The ATM Forum

BISDN Inter Carrier Interface (B-ICI) Specification

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ATM BISDN Inter Carrier Interface Specification
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1 Introduction

Asynchronous Transfer Mode (ATM) based public networks belonging to different carriers must be interconnected in order to facilitate the end-to-end national and international ATM/BISDN services. Methods are required to support the efficient and manageable multiplexing of multiple services for inter-carrier delivery. This is accomplished by connecting multiple public carrier's networks. The set of specifications required to meet these goals, called a BISDN Inter Carrier Interface (B-ICI)[1], is the subject of this document.

The B-ICI specification in this document will facilitate carrier-to-carrier connection. The ATM Forum B-ICI specification is intended as an implementation agreement that, when followed, will result in increased interoperability. This specification will also result in the early availability of the goals of network interconnection and ubiquitous service offerings.

The B-ICI is an interface between two different public network providers or carriers. It is the demarcation point that designates the boundary between the public carriers' networks. The physical layer of the interface between the two carriers is based on the CCITT[2] defined Network Node Interface (NNI) with the addition of a DS3 physical layer.

The B-ICI specification also includes service specific functions above the ATM layer required to transport, operate and manage a variety of inter-carrier services across the B-ICI. These functions need not necessarily be physically located at the B-ICI. For example, ATM switching nodes may exist between the network equipment supporting the service specific functions and the B-ICI physical location.

Figure 1.1 The B-ICIs Connecting Public ATM Networks

Figure 1.1 illustrates the reference configuration of the B-ICIs connecting two public ATM networks (belonging to different carriers) via a public transit ATM network. Also, B-ICI is shown to connect directly two public ATM networks belonging to different carriers. The purpose of the B-
ICI is to carry traffic between the generic user-to-network interfaces across the public carriers' networks.
A generic reference configuration for the multi-service B-ICI is illustrated in Figure 1.2. In this Figure, "UNI" represents an access interface in a general sense, independent of any particular technology. Multiple service specific customer access interfaces (ATM/non-ATM) can be

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[1] The first release of the specification in this document does not cover all aspects (e.g., signaling) of BISDN. Additional aspects of BISDN will be covered in the future Versions of this document.

[2] CCITT (International Telegraph and Telephone Consultative Committee) is an international standards body. Recently it's name has changed to International Telecommunication Union (ITU)-Telecommunication Standardization Sector (ITU-T).

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connected to a carrier's ATM network. The B-ICIs are shown as providing inter-carrier network connectivity between the Carrier A, Carrier B, and Carrier C. There may be no tandem ATM network, or multiple ATM networks in tandem. The role(s) which a particular carrier must take can vary in this generic reference model subject to regulations and bilateral agreements.

Figure 1.2 Generic B-ICI Reference Configuration

Figure 1.3 illustrates a generic inter-carrier interconnection example of the B-ICIs connecting different carrier's public ATM networks. In this example, the B-ICIs provide connectivity between:

- o A Local Exchange Carrier (LEC) ATM network and an Inter Exchange Carrier (IEC) ATM network,
- o A LEC ATM network and an Independent Local Exchange Carrier (ILEC) ATM network,
- o An IEC ATM network and an ILEC ATM network,
- o A LEC, an IEC, or an ILEC ATM networks and any other public carrier ATM network.

Figure 1.3 illustrates a generic example which shows that any category of carrier, namely, LEC, IEC, ILEC, and any other Carrier can have a service specific User Network Interface (UNI), and be connected to any other carrier via a B-ICI. This is desirable in order to meet the objective of ubiquitous service offerings. These interconnections are subject to regulation and/or reached by bilateral agreements. This is not an exhaustive example, and other configurations are possible.

Figure 1.3 An Example of the B-ICIs Connecting Different Carriers Public ATM Networks

1.1 Purpose

This document provides the initial B-ICI Specification for supporting Permanent Virtual Connection (PVC) services and Switched Multi-megabit Data Service (SMDS) on ATM/BISDN. This will include mostly user plane (U-plane) and management plane (M-plane) communication capabilities, and no control plane (C-plane) communication capabilities.

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In the next Version, the work will be directed towards the B-ICI Specification for supporting Switched Virtual Connection (SVC) services on ATM/BISDN. It is expected that the B-ICI specification for supporting SVC services can be generated by adding the control plane communication capabilities (e.g., network signaling) to the B-ICI specification for PVC services generated initially.

1.2 Scope

To satisfy the purpose stated above, the scope of this document can be summarized as follows:

1. The initial B-ICI will support inter-carrier connections to offer services based on the Permanent Virtual Connections (PVC). In the next phase, B-ICIs capabilities will evolve towards supporting carriers connections to offer services based on the Switched Virtual Connections (SVC).

2. The initial B-ICI will support inter-carrier services to offer: (i) PVC-Based Cell Relay Service (CRS), (ii) Circuit Emulation Service (CES), (iii) PVC-Based Frame Relay Service (FRS), and (iv) Switched Multi-megabit Data Service (SMDS). The target B-ICI is a multi-service (e.g., CRS, CES, FRS, SMDS) interface.

3. A multi-service B-ICI can be configured to support at least one service, or any combination of the above services to meet the traffic needs.

4. The ATM-based B-ICI is based on the Network Node Interface (NNI).

5. The B-ICI physical layer specification includes both DS3 and SONET rates.

6. The B-ICI ATM layer specification is common to all the B-ICI physical layers.

7. The B-ICI related service specific functions above the ATM layer include ATM Adaptation Layer (AAL) and network interworking.

8. B-ICI specification includes traffic management and network performance.

9. B-ICI specification includes operations and maintenance.

1.3 Document Organization

This document is organized in four major parts:

- Part I: B-ICI Definition, Scope, and Architecture - Sections 1, 2.
- Part II: B-ICI Common Aspects - Sections 3, 4, 5, 6, 7.
- Part III: B-ICI Inter-Carrier Service Aspects - Sections 8, 9, 10, 11.

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- Part IV: Others - Section 12.

o Section 1 (Introduction) provides B-ICI definition, some generic B-ICI reference configurations, purpose, scope, terminology, and related documents.

o Section 2 (Network Aspects) provides relation of a B-ICI to the Network Node Interface (NNI), relation to other interfaces, multi-service aspects, and B-ICI related network interworking functions.

o Section 3 (B-ICI Physical Layer Specification) provides signal formats at the B-ICI, physical layer characteristics of the 155.520 Mbit/s (STS-3c), 622.080 Mbit/s (STS-12c) and 44.736 Mbit/s (DS3) rate B-ICI.

o Section 4 (B-ICI ATM Layer Specification) provides ATM layer services, services expected from the physical layer, ATM cell structure and encoding, and ATM layer functions (U-Plane) at the B-ICI.

o Section 5 (Common B-ICI Traffic Management and Network Performance) provides B-ICI traffic management and network performance considerations that are common to all inter-carrier services.

o Section 6 (Common B-ICI Operations and Maintenance) provides B-ICI operations for the physical layer and the ATM layer that are common to all inter-carrier services.

o Section 7 (B-ICI Signaling) is a place holder for future releases of this document which are expected to specify a B-ICI for supporting switched inter-carrier services.

o Section 8 (PVC-Based Inter-carrier CRS Support on a B-ICI) provides the service definition, service specific functions (U-Plane), traffic management and network performance, and operations for the inter-carrier CRS supported by a B-ICI.

o Section 9 (PVC-Based Inter-Carrier CES Support on a B-ICI) provides the service definition, service specific functions (U-Plane), traffic management and network performance, and operations for the inter-carrier DS1/DS3 CES supported by a B-ICI.

o Section 10 (PVC-Based Inter-Carrier FRS Support on a B-ICI) provides the service definition, service specific functions (U-Plane), traffic management and network performance, and operations for the inter-carrier FRS supported by a B-ICI.

o Section 11 (SMDS Support on a B-ICI) provides the service definition, service specific functions (U-Plane), traffic management and network performance, and operations for the inter-carrier SMDS supported by a B-ICI.

o Section 12 (Usage Metering) provides some preliminary considerations for metering the tranfer of service between carriers connecting through a B-ICI.

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1.4 Terminology

This document uses two levels for indicating the degree of compliance necessary for specific functions/procedures/coding associated with the B-ICI:

Requirement (R): Functions/procedures/coding necessary to satisfy the inter-carrier service needs of carriers connecting via a B-ICI. Meeting a requirement will facilitate operational compatibility. Requirements are indicated by the word **"shall"** and are labeled by **(R)**.

Option (O): Functions/procedures/coding that may be useful but are not necessary to satisfy the inter-carrier service needs of carriers connecting via a B-ICI. Failure to meet an option is unlikely to hinder the operational compatibility. Options are indicated by the words **"should"**, **"may"**, or "**it is an option**", and are labeled by **(O)**.

Permanent Virtual Connection (PVC) - An ATM connection that is established through provisioning based procedures.

Switched Virtual Connection (SVC) - An ATM connection that is established and torn down through signaling based procedures.

1.5 Related Documents

o CCITT/ITU-T Recommendations:

1. F.811 - *Broadband Connection-Oriented Bearer Services,* August, 1992.

2. F.812 - *Broadband Connectionless Data Bearer Service,* August, 1992.

3. I.150 - *BISDN Asynchronous Transfer Mode Functional Characteristics,* June, 1992.

4. I.211 - *BISDN Service Aspects,* June, 1992.

5. I.311 - *BISDN General Network Aspects,* June, 1992.

6. I.361 - *BISDN ATM Layer Specification,* June, 1992.

7. I.362 - *BISDN ATM Adaptation Layer (AAL) Functional Description,* June, 1992.

8. I.363 - *BISDN ATM Adaptation Layer (AAL) Specification,* June, 1992.

9. I.364 - *Support of Broadband Connectionless Data Service On BISDN,* June, 1992.

10. I.371 - *Traffic Control and Congestion Control in BISDN,* June, 1992.

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11. I.610 - *BISDN Operations and Maintenance Principles and Functions,* June, 1992.

12. I.555 - *Frame Relaying Bearer Service Interworking,* July, 1993.

13. I.363 - *AAL Type 5, Section 6,* July, 1993.

14. I.365.1 - *Frame Relaying Service Specific Convergence Sublayer (FR-SSCS),* July, 1993.

o ANSI-T1 Recommendations:
See REFERENCES.

o Other Industry Documents:
See REFERENCES.

2 Network Aspects

This Section provides network principles, BISDN protocol architecture, relation of the B-ICI to the Network Node Interface (NNI) and other interfaces, multi-carrier network configuration, multi-service aspects of the B-ICI, and related network interworking functions.

2.1 Principles

A BISDN functional principle is the support of a wide range of data, video and voice applications in the same network. A key element of service integration for such a network is the provision of a range of services using a limited number of connection types and multipurpose interfaces. BISDNs support both switched and non-switched connections. BISDNs support services requiring both circuit-mode and packet-mode information transfer capabilities. BISDNs support both connection-oriented and connectionless services. BISDNs will support capabilities for the purpose of providing service features, maintenance, and network management functions.

2.2 BISDN Protocol Architecture

The Protocol Reference Model (PRM) introduces the concept of separated planes for the segregation of user, control, and management functions. A generic BISDN protocol architecture model is shown in Figure 2.1. This architecture model consists of a user plane, a control plane, and a management plane.

o User Plane:
The user plane, with its layered structure provides for user information flow transfer along with
associated controls (e.g., flow control and recovery from errors).

o Control Plane:
This plane has a layered structure and it performs the call control and connection control functions. It deals with the signaling functions necessary for call and connection set up, supervision, and release.

o **Management Plane:**
The management plane provides two types of functions, namely, Layer Management functions and Plane Management functions.

- Plane Management Functions - The Plane Management performs management functions related to a system as a whole and provides coordination between all the planes; Plane Management has no layered structure.

- Layer Management Functions - The Layer Management performs management functions related to resources and parameters residing in its protocol layer entities (e.g., meta-

signaling is an ATM Layer Management function). Layer Management also handles the Operation and Maintenance information flows specific to the layer concerned.

The layered protocol architecture model can be described on the basis of functions associated with each layers:

- **Physical Layer:** The Physical Layer, for a B-ICI, is based on DS3 and SONET principles.

Figure 2.1 BISDN Protocol Architecture Model

- **ATM Layer:** The ATM Layer, above the Physical Layer, provides the cell transfer capability and is common to all services. The cell information field is transported transparently by the ATM layer of the network; no processing (e.g., error control) is performed on the information field at the ATM layer. The cell header and the information field each consists of a fixed number of octets (5 and 48 octets, respectively) at a given reference point. The ATM cell header format for NNI/B-ICI will be described in a later Section. The information field length is the same for all connections at all reference points where the ATM technique is applied. ATM is a connection-oriented technique that can be used for supporting both connection-oriented and connectionless services. Signaling and user information are carried on separate virtual channels. ATM is designed to offer a flexible transfer capability common to all services.

- **ATM Adaptation Layer (AAL):** ATM Adaptation Layer (AAL) provides service-dependent functions to the layer above the AAL. The boundary between the ATM layer and the service-dependent AAL corresponds to the boundary between functions devoted to the cell header and functions devoted to the cell information field, respectively. The AAL supports higher layer functions of the User and Control planes. Information is mapped by the AAL into ATM cells. At the transmitting end, the information units are segmented or collected to be inserted into ATM cells. At the receiving end, the information units are reassembled or read-out from ATM cells. Any AAL specific information (e.g., information field length, sequence number) that must be passed between peer AAL is contained in the information field of each ATM cell. The AAL could be terminated in Terminal Equipment (TE), Terminal Adaptor (TA), NT2, NT1, Exchange Termination (ET), and Network Adaptor (NA). NA function includes those adaptation functions that are necessary between ATM and non-ATM networks. The AALs are terminated in the network for connectionless service, signaling, etc..

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- **Layers above the AAL:** The layers above the AAL in the control plane provides call control and connection control. The management plane provides network supervision functions. Layers above the AAL in the user plane are service dependent. Examples of functions provided by this layer include inter-carrier service specific functions.

Figure 2.2 Relation of a B-ICI to the NNI

2.3 Network Node Interface

(R)-1 B-ICI specification shall be based on the CCITT defined[1][2][3] Network Node Interface (NNI).

Figure 2.2 illustrates the relation between a B-ICI and the NNI. The NNI specification includes Synchronous Optical netwprk (SONET)/Synchronous Digital Hierarchy (SDH) physical layer and the ATM layer. The B-ICI specification includes SONET and DS3 physical layer[3] , and the ATM layer. The B-ICI specification also includes layers above the ATM (e.g., AAL, other inter-carrier service specific layers) when supporting CES, FRS, and SMDS. The B-ICI is specified for both electrical and optical media to meet the near-term and long-term business needs.

2.4 Multi-Carrier Network Configuration

A B-ICI may provide inter-carrier services directly by means of service specific functions located inside the network, or it may provide an interconnection among service specific networks based on ATM and/or non-ATM technologies.

Figure 2.3 An Example of a Multi-Carrier Network Configuration

Figure 2.3 shows an example of a generic multi-carrier network configuration which includes B-ICIs, service specific (non-ATM) and ATM access interfaces, service specific (non-ATM) and ATM networks, and network Inter-Working Functions (IWF).

[3] Other physical layers (e.g., compliant to European Hierarchies) will be considered in future Versions of this document.

2.5 Relation of the B-ICI to Other Interfaces

Figure 2.4 shows a B-ICI in relation to other interfaces supporting inter-carrier service offerings of the carriers A and B. On the trunk side, FRS and SMDS specific non-ATM interfaces - FRS NNI and SMDS ICI, respectively, and multi-service ATM-based B-ICI are shown. This document specifies an ATM-based multi-service B-ICI. The FRS NNI and SMDS ICI are beyond the scope of this document.

Figure 2.4 Interfaces Supporting Inter-Carrier Service Offerings

2.6 Multi-Service Aspects of the B-ICI

A multi-service B-ICI allows the transfer of cell structured information to support inter-carrier services for end-users utilizing CRS, CES, FRS, or SMDS. End-user traffic is accepted by the serving carrier in the form of ATM cells, DSn frames, FRS frames, or SMDS L3_PDUs, and when necessary, converted into a standard 53-octet ATM cell format for transmission over DS3/SONET trunks to another carrier. The conversion will be transparent to the end-user. No conversion is required for the CRS end-users accessing the ATM network, since the end-user traffic is already in the ATM cell format. A multi-service concept applicable to the B-ICI is illustrated in Figure 2.5.

The end-user service characteristics and features for each of these services should be preserved across the B-ICI. End-users will negotiate with carriers for particular performance parameters and QOS, and these parameters and QOS should be preserved across the B-ICI.

A B-ICI supports an inter-carrier multi-service interface between carriers transporting:

1. CRS ATM cells over PVCs;

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2. CES DSn frames encapsulated in AAL Type 1 PDUs;

3. FRS frames and functions encapsulated in AAL Type 5 and/or mapped to ATM cells;

4. SMDS Interface Protocol (SIP) L3_PDUs encapsulated in Inter Carrier Interface Protocol (ICIP) Connectionless Service (ICIP_CLS) PDUs and AALType 3/4, and/or mapped to ATM cells.

Figure 2.5 Multi-Service B-ICI

These ATM cells are multiplexed together and passed to another carrier over DS3, or SONET facilities. The B-ICI supports multiple services by the ATM network establishing one or more Virtual Path Connections (VPC) or Virtual Channel Connections (VCC) via bilateral agreement from a set of available VPI/VCI values supported on the interface.

(R)-2 A multi-service B-ICI shall be reconfigurable to support one service, or any combination of the inter-carrier services (i.e., CRS, CES, FRS, SMDS) to meet the traffic needs.

Details of supporting inter-carrier services (i.e., CRS, CES, FRS, SMDS) are provided in Sections 8 through 11 of this document.

Channel bandwidth may be assigned based on the traffic contracts for the CRS, Committed Information Rate (CIR) and Excess Information Rate (EIR) for the FRS, and access class for the SMDS. No dynamic bandwidth allocation will occur in the initial service.

Either traffic and/or usage measurements may be conducted at both the sides of the B-ICI. These include the following:

o End-user cells corresponding to CRS, CES, FRS frames, or SMDS L3_PDUs metered;

o Cells transported from one carrier to another carrier metered;

o Time-of-day usage patterns, burstiness, etc. recorded.

Details of the B-ICI usage measurements are for further study.

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Figure 2.6 Multi-Service B-ICI Supporting Inter-Carrier Services (Example 1)

In Figure 2.6, a B-ICI is shown connecting a source Carrier A and a destination Carrier C. Multiple inter-carrier services are supported by a B-ICI. At the B-ICI, different sets of VPC/VCC (not necessarily contiguous) are assigned for the transfer of traffic related to different inter-carrier services according to the following *guidelines:*

1. CRS requires some relation between a B-ICI VPC and a UNI VPC. CRS VCCs should be translated to unique VCCs on the B-ICI by bilateral agreement (for example, to account for the "collisions" on VPI/VCI usage that are likely to occur on the CRS UNIs).

2. CES (DS1/DS3 frames) requires some relation between a B-ICI VPC and a UNI VPC. CES VCCs should be translated to unique VCCs on the B-ICI by a bilateral agreement (for example, to account for the "collisions" on VPI/VCI usage that are likely to occur on the CES UNIs).

3. FRS frames may be encapsulated in AAL Type 5, where the DLCI would be carried from end-to-end. If the FRS frames are encapsulated, then a set of VPCs may be appropriate. FRS frames may be mapped to the ATM layer, where the DLCI is translated to a VPI/VCI. If the FRS frames are mapped, then a set of VCCs may be appropriate.

4. SMDS L3_PDUs may be encapsulated in ICIP_CLS_PDUs and AAL Type 3/4, or SMDS L2_PDUs may be mapped to specific VPC or VCC values for delivery to the destination carrier's network. Depending on how and whether SMDS is mapped or encapsulated, a set of VPCs or VCCs may be appropriate.

The appropriate process undertaken by the Carrier A from a source user access interface to the B-ICI for delivery to Carrier C for eventual delivery to the destination user access interface are considered in later Sections.

As appropriate, Network Parameter Control (NPC) may be done on a VPC and/or VCC basis. The NPC is further discussed in later Sections.

Depending on the bandwidth associated with each VPC/VCC and the service bandwidth, multiple VPCs/VCCs may carry the same service types.

Mixing of ATM cells corresponding to different service types on the same VP should be studied, in particular, for relatively lower bandwidth services.

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Figure 2.7 Multi-Service B-ICI Supporting Inter-Carrier Services (Example 2)

In Figure 2.7, a transit carrier B is shown as supporting multiple inter-carrier services via the B-ICIs. In this role, the Carrier B relays services from one B-ICI to another B-ICI. The various sets of VPC/VCC used across the B-ICI for different inter-carrier services may be assigned by a bilateral agreement between the carriers.

In Figures 2.6 and 2.7, the specific VCI/VPI value assigned is, in general, independent of the service provided over that VCC/VPC in accordance with the CCITT Recommendations I.150 and I.361. To guarantee the uniqueness of the VPI/VCI values across the B-ICI, and in the transit/destination ATM network, a translation of VPI/VCI is applied at the B-ICI.

Figure 2.8 illustrates an example of VPC/VCC grooming by the destination Carriers. In this example, Carrier B is grooming VPCs/VCCs originating from the Carrier A's network and going to the destination Carrier C's network and/or Carrier D's network.

2.7 Network Interworking Functions and the Multi-Service B-ICI

An example of a functional network architecture illustrating B-ICI functions is shown in Figure 2.9. The multi-service B-ICI functions include both common functions (e.g., Physical Layer, ATM Layer) and the service-specific functions (e.g., AAL).

Figure 2.8 An Example Of VPCs/VCCs Grooming by the Destination Carrier

Furthermore, for connecting a CES DSn interface to an ATM network, for connecting a FRS network to an ATM network, and for connecting a SMDS network to an ATM network, network interworking functions need to be defined. Some of the network interworking functions may also relate to service interworking which is not considered within the scope of the B-ICI specification.

The impact of the B-ICI related service specific network interworking functions on the multi-service B-ICI specification, and the related Requirements/Options are covered in later Sections.

Note 1: Intermediate (tandem) ATM switching nodes may exist between the ATM node supporting the service specific functions and the B-ICI physical location.

Note 2: Service specific function(s) associated with interfaces (e.g., B-ICI, SNI) may be located on a single node.

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Note 3: The initial set of functions will meet the requirements of PVC-based services and SMDS. Additional C-Plane functions will be required for supporting SVC-based services.

Note 4: The list of interworking functions identified in Figure 2.9 does not imply any physical location.

Note 5: The B-ICI in Figure 2.9 still applies when the users access the network through a multi-service ATM-based UNI.

Figure 2.9 Multi-Service B-ICI and the Network Interworking Functions

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3 B-ICI Physical Layer Specifications

This Section provides media, rates, and formats for the B-ICI. The U-plane is specified in this Section, and the M-plane is specified in a later Section.

This section specifies B-ICI physical layer requirements. These requirements are closely aligned with existing BISDN UNI requirements and are consistent with the NNI requirements. The term NNI originated in CCITT and referred to Synchronous Digital Hierarchy (SDH) frame formats and related recommendations. By adopting this term for use in BISDN requirements, it should be noted that its meaning has been expanded to include non-SONET interfaces such as DS3.

The physical layer characteristics at the B-ICI depend on implementation specific details of the actual inter-carrier circuit connection. As examples, the B-ICI may be realized as an optical mid-span meet, or as an electrical or short-reach optical interface. The B-ICI signal at the physical carrier-to-carrier demarcation point may be realized as an embedded tributary of a higher rate, multiplexed signal. These possibilities impact such physical layer issues as protection switching and control communications. Whenever appropriate, related aspects are incorporated into the following specifications.

3.1 Signal Formats at the B-ICI

The logical frame structure at the B-ICI can take several forms depending on traffic rate experienced and on whether the interface allows the transport of multiplexed signals. The SONET STS-3c and STS-12c frame structures are focused in this document.

In addition, during the early stages of the B-ICI deployment, DS3 frame structure is also considered, and is specified in this document.

3.2 Physical Layer Characteristics of the 155.520 Mbit/s STS-3c B-ICI

The B-ICI at 155.520 Mbit/s is SONET-based and utilizes the concatenated STS-3 payload structure (STS-3c).

3.2.1 Bit Rate

(R)-3 The bit rate of the line signal shall be nominally 155.520 Mbit/s. (Also see (R)-16).

(R)-4 The bit rate available for user information cells, signaling cells and ATM layer OAM cells, excluding Physical Layer related OAM informatiion transported in overhead bytes shall be nominally 149.760 Mbit/s.

149.760 Mbit/s is equivalent to the STS-3c Synchronous Payload Envelope (SPE) information bandwidth (i.e., the total STS-3c SPE bandwidth minus the bandwidth portion allocated to POH).

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3.2.2 Signal Format

(R)-5 The 155.520 Mbit/s B-ICI shall utilize the SONET STS-3c frame structure as specified in ANSI-T1.105[4].

3.2.2.1 Framing Information

(R)-6 Framing information shall be contained in the A1 and A2 bytes.

(R)-7 Equipment on either side of the B-ICI shall meet the requirements for -

- o Going from an in-frame condition to an out-of-frame condition, and
- o Going from an out-of-frame condition to an in-frame condition as specified in TR-NWT-000253[5].

3.2.2.2 Overhead Bytes Active Across the B-ICI

The overhead bytes applicable at the B-ICI are specific to the implementation details of the physical inter-carrier circuit connection. To maintain flexibility while still allowing specific requirements on overhead activation and functionality, the diagram of Figure 3.1 is introduced. In this Figure, the points are identified where B-ICI characteristics are relevant. They are labeled B-ICI, B-ICI', B-ICI" and are explained below in detail.

Figure 3.1 Physical Realization of the B-ICI

In Figure 3.1, the B-ICI is defined as the logical interface between two carrier's public ATM networks. The B-ICI is physically realized in three types of interconnection:

B-ICI: A direct inter-office interconnection between two ATM Network Elements (NEs) belonging to different network operators (e.g., OC-3 interconnection with STS-3c structure).

B-ICI corresponds to the physical realization of a 155.520 Mbit/s SONET interface at the carrier boundary (the demarcation point between two carriers). As such, specific requirements are specified below and take into account the various arrangements under which the B-ICI is realized (e.g., intra-office versus inter-office).

B-ICI': An interconnection that is part of a multiplexed inter-office interconnection between two transport NEs (e.g., multiplexer or cross-connect) belonging to different network operators (e.g., an STS-3c in a OC-12 signal).

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The interpretation of B-ICI' corresponds to realizations of inter-carrier circuit connections involving intermediate transport systems (e.g., a multiplex system). In this case, there exists an underlying logical channel, or a tributary that traverses the carrier boundary. Although the section and line level functionality at the carrier boundary is dictated by the specific transport system and is, consequently, by arrangements beyond the scope of this document, the path level overhead activation for B-ICI' is preserved and must be specified.

B-ICI'': An interconnection (usually intra-office) between the transport NE and the ATM NE. Both of these NEs typically belong to the same network operator, and in this sense the B-ICI'' is a reflection of the B-ICI' on the ATM NE (e.g., STS-3c interconnection).

Also, important in the overall carrier-to-carrier interconnection is the physical realization of the logical B-ICI' channel within each carrier's network and likely at the ATM switching system interface. This physical interface is labeled B-ICI''. Although this interface occurs within a carrier's network, its characteristics directly impact the overall interconnection and B-ICI', as described above. Therefore, specific information and guidance is provided here so that ATM switch trunk side interface design can proceed in a consistent and standard manner.

In all the above realizations, the following requirement applies:

(R)-8 The overhead bytes active across the B-ICI (including B-ICI' and B-ICI'' as described above) shall be consistent with the specifications given in ANSI-T1.105[4]. [Note: Except for some differences between ANSI T1.105 and B-ICI specification, for example, Path RDI (Remote Defect Indicator), Line FEBE].

A summary of the SONET overhead bytes and their requirement status is provided in Table 3.1.

In User Channels (F1 and F2), "user" refers to the network operator. This channel is reserved for use by an individual carrier. Therefore, this channel is not activated across administrative boundaries as it would be then subject to use by multiple users, inconsistent with the intent of the SONET specifications.

3.2.3 Powering Arrangements

(R)-9 Power shall not be provided across the B-ICI

3.2.4 HEC Generation and HEC Check

(R)-10 The HEC generation and error checking functions (specified in Section 3.5) shall be implemented for the 155.520 Mbit/s SONET STS-3c based B-ICI.

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Table 3.1 B-ICI SONET Physical Layer Overhead Requirements

Function	Signal	B-ICI''	B-ICI'	B-ICI
Section Overhead*				
Framing	A1, A2	R	&	R
Error Monitoring	B1	R @	&	R
Data Communication	D1-D3	NA	&	#
STS ID	C1	R	&	R
Order Wire	E1	NA	&	O
User Channel	F1	NA	NA	NA
Line Overhead*				
Error Monitoring	B2	R	&	R
Data Communication	D4-D12	O	&	O
Order Wire	E2	NA	&	O
SPE Pointer	H1-H3	R	&	R
Path AIS	H1, H2	R	&	R
APS	K1, K2	O	&	O
Line AIS	K2 (6-8)	R @	&	R
Line RDI (FERF)	K2 (6-8)	R	&	R
Line FEBE	3 Z2 (1-8)	R	&	R
Sync. Messages	Z1	O	&	O
Path Overhead*				
Trace	J1	O	O	O
Error Monitoring	B3	R	R	R
Signal Label	C2	R	R	R
Path FEBE	G1 (1-4)	R	R	R
Path RDI (FERF)	G1 (5)	R	R	R
User Channel	F2	O	NA	NA

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R = Required, NA = Not Activated, O = Optional; * = All other overheads of the layer are NA; # = STEs and LTEs in an application requiring communications over the SONET interfaces shall support the Section DCC; & = As dictated by the multiplex/transport system; @ = Not applicable for interconnection without regenerators.

3.2.5 Cell Payload Scrambler

(R)-11 The cell payload (self-synchronous) scrambler (specified in Section 3.5) shall be implemented for the 155.520 Mbit/s SONET STS-3c based B-ICI.

3.2.6 Cell Mapping and Delineation

The mapping of ATM cells is performed by aligning by row the byte structure of every cell with the byte structure of the SONET STS-3c payload capacity (i.e., Synchronous Payload Envelope less POH). The entire STS-3c payload capacity is filled with cells, yielding a transfer capacity for ATM cells of 149.760 Mbit/s. Because the STS-3c payload capacity is not an integer multiple of the cell length, a cell may be mapped across a SPE boundary.

(R)-12 Equipment supporting a B-ICI shall map ATM cells into the SONET STS-3c signal as specified in ANSI T1.624[6] and ANSI T1.105[4] (see also CCITT Recommendation I.432[7] and G.709[2]).

(R)-13 The cell delineation functions (specified in Section 3.5) shall be implemented for the 155.520 Mbit/s B-ICI.

(R)-14 For the 155.520 Mbit/s B-ICI, the time to declare Sync state (specified in Section 3.5) shall be less than 150 micro-seconds. This requirement pertains to an in-frame SONET condition and supplements the re-frame requirements given earlier to specify total time from out-of-frame to cell delineation.

3.2.7 PMD Characteristics of the 155.520 Mbit/s STS-3c B-ICI

(R)-15 The B-ICI shall meet the PMD specifications given in TR-NWT-000253 for either the short-reach, intermediate-reach or long-reach optical OC-3 or the electrical STSX-3 application. The choice of interface parameter set is application specific.

3.2.8 Synchronization, Timing and Jitter

3.2.8.1 Synchronization and Timing

(R)-16 In normal operation, the signal at the B-ICI shall be synchronized by a source traceable to a Primary Reference Source (PRS, or Stratum 1 clock) as described in ANSI T1.101[8] When the system is not synchronized

(e.g., free running mode), a failure sync condition exists, and shall be rectified according to a bilateral agreement.

3.2.8.2 Jitter

(R)-17 At the B-ICI, the network output jitter limits specified in ANSI T1X1/LB-93-03[9] shall apply.

3.2.9 Connectors

(R)-18 Optical connectors shall meet the performance criteria specified in Bellcore's TR-NWT-000326.[10]

The selection of a particular connector type for application at the B-ICI is a matter for bilateral agreement.

3.3 Physical Layer Characteristics of the 622.080 Mbit/s STS-12c B-ICI

The B-ICI at 622.080 Mbit/s is SONET-based and utilizes the concatenated STS-12 payload structure (STS-12c).

3.3.1 Bit Rate

(R)-19 The bit rate of the line signal shall be nominally 622.080 Mbit/s. (Also see (R)-32).

(R)-20 The bit rate available for user information cells, signaling cells and ATM layer OAM cells, excluding Physical Layer related OAM information transported in overhead bytes shall be nominally 599.040 Mbit/s.

599.040 Mbit/s is equivalent to the STS-12c Synchronous Payload Envelope (SPE) information bandwidth (i.e., the total STS-12c SPE bandwidth minus the bandwidth portion allocated to POH).

3.3.2 Signal Format

(R)-21 The 622.080 Mbit/s B-ICI shall utilize the SONET STS-12c frame structure specified in ANSI T1.624[6].

3.3.2.1 Framing Information

(R)-22 Framing information shall be contained in the A1 and A2 bytes.

(R)-23 Equipment on either side of the B-ICI shall meet the requirements for:

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- Going from an in-frame condition to an out-of-frame condition, and
- Going from an out-of-frame condition to an in-frame condition as specified in TR-NWT-000253[5].

3.3.2.2 Overhead Bytes Active Across the B-ICI

See Section 3.2.2.2.

(R)-24 The overhead bytes active across the B-ICI (including B-ICI' and B-ICI" as described in Section 3.2.2.2) shall be consistent with the specifications given in ANSI T1.105[4]. [Note: Except for some differences between ANSI T1.105 and B-ICI specification, for example, Path RDI, Line FEBE].

3.3.3 Powering Arrangements

(R)-25 Power shall not be provided across the 622.080 Mbit/s B-ICI.

3.3.4 HEC Generation and HEC Check

(R)-26 The HEC generation and error checking functions (specified in Section 3.5) shall be implemented for the 622.080 Mbit/s SONET STS-12c based B-ICI.

3.3.5 Cell Payload Scrambler

(R)-27 The cell payload (self-synchronous) scrambler (specified in Section 3.5) shall be implemented for the 622.080 Mbit/s SONET STS-12c based B-ICI.

3.3.6 Cell Mapping and Delineation

The mapping of ATM cells is performed by aligning by row the byte structure of every cell with the byte structure of the SONET STS-12c payload capacity (i.e., Synchronous Payload Envelope less POH). The entire STS-12c payload capacity is filled with cells, yielding a transfer capacity for ATM cells of 599.040 Mbit/s. Because the STS-12c payload capacity is not an integer multiple of the cell length, a cell may be mapped across a SPE boundary.

(R)-28 Equipment supporting a B-ICI shall map ATM cells into the SONET STS-12c signal as specified in ANSI T1.624[6] and ANSI T1.105[4] (see also CCITT Recommendation I.432[7] and G.709[2]).

(R)-29 The cell delineation functions (specified in Section 3.5) shall be implemented for the 622.080 Mbit/s B-ICI.

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(R)-30 For the 622.080 Mbit/s B-ICI, the time to declare Sync state (defined in Section 3.5) shall be less than 150 micro-seconds. This requirement pertains to an in-frame SONET condition and supplements the re-frame requirements given earlier to specify total time from out-of-frame to cell delineation.

3.3.7 PMD Characteristics of the 622.080 Mbit/s STS-12c B-ICI

(R)-31 The B-ICI shall meet the PMD specifications given in TR-NWT-000253 for either the short-reach, intermediate-reach or long-reach optical OC-12 application. The choice of interface parameter set is application specific.

3.3.8 Synchronization, Timing and Jitter

3.3.8.1 Synchronization and Timing

(R)-32 In normal operation, the signal at the B-ICI shall be synchronized by a source traceable to a PRS (Stratum 1 clock) as described in ANSI T1.101[8]. When the system is not synchronized (e.g., free running mode) a failure sync condition exists, and shall be rectified according to a bilateral agreement.

3.3.8.2 Jitter

(R)-33 At the B-ICI, the network output jitter limits specified in ANSI T1X1/LB-93-03[9] shall apply.

3.3.9 Connectors

(R)-34 Optical connectors shall meet the performance criteria specified in Bellcore's TR-NWT-000326[10].

The selection of a particular connector type for application at the B-ICI is a matter for bilateral agreement.

3.4 Physical Layer Characteristics of the 44.736 Mbit/s B-ICI

(R)-35 The Physical Layer Convergence Procedure (PLCP)-based ATM mapping format shall be used for the 44.736 Mbit/s (DS3) B-ICI.

This approach is similar to the specification for the DS3 ATM UNI, and uses an embedded PLCP frame. This makes use of the DS3 multiframe format with C-bit parity application. The physical layer specification for the PLCP-based ATM mapping follows.

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3.4.1 PLCP-Based ATM Mapping

3.4.1.1 Bit Rate

(R)-36 The bit rate at the B-ICI shall be 44.736 Mbit/s ± 20 PPM.

(R)-37 The transfer capacity available for the transport of ATM cells in the DS3 PLCP-based format shall be nominally 40.704 Mbit/s.

3.4.1.2 Frame Structure

The basic frame structure at 44,736 kbit/s is partitioned into M (multi)-frames of 4760 bits each. The M frames are divided into seven M-subframes having 680 bits each. Each M-subframe is further divided into 8 blocks of 85 bits with 84 of the 85 bits available for payload and one bit is used for frame overhead. The DS3 Multi Frame structure[11] is shown in Figure 3.2.

Frame Overhead: There are 56 overhead bits per multiframe. They are divided into M frame alignment channels (M1, M2 and M3), M subframe channels (F1, F2, F3 and F4), a P-bit channel (P1 and P2), X-bit channel (X1 and X2), and the C-bit channel (the Cxy bits). The DS3 basic frame possesses the following characteristics:

— Length of M frame = 4760 bits (4704 information bits + 56 overhead bits)

— Total bit rate = 44,736 kbit/s

— Repetition frequency = $\frac{44{,}736}{4760}$ = 9.3983193 kHz = 106.402 micro-seconds

Figure 3.2 DS3 Multi-Frame Structure

3.4.1.3 C-Bit Channel Definition

The DS3-based B-ICI is defined to use the C-bit parity format. This format has 21 bits per DS3 frame that is referred to as the C-bit channel. Within the C-bit channel there are a number of functions. The bit functions and uses are defined below[11]:

o C1 - Application Identification Channel

(R)-38 For the C-bit parity application, this bit shall be set to "1" at the transmitter and verified at the receiver.

Note: If C1 is received as "0", at a minimum, a report to an Operations System (OS) should be made.

o C2 - Network Requirement Bit

(R)-39 This bit shall be set to "1" at the transmitter and ignored at the receiver.

o C3 - Far End Alarm and Control Channel

The FEAC channel has two parts: (i) alarm/status channel, and (ii) command (or control) channel. The FEAC support is desirable.

(O)-1 The FEAC channel implementation should support seven (7) alarm/status messages. The Alarms/Status Conditions and associated Codewords are given in Table 3.2.

Table 3.2 FEAC Alarm/Status Conditions and Codewords

Alarm/Status Conditions	Codeword
DS3 Equipment Failure (SA)	0011001011111111
DS3 LOS	0001110011111111
DS3 Out-Of-Frame	0000000011111111
DS3 AIS Received	0010110011111111
DS3 IDLE Received	0011010011111111
DS3 Equipment Failure (NSA)	0001111011111111
Common Equipment Failure (NSA)	0011101011111111

SA = Service Affecting; NSA = Not Service Affecting; LOS = Loss Of Signal

(O)-2 The three (3) FEAC Command Functions and Codewords applicable for the B-ICI are listed in Table 3.3, and should be supported if there is a bilateral agreement between the carriers.

Table 3.3 FEAC Command Functions and Codewords

Command Function	Codeword
Line Loopback Activate	0000111 0 11111111
Line Loopback Deactivate	0011100 0 11111111
DS3 Line	0011011 0 11111111

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Note 1 - The rightmost bit of each Codeword shall be transmitted first.
Note 2 : All other codewords are to be ignored.

o C4-C6 - Not Used
These bits are not used and should be set to "1" by the transmitter and ignored by the receiver.

o C7-C9 - CP-bit

(R)-40 These bits are used to indicate the parity of the DS3 payload. They shall be set by the transmitter the same as the P-Bits and compared to the re-calculated parity by the receiver according to the procedures specified in T1.107a[11]. If an error is detected, it is indicated with the FEBE (C10-C12).

o C10-C12 - FEBE Function

(R)-41 These bits are used to indicate the received Far End Block Errors of the DS3 payload. They shall be set by the transmitter whenever an error is detected by the receiver in the CP-Bits, according to the procedures specified in T1.107a[11]. The receiver should count the number of received FEBEs.

o C13-C15 - Terminal-to-Terminal Path Maintenance Data Link

(O)-3 These bits are for a terminal-to-terminal path maintenance data link and are optional. If used, this function should comply to the ANSI T1.107a[11] definition.

o C16-C18 - Not Used
These bits are not used and should be set to "1" by the transmitter and ignored by the receiver.

o C19-C21 - Not Used
These bits are not used, and should be set to "1" by the transmitter and ignored by the receiver.

The B-ICI DS3 C-bit parity Requirements are summarized in Table 3.4. Further details on C-bit parity are given in[11].

Table 3.4 B-ICI DS3 C-Bit Parity Requirements

Function	Signal	B-ICI''	B-ICI'	B-ICI
Application ID	C1	R	R	R
Network	C2	R	R	R

FEAC Command	C3	O	O	O
FEAC Control	C3	O	O	O
Error Monitoring	C7, C9	R	R	R
FEBE	C10-C12	R	R	R
Path Data link	C13-C15	O	O	O
Remaining C-bits	C4-C6, C16-C21	NA	NA	NA

R = Required, NA = Not Activated, O = Optional

3.4.1.4 Signal Format

As there is no need to use the stuffing indicator bits (C-bits) for frequency justification (because this is done by the PLCP), the C-bits can be used for other purposes. The use of the freed C-bits is defined in the C-bit parity DS3 standard T1.107a. The B-ICI uses C-bit parity DS3 according to T1.107a, but with one difference. T1.107a[11] specifies that all seven stuff time slots of a DS3 frame shall always be stuffed. This application requires that all stuffing bit locations be used as data bits. This is necessary to allow the PLCP to be nibble-aligned when mapped onto the DS3.

(R)-42 The interface format at the physical layer for the B-ICI shall be based on asynchronous DS3 using the C-Bit Parity application as defined in ANSI T1.107a[11]. This unchannelized payload application of C-bit parity DS3 requires that all stuffing bit locations be used as data bits.

(R)-43 ATM traffic shall be carried over DS3 44.736 Mbit/s communication facilities by utilizing the PLCP frame This PLCP is a subset of the PLCP defined in IEEE P802.6 and is the same as that used at the User-Network Interface.

Mapping of ATM cells into the DS3 is accomplished by inserting the 53 byte ATM cells into the DS3 PLCP. The PLCP shall then be mapped into the DS3 information payload. Note that the125 micro-seconds PLCP sub-frame is longer than the 106.4 micro-seconds DS3 frame.

3.4.1.4.1 PLCP Format

The DS3 PLCP consists of a 125 micro-seconds frame within a standard DS3 payload. Note there is no fixed relationship between the DS3 PLCP frame and the DS3 frame, i.e., the DS3 PLCP may begin anywhere inside the DS3 payload. The DS3 PLCP frame consists of 12 rows

of ATM cells, each preceded by 4 octets of overhead. Nibble[4] stuffing is required after the twelfth cell to fill the 125 micro-seconds PLCP frame. Although the DS3 PLCP is not aligned to the DS3 framing bits, the octets in the DS3 PLCP frame are nibble aligned to the DS3 payload envelope. Nibbles begin after the control bits (F, X, P, C or M) of the DS3 frame. Octets comprising the DS3 PLCP frame are described below.

(R)-44 The following PLCP overhead bytes/nibbles are required to be activated across the B-ICI:

A1 - Frame Alignment

A2 - Frame Alignment

B1 - Bit Interleaved Parity

C1 - Cycle/Stuff Counter

G1 - PLCP Path Status

Px - Path Overhead Identifier

Zx - Growth Octets

Trailer Nibbles

The DS3 PLCP frame is shown in Figure 3.3.

Framing Octets (A1, A2)

(R)-45 The PLCP framing octets shall use the same framing pattern used in SONET. These octets are A1=11110110, A2 = 00101000.

(R)-46 Equipment at a B-ICI shall support the PLCP framing requirements described in TR-TSV-000773[12].

Bit Interleaved Parity (BIP)-8 (B1)

(R)-47 The BIP-8 (B1) field supports PLCP path error monitoring, and shall be calculated over a 12 x 54 octet structure consisting of the POH field and the associated ATM cells (648 octets) of the previous PLCP frame.

---

4 A nibble is 4 bits.

PLCP Framing		POI	POH	PLCP Payload	
A1	A2	P11	Z6	First ATM Cell	
A1	A2	P10	Z5	ATM Cell	
A1	A2	P9	Z4	ATM Cell	
A1	A2	P8	Z3	ATM Cell	
A1	A2	P7	Z2	ATM Cell	
A1	A2	P6	Z1	ATM Cell	
A1	A2	P5	X	ATM Cell	
A1	A2	P4	B1	ATM Cell	
A1	A2	P3	G1	ATM Cell	
A1	A2	P2	X	ATM Cell	
A1	A2	P1	X	ATM Cell	
A1	A2	P0	C1	Twelfth ATM Cell	Trailer
1 Octet	1 Octet	1 Octet	1 Octet	53 Octets	13 or 14 Nibbles

POI = Path Overhead Indicator
POH = Path Overhead
BIP-8 = Bit Interleaved Parity - 8
X = Unassigned - Receiver required to ignore

Figure 3.3 DS3 PLCP Frame (125 micro-seconds)

Cycle/Stuff Counter (C1)

The Cycle/Stuff Counter Provides a nibble stuffing opportunity and Trailer length indicator for the PLCP frame.

(R)-48 A stuffing opportunity shall occur every third frame of a 3 frame (375 micro-seconds) stuffing cycle. The value of the C1 code shall be used as an indication of the phase of the 375 micro-seconds stuffing opportunity cycle.

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PLCP Path Status (G1)

(R)-49 The PLCP Path Status shall be allocated to convey the received PLCP status and performance to the transmitting far-end. This octet permits the status of the full receive/transmit PLCP path to be monitored at either end of the path. The G1 octet subfields are as follows: a 4-bit Far End Block Error (FEBE), a 1-bit RAI (Yellow), and 3 X bits (receivers shall be capable of ignoring the value of X bits).

Path Overhead Identifier (P0-P11)

(R)-50 The POI bytes shall index the adjacent POH octet of the DS3 PLCP. Table 3.5 provides the coding for each of the POI octets.

Table 3.5 POI Code Definitions

POI	POI Code	Associated POH
P11	00101100	Z6
P10	00101001	Z5
P9	00100101	Z4
P8	00100000	Z3
P7	00011100	Z2
P6	00011001	Z1
P5	00010101	X
P4	00010000	B1
P3	00001101	G1
P2	00001000	X
P1	00000100	X
P0	00000001	C1

X - Receiver Ignores

Growth Octets (Z1-Z6)

(R)-51 The Growth Octets shall be reserved for future use. These octets shall be set to Zi=00000000, by the transmitter (i = 1, 2..., 6). The receiver shall be capable of ignoring the value contained in these fields.

Trailer Nibbles

(R)-52 The contents of each of the 13/14 Trailer nibbles shall be 1100.

3.4.1.5 Timing

(R)-53 The PLCP frame must have timing traceable to a PRS.

3.4.1.6 HEC Generation and HEC Check

(R)-54 The HEC functionality (specified in Section 3.5) shall be supported at the B-ICI.

3.4.1.7 Cell Payload Scrambler

For some DS3 physical links, cell scrambling can provide a solution to some transmission equipment's unexpected behaviour sensitive to bit patterns in the ATM cell payload (e.g., "101010....", or "000000...." patterns). Another solution to this problem could be to disable alarm monitoring/reporting on transmission equipment. This, however, reduces alarm visibility and fault isolation capability.

(R)-55 Equipment supporting DS3 based B-ICI shall implement the cell payload scrambler as described in Section 3.5.3. This scrambler shall have the capability of being enabled or disabled.

(R)-56 As a default mode, the cell payload scrambler shall be disabled for the DS3 based B-ICI.

(O)-4 As a configurable option, a cell payload scrambler may be enabled for the DS3 based B-ICI.

Note: The use of scrambling/de-scrambling may increase the bit error rate through error multiplication.

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3.4.1.8 Cell Delineation

(R)-57 The cells are in predetermined locations within the PLCP. Framing on the DS3 and then on the PLCP is sufficient and shall be used to delineate cells at the B-ICI. The PLCP framing requirements can be found in TR-TSV-000773[12].

(R)-58 The criteria in TR-TSY-000191[13] defining framing requirements for DS3 signals, shall be met at the B-ICI.

3.4.1.9 Powering Arrangements

(R)-59 Power shall not be provided across the B-ICI.

3.4.1.10 PMD Characteristics of the 44.736 Mbit/s B-ICI

(R)-60 The B-ICI for the DS3 shall meet the electrical PMD interface characteristics specified in ANSI T1.102.[14]

3.4.1.11 Jitter

(R)-61 The maximum output jitter that will appear at the 44.736 Mbit/s B-ICI shall meet the requirements given in TR-NWT-000499.[15]

3.4.1.12 Connector

The selection of a particular connector type for the 44.736 Mbit/s B-ICI is a matter for bilateral agreement.

3.5 HEC Functions and Cell Delineation

3.5.1 HEC-Generation

(R)-62 The following procedures[7]shall be performed to generate the HEC (Header Error Control) sequence by each cell originator.

Procedure:
The following polynomials are used to specify the HEC value:

$G(x) = x^8 + x^2 + x + 1$

$C(x) = x^6 + x^4 + x^2 + 1$

Where:

G(x) is the generating polynomial, and

C(x) is the coset plynomial.

The HEC value corresponding to a given header shall be obtained by the following procedures:

— The 32 bits of octets 1, 2, 3 and 4 of the header are considered to be the coefficients of a polynomial M(x) of degree 31 (bit 8 of octet 1 of the header corresponds to the x^{31} term and bit 1 of octet 4 of the header corresponds to the x^0 term).

— M(x) shall be multiplied by x^8 and divided (modulo 2) by G(x). C(x) shall be added modulo 2 (exclusive OR) to the remainder of this division producing a polynomial R(x) of degree < 8.

— The coefficients of R(x) are considered to be an 8-bit sequence. This 8-bit sequence is the HEC. The 8 bits of the HEC shall be placed in the HEC field so that the coefficient of the x^7 term is bit 8 and the coefficient of the x^0 term is bit 1.

3.5.2 HEC-Check

The HEC function of the receiver on either side of the B-ICI has two states, Correction state and Detection state.

(R)-63 Network equipment supporting a B-ICI shall implement HEC error detection as defined in the CCITT Recommendation I.432[7] and ANSI T1.624[6].

(O)-5 Network equipment supporting a B-ICI may also implement single bit error correction in addition to error detection. In this case, the two modes of operation shall interact in accordance to the procedure defined in the CCITT Recommendation I.432[7] and ANSI T1.624[6].

(R)-64 In Detection state, all the cells with detected header errors shall be discarded.

The header error analysis process performed by the receiving physical layer equipment is illustrated in Figure 3.4. In Figure 3.4, the following Notes apply:

Note 1: Definition of "valid cell": A cell where the header is declared by the header error control process to be free of errors (CCITT Rec. I.113).

Note 2: An example of an impermissible header is a header whose VPI/VCI is neither allocated to a connection nor pre-assigned to a particular function (idle cell, OAM cell, etc.). In many instances, the ATM layer will decide if the cell header is permissible.

Note 3: A cell is discarded if its header is declared to be invalid; or if the header is declared to be valid and the resulting header is impermissible.

3.5.3 Cell Payload Scramber

The following specifications apply to SONET and DS3 based B-ICIs:

(R)-65 A cell payload (self-synchronizing) scrambler, with polynomial $1 + X^{43}$ shall be used to scramble/de-scramble the 48 byte information field of ATM cells.

(R)-66 The scrambler shall operate continuously through the stream of ATM cells, bypassing ATM cell headers. Hence, ATM cell headers are not scrambled.

(R)-67 The scrambler state at the beginning of a cell payload shall be the state at the end of the previous cell payload.

(R)-68 Descrambling shall be disabled during the cell delineation hunt state (described later).

(R)-69 During the cell delineation presync and sync states (described later), the scrambler shall be enabled for a number of bits equal to the length of the information field and disabled for the following assumed header.

Figure 3.4 Cell Header Error Analysis

3.5.4 Cell Delineation

Cell delineation is performed using the HEC byte of the ATM cell header. For the DS3 based B-ICI, however, the ATM cells are explicitly delineated upon PLCP framing.

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Figure 3.5 Cell Delineation Diagram

(R)-70 For the SONET-based B-ICIs, the location of cell boundaries within an octet stream shall be obtained by determining the location at which the HEC coding rule is obeyed. This cell delineation process is described by the state diagram shown in Figure 3.5. This process has three states of operation: Sync state, Hunt state, and Presync state. These are described below:

—*Sync State*: In this state, cell boundary is assumed to be correct. The process remains in this state until the HEC coding rule is determined to be incorrect Alpha consecutive times. When this occurs, the process moves to the Hunt state.

—*Hunt State:* In this state, the delineation process is performed by checking whether the HEC coding rule is obeyed for the assumed header field. The first time the HEC coding rule is obeyed, the process passes to the Presync state.

—*Presync State:* In this state, the HEC rule is applied at the next location that a cell header is expected. The process repeats until either:

o The HEC coding rule has been confirmed Delta consecutive times. The process then passes to the Sync state.

o One incorrect HEC is detected. The process then returns to the Hunt state.

Robustness against false misalignment due to bit errors depends on the value of Alpha. Robustness against false delineation in the synchronization process depends on the value of Delta. Suggested values for Alpha and Delta are 7 and 6, respectively.

4 B-ICI ATM Layer Specification

This Section provides CCITT/T1 defined ATM layer (including ATM cell header) functions. The U-plane is specified in this Section, and the M-plane is specified in a later Section .

4.1 ATM Layer Services

The ATM layer[16] provides for the transparent transfer of fixed sized ATM layer service data units (ATM-SDUs) between communicating upper layer entities (e.g., AAL-entities). This transfer occurs on a pre-established ATM connection with negotiated parameters such as cell-loss ratio, cell delay, cell delay variation, throughput and traffic parameters. Each connection is characterized by a traffic descriptor of one or more parameters. Traffic submitted to a connection on a B-ICI is expected to conform to these parameters, although some network induced cell delay variation may have accumulated on the connection before reaching the B-ICI.

Two levels of virtual connections can be supported at the B-ICI:

- o A point-to-point Virtual Channel Connection (VCC) which consists of a single connection established between two ATM VCC end-points.

- o A point-to-point Virtual Path Connection (VPC) which may consist of a bundle of VCCs carried transparently between two ATM VPC end-points.

Traffic monitoring and throughput enforcement may be performed on VCCs/VPCs at the B-ICI ingress to a carrier's network. For VPCs at the B-ICI, shaping, traffic monitoring and throughput enforcement (i.e., NPC) may be performed across all cells carried on the same VPI independently of the VCI values.

> **(R)-71** From a single source the relay of cells within a VPC and/or VCC shall preserve cell sequence integrity.

No retransmission of lost or corrupted information is performed by this layer. The ATM layer also provides its users with the capability to indicate the loss priority of the data carried in each cell. The information exchanged between the ATM layer and the upper layer (e.g., the AAL) across the ATM-SAP includes the primitives in Figure 4.1.

Figure 4.1 ATM Service Access Point (SAP) Primitives

These primitives make use of the parameters in Figure 4.2.

Figure 4.2 ATM-SAP Parameters

The primitives provide the following services:

- **ATM-DATA.request**: Initiates the transfer of an ATM-SDU and its associated SDU-Type to its peer entity over an existing connection. The loss priority parameter and the SDU-Type parameter are used to assign the proper CLP and PTI fields to the corresponding ATM-PDU generated at the ATM layer.

- **ATM-DATA.indicate:** Indicates the arrival of an ATM-SDU over an existing connection, along with a congestion indication and the received ATM-SDU. In the absence of errors, the ATM-SDU is the same as the ATM-SDU sent by the corresponding remote peer upper layer entity in an ATM-DATA.request.

The following parameters are passed within one or more of the previous primitives:

- **ATM-SDU:** This parameter contains 48 bytes of ATM layer user data to be transferred by the ATM layer between peer communicating upper layer entities.

- **SDU-Type:** This parameter is only used by the ATM layer user to differentiate two types of ATM-SDUs associated with an ATM connection.

- **Loss-Priority:** This parameter indicates the explicit loss priority (CLP = 0 or 1) for this ATM SDU relative to the other cells in the same VPC/VCC. It can take only two values, one for high priority and the other for low priority.

- **Congestion-Experience:** This parameter indicates that the received ATM-SDU has passed through one or more network nodes experiencing congestion.

4.2 Service Expected from the Physical Layer

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The ATM layer expects the physical layer to provide for the transport of ATM cells between communicating ATM-entities. The information exchanged between the ATM layer and the physical layer across the PHY-SAP includes the primitives in Figure 4.3.

Figure 4.3 PHY-SAP Services Required by the ATM Layer

4.3 ATM Cell Structure and Encoding at the B-ICI

(R)-72 Network equipment supporting a B-ICI shall encode and transmit cells according to the structure and field encoding convention defined for the NNI[3] (Figure 4.4 and 4.5).

The structure of the ATM cell is shown in Figure 4.4. It contains the following fields[17]:

(i) Virtual Path/Virtual Channel (VPI/VCI) Identifier: The actual number of routing bits in the VPI and VCI subfields used for routing is negotiated between the two carrier networks. This number is determined on the basis of the lower requirement of the networks.

(R)-73 The bits within the VPI and VCI fields used for routing shall be allocated using the following rules:

—The allocated bits of the VPI subfield shall be contiguous;

—The allocated bits of the VPI subfield shall be the least significant bits of the VPI subfield, beginning at bit 5 of octet 2;

—The allocated bits of the VCI subfield shall be contiguous;

—The allocated bits of the VCI subfield shall be the least significant bits of the VCI subfield, beginning at bit 5 of octet 4.

(R)-74 Any bits of the VPI subfield that are not allocated are set to 0. Any bits of the VCI subfield that are not allocated are set to 0.

(R)-75 Unallocated bits of the VPI for VP switching and VPI/VCI for VC switching shall be checked to be zero "0" at the receiver. Cells with invalid VPI/VCI shall be discarded.

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Figure 4.4 ATM Cell Structure at the B-ICI

(ii) Payload Type Indicator (PTI): This is a 3-bit field used to indicate whether the cell contains user information or Connection Associated Layer Management information (F5 flow). It is also used to indicate a network congestion state, or for network resource management. The detailed coding and use of the PTI field will be described in Section 4.4.4.

(iii) Cell Loss Priority (CLP): This is a 1-bit field which allows the user or a network to optionally indicate the explicit loss priority of the cell. More details on the use of the CLP bit are given in Section 4.4.5.

Figure 4.5 ATM Field Encoding Convention

(iv) Header Error Control (HEC): The HEC field is used by the physical layer for detection/correction of bit errors in the cell header. It may also be used for cell delineation.

4.4 ATM Layer Functions Involved at the B-ICI (U-plane)

This Section describes ATM layer functions that need to be supported at the B-ICI (see Figure 4.6). It does not cover those ATM functions that are described in standards but have no impact on the B-ICI specification.

Figure 4.6 Functions Supported at the B-ICI (U-plane)

4.4.1 Multiplexing Among Different ATM Connections

This function multiplexes ATM connections with different QOS requirements. ATM connections may have either a specified or an unspecified QOS. An ATM connection with a specified QOS is characterized by values of one or more of the following parameters: cell transfer delay, cell delay variation, and cell loss ratio. An ATM connection with unspecified

QOS has no values for the above parameters. This document identifies the required set of specified QOS classes, and one unspecified QOS class.

The QOS is the same for all cells belonging to the same ATM connection, and remains constant for the duration of the connection.

(R)-76 Network equipment supporting a B-ICI shall support the required set of the specified QOS classes[18].

(O)-6 Network equipment supporting a B-ICI may support the unspecified QOS class[18].

4.4.2 Cell Rate Decoupling

The cell rate decoupling function at the sending entity adds unassigned cells to the assigned cell stream (cells with valid payload) to be transmitted, transforming a non-continuous stream of assigned cells into a continuous stream of assigned and unassigned cells. At the receiving entity the opposite operation is performed for both unassigned and invalid cells. The rate at which the unassigned cells are inserted/extracted depends on the bit rate (rate variation) of assigned cell and/or the physical layer transmission rate. The unassigned and invalid cells are recognized by specific header patterns[5] which are shown in Figure 4.7.

(R)-77 Network equipment supporting a B-ICI shall generate unassigned cells in the flow of cells passed to the physical layer in order to adjust to the cell rate required by the payload capacity of the physical layer.

(R)-78 Network equipment supporting a B-ICI shall encode the header fields of unassigned cells in accordance with the pre-assigned header field values defined in [3] and [17]. The information field of the unassigned cell shall be encoded in accordance with [3].

(R)-79 The receiving ATM entity shall extract and discard the unassigned and invalid cells from the flow of cells coming from the physical layer.

Note: The cell rate governing the flow between physical and ATM layer will be extracted from physical layer (e.g. SONET, DS3) timing information, if required.

4.4.3 Cell Discrimination Based on Pre-defined Header Field Values

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[5] The term "Cell Rate Decoupling" has a different mening in CCITT, and it refers to a physical layer process involving physical layer cells (e.g., idle cells[7]). Further, the term "invalid' when applied to a cell or pattern refers to the illegal appearance of a physical layer cell at the ATM layer.

The pre-defined header field values[17] defined for the NNI apply at the B-ICI, and are given in Figure 4.7.

Sixteen VCI values (VCI = 0-15) are reserved by CCITT (I.361) for various applications:

1. VCI = 0 is only for Unassigned Cell indication (Figure 4.7).

2. VCI = 1-2 are only used for signaling function which may only be applicable in user-to- user and user-to-network VPs.

3. VCI = 3-4 are used for OAM functions (Figure 4.7).

4. VCI = 5 is used for point-to-point signaling (Figure 4.7).

5. VCI = 6-7 are reserved to provide the same functions for VPs as PTI values 110 and 111, respectively, will provide for VCs.

6. VCI = 8-15 are reserved for future standardization functions.

Figure 4.7 Pre-Defined Header Field Values

The Virtual Path Connection (VPC) operation flow (F4 flow) is carried via specially designated OAM cells. F4 flow OAM cells have the same VPI value as the user-data cell transported by the VPC but are identified by two unique pre-assigned virtual channels within this VPC. At the B-ICI, the virtual channel identified by a VCI value = 3 is used for VP level management functions between ATM nodes on both sides of the B-ICI (i.e., single VP link segment) while the virtual channel identified by a VCI value = 4 can be used for VP level end-to-end (User <-> User) management functions.

The detailed layer management procedures making use of the F4 flow OAM cells at the B-ICI, and the specific OAM cell format will be covered in a later Section.

(R)-80 Network equipment supporting VP level management functions at the B-ICI shall encode the VCI field of the F4 flow OAM cells with the appropriate values as defined in [17] and shown in Figure 4.7.

(R)-81 Network equipment supporting VP level management functions at the B-ICI shall have the capability to identify F4 flow OAM cells within each VPC.

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4.4.4 Cell Discrimination Based On Payload Type Indicator (PTI) Field Values

The main purpose of the PTI field is to discriminate between user cells (i.e., cell carrying user information) from non-user cells (see Figure 4.8). Code points 0 to 3 are used to indicate user cells. Within these code points, values 2 and 3 are used to indicate that congestion has been experienced in the network. Code points 4 and 5 are used for VCC level management functions. The PTI value of 4 is used for identifying OAM cells communicated within the bounds of a VCC segment (i.e., single link segment across the B-ICI) while the PTI value of 5 is used for identifying end-to-end OAM cells.

The detailed layer management procedures making use of the F5 flow of OAM cells at the B-ICI, and the specific OAM cell format is covered in a later Section.

Figure 4.8 Payload Type Indicator Encoding

(R)-82 Network equipment supporting VC level management functions at the B-ICI shall encode the PTI field of the F5 flow OAM cells with the appropriate code points as defined in [17].

(R)-83 Network equipment supporting VC level management functions at the B-ICI shall have the capability to identify F5 flow OAM cells within each VC.

4.4.5 Loss Priority Indication and Selective Cell Discarding

The CLP field may be used for loss priority indication by the ATM end point and for selective cell discarding in network equipment. Users can set the CLP bit to indicate a lower priority cell. If the CLP is not set the cell has normal priority. Upon entering the network, a cell with CLP value = 1 may be subject to discard depending on network traffic conditions.

The treatment of cells with the CLP bit set to 1 (low priority cells) by the network traffic management functions is covered in later Sections.

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5 Common B-ICI Traffic Management and Network Performance

This Section provides B-ICI traffic management functions and network performance considerations that are common to all services being supported across a B-ICI. The service-specific considerations for a B-ICI are discussed in later Sections. The considerations developed in the ATM Forum's 1993 release of the UNI Specification[19] are used where applicable for a B-ICI.

To obtain numerical objectives on network performance parameters may be desirable after sufficient operating experience. Bilateral agreements between the carriers should address such numerical objectives on an interim basis. These objectives can be very dependent upon the actual service and configuration.

A traffic management function can generally be classified as being either a Traffic Control function or a Congestion Control function. ATM layer Traffic Control refers to the set of actions taken by the network to avoid congested conditions. ATM layer Congestion Control refers to the set of actions taken by the network to minimize the intensity, spread and duration of congestion. Congestion Control actions are triggered by congestion in one or more Network Elements.

In a BISDN, congestion is defined as a state of Network Elements (e.g., switches, concentrators, cross-connects and transmission links) in which the network is not able to meet the negotiated network performance objectives for the already established connections and/or for the new connection requests. In general, congestion can be caused either by unpredictable statistical fluctuation of traffic flows or by fault conditions within the network. Congestion is distinguished from the state where buffer overflow is causing cell losses, but the negotiated Quality of Service is still being met.

The primary role of Traffic Control and Congestion Control parameters and procedures is to protect the network and the user in order to achieve network performance objectives. An additional role is to optimize the use of network resources.

The uncertainties of broadband traffic patterns and the complexity of Traffic Control and Congestion Control suggest a step-wise approach for defining traffic parameters and network Traffic Control and Congestion Control mechanisms. This Section defines a restricted initial set of Traffic Control and Congestion Control capabilities aiming at simple mechanisms and realistic network efficiency.

It may subsequently be appropriate to consider additional sets of such capabilities, for which additional Traffic Control mechanisms will be used to achieve increased network efficiency.

The objectives of ATM layer Traffic Control and Congestion Control for a BISDN are as follows:

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- ATM layer Traffic Control and Congestion Control should support a set of ATM layer Quality Of Service (QOS) classes sufficient for all foreseeable BISDN services; and the specification of these QOS classes should be consistent with the 1993 release of the ATM Forum UNI Specification[19].

- ATM layer Traffic Control and Congestion Control should not rely on AAL protocols which are BISDN service specific, nor on higher layer protocols which are application specific. Protocol layers above the ATM layer may make use of information which may be provided by the ATM layer to improve the utility those protocols can derive from the network.

- The design of an optimum set of ATM layer Traffic Controls and Congestion Controls should minimize network and end-system complexity while maximizing network utilization.

To meet the above objectives, the following functions form a framework for managing and controlling traffic and congestion in ATM networks and may be used in appropriate combinations.

- Network Resource Management (NRM): Provisions may be used to allocate network resources in order to separate traffic flows according to service characteristics.

- Connection Admission Control (CAC): Defined as the set of actions taken by all involved carriers in order to determine whether a request to establish a new ATM connection will be accepted or rejected (or whether a request for re-allocation of an ATM connection's capacity can be accommodated). Routing is part of CAC actions.

- Feedback Controls: Defined as the set of actions taken by the network and by the users to regulate the traffic submitted on ATM connections according to the state of Network Elements.

- Network Parameter Control (NPC): Defined as the set of actions taken by a carrier to monitor and control traffic, in terms of traffic offered and validity of the ATM connection, at a B-ICI. Its main purpose is to protect network resources and the QOS of other already established ATM connections during occurrences of network equipment malfunction or misoperation by detecting violations of negotiated parameters and taking appropriate actions.

- Priority Control: The end user may generate different priority cell streams on an ATM connection by using the Cell Loss Priority (CLP) bit. A Network Element may selectively discard cells with low priority if necessary to protect as far as possible the network performance experienced by cells with high priority.

- Other control functions are for further study.

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All of these functions can make use of information that passes across the B-ICI. As a general requirement, it is desirable that a high level of consistency be achieved between the above Traffic Control and Congestion Control functions.

For this Version of the B-ICI Specification, those ATM layer Traffic Control and Congestion Control functions for a B-ICI that are common to all services will use the following simplifying assumptions:

- Other than supporting the exchange of information across a B-ICI, no feedback control actions are to be required of Network Elements.
- Bilateral agreement on availability may be needed, but is not quantified here.
- When it is present, Network Parameter Control is only required to enforce peak cell rate on a VPC.
- No Traffic Shaping function for traffic going into a B-ICI link is required of Network Elements.

The following Sections address common B-ICI aspects of network performance, the traffic contract, and the traffic management functions.

5.1 Network Performance Considerations

The ATM layer performance parameters defined in the 1993 release of the ATM Forum UNI Specification[19] are adopted without modification for use in those B-ICI network performance considerations that are common to all services.

Further network performance considerations addressed in this Specification are the definition of reference traffic loads for use when measuring the performance of a B-ICI link, and the establishment of network performance allocation principles based on appropriate reference configurations.

5.1.1 Reference Traffic Loads

Measurement of certain traffic-sensitive network performance parameters to verify agreement with specified values of those parameters has meaning in the presence of a known or reference traffic load. In particular, it is necessary to identify the traffic loads under which a specific B-ICI link is to operate when complying with the ATM layer performance objectives that can be allocated to this link.

These reference traffic loads can be characterized in terms of the utilization factor for the relevant type of physical link that is carrying the VPC or VCC whose performance is being specified. Table 5.1 provides three types of reference traffic loads. Reference Traffic Load Type 1 is intended to represent CBR traffic, and Reference Traffic Loads Type 2 and Type 3 are intended to provide initial representations of VBR traffic.

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Three types of physical link are considered here. These are a DS3 using the PLCP cell mapping defined for BISDN, a SONET STS-3c, and a SONET STS-12c.

o Reference Traffic Load Type 1 is generated as follows. Apply the number of active traffic sources shown in Table 5.1, each of which provides DS1 circuit emulation, to each link under test. Each such traffic source shall produce cells at the rate of 4,106 cells/second. The initial phasing of these sources with respect to each other shall be random, and shall have a uniform distribution over a 244 micro-second interval.

This source traffic rate is compatible with a Type 1 AAL since $\frac{1.544 \text{ Mbit/s}}{47 \infty 8 \text{ bits/cell}} = 4106$ cells/second.

The interval for the initial phasing distribution is determined as the time between two adjacent cells from the same source, which is $\frac{1}{4106 \text{ cells/second}} = 244$ micro-seconds.

o Reference Traffic Load Type 2 is generated as follows. Each cell time slot on a link under test shall contain a cell with probability equal to the specified link utilization factor, and shall not contain a cell with probability equal to one minus the specified link utilization factor. The probability of one cell time slot containing a cell shall be independent of whether or not other cell slot times contain cells.

This type of traffic load is often referred to as a Bernoulli traffic load.

Table 5.1 Reference Traffic Loads for PVC Performance Specification

Reference Traffic Load Type	Link's Capacity	Number of Active Traffic Sources to Provide Link Utilization Factor	Link Utilization Factor
1	DS3 PLCP	20	0.86
1	STS-3c	73	0.85
1	STS-12c	292	0.85
2	DS3 PLCP	Not Applicable	0.85
2	STS-3c	Not Applicable	0.85
2	STS-12c	Not Applicable	0.85

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3	DS3 PLCP	66	0.70
3	STS-3c	242	0.70
3	STS-12c	969	0.70

Note:

1. Reference Traffic Load Type 1 is based on DS1 circuit emulation.

2. Reference Traffic Load Type 2 is based on Bernoulli traffic.

3. Reference Traffic Load Type 3 is based on methodology given in[19], and the model shown in Figure 5.1.

o Reference Traffic Load Type 3 is generated as follows. Apply a number of traffic sources shown in Table 5.1, each of which provides emulation of a VBR source with Peak Cell Rate (PCR) at the DS1 rate and a Sustainable Cell Rate (SCR) of 384 kb/s with a Maximum Burst Size (MBS) corresponding to 25 cells.

More details on this type of traffic source are provided in[19]. Figure 5.1 shows a model for this type of traffic source.

Figure 5.1 Traffic Source Model Used to Provide Reference Traffic Load Type 3

$$SCR = \frac{1}{Ts}; \qquad PCR = \frac{1}{T}$$

$$MBS = \in 1 + \frac{\tau s}{Ts - T} _$$

τs = burst tolerance; $\in x _$ = greatest integer less than or equal to x.

(R)-84 The mixture of Type 1, Type 2 and Type 3 or other Reference Traffic Loads, and associated parameters applicable to a particular B-ICI link shall be established by bilateral agreement between the carriers for determining compliance with ATM layer performance objectives.

5.1.2 Allocation Principles for Network Performance

The 1993 release of the ATM Forum UNI Specification[19] defines ATM network performance parameters and their relationships with fundamental references such as CCITT's draft Recommendation I.35B. The five primary ATM network performance parameters so defined are listed in Table 5.2. This Section considers the principles to be used when allocating to individual network portions the objective maximum amounts of the network impairments characterized by these network performance parameters. These principles indicate the manner in which the performance impairment characterized by each such parameter builds up through a representative chain of Network Elements.

Table 5.2 Buildup of Performance Impairments for Traffic-Sensitive ATM Network Performance Parameters

ATM Network Performance Parameters	Reference Traffic Load Required	Build-up of Impairment on ATM Switches	Build-up of Impairment on BISDN Links
Cell Transfer Delay	No, to first order	Fixed delay per ATM switch; additive between ATM switches	Proportional to link length; additive between links
Cell Delay Variation	Yes	Generally convolution-based build-up between ATM switches	Independent of link length, consider with ATM switch
Cell Error Ratio	No	Fixed (small) per ATM switch; negligible w.r.t. links	Proportional to link length
Cell Loss Ratio	Yes	Additive between ATM switches	No impact
Cell Misinsertion Rate	No	For further study	No impact

A representative chain of Network Elements that is established to support the allocation of network performance objectives is called a "reference configuration". Such a reference configuration must identify the number and type of performance-affecting Network Elements in each of the various network portions involved with a performance allocation, as well as the relationships among these network portions. Each network portion in a reference configuration is demarcated by two jurisdictional boundaries which can be either a T_B reference point on a UNI link or a Portion Boundary (PB) on a B-ICI link.

A reference configuration is intended to provide this information for a particular class of network or carrier-to-carrier configurations. For example, one class of network configurations is

two carrier networks jointly providing an end-to-end connection. Figure 5.2 shows an example of a reference configuration.

Figure 5.2 An Example of a Reference Configuration and its Role in Network Performance Allocation

For each of the primary ATM network performance parameters, Table 5.2 identifies whether or not a reference traffic load is relevant to its measurement, the manner in which the associated performance impairment builds up through ATM switches, and the manner in which the associated performance impairment builds up through BISDN transmission links. Reference traffic loads are relevant for characterizing values of Cell Delay Variation (CDV) and Cell Loss Ratio. The following considerations apply to characterizing the build-up of CDV.

In principle, the build-up of CDV through a chain of ATM switches could be precisely determined by a detailed consideration of the correlations between all of the traffic streams passing through each of the ATM switches, together with the impacts of cell spacing (traffic shaping) functions that may optionally be present. As a practical matter, however, three simplifying assumptions can be used:

1. First, assuming independence of cell spacing between each of the traffic streams and the absence of a cell spacing function allows the distribution of the CDV that is built up on a VCC or VPC through several ATM switches to be estimated as a convolution of the CDV distributions that each of the ATM switches would add to a "pure" (zero CDV) input stream.

2. Second, there is a way to roughly estimate an extreme value, such as a 10^{-x} quantile, of the convolved CDV that is built up through a chain of ATM switches that starts at a "pure" stream on an input to the first ATM switch. This quantity is roughly approximated by multiplying the extreme value (say the 10^{-x} quantile) of the CDV that any one ATM switch typically adds to a "pure" input stream by the square root of the number ATM switches in that chain.

3. Third, the extreme value of CDV on a VCC or VPC at a point where it has just exited from a cell spacing function is some value to be specified by the carrier which operates that function.

Availability, which is a derived network performance parameter expressible in terms of the primary parameters, may be considered in future releases of this document.

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5.2 Traffic Contract

The 1993 release of the ATM Forum UNI Specification[19] defines the user-network traffic contract for an ATM connection at a UNI as well as definitions for traffic parameters, a Connection Traffic Descriptor and a Generic Cell Rate Algorithm (GCRA). The UNI Specification's GCRA is adopted without modification for use in B-ICI traffic contract considerations. With the modifications noted herein, these traffic parameter and Connection Traffic Descriptor definitions also applies to a B-ICI.

A carrier-to-carrier traffic contract specifies the negotiated characteristics for each direction of transmission over an ATM connection, i.e., a VPC or a VCC, at a B-ICI. In general, these characteristics may be different for each direction of transmission, as illustrated in Figure 5.3.

Figure 5.3 Direction-Dependent Aspects of a Carrier-to-Carrier Traffic Contract for a B-ICI

(R)-85 For each direction of transmission over a B-ICI, the carrier-to-carrier traffic contract shall consist of the Connection Traffic Descriptor, the requested QOS class, and the definition of a compliant ATM connection.

The QOS class defined in[19] applies without modification at a B-ICI. The definitions of the Connection Traffic Descriptor and a Compliant ATM Connection are modified for a B-ICI as described below.

5.2.1 Connection Traffic Descriptor

Separate consideration is provided here for the Connection Traffic Descriptors used for a VCC and for a VPC at a B-ICI.

For a VCC at a B-ICI, connecting carriers may agree to apply either the simplified Connection Traffic Descriptor defined below for a VPC, or else adapt a more complete Connection Traffic Descriptor[19]. Adaptation to a B-ICI of the Connection Traffic Descriptor from the 1993 ATM Forum UNI Specification would include consideration of a possibly increased CDV Tolerance at a B-ICI.

For a VPC at a B-ICI, some simplification is made to the Connection Traffic Descriptor.

The Connection Traffic Descriptor for a cell stream on a VPC at a B-ICI consists of all parameters and the Conformance Definition used to unambiguously specify the conforming cells of the VPC. These are:

- Source Traffic Descriptor including only the Peak Cell Rate (additional parameters such as Sustainable Cell Rate and Burst Tolerance are optional).
- CDV Tolerance
- Conformance Definition based on one application of the Generic Cell Rate Algorithm (GCRA).

The Cell Loss Priority (CLP) bit may be used to delineate two priority levels for cells within a VPC/VCC. If this CLP bit usage is supported for a particular VPC, then two applications of the Conformance Definition based on the GCRA would apply — one for the peak cell rate of the CLP = 0+1 cell stream, and second for the peak cell rate of the CLP = 0 cell stream. (The notation CLP = 0+1 means that the CLP bit may take the value of either 0 or 1).

The definition of CDV tolerance provided in[19] will also apply at a B-ICI, though its value at a B-ICI may differ from its value at a UNI.

5.2.2 Compliant ATM Connection

The Conformance Definition based on the GCRA[19] is used to unambiguously specify the conforming cells of a VPC at a B-ICI.

The Conformance Definition should not be interpreted as the NPC algorithm. Although traffic conformance at the B-ICI is defined by the Conformance Definition based on the GCRA, each network provider may use any NPC as long as the operation of the NPC does not violate the QOS objectives of a compliant connection.

> **(R)-86** The definition of a compliant ATM connection at a B-ICI shall be established by agreement between the connecting carriers.

For example, such an agreement may allow up to a certain percentage of the User Information cells on a particular VPC to violate the Conformance Definition based on the GCRA. Also, the carrier on each side of a B-ICI may wish to apply the GCRA-based Conformance Definition, and both carriers may wish to agree that a particular VPC is compliant only if both applications of the Conformance Definition (i.e., on each side of the B-ICI) indicate it to be compliant.

> **(R)-87** For compliant ATM connections, the network performance objectives (established by agreement between the connecting carriers) allocated to each network portion, demarcated by the B-ICI, shall be supported.

5.3 Traffic Management Functions

The traffic management functions that are common to all services at a B-ICI were introduced earlier. The 1993 release of the ATM Forum UNI Specification[19] provides information on these functions as they apply to a UNI. Traffic management functions at a B-ICI can be provided with some significant simplifications at a B-ICI. The objective is to be consistent with the 1993 ATM Forum UNI traffic management functions and principles which are used where applicable. An attempt is made to use the least complex functionality for achieving a satisfactory network performance across a B-ICI and reasonable levels of B-ICI link utilization.

5.3.1 Connection Admission Control

Connection Admission Control (CAC) is defined as the set of actions taken by all involved carriers in order to determine whether a request to establish a new ATM connection will be accepted or rejected (or whether a request for re-allocation of an ATM connection's capacity can be accommodated). This issue of the B-ICI Specification considers only PVC capabilities, for which new ATM connections are established on an administrative basis together with appropriate OAM procedures.

A new ATM connection is to be established on a B-ICI link only when sufficient resources are available to: (1) support that connection through all involved network portions at its required QOS, and (2) maintain the agreed QOS of existing ATM connections. It is possible that a requested new ATM connection can be so supported on a particular B-ICI link but not on other Network Elements within a given network portion, and in such a circumstance this requested new ATM connection cannot be established on that particular B-ICI link. Routing considerations help to identify when all Network Elements intended to support a requested new connection are capable of doing so.

(R)-88 A carrier requesting that a new ATM connection be established across a B-ICI shall provide at least the following information:

- o Source Traffic Descriptor[19] including only the Peak Cell Rate;
- o Required QOS class[19];
- o CDV Tolerance[19] at the B-ICI, as adjusted for build-up through the Network Elements between the originating UNI(s) and the B-ICI;
- o Conformance Definition[19].

(R)-89 The CAC function of the carrier receiving a request that a new ATM connection be established across a B-ICI shall determine:

- o Taffic parameters needed by this carrier's NPC function;
- o Routing and allocation of network resources within this carrier's network.

o Whether or not this new ATM connection will be accepted by this carrier's network at its required QOS class.

The following steps will allow a "least common denominator" approach for resource allocation on a B-ICI link. It focuses on the aggregated cell stream in each direction of an ATM connection.

1. In order to ensure network performance and to protect the network, both the CLP = 0+1 and the CLP = 0 cell streams in each direction of transmission over an ATM connection can be allocated resources on a B-ICI link whenever usage of the CLP bit is supported on that B-ICI.

2. When the carriers on either side of a B-ICI support different modes of CLP bit usage (e.g., tagging NPC versus non-tagging NPC), it is necessary to allocate resources to the CLP = 0+1, or aggregated, cell stream in each direction of transmission over an ATM connection on a B-ICI link.

3. As determined by the bilateral agreement, allocation of resources to only the CLP = 0+1 flow may be performed even when the carriers on either side of a B-ICI support the same modes of CLP usage.

Information such as the measured B-ICI link load may be used when performing this CAC function, and this information may allow a carrier to achieve increased utilization of network equipment while still meeting network performance objectives.

Each carrier may select its own CAC function. A new ATM connection would be established only if the CAC functions of all carriers being requested to participate in its support determine to accept it.

Routing considerations are beyond the scope of the current release of this document. Here, only a portion of the overall CAC process pertaining to the support of PVC ATM connections on a particular B-ICI link itself is considered.

Use of Virtual Path Connections

VPCs are an important component of Network Resource Management[19] [20] which is applicable to B-ICI links. VPCs or VPC links can be used on a B-ICI link to:

- Simplify that portion of the CAC function pertaining to a B-ICI link;
- Aggregate VCCs carrying like types of services so that the NPC can be applied to an aggregated traffic flow;

- Implement a form of priority control by segregating traffic types requiring different QOS;

- Efficiently distribute messages for the operation of traffic control schemes (for example to indicate congestion in a network portion by distributing a single OAM or Resource Management message for all VCCs within a VPC).

By reserving capacity on a VPC over a B-ICI link for like types of services, the CAC processing needed to establish individual VCCs is reduced. For this purpose, a VCC's service type could be determined from the source traffic descriptors and QOS class provided during the CAC process. The CAC decision as to whether a newly requested VCC can be supported on this link is thereby reduced to a simple, threshold-oriented decision.

An example of this use of VPCs for the CAC function is illustrated in Figure 5.4. It is applied to a specific B-ICI link in two stages. In the first or engineering stage, capacity is allocated to a VPC for like service types (e.g., similar source traffic descriptors and same QOS class), and the maximum number of simultaneously active VCCs (or threshold) permitted on each VPC is determined. This engineering stage would incorporate where appropriate a priori and/or measurement-based estimates of the statistical multiplexing efficiencies achievable with particular service types. In the second or admission stage, a new VCC is accepted only if there is room in the VPC corresponding to its service type, i.e., until the threshold determined in the engineering stage is met.

Strategies for the reservation of capacity on VPCs will be determined by the tradeoff between increased capacity costs and reduced control costs. These strategies are left to each carrier's decision.

Figure 5.4 An Example of a VPC-based CAC for B-ICI Links

5.3.2 Network Parameter Control

The Network Parameter Control (NPC) function is defined as the set of actions taken by a carrier to monitor and control traffic, in terms of traffic offered and validity of the ATM connection, at a B-ICI. Its main purpose is to protect network resources and the QOS of other already established ATM connections during occurrences of network equipment malfunction or misoperation by detecting violations of negotiated parameters and taking appropriate actions. Each carrier determines whether or not to implement the NPC function on the ingress direction to its network portion.

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Each carrier may use any implementation of the NPC function so long as it does not violate the QOS objectives of a valid and compliant ATM connection. The traffic parameters that are subject to an NPC are those which are included in the source traffic descriptor. The information on an ATM connection's source traffic descriptors and Conformance Definition[19] that is provided during the CAC process can in principle support the NPC enforcement of a number of traffic parameters.

To a significant extent, the purpose of the NPC function can be achieved with a reduced set of traffic enforcement functions that only enforce peak cell rate on the VPCs of a B-ICI link.

(R)-90 When the NPC function is present, it shall provide at least the following actions:

- o Verification of the validity of each VPI (i.e., whether the VPI value is associated with active VCCs);
- o Enforcement of the peak cell rate for each VPC.

When a VPC contains an aggregation of VCCs carrying like types of services as described in the previous Section, the above **(R)** facilitates a simplified implementation of the NPC function.

At the cell level, actions of the NPC function may include:

- o Cell passing — mandatory for conforming cells;
- o Cell re-scheduling (when traffic shaping and network parameter control are combined);
- o Cell tagging (carrier option) — cell tagging operates on CLP = 0 cells only by overwriting the CLP bit to 1;
- o Cell discarding.

At a carrier's option, two applications of the NPC function may be established for a VPC — one for the peak cell rate of the CLP = 0+1 cell stream, and second for the peak cell rate of the CLP = 0 cell stream.

Since cell sequence integrity must be maintained on any ATM connection, the NPC function, including its optional tagging action, should meet the following requirement:

(R)-91 An NPC function shall maintain cell sequence integrity on every ATM connection it acts upon.

At the connection level, actions of the NPC function may include:

- Releasing the ATM connection.

5.3.3 Priority Control

The end user may generate different priority cell streams on an ATM connection by using the Cell Loss Priority (CLP) bit. A Network Element may selectively discard cells with low priority (CLP = 1) if necessary to protect as far as possible the network performance experienced by cells with high priority (CLP = 0). The relation between values of the CLP bit and QOS classes is established[19].

If the tagging option is used by a carrier in its NPC function, those CLP = 0 cells identified as nonconforming by this NPC function (when acting on the CLP = 0 cell stream) are converted to CLP = 1 cells, and merged with the CLP = 1 cell stream on that same ATM connection[19].

The following is a minimum requirement on the relation between the priority control and NPC functions.

(R)-92 Any cell, regardless of its CLP bit value, that is identified as nonconforming by the NPC function when acting on the aggregate CLP = 0+1 cell stream of an ATM connection shall be discarded.

5.3.4 Explicit Forward Congestion Indication

The Explicit Forward Congestion Indication (EFCI) is an ATM level congestion notification mechanism that uses certain code points in the Payload Type Identifier (PTI) field of the cell header. Its purpose is to notify end user equipment that a cell has passed through a congested network resource, e.g., a congested ATM switch. Such a notification may be optionally used by end user equipment in establishing feedback controls to reduce the impact of network congestion on that end user equipment. A carrier should not rely on this mechanism to control network congestion.

After a cell has been transferred across a B-ICI, it is desirable to prevent the clearing of a cell's previously set EFCI value that indicates "congestion experienced". If such information were cleared, it would be lost to the end user equipment.

(R)-93 A network portion shall not modify the value of the EFCI code points (to preserve the EFCI integrity) in any User Information cell received across a B-ICI, except to set such code points to indicate the "congestion encountered" state when that network portion determines this would be appropriate.

6 Common B-ICI Operations and Maintenance

This Section provides B-ICI Operations and Maintenance functions applicable to Carrier-to-Carrier connections of public ATM-based networks. The operations functions common to all services are discussed in this Section, and service specific operations functions are discussed in later Sectons.

6.1 Physical Layer Operations

This Section provides specifications of operations and maintenance for the Physical Layer, which includes the Physical Medium Dependent (PMD) sublayer and the Transmission Convergence (TC) sublayer. DS3, STS-3c, and STS-12c rate B-ICIs are considered.

6.1.1 Physical Layer Operations for the 44.736 Mbit/s DS3 B-ICI

Operations and maintenance functions and framing formats required for DS3 transmission are described in ANSI T1.107[21] , ANSI T1.107a[11], and TR-TSV-000773[12]. For ATM, the Physical Layer Convergence Procedure (PLCP) path layer operations are a subset of those specified in the IEEE 802.6 standard [22] and TR-TSV-000773[12] . Specifically, the PLCP path User Channel (F1), the Control Information bytes (M2 - M1) and the Link Status Signal of the Path Status byte (G1) are not supported at the B-ICI. Additional information on the parameters specified in this Section can be found in ANSI T1.624[6] .

6.1.1.1 DS3 Layer Operations and Maintenance

> **(R)-94** The DS3 transmission system shall meet the operations and maintenance requirements specified in ANSI T1.107[21] and ANSI T1.107a[11]. This includes provisions for performance monitoring, failure detection, alarms and maintenance.

These requirements are also described in ANSI T1.624[6] and TR-TSV-000773[12] .

6.1.1.2 DS3 PLCP Operations and Maintenance

This Section specifies Physical Layer Convergence Procedure (PLCP) level operations functions of PLCP error monitoring, PLCP Far End Block Error (FEBE) encoding, and PLCP Remote Alarm Indication (RAI)[6] for the 44.736 Mbit/s B-ICI. These functions are summarized in Table 6.1.

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6 The RAI is sometimes also referred to as a "Yellow Alarm".

Figure 6.1 illustrates the PLCP path status (G1) byte subfields: a 4-bit FEBE, a 1-bit RAI (Yellow), and 3 X bits (X bits are ignored).

Table 6.1 DS3 PLCP Layer Maintenance

Function	Overhead Byte	Coding
PLCP Error Monitoring	B1 of PLCP	BIP-8
PLCP FEBE	G1 (bits 1-4) of PLCP	B1 Error Count
PLCP RAI (Yellow)	G1 (bit 5) of PLCP	0 or 1

Figure 6.1 PLCP Path Status (G1) Byte

6.1.1.2.1 DS3 PLCP Performance Monitoring

The Bit Interleaved Parity - 8 (BIP-8) for the PLCP is an 8 bit code in which the n-th bit of the BIP-8 code calculates the even parity over the n-th bit of each byte covered by the BIP-8. Thus, the BIP-8 provides for 8 separate even parity calculations.

(R)-95 The PLCP performance parameters shall be monitored at the PLCP layer, as described in ANSI T1.624[6] . Monitored parameters include Coding Violations (CV), Errored Seconds (ES), Severely Errored Seconds (SES), Severely Errored Framing Seconds (SEFS), and Unavailable Seconds (UAS).

A CV occurs when a received BIP-8 code (in the B1 byte of the PLCP) is not identical to the corresponding locally-calculated code. One received B1 byte can contain from 0 to 8 CVs. An ES is a second with at least one CV. An SES is any second with 5 or more CVs. An SEFS is a count of one-second intervals in which one or more PLCP Out of Frame (OOF) events occur (PLCP OOFs are discussed below). A UAS is a second in which service becomes unavailable at the declaration of a transmission failure condition.

(R)-96 The operations of the PLCP Far End Block Error (FEBE) shall conform to ANSI T1.624[6]. The FEBE field shall provide a count of 0 to 8 BIP-8 errors received in the previous PLCP frame, i.e., G1(FEBE) = 0000 through G1(FEBE) = 1000. Any other value of G1 would be caused by other errors and shall be interpreted as 0 errors.

6.1.1.2.2 DS3 PLCP Loss of Frame (LOF)

The PLCP LOF state is defined in the IEEE 802.6 standard[22] as the persistence of a PLCP Out of Frame (OOF) for 1 milli-second. The PLCP OOF is declared when an error in both the A1 and A2 PLCP framing bytes occurs, or two consecutive invalid (i.e., non-sequential)[7] Path Overhead Identified (POI) bytes occur.

(R)-97 The PLCP LOF state shall be declared when a PLCP OOF, as defined in IEEE 802.6[22], persists for 1 milli-second.

This is also specified in TR-TSV-000773[12] .

6.1.1.2.3 DS3 PLCP Path RAI (Yellow)

The RAI (Yellow) shall follow the procedures specified in Section 6.2.2 of ANSI T1.624[6] , which are summarized below.

(R)-98 The RAI (Yellow) field shall alert the transmitting PLCP that a received failure indication has been declared along the path.

(R)-99 When an incoming failure condition is detected that persists for a "soaking period" (typically 2 - 10 seconds), an RAI (Yellow) shall be sent to the upstream end by setting G1(RAI)=1. The RAI (Yellow) shall be detected (by the upstream end) when G1(RAI)=1 for 10 consecutive PLCP frames.

The indication is cleared at the downstream end by setting G1(RAI)=0 when the incoming failure has ceased for 15 ± 5 seconds. At the upstream end, removal of the RAI (Yellow) signal is recognized by detecting G1(RAI)=0 for 10 consecutive PLCP frames.

Note: A PLCP path level Far End Receive Failure (FERF) is not supported at present. The specification of a PLCP Path RDI (Remote Defect Indicator) in addition to or in replacement of PLCP Path RAI is for further study.

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[7] For example, the POI sequence of 11, 10, 9, 4, 7 would not cause a PLCP OOF, while the sequence 11, 10, 9, 4, 5 would.

6.1.2 Physical Layer Operations for the 155.520 Mbit/s STS-3c B-ICI

Maintenance signals that traverse the SONET B-ICI terminate at three layers: the SONET Section, Line and Path layers. Capabilities associated with the three layers include performance monitoring, alarm surveillance and facility testing. These capabilities are made possible by the Section Overhead (SOH), Line Overhead (LOH), and Path Overhead (POH) fields of the SONET framing structure.

T1E1.2/93-020R1[23] specifies the operation of transmission performance monitoring, failure states, and fault management signals. TR-NWT-001112[24] and TR-NWT-000253[5] also address these issues.

6.1.2.1 Transmission Performance Monitoring

Transmission performance monitoring is accomplished using a combination of the B1, B2, and B3 bytes. These bytes are encoded into the transmitted signal as specified in T1E1.2/93-020R1[23]. The following **(R)** may or may not apply depending on the B-ICI configurations (B-ICI, B-ICI', B-ICI") summarized in Table 3.1.

(R)-100 Section BIP-8 shall be calculated over all bits of the previous STS-Nc frame after scrambling by the frame synchronous scrambler. The computed BIP-8 shall be placed in the first B1 byte location of the subsequent STS frame before scrambling.

(R)-101 Line BIP-8N shall be calculated over all bits of the LOH and STS Envelope capacity of the previous STS frame before scrambling by the frame synchronous scrambler. The computed BIP-8N shall be placed in each B2 byte of the STS frame before scrambling.

(R)-102 Path BIP-8 shall be calculated over all bits (N ∞ 783 bytes for STS-Nc, regardless of pointer justification) of the previous STS SPE before scrambling by the SONET frame synchronous scrambler, and placed in the B3 byte of the current STS SPE before scrambling.

The parity errors detected by the line BIP-8N are accumulated into a single error count for the STS-N (or STS-Nc) Line.

At the termination point, the B1, B2, and B3 bytes of the incoming signal are monitored for errors.

(R)-103 Monitoring of the incoming signal shall be accomplished by calculating the values of the Section BIP-8, the Line BIP-8N, and Path BIP-8 and comparing them to the incoming B1, B2, and B3 bytes.

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(R)-104 SONET path performance parameters shall be monitored as described in ANSI T1.624[6]. Monitored parameters include STS Path Coding Violations (CVs), STS Path Errored Seconds (ESs), STS Path Severely Errored Seconds (SESs), and STS Path Unavailable Seconds (UAS).

(R)-105 A count of the difference in the calculated Path BIP-8 and the received B3 byte shall be placed in bits 1 through 4 of the G1 byte.

Errors are reported to the layer management entity.

6.1.2.2 Failure States

ATM equipment on both sides of the SONET B-ICI detect failure states relevant to the layer of functionality the equipment provides (i.e., SONET Section, Line and Path Layers). The following failure states can be declared within the functional equipment on the receiving side of the interface. The following requirements are based on Section 13 of T1E1.2/93-020R1[23] .

6.1.2.2.1 Loss of Signal (LOS)

(R)-106 The network equipment supporting a B-ICI shall enter an LOS state on the incoming signal within 100 micro-seconds of the onset of an all-zeros pattern lasting 2.3 micro-seconds or longer. An "all-zeros pattern" corresponds to no light pulses for OC-N optical interfaces and no voltage transitions for STS-N electrical interfaces[8].

(R)-107 The network equipment supporting a B-ICI shall exit the LOS state when two consecutive valid frame alignment patterns have been detected and, during the intervening time, no "all-zeros pattern" considered as LOS was detected in the incoming signal.

6.1.2.2.2 Loss of Frame (LOF)

(R)-108 The network equipment supporting a B-ICI shall enter an LOF state when an Out-of-Frame (OOF) on the incoming signal persists for 3 milli-seconds. An OOF is declared when four or more consecutive errored framing patterns have been received.

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8 T1M1.3 is proposing a slight change to the LOS definition, but this change will not be approved until later. The current proposed definition [T1M1.3/92-005 (R3), October 1992, Layer 1 Performance Monitoring] is, "An LOS defect is the occurrence of no transitions on the incoming signal (before descrambling) for time T, where $2.3 \leq T \leq 100$ micro-seconds."

(R)-109 The network equipment supporting a B-ICI shall exit the LOF state within 3 milli-seconds of a continuous in-frame signal in the incoming signal.

6.1.2.2.3 Loss of Pointer (LOP)

(R)-110 The network equipment supporting a B-ICI shall enter an LOP state when a valid STS pointer cannot be obtained using the pointer interpretation rules described in ANSI T1.105[4]. The network equipment supporting a B-ICI also enters an LOP state if a valid pointer is not found in 8, 9, or 10 consecutive frames, or if 8, 9, or 10 consecutive New Data Flags (NDFs) are detected.

Bits 1 through 4 of the pointer word (comprised of H1 and H2 bytes) carry the NDF. More information on the NDF can be found in TR-NWT-000253[5].

(R)-111 The network equipment supporting a B-ICI shall exit the LOP state when a valid STS pointer with normal NDF, or a concatenation indicator, is detected in three consecutive frames in the incoming signal.

6.1.2.2.4 Loss of Cell (LOC) Delineation

The network equipment supporting a B-ICI may enter the LOC state when the HEC coding rule is determined to be incorrect seven consecutive times for the incoming signal (i.e., Alpha = 7). A precise definition of LOC state is under study in standards.

The network equipment supporting a B-ICI may exit the LOC state when the HEC coding rule has been confirmed seven consecutive times for the incoming signal (i.e. Delta = 6, Hunt = 1, Delta + Hunt = 7).

See Section 3.5 of this document for further information concerning HEC, Alpha, Delta, and Hunt. LOC is also discussed in Section 10 of T1E1.2/93-020R1[23] and Section 4.5 of I.432[7].

6.1.2.2.5 Path Signal Label Mismatch

(R)-112 The network equipment supporting a B-ICI shall follow the Path Signal Label Mismatch states defined in TR-NWT-000253[5].

6.1.2.3 Fault Management Signals

The following Fault Management signals are generated and transmitted/received across the interface to report failure states that persist for a defined period of time. These signals are consistent with those defined in ANSI T1.624[6] and TR-NWT-000253[5].

(R)-113 The network equipment on either side of a B-ICI shall meet the requirements associated with generation, detection, activation, and deactivation of Line AIS, Path AIS, Line RDI, and Path FEBE as specified in TR-NWT-000253[5].

Note: Line RDI is called Line FERF in TR-NWT-000253.

- **Path RDI:**

  Path RDI alerts the upstream STS Path Terminating Equipment (PTE) that a downstream failure has been detected along the STS Path.

  (R)-114 Path RDI shall be generated within 250 micro-seconds by an STS PTE upon entering LOS, LOF, LOP, or LOC state, or upon detecting Line AIS or Path AIS, by setting bit 5 in the Path Status byte (G1) to '1'. This bit retains this value for the duration of the RDI condition. Transmission of the RDI signal shall cease within 250 micro-seconds when the STS PTE no longer detects the above failure states or Line AIS or Path AIS.

- **Line FEBE:**

  The Line FEBE signal is used to convey the count of the interleaved bit blocks that have been detected to be in error by the Line BIP-8N (B2) bytes. The count has (8N+1) legal values, namely, 0 to 8N errors. The remaining possible values (255 - 8N), represented by the 8 bits of Z2 shall be interpreted as zero errors. N equals 3 for the STS-3c based 155.520 Mbit/s B-ICI.

The following Line FEBE specification was adopted in SONET standards (ANSI T1X1.5).

(R)-115 A count of the differences in the calculated BIP-8N and the received B2 bytes shall be placed in the 3rd Z2 byte of the STS-3c frame.

6.1.2.4 State Tables for Precedence of Fault Management Signals

To specify the transitions in case of multiple fault conditions, it is necessary to identify the priority of the various fault conditions. Equipment at each side of the B-ICI informs the other of fault conditions in a manner that can be depicted in detail by state tables. Two state tables are defined, one at each side of the B-ICI. Information on these fault conditions are exchanged between the two sides in the form of the fault management signals specified earlier.

(R)-116 Equipment at each side of the B-ICI shall transition to failure states on the basis of bilateral agreements.

Transitions are specified by the state tables of I.432[7], T1E1.2/93-020R1[23], and TR-NWT-001112[24].

6.1.3 Physical Layer Operations for the 622.080 Mbit/s STS-12c B-ICI

(R)-117 The operations and maintenance functionality defined for the STS-3c (155.520 Mbit/s) B-ICI shall also apply to the STS-12c (622.080 Mbit/s) B-ICI.

6.2 ATM Layer Operations

This Section focuses on the use of OAM cells, identifies the ATM Layer Management functions and procedures at the B-ICI. Management functions at the B-ICI require some level of cooperation between network equipment of the two carriers. The ATM Layer Management functions supported at the B-ICI are grouped into the categories of Fault Management and Performance Management (see Figure 6.2). All functions use OAM cells. Performance management cells could play a larger role in the B-ICI as compared to the UNI.

- Fault Management includes Alarm Surveillance and Connectivity Verification functions. OAM cells are used for exchanging related operations information.

- Performance Management is activated only for selected connections. When active, Performance Management includes the counting of lost or misinserted cells, and the monitoring of bit errors in the payloads of the connection's cells. Cell delay may also be measured, which can be used to estimate the cell delay variation experienced on a connection.

Support of continuity check fault management function and configuration management function (e.g., VP/VC status) are for further study.

In this Version of the document, ATM layer OAM functions apply for point-to-point connections. ATM layer OAM functions for multipoint connections will be provided in future Versions of this document.

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Figure 6.2 ATM Layer Management Functions at the B-ICI

6.2.1 ATM Layer Management Information Flows

Figure 6.3 shows the OAM flows defined for the exchange of operations information between nodes. At the ATM layer, the F4-F5 flows will be carried via OAM cells[9]. The F4 flow is used for segment[10] or end-to-end (VP termination) management at the VP level using VCI values 3 and 4. The F5 flow is used for segment[11] or end-to-end (VC termination) management at the VC level using Payload Type Indicator (PTI) code points 4 and 5. A detailed explanation of the OAM cell flow mechanism is given in CCITT Recommendation I.610[25] and T1S1.5/92-029R3[26].

Figure 6.3 ATM Layer OAM Flows at the B-ICI

Virtual Paths and Virtual Channels are always visible at the B-ICI, so the F4 and F5 flows are always supported.

(R)-118 Network equipment at a B-ICI shall support the F4 and F5 Management flows as defined in CCITT Recommendation I.610[25] and T1S1.5/92-029R3[26] for the OAM functions defined in Section 6.2.3.

More detail on OAM flows may be found in Section 4 of CCITT Recommendation I.610[25], Section 3 of T1S1.5/92-029R3[26], and Section 4 of TA-NWT-001248[27].

6.2.2 ATM OAM Cell Formats

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9 The F1-F5 flows are defined in CCITT Recommendation I.610. F1-F3 are defined for the physical layer, and F4 and F5 are defined for the ATM Layer.

10 For the B-ICI specification, this always includes the case where the segment is the link between the nodes on either side of the B-ICI.

11 For the B-ICI specification, this always includes the case where the segment is the link between the nodes on either side of the B-ICI.

The Virtual Path (VP) operations information is carried via the F4 flow OAM cells. These cells have the same VPI value as the user-data cells but are identified by pre-assigned VCI values. Two unique VCI values are used for every VPC as shown in Figure 6.4. The VCI value = 3 is used to identify a connection between ATM layer management entities (LMEs) on both sides of the B-ICI (e.g., single link segment), and VCI value = 4 is used to identify a connection between end-to-end ATM LMEs.

Figure 6.4 Format of the Common Part of the OAM Cell

The Virtual Channel (VC) operations information is carried via the F5 flow OAM cells. These cells have the same VPI/VCI values as the user-data cells but are identified by pre-assigned code points of the PTI field. Two unique PTI values are used for every VCC as shown in Figure 6.4. The PTI value = '100' (i.e., 4) is used to identify the connection between ATM LMEs on both sides of the B-ICI (e.g., single link segment) while the PTI value = '101' (i.e., 5) is used to identify connections between end-to-end ATM LMEs.

End-to-end OAM cells must be passed unmodified by all intermediate nodes. The contents of these cells may be monitored by any node in the path. These cells are only to be removed by the end point of the VPC (F4 flow) or VCC (F5 flow). Segment OAM cells shall be removed at the end of a segment. The format of the common part of the OAM cell is shown in Figure 6.4.

The OAM Cell Type field and the Function Type fields, as specified in CCITT Recommendation I.610[25] and T1S1.5/92-029R3[26], are shown in Table 6.2.

Table 6.2 OAM Type/Function Identifiers

OAM Cell Type	Value	OAM Function Type	Value
Fault Management	0001	AIS	0000
		FERF	0001
		Continuity Check	0100
		Loopback	1000
Performance Management	0010	Forward Monitoring	0000
		Backward Reporting	0001
		Monitoring & Reporting	0010
Activation/Deactivation	1000	Performance Monitoring	0000

		Continuity Check	0001

The format of the function-specific fields of the Fault Management OAM cell, as defined in[28], is shown in Figure 6.5.

The format of the function-specific fields of the Performance Management OAM cell, as defined in CCITT Recommendation I.610[25] and T1S1.5/92-029R3[26], is shown in Figure 6.6.

The format of the function-specific fields of the Activation/Deactivation cell, as defined in CCITT Recommendation I.610[25] and T1S1.5/92-029R3[26], is shown in Figure 6.7.

Figure 6.5 Fault Management-Specific Fields

Figure 6.6 Performance Management-Specific Fields

Figure 6.7 Activation/Deactivation Management-Specific Fields

(R)-119 Network equipment at a B-ICI shall encode/interpret the OAM cells according to the format and encoding rules defined in T1S1.5/92-029R3[26] and CCITT Recommendation I.610[25] for the OAM functions defined in Section 6.2.3.

Further discussion on each of these cell types may be found in CCITT Recommendation I.610[25], T1S1.5/92-029R3[26], and TA-NWT-001248[27].

6.2.3 OAM Functions

This Section discusses the Fault Management and Performance Management OAM functions to be supported over the B-ICI.

6.2.3.1 ATM Fault Management Functions at the B-ICI

The Fault Management functions at the B-ICI are grouped into three categories: Alarm Surveillance, Connectivity Verification, and Continuity Check.

6.2.3.1.1 Alarm Surveillance

Alarm surveillance at the B-ICI involves detection, generation, and propagation of VPC/VCC failures (failure indications). In analogy with the SONET physical layer, the failure indication signals are of two types: Alarm Indication Signal (AIS) and Far End Receive Failure (FERF). These signals are carried via OAM cells as defined in Section 6.2.2. The VP/VC AIS (VP-AIS and VC-AIS) is generated by a VPC/VCC node at a connecting point to alert the downstream VPC/VCC nodes that a failure has been detected upstream. The VP-AIS/VC-AIS can be caused by the detection of a VPC/VCC failure or by the notification of a physical layer failure. Upon receiving a VP-AIS/VC-AIS, a VPC/VCC end point at the B-ICI will return a VP-FERF/VC-FERF to alert the upstream nodes that a failure has been detected downstream.

Network equipment at a B-ICI may terminate a connection, or act as an intermediate (i.e., connecting) node. This is shown in Figure 6.8.

Figure 6.8 Terminating and Intermediate Equipment at a B-ICI

The following requirements apply to network equipment at the B-ICI that terminates a connection.

(R)-120 Network equipment terminating a VPC at the B-ICI shall detect incoming VP-AISs and shall generate VP-FERFs in the upstream direction (toward the other carrier's network) to alert the ATM nodes about the failure.

(R)-121 Network equipment terminating a VCC at the B-ICI that detects an incoming VC-AIS shall generate, for selected VCCs, a VC-FERF in the upstream direction (toward the other carrier's network).

The following requirements apply to equipment at the B-ICI that acts an an intermediate connection.

(R)-122 Network equipment at a B-ICI, acting as an intermediate VP node, shall generate a VP-AIS upon detection of a VPC failure or upon receiving a physical layer failure notification.

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(R)-123 Network equipment at a B-ICI, acting as an intermediate VC node, shall generate, for selected VCCs, a VC-AIS upon detection of a VCC failure or upon receiving a physical layer failure notification.

The following requirement applies to both intermediate and terminating nodes.

(R)-124 Network equipment at a B-ICI inserting Alarm Surveillance cells shall do so at a nominal rate of 1 cell per second per VPC or VCC, as specified in Section 6 of CCITT Recommendation I.610[25]. The release conditions shall be as specified in CCITT Recommendation I.610.

More detail on alarm surveillance may be found in CCITT Recommendation I.610[25], T1S1.5/92-029R3[26], and TA-NWT-001248[27].

6.2.3.1.2 Connectivity Verification

Connectivity verification is supported by the use of the OAM loopback capability for both VP and VC connections. More complete details on this loopback function can be found in the modified text of I.620[28] The VCC or VPC being checked can remain in service while this loopback function is being performed. The OAM Cell Loopback function supported at the B-ICI includes the following four fields:

- Loopback Indication - This eight-bit field identifies, for the end point receiving the OAM cell, whether the incoming cell is to be looped back. A value of '01' indicates that the cell should be looped back. All other values indicate that the cell is to be discarded. Before the cell is looped back, the end point shall decrement the value of the Loopback Indication field.

- Correlation Tag - At any given time, multiple OAM Fault Management Loopback cells may be inserted in the same virtual connection. As a result, the OAM cell loopback mechanism requires a means of correlating transmitted OAM cells with received OAM cells. The node inserting the OAM cell may put any value in this 32-bit field, and the end point looping back the cell shall not modify it.

- Loopback Location ID (Optional) - This 96-bit field identifies the point(s) along a virtual connection where the loopback is to occur. The default value of all ones is used by the transmitter to indicate the end point.

- Source ID (Optional) - This 96-bit field can be used to identify the originator of the Loopback cell so the originator can identify the looped back cell when it returns. This may be encoded any way that enables the originating point to be certain that it has received the cell it transmitted. The default value is all ones.

(R)-125 Network equipment terminating a connection at a B-ICI that receives OAM cells with a Loopback Indication value other than '00000001', OAM Cell Type = '0001', and Function Type = '1000' shall discard the cell.

(R)-126 Network equipment terminating a connection at a B-ICI that receives OAM cells with a Loopback Indication value of '00000001', OAM Cell Type = '0001', and Function Type = '1000', shall decrement the Loopback Indication value and then loopback the cell within one second.

Network equipment inserting loopback cells will do so at a rate low enough to insure that loopback cells amount to less than one percent of the capacity of any link in the connection. No requirement should be made that loopback cells support delay measurement.

6.2.3.1.2.1 Segment Loopback

An ATM-level loopback can be performed across the B-ICI using segment loopback cells which are looped back by the end point of a VPC or VCC segment. The segment can be defined as the link between the ATM nodes on either side of the B-ICI. Segment end points must either remove these cells or loop them back depending on the value in the Loopback Indication field. That is, these cells must not travel beyond the segment in which they are generated. Segment loopback cells are indicated by a PTI value of '100' for VCCs and a VCI value of 3 for VPCs. An example of how the segment loopback cell is used is shown in Figure 6.9.

6.2.3.1.2.2 End-to-End Loopback

End-to-end loopback cells (i.e., those with a Loopback Location ID of all 1s) are only looped back by the end point of a VPC or VCC. These cells may be inserted by any node in the connection (intermediate or end point) and may be monitored by any node. However, only end points may remove these cells. End-to-end loopback cells are indicated by a Payload Type Indicator (PTI) value of '101' for VCCs and a VCI value of 4 for VPCs. An example of how the end-to-end loopback cell is used is shown in Figure 6.9.

The switch supporting the B-ICI shall support the insertion of end-to-end loopback cells. It shall also support the copying of received loopback cells to check for the return of loopback cells it initiated.

Figure 6.9 The Loopback Function

6.2.3.1.3 Continuity Check

The need for Continuity Check is for further study. If used for a connection that crosses a B-ICI, it must be activated/deactivated using the activation/deactivation "handshaking" procedures of CCITT Recommendation I.610[25]. More detail on the Continuity Check procedure, and its activation/deactivation, may be found in TA-NWT-001248[27].

6.2.3.2 Performance Management Functions at the B-ICI

Performance Management functions at the B-ICI consist of monitoring selected connections for lost or misinserted cells, bit errors, and (optionally) cell delays. A node needs to only support performance monitoring for a limited number of connections or segments that it terminates. When used across a B-ICI, it must first be activated using Activation/Deactivation OAM cells, as specified below in Section 6.2.3.3.

6.2.3.2.1 Performance Management Cell Payload Structure

The Performance Management cell payload structure is specified in CCITT Recommendation I.610[25] and T1S1.5/92-029R3[26], and its function-specific fields are shown in Figure 6.6. The fields of the Performance Management cell are described below.

- OAM Type: The OAM Type is "Performance Management," encoded as 0010.

- Function Type: The Function Type field specifies whether the cell is to be used for Forward Monitoring (0000), Backward Reporting (0001), or Monitoring & Reporting (0010). Although there are three function types, there are only two distinct functions of the PM cell: forward monitoring and backward reporting. Figure 6.6 shows which fields are used only for the forward monitoring function, and which are used only for the backward reporting function.

- Monitoring Sequence Number (MSN): This field carries the sequence number of the Performance Management cell, modulo 256. This field allows for the detection of a lost or misinserted Performance Management OAM cell.

- Total User Cell (TUC) Number: This field indicates the total number (modulo 65536) of user cells transmitted on a connection just before a monitoring cell is inserted.

- Block Error Detection Code: This field contains the even parity BIP-16 error detection code computed over the information fields of the block of user-data cells transmitted after the last monitoring cell.

- Time Stamp: This forward monitoring field is optional and may be used to represent the time at which the OAM cell was inserted. T1S1.5/92-029R3[26] specifies that the time is encoded in units of .01 micro-seconds. However, the node does not need to be accurate to

.01 micro-seconds. (An accuracy[12] of at least one micro-second seems sufficient.) If the field is not used in a cell used for forward monitoring, this field is set to all 1s.

- Unused: Octets in this field are encoded as "6A" hexadecimal ('01101010').

- Block Error Result: This field carries the number of errored BIP-16 bits in the BIP-16 code of a received monitoring cell. The field is used for backward reporting.

- Lost/Misinserted Cells: This field carries the count of lost or misinserted cells computed over the received block. The value is calculated at the receiving ATM switch as the number of cells received minus the number of cells expected (i.e., actual - expected). T1S1.5/92-029R3[26] specifies that the most significant bit is used to indicate the sign of the field. A '1' is used to encode negative field values; i.e., for a count of lost cells. A '0' indicates positive field values; i.e., to encode a count of misinserted cells. This field is used for backward reporting.

When fields are not used (e.g., the Monitoring fields are not used in the Reporting PM cell), the fields will be treated as "unused" fields, and encoded accordingly. Note, however, when a PM cell uses the monitoring fields but does not encode a time stamp into the Time Stamp field, it is not considered "unused". In this case the Time Stamp field is encoded to its default value of all 1s.

6.2.3.2.2 Mechanism for VP/VC PM Cell Generation

This Section describes the procedure of generating Performance Management OAM cells at a B-ICI. A Performance Management cell contains information about a block of user-information cells of one connection; Performance Management and other OAM cells such as Fault Management cells are not part of the block. Figure 6.10 illustrates the concept of a block. The allowable nominal block sizes are 128, 256, 512, and 1024 cells.

Figure 6.10 A Performance Monitoring Block

A Performance Management cell may contain forward monitoring information, backward report information, or (if desired) both.

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[12] Here "accuracy" refers to the smallest counting unit, and not the drift of the clock. Thus a node with an accuracy of 1 sec would increment the Time Stamp field in multiples of 100.

6.2.3.2.2.1 Segment VP/VC Monitoring

The steps for generating PM cells when performing segment VP/VC performance monitoring are listed below.

1. The originating VP/VC segment end point will generate a BIP-16 error detection code over the payloads of the user information cells in the block. Then the end point will place the following information in the payload of a Performance Management OAM cell: the Monitoring Sequence Number of the PM cell, the Total User Cell number (modulo 65536), the BIP-16, and an optional Time Stamp. This OAM cell will be transmitted before the next user-information cell of the VPC/VCC. Although the block size for a segment has a nominal value, the actual size of any given block may vary from that nominal value. This variation allows PM cells to be inserted without delaying the flow of user cells.

2. The far-end VP/VC segment end point will compare the number of the cells received in the block with the difference between the received Total User Cell (TUC) count and the TUC count at the end of the last received block. A mis-match in this comparison indicates lost or misinserted cells. If no cells have been lost or misinserted, the end point will compare the BIP-16 in the forward monitoring cell with the result of an identical BIP-16 calculation it has performed over the same number of user-information cells. A mis-match in this comparison indicates bit errors in the block. The results from this block - the count of lost/misinserted cells and (if the cell counts match) the number of errored parity bits in the BIP-16 code - are stored until the backward reporting cell is sent. If the cell counts do not match, the Block Error Result in the backward report is set to 0.

3. The far-end VP/VC segment end-point will report the results (number of lost/misinserted cells and number [0-16] of errored parity bits) back to the originating (i.e., near-end) VPC/VCC end point, using a Performance Management OAM cell to send a backward report. This report may be used by monitor points along the VPC/VCC to monitor end-to-end performance.

More detailed discussion about this procedure may be found in TA-NWT-001248[27].

(R)-127 Network equipment at a B-ICI that terminates a segment on which performance monitoring is active in the outgoing direction, shall generate PM cells containing forward monitoring information. These cells shall be generated according to the procedures specified in CCITT Recommendation I.610[25] and T1S1.5/92-029R3[26], and described in this Section.

(R)-128 Network equipment at a B-ICI that terminates a segment on which performance monitoring is active in the incoming direction, shall generate PM cells containing backward reporting information. These backward reports shall be generated according to the procedures specified in CCITT

Recommendation I.610[25] and T1S1.5/92-029R3[26], and described in this Section.

(R)-129 Network equipment at a B-ICI that sends backward reports shall send those reports within one second after receiving the PM cell with the forward monitoring information. The end point shall send backward reports in the same sequence in which the corresponding forward monitoring OAM cells were received.

This procedure is performed symmetrically for both directions of VPC/VCC transmission if bidirectional PM has been activated. Figure 6.11 shows a connection segment in which PM is active in both directions. This provides each VPC/VCC node in the segment the capability to monitor the bidirectional VPC/VCC. In Figure 6.11, the left-most point collects history data for both the left-to-right and right-to-left directions of user data flow. In configurations in which there are intermediate points, the intermediate point can collect history data for both directions as well.

Figure 6.11 Segment Performance Monitoring Across a B-ICI

A user may wish to have only uni-directional performance monitoring. In this case, there is still a bi-directional flow of PM OAM cells, because the reporting flow is needed across a B-ICI. There is one pair of PM cell flows for each direction of user data flow that is being monitored.

Network equipment at a B-ICI that is an intermediate point of a connection/segment over which PM cells are being generated should be capable of monitoring (i.e., copying) the PM cells to read the backward report. This allows a carrier to monitor the performance of connection/segment from one switch, when desired.

(R)-130 Network equipment at a B-ICI shall be capable of generating PM cells on a minimum number of simultaneous connections/segments. This minimum number depends on the rate of the interface.

6.2.3.2.2.2 End-to-End VP/VC Monitoring

In some cases, equipment at one end of a B-ICI may be at the end point of a connection on which end-to-end performance monitoring is desired. Thus equipment that terminates a B-ICI should
support performance monitoring of end-to-end VP/VC connections. Figure 6.12 shows an end-to-end connection that terminates at a B-ICI at one end point. (For example, the network equipment supporting the B-ICI might provide SMDS service.) In this example, only one direction of user information cells is being monitored, and history data is collected only at the intermediate point.

Figure 6.12 End-to-End Performance Monitoring Across a B-ICI

The procedures for end-to-end VP/VC performance monitoring are essentially the same as the end-to-end procedure described earlier. One difference is that Performance Management OAM cells are inserted and extracted at the end points of the connection, instead of at end points of a segment. The second difference, as specified in CCITT Recommendation I.610[25] and T1S1.5/92-029R3[26], is that PM cells are "forced" into the connection when necessary to ensure that a fixed average block size is maintained. However, the actual size of any given block may vary $\pm$ 50% from that nominal value. This variation allows PM cells to be inserted without delaying the flow of user cells in most cases.

(R)-131 Network equipment at a B-ICI shall support end-to-end performance monitoring for specified VPC/VCC connections. This entails following the same requirements as for segment performance monitoring, except that the generation of Performance Management cells occurs at connection end points, and an average block size is enforced.

6.2.3.3 OAM Activation/Deactivation Functions at the B-ICI

This Section presents the procedure for activating and deactivating the VP/VC level performance monitoring function across a B-ICI. The procedures presented here apply to equipment at a B-ICI activating the monitoring function for either end-to-end VP/VC connections or VP/VC segments, *as long as at least one connection/segment end point is at a B-ICI*. The term "connection/segment" is used to refer to either the entire end-to-end VP/VC connection or a segment of it. One or both end points of the connection/segment may be at a B-ICI, as shown in Figure 6.13.

Figure 6.13 Examples of Performance Monitoring of Connections and Segments

The activation/deactivation of VP/VC performance monitoring at a B-ICI is a system management function, initiated by the appropriate Management System through the Telecommunications Management Network (TMN). Activation/deactivation cells are used in the network to provide "handshaking" between the two ends of the connection/segment. The performance monitoring activation/deactivation "handshaking" procedure is an ATM Layer Management function that serves two purposes: (1) to coordinate and synchronize the beginning or end of the transmission and downstream reception of PM OAM cells, and (2) to establish agreement, based on the system management activation/deactivation request, on the Block Size and the direction(s) of transmission to start or stop monitoring.

6.2.3.3.1 Activation/Deactivation Cell Payload Structure

The activation/deactivation cell format, as defined in CCITT Recommendation I.610[25] and T1S1.5/92-029R3[26], is shown in Figure 6.7, and each field is briefly described below.

Message	Value
Activate	000001
Activation Confirmed	000010
Activation Request Denied	000011
Deactivate	000101
Deactivation Confirmed	000110
Deactivation Request Denied	000111

Table 6.3 Message ID Field Values in the Activation/Deactivation Cell

- Message ID (6 bits): This field indicates the message ID for activating or deactivating VP/VC functions. Code values for this field are shown in Table 6.3.

- Directions of Action (2 bits): This field identifies the direction(s) of transmission to activate or deactivate the OAM function. The A-B and B-A notation is used to differentiate between the direction of user data transmission away from or towards the activator/deactivator, respectively. This field value is used as a parameter for the

"Activate" and "Deactivate" for A-B, '11' for two-way messages. This field shall be encoded as '01' for B-A, '10' action, and '00' (default value) when not applicable.

- Correlation Tag (8 bits): A correlation tag is generated for each message so nodes can correlate commands with responses.

- PM Block Sizes A-B (4 bits): This field specifies the A-to-B PM block size or block size choices supplied by the activator for Performance Monitoring. Each of the four bit positions in this field, from the most significant bit to the least significant bit, if set, indicates block sizes of 128, 256, 512, or 1024 user information cells, respectively. For example, a value of '1010' would mean that block size 128 or 512 may be used, but 256 and 1024 can not. This field value is used as a parameter for the "Activate" and "Activation Confirmed" messages. The default value for this field shall be '0000'.

- PM Block Sizes B-A (4 bits): This field specifies the B-A block size or block size choices supplied by the activator. It is encoded and used in the same manner as the PM Block Sizes A-B field.

6.2.3.3.2 PM Activation and Deactivation Procedures

The performance monitoring activation and deactivation handshaking procedures are illustrated in Figure 6.14. In the figure, the vertical flows represent messages or stimuli provided by an external source, such as a Management System via the TMN, to activate performance monitoring over a particular VP/VC connection or segment. The horizontal flows represent operations messages internal to the VP/VC itself via OAM cells. For the purposes of this specification, at least one, and possibly both, of the end points are at a B-ICI. The message flows for activating and deactivating performance monitoring (PM) are specified in CCITT Recommendation I.610[25] and T1S1.5/92-029R3[26].

Figure 6.14 Handshaking Procedure for PM Activation and Deactivation

The following two Sections provide a verbal description of the figure, to clarify the actions implied by the "handshaking" figure.

6.2.3.3.2.1 PM Activation Procedure

Below is a verbal description of the activation "handshaking" procedure.

o Request for PM Activation: An end user or Management System initiates a request at one end of the connection/segment. By definition, this end point is "A", and the other end point is "B". The initiation includes a specification of the direction(s) of PM to activate, and the requested block size(s) in the A-B direction (if appropriate) and the B-A direction (if appropriate). If end point A can accept the request, then end point A starts a (e.g., two-second) timer. If end point A can support the PM request, it sends an "Activate" message, including the block size value(s) and directions of action, to end point B.

o Send "Activation Confirmed" message or "Activation Request Denied" message: End point B determines which of the requested block size value(s) it can support. If it can support multiple block sizes for a direction, it picks one. If there is at least one valid block size (one in each direction, in the case of a two-way monitoring request), then it sends an "Activation Confirmed" message to end point A. End point B begins the following processes: (1) it generates PM cells, if PM was activated in the B-A direction[13], and (2) it waits to receive PM cells, if PM was requested in the A-B direction[14].

If end point B cannot support the PM activation request, it sends an "Activation Request Denied" message back to end point A. End point A informs the PM activation requester of the denial.

o Beginning of PM at End Point A: When end point A receives the confirmation, it begins the same activities that end point B did, where appropriate, and notifies its Management System that performance monitoring activities have begun.

6.2.3.3.2.2 PM Deactivation Procedure

The performance monitoring deactivation handshaking procedure is described below.

o Request for PM Deactivation: An end user or Management System initiates a request at one end of the connection/segment. By definition, this end point is "A", and the other end point is "B". The initiation includes a specification of the direction(s) of PM to deactivate. The two PM Block Sizes fields are not used, and hence are coded as '0000'. End point A first determines whether PM cells are being generated in the requested direction. If not, the request is denied, and the PM deactivation requester is informed. If end point A can accept the request, then end point A starts a (e.g., two-second) timer. If end point A has no reason to deny the deactivation request, it relays a "Deactivate" message to end point B.

o Send "Deactivation Confirmed" message or "Deactivation Request Denied" message: If end point B can honor the deactivation request, it sends a "Deactivation Confirmed" message to end point A. End point B makes sure that PM cells are not being

[13] I.e., if the "Direction of Action" field = '01' or '11'.
[14] I.e., if the "Direction of Action" field = '10' or '11'.

generated for the appropriate directions, if the deactivation request included the B-A direction.

If end point B can not support the PM deactivation request, it sends a "Deactivation Request Denied" message back to end point A. End point A informs the PM deactivation requester of the denial.

- Deactivation of PM at End Point A: When end point A receives the confirmation, it ends the same activities that end point B did, where appropriate, and notifies the appropriate Management System that performance monitoring activities have ended. If a "Deactivation Confirmed" message is not received before the timer expires, the request is denied, and the PM deactivation requester is informed.

More details on the PM activation/deactivation procedures are specified in TA-NWT-001248[27].

6.2.3.3.2.3 Responses and Actions Resulting from a Deactivation Request

The following matrix indicates the response that should be returned and the actions that should be taken when a deactivation request is received.

The matrix indicates the four possible PM states (across the top of the matrix) that the receiving switch can be in when it receives the Deactivation request. These four states are:

1. PM is not active,
2. PM is active in the user data flow A-B,
3. PM is active in both user data flows A-B and B-A, and
4. PM is active in the user data flow B-A.

There are three possible deactivation requests that can be received at B. They are:

1. Deactivate PM flow A-B,
2. Deactivate PM flow in both directions A-B and B-A, and
3. Deactivate PM flow B-A.

The matrix shown in Figure 6.15 shows all combinations of possible activation states and received deactivation messages. There are two items described in each location of the matrix: 1) the response to the deactivation request by B, and 2) the action taken by B.

6.2.3.3.3 Performance Monitoring Activation/Deactivation Requirements

(R)-132 In support of on-demand VP/VC Performance Monitoring for connections and/or segments terminated at a B-ICI, network equipment at a B-ICI shall provide the capability of activating and deactivating the VP/VC Performance Monitoring function according to the procedures specified in I.610[25] and T1S1.5/92-029R3[26], and described in Section 6.2.3.3.2.

In order to provide for early interoperability, initially only one-way activation is required.

(R)-133 Network equipment at a B-ICI that receives an "Activate" message for Performance Monitoring shall support requests for PM in the direction of A-B (i.e., when the "Directions of Action" field = '10'). It may also support activation requests for the direction B-A or for bi-directional activation (both A-B and B-A).

Figure 6.15 Responses to PM Deactivation Requests

(R)-134 When network equipment at a B-ICI receives an "Activate" or "Deactivate" message for Performance Monitoring, it shall send the appropriate return message within 1 second.

(R)-135 Network equipment at a B-ICI can disable Performance Monitoring even if no response is received, or a denial is received, from a deactivation request. For interoperability, the network equipment at a B-ICI shall send the deactivation request before disabling Performance Monitoring.

Network equipment at a B-ICI may choose to collect data on any VP/VC it terminates or accesses, on which Performance Monitoring is active (i.e., when PM cells flow over the connection/segment). Data collection is performed when requested by the appropriate Management System.

6.3 Additional Operations Considerations

Agreement will be needed on aspects of some service management processes to allow carriers to negotiate and manage ATM connections that cross the B-ICI. Figure 6.16 shows exchange of management information between carriers. Agreement is also needed on which management data

should be exchanged. This will satisfy a short-term need to support manual methods, and provide a basis for establishing automated interfaces (where appropriate) in the future. It is acknowledged that some management information exchange may be unique between a given pair of carriers; such exchanges may be defined via bilateral agreements.

In this release of the B-ICI Specification, some guiding principles and a framework for further work is provided.

The following guidelines are proposed:

- Management information for inter-carrier CRS, FRS, and SMDS should be exchanged between carriers using existing methods where appropriate. For example, it is desirable that the ATM-specific aspects of procedures for FRS and SMDS, be consistent with the procedures of the Frame Relay Forum's (FRF's) Inter-Carrier Committee (see [29]) and the SMDS Interest Group's (SIG's) Inter-Carrier Working Group (see [30] and [31] where applicable.

- Management information to be exchanged between carriers should be identified by examining service management processes. (These processes are defined below.)

- This Section should document agreements on ATM network-specific information to be exchanged, or changes in existing procedures.

6.3.1 Service Management Processes

The need for management information exchange between carriers will be identified by analyzing the service management processes (i.e., work processes) required by carriers to offer service. The activities that may require the exchange of management information between carriers may be categorized as:

- *o* Service Activation and Deactivatiivation: "Service Activation" refers to the set of activities required to establish new service (e.g., a new CRS connection) for a customer. The term "Ordering and Provisioning" is sometimes used. "Service Deactivation" refers to the activities required to terminate a service for a customer.

Procedures exist for one carrier to order non-ATM-based services from another carrier, so procedures and systems are in place that can be modified or supplemented to support ATM. In addition, procedures are being defined for FRS and SMDS for ordering and provisioning these two services.

Figure 6.16 Exchange of Management Information Between Carriers

- Service Assurance: "Service Assurance" refers to the set of activities required to maintain the services provided to customers. It may be reactive (responding to troubles reported by a customer) or pro-active (e.g., continuous monitoring of the network to detect alarms). This includes activities such as Trouble Administration and Performance Monitoring.

Trouble administration includes: one carrier detecting a trouble and reporting it to another carrier, one carrier requesting trouble status information from another, and a carrier asking the carrier with the trouble for its estimate of the required repair time. Other activities are possible. Procedures to support a B-ICI should be consistent with existing procedures, with modifications or supplements to satisfy ATM-specific needs.

Carriers may exchange management information about traffic and performance of B-ICI links and connections within those links. This can include information about both the ATM layer and the service layer.

- Usage Metering: "Usage Metering" refers to the activities required to gather the information needed to support accounting management for services. Procedures to exchange accounting information between carriers have been specified for non-ATM-based services, so those procedures and systems can be modified or supplemented to support ATM. It is desirable that the procedures for usage metering for CRS, and the ATM-specific aspects of usage metering for CES, FRS or SMDS on a B-ICI, be consistent with similar procedures defined elsewhere. (For example, see [29] and [31].)

6.3.2 Management Information to Be Exchanged Between Carriers

Below are various types of information that may be exchanged between carriers. The list below is an initial framework for future efforts to make a more detailed specification. In the discussion of each type, examples are given.

a. General System and B-ICI Information: This includes general system and B-ICI information, such as the system's name, location, the contact person, interface description (e.g., DS3, STS-3c), and administrative status (e.g., In-Service, Out-of-Service).

b. Ordering and Provisioning Information: This is information needed for one carrier to order service from another, except for configuration information, which is listed separately. The procedure followed will vary depending on factors such as whether physical facilities already exist, or whether the service already exists on the B-ICI (e.g., an order may be the first request for CRS on an established B-ICI that currently carries only FRS). The procedures used for the physical layer should be very similar to today's procedures. It will include information such as the service being ordered, the required bandwidth, a requested VPI/VCI, and the date for which service is requested.

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c. Physical Layer and ATM Layer Specific Configuration Information: This information type includes physical and ATM-layer configuration information about a B-ICI. This allows carriers to confirm that they share the same view of the B-ICI at the physical and ATM layers. This type of information would be used by multiple service management processes. Configuration information for B-ICIs should include physical-level and ATM-level items such as:

— Physical: Switch ID, B-ICI physical link ID, transmission type, and media type.

— ATM Layer: Maximum number of VPCs, number of configured VPCs; maximum number of VCCs, and number of configured VCCs.

— VP Layer: VPI, and the following, if applicable: shaping descriptor, policing traffic descriptor, and QOS Category.

— VC Layer: VCI, and the following, if applicable: shaping descriptor, policing traffic descriptor, and QOS Category.

In order to satisfy customers desiring high-reliability service across a B-ICI, it is desirable for carriers on each side of a B-ICI to have the information required to quickly reroute or quickly reconfigure traffic to an alternate route in the event of a failure. An example of this would be to pre-provision a VPC/VCC that will serve as an alternate route when a fault is detected in the primary route.

d. Service-Specific Configuration Information: Service-specific configuration information will also be needed. Principles for specifying FRS and SMDS specific information will be established in the FRF's Inter-Carrier Working Group and SIG's Inter-Carrier Working Group. (See references [29], [30], and [31].) This Section should point to service-specific configuration information in those documents, where applicable. (More detailed information is also available in [32] for SMDS and [33] for FRS.)

e. Accounting Information: Accounting information gathered by a switch may be used to support accounting management arrangements between carriers and between a carrier and its customers. Carriers will have to agree, for a B-ICI or connections on a given B-ICI, what method is used to exchange accounting information. In addition, carriers will also need to reach agreement about inter-company billing arrangements and/or cost separations, but these issues are beyond the scope of this document. Issues should be similar to those for existing services.

f. Trouble Administration Information: This includes information such as description of trouble (e.g., "failed physical facility"), trouble status information (e.g., "under investigation"), and estimated repair time. Much of this information should be similar to that used for existing (non-ATM) services, but some information should be specific to ATM.

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g. Performance Information: This includes physical-layer performance information, information about cell traffic at the ATM layer, and information about service traffic at the service layer. Examples of performance information at the ATM layer include: cells transmitted at a B-ICI, cells received at a B-ICI, and cells dropped at a B-ICI.

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7 B-ICI Signaling

Initial B-ICI Specification in this document addresses PVC-based inter-carrier services support which does not require signaling. Network signaling required to support SVC-based inter-carrier services on a B-ICI will be considered in the future Versions of this document.

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8 PVC-Based Inter-Carrier CRS Support on a B-ICI

The PVC-based ATM Cell Relay Service (CRS) is one of the inter-carrier services supported by a multi-service B-ICI. This Section provides the definition, service specific functions (U-Plane), traffic management and network performance, and operations for supporting the inter-carrier CRS on a B-ICI.

Network configurations supporting services across a B-ICI can be very different, depending on the topology and the number of carriers involved. The ATM network segment provides transport functions, and it may also include service layers on the top, where the ATM layer protocol is terminated and the service specific functions are processed.

8.1 Definition

The ATM Cell Relay Service (CRS)[34] [35] is a cell-based, information transfer service which offers users direct access to the ATM layer at virtually any rate up to the access line rate. An end-to-end user access configuration for this service is shown in Figure 8.1. The supported ATM connections can be of two types: Virtual Path Connection (VPC), and Virtual Channel Connection (VCC), depending on which ATM sublayer[36] they refer to. The inter-carrier connectivity is obtained by establishing a VCC and/or a VPC at the B-ICI, with a Quality of Service (QOS) suitable to meet the QOS requested by the user for the end-to-end connection.

The CRS allows flexibility in carrying various user application traffic streams. It supports both Constant Bit Rate (CBR) and Variable Bit Rate (VBR) applications. The CRS can be used with an appropriate ATM Adaptation Layer (AAL) to support a given application. Initially, the CRS will be supported via provisioned PVCs. Switched CRS based on standard signaling protocols will follow.

This Section discusses the characteristics of the inter-carrier CRS based on the establishment of PVCs. The term (point-to-point) PVC denotes an ATM layer virtual connection (VPC or VCC) from a source ATM Service Access Point (SAP) to a destination ATM SAP, that allows transmission of sequenced ATM cells through the network. With PVC-based inter-carrier CRS, connections are established through a provisioning process, or a service order process. Multipoint capabilities allow communication from a set of source ATM SAPs to a set of destination ATM SAPs. No call establishment or call termination is associated with a PVC. The PVC connections are not switched by the end-user or the network.

Figure 8.1 Inter-Carrier CRS Support on a B-ICI

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8.1.1 Service Rates

The PVC-based inter-carrier CRS rates include up to the DS3, SONET STS-3c/OC-3, and STS-12c/OC-12 rates. Data transfer rates per VCC/VPC for the PVC-based inter-carrier CRS can range up to approximately 570 Mbps.

8.1.2 Communication Configuration

The inter-carrier CRS supports point-to-point, multipoint, and multicasting communication configurations[34] capabilities between the public ATM carrier networks. Multipoint capabilities include: (i) point-to-multipoint, (ii) multipoint-to-point, and (iii) multipoint-to-multipoint connections. Multicasting capabilities include broadcasting capabilities. The configurations of information flows that can be established include uni-directional, bi-directional symmetric, and bi-directional asymmetric.

8.1.3 Originating, Terminating, and Transit Inter Carrier CRS

The PVC-based inter-carrier CRS offers originating, terminating, and transit capabilities. Once a connection is established between two carriers, both carriers can transmit and receive correctly formatted ATM cells across the B-ICI. Each carrier processes the ATM cell header to determine the routing information based on VCIs and VPIs. A carrier provides originating inter-carrier CRS when, upon receipt of ATM cells from an end-user, it delivers the cells to the other carrier. A carrier provides terminating inter-carrier CRS when receiving ATM cells from another carrier, for delivery directly to an end-user. A carrier provides transit inter-carrier CRS when receiving ATM cells from a carrier and relaying them to another carrier.

The originating PVC-based inter-carrier CRS supports the service features offered by the Carrier A to the end-user. The terminating PVC-based inter-carrier CRS supports the service features offered by the Carrier B to the Carrier A. For the originating PVC-based inter-carrier CRS, the arrangement of VPCs and/or VCCs established by an end-user is maintained as the Carrier A delivers cells to the Carrier B. For the terminating PVC-based inter-carrier CRS, the arrangement of VPCs and/or VCCs received by the Carrier B from the Carrier A is maintained.

8.1.4 Carrier Selection

The PVC-based CRS allows carrier selection on a pre-selection or pre-subscription basis. The explicit carrier selection feature does not apply for the PVC-based CRS.

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8.1.5 Addressing

In general, PVC-based services are offered, for example, by the use of a service order arrangement. The source and destination points of a PVC are pre-defined, and they are fixed for the duration of the connection. Thus, PVC-based CRS, for a point-to-point connection, uses the VPI (for VP service), or VPI/VCI (for VC service) fields as a locally significant address at each end to represent the desired destination(s). These fields are processed by the ATM network element to determine the connecting points and end-points of the ATM connection.

8.1.6 Routing

The routing process for PVC inter-carrier CRS provides a fixed path between the known source and destination points. For the PVC-based CRS, route determination is part of the provisioning and service order process, and will be static. Alternate routing for PVC-based CRS could also be pre-established in those situations when the direct route is not available (e.g., in a failure situation). Alternate routing can be offered as an inter-carrier CRS feature. Coordination of alternate routes between carriers is for further study.

8.1.7 Performance and Quality of Service Objectives

For the PVC-based ATM CRS, only the "information transfer phase" is considered here; the "call establishment" and "call release" phases will be considered for SVC-based ATM CRS in a later Version of this document. The generic performance criteria[37] include the primary (i.e., directly observable) performance parameters, and the derived (i.e., calculated from the primary performance parameters) performance parameters. The first three of the following objectives are the primary performance parameters, and the fourth one is a derived performance parameter:

— Speed (Delay and Bandwidth)

— Accuracy

— Dependability

— Availability

The above objectives are defined by the parameters including[38] : Cell Transfer Delay, Cell Delay Variation (CDV), Cells Mis-insertion Rate, Cell Error Ratio, Cell Loss Ratio, Mean Time Between Service Outages, and Mean Time to Restore.

8.2 CRS Specific Functions

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This Section addresses B-ICI service specific functions (U-Plane) above the ATM layer, for example, ATM Adaptation Layer (AAL), and network interworking, where applicable.

For the inter-carrier CRS, B-ICI related service specific functions (above the ATM layer) in the U-Plane are not applicable for this Version of the document.

8.3 CRS Traffic Management and Network Performance

This Section provides CRS specific traffic management functions and network performance considerations that are required for a B-ICI.

8.3.1 Traffic Management

Traffic management impacts for CRS at a B-ICI are considered here. These are the additional information (beyond that needed for the B-ICI traffic contract) that should be exchanged between carriers to increase the efficiency of each carrier's CAC function, and the preservation of EFCI function's integrity across a B-ICI.

A carrier's CAC function and its engineering of its network portion can generally by facilitated by the availability of additional information beyond that required for the carrier-to-carrier traffic contract at a B-ICI, as given in Section 5.2. Additional information that may — subject to bilateral agreement — be exchanged for a VCC carrying CRS includes (as part of the Source Traffic Descriptor) a VCC's Sustainable Cell Rate and Burst Tolerance[19]. This additional information should be included for both the CLP = 0 and CLP = 0+1 cell streams on any VCC carrying CRS whenever a carrier supports both of these cell streams.

8.3.2 Network Performance

For this Version of the B-ICI Specification, no additional performance considerations are included beyond those given in Section 5.1. Section 5.1 makes use of the ATM layer network performance parameters defined in[19].

8.4 CRS Operations and Maintenance

For the inter-carrier CRS, the common B-ICI operations and maintenance provided in Section 6 apply.

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9 PVC-Based Inter-Carrier CES Support on a B-ICI

The PVC-based Circuit Emulation Service (CES) is one of the inter-carrier services supported by a multi-service B-ICI. This Section provides the definition, service specific functions (U-Plane), traffic management and network performance, and operations for supporting the inter-carrier DSn (n = 1, 3) CES on a B-ICI. (Note: DS1 and DS3 sub-rate grooming capability is not considered part of the CES support on the B-ICI.)

9.1 Definition

Circuit Emulation Service (CES) provides support for transporting CBR signals (or "circuits") using ATM technology. An example of this service is DS1 and DS3 circuit emulation. The CES allows the CBR users to communicate with each other using an ATM UNI or a DSn interface supported by the respective carriers, and with a B-ICI providing the inter-carrier connectivity.

Figure 9.1 shows examples of CES and its role in supporting CBR services.

In Case (a), a B-ICI supports the transport of DSn signals between the Carrier A and Carrier B networks which are connecting the users with the ATM UNIs at both ends. In this Case, a B-ICI supports the inter-carrier CBR service using CRS. *(Note: This case is covered under the CRS if the AAL Type 1 is only present in the Customer Premises Equipment (CPE), If the network supports the AAL Type 1, higher layer requirements on the B-ICI will apply).*

In Case (b), a B-ICI supports the transport of DSn signals between the Carrier A and Carrier B networks which are connecting the users with an ATM UNI on one end and a DSn interface at the other end. In this Case, a B-ICI supports the inter-carrier CBR service using network interworking functions and the AAL Type 1 performed by the Carrier B.

In Case (c), a B-ICI supports the transport of DSn signals between the Carrier A and Carrier B networks which are connecting the users with the DSn interface at both ends. In this Case, a B-ICI supports the inter-carrier CBR service using network interworking functions and the AAL Type 1 performed by both the Carrier A and Carrier B.

9.2 CES Specific Functions

This Section provides the B-ICI service specific functions (U-Plane) above the ATM layer, for example, ATM Adaptation Layer (AAL), and network interworking, where applicable.

The Circuit Emulation Service (CES) specific functions at the sending end converting a DSn signal into ATM cells, and at the receiving end converting the stream of ATM cells back into a DSn signal are shown in Figure 9.2. This Section describes the CES specific interworking functions between the DSn and Convergence Sublayer (CS), and between the CS and DSn, as a

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signal flows from the sending end to the receiving end. In addition, the functions performed by the AAL Type 1 SAR and CS, are also identified.

Figure 9.1 CBR Services Support Using Inter-Carrier CES on a B-ICI

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Figure 9.2 CES Specific Functions at the Sending and Receiving Ends

Circuit emulation of Constant Bit Rate (CBR) service, such as DS1 or DS3, is supported with the functions of the CBR ATM Adaptation Layer (AAL) which resides above the ATM Layer. The subset of CBR AAL functions and protocols used to support DS1/DS3 circuit emulation are referred to as Unstructured Data Transfer[15] (UDT).

9.2.1 CBR AAL Functions

This Section describes the CBR AAL functions used to support UDT for DS1 and DS3 circuit emulation. The CBR AAL consists of two sublayers, the Segmentation and Reassembly (SAR) sublayer and the Convergence Sublayer (CS). The SAR sublayer is the lower sublayer and the CS is the higher sublayer of the AAL.

Sending End:

At the sending end, DS1 or DS3 termination functions and the interworking between the DSn and CS of the AAL Type 1 are performed.

At the sending AAL-entity, the CS performs the following functions:

1. Blocks DS1 and DS3 bits into 47-octet CS_PDUs for transport as SAR_PDU payloads.

2. Generates sequence count cycle values (Modulo 8) to be associated with each 47-octet CS_PDU blocked.

3. Uses the Synchronous Residual Time Stamp (SRTS) method for clock recovery when a common reference clock is available on both sides of the B-ICI. When a common reference clock is not available, other methods (e.g., Adaptive Clock Recovery) could be used.

4. Specifies the Convergence Sublayer Indicator bit value associated with each sequence count value and 47-octet CS_PDU.

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[15] The transfer of AAL-user information supported by the CBR AAL when the AAL-user data transferred by the AAL is not organized into data blocks.

5. Passes the information to the sending-AAL SAR for the generation of SAR_PDUs.

At the sending AAL-entity, the SAR sublayer performs the function of generating the SAR_PDU header, and the SAR_PDU from information parameters provided by the sending-AAL CS. The AAL Type 1 SAR_PDU structure is shown in Figure 9.3.

Figure 9.3 AAL Type 1 SAR_PDU Structure

The sending AAL-entity also assumes in the case of DS1 and DS3 circuit emulation that DS1 and DS3 Loss of Signal (LOS) detection is performed as an interworking function to support fault location. This is required by the ANSI CBR AAL standard. The generation of a DS1 or a DS3 Alarm Indication Signal (AIS) in response to a LOS condition may also be needed as an interworking function, but this is an open issue in standards. LOS and AIS detection are discussed further in Section 9.4.

Receiving End:

At the receiving AAL-entity, the SAR sublayer performs the function of processing cell payloads received as SAR_PDUs to recover the SAR_PDU header and 47-octet SAR_PDU payload of AAL user information, checking the integrity of the SAR_PDU header (i.e., bit error correction/detection), and passing information parameters to the receiving-AAL CS.

At the receiving AAL-entity, the CS performs the following functions[16]:

1. Recognizes a starvation condition to exist when no AAL_SDUs (i.e., user information bits) are available to pass to the AAL user. The starvation condition is cleared through the arrival of CS_PDUs.

2. Detects the loss of CS_PDUs due to cell loss events which do not result in a starvation condition. (These events are detected using the cyclic sequence count values.)

3. Triggers the generation of dummy AAL_SDUs corresponding to a DS1 or DS3 Alarm Indication Signal (AIS) to maintain bit count integrity to the AAL user. For the case of cell loss which results in no starvation condition the AIS generation shall be done in

[16] Detailed specifications associated with these functions and further discussion of SRTS clock recovery, can be found in the ANSI CBR AAL standard.

47-octet segments which replace the AAL_SDUs associated with the CS_PDUs identified as lost. For the case of a starvation condition the AIS generation continues until the starvation condition is cleared and normal operation is resumed.

4. Recovers the DS1 or DS3 asynchronous clock using the SRTS method if the SRTS method is used at the sending end. Other methods (e.g., Adaptive Clock Recovery) could be used when SRTS is not supported.

5. Deblocks the 47-octet CS-PDUs and uses the recovered clock to pass the AAL_SDUs (i.e., user information bits) to the AAL user.

At the receiving end, no CS/DSn interworking functions are performed.

(R)-136 Network equipment associated with a multi-service B-ICI supporting DS1 or DS3 CES shall support CBR AAL Unstructured Data Transfer (UDT) functions as specified in ANSI T1.CBR[39].

9.3 CES Traffic Management and Network Performance

This Section provides CES specific traffic management functions and network performance considerations that are required for a B-ICI.

9.3.1 Traffic Management

A carrier's CAC function and its engineering of its network portion can generally by facilitated by the availability of additional information beyond that required for the carrier-to-carrier traffic contract at a B-ICI, as given in Section 5.2. Additional information may — subject to bilateral agreement — be exchanged for a VCC carrying the CES.

9.3.2 Network Performance

For this Version of the B-ICI Specification, the network performance considerations are as given in Section 5.1, including use of the ATM layer network performance parameters defined in[19]. DS3 and DS1 CES should receive a QOS class[19] having a stringent objective for Cell Loss Ratio.

9.4 CES Operations and Maintenance

This Section provides the AAL Type 1 operations above the ATM layer. Operations for layers above the AAL are not discussed in this Version. Section 9.4.1 discusses operations for the

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common part of the AAL Type 1, and Section 9.4.2 discusses operations for the service specific part of the AAL Type 1.

9.4.1 Operations for Common Part of the AAL Type 1

This Section specifies performance measurements needed to monitor service independent errors for AAL Type 1. Performance measurements are needed at AAL Type 1 entities to record errors in transmission.

At the sending Interworking Function (IWF)[17], it is possible that the ATM Layer is not providing adequate transport for the SAR_PDUs sent by the AAL Type 1. In this case, the sending IWF can become congested and SAR_PDUs may be discarded. At the sending IWF, the following error condition may occur:

- Congestion at the sending IWF: The number of SAR_PDUs discarded to relieve congestion should be counted.

At the receiving IWF, the following error conditions may occur:

- Buffer overflows: The number of SAR_PDUs dropped should be counted.

- Cell losses: Cell loss is detected through sequence count value violations during non-starvation conditions. The number of cell payloads identified as lost is estimated.

- Starvation conditions: Starvation conditions occur when no cells are in the buffer of the receiving IWF. The AAL Type 1 reports the status of a starvation condition by reporting the start and stop times of AIS generation. The number of starvation events during a measurement interval, and the total time in the starvation condition, should be measured.

(R)-137 Network equipment at a B-ICI performing receiving IWF functions (with an AAL Type 1 supporting UDT) shall measure buffer overflows, cell loss, number of starvation events, and time in the starvation condition.

A typical value for a measurement interval could be 15 minutes, and at least 8 hours of history should be kept. The measurement interval and amount of history data will be established by bilateral agreements between the carriers.

9.4.2 Operations for Service Specific Part of the AAL Type 1 and IWF

[17] The sending and receiving IWFs are illustrated in Figure 9.4.

This Section discusses the operations functions required to support Unstructured Data Transfer (UDT), which is used to support the inter-carrier DS1/DS3 Circuit Emulation Service (CES). As discussed in the AAL Type 1 Standard[39], many of the operations functions that will be discussed in this Section are considered "common". However, AAL Type 1 is not formally divided into a common part and a service-specific part. Thus, although the text in this discussion is written in the service-specific context of DS1/DS3 CES, many of the functions are expected to be generic for all services supported by AAL Type 1.

As discussed in Section 9.2, the DSn/Convergence Sublayer (CS) interworking at the sending Interworking Function (IWF) *must* detect LOS. (This is a requirement stated in the AAL Type 1 Standard[39]). LOS is declared when 175 $\pm$ 75 consecutive 0s, or no pulses, are received.

(R)-138 A sending IWF supporting UDT at a B-ICI shall detect LOS, as specified in ANSI T1.CBR-1993[39].

DSn/CS interworking may also detect Loss of Frame (LOF) and report it to the DSn/CS interworking function as an LOS.

Upon detection of LOS by DSn/CS interworking, two possible options are: (a) the AAL Management can suspend the AAL Type 1 generation of SAR_PDUs, or (b) the AAL Type 1 user (i.e., DSn/CS interworking) can generate a DSn Alarm Indication Signal (AIS) and map it into SAR_PDUs. A drawback of option (a) is that the receiving IWF cannot distinguish between an ATM failure or not. The implementation of option (b) will result in no problem detected at the receiving AAL Type 1 entity when a DSn problem has been detected prior to the DSn signal being converted to ATM cells. The AIS will be detected by DSn equipment downstream of the AAL Type 1 entity. Alarms detected at the receiving IWF will indicate problems in the ATM network only.

(R)-139 Network equipment at a B-ICI performing sending IWF functions (with an AAL Type 1 supporting UDT) shall generate a DSn AIS signal, and map it into SAR_PDUs, upon being informed of an LOS by DSn/CS interworking.

The above requirement only applies when the LOS is first detected at the sending IWF. If the sending IWF receives a DSn AIS from an upstream device, it simply transports the AIS. If a fault occurs within the ATM network resulting in a starvation condition occurring at the receiving IWF, the AAL Type 1 at that IWF shall generate dummy AAL-SDUs corresponding to a DSn AIS. Figure 9.4 shows the various places a fault may occur, and the resulting actions in the network.
[Note: DSn Xcon. = DSn Cross-connect; ATM Sw. = ATM Switch].

Figure 9.4 Alarm Propagation Behavior for Different Fault Locations

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10 PVC-Based Inter-Carrier FRS Support on a B-ICI

The PVC-based Frame Relay Service (FRS) is one of the inter-carrier services supported by a multi-service B-ICI. This Section provides the definition, service specific functions (U-Plane), traffic management and network performance, and operations for supporting the inter-carrier FRS on a B-ICI.

10.1 Definition

The FRS[40] is a connection-oriented data transport service that provides for the bi-directional transfer of variable-length packets for LAN interconnection and terminal-host applications[41].

The FRS[42] requires the initial establishment of end-to-end connections, either through provisioning or call setup procedures. Initial FRS will be based on provisioned PVCs. Requirements for SVC-based FRS are expected to follow in future Versions of this document. Customer access to the FRS will initially be over service specific customer interface. The carrier network or Broadband Customer Premises Equipment (B-CPE) provides an interworking function to convert FRS data to ATM cells as detailed later in this Section.

The inter-carrier FRS[43] includes the following[44]:

- Service Characteristics and Attributes: These include FRS rates, FRS feature transparency, and service features, e.g., point-to-point, multipoint, multicasting.
- Network Assumptions
- Carrier Selection
- Addressing
- Routing
- Performance and Quality of Service Objectives: For the PVC-based ATM FRS, only the "information transfer phase" is considered here; the "call establishment" and "call release" phases will be considered for SVC-based ATM FRS in a later Version of this document. The generic performance criteria[37] include the primary (i.e., directly observable) performance parameters, and the derived (i.e., calculated from the primary performance parameters) performance parameters. The first three of the following objectives are the primary performance parameters, and the fourth one is a derived performance parameter:
  - — Speed (Delay and Bandwidth)
  - — Accuracy

— Dependability

— Availability

The above objectives are defined by the parameters including[45]: Frame Transfer Delay, Residual Errored Ratio, Frame Loss Ratio, Bit Loss Ratio, Extra Frame Rate, Mean Time Between Service Outages, and Mean Time to Restore.

10.2 FRS Specific Functions

This Section describes a FRS specific functions including the FR//BISDN Inter-Working Function (IWF) which is required to support carriage of PVC FRS across a multiservice B-ICI. This IWF conforms to the CCITT Recommendations I.555[46] and I.365.1[47].

Figure 10.1 illustrates three FRS access configurations labelled A1 through A3 (or B1 through B3) supported by the B-ICI. Interconnection between any of the access configurations shall be supported. These interconnections lead to six possible reference configurations. A complete list of reference configurations is:

1. A1 to B1
2. A1 to B2
3. A1 to B3
4. A2 to B2
5. A2 to B3
6. A3 to B3

Figure 10.1 FRS Support on an ATM-based Multi-Service B-ICI

Figure 10.1 does not imply any particular physical location for an IWF. Three examples of where the IWF may be implemented are illustrated in Figure 10.2. From the perspective of the B-ICI, all of the examples are functionally equivalent (i.e., provide the same IWF).

Figure 10.2 Example Realizations of IWF Which are Equivalent for the B-ICI

(a) - Possible realization of access configuration A2 or A3 from Figure 10.1

(b) - Possible realization of access configuration A1 or A2 from Figure 10.1
(c) - Possible realization of access configuration A1 or A2 from Figure 10.1

10.2.1 Network Inter-Working Scenarios

There are two Network Interworking scenarios that are defined in the CCITT Recommendation I.555[46]. Scenario 1 connects two Frame Relay Networks/CPE using BISDN. Scenario 2 connects a Frame Relay Network/CPE with a B-CPE using BISDN. These two scenarios cover the six reference configurations that are described earlier. These two scenarios showing network interworking between Frame Relay Bearer Service (FRBS) and BISDN are described below.

10.2.1.1 Network Inter-Working Scenario 1

The U-plane protocols associated with high speed interconnection based on ATM between two FR Network/CPE are shown in Figure 10.3.

The use of the BISDN network by two FR Networks/CPE is not visible to the end users. The end user protocol suites remain intact. The IWF provides all mapping and encapsulation functions necessary to ensure that the service provided to FR-CPE is unchanged by the presence of an ATM transport. See CCITT Recommendation I.555 [46] for more details.

The reference configurations that are supported by Network Inter-Working Scenario 1 are: A1-B1, A1-B2, and A2-B2 listed earlier.

Figure 10.3 Network Inter-Working Between FRBS and BISDN (I.555 Scenario 1)

10.2.1.2 Network Inter-Working Scenario 2

The U-plane protocols associated with interconnection between FR Network/CPE and a B-CPE are shown in Figure 10.4.

The use of the BISDN by a FR Network/CPE and a BISDN CPE is not visible to the FR end users. The BISDN CPE must support the FR Service Specific Convergence Sublayer (FR-SSCS) in its protocol stack. The IWF provides all functions necessary to ensure that the service provided to the FR-CPE is unchanged by the presence of an ATM transport. See CCITT Recommendation I.555 [46] for more details.

The reference configurations that are supported by Network Inter-Working Scenario 2 are: A1-B3 and A2-B3 listed earlier.

Reference configuration (A3-B3), B-CPE to B-CPE, is not explicitly covered by the CCITT Recommendation I.555 Network Inter-Working Scenarios. No IWF exists in the network for this configuration.

Figure 10.4 Network Inter-working Between FRBS and BISDN (I.555 Scenario 2)

10.2.2 Network Inter-Working Functions

The IWF provides functional mapping between FRS functions and BISDN functions. FRS features to be supported include the following:

1. Variable Length PDU Formatting and Delimiting
2. Error Detection
3. Connection Multiplexing
4. Loss Priority Indication
5. Congestion Indication (Forward & Backward)
6. PVC Status Management

Figure 10.5 illustrates the internal protocol architecture of the FR/BISDN IWF. The BISDN sublayers and the support of the above FRS features by these sublayers are described below.

10.2.2.1 Frame Formatting and Delimiting

The FRS Specific Convergence Sublayer uses a PDU format identical to Q.922 Core minus the CRC-16, FLAGs and zero bit insertion (Figure 10.6).

(R)-140 The FR/ATM IWF shall use the FR-SSCS as specified in [47].

(R)-141 The default (2 octet) address field format shall be supported.

(O)-7 The support of 3 and 4 octet address field formats is an option.

The Segmentation and Reassembly (SAR) and Common Part Convergence Sublayer (CPCS) of the ATM Adaptation Layer (AAL) Type 5 in conjunction with the ATM layer

ATM_user_to_ATM_user indication provides segmentation and reassembly (frame delimiting) for FR-SSCS PDUs.

(R)-142 The FR/ATM IWF shall utilize the AAL Type 5 CPCS and SAR as specified in the CCITT Recommendation I.363 [48] (Figure 10.7).

Figure 10.5 FR/BISDN IWF Internal Architecture

Figure 10.6 Structure of FR-SSCS-PDU With 2, 3, 4 Octet Header Formats (I.365.1)

Figure 10.7 AAL Type 5 Common Part (CP) PDU Formats (I.363)

10.2.2.2 Error Detection

The AAL Type 5 CPCS CRC-32 provides error detection over the FR-SSCS PDU.

10.2.2.3 Connection Multiplexing

The FR-SSCS can support connection multiplexing using the DLCI field. In addition, the ATM layer supports connection multiplexing using its VPI/VCI. CCITT Recommendation I.555[46] identifies two methods of multiplexing FR connections over BISDN:

1. **Many-to-One:** Multiple FR logical connections are multiplexed into a single ATM Virtual Channel Connection (VCC). Multiplexing is accomplished at the FR-SSCS sublayer using DLCIs.

(R)-143 The IWF shall support many-to-one multiplexing. The FR-SSCS DLCI value(s) used shall be agreed upon between the two ATM end systems (e.g., ATM end users or IWFs).

Many-to-one method may be used only for FR PVCs that terminate on the same ATM-based end systems (e.g., ATM end users or IWFs).

2. One-to-One: Each FR logical connection is mapped to a single ATM VCC. Multiplexing is performed at the ATM-layer using VPI/VCIs.

(R)-144 The IWF shall support one-to-one multiplexing. The FR-SSCS DLCI value used shall be agreed upon between the two ATM end systems (e.g., ATM end users or IWFs).

An objective is that many-to-one and one-to-one multiplexing schemes will interoperate.

10.2.2.4 Discard Eligibility and Cell Loss Priority Mapping

(i) Frame Relay to BISDN Direction

The network provider can select between two modes of operation for loss priority mapping in the FR to BISDN direction (Figure 10.8).

(R)-145 IWF equipment shall support both of the following two modes, selectable for each ATM connection:

Mode 1: The Discard Eligibility (DE) field in the Q.922 Core frame shall be copied unchanged into the DE field in the FR-SSCS-PDU header, and mapped to the ATM Cell Loss priority (CLP) of every ATM cell generated by the segmentation process of that frame.

Mode 2: The Discard Eligibility (DE) field in the Q.922 Core frame shall be copied unchanged into the DE field in the FR-SSCS-PDU header, and the ATM Cell Loss Priority (CLP) of every ATM cell generated by the segmentation process of that frame shall be set to a constant value (either 0 or 1). The value is decided when the ATM connection is set up, and is used for all cells generated from the segmentation process of every frame, until the ATM connection characteristics are changed.

(ii) BISDN to Frame Relay Direction

The network provider can select between two modes of operation for loss priority mapping in the BISDN to FR direction (Figure 10.8).

(R)-146 IWF equipment shall support both of the following two modes, selectable for each ATM connection:

Mode 1: If one or more ATM cell belonging to a frame has its CLP field set or if the DE field of the FR-SSCS-PDU is set, the IWF shall set the DE field of the Q.922 Core frame.

Mode 2: No mapping shall be performed from the ATM layer to Q.922 Core layer. The FR-SSCS-PDU DE field is copied unchanged to the Q.922 Core frame DE field, independent of CLP indication(s) received at the ATM layer.

Figure 10.8 DE/CLP Mapping

10.2.2.5 Congestion Indication

10.2.2.5.1 Congestion Indication (Forward)

Forward congestion indication is supported at the frame level with Forward Explicit Congestion Notification (FECN) and at the cell level with Explicit Forward Congestion Indication (EFCI).

(i) Frame Relay to BISDN Direction

Frame level FECN is not mapped to cell level EFCI (Figure 10.9).

(R)-147 The FECN field of the Q.922 Core frame shall be copied unchanged into the FECN field in the FR-SSCS-PDU. The EFCI field of all ATM cells shall be always set to '0'.

(ii) BISDN to Frame Relay Direction

Cell level EFCI is mapped to frame level FECN (Figure 10.9).

(R)-148 If the EFCI field in the last ATM cell of a segmented frame received is set, or if the FECN field of the received FR-SSCS-PDU is set, then the IWF shall set the FECN of the Q.922 Core frame.

Figure 10.9 FECN/EFCI Mapping

10.2.2.5.2 Congestion Indication (Backward)

Backward congestion indication is supported only at the frame level by the Backward Explicit Congestion Notification (BECN) field (Figure 10.10).

(i) BISDN to Frame Relay Direction

(R)-149 The BECN field in the FR-SSCS-PDU shall be copied unchanged into the BECN field of the Q.922 Core frame.

(ii) Frame Relay to BISDN Direction

(R)-150 The BECN field in the FR-SSCS-PDU shall be set to "1" by the IWF if either of the following two conditions is met:

1. BECN is set in the Q.922 Core frame relayed in the FR to BISDN direction, or
2. EFCI was set in the last ATM cell of the last segmented frame received in the BISDN to FR direction for this bi-directional connection (i.e., EFCI = 1 to FECN mapping was performed by the IWF in the BISDN to FR direction).

(O)-8 A mechanism may be needed to exit the congestion state dependent on the traffic activity of the ATM virtual channels. As an example (Figure 10.10), a timer can be used to reset the congestion state (condition 2 above) after a time period T if no new congestion information is received in the BISDN to Frame Relay (FR) direction. If the EFCI of the last cell of the next frame received is not set, the congestion state is cleared. Otherwise, the timer is restarted. The value of the FECN received in the FR-SSCS-PDU is not mapped to the BECN of the FR-SSCS-PDU in the opposite direction.

Figure 10.10 Congestion State Diagram for VCC

10.2.2.6 FR PVC Status Management

The management of the ATM layer and the FR PVC Status Management of the FR-SSCS layer can operate independently. Possible interaction between the FR PVC Status Management and the ATM PVC management are for further study. Each layer has its own responsibility for the layer management (e.g., some functions of the management in the ATM layer will be performed by usage of the OAM cell flows).

The management of FR PVCs for FR UNI and FR NNI will remain unchanged. The PVC management procedures described here only covers the management of the FR PVCs carried by the ATM network (i.e., FR-SSCS management). The protocol stacks of the IWF and the FRS supporting B-CPE with status management are shown in Figure 10.11.

Figure 10.11 Protocol Stacks of IWF and B-CPE With FR PVC Status Management

(R)-151 The management of the FR-SSCS layer shall be performed by bi-directional (symmetric) PVC management procedures adopted from the CCITT Recommendation Q.933 Annex A. Selection of specific options within the Q.933 Annex A shall be aligned with the FR Forum Implementation Agreement.

Note: This applies for the B-CPE emulating FR (Figure 10.1). This allows all six connection possibilities of Figure 10.1, including the A3 to B3 Case.

For FR PVC Status Management of FR connection(s) carried by an ATM VCC, DLCI = 0 is used to exchange PVC status management between IWF(s) and/or B-CPE emulating FR.

10.3 FRS Traffic Management and Network Performance

This Section provides FRS specific traffic management functions and network performance considerations that are required for a B-ICI.

10.3.1 Traffic Management

Traffic management impacts for FRS at a B-ICI are considered here. These are the additional information (beyond that required for the carrier-to-carrier traffic contract at a B-ICI) that can increase the efficiency of a carrier's CAC function, and the preservation of Frame Relay's Forward Error Congestion Notification (FECN), Backward Error Congestion Notification (BECN) and Discard Eligibility (DE) functions' integrity across a B-ICI.

A carrier's CAC function and its engineering of its network portion can generally by facilitated by the availability of additional information beyond that required for the carrier-to-carrier traffic contract at a B-ICI. Additional information that may — subject to bilateral agreement — be exchanged for a VCC carrying FRS are: FRS subscriber's Committed Information Rate (CIR), Excess Information Rate (EIR), Committed Burst Length (CBL) and Excess Burst Length (EBL)[40]. The Peak Cell Rate (PCR) and Sustained Cell Rate (SCR) associated with a FRS subscriber are also included with such additional information.

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It is important to preserve the integrity of the FECN, BECN and DE functions associated with FRS when that service is supported across a B-ICI. Congestion conditions in an ATM network segment generally cause the ATM layer EFCI code points to be set, and these EFCI code points require translation to the FRS layer FECN and BECN bits that are available to end users of FRS.

In the many-to-one scheme of multiplexing, a VCC may carry a large number of frame relay connections. In the one-to-one scheme of multiplexing, a VPC may carry a large number of VCCs carrying frame relay traffic.

When the number of frame relay connections carried on a single ATM connection is large, the aggregated frame relay traffic may be characterized by a peak cell rate. When the number of multiplexed connections is small, then the traffic at the ATM layer may need to be characterized by the traffic at the FRS layer alone.

Some initial guidelines for the inter-carrier FRS traffic characterization and enforcement including the relationship between Frame Relay's CIR/EIR and BISDN's PCR/SCR are provided in the Appendix A. Examples of ATM traffic conformance definitions to support FRS can be found in the 1993 ATM Forum UNI Specification[19].

10.3.2 Network Performance

Network performance parameters for Frame Relay have been defined[45]. These parameters are generally based on FRS "Frame" protocol data unit. No additional FRS specific performance considerations are included in this Version of the B-ICI Specification.

10.4 FRS Operations and Maintenance

This Section provides the AAL Type 5 operations above the ATM layer. Operations for layers above the AAL are not discussed in this Version. Section 10.4.1 discusses operations for the common part of the AAL Type 5, and Section 10.4.2 discusses operations for the service specific part of the AAL Type 5.

10.4.1 Operations for Common Part of the AAL Type 5

This Section specifies performance measurements needed to monitor errors for the common part of the AAL Type 5. Figure 10.12 shows the format of the common part of the AAL Type 5 PDU (I.363). In this Figure, the CPCS-UU is the Common Part Convergence Sublayer - User-to-User

indication field. It is used to transfer user-to-user information, and so is not monitored by the network.

Figure 10.12 Format of the Common Part of the AAL Type 5 PDU (I.363)

The following error conditions may occur at the receiving point:

- Invalid format of Common Part Indicator (CPI) field. The only valid value currently defined for the CPI field is all 0s.

- Length violation. An error occurs when the Length, which is measured in bytes, is not consistent with the length of the CPCS-PDU. If the length of the CPCS-PDU in bytes minus the value of the Length field is not in the range [8-55], the two are not consistent. One exception is when the Length field has a value of 0, which is an indication of a forward abort. This case shall not be counted as a length violation.

- Oversized Received Service Data Unit (SDU): This error condition occurs if a partial or whole CPCS-PDU is received in which the SDU (i.e., User Data) exceeds the maximum allowed length.

- CRC violation.

- If the receiving entity implements a reassembly timer (which is optional, as specified in I.363), then the number of timer expirations shall be counted.

(R)-152 Network equipment at a B-ICI terminating the AAL Type 5 common part shall count the occurrences of the listed errors at the receiving point.

A typical value for a measurement interval could be 15 minutes, and at least 8 hours of history should be kept. The measurement interval and amount of history data will be established by bilateral agreements between the carriers.

10.4.2 Operations for FRS Specific Part of the AAL Type 5

Operations for FRS specific part of the AAL Type 5 will be provided in future Versions of this document.

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11 SMDS Support on a B-ICI

Switched Multi-megabit Data Service[18] (SMDS) is one of the inter-carrier services supported by a multi-service B-ICI. This Section provides the definition, service specific functions (U-Plane), traffic management and network performance, and operations for supporting the inter-carrier) SMDS on a B-ICI.

11.1 Definition

SMDS is a public packet-switched service that provides for the transfer of variable length data units at high speeds, without the need for call establishment procedures. These data units can be transferred from a single source to single destination (single cast), or from a single source to multiple destinations (multicast). The integrity of each delivered data unit is preserved with a high degree of reliability. SMDS is specified such that, under normal conditions, end users' end-to-end protocols and applications easily ride on top of the SMDS service layer. This provides the capability of supporting user applications such as LAN interconnection, and data and image transfer. Customer access to the SMDS will initially be over a service specific customer interface, i.e., the SMDS Subscriber Network Interface (SNI). The carrier network provides an interworking function for the necessary encapsulation as detailed later in this Section. The impact of customer access to SMDS through ATM-based UNI will be considered in future Versions of this document.

The definitions[49] (Figure 11.1) of Exchange SMDS, Exchange Access SMDS, and Inter-Exchange SMDS follow:

- Exchange SMDS: Refers to the end-users in the same exchange serving area communicating using SMDS. A LEC offers the service to the end-users via a Subscriber Network Interface (SNI).

- Exchange Access SMDS: An access service provided by a LEC to an IEC to support the IEC's inter-exchange service offering. The IEC uses Exchange Access SMDS to originate and/or terminate the delivery of SMDS data units of the end users served directly by the LEC network.

- Inter-Exchange SMDS: Refers to end-users located in different exchange serving areas communicating using SMDS. An IEC offers the service to the end-user. In some jurisdictions, carriers may also offer inter-exchange service within an exchange serving area, if the source explicitly chooses the service of the IEC.

Because SMDS is a public switched service, LECs are expected to offer Exchange SMDS to the end users and Exchange Access SMDS to the IECs to support IECs' inter-exchange SMDS

[18] Within the European context, the connectionless data service, called Connectionless Broadband Data Service (CBDS), is specified in [ETSI ETS 300 217 CBDS], and includes SMDS as a subset. The considerations for the support of SMDS are applicable to the CBDS as well.

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offerings. LECs within an exchange serving area may also establish serving arrangements that define the way the LECs support the exchange and exchange access service each offers. Likewise, IECs also may make serving arrangements with one another to support their inter-exchange services.

11.1.1 Exchange SMDS

Exchange SMDS consists of the following features[50]:

- Carrier Selection[19] ;
- Individually Addressed Data Unit Transport;
- Local Communications for Multi-CPE Access Arrangements;
- Addresses;
- Source Address Validation;
- Group Addressed SMDS Data Unit Transport;
- Address Screening;
- Access Classes; and
- Multiple Data Units in Transit Concurrently (over the SNI).

In addition, the performance and quality of service objectives defined in[50] apply to Exchange SMDS.

Figure 11.1 Exchange SMDS, Exchange Access SMDS, and Inter-Exchange SMDS Definitions

11.1.2 Exchange Access SMDS

[19] The Carrier Selection feature defines how a carrier (serving the source) decides whether to provide Exchange SMDS or Exchange Access SMDS when an end user sends a data unit.

The source end user is the customer of the IEC for inter-exchange service; the IEC is the customer of the LEC for Exchange Access SMDS. The same SNI is used for Exchange and Exchange Access SMDS. The features of Exchange Access SMDS[49] include:

- o Individually Addressed Data Unit Transport;
- o Addresses (including addresses that identify geographical parts of North America, international addresses, and addresses structured as embodied Service Access Codes (SACs) and External SACs);
- o Carrier Selection (by pre-selection and explicit selection);
- o Source Address Validation;
- o Group-Addressed Data Unit Transport (inter-network aspects);
- o End-User Blocking;
- o Routing to IEC Networks; and
- o Other features at the SNI (i.e., Access Classes, Address Screening, and Multiple Data Units in Transit Concurrently).

In addition, the performance and quality of service objectives, and usage measurements to support billing for the Exchange Access SMDS defined in[49] apply.

To expedite the availability, Exchange Access SMDS features are phased in[51]. The first phase comprises all features of the Exchange Access SMDS except the following, which are considered as part of the Phase 2 deployment:

- o Address feature related to External SACs;
- o Carrier Selection feature related to explicit carrier selection;
- o Group-Addressed Data Unit Transport feature related to the (local) resolution option[49];
- o End-User Blocking.

The B-ICI defined in this document supports Phase 1 of the Exchange Access SMDS. To ensure compatibility, the B-ICI supports the Phase 2 features to the extent possible.

11.1.3 Inter-Carrier Serving Arrangements for SMDS

In many exchange serving areas, several carriers can provide telecommunications services. Each carrier may offer services separately to its customers. To provide SMDS, the carriers in an exchange serving area may choose to interoperate. To do so, the carriers establish serving arrangements that define locally the way in which the companies support the services that each offers.

For example, to provide Exchange SMDS to its customer, a LEC that serves the source end user may arrange to use the facilities of another LEC to reach those destinations that the latter LEC serves. The IECs may also make SMDS serving arrangements with one another that define the way in which the IECs support the inter-exchange services that each offers.

11.2 SMDS Specific Functions

This Section provides the SMDS specific functions (U-Plane), for example, network interworking, ATM Adaptation Layer (AAL), and the connectionless service layer.

To support SMDS, a carrier may provide processing at several different levels. These levels range from point-to-point traffic transport between carriers to full processing and routing of SMDS packets (e.g., Inter Carrier Interface Protocol Connectionless Service (ICIP_CLS) Protocol Data Units (PDUs)) based on their packet level addresses. The requirements in this document support configurations where each carrier provides full SMDS processing. Additionally, these requirements may support some configurations where not all carriers provide full SMDS processing; however, such configurations require further study.

11.2.1 SMDS/ATM Network Interworking Functions

This Section describes B-ICI related SMDS/ATM network interworking. In the case of SMDS, when a non-ATM user is connected to a Carrier A's ATM network, this Carrier performs some SMDS/ATM network Inter-Working Functions (IWF) as part of the inter-carrier service before it connects to another Carrier B's ATM network via a B-ICI. The SMDS/ATM network interworking functions that are likely to be performed by the originating Carrier A's network, as part of the processing before delivering to the destination Carrier B's network, include the following:

1. The IEEE 802.6-based SMDS Interface Protocol (SIP) is mapped to the ATM-based B-ICI protocols. This includes encapsulation of the SIP L3_PDU within an ICIP_CLS PDU. The CCITT AAL Type 3/4 is used to support the transport of an ICIP_CLS_PDU within ATM cells.

2. Mapping Functions (MF) include routing, carrier selection, group address resolution, etc.

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3. Mapping of SMDS related QOS and performance parameters to ATM related QOS Class and network performance parameters are addressed in a later Section.

The protocol architecture in Figure 11.2 illustrates the role of SMDS/ATM network interworking functions in supporting an end-to-end inter-carrier SMDS service using a B-ICI.

11.2.2 AAL Specification

This Section describes the AAL to support SMDS on the multi-service B-ICI. The AAL performs the functions necessary to adapt the ATM Layer service to the service provided by the SMDS specific layer above the AAL, called the ICIP Connectionless Service (ICIP_CLS) Layer for the B-ICI.

The AAL defined in this Section is based on the AAL Type 3/4 specification in CCITT Recommendation I.363[52]. The criteria in this Section represent a specific configuration of the more generic AAL Type 3/4 defined in [52]. This configuration facilitates interoperability with the pre-ATM SMDS. This Section defines the mapping of the protocol layer functions in [52] into interface criteria that may be easily verified.

As in reference[52], the AAL is divided into two sublayers: the Segmentation and Reassembly (SAR) Sublayer, and the Common Part Convergence Sublayer (CPCS). This Section defines the formats and procedures for the SAR Sublayer and the CPCS. The SAR sublayer and CPCS criteria apply to a single ATM layer connection (e.g., VCC) between the AAL entities.

Figure 11.2 An Example of SMDS/ATM Network Interworking Functions

Protocol Conventions:

The following conventions[20] are followed for the presentation of the AAL protocols:

- A protocol data unit (PDU) is a unit of data that is exchanged between peer entities within a particular layer. For example, peer Common Part Convergence Sublayer (CPCS) entities exchange CPCS_PDUs.

- In the specification of PDU formats, fields are depicted in the order of their transmission (i.e., from left to right). Likewise, the bits of each field are also transmitted left-to-right,

[20] The conventions for the presentation of the B-ICI Physical Layer specification (Section 3) differ from those presented here which applies to ATM Layer (Section 4) and ATM Adaptation Layer.

with the leftmost, or most-significant bit, transmitted first (see Figure 11.3). When decimal digits are used to represent the value of a field, the most significant bit of the binary representation of the digit is transmitted first.

Figure 11.3 Conventions for Specification of PDU Formats

11.2.2.1 SAR_PDU Format

The format of the SAR_PDU is shown in Figure 11.4 (I.363), along with the lengths of the fields. SAR_PDUs are created by adding a 2-octet SAR_PDU header and a 2-octet SAR_PDU trailer to each 44-octet unit of SAR_PDU payload. Units of SAR_PDU payload result from the segmentation of the variable-length CPCS_PDU. The requirements for the meaning and use of each field of the SAR_PDU are stated below.

(R)-153 The SAR_PDU shall have the format shown in Figure 11.4 (I.363).

Segment Type (ST)

(R)-154 The 2-bit Segment Type field shall be used to delimit CPCS_PDUs. The Segment Type field shall indicate whether the SAR_PDU contains the beginning of a CPCS_PDU (a Beginning of Message SAR_PDU); the continuation of a CPCS_PDU (a Continuation of Message SAR_PDU); the end of a CPCS_PDU (an End of Message SAR_PDU); or fully contains a CPCS_PDU (a Single Segment Message SAR_PDU). The field shall be encoded as in Table 11.1 (I.363)[21].

Figure 11.4 SAR_PDU Format (I.363)

Sequence Number (SN)

(R)-155 The 4-bit Sequence Number field shall be used by the AAL entity in receiving a CPCS_PDU to verify that all of the SAR_PDUs of the

[21] SSMs can never be generated at the B-ICI, because the header information at the CPCS and the ICIP_CLS Layer consumes an entire cell. However, the specification supports procedures for SSMs to be compatible with more general AAL implementations.

CPCS_PDU have been received and concatenated in the correct sequence. The value of this field is incremented (modulo 16) for each successive SAR_PDU derived from the same CPCS_PDU.

Table 11.1 Segment Type Values (I.363)

Value	Meaning
00	Continuation of Message (COM)
01	End of Message (EOM)
10	Beginning of Message (BOM)
11	Single Segment Message (SSM)

Multiplexing Identification (MID)

(R)-156 The 10-bit MID field shall contain information used to allow association of SAR_PDUs with a CPCS_PDU. The MID shall be the same for all SAR_PDUs of a given CPCS_PDU, and unique among CPCS_PDUs concurrently in transit in a given direction. Valid MIDs shall range from 1 to 1023. MID = 0 shall not be used.

The MID range is configured in this way to facilitate the transition from IEEE 802.6 to ATM. The value MID = 0 is excluded because it is a special value that may be treated differently by IEEE 802.6-based equipment and CCITT-compliant equipment[22].

SAR-PDU Payload

(R)-157 The 44-octet SAR_PDU Payload shall contain a portion of the CPCS_PDU. This field shall be composed of two subfields:

- User Information — This subfield shall contain up to 44 octets of a CPCS_PDU.

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22 IEEE 802.6-based equipment reserves MID = 0 for SSMs, which are never generated at the SMDS ICI. CCITT- compliant equipment uses MID = 0 only when it does not support multiplexing of multiple CPCS_PDUs on a single ATM layer connection, however, SMDS requires implementations that use multiplexing.

- Fill — This subfield shall contain a sufficient number of octets to completely fill the 44-octet SAR_PDU Payload after the User Information subfield is inserted. The Fill subfield shall be encoded with all zeros.

Length Indication (LI)

(R)-158 The 6-bit LI field shall indicate how many of the 44 octets of the SAR_PDU Payload contain User Information (i.e., a portion of a CPCS_PDU). For BOM and COM SAR_PDUs, this field shall indicate 44 octets. For EOM SAR_PDUs, this field shall take values 4, 8,.....44 octets. For SSM SAR_PDUs, this field shall take values 8, 12,.....44 octets.

(O)-9 The LI field value 63 should be used to indicate an Abort_SAR_PDU[52]. The Segment Type of an Abort_SAR_PDU should be encoded as EOM.

Cyclic Redundancy Check (CRC)

(R)-159 The 10-bit CRC shall provide for the detection of errors in the SAR_PDU. The value of the CRC field shall be formed by the coefficients of the polynomial remainder of the modulo 2 division by the generating polynomial $x^{10}+x^9-x^5+x^4+x+1$ of the product of x^{10} and the polynomial representing the content of the SAR_PDU. The polynomial representing the content of the SAR_PDU shall be generated by using the first bit of the SAR_PDU as the coefficient of the highest-order term.

11.2.2.2 SAR Sublayer Procedures

11.2.2.2.1 SAR Sender Procedures

Segmentation of the CPCS-PDU

(R)-160 A SAR sender shall segment each CPCS_PDU created into one or more units of SAR_PDU payload. Each unit of SAR_PDU payload shall contain 44 octets of the CPCS_PDU, with the exception of the last unit of SAR_PDU payload for a CPCS_PDU, which may contain less than 44 octets of the CPCS_PDU. The order of octets in the CPCS_PDU shall be preserved by the segmentation.

Creation of the SAR-PDUs

(R)-161 Upon segmentation of a CPCS_PDU, a SAR sender shall create a SAR_PDU for each unit of SAR_PDU payload created. The type of SAR_PDU created is determined as follows:

- **CPCS_PDU of one unit of SAR_PDU payload:** If the length of the CPCS_PDU is less than or equal to 44 octets, then only one unit of SAR_PDU payload shall be generated, containing the entire CPCS_PDU. The associated SAR_PDU shall be an SSM.

- **CPCS_PDU of two or more units of SAR_PDU payload:** If the length of the CPCS_PDU is greater than 44 octets, then more than one unit of SAR_PDU payload shall be generated. The SAR_PDU associated with the first unit of SAR_PDU payload shall be a BOM. The SAR_PDUs associated with all of the other units of SAR_PDU payload, except the last, shall be COMs. The SAR_PDU associated with the last unit of SAR_PDU payload of the CPCS_PDU shall be an EOM.

(R)-162 Each field in a SAR_PDU shall be populated as described in Section — "SAR_PDU Format".

(R)-163 A SAR sender shall maintain a Transmit Sequence Number (TxSN) counter for each MID it uses. Prior to transmitting a BOM, the TxSN counter shall have an initial value in the range 0 to 15. For each BOM, COM and EOM SAR_PDU of a CPCS_PDU transmitted, the SAR sender shall insert in the Sequence Number field the value of the TxSN counter associated with the MID. After setting the Sequence Number field of a BOM or a COM SAR_PDU, the SAR sender shall increment the value of the TxSN counter by one (modulo 16) for use with the next SAR_PDU associated with the same MID.

The TxSN counter associated with a particular MID is not required to be maintained between CPCS_PDUs with that MID. For example, implementations where each BOM SAR_PDU has a Sequence Number field value of 0 are allowed.

(R)-164 The SAR sender shall transfer each created SAR_PDU to the ATM layer entity, which shall perform the appropriate "ATM Layer Functions Involved at the B-ICI" defined in Section 4.

The inter-layer transaction in the above Requirement may be modeled by the transfer of an ATM-DATA.request primitive from the SAR entity to the ATM layer entity, with the parameters of the ATM-DATA.request set as follows:

- ATM-SDU contains the SAR_PDUs
- SDU-Type is set to 0
- Congestion Experienced is set to False

The setting of the Loss Priority is for further study.

(R)-165 A SAR sender shall support the transfer of a maximum of 1023 CPCS_PDUs in transit concurrently.

11.2.2.2.2 SAR Receiver Procedures

Receiving a SAR-PDU

(R)-166 Upon receipt of a SAR_PDU, the SAR receiver shall check that:

- the SAR_PDU CRC is valid; and
- the value in the MID field is in the range [1,1023][23].

If either of these checks fails, the SAR_PDU shall be discarded. If the SAR_PDU passes both checks, the SAR receiver shall forward the SAR_PDU to the Receiver State Machine (RSM) associated with the MID value contained in the SAR_PDU header. In this case, the SAR receiver shall implement the functional equivalent of the Requirements defined for the — "SAR Receive Process".

(R)-167 A SAR receiver shall support 1023 concurrent active RSMs (one per MID).

SAR Receive Process

Figure 11.5 (I.363) shows the RSM for a particular MID, X. Only SAR_PDUs with MID = X that pass the appropriate checks are passed to this state machine. In the notes in Figure 11.5, "Process SAR_PDU" refers to CPCS processing, ICIP_CLS Layer processing, ICIP User processing, and service feature processing. This processing can be characterized as either pipelining or reassembly. In the case of reassembly, SAR_PDU processing will include storing the payload of the SAR_PDU until the entire CPCS_PDU is completely received. Pipelining has no such storage requirements, and SAR_PDUs may be forwarded before the entire CPCS_PDU is completely received.

(R)-168 If a SAR_PDU is received with Segment Type = BOM and MID = X, the SAR_PDU shall be processed as follows:

1. If the RSM for MID = X is in the REASS state, any partially received CPCS_PDU for the associated receive process shall be considered to be unusable.

[23] This check enforces the MID configuration defined earlier.

2. The receive process is started for the new BOM. The RSM for MID = X shall be in the REASS state. The SAR receiver shall begin measuring the time elapsed while the process is in the REASS state.

3. If the value of the LI field in the BOM SAR_PDU is different than 44, the SAR receiver shall stop processing the SAR_PDU, the SAR_PDU shall be discarded, and the RSM for MID = X shall return to the IDLE state. Otherwise, the SAR receiver shall continue with step 4.

4. The SAR receiver shall establish a Receive Sequence Number (RxSN) counter, associated with MID = X. The SAR receiver shall initialize the value of the RxSN counter to the value of the Sequence Number field of the BOM SAR_PDU plus one (modulo 16).

Figure 11.5 Instance of SAR Receiver State Machine for MID-X (I.363)

(R)-169 If a SAR_PDU is received with Segment Type = COM and MID = X, the SAR_PDU shall be processed as follows:

1. If the RSM for MID = X is in the IDLE state, the SAR receiver shall stop processing the SAR_PDU, the SAR_PDU shall be discarded, and the RSM for MID = X shall remain in the IDLE state.

2. If the value of the LI field in the COM SAR_PDU is different than 44, the SAR receiver shall stop processing the SAR_PDU, the SAR_PDU shall be discarded, and the RSM for MID = X shall return to the IDLE state. Any partially received CPCS_PDU for the associated receive process shall be considered to be unusable. Otherwise, the SAR receiver shall continue with step 3.

3. If the value of the Sequence Number field of the COM SAR_PDU is different from the expected value contained in the RxSN counter for MID = X, the SAR receiver shall stop processing the SAR_PDU, the SAR_PDU shall be discarded, and the RSM for MID = X shall return to the IDLE state. Any partially received CPCS_PDU for the associated receive process shall be considered to be unusable. If the value of the Sequence Number field of the COM SAR_PDU is equal to the expected value contained in the RxSN counter for MID = X,

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the SAR receiver shall increment the value of the RxSN counter by one (modulo 16).

(R)-170 If a SAR_PDU is received with Segment Type = EOM and MID = X, the SAR_PDU shall be processed as follows:

1. If the RSM for MID = X is in the IDLE state, the SAR receiver shall stop processing the SAR_PDU, the SAR_PDU shall be discarded, and the RSM for MID = X shall remain in the IDLE state.

2. If the value of the LI field in the EOM SAR_PDU is less than 4 or greater than 44, the SAR receiver shall stop processing the SAR_PDU, the SAR_PDU shall be discarded, and the RSM for MID = X shall return to the IDLE state. Any partially received CPCS_PDU for the associated receive process shall be considered to be unusable. Otherwise, the SAR receiver shall continue with step 3.

3. If the value of the Sequence Number field of the EOM SAR_PDU is different from the expected value contained in the RxSN counter for MID = X, the SAR receiver shall stop processing the SAR_PDU, the SAR_PDU shall be discarded, and the RSM for MID = X shall return to the IDLE state. Any partially received CPCS_PDU for the associated receive process shall be considered to be unusable. If the value of the Sequence Number field of the EOM SAR_PDU is equal to the expected value contained in the RxSN counter for MID = X, the SAR receiver shall complete the SAR receive process, return the RSM for MID = X to the IDLE state, and deliver the CPCS_PDU to the CPCS receiver (see Section - "CPCS Receiver Procedures").

(R)-171 If a SAR_PDU is received with Segment Type = SSM and MID = X, the SAR_PDU shall be processed as follows:

1. If the RSM for MID = X is in the REASS state, any partially received CPCS_PDU for the associated receive process shall be considered to be unusable.

2. If the value of the LI field in the SSM SAR_PDU is less than 8 or greater than 44, the SAR receiver shall stop processing the SAR_PDU, the SAR_PDU shall be discarded, and the RSM for MID = X shall return to the IDLE state. Otherwise, the SAR receiver shall continue with step 3.

3. The SAR receiver shall complete the SAR receive process, return the RSM for MID = X to the IDLE state, and deliver the

CPCS_PDU to the CPCS receiver (see Section - "CPCS Receiver Procedures").

(R)-172 The maximum time that is allowed to elapse between the receipt of a BOM SAR_PDU and the corresponding EOM SAR_PDU shall be specified by the value of the parameter SAR Receive Interval (SRI). An active receive process shall be terminated (i.e., go to the IDLE state) if the elapsed time exceeds the SRI. The value of the SRI is for further study.

By measuring the elapsed time, the SAR receiver can guard against the SAR receive process running indefinitely (e.g., due to loss of the EOM).

(O)-10 A SAR receiver should terminate an active receive process if the SAR receiver determines, before the full CPCS_PDU associated with that receive process has been received, that the CPCS_PDU must not be delivered. Reasons that the SAR receiver may determine this include:

- CPCS_PDU or ICIP_CLS_PDU format validation performed prior to reception of the EOM determines that the data unit contains errors; or

- Feature processing, performed prior to the reception of the EOM, determines that the ICIP_CLS_PDU encapsulated within the CPCS_PDU must not be delivered.

11.2.2.3 CPCS_PDU Format

The format of the CPCS_PDU is shown in Figure 11.6 (I.363), along with the lengths of the fields. The CPCS_PDU is created by adding both a CPCS_PDU header and a CPCS_PDU trailer to a variable-length ICIP_CLS_PDU received from the ICIP_CLS Layer. The ICIP_CLS_PDU is the User Information subfield of the CPCS_PDU.

Figure 11.6 CPCS_PDU Format (I.363)

The requirements for the meaning and use of each field of the CPCS_PDU are stated below.

(R)-173 The CPCS_PDU shall have the format shown in Figure 11.6 (I.363).

Common Part Indicator (CPI)

This 1-octet field is used to indicate the type of message contained in the CPCS_PDU and defines the counting unit for the values specified in the BASize and Length fields.

(R)-174 The 1-octet CPI field shall be encoded with all 0's.

A CPI value of all zeros indicates that the BASize and Length field values are encoded in octets.

Beginning Tag (Btag) and End Tag (Etag)

The 1-octet Btag field in the CPCS_PDU header is used in conjunction with the 1-octet Etag field in the CPCS_PDU trailer to form an association between the Beginning of Message (BOM) SAR_PDU and the End of Message (EOM) SAR_PDU derived from the same CPCS_PDU.

(R)-175 The 1-octet Btag field shall contain the same binary encoded value as the Etag field, ranging from 0 through 255.

Buffer Allocation Size (BASize)

(R)-176 The 2-octet BASize field shall give the length, in units indicated by the CPI field, of the User Information subfield of the Payload field. The BASize field shall be encoded in binary format.

To support SMDS, the BASize field value is set equal to the length of the User Information subfield of the Payload field. More general AAL Type 3/4 implementations allow the BASize to be set to a value greater than or equal to the length of the User Information subfield of the Payload field[52].

Payload

(R)-177 The variable-length Payload field shall be composed of two subfields:

- User Information — This subfield shall contain an ICIP_CLS_PDU.
- PAD — This subfield shall contain the adequate number of octets, from 0 to 3 octets, to ensure that the CPCS_PDU Payload field is 4-octet aligned.

Since all ICIP_CLS_PDUs are 4-octet aligned, the PAD field will be 0 octets in length.

Alignment (AL)

This 1-octet field is used to provide 4-octet alignment of the CPCS_PDU trailer.

(R)-178 The 1-octet AL field shall be encoded with all 0's.

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Length

(R)-179 The 2-octet Length field shall give the length, in octets, of the User Information subfield of the Payload field.

11.2.2.4 Convergence Sublayer Procedures

11.2.2.4.1 CPCS Sender Procedures

(R)-180 Upon receipt of an ICIP_CLS_PDU from the ICIP_CLS Layer, a CPCS sender shall create a CPCS_PDU, based on the ICIP_CLS_PDU.

(R)-181 Each field in a CPCS_PDU shall be populated as described in Section - "CPCS_PDU Format".

(R)-182 The value of the Btag for a CPCS_PDU shall be different than the value used in the previous CPCS_PDU which was sent by the CPCS sender using the same MID value that will be used for the current CPCS_PDU.

(R)-183 The CPCS sender shall deliver the CPCS_PDU to the SAR entity, which shall perform the "SAR Sender Procedures" defined earlier.

11.2.2.4.2 CPCS Receiver Procedures

(R)-184 Upon receipt of a complete CPCS_PDU from a completed receive process, a CPCS receiver shall check the CPCS_PDU for the following errors:

- Values of the Btag field in the CPCS_PDU header and the Etag field in the CPCS_PDU trailer that are not equal.
- A Length field value that is greater than the number of received CPCS_PDU octets minus 8 (4 octets of CPCS_PDU header and 4 octets of CPCS_PDU trailer).
- A Length field value that is less than the number of received CPCS_PDU octets minus 11 (4 octets of CPCS_PDU header, 4 octets of CPCS_PDU trailer, and 3 octets of possible padding).
- A CPCS_PDU length that is not a multiple of 4 octets.

- A Length field value that is not equal to the BASize field value[24].

If any of the above errors occur, the CPCS_PDU shall be discarded. Discarding a CPCS_PDU is accomplished by discarding one or more of the SAR_PDUs associated with the CPCS_PDU.

(O)-11 If the implementation of the CPCS receiver permits, then that CPCS receiver shall, upon receipt of a complete CPCS_PDU from a completed receive process, check the CPCS_PDU for the following errors:

- An invalid CPI field value. (The only valid CPI value currently defined for SMDS is 0.)

- An AL field that is not equal to 0.

CPCS receiver implementations that comply with the CCITT Recommendation I.363 will perform the checks in the Option above. However, the checks are listed as Options to ease the transition from IEEE 802.6 to ATM (since IEEE 802.6-based equipment does not perform the checks).

(R)-185 The CPCS Receiver shall deliver the CPCS_PDU User Information to the ICIP_CLS Layer entity, which shall perform the "ICIP_CLS Layer Receiving Procedures" defined later.

The inter-layer transaction in the Requirement above may be modeled by the transfer of one or more CPCS_UNITDATA.signal primitives[52] from the CPCS entity to the ICIP_CLS Layer entity, with the parameters of each CPCS-UNITDATA.signal set as follows:

- Interface Data (ID) contains either a portion of or the entire CPCS_PDU User Information.

- More (M) is ser to 0 when the ID parameter contains the end of the CPCS_PDU User Information. (The M parameter is used for Streaming Mode only).

- Maximum Length (ML) is set to the value of the BASize field. The ML parameter is used only on the first CPCS-UNITDATA.signal for a CPCS_PDU. (The ML parameter is used for Straeming Mode only).

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24 This check enforces the Requirement for the BASize, which sets BASize equal to the length (in octets) of the User Information subfield of the Payload field. The check and the Requirement for the BASize are necessary to allow SMDS supporting interfaces (e.g., B-ICI) based on AAL Type 3/4 to interoperate with those interfaces (e.g., SNI and SMDS ICI)) based on IEEE 802.6. Because of these Requirements, the AAL Type 3/4 for SMDS may be viewed as operating in Message Mode, or in a specific implementation of Streaming Mode.

- Reception Status (RS) is not used, since the corrupted data delivery option is not used.

11.2.3 ICIP_CLS Layer Specification

This Section specifies the ICIP Connectionless Service (ICIP_CLS) Layer. The ICIP_CLS Layer supports functions for the connectionless transfer of variable-length SMDS data units between carrier networks. This layer supports the transfer of end-user data units by encapsulating those data units with header information; the encapsulation technique is consistent with the method defined for the SMDS ICI[49] and broadband connectionless data service on BISDN[53]. Figure 11.7 summarizes the SMDS_PDU formats at the B-ICI, and illustrates the encapsulation by the ICIP_CLS Layer.

The ICIP_CLS Layer is a subset of ICIP Level 3[49] (see Figure 11.7) for two reasons:

1. ICIP Level 3 contains protocol elements defined at both the ICIP_CLS Layer and CPCS of the B-ICI protocol architecture.

2. ICIP Level 3 supports specific inter-carrier SMDS arrangements[49]. The ICIP_CLS Layer defined here is consistent with ICIP Level 3. However, it is generalized so that it supports the inter-carrier SMDS arrangements defined in [49], as well as other inter-carrier SMDS arrangements. For example, the ICIP_CLS Layer specification provides address field structure requirements that are consistent with ICIP Level 3; however, requirements on how to populate the Destination Address and Source Address fields are not given, since these depend on the specific inter-carrier SMDS arrangement[25].

Because the ICIP_CLS Layer is a subset of ICIP Level 3, equipment that conforms to the ICIP Level 3 specification also conforms to the ICIP_CLS Layer protocol defined in this Section.

Figure 11.7 Overview of SMDS_PDU Formats at the B-ICI

Note: The combined functions of the ICIP_CLS Layer and the CPCS are nearly identical to those of the "ICIP Level 3".

11.2.3.1 ICIP_CLS_PDU Format

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[25] Requirements specific to XA-SMDS and serving arrangements between LECs within an exchange serving area can be found in [49] and [54].

Figure 11.8 illustrates the format of the ICIP_CLS_PDU and the lengths of the fields. The requirements for the meaning and use of each field are stated below.

(R)-186 The ICIP_CLS_PDU shall use the format shown in Figure 11.8.

Figure 11.8 ICIP_CLS_PDU Format

Destination Address and Source Address

The Destination Address and Source Address fields each have the same format. Each address field has two subfields: Address Type and Address, as shown in Figure 11.9.

(R)-187 The Address fields shall each be 8 octets (64 bits) long. The first 4 bits shall identify the Address Type and shall contain the value 1100 for public 60-bit individual addresses and 1110 for public 60-bit group addresses. Other Address Type values are not used.

(R)-188 The remaining 60 bits shall identify an address. Addresses that begin with the E.164[55] Country Code "1" shall be followed immediately by an address of 10 decimal digits. Other Country Codes may be used for international service. In this case, the Country Code (from 1 to 3 decimal digits) shall precede the address.

(R)-189 The Country Code and address shall be encoded with the Binary-Coded Decimal (BCD) digits of its value, and shall be left-justified within the Address Subfield. To encode the Country Code "1", the four most significant bits of the address shall be set to the binary value 0001. To encode the 10 decimal digit address, the next 40 bits shall be the BCD value of the address. The remaining 16 least-significant bits shall be filled with 1's. For international service, SMDS addresses may use the entire 60 bits of the Address subfield. The least-significant bits which are not used shall be filled with 1's.

Figure 11.9 Address Field Format

Protocol Identification (PI)

For a given ICIP_CLS_PDU, the PI field identifies the user of the services provided by the ICIP_CLS Layer. The users of the ICIP_CLS Layer services are called *ICIP Users.* The service interface between the ICIP_CLS Layer and the ICIP Users may be modeled using the ICIP-UNITDATA.request and ICIP-UNITDATA.indication primitives[52].

(R)-190 The 6-bit binary-encoded Protocol Identification (PI) field shall identify the ICIP User. The value of the PI field for all versions of the ICIP shall fall between the decimal values 48 and 63.

Pad Length (PL), Quality of Service (QOS), and CRC32 Indicator Bit (CIB)

The PL field, QOS field, and CIB are present to align the ICIP_CLS_PDU with the ICIP L3_PDU[52].

(R)-191 The 2-bit PL field shall be encoded with the binary value 00.

(R)-192 The 4-bit QOS field shall be encoded with the binary value 0000.

(R)-193 The CIB shall be set to 0.

Header Extension Length (HEL)

(R)-194 The 3-bit Header Extension Length (HEL) field shall be encoded with the value 011, indicating a 12-octet Header Extension field.

Bridging

The Bridging field is present to align the ICIP_CLS_PDU with the ICIP L3_PDU[52].

(R)-195 The 2-octet Bridging field shall be filled with 0's.

Header Extension

(R)-196 The Header Extension field shall be 12 octets long.

Service Specific Information (SSI)

This 8-octet field carries information that is needed to support SMDS on the B-ICI. For the transport of end-user data, three subfields are defined: ICIP Version, Carrier, and Explicit Selection. The remainder is reserved[26] to support future growth, and has the default encoding of all 0's.

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[26] The European SMDS Interest Group (ESIG) has proposed the first 3 bits of the Reserved Field for the Hop Count indicator field.

(R)-197 For the transport of end-user data, the 8-octet Service Specific Information (SSI) field shall be formatted as shown in Figure 11.10.

Figure 11.10 Service Specific Information Field Format

ICIP Version

The ICIP Version field identifies the version of the ICIP_CLS Layer protocol.

(R)-198 The 1-octet ICIP Version subfield shall be encoded with the binary value 1, meaning ICIP Version 1[52].

Carrier and Explicit Selection Subfields

The Carrier and Explicit Selection subfields are reserved for carrier selection purposes. The details of their use are to be defined.

ICIP-User Data

The variable-length ICIP-User Data field carries the information to be transported between peer ICIP Users.

(R)-199 For the transport of end-user data, the variable-length ICIP-User Data field shall contain the end-user's SMDS Interface Protocol (SIP) L3_PDU without its SIP L3_PDU Trailer.

11.2.3.2 ICIP_CLS Layer Procedures

This section describes the protocol procedures used for sending and receiving ICIP_CLS_PDUs between peer ICIP_CLS Layer entities.

11.2.3.2.1 Sending Procedures

When an ICIP User provides (in an ICIP-UNITDATA.request primitive[49]) an ICIP_CLS Layer entity with a SIP L3_PDU to be transferred, the ICIP_CLS Layer entity encapsulates the SIP L3_PDU, without its trailer, within an ICIP_CLS_PDU, as described in the previous Section.

(R)-200 When sending an ICIP_CLS_PDU, an ICIP_CLS Layer entity shall generate each field as described in Section — "ICIP_CLS_PDU Format".

(R)-201 The ICIP_CLS Layer sender shall transfer each created ICIP_CLS_PDU to the CPCS entity, which shall perform the "CPCS Sender Procedures" defined earlier.

The inter-layer transaction in the above Requirement may be modeled by the transfer of one or more CPCS_UNITDATA.invoke primitives[52] from the ICIP_CLS Layer entity to the CPCS entity, with the parameters of each CPCS-UNITDATA.invoke set as follows:

- Interface Data (ID) contains either a portion of or the entire ICIP_CLS_PDU.
- More (M) is ser to 0 when the ID parameter contains the end of the CPCS_PDU User Information. (The M parameter is used for Streaming Mode only).
- Maximum Length (ML) is set to the length of the ICIP_CLS_PDU[27]. The ML parameter is used only on the first CPCS-UNITDATA.invoke for a CPCS_PDU. (The ML parameter is used for Streaming Mode only).
- Reception Status (RS) is not used, since the corrupted data delivery option is not used.

11.2.3.2.2 Receiving Procedures

Once an ICIP_CLS Layer entity transmits a PDU to its peer ICIP_CLS Layer entity, the ICIP_CLS Layer receiver performs specific validation procedures and takes action accordingly. For instance, an ICIP_CLS receiver will not deliver an ICIP_CLS_PDU to its destination if an error has occurred. In the following description of the procedures, the phrase, "shall discard the ICIP_CLS_PDU" means that the ICIP_CLS receiver shall take whatever action is necessary to assure that the data is not delivered by the network providing service. The action may be taken when the failure condition is detected, even if the full ICIP_CLS_PDU has not been received.

The rest of this section specifies that action that occurs following the failure. The actions taken by Carrier A and Carrier B are the same. These actions are consistent with the ICIP Level 3 receive checks defined in [52]. If no receive checks fail, the protocol processing at the B-ICI is complete, and the ICIP_CLS Layer entity passes the SIP L3_PDU, without its trailer, (in an ICIP-UNITDATA.indication primitive[52]) to the appropriate ICIP User.

Invalid Address Format

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[27] For Streaming Mode implementations of AAL Type 3/4, this ensures that the CPCS_PDU BASize field is encoded with the length of the CPCS_PDU User Information, as defined in the Requirement for the BASize.

(R)-202 If the Destination Address or Source Address formats are incorrect or the Address Type is not a recognized value, then the ICIP_CLS receiver shall discard the ICIP_CLS_PDU.

Invalid Protocol Identification

(R)-203 If the Protocol Identification field value is not between the decimal values 48 and 63 inclusive, then the ICIP_CLS receiver shall discard the ICIP_CLS_PDU.

Invalid Pad Length

(R)-204 If the Pad Length field does not equal 00, then the ICIP_CLS receiver shall discard the ICIP_CLS_PDU.

Invalid Quality of Service Field

(R)-205 If the Quality of Service field does not equal 0000, then the ICIP_CLS receiver shall discard the ICIP_CLS_PDU.

Invalid CRC-32 Indicator Bit

(R)-206 If the CRC-32 Indicator Bit does not equal 0, then the ICIP_CLS receiver shall discard the ICIP_CLS_PDU.

Invalid Header Extension Length

(R)-207 If the Header Extension Length does not equal 011, then the ICIP_CLS receiver shall discard the ICIP_CLS_PDU.

Invalid Bridging Field

(R)-208 If the Bridging field is not filled with 0's, then the ICIP_CLS receiver shall discard the ICIP_CLS_PDU.

Invalid ICIP Version

(R)-209 If the value in the ICIP Version subfield is not equal to the binary value 1, then the ICIP_CLS receiver shall discard the ICIP_CLS_PDU.

Invalid Reserved Subfield

(R)-210 If the Reserved subfield of the Service Specific Information field is not filled with 0's, then the ICIP_CLS receiver shall discard the ICIP_CLS_PDU.

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Invalid SIP L3-PDU Header Extension

(R)-211 The ICIP_CLS layer receiver shall verify that the SIP L3_PDU satisfies the following conditions defined in [50]:

- The Version element appears first within the Header Extension.
- For the Version element type, the Element Value is encoded with the binary value "1".
- For the Carrier Selection element type appearing second within the Header Extension field, the value in the Element Length subfield specifies a length of 4, 6, or 8.
- Within the Element Value subfield of a Carrier Selection element appearing second within the Header Extension field, the carrier value is encoded as four decimal, BCD digits.

If any are incorrect, the ICIP_CLS layer receiver shall discard the ICIP_CLS_PDU.

(R)-212 If the length of the ICIP_CLS_PDU is not an integral multiple of 4 octets in the range [76, 9268] octets, the ICIP_CLS Layer receiver shall discard the ICIP_CLS_PDU.

If none of the preceding checks fails, the ICIP_CLS Layer entity passes the ICIP-User data to the ICIP User identified in the Protocol Identification field.

11.3 SMDS Traffic Management and Network Performance

This Section provides SMDS specific traffic management functions and network performance considerations that are required for a B-ICI.

11.3.1 Traffic Management

Traffic management impacts for SMDS at a B-ICI are considered here. These are the additional information (beyond that required for the carrier-to-carrier traffic contract at a B-ICI) that can increase the efficiency of a carrier's CAC function.

A carrier's CAC function and its engineering of its network portion can generally by facilitated by the availability of additional information beyond that required for the carrier-to-carrier traffic contract at a B-ICI. Additional information that may — subject to bilateral agreement — be

exchanged is information on the SMDS Access Classes (for example, an estimate of the number of subscribers in each Access Class) being supported by the B-ICI. If there is any need for clarification, the peak cell rate associated with an SMDS subscriber is to be exchanged.

For this Version of the B-ICI Specification, no further SMDS specific traffic management requirements are considered.

11.3.2 Network Performance

Network performance parameters for SMDS have been defined[49]. These parameters are generally based on the SMDS Interface Protocol's Level 3 Protocol Data Units (L3_PDUs). No additional SMDS specific performance considerations are included in this Version of the B-ICI Specification.

11.4 SMDS Operations and Maintenance

This Section specifies the SMDS operations for the layer above the ATM layer (i.e., the AAL Type 3/4). Operations for layers above the AAL are not discussed in this Version. Section 11.4.1 discusses operations for the AAL Type 3/4, and Section 11.4.2 is a placeholder for SMDS operations for the layers above the AAL Type 3/4 (e.g., ICIP_CLS Layer).

11.4.1 Operations for the AAL Type 3/4

This Section specifies performance measurements needed to monitor errors for the AAL Type 3/4.

11.4.1.1 SAR Sublayer

At the SAR sublayer, the following errors may occur:

- Multiplexing IDentification (MID) field value out of range[28].
- Length Indicator (LI) _ 44 for a BOM or COM segment.

These indicate problems in the implementation of the protocol. One possible implementation approach is to have only one counter for these two error possibilities, because further diagnosis will be required.

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[28] For example, as stated in Section 11.2.2.1, the allowable MID range for SMDS is [1-1023], so in this case a MID value of 0 would be out of range and counted as an error. (The notation [x-y] refers to all values from x to y, including x and y).

The following errors indicate a transmission or procedural error at the SAR sublevel, such as lost or misinserted cells, and should be counted:

- Incorrect SAR_PDU CRC.
- COM or EOM segment with unexpected Sequence Number.
- BOM/EOM Segment with unexpected MID; i.e., a BOM is received with a currently active MID, or an EOM is received for which a MID is not currently active.
- Number of times an EOM is not received before SAR Receive Interval (SRI) expires.
- Optionally, the number of aborts received (i.e., an EOM is received with Length Indication = 63) may be counted.

11.4.1.2 Common Part Convergence Sublayer (CPCS)

At the CPCS, the following protocol errors may occur:

- Common Part Indicator (CPI) _ 0.
- Alignment Field _ 0.

The following procedural or transmission errors may occur at the CPCS:

- BTag _ ETag.
- BASize inconsistent with Length field. If the connection is operating in message mode (which is used by SMDS), there is an error if BASize _ Length. In streaming mode, there is an error if BASize < Length[29].
- Length of CPCS-PDU not consistent with Length field. Specifically, an error occurs if the length of the CPCS-PDU minus the length specified in the Length field is not in the range [0-3].

(R)-213 Network equipment at a B-ICI terminating the AAL Type 3/4 shall measure the SAR and CPCS errors listed in this Section.

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[29] In streaming mode, the originating point of the packet may begin sending the first cells of the CPCS-PDU before it knows how long the CPCS-PDU will be. In this case, the BASize field is encoded to the largest size that the originating point expects to send, so the BASize must be ≥ Length. In message mode, the size of the packet is known when the BASize is encoded, and it must be set = Length.

A typical value for a measurement interval could be 15 minutes, and at least 8 hours of history should be kept. The measurement interval and amount of history data will be established by bilateral agreements between the carriers.

11.4.2 Operations for Layers Above the AAL Type 3/4

Operations for layers above the AAL Type 3/4 will be provided in future Versions of this document.

12 Usage Metering

Some agreements on metering the transfer of service between carriers connected via a B-ICI will likely be required for the purpose of accounting. Usage metering procedures will need to be developed for services offered between carriers. A major consideration is the application of existing and planned usage metering procedures for multi-service B-ICIs.

More details of B-ICI related usage metering are for further study.

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Acronyms

AAL	ATM Adaptation Layer
AIS	Alarm Indication Signal
ANSI	American National Standards Institute
ATM	Asynchronous Transfer Mode
BECN	Backward Explicit Congestion Notification

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B-ICI	BISDN Inter Carrier Interface
BISDN	Broadband Integrated Services Digital Network
CAC	Connection Admission Control
CBR	Constant Bit Rate
CCITT	International Telephone and Telegraph Consultative Committee
CDV	Cell Delay Variation
CES	Circuit Emulation Service
CLP	Cell Loss Priority
CPE	Customer Premises Equipment
CPCS	Common Part Convergence Sublayer
CRC	Cyclic Redundancy Check
CRS	Cell Relay Service
DE	Discard Eligibility
DLCI	Data Link Connection Identifier
EA	Address Extension
EFCI	Explicit Forward Congestion Indication
FEBE	Far End Block Error
FECN	Forward Explicit Congestion Notification
FERF	Far End Receive Failure
FRS	Frame Relay Service
HEC	Header Error Control
ICIP	Inter Carrier Interface Protocol
ICIP_CLS	ICIP Connectionless Service
IEC	Inter Exchange Carrier
ITU	International Telecommunication Union
IWF	Inter-Working Function
LEC	Local Exchange Carrier
NNI	Network Node Interface
NPC	Network Parameter Control
PCR	Peak Cell Rate
PLCP	Physical Layer Convergence Procedure
PMD	Physical Medium Dependent
PVC	Permanent Virtual Connection
RDI	Remote Defect Indicator
SCR	Sustained Cell Rate
SMDS	Switched Multi-megabit Data Service
SONET	Synchronous Optical NETwork
SPE	Synchronous Payload Envelope
SSCS	Service Specific Convergence Sublayer
STS	Synchronous Transport Signal
SVC	Switched Virtual Connection
UDT	Unstructured Data Transfer
UNI	User Network Interface
VBR	Variable Bit Rate
VCC	Virtual Channel Connection
VPC	Virtual Path Connection

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Annex A - Summary of Requirements and Options

I. Summary of Requirements (R)

1. Introduction

None.

2. Network Aspects

(R)-1 Network	B-ICI specification shall be based on the CCITT defined Node Interface (NNI).	[1] [2] [3]

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(R)-2 A multi-service B-ICI shall be reconfigurable to support one service, or any combination of the inter-carrier services (i.e., CRS, CES, FRS, SMDS) to meet the traffic needs.

3. B-ICI Physical Layer Specification

(R)-3 The bit rate of the line signal shall be nominally 155.520 Mbit/s. (Also see (R)-16).

(R)-4 The bit rate available for user information cells, signaling cells and ATM layer OAM cells, excluding Physical Layer related OAM information transported in overhead bytes shall be nominally 149.760 Mbit/s.

(R)-5 The 155.520 Mbit/s B-ICI shall utilize the SONET STS-3c frame structure as specified in ANSI T1.105 [4].

(R)-6 Framing information shall be contained in the A1 and A2 bytes.

(R)-7 Equipment on either side of the B-ICI shall meet the requirements for —

- Going from an in-frame condition to an out-of-frame condition, an
- Going from an out-of-frame condition to an in-frame condition as specified in TR-NWT-000253 [5].

(R)-8 The overhead bytes active across the B-ICI (including B-ICI' and B-ICI" as described above) shall be consistent with the specifications given in ANSI T1.105 [4]. [Note: Except for some differences between ANSI T1.105 and B-ICI specification, for example, Path RDI (Remote Defect Indicator), Line FEBE].

(R)-9 Power shall not be provided across the B-ICI.

(R)-10 The HEC generation and error checking functions (specified in Section 3.5) shall be implemented for the 155.520 Mbit/s SONET STS-3c based B-ICI.

(R)-11 The cell payload (self-synchronous) scrambler (specified in Section 3.5) shall be implemented for the 155.520 Mbit/s SONET STS-3c based B-ICI.

(R)-12 Equipment supporting a B-ICI shall map ATM cells into the SONET STS-3c signal as specified in ANSI T1.624 [6] and ANSI T1.105 [4] (see also CCITT Recommendations I.432 [7] and G.709 [2]).

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(R)-13 The cell delineation functions (specified in Section 3.5) shall be implemented for the 155.520 Mbit/s B-ICI.

(R)-14 For the 155.520 Mbit/s B-ICI, the time to declare Sync state (specified in Section 3.5) shall be less than 150 micro-seconds. This requirement pertains to an in-frame SONET condition and supplements the re-frame requirements given earlier to specify total time from out-of-frame to cell delineation.

(R)-15 The B-ICI shall meet the PMD specifications given in TR-NWT-000253 for either the short- reach, intermediate-reach or long-reach optical OC-3 or the electrical STSX-3 application. The choice of interface parameter set is application specific.

(R)-16 In normal operation, the signal at the B-ICI shall be synchronized by a source traceable to a Primary Reference Source (PRS, or Stratum 1 clock) as described in ANSI T1.101 [8]. When the system is not synchronized (e.g., free running mode), a failure sync condition exists, and shall be rectified according to a bilateral agreement.

(R)-17 At the B-ICI, the network output jitter limits specified in ANSI T1X1/LB-93-03 [9] shall apply.

(R)-18 Optical connectors shall meet the performance criteria specified in Bellcore's TR-NWT- 000326 [10].

(R)-19 The bit rate of the line signal shall be nominally 622.080 Mbit/s. (Also, see (R)-32).

(**R)-20** The bit rate available for user information cells, signaling cells and ATM layer OAM cells, excluding Physical Layer related OAM information transported in overhead bytes shall be nominally 599.040 Mbit/s.

(R)-21 The 622.080 Mbit/s B-ICI shall utilize the SONET STS-12c frame structure specified in ANSI T1.624 [6].

(R)-22 Framing information shall be contained in the A1 and A2 bytes.

(R)-23 Equipment on either side of the B-ICI shall meet the requirements for —

- Going from an in-frame condition to an out-of-frame condition, and
- Going from an out-of-frame condition to an in-frame condition as specified in TR-NWT-000253 [5].

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(R)-24 The overhead bytes active across the B-ICI (including B-ICI' and B-ICI" as described in Section 3.2.2.2) shall be consistent with the specifications given in ANSI T1.105 [4]. [Note: Except for some differences between ANSI T1.105 and B-ICI specification, for example, Path RDI, Line FEBE].

(R)-25 Power shall not be provided across the 622.080 Mbit/s B-ICI.

(R)-26 The HEC generation and error checking functions (specified in Section 3.5) shall be implemented for the 622.080 Mbit/s SONET STS-12c based B-ICI.

(R)-27 The cell payload (self-synchronous) scrambler (specified in Section 3.5) shall be implemented for the 622.080 Mbit/s SONET STS-12c based B-ICI.

(R)-28 Equipment supporting a B-ICI shall map ATM cells into the SONET STS-12c signal as specified in ANSI T1.624 [6] and ANSI T1.105 [4] (see also CCITT Recommendations I.432 [7] and G.709 [2]).

(R)-29 The cell delineation functions (specified in Section 3.5) shall be implemented for the 622.080 Mbit/s B-ICI.

(R)-30 For the 622.080 Mbit/s B-ICI, the time to declare Sync state (defined in Section 3.5) shall be less than 150 micro-seconds. This requirement pertains to an in-frame SONET condition and supplements the re-frame requirements given earlier to specify total time from out-of-frame to cell delineation.

(R)-31 The B-ICI shall meet the PMD specifications given in TR-NWT-000253 [5] for either the short-reach, intermediate-reach or long-reach optical OC-12 application. The choice of interface parameter set is application specific.

(R)-32 In normal operation, the signal at the B-ICI shall be synchronized by a source traceable to a PRS (Stratum 1 clock) as described in ANSI T1.101 [8]. When the system is not synchronized (e.g., free running mode) a failure sync condition exists, and shall be rectified according to a bilateral agreement.

(R)-33 At the B-ICI, the network output jitter limits specified in ANSI T1X1/LB-93-03 [9] shall apply.

(R)-34 Optical connectors shall meet the performance criteria specified in Bellcore's TR-NWT- 000326 [10].

(R)-35 The Physical Layer Convergence Procedure (PLCP) based ATM mapping format shall be used for the 44.736 Mbit/s (DS3) B-ICI.

(R)-36 The bit rate at the B-ICI shall be 44.736 Mbit/s ± 20 PPM.

(R)-37 The transfer capacity available for the transport of ATM cells in the DS3 PLCP based format shall be nominally 40.704 Mbit/s.

(R)-38 For the C-bit parity application, this bit shall be set to "1" at the transmitter and verified at the receiver.

(R)-39 This bit shall be set to "1" at the transmitter and ignored at the receiver.

(R)-40 These bits are used to indicate the parity of the DS3 payload. They shall be set by the transmitter the same as the P-Bits and compared to the re-calculated parity by the receiver according to the procedures specified in T1.107a[11]. If an error is detected, it is indicated with the FEBE (C10-C12).

(R)-41 These bits are used to indicate the received Far End Block Errors of the DS3 payload. They shall be set by the transmitter whenever an error is detected by the receiver in the CP- Bits, according to the procedures specified in T1.107a[11]. The receiver should count the number of received FEBEs.

(R)-42 The interface format at the physical layer for the B-ICI shall be based on asynchronous DS3 using the C-Bit Parity application as defined in ANSI T1.107a[11]. This unchannelized payload application of C-bit parity DS3 requires that all stuffing bit locations be used as data bits.

(R)-43 ATM traffic shall be carried over DS3 44.736 Mbit/s communication facilities by utilizing the PLCP frame. This PLCP is a subset of the PLCP defined in IEEE P802.6 and is the same as that used at the User-Network Interface.

Mapping of ATM cells into the DS3 is accomplished by inserting the 53 byte ATM cells into the DS3 PLCP. The PLCP shall then be mapped into the DS3 information payload. Note that the 125 micro-seconds PLCP sub-frame is longer than the 106.4 micro-seconds DS3 frame.

(R)-44 The following PLCP overhead bytes/nibbles are required to be activated across the B-ICI:

A1 - Frame Alignment
A2 - Frame Alignment
B1 - Bit Interleaved Parity
C1 - Cycle/Stuff Counter
G1 - PLCP Path Status

Px - Path Overhead Identifier
Zx - Growth Octets
Trailer Nibbles

(R)-45 The PLCP framing octets shall use the same framing pattern used in SONET. These octets are A1=11110110, A2=00101000.

(R)-46 Equipment at a B-ICI shall support the PLCP framing requirements described in TR-TSV-000773 [12].

(R)-47 The BIP-8 (B1) field supports PLCP path error monitoring, and shall be calculated over a 12 x 54 octet structure consisting of the POH field and the associated ATM cells (648 octets) of the previous PLCP frame.

(R)-48 A stuffing opportunity shall occur every third frame of a 3 frame (375 micro-seconds) stuffing cycle. The value of the C1 code shall be used as an indication of the phase of the 375 micro-seconds stuffing opportunity cycle.

(R)-49 The PLCP Path Status shall be allocated to convey the received PLCP status and performance to the transmitting far-end. This octet permits the status of the full receive/transmit PLCP path to be monitored at either end of the path. The G1 octet subfields are as follows: a 4-bit Far End Block Error (FEBE), a 1-bit RAI (Yellow), and 3 X bits (receivers shall be capable of ignoring the value of X bits).

(R)-50 The POI bytes shall index the adjacent POH octet of the DS3 PLCP. Table 3.5 provides the coding for each of the POI octets.

(R)-51 The Growth Octets shall be reserved for future use. These octets shall be set to Zi=00000000, by the transmitter (i=1, 2..., 6). The receiver shall be capable of ignoring the value contained in these fields.

(R)-52 The contents of each of the 13/14 Trailer nibbles shall be 1100.

(R)-53 The PLCP frame must have timing traceable to a PRS.

(R)-54 The HEC functionality (specified in Section 3.5) shall be supported at the B-ICI.

(R)-55 Equipment supporting DS3 based B-ICI shall implement the cell payload scrambler as described in Section 3.5.3. This scrambler shall have the capability of being enabled or disabled.

(R)-56 As a default mode, the cell payload scrambler shall be disabled for the DS3 based B-ICI.

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(R)-57 The cells are in predetermined locations within the PLCP. Framing on the DS3 and then on the PLCP is sufficient and shall be used to delineate cells at the B-ICI. The PLCP framing requirements can be found in TR-TSV-000773 [12].

(R)-58 The criteria in TR-TSY-000191[13] defining framing requirements for DS3 signals, shall be met at the B-ICI.

(R)-59 Power shall not be provided across the B-ICI.

(R)-60 The B-ICI for the DS3 shall meet the electrical PMD interface characteristics specified in ANSI T1.102 [14].

(R)-61 The maximum output jitter that will appear at the 44.736 Mbit/s B-ICI shall meet the requirements given in Bellcore's TR-NWT-000499 [15].

(R)-62 The following procedures [7] shall be performed to generate the HEC (Header Error Control) sequence by each cell originator.

Procedure:
The following polynomials are used to specify the HEC value:
$G(x) = x^8 + x^2 + x + 1$
$C(x) = x^6 + x^4 + x^2 + 1$
Where:
G(x) is the generating polynomial, and
C(x) is the coset polynomial.

The HEC value corresponding to a given header shall be obtained by the following procedures:

— The 32 bits of octets 1, 2, 3 and 4 of the header are considered to be the coefficients of a polynomial M(x) of degree 31 (bit 8 of octet 1 of the header corresponds to the x^{31} term and bit 1 of octet 4 of the header corresponds to the x^0 term).

— M(x) shall be multiplied by x^8 and divided (modulo 2) by G(x). C(x) shall be added modulo 2 (exclusive OR) to the remainder of this division producing a polynomial R(x) of degree < 8.

— The coefficients of R(x) are considered to be an 8-bit sequence. This 8-bit sequence is the HEC. The 8 bits of the HEC shall be placed in the HEC field so that the coefficient of the x^7 term is bit 8 and the coefficient of the x^0 term is bit 1.

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(R)-63 Network equipment supporting a B-ICI shall implement HEC error detection as defined in the CCITT Recommendation I.432 [7] and ANSI T1.624 [6].

(R)-64 In Detection state, all the cells with detected header errors shall be discarded.

(R)-65 A cell payload (self-synchronizing) scrambler, with polynomial $1 + X^{43}$ shall be used to scramble/de-scramble the 48 byte information field of ATM cells.

(R)-66 The scrambler shall operate continuously through the stream of ATM cells, bypassing ATM cell headers. Hence, ATM cell headers are not scrambled.

(R)-67 The scrambler state at the beginning of a cell payload shall be the state at the end of the previous cell payload.

(R)-68 Descrambling shall be disabled during the cell delineation hunt state (described later).

(R)-69 During the cell delineation presync and sync states (described later), the scrambler shall be enabled for a number of bits equal to the length of the information field and disabled for the following assumed header.

(R)-70 For the SONET based B-ICIs, the location of cell boundaries within an octet stream shall be obtained by determining the location at which the HEC coding rule is obeyed. This cell delineation process is described by the state diagram shown in Figure 3.5. This process has three states of operation: Sync state, Hunt state, and Presync state. These are described below:

— Sync State: In this state, cell boundary is assumed to be correct. The process remains in this state until the HEC coding rule is determined to be incorrect Alpha consecutive times. When this occurs, the process moves to the Hunt state.

— Hunt State: In this state, the delineation process is performed by checking whether the HEC coding rule is obeyed for the assumed header field. The first time the HEC coding rule is obeyed, the process passes to the Presync state.

— Presync State: In this state, the HEC rule is applied at the next location that a cell header is expected. The process repeats until either:

- The HEC coding rule has been confirmed Delta consecutive times. The process then passes to the Sync state.

- One incorrect HEC is detected. The process then returns to the Hunt state.

Robustness against false misalignment due to bit errors depends on the value of Alpha. Robustness against false delineation in the synchronization process depends on the value of Delta. Suggested values for Alpha and Delta are 7 and 6, respectively.

4. B-ICI ATM Layer Specification

(R)-71 From a single source the relay of cells within a VPC and/or VCC shall preserve cell sequence integrity.

(R)-72 Network equipment supporting a B-ICI shall encode and transmit cells according to the structure and field encoding convention defined for the NNI[3] (Figure 4.4 and 4.5).

(R)-73 The bits within the VPI and VCI fields used for routing shall be allocated using the following rules:

- The allocated bits of the VPI subfield shall be contiguous;
- The allocated bits of the VPI subfield shall be the least significant bits of the VPI subfield, beginning at bit 5 of octet 2;
- The allocated bits of the VCI subfield shall be contiguous;
- The allocated bits of the VCI subfield shall be the least significant bits of the VCI subfield, beginning at bit 5 of octet 4.

(R)-74 Any bits of the VPI subfield that are not allocated are set to 0. Any bits of the VCI subfield that are not allocated are set to 0.

(R)-75 Unallocated bits of VPI for VP switching and VPI/VCI for VC switching shall be checked to be zero "0" at the receiver. Cells with invalid VPI/VCI shall be discarded.

(R)-76 Network equipment supporting a B-ICI shall support the required set of the specified QOS classes [18].

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(R)-77 Network equipment supporting a B-ICI shall generate unassigned cells in the flow of cells passed to the physical layer in order to adjust to the cell rate required by the payload capacity of the physical layer.

(R)-78 Network equipment supporting a B-ICI shall encode the header fields of unassigned cells in accordance with the pre-assigned header field values defined in [3] and [17]. The information field of the unassigned cell shall be encoded in accordance with [3].

(R)-79 The receiving ATM entity shall extract and discard the unassigned and invalid cells from the flow of cells coming from the physical layer.

(R)-80 Network equipment supporting VP level management functions at the B-ICI shall encode the VCI field of the F4 flow OAM cells with the appropriate values as defined in[17] and shown in Figure 4.7.

(R)-81 Network equipment supporting VP level management functions at the B-ICI shall have the capability to identify F4 flow OAM cells within each VPC.

(R)-82 Network equipment supporting VC level management functions at the B-ICI shall encode the PTI field of the F5 flow OAM cells with the appropriate code points as defined in [17].

(R)-83 Network equipment supporting VC level management functions at the B-ICI shall have the capability to identify F5 flow OAM cells within each VC.

5. Common B-ICI Traffic Management and Network Performance

(R)-84 The mixture of Type 1, Type 2, Type 3, or other Reference Traffic Loads, and associated parameters applicable to a particular B-ICI link shall be established by bilateral agreement between the carriers for determining compliance with ATM layer performance objectives.

(R)-85 For each direction of transmission over a B- ICI, the carrier-to-carrier traffic contract shall consist of the Connection Traffic Descriptor, the requested QOS class, and the definition of a compliant ATM connection.

(R)-86 The definition of a compliant ATM connection at a B-ICI shall be established by agreement between the connecting carriers.

(R)-87 For compliant ATM connections, the network performance objectives (established by agreement between the connecting carriers) allocated to each network portion, demarcated by the B-ICI, shall be supported.

(R)-88 A carrier requesting that a new ATM connection be established across a B-ICI shall provide at least the following information:

- Source Traffic Descriptor [19] including only the Peak Cell Rate;
- Required QOS class [19];
- CDV Tolerance [19] at the B-ICI, as adjusted for build-up through the Network Elements between the originating UNI(s) and the B-ICI;
- Conformance Definition [19].

(R)-89 The CAC function of the carrier receiving a request that a new ATM connection be established across a B-ICI shall determine:

- Traffic parameters needed by this carrier's NPC function;
- Routing and allocation of network resources within this carrier's network.
- Whether or not this new ATM connection will be accepted by this carrier's network at its required QOS class.

(R)-90 When the NPC function is present, it shall provide at least the following actions:

- Verification of the validity of each VPI (i.e., whether the VPI value is associated with active VCCs),
- Enforcement of the peak cell rate for each VPC.

(R)-91 An NPC function shall maintain cell sequence integrity on every ATM connection it acts upon.

(R)-92 Any cell, regardless of its CLP bit value, that is identified as nonconforming by the NPC function when acting on the aggregate CLP = 0+1 cell stream of an ATM connection shall be discarded.

(R)-93 A network portion shall not modify the value of the EFCI code points (to preserve the EFCI integrity) in any User Information cell received across a B-ICI, except to set such code points to indicate the "congestion encountered" state when that network portion determines this would be appropriate.

6. Common B-ICI Operations and Maintenance

(R)-94 The DS3 transmission system shall meet the operations and maintenance requirements specified in ANSI T1.107 [21] and ANSI T1.107a [11]. This

includes provisions for performance monitoring, failure detection, alarms and maintenance.

(R)-95 The PLCP performance parameters shall be monitored at the PLCP layer, as described in ANSI T1.624[6]. Monitored parameters include Coding Violations (CV), Errored Seconds (ES), Severely Errored Seconds (SES), Severely Errored Framing Seconds (SEFS), and Unavailable Seconds (UAS).

(R)-96 The operations of the PLCP Far End Block Error (FEBE) shall conform to ANSI T1.624 [6]. The FEBE field shall provide a count of 0 to 8 BIP-8 errors received in the previous PLCP frame, i.e., G1(FEBE) = 0000 through G1(FEBE) = 1000. Any other value of G1 would be caused by other errors and shall be interpreted as 0 errors.

(R)-97 The PLCP LOF state shall be declared when a PLCP OOF, as defined in IEEE 802.6[22], persists for 1 milli-second.

(R)-98 The RAI (Yellow) field shall alert the transmitting PLCP that a received failure indication has been declared along the path.

(R)-99 When an incoming failure condition is detected that persists for a "soaking period" (typically 2 - 10 seconds), an RAI (Yellow) shall be sent to the upstream end by setting G1(RAI)=1. The RAI (Yellow) shall be detected (by the upstream end) when G1(RAI)=1 for 10 consecutive PLCP frames.

The indication is cleared at the downstream end by setting G1(RAI)=0 when he incoming failure has ceased for 15 ±5 seconds. At the upstream end, removal of the RAI (Yellow) signal is recognized by detecting G1(RAI)=0 for 10 consecutive PLCP frames.

(R)-100 Section BIP-8 shall be calculated over all bits of the previous STS-Nc frame after scrambling by the frame synchronous scrambler. The computed BIP-8 shall be placed in the first B1 byte location of the subsequent STS frame before scrambling.

(R)-101 Line BIP-8N shall be calculated over all bits of the LOH and STS Envelope capacity of the previous STS frame before scrambling by the frame synchronous scrambler. The computed BIP- 8N shall be placed in each B2 byte of the STS frame before scrambling.

(R)-102 Path BIP-8 shall be calculated over all bits (N x 783 bytes for STS-NC, regardless of pointer justification) of the previous STS SPE before scrambling by the SONET frame synchronous scrambler, and placed in the B3 byte of the current STS SPE before scrambling.

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(R)-103 Monitoring of the incoming signal shall be accomplished by calculating the values of the Section BIP-8, the Line BIP-8N, and Path BIP-8 and comparing them to the incoming B1, B2, and B3 bytes.

(R)-104 SONET path performance parameters shall be monitored as described in ANSI T1.624 [6]. Monitored parameters include STS Path Coding Violations (CVs), STS Path Errored Seconds (ESs), STS Path Severely Errored Seconds (SESs), and STS Path Unavailable Seconds (UAS).

(R)-105 A count of the difference in the calculated Path BIP-8 and the received B3 byte shall be placed in bits 1 through 4 of the G1 byte.

(R)-106 The network equipment supporting a B-ICI shall enter an LOS state on the incoming signal within 100 micro-seconds of the onset of an all-zeros pattern lasting 2.3 micros-seconds or longer. An "all zeros pattern" corresponds to no light pulses for OC-N optical interfaces and no voltage transitions for STS-N electrical interfaces.

(R)-107 The network equipment supporting a B-ICI shall exit the LOS state when two consecutive valid frame alignment patterns have been detected and, during the intervening time, no "all- zeros pattern" considered as LOS was detected in the incoming signal.

(R)-108 The network equipment supporting a B-ICI shall enter an LOF state when an Out-Of-Frame (OOF) on the incoming signal persists for 3 milli-seconds. An OOF is declared when four or more consecutive errored framing patterns have been received.

(R)-109 The network equipment supporting a B-ICI shall exit the LOF state within 3 milli-seconds of a continuous in-frame signal in the incoming signal.

(R)-110 The network equipment supporting a B-ICI shall enter an LOP state when a valid STS pointer cannot be obtained using the pointer interpretation rules described in ANSI T1.105 [4]. The network equipment supporting a B-ICI also enters an LOP state if a valid pointer is not found in 8, 9, or 10 consecutive frames, or if 8, 9, or 10 consecutive New Data Flags (NDFs) are detected.

(R)-111 The network equipment supporting a B-ICI shall exit the LOP state when a valid STS pointer with normal NDF, or a concatenation indicator, is detected in three consecutive frames in the incoming signal.

(R)-112 The network equipment supporting a B-ICI shall follow the Path Signal Label Mismatch states defined in TR-NWT-000253 [5].

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(R)-113 The network equipment on either side of a B-ICI shall meet the requirements associated with generation, detection, activation, and deactivation of Line AIS, Path AIS, Line RDI, and Path FEBE as specified in TR-NWT-000253 [5].

(R)-114 Path RDI shall be generated within 250 micro-seconds by an STS PTE upon entering LOS, LOF, LOP or LOC state or upon detecting Line AIS or Path AIS, by setting bit 5 in the Path Status byte (G1) to '1'. This bit retains this value for the duration of the RDI condition. Transmission of the RDI signal shall cease within 250 micro-seconds when the STS PTE no longer detects the above failure states or Line AIS or Path AIS.

(R)-115 A count of the differences in the calculated BIP-8N and the received B2 bytes shall be placed in the 3rd Z2 byte of the STS-3c frame.

(R)-116 Equipment at each side of the B-ICI shall transition to failure states on the basis of bilateral agreements.

(R)-117 The operations and maintenance functionality defined for the STS-3c (155.520 Mbit/s) B-ICI shall also apply to the STS-12c (622.080 Mbit/s) B-ICI.

(R)-118 Network equipment at a B-ICI shall support the F4 and F5 Management flows as defined in CCITT Recommendation I.610[25] and T1S1.5/92-029R3[26] for the OAM functions defined in Section 6.2.3.

(R)-119 Network equipment at a B-ICI shall encode/interpret the OAM cells according to the format and encoding rules defined in T1S1.5/92-029R3[26] and CCITT Recommendation I.610[25] for the OAM functions defined in Section 6.2.3.

(R)-120 Network equipment terminating a VPC at the B- ICI shall detect incoming VP-AISs and shall generate VP-FERFs in the upstream direction (toward the other carrier's network) to alert the ATM nodes about the failure.

(R)-121 Network equipment terminating a VCC at the B- ICI that detects an incoming VC-AIS shall generate, for selected VCCs, a VC-FERF in the upstream direction (toward the other carrier's network).

(R)-122 Network equipment at a B-ICI, acting as an intermediate VP node, shall generate VP-AIS upon detection of a VPC failure or upon receiving a physical layer failure notification.

(R)-123 Network equipment at a B-ICI, acting as an intermediate VC node, shall generate, for selected VCCs, a VC-AIS upon detection of a VCC failure or upon receiving a physical layer failure notification.

(R)-124 Network equipment at a B-ICI inserting Alarm Surveillance cells shall do so at a nominal rate of 1 cell per second per VPC or VCC, as specified in Section 6 of CCITT Recommendation I.610[25]. The release conditions shall be as specified in CCITT Recommendation I.610.

(R)-125 Network equipment terminating a connection at a B-ICI that receives OAM cells with a Loopback Indication value other than '00000001', OAM Cell Type = '0001', and Function Type = '1000' shall discard the cell.

(R)-126 Network equipment terminating a connection at a B-ICI that receives OAM cells with a Loopback Indication value of '00000001', OAM Cell Type = '0001', and Function Type = '1000', shall decrement the Loopback Indication value and then loopback the cell within one second.

(R)-127 Network equipment at a B-ICI that terminates a segment on which performance monitoring is active in the outgoing direction, shall generate PM cells containing forward monitoring information. These cells shall be generated according to the procedures specified in CCITT Recommendation I.610[25] and T1S1.5/92-029R3[26], and described in this Section.

(R)-128 Network equipment at a B-ICI that terminates a segment on which performance monitoring is active in the incoming direction, shall generate PM cells containing backward reporting information. These backward reports shall be generated according to the procedures specified in CCITT Recommendation I.610[25] and T1S1.5/92-029R3[26], and described in this Section.

(R)-129 Network equipment at a B-ICI that sends backward reports shall send those reports within one second after receiving the PM cell with the forward monitoring information. The end point shall send backward reports in the same sequence in which the corresponding forward monitoring OAM cells were received.

(R)-130 Network equipment at a B-ICI shall be capable of generating PM cells on a minimum number of simultaneous connections/segments. This minimum number depends on the rate of the interface.

(R)-131 Network equipment at a B-ICI shall support end-to-end performance monitoring for specified VPC/VCC connections. This entails following the same requirements as for segment performance monitoring, except that the

generation of Performance Management cells occurs at connection end points, and an average block size is enforced.

(R)-132 In support of on-demand VP/VC Performance Monitoring for connections and/or segments terminated at a B-ICI, network equipment at a B-ICI shall provide the capability of activating and deactivating the VP/VC Performance Monitoring function according to the procedures specified in I.610[25] and T1S1.5/92-029R3[26], and described in Section 6.2.3.3.2.

(R)-133 Network equipment at a B-ICI that receives an "Activate" message for Performance Monitoring shall support requests for PM in the direction of A-B (i.e., when the "Directions of Action" field = '10'). It may also support activation requests for the direction B-A or for bi-directional activation (both A-B and B-A).

(R)-134 When network equipment at a B-ICI receives an "Activate" or "Deactivate" message for Performance Monitoring, it shall send the appropriate return message within 1 second.

(R)-135 Network equipment at a B-ICI can disable Performance Monitoring even if no response is received, or a denial is received, from a deactivation request. For interoperability, the network equipment at a B-ICI shall send the deactivation request before disabling Performance Monitoring.

7. B-ICI Signaling

None.

8. PVC-Based Inter-Carrier CRS Support on a B-ICI

None.

9. PVC-Based Inter-Carrier CES Support on a B-ICI

(R)-136 Network equipment associated with a multi- service B-ICI supporting DS1 or DS3 CES shall support CBR AAL Unstructured Data Transfer (UDT) functions as specified in ANSI T1.CBR [39].

(R)-137 Network equipment at a B-ICI performing receiving IWF functions (with an AAL Type 1 supporting UDT) shall measure buffer overflows, cell loss, number of starvation events, and time in the starvation condition.

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(R)-138 A sending IWF supporting UDT at a B-ICI shall detect LOS, as specified in ANSI T1.CBR-1993 [39].

(R)-139 Network equipment at a B-ICI performing sending IWF functions (with an AAL Type 1 supporting UDT) shall generate a DSn AIS signal and map it into SAR_PDUs, upon being informed of an LOS by DSn/CS interworking.

10. PVC-Based Inter-Carrier FRS Support on a B-ICI

(R)-140 The FR/ATM IWF shall use the FR-SSCS as specified in [47].

(R)-141 The default (2 octet) address field format shall be supported.

(R)-142 The FR/ATM IWF shall utilize the AAL Type 5 CPCS and SAR as specified in the CCITT Recommendation I.363 [48] (Figure 10.7).

(R)-143 The IWF shall support many-to-one multiplexing. The FR-SSCS DLCI value(s) used shall be agreed upon between the two ATM end systems (e.g., ATM end users or IWFs).

(R)-144 The IWF shall support one-to-one multiplexing. The FR-SSCS DLCI value used shall be agreed upon between the two ATM end systems (e.g., ATM end users or IWFs).

(R)-145 IWF equipment shall support both of the following two modes, selectable for each ATM connection:

Mode 1: The Discard Eligibility (DE) field in the Q.922 Core frame shall be copied unchanged into the DE field in the FR- SSCS-PDU header, and mapped to the ATM Cell Loss Priority (CLP) of every ATM cell generated by the segmentation process of that frame.

Mode 2: The Discard Eligibility (DE) field in the Q.922 Core shall be copied unchanged into the DE field in the FR-SSCS-PDU header; and the ATM Cell Loss Priority (CLP) of every ATM cell generated by the segmentation process of that frame shall be set to a constant value (either 0 or 1). The value is decided when the ATM connection is set up, and is used for all cells generated from the segmentation process of every frame, until the ATM connection characteristics are changed.

(R)-146 IWF equipment shall support both of the following two modes, selectable for each ATM connection:

Mode 1: If one or more ATM cell belonging to a frame has its CLP field set or if the DE field of the FR-SSCS-PDU is set, the IWF shall set the DE field of the Q.922 Core frame.

Mode 2: No mapping shall be performed from the ATM-layer to Q.922 Core layer. The FR-SSCS-PDU DE field shall be copied unchanged to the Q.922 Core frame DE field, independent of CLP indication(s) received at the ATM layer.

(R)-147 The FECN field of the Q.922 Core frame shall be copied unchanged into the FECN field in the FR-SSCS-PDU. The EFCI field of all ATM cells shall be always set to '0'.

(R)-148 If the EFCI field in the last ATM cell of a segmented frame received is set, or if the FECN field of the received FR-SSCS-PDU is set, then the IWF shall set the FECN of the Q.922 Core frame.

(R)-149 The BECN field in the FR-SSCS-PDU shall be copied unchanged into the BECN field of the Q.922 Core frame.

(R)-150 The BECN field in the FR-SSCS-PDU shall be set to "1" by the IWF if either of the following two conditions is met:

1. BECN is set in the Q.922 Core frame relayed in the FR to B-ISDN direction, or

2. EFCI was set in the last ATM cell of the last segmented frame received in the BISDN to FR direction for this bi-directional connection (i.e., EFCI = 1 to FECN mapping was performed by the IWF in the BISDN to FR direction).

(R)-151 The management of the FR-SSCS layer shall be performed by bi-directional (symmetric) PVC management procedures adopted from the CCITT Recommendation Q.933 Annex A. Selection of specific options within the Q.933 Annex A shall be aligned with the FR Forum Implementation Agreement.

(R)-152 Network equipment at a B-ICI terminating the AAL Type 5 common part shall count the occurrences of the listed errors at the receiving point.

11. SMDS Support on a B-ICI

(R)-153 The SAR_PDU shall have the format shown in Figure 11.4 (I.363).

(R)-154 The 2-bit Segment Type field shall be used to delimit CPCS_PDUs. The Segment Type field shall indicate whether the SAR_PDU contains the beginning of a CPCS_PDU (a Beginning of Message SAR_PDU); the continuation of a CPCS_PDU (a Continuation of Message SAR_PDU); the end of a CPCS_PDU (an End of Message SAR_PDU); or fully contains a CPCS_PDU (a Single Segment Message SAR_PDU). The field shall be encoded as in Table 11.1 (I.363).

(R)-155 The 4-bit Sequence Number field shall be used by the AAL entity in receiving a CPCS_PDU to verify that all of the SAR_PDUs of the CPCS_PDU have been received and concatenated in the correct sequence. The value of this field is incremented (modulo 16) for each successive SAR_PDU derived from the same CPCS_PDU.

(R)-156 The 10-bit MID field shall contain information used to allow association of SAR_PDUs with a CPCS_PDU. The MID shall be the same for all SAR_PDUs of a given CPCS_PDU, and unique among CPCS_PDUs concurrently in transit in a given direction. Valid MIDs shall range from 1 to 1023. MID = 0 shall not be used.

(R)-157 The 44-octet SAR_PDU Payload shall contain a portion of the CPCS_PDU. This field shall be composed of two subfields

- User Information — This subfield shall contain up to 44 octets of a CPCS_PDU.
- Fill — This subfield shall contain a sufficient number of octets to completely fill the 44-octet SAR_PDU Payload after the User Information subfield is inserted. The Fill subfield shall be encoded with all zeros.

(R)-158 The 6-bit LI field shall indicate how many of the 44 octets of the SAR_PDU Payload contain User Information (i.e., a portion of a CPCS_PDU). For BOM and COM SAR_PDUs, this field shall indicate 44 octets. For EOM SAR_PDUs, this field shall take values 4, 8,....44 octets. For SSM SAR_PDUs, this field shall take values 8, 12,....44 octets.

(R)-159 The 10-bit CRC shall provide for the detection of errors in the SAR_PDU. The value of the CRC field shall be formed by the coefficients of the polynomial remainder of the modulo 2 division by the generating polynomial $x^{10} + x^9 + x^5 + x^4 + x + 1$ of the product of x^{10} and the polynomial representing the content of the SAR_PDU. The polynomial representing the content of the SAR_PDU shall be generated by using the first bit of the SAR_PDU as the coefficient of the highest-order term.

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(R)-160 A SAR sender shall segment each CPCS_PDU created into one or more units of SAR_PDU payload. Each unit of SAR_PDU payload shall contain 44 octets of the CPCS_PDU, with the exception of the last unit of SAR_PDU payload for a CPCS_PDU, which may contain less than 44 octets of the CPCS_PDU. The order of octets in the CPCS_PDU shall be preserved by the segmentation.

(R)-161 Upon segmentation of a CPCS_PDU, a SAR sender shall create a SAR_PDU for each unit of SAR_PDU payload created. The type of SAR_PDU created is determined as follows:

- **CPCS_PDU of one unit of SAR_PDU payload:** If the length of the CPCS_PDU is less than or equal to 44 octets, then only one unit of SAR_PDU payload shall be generated, containing the entire CPCS_PDU. The associated SAR_PDU shall be an SSM.

- **CPCS_PDU of two or more units of SAR_PDU payload:** If the length of the CPCS_PDU is greater than 44 octets, then more than one unit of SAR_PDU payload shall be generated. The SAR_PDU associated with the first unit of SAR_PDU payload shall be a BOM. The SAR_PDUs associated with all of the other units of SAR_PDU payload, except the last, shall be COMs. The SAR_PDU associated with the last unit of SAR_PDU payload of the CPCS_PDU shall be an EOM.

(R)-162 Each field in a SAR_PDU shall be populated as described in Section — "SAR_PDU Format".

(R)-163 A SAR sender shall maintain a Transmit Sequence Number (TxSN) counter for each MID it uses. Prior to transmitting a BOM, the TxSN counter shall have an initial value in the range 0 to 15. For each BOM, COM and EOM SAR_PDU of a CPCS_PDU transmitted, the SAR sender shall insert in the Sequence Number field the value of the TxSN counter associated with the MID. After setting the Sequence Number field of a BOM or a COM SAR_PDU, the SAR sender shall increment the value of the TxSN counter by one (modulo 16) for use with the next SAR_PDU associated with the same MID.

(R)-164 The SAR sender shall transfer each created SAR_PDU to the ATM layer entity, which shall perform the appropriate "ATM Layer Functions Involved at the B-ICI" defined in Section 4.

(R)-165 A SAR sender shall support the transfer of a maximum of 1023 CPCS_PDUs in transit concurrently.

(R)-166 Upon receipt of a SAR_PDU, the SAR receiver shall check that:

- the SAR_PDU CRC is valid; and
- the value in the MID field is in the range [1,1023].

If either of these checks fails, the SAR_PDU shall be discarded. If the SAR_PDU passes both checks, the SAR receiver shall forward the SAR_PDU to the Receiver State Machine (RSM) associated with the MID value contained in the SAR_PDU header. In this case, the SAR receiver shall implement the functional equivalent of the Requirements defined for the — "SAR Receive Process".

(R)-167 A SAR receiver shall support 1023 concurrent active RSMs (one per MID).

(R)-168 If a SAR_PDU is received with Segment Type = BOM and MID = X, the SAR_PDU shall be processed as follows:

1. If the RSM for MID = X is in the REASS state, any partially received CPCS_PDU for the associated receive process shall be considered to be unusable.
2. The receive process is started for the new BOM. The RSM for MID = X shall be in the REASS state. The SAR receiver shall begin measuring the time elapsed while the process is in the REASS state.
3. If the value of the LI field in the BOM SAR_PDU is different than 44, the SAR receiver shall stop processing the SAR_PDU, the SAR_PDU shall be discarded, and the RSM for MID = X shall return to the IDLE state. Otherwise, the SAR receiver shall continue with step 4.
4. The SAR receiver shall establish a Receive Sequence Number (RxSN) counter, associated with MID = X. The SAR receiver shall initialize the value of the RxSN counter to the value of the Sequence Number field of the BOM SAR_PDU plus one (modulo 16).

(R)-169 If a SAR_PDU is received with Segment Type = COM and MID = X, the SAR_PDU shall be processed as follows:

1. If the RSM for MID = X is in the IDLE state, the SAR receiver shall stop processing the SAR_PDU, the SAR_PDU shall be discarded, and the RSM for MID = X shall remain in the IDLE state.

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2. If the value of the LI field in the COM SAR_PDU is different than 44, the SAR receiver shall stop processing the SAR_PDU, the SAR_PDU shall be discarded, and the RSM for MID = X shall return to the IDLE state. Any partially received CPCS_PDU for the associated receive process shall be considered to be unusable. Otherwise, the SAR receiver shall continue with step 3.

3. If the value of the Sequence Number field of the COM SAR_PDU is different from the expected value contained in the RxSN counter for MID = X, the SAR receiver shall stop processing the SAR_PDU, the SAR_PDU shall be discarded, and the RSM for MID = X shall return to the IDLE state. Any partially received CPCS_PDU for the associated receive process shall be considered to be unusable. If the value of the Sequence Number field of the COM SAR_PDU is equal to the expected value contained in the RxSN counter for MID = X, the SAR receiver shall increment the value of the RxSN counter by one (modulo 16).

(R)-170 If a SAR_PDU is received with Segment Type = EOM and MID = X, the SAR_PDU shall be processed as follows:

1. If the RSM for MID = X is in the IDLE state, the SAR receiver shall stop processing the SAR_PDU, the SAR_PDU shall be discarded, and the RSM for MID = X shall remain in the IDLE state.

2. If the value of the LI field in the EOM SAR_PDU is less than 4 or greater than 44, the SAR receiver shall stop processing the SAR_PDU, the SAR_PDU shall be discarded, and the RSM for MID = X shall return to the IDLE state. Any partially received CPCS_PDU for the associated receive process shall be considered to be unusable. Otherwise, the SAR receiver shall continue with step 3.

3. If the value of the Sequence Number field of the EOM SAR_PDU is different from the expected value contained in the RxSN counter for MID = X, the SAR receiver shall stop processing the SAR_PDU, the SAR_PDU shall be discarded, and the RSM for MID = X shall return to the IDLE state. Any partially received CPCS_PDU for the associated receive process shall be considered to be unusable. If the value of the Sequence Number field of the EOM SAR_PDU is equal to the expected value contained in the RxSN counter for MID = X, the SAR receiver shall complete the SAR receive process, return the RSM for MID = X to the IDLE state, and deliver the CPCS_PDU to the CPCS receiver (see Section — "CPCS Receiver Procedures").

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(R)-171 If a SAR_PDU is received with Segment Type = SSM and MID = X, the SAR_PDU shall be processed as follows:

1. If the RSM for MID = X is in the REASS state, any partially received CPCS_PDU for the associated receive process shall be considered to be unusable.

2. If the value of the LI field in the SSM SAR_PDU is less than 8 or greater than 44, the SAR receiver shall stop processing the SAR_PDU, the SAR_PDU shall be discarded, and the RSM for MID = X shall return to the IDLE state. Otherwise, the SAR receiver shall continue with step 3.

3. The SAR receiver shall complete the SAR receive process, return the RSM for MID = X to the IDLE state, and deliver the CPCS_PDU to the CPCS receiver (see Section — "CPCS Receiver Procedures").

(R)-172 The maximum time that is allowed to elapse between the receipt of a BOM SAR_PDU and the corresponding EOM SAR_PDU shall be specified by the value of the parameter SAR Receive Interval (SRI). An active receive process shall be terminated (i.e., go to the IDLE state) if the elapsed time exceeds the SRI. The value of the SRI is for further study.

(R)-173 The CPCS_PDU shall have the format shown in Figure 11.6 (I.363).

(R)-174 The 1-octet CPI field shall be encoded with all 0's.

(R)-175 The 1-octet Btag field shall contain the same binary encoded value as the Etag field, ranging from 0 through 255.

(R)-176 The 2-octet BASize field shall give the length, in units indicated by the CPI field, of the User Information subfield of the Payload field. The BASize field shall be encoded in binary format.

(R)-177 The variable-length Payload field shall be composed of two subfields:

- User Information — This subfield shall contain an ICIP_CLS_PDU.

- PAD — This subfield shall contain the adequate number of octets, from 0 to 3 octets, to ensure that the CPCS_PDU Payload field is 4-octet aligned.

(R)-178 The 1-octet AL field shall be encoded with all 0's.

(R)-179 The 2-octet Length field shall give the length, in octets, of the User Information subfield of the Payload field.

(R)-180 Upon receipt of an ICIP_CLS_PDU from the ICIP_CLS Layer, a CPCS sender shall create a CPCS_PDU, based on the ICIP_CLS_PDU.

(R)-181 Each field in a CPCS_PDU shall be populated as described in Section — "CPCS_PDU Format".

(R)-182 The value of the Btag for a CPCS_PDU shall be different than the value used in the previous CPCS_PDU which was sent by the CPCS sender using the same MID value that will be used for the current CPCS_PDU.

(R)-183 The CPCS sender shall deliver the CPCS_PDU to the SAR entity, which shall perform the "SAR Sender Procedures" defined earlier.

(R)-184 Upon receipt of a complete CPCS_PDU from a completed receive process, a CPCS receiver shall check the CPCS_PDU for the following errors:

- Values of the Btag field in the CPCS_PDU header and the Etag field in the CPCS_PDU trailer that are not equal.
- A Length field value that is greater than the number of received CPCS_PDU octets minus 8 (4 octets of CPCS_PDU header and 4 octets of CPCS_PDU trailer).
- A Length field value that is less than the number of received CPCS_PDU octets minus 11 (4 octets of CPCS_PDU header, 4 octets of CPCS_PDU trailer, and 3 octets of possible padding).
- A CPCS_PDU length that is not a multiple of 4 octets.
- A Length field value that is not equal to the BASize field value.

If any of the above errors occur, the CPCS_PDU shall be discarded. Discarding a CPCS_PDU is accomplished by discarding one or more of the SAR_PDUs associated with the CPCS_PDU.

(R)-185 The CPCS Receiver shall deliver the CPCS_PDU User Information to the ICIP_CLS Layer entity, which shall perform the "ICIP_CLS Layer Receiving Procedures" defined later.

(R)-186 The ICIP_CLS_PDU shall use the format shown in Figure 11.8.

(R)-187 The Address fields shall each be 8 octets (64 bits) long. The first 4 bits shall identify the Address Type and shall contain the value 1100 for public 60-bit individual addresses and 1110 for public 60-bit group addresses. Other Address Type values are not used.

(R)-188 The remaining 60 bits shall identify an address. Addresses that begin with the E.164 [55] Country Code "1" shall be followed immediately by an address of 10 decimal digits. Other Country Codes may be used for international service. In this case, the Country Code (from 1 to 3 decimal digits) shall precede the address.

(R)-189 The Country Code and address shall be encoded with the Binary-Coded Decimal (BCD) digits of its value, and shall be left-justified within the Address Subfield. To encode the Country Code "1", the four most significant bits of the address shall be set to the binary value 0001. To encode the 10 decimal digit address, the next 40 bits shall be the BCD value of the address. The remaining 16 least-significant bits shall be filled with 1's. For international service, SMDS addresses may use the entire 60 bits of the Address subfield. The least-significant bits which are not used shall be filled with 1's.

(R)-190 The 6-bit binary-encoded Protocol Identification (PI) field shall identify the ICIP User. The value of the PI field for all versions of the ICIP shall fall between the decimal values 48 and 63.

(R)-191 The 2-bit PL field shall be encoded with the binary value 00.

(R)-192 The 4-bit QOS field shall be encoded with the binary value 0000.

(R)-193 The CIB shall be set to 0.

(R)-194 The 3-bit Header Extension Length (HEL) field shall be encoded with the value 011, indicating a 12-octet Header Extension field.

(R)-195 The 2-octet Bridging field shall be filled with 0's.

(R)-196 The Header Extension field shall be 12 octets long.

(R)-197 For the transport of end-user data, the 8-octet Service Specific Information (SSI) field shall be formatted as shown in Figure 11.10.

(R)-198 The 1-octet ICIP Version subfield shall be encoded with the binary value 1, meaning ICIP Version 1[52].

(R)-199 For the transport of end-user data, the variable-length ICIP-User Data field shall contain the end-user's SMDS Interface Protocol (SIP) L3_PDU without its SIP L3_PDU Trailer.

(R)-200 When sending an ICIP_CLS_PDU, an ICIP_CLS Layer entity shall generate each field as described in Section — "ICIP_CLS_PDU Format".

(R)-201 The ICIP_CLS Layer sender shall transfer each created ICIP_CLS_PDU to the CPCS entity, which shall perform the "CPCS Sender Procedures" defined earlier.

(R)-202 If the Destination Address or Source Address formats are incorrect or the Address Type is not a recognized value, then the ICIP_CLS receiver shall discard the ICIP_CLS_PDU.

(R)-203 If the Protocol Identification field value is not between the decimal values 48 and 63 inclusive, then the ICIP_CLS receiver shall discard the ICIP_CLS_PDU.

(R)-204 If the Pad Length field does not equal 00, then the ICIP_CLS receiver shall discard the ICIP_CLS_PDU.

(R)-205 If the Quality of Service field does not equal 0000, then the ICIP_CLS receiver shall discard the ICIP_CLS_PDU.

(R)-206 If the CRC-32 Indicator Bit does not equal 0, then the ICIP_CLS receiver shall discard the ICIP_CLS_PDU.

(R)-207 If the Header Extension Length does not equal 011, then the ICIP_CLS receiver shall discard the ICIP_CLS_PDU.

(R)-208 If the Bridging field is not filled with 0's, then the ICIP_CLS receiver shall discard the ICIP_CLS_PDU.

(R)-209 If the value in the ICIP Version subfield is not equal to the binary value 1, then the ICIP_CLS receiver shall discard the ICIP_CLS_PDU.

(R)-210 If the Reserved subfield of the Service Specific Information field is not filled with 0's, then the ICIP_CLS receiver shall discard the ICIP_CLS_PDU.

(R)-211 The ICIP_CLS layer receiver shall verify that the SIP L3_PDU satisfies the following conditions defined in [50]:

- The Version element appears first within the Header Extension.

- For the Version element type, the Element Value is encoded with the binary value "1".
- For the Carrier Selection element type appearing second within the Header Extension field, the value in the Element Length subfield specifies a length of 4, 6, or 8.
- Within the Element Value subfield of a Carrier Selection element appearing second within the Header Extension field, the carrier value is encoded as four decimal, BCD digits.

If any are incorrect, the ICIP_CLS layer receiver shall discard the ICIP_CLS_PDU.

(R)-212 If the length of the ICIP_CLS_PDU is not an integral multiple of 4 octets in the range [76, 9268] octets, the ICIP_CLS Layer receiver shall discard the ICIP_CLS_PDU.

(R)-213 Network equipment at a B-ICI terminating the AAL Type 3/4 shall measure the SAR and CPCS errors listed in this Section.

12. Usage Metering

None.

II. Summary of Options (O)

1. Introduction

None.

2. Network Aspects

None.

3. B-ICI Physical Layer Specification

(O)-1 The FEAC channel implementation should support seven (7) alarm/status messages. The Alarms/Status Conditions and associated Codewords are given in Table 3.2.

(O)-2 The three (3) FEAC Command Functions and Codewords applicable for the B-ICI are listed in Table 3.3, and should be supported if there is a bilateral agreement between the carriers.

(O)-3 These bits are for a terminal-to-terminal path maintenance data link and are optional. If used, this function should comply to the ANSI T1.107a[11] definition.

(O)-4 As a configurable option, a cell payload scrambler may be enabled for the DS3 based B-ICI.

(O)-5 Network equipment supporting a B-ICI may also implement single bit error correction in addition to error detection. In this case, the two modes of operation shall interact in accordance to the procedure defined in the CCITT Recommendation I.432 [7] and ANSI T1.624[6] .

4. B-ICI ATM Layer Specification

(O)-6 Network equipment supporting a B-ICI may support the unspecified QOS class [18].

5. Common B-ICI Traffic Management and Network Performance

None.

6. Common B-ICI Operations and Maintenance

None.

7. B-ICI Signaling

None.

8. PVC-Based Inter-Carrier CRS Support on a B-ICI

None.

9. PVC-Based Inter-Carrier CES Support on a B-ICI

None.

10. PVC-Based Inter-Carrier FRS Support on a B-ICI

(O)-7 The support of 3 and 4 octet address field formats is an option.

(O)-8 A mechanism may be needed to exit the congestion state dependent on the traffic activity of the ATM virtual channels. As an example (Figure 10.10), a timer can be used to reset the congestion state (condition 2 above) after a time period T if no new congestion information is received in the B-ISDN to Frame Relay (FR) direction. If the EFCI of the last cell of the next frame received is not set, the congestion state is cleared. Otherwise, the timer is restarted. The value of the FECN received in the FR-SSCS-PDU is not mapped to the BECN of the FR-SSCS-PDU in the opposite direction.

11. SMDS Support on a B-ICI

(O)-9 The LI field value 63 should be used to indicate an Abort_SAR_PDU[52]. The Segment Type of an Abort_SAR_PDU should be encoded as EOM.

(O)-10 A SAR receiver should terminate an active receive process if the SAR receiver determines, before the full CPCS_PDU associated with that receive process has been received, that the CPCS_PDU must not be delivered. Reasons that the SAR receiver may determine this include:

- CPCS_PDU or ICIP_CLS_PDU format validation performed prior to reception of the EOM determines that the data unit contains errors; or
- Feature processing, performed prior to the reception of the EOM, determines that the ICIP_CLS_PDU encapsulated within the CPCS_PDU must not be delivered.

(O)-11 If the implementation of the CPCS receiver permits, then that CPCS receiver shall, upon receipt of a complete CPCS_PDU from a completed receive process, check the CPCS_PDU for the following errors:

- An invalid CPI field value. (The only valid CPI value currently defined for SMDS is 0.)

- An AL field that is not equal to 0.

CPCS receiver implementations that comply with CCITT Recommendation I.363 will perform the checks in the Option above. However, the checks are listed as Options to ease the transition from IEEE 802.6 to ATM (since IEEE 802.6-based equipment does not perform the checks).

12. Usage Metering

None.

Appendix A - Initial Guidelines for FRS Traffic Characterization at the B-ICI

The FR traffic parameters can be used to determine approximately equivalent ATM traffic parameters as described below. Note that this description only provides the guidelines to characterize FR traffic in terms of ATM traffic conformance parameters; it does not specify ATM traffic conformance parameters that FR traffic must conform to. These guidelines are based on the traffic conformance parameters and functions described in the ATM Forum UNI Specification, 1993.

A.1 1-To-1 Mapping

The following methods can be used to characterize FR traffic in terms of ATM traffic conformance parameters for 1-to-1 mapping.

A.1.1 Method 1

This method characterizes FR traffic using 3 Generic Cell Rate Algorithms (GCRAs) as described in Example 2a in Appendix B of the ATM Forum UNI Specification, 1993.

For frames with 'n' user information bytes:

$$PCR_{0+1} = \frac{AR}{8}\left[OHA\ (n)\right]$$

$$SCR_0 = \frac{CIR}{8}\left[OHB\ (n)\right]$$

$$MBS_0 _ \left[\frac{Bc}{8}\left(\frac{1}{1-\frac{CIR}{AR}}\right) + 1\right]\ \left[OHB\ (n)\right]$$

$$SCR_1 = \frac{EIR}{8}\left[OHB\ (n)\right]$$

$$MBS_1 _ \left[\frac{Be}{8}\left(\frac{1}{1-\frac{EIR}{AR}}\right) + 1\right]\ \left[OHB\ (n)\right]$$

Where:

n = Number of user information octets in a frame

AR = Access Line Rate (bits/sec)

CIR = Committed Information Rate, $\frac{Bc}{T}$, (bits/sec)

EIR = Excess Information Rate, $\frac{Be}{T}$, (bits/sec)

CIR + EIR _ AR

Bc = Committed Burst size (bits)

Be = Excess Burst Size (bits)

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T = Measurement Interval (sec)

PCR = Peak Cell Rate (cells/sec)

SCR = Sustained Cell Rate (cells/sec)

MBS = Maximum Burst Size (cells)

CDVT = Cell Delay Variation Tolerance (sec)

$\cup X_$ = Stands for the smallest integer greater than or equal to X

$$OHA(n) = \left[\frac{\cup \frac{n+h1+h2}{48} _}{n+h1+h3} \right] = \text{Overhead Factor for Access Rate (cells/byte)}$$

h1 = Frame Relay Header Size (octets), 2-octet, 3-octet, or 4-octet headers

h2 = AAL Type 5 PDU Trailer Size (8 octets)

h3 = Frame Relay High-Level Data Link Control (HDLC) overhead of CRC-16 and Flags (4 octets)

$$OHB(n) = \left[\frac{\cup \frac{n+h1+h2}{48} _}{n} \right] = \text{Overhead Factor for Committed/Excess Rate (cells/byte)}$$

Subscript 0+1, 0, or 1 applied to PCR, SCR, CDV, or MBS implies the parameter value for CLP = 0+1 cell stream, CLP = 0 cell stream, and CLP =1 cell stream, respectively.

In the above equations, (n+h1+h2) is the total size of an AAL Type 5 PDU containing the FR-SSCS-PDU corresponding to the n-octet frame. The overhead of FR-SSCS-PDU is h1 octets, the overhead of an AAL Type 5 PDU is h2 octets.

Note: At the IWF, in FR to ATM direction, a CDVT that includes the delay variation introduced by the IWF and the FR network needs to be specified. At the B-ICI, in FR to ATM direction, a CDVT that includes the delay variation introduced by the FR network, by the IWF, and by the ATM network segment between the IWF and the B-ICI needs to be specified. For example, CDVT value equal to $\frac{1}{PCR_{0+1}}$ may be appropriate for some networks. The $CDVT_{0+1}$ value should be negotiated for a bilateral agreement between the carriers.

For a typical connection (FR PVC) with variable size frames, networks can calculate PCR, CDV, SCR, and MBS using a typical frame size, using a mean frame size, or using the worst case scenario. If these values are expected to be used for traffic policing, then the worst case values should be used.

This choice and the resulting values of ATM traffic parameters that characterize the FR traffic should be decided by a bilateral agreement between the carriers.

Some examples for PCR_{0+1} and SCR_0 for 2 octet Frame Relay header are:

n = 1: $PCR_{0+1} = \frac{AR}{8}(1/7)$; $SCR_0 = \frac{CIR}{8}(1/1)$

n = 38: $PCR_{0+1} = \frac{AR}{8}(1/44)$; $SCR_0 = \frac{CIR}{8}(1/38)$

n = 8188: $PCR_{0+1} = \frac{AR}{8}(171/8194)$; $SCR_0 = \frac{CIR}{8}(171/8188)$

n -> _: $PCR_{0+1} = \frac{AR}{8}(1/48)$; $SCR_0 = \frac{CIR}{8}(1/48)$

The factor OHB(n) represents the overhead of FR-SSCS and a AAL Type 5 Common Part (CP). Let us call this factor the "overhead factor". The overhead can be viewed to consist of two components:

(a) Fixed overhead of (h1+h2) bytes per frame.

(b) Variable overhead of 0 to 47 bytes per frame.

If frame length distribution is uniform or exponential, the component (b) of the overhead has a mean value of 23.5 _ 24 bytes per frame.

A.1.2 Method 2

This method characterizes the FR traffic using 2 GCRAs, as described in Example 2b in Appendix B of the ATM Forum UNI Specification, 1993.

Two options are described here to characterize FR traffic using the GCRA configuration of Example 2b in Appendix B of the ATM Forum UNI Specification, 1993.

Option 1:

$$PCR_{0+1} = \frac{AR}{8}\left[OHA\ (n)\right]$$

$$SCR_0 = \frac{CIR}{8}\left[OHB\ (n)\right]$$

$$MBS_0 _ \left[\frac{Bc}{8}\left(\frac{1}{1-\frac{CIR}{AR}}\right) + 1\right]\ \left[OHB\ (n)\right]$$

This method does not provide a direct characterization of Be or EIR. The allowed EIR can be derived using the difference between the AR and the CIR, both expressed in cells per second.

$$\text{Allowed EIR} = \frac{8\left[PCR_{0+1} - SCR_0\right]}{OHB(n)} = \frac{AR}{8}\left[\frac{n}{n+h1+h2}\right] - \frac{CIR}{8}$$

Allowed Be _ _

If originally negotiated FR EIR (i.e., Be/T) is the same as the "Allowed EIR" above, then this Method is equivalent to Method 1.

Note: At the IWF, in FR to ATM direction, a CDVT that includes the delay variation introduced by the IWF and the FR network needs to be specified. At the B-ICI, in FR to ATM direction, a CDVT that includes the delay variation introduced by the FR network, by the IWF, and by the ATM network segment between the IWF and the B-ICI needs to be specified. For example, CDVT value equal to $\frac{1}{PCR_{0+1}}$ may be appropriate for some networks. The $CDVT_{0+1}$ value should be negotiated for a bilateral agreement between the carriers.

For a typical connection (FR PVC) with variable size frames, networks can calculate PCR, CDV, SCR, and MBS using a typical frame size, using a mean frame size, or using the worst case scenario. If these values are expected to be used for traffic policing, then the worst case values should be used.

This choice and the resulting values of ATM traffic parameters that characterize the FR traffic should be decided by a bilateral agreement between the carriers.

Option 2:

$$PCR_{0+1} = \left[\frac{CIR + EIR}{8} \right] [OHB(n)]$$

$$SCR_0 = \frac{CIR}{8} [OHB(n)]$$

$$MBS_0 _ \left[\frac{Bc}{8} \left(\frac{1}{1 - \frac{CIR}{AR}} \right) + 1 \right] [OHB\ (n)]$$

This method does not provide a characterization of AR.

Notes:

1. This method implies that FR traffic is shaped to achieve a PCR_{0+1} of [CIR + EIR] [OHB(n)]/8.

2. It is possible to view [CIR + EIR] [OHB(n)]/8 as SCR_{0+1} rather than PCR_{0+1}; and choose MBS_{0+1} to be:

$$\left[\frac{Bc + Be}{8} \right] \left[\left(\frac{1}{1 - \frac{CIR+EIR}{AR}} \right) + 1 \right] [OHB\ (n)]$$

In this case, an alternative method, again using 2 GCRAs could be defined. The configuration of these 2 GCRAs is similar to the GCRA configuration in Example 2b in Annex A of the ATM Forum UNI Specification, 1993; with the difference that the GCRA in relation to PCR_{0+1} is replaced by GCRA in relation to SCR_{0+1}.

3. At the IWF, in FR to ATM direction, a CDVT that includes the delay variation introduced by the IWF and the FR network needs to be specified. At the B-ICI, in FR to ATM direction, a CDVT that includes the delay variation introduced by the FR network, by the IWF, and by the ATM network segment between the IWF and the B-ICI needs to be specified. For example, CDVT value equal to $\frac{1}{PCR_{0+1}}$ may be appropriate for some networks. The $CDVT_{0+1}$ value should be negotiated for a bilateral agreement between the carriers.

For a typical connection (FR PVC) with variable size frames, networks can calculate PCR_{0+1}, $CDVT_{0+1}$, SCR_0, and MBS_0, using a typical frame size, using a mean frame size, or using the worst case scenario. If these values are expected to be used for traffic policing, then the worst case values should be used.

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This choice and the resulting values of ATM traffic parameters that characterize the FR traffic should be decided by a bilateral agreement between the carriers.

The choice of Method 1 or Method 2, or a value of PCR_{0+1} between the values given by Method 1 and Method 2 should also be determined by a bilateral agreement between the carriers.

A.2 N-to-1 Mapping

For N-to-1 mapping, the following methods can be used to characterize FR traffic in terms of ATM traffic conformance parameters.

A.2.1 Method 1

This method is suitable only when the number of DLCIs multiplexed in a VCC is large. This method is based on the assumption that statistical multiplexing of traffic from several DLCIs will yield a smooth traffic that can be characterize by the PCR.

$$PCR_{0+1} = \sum_{\text{All DLCIs}} \left[\frac{CIR + EIR}{8} \right] \left[OHB(n) \right]$$

A smaller value of PCR_{0+1} can be negotiated between the carriers for a bilateral agreement. If all DLCIs mapped in a VCC are not expected to simultaneously transmit (receive) at [CIR + EIR], it is reasonable to use a PCR_{0+1} value smaller than that obtained from the above equation.

The determination of CDVT involves the same considerations as those for 1-to-1 mapping.

A.2.2 Method 2

This method provides characterization of N-to-1 mapped FR traffic in terms of PCR and SCR.

This method does not assume the traffic smoothing effect of statistical multiplexing, and accommodates the worst case.

$$PCR_{0+1} = \sum_{\text{All Interfaces}} \frac{AR}{8} \left[OHA(n) \right]$$

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$$= \sum_{\text{All Interfaces}} \left[PCR_{0+1} \text{ Calculated as per 1-to-1 Mapping Method 1}\right]$$

$$SCR_0 = \sum_{\text{All DLCIs}} \frac{CIR}{8} \left[OHB(n)\right]$$

$$= \sum_{\text{All DLCIs}} \left[SCR_0 \text{ Calculated as per 1-to-1 Mapping Method 1}\right]$$

$$MBS_0 - \sum_{\text{All DLCIs}} \left[\frac{Bc}{8}\left(\frac{1}{1-\frac{CIR}{AR}}\right) + 1\right] \left[OHB\ (n)\right]$$

$$- \sum_{\text{All DLCIs}} \left[\ MBS_0 \text{ Calculated as per 1-to-1 Mapping Method 1}\right]$$

SCR_1 and MBS_1 can similarly be determined.

The determination of CDVT involves the same considerations as those for 1-to-1 mapping.

For typical connections (FR PVCs) with variable size frames, networks can calculate PCR_{0+1}, $CDVT_{0+1}$, SCR_0, SCR_1, MBS_0, and MBS_1, using a typical frame size, using a mean frame size, or using the worst case scenario. If these values are expected to be used for traffic policing, then the worst case values should be used.

This choice and the resulting values of ATM traffic parameters that characterize the FR traffic should be decided by bilateral agreement between the carriers.

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