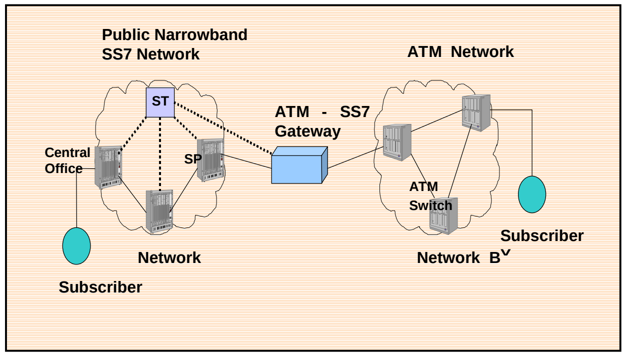
ATM-SS7 Interworking

White Paper from Hughes Software Systems
Discusses the Evolution of Communication Networks and the convergence of voice and data networks

Asynchronous transfer mode (ATM)–signaling system 7 (SS7) interworking enables high-bandwidth ATM networks to integrate seamlessly with traditional circuit-switched SS7–based digital telecommunications networks. The interworking allows subscribers in one network to communicate transparently with subscribers in the other network



This paper first delves on the evolution of Communication Networks and then describes the need for interworking between voice and data networks. It also describes the architecture and functions of an ATM-SS7 signaling gateway.

Overview

Major carriers are rapidly deploying ATM in both public and private networks as a result of its simplicity, flexibility, and capability to support high-bandwidth applications efficiently. Even the third-generation networks, which present a uniform view to both mobile and fixed subscribers, have also been widely using ATM as an underlying technology. The traditional SS7–based telephony networks are widely deployed around the entire globe. Whenever a new network is set up, it must provide connectivity with the existing networks. Thus, wherever the ATM and SS7 networks interface, interworking functions should be defined to interconnect the two and provide services transparently to the subscribers of these networks. Interworking between SS7 and ATM networks primarily involves signaling interworking, bearer service mapping, and traffic interworking, among other functions. In this tutorial, we examine how such interworking takes place, including the essential components of the interworking functions. A selection of typical network interworking scenarios between ATM and SS7 is also examined.

The Evolution of Telecommunication Networks

Beginning with analog transmission and crossbar switches, telecommunication networks have evolved significantly over the past several decades. The early networks used primitive signaling schemes, such as R2 (a series of specifications that refers to European analog and digital trunk signaling) and E&M (a trunking arrangement), to set up and tear down calls node by node (see *Figure 1*). Due to limitations in signaling and transmission technology, the subscribers to these networks could only be provided with a limited set of services. The services offered were basic voice and voiceband services.

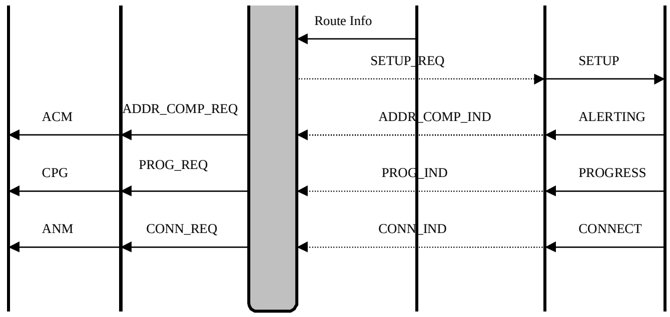


Figure 1: Early Dedicated Telecommunications Networks

As transmission technology advanced, the analog transmission infrastructure was replaced by digital transmission systems. This change resulted in better quality of service (QoS) and lower cost for service providers. Initially, these digital transmission systems were based on plesiochronous digital hierarchy (PDH) technology. However, with rapid developments in optical and high-speed switching technologies, synchronous digital hierarchy (SDH) replaced these PDH systems. This greatly simplified the transmission network and allowed for interoperability between high-bandwidth equipment. Signaling also evolved from primitive forms of channel associated signaling (CAS)–based to common channel signaling (CCS)–based signaling system 7 (SS7) (see *Figure 2*). CCS had several advantages over CAS in terms of ease of implementation, centralized control, and lower equipment costs. Additionally, the high reliability of SS7, coupled with faster operations and increased capabilities, proved to be an important point in the evolution. SS7 provided the signaling capability with which the users could specify QoS requirements—in terms of bandwidth—from the network. End-to-end digital connections could now be set up and torn down dynamically. SS7 signaling also allowed services other than voice.

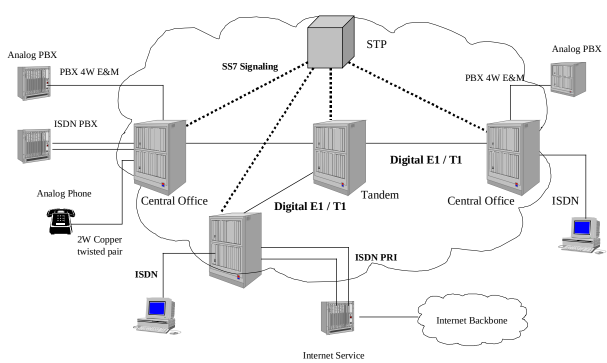


Figure 2: Telecommunication Networks Based on SS7 with Digital Backbone

However, the switching technology at the core of the telecommunication networks continued to be circuit-switched, which severely limited the spectrum of services that could be provided efficiently over these networks. For, in a circuit-switched connection, the entire bandwidth is dedicated for the entire duration of the call. The service providers incurred high costs in providing premium services such as motion-video and high-speed remote access for distributed computing. Another option was to install separate networks (for example, frame-relay networks) to carry traffic for these premium services. From the point-of-view of carriers, this arrangement was not a cost-effective one. It meant deploying two, almost totally disjointed networks. The costs of such an arrangement, in terms of duplicated physical plants, transmission facilities, and management capabilities, were substantial. These problems propelled the search for a multiservice technology that could efficiently carry all types of traffic at a very high speed on a single transmission system.

ATM has emerged as one of the key technologies in such a multiservice network. A number of carriers have already deployed ATM in public and private networks. ATM is a cell-based (small, fixed-size structure) technology employing statistical multiplexing techniques to allow full usage of transport bandwidth. From its inception, ATM has been designed to optimize use of high-bandwidth optical cables. It can efficiently carry almost any type of traffic requiring any amount of bandwidth, thus enabling the introduction of a wide spectrum of services at a competitive price (see *Figure 3*). ATM networks represent a milestone in the convergence of voice and data networks.

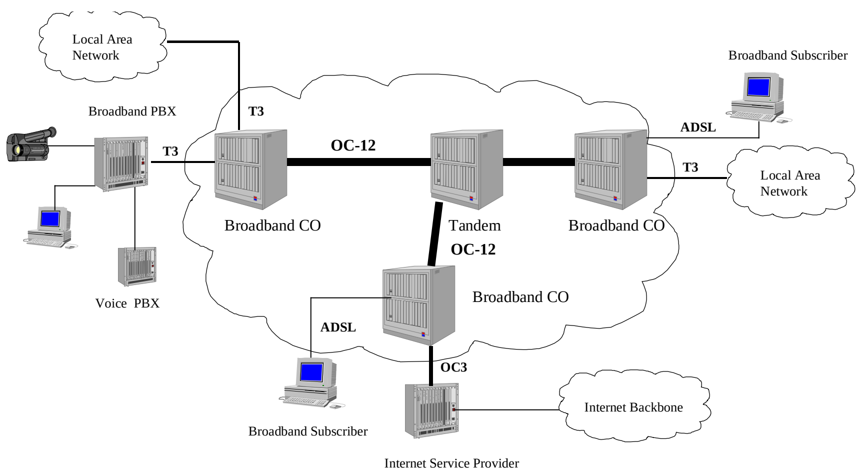


Figure 3: ATM Network Consolidating Various Types of Traffic

Need for ATM–SS7 Interworking

In-spite of growth in ATM networks, SS7 networks will continue to exist. Among the major reasons are huge investments that have been made in these networks and the fact that in a large number of geographical areas around the world little need exists for services other than the basic ones. It is also possible that ATM is introduced only in the toll network to maintain the stability of the services offered by SS7 networks. It is evident that even as ATM networks come up, SS7–based narrowband networks will continue to exist and grow.

This can result in primarily two types of network configurations in which interworking between these two networks is required. In one of these scenarios, SS7–based narrowband networks are connected through an ATM backbone network. This backbone ATM network could possibly be owned by an independent carrier, as shown in *Figure 4.*

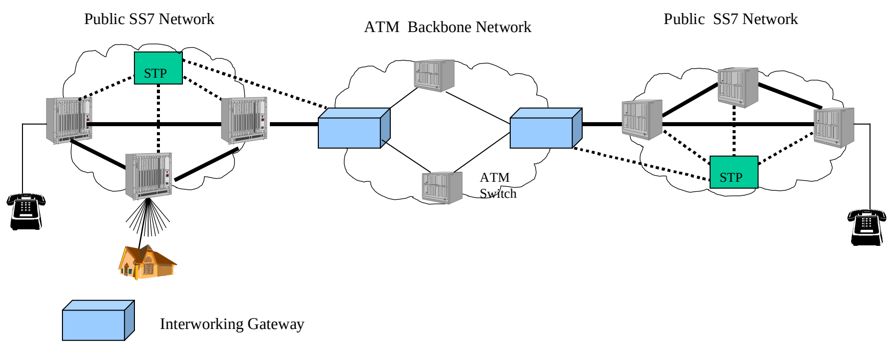


Figure 4: Interworking Scenario A

In the second scenario, an ATM network is set up by a service provider in a local area while the long-distance carrier continues to be SS7–based narrowband (see *Figure 5*). The ATM network in question could be a private or a public network providing ATM services in a local area.

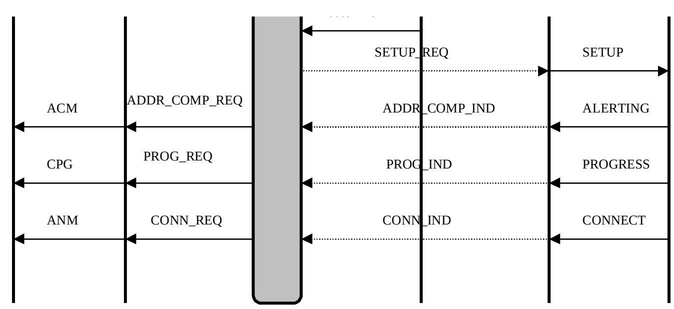


Figure 5: Interworking Scenario B

Both of these scenarios require an interworking solution to bridge the gap between the two networks and allow seamless integration. The interworking solution is in the form of an ATM–SS7 gateway at the boundary of the two networks, which interprets the traffic and signaling going in either direction and performs the appropriate mapping and conversion between the networks on either side. The gateway takes care of the differences between the two networks such as differences in signaling, addressing, and transport technology. The gateway can either be located at the edge of the ATM network (in an ATM switch) or as a stand-alone system between the edges of the two networks.

Some of the important requirements from such an interworking solution are the following:

- Bearer service interworking should be possible between the two networks. As the services provided in the narrowband SS7 network are a subset of the services provided in the ATM, the services offered across the two networks will be limited to the narrowband circuit-mode services.
- The interworking should take place transparently. A user in the ATM network is not expected to invoke any special procedure or install additional hardware to place a call to a narrowband subscriber. Similarly, a user in the narrowband network should be able to place calls to the ATM subscriber using existing procedures and user equipment.
- There should be no loss in service quality when the call transits from one network to another.
- The existing SS7 and ATM networks should not require any hardware and software upgrades or changes.

ATM–SS7 Gateway

In the configuration shown in *Figure 6*, both of the networks attached to the ATM–SS7 gateway assign it an address (for routing based on the network format used). The gateway will have a SS7 point code and an ATM address to identify the points of attachment to the narrowband SS7 network and ATM network, respectively. The routing tables in the two networks are configured in such a way that a call request (signaling) originating in the narrowband network and destined for the ATM network or vice versa gets routed to the gateway.

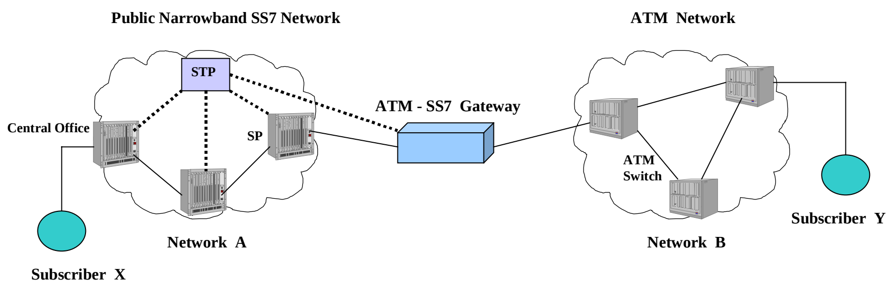


Figure 6: Reference Network Scenario for ATM–SS7 Interworking

The basic operation of the gateway can be best explained by describing the scenario of a connection set up across the two subscribers shown in *Figure 6*: subscriber X in the SS7–based narrowband network A and subscriber Y in the ATM network B. When subscriber X places a call to subscriber Y, the call request (signaling) is routed through a series of signaling transfer point (STPs) and signaling points (SPs) in the narrowband SS7 network to the gateway, allocating circuit resources along the path.

When the call request reaches the gateway, a routing table lookup at the gateway determines the network where subscriber Y lies (network B in this example). It also determines the signaling protocol and other parameters to be used on network B, including addressing method. It performs a mapping of the received call setup request (an SS7 signaling message) from network A to the corresponding signaling protocol message on network B. To preserve service integrity, the gateway keeps as much signaling information intact as is possible across the two networks.

Bearer service mapping is then performed at the gateway to map the bearer service requested by subscriber X in SS7 (network A), such as voice and 3.1 kHz audio, to that in ATM (network B). Based on the requested bearer service, appropriate QoS and traffic parameters are chosen. Also, as the called subscriber Y in the ATM network may be addressed in a way different than subscriber X, address translation is done to map the addressing schemes. This request is then sent across to the ATM switch in network B. The ATM switch then routes it further to the destination switch, toward subscriber Y.

The user traffic starts flowing in either direction when the signaling sequence to set up the call is completed. At this point, traffic interworking between incoming and the outgoing streams of user traffic is activated at the gateway. Subsequently, when subscriber Y (or subscriber X) initiates release of the call, it is indicated to the gateway by the respective signaling protocol. The gateway then initiates release of the call in the other network. Interworking is a continuous function and is performed at every point of the call duration, from connection setup request to user traffic flow and subsequent call release.

A call setup request in the broadband to narrowband direction is treated in a similar manner at the gateway. However, only those calls from the ATM network, in which a narrowband service is requested, are allowed to go through by the gateway. Including the narrowband information elements in the signaling messages for call setup indicates such calls. This is not a restriction but a guideline facilitating seamless interworking between narrowband and ATM subscribers. If a broadband service is requested, the call setup is rejected by the gateway with an appropriate cause.

Functions of the ATM–SS7 Gateway

The main function of an ATM–SS7 gateway can be broadly categorized as the following:

- control and signaling interworking
- traffic interworking

Control and Signaling Interworking

This refers to the capability of the gateway to map control and signaling between the two networks. It involves signaling interworking, service interworking, routing, and addressing. Each of these is now discussed in detail.

Signaling Interworking

Narrowband SS7 networks use narrowband integrated services digital network (ISDN) user part (N–ISUP) as the protocol for signaling between the SS7 nodes. Public ATM networks widely use broadband ISDN user part (B–ISUP) protocol for signaling while their private counterparts use Private network-to-node interface (PNNI) signaling for setting up and tear down calls. On the ATM user interface, user-to-network interface (UNI) protocol is most widely used. These protocols are essentially message-based, with their contents defined by the standard organizations.[1] The information in the protocol messages is interpreted by the nodes and acted on according to defined procedures. This may involve sending out a new message to another node, feeding a tone, or performing any other action required by the procedures.

The signaling messages and procedures used to set up and tear down calls are different in ATM and SS7 networks. More apparent is the difference in the information carried in signaling messages. Thus, one of the important functions of the gateway is to perform signaling interworking (i.e., to map the signaling messages, information elements, and procedures used in one network to the corresponding messages, information elements, and procedures used in the other network).

Bearer Service Interworking

Bearer service interworking at the gateway allows bearer services supported by the ATM network to be mapped transparently to those in SS7 network and vice versa. Bearer services supported by the SS7 network are limited to circuit-mode services requiring bearer capabilities such as voice, 3.1 kHz audio, and nx64 unrestricted. Bearer capability for services in ATM networks are defined in terms of cell rate and type of traffic (such as constant bit rate [CBR] and variable but rate [VBR]). The gateway is responsible for mapping bearer capabilities between SS7 and ATM (see *Table 1*).

Bearer Service on SS7	Bearer Service on ATM
Speech	CBR–based native mode ATM connection (without any AAL) effectively emulating a 64–kbps connection CBR connection using AAL1, effectively emulating a 64–kbps connection VBR–based AAL2 connection with silence detection, suppression, and voice encoding schemes such as 16 kbps and 12.8 kbps based on International Telecommunications Union–Telecommunications (ITU–T) Recommendation G.728 CBR connection using AAL5, effectively emulating a 64–kbps connection
3.1 kHz Audio	CBR–based native mode ATM connection (without any AAL), effectively emulating a 64–kbps connection CBR connection using AAL1, effectively emulating a 64–kbps connection VBR–based AAL2 connection with a standard modem tone detection and encoding scheme [2] CBR connection using AAL5, effectively emulating a 64–kbps connection
nx64 Unrestricted	CBR connection using AAL1, with end-to-end timing CBR connection using AAL2, with end-to-end timing

Table 1:Bearer Service Interworking

As is clear from *Table 1*, there are several possibilities on the ATM network interface for mapping a given bearer capability on the SS7 interface. The decision to map a narrowband service to an ATM service such as ATM adapation Layer 1 (AAL1), AAL2, or AAL5 can depend on several factors including the following:

- capabilities of the destination/incoming ATM network
- capabilities of the ATM hardware in the gateway
- timing arrangements between the two networks

The advantage of using AAL2 as the adaptation layer is that it allows for voice compression, and silence detection and removal. AAL5 is also used, as it is required for signaling and thus present in virtually every ATM node. AAL1 offers advantage in terms of simplicity and interoperability between vendors.

In the reverse direction, only circuit-mode services from an ATM network can be interworked with those in SS7 network. If a broadband-specific service is requested, interworking is not possible and the call is rejected.

Address Mapping

Each end-point in a network should be assigned an address to allow calls to and from it. In an ATM network, the address can be either a 20-byte ATM end system address (AESA) or a native E.164 address. Public ATM networks typically use E.164 format, as it is supported by the existing public network infrastructure. Private ATM networks may use either format. On the other hand, SS7 networks typically route based on E.164 address. If an ATM subscriber requests a narrowband service the end-user may be an ATM subscriber or a narrowband user. Accordingly, the address of the called party may be specified as an AESA or an E.164 address.

When this call is routed to the gateway, it should be converted to an E.164 address that can be routed by the SS7 network. This conversion can be done by using a local back end in the gateway (for small networks) or by using the services of an address resolution server (for large networks). In the reverse direction, an E.164 address received from the SS7 network may need to be mapped to an AESA address using any of the schemes mentioned earlier.

Routing

The SS7–ATM gateway should support call-by-call routing capability to support switched operation. The gateway should have an interface to the routing in order to request an outgoing path for the incoming call. The request to the routing module includes information such as called party number, resource type requested, and implementation-specific information. Routing results in the selection of an outgoing facility (e.g., a narrowband trunk group or ATM virtual connection) on which to route the call.

Connection and Admission Control

The gateway should perform local connection admission control (CAC) function. The local CAC function should be able to determine, based on the traffic and QoS parameters requested in the call setup request, whether setting up the connection violates the QoS guarantee of the established connections. It also finds out if enough resources are available to accommodate the call. If it reports failure, the gateway should reject the connection setup request.

Operations, Administration, and Maintenance Functions

The operations, administration, and maintenance (OAM) functions, which should be performed by the gateway toward the ATM networks, include defect and failure detection, fault localization, and system information. On the SS7 network interface, alarms related to physical transmission failures and interruptions should be handled by the gateway. Appropriate treatment should be given to the calls by the gateway if a failure or loss of continuity is detected on any of the interfaces. The gateway, being a critical point in the network, should have high-availability. This involves the capability of the gateway to handle both faults and failures.

Billing and Charging

In circuit switched networks, the charging plan is well defined and based on the time for which connection is active, given that the entire bandwidth is reserved for the user. However, in ATM networks, bandwidth is shared; thus, a similar charging plan would be inappropriate. Charging in ATM networks has not yet fully evolved. It could be based on several factors, such as the type of QoS guarantee, port-based charging, or number of cells transferred successfully. As these networks become integrated, charging becomes more complex, and bilateral agreements should be established between the owners of the two networks

Traffic Interworking

TDM–ATM Conversion

The transfer technology in ATM is cell-based(fixed size packets of 53 bytes). An ATM connection can be viewed as a stream of cells arriving at a mean interval depending on the type of traffic. At the receiving end (AAL), the cells are adapted to the type of application.

Transfer technology in time division multiplex (TDM) is based on circuit switching, which can be viewed as a stream of octets arriving at a fixed interval. The octets arrive at a fixed rate of 8000 times a second, achieving a bit rate of 64 kbps.

The TDM–ATM bridge performs the conversion of TDM–encoded octets to ATM cells in the physical plane under the control of bearer service interworking, depending on the specified type of AAL, cell rate, and QoS parameters. These adaptations take place in hardware under software control. They may also include voice activity detection (VAD) and voice compression capabilities to support efficient bandwidth usage using AAL2. It may also support fax modulation and demodulation standards, again to allow efficient usage of bandwidth.

Echo Control and End-to-End Delay Handling

Echo is normally caused by feedback from end-user devices (acoustical feedback) and hybrids in the network. Delay is introduced into an end-to-end connection by factors such as packetization, compression algorithms, physical transmission time, and queuing delays at the ATM switches in the path. Echo signals become objectionable with increased delays and feedback levels. In SS7 and ATM networks, echo is removed by inserting echo cancellers in the voice path, which electronically remove the echo from voice signals.

The gateway should be able to identify whether or not echo control is required. The information that influences this decision includes address information, nature of circuit, signaling information received about echo control, bearer capability requested, and propagation delay information. The gateway then uses echo control logic procedures to analyze the available information related to echo-control requirements in order to optimize the locations at which echo-control devices are provided in the connection. Echo control logic is invoked when the bearer capability information indicates speech or 3.1 kHz audio.

Synchronization of Timing Sources

Both SS7 and ATM networks may be timed from separate sources. These sources may or may not be highly accurate in nature. Even with highly accurate timing sources, minor drifts in frequency and phase may occur. This can result in overflow or underflow of buffers for voice and data packets. The gateway should be able to absorb these differences by providing jitter and wander buffers of an appropriate size.

Depending on the location of the gateway and bilateral agreement between the two operators of networks, the gateway may use a simpler scheme in which only one source of timing is used by both the networks. Some services, such as nx64 structured, require end-to-end timing all through the network and between the two user terminals. The gateway should take this into account while such calls are being routed.

ATM–SS7 Gateway Architecture

The main functional components of the ATM–SS7 gateway (see *Figure 7*) are as follows:

- signaling protocol stacks with their respective stack handlers
- call control and signaling interworking function
- traffic interworking function to map user traffic in either networks
- a call routing and resource management function for performing functions such as digit analysis and physical resource (voice circuits, bandwidth) management.
- a management entity

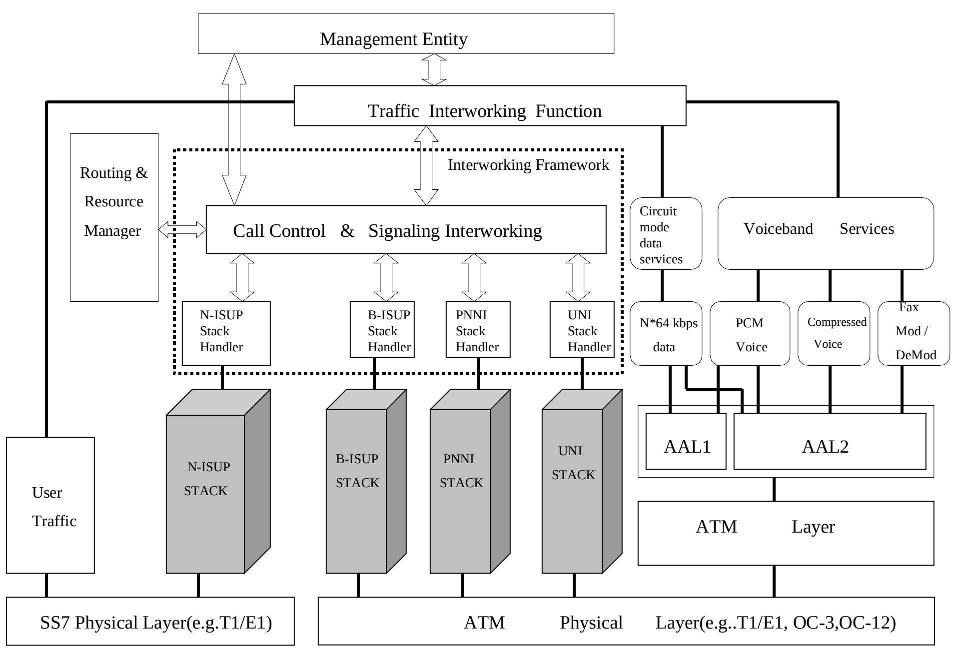


Figure 7: Functional Architecture of the ATM–SS7 Gateway

In addition to these, there are other modules such as the call details record (CDR) manager, maintenance entity, and redundancy manager. The main functionality of the gateway is divided between handling the user plane traffic and the control plane or signaling traffic.

Signaling Stacks

Each of the signaling stacks has its respective stack handler, which interfaces with the call control. In addition to the N–ISUP (SS7) stack, there may be one or more ATM signaling stacks in the ATM–SS7 gateway, depending on its application and location in the network. If the gateway is placed in such a way that it must provide interworking between SS7 (employing N–ISUP), an ATM public network (employing B–ISUP), and an ATM private network (employing P–NNI), then it must house all three protocol stacks. The stacks perform message handling and protocol procedures from the succeeding and preceding nodes and communicate with the call-control module.

Signaling Interworking and Control Function

The main function of this module is to handle call-related events reported by the protocol stacks. These events include call setup and release requests and other call-related events during the call. It also performs signaling interworking between the two signaling systems and interfacing to routing and resource management. Signaling interworking is used to translate the messages and procedures from the SS7 signaling protocol (N–ISUP) to the ATM signaling protocol (B–ISUP, P–NNI, UNI) and vice versa (see *Figure 8*). For example, in case of an SS7 to P–NNI call, the call control receives an initial address message (IAM) with the associated information elements in it. This message must be mapped to a P–NNI SETUP message and sent to the P–NNI interface. The signaling interworking module performs this conversion (*see* Figure **8**) and maps the corresponding information elements in the two signaling protocols. Similarly, the CONNECT that arrives from the P–NNI stack is converted to an answer message (ANM) by the signaling interworking and sent to the SS7 stack .

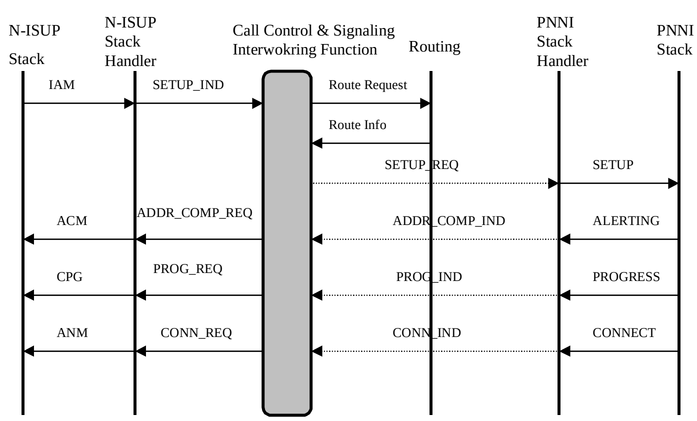


Figure 8: N–ISUP to P–NNI Signaling Control Flow

Figure 9 depicts the flow of events across the system using narrowband SS7 N–ISUP signaling to broadband SS7 B–ISUP signaling interwoking. The example given is of a basic successful call setup, with the call originating in the narrowband network.

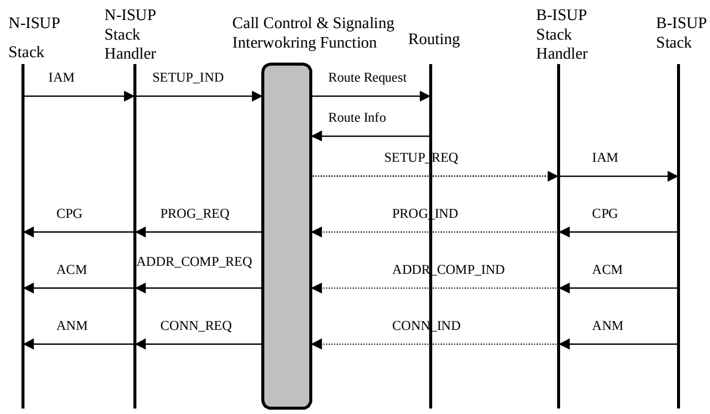


Figure 9: N–ISUP to B–ISUP Signaling Control Flow

The IAM received on the SS7 interface is the initial call setup message and contains information such as calling and called party numbers, call indicators, user service information, and calling party category. The interworking function maps this IAM to a B–ISUP IAM message on the ATM interface with corresponding information elements. The user service information gets mapped to narrowband bearer capability element, call indicators to narrowband interworking indicators, and calling and called party numbers to the corresponding format used in ATM network. The IAM message is passed to the call control for initiating a connection setup on the ATM interface. Similarly, when an address complete message (ACM) is received on the ATM interface, it is mapped to ACM on the N–ISUP side.

Routing and Resource Management Function

On receiving a call setup indication, the call control sends a request to the routing module, to select an outgoing route for the incoming call. The request contains information such as the calling and called party numbers, resource type requested (e.g. 3.1 kHz audio, 64kbps) and other implementation-specific information that might affect the routing. If successful in finding a valid route for the call, routing allocates a suitable channel and returns the response to the call-control function. The routing module interacts with the resource manager to allocate the resources requested for the call.

Traffic Interworking Function

The traffic interworking function is mostly implemented in hardware and firmware because of the speed at which this should be performed. It provides for adapting the user traffic received on the narrowband SS7 interface to the cell-based user traffic on the ATM interface and vice versa under the control of call control. This function, optionally, may also include echo cancellation, voice activity detection (VAD), voice compression, and other features.

Management Entity

At the ATM–SS7 gateway, the management entity functions include configuration management, local OAM functions such as fault management and reporting defects. Also, there is a need to interpret the information produced by the OAM functions in the ATM networks and maintenance messages in the narrowband SS7 networks. For example, a circuit group reset message received on the narrowband interface should result in initiating a release of the end-to-end connection.

Related Standards

SS7 ATM interworking specifications are only now beginning to develop. Some guidelines have emerged with regard to signaling interworking. However, bearer service interworking has a multitude of possibilities and is still not clearly specified. Listed below are specifications from various standards bodies that are directly or indirectly related to ATM SS7 interworking.

- ITU–T Q.2660; interworking between SS7 B–ISUP and N–ISUP
- ATM Forum voice and telephony over ATM (VToA) 0089.000; ATM trunking using AAL1 for narrowband services
- ATM Forum VToA 0113.000; ATM trunking using AAL2 for narrowband services
- ATM Forum VToA 0083.001; VtoA to the Desktop
- ANSI tier 1 (T1).656–Telecommunications; Broadband ISDN; Interworking between SS7 B–ISUP and ISUP

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