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ASYNCHRONOUS TRANSFER MODE (ATM) ADDRESSING ISSUES

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OFFICE OF THE MANAGER
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701 SOUTH COURT HOUSE ROAD
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ASYNCHRONOUS TRANSFER MODE (ATM) ADDRESSING ISSUES

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PROJECT OFFICER:

DALE BARR, Jr.
Senior Electronics Engineer
Technology and Standards
Division

APPROVED FOR PUBLICATION:

NICHOLAS ANDRE
Chief, Technology
and Standards Division

FOREWORD

Included within the responsibilities of the Office of the Manager, National Communications System (NCS), is the management of the Federal Telecommunications Standards Program. In support of this program, the NCS, with the assistance of the Federal Telecommunications Standards Committee, identifies, develops, and coordinates proposed Federal Standards which either contribute to the interoperability of functionally similar Federal telecommunications systems or to the achievement of a compatible and efficient interface between computer and telecommunications systems. These systems constitute a significant element of the overall infrastructure upon which the functioning of Government and the nation's economy is dependent. The proposed global deployment of switched virtual circuits (SVCs) in Asynchronous Transfer Mode (ATM) networks will provide considerable enhancements in the flexibility, connectivity, and efficiency of network capacity to support national security and emergency preparedness (NS/EP) operations. However, full achievement of the promised enhancements require an addressing scheme that transparently supports seamless connectivity of public and private networks and internetworking on a global basis. Both the ATM Forum and the International Telecommunication Union (ITU)-Telecommunications Standardization Sector (ITU-T) are actively seeking consensus on addressing issues. This report examines from a NS/EP perspective selected ATM network addressing issues. Comments or statements of requirements which may assist in the advancement of this work are solicited and should be forwarded to:

Office of the Manager
National Communications System
Attn: Technology and Standards Division (N6)
701 S. Court House Road
Arlington, VA 22204-2198

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by

SETA Corporation
6862 Elm Street
McLean, VA 22101

(703) 821-8178
Fax: (703) 821-8274

ABSTRACT

Due to its capability to accommodate a broad range of traffic from diverse sources, support high data rates, and provide gains in bandwidth use efficiency, Asynchronous Transfer Mode (ATM) is gaining broad acceptance as the preferred transport mode for broadband terrestrial communications. The proposed global deployment of switched virtual circuits (SVCs) in ATM networks) where connections are established automatically on a dynamic basis by the use of signalling protocols) require an addressing scheme that transparently supports seamless connectivity of public and private networks and internetworking on a global basis. Both the ATM Forum and the International Telecommunication Union (ITU)-Telecommunications Standardization Sector (ITU-T) are actively seeking consensus on addressing issues. This report presents results of an examination from a national security and emergency preparedness (NS/EP) perspective of selected ATM network addressing issues.

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PURPOSE

This report presents the results of an examination from a national security and emergency preparedness (NS/EP) perspective of selected Asynchronous Transfer Mode (ATM) network addressing issues.

BACKGROUND

The introduction of switched virtual circuits (SVCs) in ATM networks) where connections are established automatically on a dynamic basis by use of signalling protocols) will provide considerable improvement in the flexibility, connectivity, and efficiency of network capacity to support NS/EP operations. However, full achievement of the flexibility, connectivity, and efficiency enhancements promised by the proposed global deployment of SVC capabilities will require an addressing scheme that transparently supports seamless connectivity of public and private ATM networks and internetworking on a global basis. Attainment of this objective is complicated by the current multiplicity of ATM addressing schemes proposed for use, use of disparate internal addressing schemes in some private ATM networks, and international considerations arising from the global nature of the ATM deployment. Both the ATM Forum and the International Telecommunication Union (ITU)-Telecommunications Standardization Sector (ITU-T) are actively seeking consensus on addressing issues. The primary emphasis in this report is on ATM network addressing issues that appear to have potential implications for NS/EP users of ATM services, using ATM Forum established requirements and goals as criteria.

ADDRESSING OVERVIEW

The ATM Forum has specified E.164) the ITU-T standard that specifies the telephone number-type format used for the Integrated Services Digital Network (ISDN)) as the addressing standard to be used in ATM public networks. This election allows legacy public telecommunications operator (PTO) networks to be migrated to ATM without having to undergo major re-numbering. Concurrently, the ATM Forum has defined three types of ATM End System Addresses (AESAs) for use in private networks. An AESA is a 20-byte number that is used to identify an ATM endpoint from any other endpoint in a global network. The AESA structure is derived from the address structure of a generic Open Systems Interconnection (OSI) network addressing standard) the Network Service Access Point (NSAP). For this reason, AESAs are often referred to as ATM NSAPs. The three ATM NSAP AESA formats are the Data Country Code (DCC) AESA, the International Code Designator (ICD) AESA, and the E.164 AESA. The Federal Government has selected the ICD AESA addressing format for use in its Government Open Systems Interconnection Profile (GOSIP).

The E.164 address format is the same as the format used in the public telephone network. E.164 addresses identify interfaces, not endpoints as is the case with ATM NSAP AESA addresses. The address prefixes within E.164 are assigned on a world zone, and then a country-by-country basis. Each country then determines its own numbering plan. The E.164 address format limits the maximum length of an address to 15 digits) the first one to three of which are assigned as a region code to designate a specific country. Within a given region, a Numbering Plan Authority decides how the remaining digits after the region code are to be structured and assigned. In the United States, the well-known North American Numbering Plan (NANP)) with its three-digit numbering plan code or area code, three-digit central office code or prefix, and four-digit line number make-up) provides an excellent example of an E.164 address structure. ISO recommendations describe a hierarchical structure for the NSAP address. The major difference in the various types of ATM NSAP AESA addresses is mostly in what authority assigns them to users. Assignment of AESA addresses generally are accomplished by a series of authorities, with a top level authority assigning some portion of the prefix and delegating to a lower level authority to assign the remainder of the address.

ATM ADDRESSING ISSUES

Addressing in public ATM networks appears to be straightforward for public ATM networks not requiring internetworking with private networks. As previously stated, the ATM Forum has specified E.164 as the public network addressing standard. The format of native E.164 addresses is familiar and well understood. The three features of the E.164 address structure critical to the provisioning of SVC-type services in public networks) fixed length, hierarchical organization, and geographical assignment) support the address aggregation necessary for scalability and routing on a global basis. The fixed length of the E.164 address makes it relatively easy for a network to determine what does and does not constitute a valid address. If addresses are invalid, networks can economize upon resources by not even attempting to route calls. The hierarchical and geographical features of the E.164 address uniquely identifies each network and enables networks to route calls based on a subset of the full address. These features greatly simplify and reduce the size of required routing tables, and facilitate routing across globally interconnected networks.

Most Federal ATM networks will be constructed using Private Network-Network Interface (PNNI) protocols that only support AESA formats. Since three different types of AESA addresses have been defined for use in private ATM networks, the addressing situation with respect to private networks appears to be more complicated than that of public networks, especially for private networks requiring interconnection with a global public ATM internetwork. Issues arising from this requirement appear to have the greatest potential implications for NS/EP planners, providers, and users of ATM services. Specific issues as defined by the ATM Forum [7] are: (1) global assignment/routability, (2) address space administration, (3) legacy system interworking, (4) address translation, (5) address registration, and (6) bi-level addressing.

GLOBAL ASSIGNMENT/ROUTABLITY

The assignment and administration of addresses must balance the often conflicting requirements of (1) maintaining centralized control over the process to ensure maintenance of the uniqueness and global topological significance of addresses, and (2) supporting the need for local autonomy and flexibility required to adequately respond to network changes as they occur. To ensure a manageable routing system, an address should have significance within the network topology) that is, it should be a locator that indicates the network location where the interface can be found. ATM network addresses may be either service provider or customer owned. A service provider ATM address is one where the main stem of the address is allocated to the network operator by an appropriate national or a world registration authority. The service provider then sub-allocates part of the address space to its customers. As a result, all customers attached to a service provider's ATM network can be aggregated or summarized by one code or stem.

ATM customer-owned addresses are AESA addresses only. A customer-owned address is one where the main stem of the address has been allocated directly to the private networking customer by a world or national registration authority. There is no central ATM address registration authority for such addresses. Customer-owned addresses are usually topologically significant within the customer network, but are not topologically significant within the larger global network context. Due to this lack of topological significance, addresses used within the private ATM network may bear no relationship to the topology of the larger public ATM service provider network addressing plan. Consequently, the ATM service provider networks will be unable to aggregate such addresses for routing purposes and must therefore support each interface as an exception. This inability to aggregate private network routing tables, thus allowing ATM service provider networks to scale, generate a requirement for routing tables at each switch in the service provider network to maintain address assignment information on each private network. This arrangement may have a significant impact on global ATM routing by increasing significantly the size of required routing tables and making internetwork operations considerably more complex to manage.

ADDRESS SPACE ADMINISTRATION

Most private ATM networks presently use only the ICD AESA format) the only address format currently supported by major private ATM network equipment vendors. However, since three different types of AESA addresses have been defined for use in private ATM networks) as major private ATM network equipment vendor support for the other AESA address types is provided) use of the other AESA address types may also be expected. With the use of ICD and DCC AESAs, most private network providers desiring their own address space must obtain addresses from the administrative authority within their home country. Since each country uses different procedures to apply for address space and the address space structure may vary from country to country, internationally standardized procedures are generally not available. Additionally, the unsettled nature of the environment and the long-term cost associated with an incorrect decision has resulted in considerable reluctance on the part of some service providers to make a firm commitment to a specific address format. This problem is further exacerbated by the current lack of support for non-ICD AESA private network address types by major private ATM network equipment vendors. Given the current situation, it appears prudent that NS/EP ATM end system users consider obtaining multiple AESA addresses from appropriate administrative authorities in advance to avoid potential coordination problems during disasters or emergencies.

LEGACY SYSTEM INTERWORKING

Due to the evolutionary manner in which the current public and private telecommunications infrastructure has developed, many of the current high speed telecommunications networks consist of a mixture of both legacy and evolving technology systems (e.g., Plain Old Telephone Service (POTS), Internet Protocol (IP), Frame Relay, X.25, and customer-owned/leased private networks) employing several different addressing schemes (e.g., E.164, AESA, X.121, and IP Version 6 (IPV6)). In such a multiprotocol environment, interworking between networks for end-to-end information transport becomes a critical issue. Support of interoperation of such heterogenous networks requires considerable interworking between legacy systems and supporting addressing schemes. Because of the considerable government investment in the existing telecommunications infrastructure, the ATM Forum's efforts to ensure such interworking is an endeavor that the NS/EP community should strongly support.

ADDRESS TRANSLATION

Interworking between the AESA addressing schemes used in private networks and the E.164 addressing scheme and protocols used at the public user-network interface (UNI) and Broadband Integrated Services Digital Network (B-ISDN) Inter-Carrier Interface (B-ICI) are critical to the success of scalable and robust connectivity on a global basis. One of the functions of an address translation capability is to enable private networks requiring connection to the public network to use addressing schemes and protocols other than those employed in the public network. This is accomplished during call establishment by translating the private network address to the desired network address required to complete the call. The current B-ICI specification supports interworking of E.164 AESAs with E.164 addresses; and <u>within</u> private networks any recognized AESA is accepted and routed. Additionally, the PNNI protocol supports the same Called Party Number and Called Party sub-address information element (IE) as the private UNI. Any Called Party Number received from the private UNI (or from another PNNI) will be sent over the PNNI. Also, any sub-address received from a private UNI or PNNI will be forwarded transparently. At the private UNI and the PNNI, if an E.164 AESA is present within the Called Party Number IE, it is carried without conversion. However, a problem exists in establishing global connectivity using ICD and DCC AESA address formats. The current B-ICI and PNNI specifications [4, 2] do not provide a mechanism to support routing of private AESA addresses other than private E.164 AESA addresses through public ATM networks.

ADDRESS REGISTRATION

Address registration is the dynamic exchange of addressing information) network routing prefixes on the network side and end system identifiers on the host side) between the user and the network at the UNI at initialization and at other times as required. Through this exchange, the user and the network agree on the ATM address(es) in effect at that UNI. The address registration mechanism defined in the ATM Forum's Integrated Local Management Interface (ILMI) Specification - Version 4.0 [3] seems adequate to support the administration and configuration of ATM addresses across the UNI. The ILMI specification specifies use of an ATM interface Management Information Base (MIB) to provide any ATM device) e.g., end systems, switches, etc.) status and configuration information concerning registered ATM network prefixes, registered ATM addresses, registered services, and capabilities available at its ATM interfaces. For the exchange of addressing information, two MIB tables are defined) one table to contain network prefixes, and the other to contain registered ATM addresses.

BI-LEVEL ADDRESSING

Bi-level addressing uses two levels of ATM addresses for end-to-end connectivity. The first level) the network-level address) is used for global internetwork connectivity. The network-level address is a service-provider owned address that uniquely identifies an interface to a destination private network. The second level) the user-level address) uniquely identifies an end system within the destination private network. In certain situations, the network-level address and the user-level address may be the same. Bi-level addressing can be initiated by an end system, by a capable private network node, or by a capable ATM service provider network node. Bi-level addressing initiated within an ATM service provider network must use only globally unique registered addresses. Bi-level addressing initiated within a private network) by a node or an attached end system) must produce a globally unique and registered network-level address, but the user-level address must only be unique to the destination private network. For private networks not requiring connectivity to the public network, bi-level addressing does not appear to be an issue. However, with the addition of the ATM Forum stated requirement for global routability, the situation becomes more complex. Because of incompatible addressing schemes, direct connectivity to the public network for user-level addresses using ICD and DCC formats is not possible. For transport in the global network, such addresses require the use of a translation mechanism to translate the user-level address format into a format that is compatible with the addressing scheme used in the public network. With E.164 AESA addresses, no such incompatibility exists. Thus, it appears that a bi-level addressing scheme restricted to use of E.164 addresses in private networks would provide enhanced transparent interoperation with the existing public network infrastructure.

SECTION 1.0

INTRODUCTION

1.1 PURPOSE

This report presents the results of an examination from a national security and emergency preparedness (NS/EP) perspective of selected Asynchronous Transfer Mode (ATM) network addressing issues.

1.2 SCOPE

This report contains (1) an overview of ongoing approaches to ATM network addressing associated with the ubiquitous deployment of ATM in public and private networks, and (2) an examination from an NS/EP perspective of related network addressing issues.

1.3 BACKGROUND

Past offerings of ATM telecommunications services have been supported largely by permanent virtual circuits (PVCs). PVCs are connections with fixed endpoints and static routes between the endpoints defined in advance. Establishment of PVCs generally requires some type of external mechanism) e.g., network management) to program switches between ATM source and destination endpoints with the appropriate virtual path identifier(VPI)/virtual channel identifier (VCI) values required to identify the virtual path/channel over which the ATM cells should be routed. However, because of the pre-defined nature of such connections, addressing schemes are generally not required.

The introduction of switched virtual circuits (SVCs) in ATM networks) where connections are established automatically on a dynamic basis by the use of signalling protocols) will provide considerable improvement in the flexibility, connectivity, and efficiency of network capacity to support NS/EP operations. However, because of the dynamic fashion in which SVC connections are established, each user endpoint must be assigned a unique address to enable networks to identify desired endpoints and successfully route connection requests. Full achievement of the flexibility, connectivity, and efficiency enhancements of the proposed global deployment of SVC capabilities will require an addressing scheme that transparently supports seamless connectivity of public and private ATM networks and internetworking on a global basis. Attainment of this objective is complicated by the current multiplicity of ATM addressing schemes proposed for use, use of disparate internal addressing schemes in some private ATM networks, and international considerations arising from the global nature of the ATM deployment. Both the ATM Forum and the International Telecommunication Union (ITU)-Telecommunications Standardization Sector (ITU-T) are actively seeking consensus on addressing issues. In furtherance of its efforts, the ATM Forum has established the following requirements and goals for ATM addressing schemes [7]:

Addressing Requirements:

- ATM addresses will be globally unique, assignable, and routable.
- The addressing scheme will support global connectivity using a well controlled and administered address space.
- The addressing scheme will not preclude interworking of addressing with legacy systems.
- Address translation may be performed at either the public network, private network, or end station) this does not require that all addresses must be translatable at all points.
- The addressing scheme must support authenticated address registration.
- The addressing scheme must support bi-level addressing in which an E.164 address identifies an interface (or group of interfaces between a public switch and a private network) and ATM end system addresses (AESAs) which identify end users.

Addressing Goals:

- To ensure that the addressing scheme is easy to administer.
- To construct a scalable address structure.
- To provide the ability to identify one or more endpoints.
- To accommodate public/private interworking using existing technology where appropriate.

The primary emphasis in this report is on ATM network addressing issues with potential implications for NS/EP users of ATM services, using the above requirements and goals as criteria.

1.4 ORGANIZATION

This document is further divided into the following subsequent sections:

- Section 2.0, *Addressing Overview;* Provides a brief overview of ongoing approaches to ATM network addressing associated with the ubiquitous deployment of ATM in public and private networks.

- Section 3.0, *ATM Addressing Issues*; Examines from an NS/EP perspective selected ATM addressing issues.

1.5 REVISIONS

This document will be updated as directed by the Technology and Standards Division (N6), Office of the Manager, National Communications System (OMNCS). Comments and recommendations which may assist in the advancement of this effort are solicited and should be forwarded to:

Office of the Manager
National Communications System
Attn: Technology and Standards Division (N6)
701 S. Court House Road
Arlington, VA 22204-2198

SECTION 2.0

ADDRESSING OVERVIEW

An ATM address may identify either an endpoint or an interface)   i.e., a user-network interface (UNI) or its virtual equivalent. As an example, for a private ATM network attached to a public UNI, the device attached at the interface is likely to be an ATM switch. While the public network may assign an address to the interface and consider the connection terminated, the connection will usually not be terminated there but continued beyond that interface by linking other connection segments within the private network, or attaching it to an end system. Consequently, to enable the routing system to establish SVC connections, the addressing scheme must provide sufficient capability to indicate to network elements where in the network the interface or endpoint can be found. The ATM Forum has specified E.164) the ITU-T standard that specifies the telephone number-type format used for the Integrated Services Digital Network (ISDN)) as the addressing standard to be used in ATM public networks. This election allows legacy public telecommunications operator (PTO) networks to be migrated to ATM without having to undergo major re-numbering. Concurrently, the ATM Forum has defined three types of AESAs for use in private networks. An AESA is a 20-byte number that is used to identify an ATM endpoint from any other endpoint in a global network. The AESA structure is derived from the address structure of a generic Open Systems Interconnection (OSI) network addressing standard) the Network Service Access Point (NSAP). For this reason, AESAs are often referred to as ATM NSAPs. The three ATM NSAP AESA formats are the Data Country Code (DCC) AESA, the International Code Designator (ICD) AESA, and the E.164 AESA. The Federal Government has selected the ICD AESA addressing format for use in its Government Open Systems Interconnection Profile (GOSIP).

2.1 E.164 ADDRESS STRUCTURE

The E.164 address format is the same as the format used in the public telephone network. E.164 addresses identify interfaces, not endpoints as is the case with ATM NSAP AESA addresses. The address prefixes within E.164 are assigned on a world zone, and then a country-by-country basis. Each country then determines its own numbering plan. The E.164 address format limits the maximum length of an address to 15 digits) the first one to three of which are assigned as a region code to designate a specific country. Within a given region, a Numbering Plan Authority decides how the remaining digits after the region code are to be structured and assigned. In the United States, the well-known North American Numbering Plan (NANP)) with its three-digit numbering plan code or area code, three-digit central office code or prefix, and four-digit line number make-up) provides an excellent example of an E.164 address structure. NANP numbers are ten digits in length) plus "1" for the North American region code which brings the total to 11 digits. A typical long distance call is dialed as “1-NPA-NXX-XXXX.” Each letter represents a digit. N is any digit 2-9. P, A, and X are any digit 0-9. NANP addresses are of fixed length, organized hierarchically, and geographically assigned to minimize the size of network routing tables, support a high level of scalability, and unambiguously define each unique endpoint. The digits of the E.164 number are encoded in Binary Coded Decimal (BCD) syntax) groups of binary digits representing decimal numbers, with each decimal number allocated four binary digits. The E.164 address is padded with as many leading semi-octets 0000 as needed to reach the 15-digit maximum length. An octet is a group of eight binary digits, usually operated on as an entity (used synonymously with byte). A single semi-octet 1111 is added at the end to obtain an integral number of octets.

2.2 NSAP AESA ADDRESS STRUCTURE

International Standards Organization (ISO) recommendations describe a hierarchical structure for the NSAP address. The major difference in the various types of ATM NSAP AESA addresses is mostly in what authority makes assignments to users. Assignment of AESA addresses generally are accomplished by a series of authorities, with a top level authority assigning some portion of the prefix and delegating authority to a lower level authority to assign the remainder of the address. AESA addresses are represented in hexadecimal form) that is as a numeral in the hexadecimal (base 16) numbering system, represented by the characters 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F optionally preceded by H'. Each AESA address is 20 octets in length. The first 13 octets of the AESA address have been designated the network prefix. It was intended to serve as an identifier for a UNI to be assigned by the network. As such, the identifier forms the common part for all addresses on the user side of the interface. However, despite the original intent of the network prefix, now the 13 most significant octets are not necessarily common to all addresses on the user side of the interface. In certain addressing scenarios, the number of most significant bits that are common to addresses on the user side may be smaller than 13 octets.

The AESA address consists of two parts: (1) the Initial Domain Part (IDP) or network prefix part, which defines the type of address scheme used and the regulatory authority responsible for allocating and administering the address, and (2) the Domain-Specific Part (DSP), which contains routing information. There are two sub-fields in the IDP: (1) an Authority and Format Indicator (AFI) field, which contains a two-digit value between 00 and 99 to indicate the addressing scheme used (e.g., DCC, ICD, E.164, Local); and (2) an Initial Domain Identifier (IDI) field, which specifies the addressing domain and identifies the administrative authority assigned by the ISO to allocate values in certain fields of the DSP. For ATM, the AFI field is coded as follows: 39 = DCC ATM format, 47 = ICD ATM format, and 45 = E.164 format.

The DSP is also divided into multiple sub-fields: (1) a High Order Domain Specific Part (HO-DSP) field which identifies a segment of address space that is assigned to a particular user or subnetwork; and (2) a Low Order DSP (LO-DSP) consisting of an End System Identifier (ESI) field and a Selector (SEL) field. The ESI field uniquely identifies an ATM end system within a specified subnetwork (e.g., a computer). The SEL field has no significance for ATM routing and consequently is not used in ATM networks. However, the SEL field may be used within an end system, if desired (e.g., to differentiate between applications/processes). Even with the same ESI, use of a different SEL byte provides the required differentiation to make each application/process address unique. A brief discussion of the specific difference between each AESA is provided below.

2.2.1 DCC AESA Structure

DCC AESA addresses are assigned by the ISO to national authorities. Each country is assigned a unique DCC code value. With DCC AESA addresses, the AFI and the IDI fields are used to identify the address as a DCC AESA address and to specify the country in which the address is registered.

The AFI is coded in BCD format and the value is fixed at '39' to identify the address as a DCC AESA address. The IDI sub-field contains the DCC) a two byte BCD-encoded field that uniquely identifies the country where the address is registered. The values of the DCC field are administered by the local ISO national member body. The first octet after the AFI and DCC code is assigned as a Domain Format Indicator (DFI)) a field that, depending on the value of the DFI, allows subsequent fields to be formatted differently. The three octets after the DFI are allocated to a field called the "Organization Name") a 24-bit value assigned to the administrative authority (AA) by the American National Standards Institute (ANSI). The remaining fields in the HO-DSP are the Reserved (RSVD) field, the Routing Domain (RD) identifier field (which specifies a unique domain within an AESA), and the Area field (which identifies a unique area within a routing domain). Figure 2-1 provides a generalized overview of the DCC AESA address structure.

2.2.2 ICD AESA Structure

The ICD AESA address structure is very similar to the DCC AESA address structure. However, there are some significant differences. ICD AESA addresses are assigned by the British Standards Institute (BSI), the registration agent, on behalf of the ISO. With ICD AESA addresses, the AFI field value is set to '47' instead of '39') to identify the address as an ICD AESA address. The IDI sub-field contains a two-byte ICD code instead of a DCC, to uniquely identify the international

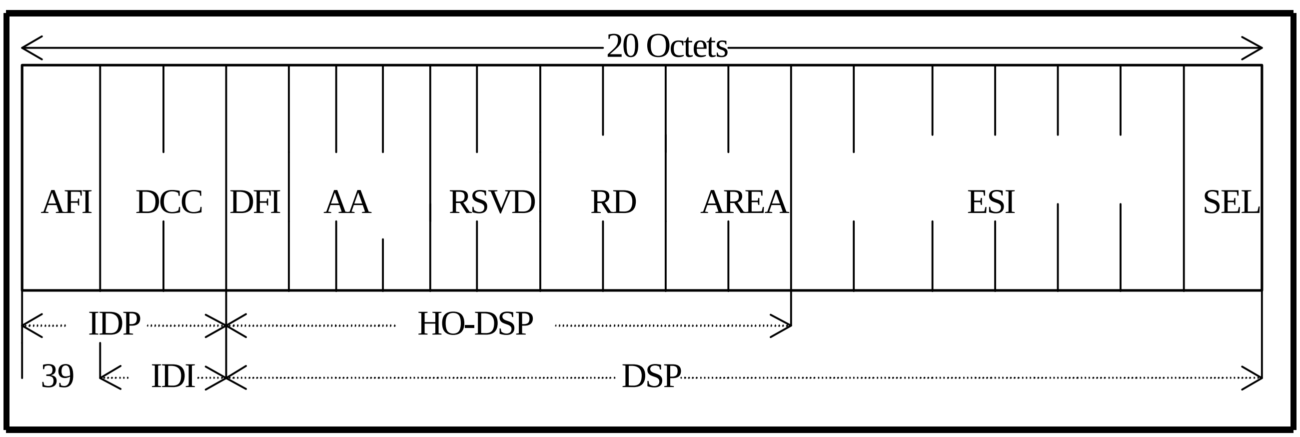

Figure 2-1. DCC AESA Address Structure

organization responsible for administering the ICD address. The values of the ICD field are administered by the BSI. Each assignee is free to determine the structure and rules used for assignment of the DSP. Figure 2-2 provides a generalized overview of the ICD AESA address structure.

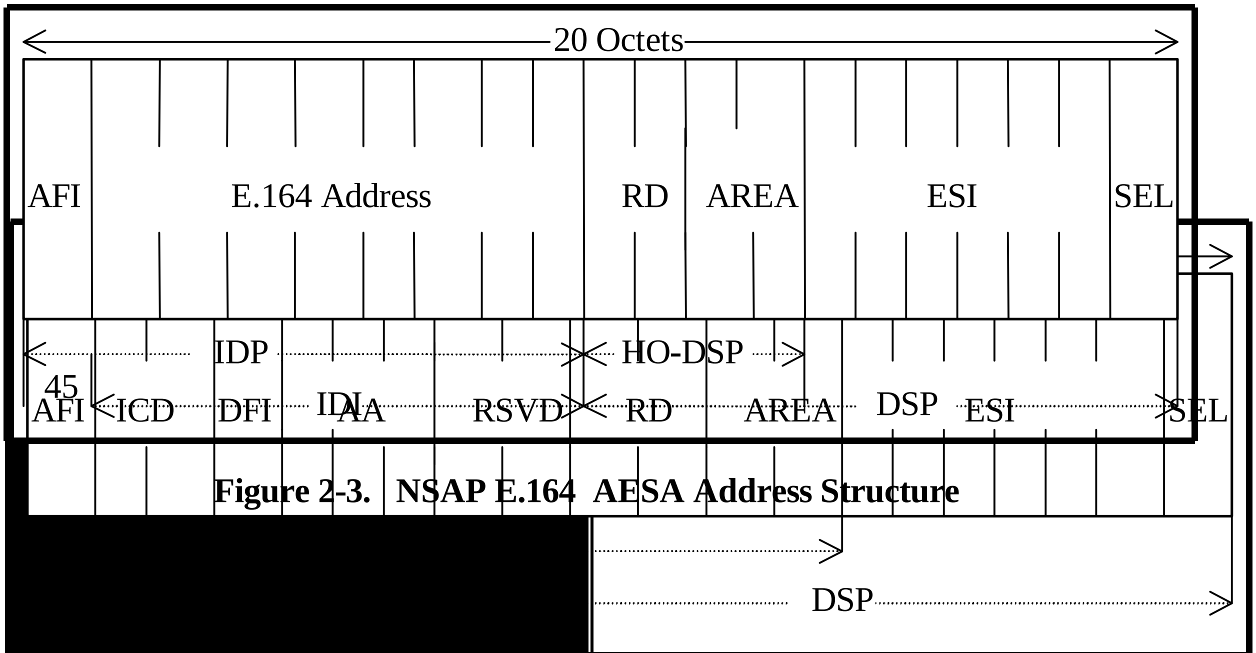

Figure 2-3. NSAP E.164 AESA Address Structure

[redacted] **ESA Address Structure**

2.2.3 NSAP E.164 AESA Structure

The structure of ATM NSAP E.164 AESA addresses differs markedly in some respects from those of DCC AESA and ICD AESA addresses. An NSAP E.164 address is constructed by filling in the IDI field of the AESA with a valid E.164 address. This format allows connection to other E.164 hosts through public network service providers. However, call setup to non-E.164 hosts still requires address translation. The essential feature of E.164 used in the NSAP E.164 AESA address structure is an implicit hierarchy with geographic significance that facilitates the aggregating of addresses. For NSAP E.164 AESA addresses, the AFI is a BCD-encoded field that is fixed at '45'. In this format, the IDI sub-field contains an eight-byte BCD-encoded E.164 address composed of up to 15 digits, which functions much the same as a conventional telephone number. The IDI sub-field always ends with a half-byte of ones and is padded with as many leading zeroes as needed to reach the 15-digit maximum length. When the HO-DSP, ESI, and SEL are all encoded as zero, ATM Forum specifications recognizes this as equivalent to a “native” E.164 address) an address that matches one of a given node’s summary addresses, and is often referred to as an embedded E.164 AESA. There is no international standards body charged with administering NSAP E.164 AESA addresses. Figure 2-3 provides a generalized overview of the NSAP E.164 AESA address structure.

SECTION 3.0

ATM ADDRESSING ISSUES

Public Law 93-288, as amended by Public Law 100-707) and retitled as the Robert T. Stafford Disaster Relief and Emergency Assistance Act) provides the authority for the Federal government to respond to disasters and emergencies in order to provide assistance to save lives and protect public health, safety, and property. The Federal Response Plan (for Public Law 93-288, as amended) requires that agencies and departments of the Federal government be capable of responding quickly to a broad range of scenarios which might require Federal response assistance in a disaster or emergency situation. A viable NS/EP telecommunications infrastructure is critical to attaining this goal. Because the nature, time, location, and magnitude of such occurrences can generally not be predicted with any degree of certainty, considerable flexibility is required of the supporting telecommunications infrastructure. Seamless interworking of Federally owned and public leased telecommunications facilities and services is required to coordinate emergency support. Addressing is a major element in achieving this internetwork transparency. The National Institute of Standards and Technology (NIST) in its position paper on ATM network addressing [20] has defined as major addressing issues the ability to (1) aggregate groups of addresses to enable hierarchical routing, and (2) support decentralized [address] administration to simplify network management and routing maintenance. The NIST definition of issues are consistent with the ATM Forum addressing requirements and goals outlined in Section 1.3 of this bulletin, and appears to provide fundamental support for the seamless NS/EP telecommunications interworking objective stated above.

Addressing in public ATM networks appears to be straightforward for public ATM networks not requiring internetworking with private networks. The ATM Forum has specified E.164 as the public network addressing standard. The format of native E.164 addresses is familiar and well understood. The three features of the E.164 address structure critical to the provisioning of SVC-type services in public networks) fixed length, hierarchical organization, and geographical assignment) support the address aggregation necessary for scalability and routing on a global basis. The fixed length of the E.164 address makes it relatively easy for a network to determine what does and does not constitute a valid address. If addresses are invalid, networks can save on resources by not even attempting to route the calls. The hierarchical and geographical features of the E.164 address uniquely identifies each network and enables the network to route calls based on a subset of the full address. These features greatly simplify and reduce the size of required routing tables, and facilitate routing across globally interconnected networks.

Most Federal ATM networks will be built using Private Network-Network Interface (PNNI) protocols that only support AESA formats. Although three different types of AESA addresses have been defined for use in private ATM networks, the ATM Forum has specified that:

> "The ability of an endpoint to originate a call to any other endpoint shall be independent of the ATM address of the called system. All private networks shall be able to accept the initial call setup messages containing ATM addresses with any of the IDI formats... ...and progress the corresponding call towards the destination endpoint, if it is reachable" [1].

Consequently, the addressing situation with respect to private networks appears to be more complicated than that of public networks, especially for private networks requiring interconnection with a global public ATM internetwork. Issues arising from this requirement appear to have the greatest potential implications for NS/EP planners, providers, and users of ATM services. Specific issues as defined by the ATM Forum [7] are: (1) global assignment/routability, (2) address space administration, (3) legacy system interworking, (4) address translation, (5) address registration, and (6) bi-level addressing. It is these issues that will be the focus of the remainder of this report.

3.1 GLOBAL ASSIGNMENT/ROUTABLITY

The assignment and administration of addresses must balance the often conflicting requirements of (1) maintaining centralized control over the process so as to ensure maintenance of the uniqueness and global topological significance of addresses; and (2) supporting the need for local autonomy and flexibility required to adequately respond to network changes as they occur. ATM network addresses may be either service provider or customer-owned addresses. A service provider ATM address is one where the main stem of the address is allocated to the network operator by an appropriate national or a world registration authority. The service provider then sub-allocates part of the address space to its customers. As a result, all customers attached to a service provider's ATM network can be aggregated or summarized by one code or stem. On an international level, any public UNI worldwide can be reached through the summarized address of its service provider. Service provider addresses include native E.164 addresses and AESA addresses.

ATM customer-owned addresses are AESA addresses only. A customer-owned address is one where the main stem of the address has been allocated directly to the private networking customer by a world or national registration authority (e.g., the ISO administrative authority for ICD AESA addresses and ANSI or BSI national registration authorities for DCC AESA addresses). There is no central ATM address registration authority for such addresses. For E.164 addresses, the source for customer-owned addresses is the service provider. ATM private network addresses/ATM endpoint identifiers are hierarchically structured to allow distributed administration and efficient routing within the customer-controlled domain. Distributed administration permits sub-delegated addressing authorities to further structure the portion of the AESA spaces under their delegated control.

To ensure a manageable routing system, an address should have significance within the network topology) that is, it should be a locator that indicates the network location where the interface can be found. Customer-owned addresses are usually topologically significant within the customer network, but are not topologically significant within the larger global network context. Due to this lack of topological significance, addresses used within the private ATM network may bear no relationship to the topology of the larger public ATM service provider network addressing plan. Consequently, the ATM service provider networks will be unable to aggregate such addresses for routing purposes and must, therefore, support each interface as an exception. This inability to aggregate private network routing tables, thus allowing ATM service provider networks to scale, generates a requirement for routing tables at each switch in the service provider network to maintain address assignment information on each private network. This arrangement may have a significant impact on global ATM routing by increasing significantly the size of required routing tables and making internetwork operations considerably more complex to manage.

Since AESA address prefixes are common within a private network, address aggregation is easily accomplished and routing within such a network is efficient. However, since non-E.164 AESA address prefixes are not supported in ATM networks on a global basis, the use by private ATM networks of AESA address prefixes that only have topological significance within that network creates considerable difficulty in routing in the E.164-based public network. Of the three AESA address formats (ICD, DCC, and NSAP E.164), it appears that the structure of NSAP E.164 AESA addresses best supports routability on a global basis. Only the NSAP E.164 AESA address provides transparent connectivity of AESA addresses to the public network, and direct connection to legacy E.164 hosts through public network providers. With this structure, the IDI is an E.164 number) that is to say, the address prefix is based on the familiar ITU-T recommended E.164 number structure already in use in the public networks. However, since the most significant portion of this address format belongs to the service provider, and call attempts are always rerouted to that service provider, E.164 numbers are currently not portable. Consequently, a subscriber wishing to change carriers must also surrender the number assigned to him.

Northern Telecom, Inc., in a contribution to the ATM Forum [18], has proposed assigning a single E.164 number to a [private or enterprise] site connected to an ATM carrier network, and routing all calls [for that site] to that ATM E.164 number, no matter what DSP was included in the called party address. Another site (for the same or different enterprise) would have a different ATM E.164 number assigned. Within a site, the [private or] enterprise network planner would use the HO-DSP field to make the network prefix of each enterprise ATM switch port unique. The Northern Telecom contribution states:

> "One such plan might entail utilizing the first octet as a building identifier, the second as a floor or closet number, the third as a switch number, and the fourth as the port number. This would allow support of multiple ESIs beyond the ATM switch port. Calls addressed to any ATM E.164 address that is not on the same site would be routed by the enterprise switches at the site to the interfaces connecting the site to the carrier network. This would allow connectivity to any device attached to the carrier's network, including those that were on other sites of the same, or even different, enterprises."

An alternative but related approach described by Katie Taaffe of British Telecom [17] which was recently implemented in the Internet is to have all ATM addresses line up behind a service provider address. Using that approach, all customers could be summarized by the service provider's address thereby reducing entries from routing tables and minimizing the problem of route table explosion.

3.2 ADDRESS SPACE ADMINISTRATION

Most private ATM networks currently use only the ICD AESA format) the only address format currently supported by major private ATM network equipment vendors. However, because three different types of AESA addresses have been defined for use in private ATM networks, as major private ATM network equipment vendor support for the other AESA address types is provided, use of the other AESA address types can also be expected. With the use of ICD and DCC AESAs, most private networks desiring their own address space will need to obtain addresses from the administrative authority within their home country. Since each country uses different procedures to apply for address space and the structure of the address space may vary from country to country, internationally standardized procedures are generally not available. Additionally, the unsettled nature of the environment and the long-term cost associated with a wrong decision has resulted in considerable reluctance on the part of some service providers to make a firm commitment to any one address format. The matter is further exacerbated by the current lack of support for non-ICD AESA private network address types by major private ATM network equipment vendors.

Non-E.164 ATM AESA addresses are not allocated by a single authority as in the case of the ITU recommended E.164 address. The DCC and ICD address format specifications were created with the principal objective of distributed administration and permitting sub-delegated addressing authorities) as allowed by the delegator) to further structure the portion of the address space under their delegated control. Accommodating this distributed authority by the subnetwork requires little or no prior knowledge of the service provider's addressing structure. However, the requirement to coordinate with multiple administrative authorities on addressing issues could result in significant delay in reaching the specific organization responsible for resolving the government's address space needs during major NS/EP disasters or emergencies. In an article in the April 1997 issue of *Telecommunications* [6], Mark Phelan, European Marketing Manager, Cascade Communications, Inc., suggests an approach as one potential solution. His suggested approach involves the use of multiple AESAs by private ATM networks interfacing the public E.164 ATM network. In his article, he writes:

> "...Second generation ATM WAN [wide area network] switches available today obviate the need to exclusively choose one addressing format. Assuming that the ATM switch selected by the service provider supports multiple address formats simultaneously, the ATM service provider can design a quad-format address overlay numbering plan. In such a scheme, different endpoints in the same network can use different address formats. Also any one endpoint can have multiple addresses in multiple formats simultaneously. So, for instance, an ATM endpoint might use an ICD AESA address when talking to another private ATM network endpoint across the public ATM service, but may also use native E.164 addresses when establishing an SVC to a different endpoint in the public ATM network."

DCC and ICD AESA addresses are readily obtainable for a modest administrative fee by any entity that requests one. However, national policy constraints and international treaty organizations limit which entities may obtain blocks of E.164 numbers. Given the current unsettled nature of the environment, the option outlined above by Mr. Phelan seems worthy of consideration. It appears prudent that NS/EP ATM end system users desiring AESA address space might wish to consider obtaining multiple AESA addresses from appropriate administrative authorities in advance to avoid the potential coordination problem cited above during disasters or emergencies.

3.3 LEGACY SYSTEM INTERWORKING

Due to the evolutionary manner in which the current public and private telecommunications infrastructure has developed, many of the current high speed telecommunications networks consist of a mixture of both legacy and evolving technology systems (e.g., Plain Old Telephone Service (POTS), Internet Protocol (IP), Frame Relay, X.25, and customer-owned/leased private networks) employing several different addressing schemes (e.g., E.164, AESA, X.121, and Internet Protocol Version 6 (IPV6)). In such a multiprotocol environment, interworking between networks for end-to-end information transport becomes a critical issue. Support of interoperation of such heterogenous networks requires considerable interworking between legacy systems and supporting addressing schemes. Because of the considerable government investment in the existing telecommunications infrastructure, the ATM Forum's efforts to ensure such interworking is an endeavor that the NS/EP community should strongly support.

Current AESA addresses allow the interconnection of private networks using similar 20 octet addressing. Since such private networks can only be directly interconnected internally, legacy networks are not directly supported. Connectivity and interworking of non-E.164 AESA addresses with legacy systems can be achieved indirectly by mapping an AESA address to an E.164 address. However, this involves the translation of a DCC-based AFI=39 or ICD-based AFI=47 format address to an encapsulated E.164 address. E.164-based AESAs can then be handled in a straightforward fashion at the public-to-private network interface. For such arrangements, the terminating carrier uses the E.164 address to route calls to destination UNIs where the DCC or ICD addresses are extracted and delivered to the appropriate endpoint. Because most legacy networks have long-standing compatibility with the public E.164, compatibility and interworking between private ATM networks employing E.164 AESA addresses and legacy networks are facilitated.

When a call is progressed from a private ATM end system using either an ICD or DCC addressing scheme to a legacy network employing E.164 AESA addressing, the called party address is embedded in the E.164 AESA at the public or private UNI. At the interface, the ATM service provider's called party address is limited to the service provider's ATM address only. The encapsulated E.164 address is converted into native E.164 number at the interface between public networks. In the private-public case when the public network is a B-ISDN network, both the public and private network will implement Q.2931 (an ITU-T recommendation that specifies the procedures messages required for call/connection control at the B-ISDN UNI) as the interworking protocol. Therefore address translation is not required. The capability of the AESAs to support networks with varying addresses allows customers or end users to retain addresses when internal locations change or move to a new facility thus facilitating number portability for network level addresses. The capability to translate non-E.164 legacy system addresses to E.164 addresses at the public UNI provides private networks the option of changing service providers or connecting to multiple service providers.

Private networks with existing E.164 numbers may use such numbers to build a numbering plan using the E.164 AESA format. Such networks may have their (NSAP format) addressing based on the E.164 address of the public UNI to which they are connected and take the address prefix from the E.164 number, identifying local nodes by the lower order bits. The public network must still analyze the AESA construct. However, since most legacy user networks and number structures are fashioned based on the E.164 addressing mode, this arrangement provides an unrestricted address structure which is compatible with the addressing used in a number of existing public legacy networks. Since private legacy networks employing E.164 are not required to renumber or restructure their networks, moves and changes are generally facilitated.

3.4 ADDRESS TRANSLATION

Interworking between the AESA addressing schemes used in private networks and the E.164 addressing scheme and protocols used at the public UNI and Broadband Integrated Services Digital Network (B-ISDN) Inter-Carrier Interface (B-ICI) are critical to the success of scalable and robust connectivity on a global basis. One of the functions of an address translation capability is to enable private networks requiring connection to the public network to use addressing schemes and protocols other than those employed in the public network. This is accomplished during call establishment by translating the private network address to the desired network address required to complete the call. The current B-ICI specification supports interworking of E.164 AESAs with E.164 addresses; and within private networks any recognized AESA is accepted and routed. Additionally, the PNNI protocol supports the same Called Party Number and Called Party sub-address information element (IE) as the private UNI. Any Called Party Number received from the private UNI (or from another PNNI) will be sent over the PNNI. Also, any sub-address received from a private UNI or PNNI will be forwarded transparently. At the private UNI and the PNNI, if an E.164 AESA is present within the Called Party Number IE, it is carried without conversion. However, a problem exists in establishing global connectivity using ICD and DCC AESA address formats. The current B-ICI and PNNI specifications [4, 2] do not provide a mechanism to support routing of private AESA addresses other than private E.164 AESA addresses through public ATM networks.

The principal obstacle is incompatibility of the B-ICI and PNNI interlock codes. The B-ICI interlock code is a four-octet code based on the E.164 address structure. It is assigned by public operators. The PNNI interlock code is a 13-octet code based on the NSAP-based ATM addressing format adopted by the ATM Forum. The 13-octet address prefix of the PNNI interlock code cannot be carried by B-ICI interfaces and the four-octet address prefix of the B-ICI cannot be carried by PNNI signaling. Currently, there is no mechanism available to support direct routing from networks which utilize a private addressing scheme other than E.164 AESA through public ATM networks. For such routing to be accomplished, translation from the private AESA address to a public E.164 address has to be performed at the public UNI providing connection to the public ATM network.

When the connection traverses a switch at the private/public network boundary or public UNI shown in Figure 3-1, if necessary, the switch translates the AESA Called Party address into an E.164 address. This is accomplished by embedding the Called Party AESA address in the E.164 address. In the public network, the E.164 network identifier of the Called Party is used to route the call to the terminating switch. Once the call is received at the terminating switch, the DCC and/or ICD Called Party Number is re-translated and utilized to route the call to the terminating customer's UNI. For calls coming into a private ATM network from a public network, the reverse is applied. The E.164 AESA address is not translated into a higher level address. At the UNI, the E.164 AESA higher level address is only picked from the Called Party sub-address field and placed into the Called Party address field for further connection routing.

Since most private or enterprise ATM networks will use a private addressing plan for internal routing, a capability or translation mechanism that will work both on a national and ideally a global scale needs to be developed to accommodate the aforementioned functionality at the public ATM network. Consequently, it appears that NS/EP users of such services should actively support proposed

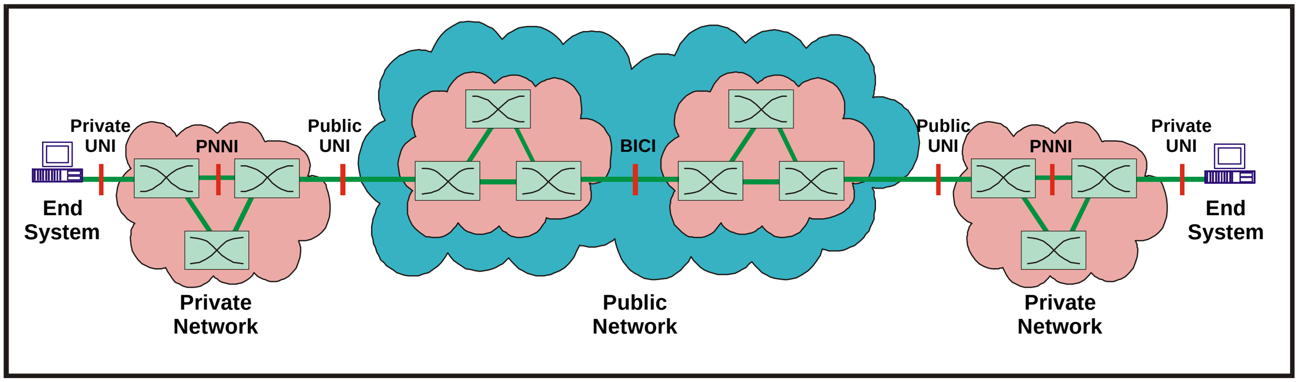

Figure 3-1. Private - Public ATM Network Interfaces

intelligent network solutions based on switch-based translation and screening capabilities that are transparent to the user. One approach proposed by MCI Telecommunications is the maintenance of a database by carriers which stores the private addressing scheme of private networks at all the various sites at service subscription. Additionally, MCI proposes that carriers maintain the capability to translate a given private address to a public E.164 UNI address. The private ATM network would still need to support at least a single public E.164 address at the interconnecting UNI with the public ATM network. All private addresses at a given location would translate to this public E.164 address in the database. Upon call set-up from the private network to the public network, the contents of the Called Party Number IE in the SETUP message would be used to perform a translation to a public E.164 address by the public ATM service provider. If the address cannot be translated, the call would be released [23].

3.5 ADDRESS REGISTRATION

Address registration is the dynamic exchange of addressing information (i.e., network routing prefixes on the network side and end system identifiers on the host side) between the user and the network at the UNI at initialization and at other times as required. Through this exchange, the user and the network agree on the ATM address(es) in effect at that UNI. These ATM addresses are then used in the Calling Party Number IEs of signaling messages sent by the user, and in Called Party Number IEs of signaling messages sent to the user. As indicated in Section 2.2, the ATM private AESA address structure consists of two parts containing multiple fields. The Low Order part consisting of the ESI and SEL fields form the user part and are supplied by the user side of the UNI. All other fields are in the High Order part and form the network prefix for ATM addresses. The value of the network prefix is supplied by the network side of the UNI and are typically the same for all ATM addresses on the same ATM UNI. The network side is allowed to supply multiple network prefixes for use at a single UNI. However, it is generally expected that only one network prefix per UNI will normally be supplied. An ATM address for a user terminal is obtained by appending values for the ESI and SEL fields to the network prefix(es) for that UNI. For the purpose of address registration, the value of the SEL field is irrelevant (i.e., one user part is a duplicate of another if they have the same ESI value even if they have different SEL values). ATM addresses in public networks have the same private ATM address structure as private networks, unless they are E.164 addresses. For a public network with E.164 addresses, the network side supplies the whole ATM address (in effect, the network prefix is the whole address [22]).

The address registration mechanism defined in the ATM Forum's Integrated Local Management Interface (ILMI) Specification - Version 4.0 [3] seems adequate to support the administration and configuration of ATM addresses across the UNI. The ILMI specification specifies use of an ATM interface Management Information Base (MIB) to provide any ATM device (e.g., end systems, switches, etc.) status and configuration information concerning registered ATM network prefixes, registered ATM addresses and services, and capabilities available at its ATM interfaces. For the exchange of addressing information, two MIB tables are defined) one table to contain network prefixes, and the other to contain registered ATM addresses. The network prefix table contains one entry for each registered prefix. The address table contains one entry for each registered ATM address. At initialization, the registration of network prefixes by the network-side interface management entity (IME)) an entity associated with each ATM interface that supports the ILMI functions for that ATM interface) occurs first. Next, the user-side IME combines each of the user parts it wishes to use with one or more of the registered network prefixes to form a set of ATM addresses. The user-side IME then registers these addresses. After initialization, the network-side IME issues SetRequest messages to create/delete entries in the network prefix table when new network prefixes need to be added or deleted. Similarly, the user-side IME issues SetRequest messages to create/delete entries in the ATM address table when new ATM addresses must be added or existing ATM addresses de-registered. If the user-side IME loses ILMI connectivity, all addresses are de-registered [3].

3.6 BI-LEVEL ADDRESSING

Bi-level addressing uses two levels of ATM addresses for end-to-end connectivity. The first level) the network-level address) is used for global internetwork connectivity. The network-level address is a service-provider owned address that uniquely identifies an interface to a destination private network. The second level) the user-level address) uniquely identifies an end system within the destination private network. In certain situations, the network-level address and the user-level address may be the same. Bi-level addressing can be initiated by an end system, by a capable private network node, or by a capable ATM service provider network node. Bi-level addressing initiated within an ATM service provider network must use only globally unique registered addresses. Bi-level addressing initiated within a private network) by a node or an attached end system) must produce a globally unique and registered network-level address, but the user-level address need be unique only to the destination private network [7].

For private networks not requiring connectivity to the public network, bi-level addressing does not appear to be an issue. In fact, for such networks, the use of user- or single-level addressing alone might offer several potential advantages. Any of the AESA formats previously discussed, or a specifically tailored private network derived addressing scheme, might provide an adequate solution. By using user-level addresses that are separate from network addresses, the user is able to establish an internal network addressing scheme independent of any other private or service provider’s network addressing scheme. This capability not only facilitates rehoming (the changing of service provider) and multihoming (the use of multiple service providers), but also decreases the effort required to reconfigure network equipment or support address relocation. However, with the addition of the ATM Forum stated requirement for global routability, the situation becomes more complex. Direct connectivity to the public network for user-level addresses using ICD and DCC formats is not possible. Because of incompatible addressing schemes, such addresses require the use of a translation mechanism to translate the user-level address format into a format that is compatible with the addressing scheme used in the public network for transport in the global network.

Since the public network addressing scheme is based on E.164 addressing, only user-level addresses using the NSAP E.164 AESA format can obtain direct connectivity via the public UNI and end-to-end transparent global transport via the public network. Direct connectivity for user-level addresses using ICD and DCC formats is not possible. Because of incompatible addressing schemes, such addresses require the use of a mechanism to translate the user-level address format into a format that is compatible with the addressing scheme used in the public network for transport in the global network. If network service providers are required to support other than E.164 AESA unique end-point addresses for end-to-end connectivity, the impact on routing table size, complexity, and manageability will be significant. However, with E.164 AESA addresses, no such incompatibility exists. It appears that a bi-level addressing scheme restricted to the use of E.164 addresses in private networks would facilitate address aggregation at the network level in public networks and provide enhanced transparent interoperation with the existing public network infrastructure.

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ACRONYMS

AA	Administrative Authority
AESA	ATM End System Address
AFI	Authority and Format Identifier
ANSI	American National Standards Institute
ATM	Asynchronous Transfer Mode
B-ICI	B-ISDN Inter-Carrier Interface
B-ISDN	Broadband-ISDN
BCD	Binary Coded Decimal
BSI	British Standards Institute
DCC	Data Country Code
DFI	Domain Format Indicator
DSP	Domain Specific Part
E.164	Public network addressing standard
ESI	End System Identifier
GOSIP	Government Open Systems Interconnection Profile
HO-DSP	High Order-Domain Specific Part
ICD	International Code Designator
IDI	Initial Domain Identifier
IDP	Initial Domain Part
IE	Information Element
ILMI	Integrated Local Management Interface
IME	Interface Management Entity
IP	Internet Protocol
ISDN	Integrated Services Digital Network
ISO	International Standards Organization
ITU	International Telecommunication Union
ITU-T	ITU-Telecommunications Standardization Sector
LO-DSP	Low Order-Domain Specific Part
MIB	Management Information Base
N6	OMNCS Technology and Standards Division
NANP	North American Numbering Plan
NIST	National Institute of Standards and Technology
NPA	Numbering Plan Area
NS/EP	National Security and Emergency Preparedness
NSAP	Network Service Access Point
OMNCS	Office of the Manager, National Communications System
OSI	Open Systems Interconnection
PNNI	Private Network-Network Interface
POTS	Plain Old Telephone Service
PTO	Public Telecommunications Operator

PVC	Permanent Virtual Circuit
RD	Routing Domain
RSVD	Reserved
SEL	Selector
SVC	Switched Virtual Circuit
U.S.	United States
UNI	User-Network Interface
VCI	Virtual Channel Identifier
VPI	Virtual Path Identifier
WAN	Wide Area Network