B-ISDN and the OSI Protocol Reference Model

The service offered by the ATM layer in the B-ISDN protocol reference model is equivalent to the service offered by the OSI physical layer.

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Considering the growing need for network interconnection, a common platform for the B-ISDN and OSI protocol reference models (PRMs) is necessary for an efficient interworking between OSI and B-ISDN networks. The purpose of this paper is to define the relationship between OSI and B-ISDN.

The paper presents the evolution of present public telecommunication networks toward B-ISDN. Next, we introduce the Asynchronous Transfer Mode (ATM) in support of B-ISDN and present the B-ISDN protocol reference model. Finally, the relationship between the B-ISDN protocol reference model and the OSI one is discussed. Within this framework, we also consider the emergence of the MAN standard as intermediate support for broadband services.

The Present Situation

Today there are plenty of telecommunication networks heterogeneous in nature and service specific. For instance, consider the cases of telephony, telex, cable TV, and so forth.

Besides obvious political and commercial reasons, each network was introduced to support a well-identified and specific application in an optimized way. Unfortunately, past technology was unable to offer a common networking solution for the entire applications spectrum. This was further complicated by application needs arising at different moments and investments in a given technology suffering from a large inertia.

The first telecommunication network was exclusively tuned for voice from its introduction through all evolution steps. When the need for long-haul data transfer arose, a dedicated data network naturally followed its own parallel way. On their side, LANs, supporting local data transport, followed another way.

The scene for internetworking emerged — a set of heterogeneous networks with differences at all levels: for example, packet or circuit switching, connection oriented or connectionless operation modes, various protocols, uncorrelated addressing schemes, a difference in bit rate of at least six orders of magnitude (say from 1 kb/s to 1 Gb/s), a difference of several orders of magnitude for the basic quality of transmission (e.g., BER of 1.E-6 to 1.E-10), distinct protocol reference models, and diverging privacy and security requirements.

One now recognizes that such a diversity becomes problematic and a general trend is to seek network integration.

A first push toward this network integration came with the narrowband ISDN (N-ISDN), capable of integrating voice, data, and low-grade video (64 kb/s to 2 Mb/s) on the access of the digital voice network. Even if the achieved integration does represent a positive step, it has limited ambitions. The N-ISDN is not suited to offer faster services (e.g., broadcast video or very high speed data transfer for LAN interconnection). Rather, N-ISDN can be considered as an intelligent way to exploit the latest generation of voice networks for cost efficiency and services offered.

If we envisage a universal network, it must be able to transport a large number of services such as the following:

- Low speed (e.g., telemetry, telecontrol, telealarm, voice, telefax, low-speed data).
- Medium speed (e.g., hi-fi sound, video telephony).
- High-speed data.
- Very high speed (e.g., high-quality video distribution, video library, video education).

Therefore, the transfer mode for this universal network cannot be designed specifically for one service. As is shown in Fig. 1 there is a large range of services, with an estimated bit rate of a few b/s up to some hundreds of Mb/s. Also, the holding times vary from subsecond up to hours.

Clearly the need for a faster, smarter, and more flexible network continues. This is the target of B-ISDN.

B-ISDN Concept

The network platform of the future must be service independent. Such a network platform must include the following three items.

First, the platform must be flexible and future-safe. New services require increasing bandwidth, even if advances in the state-of-the-art of coding algorithms and VLSI technology may reduce the

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bandwidth requirements of some existing services. A network capable of transporting all kinds of services will be better able to adapt itself to changing or new needs.

Second, the platform must be efficient in the use of the available resources. All available resources can be shared between all services, such that an optimum statistical sharing of the resources can be obtained.

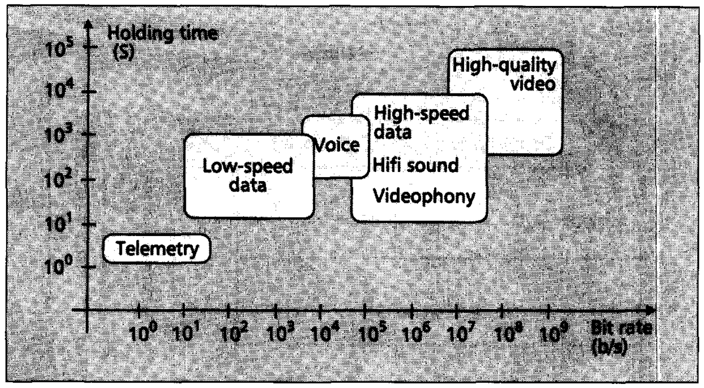
Finally, the platform must be less expensive since only one network needs to be designed, manufactured, and maintained, the overall costs of the design, manufacturing, and operations will be smaller.

The definition of such a performant and service-independent network platform has been influenced by two important parameters: the progress in technology and the progress in system concepts.

In recent years, a large technological progress has occurred, in the fields of electronics and optical equipment. The most promising VLSI technologies to develop broadband communication systems are CMOS and Silicon bipolar. The optical fiber technology is evolving quite rapidly as well: bit rate, distance, quality, and cost have been enhanced every year.

This technological progress allows the economical development of a new networking technique running at very high speeds that releases (at least at the lowest level) the need to have a multiplicity of totally incompatible networks.

Conceptually, the most flexible network in terms of bandwidth requirements and the most efficient network in terms of resource usage is based on the concepts of packet switching. However, the initial packet switching networks (e.g., based on X.25) suffer from high complexity and do not allow the transport of services with stringent delay/bandwidth constraints. The packet switching concept had to evolve.

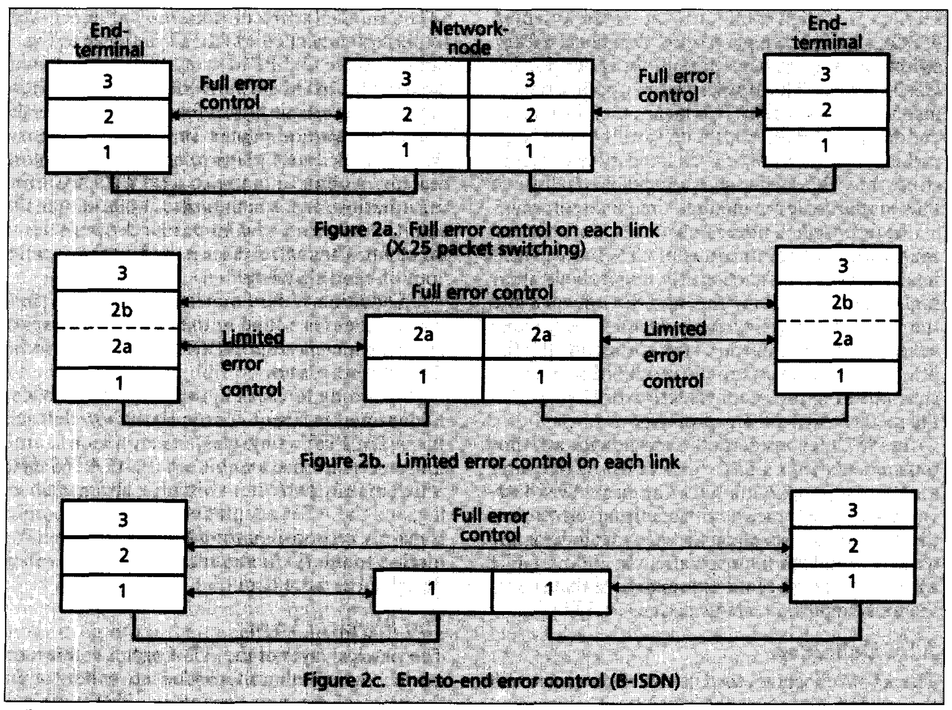


■ **Figure 1.** *Ranges of services expected in broadband networks.*

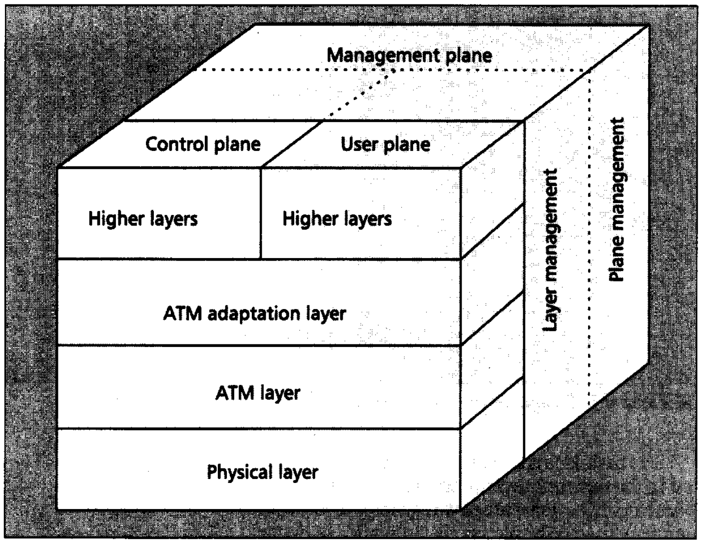
The basic idea is that functions must not be repeated in the network several times if the required service can still be guaranteed when these functions are implemented only once at the network's boundary. This basic idea can be applied to two functions offered by the network: semantic and time transparency.

Semantic transparency is the function that guarantees the correct delivery at the destination of the bits, which were transmitted by the source. Of course, the network is not ideal and some errors will occur, but with a very small probability.

In the initial packet-switched networks, the quality of the transmission media was such that in order to guarantee an acceptable end-to-end quality, error control was performed on every link as is shown in Fig. 2a. This error control is supported by an HDLC protocol that includes core functions such as frame delimiting, bit transparency, error checking, and other functions such as error recovery (retransmission).



■ **Figure 2.** *Evolution in system concepts (according to the OSI protocol reference model).*



■ **Figure 3.** *B-ISDN protocol reference model.*

As technology improved, the quality of the transmission and switching systems increased, thus reducing the errors within the network. In such a high-quality network only the core functions of the HDLC protocol are implemented on a link-by-link basis; the other functions are implemented on an end-to-end basis (Fig. 2b). This leads to the concept of frame relaying.

For B-ISDN this idea is extended further. In this case packets continue to be used, but the error recovery functions also have been shifted to the network's edges (Fig. 2c). In the case of B-ISDN, packets are named "cells."

Some services require that the continuity of the bit stream be respected (time transparency). These services are called continuous bit-stream-oriented (CBO); a typical example is voice. Traditional packet-switching systems have difficulties in supporting CBO services. These systems can operate only at medium-to-low speeds. This means that the end-to-end delay and the jitter on the delay will be quite large, making it impractical or even impossible to reconstruct the CBO service with acceptable quality and thus to guarantee the required time transparency.

As opposed to other networking techniques, the asynchronous transfer mode (ATM) needs a minimal network node functionality, thus it allows a very high speed. The delay through the network and the jitter on this delay are reduced to very small values (a few hundreds of microseconds for the jitter on the delay in broadband ATM networks), thus allowing the reconstruction of the CBO at the receiver without any problem.

In 1987, the considerations on semantic and time transparency led CCITT to select the ATM bearer service to support B-ISDN [1]. The term "ATM bearer service" simply means "an underlying telecommunication service based on the ATM technique and which is application unspecific." In 1990, CCITT agreed on a set of 13 recommendations that specify the most important characteristics of ATM [2].

ATM Definition

The ATM concept is based on two approaches: shift the semantic transparency, as well as the time transparency, to the boundary of the network. The ATM concept results from the merging of two well-known concepts: packet switching and time division multiplexing (TDM). Each of these techniques has been modified in the following manner related to packet switching:

- No error control (on the data field) nor flow control on the links inside the ATM network.
- Connection oriented at the lowest level. All information is transferred in a virtual circuit assigned for the complete duration of the connection.
- Packets have a fixed and small length. Instead of allowing variable-length packets to be switched, only fixed, small fixed-length packets (called cells) are accepted by the network. This choice allows the use of very high-speed switching nodes and puts no constraints on services, since large information entities will be segmented into cells.
- Limited functionality in the header of the cells. The primary functionality supported by the header of the ATM cells is the identification and characterization of the virtual circuits. In addition, some error detection and correction on this virtual circuit identifier are provided.

Related to TDM, the time-slotted operation is kept, but the time transparency is shifted to the network's edges. This means that no time relation is maintained inside the network: time slots are no longer characterized by their relative position in a frame as was the case in TDM (this is the meaning of the "A" of "ATM"). That explains the need to identify a certain time slot by having an additional field called a header containing a virtual circuit identifier. In order to keep the overhead due to the header acceptable, the size of a cell is set to 53 bytes, the header being 5 bytes long and the cell information field is 48 bytes.

ATM Layered Model

The B-ISDN protocol reference model for ATM as recommended by CCITT is shown in Fig. 3. Similar to the OSI PRM, a layered architecture is used for the ATM B-ISDN PRM. One sees however a characteristic typical for ISDN networks [3]: it contains several planes. In B-ISDN, there are three planes: a user plane to transport user information, a control plane to deal with signaling information, and a management plane to maintain the network and to perform operational functions. The control plane is used for the so-called "out-of-band signaling."

In addition, a third dimension called the plane management is added to the protocol reference model, which is responsible for management of the different planes.

According to CCITT, the planes are divided as depicted in Fig. 3. Three layers are defined: the ATM PHY (physical) layer, which mainly transports information (bit/cells); the ATM layer, which mainly performs switching and multiplexing; and the ATM adaptation layer (AAL), which is mainly responsible for adapting service information to the ATM stream. These layers will be described in more detail.

The Physical Layer

The physical layer of the ATM protocol reference model can be further subdivided into two sublayers: the physical-medium-dependent (PMD) sublayer and the transmission convergence (TC) sublayer.

The physical medium sublayer is responsible for the correct transmission and reception of bits on the physical medium and is medium-dependent (optical, electrical). The transmission convergence sublayer's main function after bit reconstruction is the mapping of the ATM cells to the transmission system used (synchronous, plesiochronous, or cell-based hierarchies).

ATM Layer

The ATM layer is fully independent of the physical medium used to transport the ATM cells and thus of the physical layer. The virtual channel (VC) concept is introduced. This concept describes the unidirectional transport of ATM cells associated to a common unique identifier value, the VC identifier (VCI). Similarly, one also defines the virtual path concept (VP) as being a bundle of VCs. Consequently, in addition to their VCI, cells also contain a VP identifier (VPI).

The four main functions that must be performed in the ATM layer include the following:

- Multiplexing and demultiplexing of cells of different connections (identified by different VCI) onto a single cell stream.
- Cell header is extracted (added) before (after) the cell is delivered to (from) the adaptation layer.
- Translation of the VCI might be required at ATM switching nodes.
- An access flow control mechanism may be implemented on the user network interface.

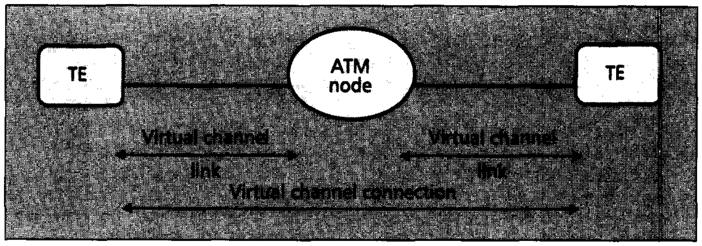
This leads to additional definitions. The first one relates to the application of the virtual channel concept to a single link. A virtual channel link is a means of unidirectional transport of ATM cells between a point where the VCI value is assigned and the point where that value is translated or removed. The second definition considers the virtual channel concept on an end-to-end basis. A virtual channel connection is a concatenation of virtual channel links that extends between two points where the higher layer (AAL) is accessed (Fig. 4). Similar definitions also hold for the VP.

ATM Adaptation Layer

By definition, the common low-level bearer service offered by the ATM layer is not tailored to any application. Although nothing prevents a user to use directly the ATM services, for some applications it might not be directly usable. Hence, there can be a need to enhance the ATM service for distinct classes of applications (i.e., the role devoted to the ATM adaptation layer (AAL). The AAL enhances the service provided by the ATM layer according to the requirements of specific services. These services can be user services as well as control and management functions. The AAL maps the user, control, or management protocol data units into the information field of the ATM cell and vice versa.

To reflect the spectrum of applications, four service classes have been defined by CCITT [4]. For instance, in addition to segmentation and reassembling of computer messages, the AAL can improve the quality of service provided by the ATM layer (e.g., by detecting lost cells).

As shown in Fig. 5, the classification is performed according to three parameters: the time relation between source and destination, constant or variable bit rate, and the connection mode.



■ **Figure 4.** *Virtual channel link and connection.*

	Class A	Class B	Class C	Class D
Timing between source and destination	Required		Not required	
Bit rate	Constant	Variable		
Connection mode	Connection oriented			Connectionless

■ **Figure 5.** *Service classes for the AAL.*

In class A, a time relation exists between source and destination. The bit rate is constant and the service is connection-oriented. A typical example is 64 kb/s voice; Another example is the transparent carriage of T1 or E1 signals. The offering of this service over an ATM network is sometimes called circuit emulation.

Also, in class B, a time relation exists between source and destination, for a connection-oriented service. However, the difference with class A is that class B sources have a variable bit rate. Typical examples are variable video and audio bit rate.

In class C, there is no time relation between source and destination and the bit rate is variable. The service is connection-oriented. Examples are connection-oriented data transfer in the user plane and signaling in the control plane.

Finally, class D is close to class C, but it is connectionless. An example of such a service is connectionless data transport (e.g., LAN interconnection traffic).

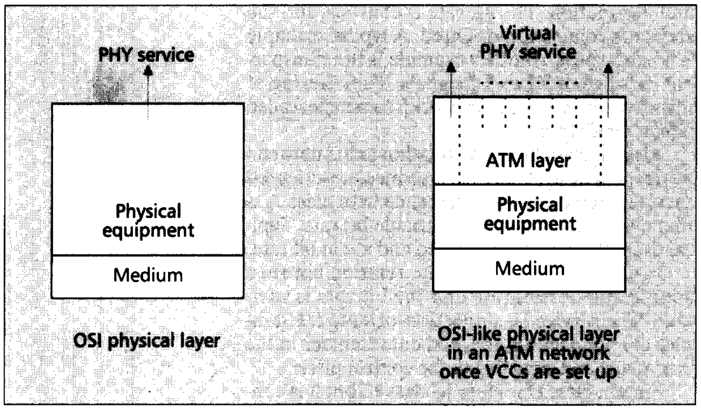
CCITT has recommended three types of AAL to support the four service classes: types 1, 2, and 3/4. Although the AAL types are in consonance with the service classes, the user is free to select any AAL type for any service class for user-to-user communications. CCITT also has left open the possibility to have an empty AAL for users who may find the ATM services sufficient for their requirements.

It is interesting to note that CCITT initially defined distinct types 3 and 4, respectively, for connection-oriented and connectionless data. Discussions soon made it clear that the distinction between types 3 and 4 was increasingly artificial. It was then preferred to merge them into one single 3/4 type whose procedures could be applied in a connection-oriented or connectionless manner.

One should note that a fifth AAL type currently is under discussion in standardization bodies, [6,7]. This AAL type 5, sometimes called the simple and efficient adaptation layer (SEAL), was initially proposed by the computer industry as a

An elementary physical layer: OSI point-to-point baseband physical layer	A sophisticated physical layer: ATM layer (assume baseband transmission)
1. The connection is permanent: cable is laid and disconnected only in case of failure and network reconfiguration.	**1. Connections are very dynamic: subsecond to semipermanent establishment is possible.**
2. The bandwidth of the connection is equal to the bit rate of the physical link.	**2. The bandwidth of a virtual channel connection can be anywhere between zero and the physical link bit rate. There are generally many virtual channels connections per physical link.**
3. The procedure for opening/closing a physical connection can be degenerated (e.g., physically connecting or disconnecting cables).	**3. Connection setup and release procedures are done via the control plane.**
4. There is a real copper/fiber connectivity.	**4. There is no copper/fiber connectivity anymore: virtual connectivity.**

■ **Table 1.** *Comparing the OSI physical layer to the ATM layer.*



■ **Figure 6.** *OSI and ATM networks: the physical service.*

reaction to the high complexity of AAL3/4 mechanisms. The AAL5 allows the transport of noninterleaved data frames in a connection-oriented manner (e.g., suitable to transport class C information). Although, the initial idea of the AAL 5 was simplicity, the first results of discussions within CCITT do not look promising from the complexity point of view. For instance, one can bet that the AAL5 CPCS-PDU header for which "the need and the functions are for further study" [*sic*] [8] will become cumbersome.

The AAL for each type is subdivided in two sublayers: segmentation and reassembling (SAR) sublayer and convergence sublayer (CS). The prime functions of the SAR are the segmentation of PDUs into ATM cells and reassembling of cells into a PDU. The convergence sublayer is service dependent.

To allow a common AAL type 3/4, the AAL 3/4 CS is further subdivided into two sublayers: a CS common part sublayer and a CS service specific sublayer [9].

B-ISDN and OSI Protocol Reference Models

Up to this point, the relation between the B-ISDN and OSI PRMs has not received a clear and definite outcome in standardization bodies.

For instance, the European Telecommunication Standards Institute (ETSI) has not yet come to an agreement on that matter: "It was not clear what services were provided by the AAL and what services the AAL should support, particularly the relationship of the AAL layer to the OSI model." [*sic*] [10].

Even CCITT suggests further study on the relationship between B-ISDN and OSI: "The exact relationship between the lower layers of the OSI model and the AAL, ATM and [ATM] physical layer of the B-ISDN protocol reference model are for further study," [*sic*] [4].

It is interesting to note that the situation for N-ISDN is hardly better. In CCITT [3] one recognizes that "The [N]ISDN PRM and the OSI RM . . . have both commonalities and differences" [*sic*]. One reason is that the OSI PRM was elaborated for data communication services only, whereas the ISDN is applicable to a broader range of telecommunication services.

It is not our intention to fully map the B-ISDN PRM onto the OSI PRM. Rather, we take the pragmatic approach to find a level in both PRMs where services are comparable. One must be aware that even for this pragmatic approach, encompassing all services offered by B-ISDN might require extensions of the OSI PRM (e.g., when a time relation exists between source and destination). Since this paper's intent is not to fully cover the subject, we will limit discussion to support of data in B-ISDN.

Now, let us illustrate the similarities between the services offered by the AAL layer and the OSI data link layer. In our opinion, this is the most effective area for the interworking between OSI and B-ISDN. However, since the AAL layer also can be empty, we first analyze the service offered by the ATM layer. Note that in the following, we consider that the virtual channel connection already is set up.

ATM Layer and the OSI Model

Let us first recall the two ATM characteristics that are most relevant for our discussion. First, ATM is connection-oriented: virtual channel connections are established with reserved bandwidth before data transfer begins. Second, ATM uses out-of-band signaling: the control traffic for setting up and releasing virtual channel connections flows on separate virtual channel connections. This is in contrast with the in-band signaling mode of the OSI protocols or X.25 where control packets are mixed with data packets.

The latter point explains the dedicated "control plane" in the B-ISDN protocol reference model as mentioned earlier. So, during virtual channel connection setup, only the control plane is active, and during the data transfer, only the user plane is active. In OSI, the two planes are merged and indistinguishable.

We are now ready to address the question: "Where can we situate the ATM layer in the OSI protocol reference model?"

We believe that an ATM virtual channel connection between users A and B is similar to a virtual wire between A and B. This is the simplest and most straightforward interpretation if one remembers the evolution of telecommunication.

- An operator linking A and B with a copper cable.
- An automatic analog switch building a copper path between A and B.
- A digital telephone switch (pulse code modulation, PCM) building a 64 kb/s channel between A and B (no copper connectivity any longer).
- An N-ISDN switch (PCM) able to establish up to two 64 kb/s channels plus a 16 kb/s data channel between A and B (basic access) [11]. (Note that now several terminals can be associated to A and B.)
- A B-ISDN switch (ATM) able to establish any number of virtual channel connections between A and B, up to a total bandwidth of 150 Mb/s (600 Mb/s planned). (Note that in B-ISDN, one refers to A and B as "Customer Premises Network" with possibility of many connected terminals.)

So, the service delivered by the ATM layer is an OSI-like physical layer, or virtual physical service. The following comparison illustrates the differences (Table 1).

Note that, at the lowest level, the ATM virtual channel links are supported by some physical equipment, modeled by the physical layer in the B-ISDN protocol reference model. One can note that both ATM and OSI can use FDM or WDM techniques. This also is included in the "physical equipment." These considerations lead to Fig. 6.

In summary, the ATM layer offers an OSI-like physical layer service with an extremely elaborated multiplexing facility.

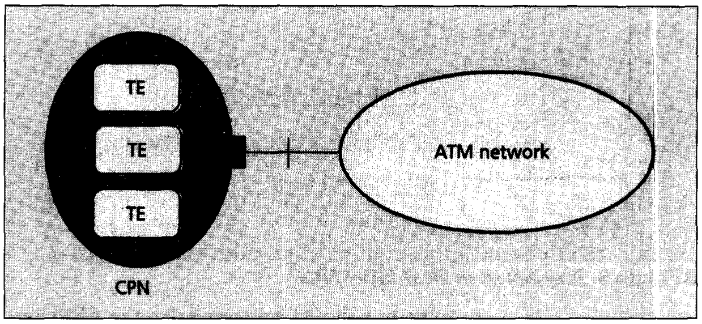
It offers the capability of realizing virtual wires (i.e., VC connections) in a dynamic way, which merely exist for the connection's duration.

Up until this point, we have associated the ATM virtual channel connections to OSI point-to-point physical connections as shown in Fig. 4. Actually, at a given access to the ATM network, there can be (and generally will be) several terminals sharing the access. This is obvious considering that B-ISDN integrates different services at the user-to-network interface (UNI) and that each service generally is associated with one dedicated terminal (e.g., telephone, computer, television), at least before multimedia terminals become widely available. In the B-ISDN terminology, the interconnected terminals form the customer premises network (CPN), a sort of ISDN LAN as shown in Fig. 7.

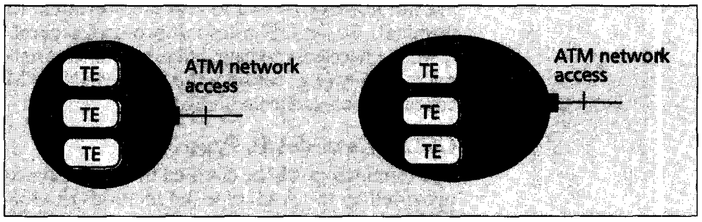
CCITT has not imposed the way the terminals are interconnected at the customer premises. Solutions such as those shown in Fig. 8 are both allowed.

The star configuration does not give rise to problems when the point-to-point physical layer model is used. When a shared medium is used, however, there is a need to perform contention resolution and bandwidth sharing at the ATM network access.

CCITT has defined a field in the ATM header named generic flow control (GFC) for optional use [12]. Although it was hoped that this field would solve the contention problem in a shared medium CPN, it is fair to recognize that after its introduction in CCITT three years ago (July 1989), no unanimity has yet been reached in CCITT to use it in a suitable mechanism or even to recognize its usefulness. This can be easily understood by noting that the real rationale (more or less hidden) for introducing the GFC was to align the ATM cell format on the DQDB slot format (cf., ACF field).



■ **Figure 7.** *A cluster of terminals sharing an ATM network access.*



■ **Figure 8.** *CPNs with star and shared medium configurations.*

If one considers using the GFC for contention resolution in a shared medium, the term "flow control" should not be confused with "terminal to terminal flow control." The term "access fairness control" or "access control" probably would have been better. As such, the GFC function is similar to the well-known MAC function in the LAN environment.

The location of the MAC function in the OSI PRM has given rise to some discussions between people advocating it as a physical layer function and those arguing that it was the lowest part of the data link layer. Finally, the MAC has been located in the data link layer. In B-ISDN, the other trend was followed. Our opinion is that this discrepancy does not matter very much, especially if one considers that the real point of importance for service similarity is the AAL and data link layer.

The AAL Layer and OSI Model

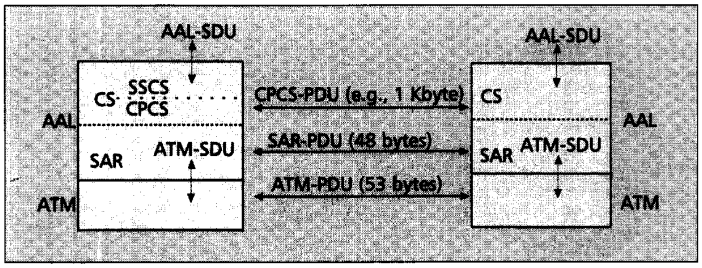
In the following, we will limit our discussion to the support of data services over an ATM network (AAL type 3/4). We will demonstrate in the next subsections that once the virtual channel connection is set up, the AAL type 3/4 service in the user plane is similar to an OSI data link service.

Architecturally, the AAL is a layer between the ATM layer and the next higher layer in the protocol reference model. In the connectionless data environment, the next higher layer is the OSI network layer.

CCITT is specific about this matter:

"The additional functions which are required to support the connectionless service include network layer addressing and routing. These additional functions provide the connectionless service by using the service of the AAL; thus, they reside in a layer above the AAL." [*sic*] [5].

Whatever the functionality included in the AAL



■ **Figure 9.** *Terminology in the B-ISDN PRM.*

layer, one should not forget that the ATM network is a subnetwork. As the AAL functions are terminated at the ATM network boundaries, they are not necessarily end to end (i.e., terminal to terminal). So, an OSI transport protocol generally will be necessary to have full terminal-to-terminal reliability (e.g., consider the LAN-MAN-ATM concatenation as shown in Fig. 10).

CCITT View of AAL Type 3/4

The terminology will be clarified by Fig. 9. Service provided by the AAL type 3/4 includes the following.

Two AAL type 3/4 transport modes are identified [13]:

Message mode service — One AAL-SDU is passed across the AAL interface in exactly one AAL interface data unit. Fixed size or variable-length AAL-SDUs are allowed. Several cases are possible:

- One or more fixed size AAL-SDUs can be transported in one SSCS-PDU (blocking/deblocking).
- A variable length AAL-SDU can be transported in one or more SSCS/PDUs (segmentation and reassembling).

Streaming mode service — One AAL-SDU is passed across the AAL interface in one or more AAL interface data units. Only variable-length AAL-SDUs are allowed. The streaming mode service includes an abort service by which the discarding of an AAL- SDU partially transferred across the AAL interface can be requested. Several cases also are possible here:

- Pipelining is possible. The sending AAL entity can begin the transfer of the AAL-SDU before the complete AAL-SDU is available.
- An AAL-SDU can be transported in one or more SSCS/PDUs (segmentation and reassembling).

For both transport modes, the following two operation modes are possible (peer-to-peer procedures):

- Assured operation — all AAL-SDUs are correctly delivered by retransmission of errored or missing SSCS-PDUs. Flow control is mandatory. This mode of operation could be restricted to point-to-point ATM connections.
- Nonassured operation — AAL-SDUs can be lost or corrupted, no retransmission is foreseen, and flow control is an option.

Primitives — Following the principles of layered protocol reference models, several primitives provided by the AAL type 3/4 currently are discussed in CCITT.

AAL-UNITDATA-REQ — the upper layer requests the transfer of an AAL-SDU from the local AAL entity to remote peer AAL entity(ies)

AAL-UNITDATA-IND — this primitive indicates the delivery of an AAL-SDU from the AAL layer to (the) AAL service user entity(ies).

Specifically for the streaming mode, one also finds primitives for requesting and indicating an AAL-SDU abort.

Functions — In the SAR sublayer (i.e., for each cell) the following functions are identified: segmentation/reassembling, error detection and multiplexing, and aborting SAR-SDU.

The first function is the segmentation and reassembling of a CPCS-PDU into and from segments which form the payload of ATM cells. This procedure requires a segment number, a segment type indication (begin, continuation, end, or single segment) and an SAR-PDU payload fill indication (number of octets of the CPCS-PDU contained within the SAR-PDU).

The error detection provides a means to detect bit errors in the SAR-PDU, and lost or misinserted SAR-PDUs.

The third function allows multiplexing of several CPCS-PDUs (cell interleaving) over a single ATM virtual channel connection between AAL entities using a multiplexing identification field. The latter field is specific to a given CPCS-PDU in order to reassemble CPCS-PDUs at the receiving AAL entity.

Finally, in streaming mode, the SAR can abort an SAR-SDU.

The CS sublayers (SSCS and CPCS) have the basic functionality to support connectionless as well as connection-oriented services (respectively, classes D and C). For the support of connectionless data, the SSCS is empty.

In the CS, for each AAL-SDU, the following functions are foreseen (not exhaustive and for further study within CCITT):

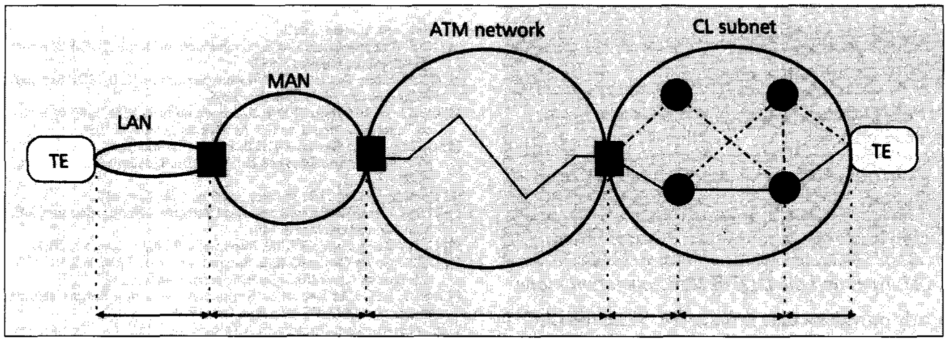
- Mapping between AAL-SAPs and ATM layer connections — this offers the capability to select the quality of service.
- Preservation of the CPCS-SDU (delineation and transparency).
- Buffer allocation size — an indication to the receiving peer entity of the maximum buffer requirements to receive the CPCS-PDU.
- Error detection and handling — an option is to discard corrupted CPCS-PDUs.
- Means to abort a partially transmitted CPCS-SDU.

The AAL Type 3/4

Message Size — The service provided by the AAL type 3/4 decouples the AAL-SDU length and the CPCS-PDU length. Depending on the type of AAL-SDU (e.g., IP, XNS packet), the AAL-SDU can be transported in one or several CPCS-PDU(s), or conversely one CPCS-PDU can transport several AAL-SDUs. Of course, for a higher efficiency, one AAL-SDU should correspond to one CPCS-PDU.

Error Recovery —

- Connectionless mode — Let us consider for simplicity the case where an AAL-SDU fits in one SSCS-PDU. No retransmission nor flow control procedures are required nor possible between SSCS-PDUs; these simply are connectionless packets. In this sense the nonassured mode of operation makes sense: a connectionless service does not guarantee nonloss of packets. Although one AAL-SDU may be fragmented in several SSCS-PDUs, this definitely should be avoided.



■ **Figure 10.** *The data link sections in a combination of subnetworks.*

- Connection-oriented mode—Although the SSCS could include the means for retransmitting corrupted/lost SSCS-PDUs and performing flow control, this is interesting only in a homogeneous ATM environment where the AAL is really end to end (i.e., terminal to terminal). In this case, the communicating terminals see an error-free service that makes additional recovery protocols (with inherent throughput degradation) unnecessary. An example of such a situation would be the signaling protocol used in the ATM network (note that there is no unanimity that the AAL 3/4 should be used for signaling).

In a general network configuration, however, where the ATM network is interconnected to other types of networks (such as MANs or LANs), an upperlying transport protocol with a complete recovery/ flow control mechanism will be used anyway. Since the ATM service will provide an extremely high quality of service (say end-to-end: cell loss ratio 10-8, BER 10-8). Recovery at the AAL layer (i.e., on a data link) is not worthwhile. One should note that not all users are convinced that ATM can offer such a quality of service. One argument sometimes cited is "not yet solved congestion problems due to the statistical multiplexing nature of ATM." One should realize that this argument does not hold because the ATM connections are set up with bandwidth reservation (refused if insufficient bandwidth is available) and that the ATM network ensures that the user behaves as declared (e.g., by discarding any cells in excess of the negotiated contract).

Function Selection in the AAL — As has been shown, a number of options are open for the functions that the AAL type 3/4 should perform. We believe the most logical way to support data is to use the AAL type 3/4 in its most simple mode (i.e., nonassured). One should note that the proposal for AAL5 (simple and efficient adaptation layer) goes that way, too. We think that simplicity is a fundamental condition to sustain high throughputs.

All of the functions which are proposed by CCITT in the AAL type 3/4 can be related to the functions of an OSI data link layer.

Indeed, in some cases, the SSCS simply will ensure that the offered AAL service becomes equivalent to existing OSI data link services (e.g., HDLC).

Figure 10 shows how an ATM subnetwork fits in an internetwork. It behaves as a data link.

ATM AND IEEE 802.6 MAN

In parallel to the ATM developments in standardization bodies such as ETSI and CCITT, a standard for metropolitan area networks (MANs) has been agreed upon by the IEEE and in ETSI [15, 16].

MANs will promote B-ISDN by enabling network operators to offer a subset of B-ISDN services, thus stimulating user's demand and ease its introduction by facilitating user access. This explains the parallel efforts pursued by standardization bodies in the broadband context.

MAN technology is now available as product implementation, whereas ATM remains in a prototype/preproduct phase. A MAN, however, offers a shared bandwidth (for example, 150 Mb/s) amongst all connected users while ATM can offer each user a dedicated 150 Mb/s access.

"Basically a MAN is defined as a digital network that is oriented to a public domain network application; is based on a shared access broadband medium; covers a restricted geographical area, but with the capability to be interconnected to other MANs in order to cover a much larger area; and is a means to provide integrated support of narrowband and broadband services . . . ," [*sic*] [10]. These services are supported by the following three basic operation modes:

- Connectionless (e.g., data).
- Isochronous (e.g., voice).
- Nonisochronous connection-oriented (e.g., data, variable bit rate video).

Since the MAN is a shared medium, a medium access control (MAC) is required. The access protocol for the MAN is the distributed Queue Dual Bus (DQDB) protocol which has been standardized by the IEEE 802.6, [16]. Information is transported in segments in DQDB. These segments are similar to the ATM cells: they have the same length, consist of a header and payload field, and the header supports similar functions.

The operation modes have direct implication on the MAC. In fact, three distinct MAC mechanisms can be identified, one for each operation mode: in case of connectionless traffic, a frame of up to 9 kilobyte is passed to the MAC. In case of isochronous traffic, octets are passed to the MAC. In case of nonisochronous, connection-oriented traffic, segments are passed to the MAC.

In our view, comparing the AAL types and the DQDB MAC operation mode results in Table 2.

One can conclude that the service provided by the DQDB MAC layer is a subset of the service provided by the AAL layer. This conforms to the evolution scenarios where DQDB MANs are a first step toward B-ISDN.

When one associates a standard LLC type 1 sublayer on top of the DQDB MAC sublayer, one

■ ■ ■ ■ ■

All of the functions that are proposed by CCITT in the AAL type 3/4 can be related to the functions of an OSI data link layer.

ATM Adaptation layer	DQDB MAN
AAL type 1 (any bit rate)	Isochronous traffic (only voice)
AAL type 2	No equivalence (isochronous channels have fixed bit rates)
AAL type 3/4	Connectionless traffic (no connection oriented frames)
Empty AAL	Non isochronous connection oriented traffic.

■ **Table 2.** *A comparison of AAL types and the DQDB MAC operation mode.*

clearly provides a data link service. Since the LLC 1 doesn't bring many additional functionalities to the MAC, this enforces our view of the AAL layer in relation to the OSI protocol reference model.

Conclusion

The coexistence of several distinct networks is a historical fact and probably will remain. Thus, the need arises to make these networks interwork.

Considering the context of B-ISDN, a consistent relation between the B-ISDN and OSI protocol reference model has been set. This represents a necessary step for an efficient interworking between OSI and B-ISDN networks.

We have demonstrated that the service offered by the ATM layer in the B-ISDN protocol reference model is equivalent to the service offered by the OSI physical layer.

Furthermore, we have shown that the service offered by the AAL type 3/4 is similar to an OSI data link service. In fact, some SSCS will be defined for offering existing OSI data link service (e.g., HDLC).

Finally, we have considered the emergence of the MAN standard as an intermediate support for broadband services and demonstrated similarities between the DQDB MAC and the AAL type 3/4 in its connectionless mode.

A common protocol reference model will form the basis for exploiting the latest advances of modern networks. Moreover, it offers the opportunity to develop new, higher-layer protocols that will provide the user with true, high performance.

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Biographies

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ROBERT PESCHI was born in Belgium in 1960. He received an M.S. degree in electrical engineering from the University of Liege in 1983. He was employed for three years as a reseacher in computer networks at the University of Liege in the team of Prof. A. Danthine. In 1987, he joined the Research Center of Alcatel Bell Telephone where he was involved in the early studies of ATM concepts and architectures. Robert Peschi has worked in several international research projects and has contributed for one year to ATM standardization activities (ETSI, CCITT) as the Alcatel Bell Telephone representative. He is currently head of the System Concept group of the Research Center, Antwerpen, Belgium. His main areas of interest are architectural and system aspects of ATM broadband networks, among others the support of broadband datacommunications and the interworking with existing data networks.

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