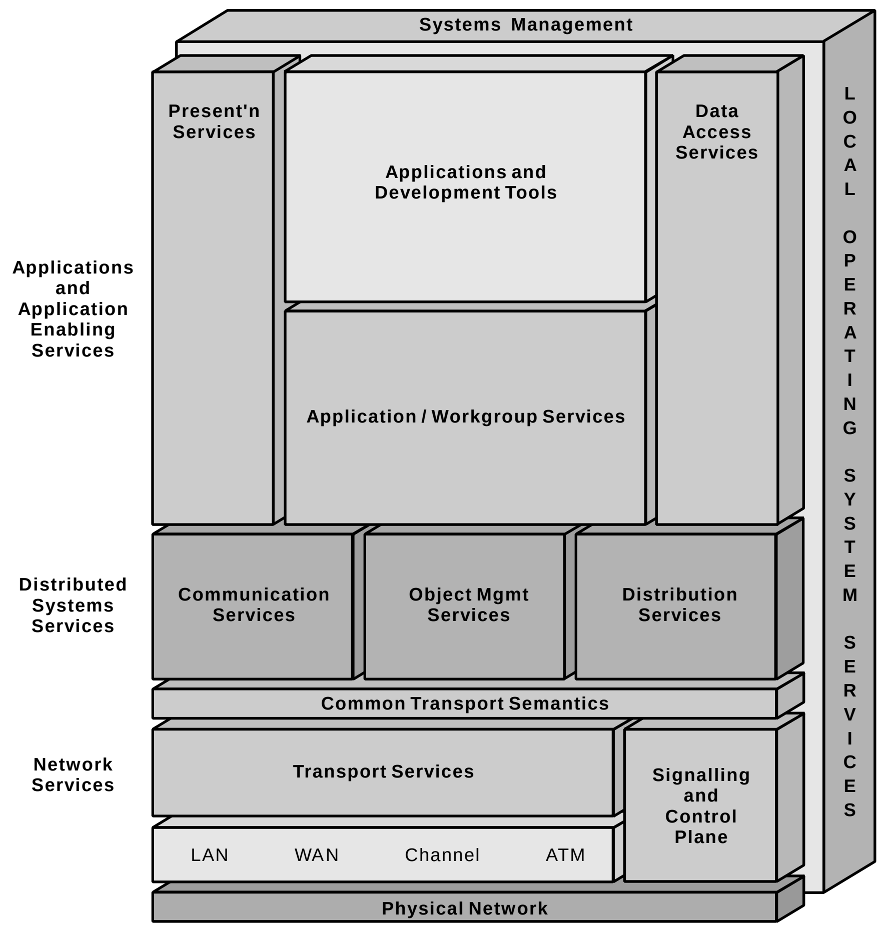
Open Blueprint

Asynchronous Transfer Mode and the Signalling and Control Plane in the Open Blueprint



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Open Blueprint

IBM

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About This Paper

Open, distributed computing of all forms, including client/server and network computing, is the model that is driving the rapid evolution of information technology today. The Open Blueprint structure is IBM's industry-leading architectural framework for distributed computing in a multivendor, heterogeneous environment. This paper describes the Asynchronous Transfer Mode and the Signalling and Control Plane component of the Open Blueprint and its relationships with other Open Blueprint components.

The Open Blueprint structure continues to accommodate advances in technology and incorporate emerging standards and protocols as information technology needs and capabilities evolve. For example, the structure now incorporates digital library, object-oriented and mobile technologies, and support for internet-enabled applications. Thus, this document is a snapshot at a particular point in time. The Open Blueprint structure will continue to evolve as new technologies emerge.

This paper is one in a series of papers available in the *Open Blueprint Technical Reference Library* collection, SBOF-8702 (hardcopy) or SK2T-2478 (CD-ROM). The intent of this technical library is to provide detailed information about each Open Blueprint component. The authors of these papers are the developers and designers directly responsible for the components, so you might observe differences in style, scope, and format between this paper and others.

Readers who are less familiar with a particular component can refer to the referenced materials to gain basic background knowledge not included in the papers. For a general technical overview of the Open Blueprint, see the *Open Blueprint Technical Overview*, GC23-3808.

Who Should Read This Paper

This paper is intended for audiences requiring technical detail about the Asynchronous Transfer Mode and the Signalling and Control Plane in the Open Blueprint in the Open Blueprint. These include:

- Customers who are planning technology or architecture investments
- Software vendors who are developing products to interoperate with other products that support the Open Blueprint
- Consultants and service providers who offer integration services to customers

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Introduction

The emergence of fiber optic and copper-based high-speed transmission technology enables a whole new class of realtime and non-realtime applications that incorporate audio, video and data.

To meet the various requirements of audio, video, and data traffic in a single network infrastructure, the International Technical Union - Telecommunications Standardization Sector (ITU-T), formerly the CCITT, has been specifying the Broadband Integrated Services Digital Network (B-ISDN). Asynchronous Transfer Mode (ATM) is the switching and multiplexing technology in B-ISDN. To assist the ITU-T and ensure multi-vendor interoperability, an industry consortium called the ATM Forum was formed. The ATM Forum specifies implementation agreements among the various member companies.

ATM viewed simply as a new and faster customer premises or wide area subnetworking technology will accommodate all the existing data communication protocols such as IP, IPX, Advanced Peer-to-Peer Networking (APPN), and classical SNA, and will support existing applications such as e-mail, distributed database, and distributed transaction processing. But, what makes ATM truly unique as an emerging technology is its support of multimedia. It is this aspect of ATM that is literally changing the world of communications.

Multimedia is the blending together of computer data processing, audio/video, and display technology in an interactive environment. Evolving multimedia applications such as enhanced workgroup (collaborative) computing, desktop conferencing, and video-on-demand bring with them the need for network access to shared or common realtime data.

Some key characteristics of multimedia communication are:

- Large amounts of information
- High bandwidth and throughput requirements
- Multicast/broadcast applications
- Continuous streams of information
- Loss tolerance
- Temporal value of information (realtime)

The last three characteristics differentiate multimedia communication from ordinary “fast” data communication. To insure a continuous stream of information and to maintain the temporal value of the information, an end-to-end Quality of Service (QoS) must be guaranteed. This guarantee must be from input device to output device; it affects every layer of the Open Blueprint. Stream awareness, bandwidth and throughput, loss toleration, latency and jitter limits must be understood by all components in the path.

ATM is a subnetworking technology that addresses these requirements. Some key attributes of ATM are:

- Integration of audio, video, and data traffic
- Separation of control and data (out-of-band signalling)
- Connection oriented

  High bandwidth point-to-point and point-to-multipoint connections. Multipoint-to-multipoint connections are also envisioned to be supported.
- Bandwidth-on-demand
- Scalable in speed
- Scalable in distance
- End-to-end stream management

- Quality of Service parameters and end-to-end guaranteed service levels

This paper explores the Asynchronous Transfer Mode (ATM) subnetworking technology and then discusses a new Open Blueprint component: the Signalling and Control Plane.

ATM Technology

ATM is a switch-based subnetworking technology (see Figure 1). Each end station is attached to a switch using a point-to-point link. All communications between end stations must be routed through at least one ATM switch.

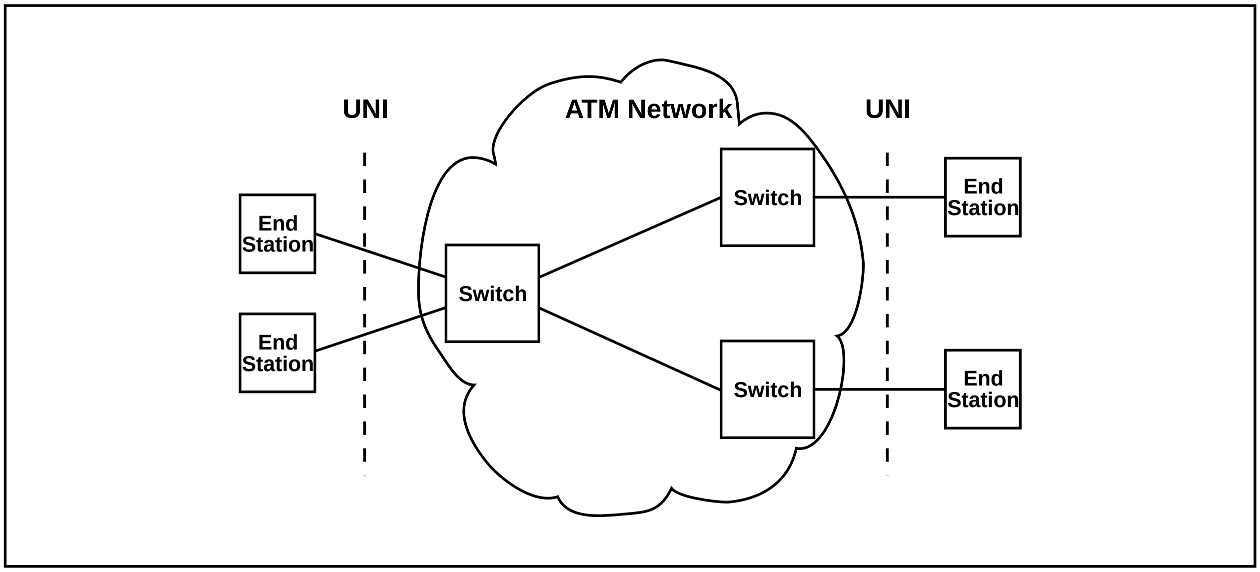

Figure 1. ATM Network

End stations connect to an ATM network across the User-Network Interface (UNI) [7]. The UNI specifies the physical media, the control protocols, and the transmission technology necessary to use an ATM network.

Connections between end stations may be either permanent or temporary (switched). Permanent Virtual Circuits (PVCs) are set up by network provisioning and are similar to leased lines. Switched Virtual Circuits (SVCs) are connected on demand and disconnected when the circuit is no longer needed.

Since ATM is switch-based, it scales from small customer premise networks (LAN environments) to very geographically large networks. With a single technology, it dissolves the differences between local and wide area networks.

ATM will be used in both public networks (that is, carrier networks such as AT&T, etc.) and private networks.

ATM Cell Switching

In order to minimize delay for realtime applications such as voice, ATM uses a fixed-size packet called a cell. The cell size chosen by the ITU has a 48-byte payload and a 5-byte header. These 53-byte cells are switched through the ATM subnetwork using a routing field found in the 5-byte header. This field consists of two identifiers: a Virtual Path Identifier (VPI) and a Virtual Channel Identifier (VCI). The VPI provides a local-only identifier for a virtual path connection (VPC) which can contain many virtual channel connections (VCC) each identified by a VCI. This framework provides a two-level-routing hierarchy. The relationship of VPC and VCC is shown in Figure 2 on page 3.

The cells of different connections are interleaved on the physical link by using different connection (VPI/VCI) identifiers.

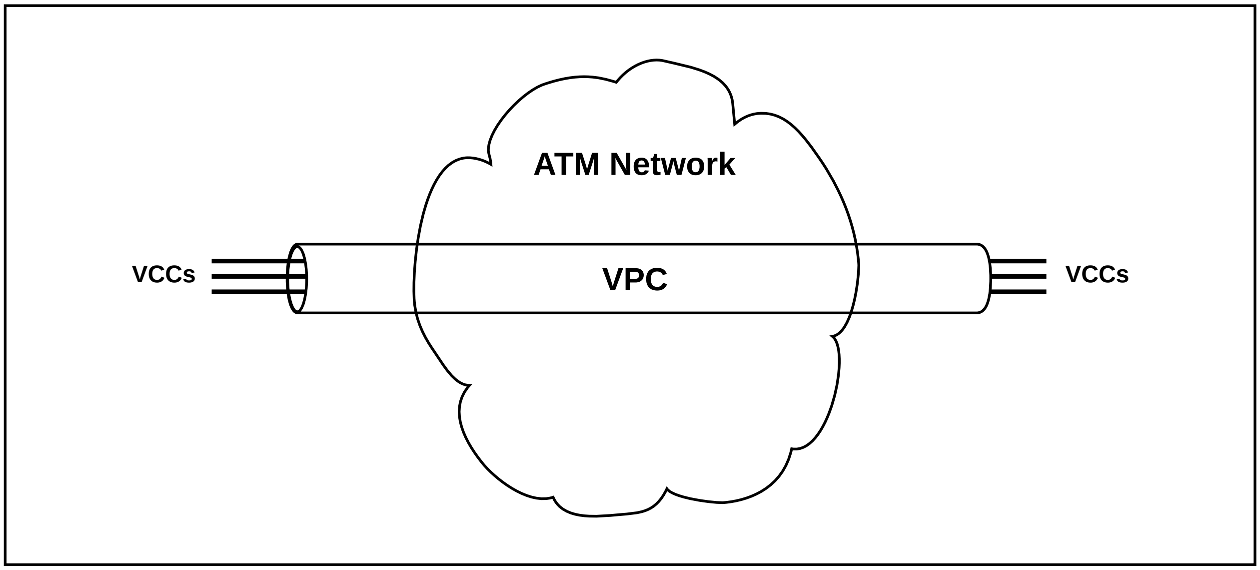

Figure 2. Relationship of VPC and VCCs

The VCI and VPI values have local significance only. VCI values are unique only in a particular VPC (VPI value) and VPI values are unique only in a particular physical link. As the cells traverse a network, the VPI/VCI values can be changed at every switch. This technique, known as label swapping, is highlighted in Figure 3 on page 4.

Each ATM switch has a routing table. When a cell arrives, the switch looks into the table to determine which outbound link it should forward the cell on. The routing information in each table can be statically configured through network provisioning or dynamically changed when switched connections are set up.

In Figure 3 on page 4, TE-1 has two virtual channel connections identified as VPI_a/VCI_a and VPI_a/VCI_b. These two connections are with different remote end stations, TE-2 and TE-3. As the connections are routed across the network, their identifiers change. The connection between TE-1 and TE-3 is known by TE-1 as VPI_a/VCI_a; it is known by TE-3 as VPI_d/VCI_d.

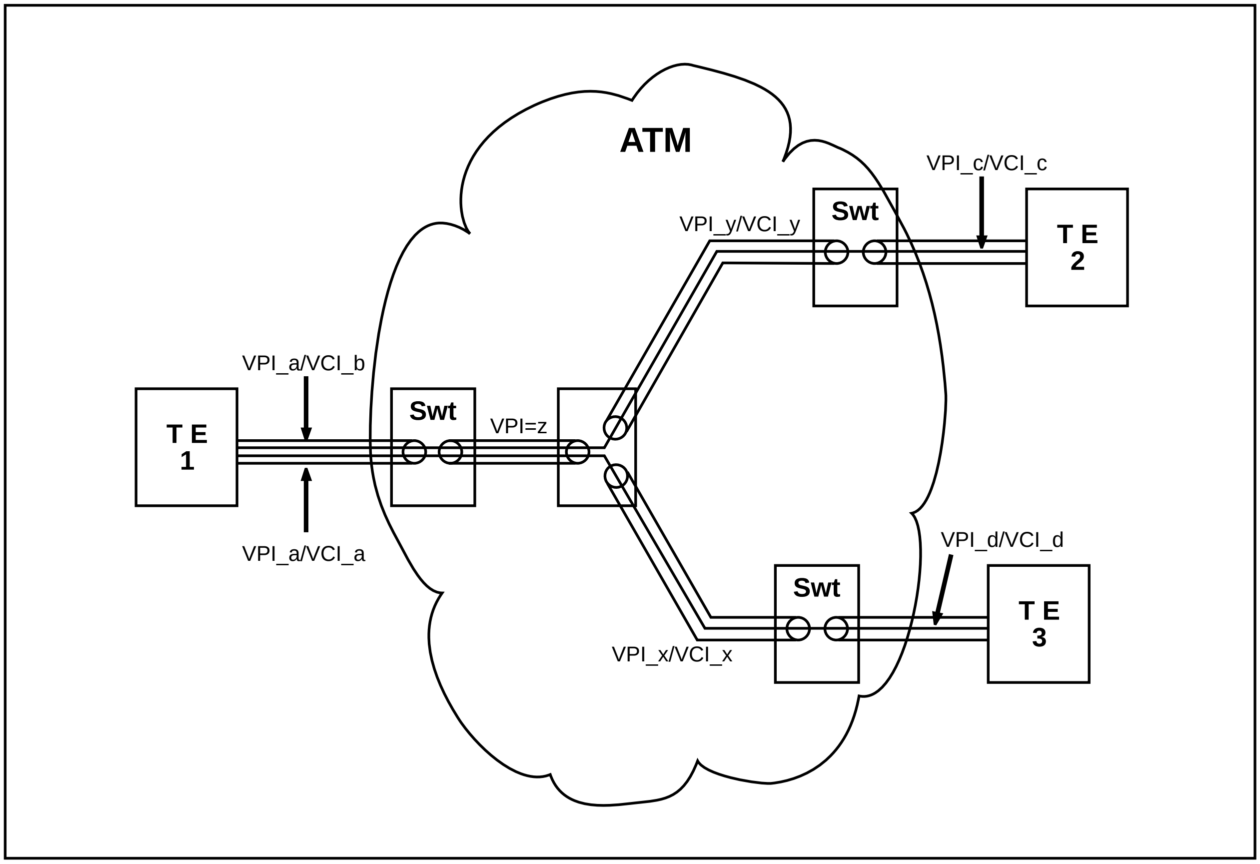

Figure 3. Effects of Label Swapping

For an end-to-end virtual path service, the network switches along the virtual path only need to use the VPI for routing; in this case the VCI is used only by the VPC end-points to route the traffic. But in general, because of the trade-off between simple VPI routing at the switches and the need for efficient utilization of network resources, a combination of VPI routing and VPI/VCI routing will be used by the switches in an ATM network.

The ATM Reference Model

Figure 4 on page 5 shows the B-ISDN layers and sublayers associated with ATM. The B-ISDN Reference Model consists of a control plane, a management plane, and a user plane.

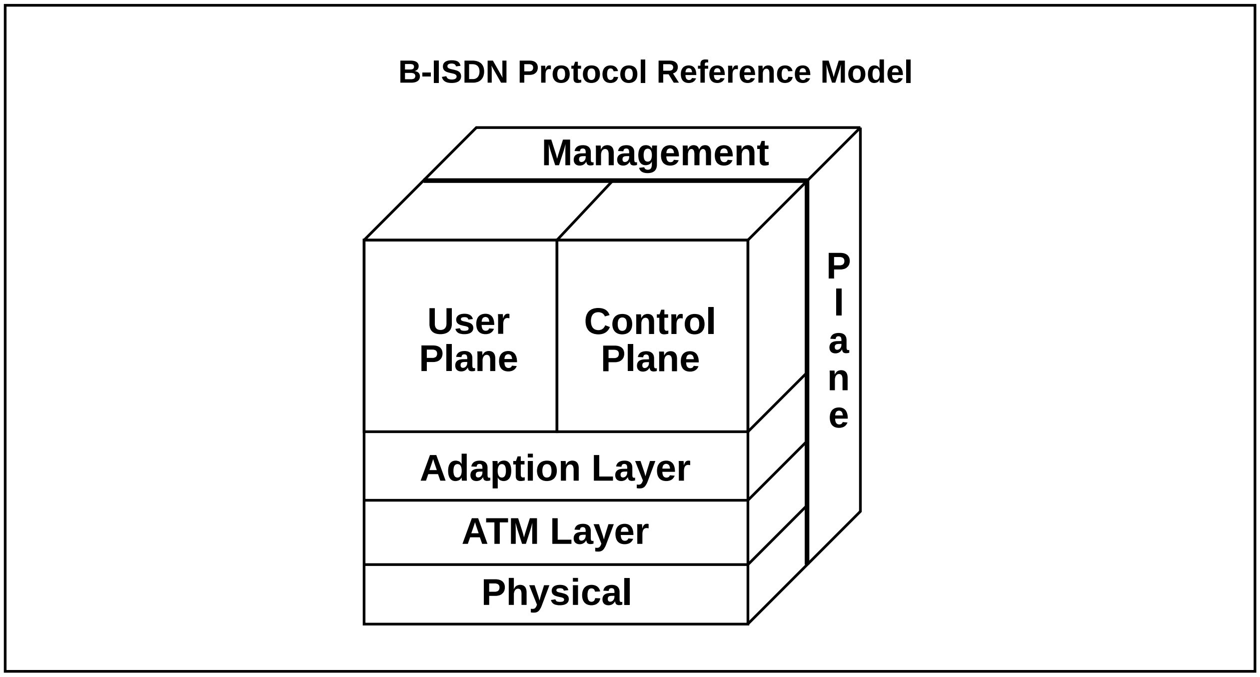

Figure 4. B-ISDN Protocol Reference Model

ATM separates control from data. The control plane is used for connection control including the connection setup and release functions. Once a connection is established, the application data is transmitted in the user plane. Both of these planes use lower layers to transmit their messages and data.

The B-ISDN Protocol Reference Model has the following characteristics:

- The ATM Adaptation Layer (AAL) supports the higher-layer functions of user and control planes. Examples of adaptation functions include continuous bit-stream-oriented services, connectionless services, and packet mode services.
- The ATM layer handles cell multiplexing and switching.
- The Physical layer is the underlying transmission facility of the network.

The Management Plane interacts with the User Plane, the Control Plane, and each of the underlying layers to gather operational/error statistics, provide local configuration support, and other associated functions. The B-ISDN Management Plane interacts with the ATM specific layers in the same manner as the Open Blueprint Management Plane.

Figure 5 on page 6 expands on the previous reference diagram and explicitly shows the AAL types and the protocol used for signalling and control.

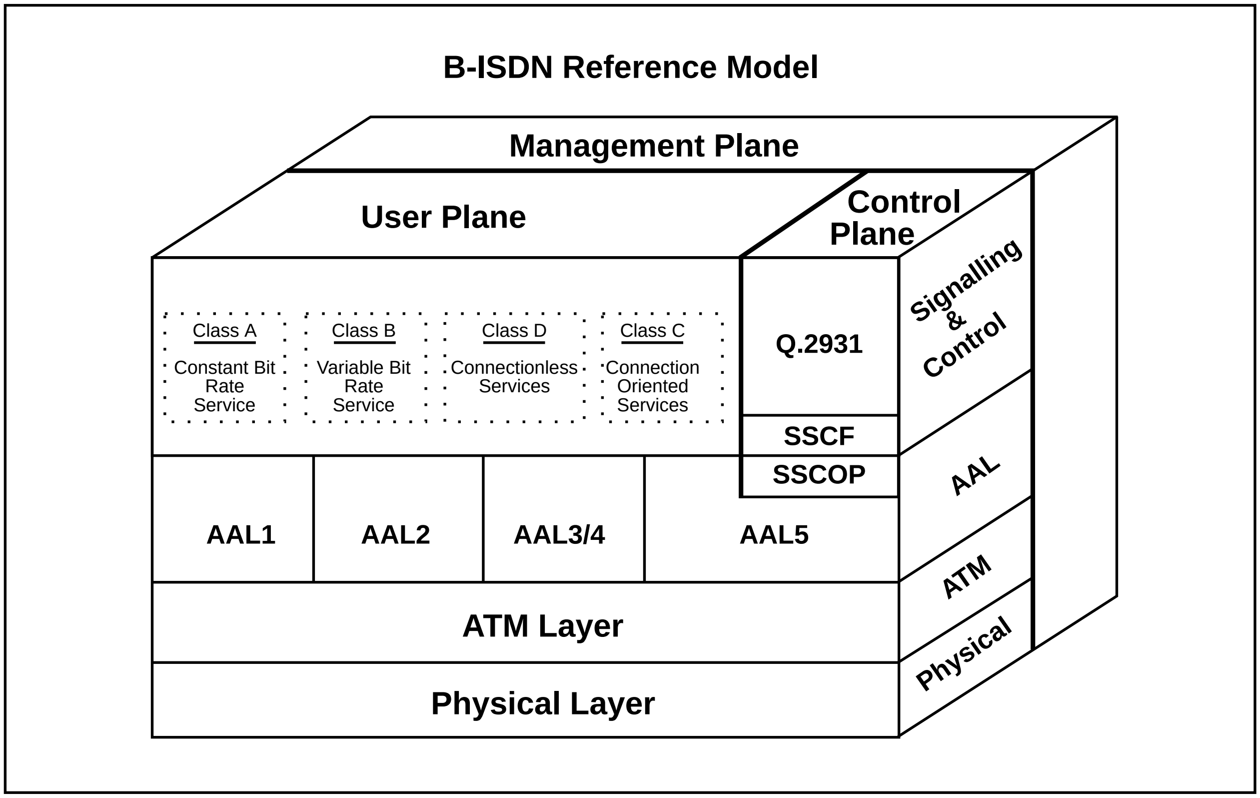

Figure 5. An Expanded Reference Model

Physical Layer: The physical layer contains a Physical Media Dependent (PMD) sublayer that performs media-specific functions and a Transmission Convergence (TC) sublayer that performs the functions common across different physical media.

The physical layer provides for the electrical or optical transmission and receipt for the physical media. It is also responsible for cell delineation, rate decoupling, and the generation and verification of the ATM header error control field that protects the ATM header (but not the payload).

Supported speeds include 1.54 Mbps T1 through 622.08 Mbps (OC-12) and eventually go up to OC-48, which is 2488.32 Mpbs.

The following sections provide more information on the B-ISDN Reference Model layers.

ATM Layer: The ATM layer provides the forwarding and multiplexing functions. These include the following:

- Flow control and queuing priority to meet service guarantees for delay
- Cell loss priority
- Payload type identification (user cells vs. control or management cells)
- Multiplexing and demultiplexing of the cells associated with different virtual paths and virtual channels on the physical media.

AAL Layer: The ATM Adaptation Layer (AAL) is split into 3 sublayers:

- The Service-Specific Convergence Sublayer (SSCS), which performs the functions unique to the service class supported by the AAL
- The Common Part Convergence Sublayer (CPCS) which performs the common AAL functions
- The Segmentation and Reassembly (SAR) sublayer which performs the generation of cells from and reassembly of cells into the data units seen by the using application layers.

The ATM Adaptation Layer provides the functions associated with the different service classes defined in ATM. The following service classes are defined:

A — Connection-oriented, constant-bit-rate (CBR) service with timing required between the source and destination (for example, circuit emulation). Uses AAL type 1.

B — Connection-oriented, variable-bit-rate (VBR) service with timing required between the source and destination. Uses AAL type 2 which is currently undefined. Work is underway within the ITU-T evaluating the needs and requirements for this AAL type.

C & D — Connection-oriented or connectionless variable-bit-rate service without timing required between the source and destination. Uses AAL type 3/4 or AAL type 5. AAL3/4 is a combined AAL for the connection and connectionless service classes, but its complexity has led to the creation of AAL5, sometimes called Simple and Efficient Adaptation Layer (SEAL). AAL5 is commonly used for data communication but is also being used for video delivery when the time base recovery is performed by the user. An example of this is "The ATM Forum Video-On-Demand Application" on page 9.

AAL5 permits the use of a non-null SSCS:

- The Frame Relay Service Specific Convergence Sublayer (FR-SSCS) provides a frame relay emulation service.
- The Service Specific Connection-Oriented Protocol (SSCOP) SSCS is used to provide reliable data delivery. [2]. It was initially defined to support the ATM UNI signalling protocol (Q.2931). AAL5 with the SSCOP is referred to as the Signalling ATM Adaptation Layer (SAAL).

X — Class X (not shown in Figure 4) is a connection-oriented ATM Transport where the AAL, traffic type (VBR or CBR), and timing requirements are user-defined and transparent to the network. The user chooses only the desired bandwidth and QoS at the time the connection is set up to establish a Class X connection.

B-ISDN Control Plane: Q.2931 specifies the signalling protocol for dynamically establishing, maintaining, and clearing of network connections at the B-ISDN user-network interface [4]. It is defined as an OSI layer 3 procedure that requests services from SSCOP/AAL5 through primitives defined by the Service Specific Coordination Function (SSCF) [3].

Q.2931 uses a dedicated out-of-band channel (VPI=0/VCI=5) to communicate to the ATM Network. This VPI/VCI is statically defined and is always connected to the network.

Using Q.2931, it is possible to:

- Request point-to-point and point-to-multipoint connections
- Request connections with:
  - Symmetric or asymmetric bandwidth requirements
  - Different Quality of Service attributes, such as delay bounds, data integrity requirements, and loss rate
- Perform end-to-end compatibility exchange and negotiation

Within the context of the Open Blueprint, the user of Q.2931 is an application, a resource manager or a Network Services protocol stack that needs to establish an ATM connection.

An ATM Virtual Circuit Connection Example

Figure 6 highlights some possible connection scenarios between two ATM end stations.

Over a single physical link, it is possible for two desktop workstations to have several ATM virtual connections between them. Each of these connections can have different bandwidth, traffic characteristics, and QoS.

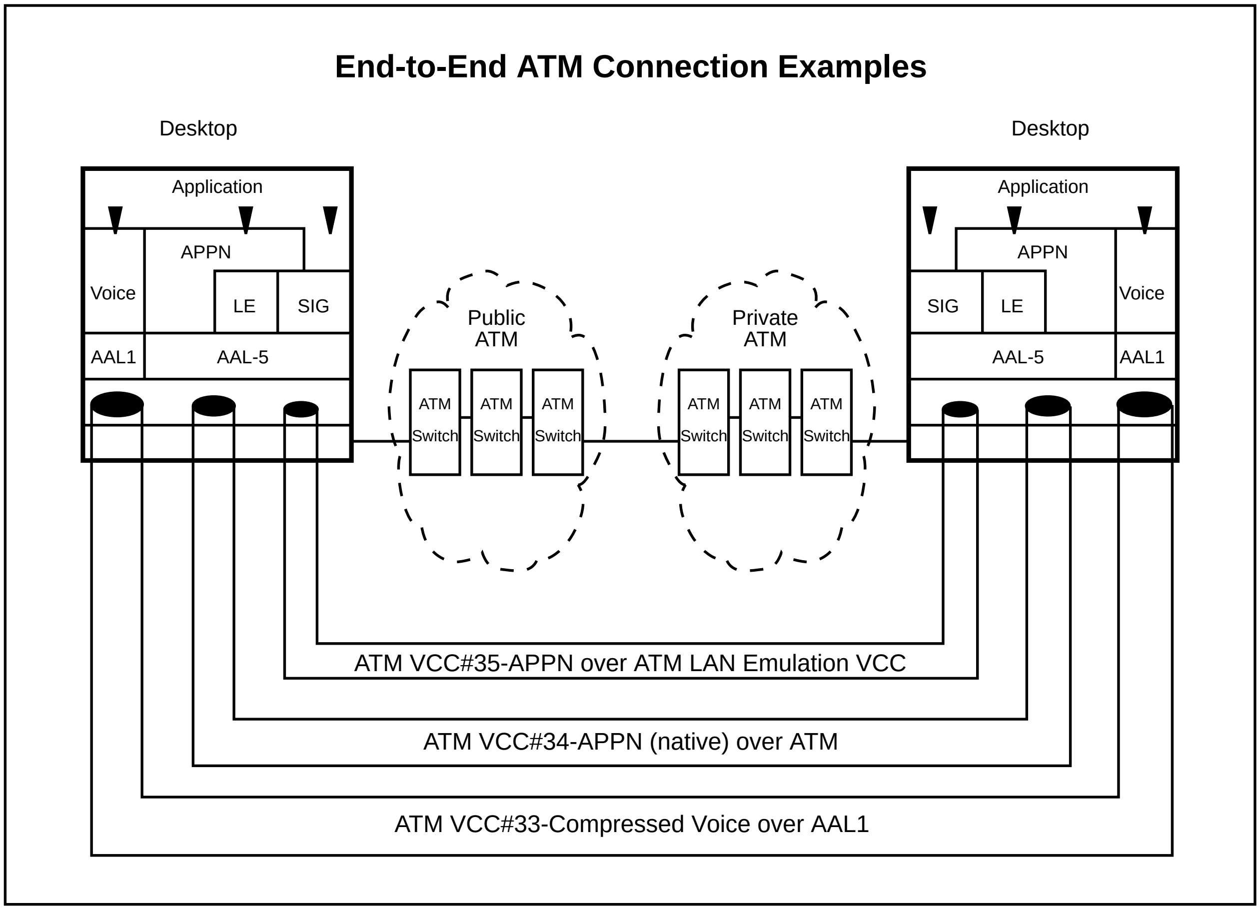

Figure 6. Possible Uses of ATM Virtual Circuits

In the Figure 6, three VCs are shown: one VC using AAL1 for voice and the other VCs using AAL5 for two different types of data traffic. One AAL5 connection is carrying native APPN flows, while the other is communicating using LAN Emulation. LAN Emulation is a migration facility defined by the ATM Forum to make an ATM network look and feel like a traditional LAN. LAN Emulation allows software written for LANs to operate over ATM without change. When LAN Emulation is used, none of the bandwidth management or QoS features of ATM are exposed to the using software.

Even though APPN is used in this example, it should be noted that other Network Services protocols such as classical IP (TCP/IP) will also use AAL5 and Q.2931 signalling to communicate across an ATM subnetwork.

The ATM Forum Video-On-Demand Application

A key example of a standards-based application that is exploiting ATM is the Video-on-Demand Over ATM work in the ATM Forum.[1]

Both the ATM Forum and the ITU-T Study Group 15 Standards body[2] are involved in defining subnetwork specific solutions for multimedia over ATM. The initial work in the ATM Forum is focused on developing an implementation agreement for Video-on-Demand (VOD) over ATM [10]. This implementation agreement specifies that the source information (movies) will be compressed using the MPEG-2 standard [6] and sent across the ATM network using AAL5. It is anticipated that this work will flow into the ITU-T Study Group 15 H.Series Standards.

Figure 7 highlights the essential components necessary for transmitting stored video across an ATM network.

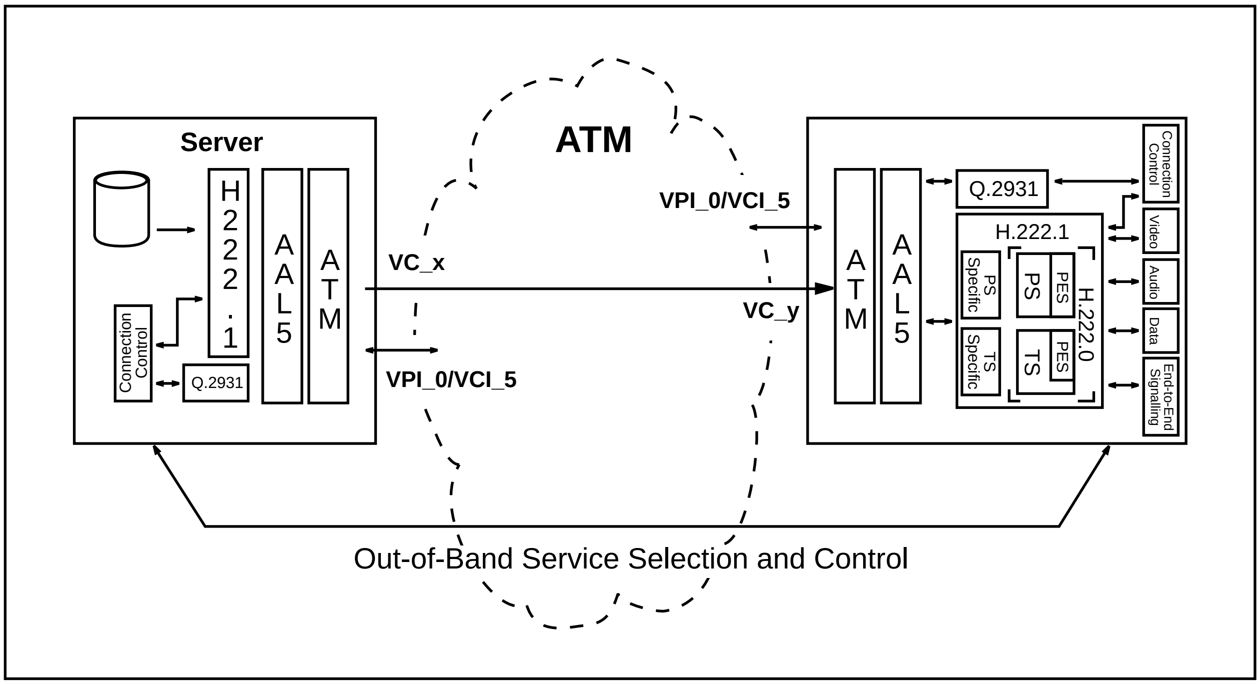

Figure 7. Video-on-Demand Generic Reference Configuration

The MPEG-2 data flows from a file system through the Network Adaptation Layer (H.222.1) and across an AAL-5 ATM Virtual Circuit to the target system. There it is received, passed to H.222.1, and eventually delivered to the MPEG-2 Systems layer (H.222.0) for demultiplexing and eventual presentation.

The Network Adaptation Layer provides packetized stream control, synchronization, and multiplexing of the various components of the multimedia application. The network adaptation layer is functionally decomposed into H.222.0 (the MPEG-2 Systems Standard) and H.222.1.

The MPEG-2 Systems Standard (H.222.0) [6] specifies how to combine multiple audio, video, and private-data streams into a single multiplexed stream. It is designed to support a wide range of broadcast, interactive communications, computing, and storage applications.

MPEG-2 Systems defines two kinds of streams: Program and Transport.

- The Program Stream supports the creation of a single audio-visual program. It utilizes variable-length packets and is designed for transmission in relatively error-free environments.

- The Transport Stream multiplexes a number of programs, comprising video, audio, and private data, for transmission and storage. It is designed for transmission in any-loss or noisy environment and utilizes a fixed-size 188-byte packet.

H.222.1 includes any unique function (PS-Specific or TS-Specific) that is necessary to adapt the MPEG-2 System Layer (H.222.0) to the AAL support.

The information (movies, commercials, etc.) is stored in files in MPEG-2 Single Program Transport Stream format. Metadata associated with each file provides additional information, such as:

- The MPEG-2 bit rate
- Whether the compressed data is variable or constant-bit-rate
- Any other necessary QoS information.

Since the video and audio information is already compressed and formatted, no encoder or multiplexer is present at the server.

The actual service and content selection (movie to be played) is performed through an out-of-band data exchange. This exchange provides the ATM Address (E.164 or Private ATM address), the movie title, and a request ID to help correlate multiple requests when more than one connection is set up between the server and client.

This information, along with the QoS and Bandwidth Metadata, is used to establish a unidirectional VC (possibly an asymmetrical bi-directional VC with limited back-channel capability) between the server and the client. The circuit setup is initiated by the server, and each VC carries one MPEG-2 single program transport stream. The ATM cell transfer rate is the MPEG-2 rate specified in the file metadata plus all transmission overhead (headers, cell and AAL structures, and other associated factors).

The Open Blueprint Signalling and Control Plane

Direct access to subnetworking functionality will be required by such emerging applications as:

- The ATM Forum Video-on-Demand described in “The ATM Forum Video-On-Demand Application” on page 9.
- Computer-based telephony, with the notion of making a telephone call (voice only) from a computer, is getting wide-spread acceptance. Such telephony applications will require first-party connection control and direct access to the subnetworking layer, without going through a traditional Network Services protocol stack.
- Conferencing based on the ITU-T H.Series standards [5].

  (For details concerning the ITU-T H.Series Standards and first party connection control, see *Open Blueprint Telephony Resource Manager* [11] and *Open Blueprint Collaboration Resource Manager* [12] white papers.)

The Open Blueprint Signalling and Control Plane highlighted in Figure 8 on page 11 provides this access.

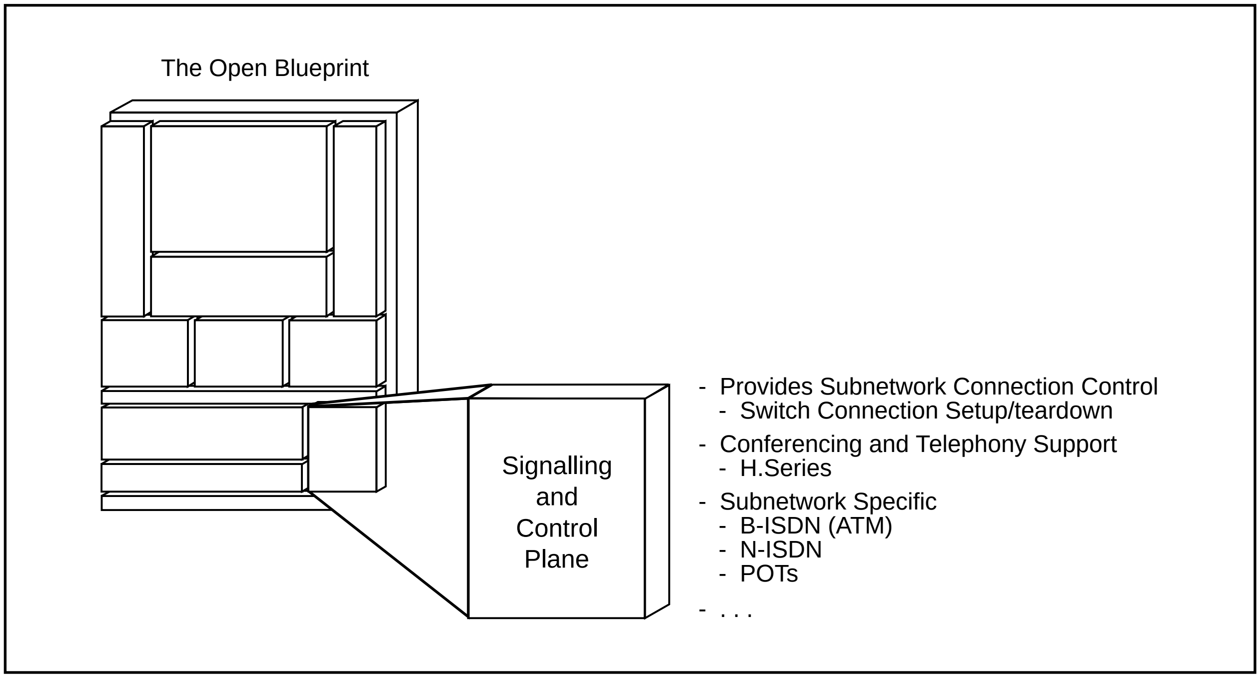

Figure 8. The Open Blueprint Signalling and Control Plane

Signalling and Control

Signalling in a communication network is the collection of procedures used to dynamically establish, maintain, and terminate connections, which require information exchange between the network users and the switching nodes. For each function performed, the corresponding signalling procedures define the sequence and format of messages which are exchanged across the network interface.

The Open Blueprint's Signalling and Control Plane is based on the ITU-T Integrated Services Digital Network (ISDN) Control plane. But it has been generalized to include the switch connection support for other network types as well as providing the control for the low level multiplexing of video, audio and data needed by the ITU-T H.Series conferencing standards.

It is important to realize that each different subnetwork has its own unique connection setup interface. The Open Blueprint Signalling and Control Plane is a superset of these various subnetwork connection protocols and subnetwork specific control functions.

It includes the following:

- For ATM it includes the Q.2931 B-ISDN Signalling and associated control plane functions described in "B-ISDN Control Plane" on page 7.
- For Narrowband ISDN, it includes the Q.931 signalling protocol.
- For Public Switched Telephone (plain old telephone service (POTs)) Networks, it includes the physical layer and modem-related interface manipulation necessary to establish a switch connection.

For some subnetworks, it goes all the way to the physical layer. For other subnetworks such as ATM, it uses the AAL layer.

The Signalling and Control Plane will be used by both the existing data communication protocols (Network Services), resource managers and by the emerging subnetwork specific applications for such functions as call setup/teardown and video or audio conference control. It is anticipated that the H.Series conference control functions will be shared among the Telephony resource manager, the Collaboration resource manager, and the Signalling and Control Plane.

An Example Using ATM

Using an ATM subnetwork as an example, Figure 9 shows the functional relationship of the Signalling and Control Plane to various other components in the Open Blueprint.

For an ATM subnetwork, the Signalling and Control Plane builds on the ITU B-ISDN Reference Model and uses the AAL layer. Various Transport Services such as TCP/IP or APPN will use this plane to establish connections across the ATM network. It is expected that applications will be able to request bandwidth and quality of service guarantees from the Network Services protocol stacks using extensions to current communications programming interfaces such as sockets and Common Programming Interface Communications (CPIC) The protocol stacks will in turn request the appropriate QoS and bandwidth guarantees from the ATM subnetwork using Q.2931 signalling.

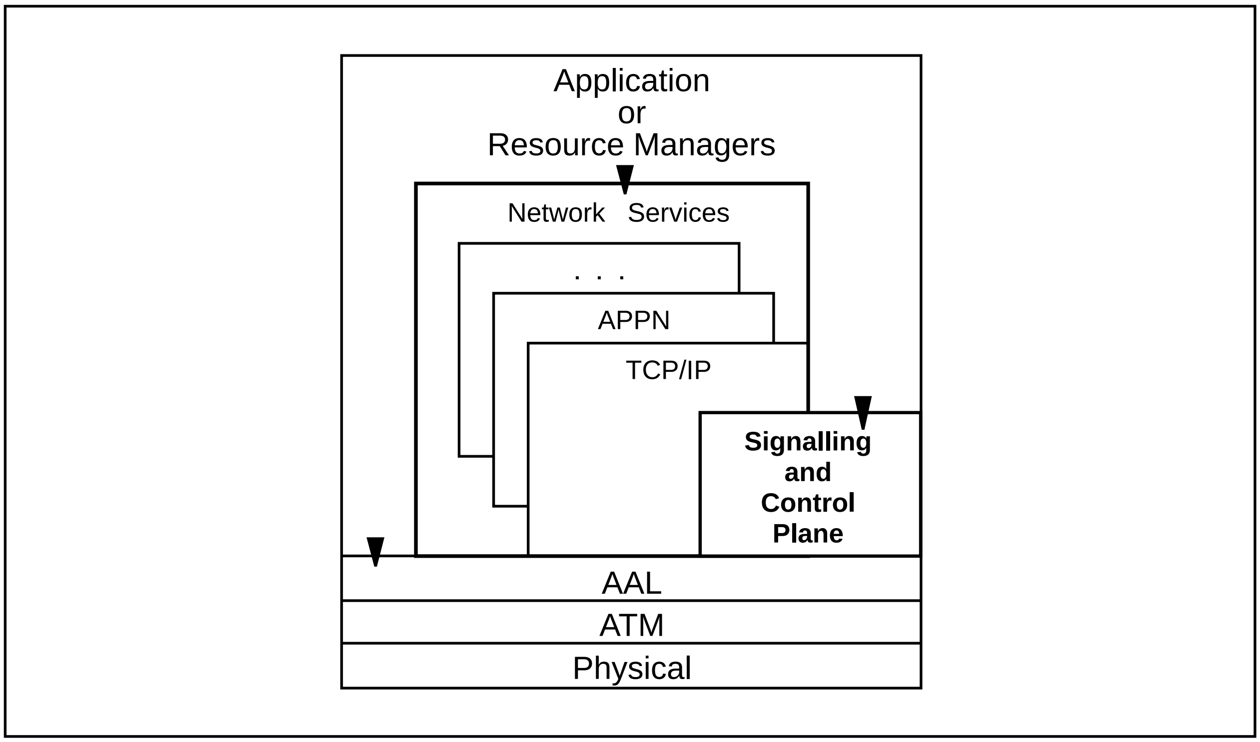

Figure 9. The Open Blueprint Signalling and Control Plane in an ATM Environment

Applications and resource managers requiring the ability to directly establish subnetwork-specific connections will interface directly to the Signalling and Control Plane.

It is envisioned that a single multimedia application could use the Network Services (TCP/IP, and so on) to send and receive data while simultaneously using the Signalling and Control Plane to set up connections to send and receive video or audio directly over the AAL.

Summary

The Open Blueprint diagram highlights ATM as a specific subnetworking technology and illustrates the key aspects of supporting subnetwork-specific multimedia communications.

Previously, the Open Blueprint subnetworking layer has been described in terms of the general categories of technology (local and wide-area networks, etc.). Since ATM is emblematic of a new type of technology, one that dissolves the differences between local and wide-area networks, it is added as a separate category.

For purposes of better supporting the merging worlds of data and telecommunications, the Signalling and Control Plane has been added. This plane will be used for such functions as call setup/teardown and video or audio conference controls. IBM's support of the Signalling and Control Plane will embrace existing and emerging standards in this area, such as ATM's Q.2931 and ITU-T H-Series standards.

To support subnetwork-specific solutions, such as the ATM Forum Video on Demand scenario, the possibility of direct access to the subnetworking layer, without going through a traditional Network Services protocol stack, is supported. This is possible in configurations where the subnetwork provides true end-to-end connectivity.

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1 The Audiovisual and Multimedia Services (AMS) subcommittee of the Service Aspects and Applications (SAA) Subworking Group in the ATM Forum.

2 The Video and Systems Expert Group in ITU Study Group 15.

Appendix A. Bibliography

1. International Telecommunication Union, Telecommunication Standardization Sector *Q.2100: B-ISDN Signalling ATM Adaptation Layer (SAAL) Overview Description*, Geneva, March 17, 1994.
2. International Telecommunication Union, Telecommunication Standardization Sector *Q.2110: B-ISDN ATM Adaptation Layer - Service Specific Connection Oriented Protocol (SSCOP)*, Geneva, March 17, 1994.
3. International Telecommunication Union, Telecommunication Standardization Sector *Q.2130: B-ISDN Signalling ATM Adaptation Layer - Service Specific Coordination Function for Support of Signalling at the User-to-Network Interface (SSCF at UNI)*, Geneva, March 17, 1994.
4. International Telecommunication Union, Telecommunication Standardization Sector *Q.2931: B-ISDN Signalling - User Network Interface Layer 3 Specification for Basic Call/Connection Control*, Geneva, March 17, 1994.
5. International Telecommunication Union, Telecommunication Standardization Sector, Study Group 15 *H.320 - Narrowband Visual Telephone Systems and Terminal Equipment*, Geneva, May 1992.
6. "MPEG-2" *International Organization for Standardisation, Organization Internationale De Normalisation (ISO/IEC JTC1/SC29/WG11) Coding of Moving Pictures and Associated Audio*.
7. "ATM User-Network Interface, Version 3.1 Specification" *ATM Forum*, July 21, 1994.
8. "Asynchronous Transfer Mode (Broadband ISDN) Technical Overview" IBM Technical Reference, GG24-4330-00, July 1994.
9. Sakae Okubo, "Seventh Progress Report of the Experts Group for Video Coding and Systems in ATM and Other Network Environments, Questions: 2/15" *International Telecommunication Union, Telecommunication Standardization Sector, Study Period 1993-1996*, Geneva, February 6-17, 1995.
10. Wright S. (Editor), "SAA Audiovisual Multimedia Service (AMS) Implementation Agreement" *The Audiovisual and Multimedia Services (AMS) subcommittee of the Service Aspects and Applications (SAA) Subworking Group in the ATM Forum*, ATM Forum Contribution 95-0012R1, April 9-14, 1995.
11. *Open Blueprint Telephony Resource Manager*, IBM.
12. *Open Blueprint Collaboration Resource Manager* IBM.

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