A Survey of UNI Signaling Systems and Protocols for ATM Networks

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Abstract

The main aspect covered by signaling systems and protocols for ATM networks concerns the possibility to manage, maintain, and control a user-driven communication between arbitrary ATM end-systems connected to an ATM network. The tasks and procedures defined for, e.g., *setting-up an ATM connection, are often very different concerning the relevant specifications of various working bodies (such as ITU-T or ATM-Forum) or certain vendors, although the basics to be done for maintaining ATM connections are always principally the same. The reason for this situation is, that the intentions of working bodies are different and each one of them follows specific strategies for certain scenarios (such as for point-to-point unicast or point-to-multipoint multicast). Nevertheless, various types of characteristics (such as addressing, multicast, or interworking) are requested from applications residing on top of ATM networks.*

Therefore, this survey of signaling systems and protocols for ATM networks identifies for several of selected approaches (such as Q.2931, UNI 3.1, or CMAP) important characteristics and relevant scenarios. Furthermore, a table-based comparison of some approaches has been added.

1 Introduction

Emerging high-speed networks for wide areas, such as the ATM (Asynchronous Transfer Mode)-based B-ISDN (Broadband-Integrated Services Digital Network), do require in an irregular meshed topology appropriate signaling protocols and systems to allow for the correct management of user-to-user communications, *e.g.,* between digital voice devices, IP (Internet Protocol) hosts, or LAN (Local Area Networks) interworking devices. The general picture for the interoperation of communication protocols in an ATM environment providing user-to-user communications is stated in the B-ISDN protocol reference model [1]. *Signaling* — being part of the ATM control and management plane as well — is the critical issue of interoperability in wide area ATM networks. It is necessary for finally transferring user data between ATM end-systems within well defined ATM connections while dynamically generating outgoing call set-ups and clearings, accepting incoming call set-ups and clearings, processing status maintenance and notification tasks, and running connection control issues according to user requirements for modern services. The underlying ATM concept of virtual path identifiers and virtual channel identifiers [2] is "materialized" into a set of supporting signaling procedures and messages (exchanged between ATM switches and ATM end-systems as well) that are summarized as *call and connection control* issues.

A network scenario as presented in Figure 1 is quite common, where private (corporate) and public ATM switches are interconnected. Two different types of *User-Network Interfaces (UNI)* are distinguished. Private UNIs are located between ATM end-systems and private ATM switches. Instead, public UNIs are located between ATM end-systems and public ATM switches. Public ATM switches may define a public ATM network, where private ATM switches define a private ATM network. A main difference involves the administrative responsibility for all domains. While private domains may follow a local management scheme, which offers only dedicated interconnection points to the outside world, public

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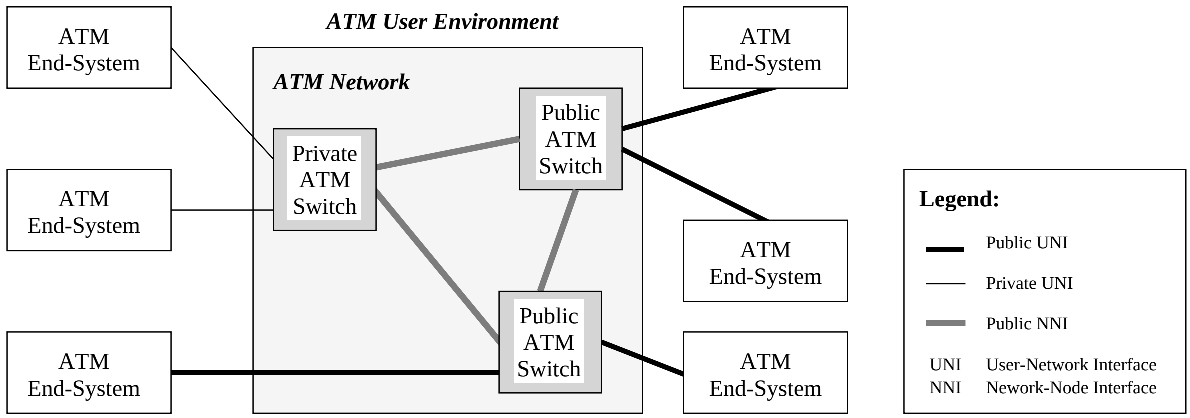

Figure 1: A Common Scenario for Interconnected ATM Switches and ATM End-systems

domains have to offer well-defined interconnection points and signaling systems as well. Additionally, the *Network-Node Interface (NNI)* between private or public ATM switches is not visible to any ATM end-system or user.

A wide range of signaling systems for ATM-based networks has been developed, in each case leading to the special focus of various working bodies or vendors. Most of todays signaling protocols as well as generalized signaling systems are still in the progress of definition or standardization. The main focus throughout this survey lays on the *User-Network Interface (UNI) Signaling* — besides *Network-Node Interface (NNI) Signaling* — without regarding ATM Adaptation Layer Signaling or Physical Network Signaling. In summary, UNI signaling specifies tasks and procedures between an ATM end-system and the next directly connected ATM switch.

In the N-ISDN (Narrowband-Integrated Services Digital Network) environment the International Telecommunications Union – Telecommunications Standardization Sector (ITU-T) Recommendation Q.931 [3] has been introduced as a UNI signaling system. Nevertheless, this *Digital Subscriber Signaling System No. 1 (DSS 1)* could not be applied to ATM-based B-ISDN networks directly, since it did not include schemes for dealing with virtual paths and virtual channels. Therefore, the *Digital Subscriber Signaling System No. 2 (DSS 2)* in the Recommendation Q.2931 [4] (as well as extensions, such as multicast [5] and Quality-of-Service parameter negotiation [6], [7], [8]) has received final preparation at the ITU Study Group 11/Working Party 2, Question 15 "Updating and enhancement of ISDN user-network call control protocols". Additionally, the ATM-Forum is in progress of aligning the standardization process with market opportunities and it produces pre-standardization specifications that are supported by multiple vendors, network operators, and users. The ATM-Forum signaling system is specified as UNI Specification 3.0 [9], now being updated in UNI Specification 3.1 [10]. These specifications are based on subsets and extensions of the above mentioned ITU-T Broadband Access Signaling Protocol Recommendations. An example of a vendor specific approach is SPANS (Simple Protocol for ATM Network Signaling) as Fore's interim signaling protocol for ATM LANs [11], [12]. Finally, an example that has been developed in a university environment (Washington University, St. Louis, U.S.A.), is the "Connection Management Access Protocol" [13], [14] or the "MultiService Network Architecture Connection Management" from the University of Cambridge, England, U.K. [15], [16].

The target of this survey is the identification of commonalities and differences between a number of regarded signaling systems and protocols, while focussing on their main features, characteristics, and procedures. Therefore, this survey is organized as follows. Providing a common basis on important issues, a concise introduction into signaling and into the ATM-based B-ISDN is presented in Section 2. Afterwards, Section 3 focusses on an overview of several signaling systems and protocols while contrasting differences in a table-based comparison. Finally, concluding this survey, Section 4 proposes briefly important issues and characteristics for future signaling systems and protocols.

2 Signaling in the ATM-based B-ISDN

Relevant protocols for ATM are defined within a generic protocol architecture, the *B-ISDN Protocol Reference Model* [1], which contains orthogonal dimensions for different layers and various functions. Horizontal layers encompass:

- *Physical Layer*, specifying media technology-dependent issues;
- *ATM Layer*, including ATM specific functions, such as the generation of ATM cell headers, the (de-)multiplexing of cells, and mapping functions for identifiers;
- *ATM Adaptation Layer (AAL)*, including AAL specific functions, such as segmentation/reassembling of higher layer protocol data units into ATM cells, and convergence functions; and
- *Higher Layers* for application specific functions.

The vertical structure defines the *User Plane*, the *Control Plane*, and the *Management Plane*. User and control plane use identical physical and ATM layers respectively, but use different AAL and higher layers. Especially the user plane is responsible for transmission of user data, where the control plane handles all relevant issues on *Signaling*. This is the set-up, maintenance, and clear of calls and connections, while supporting different kinds of unicast, multicast, broadcast, and multipeer communication scenarios, negotiation and renegotiation of QoS (Quality-of-Service) parameters during set-up, admission control functions, ongoing QoS monitoring during the data transfer phase, and routeing of set-up requests through the network. Finally, the management plane encompasses relevant functions to interact and coordinate between user and control plane activities.

2.1 The Virtual Path and Virtual Channel Concept

Cells are small 53 byte long units of transportation. The relevant format is defined in I.361 [17]. They are exchanged between an *originator* or "calling party" and a *responder* or "called party" that are identified by ATM addresses. Various addressing formats (such as IP addressing [18], public ISDN network E.164 addressing [19], or OSI NSAP addressing [20]) may be used for ATM. The ATM address is divided into an address and a sub-address [9], [21].

A *Virtual Channel (VC)* describes a unidirectional logical ATM connection between two or more ATM end-systems, which has some amount of reserved resources, *e.g.,* bandwidth. In contrast, a *Virtual Path (VP)* defines a number of virtual channels as a unit of observation for unidirectional traffic between an ATM end-system and an ATM switch. Connections relying on either type are logically equal. A *Virtual Channel Link (VCL)* is bounded by ATM switches on either side, which can be uniquely referred to by a *Virtual Channel Identifier (VCI)*. Instead, a *Virtual Path Link (VPL)* defines a physical end-to-end connection between either an ATM end-system or an ATM switch or ATM cross connect respectively (cf. Figure 2). Any VPL is identified by a *Virtual Path Identifier (VPI)*. Finally, one or multiple interconnected virtual channel links are regarded as a *Virtual Channel Connection (VCC)* and one or multiple interconnected virtual path links are regarded as a *Virtual Path Connection (VPC)*. An *ATM Cross Connect* — also known as a *VP Switch* — switches VPIs only, while an *ATM Switch* — also referred to as an *VC(+VP) Switch* — switches VCIs and VPIs. Nevertheless, throughout this survey both types of switches are regarded as ATM switches. *ATM connections* are referred to as switched physical or virtual channels between ATM end-systems. Finally, a *call* defines an abstract issue of an originator to set-up or maintain one or multiple connections to one or multiple responders. Therefore, the call includes more application specific details such as multicast or multipeer requirements [22].

2.2 Key Issues in an ATM Signaling Scenario

Signaling Protocol Architecture – A necessary prerequisite for transferring signaling messages is a reliable network service. Therefore, a SAAL (Signaling ATM Adaptation Layer) based on AAL type 5 [23] has been defined in the Recommendations Q.2100 [24], Q.2110 [25], Q,2120 [26], and Q.2130 [27]. *E.g.,* Q.2931 [4] runs on top of SAAL, which in turn runs on top of the ATM layer. Different types of AAL may be used as well, *e.g.,* SPANS [11] runs on top of either AAL type 3 or type 5. Moreover, the UNI signaling may be processed on top of a TCP/IP (Trans-

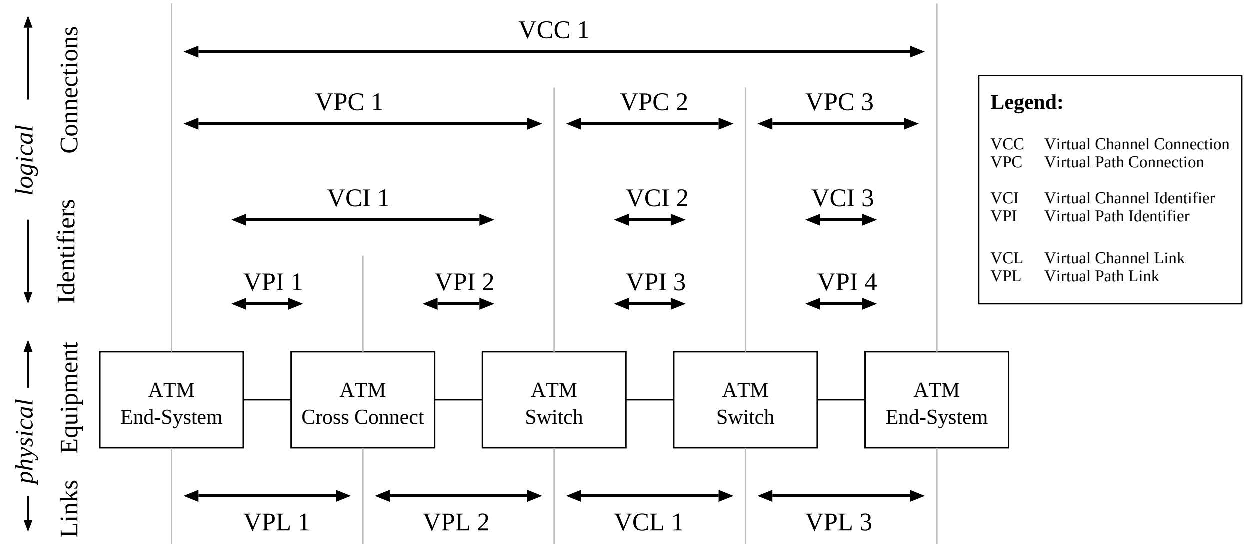

Figure 2: Links, Equipment, Identifiers, and Connections

mission Control Protocol/Internet Protocol) [28], [18] stack and may be used for transmitting signaling messages, to ensure the reliable transfer of these messages, as it is done by the Q.93B-based Netcomm signaling protocol [29]. Finally, signaling protocols may not require reliable signaling message transfer services at all, when the application itself is responsible for dealing with errors, such as corrupted, lost, or duplicated signaling messages.

For Network-Node Interface signaling in B-ISDN a specific B-ISUP (Broadband-ISDN User Part) ([30], [31], [32], [33], [34], and [35]) based on the ISUP (ISDN User Part) ([36], [37], [38], and [39]) of the *Signaling System No. 7 (SSN 7)* — defined completely in Q.700-Q.782 [40] — is located on top of the MTP 1, 2, or 3 (Message Transfer Part) [41] of SSN 7. This regular layer 3 of SSN 7 runs on top of the already mentioned SAAL [24]. Finally, meta signaling is defined in Q.142x [42] and done directly inside the ATM layer, as an internal extension of the ATM layer.

Signaling Features and Tasks – Any signaling system has to hide completely any internals of the network and its topology from the user perspective. That is an important reason for the definition of the User-Network Interface, where the user only recognizes access methods that are handled with the "first" connected ATM switch, but has no knowledge on, *e.g.,* how to reach the potential receiver somewhere connected to the network. In general, signaling in ATM has to be regarded within three different layers:

- Layer 1 signaling is done between physical hardware devices;
- Layer 2 signaling allows for the interconnection of Interworking Units, *e.g.,* between LANs, using layer 2 endpoints; and
- Layer 3 signaling supports the establishment of calls and connections between digital voice devices, IP or IPX hosts, relying on layer 3 endpoints.

Therefore, UNI signaling in the B-ISDN environment is located in layer 3 and defines peer functions for the network connection control. Furthermore, signaling issues may be separated into two distinct control areas:

- *Connection (Bearer) Control* defines procedures to set-up or initialize features of the user data connection, *e.g.,* the ATM connection, or the process of connecting that type of connection.
- *Call Control* defines procedures for maintaining the connection itself, *e.g.,* associating specific VPIs or VCIs with a calling user, calling of any destination, or clearing VPI/VCI tables.

Two important tasks exist in any signaling scenario: network-dependent and service-dependent signaling tasks. The specific target of signaling within ATM networks includes two main ATM *network-dependent tasks*, only:

- Set-up, maintenance, and clear of VCCs and VPCs and
- negotiation of traffic characteristics.

Service-dependent tasks are in general completely independent of any specific network feature and are relevant for signaling systems. But they are *not* compulsory for signaling systems and *may* only be integrated in the signaling system definition approach, *e.g.:*

- The definition of multicast and multipeer scenarios and its direct support;
- the symmetric or asymmetric behavior of connections; or
- QoS parameter negotiation (such as bandwidth, latency, or error rates) for services.

Unfortunately, in case of ATM, QoS is related to services *and* the network as well, *e.g.,* any service requirement regarding throughput has to be mapped onto the network specific ATM peak cell rate, sustainable cell rate, or maximum burst size. Therefore, a complete signaling system *shall* include network-dependent tasks *and* service-dependent tasks as well.

Virtual Signaling Channels – In ATM-based B-ISDN networks *Out-of-Band Virtual Signaling Channels (VSC)* are used. They form the main basis for processing signaling tasks, *e.g.,* transmitting and receiving signaling control messages. In general, three different types of SVCs are distinguished:

- Meta Virtual Signaling Channel (MVSC),
- Broadcast Virtual Signaling Channel (BVSC), and
- Point-to-Point Virtual Signaling Channel (PVSC).

MVSCs are always bidirectional and are used to establish BVSCs or PVSCs as necessary. These in turn, are used to signal all types of ATM connection signaling messages between different ATM end-systems and ATM switches. BVSCs use to be unidirectional, while PVSCs are bidirectional. At least, one VSC of either type is mandatory and, therefore, permanent for each single UNI. However, one static VSC, regardless of which type, has to be assigned at a defined (pair of) VPIs and VCIs initially for each ATM end-system. *E.g.,* for a PVSC the VCI is always set to 5 and the VPI is always non-zero, while a MVSC is defined by a VCI set to 1 and the VPI equals always non-zero, if the signaling is done with remote networks. Otherwise (the VPI equals zero), user signaling is processed with the local switch [17], [43].

Comparison of ATM Signaling with X.25 Signaling – The manner of setting-up an ATM-connection is briefly compared with existing connection establishment procedures. Since a reliable ATM transport service for signaling messages (cf. above) is necessary, ATM signaling messages can not be sent directly into the network via the ATM layer. Instead, in a traditional signaling system and protocol X.25 [44] a "call request message" is delivered directly to the end-system via the reliable network layer, which is used for user data transmissions as well.

Additionally, X.25 signaling is defined between end users. In contrast, an ATM end-system transmits a set-up message to the next ATM switch and this switch will proceed with the necessary set-up tasks between following ATM switches or any final responder ATM end-system.

However, the introduction of a UNI between ATM end-systems and ATM switches is quite similar to the abstraction of the DTE/DCE (Data Terminal Equipment/Data Circuit-Terminating Equipment) concept in X.25, since a user access is processed between the ATM end-system and the ATM switch. But in contrast to X.25, each ATM connection may be additionally specified with a certain set of characteristics (such as QoS parameters), which in turn may be negotiated with the ATM network.

3 Overview and Comparison of Signaling Systems and Protocols

Existing signaling systems and protocols are listed in an overview in Table 1, which is not complete, but presents several relevant approaches. The Figures 5 and 6 include a table-based comparison of several approaches, while depicting a number of important capabilities of signaling protocols.

The ITU-T Recommendations for the Signaling System No. 7 (SSN 7) in the Q.700-series [40] encompass the N-ISDN version of an NNI signaling system. Recommendations for the voice standard in N-ISDN are defined in Q.930 [45], Q.931 (similar to I.451) [3], and Q.93B [46]. The Digital Subscriber Signaling System No. 2 (DSS 2) for B-ISDN in the final text of Q.2931 [4] and the draft text of Q.298x [5] is based on older versions (as Q.93B and Q.931). ETSI (European Telecommunications Standards Institute) is in progress of

Organization	Standard	Content	Remarks
ITU-T	Q.700 series	NNI Signaling	SSN 7
ITU-T	Q.930/Q.931	N-ISDN Voice Standard	DSS 1
ITU-T	Q.93B	Basic Call	Preliminary DSS 2
ITU-T	Q.2931	Point-to-Point	DSS 2
	Q.298x	Point-to-Multipoint	DSS 2
	Q.29xy	Various additional features	DSS 2
ETSI	DE/SPS-5024	Basic Call	
	DE/SPS-5034	Supervisory Call	
ATM Forum	UNI Spec 3.0	Point-to-Point and Point-to-Multipoint	
	UNI Spec 3.1	Point-to-Point and Point-to-Multipoint	
Fore Systems	SPANS	Point-to-Multipoint	For ATM LANs
Netcomm	Q.93B-based	Point-to-Point	
NetExpress	FAST Select	Fast Call Set-up procedure	
Bellcore	EXPANSE	Multimedia Services	
AT&T Bell Laboratories	GSP	Connection Management	For various environments
Washington University	CMAP	Multipoint-to-Multipoint	
University of Melbourne	gNET	Point-to-Multipoint	For ATM LANs
University of Cambridge	MSNL-CM	RPC-based Message Transfer	For Fairisle

Table 1: Overview of Several Signaling System Drafts, (Pre-)Standards, and Definitions

defining a UNI signaling protocol, which is subdivided into *basic call* [47] and *supervisory call* [48] issues. The ATM-Forum defined the UNI Specification 3.0 [9], now being updated in UNI Specification 3.1 [10], which is not interoperable with the former version. A proposal for UNI 4.0 is under discussion [49]. These specifications are based on subsets and extensions of the ITU-T Broadband Access Signaling Protocol Recommendations. Additionally, examples of vendor specific signaling protocols are SPANS [11], [12], a Q.93B-based protocol [29], and FAST Select [50]. Furthermore, Bellcore worked on EXPANSE in support of complex multimedia services [51], and Bell invented GSP (Generic Signaling Protocol) [52], [53]. Finally, university work has been driven by project requirements, such as CMAP (Connection Access Management Protocol) [13], [14], [54], gNET [55], and MSNL-CM (MultiService Network Layer-Connection Management) [15], [16].

3.1 Signaling Capabilities, Messages, and Procedures

User communications in an ATM network takes place after a set-up of an ATM connection, which is based on signaling messages transmitting set-up request information to one or multiple destinations. Depending on the request, either the network (an ATM switch) or the destination (an ATM end-system) agrees upon the information included in the message. A set-up includes other tasks to be managed, *e.g.,* the selection of an appropriate VP, the mapping of VCIs and VPIs in intermediate switches, resource negotiations between switches, and the call and connection control in the calling and called ATM end-system.

Capabilities – Q.2931/Q.298x, UNI 3.0, and UNI 3.1 include the specification of procedures and messages to achieve capabilities, which define the purpose of signaling in various scenarios. They encompass switched connections for point-to-point as well as point-to-multipoint connections that support traffic having symmetrical or asymmetrical bandwidth requirements. A statically pre-defined out-of-band signaling channel allows for maintaining these connections with uni- or bidirectional traffic in terms of user-/network-driven joining or leaving additional partners to/from an existing single connection call. Class X, A, and C ATM data link layer services (ATM transport services) are supported, while public UNI addressing formats for unique identifications of ATM end-points are used. Furthermore, error recovery, end-to-end compatibility parameter identification, and signaling interworking with N-ISDN (Q.29xy only) are provided. Furthermore, Q.2931 runs on top of SAAL [24], while UNI 3.1 needs any type of reliable network service.

Class	Type	Q.2931/Q.298x	UNI 3.0/3.1
Point-to-Point	Set-up	Alerting	—
		Call proceeding	Call proceeding
		Connect	Connect
		Connect acknowledge	Connect acknowledge
		Set-up	Set-up
	Clearing	Release	Release
		Release complete	Release complete
	Managing	Notify	—
		Status	Status
		Status enquiry	Status enquiry
		—	Restart
		—	Restart acknowledge
Point-to-Multipoint	Joining	Add-connection	Add party
		Connection-added	—
		Connection-added acknowledge	Add party acknowledge
		—	Add party reject
	Leaving	Release-connection	Drop party
		Release-connection complete	Drop party acknowledge

Table 2: Messages for Q.2931/Q.298x and UNI3.0/3.1

Messages and Information Elements – A message acts as a pre-defined function for exchanging signaling information, that is further refined in information elements. Depending on the message different directions (from the originator or from the responder of a call) degrees of significance (local, access, dual, and global) are distinguished. Table 2 lists defined messages of two classes and five types within Q.2931/ Q.298x and UNI 3.0/3.1. The structure of each message, possibly consisting out of several variable length information elements, is defined in Figure 3. The *Protocol Discriminator (PD)* distinguishes a specific message from other messages of different protocols that might be used, such as user-network call control messages as defined in Q.931, Q.93B, or X.25. The *Call Reference* consists out of a length field (LCRV), a call reference flag (F), and the value (CRV) itself. It is used — instead of an end-to-end significance — as a local identification of the call. The call reference value is fixed for the lifetime of a call at the originating side. Since multiple calls may be processed within one virtual signaling channel, the call reference value distinguishes messages from different calls. The flag defines, whether the message is being sent from the side that originated the call reference or from the responder. The *Message Type (MT)* specifies the type of the message (cf. Table 2) being sent. Obviously, the *Message Length (ML)* defines the length of the following one or multiple variable length information elements.[1]

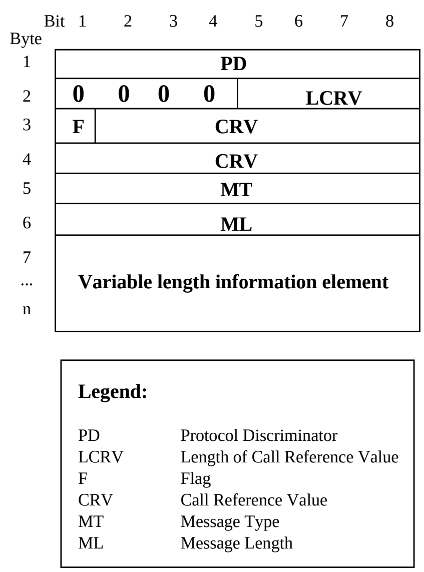

Figure 3: The Structure of Signaling Messages Defined out of Information Elements

Every single information element contains information necessary for the network and/or the responder relating to the processed call. Certain coding rules for the information elements are defined. A general information element format includes identifiers for information elements, such

[1] It is important to recognize that multiple information elements may be used in a single message. *E.g.,* a "Set-up" message at least contains an "ATM Traffic Descriptor", the "Called Party Number", and the "Calling Party Number".

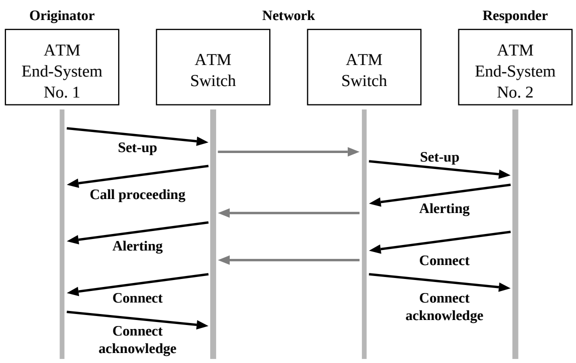

Figure 4: A Simple ATM Connection Set-up Using Messages

as "Broadband-Sending Complete", "ATM Traffic Descriptor", or "Quality-of-Service Parameter". *E.g.,* the "ATM Traffic Descriptor" contains the forward peak cell rate and the backward peak cell rate as defined in I.371 [56]. Reasons for a message and relevant diagnoses are transmitted by "Cause". The "End-to-End Transit Delay" information element defines the selection of the end-to-end transit delay, while the "Connection Identifier" allows for the specification of the controlled connection. A "Number" defines a network addressing, whereas a "Subaddress" defines full addressing. The designation of the desired transit network is specified within the "Transit Network Selection".

Example Procedure: ATM Connection Set-up – The use of some signaling messages is explained in a simple point-to-point scenario (cf. Figure 4), where originator and responder act differently. The originator initially requests a call by transmitting the "Set-up" message. If the call can be accepted, either in the "Call proceeding" or in the "Connect" message the newly allocated VPI/VCI is determined for the initiating ATM end-system No. 1. Otherwise, the "Release complete" message heading for the originator of the call determines that the network or the responder ATM end-system No. 2 are unable to connect. A responder receives a "Set-up" message for an offered call. An "Alerting" and a "Connect" message are transmitted accepting the incoming call or the "Release complete" message is used to determine a rejection. Finally, between each end-system and the directly connected switch the "Connect acknowledge" is exchanged.

CMAP Capabilities – The CMAP (Connection Management Access Protocol) [13], [14], [54] has been defined to manage complex multipoint connection scenarios in an ATM-based network environment. CMAP specifies different kinds of access procedures for set-up, clearing, and monitoring multipoint calls and connections that are handled as a distributed object throughout the ATM network. The main contribution of CMAP capabilities is a great variety of signaling procedures that are used within multipoint connections defining a dynamic call model, where *e.g.,* multiple connections may be added dynamically as a call is set-up. This can happen originator-driven or responder-driven, where the responder might or might not be member of that call. A number of procedures — operations in CMAP terminology — are defined as call procedures to set-up, modify, join, leave, clear, and trace calls, and as connection procedures to set-up, join, or leave connections. Managing procedures allow for the request of status information, alerting, resetting, and reporting. Furthermore, characteristics of calls (such as type, accessibility, originator identification, modifiability, or connection lists) and of connections (such as bandwidth, permissions, or notification) can be defined initially or during a two-way handshake negotiation phase.

3.2 Selected Comparisons

UNI 3.0 versus UNI 3.1 – UNI 3.0 is based on Q.93B and is extended with certain features for addressing multicast issues. UNI 3.1 is the result of an update[2] of UNI 3.0 to become compatible with Q.2931 in most parts, including certain multicast features as defined in Q.298x. However, UNI 3.0 is not compatible with UNI 3.1 due to detailed changes in the signaling part. Important changes are the refinement of the Domain Specific Part of an E.164 Address and of the "General Message Format and Information Element Encoding" (mainly the variable length information elements of "ATM Adaptation Layer Parameters", "Broadband High Layer Information", "Broadband Low Layer Information", "Called Party Subaddress" , "Called Party Number", "Calling Party Subaddress" , "Calling Party Number", and "Quality-of-Service Parameter") and their corresponding procedures and states.

[2] A further collection of new features for another updated UNI version, now called UNI 4.0, has been proposed already in an ATM-Forum signaling subgroup meeting [49].

Call Management Capabilities				Q.29xy [0]	UNI 3.0	UNI 3.1	UNI 4.0 [7]	SPANS	CMAP	gNET	MSNL-CM
Scenario	Addressing	Private UNI		no	yes	yes [6]	yes	yes	yes	yes	yes
		Public UNI		yes	yes	yes	yes	no	yes	no	no
	Unicast			yes	yes	yes	yes	yes	yes	yes	yes
	Multicast			yes	yes	yes	yes	yes	yes	yes	yes [10]
	Multipeer			no	no [1]	no [1]	yes	no	yes [9]	no	yes [10]
Special Features	Traffic descriptors			yes	yes [5]	yes	yes	-	(yes)	-	-
	Client registration			no	yes	yes	yes	-	yes	-	-
	Trace			yes	yes	yes	yes	-	yes	-	-
Set-up	Number of connections per call			1 [4]	1	1	multiple	1	multiple	1	1
	ATM transport service		Class A	yes	yes	yes	yes	-	-	yes	-
			Class C	yes	yes	yes	yes	-	-	yes	-
			Class D	-	no [2]	no [2]	yes	-	-	-	-
			Class X	yes	yes	yes	yes	-	-	-	-
	QoS negotiation			no [3]	no [3]	no [3]	yes	no	yes [4]	yes	no
Maintaining	Static			yes	yes	yes	yes	-	yes	-	yes [10]
	Dynamic	Joining	User-driven	yes	yes	yes	yes	-	yes	-	yes [10]
			Network-driven	-	-	-	-	-	-	-	-
		Leaving	User-driven	yes	yes	yes	yes	-	yes	-	yes [10]
			Network-driven	-	yes	yes	yes	-	no	-	yes [10]
Clearing	User-driven			yes	yes	yes	yes	-	yes	-	yes [10]
	Network-driven			-	yes	yes	yes	-	no	-	yes [10]

Note (0): This includes ITU-T Recommendations Q.2931 and Q.298x.
Note (1): The use of a Multicast-Server as a mapping system will provide multipeer functionality.
Note (2): The use of a Connectionless-Server with transport service classes C or X will provide a class D service.
Note (3): A rudimentary negotiation scheme is availabe: if the network can not support the QoS, it rejects the call.
Note (4): Only within point-to-point calls.
Note (5): Terminology in UNI 3.1 is set as "user cell rate", while referring to the content of a traffic descriptor.
Note (6): UNI 3.1 includes a completely updated and newer version of addressing features than defined in UNI 3.0.
Note (7): Entries in this column are of preliminary status, since the UNI version 4.0 is still under discussion.
Note (8): Any negotiation takes place dynamically for bandwidth requirements.
Note (9): Source descrimination is done via different VPs.
Note (10): Done in higher layers of the MultiService Network Architecture

Legend:

yes	existing feature
no	non existing feature
-	no statement possible

Figure 5: A Comparison of Call Management Capabilities

Q.2931 versus UNI 3.1 – A comparison of the Q.2931 Recommendation and UNI 3.1 identifies *non-supported issues* and *extensions*. *E.g.,* UNI 3.1 does not provide the messages "Alerting" and "Notify", and includes non-similar information elements "Information", "OAM Traffic Descriptor", "Notification Indicator", and "End-to-End Transit Delay" as well as their corresponding procedures and states. Extensions in UNI 3.1 encompass information elements concerning the point-to-point multipoint procedures, which are defined separately in the Q.298x Recommendation. Minor but *important differences* comprise (1) the set-up message. The "Called Party Number" and the "Connection Identifier" are mandatory, while the maximum lengths of these parameters are specified. Since the "Connection Identifier" is missing, appropriate error handling procedures are defined. The retransmission of a set-up is defined as optional. Additionally, only two combinations of type of number and addressing plan identifications according to E.164 are supported. (2) For each supported information element the maximum length and the number of valid occurrences are defined. (3) For coding QoS parameters the network specific standard is used. The selection procedures for these parameters are extended with error procedures for any unsupported combination of these parameters.

3.3 A Table-based Comparison of Signaling Systems and Protocols

Based on the above mentioned proposals, standards, and recommendations as well as from previous works such as [57], [58], [59], [60], [61], [62], [63], and [64] the table-based comparison has been developed. A main distinction can be initially used for signaling systems:

- Call management and
- Connection management.

These two categories are based on the connection and control issues defined in Subsection 2.2, using a slightly modified term of management that involves only call and connection related features respectively. This is an important criteria for B-ISDN, since in a multicast environment a call may need a set of connections to different users, *e.g.,* for different media, such as video and text.

Connection Management Capabilities				Q.29xy (0)	UNI 3.0	UNI 3.1	UNI 4.0 (5)	SPANS	CMAP	gNET	MSNL-CM
Scenario	Permanent connection	Single		no	no	no	yes	-	-	-	-
		Multiple		no	no	no	yes	-	-	-	-
	Switched connection	Single		yes	yes	yes	yes	-	yes	yes	yes
		Multiple		yes	yes	yes	yes	-	yes	yes	yes
	Symmetric			yes	yes	yes	yes	-	no (7)	-	-
Special Features	QoS support	Bandwidth	Symmetrical	yes	yes	yes	yes	no	yes	yes	-
			Asymmetrical	yes	yes	yes (1)	yes	yes (3)	yes	yes	-
		Delay/Error rate		-	-	-	yes/-	-	-/yes (6)	yes/-	-
	Data flow directions		Unidirectional	yes	yes	yes	yes	yes	yes	yes	yes
			Bidirectional	yes	yes	yes	yes	no	yes	no (9)	yes
	Signalling channel (predefined, static)		In-band	no	no	no	no	no	yes	yes	no
			Out-band	yes	yes	yes	multiple	yes	no	(no)	one
	Broadcast signalling			no	no	no	-	-	yes (8)	yes	-
	Meta signalling			no	no	yes	yes	-	yes	-	yes
	N-ISDN interworking			yes	no	no	yes	-	no	-	-
Maintaining	Static			yes	yes	yes	yes	yes	yes	yes	yes
	Dynamic	Adding	Single	yes	yes (2)	yes (2)	yes	yes	yes	yes	yes
			Multiple: Sequential	yes (4)	yes (2)	yes (2)	yes	yes (4)	yes (4)	yes (4)	yes
			Multiple: Parallel	yes (4)	yes (2)	yes (2)	yes	yes (4)	yes (4)	yes (4)	yes
		Dropping		yes	yes (2)	yes (2)	yes	(yes)	yes	yes	yes

Note (0): This includes ITU-T Recommendations Q.2931 and Q.298x.
Note (1): In the backward direction the bandwidth equals zero for point-to-multipoint connections.
In the forward direction the bandwidth is identical to all destinations in point-to-multipoint connections.
Note (2): The dynamic behavior is initiator-driven, which is the originator of a point-to-multipoint connection.
Note (3): Since of unidirectional flow of data, an asymmetrical bandwidth support is possible, only.
Note (4): There is no explicit mentioning of either sequential or parallel adding of additional connections.
Note (5): Entries in this column are of preliminary status, since the UNI version 4.0 is still under discussion.
Note (6): The error rate is defined in this case as "cell loss rate".
Note (7): Receive or transmit direction may have different characteristics set individually.
Note (8): A type of "surrogate" has been introduced, defining a certain type of proxy.
Note (9): AAL users may establish bidirectional communication scenarios.

Legend:

yes	existing feature
no	non existing feature
-	no statement possible

Figure 6: A Comparison of Connection Management Capabilities

Figure 5 summarizes the area of **call management capabilities**.[3] A *scenario* is described by identifying different addressing schemes (such as IP, E.164, or NSAP) that identify unique ATM endpoints and various communications types (such as unicast, multicast, or multipeer). *Special features* include traffic descriptors that are used to specify the type of traffic the application will hand over to the network, a registration of clients that can be used for the integration of a data base for registered end-system's addressing information, and a trace of a call that allows for tracking of the actual physical and virtual path links used within a certain call.

Dependent on the phases of establishing, maintaining, and clearing a call, various differences are identified. During *set-up* time the number of connections per call defines the supported maintenance effort to be handled within the state machines of a signaling protocol. Different ATM transport services (data link layer services in the ISO/OSI Basic Reference Model [65]) can be supported. Additionally, the possibility to (re-)negotiate QoS parameters is important for traffic characteristic variations over the lifetime of a call. *Maintaining* issues concern the static or dynamic behavior of a call. Finally, any *clearing* procedure of a call can be initiated by users or the network.

Figure 6 summarizes the area of **connection management capabilities**. Relevant features encompass a *scenario*, dependent on the type of connection used. Certain *special features* are distinguished. QoS support is defined for bandwidth requirements that are symmetrical or asymmetrical. Further QoS parameters, such as delay or error rates, can be provided. The directions of the data flow is uni- or bidirectional. Signaling support is reflected in the signaling channels provided. A pre-defined and static signaling channel may be used as out-of-band or in-band. Furthermore, broadcast signaling channels and meta signaling can be provided. Finally, interworking with N-ISDN defines upward compatibility with narrowband systems.

[3] In this Figures a *yes* states the existence of the feature, while a *no* states the non-existence. A dash "-" indicates that no reliable information has been identified in the inspected references and no statement can be given.

Issues of *maintaining* a connection may have different characteristics as well. Distinguishing between static and dynamic connection management, the dynamics are refined in terms of different scenarios for joining or leaving connections. Adding or dropping single or multiple connections (sequential or in parallel) within an existing call is supported.

4 Conclusions

Important features of recent standardization work on signaling systems and protocols (such as capabilities, procedures, messages, and information elements) have been briefly described to allow for an insight in signaling tasks. The table-based comparison identifies at a capability-based level main differences of several regarded approaches. Additionally, the following list includes analyzed aspects for a generic signaling system comprising a broader capability- and services-based view of important signaling issues:

- Support of switched and permanent channel connections including single and multiple connections per call in (multi-)point-to-(multi-)point communication scenarios.
- Definition of basic signaling functions via similar signaling protocol messages, information elements, and procedures for each communication scenario.
- Support of uni/bidirectional and symmetric/asymmetric connections concerning QoS requirements, such as bandwidth or error rates for each communication scenario.
- Provision of information for resource negotiation and reservation during connection/call set-up (admission control) and renegotiation during data transfer including resource monitoring, such as for QoS parameters.
- Using a highly dynamic call model including detailed characterizations of calls, such as accessabilities or identifications of originator.
- Multiple simultaneous call and connection set-ups for each communication scenario.
- Support of simultaneous joining/leaving of one or multiple calls/connections into/from existing ones (user-driven and network-driven), while supporting mandatory and optional network connections.
- Using a final call and connection clearing.
- Support of all ATM transport services as well as other data link services.
- One statically defined virtual meta signaling channel, providing the facility to dynamically establish broadcast- and/or point-to-point-virtual signaling channels, or associating a pre-defined static point-to-point virtual signaling channel.
- Support of public and private UNI addressing formats for unique identification of ATM endpoints (such as E.164, OSI-NSAP, IEEE 802.6, or IP addresses).
- Definition of client registration mechanisms/ services for exchange of addressing information across UNIs.
- Specification of error detection and recovery (such as alerting and resetting).
- Provision of end-to-end parameter compatibility and identification, *e.g.,* for QoS parameters or signaling parameters including target platform independent (such as from the operating system or the equipment used) encoding rules for all parameters.
- Independent specification of the signaling system and protocol of the underlying reliable network service (such as with AAL type 3, AAL type 5, SAAL or TCP/IP).
- Independence of the requested service (*e.g.,* multimedia, client/server, or RPC) and of the used protocol for transmitting user data, while supporting different subscriber equipment.

These generic features reflect the needs for a modern signaling system and protocol that will be able to interwork with a wide range of ATM network scenarios and equipment as well. This catalogue should be taken into account for a future development of a *Global Signaling System Architecture*, which is based on distributed system architectures. It includes general mapping schemes and rules for different signaling message types and message contents; on one hand for the integration and experimentation of many different signaling systems and protocols, and on the other hand for signaling simplifications of complex communication and service scenarios. As the variety of existing signaling systems and protocols does not seem to converge to a single signaling system or protocol, an overlayed global signaling system should allow for an interoperable, different ATM networks embracing approach.

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