

Principles and Standards for Broadband ISDN

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Broadband ISDN was developed with the goal of providing a multiplicity of services over a standardized interface. The fast-packet technology of asynchronous transfer mode (ATM) makes it possible to transport information with widely differing characteristics, from bursty data services to high-definition television signals, over a range of speeds. With ATM technology, it is possible to build new high-speed networking equipment for the customer. These new products, plus a defined interface to Synchronous Optical Network (SONET) standards, and powerful signaling and control capabilities for multimedia services, are making broadband ISDN the basis for the next generation of network infrastructures. To provide global broadband products and services, international broadband standards are critical. This paper reviews the work of domestic and international standards bodies on a number of important standards for ATM transport, broadband signaling, and other aspects of broadband ISDN, and discusses how industry forums are working to ensure the compatibility of products and services of multiple vendors.

Introduction

The emerging new data and multimedia asynchronous transfer mode (ATM) technologies can provide a powerful platform to implement new products and services. Recognizing the potential of ATM to support and to transmit sophisticated multimedia applications, computing and communications companies have committed to bringing ATM products to market quickly. The success of this ambitious vision rests, in large part, on the development of well-defined broadband ATM standards. Substantial progress has already been achieved in ATM standardization, and a number of "show stopper" issues have been resolved.

The desire of many companies to get products to market quickly has altered the traditional standards process, and accelerated the development of ATM standards. While this aggressive schedule is not without risk, on the whole it has produced a rich set of solutions for customers, due to the increased interactions between computing and communications vendors. The challenge is to ensure that the many standards forums do not produce

conflicting standards, but rather work together to complement each other's efforts.

History of ATMs

To fully appreciate the progress in ATM standardization and its implications, a bit of history may be helpful. The CCITT, now called the International Telecommunications Union (ITU), is the international standards body that deals with public carrier issues. The ITU began discussing broadband ISDN standards (multiples of 45-53 Mbits/s) in 1985. The goal then was to develop a high-bandwidth version of the 1.544 Mbits/s "narrowband" ISDN for data and multimedia applications. Early proposals revolved around the ATM user-network interface structure. There was general agreement on re-using the narrowband ISDN concept of defining a multi-services interface, but few could agree on the precise nature of such an interface. One major question was what interface structure to use, synchronous transfer mode (STM), which is loosely translated to mean circuit switching, or ATM. STM had a number of advocates who cited, as benefits, the efficiency of

Panel 1. Acronyms Used in This Paper

AAL	— ATM adaptation layer
ATM	— Asynchronous transfer mode
BISDN	— Broadband integrated services digital network
CBR	— Constant-bit rate
CCITT	— International Telegraph and Telephone Consultative Committee, now called the International Telecommunications Union (ITU)
CPE	— Customer premises equipment
DS1	— 1.544 Mb/s North American transport rate
DS3	— 45 Mb/s North American transport rate
E3	— 45 Mb/s European transport rate
ETSI	— European Telecommunications Standards Institute
ISDN	— Integrated services digital network
ISUP	— ISDN services user protocol
ITU	— International Telecommunications Union
MAC	— Media access control
MIB	— Management information base
MPEG	— Motion Picture Experts Group
NA5	— Network Aspects technical committee
OA&M	— Operations, administration, and maintenance
SNMP	— Simple network management protocol
SONET	— Synchronous optical network
SDH	— Synchronous digital hierarchy
SS7	— Signaling System 7
SSCOP	— Service specific connection-oriented protocol
STM	— Synchronous transfer mode ($N \times 155$ Mb/s)
STS	— Synchronous transport signal ($N \times 53$ Mb/s)
T1S1	— U.S. standards forum for BISDN
TSS	— Technical Standards Sector
UTP	— Unshielded twisted pair
VBR	— Variable-bit rate

the existing systems and the prior experience of vendors with this technology. ATM was chosen as the basis for the transport unit, however, for a number of reasons:

- A single, universal ATM packet fabric could handle many types of services, such as voice, data, and video,
- Circuit-based approaches grew cumbersome as the number of channels increased, and
- Manufacturers and users had enormous interest in the potential of ATM technology.

ATM: Fixed Versus Variable Size. Once it was agreed that packet technology should provide the basis for ATM, the next debate was over whether the packet, or "cell" in ITU jargon, should be fixed or variable in size. The fixed size was chosen because of the ease of switching at broadband speeds, the controlled, or "fair," handling of multiple data streams, and the more predictable cell-

delay variation—an important issue for constant-bit-rate (CBR) services. One disadvantage of a fixed-size cell was the increased overhead needed to adapt various data streams into fixed-size cells, but many felt that bandwidth would be plentiful in the future to handle this need.

The ATM Cell Size. Of all the ATM standards issues, none provoked as much conflict as the choice of the actual size for the ATM cell. At the same time, it was critical to achieve international agreement on size. Without such an agreement, it would be almost impossible to deploy global broadband services. The main reason for such differing viewpoints was the difference in philosophy between various countries on the initial application for ATM.

The U.S. felt, for example, that data networking applications for ATM would drive the initial need for a relatively large cell payload of 64 bytes, and a header of five bytes. Many countries in Europe, on the other hand, favored short headers of two or four bytes and short payloads of 16 or 32 bytes. They felt voice traffic could be better handled by short cells with less packetization delay. After a long stalemate, the CCITT Study Group XVIII (now ITU Study Group 13) in June 1989 produced a compromise—the universal ATM cell size consisting of a 5-byte header and a 48-byte payload was born.

Other aspects of the agreement included a SONET-based physical layer, and adaptation-layer protocols for handling bursty data. In retrospect, this agreement proved to be a major milestone. It helped catalyze interest in ATM by computer vendors, and it resulted in a reshaping of the original vision of ATM as a carrier supporting both a more flexible, premises-based networking technology, as well as public carrier-based technology.

BISDN Standardization Process

Traditionally, standards development in both the U.S. and Europe have followed similar paths. The most important common thread is that both the U.S. and European processes are consensus-based. To illustrate, let's look at the U.S. broadband ISDN (BISDN) standards process. In the T1S1 committee, the U.S. standards forum where BISDN standards are discussed, member companies offer for discussion technical proposals, or "contributions," to create or enhance technical standards.

When consensus is reached amongst the interested parties, the issue is considered resolved. The agreement is then reflected in either a "living" list of issues, or in a T1S1.5 draft standard. Typically, reaching

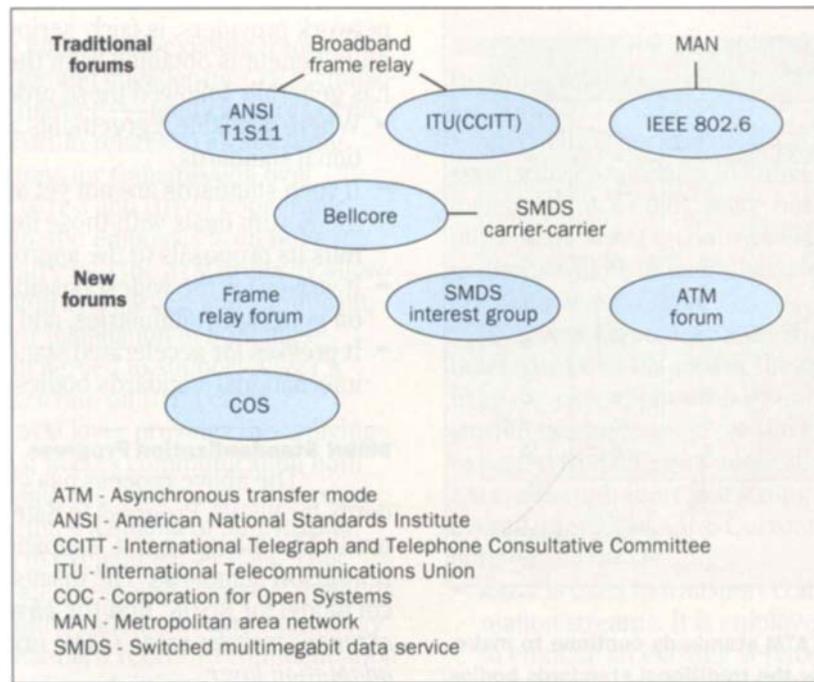


Figure 1. A number of new industry forums have been created, reflecting the strong interest in asynchronous transfer mode (ATM) technology, as well as switched multimegabit services, and frame relay.

consensus on a major issue also will result in the T1S1.5 committee drafting a contribution to the appropriate ITU Technical Standards Sector (TSS) study group, such as the Study Group 13 dealing with ATM. Once approved by the parent T1S1 committee, the contribution is forwarded to the U.S. State Department Study Group B, where the content is discussed and, if it is agreed to, forwarded to the ITU as a firm U.S. position. The U.S. delegates to the meeting are bound to support this position, unless the position is formally changed during a delegation meeting.

In the context of the ITU, the consensus-reaching process is repeated. That is, the positions of the various ITU members are presented and debated, and a compromise is reached that is acceptable to all. This agreement is documented as a "recommendation," and is published by the ITU. Typically, technical changes to the U.S. position will result from the consensus-reaching process. These changes are, in turn, fed back into the T1S1 committee and, ideally, a unique worldwide agreement is reached.

As mentioned earlier, the European process parallels that of the U.S. ATM-related standards are discussed in the European Telecommunications Standards Institute (ETSI) Network Aspects (NA5) technical committee. ETSI strives to reach pan-European agreement on important technical issues, with the goal of having a

unique European-wide standard, and of presenting a united front in ITU meetings. Once an ETSI position is reached, the ETSI member nations are expected to abide by the agreement. National sovereignty being what it is, ETSI is not always able to reach a consensus. In these cases, individual members will bring in national contributions to the ITU meeting. As is the case in the U.S., ETSI members typically desire a worldwide, common standard and, hence, also bring back to ETSI for further discussion the proposed compromises reached during the ITU meetings.

The reader has probably concluded, rightfully, that the standards process is time-consuming, to say the least. This is especially true in an industry where change and innovation are as rapid and as pervasive as ours. To meet this concern, the ITU recently has streamlined its standards-development process, doing away with fixed, four-year development and publication cycles. Despite the time-consuming nature of the consensus process, however, some very stable and mature standards have resulted.

The strong level of interest in ATM technology, however, has significantly reshaped the standards process, as illustrated in Figure 1. A number of new industry forums have sprung up, such as the ATM Forum, with the

Standard	T1S1/ ETSI	ITU (CCITT)	ATM forum
Physical layer	✓		✓
-DS-3/E3	✓		✓
-SONET/SDH	✓	✓	✓
ATM layer	✓	✓	✓
-Initial	●	●	●
-Final	●	●	●
Data services	●	●	●
Voice service	●	●	●
Video service	●	●	●
Circuit service	✓	✓	●
PVC management	●	●	●
Call control			
-Simple	●	●	●
-Supplemental services	●	●	●
OA&M	●	●	●

✓ Done
 ● Near completion
 ● Later

Figure 2. Efforts for global ATM standards continue to make progress, driven not only by the traditional standards bodies, but also by new organizations, such as the ATM Forum. This table reflects the status of a number of standards issues in the T1S1/ETSI, the CCITT/ITU, and the ATM Forum.

goal of accelerating the development of ATM standards. These forums are characterized by more active participation from computing vendors, unlike the more traditional telecommunications standards bodies. In theory, there is no overlap between the traditional standards-setting bodies and the new industry forums. The stated goal of the ATM Forum, for example, is to develop implementation agreements that are based on available standards.

In fact, it finds itself also operating as a standards-setting body, albeit one that operates in a different fashion—by majority rule rather than by consensus. This mode of operation both helps and hinders the effectiveness of the forums. Taking the ATM Forum as the most relevant example, quick agreement has been reached on many important issues, leading to strong support from the customer premises equipment (CPE) segment of the industry that did not develop during the T1S1/ETSI/ITU process. Due to the potential for block voting that can exist under operating rules, like those of the forums, however, simple, close majorities can yield fleeting agreements. The risk of hasty agreement on complex technical issues, which will have vast impact on public

network providers, is fairly serious. To ensure that maximum benefit is obtained from the process, the Forum has generally followed these procedures:

- Where available, agreements are based on international standards.
- If such standards are not yet available in some areas, the Forum deals with those items anyway, and submits its proposals to the appropriate standards body.
- It strives for the widest possible representation, based on geography, industries, and users.
- It presses for accelerated standards development in international standards bodies.

BISDN Standardization Progress

The above process has yielded a solid set of standards for BISDN. Progress to date is summarized in Figure 2. The following is a “snapshot” of the status of current BISDN standards. The discussion parallels the protocol model for BISDN: first the *physical layer*, then the *asynchronous transfer mode (ATM) layer*, and finally, the *ATM adaptation layer*.

Physical Layer. The physical layer standards define the fundamental schemes for basic digital transmission to support ATM, including signal definitions, coding, formats, and operations and maintenance capabilities. One aspect of these standards is unique to ATM: They all define a mechanism to delineate ATM cells.

A surprisingly wide range of physical-layer transport options exist for ATM. Definitions for ATM transport over DS3 and E3 facilities of 45 Mbits/s have been agreed to by T1S1 and ETSI, respectively. There is a growing interest in “lowering the price of admission” into the ATM arena by also producing a standard for ATM transport at the DS1 rate of 1.544 Mbits/s. Standards for ATM transport over Synchronous Optical Network (SONET) have been agreed to by T1S1, and for ATM transport over the Synchronous Digital Hierarchy (SDH) in the ETSI and ITU. In the case of SONET, transmission rates are STS-1 at 53 Mbits/s, STS3-C at 155 Mbits/s, STS-12C at 622 Mbits/s, and STS-48C at 2.4 Gbits/s. For SDH, ATM transport rates are STM-1 at 155 Mbits/s, STM-4 at 622 Mbits/s, and STM-16 at 2.4 Gbits/s.

The ATM Forum has filled a significant void in the ATM standards process by defining the physical layers appropriate for transmission on the customer’s premises. In particular, the ATM Forum has defined interfaces—at 100 Mbits/s and 155 Mbits/s—that

operate over multimode fiber, using existing transceiver chips. This makes it easier and cheaper for CPE manufacturers to get product to market. A significant area of ongoing work in the ATM Forum relates to establishing physical-layer specifications for transmission over unshielded twisted pair (UTP-3 and UTP-5) copper telephone wiring. Here again, the emphasis is on reducing the customer's cost of entry into the ATM arena by allowing the re-use of the customer's earlier, and significant, investment in twisted-pair installation in buildings. Recently, the ATM Forum agreed to support AT&T's proposal at the 51-Mbits/s rate on UTP-3 cable.

ATM Layer. The ATM layer provides the unifying architectural concept that makes communication both feasible and attractive using the wide range of physical layers. The ATM layer defines a quanta of information, which the ATM cell uses to exchange user data. This layer is constant across all access and transport methods. For this reason, ATM is often called *cell-relay* technology.

The ATM-layer standard (CCITT Recommendation I.361) defines the required capabilities for transferring information at this layer in the BISDN protocol model. The standard currently defines the mechanisms for identifying particular user information flows: specifically, the user's assigned path through the network, called virtual path connections (VPC); the virtual circuit connections (VCC) that ride in the VPCs; and the policing mechanisms to ensure that users do not use more than their allocated bandwidth. In addition, there are capabilities built into the control field of the ATM cell that indicate how the cell should be interpreted, such as one of two kinds of user information, or as an operations and maintenance message.

Finally, two mechanisms for controlling traffic overloads are defined. The first is an indication as to whether the cell encountered congestion along the path it has traversed. The second is a mechanism to indicate whether cells should be given lower loss priority. Cells with this lower priority, for example, cells exceeding the user's allocated bandwidth, could be discarded in the event of network congestion.

There are several areas in which additional agreements will need to be reached in order to complete the ATM layer standard, including the specification of the general flow-control protocol. This protocol will allow for sharing of multipoint physical access arrangements, much like the media access control (MAC) mechanisms

used by such local area networks as Ethernet or token ring. (Ethernet is a registered trademark of the Xerox Corporation.)

The other significant activity for future ATM-layer standardization relates to enhanced methods for traffic management. Coding space has been set aside for this purpose in the ATM control field, and it is expected that methods will be defined that allow users to realize greater statistical gain.

ATM Adaptation Layer. The role of the ATM adaptation layer (AAL) is to mask the specifics of ATM transport from the user application by enhancing the ATM layer capabilities to better serve the needs of applications. It is expected that different applications will have different AALs, although there is a strong desire to minimize the overall number of AALs. Currently, there are three AALs defined:

- *AAL 1* is used to transport constant-bit rate (CBR) information streams. It is employed when the user desires to emulate an existing service, for example, a DS-1 circuit, across an ATM network.
- *AAL 2* provides the required capabilities to perform clock synchronization across the network, to detect impairments of the information stream, and to frame the user information. Information is transported at varying rates. The application of *AAL 2* is expected to be for video transport.
- *AAL 3/4* and *AAL 5* carry variable-bit rate (VBR) "bursty" data, such as the signals that would be presented by a computer workstation. These AALs provide services like data framing, error detection, and multiplexing.

TISI and the ITU TSS also have nearly completed the specification for a new high-performance link-layer protocol suited to transport in an ATM environment. This protocol, the service specific connection-oriented protocol (SSCOP), initially will be used to carry signaling traffic. Work is continuing in the adaptation layer area to define the protocols for transporting video streams, such as Motions Pictures Experts Group 2 (MPEG 2), as well as voice and multimedia.

Call Control. The standards for call-control signaling are currently being worked on in TISI, ETSI, the ITU, and the ATM Forum. All of these groups have chosen the approach of extending existing ISDN signaling protocols to meet the special needs of BISDN. Thus, the Q.931 access-signaling protocol is being extended to support BISDN access signaling, while the Signaling System 7 (SS 7) ISDN

services user protocol (ISUP) is being extended to support network-to-network signaling. These protocols are referred to as Q.93B and B-ISUP, respectively. Currently, the Q.93B protocol specification is basically complete for a simple point-to-point call. Uni-directional point-to-multipoint call setup has been completed in the ATM Forum, and will likely be completed soon in ITU Study Group 11. The more complex specification of bi-directional multipoint-to-multipoint call control, and control of advanced supplementary services, will require another year of standardization work to be considered mature.

Operations, Administration, and Maintenance. The crucial area of network operations, administration, and maintenance (OA&M) has in the past year gained greater prominence, and its specification is progressing rapidly. T1S1, ETSI, and the ITU have a robust maintenance architecture in place and are nearing completion of the final detailed protocol issues to support basic service. The ATM Forum has defined subsets of these capabilities that CPE must support. It has also specified the use of the simple network management protocol (SNMP), and defined the management information base (MIB) that is used in SNMP to check network equipment status and configuration.

Summary

Beginning with the agreement on a universal ATM cell size, broadband ISDN standards have been quickly developed to respond to the interest in ATM technology. A number of important agreements have been reached in T1S1, ETSI, ITU and the ATM Forum. The participation of computer vendors in these activities has raised some exciting possibilities for end-to-end multimedia

services. Important challenges remain in the area of network signaling, congestion control, and network management for the promise of ATM technology to be realized.

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