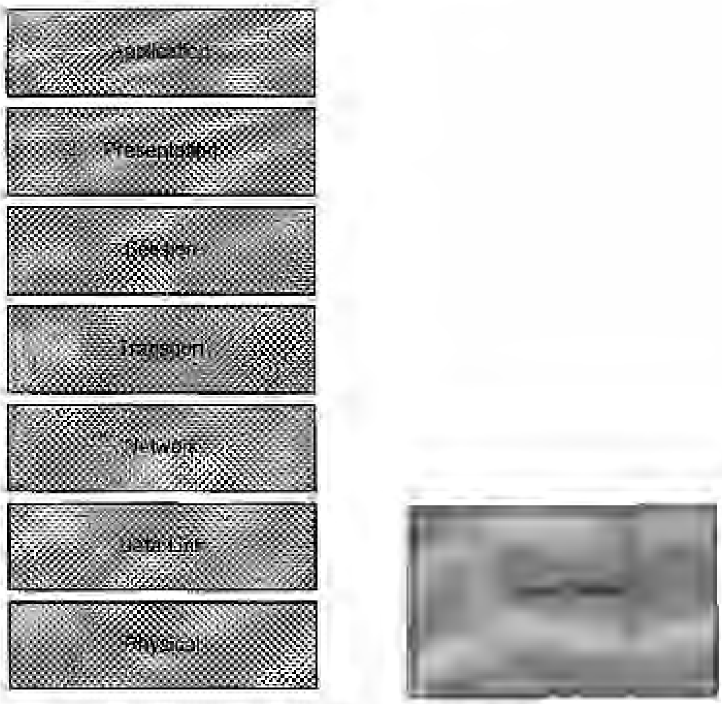


Figure 2-6: Frame Relay and the OSI Model

Frame relay supports the bottom two layers of the OSI stack, as such it can be mapped directly to the Physical and Data Link layers of this model.

2.5.5. ISDN

Overview

In order to provide a standard approach to integrate voice and data on digital telephone networks the ITU has specified Integrated Services Digital Network (ISDN). This standard was later upgraded to use multiples of 155 Mb/s on optic fiber (ISDN uses 64 Kb/s), the enhanced version is known as Broadband ISDN (B-ISDN).

ISDN requires converting the analog telephone network to a digital based network in order to send both digital data and telephone signals over the same media. Thus ISDN provides standards for the integration of digital and analog signals using digital networks. [HMS94, p16]

ISDN uses TDM for multiplexing on the physical layer. Addressing is done per physical device on the data-link-mac layer. ISDN uses packet switching and provides LLC-level flow control and frame sequencing. ISDN can be used for circuit switched or packet switched connections.

Users can access several standard rate multiplexed digital channels known as bit pipes. These pipes are available as:

- Channel A : 4 KHz analog
- Channel B : 64 Kb/s digital
- Channel C : 8 or 16 Kb/s digital for out of band signaling
- Channel D : 16 or 64 Kb/s digital for out of band signaling
- Channel E : 64 Kb/s digital for internal ISDN signaling
- Channel H : 384, 1536 or 1920 Kb/s digital

Mapping ISDN to the OSI

Normal ISDN and B-ISDN can be mapped to the lower layers of the OSI model (Transport to physical). In order to provide acknowledged, connectionless, full duplex services on the data link layer, the ISDN specifications includes the LAPD protocol for use by the ISDN Channel D.

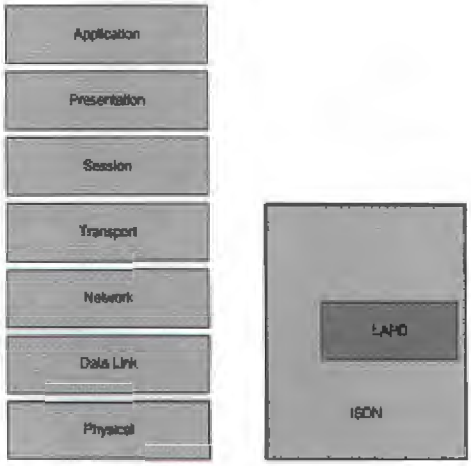


Figure 2-7: ISDN and the OSI Model [NT94 p 13-67]

2.5.6. SMDS

Overview

Switched Megabit Data Service (SMDS) is a data link layer standard defined by Bell Communications in 1991. Some sources [NT94 p 13-72] see this protocol as a precursor to, or even a type of ATM. SMDS is normally a MAN or WAN based protocol.

SMDS is a connectionless data link layer protocol that can be implemented on DQDB SONET. It performs cell switching using Isochronous transmission synchronization, bit rates varies between 1.544 and 45 Mb/s.

Mapping SMDS to the OSI model

SMDS is designed to be implemented on top of DQDB, SONET or SDH, as such it does not extend to the physical layer, but can be mapped to the upper portion of the data link and the network layer.

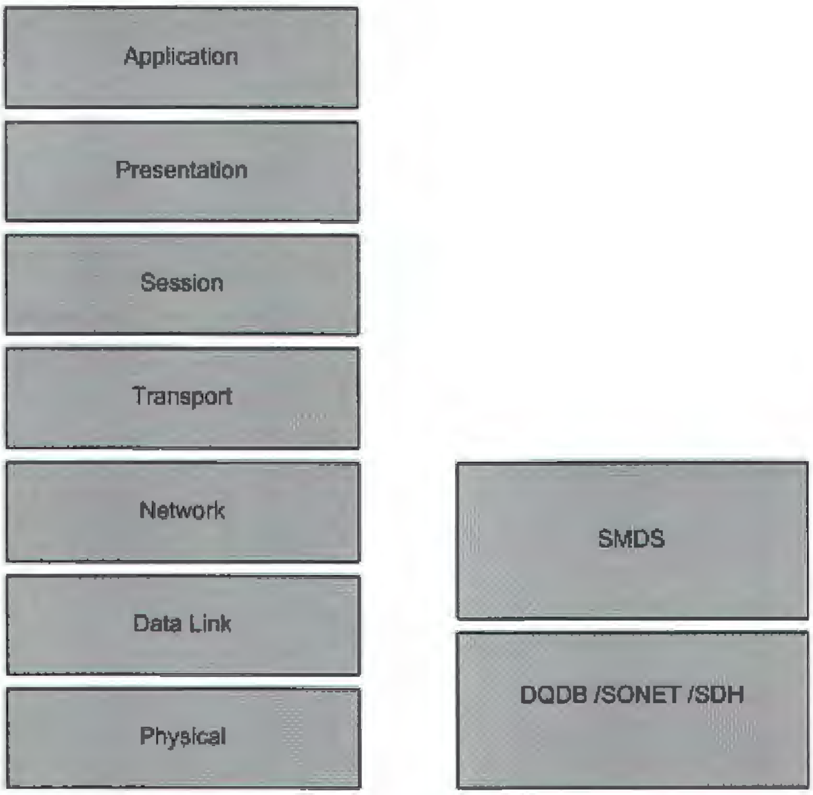


Figure 2-8: SMDS and the OSI Model [NT94 p 13-72]

2.5.7. SONET/SDH

Overview

Synchronous Optical Network (SONET) was designed by Bell Communications in 1984 and later accepted by ANSI. The ITU generated a similar specification called Synchronous Digital Hierarchy (SDH) in 1988. Due to regional differences however these standards were adapted for various geographical locations. This resulted into SDH-Europe, SDH-Japan and SONET (in use in North America).

SONET and SDH provide specifications for physical services in a WAN environment. SONET/SDH uses point to point connections in a MESH or Ring physical topology. TDM is used for multiplexing [NT94 P 13-75]. SONET and SDH can be used as physical layer specifications on which FDDI, DQDB and ATM can be based.

SONET can use various data rates, specified as STS/OC designations:

OC 1	51.84 Mb/s
OC 2	155.52 Mb/s
OC 3	622.08 Mb/s
OC 24	1 244.16 Mb/s

These rates differ between the North American and European regions due to difference in standard data rates provided by service providers in these regions. OC rates are used in North America while the CCITT have specified an STM designation with STM-1 = OC-3 [Par94 P 29].

SONET sends data in frames. Each frame is seen as a two dimensional block of bytes, consisting of 90 columns and 9 rows. For a given OC rate the unit of transmission is the corresponding amount of frames, i.e. OC-3 handles three frames at a time.

Mapping SONET to the OSI Model

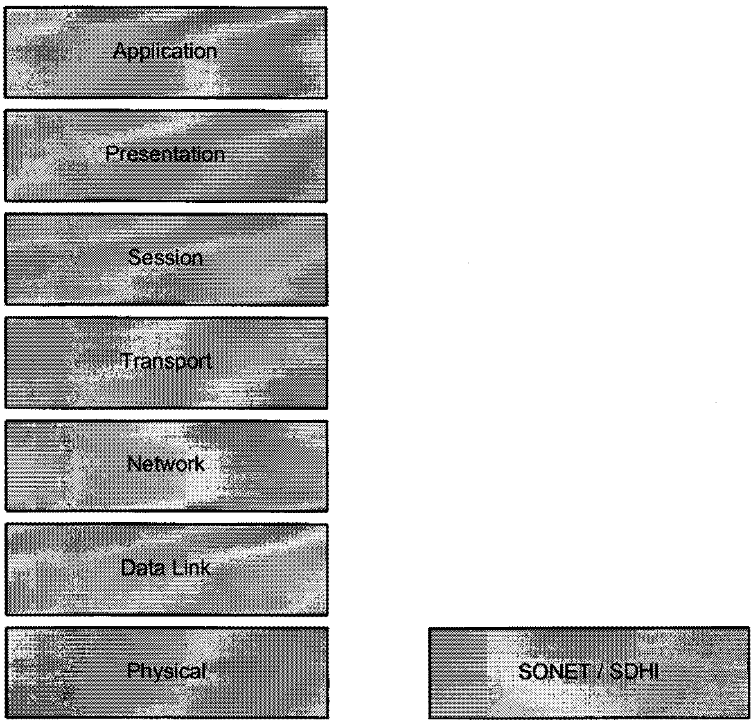


Figure 2-9: SONET and the OSI Model [NT94 P 13-75]

2.5.8. ATM

Asynchronous Transfer Mode (ATM) is a standard that is being evolved from the B-ISDN and cell relay networking protocols by the ITU's Telecommunications Standards Sector (TSS) and the ATM Forum.

ATM is entering the market as a WAN protocol but it is considered usable in the WAN and LAN environment as well. ATM uses fixed size packets (53 bytes with a 5 byte header [Par94 p 65]) called cells to render a scaleable network service to both the telecommunication and datacommunication environments.

As it's name implies ATM uses isochronous transmission. Static routing is used with a connection orientated approach. Virtual pipes are used to manage these connections in a hierarchical manner, these can be subdivided into virtual paths and virtual channels.

Although the specifications of ATM spans the bottom three layers of the OSI model, ATM can use SONET, SDH or FDDI at the Physical layer. This enables the ATM protocols to operate in a media independent manner, which in turn enables it to be rate independent from the physical level upwards.

In order to group the types of applications that can run on the upper layers of an ATM network, the ITU-TSS has defined a number of standards called the I-series [NT94 p 13-71]. These standards, identifies a number of classes of service for upper layer protocols:

- Constant bit-rate traffic
- Variable bit rate delay sensitive data
- Connection oriented data
- Connectionless data

Each of these classes is meant to be optimized for a different type of data stream (i.e. video over the constant bit rate, etc.). In order to interface between these upper layer protocols and the ATM layer, an ATM adaption layer protocol (AAL) is used. Initially four AALs were defined, one for each of the above mentioned classes. A fifth AAL were later defined, both as an enhancement and a simplification to the AAL 3/4 combination.

Mapping ATM to the OSI model

ATM can be mapped to the bottom three layers of the OSI model. The protocol can operate on top of various other physical layer standards (i.e. FDDI, SDH and SONET). By means of the AALs it is also possible for a number of top layer protocols to run on top of ATM. Internally ATM is subdivided into three layers:

- The ATM adaption layer
- The ATM layer
- The Physical layer

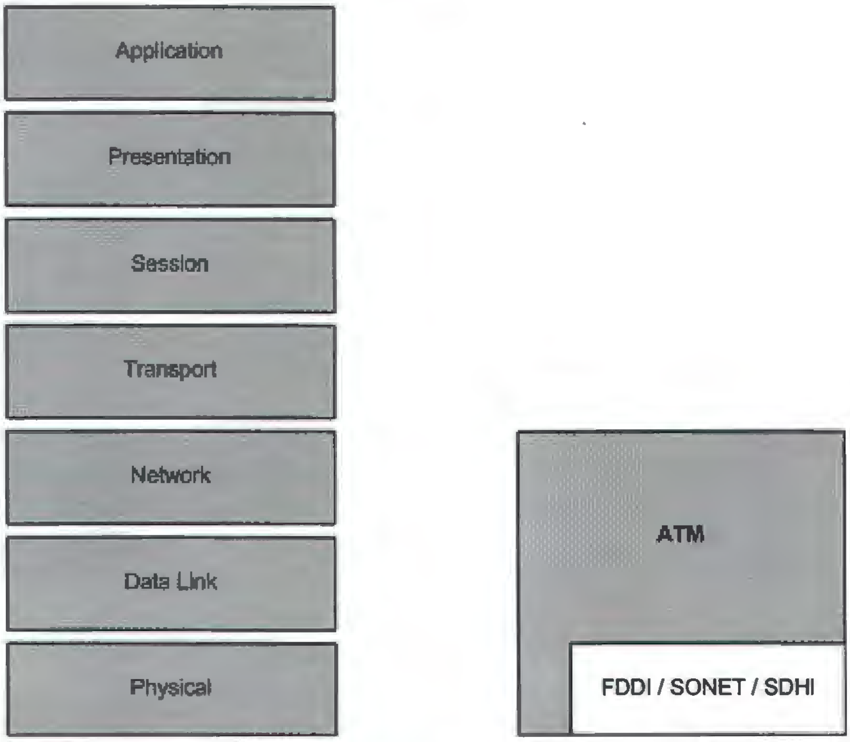


Figure 2-10: ATM and the OSI Model

Scalability

One of the strong points of ATM is that it's supported bit rates are already scaleable. As such ATM can be scaled into the Gigabit range as and when required. Partridge [Par94 p 61] mentions that the current ATM standards (in North America) already make provision for users to access the network at speeds of up to 622 Mb/s. (A number of switch manufacturers providing ATM switches (i.e. Hughes) already boasts an ATM bit rate well within the Gigabit range on their hardware backplanes.)

2.5.9. Other protocols

In [Par94] Partridge discuss various other high speed protocols, like ATOMIC, HIPI, DQDB, etc. However, it is the intention that the work done in this study should be of practical value after completion. Thus the discussion regarding protocols in this section will be limited to those that are most prevalent in the industry today (or perceived to be so in the near future). As such these *other* protocols will be seen to fall outside the scope of this study.

2.5.10.The complete protocol picture

In the previous sections a number of protocols have been discussed. These protocols have been shown to vary regarding speed (bit rates) as well as application area. Some of these have been pointed out to fit better into a MAN/WAN and others better into the WAN/Internet environment, they were also shown to map to various levels of the OSI model.

In [Ben94 p 10] the following summary of protocols, their bandwidth and application area is given:

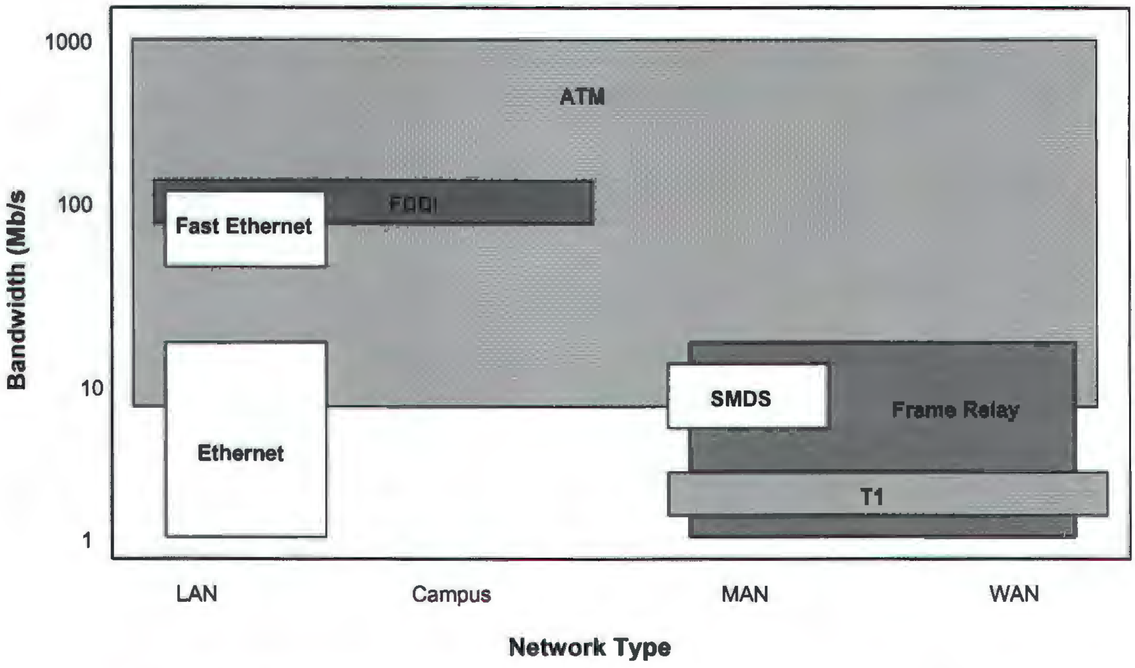


Figure 2-11: Protocols vs Network Type

Partridge points out that there is more than one way to view ATM. These views vary from seeing ATM as just another network service to seeing it as a protocol in its own right. An interesting point of view is discussed in [Par94 p 86], describing ATM as a service that replaces bits on a wire with cells on a wire.

When ATM is viewed as a protocol in its own right, it also implies that it can be combined with other protocols in the networking environment. This is exactly what some of the Internet Engineering Task Force's working groups have noted, i.e. the IP over ATM Working Group. This group is developing ATM internetworking architecture models in order to define the IP over ATM protocols.

In [HMS94 p 19] the advantages of using ATM over fiber are pointed out, [NT94] also points out that one way to do this is to use SONET on the physical layer. Once again this will imply a combination of protocols.

It is also pointed out in [Ben94 p 25] how ATM can be made to emulate normal Ethernet LAN technology (for the sake of existing legacy devices) by means of LAN emulation (LES).

Given the speed, scalability and media independence of ATM, the growing popularity and increasing use of TCP/IP as well as the expected migration of the telephone community to SONET, a protocol stack consisting of the combination of these may be particularly successful.

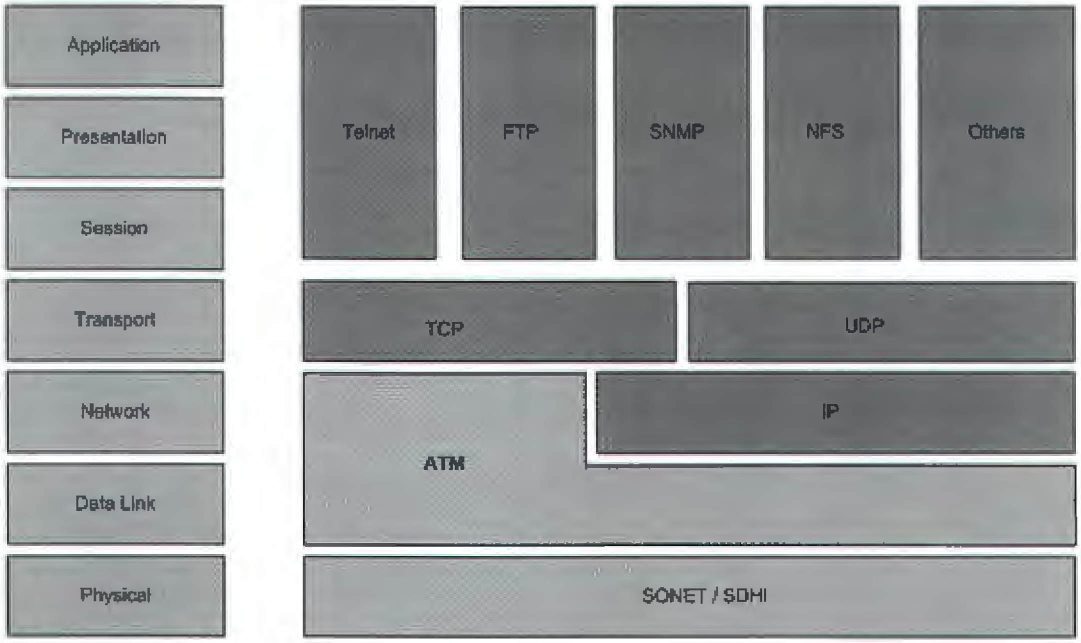


Figure 2-12: Combination of protocols

2.6. High speed networking devices

When considering a high speed networking protocol that is to operate in the WAN / Internetwork environment, the network devices deployed on such a network is bound to have an effect.

To date, a number of devices has been deployed in networks, these varies from repeaters to gateways, each performing a specific function:

- Gateways: This is a device that connects dissimilar networks and performs a high level of protocol and representation translation during the transfer from the one network to the other.

- Routers: A device that connects similar or dissimilar networks together and performs redirection of messages on the network layer by means of internetwork address comparisons.
- Bridges and Switches: A device that operates on the data link layer. It connects networks of a similar type. It performs filtering and redirection of messages based on the MAC addresses that it has observed on various segments of the network.
- Repeaters, Hubs and Media converters: These devices operate on the physical layer. A repeater is used to connect two wire segments in such a fashion that they appear to be one logical segment. This is done by regenerating traffic, observed on one segment, onto the next.

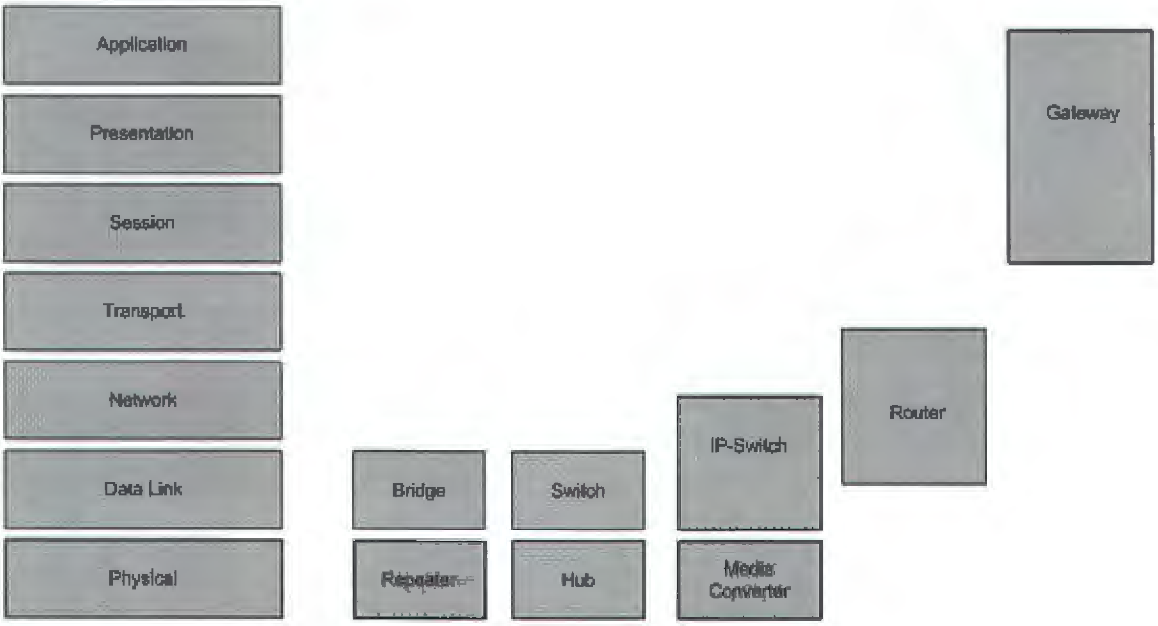


Figure 2- 13: Network Devices and the OSI

A number of hybrid devices have also been developed. These includes devices like routing, bridges (brouters) as well as switches which can do IP switching. A recent addition to these is a router switch combination, consisting of a single port router linked to a port on a workgroup switch, this solution seems to be aimed specifically at the Intranet market.

Another interesting combination is the IPX/IP gateway that has recently been released. This gateway allows multiple LAN users to share a single TCP/IP address over IPX. It also provides filtering of TCP/IP traffic between a LAN and the Internet.

Bearing in mind that our proposed accounting scheme is aimed at the WAN/ Internet environment, it should obviously take devices that are commonly found in these environments into consideration. Normally devices like repeaters and hubs are not found in the WAN /

]

Internet environment, although they are not completely restricted to LAN applications. Most Internetwork environments are managed by means of routers. Until not to long ago this has also been the case in the WAN environment recently however a number of these routers have been replaced by backbone switches.

This utilization of routers and switches in the WAN / Internet environment implies that whichever protocol we choose for implementation of the proposed accounting scheme, must be able to operate on the network and data link layers of the OSI model.

2.7. Accounting in a high speed networking environment

Given the discussion above regarding network protocols and devices, we are now in a position to motivate the choice of ATM as an underlying protocol for the network accounting scheme. In order to validate the choice, the following criteria should be born in mind:

- The protocol must be able to handle performance guarantees;
- It must be acceptable to the IT and networking market;
- It must be usable in the WAN/Internet environment;
- It must be scaleable to Gigabit speeds.

When considering the network protocol to hardware interface, it is obvious that the protocol in question should also make provision for accounting across interfaces like:

- routers
- switches
- switch-router combinations (i.e. the IP switch)

As far as switches are concerned, this means that it must be possible to implement the protocol in silicon, as many new generation switches have moved away from RISC based to ASIC based systems.

Based on these considerations, the ATM protocol seems the best suited to the task in hand. As such, it will no doubt be relevant to have a closer look at this particular protocol. This is done in chapter three.

2.8. Summary

In this chapter it was indicated current mature and stable, but slow network technologies will no longer be sufficient to render a usable network service. As such, newer, high speed networking technologies should be considered in order to cope with the ever increasing demand in bandwidth. It was also pointed out that this technology will include high speed protocols like ATM as well as high speed networking devices like switches. These were briefly discussed in order to aid the discussion in following chapters regarding the proposed Network Accounting System, which makes use of these protocols and devices.

Chapter 3

ATM Protocols

3.1. Introduction

In the previous chapter a general overview of the high speed networking environment was given. In this chapter we concentrate on Asynchronous Transfer Mode (ATM).

Benham [Ben94 p1] points out that ATM is changing the way we think about traditional data- and telecommunications. Although ATM started off in the telecommunications industry, it's application to data communication networks is fast surpassing that of pure telecommunications [Par94]. In support of [HMS94], Benham also mentions that ATM has started off as just another method of moving data across B-ISDN networks, but that it has since developed into a core network protocol, giving a uniform method of transporting, multiplexing, routing and switching all types of traffic at unprecedented speeds.

3.2. Defining ATM

Partridge [Par94 p 63] and [HMS94 p 16] indicate that Asynchronous Transfer Mode is a connection-oriented, cell-based hierarchical, network technology which is rate and media independent.

In order to clarify this definition, each of the separate terms is discussed briefly:

3.2.1. Asynchronous

In [HMS94] *asynchronous* is explained to refer to the irregular recurrence pattern which may be displayed by cells belonging to the same connection, when viewed within the context of multiplexed transmissions.

This situation can best be explained by means of a diagram, as seen in Fig 3.1. The Synchronous transfer mode only makes provision for the use of a specific slot (in a time referenced scale) by a specific channel. This is not the case in ATM where multiplexing and switching of cells are done independent of the application itself.

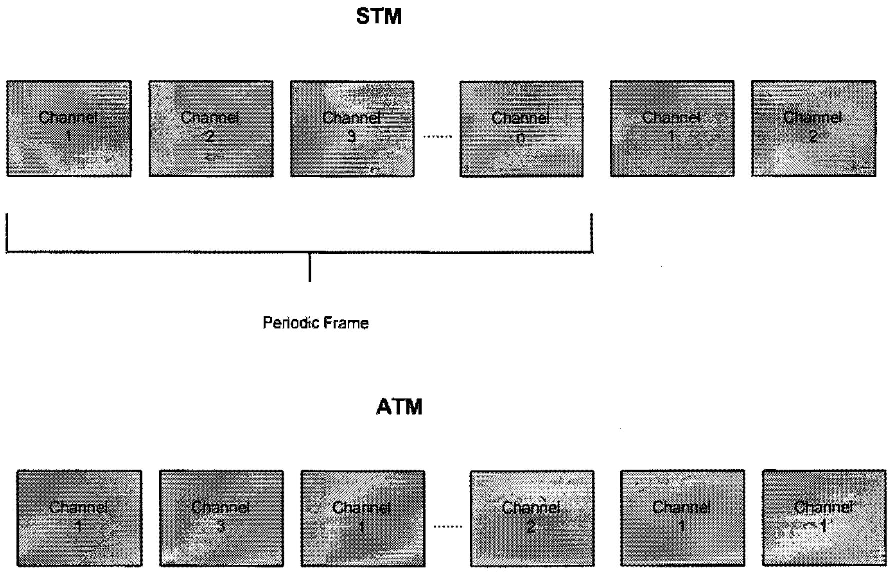


Figure 3- 1 : STM vs ATM ***adapted from [HMS94 p 17]***

3.2.2. Transfer

The term *transfer* is seen to include both transmission and switching perspectives. As such [HMS94, p 16] defines a transfer mode as a specific way of transmitting, switching and routing of information in a network.

3.2.3. Connection-oriented

Handel describes ATM as a circuit-oriented hardware controlled concept of virtual channels. Being *connection oriented* this implies that the hardware/software at two stations must first set up a connection between the two of them before data transfer can commence. An ATM connection will specify the transmission path on a per hop basis, but also allows cells to self route through the larger ATM network during connection setup.

In [Ben94 p 8] it is pointed out that the connection oriented nature of ATM allows the protocol to only allocate bandwidth when a connecting station requests it. This together with the flow spec used during the request makes it possible to render service guarantees for each connection.

3.2.4. Cell based

ATM uses fixed size packets, called cells, for the transmission of data. Each cell consists of 53 bytes, this includes a 48 byte data and a 5 byte header section. The data section is available to users, while the header is used for ATM specific functionality [HMS94 p 17] like identification, control priority and routing information.

According to Partridge [Par94 p 49] as well as [Ben94 p 8] the use of cells has the advantage that it:

- provides easier support for multicasting,
- offers better multiplexing schemes,
- allows the mixing of various types of traffic due to low latency per cell and
- allows for user access at scaleable data rates.

3.2.5. Hierarchical

This indicates the structure of the network itself. Partridge foresees that ATM networks will be structured in a similar manner to the current hierarchy in the telecommunication networks. Thus, a user's computer may be connected to a regional ATM provider who in turn will be connected to the National provider who will be connected to the International provider.

This structure is also incorporated in the manner that connections between networks and network equipment are done. As such, the method used will vary, depending on the position of the connecting point in the hierarchy. ATM user equipment will thus connect to the network by means of a user network interface (UNI) while networks will connect by means of a network to network interface (NNI) [Par94 p 63].

3.2.6. Rate and media independence

By definition, the ATM protocol is not set to work only at a specific data rate (like Ethernet) or over a specific media type (like FDDI). Due to the fact that it can use various other protocols at the data link layer, ATM can run at data rates compatible to these types over media supported by them. This makes ATM implementations independent of a specific data rate or media type.

3.3. ATM protocol description

3.3.1. The ATM layered Architecture

In the previous chapter it was already mentioned that ATM consists of a three layered structure (ATM Adaption Layer, ATM layer and Physical layer) which maps to the bottom three layers of the OSI model.

Benham mentions that the AAL and Physical layers can both be further subdivided into two sublayers each. In case of the AAL the sublayers are the Convergence

Sublayer (CS) and the Segmentation and Reassembly sublayer (SAR). The Physical layer in it's turn can be subdivided into a Transmission Convergence (TC) part and a Physical Medium Dependent layer (PMD).

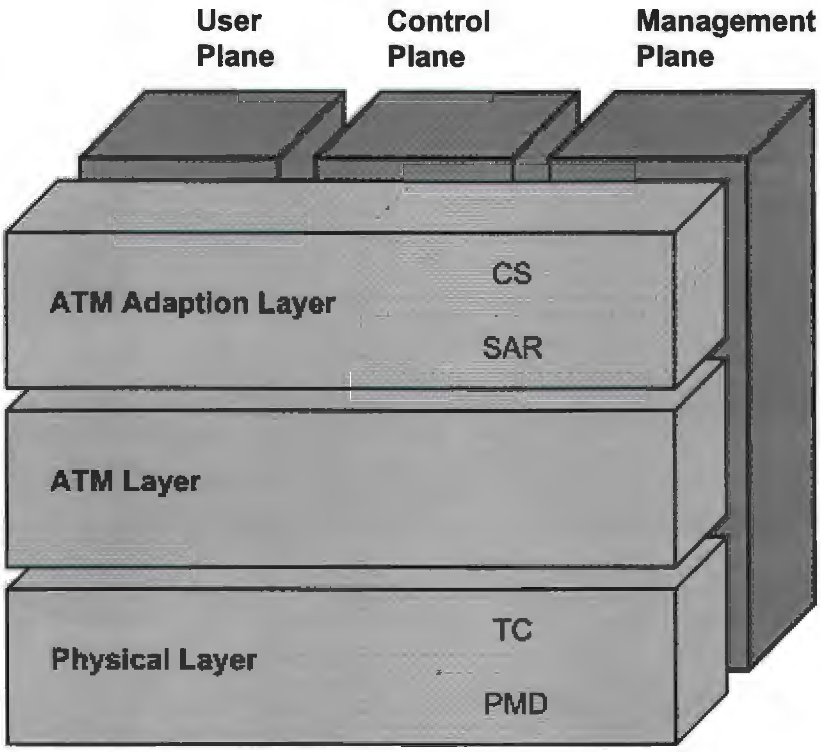


Figure 3- 2 : ATM architecture

In [Ben94 p 34] Benham indicates that except for layers the ATM model can also be seen to include a number of planes, rendering functions that span all the layers in the architecture model. These are the User Plane, the Control Plane and the Management Plane.

The Management Plane offers network management functionality for both the network and endpoints. The Control Plane grants network wide control signaling (i.e. the signaling used to set up Switched Virtual Circuits (SVCs) between endpoints. The User plane's function is to render end-to-end data transfers.

3.3.2. ATM physical layer functions

The main function of the ATM physical layer is to define characteristics specific to the physical medium (i.e. bit timing) and to pass the cells from this media to the ATM layer and the opposite.

To make ATM media independent it was necessary to segment the physical layer into two sublayers. That part of the physical layer functions that are independent of the media in use, is done on the TC layer, while the media dependent functions are handled on the PMD layer.

Each PMD is aimed at a specific type of physical medium. The PMDs include standards for bit timing as well as proper cabling specifications. From this sublayer upwards the ATM functions are implemented in the same way regardless of the medium used. According to Benham [Ben94], PMD layer definitions exist for optical fiber, Cat-3 and Cat-5 UTP.

The TC sublayer fulfills a convergence function, this is done by extracting (delineating) cells from the bit stream presented to it by the PMD. To do this, the Header Error Control (HEC) field in the ATM header is used. Other functions of the TC layer include the adaption of the ATM layer cell stream to the cell rate of the physical layer, as well as error checking by testing the HEC fields.

3.3.3. ATM layer functions

The ATM layer is responsible for the transmission of cells between itself and the ATM layer of other network devices. It communicates with these *other* ATM layer agents through the 5 byte ATM header.

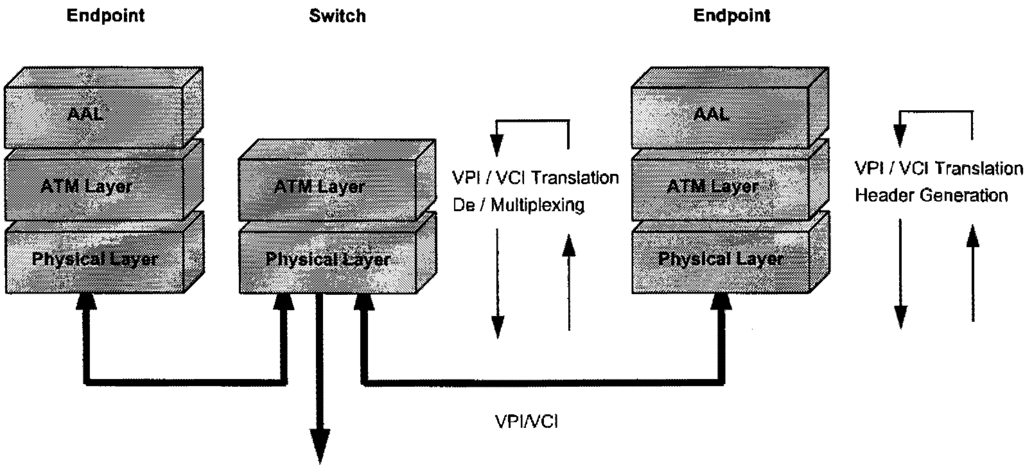


Figure 3- 3: ATM Layer in operation (Adapted from Ben94])

Benham, [Ben94 p34] gives the main functions of the ATM layer as:

- Cell header generation / removal

- Switching

Switching can be seen to include functions like:

- VPI/VCI address translation
- Cell multiplexing / de-multiplexing

Each of these functions will be discussed in more detail in the paragraphs below, (although not in the exact same order as mentioned above).

It should be noted that the extent to which these functions are executed varies from one type of network device to the other.

For instance, in a switch the cells will be multiplexed between the various switch ports, also the VPI/VCI pair on the incoming port will be compared with the switch's table and translated to the new VPI/VCI pair for the correct outgoing port. It is also this layer's function to stop the misordering of cells on the same virtual circuit, to provide buffer space and to do traffic policing.

In an ATM endpoint however, the emphasis falls on cell header removal and generation instead. In this case the ATM layer will be transferring data from the higher layers to the Physical layer. As part of the transfer from the AAL to the ATM layer, the ATM layer will generate a header for each cell, or strip the header in case of an ATM Layer to AAL transfer. The ATM layer will then exchange this stream of cells with the physical layer, idle cells will be sent in cases where there are no data to be transferred from the AAL.

VPI/VCI Translation

In [HMS94 p 23] the ATM layer is seen to consist of two hierarchical levels, being the topmost, Virtual channel (VC) with the Virtual Path (VP) level below that. These run on top of the Transmission path level (seen by HMS94) as the topmost level of the Physical layer.

In figure 3-4, a VP is seen as a pipe running between ATM nodes, each VP can be seen to house several VC's. These VPs and VCs are identified by means of unique identifiers, called the Virtual Path Identifier (VPI) and the Virtual Channel Identifier.(VCI) respectively. These identifiers are included in the cell headers in order to facilitate switching and routing of ATM cells.

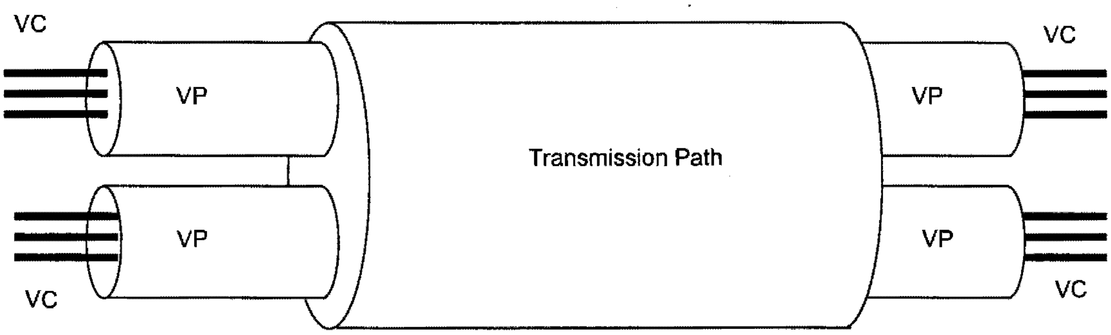
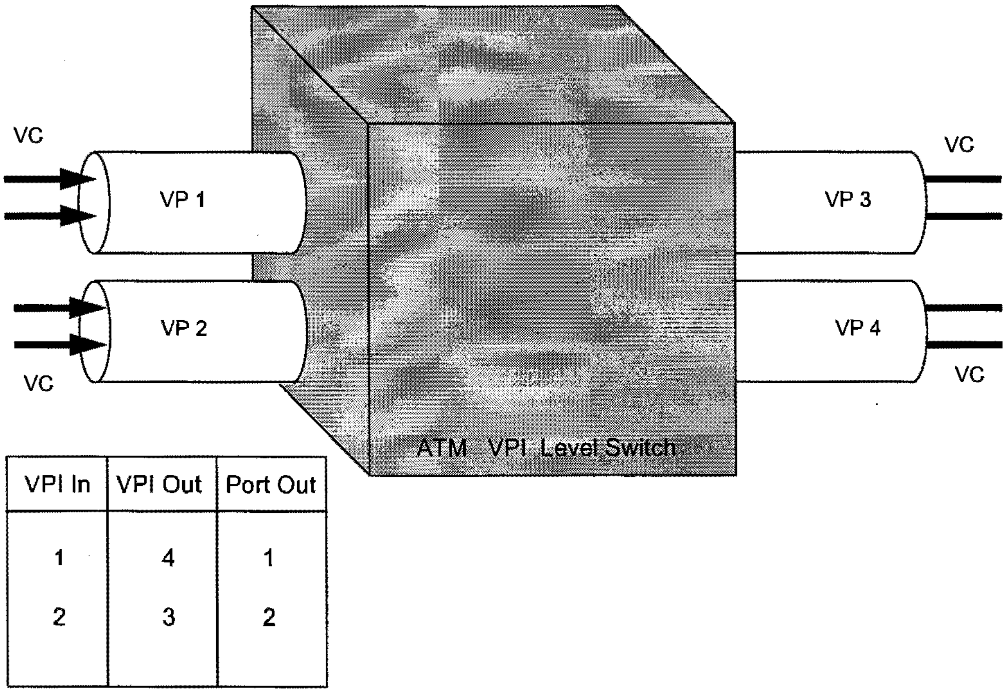


Figure 3- 4 : VPI and VCI [HMS94]

Partridge [Par94 p 52] explains that the source routing method leads to a large path identifier in the cell header. The solution to this problem is to make the path identifiers (i.e. VPIs and VCIs) unique on a per-hop-only basis instead of on a per network basis.

This approach makes it possible to use the VPI and VCIs as an index to a routing or switching table. As partridge points out, it is now sufficient to keep a routing / switching table per port or per switch, it is also not necessary to include the complete path in the cell header as these tables will allow a cell to auto-route through the network.



VPI In	VPI Out	Port Out
1	4	1
2	3	2

Figure 3- 5 : VPI translation inside an ATM switch (adapted from [HMS94])

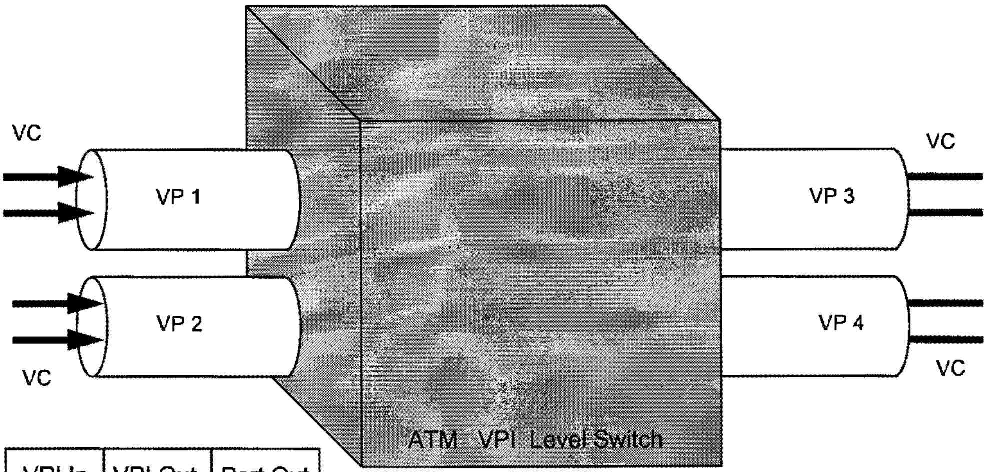
In figure 3-5 an example of such a switching table can be seen. It should also be clear how VPI level switching can be done based on such a table. In a similar manner, it is also possible to do VCI switching, or a combination of VPI and VCI switching.

These switching tables need to be set up during connection setup, and the values inside the cell headers need to be translated when changing from hop to hop. Both these functions lie with the ATM layer protocol.

Multiplexing / de-multiplexing

In figure 3-5, a simple *cross over* operation is performed (referred to by [Pry95] as space switching). It is however also possible to find situations where a multiplexing or de-multiplexing operation needs to be performed (see fig 3-6).

It is important to note that the streams of cells in an ATM network may not be reordered (by definition). The operation above may require two cells arriving at different ports of a switch (at the same instance of time) to be routed to the same outgoing port. This implies that a certain amount of buffer space may be needed in order to buffer the input of one of these ports until the outgoing port is available.



VPI In	VPI Out	Port Out
1	3	2
2	3	2

Figure 3- 6 : Multiplexing in an ATM switch

In [Pry95] de Pryker categorizes ATM buffering during switching into three different types:

- Input queuing

- Output queuing
- Central queuing

These types each use a different stage of the switching process as its target for buffering (as the name implies).

Cell header generation / removal

As mentioned above, the ATM layer is also responsible for the generation and removal of cell headers. These headers are always 5 bytes in length, but the contents vary slightly depending on the type of interface used.

As seen in par 3.2.5 ATM makes provision for the use of a Network to Network Interface (NNI) as well as a User to Network Interface (UNI). The headers for these interfaces differ only in the first byte, where the UNI defines a four bit Generic Flow Control (GFC), which has been left out in the case of the NNI. In the NNI this space is available for the VPI field, allowing a greater number of Virtual Paths. The exact layout of these headers is given in fig 3-6.

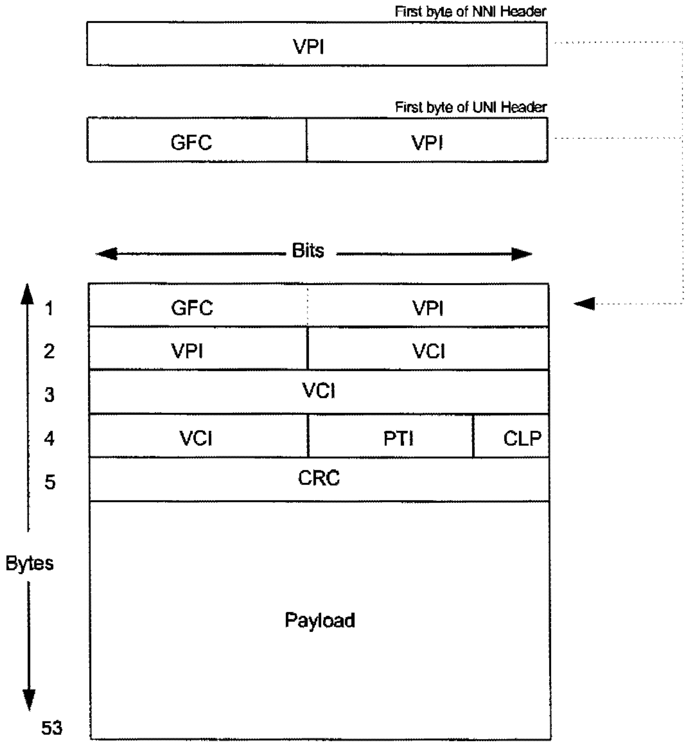


Figure 3- 7 : ATM Header

The function of the header fields are defined by [Ben94 p 35] and [Par94 p 70] as:

- GFC: This field allows the UNI to negotiate with shared access networks regarding the multiplexing of the shared access network among the cells of ATM connections. This field is not available in the NNI.

- VPI: The Virtual Path Indicator, uniquely identify a virtual path on a per hop basis. This field is 12 bits for the NNI and 8 bits in case of the UNI header. In idle cells these bits are all set to zero. Benham also mentions that a number of non zero values for this field has been defined to identify cells that are used for operations administration and management (OAM) functions.

- VCI: The virtual channel identifier, uniquely identify a virtual circuit on a per hop basis. This field is 16 bits for the NNI and UNI header. In idle cells these bits are all set to zero. Once again certain non-zero values have been reserved for special purposes (i.e. VPI=0 / VCI=5 is used for signaling / connection requests).

- PTI: The three bit Payload Type identifier is used to identify the payload type of a cell. This field can also be used to identify OAM procedures. The first bit indicates a user data cell if set to 0 and an OAM cell if set to 1. In the case of user cells, the second bit indicates congestion if set, while the third is used for user signaling (i.e. by AAL 5 to indicate the end of a datagram). The bit combinations currently in use for OAM are:

100:	OAM link associated cell
101	OAM end to end associated cell
110	Resource management cell

- CLP: This single bit field indicates to devices on the ATM layer that a cell can be discarded in order to relieve congestion if set to 1. This bit can also be set by the ATM layer in order to enforce network policing, when a connection is exceeding the QoS negotiated during setup.

- CRC / HEC This field known as Header Error Correction or Cyclic Redundancy Code does error correction of 1 bit errors in the five byte header. It can also detect a large number of two bit errors. To do this a CRC method is used with $X^8 + X^2 + x + 1$ as the polynomial. This field is computed by the physical layer, which uses it for cell delineation.

3.3.4. ATM adaption layer functions

As discussed in the previous chapter ATM makes provision for different kinds of traffic. In order to interface to the higher layers the ATM Adaption Layer (AAL) provides various standards for these types of traffic.

The following AALs have been defined:

- AAL1: For constant bit-rate traffic
- AAL2: For variable bit rate delay sensitive data
- AAL3/4: For framing services on connection/ connectionless oriented data
- AAL5: A *simple and efficient* extension of AAL 3/4

To date the definition of AAL 2 has not been developed into a useable form. Each of these AALs were further divided into two sublayers [Par94 p 73] consisting of a :

- Segmentation And Reassembly (SAR) layer responsible for breaking data into cells and reassembling cells into data as well as a
- Convergence layer responsible for, in part, managing the flow of data to and from the SAR layer.

AAL 1

This AAL is targeted at rendering constant bit rate services. Partridge indicates that most of the convergence layers that has been defined for this AAL is similar to fractional T1 services offered by some phone carriers. The exception to this being a standard that describes the sending of video as a constant bit rate stream. This convergence layer standard sends video in blocks of 128 columns, and 47 rows, it is described in [Par94 p 75].

Various texts have varied descriptions of the AAL SAR fields (see [Par94], [Ben94] and [Pry95]), Partridge describes these fields as :

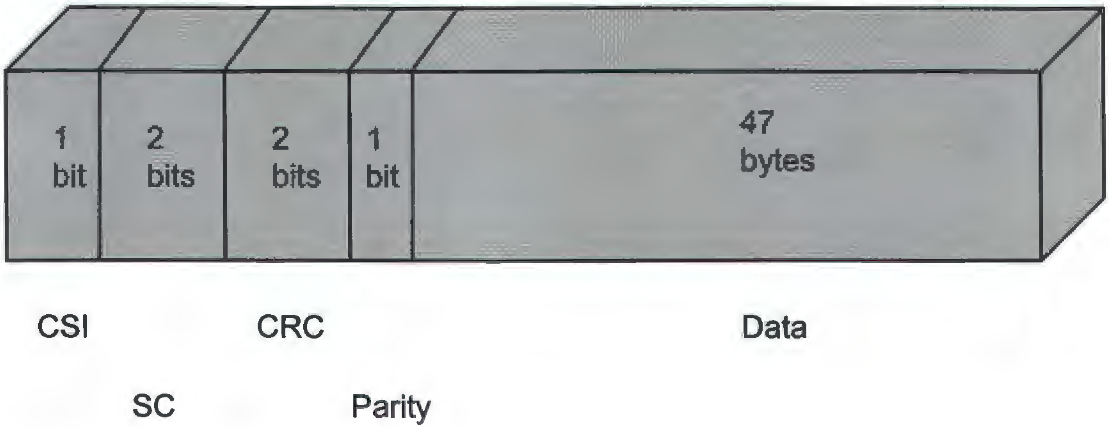


Figure 3- 8 : AAL1 SAR Format

- CSI convergence sublayer indicator used for signaling
- SC sequence count used to test for correct cell order
- CRC cyclic redundancy code computed over first nibble
- Parity parity bit computed over first 7 bytes

AAL 3/4

This Adaption layer is the result of combining ATM traffic category 3 and 4. Although this AAL was targeted at framing services for connection oriented as well as connectionless data protocols, Partridge indicates it to be less than successful at this goal. This lead to the development of AAL5.

The SAR format for this AAL is described by [Par94 p 76] as:

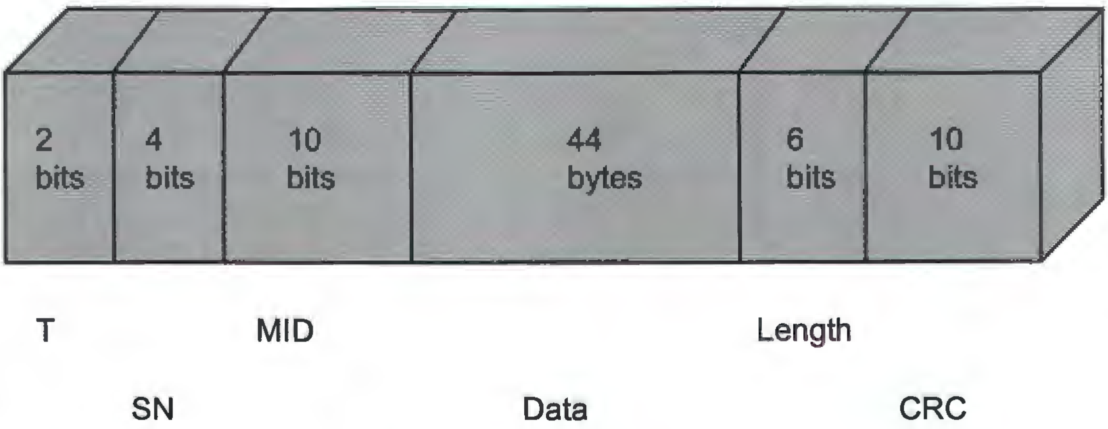


Figure 3- 9 : AAL3/4 SAR Format

- Type This field indicates the relative position of the cell in a packet

- SN Sequence Number (Mod 16) to test for cell order
- MID Multiplexing Identifier used to identify multiplexed cells of a packet
- Length This field must be 44 in all except the last cell of a packet (or single cell packet).
- CRC Cyclic redundancy code that can correct 1 bit errors

Above the SAR the convergence layer uses the following format:

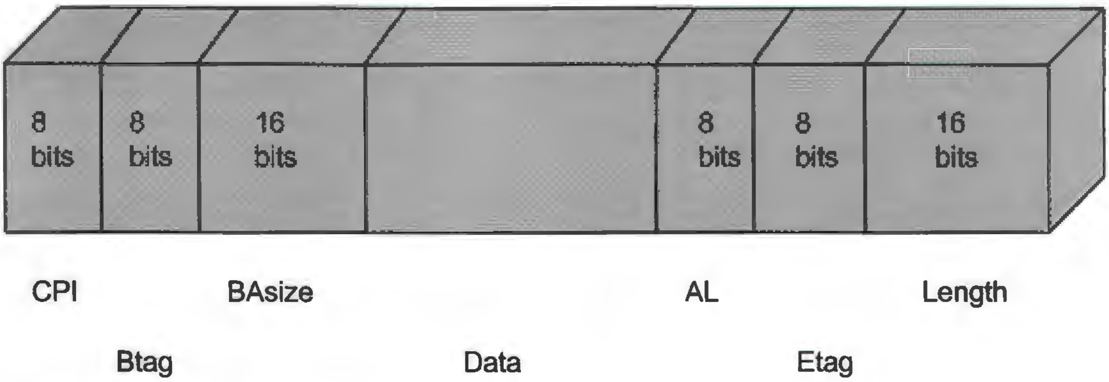


Figure 3- 10 : AAL 3/4 Convergence Format

- CPI Common part indicator allowing redefinition of the header
- Btag Beginning tag
- Etag End tag, works with Btag to test that the header and trailer belongs together
- BAsize This field indicates to the receiver how much buffer space will be needed for the packet.
- Len Length field indicating the total length of the packet
- AL This is an alignment byte (all 0's) to make the trailer 32 bits long

AAL 5

AAL 3/4 had serious computational limitations. This AAL required that the receiver process each cell as it is received, in order to detect the nature of the cell by means of the Segment Type field. Partridge [Par94 p 79] points out that it is possible to build a packet by joining consecutive cells and then to process only on the packet level. This is exactly what the aim of AAL 5 was, as this would imply lower overhead and higher speed.

The AAL 5 SAR uses a single bit in the ATM header itself:

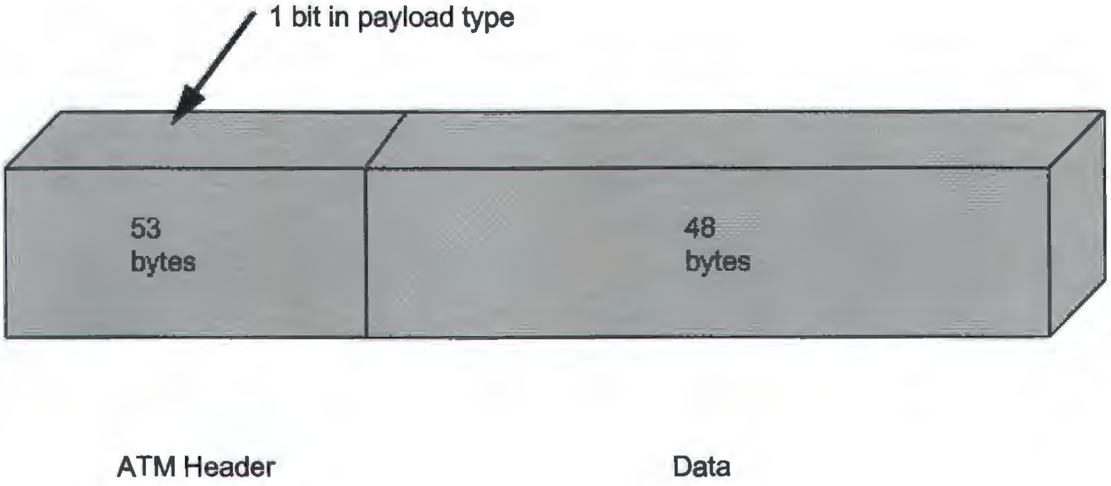


Figure 3- 11 : AAL 5 SAR Format

In this case a single bit in the payload type indicator is set to indicate that a specific cell is the last in a packet. As such all cells in a packet can be buffered until the last one is received, after which the packet can be processed as a whole.

The convergence layer is implemented in an equally simple fashion. All cells except the last cell of the packet are completely filled with data. The last cell caries 40 bytes of data (which may include padding) and four fields in a trailer:

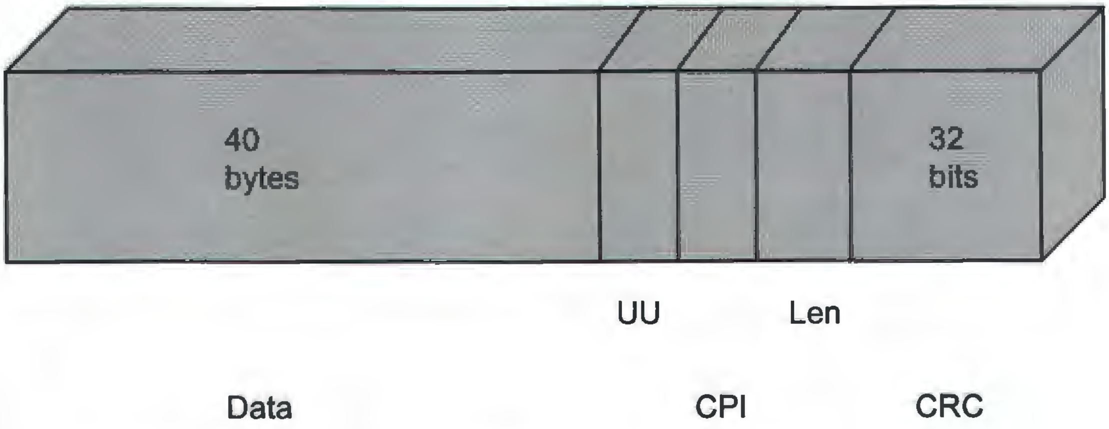


Figure 3- 12 : AAL 5 Convergence Format

- UU User to user indication (currently unused [Par94 p81])
- CPI Common part indicator unused

- Len Length of data in packet (not counting padding)
- CRC Cyclic redundancy code, detecting lost and misordered cells

According to [Ben94 p 39] AAL 5 is particularly well suited to traffic in the current LAN scenarios. It's buffering properties in the receiver can however still be improved, by giving an indication of total buffer space needed (although this will once again add complexity).

3.4. Setting up ATM connections

The previous two sections gave a broad overview of the ATM protocol definition as well as the different functions implemented on the various layers of the ATM protocol stack. In order to ease discussions in the next chapter, it is however necessary to look at the ATM connection setup process.

3.4.1. ATM signaling

As mentioned earlier, ATM is connection oriented, with VPIs and VCIs being used to identify the connection. Obviously this connection must be set up before it can be used. Due to the fact that a VPI, and VCI is only unique on a per hop basis, this connection setup must include the assignment of VPI, VCI numbers. The Quality of Service (QoS) is also agreed upon at this stage of the connection's life time.

The QoS includes [Ben94 p 18] :

- Desired bandwidth
- Traffic type
- Acceptable jitter
- Cell loss priority
- Acceptable delay

It is also possible to request a connection without specifying the QoS, in cases like this the ATM network will service this connection on a "best effort" basis.

This connection setup is done by means of a separate signaling protocol. Between the end users and the network, UNI signaling is used, while the various switches and routers along the ATM path uses NNI signaling between themselves. After both the destination and source user as well as the ATM network in-between, agrees to set up a connection that fits the required QoS, a virtual connection is established. At this stage the VPIs and VCIs are allocated and routing tables in the network nodes along the way are updated accordingly. After this stage the various VCIs and VPIs may be used to identify the connection, without involving the physical destination address en route.

In both the case of UNI and NNI signaling an existing protocol was simply extended to include ATM functionality. For UNI signaling the ITU Q.931 signaling standard for Narrow band ISDN (NISDN) was extended to include:

- Originator or distributed Point-to-Multipoint support
- Support of symmetric operations
- Additional traffic information parameters
- Additional NSAP address structures
- Re-negotiation of traffic parameters
- Multiple connections per call

The extended signaling protocol was initially named Q.931B but later renamed to Q.2931.

For NNI signaling the ISUP NISDN protocol was adapted to include:

- Channel identification
- Cell rate specifications
- OAM procedures

Messages sent by means of these protocols can have a number of optional fields, but must always contain certain mandatory informational elements. These include [Pry95 p 155]:

- Connection Identifier (VPI/VCI pair)
- Destination address (called party number)
- Requested ATM cell rate
- Requested QoS class

Optional elements can include information regarding:

- AAL parameters
- Calling party address

- Bearer capability

The ATM Signaling protocols are currently under further development by both the ATM form (for private ATM networks) and the ITU-T (for public ATM networks) [SCO96].

In order to manage ATM signaling, a separate AAL called the Signaling AAL (SAAL) was devised by adapting AAL-5. This AAL consists of a service specific part that is implemented on top of a common part (AAL5). This service specific part consists of a Service Specific Connection Oriented Protocol (SSCOP) and Service Specific Coordination Functions (SSCF).

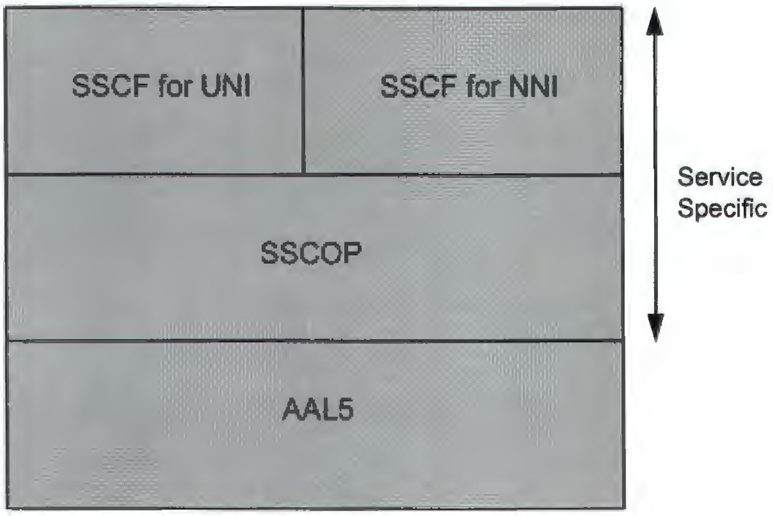


Figure 3- 13 : ATM SAAL [Pry95 p 153]

As signaling needs to be performed at the UNI and NNI level, the SAAL has to make separate provision for both these interfaces (See fig 3.13). The SSCOP performs classical data link protocol functions i.e. sequence integrity, error correction, flow control, link management, etc. [Pry95 p 153].

The connection setup for ATM connections is thus performed over the SAAL, in order to assign VPI/VCI address pairs which can be used instead of physical addresses. The connection setup process can be depicted as seen in Fig 3-17.

The initial request is sent over a reserved ("*well known*" [Ben94]) VPI, VCI pair with VPI=0 and VPI=5. As these values does not give a unique destination address the Network Access Service Point (NSAP) addressing scheme is used to identify the destination address during connection setup. (Refer to section 3.4.3 on ATM addressing)

3.4.2. Signaling message format

In Fig 3-14 a number of point to point signals are shown in use. In [OSC96 p 315] several of these point to point signaling message types are identified, these include:

- **Call establishment messages**

  Call Proceeding: *call establishment has been initiated and no more establishment information can be added*

  Connect *call acceptance*

  Connect Acknowledge Setup *user has been acknowledged the call*

- **Call clearing messages**

  Release: *equipment sending the message has disconnected the virtual connection and will next release the VC and call reference*

  Release complete: *the VC and call reference are released and that the VC is available to be used again*

- **Miscellaneous messages**

  Restart: *request to release all the resources associated with the specific VC(s) controlled by the signaling channel*

  Restart Acknowledge: *response to restart to indicate completion*

  Status Enquiry: *request a status message*

  Status: *response to status query, or any other time to report certain error conditions*

The format of these signaling messages is defined in [OSC96] as seen in Fig 3-14. The various fields are used for :

- Protocol discriminator: Used to differentiate between Q.2931 signaling and other protocols
- Length of Call Reference: Indicates the length of the call reference in octets.
- Call reference: Identifies the call at the UNI.
- Flag: Indicates at which end of the virtual signaling channel the call reference was assigned.

- Message type: Indicates function of the message being sent (i.e. call establishment, clearing, or miscellaneous messages mentioned above)
- Message Length: Indicates the number of octets of the contents of the message
- Information elements: Each signaling message may contain one or more informational element (i.e. an element requesting a *release*, or *release complete*, etc.

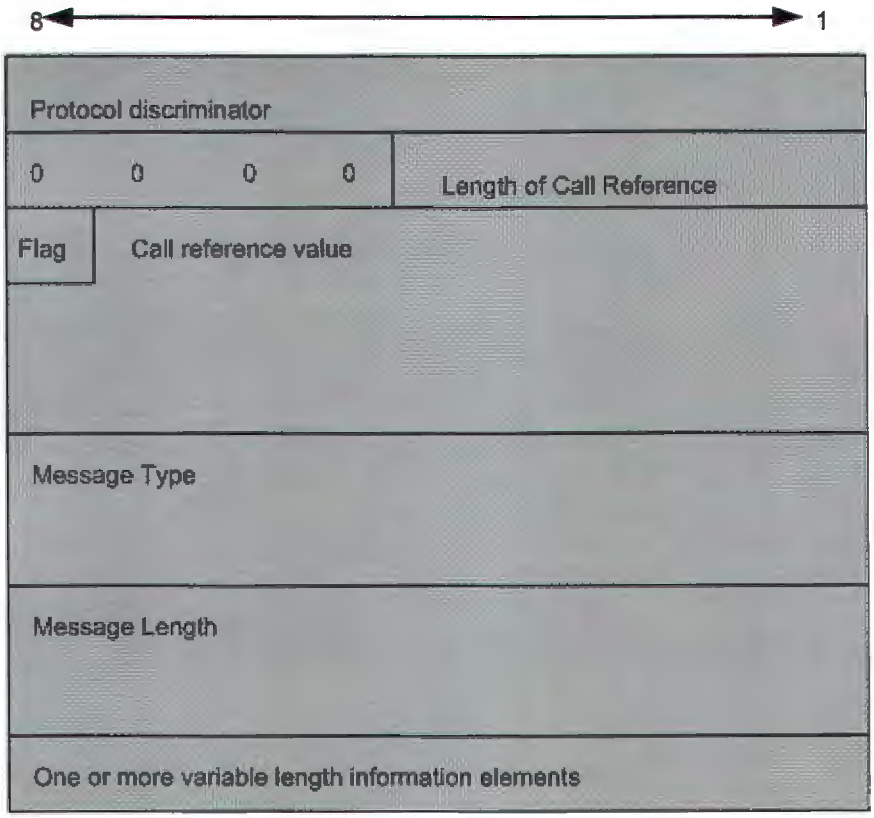


Figure 3- 14 : Q.2931 signaling message format [OSC96 p 314]

3.4.3. ATM addressing

According to Benham [Ben94 p 19] the NSAP scheme will be exclusively used for ATM device identification at this stage. The three original NSAP addressing schemes defined included a DCC ATM format, an ICD ATM format and an E.164 format.

These formats differ regarding their approach to the second field show in Fig 3-16 the first uses a Data Country Code (DCC) approach and the second an International Code Designator (ICD). The third format makes provision for the incorporation of the current public telephony address (E.164) as part of the NSAP address. The first field is used to indicate the type of address format used in the rest of the frame.

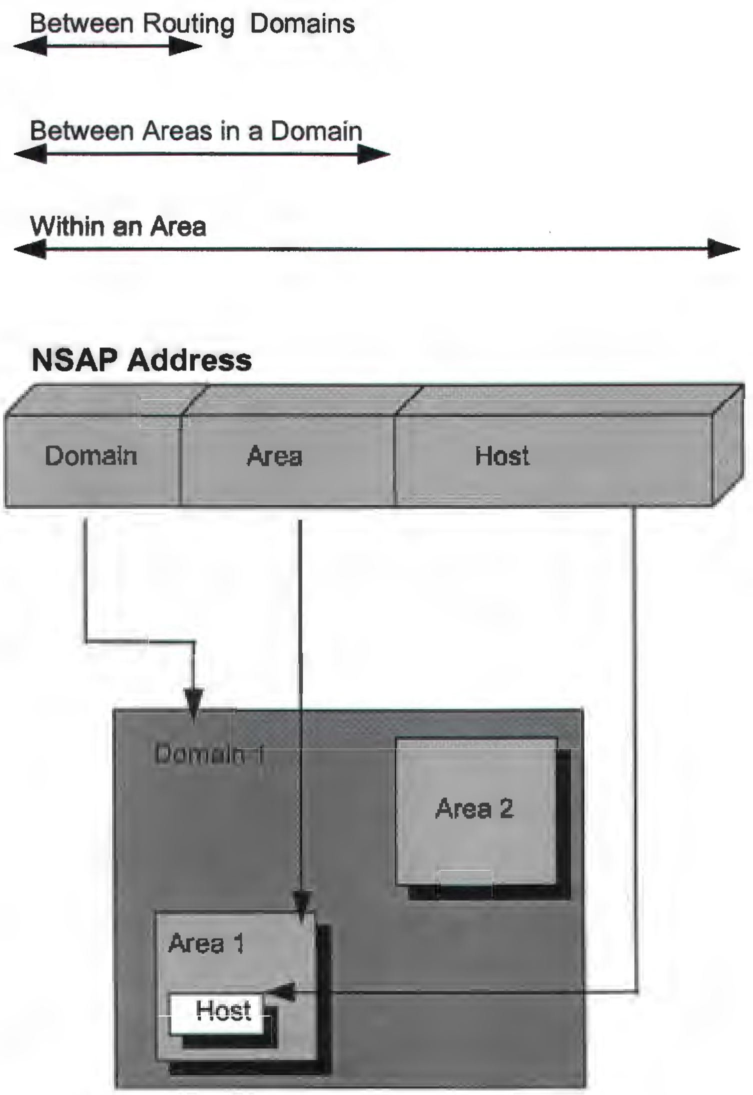
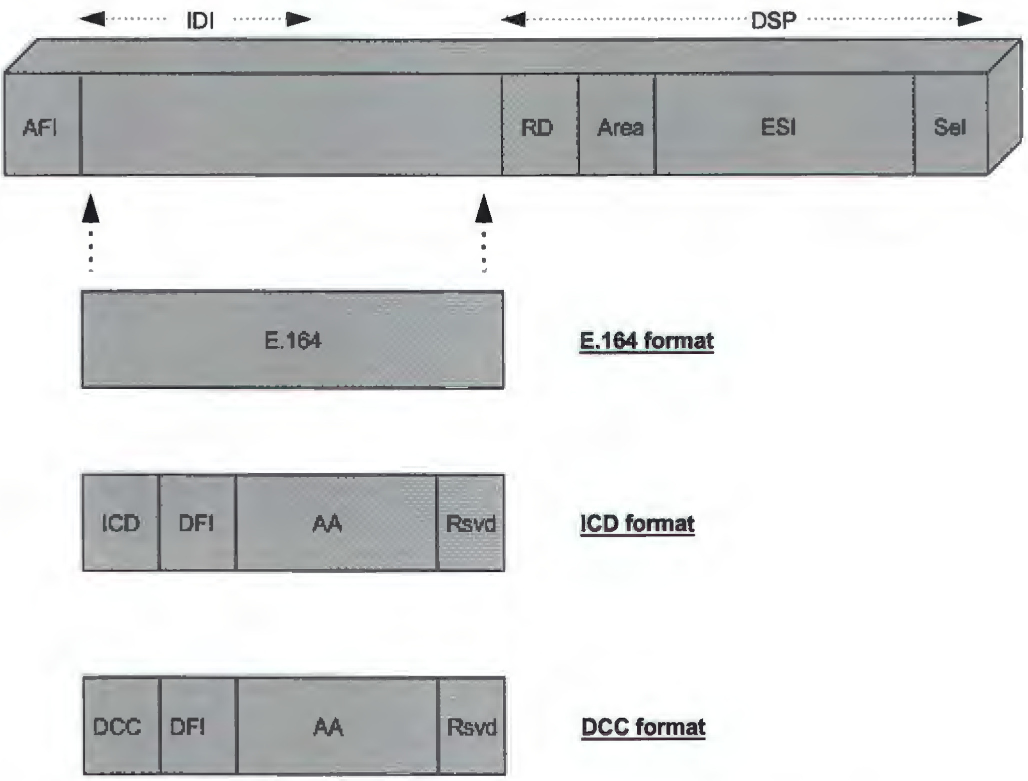


Figure 3-15 : NSAP Address example [OSC96]

In [OSC96 p 308] it is pointed out that these addresses can be seen to be divided into three basic parts, being a Domain, Area and Host section the hierarchical nature of the address scheme can be seen from Figure 3-16.

The basic NSAP format is divided in an Initial Domain Identifier (IDI) and a Domain Specific Part (DSP) [Ben94]. The address consists of 20 octets, with the last seven bytes reserved to identify the host in each case [OSC96 p 309].



IDI	Initial Domain Identifier	DSP	Domain Specific part
AFI	Auth & Format Identifier	DCC	Data Country Code
ICD	International Code Identifier	DFI	DSP Format Identifier
AA	Administrative Authority	RD	Routing Domain
RD	Routing Domain	Area	Area Identifier
ESI	End Station Identifier	Sel	NSAP Selector

Figure 3- 16 : NSAP Address format [Ben94 p 20]

Provision is also made for addressing in LANs where the ESI field will be set equal to the MAC address of the client. This implies that the PC-Client will have to register it's address with the network. This registration service will then reply with the relevant NSAP address, while keeping track of the corresponding VPI/VCI pair, switch port, MAC address, etc. This function is performed by the Interim Local Management Interface (ILMI).

3.4.4. Traffic description

As mentioned in 3.4.1 part of the information transferred by means of Q.2931 signaling include the QoS and traffic parameters. For obvious reasons the QoS and traffic parameters should describe the traffic characteristics across a given ATM connection as accurately as possible.

Jung gives a number of generic QoS parameters in [Jun96 p 1757], these include:

- Frame Error Ratio (FER) :

This parameter refers to the amount (percentage) of frames received errored at the AAL layer. With FER $_{max}$ defined such that

$FER \leq FER_{max}$ and

FER = errored_frames / total_frames

- Throughput Bound (W) :

  This parameter refers to the throughput of a connection, indicating a measure of the bit rate attainable by the connection at the AAL layer. Jung indicates that W $_{min}$ can be defined by the AAL as part of the QoS such that:

  $W \geq W_{min}$

  for all different network layers along the connection path. This specifies a lower bound to the throughput.

- Frame Delay Bound (D $_{max}$) :

  This parameter refers to the delay with which a frame is delivered to the destination (at the AAL layer) for instance the *i* th frame is delivered in delay D_i with

  $D_i \leq D_{max}$ for all i

- Frame Delay Variation (Jitter) Bound (J $_{max}$) :

  This parameter refers to the variance in delay D_i with

  $(J_i = | D_i - D |) \leq J_{max}$ for all i

  J_i is the Jitter of the *i* th frame when delivered to the destination.

- Cell Loss Ratio (CLR) :

  This parameter refers to the ratio of cells lost at the ATM layer according to Jung it results mainly from buffer overflow in ATM switches due to congestion.

- Cell Missinsertion Rate (CMR) Bound:

  This parameter refers to the cells lost due to error(s) in the ATM header. Normally the CMR can be considered negligible compared to the CLR. Jung attributes this to the ability of ATM switches to detect and discard cells with errored headers.

In addition to these [OSC96 p 310] also mentions :

- Peak Cell Rate (PCR) :

  The maximum cell rate a source can handle.

- Sustainable Cell Rate (SCR) :

  The maximum cell rate a source can handle over an indefinite period of time.

- Burst Tolerance :

  An indication of a node's sensitivity to bursty traffic.

It is clear that the use of the above traffic and QoS descriptors should allow for a detail description of the expected traffic characteristics of a given ATM connection. These parameters can clearly be used for routing in an ATM network during connection setup. It must be noted however that the accuracy of these parameters will have an influence on traffic circumstances along the route (i.e. possible congestion or under utilization of a link).

3.4.5. Route selection

According to Benahm [Ben94 p 22] the Private Network to Network Interface (P-NNI) routing protocol will be used for route selection. He further indicates that at it's fully developed stage, this protocol will contain attributes of the Open Shortest Path First (OSPF), Intermediate System to Intermediate System (IS-IS), Border Gateway Protocol (BGP) and Inter Domain Routing Protocol (IDRP) protocols. Most of these protocols have been in operation for some time in TCP/IP environments in WANs and the Internet.

In most of the protocols mentioned above the cost (number of hops) is used as the primary metric for the selection of a route from a number of nodes. Due to the service guarantees build into ATM the normal route calculations will have to be adapted in order to select the route based on the QoS as a whole. This will imply that these calculations will have to include link and endpoint metrics in their parameters.

Benham gives the minimum metrics exchanged by P-NNI Routing protocols as:

- Cost (Hops)
- Link capacity and constraints
- Propagation delay
- Cell delay (Latency)

- Cell delay variance (Jitter)
- Current sustained capacity

Of these parameters the first three can be seen as static, while the last three should be considered dynamic in nature.

In [Ben94 p 22] it is pointed out that these additional metrics will complicate ATM route selection, but that due the fact, that the route is only selected once (during connection setup) a lower routing overhead than in today's IP networks can still be expected.

3.4.6. Connection setup sequence

With the above discussion in mind we are now in a position to give the steps used to set up an ATM point-to-point connection by means of Q.2931 signaling. Given a source terminal (A) and a destination terminal (B) as indicated in Fig 3-17, Onvural indicate the setup process at the UNI to consist of the following [OSC96 p 317] :

- A sends a SETUP message to the network node it is attached to. This message contains the address details of the end station B (NSAP address as discussed in par 3.4.3) as well as the connection characteristics (as discussed in 3.4.4) and other detail (listed in par 3.4.1) for the compulsory and optional setup signal fields.
- The network node replies to A by sending a CALL PROCEEDING message, indicating that it has received the SETUP message and is busy with the rest of the connection setup. At this stage, part of the CALL PROCEEDING MESSAGE also supplies A with a VPI/VCI pair.
- The network will now forward the SETUP message to the node to which B is attached, using P-NNI route selection based on QoS and traffic parameters (as discussed in par 3.4.5).
- The network then delivers the SETUP message to B, also issuing B a VPI/VCI pair for future use between B and it's node for that particular connection.
- If B decides to accept the connection, it will return a CONNECT message to its network node.
- The network node will then send a CONNECT ACKNOWLEDGE message to B and forward B's CONNECT message information to A's network node.
- The network node at A sends a CONNECT message to A after receiving the connect acknowledge information from B's node.

- A will now process the CONNECT message and answer the network with a CONNECT ACKNOWLEDGE returned to the network node.
- At this stage A and B can start to communicate by sending data cells across the connection

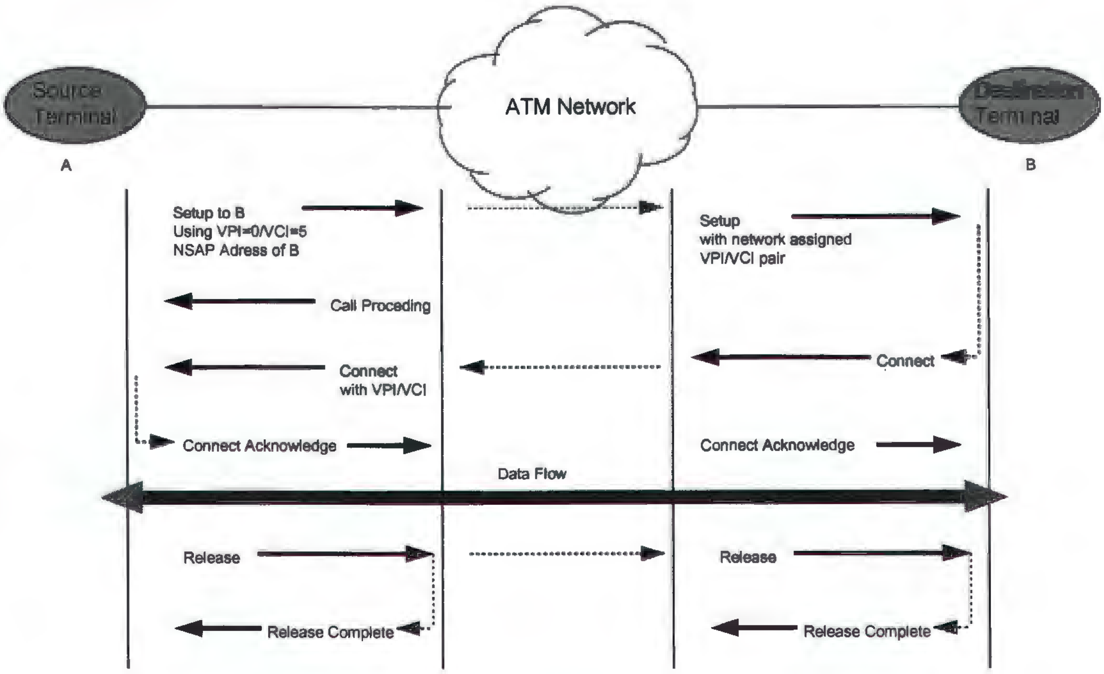


Figure 3- 17 : ATM Connection setup [OSC96 p 316]

In order to break the connection UNI signaling will consist of [OSC96 p 317] :

- A sends a RELEASE message to the network
- The network acknowledge the end of the connection to A by sending a RELEASE COMPLETE to A, at this stage the connection between A and the network is taken down.
- The network now sends a RELEASE message to B's node and eventually to B itself.
- B, replies to the network by means of an RELEASE COMPLETE message, after which the connection between itself and the network is taken down.

This concludes the discussion on ATM signaling and connection setup. Before a method is developed to include the use of electronic payment as part of this setup, electronic cash needs to be examined in more detail. This will be done in the next chapter.

3.5. Summary

This chapter took a closer look at ATM, as well as the definition thereof. The discussion included the different layers of the ATM implementation and indicated the various sub protocols operating at each layer. Closer attention was also paid to the functions of each of these layers. The chapter concluded with a section indicating the signaling, addressing and routing necessary for ATM connection setup, as well as a summary of the messages sent during setup.

Chapter 4

Electronic Payment

4.1. Introduction

In this chapter various electronic payment techniques are discussed. Due to the fact that the understanding of Ecash is one of the main objectives of this study special reference is made to the use of electronic cash. In order to better understand the electronic cash payment system discussed here, it is also necessary to look at the definition (and requirements) of a payment system in general. As a matter of fact, electronic cash can be seen as just another evolutionary development of payment systems in general. This is especially clear when a closer look is taken at the background and development of the various electronic payment methods.

4.2. Background

In an age of credit cards, automatic teller machines and banking computers, the idea of electronic payments is not a new one. Until recently however, it was accepted that these transactions will take place between individuals and / or organizations that must have each other's account details. This obviously also implies that such a person must have an account, with a bank or other organization in order to participate.

Although there are cases where these types of electronic transactions will be acceptable and sufficient, they may allow certain negative aspects to be explored if used for payment over *open* networks (like the Internet). For instance it will be possible to trace and set up a dossier on an individual's spending habits, rendering electronic privacy obsolete. Furthermore the fact that the client must have an account with the supplier, limits the availability of this method (to those with accounts) and also adds cost (i.e. admin, and billing costs).

One method to overcome the above problems is to visit the supplier in person and to pay in cash, this is however only practical when the service provider and client are in the same geographical area. With the advent of trading over the Internet these problems became even more prominent. This lead to the development of various other methods of handling electronic payment (including various forms of electronic / digital cash) which were progressively more and more network based.

4.3. Development history of network based cash electronic payments

As mentioned above, the idea of sending money across a communication network has been in use in the banking environment for some time. However, it has always been limited to transactions between parties, which have each other's account details. As such, these transactions could not truly be compared to a "real world" cash transaction. To a certain extent the development history of network based cash electronic payments has its roots in the Internet and can be said to be motivated, in a large degree, by trading possibilities on the Internet.

According to [DigMon] the use of money on the Internet went through a number of evolutionary phases:

4.3.1. External Payments

The first payments for services on the Internet were conventional ones external to the Internet itself. Subscribers transfer monthly amounts from their bank accounts to that of the service provider. These payments would obviously be expensive and also take a long time to process, especially when the transfer is from one country to the other. ([Smu95] points out the drawbacks of a scheme where use of a service and payment thereof is not closely linked in time.) It should be obvious that this scheme is not really suited to one time payments, although it could work for long term relations. (The payment of CompuServe services in the RSA is an example of such a scheme.)

4.3.2. Payments using credit card details

The next possibility was thus to use payment by credit card. The client would simply include his credit card details in the order to the service provider. The credit organization will then handle this payment like any normal transaction. Although this method makes payment much easier it does have certain drawbacks:

- It is insecure, the client's credit card details are sent in an open message across an open network. As such it can be intercepted and used for fraudulent withdrawals on the client's account. It is also possible for an external party to track an individual's spending habits by keeping track of messages that includes his credit card number.
- It costs money, as such the credit card transaction may be more expensive than certain low cost network transactions.

4.3.3. Payments using encrypted credit card details

Taking the above into consideration, it is no surprise that the use of encrypted credit card details was the next step in the evolutionary process. This method took care of the security problem, but still leaves the problem of overhead costs when dealing with small amounts. As in the case of external payments (4.3.1.) there are certain cases where this method will however be sufficient.

4.3.4. Payments using third parties

In order to solve the problem of overhead costs, one solution would be to introduce a third party. This third party would typically be a company that collects and approves payments from one client to the other. After a certain period of time a single credit card transaction can then be done for the total amount of these smaller transactions.

Once again this solution is not optimal, for instance:

- Who pays the third party? This means more overhead costs.
- Payments may be refused due to a credit limit being reached, before the single large credit card transaction is done.
- Once again the *spending profile* of a client is readily available, and kept in a central place (at the third party).

4.3.5. Payments using ecash

These, and other problems lead to the development of smart cards as described in [Cha92]. These systems consist of a tamper proof, card based chip, that can be seen as the electronic equivalent of a purse. The original systems had the same drawback as cash, the client, service provider and smart card had to be in the same shop. However, it did not take long for the first software only, systems to be developed (i.e. Cyberbucks or Digicash's ecash system).

- These systems have the same advantages as conventional cash, but it negates some of the problems of conventional cash. (For instance immediate ecash payments over great distances is now possible.)

4.4. What is payment?

Although the word *payment* is mentioned quite often in everyday life, it may ease the discussion in the rest of this chapter if we can formalize it's intended meaning within the scope of this thesis. For the purpose of this study payment can thus be defined as:

> The transfer (from client to service provider) of a token which directly or indirectly constitutes a value in some monetary system.

As such, any payment system will need some form of *token* as well as some kind of *transfer process*, in order to function. In certain cases a verification method is also needed, in order to check that a token does indeed constitute the claimed monetary value. Referring back to the development history discussed in par 4.3, it can be seen that this is indeed the case in all the payment systems developed to date.

4.5. Requirements of a payment system

As seen in par 4.3, the development of new payment systems often takes place due to a perceived lack in the existing methods (i.e. the lack of privacy that prompted the development of Ecash). In general a payment system should thus meet certain requirements in order to succeed:

- Tokens must constitute value in some monetary system;
- It must be possible for a receiver to verify the value of a token;
- Tokens must be transferable from one owner to another;
- The transfer of tokens must be secure;
- It must not be possible to generate tokens without having it backed by monetary value, (as such the counterfeit or double spending of tokens should not be possible).

It is possible to define various payment techniques that will enable a payment system to satisfy the above requirements. Such techniques can be broadly divided into two categories, being electronic and non electronic payment techniques.

4.6. Non-electronic payment techniques

Various non-electronic payment systems have been developed to date. For the purpose of this study a non electronic payment system can be defined as a system using:

- non-electronic tokens;
- a non-electronic or electronic transfer method;
- a non-electronic or electronic method of verification.

4.6.1. Cash payments

This form of payment constitutes the use of currency as token, often with the issuing country's gold reserve backing the paper or coin form of token. It is easy to see that this system does indeed satisfy the above requirements of a payment system.

Conventional cash can furthermore be considered to possess certain characteristics, for instance [Smu95] indicates that:

- cash can be accepted on face value;
- cash is normally not traceable and thus provides anonymity;
- payment by cash does not incur an overhead cost.

As such it is possible for the client to pay by cash, without having to consider an overhead fee, while the service provider does not need to check the client's credentials before accepting the payment. Furthermore it is also possible to grant a measure of privacy due to the intractability of the transaction.

4.6.2. Cheques

Payment by cheque normally consist of a note written by the payer, giving the bank authorization to debit his own account and credit that of the service provider. In this case the signed note acts as a token. This token is assumed to be backed by currency available in the payer's account.

Once again certain characteristics can be attributed to this payment system:

- cheques can not be accepted on face value (the bank can still refuse payment if the payee does not have sufficient funds in his/her account);
- unlike cash, a cheque needs to be signed by the spender before it represents value;
- a cheque can represent an exact amount (as such it is not necessary to *build up the required value* by means of a number of cheques, as is the case with cash notes);
- at least one of the parties in question (the payer), must have an account with the bank who's cheque is used as payment;
- due to the above, cheques are traceable and thus does not provide anonymity;
- payment by cheque does incur an overhead cost for the payer.

4.6.3. Money Orders and Bearer Bonds

This form of payment uses a token which consist of a note backed by (normally) a government's currency. Payment is guaranteed and can be done directly to the bearer.

Characteristics that can be attributed to this payment system includes:

- money orders can be accepted on face value;
- none of the parties in question needs an account with an financial institution;
- money orders does provide anonymity;

4.7. Electronic payment techniques

In most cases electronic counterparts have been developed for each of the various non-electronic payment systems developed to date. For the purpose of this study an electronic payment system can be defined as a system using:

- electronic tokens;
- an electronic transfer method;
- an electronic method of verification (when applicable).

4.7.1. Electronic fund transfers

This kind of payment system uses electronic means to transfer an electronic representation of currency from one account to the other. (This is the oldest of the electronic methods discussed here, having been in use for a number of years in the banking industry.)

Characteristics of this system includes:

- both parties involved needs an account of one kind or the other;
- payment is guaranteed after successful completion of the transaction;
- electronic transfers does not provide anonymity;
- electronic transfers do have overhead costs.

4.7.2. Credit Cards

In this case a third party (the credit organization) undertakes to pay accounts on behalf of the payer in return for a monthly lump sum payment by the payer. Electronic representation of currency is used as tokens with the transfer taking place electronically. Verification can be either by means of a signature (non-electronic) or purely electronic. (Making this system a hybrid system in terms of our definition of an electronic payment system.)

In this case the characteristics of the payment system includes:

- at least one of the parties involved needs an account with the credit organization;
- payment can be refused due to insufficient credit in the payer's account;
- credit cards does not provide anonymity for either party;
- the use of credit cards does incur an overhead cost.

4.7.3. Electronic cash

Electronic cash (ecash) uses electronic tokens transferred in an electronic means to enable payment. These tokens represent a monetary value in themselves and do not simply act as an electronic cheque that promises payment at a later stage.

Like the previous systems mentioned we would expect ecash to have certain characteristics. According to [Sch94, p 123] these must include:

- Independence, the security of ecash is not dependent on a specific physical location;
- Security, ecash can not be copied and reused;
- Privacy, the privacy of users is protected, the transaction is not traceable between user and point of purchase;
- Off-Line Payment, when a user pays using ecash, it must be possible to complete the protocol between the shop and the user off-line;
- Transferability, ecash is transferable between users, and not just between a user and a bank or merchant;
- Divisibility, it is possible to divide an ecash note into smaller denominations with the same total value.

When considering these characteristics, it should be clear why ecash can be seen as the electronic equivalent of normal cash.

- ecash is versatile, it can be used for on-line payments over the phone, to handle road toll payments automatically (without the need to stop) or to buy goods directly over the counter;
- ecash is secure, due to its unique digital signature it can not be spent more than once and is signed by the bank as acceptable cash even before it is issued;
- ecash is private, it makes it impossible to connect payment and payer while still allowing the user to prove that payment was made.

That leaves the question, what's in it for the service provider (or for that matter the Internet shop)? From this point of view, the above mentioned advantages still holds, however in addition to these the following can also be to their advantage:

- payment is immediate, increasing cash flow;
- payment is guaranteed when checked on-line with the bank (the need to check can also be seen as an disadvantage);
- administration overheads are limited.

As with most things in life ecash has it's negative points as well. In [Sch94] it is pointed out that ecash's privacy can be used to engineer the perfect anonymous crime. Furthermore, due to the electronic nature of ecash it can be adversely influenced by hard disk crashes, unavailable network links, etc.

Keeping our aim with the use of Ecash (payment of network services) in mind, a serious drawback is that double spending during offline transactions can at most be detected, but not prevented.

Another disadvantage to ecash is that it does require a high technology infrastructure in order to be used. For the purpose of this study however this can be ignored as the same infrastructure is taken for granted in the network environment for which we aim to develop a payment scheme.

4.13. Summary

This chapter introduced the concept of electronic cash, as money that is represented by numbers. The characteristics of ecash were discussed and compared with that of normal cash. An overview of a general ecash transaction was given after which the techniques used in the ecash protocols were discussed. Finally an ecash protocol was presented, and an example given to indicate how a transaction between a payer, a service provider and the bank should take place.

4.8. How to pay for network use

One of the objectives of this research is to propose an ATM embedded billing and payment method. In order to do this one of the payment methods discussed in par 4.6 and 4.7 will no doubt need to be used.

From the above discussion it can be deduced that the electronic based payment systems (in general) should be easier (as well as more efficient) to use in a network based environment than their non-electronic counterparts.

Due to the fact that ecash does not require an account with a bank or credit organization, it may be particularly well suited for the on-line payment of network services. As such, this topic no doubt requires a more in depth discussion.

4.9. Overview of an ecash transaction

In order to clarify our discussion on how ecash works, it may be necessary to give a brief overview of a normal ecash transaction. The whole transaction can be broken down into a number of distinct steps.

Let us first consider an ecash withdrawal:

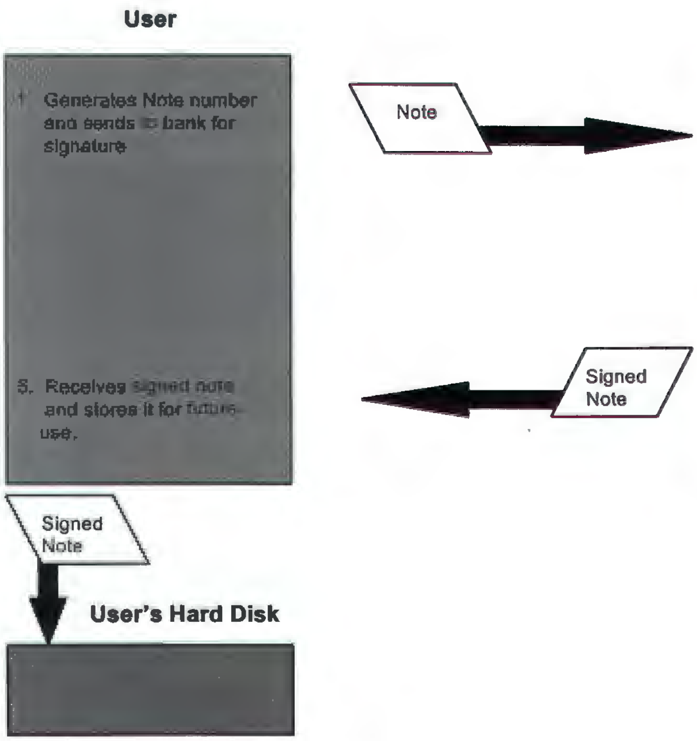

User
Bank
1 Generates Note number and sends to bank for signature
Note
2 Receives note and signs it
3 Deducts the corresponding ammount from user's account
4. Return Note to user
Signed Note
5. Receives signed note and stores it for future use.
Signed Note
User's Hard Disk

Figure 4-1 : The ecash withdrawal

In this case the steps in question can be seen to consist of:

- The user's equipment generates an ecash note and send it to the bank to be signed;
- The bank signs the ecash note and move the corresponding amount of funds from the user's account to its own;
- The bank then returns the note to the user;
- The user stores the note on his computer for later use.

When relating the above to our definition of electronic payment, we can once again see that an electronic token (the ecash note) is transmitted from the bank (by means of an electronic transfer method) to the user. Note that the bank removes the funds from the user's account before completing the transaction thus, also doing electronic verification (checking that the user have funds available) as part of the process.

In a similar fashion as this withdrawal a payment can be done as indicated bellow. Once again it is clear that the token and transfer method, as well as the verification is of an electronic nature.

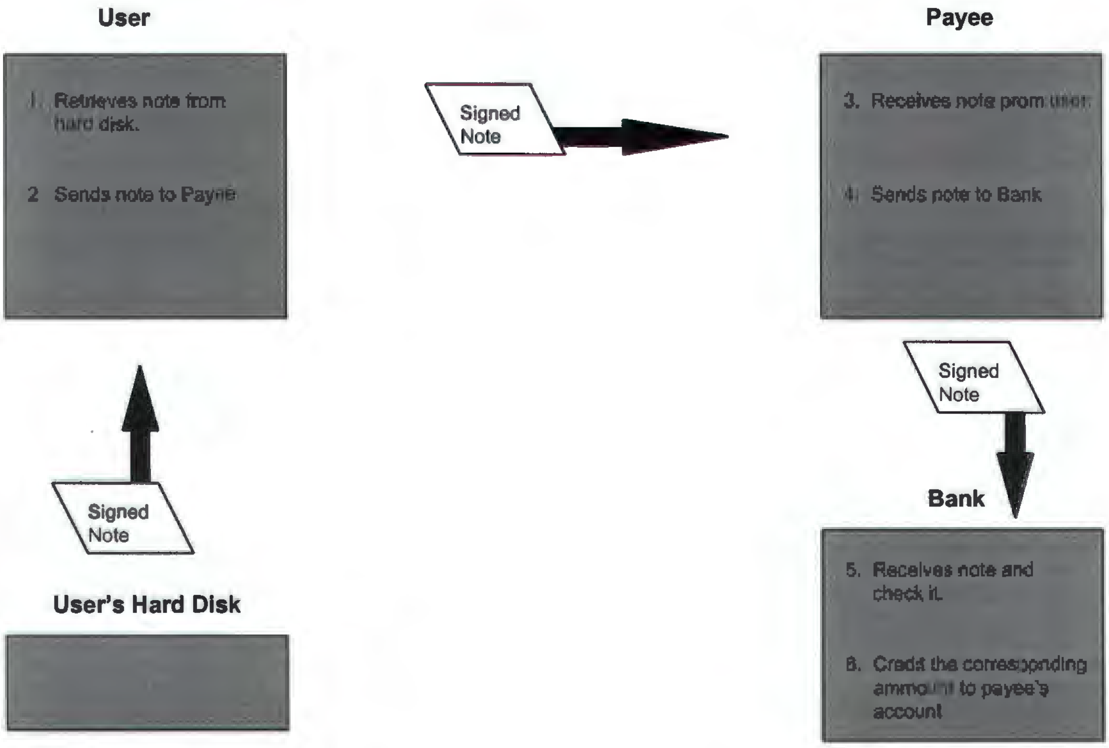

User
1. Retrieves note from hard disk.
2 Sends note to Payne
Signed Note
Payee
3. Receives note prom user
4. Sends note to Bank
Signed Note
Signed Note
User's Hard Disk
Bank
5. Receives note and check it.
6. Credit the corresponding ammount to payee's account

Figure 4-2 : An ecash payment

In this case the relevant steps are:

- The user retrieves the note from his hard drive and sends it to the payee
- The payee checks that the note's digital signature is authentic and sends it on to the bank;
- The bank checks the digital signature and credits the payee to the according amount.

4.10. How ecash works

The above discussion gives an overview of an ecash transaction, without going into ecash in detail. In our definition of payment (in par 4.4) a token, a transfer method and a verification method was mentioned. In order to understand ecash, it is necessary to look closer at these terms within the ecash environment.

Due to the electronic nature of ecash, it's environment can be expected to be electronic as well. In order to function ecash will need an infrastructure consisting of:

- a communication system to enable transfers of electronic tokens;
- a computer or smart card in order to manipulate and store these tokens;
- a software system in order to do verification and validation on the tokens.

The communication system on which ecash is implemented is normally network based. As various forms of network systems has been mentioned in the previous chapters, only the electronic representation and verification of tokens need further discussion. Due to the fact that the verification of ecash tokens forms an integral part of the representation of such tokens, these two facets should not be discussed under separate headings. Instead, the underlying principles of ecash's representation and verification are discussed first, after which we will be in a position to discuss a general ecash protocol.

4.10.1.The electronic representation of ecash tokens

Ecash is represented by a *digital note* consisting basically of a random number generated by the user's or bank's computer. This token also indicates the note's value and authenticity while at the same time maintaining privacy.

In order to indicate it's authenticity the note must contain a digital signature from the bank which guarantees it's payment. This can be done by encrypting the *digital note*'s number by means of an RSA encryption system, with the bank holding the private key.

To preserve privacy it is necessary for the note to carry a blinding factor when sent to the bank for signing. This can be done by the user by simply multiplying the note number by a random number before presenting it to be signed, and dividing it by the same number after the signature has been applied.

Due to the digital nature of ecash, it can be copied. To stop users from spending the same note twice a set of identity strings will also have to be included in the note structure. (These strings will give away a user's identity as soon as he tries to spend the same note the second time.)

As in the case of normal cash the note should also carry an indication of it's value. This can be stored as a separate field or it can be encoded as part of the bank's signature.

In order to clarify these different components of an ecash note, each of them is discussed in more detail in the following sections.

4.10.2.What is a digital signature

The aim of a signature is to provide a means by which a message can be authenticated. This also holds true for a digital signature, but a digital signature goes further by also indicating that the message has not been changed en route, prior to delivery.

A digital signature is defined by [DigSig] as a small amount of data that is recorded on an electronic medium. This signature is produced by the sender by applying a certain calculation to the message. This calculation is called the '*signature function*'. The resulting signature, which looks like random data, will only have meaning when read in conjunction with the message (in the case of ecash, the note number) used to create it. The recipient of the message checks this signature by performing another set of calculations (called the '*verification function*') on the signature and the message. The outcome of these calculations reveals whether or not the signature is a genuine and thus also authenticates both the sender and the message.

It is possible to use either secret or public key encryption methods to affect the signature mentioned above. However, the use of a secret key system is not really suitable to payments over an open network. This is due to security risks involved, when both the sender and the receiver must know the secret key.

4.10.3.Digital signatures by means of RSA encryption

When RSA public/private key functions is used, it is possible to let the receiver know the public key, without revealing the private key and thus to maintain a higher level of security.

One such method is described by [DigNum] as a system where the note number is raised to a power that corresponds to the appropriate key. Further more these exponentiations will be done in a modular arithmetic system where only the result of a modular division is stored. It is also recommended that the modules should be a sufficiently large number, at least 150 digits long.

To start with the sender (in this case the digital bank) generates two large primes **p** and **q**. The encryption algorithm is based on the fact that

$$x^{(p-1)(q-1)} = 1 \ (mod \ \ pq)$$

The next step for the bank is to choose an *e* and *d* so that

$$ed = 1(mod \ \ pq)$$

where *e* will be the public and *d* the private key. As such it will be possible to decrypt anything encrypted by *d* by using *e* due to the fact that :

$$(x^d)^e = x \ (mod \ pq)$$

Also note that the receiver can not deduce *d* (which the bank obviously keeps secret) without knowing *p* and *q* even though he does know *pq* and *e*, due to the many to one nature of the relationship above.

Taking the above into consideration it is possible for an ecash bank to use digital signatures as follows:

- To get a note signed the user presents the bank with x^e *(mod pq)* where *x* represents the note number.
- The bank signs this by raising it to the power d that is $(x^e)^d$ and returns it to the user.
- The user receives $(x^e)^d$ as x^d *(mod pq)* and stores x^d (which he/she can compute knowing *pq*) as the note to pay with.

4.10.4.Blind signatures

Due to the fact that the bank, can compute x (knowing the precise value of *d*), it will be possible for the bank to store the note numbers and as such to build up a spending profile for a particular user. In order to negate this possibility blind signatures are introduced.

This implies that the bank will sign a note without knowing the true note number, while still keeping the ability to recognize it's own signature at a later stage (i.e. when the note is presented as payment).

In order to achieve this, the user generates the note number (not the bank) and then multiply the note number by a blinding factor *r*. After the note is signed, the user simply divides out the blinding factor to get his original, but signed, note.

This means that the signing process described above will then change to:

- The user chooses a random blinding factor *r*.
- The user presents the bank with rx^e *(mod pq)* where *x* once again represents the note number.
- The bank signs this by raising it to the power d that is $(xr^e)^d$ and returns it to the user.
- The user receives $(xr^e)^d$ as rx^d *(mod pq)* and divides out *r*.
- Finally the user stores x^d as the note to pay with.

This scheme adds an important extension to ecash's digital signature, being that of payer anonymity. Except for this privacy, it also enables the user to prove that a payment was done, by revealing the blinding factor (which is only known to him/her).

4.10.5.Indicating a notes value

In his article On-line Cash Checks [DigChk], Chaum shows how the exponents in an RSA encryption system can be used to indicate an electronic note's value. It is easier to show how this can be done by means of an example, rather than a pure factual discussion.

In Chaum's scheme the odd prime exponents are used to indicate 1's in the corresponding position of a binary representation. This can be done by representing each successive power of two value by a corresponding odd prime root in the RSA system, all with the same modulus. In his example in [DigChk] he shows how the (arbitrary) value of 1 cent can be assigned to the public exponent three, that of 2 cents to exponent five, 4 cents to exponent seven, etc.

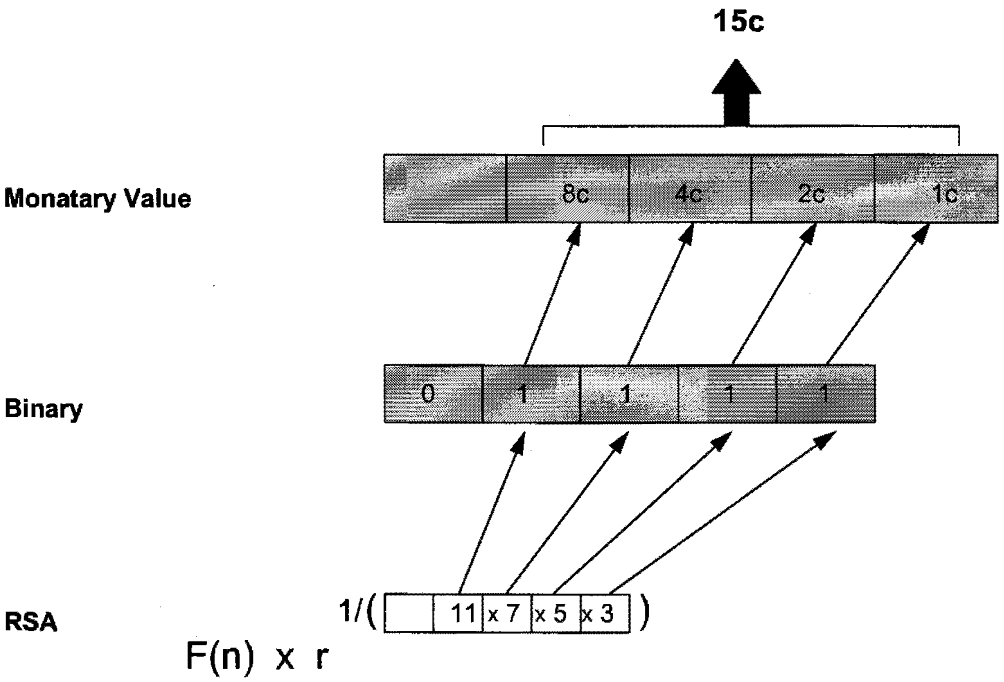


Figure 4-3 : Converting RSA exponents to Monetary Value

Keeping in mind the above discussions on blind signatures and an ecash note being represented as simply a number, consider the case where the user want's to withdraw 15 cents from the bank (assume that above allocations to cent values are used):

- let the note number generated by the user's equipment be **n**;
- let the blinding factor be **r**;
- let the bank sign by taking the **h-th** root;
- let **f** be an one way RSA public key encryption function

As such the user will choose n and r and start communicating with the bank. This communication will consist of a two way process:

- the user will present the bank with $f(n) * r^{h}$ in this case : $f(n) * r^{(3*5*7*11)}$
- the bank will answer with $f(n) * r^{1/h}$ in this case : $f(n) * r^{1/(3*5*7*11)}$

This scheme holds a number of advantages. Not only is the note's value an integral part of the signature but it is also relatively easy to devaluate, thus enabling partial payments, or a change system. (Several methods of handling change are discussed in [DigChk].)

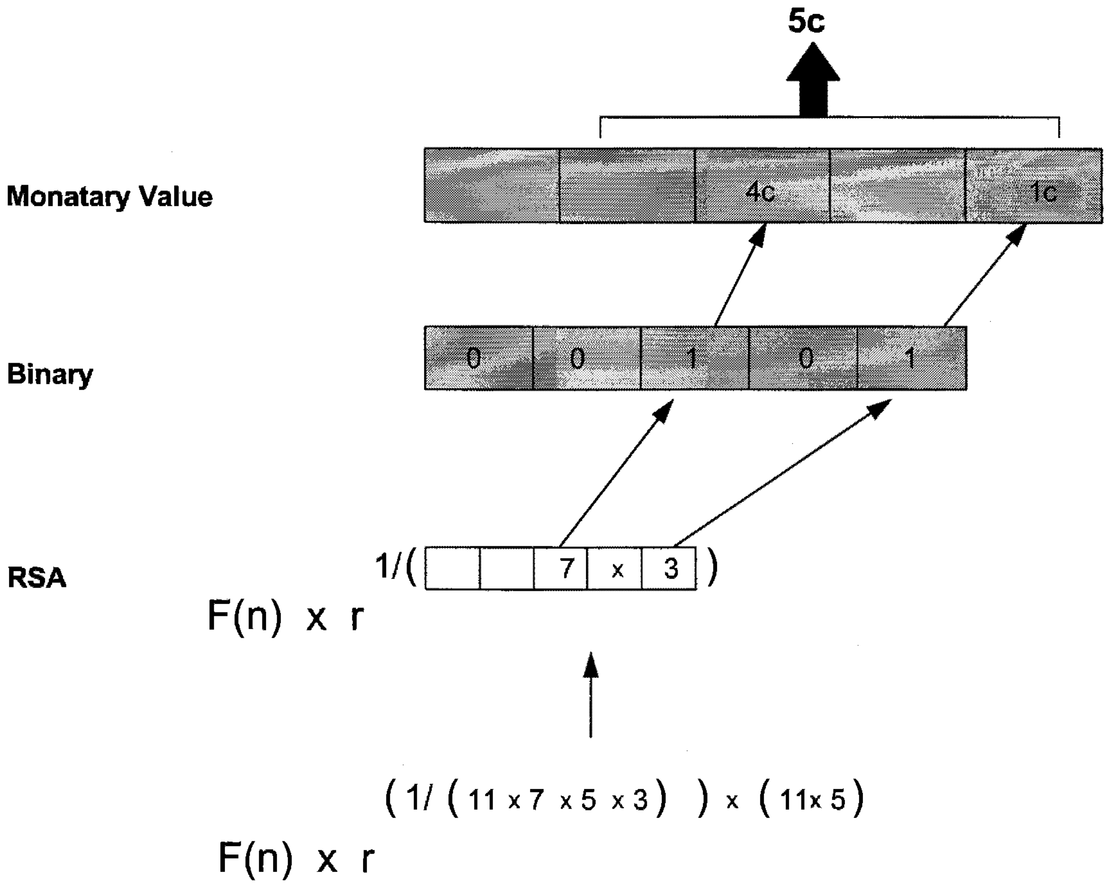


Figure 4-4 : How to devaluate ecash

To see how to devaluate a note, consider a partial payment of 5 cents using the 15 cents ecash note in the example. In order to break the note into the correct denominations we simply need to raise it to the 55th power to devaluate it to the required 5 cents, while the residue can be incorporated into a change scheme. That is:

- a payment represented by $f(n) * r^{1/(3*7)}$
- change represented by $f(n) * r^{1/(5*11)}$

4.10.6.Preventing double spending

Keeping in mind that ecash is represented by a digital number, it is therefore possible to copy your ecash. Although this means that you can keep a backup of your cash, it also means that a user can attempt to spend the same note twice. There are different methods of preventing this. Obviously this fraud can be attempted by either the merchant or the user, as shush it would be preferable for the prevention method to also indicate the identity of the culprit when detected. One such scheme is discussed by Bruce Shneier in [Sch94].

This scheme consists of the bank keeping a record of spent notes, with new payments being checked against this database of note numbers to indicate that they have not been spent before. In order to include the user's identity in case of fraud but protect his privacy otherwise, Schneier proposes the inclusion of 100 identity strings with each money order. These strings are formed by combining the user's name and address into a single string (S), which in turn is split into two strings (S_L and S_R) using a secret splitting protocol.

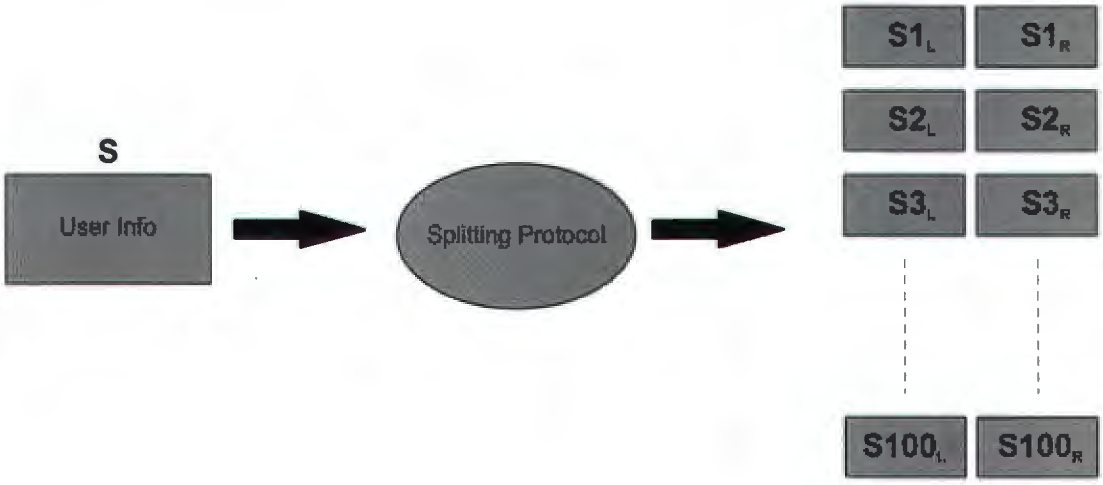


Figure 4-5 : Creating Identity Strings

These strings are created in such a fashion that any Si_L and Si_R (but not Si_L and Sj_R) can be combined to give the user's information (S). Shneier now adapts the verification process at the bank to include the user revealing either the left or the right half of each identity string. The choice is based on a 100 bit selector string, which the bank presents to the user. For instance if the corresponding bit in the string is a 1 the user will reveal the right hand side and if it is a 0 the user will reveal the left side (see fig 4.6).

The bank stores the note number as well as these identity strings for each spent note. Should the user now try to reuse a note, the bank will see from the note number that the note has already been used, further more it will now be in possession of another set of identity strings. Thus the bank can now find a Si_L and Si_R from these two sets that will reveal the user's identity. As Shneier points out this scheme will only fail if the bank issued the same selector string to the same user twice, a chance of 1 in 2^{100} i.e. not very likely.

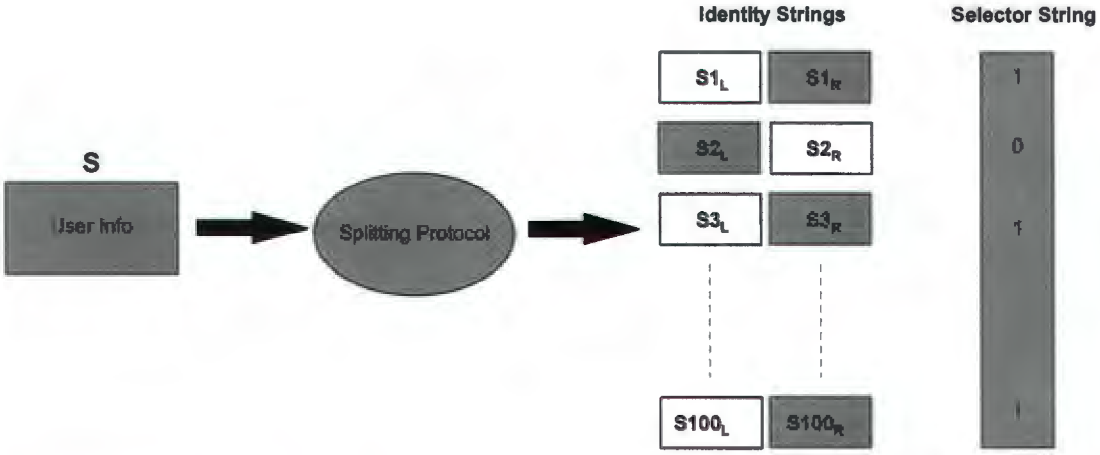


Figure 4-6 : Using a selector string

As such not only can the bank detect an attempt at double spending, but it can also determine the identity of the user in question.

(In [DigNum] Chaum mentions an adaption of this scheme that uses a combination of the note number and the user's information as **S** and does not require the bank to keep a copy of each note number.)

4.10.7.Error detection on a blinded ecash note

The technique described in par 4.10.6 will stop a user spending a note twice. This leaves the problem of a user tampering with the note. Any tampering after the bank has signed the note should be detected by the receiver as the bank's signature should no longer be intact (using public key encryption and assuming the user does not know the private key.)

However, because the bank signs a blinded note, it may be difficult for him to detect if the note he is signing is in fact well formed (i.e. is it a money order for R10 as it claims to be or is it one for R1000, claiming to be worth R10). This leaves one of two options, either make the note's value an inherent part of the bank's signature or build in a form of error detection. The first option has already been discussed in 4.10.5, while [Sch94] gives an example of the second.

Schneier recommends that the user submits 100 money orders to the bank. Each of these orders should have a different note number, while all of them must have the same identity information and monetary value.

The bank now selects a single order at random, which it will sign and return to the user. However before the note is returned the bank asks the user to unblind all of the remaining 99 orders and to reveal their identity strings. The bank can then verify that all the amounts are the same and that the identity information does actually refer to the user in question.

This scheme is not foolproof, but as Shneier points out, if you make the penalty for cheating high enough the 100 to 1 odds against the user getting away with it should be enough to stop him from trying.

4.11. The ecash protocol

With the above facts in mind, a general ecash protocol can now be put forward. This protocol is derived and discussed in [Sch94 p 66]. In order to simplify the discussion the transactions will be assumed to be done on-line (as will be the case during ATM transactions discussed in chapter five). Three entities will be taken into account a payer called Alice, a service provider called Bob and the Bank, *(the names Bob, and Alice are traditionally used in cryptography discussions)*. Let the transaction consist of a payment of R10 from Alice to Bob, the withdrawal from Alice's account and the deposit into Bob's account will also be included as part of the transaction as a whole. The steps to follow will then include:

4.11.1.Preparation of money orders

The user, Alice, prepares 100 anonymous money orders for R10 each. Each of these orders includes information regarding :

- amount (as discussed in 4.10.5)
- a uniqueness string (the note number as mentioned in 4.10.1)
- identity strings (100 split strings as discussed in par 4.10.6)

4.11.2.Blinding of money orders

Alice now blinds all 100 money orders (using the technique discussed in par 4.10.4)

Alice then sends all her orders to the bank.

4.11.3. Verification by bank

The Bank will now ask Alice to unblind 99 of her money orders and to reveal their identity strings. The Bank verifies the amounts and identity information (as discussed in 4.10.7).

4.11.4. Signing of order

The Bank will now sign the remaining money order in it's blinded form and return it to Alice, after deducting the corresponding amount from her account.

4.11.5. Unblinding of money order

Alice now unblinds her signed money order (as discussed in par 4.10.4) and sends this note, as payment, to Bob.

4.11.6. Verification by service provider

Bob now checks the bank's signature to make sure the note is valid. Bob then asks Alice to reveal either half of each of the identity strings (using a 100 bit selector string as discussed in par 4.10.6) Bob sends his money to the bank.

4.11.7. Final Verification by bank

The bank verifies the note's signature and check it's database of spent note numbers. If the same note number has not been deposited before it records the note number as well s the identity information. The bank credits Bob's account with the corresponding amount. If the same note has been spent before the bank will refuse payment and can find the perpetrator's identity by means of the identity strings (as discussed in par 4.10.6).

4.12. The advantages and disadvantages of using ecash

When considering the use of ecash to pay for network transactions, it is obvious that both the user and the service provider must derive certain perceived benefits from doing so. If this was not the case they could be expected to use another payment method instead.

Dr David Chaum, the director of the Digicash company sites the following as reasons why users are moving to ecash:

- ecash is versatile, it can be used for on-line payments over the phone, to handle road toll payments automatically (without stopping) or to buy goods over the counter;
- ecash is secure, due to its unique digital signature it can not be spent more than once and is signed by the bank as acceptable cash even before it is issued;
- ecash is private, it makes it impossible to connect payment and payer while still allowing the user to prove that payment was made.

That leaves the question, what's in it for the service provider (or for that matter the Internet shop)? From this point of view, the above mentioned advantages still holds, however in addition to these the following can also be to their advantage:

- payment is immediate, increasing cash flow;
- payment is guaranteed when checked on-line with the bank (the need to check can also be seen as an disadvantage);
- administration overheads are limited.

As with most things in life ecash has it's negative points as well. In [Sch94] it is pointed out that ecash's privacy can be used to engineer the perfect anonymous crime. Furthermore, due to the electronic nature of ecash it can be adversely influenced by hard disk crashes, unavailable network links, etc.

Keeping our aim with the use of Ecash (payment of network services) in mind, a serious drawback is that double spending during offline transactions can at most be detected, but not prevented.

Another disadvantage to ecash is that it does require a high technology infrastructure in order to be used. For the purpose of this study however this can be ignored as the same infrastructure is taken for granted in the network environment for which we aim to develop a payment scheme.

4.13. Summary

This chapter introduced the concept of electronic cash, as money that is represented by numbers. The characteristics of ecash were discussed and compared with that of normal cash. An overview of a general ecash transaction was given after which the techniques used in the ecash protocols were discussed. Finally an ecash protocol was presented, and an example given to indicate how a transaction between a payer, a service provider and the bank should take place.

Chapter 5

Proposed Invoicing/Payment Scheme

5.1. Introduction

The previous chapters gave an overview of current developments in the ATM as well as ecash fields; this should now enable us to develop an invoicing, billing and payment scheme that runs as an integrated part of the ATM protocol. To start off, this chapter delimits the bounds of the scheme, continues to define terminology (like clients, servers and owners) and summarizes simplified ATM setup and ecash protocols. Finally these protocols are combined into an invoicing and payment scheme. Two schemes will be examined, the one with a minimum overhead, and the other with maximum security in mind.

5.2. The preferred platform for implementation

In order to implement the proposed Invoicing/Payment Scheme (IPS) a certain amount of processing capabilities will be necessary. This implies that it will, for obvious reasons, not be possible to implement this scheme on the links between nodes, but only at the nodes themselves. As such implementation platforms could consist of:

- Computers
- Routers
- Switches
- Modified Repeaters or Hubs
- Specially developed network based equipment

The last two options will make the implementation overly expensive and will also limit it in scope. The first three options should however be possible to use as implementation platforms.

The use of computers exclusively, will however impose certain limitations. For instance it will imply that only end nodes can be used for invoicing and payment handling. This would mean that the service provider providing a pure communication service, consisting of a switched network, can not be compensated directly, which in turn would imply a separate payment system, exactly what we are trying to avoid.

This leaves routers and switches, as viable alternatives. The current industry trend seems to be towards more extensive use of switches, with routers being used only to connect subnetworks of switches. As such, the exclusive use of routers will exclude a large section of the network from the invoicing/payment process. The exclusive use of switches however, may lead to routing problems, in cases where routers are used to connect two subnetworks.

It should thus be clear that both switches and routers must be *aware* of an IPS when implemented in order to facilitate routing and connection setup based on IPS parameters inside an extended QoS. However, these devices are often engineered for a single purpose, without additional leeway to implement payment details and E-Cash note storage, etc.

With the above taken into consideration, it is the author's opinion that a two tiered approach will have to be used, where invoicing and (monetary) cost based routing will have to be done at switches and routers with the handling of payments being done at end nodes (or switch and dedicated computer pairs). This may imply that the service provider will have to implement dedicated workstations inside his network to handle the collection of payments.

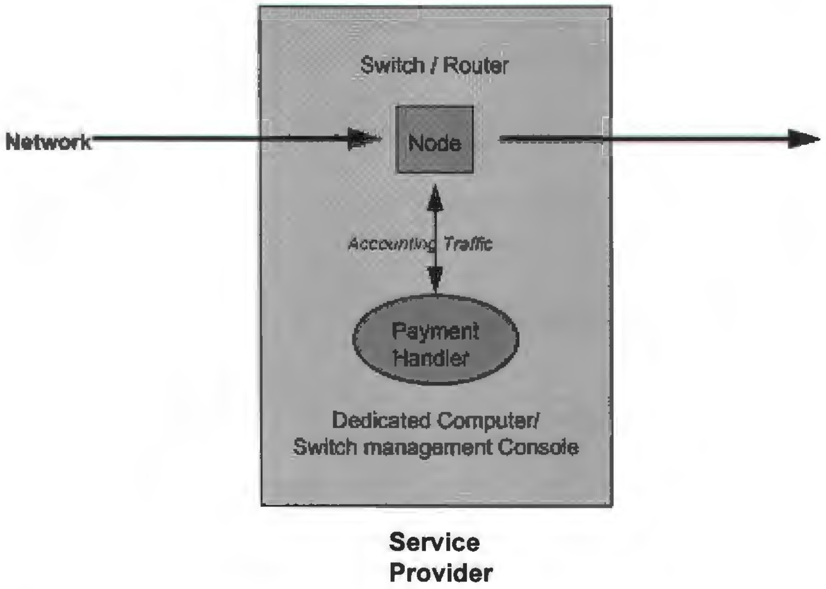


Fig 5- 1 : Architecture of IPS node

Referring to Fig 5-1 the service provider's node may thus consist of a dedicated PC or monitoring station connected to a switch, with the IPS implemented on the switch / computer pair.

5.3. The preferred level of implementation in the ATM protocol stack

When deciding on the ATM layer best suited to implementation of an IPS, the implementation platform will no doubt play an important role. For instance, refer to Fig 3-3 (repeated below as Fig 5-2 for ease of reference).

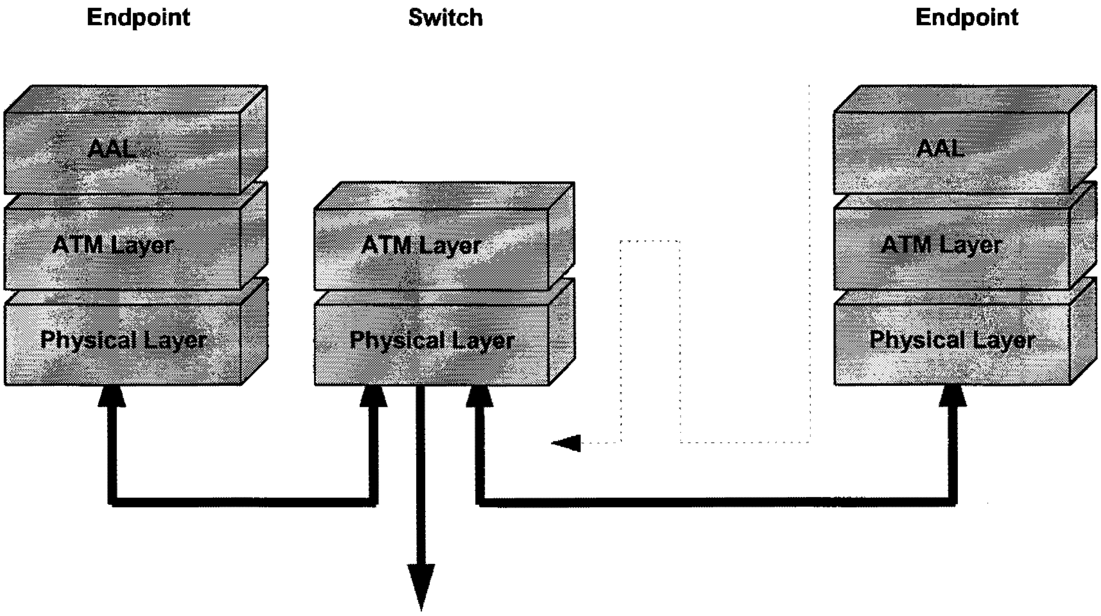


Fig 5- 2 : ATM Layers in use at different nodes

It can be seen that an ATM switch does not operate at the AAL level, although this is the position in the ATM stack where a computer / end node operates. Given this fact makes more sense to aim our proposed protocol extension at the ATM layer.

5.4. The simplified accounting environment

Throughout this chapter, an accounting environment will be used, consisting of the following:

- a client (the person / device that is using the communication service);
- a communication service provider (the device / organization that is rendering the service);

(Please note that this does not refer to the *normal* use of the term client/server, referring to a database engine as server and client that submits queries to it. Instead, the term client in this instance should be seen to refer to the *service user.*)

In most cases the *client* will be making use of the *service provider's* communication services to communicate with another client. This situation can be depicted as seen in Fig 5.3:

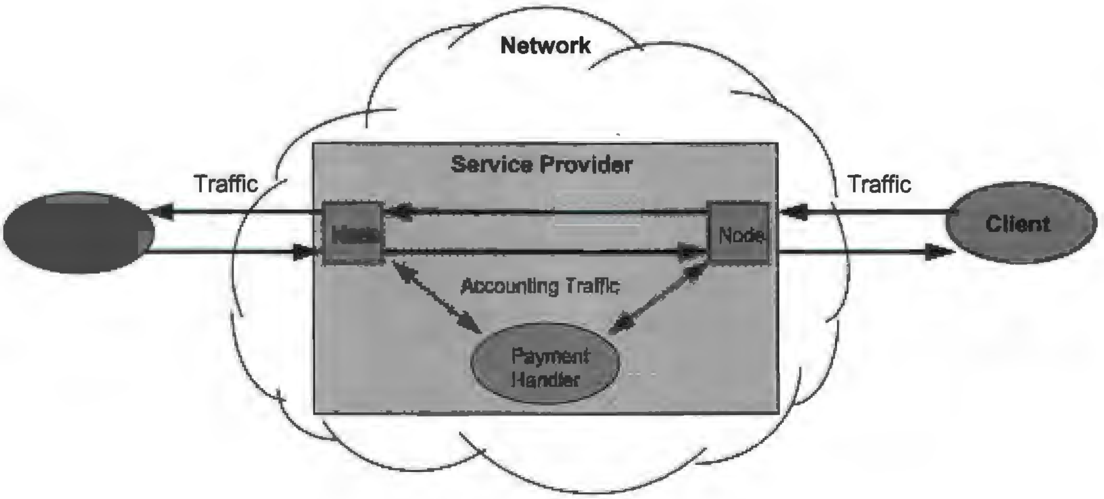


Fig 5-3 : The network accounting environment

Note that the service provider can choose how to monitor traffic over his network, he should be able to monitor the flow of traffic between two points, over a single point, etc. Further more it should be possible to have more than one service provider in cases where several interconnected networks are crossed as seen in Fig 5-4.

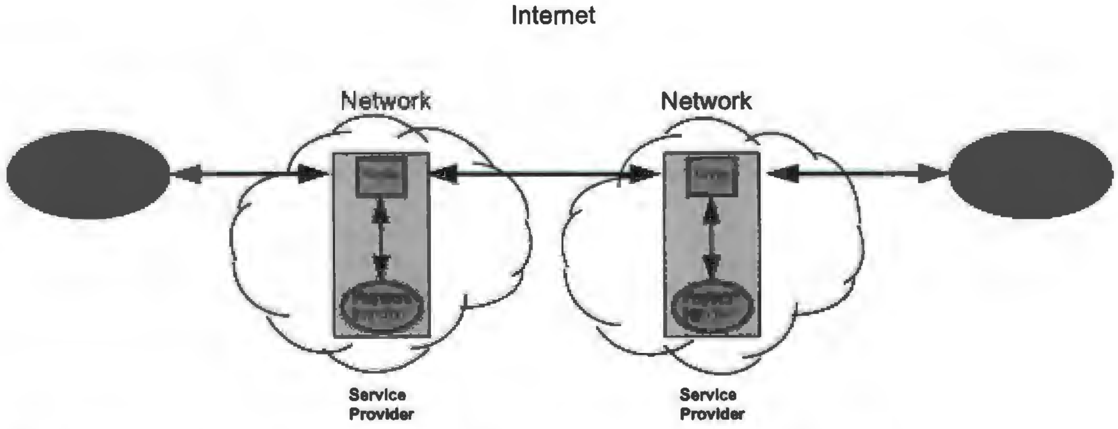


Fig 5- 4 : Multiple owners and networks in an accounting environment

In order to simplify our discussion, the research in this chapter will concentrate on the situation where a single owner, monitors and charges for traffic, across a single point in his network. Refer to Fig 5-5.

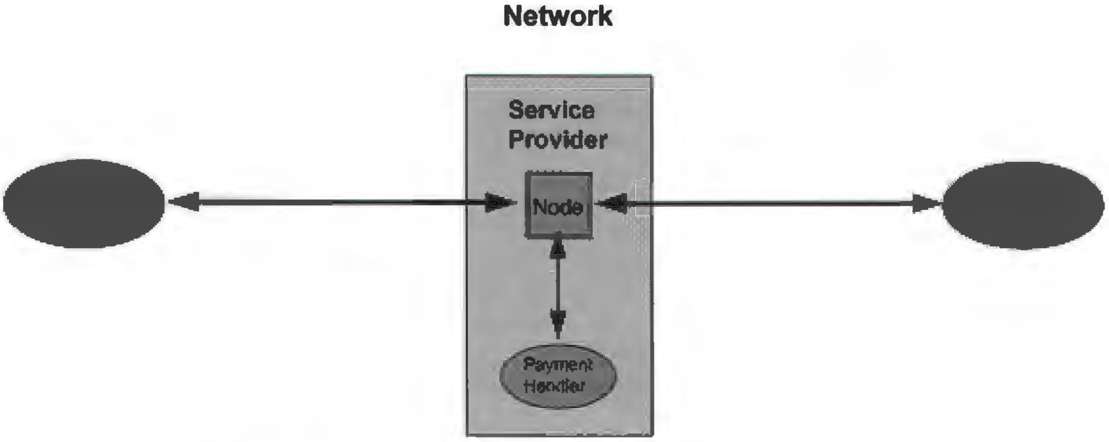


Fig 5- 5 :Simplified network accounting environment

It is necessary however, to note that this simplification can be done without loss of generality. To see that this is indeed the case consider the following:

- To monitor between two nodes on his network, the owner has to implement the above (single node) accounting scheme at both nodes, probably at those ports of the networking equipment that connect these points.
- To monitor the traffic crossing his network from his neighbor's network the owner has to implement the accounting scheme at the point of entry to his own network.
- To handle traffic crossing multiple networks, every owner of a network in between the two clients can use either of the above mentioned methods to monitor and charge for traffic crossing his network.

5.5. The simplified ATM connection setup process

In par 3.4.6 the signaling messages making up an ATM connection setup process was explained with reference to [OSC96 p 317]. To aid our discussion in the rest of this chapter, let us consider the setup process between two client's, A and B, across the ATM network. Let the network traffic be initiated by Client A, with Client B as the destination.

The setup process has been depicted in Fig 3-17, in it's most simplified form we can consider only those messages that convey information end-to-end. This situation is depicted in Fig 5-6. Note that three major steps can be identified:

- Setup information sent from A to B
- Connection Acknowledge information sent from B to A
- Transfer of data between A and B

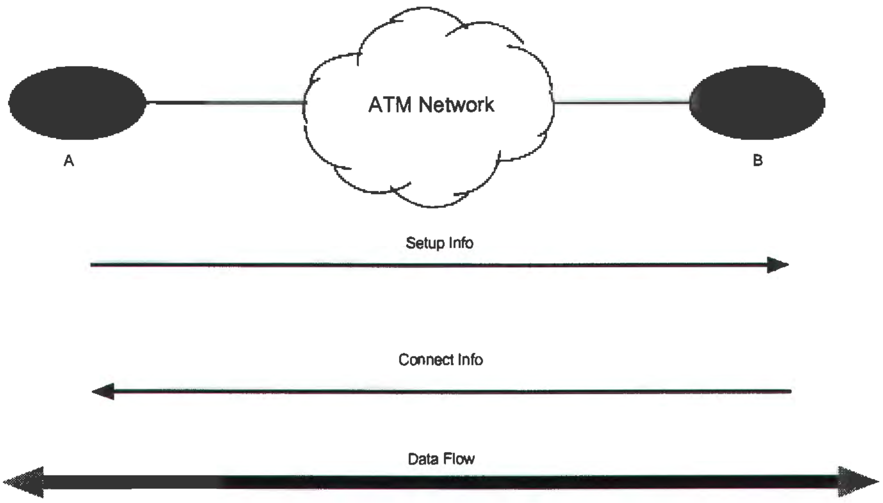


Fig 5- 6 : Simplified ATM connection setup

In the context of Fig 5-6 the setup process discussed in par 3.4.6 can be simplified to:

- A sends a SETUP message to B, this message contains the address details as well as the connection characteristics and optional setup fields.
- The network forwards the SETUP message to B using P-NNI route selection based on QoS and traffic parameters.
- If B decides to accept the connection, it returns a CONNECT message to its network node.
- The network returns the CONNECT information to A across the existing VC.
- After terminal A process' the CONNECT message information A and B can start to communicate across the connection

5.6. The simplified ecash protocol

Let us now consider the ecash protocol as discussed in section 4.11, when applied to our network accounting environment. Let the network traffic be initiated by Client A, with Client B as the destination. The Service Provider and the bank will also be part of the transaction. This situation can be depicted as follows:

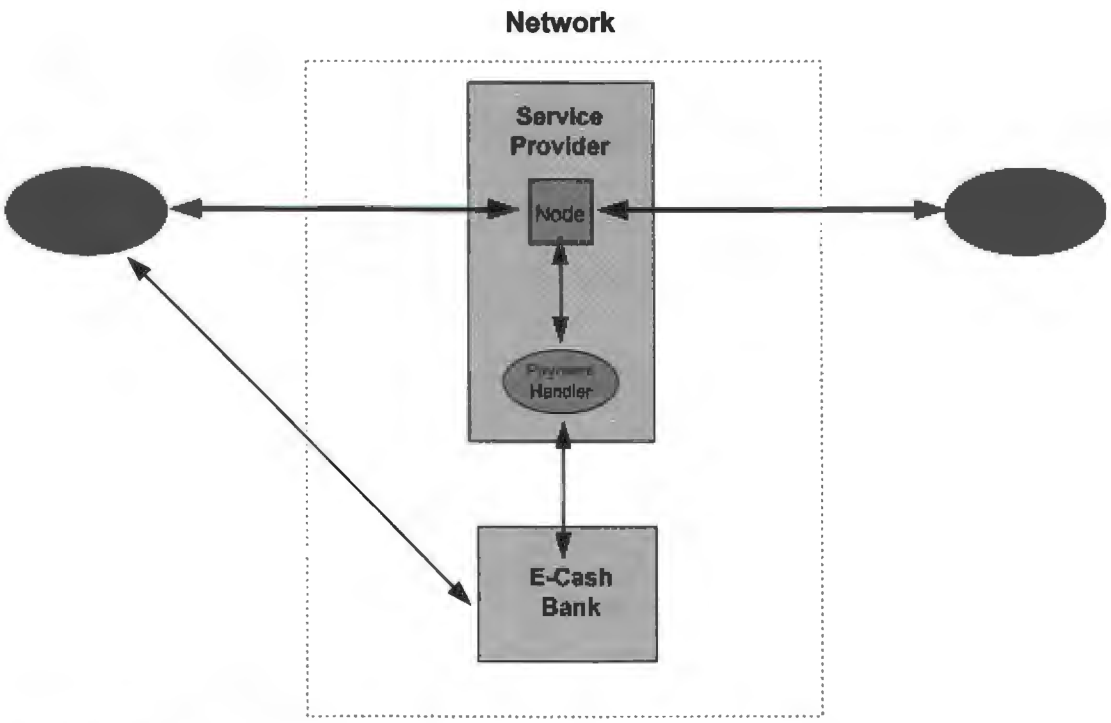


Fig 5- 7 : E-Cash protocol in a network accounting environment

Note that the service provider and client may obviously use different banks, with money transfers taking place between the banks. This situation can, however, without loss of generality be simplified to the case where a single bank is used.

The protocol can be simplified into three separate steps, being:

- Client A drawing money from bank
- Client A sending E-Cash to Service Provider
- The Service Provider deposits the money into his account in the Bank

Each of these steps can be further broken down (with specific reference to Chapter 4):

5.6.1. Withdrawal of funds

This part of the transaction must be done on-line with the bank, but can be done without any connection between Client A and the Service provider. As discussed in Chapter 4 the steps consist of the following:

Preparation of money orders

Client A, prepares 100 anonymous money orders for the amount he wants to draw. Each of these orders includes information regarding :

- amount (as discussed in 4.10.5)

- a uniqueness string (the note number as mentioned in 4.10.1)
- identity strings (100 split strings as discussed in par 4.10.6)

Blinding of money orders

Client A now blinds all 100 money orders (using the technique discussed in par 4.10.4) he then sends all his orders to the bank.

Verification by bank

The Bank will now asks Client A to unblind 99 of his money orders and to reveal their identity strings. The Bank verifies the amounts and identity information (as discussed in 4.10.7).

Signing of order

The Bank will now sign the remaining money order in it's blinded form and return it to Client A, after deducting the corresponding amount from his account.

Unblinding of money order

Client A now unblinds his signed money order (as discussed in par 4.10.4)

This completes the withdrawal process. Client A can now save his E-Cash on a hard disk for future use, or transmit it immediately to the Service Provider. At this stage, Client A can break his connection with the Bank.

5.6.2. Transfer of payment

During the next phase, Client A will transfer his E-Cash to the Service Provider, this can be done as part of the normal network traffic between the two parties. For obvious reasons, at least Client A and the Service Provider, must have a valid network connection at this stage. The Bank does not need to have a connection to either of these parties during this phase.

Payment is sent to Service Provider

Client A send his E-Cash note(s), as payment, to the Service Provider where it is accepted by the Payment Handler (this can be done either as one payment or as a number of separate smaller payments).

Verification by service provider

The Payment Handler now checks the bank's signature to make sure the note is valid. the Payment Handler then asks Client A to reveal either half of each of the identity strings (using a 100 bit selector string as discussed in par 4.10.6)

This concludes the transfer phase, the E-Cash has now been successfully transmitted from Client A to the Service Provider's Payment Handler. At this stage the connection between the Service Provider and Client A may be broken as far as payment transactions is concerned (it may however need to stay up as part of the service that is rendered to Client A). The Service Provider can now save his E-Cash on a local hard disk (i.e. the Payment Handler's disk) or he may choose to deposit his E-Cash funds into his account at the Bank.

5.6.3. Deposit of funds

During this third and final phase, the Service Provider, deposit's his E-Cash at the Bank, in order to complete the transaction. In this case the Service Provider and Bank must have a valid network connection. A Connection from either of these parties to the Client is not required at this stage.

Transfer of funds to bank

The Payment Handler sends his money to the bank.

Final Verification by bank

The bank verifies the note's signature and check it's database of spent note numbers. If the same note number has not been deposited before it records the note number as well s the identity information. The bank credits the Service Provider's account with the corresponding amount. If the same note has been spent before the bank will refuse payment and can find the perpetrator's identity by means of the identity strings (as discussed in par 4.10.6).

This completes the E-Cash transactions, between the Client and the Service Provider. At this stage the Service Provider may use his payment in normal monetary form, or withdraw it from the Bank in the form of E-Cash to pay other service providers (when acting as client).

5.7. Combining ATM and ecash protocols into a simple IPS

In par 5.6 three major steps were identified in our simplified ecash protocol. With reference to the previous two sections it should be clear that the second of these steps can be combined with the simplified ATM connection setup process to render an IPS integrated into ATM. The IPS protocol can then be seen to consist of the following major steps:

- A drawing money from bank
- Ecash transaction between A and Service Provider(s) :
    - Step 1: Setup information sent from A to B with possible routing based on monetary cost along the way.
    - Step 2: Connection Acknowledge information sent from B to A with quotation/invoice included.
    - Step 3: Transfer of data between A and B, intermingled with ecash payments to service provider(s) along the way.
- The Service Provider(s) deposits the money into his account in the bank

Note that as discussed in par 5.6 the initial withdrawal can be done between the bank and A without intervention of the service provider, while the last step, the deposit, can be done without an on-line connection between A and the service provider. As such these steps do not need any adaptions to the ATM protocols itself, as they do not differ from that already developed by Chaum, as discussed in chapter 4. The steps marked as Step 1 to Step 3 above do however warrant closer inspection.

5.7.1. Adaption to SETUP message of signaling protocol

The SETUP message of the Q.2931 signaling protocol needs to be modified in order to include the gathering of cost information while in transit between the source and destination UNI. It should also indicate to the NNI if routing should be done to minimize delay (traditional routing methods like OSPF) or whether it should be done to minimize monetary cost (regardless of delay).

In [Pry95 p 155] a number of mandatory as well as optional informational elements are discussed (see par 3.4.1). The addition of four optional information elements is proposed. These are:

- Monetary Routing:

  A single bit field, indicating that minimizing monetary cost should take precedence over the delay cost during routing decisions when set to 1, vice versa when set to 0.

- Total Monetary Cost:

  This field is used to indicate the total cost involved per time limit or per cell. (I.e., a certain monetary value per 3 min interval.)

- Time / Cell count indicator

  A single bit field, indicating if the cost is computed based on time (if set to 1) or on amount of cells (if set to 0).

- Payment Interval:

  This field is used to indicate how often during the connections lifetime a payment should be made. It could be a measure of the amount of cells, or of the time elapsed.

Motivation of and comments on the additional setup fields

The use of these additional fields (informational elements) are seen as one possible solution to the problem, no doubt it will be possible to identify others as well.

Regarding the *Monetary Routing* field: This field is not essential as the IPS will function without it. It further implies certain adaptions to the P-NNI routing schemes mentioned in 3.4.5 in order to route on other traffic characteristics than the normal delay / hop based routing. These adaptions are seen to fall outside the scope of this study and will not be discussed further. It should however be noted that the inclusion of this field opens up another facet to the possible applications of an integrated IPS. By means of this field a delay insensitive application (i.e. an e-mail application) should be able to indicate to the network to give it a low cost connection, thus cutting cost and providing the *"most bang for the buck"* to the user.

Regarding the *Total Monetary Cost* field: The inclusion of this field is seen as essential for the functioning of the IPS. The intention is that this field should indicate to the client the total cost involved for maintaining his connection per time / cell unit. For the purpose of this study the value of this field will refer to a monetary value in cent.

Regarding the *Payment Interval* field: This field should indicate the maximum time (or amount of cells) that may elapse between payments to the service provider(s). For the purpose of this study the value of this field will refer to an amount of time measured in seconds when time based, or amount of cells when cell based payment is used.

Regarding the *Time / Cell count indicator* field: This field allows a user to select either time based or cell based payment. Time based payment is not suited to payment for low data rate/ low priority, long term connections.

Note that the *Payment Interval* and *Total Monetary Cost* fields are structured for incremental payments. This implies that the client will be paying as he/she uses the service provider's service and not afterwards or before. Motivation for this choice is twofold:

- The service provider can not cheat by receiving payment and then breaking the connection as is possible in the case of a pay before use scheme.
- The client can not cheat by using the service and breaking the connection before payment has been sent, as is possible in the case of a use before pay scheme.

For obvious reasons the service provider will have to consider the chosen value of the *Payment Interval* field with care, so as to limit monetary loss in case of a lost connection, while maintaining efficiency. The following should be born in mind when deciding on a value for this field:

- Small frequent payments will have a large bandwidth overhead, while limiting any disputes to values that are small enough to ignore.
- Large infrequent payments will have a small bandwidth overhead, but may cause disputes to end up in court.

Computing cost and interval setup field values

Although the values of the *Total monetary Cost* and *Payment Interval* fields are required at the UNI level they will have to be computed en route during NNI signaling. This implies that the values at the NNI will have to be translated to the UNI for use by the client (see [Jun96] for translation methods between UNI and NNI).

The following methods of computation are proposed. Let every node at the NNI level where the IPS is active identify values for the following:

- M: The monetary value payable to it's payment handler for use of it's services.

- T: The time interval with which payments need to be made to it.

When receiving a SETUP message at the NNI, the node then performs the following actions before transmitting the message to the next network node en route to the destination UNI (note that this will only happen in cases where more than one service provider is used):

- If T is smaller than the existing value in the SETUP message's *Payment Interval* field: Adapt the value in the *Total Monetary Cost* field to the same time / cell interval as T and replace the value in the *Payment Interval* field with T.
- Add M to the value in the SETUP message's *Total Monetary Cost* field.

Thus, upon reaching the destination UNI the *Total Monetary Cost* field will hold the total cost per time interval, payable along the complete route by the client, while the *Payment Interval* field will indicate the maximum time limit allowable between such payments.

5.7.2. Adaption to CONNECT message of signaling protocol

When routing the SETUP message through the network, the *Total Monetary Cost* and *Payment Interval* values are computed. At the destination these values can then be copied to the CONNECT message sent by the destination UNI to the network and finally by the network to the source UNI. As such, it is proposed to include only two additional fields to the CONNECT message being :

- Total Monetary Cost
- Payment Interval (per second or per cell)

As the connection route is already set when the CONNECT message is sent, the inclusion of the *Monetary Routing* field in this message is not necessary.

Note that it is also possible to compute the value of these fields while the CONNECT message is sent through the network, instead of doing the computation while sending the SETUP message. This will keep the SETUP message smaller and may thus be more efficient. However, the basic principle will still be the same. The advantage of including these fields in the SETUP message is that their component values will in any case be needed for Monetary Routing.

These fields in the CONNECT message can be seen as a quotation for cost that is presented to the client. The moment he accepts the connect message by sending a

CONNECT ACKNOWLEDGE these fields can be seen as an invoice for payment. If the cost is too high to the client's liking, he does not send a CONNECT ACKNOWLEDGE, thus refusing payment and breaking the connection.

(Instead of the above method, it would also be possible to add a monetary budget to the SETUP message, that is *used up* during the connect process, in a similar way as a delay budget is handled. If the budget is reduced to zero before the destination is reached the connection process can be stopped immediately.)

5.7.3. The use of STATUS signals for payment

In order to handle the transmission of payment from a client to the service provider(s) the use of the STATUS message is proposed. Onruval [OSC96 p 315] indicates that a STATUS message can be sent in answer to a STATUS ENQUIRY or at any other time (mostly to indicate error conditions). He also indicates that both an end user (client) and the network itself can be the recipient of a STATUS message.

It is proposed that the STATUS message format be adapted so that it may include an ecash note and that payment be performed as follows:

- The client (A in our previous example) retrieves an ecash note of value equal to *Total Monetary Cost* from the bank or secondary storage, packs it in an STATUS message and sends it to the destination (B in our previous example).
- An intermediate network node running IPS devaluates the ecash note in the STATUS message with M (as discussed in par 4.10.5). It then sends the modified note (with value = received value - M) on to the next node en route to B, while sending the deducted ecash note (value = M) on to it's own payment handler for storage.

Note that the intermediate nodes, which may be different service providers, should also keep a timer indicating the amount of time elapsed between payments. If at any stage a specific node should find $T_{elapsed} > T$ negotiated during setup, it will generate a RELEASE message to both A and B, breaking the connection.

5.7.4. Use of IPS by end nodes

Note that the IPS is intended for use by the service provider (i.e. intermediate nodes) the scheme is however usable without adaption for payment of end users as well. Consider the case where client A uses information services at end node B (just another client from the service provider's point of view) using the service provider C's network. A can now pay both C and B by means of the same scheme. All that is required of B is to add it's own cost to the quotation that is generated by means of the SETUP message, thus ensuring that A will include funds for it's own payment into the message.

Thus far we have always assumed that the client setting up the connection will be the one to pay the connection costs. It should however be possible to adapt the scheme to work the other way round if necessary.

5.8. Extending the simplified IPS to a secure system

The simplified IPS scheme presented above will work inside a private domain where all service providers can be seen as trusted. (One such example is where divisions of a mother company use internal funds to pay cost centers inside the company for wide area network services.) However, if used in an *open* environment the following problems can be identified:

- Payment is sent in an un-encrypted format. As such, the payments can be intercepted by any node along the way.
- The same payment message is routed past all the IPS nodes, if a node takes more than it's due, the client has no way to find where the problem originated.
- Devaluation of the ecash payment along the VC, implies that the cell stream, must be buffered while a payment message is built from consecutive cells.

In order to counter these problems certain adaptations to the SETUP message, as well as the payment method will be necessary.

5.9. Setup for a secure IPS

Instead of the four single valued fields proposed in the simple IPS, it is proposed that a matrix of values are sent as part of the SETUP. Each row of this data entity should refer to a specific service provider. The fields relevant to each service provider's IPS node will then consist of:

- Total Monetary Cost
- Time / Cell count indicator
- Payment Interval
- Public Encryption Key data
- IPS node's NSAP address

All these fields except the last two are identical to those discussed in the simple IPS. The last two fields are used to enable the client to make an encrypted payment to a specific service provider. As in the case of the simple IPS a single bit *Monetary Routing* field can be added to the SETUP, over and above these multi valued fields.

5.10. Adding cost and interval data

In the simple IPS a node re-computes the interval and adds to the cost field when receiving a SETUP on the NNI. In the case of the secure IPS a multiple valued SETUP message is used, making these computations unnecessary, instead the node simply adds another informational element (containing the above fields) to the SETUP message.

5.11. Connect for a secure IPS

In a similar way as is done for the SETUP, the CONNECT message will have to be changed in the case of a secure IPS. Once again the data collected in the SETUP message needs to be returned by means of the CONNECT message as a matrix instead of a number of single valued fields.

5.12. Status (payment) messages in a secure IPS

After the initial CONNECT message is received, the client can use the NSAP addresses returned to him to set up connections to each of the service providers that requires payment (See Fig 5.8). The client also keeps a table of the amounts and minimum payment intervals required by each service provider. At the specified interval the client will:

- Retrieve an ecash note of the required amount and encrypt it using the specific service provider's public key.
- Send this ecash note in a STATUS message down the VC set up to the specific service provider.

A service provider's IPS node will:

- Decrypt any payments that are addressed to it.
- After successful decryption, he will store the ecash note on the payment handler's hard drive.

It is not necessary to devaluate the note as mentioned in the case of the simple IPS.

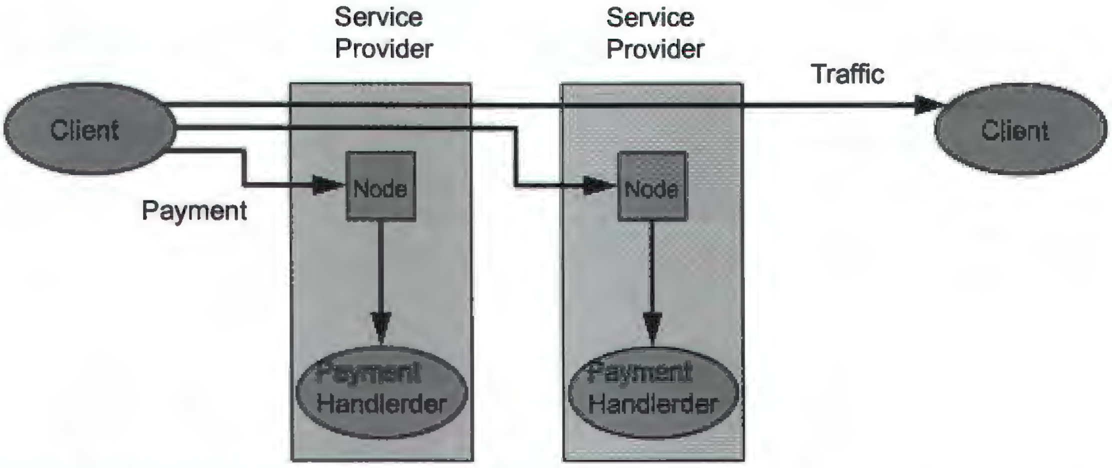


Fig 5- 8: Separate payment connections in a secure IPS

A different approach that can be identified as a subject for future study, would be to define a payment message consisting of a matrix layout, similar to the SETUP message discussed above. In such a case each service provider will find his encrypted payment in a single row of the matrix inside the STATUS message.

5.13. Summary

In this chapter a proposal was made for a network accounting system that implements invoicing and payment as an integral part of the ATM protocol. The scheme is based on the assumption that the cost attribute of a network transaction can be handled as a characteristic of the traffic across an ATM connection. The IPS was seen to consist of a combination of a simplified ecash protocol and an ATM connection setup protocol. The system is based on payment by means of ecash at regular time intervals to the service providers involved. The first step involve determining the amount payable and the applicable time intervals, this can be done by means of a modified SETUP message. After this the connection is available for data exchange. The actual payments are done by means of a periodic modified STATUS message. A simplified IPS scheme was presented first, with modifications done to render a second, more secure scheme.

Chapter 6

Evaluation

6.1. Introduction

The previous chapter concentrated on the proposal of an accounting scheme that is embedded into the ATM protocol itself, without necessarily indicating how feasible such a scheme may be in real life. In this chapter we will take a closer look at the overhead as well as the advantages and disadvantages of this scheme in order to evaluate the proposed scheme. Due to the fact that an implementation of this scheme will imply a change in all ATM equipment used in the trial, it is not practical to implement a test network. The programming of a simulation, although practical, is not seen to fall inside the scope of this study. It will however, be possible to investigate the viability of this scheme by means of an analytical approach.

6.2. Changes to the ATM signaling and routing protocols

In the previous chapter the following changes to ATM were proposed:

Changes to the routing algorithm to allow routing on monetary cost

Additions to the Q.2931 signal informational elements

The first of these changes were shown to be optional, although it's inclusion will open a number of new possible avenues to IPS application. As routing methods were not seen as part of the scope of this study, this option will not form part of our evaluation.

The second change does however influence the viability of our proposed IPS as it can not be seen to be optional.

By simply adding informational elements to the Q.2931 SETUP signal, the impact of the IPS on the ATM architecture is kept to a minimum. It does however imply that a certain penalty will be paid regarding the number of bits needed to complete the setup.

6.3. Simple IPS overhead during ATM connection setup

In [OSC96 p 315] Onruval shows the general informational element format to be as indicated in Fig 6-1. These elements are packed into the last field in the Q.2931 message format as described in chapter 3 (see Fig 3-14).

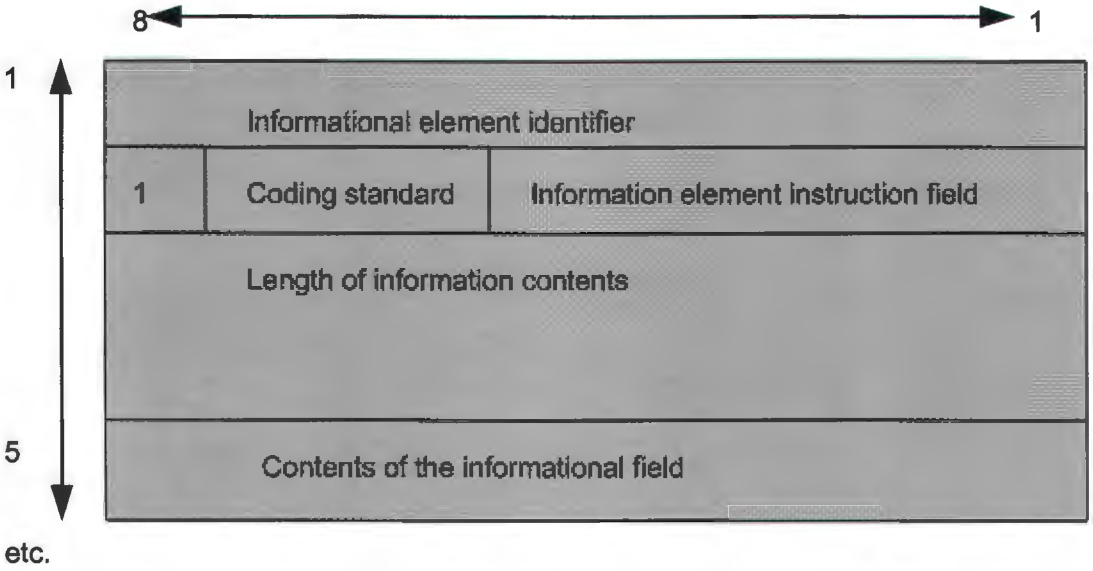

8
1
1
Informational element identifier
1
Coding standard
Information element instruction field
Length of information contents
5
Contents of the informational field
etc.

Fig 6-1: Information Element Format [OSC96 p 315]

As can be seen, the minimum length for a single informational element is 5 bytes. This consists of a 4-byte header (H) as well as a single byte, information element value. This implies a minimum overhead of 20 bytes in every SETUP message during the connection setup process if a separate informational element is used for each of the four extra fields proposed in our Simple IPS, being:

Monetary Routing

Time / Cell Count Indicator

Total Monetary Cost

Payment Interval

Another option should be to combine all the additional information into a single informational element. In such a case the minimum overhead will depend on the number of bits used by each of the extra fields. In case of the Monetary Routing field (R) and the Count Indicator (C) this is 1 bit. For the other fields the length can be decided on as follows:

Total Monetary Cost (M):

This field has been defined to indicate a certain coin value indicated in cent. For reasons discussed in chapter five, the payment interval is expected to be quite small. As such the total monetary cost is not expected to be extremely high, a value of 2^{16} is expected to be sufficient. This implies a minimum of 2 bytes to be reserved for this field, rendering a total amount of 65535c (R/$ 655.35) per payment.

Take note that this field indicates a quotation, and as such can use an *open* format, and will thus not carry the encryption and other overheads that ecash has to carry.

Payment Interval (T):

Once again the relative small expected time intervals between payments will influence the length of this field. To use only one byte for this field will imply a restriction of 4 min between payments. This may be sufficient for most transactions, but it was the author's opinion that at least a 10-min interval should be possible. It is therefore proposed to use 2 bytes in this case as well, giving a maximum value of 18 hours between payments.

If a combined approach is therefore taken, the total difference in the number of bits (L) would then be:

$$\text{Delta } L_{setup} = L_H + L_R + L_c + L_M + L_T$$

$$= (8 \times 4) + (1) + (1) + (8 \times 2) + (8 \times 2)$$

$$= 66 \text{ bits}$$

If two bits in one of the T bytes are used to store R and C, the above 66 bits can be shrunk to a minimum of 8 bytes overhead in each SETUP message sent.

Depending on the method chosen, L_{setup} can therefore be seen to incur an additional cost of between 8 and 20 bytes. (Note that the implementation giving Delta L_{setup} = 20 bytes may still be better due to simplicity during application development. This will also give more adaptability during future extensions.)

Referring back to Fig 3-14 and Fig 6-1, the minimum length for a Q.2931 message can be seen to be:

$$L = L_{Q.2931 \text{ Header}} + L_{Inf \text{ Element}}$$

$$= (8 \times 9) + (8 \times 5)$$

$$= 112 \text{ bits}$$

However [Pry95 p 155] lists at least four compulsory informational elements for a SETUP message. (See par 3.4.1 for detail.) That implies that L_{setup} should be at least:

$$\begin{aligned} L_{setup} &= L_{Q.2931\ Header} + (4 \times L_{Inf\ Element}) \\ &= (8 \times 9) + 4 \times (8 \times 5) \\ &= 232 \text{ bits} \end{aligned}$$

Giving our new minimum length for a SETUP message L'_{setup} with IPS active as:

$$\begin{aligned} L'_{setup} &= L_{setup} + \text{Delta } L_{setup} \\ &= 232 + 66 \\ &= 298 \end{aligned}$$

This implies a percentage increase of:

$$\begin{aligned} \text{IPS Overhead}_{setup} &= 100 \times (L'_{setup} - L_{setup}) / L_{setup} \\ &= 28.44\ \% \end{aligned}$$

For obvious reasons the increase in length of the CONNECT message will increase with the same amount (only the one bit Monetary Routing Field falls away). As mentioned in chapter 5 it is possible to change the proposed scheme to make the *Total Monetary Cost* and *Payment Interval* fields fall away in the SETUP message. If this route is followed during implementation it would imply a Delta L_{setup} = 40 bits and a Delta $L_{connect}$ = 66.

It should however be pointed out that this overhead is only paid during setup, which occurs only once in a connections lifetime. Thus, at ATM bit speeds the setup overhead should be a negligible percentage of total traffic.

6.4. Overhead of Secure IPS during ATM connection setup

As discussed in the previous chapter, the Simple IPS can be adapted, by trading overhead for security, in order to render a Secure IPS. This version of the IPS uses a matrix layout inside the SETUP message with one line for each service provider in the path.

As discussed in chapter 5 this version uses two additional fields, being:

NSAP Address (A):

As seen in chapter 3, the 20-byte NSAP address format is used for node identification [Ben94].

Encryption Key (K):

In order to encrypt the payment to a specific service provider, the service provider must provide a public encryption key to the client. According to Rabe [Rab95], this key can be between 128 and 64 bits in length, depending on the type of encryption used. We will use 128 bits for the porpose of our computations.

With the above fields added to those discussed for the Simple IPS, Delta $L_{secure\ setup}$ will then be:

$$\text{Delta } L_{secure\ setup} = L_H + L_R + L_c + L_M + L_T + L_A + L_K$$

$$= (8 \times 4) + (1) + (1) + (8 \times 2) + (8 \times 2) + (8 \times 20) + (128)$$

$$= 354 \text{ bits}$$

Note that this is for a single service provider, as the Delta L_{setup} will be a function of $N_{provider}$ (the amount of service providers) in the case of the Secure IPS.

With the Secure IPS, the client must however, also perform an additional connection setup to each of the service providers along the route.

For a single service provider this implies a percentage overhead of:

$$\text{IPS Overhead}_{secure\ setup} = 100 \times ((L'_{setup} - L_{setup}) + L_{setup}) / L_{setup}$$

$$= 100 \times (232 + 354) / 232$$

$$= 252.58 \%$$

For multiple service providers the overhead can be computed as:

$$\text{IPS Overhead}_{secure\ setup} = 100 \times (N_{provider} \times (L'_{setup} - L_{setup}) + N_{provider} \times L_{setup}) / L_{setup}$$

$$= 100 \times N_{provider} \times L'_{setup} / L_{setup}$$

This is no doubt a substantial overhead, but once again it must be pointed out that the SETUP process will occur only once during a connections lifetime.

6.5. Overhead during data transfer of Simple IPS

The overhead during payment by ecash can, be considerable and will be incurred more than once during a connections lifetime. Due to the nature of our proposed IPS, the precise value will vary according to the Payment Interval (T) chosen by the service provider(s).

In chapter 5 it was proposed to handle payment by inserting ecash into the STATUS message available as part of the Q.2931 signaling protocol. As in the previous section it will be necessary to examine how many additional bits are necessary to implement IPS.

The same message format as that described by Fig 3-14 and Fig 6-1 will be used to send the STATUS message. However, unlike the case of the SETUP message, the whole message will have to be interpreted as overhead in this case.

It should be clear that the exact length of the STATUS/Payment message will depend heavily on the length used for ecash representation. This in turn will depend on the specific ecash implementation scheme being used. However, we can make certain assumptions regarding the minimum length of a generic ecash implementation. From the discussion in Chapter 4 we can assume that at least the following information will have to be represented in the ecash note:

Note number (uniqueness string)

Signature

Monetary value

Identity strings

As discussed in par 4.10.5 it is possible to include the monetary value in the signature itself. In par 4.10.3 it was also mentioned that the signature can be applied by using RSA encryption on the note number itself. Using these techniques will allow us to implement ecash using a representation that will pack all of the above mentioned logical fields into a record containing only a note number and Identity string fields.

When examining these two fields we can make assumptions on their minimum length based on the following:

Note number:

In par 4.10.3 it was pointed out that 150 digits can be considered as the minimum length for a note number when using RSA encryption on it [DigNum]. If using a normal ASCII representation of these digits or possibly a packed decimal representation, we can thus assume a 150-byte string.

Identity Strings:

In [Sch94] Shneier proposes the use of 100 identity strings, each consisting of a left and a right half, that will reveal the user's identity in case of double spending. If the normal *Pascal* type string is used this implies 100 x 256 bytes. It should however be possible to develop an implementation using a smaller string value, or to use fewer strings in order to limit the number of bits required. Another option is to do away with the anonymous property of ecash and replace these strings by a single identity string in non-encrypted form. We will however, use the 100 x 256 bytes, worse case, for our computations in this section.

This brings the minimum length for a payment message to:

$$L_{pay} = L_{\text{Message Header}} + L_{\text{information Element Header}} + L_{\text{Note Number}} + L_{\text{Identity}}$$

$$= (8 \times 9) + (8 \times 4) + (8 \times 150) + (8 \times 100 \times 256)$$

$$= 206{,}104 \text{ bits}$$

Depending on the value of T, this value can be said to be big enough to make a difference in the throughput of the ATM connection. When carefully chosen however, the overhead can be surprisingly small. As an example consider a 100 Mb/s connection with a value of T = 60 sec (1 min).

This will imply that the total amount of bits sent per minute is :

$$\text{Total Bits sent} = 100 \times 1024 \times 1024 \times 60$$

$$= 6{,}291{,}456{,}000$$

However, with L_{pay} at a minimum equal to 206,104 bits (as discussed above) the amount of bits available to transport normal ATM cells is:

$$\text{Normal ATM bits} = \text{Total Bits sent} - L_{pay}$$

$$= 6{,}291{,}456{,}000 - 206{,}104$$

$$= 6{,}291{,}249{,}896$$

Expressed as a total percentage of the throughput, this represents an overhead of :

$$\text{IPS Overhead}_{pay} = 100 \times (6{,}291{,}456{,}000 - 6{,}291{,}249{,}896) \;/\; 6{,}291{,}456{,}000$$

$$= 0.00328\ \%$$

(Note that the above disregards the overhead of the ATM header itself, which will be added to both the normal and the payment parts of the traffic flow during SAR.) In a similar manner the percentage overhead for other values of T can be estimated.

6.6. Overhead during data transfer of Secure IPS

The Secure IPS uses a separate payment message to each of the service providers along the way. As such the overhead during data transfer will once again be a function of $N_{provider}$ (the amount of service providers).

It should be clear that the case of a single service provider is equivalent to the overhead of the Simple IPS as discussed above, as both require a single payment message with the exact same fields. The situation will however differ considerably in the case of multiple service providers where L_{pay} needs to be multiplied by $N_{provider}$. This implies that the Normal ATM bits will be:

$$\text{Normal ATM bits} = \text{Total Bits sent} - (L_{pay} \times N_{provider})$$

bringing the percentage overhead to :

$$\text{IPS Overhead}_{pay} = 100 \times (L_{pay} \times N_{provider}) \;/\; \text{Total Bits sent}$$

$$= 20{,}610{,}400 \times N_{provider} \;/\; \text{Total Bits sent}$$

6.7. Conclusion regarding feasibility

From the above it can be seen that a simple IPS will carry a 28% overhead during connection setup and a 0.003% or lower overhead during data transfer (due to periodic payment) for transfer rates of 100 Mb/s and higher and payment intervals of 1 min and above. (Less than 0.0005 % at T=10 min)

Thus it can be inferred on bit overhead considerations, that the Simple IPS is viable. The viability of the Secure IPS will depend on the number of service providers involved. It will however be wise to also consider added latency per node due to the additional computational overhead. However, this value will be heavily dependent on the computational ability and speed of nodes themselves and is thus not considered to lend itself to analytical evaluation.

As such, further research into that direction will not be conducted as part of this thesis, although it can be identified as a possible direction for future practical research.

6.8. Advantages and disadvantages of the IPS

The main advantage of the IPS is that, compared to normal payment methods, service providers get paid for services rendered, virtually in real time. This could lead to considerable savings on their part regarding interest and amount of working cash involved.

Another advantage is that the invoicing and payment process is automated, as such the service provider should be able to cut back on administrative costs. With reference to Fig 1-1, repeated below as Fig 6-2 it should be clear that service providers will need minimal staff involved in the last three processes of their network transactions.

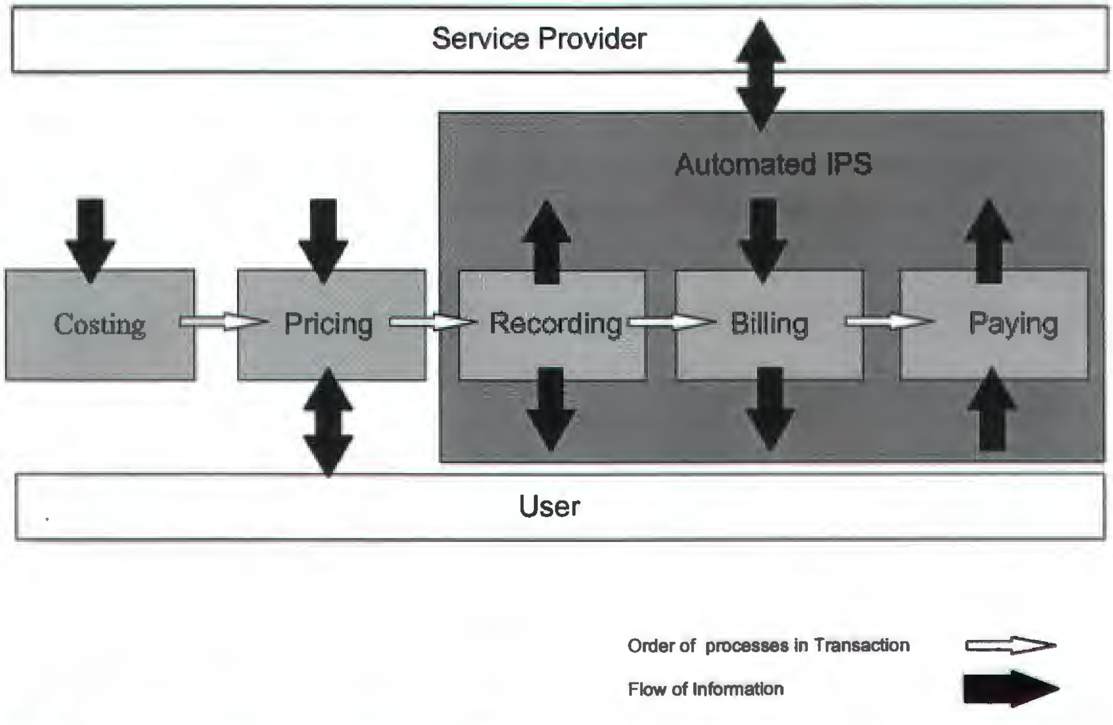


Fig 6- 2 : Processes automated by IPS

These cost savings can also lead to a less expensive service to the client (if the service provider pass some of the cost savings through to the client).

On the other hand the system does have certain drawbacks. If the Simple IPS is used it could lead to loss of income due to fraud. The Secure IPS on the other hand incurs a considerable overhead if a large number of service providers are involved.

Another problem is the possibility of double spending. Using ecash, double spending can be detected but not prevented, unless online checks is done with the bank on each ecash note before it is accepted. This implies a *credit* check per ecash note, which may lead the service provider to consider a different payment method. One possibility is the use of credit card numbers, where the *credit check* can be done per user, instead of per note, using the existing credit card infrastructures.

6.9. Summary

In this chapter the feasibility of the network accounting scheme, proposed in chapter five was investigated. By means of computations it was shown that the scheme can be considered viable for higher data transfer speeds when payment is not required at an interval shorter than 1 minute. (Overhead was shown to be close to 0.003% for 100 Mb/s transfer rate with a 1-min payment interval using a single service provider.) These computations were based on bit overhead alone and did not consider computational latency. When considering the advantages and disadvantages of the scheme, it was however pointed out that problems like the possibility of double spending, may make different electronic payment methods preferable.

Chapter 7

Conclusion

This thesis started off, by indicating the need for a more creative approach towards the payment of high speed networking services. A number of objectives were set in chapter one, with a hypothesis indicating that the use of ecash payment may be the solution to our payment problem.

In chapter two it was indicated that the mature, but low speed, protocols in use today, will no longer be sufficient to render a usable network service in the future. Thus, newer, high speed networking technologies should be considered in order to cope with the ever-increasing demand in bandwidth. It was also pointed out that this technology will include high speed protocols like ATM as well as high speed networking devices like switches. These protocols and devices were briefly discussed in order to aid the discussion in following chapters.

Chapter three took a closer look at ATM, as well as the definition thereof. The discussion included the different layers of the ATM implementation and indicated the various sub protocols operating at each layer. Closer attention was also paid to the functions of each of these layers. The chapter concluded with a section indicating the signaling, addressing and routing necessary for ATM connection setup, as well as a summary of the messages sent during setup.

Chapter four introduced the concept of electronic cash, as money that is represented by numbers. The characteristics of ecash were discussed and compared with that of normal cash. An overview of a general ecash transaction was given after which the techniques used in the ecash protocols were discussed. Finally an ecash protocol was presented, and an example given to indicate how a transaction between a payer, a service provider and the bank should take place.

In chapter five a proposal was made for a network accounting system that implements invoicing and payment as an integral part of the ATM protocol. The scheme is based on the assumption that the cost attribute of a network transaction can be handled as a characteristic of the traffic across an ATM connection. The IPS was seen to consist of a combination of a simplified ecash protocol and an ATM connection setup protocol. The system is based on payment by means of ecash at regular time intervals to the service providers involved. The first step involve determining the amount payable and the applicable time intervals, this can be done by means of a modified SETUP message. After this the connection is available for data exchange. The actual payments are done by means of a periodic modified STATUS message. Two methods were discussed, one IPS optimized for minimum overhead and the other for security.

In chapter six the workability of the network accounting scheme was investigated. Due to the fact that an implementation of the proposed IPS would imply a number of adaptions to the hardware and software at each service provider node, an implementation was not attempted as part of this research. Instead an analytical approach was taken. By means of computations it was shown that the scheme can be considered viable for higher data transfer speeds when payment is not required at an interval shorter than 1 minute. (Overhead was shown to be close to 0.003% for 100 Mb/s transfer rate with a 1-min payment interval.) These computations were based on bit overhead alone and did not consider computational latency. A major problem pointed out, was that ecash only allows the detection of double spending and not the prevention thereof (in cases where the bank is off-line). This implied that a service provider has to do a credit check per ecash note if he wants to be sure that a payment made to him is valid.

7.1. Feasibility of Proposed Extension to ATM

Based on the discussion in chapter six it was seen that a network accounting scheme implemented as an integral part of the ATM protocol is feasible, when basing a decision purely on bit overhead considerations. However, due to the nature of ecash, the possibility of double spending could cause a serious problem. As such, the anonymous nature of ecash can be seen as the only gain over payment methods such as the use of credit card numbers. A theme that can be considered for future study, is the use of credit card based payments, instead of ecash, in combination with the rest of the proposed IPS.

7.2. Objectives Reached

In chapter one it was mentioned that the objectives of this research includes:

To understand ATM;

To understand electronic billing and ecash;

To propose an ATM-embedded billing and payment method;

To evaluate this method by means of computations.

This thesis started off with a discussion regarding the general high speed networking environment of today and the future. After that ATM was discussed in more depth in chapter three, providing understanding of ATM in general and thus reaching the first objective of this research.

Further objectives were reached in chapter four during the discussion on electronic cash. Finally chapters five and six covered the last two objectives by proposing and evaluating an ATM embedded network accounting scheme.

It can therefore be stated that all the objectives stated in chapter one was reached. The next section will summarize the main issues covered in the chapter two to six of this thesis.

7.3. Conclusion

Given the above facts it can be seen that it is indeed possible to implement an accounting system by using a form of electronic cash and incorporating recording, billing and payment as an integral part of the high speed networking protocol, as was stated in the hypotheses in chapter one. However, in cases where privacy and the anonymous nature of ecash is not a priority, existing methods, like the use of credit cards, may present a lower overhead cost.

Appendices

Appendix A: Notes on Smart cards vs Ecash

One drawback of ecash, is that it is not possible to spend your money without the help of some form of electronic device to handle the transaction and on which to keep your digital purse. Although the modern day PC have become quite portable it is however not ideal to take a notebook with when shopping. In order to extend the use of ecash to off-line payments, the development of smart cards should be seen as a parallel development to that of ecash and not only as part of the development cycle of ecash itself.

In a recent address to the US House of Representatives [Cha95], dr Chaum made it clear that he sees the use of smart cards as more applicable to off-line, and that of ecash as more applicable to on-line payments. However, he also predicted that the trend would be to the convergence of these two methods into a hybrid, since people do not want incompatible forms of money and it offers the best of both worlds in terms of convenience. As the scope of this research concerns the use of ecash to pay for on-line network transactions, smart cards will not be discussed in detail.

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http//www.digicash.com/publish/cardcom.html

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http//www.digicash.com/publish/ecash_intro/ecash_intro.html

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http//www.digicash.com/ecash/moneyonnet.html

[DigNum] Digicash publications. Numbers that are money
http//www.digicash.com/publish/digibro.html

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