# The ATM Forum

# Technical Committee

# Inverse Multiplexing for ATM (IMA) Specification Version 1.1

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# Abstract

The IMA Version 1.1 (v1.1) Specification is a revision of the IMA Version 1.0 (v1.0) Specification[10]. The purpose of this revision is to introduce the IMA PICS proforma and a new version of the IMA MIBs as well as several minor corrections and clarifications to the content of IMA v1.0. It is recognized that interoperability problems were generated by different interpretations of some IMA v1.0 requirements. For this reason, the ATM Forum encourages the migration to IMA v1.1. The IMA v1.1 specification increments the OAM Label value used in the IMA OAM cells in order to differentiate v1.1 from v1.0 IMA units.

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# 1. Introduction

This is the Inverse Multiplexing for ATM (IMA) specification, the purpose of which is to provide inverse multiplexing of an ATM cell stream over multiple physical links and to retrieve the original stream at the far-end from these physical links. The multiplexing of the ATM cell stream is performed on a cell by cell basis across the multiple physical links.

This specification is offered for private and public User-to-Network Interfaces (UNIs), Network-to-Network Interfaces (NNIs) and Broadband Inter-Carrier Interfaces (BICIs). It defines a new sublayer located between the Physical Layer Interface Specific Transmission Convergence (TC) sublayer and the ATM layer: the IMA sublayer. This specification also defines modifications to the Interface Specific TC sublayer on which the IMA sublayer is implemented. It also defines the IMA Management Information Base (MIB) objects.

This specification does not deal with ATM layer functions such as, UNI/NNI/BICI implementation requirements for signaling, traffic management, and OAM.

## 1.1 Overview of Inverse Multiplexing for ATM

A methodology is described which provides a modular bandwidth, for user access to ATM networks and for connection between ATM network elements, at rates between the traditional order multiplex level. An example is to achieve rates between the DS1/E1 and DS3/E3 levels in the asynchronous digital hierarchies. DS3/E3 physical links are not necessarily readily available throughout a given network. Therefore the introduction of ATM Inverse Multiplexers provides an effective method of combining the transport bandwidths of multiple links (e.g., DS1/E1 links) grouped to collectively provide higher intermediate rates.

The ATM Inverse Multiplexing technique involves inverse multiplexing and de-multiplexing of ATM cells in a cyclical fashion among links grouped to form a higher bandwidth logical link whose rate is approximately the sum of the link rates. This is referred to as an IMA group.

Figure 1 on page 12 provides a simple illustration of the ATM Inverse Multiplexing technique in one direction. The same technique applies in the opposite direction.

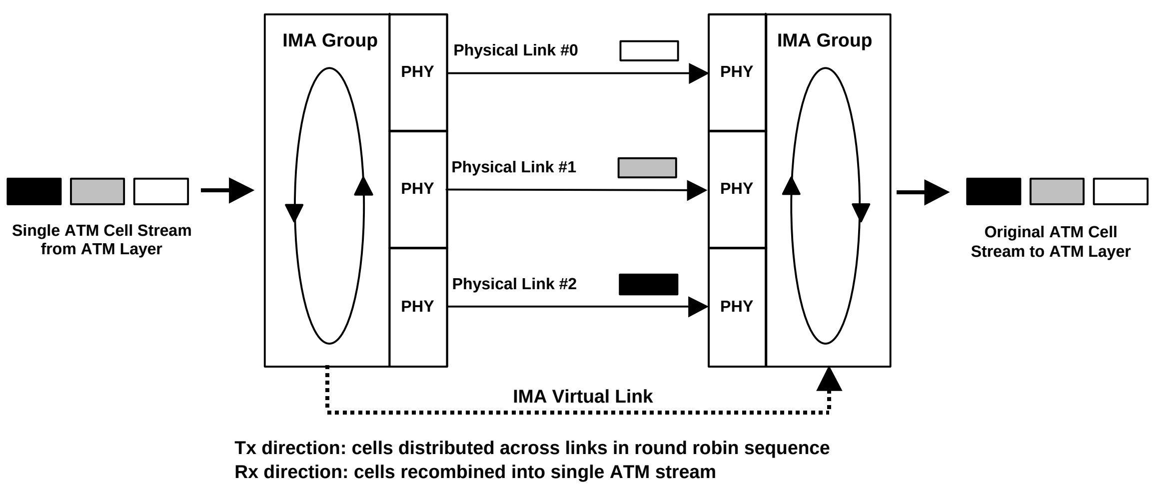



**Figure 1 Inverse Multiplexing and De-multiplexing of ATM Cells via IMA Groups**

IMA groups terminate at each end of the IMA virtual link. In the transmit direction, the ATM cell stream received from the ATM layer is distributed on a cell by cell basis, across the multiple links within the IMA group. At the far-end, the receiving IMA unit recombines the cells from each link, on a cell by cell basis, recreating the original ATM cell stream. The aggregate cell stream is then passed to the ATM layer.

The IMA interface periodically transmits special cells that contain information that permit reconstruction of the ATM cell stream at the receiving end of the IMA virtual link. The receiver end reconstructs the ATM cell stream after accounting for the link differential delays, smoothing CDV introduced by the control cells, etc. These cells, defined as IMA Control Protocol (ICP) cells, provide the definition of an IMA frame. The transmitter must align the transmission of IMA frames on all links (shown in Figure 2 on page 13). This allows the receiver to adjust for differential link delays among the constituent physical links. Based on this required behavior, the receiver can detect the differential delays by measuring the arrival times of the IMA frames on each link.

At the transmitting end, the cells are transmitted continuously. If there are no ATM layer cells to be sent between ICP cells within an IMA frame, then the IMA transmitter sends filler cells to maintain a continuous stream of cells at the physical layer. The insertion of Filler cells provides cell rate decoupling at the IMA sublayer. The Filler cells should be discarded by the IMA receiver.

A new OAM cell is defined for use by the IMA protocol. This cell has codes that define it as an ICP or Filler cell.

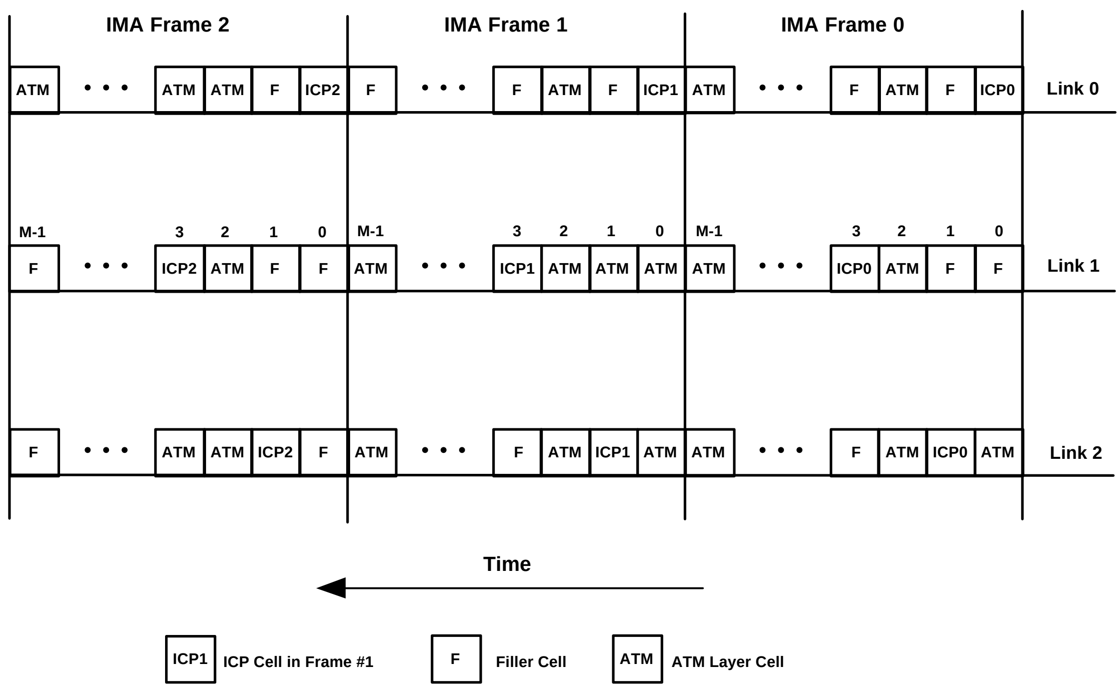



**Figure 2 Illustration of IMA Frames**

## 1.2 Terminology

This specification uses three levels for indicating the degree of compliance necessary for specific functions, procedures, and coding associated with the IMA specification:

Requirement **(R-x)**: functions, procedures, and coding necessary for operational compatibility.

- Conditional Requirement **(CR-y)**: functions, procedures, and coding, necessary for operational compatibility if the specified optional function is implemented.

Option **(O=z)**: functions, procedures and coding that may be useful, but are not necessary for operational compatibility.

A **(R-x)** at the beginning of the paragraph shall apply to all the requirements in that paragraph, unless otherwise specified. The x, y, and z represent the order of the requirement, conditional requirement, and option as they appear in this specification.

## 2. Terms and Definitions

| Term | Definition |
|---|---|
| AAL | ATM Adaptation Layer<br>Examples of AALs are AAL1, AAL2, AAL3/4, and AAL5. |
| Active | This is a link state indicating the link is capable of passing ATM layer cells in the specified direction. |
| Anomaly | Discrepancy between the actual and desired characteristic of an item. An anomaly may or may not affect the ability of an item to perform a required function (see [3]). |
| Asymmetrical Configuration | Configuration where the IMA group is not required to configure IMA links in both directions of the physical links used by the IMA unit. |
| Asymmetrical Operation | Mode where the IMA group is allowed to carry ATM traffic over physical links on which the IMA links in the both transmit and receive directions are not Active at the same time. |
| ATM | Asynchronous Transfer Mode |
| ATM Layer Cell | Cells that are exchanged between the ATM layer and IMA sublayer. |
| AVCR | Available Cell Rate |
| BICI | Broadband Inter-Carrier Interface |
| B-ISDN | Broadband ISDN |
| Blocked | This is a group state indicating that the group has been inhibited. |
| Blocking | This transitional state allows graceful transition into the Unusable state without loss of ATM layer cells. |
| CAC | Connection Admission Control |
| CBR | Constant Bit Rate |
| CDV | Cell Delay Variation |
| CID | Cell Identification (ICP CID) |
| Clear Channel Facility | This is a facility to integrally carry all cells transmitted by an IMA unit up to the far-end IMA unit located at the other end of the IMA virtual link. A clear channel facility can be bi-directional or unidirectional. The use of unidirectional clear channel facilities is allowed when the IMA unit is running in the asymmetrical operation mode. |
| CLR | Cell Loss Ratio |
| Config-Aborted | This is a group state indicating that the group has rejected the group parameters proposed by the FE IMA group. |
| CPE | Customer Premises Equipment |
| CRC | Cyclic Redundancy Check |
| CTC | Common Transmit Clock configuration<br>This is a configuration where the transmit clocks of all the physical links within the IMA group are derived from the same clock source. |
| Data Round-Robin | This represents the scheduler transmitting or receiving cells in a round-robin fashion. |
| DCB | Delay Compensation Buffer |
| Defect | A defect is a limited interruption in the ability of an item to perform a required function. It may or may not lead to maintenance action depending on the results of additional analysis. Successive anomalies of an item to perform a required function are considered as a defect (see [3]). |
| DSU | Data Service Unit |
| DXI | Digital eXchange Interface |
| ES | Errored Seconds<br>Such as defined in ANSI T1.231[3] |

| Term | Definition |
|---|---|
| Failure | A failure is the termination of the ability of an item to perform a required function (see [3]). |
| Fault | A Fault is an implementation specific NE event triggered, e.g., due to wrong LSM behavior at the FE. However, the Fault event does not include the detection of invalid ICP cell content. |
| FC | Failure Count |
| FE | Far-End |
| Filler cell | This cell is used to fill in the IMA frame when no cells are available at the ATM layer. It is used for performing cell rate decoupling at the IMA sublayer (like Idle cell for single-link interface). |
| GSM | Group State Machine<br>This state machine defines the behavior of the IMA group. |
| GTSM | Group Traffic State Machine<br>This is defined to indicate when traffic is exchanged with the ATM layer. |
| GWP | Group Wide Procedure<br>This refers to the Group Start-up and LASR procedures performed by the IMA unit to synchronize the activation of IMA links within the IMA group. |
| HEC | Header Error Check |
| HSSI | High Speed Serial Interface |
| ICO | ICP Cell Offset |
| ICP cell | IMA Control Protocol cell |
| IDCC | IMA Data Cell Clock |
| IDCR | IMA Data Cell Rate<br>This represents the rate at which IMA data cells should be exchanged between the IMA sublayer and the ATM layer. |
| IEC | Inter-Exchange Carrier |
| IESM | IMA Error State Machine |
| IETF | Internet Engineering Task Force |
| IFSM | IMA Frame Synchronization Mechanism |
| IFSN | IMA Frame Sequence Number |
| IMA | Inverse Multiplexing for ATM |
| IMA frame | The IMA frame is used as the unit of control in the IMA protocol. It is defined as M consecutive cells, numbered 0 to M-l, transmitted on each of the N links in an IMA group. One of the M cells on each of the N links is an ICP cell that occurs within the frame at the ICP cell offset position specified in the ICP cell (the offset may be different on different links). The IMA frame is aligned on all links. "Aligned" means that it is transmitted "simultaneously". Differential link delay can cause the reception to be "mis-aligned" in time: the alignment is recovered by the mechanism of link delay synchronization. M is defined during start-up: N is determined by the UM and the IMA link start-up procedure; and the ICP "stuff" mechanism is a controlled violation of the IMA consecutive frame definition. |
| IMA group | Group of links at one end used to establish an IMA virtual link to other end. |
| IMA link | An IMA link corresponds to a unidirectional logical channel carried over one direction of a clear channel facility. An IMA link is identified by the value of the LID field contained in the ICP cells carried over that IMA link. |
| IMA RR | IMA Round-Robin<br>This is the distribution or retrieval of ATM layer and Filler cells across the N links of an IMA group, when Tx=On or Rx=On respectively. |
| IMA sublayer | The IMA is a sublayer part of the Physical layer and located between the interface specific Transmission Convergence (TC) sublayer and the ATM layer. |

| Term | Definition |
|---|---|
| IMA Super-Frame (ISF) | IMA Super-Frame<br>Virtual frame composed of 256 IMA frames. The ISF starts with the IMA frame with sequence number 0 and ends with the IMA frame with sequence number 255. The concept of ISF is used in appendix to determine the maximum of the link differential delay that can be supported by the IMA protocol. |
| IMA virtual link | Virtual link established between 2 IMA units over a number of physical links (IMA group). |
| In Group | This is an event indicating that a link has been configured within an IMA group. |
| Inhibiting | This represents the action to voluntarily disable the capacity of the group or the link to carry ATM layer cells for reasons other than reported problems. |
| Insufficient-Links | Group state indicating that the group does not have sufficient links in the Active state to be in the Operational state. |
| ISDN | Integrated Services Digital Network |
| ITC | Independent Transmit Clock configuration<br>This is a configuration where there is a transmit clock of at least one link within the IMA group that is not derived from a clock source different from some of the other transmit links. |
| ITU-T | International Telecommunication Union - Telecommunication Standardization Sector |
| IV | ICP cell Violations |
| LASR | Link Addition and Slow Recovery procedure |
| Layer Management Functions | The Layer Management functions relate to processing of actions such as configuration, fault monitoring, and performance monitoring within the group. |
| LCD | Loss of Cell Delineation defect<br>The LCD defect is reported when the OCD anomaly persists for the time specified in ITU-T Recommendation I.432 [30]. The LCD defect is cleared when the OCD anomaly has not been detected for the period of time specified in ITU-T Recommendation I.432. |
| LCD-RDI | Loss of Cell Delineation Remote Defect Indicator<br>The LCD-RDI defect is reported to the FE when a link defect is locally detected. The LCD-RDI defect is not always required on the link interface. |
| LCR | Link Cell Rate<br>Cell rate (cell/sec) over the portion of the single link bandwidth available for carrying cells. |
| LDS | Link Delay Synchronization<br>The LDS is an event indicating that the link is synchronized with the other links within the IMA group with respect to differential link delay. |
| LID | Link Identifier<br>The LID field in the ICP cell is used to identify an IMA link on which the ICP cells are transmitted. The LID is been used to determine the round-robin order to retrieve cells from the incoming IMA links at the IMA receiver. |
| LIF | Loss of IMA Frame defect<br>The LIF defect is the occurrence of persistent OIF anomalies for at least 2 IMA frames. |
| Link | In this specification, the term “link” referred to an IMA link, unless the context clearly refers to a physical link. |
| Link Defect | A link defect is the occurrence of the persistent detection of an anomaly at the Interface Specific Transmission Convergence sub-layer. LOS, LOF/OOF, AIS, LOC, and LCD defects are examples of link defects reported at the Interface Specific Transmission Convergence sub-layer. |
| Link Management | This function provides direct management of the physical links (e.g., DS1/E1 links). |
| LOC | Loss Of Continuity<br>As defined in ITU-T Recommendation I.610[31]. |

| Term | Definition |
|---|---|
| LODS | Link Out of Delay Synchronization defect<br>The LODS is a link event indicating that the link is not synchronized with the other links within the IMA group. |
| LOF | Loss Of Frame |
| LOS | Loss Of Signal |
| LSB | Least Significant Bit |
| LSI | Link Stuff Indication |
| LSM | Link State Machine |
| M | IMA Frame Size |
| MIB | Management Information Base |
| MSB | Most Significant Bit |
| N | Number of links configured in an IMA group |
| NE | Near-End (local end) |
| $N_{on}$ | Number of links passing ATM layer cells in the transmitting or receiving direction. |
| NMS | Network Management System |
| NNI | Network-Node Interface |
| Not Configured | This is a group state indicating that the group does not exist yet. |
| Not In Group | This is used as an event or a state indicating that a link is no longer configured within an IMA group. |
| OAM | Operations And Maintenance |
| OCD | Out of Cell Delineation anomaly<br>As specified in ITU-T Recommendation I.432[30], an OCD anomaly is reported upon the occurrence of Alpha($\alpha$) consecutive cells with incorrect HEC, and it is no longer reported after detecting Delta($\delta$) consecutive cells with correct HEC. |
| OIF | Out of IMA Frame anomaly<br>The OIF is the occurrence of IMA anomalies listed later in this specification. |
| OOF | Out Of Frame |
| Operational | Group state indicating than the group has sufficient links on both Tx and Rx directions to carry ATM layer cells. |
| OSI | Open System Interconnection |
| Physical Link | This is the link (and/or clear channel facility) being used by the IMA units to transmit and receive ATM cells. The IMA unit may use physical links in one or both directions. |
| PMD | Physical Medium Dependent |
| ppm | part per million |
| PRC | Primary Reference Clock<br>This term is from ITU-T Recommendation G.811[23]. This is a synonym of PRS. |
| PRI | Primary Rate Interface |
| PRS | Primary Reference Source<br>This term is from ANSI T1.101[1]. This is a synonym of PRC. |
| $P_{RX}$ | Minimum number of links required to be Active in the receive direction for the IMA group to move into the Operational state. |
| $P_{TX}$ | Minimum number of links required to be Active in the transmit direction for the IMA group to move into the Operational state. |
| QoS | Quality of Service |
| RDI | Remote Defect Indicator |

| Term | Definition |
|---|---|
| RFC notes | Requests For Comments notes |
| RFI | Remote Failure Indicator |
| RM cell | Resource Management cell |
| RR | Round-Robin |
| Rx | Receive (side) |
| Rx=On | The IMA receiver is passing received ATM cells to the ATM layer. |
| Rx Failed | The Rx Failed condition is entered after a specified persistence of a link defect (e.g., LCD) or an IMA defect (LIF or LODS). It causes the LSM to enter the Unusable state. The mechanism is implementation specific and can be processed independently from the failure definition. |
| SAR | Segmentation And Re-assembly |
| SCCI field | Status and Control Change Indication field |
| SES | Severely Errored Seconds |
| SICP cell | Stuff ICP cell<br>One of the 2 ICP cells comprising a stuff event. |
| SNMP | Simple Network Management Protocol |
| Stuff event | This is an repetition of an ICP cell over one IMA link to compensate for timing difference with other links within the IMA group. |
| Start-up | This is a group state indicating that the group is waiting to see the FE in Start-up. |
| Start-up-Ack | This is a group transitional state, when both groups are in startup and the FE group parameters have been accepted. |
| Symmetrical Configuration | Configuration where the IMA unit is required to configure an IMA link in each direction of the physical links configured to be used by the IMA unit. |
| Symmetrical Operation | Mode where the IMA group is only required to carry ATM layer cells on physical links on which the IMA links in both the transmit and receive directions are Active. |
| TC | Transmission Convergence |
| TRL | Timing Reference Link<br>This is the link selected as the reference to derive the IDCR. |
| TRLCR | Timing Reference Link Cell Rate |
| Tx | Transmit (side) |
| Tx=On | The IMA transmitter is sending ATM cells coming from the ATM layer. |
| UAS | UnAvailable Seconds<br>Such as defined in ANSI Tl.231 [3]. |
| UAS-IMA | UnAvailable Seconds for IMA<br>Interval during which the IMA receiver is declared unavailable. The period of unavailability begins at the onset of 10 contiguous SES-IMA, including the first 10 seconds to enter the UAS-IMA condition. The period of unavailability ends at the onset of 10 contiguous seconds with no SES-IMA, excluding the last 10 seconds to exit the UAS-IMA condition. |
| UM | Unit Management<br>Entity managing a unit such as an IMA unit. |
| UNI | User-Network Interface |
| Unusable | This is a link state indicating the link is not in use to fault, inhibition, etc. |
| Usable | This is a link state indicating the link is ready to operate in the specified direction, but it is waiting to move to Active. |
| UUS | UnUsable Seconds<br>Number of seconds during which the link state is Unusable. |

| Term | Definition |
|---|---|
| VCI | Virtual Connection Identifier |
| VPI | Virtual Path Identifier |

# 3. IMA Objectives

The main objectives that guided the development of the IMA Specification are listed below. Only the performance objectives applicable to the case where the IMA protocol is used over DS1/E1 physical links have been identified. This does not preclude using the IMA specification at rates other than those supported on DS1/E1 physical links.

- Available for private/public UNIs and NNIs and BICIs
- Provide transport of a single ATM cell stream at rates between existing link rates (e.g., between DS1/E1 and DS3/E3 rates)
- Applicable over DS1/E1 or other interfaces carrying ATM cells
- Operating on interfaces running at the same nominal link cell rate (LCR)
- Provision bandwidth in physical link increments (e.g., DS1/E1 increments)
- Provide transparent transport of the ATM layer and higher layer signals (including the preservation of cell order, control of cell delay variation, cell format, etc.)
- Use a cell based multiplexing technique for converting a single ATM Stream into multiple lower speed ATM streams to be sent over independent links and retrieving the initial ATM cell stream from the links at the far-end
- Maintain compatibility with current ATM Forum Physical Layer specifications (i.e., same transmission convergence sublayer including the relevant transmission MIB)
- Detect and reject lines with delay greater than the provisioned maximum differential delay tolerance
- Add/delete links while maintaining the IMA group in service
- Handle link failure and automatic link recovery
- Support the use of leased and dial lines (e.g., ISDN lines) providing the same LCR, including links running in configurations where not all of the transmit clocks of the links in the IMA group are derived from the same source
- Support symmetric and asymmetric IMA configurations, and symmetric and asymmetric IMA operations
- Support of all ATM traffic/QoS classes including CBR
- When running over DS1/E1 physical links, the IMA interface should compensate for link differential delays of at least 25 milliseconds
- When running over DS1/E1 physical links, the IMA interface should contribute minimal CDV so as to support an end-to-end service objective of 1 millisecond CDV
- When running over DS1/E1 physical links, the IMA interface should exhibit cell level error performance comparable to an individual DS1/El physical link; the effects of both random and bursty errors should be considered
- Support system that can be easily integrated with current network management systems
- Provide IMA status MIB - Management Information Base. This allows re-use of existing DS1/E1 Physical Layer devices

# 4. IMA Reference Models

This section provides reference models of involving the IMA protocol.

## 4.1 IMA Sublayer in Layer Reference Model

Figure 3 on page 22 illustrates the layer reference model including the Inverse Multiplexing for ATM (IMA) sublayer. It is based on the B-ISDN protocol reference model defined in ITU-T Recommendation I.321 [27]. The IMA sublayer is part of the physical layer. It is located between the traditional Transmission Convergence sublayer and the ATM layer.

The shaded areas of Figure 3 represent an overview of the IMA functions under the scope on this specification. The functions appearing in the remaining areas are not under the scope of this specification.

| | | User Plane Functions | Layer Management Functions | Plane Management Functions |
|---|---|---|---|---|
| ATM Layer | | | | |
| Physical Layer | IMA Specific Transmission Convergence Sublayer | • ATM cell stream splitting and reconstruction<br>• ICP cell insertion/removal<br>• Cell rate decoupling<br>• IMA frame synchronization<br>• Stuffing<br>• Discarding of cells with bad HEC | • IMA connectivity<br>• ICP cell errors (OIF)<br>• LIF/LODS/RDI-IMA defect processing<br>• RDI-IMA alarm generation<br>• Tx/Rx IMA link state report | • IMA group configuration<br>• Link addition/deletion<br>• ATM cell rate change<br>• IMA group failure notification<br>• IMA statistics |
| | Interface Specific Transmission Convergence Sublayer | • No cell discarding<br>• No cell rate decoupling | | |
| | | • Cell delineation<br>• Cell scrambling & descrambling (if required)<br>• Header error correction (if required)<br>• HEC generation/verification | • HEC error indication<br>• LCD-RDI alarm generation (if required) | • LCD failure notification<br>• TC statistics |
| | Physical Medium Dependent Sublayer | • Bit timing<br>• Line coding<br>• Physical Medium | • Local alarm processing<br>• RDI alarm's generation | • Link failure notification<br>• PMD state |

**Figure 3 IMA Sublayer in Layer Reference Model**

## 4.2 Reference Model of Unit Operating the IMA Functions

This section describes the functions that characterize a unit that supports an IMA interface.

Figure 4 on page 23 shows the functional blocks of such unit. This specification only covers the IMA functions and portions of the Link and Unit Management functions required managing the IMA interface. All others are implementation dependent or defined in other ATM Forum specifications.

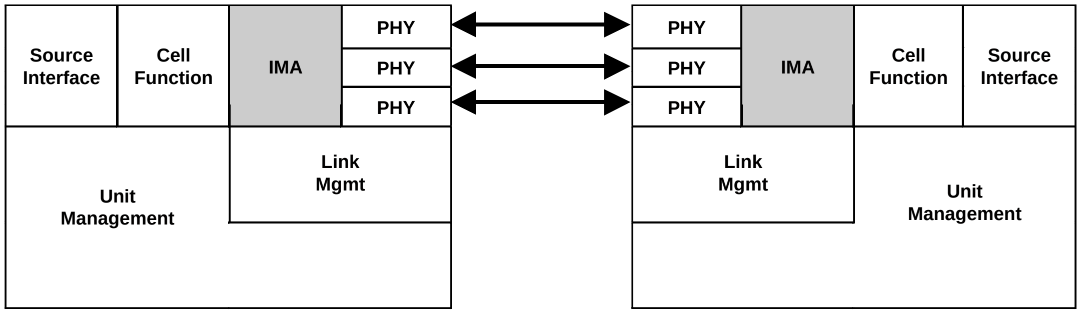



**Figure 4 Functional Blocks of Units Hosting an IMA Interface**

The following sections describe in more details the functional blocks of a unit supporting IMA functions.

### 4.2.1 Source Interface

The Source Interface provides the connection (typically proprietary) to an internal data bus (e.g., an ATM switch, router, and computer). The Source Interface might also be a standard interface (e.g., DXI over HSSI). In the first case, the IMA functionality is integrated into a network element supporting other functions and may therefore provide such (non-standardized) functions as integrated management. In the second case, the IMA unit is a stand-alone unit.

There is no requirement that a particular Source interface be supported. The Source Interface choice is vendor specific. There is also no requirement that the Source Interface, on one side, match the Source Interface on the other side. For instance, one side could be a direct interface to a data bus in an ATM switch and the other could be an ATM DSU supporting the IMA function.

### 4.2.2 Cell Function

The Cell Function is dependent upon the Source Interface:

- If the Source Interface emits ATM cells, the Cell Function is null (traffic shaping, if any, maybe be accomplished outside the unit). In this case, OAM cells, RM cells, etc., must be passed transparently through the source interface.

- If the Source Interface does not emit ATM cells, the Cell Function must arrange for the output of the source interface to be converted into ATM cells. There is no limitation on the Cell Function other than it must emit ATM cells. This requirement does not preclude the Cell Function implementing traffic shaping buffering for frames/cells, etc. Support within the cell function is an implementation issue (e.g., OAM cell flows, RM cells, VPI/VCI to frame-level mapping).

- There is no requirement that the Cell Function on one side match the Cell Function on the other. For instance, one side could not provide any function, as this would be the case with a direct interface to a data bus in an ATM switch. The other side could fully support AAL1, AAL2, AAL3/4, and AAL5 SAR functions, as this might be the case for an ATM DSU supporting the IMA functions.

### 4.2.3 Inverse Multiplexing

The main Inverse Multiplexing function is to control the distribution of cells onto the group of physical links made available to the IMA interface. Other main functions include handling of differential delays and actions to be taken when links are added or dropped or when they are failed or need to be restored. In the receive direction, the IMA interface performs differential delay compensation and recombines the cells into the original cell stream while introducing minimal cell delay variation. In essence, the Inverse Multiplexing functions emulate a single UNI/NNI/BICI physical link; the IMA process of splitting and recombining streams is as transparent to the layer above as a traditional single-link physical layer interface.

### 4.2.4 Link Management

This function provides direct management of the physical links (e.g., DS1/El physical links). This may include such functions as establishing those links; for example, DS1/E1 physical links via ISDN PRI signaling over a D channel. Other functions in Link Management include the notification of network management operations upon detection of link defects, collecting Facility Data Link information, instantiating the physical link MIB objects, etc.

Link Management functions also relate to the management and establishment of the links available to the IMA functions.

When implementing an IMA virtual link over a specific type of links (e.g., DS1/E1 links), the IMA MIB objects should inter-work with the link MIB if specified in a given RFC (e.g., RFC 1406 [16] or DS1/E1).

The Link Management function should not preclude the option of using dial-up services (e.g., ISDN service). If such are supported, the Link Management function should perform the connection management (establishment and release). Unit management should determine the establishment and release policies (i.e., when to initiate a new DS1/E1 link, when to release it, etc.).

### 4.2.5 Unit Management

The Unit Management (UM) function provides for the management of all functions of the whole unit. For example, capabilities required by users would include support of MIBs indicating the status of the IMA functions, integration of alarms in the IMA unit, provision of a configuration interface, SNMP access to the unit, etc.

The IMA MIBs which allows management of the IMA functions of the unit are specified in Section 15 on page 85 and shall be implemented if the UM is SNMP based. Other unit management functions are for further study.

## 4.3 Timing Reference Model

On a physical link basis, the unit clocking should comply with the appropriate requirements for the physical links (e.g., ATM Forum DS1 and E1 specifications [8] [9]).

On a group basis, the timing may be based on the timing configuration guideline presented in Figure 5 on page 25. Other timing configurations are feasible but are not discussed here.

Switch "Sw" and switches "Sw(0)" to "Sw(N-l)" appearing in Figure 5 indicate the possible configurations.

The "TxClock Unit" may derive its timing from an internal source, an external source or from any incoming link.

If loop timing (also referred as slave clocking[20]) is required, Sw(0) to Sw(N-1) could be set to position "1" on the associated link. Loop timing may be used when synchronizing to a digital network on a per link basis. Another example of loop timing would be using one of the incoming links as the source of the "Tx Clock Unit" and have all the link switches set to "0".

The term Independent Transmit Clock (ITC) is used for operation, where the transmit clock on each link is independently derived from a clock source. An example is illustrated Figure 5 on page 25 by having at least one of switches Sw(0) to Sw(N-l) being set to position "1".

The term Common Transmit Clock (CTC) is used when the same clock is used for all links. An example of this is illustrated in Figure 5 on page 25 by having all switches Sw(0) to Sw(N-l) being set to position "0".

Appendix H on page 179 shows application scenarios intended to provide guidance in selecting a timing configuration.

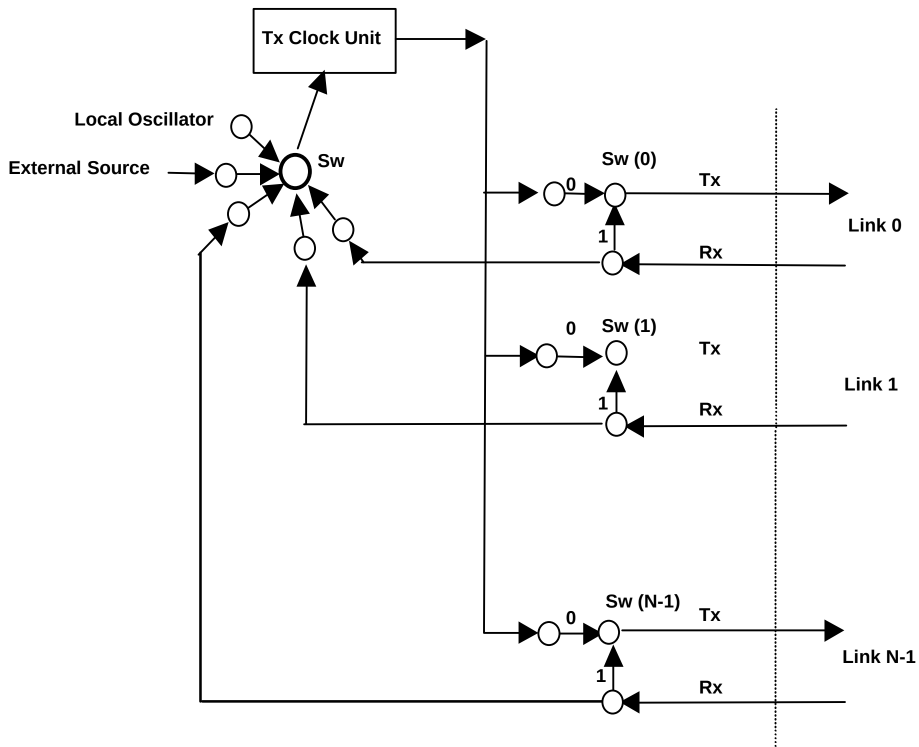



**Figure 5 IMA Timing Configuration Reference Model**

# 5. Basic IMA Protocol Definitions

This section specifies the basic architecture of the IMA unit.

## 5.1 IMA Physical Link Characteristics

**(R-1)** The IMA unit shall support a number N ($1 \leq N \leq 32$) of transmission links designated as an IMA group by the unit management (UM) and operating at the same nominal link cell rate (LCR).

**(R-2)** The IMA unit shall be connected to another IMA unit over clear channel facilities. This implies that all cells transmitted by an IMA unit shall only be terminated by the IMA unit located at the other end of the IMA virtual link.

## 5.2 Transmission Convergence Sublayer Specification

This section defines:

- exceptions to the interface specific transmission convergence functions when IMA sublayer is implemented, and
- basic IMA sublayer functions

### 5.2.1 Exceptions to the Interface Specific Transmission Convergence Sublayer

The interface specific Transmission Convergence (TC) sublayer should implement the following functions as specified in the appropriate physical layer specification for the links to be used in the IMA group:

- physical layer HEC generation/verification,
- cell header correction (if required),
- cell delineation, and
- cell payload scrambling/descrambling (if required).

The following exceptions to the interface specific Transmission Convergence (TC) sublayer shall be met:

**(R-3)** The interface specific TC sublayer shall pass all cells to the IMA sublayer or provide an indication that a cell was received (this includes HEC errored cells).

**(R-4)** Cell rate decoupling shall not be performed by the interface specific TC sublayer (i.e., no idle cells).

Cell rate decoupling is performed at the IMA sublayer as specified in Section 5.2.2.1 on page 26.

### 5.2.2 IMA Specific Transmission Convergence Sublayer Part

#### 5.2.2.1 IMA General Characteristics

**(R-5)** The IMA unit shall assign a Link Identifier (LID) unique within the IMA group to each Tx IMA link on each physical link.

**(R-6)** The LID shall not be changed while the link is a member of an IMA group.

The selected LID value is constrained between 0 and 31 based on the definition of the ICP cell (see Table 2 on page 31).

**(R-7)** The IMA transmitter shall distribute ATM cells arriving from the ATM layer (including any unassigned cells) over the N links in a cyclic round-robin fashion, and on a cell-by-cell basis.

**(R-8)** The IMA transmitter shall distribute the ATM layer cells over the links using an ascending order based on the LID assigned to each link within the IMA group.

**(R-9)** Each interface at the end of the IMA virtual link shall use the IMA Control Protocol (ICP) cell format defined in Table 2 on page 31 to convey IMA configuration, synchronization, status and defect information to the far-end (FE).

**(R-10)** The IMA transmitter shall perform cell rate decoupling by inserting IMA Filler cells in place of ATM cells when there is no cell available at the ATM layer.

**(R-11)** The IMA receiver shall:

- accept ATM cells from the N links according to ascending order based on the Link ID (LID) received in the ICP cells on the incoming link,
- compensate for differential link delays and re-build the original ATM cell stream,
- discard Filler cells,
- discard cells with bad HEC,
- process and discard ICP cells, pass the aggregate ATM cell stream to the ATM layer (this includes unassigned cells),
- preserve the order of incoming cells.

**(R-12)** The IMA receiver shall use the ICP cell to maintain protocol and link delay synchronization.

#### 5.2.2.2 IMA OAM Cell Definition

Two IMA OAM cells are defined:

- Filler cell
- IMA Control Protocol (ICP) cell

These cells are defined in Table 1 on page 28 and Table 2 on page 31[1], respectively. The transmission of the octets is row by row, from top to bottom.

**(R-13)** The IMA interface shall transmit the most significant bit of each octet (MSB = bit 7, LSB = bit 0) of the IMA OAM cell first.

The following fields are common to both Filler and ICP cells:

- cell header,
- OAM label, and
- cell identification

**(R-14)** The Filler and ICP cell header shall be as specified in Table 1 on page 28 and Table 2 on page 31, respectively.

[1] The value of octets 1 to 4 defined in this specification will be proposed to ITU-T, Study Group 13.

Octet 6 of Filler and ICP cells is set to "0x03" to indicate the use of IMA v1.1 by the IMA unit. The use of this field is explained in more detail in Section 5.2.2.3 on page 32.

**(R-15)** The Cell Identification (CID) bit, bit 7 of octet 7 of the Filler and ICP cells, shall be used to identify the IMA OAM cell as an ICP or Filler cell.

**(R-16)** Octets 52-53 shall be used as specified in ITU-T Recommendations 1.610[31], Section 7.1, for octets 52-53 of the OAM cells of the F1/F3 flows.

The following subsections give details of the Filler and ICP cells, respectively.

#### 5.2.2.2.1 Filler Cell Definition

This section defines the Filler cell. This cell is used for performing cell rate decoupling at the IMA sublayer.

**(R-17)** The IMA interface shall support the format of the Filler cell shown in Table 1 on page 28.

**Table 1 Filler Cell Format**

| Octet | Label | Comments |
|---|---|---|
| 1-5 | ATM cell header | Octet 1 = 0000 0000, Octet 2 = 0000 0000, Octet 3 = 0000 0000,<br>Octet 4 = 0000 1011, Octet 5 = 0110 0100 (valid HEC) |
| 6 | OAM Label | Bits 7-0: IMA Version Value<br>00000001: IMA Version 1.0<br>00000011: IMA Version 1.1 |
| 7 | Cell ID Link ID | Bit 7: IMA OAM Cell Type (0: Filler cell)<br>Bits 6-0: Unused and set to 0 |
| 8-51 | Unused | Set to 0x6A as defined in ITU-T Recommendation I.432[30] for unused bytes. |
| 52-53 | CRC Error Control | Bits 15-10: Reserved field for future use - default value coded all zero.<br>Bits 9-0: CRC-10 as specified in ITU-T Recommendation I.610[31]. |

The Filler cell can be validated by verifying the value of the cell header, OAM Label, CID, and CRC fields.

#### 5.2.2.2.2 ICP Cell Definition

**(R-18)** The IMA interface shall support the format of the ICP cell shown in Table 2 on page 31.

The content of the ICP cell has been divided in five classes:

- A: Link specific information, transmitted only over the specific link.
- B: Group specific information, transmitted over all links in the group.
- C: Link specific information, but transmitted over all links in the group.
- D: Unused octet
- E: End-to-end channel

**(R-19)** The content of fields appearing under class A shall be transmitted over the link for which these fields apply.

**(R-20)** The same content of fields appearing under classes B and C shall be transmitted over all links within an IMA group.

**(R-21)** Bits 4-0 of octet 7 shall be used to identify the Link ID (LID) on which the ICP cell is sent. Its range shall be from 0 to 31.

The IMA Frame Sequence Number (IFSN) field (octet 8) is used to indicate the sequence number of the IMA frame. The ICP Cell Offset field (octet 9) is used to indicate the location of the ICP cell within the IMA Frame. The use of these fields is defined in more detail in Section 5.2.2.3 on page 32.

The Link Stuff Indication (LSI) field, bits 2-0 in octet 10, is used to indicate the occurrence of the next stuff event. The use of the LSI field is specified in more detail in Section 7 on page 38.

The Status and Control Change Indication (SCCI) field (octet 11) is used to indicate changes over octets 12 through 49 (classes B and C). Its use is specified in more detail in Section 5.2.2.5 on page 35.

The IMA ID field (octet 12) is used to indicate the ID of the IMA Group. The field is set to a value between 0 and 255 inclusive (8 bits). Its use is specified in more detail in Section 5.2.2.6 on page 35.

The Group Status and Control field (octet 13) is used to indicate group status and control information. The use of the Group Status and Control field is explained in more detail in Section 5.2.2.7 on page 35 and Section 10.2 on page 55.

The Transmit Timing Information field (octet 14) is used to indicate the synchronization and the timing reference link (TRL) used by the transmit end. The use of the Transmit Timing Information field is explained in more detail in Section 8 on page 40.

The Tx Test Control, Tx Test Pattern and Rx Test Pattern fields (octets 15, 16, and 17) are used to implement the test pattern procedure as specified in Section 13 on page 81.

The Link Information fields (octets 18 to 49) are used to exchange information specific to IMA links between both ends of the IMA virtual link. The structure of the Link Information field is shown in Table 3 on page 32.

**(R-22)** The “Tx State” field, located in the Link “x” Information field in an ICP cell, shall be used to report the transmit state of the IMA link on which the near-end (NE) IMA is transmitting ICP cells carrying LID = “x” (“x” being a value between 0 and 31).

**(R-23)** The “Rx State” field, located in the Link “x” Information field in an ICP cell, shall be used to report the receive state of the incoming IMA link on which the far-end (FE) IMA is transmitting ICP cells carrying LID = “x” (“x” being a value between 0 and 31).

**(R-24)** The “Rx Defect Indicators” field, located in the Link “x” Information field in an ICP cell shall be used to report the Rx defects indicators corresponding to the incoming IMA link on which the FE IMA is transmitting ICP cells carrying LID = “x” (“x” being a value between 0 and 31).

The use of the Link Information fields is described in more detail in Section 10.1.6 on page 54 and Section 12.1.2 on page 72. Appendix C.8 on page 165 provides an example of the use of the Link Information fields.

**(R-25)** Octet 50 within the ICP cell is unused and shall be set to 0x6A as defined for unused octets in ITU-T Recommendation I.432 [30].

**(R-26)** The End-to-End channel field (octet 51) shall be reserved as a proprietary channel.

**(R-27)** The End-to-End channel field shall be set to "0" if unused.

**(R-28)** The IMA unit shall not rely on the processing of the End-to-End Channel field for any IMA functionality defined within this specification.

**(R-29)** The IMA receiver shall only consider the information within ICP cells exhibiting neither a HEC nor a CRC-10 error.

**Table 2 ICP Cell Format**

| Octet | Class | Label | Comments |
|---|---|---|---|
| 1-5 | | ATM cell header | Octet 1 = 0000 0000, Octet 2 = 0000 0000, Octet 3 = 0000 0000,<br>Octet 4 = 0000 1011, Octet 5 = 0110 0100 (valid HEC) |
| 6 | | OAM Label | Bits 7-0: IMA Version Value<br>00000001: IMA Version 1.0<br>00000011: IMA Version 1.1 |
| 7 | A | Cell ID and Link ID | Bit 7: IMA OAM Cell Type (1: ICP cell)<br>Bits 6-5: Unused and set to 0<br>Bits 4-0: Logical ID for Tx IMA link range (0...31) |
| 8 | A | IMA Frame Sequence Number | IMA Frame Sequence Number from 0 to 255 and cycling. |
| 9 | A | ICP Cell Offset | Range (0... M-1): indicates position of ICP cell within the IMA frame. |
| 10 | A | Link Stuff Indication | Bits 7-3: Unused and set to 0<br>Bits 2-0: Link Stuffing Indication (LSI)<br>111 = No imminent stuff event,<br>100 = Stuff event in 4 ICP cell locations (optional),<br>011 = Stuff event in 3 ICP cell locations (optional),<br>010 = Stuff event in 2 ICP cell locations (optional),<br>001 = Stuff event at the next ICP cell location (mandatory),<br>000 = This is one out of the 2 ICP cells comprising the stuff event (mandatory). |
| 11 | B | Status & Control Change Indication | Bits 7-0: Status change indication: 0 to 255 and cycling<br>(count to be incremented every change of octets 12-49) |
| 12 | B | IMA ID | Bits 7-0: IMA ID |
| 13 | B | Group Status and Control | Bits 7-4: Group State<br>0000 = Start-up,<br>0001 = Start-up-Ack,<br>0010 = Config-Aborted - Unsupported M,<br>0011 = Config-Aborted - Incompatible Group Symmetry,<br>0100 = Config-Aborted - Unsupported IMA Version,<br>0101, 0110 = Reserved for other Config-Aborted reasons in a future version of the IMA specification,<br>0111 = Config-Aborted - Other reasons,<br>1000 = Insufficient-Links,<br>1001 = Blocked,<br>1010 = Operational,<br>Others: Reserved for later use in a future version of the IMA specification.<br>Bits 3-2: Group Symmetry Mode<br>00 = Symmetrical configuration and operation,<br>01 = Symmetrical configuration and asymmetrical operation (optional),<br>10 = Asymmetrical configuration and asymmetrical operation (optional),<br>11 = Reserved<br>Bits 1-0: IMA Frame Length (00: M=32, 01: M=64, 10: M=128, 11: M=256) |
| 14 | B | Transmit Timing Information | Bits 7-6: Unused and set to 0<br>Bit 5: Transmit Clock Mode: (0: ITC mode, 1: CTC mode)<br>Bits 4-0: Tx LID of the timing reference (0 to 31) |
| 15 | B | Tx Test Control | Bits 7-6: Unused and set to 0<br>Bit 5: Test Link Command (0: inactive, l: active)<br>Bits 4-0: Tx LID of test link (0 to 31) |
| 16 | B | Tx Test Pattern | Bits 7-0: Tx Test Pattern (value from 0 to 255) |
| 17 | B | Rx test Pattern | Bits 7-0: Rx Test Pattern (value from 0 to 255) |
| 18 | C | Link 0 Information | Bits 7-5: Transmit State (see Table 3 on page 32)<br>Bits 4-2: Receive State (see Table 3 on page 32)<br>Bits 1-0: Rx Defect Indicators (see Table 3 on page 32) |
| 19-49 | C | Link 1-31 Info | Status and control of link with LID in the range 1-31 |
| 50 | D | Unused | Set to 0x6A as defined in ITU-T Recommendation I.432[30] for unused bytes. |
| 51 | E | End-to-end channel | Proprietary channel (set to 0 if unused). |
| 52-53 | | CRC Error Control | Bits 15-10: Reserved field for future use default value coded all zero<br>Bits 9-0: CRC-10 as specified in ITU-T Recommendation I.610[31] |

**Table 3 Encoding of the Link Information Fields**

| **Bits** | **Encoding** | | |
|---|---|---|---|
| **7-5** | **Tx State** | **State** | **Additional Information (see note 1)** |
| | 000 | Not In Group | |
| | 001 | Unusable | No reason given |
| | 010 | Unusable | Fault (vendor specific) |
| | 011 | Unusable | Mis-connected |
| | 100 | Unusable | Inhibited (vendor specific) |
| | 101 | Unusable | Failed (not currently defined) |
| | 110 | Usable | |
| | 111 | Active | |
| **4-2** | **Rx State** | | |
| | 000 | Not In Group | |
| | 001 | Unusable | No reason given |
| | 010 | Unusable | Fault (vendor specific) |
| | 011 | Unusable | Mis-connected |
| | 100 | Unusable | Inhibited (vendor specific) |
| | 101 | Unusable | Failed (not currently defined) |
| | 110 | Usable | |
| | 111 | Active | |
| **1-0** | **Rx Defect** | | |
| | 00 | No defect | |
| | 01 | Physical Link Defect (e.g.LOS, OOF/LOF, LCD) | |
| | 10 | LIF | |
| | 11 | LODS | |

Note 1: As specified in (R-80) on page 54 and (O-14) on page 54, one of the Unusable encodings shall be used, but the use of "Inhibited", "Failed", "Fault", or "Mis-connected" is optional.

#### 5.2.2.3 IMA OAM Label

The following requirement indicates that the IMA unit is using IMA v1.1.

**(R-30)** The IMA unit shall always transmit "0x03" over the OAM Label in the Filler and ICP cells.

This requirement allows an IMA unit to identify which version of the IMA specification is being used at each end of the IMA virtual link. If the far-end IMA unit transmits ICP cells with the OAM Label set to "0x01", the near-end IMA implementation might fall back to IMA v1.0. The near-end IMA implementation would no longer be compliant with the IMA v1.1 specification and consequently the associated IMA v1.1 PICS would no longer apply. Appendix C.8.1 on page 166 provides information about the interoperation of IMA v1.0 and v1.1 implementations.

**(R-31)** If the IMA unit does not support the IMA version proposed by the OAM Label received from the far-end IMA unit, the IMA unit shall report the "Config-Aborted - Unsupported IMA Version" state over the "Group Status and Control" field.

The "Config-Aborted - Unsupported IMA Version" state is provided to ease interoperability between implementations supporting different versions of the IMA specification. The use of this state will be more pertinent when developing future versions of the IMA specification.

#### 5.2.2.4 IMA Frame Definition

The IMA frame is used as the unit of control in the IMA protocol. It is defined as M consecutive cells, numbered 0 to M-1 on each link, across the N links in an IMA group. One of the M cells on each of the N links is an ICP cell that occurs within the frame at the ICP cell offset position (the offset may be different on different links). The IMA frame is aligned on all links. "Aligned" means that it is transmitted simultaneously. The presence of differential link delay can cause the reception to "mis-aligned" in time: the alignment is recovered by the mechanism executing link delay synchronization. M is defined during start-up, N is determined by the UM and the IMA link start-up procedure; and the ICP stuff mechanism, as defined in Section 7 on page 38 is a controlled violation of the IMA consecutive frame definition.

**(R-32)** An IMA Frame shall be composed of M consecutive cells transmitted on each link within the IMA group.

**(R-33)** The ICP cell shall be sent on each link once per IMA frame, hence every M cells.

**(R-34)** The IFSN field in the ICP cell shall be used to indicate the sequence number of the IMA frame.

**(R-35)** The IFSN field in the ICP cell shall increment from 0 to 255 and repeat the sequence.

**(R-36)** The IMA Frame Sequence number in the ICP cell shall increment with each IMA frame on a per-link basis, but within an IMA frame period, the sequence number contained in the ICP cell of each link shall be identical.

**(R-37)** The IMA interface shall align the transmission of IMA frames on all links within an IMA group.

Figure 6 on page 33 shows an example of the transmission of IMA frames over three links. On link 0, the ICP cells have their cell offset set to 0 (i.e., they are the first cell in each IMA frame). On link 1, the ICP cells have their ICP cell offset set to 3. In practice, these ICP cells should be distributed more evenly over the IMA frame but are shown closer for ease of illustration. It should also be noted that within an IMA frame, the ICP cells on all links have the same IMA Frame Sequence Number (IFSN). The ICP cell offset is described in more detail in the next section.

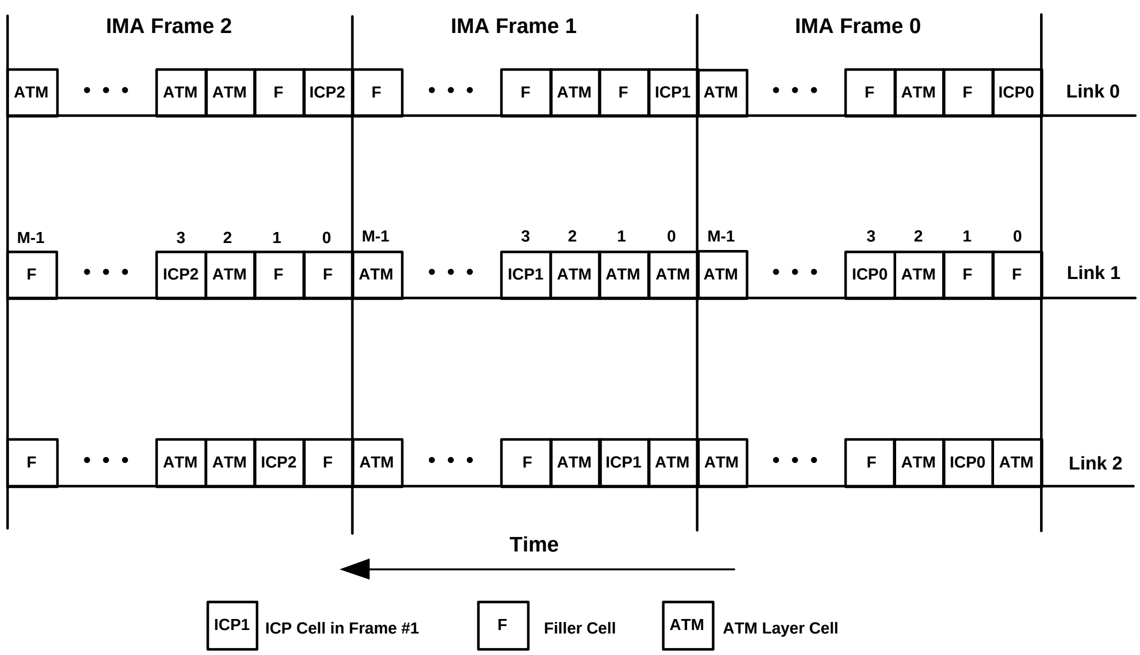



**Figure 6 Illustration of IMA Frames**

#### 5.2.2.4.1 ICP Cell Offset

The ICP cell may be located anywhere within the IMA frame (e.g., the ICP cell offset may be any value from 0 to 127 if M = 128).

An ICP cell offset of 0 means that the ICP cell is the first cell of the IMA frame on that particular link. An ICP cell offset of M-1 means that the ICP cell is the last cell of the IMA frame on that link.

**(R-38)** The ICP Cell Offset field (octet 9) shall be used to indicate the location of the ICP cell within the IMA Frame.

**(R-39)** The ICP cell offset field shall be set to a value between 0 and M-1 where M is the IMA frame length in cells.

**(O-1)** The IMA transmitter may distribute the ICP cells, from link to link within the IMA group, in a uniform fashion across the IMA frame.

An example of uniform distribution of the ICP cell is to assign the following offset to the ICP cell from the first link to be added to the last one: 0, (1/2)*M, (1/4)*M, (3/4)*M, (1/8)*M, (3/8)*M, (5/8)*M, (7/8)*M, etc. The IMA transmitter could select the first unused location appearing in the list when adding a new link to the IMA group.

**(R-40)** The offset of the ICP cell sent over any link shall be selected when the link is assigned a LID and this offset shall be retained until the link is no longer part of the group.

Spreading the ICP cells in the IMA frame from link to link allows faster notification of configuration where the links exhibit the same propagation delay and minimum delay introduction related to the handling of ICP cells.

#### 5.2.2.4.2 IMA Frame Length (M)

The IMA Frame Length (M) shall be processed as follows:

**(R-41)** The value of M used by an IMA shall always be carried to the ICP cell within the IMA frame Length field.

**(R-42)** The IMA unit shall support M equal to 128.

**(O-2)** The IMA unit may support M equal to 32, 64, or 256.

**(R-43)** The IMA unit shall only change the value M at group start-up time.

Section 10.2 on page 55 describes the group start-up procedure in more detail.

Changing the transmitted M value at any other time will affect the IMA Frame Synchronization Mechanism (see Section 11 on page 68).

**(CR-1)** If (O-2) is used, the value of M used by the IMA transmitter shall be the same as the one configured by the UM.

**(CR-2)** If (O-2) is used, the IMA unit may use different values of M in both Tx and Rx directions.

**(CR-3)** If (O-2) is used, the IMA unit shall synchronize its incoming links using the received M value for IMA frame synchronization.

**(R-44)** If the IMA unit does not support the received M, it shall abort the start-up procedure using the corresponding code defined in the "Group Status and Control" field of the ICP cell (see Section 10.2.1.2 on page 57).

**(O-3)** The value M may be configurable.

#### 5.2.2.5 Processing of the SCCI Field

The SCCI field is used as an 8-bit code to indicate that at least one of the fields in Octets 12 through 49 has been changed. This allows the IMA receiver to monitor this field only to detect and start processing any changes of the fields in Octets 12 through 49 reported by the FE IMA transmitter.

**(R-45)** The SCCI field shall be set to the previously transmitted SCCI value, incremented modulo 256, to indicate a change on at least one of the fields appearing in Octets 12 through 49 in the transmitted ICP cell (see Table 2 on page 31).

The monitoring of the ICP cell at the receiving end is implementation dependent. The receiver may select only one or more links to monitor the value of the SCCI field.

**(R-46)** The SCCI field shall be used to identify received ICP cells for processing when ICP cells are monitored on more than one link or when the monitored link has changed. Fields in octets 12 through 49 shall be processed if the SCCI field has advanced beyond the SCCI value of the last processed ICP cell.

#### 5.2.2.6 IMA ID

**(R-47)** The IMA ID shall be selected at group start-up time.

**(R-48)** The IMA ID used by the transmit end shall be carried in the IMA ID field.

Changing the transmitted IMA ID value at any other time will affect the IMA Frame Synchronization Mechanism (see Section 11 on page 68).

Both ends of the IMA virtual link can independently select an IMA ID. There is no need to ensure a unique IMA ID on each end.

**(O-4)** The IMA ID may be configurable.

#### 5.2.2.7 Group Symmetry Modes

The IMA protocol is defined to allow symmetric or asymmetric cell rate transfer over the IMA virtual link. The IMA unit can be configured in three modes:

- *Symmetrical Configuration and Operation:* this the default and mandatory mode; in this mode, the IMA unit is required to configure an IMA link in each direction of all the physical links that the IMA unit is configured to use; the IMA unit is only allowed to transmit and receive ATM layer cells over physical links on which IMA links running in both directions are Active.
- *Symmetrical Configuration and Asymmetrical Operation:* in this optional mode, the IMA unit is required to configure an IMA link in each direction of all the physical links that the IMA unit is configured to use; the IMA unit is also allowed to transmit ATM layer cells over the physical links on which the IMA link in the transmit direction is Active while the IMA link in the receive direction is not Active (or allowed to receive ATM layer cells from physical links on which the IMA link in the receive direction is Active while the IMA link in the transmit direction is not Active). This behavior is described in Appendix D on page 168.

*Asymmetrical Configuration and Operation:* in this optional mode, the IMA unit is not required to configure the IMA links in both transmit and receive directions of all physical links that the IMA unit is configured to use; the IMA unit is also allowed to transmit ATM layer cells over the physical links on which the IMA link in the transmit direction is Active while the IMA link in the receive direction is not Active (or allowed to receive ATM layer cells from physical links on which the IMA link in the receive direction is Active while the IMA link in the transmit direction is not Active). This behavior is described in Appendix D on page 168.

**(R-49)** The "Group Symmetry Mode" field, specified in Table 2 on page 31, shall be used to indicate the symmetry of the IMA group to the FE.

**(R-50)** The IMA unit shall only establish or change the symmetry of the group at group start-up time.

**(R-51)** The "Symmetrical Configuration and Operation" mode shall be supported by all IMA implementations.

**(O-5)** The use of the "Symmetrical Configuration and Asymmetrical Operation" mode is optional.

**(O-6)** The use of the "Asymmetrical Configuration and Operation" mode is optional.

**(R-52)** If the NE does not support the symmetry mode proposed by the FE or if the symmetry mode proposed by the FE and the configured symmetry mode of the NE do not match, the NE shall abort the start-up procedure using the appropriate code defined in the "Group Status and Control" field in the ICP cell (see Table 2 on page 31).

**(O-7)** In order to allow a fast recovery when (O-5) or (O-6) is used at the NE and when the FE IMA unit can only be configured to the "Symmetrical Configuration and Operation" mode, the NE may adjust to "Symmetrical Configuration and Operation".

**(R-53)** Only the valid combinations of group symmetry modes specified in Table 4 on page 36 shall be used at each end of the IMA virtual link.

**(O-8)** The group symmetry mode may be configurable.

**Table 4 Valid and Invalid Combinations of Group Symmetry Modes**

| | | | **End B** | | |
|---|---|---|---|---|---|
| | | | Symmetrical Configuration | | Asymmetrical Configuration |
| | | | Symmetrical Operation | Asymmetrical Operation | Asymmetrical Operation |
| **End A** | Symmetrical Configuration | Symmetrical Operation | Valid | Invalid | Invalid |
| | | Asymmetrical Operation | Invalid | Valid | Invalid |
| | Asymmetrical Configuration | Asymmetrical Operation | Invalid | Invalid | Valid |

# 6. Quality of Service (QoS)

**(R-54)** The IMA interface shall support all ATM traffic/QoS classes supported at the ATM layer.

Appendix C.1 on page 157 provides guidelines on handling dynamic changes of IMA data cell rate.

# 7. Support for Common and Independent Transmit Clock Operations

In order to accommodate the use of Common Transmit Clock (CTC) and Independent Transmit Clock (ITC) configurations as defined in Section 4.3 on page 24, this specification defines the insertion of a stuff event to compensate for timing difference between the IMA links within an IMA group.

The IMA link transmit interfaces may be locked to one clock source or may be plesiochronous with respect to the other links. When plesiochronous, one of the IMA transmit buffers may become depleted or overflow due to timing differences. The IMA cell stuff mechanism is provided to allow error-free ITC operation.

In the CTC mode, stuffing is also inserted on all links at nominal rate specified in Section 8 on page 40. This allows interoperation between transmitter running the CTC and ITC modes and fixes a single nominal rate for the IMA Data Cell Rate (IDCR) defined in Section 8 on page 40.

**(R-55)** The IMA unit shall indicate to the far-end (FE) in which transmit clock mode it is running in the "Transmit Clock Mode" field in the ICP cell (see Table 2 on page 31).

**(R-56)** The IMA transmitter shall support the CTC mode.

**(R-57)** The IMA transmitter shall only indicate to the FE that it is in the CTC mode when all the transmit clocks of the links in the group are derived from the same source.

**(O-9)** The IMA transmitter may also support the ITC mode.

**(O-10)** The IMA transmitter may indicate that it is in the ITC mode even if all the transmit clocks of the links in the group are derived from the same source.

**(CR-4)** If (O-9) is used, the cell stuffing mechanism procedure shall be invoked to prevent link transmit buffer under-run or over-run.

In all cases, the link transmit buffers should not deplete.

**(R-58)** The IMA transmitter shall indicate a stuff event in the ICP cell containing the Link Stuffing Indication (LSI) codes specified in Table 2 on page 31.

**(R-59)** The IMA transmitter shall perform stuffing by repeating the ICP cell containing the Link Stuffing Indication (LSI) code indicating that "this cell is 1 out of the 2 ICP cells comprising the stuff event".

One of the two ICP cells comprising the stuff event is identified as a Stuff ICP (SICP) cell. Either one may be treated as a SICP cell.

The insertion of a stuff event is illustrated in Figure 7 on page 39.

The three additional indications (010, 011, and 100) may provide greater confidence in detecting a SICP occurrence.

**(O-11)** The IMA transmitter may also indicate an incoming stuff event in the fourth, third, and second ICP cells preceding the stuff event using the optional LSI codes defined in Table 2 on page 31.

**(R-60)** At any given link, the IMA transmitter shall not introduce a stuff event more than once every 5*M ICP, Filler, and ATM layer cells.

Appendix C.5 on page 161 explains why the value "5*M cells" has been selected.

**(R-61)** The IMA receiver shall remove one of any two consecutive ICP cells with LSI code indicating that "this cell is 1 out of the 2 ICP cells comprising the stuff event". The removed SICP cell shall not be counted as a cell for the purposes of determining the IMA round-robin sequence.

**(R-62)** The IMA receiver shall operate with CTC and ITC transmission modes.

**(R-63)** When the FE IMA transmit clock mode does not match the NE IMA transmit clock mode, the NE IMA unit shall inform the UM of the mismatch. This shall not cause a restart of the group.

It is up to the implementers to decide how to process the incoming stuff cell indication codes.

**(O-12)** The IMA receiver may rely on at least one ICP cell with a correct CRC-10 in order to process the incoming stuff event indication code (this is a recommended option).

Figure 7 on page 39 shows the ICP cells before, during, and after the stuff event occurrence.

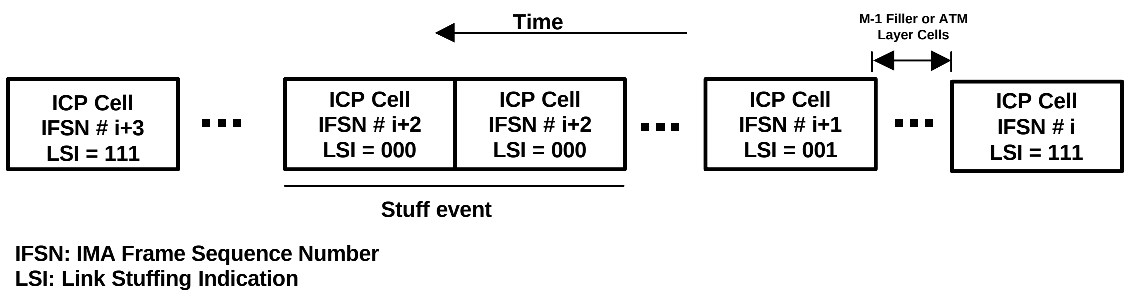



**Figure 7 Insertion of a Stuff Event over One Link (Using Mandatory Advanced Indication Only)**

# 8. IMA Data Cell Rate Implementation

The IMA Data Cell Rate (IDCR) is defined as the rate at which ATM cells should be passed from the ATM layer to the IMA sublayer on transmit and passed from the IMA sublayer to the ATM layer on receive. In order to emulate single-link physical layer interfaces, the IDCR is nominally a constant for any given configuration of links in the Active state.

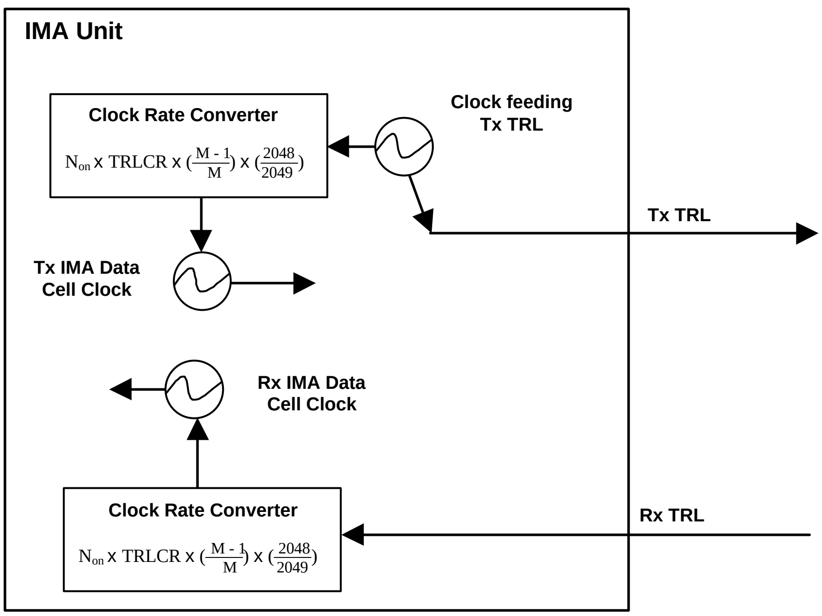
The IDCR is derived from one of the physical links identified as the timing reference link (TRL). The TRL is used to pass synchronization from the transmit to the receive end.

The IDCR is derived, at both the transmit and receive ends, according to the following equation:

$$IDCR = N_{on} \times TRLCR \times \left(\frac{M - 1}{M}\right) \times \left(\frac{2048}{2049}\right)$$

**Equation 1**

Figure 8 on page 40 shows how the Tx and Rx IDCR are derived in the Tx and Rx directions.




**Note: it is not required that the same physical link be used as the Tx and Rx TRL's.**

**Figure 8 Derivation of Tx and Rx IMA Data Cell Clocks**

In the transmit direction, $N_{on}$ represents the number of links which currently transmit cells passed from the ATM layer (Tx=On as specified in Section 10.1.3 on page 49). In the receive direction, $N_{on}$ represents the number of links which currently receive ATM layer cells to be passed to the ATM layer (Rx=On as specified in Section 10.1.3 on page 49).

TRLCR is the TRL cell rate provided via the TRL from transmitter to receiver.

M is the IMA frame length in cell units. The "(M-1)/M" factor accounts for an ICP cell every M cells.

The TRLCR is scaled down by "2048/2049" to account for the insertion of one stuff event on the TRL after every 2048 ICP, Filler and ATM layer cells (e.g., every 16 IMA frames if M equals 128). This implies that, in the case of ITC mode, the links other than the TRL could be faster or slower than the TRL. These other links would require more or less frequent insertion of a stuff event to prevent transmit buffer under-runs/over-runs on these links. Appendix C.5.2 on page 161 explains the choice of 2048.

This section defines the requirements of the IDCR implementation to minimize the introduction of CDV by the IMA virtual link.

## 8.1 Behavior of the Transmit End

Figure 9 on page 41 shows the behavior of the transmit end.

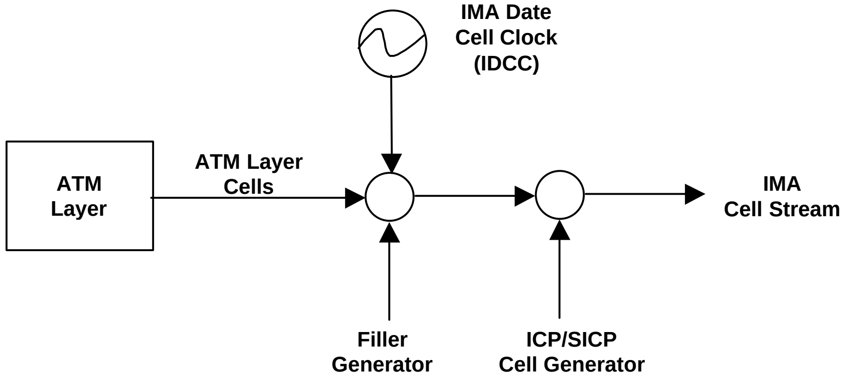



**Figure 9 Behavior of the Transmit End**

**(R-64)** The actions taken for cell rate decoupling at the IMA transmitter shall not inject a Filler cell if an ATM layer cell is available for scheduling. The IMA transmitter shall perform a check that an ATM Layer cell is available and accept that cell only when the Tx IMA Data Cell Clock (IDCC) ticks.

This means that the IMA transmitter should emulate the behavior of one physical interface while interacting with the ATM layer.

It should also be noted that the IDCR is independently determined by the transmitter at each end of the IMA virtual link. The Rx IDCR is recovered by the IMA receiver using the indicated Tx TRL.

### 8.1.1 Selection of the TRL

**(R-65)** The IMA unit shall select the TRL from the set of links whose transmit state is Active (see Section 10 on page 46).

**(R-66)** If there is no link in the Active state, the IMA unit shall select one of the links in the Usable state, if any, or one of the links in the Unusable state otherwise.

**(R-67)** The IMA unit shall select or change the TRL only during the following situations:

- during start-up,
- when the previously selected TRL's transmit state changes from Active to any other state (e.g., Usable, Unusable, or Not In Group) while another link's transmit state is Active, or

  when the previously selected TRL's transmit state changes from Usable to Unusable or Not In Group while another link's transmit state is Active or Usable.

**(R-68)** Once the IMA unit has selected or changed the TRL, the IMA transmitter shall indicate the TRL to the FE over the "Transmit Timing Information" field in the ICP cell (see Table 2 on page 31).

As long as requirements (R-65), (R-66), and (R-67) are met, the criteria for selecting the TRL at the IMA transmitter are vendor specific.

### 8.1.2 Derivation of the Transmit IDCR from the TRL

**(R-69)** The IMA transmitter shall derive the Tx IDCR from the selected TRL according to Equation 1 on page 40.

### 8.1.3 Stuffing on the TRL and Other Links

**(R-70)** When the IMA transmitter is operating in the CTC mode, the IMA transmitter shall introduce a stuff event every 2048 ICP Filler and ATM layer cells on all links.

**(CR-5)** If (O-9) is used, the IMA transmitter shall introduce a stuff event every 2048 ICP, Filler, and ATM layer cells on the TRL.

**(CR-6)** If (O-9) is used, the IMA transmitter shall introduce stuff events on all links other than the TRL in order to compensate for the timing difference between the TRL and the other links.

The previous requirements imply that, once it has detected a stuff event, the IMA receiver can use a modulo-2049 counter as an additional method to predict the occurrence of the next stuff event on the TRL, when in the ITC mode, or on all links, when in the CTC mode.

## 8.2 Behavior of the Receive End

This section defines the behavior of the IMA receiver through requirements (R-71), (R-72), and (R-73). These requirements may be regarded as not applicable to an implementation if and only if the following conditions both apply:

- the IMA receiver is directly built into end equipment that directly terminates the ATM layer (i.e., terminates all ATM connections), and
- the system is only capable of carrying services that either do not require CDV control (e.g., some data services), or where the CDV in handled in some other way (e.g., absorbed in a play-out buffer at the ATM layer connection termination).

An implementation that satisfies both of the above conditions may conform to these requirements.

The IMA receiver should remove the CDV introduced by a transmitter behaving as described in Section 8.1 on page 41. The CDV to be removed is in the form of ICP cells, including Stuff ICP (SICP) cells. Figure 10 on page 43 shows the behaviors of the IMA receiver. The CDV introduced due to the emulated single physical interface behavior, as mentioned in Section 8.1 on page 41, cannot be removed. The Rx IDCR should be derived from the incoming IMA link identified as the TRL by the FE IMA transmitter over the "Transmit Timing Information" field in the ICP cell.

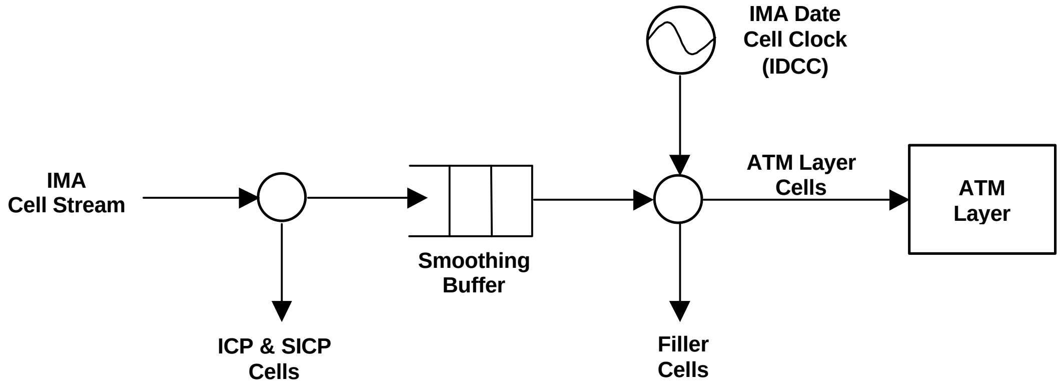



**Figure 10 Behavior of the IMA Receiver**

**(R-71)** The CDV attributed to the presence of ICP cells shall be removed by a behavior equivalent to providing a small smoothing buffer into which cells are placed after reordering and after removing ICP cells (including SICP cells), but not Filler cells.

If the smoothing buffer is physically realized, the handling of overflow and underflow conditions, if any, is implementation dependent.

**(R-72)** If the TRL is in the Working state (as defined in Figure 21 on page 73), the Rx IDCR made available to the ATM layer of the receiver shall be derived as specified in Equation 1 on page 40 using the incoming link indicated by the FE IMA transmitter as the TRL in the "Transmit Timing Information" field in the ICP cell (see Table 2 on page 31). However, the receiver behavior is implementation specific during a short period (up to 100 milliseconds) after receiving a far-end indication on a change of TRL to a different link.

If the IMA Frame Synchronization mechanism is not in the Working state, the recovery of the transmit IDCR is implementation specific until the Working state of that link is recovered or another TRL is selected by the transmitter

Appendix C.6 on page 162 gives an example of the recovery of the IDCR at the IMA receiver.

**(R-73)** Zero or one cell only shall be made available to the ATM layer at an IMA data cell clock tick. The behavior of the IMA receiver shall be equivalent to following: when the IMA data cell clock at the receiver ticks, one cell shall be removed from the smoothing buffer. If the cell is a Filler cell, then the Filler cell shall be discarded and nothing passed to the ATM layer. If the cell is not a Filler cell, then it shall be passed to the ATM layer.

If there are no cells available (e.g., in the smoothing buffer), then the behavior is implementation dependent. Note that this condition is an anomaly since there should always be a cell available even if it is only a Filler cell.

Note that the IDCR will change and be re-adjusted to the new TRL if the current TRL fails or is deleted from the IMA group.

Note that the abstract behavior described in the above requirements assumes that the cell stream, in the order required by the ATM layer, has been reconstructed in the smoothing buffer. During the addition or deletion of a link into/from the IMA group, the IDCR must be recalculated and the new rate applied. There are dependencies on the time at which the IDCR should actually change. The play-out of data that had been received at the old cell rate and that might not have been transmitted to the ATM layer (in particular the ATM layer and Filler cells that are in the delay compensation buffers) should proceed at the data rate at which they were received. This would affect the CDV during transient phases in a link addition/recovery or deletion procedure.

# 9. Link Differential Delay on IMA

## 9.1 Link Differential Delay Tolerance at IMA Transmitter

**(R-74)** The IMA transmitter shall not introduce differential delay among the constituent links of more than 2.5 cell times at the physical link rate.

The choice of 2.5 cell times at the underlying link rate should be sufficient to accommodate the following:

- a gap of 1 cell time among the inputs to the constituent physical link interface,
- plus 1 cell time to transmit a SICP cell, and
- plus 0.5 cell time for processing.

The IMA stuffing mechanism should be sufficient to ensure that the frames do not wander from alignment by more than the tolerance.

Delay compensation at the IMA receiver may be performed using the definition of the IMA frame alone with ICP cells.

## 9.2 Link Differential Delay Compensation at IMA Receiver

**(R-75)** The amount of link differential delay tolerated by an IMA implementation shall be up to at least 25 milliseconds when used over DS1/E1 links.

**(O-13)** The amount of link differential delay tolerance may be configured up to the maximum value supported by the IMA implementation.

It should be noted that both ends of the IMA virtual link may be configured with different amounts of tolerable differential delay (i.e., say one up to 25 ms and one greater than 25 ms).

Appendix B on page 153 provides a detailed example of compensation of the link differential delay.

Appendix C.4 on page 159 on page describes the limitation of the IMA protocol with respect to link differential delay.

# 10. IMA Interface Operation

This section defines the operation of the IMA individual link and group

## 10.1 IMA Link Operation

The IMA link operates independently for both the transmit and receive directions at each end of the IMA virtual link. It allows for a smooth introduction of each link in the round-robin. It also allows graceful handle of error conditions and removal of a link.

A Link State Machine (LSM) is defined for the transmit and receive directions of each IMA link.

### 10.1.1 Overview of the Link State Machine

Figure 11 on page 47 and Figure 12 on page 48 provide an overview of the link state machine (LSM) in both the transmit and receive directions respectively. A simplified Harel state machine notation [13] is used in Figure 11 and Figure 12. In this notation, the top field of a block identifies the state, while the bottom specifies actions. Arrows denote state transition paths with the event triggering the transaction shown as overlaid text. Local events or FE state transitions are used as events. Conditions such as Not In Group and Unusable are locally defined and controlled; no indications are received from the FE.

One out of 4 states in each direction can be viewed by the FE over the "'Link Information" fields defined in Table 3 on page 32:

- Not In Group: the link is not configured within an IMA group
- Unusable: link is configured, but not in use due to fault, inhibition, etc.
- Usable: link ready to operate, but waiting for the other end to be Usable or Active
- Active: link capable of passing ATM layer cells from/to the ATM layer

The LSM starts in the Not In Group state until the link is configured by the UM. Once configured, the LSM moves out to the Unusable state. From the Unusable state, the LSM provides an operating cycle between the Unusable, Usable and Active states.

The Unusable state provides a synchronization point with any vendor-dependent or group level control of link usability. Link error conditions (e.g., physical link or IMA errors) and vendor-dependent conditions (e.g., BER over certain limits) can delay the transition of the LSM into the Usable state or may bring the LSM into the Usable state or may bring the LSM back to the Unusable state from Usable or Active state.

The Unusable state also allows the IMA to voluntarily delay the restoration of the link for reasons other than detected problems. Later sections will refer to this as the inhibition of the link.

The Usable state is an extra state between the Unusable and Active states that allows coordinating the NE and FE when bringing up the link. It also provides a clear synchronization point before activating the links ready to be set Active.

The Unusable and Usable states are also used as synchronization points between the local Tx and Rx LSMs when the IMA group is operated symmetrically.

Once the Rx LSM is in the Usable state, it can move into the Active state only once the FE is reporting that the Tx LSM is Usable. This transition is also subjected to a group-wide synchronization of link activation.

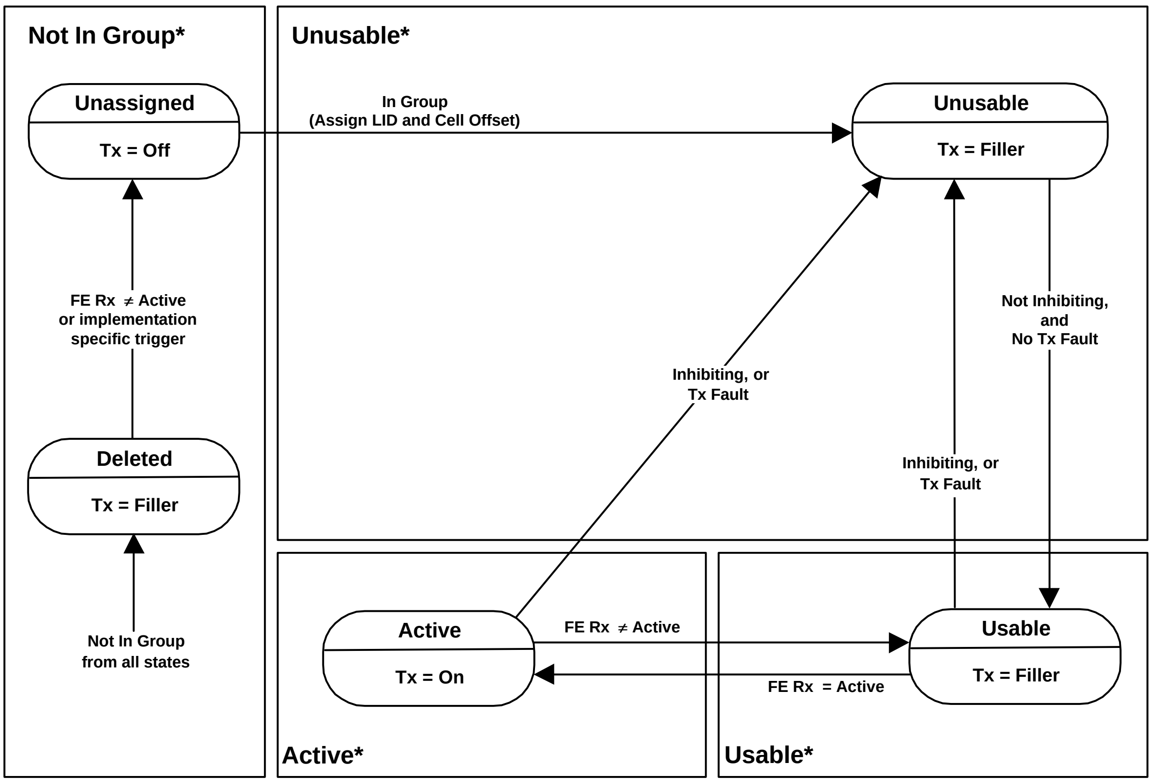
Once the Tx LSM is in the Usable state, it can move into the Active state only once the FE is reporting that the Rx LSM is Active. This transition is also subjected to a group-wide synchronization of link activation.

The Tx and Rx LSMs also have the Deleted state to provide a graceful deletion of the link without loss of ATM layer cells.

The Rx LSM also has the Blocking sub-state that is a transitional state toward the Unusable state to provide a graceful de-activation of a link without loss of ATM layer cells.

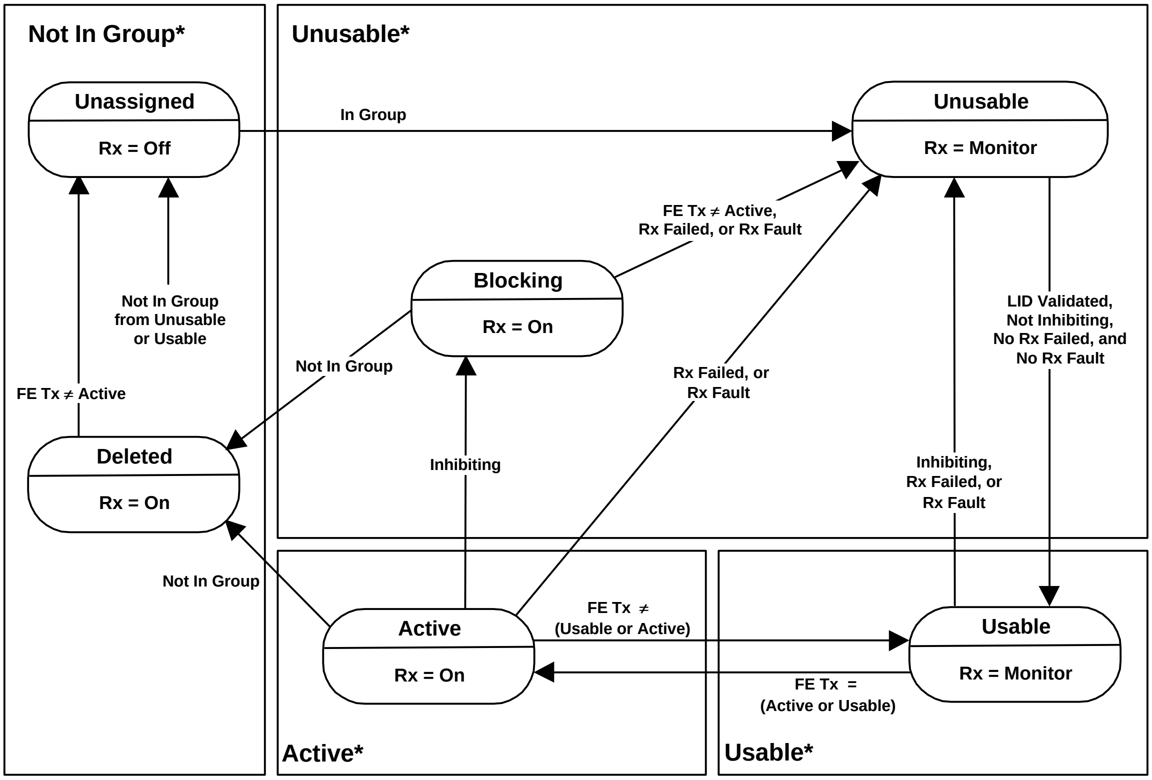
For symmetrical operation, many of the local events are handled in both Tx and Rx LSMs at the same time.

The next section provides more detail on the Tx and Rx LSM requirements.




- **Notes:**
-
- ***: State required to be signalled to the FE.**
- **The Not In Group (Unassigned) state is the initial state of the Tx LSM.**
- **Tx = Off indicates that the IMA transmitter is not expected to be sending IMA frames on that link.**
- **Tx = Filler indicates that the IMA transmitter is sending IMA frames containing Filler cells only on that link.**
- **Tx = On indicates that the transmit ATM layer cell transfer from the ATM layer has been enabled for that link.**
- **FE Rx = Active is a FE state signalled via ICP cells indicating that FE Rx is Active.**
- **FE Rx ≠ Active is a FE state signalled via ICP cells indicating that FE Rx is not Active.**
- **The transition from Unusable to Usable may be delayed due to an ongoing group-wide synchronized start-up or link addition/recovery of links (refer to corresponding group start-up and LASR procedure requirements).**
- **The transition from Usable to Active may be delayed due to an ongoing group-wide synchronized start-up or link addition/recovery of links (refer to corresponding group start-up and LASR procedure requirements).**
- **Fault: a fault in the link or in the protocol; the meaning of this may be implementation specific.**
- **A more detailed definition of the transition triggers is later provided in this section.**

**Figure 11 Transmit Link State Overview**




**Notes:**

- *: State required to be signalled to the FE.
- The Not In Group (Unassigned) state is the initial state of the Rx LSM.
- Rx = Off indicates that no cells are processed by the IMA receiver on that link.
- Rx = Monitor indicates that the IMA receiver is only processing incoming ICP cells on that link.
- FE Tx = Active is a FE state signalled via ICP cells indicating that FE transmit is Active.
- FE Tx ≠ Active is a FE state signalled via ICP cells indicating that FE transmit is not Active.
- The transition from Usable to Active may be delayed due to an ongoing group-wide synchronized start-up or link addition/recovery of links (refer to corresponding group start-up and LASR procedure requirements.
- Fault: a fault in the link or in the protocol; the meaning of this may be implementation specific.
- A more detailed definition of the transition triggers is later provided in this section.

**Figure 12 Receive Link State Machine Overview**

### 10.1.2 Definitions of the Transmit/Receive States and Events

#### 10.1.2.1 Transmit Link States

The following four transmit link states are defined:

- Not In Group: the link is not configured, there are two sub-states:
  - Unassigned: no information about the link exists.
  - Deleted: the link has been removed from the group; this transitional state ensures that the other end is still not receiving ATM layer cells before it moves to the Unassigned state.
- Unusable: the link is configured but cannot be used. There are many reasons for this state including:
  - Test failed: mis-connectivity has been found as a result of a test. The Test Pattern procedure defined in Section 13 on page 77 is an example of tests that can be done.

  - Fault: a fault has been detected either on the link or in the link protocol.
  - Inhibited: operation of the link is blocked for some locally defined application or implementation dependent reason. The link may otherwise be used.
- Usable: the link is ready to be used, it is awaiting the FE to activate its receiver before sending any ATM layer cells; IMA frames containing only Filler cells are being transmitted; but the link is not in the data round-robin
- Active: the link is capable of passing cells from the ATM layer; the IMA transmitter considers the link as part of the data round-robin.

#### 10.1.2.2 Receive Link States

The following four receive link states are defined:

- Not In Group: the link is not configured; there are two sub-state:
  - Unassigned: no information about the link exists.
  - Deleted: the link has been removed from the group; this transitional state is to ensure that the other end is no longer Active (transmitting ATM layer cells) before it moves to Unassigned sub-state.
- Unusable: the link is configured, but cannot be used; there are many reasons for this including:
  - Idle: insufficient information to start link establishment.
  - Failed: the receiver has failed due to the persistence of defined defect. Examples of defects are LCD, LIF, and LODS. These are described in more details in Section 12.1 on page 72.
  - Inhibited: operation of the link is blocked for some locally defined application or implementation dependent reason. The link may be used for testing.
- The sub-state "Blocking" has been defined under the Unusable state to allow graceful transition into the Unusable state without loss of ATM layer cells.
- Usable: the link is ready to be used for receiving ATM layer cells and it is awaiting the FE Tx to be Usable or Active before moving into the Active state. The link has been synchronized with the other receive links already in the Usable or Active state; the IMA receiver considers this link to be neither a part of the data round-robin nor included in the IDCC calculation (the IDCC calculation process is described in Section 8.2 on page 42).
- Active: the link is capable of passing cells to the ATM layer ; the IMA receiver considers this link as part of the data round-robin.

### 10.1.3 Definitions of the Transmit/Receive Link Actions

Table 5 on page 49 and Table 6 on page 50 show the actions that should be performed by the LSM in the transmit and receive directions, respectively.

**Table 5 Actions at the Transmit End**

| Action | Meaning |
|---|---|
| Tx = Off | Indicates that the transmit end is not expected to be sending IMA frames on that link. |
| Tx = Filler | Indicates that the transmit end is sending IMA frames containing only Filler cells on that link, |
| Tx = On | Indicates that the transmit ATM layer cell transfer from the ATM layer has been enabled for that link |

**Table 6 Actions at the Receive End**

| Action | Meaning |
|---|---|
| Rx = Off | Indicates that no cells are processed by the IMA receiver on that link. |
| Rx = Monitor | Indicates that the receiver is only processing incoming ICP cells on that link. |
| Rx = On | Indicates that the receive ATM layer cell transfer to the ATM layer has been enabled for that link. |

### 10.1.4 Link Events Driving the Link State Machines

Table 7 on page 50 defines the local events driving the Tx and Rx LSMs. Depending on the symmetry of the configuration, some events would be input to both Tx and Rx state transitions.

**Table 7 Local Events Driving the Transmit and Receive Link State Machines**

| Event | Meaning | Inputs to Tx and/or Rx LSMs | | |
|---|---|---|---|---|
| | | Symmetrical Configuration | | Asymmetrical Configuration |
| | | Symmetrical Operation | Asymmetrical Operation | Asymmetrical Operation |
| In Group | The assignment of a link in an IMA group by the UM. This corresponds to the moment the link is configured. | Both | Both | One only |
| Not in Group | The removal of an IMA link from a group by the UM. | Both | Both | One only |
| LID Assigned | Sufficient information for the link to begin communication. | Tx only | Tx only | Tx only |
| LID Validated | Information (IMA OAM Label, LID, IMA ID, M, and Group Symmetry) contained in the ICP cell received over the link is consistent with information in ICP cells received over other links in the IMA group. | Rx only | Rx only | Rx only |
| Rx Failed | Condition entered after the persistent detection of a defect at the receiver (see Section 12.1.3 on page 72 and Section C.2 on page 157). The criteria for entering the condition are implementation specific. | One only | One only | One only |
| No longer Rx Failed | No longer in the Rx Failed condition. | One only | One only | One only |
| Fault | Entering the Fault condition<br>A fault in the link or in the protocol. The meaning of this may be implementation dependent. | Vendor Dependent | Vendor Dependent | One only |
| No longer Fault | No longer in the Fault condition. | Vendor Dependent | Vendor Dependent | One only |
| Inhibiting | The link is not to be used for some reason (implementation and application specific). An inhibiting action on a link in the Active state is performed without loss of ATM layer cells. | Both (see note 1) | One only | One only |
| Test related | These are possible ways that the testing could be performed (see note 2). | Probably Tx only | Probably Tx only | Probably Tx only |
| No longer inhibiting | Inhibiting reason removed. | Both | One only | One only |

Note 1. Processing the Rx before the Tx direction will result in no cell loss.

Note 2. Only the transmit end is expected to perform the connectivity test.

### 10.1.5 Link State Transition Tables

Table 8 on page 52 and Table 9 on page 53 show the transition from the current to the new LSM state and the corresponding actions to be executed upon the occurrence of any possible events.

**(R-76)** The Tx LSM shall be controlled using the state machine transition specified in Table 8 on page 52.

**(R-77)** The Rx LSM shall be controlled using the state machine transition specified in Table 9 on page 53.

**(R-78)** Table 8 on page 52 and Table 9 on page 53 shall be interpreted according to the following rules:

- The current state, appearing on the first row, shall be signaled to the FE via the ICP cells.
- The sub-states, appearing on the second row, cannot be signaled, but the corresponding actions shall be performed.
- The LSMs shall be updated based on the occurrence of the events listed in the first column.
- Events that trigger the LSMs shall be treated sequentially even if they appear simultaneously. The order of treatment is implementation specific.

Table 8 on page 52 and Table 9 on page 53 contain four types of events that trigger the LSMs.

## Table 8 Detailed Transmit Link State Machine

| **Primary NE Tx State** | **Not In Group** | | **Unusable** | **Usable** | **Active** |
|---|---|---|---|---|---|
| **Sub-State** | **Unassigned<br>(Tx=Off)** | **Deleted<br>(Tx=Filler)** | **Unusable<br>(Tx=Filler)** | **Usable<br>(Tx=Filler)** | **Active<br>(Tx=On)** |
| **NE Tx Events (see note 1)** | | | | | |
| In Group | Unusable<br>Tx=Filler<br>(see note 2) | -- | -- | -- | -- |
| Not In Group | --<br>(see note 3) | -- | Deleted<br>Tx=Filler | Deleted<br>Tx=Filler | Deleted<br>Tx=Filler |
| Fault Condition | N/A<br>(see note 4) | -- | -- | Unusable<br>Tx=Filler | Unusable<br>Tx=Filler |
| No longer Fault | N/A | -- | Unusable or Usable<br>(see note 5) | N/A | N/A |
| Inhibiting | -- | -- | -- | Unusable<br>Tx=Filler | Unusable<br>Tx=Filler |
| No longer inhibiting | -- | -- | Unusable or Usable<br>(see note 5) | -- | -- |
| **FE Rx States Received in ICP cell** | | | | | |
| Not In Group | N/A | Unassigned<br>Tx=Off | -- | -- | Usable<br>Tx=Filler |
| Unusable | N/A | Unassigned<br>Tx=Off | -- | -- | Usable<br>Tx=Filler |
| Usable | N/A | Unassigned<br>Tx=Off | -- | -- | Usable<br>Tx=Filler |
| Active | N/A | -- | -- | Active or Usable<br>(see note 6) | -- |
| **NE Rx States (see note 7)** | | | | | |
| Not In Group | -- | -- | N/A* | N/A* | N/A* |
| Unusable | N/A*<br>(see note 8) | N/A* | -- | -- | Usable<br>Tx=Filler<br>(see note 9) |
| Usable | N/A* | N/A* | -- | -- | N/A* |
| Active | N/A* | N/A* | -- | Active or Usable<br>(see note 6) | -- |
| **FE Tx States received in ICP cell (see note 7)** | | | | | |
| Not In Group | -- | -- | N/A* | N/A* | N/A* |
| Unusable | N/A* | N/A* | -- | -- | Usable<br>Tx=Filler |
| Usable | N/A* | N/A* | -- | -- | -- |
| Active | N/A* | N/A* | -- | -- | -- |

1 If the NE Tx and Rx events and FE Tx and Rx events appear simultaneously they shall be treated sequentially. The order is implementation specific.

2 The LID and ICP Cell Offset shall also be assigned at this time. Afterwards, the link goes to Unusable; it may subsequently be tested, or go to Usable, or stay in Unusable because of a fault, or some inhibiting actions.

3 “--“ means the event is ignored in this state.

4 N/A indicates that this event should not happen, but may be ignored otherwise.

5 Proceed to Usable with Tx=Filler, only if there are no reasons to remain in Unusable, i.e., no Tx Fault and not inhibiting. The transition to Usable may be delayed due to an outgoing group-wide synchronized start-up or link addition/recovery of links (refer to the group start-up procedure requirement (R-97) on page 61 and the LASR procedure requirement (R-105) on page 65).

6 For symmetrical configuration and operation, proceed to Active with Tx=On, only if FE Rx is Active and NE Rx state is Active. The latter condition ensures that this direction is only used if the other direction is also Usable. Under asymmetric operation (see Appendix D on page 168), proceed to Active with Tx=On. The transition to Active with Tx=On may be delayed due to an ongoing group-wide synchronized start-up or link addition/recovery of links (refer to the group start-up procedure requirement (R-99) on page 61 and the LASR procedure requirement (R-107) on page 65).

7 These are interpreted only if the group is set in the “Symmetrical Configuration and Operation” mode.

8 N/A* indicates only that for groups set in the “Symmetrical Configuration and Operation” mode this should not happen, but may be ignored otherwise.

9 When running in the “Symmetrical Configuration and Operation” mode, the IMA shall always ensure that the report to the FE IMA of the NE Tx state equal to Active is only sent when the NE Rx state is Active. Refer to Table 10 on page 54 for more details about this.

## Table 9 Detailed Receive Link State Machine

| **Primary NE Rx State** | **Not In Group** | | **Unusable** | | **Usable** | **Active** |
|---|---|---|---|---|---|---|
| **Sub-State** | **Unassigned (Rx=Off)** | **Deleted (Rx=On)** | **Unusable (Rx=Monitor)** | **Blocking (Rx=On)** | **Usable (Rx=Monitor)** | **Active (Rx=On)** |
| **NE Rx Events (see note 1)** | | | | | | |
| In Group | Unusable Rx=Monitor (see note 2) | -- | -- | -- | -- | -- |
| Not In Group | -- (see note 3) | -- | Unassigned Rx=Off | Deleted Rx=On | Unassigned Rx=Off | Deleted Rx=On |
| Failed Condition | N/A (see note 4) | Unassigned Rx=Off | -- | Unusable Rx=Monitor | Unusable Rx=Monitor | Unusable Rx=Monitor |
| No longer Failed | N/A | -- | Unusable or Usable (note 5) | -- | -- | -- |
| Fault condition | N/A | Unassigned Rx=Off | -- | Unusable Rx=Monitor | Unusable Rx=Monitor | Unusable Rx=Monitor |
| No longer Fault | N/A | -- | Unusable or Usable (see note 5) | -- | -- | -- |
| Inhibiting | -- | -- | -- | -- | Unusable Rx=Monitor | Blocking Rx=On |
| No longer inhibiting | N/A | -- | Unusable or Usable (see note 5) | -- | -- | -- |
| **FE Tx States Received in ICP cell** | | | | | | |
| Not In Group | N/A | Unassigned Rx=Off | -- | Unusable Rx=Monitor | Unusable Rx=Monitor | Unusable Rx=Monitor |
| Unusable | N/A | Unassigned Rx=Off | -- | Unusable Rx=Monitor | -- | Usable Rx=Monitor |
| Usable | N/A | Unassigned Rx=Off | -- | Unusable Rx=Monitor | Usable or Active (see note 6) | Active or Usable (see note 7) |
| Active | N/A | -- | -- | -- | Active (see notes 6, 8) | -- |
| **NE Tx States (see note 9)** | | | | | | |
| Not In Group | -- | -- | N/A* | N/A* | N/A* | N/A* |
| Unusable | N/A* (see note 10) | N/A* | -- | -- | -- | Usable Rx=Monitor |
| Usable | N/A* | N/A* | -- | -- | Usable or Active (see note 6) | -- |
| Active | N/A* | N/A* | -- | -- | Usable or Active (see note 6) | -- |
| **FE Rx States received in ICP cell (see note 9)** | | | | | | |
| Not In Group | -- | -- | N/A* | N/A* | N/A* | N/A* |
| Unusable | N/A* | N/A* | -- | -- | -- | -- |
| Usable | N/A* | N/A* | -- | -- | -- | -- |
| Active | N/A* | N/A* | -- | -- | -- | -- |

[1] If the NE Tx and Rx events and FE Tx and Rx State events appear simultaneously they shall be treated sequentially. The order is implementation specific.

[2] The initial state will be Unusable, until the LID has been received from the FE and validated, after which if there are no reasons to remain Unusable the link will proceed to Usable.

[3] "--" means the event is ignored in this state.

[4] N/A indicates that this event should not happen, but may be ignored otherwise.

[5] Proceed to Usable with Rx=Monitor, only if there are no reasons to remain in Unusable, i.e., the LID has been received from the FE and validated, there are no failures, no fault and not inhibited.

[6] For symmetrical configuration and operation, proceed to Active with Rx=On, only if FE Tx is Active or Usable and NE Tx state is Active or Usable. Under asymmetric operation (see Appendix D on page 168) proceed to Active with Rx=On. The transition to Active with Rx=On may be delayed due to an ongoing group-wide synchronized start-up or link addition/recovery of links (refer to the group start-up procedure requirement (R-98) on page 61 and the LASR procedure requirement (R-106) on page 65).

[7] If the IMA group is operating symmetrically then; if the NE Tx state is Unusable, proceed to "Usable" with Rx=Monitor, otherwise remains Active with Rx=On.

[8] The reception of FE Tx Active state signaled via ICP cell when NE Rx is Usable is possible in some situations and should not be the source of protocol fault report. The FE Tx Active state could also be ignored although this way will lead to longer delay to return to the Active state.

[9] These are interpreted only if the group is set in the "Symmetrical Configuration and Operation" mode.

[10] N/A* indicates only that for groups set in the "Symmetrical Configuration and Operation" mode this should not happen, but may be ignored otherwise.

### 10.1.6 Processing of the Tx and Rx State Fields in the ICP Cells

**(R-79)** The IMA interface shall report any change of the Tx and Rx LSMs within the next 2*M (where M is the M used by the IMA transmitter) cells on that link over the “Tx State" and "Rx State" fields of the Link Information field (refer to Table 3 on page 32).

Synchronization of the group start-up or addition/recovery of links involves the synchronization of state transitions in multiple LSMs. This is covered in more detail in Section 10.2.1 on page 55 and Section 10.2.2 on page 64.

**(R-80)** The IMA interface shall use one of the Unusable encodings when reporting the Unusable state.

**(O-14)** The IMA interface may optionally use "Inhibited", "Failed", "Fault", or "Mis-connected" as a reason when reporting the Unusable state.

**(R-81)** The IMA interface shall re-evaluate the Tx and Rx LSMs state upon each incoming ICP cell with new state indication.

Table 10 on page 54 shows, for all group symmetry modes, the valid combinations of the states of the Tx and Rx LSMs corresponding to the Tx and Rx IMA links carried over each direction of the same physical link.

**(R-82)** Each end shall allow the valid combinations of Tx and Rx link states and disallow the invalid combinations, as specified in Table 10 on page 54.

**Table 10 Valid Combinations of the Tx and Rx Link States**

| Tx state | Rx State | Symmetrical configuration and operation mode | Symmetrical configuration, asymmetrical operation mode | Asymmetrical configuration and operation mode |
|---|---|---|---|---|
| Not In Group | Not In Group | Valid | Valid | Valid |
| Not in Group | Unusable | Invalid | Invalid | Valid |
| Not In Group | Usable | Invalid | Invalid | Valid |
| Not In Group | Active | Invalid | Invalid | Valid |
| Unusable | Not In Group | Invalid (see note 1) | Invalid (see note 1) | Valid |
| Unusable | Unusable | Valid | Valid | Valid |
| Unusable | Usable | Valid | Valid | Valid |
| Unusable | Active | Invalid | Valid | Valid |
| Usable | Not In Group | Invalid | Invalid | Valid |
| Usable | Unusable | Valid | Valid | Valid |
| Usable | Usable | Valid | Valid | Valid |
| Usable | Active | Valid | Valid | Valid |
| Active | Not In Group | Invalid | Invalid | Valid |
| Active | Unusable | Invalid | Valid | Valid |
| Active | Usable | Invalid | Valid | Valid |
| Active | Active | Valid | Valid | Valid |

1. The IMA unit shall report the Rx state as “Not In Group” until it has validated the LID of the incoming IMA link, although the actual state is Unusable.

Appendix E on page 171 presents examples of link state exchanges between both ends.

## 10.2 IMA Group Operation

This section defines the operation of the IMA group. The operation of the IMA group is governed by the Group State Machine (GSM), the Group Traffic State Machine (GTSM), and by the Link Addition and Slow Recovery (LASR) procedure. These three items are used to ensure reliable transmission and reception of ATM layer cells across all links in the Active state. This includes the negotiation of group parameters (e.g., symmetry and M values), the bringing up of the IMA group, and the graceful addition/recovery and deletion of links to and from the group.

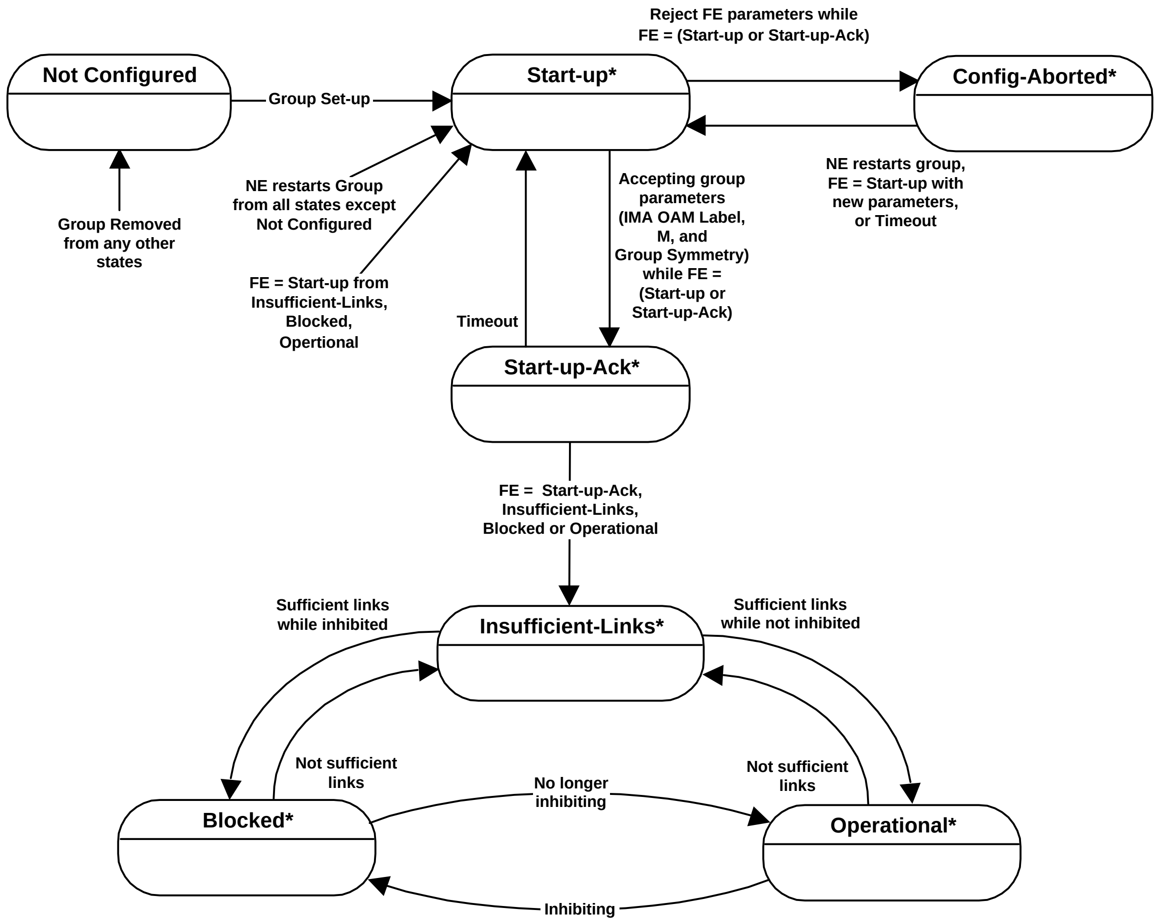
### 10.2.1 IMA Group State Machine Definition

#### 10.2.1.1 Overview of the Group State Machine

An overview of the GSM chart is shown in Figure 13 on page 56. The GSM starts in the Not Configured state and then enters the Start-up state. This transition corresponds to the time the UM configures the IMA group. In the Start-up state, the IMA unit proposes group parameters to the FE and waits to determine if the proposed parameters are accepted by the FE. This is done by monitoring the "Group Status and Control" fields in the incoming ICP cells. The FE will indicate if it accepts the proposed group parameters by returning Start-up-Ack. The FE will return Config-Aborted if it rejects the parameters.

While in the Start-up state, the local IMA unit also has to determine if it can accept the group parameters proposed by the FE. If it accepts the proposed parameters, it goes into the Start-up-Ack state. If it rejects the proposed parameters, it goes into the Config-Aborted state.

Once in the Start-up-Ack state, the local IMA unit now waits for one of the signals specified in Figure 13 to enter the Insufficient-Links state. At this point, the GSM starts paying attention to the individual LSMs. It stays in the Insufficient-Links state until it gets the number of links required to be Active. This number is specified in terms of $P_{Tx}$ and $P_{Rx}$, where $P_{Tx}$ represents the number of links required to be Active in the transmit direction and $P_{Rx}$ represents the number of links required to be Active in the receive direction. $P_{Tx}$ and $P_{Rx}$ are equal if the group is operating in the Symmetrical Configuration and Operational mode. It is required that the GSM receives indications from the individual LSMs about the status of the links.



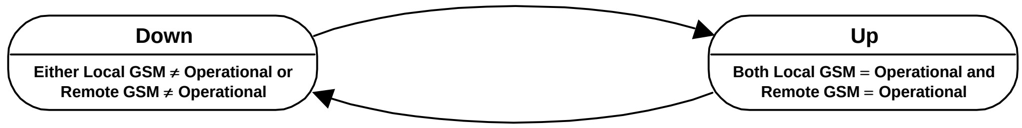

**Notes:**

- *: Group state required to be signalled to the FE.
- Config Aborted State: to avoid a race hazard, the NE GSM should remain in this state for at least one second; this is to allow for at least one round trip of communication between both ends on fhe IMA virtual links.
- Start-up-Ack: The NE GSM should wait for at least one second before moving to Start-up. This return to Start-up occurs if one of the expected signals which would cause the move to Insufficient-Links is not received from the FE GSM.
- Sufficient links transition is defined as:
  For symmetric operation: at least $P_{Tx}$ transmit links Active in both directions where $P_{Tx}$ and $P_{Rx}$ are equal.
  For asymmetric operation: at least $P_{Tx}$ transmit links Active and $P_{Rx}$ receive links Active.

**Figure 13 Overview of the Group State Machine (GSM)**

Once the group gets the number of links required to be Active, it moves into the Operational state if it has not been inhibited. Once in the Operational state, the group is allowed to receive ATM cells and pass them to the ATM layer. The NE must receive the Operational state signal from the FE before transmitting cells from the ATM layer. Figure 14 on page 57 illustrates the Group Traffic State Machine (GTSM) that indicates the capability of the group to transmit cells from the ATM layer. ATM layer cells can be only transmitted by the NE when both the NE and FE IMA groups are in the Operational state.

The GTSM allows the NE to ensure that both ends have sufficient Links before starting transmitting cells to the FE.




**Notes:**
There may be a persistence to aggregate changes between these states.
This is implementation and application specific.

**Figure 14 Group Traffic State Machine (GTSM)**

Figure 13 on page 56 also shows the presence of two time-outs. One time-out is used to allow the GSM to return from the Config-Aborted to the Start-up state to indicate to the FE that it is ready to propose and evaluate new group parameters. A second time-out is used to return from Start-up-Ack to Start-up when the NE is not receiving one of the FE signals required to transition to Insufficient-Links. In both cases, the time-out is required to be at least one second long.

The GSM also has the Blocked state defined for maintenance purpose.

### 10.2.1.2 Detailed Group State Machine Definition

This section defines the characteristics of the GSM. Table 11 on page 57 describes the state of the GSM.

**Table 11 Description of GSM States**

| State | Description |
|---|---|
| Not Configured | The group does not exist |
| Start-up | This end is in start-up and is waiting to receive the indication that the FE is in start-up. When sufficient communication with the FE is achieved, the Group Parameters (IMA OAM Label, IMA ID, M, and Group Symmetry) are recorded and the group moves to Start-up-Ack. |
| Start-up-Ack | This is a transitional state, when both groups start-up, they then move through this state to the Insufficient-Links state. While in this state, indications from the FE that it is in Start-up are ignored. |
| Config-Aborted | This state is entered when the FE tries to use unacceptable configuration parameters. This state has the following sub-states:<br>unsupported M<br>• incompatible group symmetry<br>• unsupported IMA version<br>• other reasons. |
| Insufficient-Links | This state implies that the group has accepted the FE group parameters and has been indicated that the FE has also accepted its own group parameters, and does not have sufficient links to move into the Operational state. This state is exited when "sufficient links" can be moved into the Active state (see note 1). |
| Blocked | The group is blocked (e.g., inhibited by the UM), The group can be blocked for maintenance purposes while sufficient links are Active in both directions. |
| Operational | The group is not inhibited and has sufficient links in both the Tx and Rx directions. The IMA interface has now the capability to receive ATM layer cells and pass them from the IMA sublayer to the ATM layer. |

1. The term “Sufficient Links” is defined as: for symmetrical operation, this corresponds to at least $P_{TX}$ links that are Active in both directions ($P_{Tx}$ = $P_{Rx}$); for asymmetrical operation, this corresponds to at least $P_{Tx}$ links that are Active in the transmit direction and at least $P_{Rx}$, links that are Active in the receive direction.

**(R-83)** The states listed in Table 11 on page 57, with the exception of the Not Configured state, shall be reported to the FE group using the corresponding value defined in the "Group Status and Control" field in Table 2 on page 31.

**(R-84)** The IMA transmitter shall always send over each link the same value in the "Group Status and Table 2 on page 31) for at least two consecutive IMA frames.

This is required in order to ensure that the FE is properly informed.

**(R-85)** The GSM shall validate the Rx OAM Label, Rx M, and Rx IMA ID over at least one link before moving into the Start-up-Ack state.

**(R-86)** The IMA unit shall use the validated Rx OAM Label, Rx M, and Rx IMA ID to achieve IMA frame synchronization as defined in Section 11 on page 68.

Other group fields in the ICP cells do not have to be validated over all links once the Rx OAM Label, Rx M, and Rx IMA ID have been validated.

The values of $P_{Tx}$ and $P_{Rx}$, mentioned in Table 11 on page 57, represent the numbers of links required by the GSM to move into the Operational state while synchronizing the activation of the links in both Tx and Rx directions (more details on the synchronized activation of the links in provided in Section 10.2.1.3 on page 61 and Section 10.2.2 on page 64). The assignment of $P_{Tx}$ and $P_{Rx}$ is implementation specific.

**(R-87)** The GSM shall ensure that at least $P_{Tx}$ links in the transmit direction and $P_{Rx}$ links in the receive direction can be moved into the Active state before moving the GSM into the Operational state.

**(R-88)** $P_{Tx}$ and $P_{Rx}$ shall be greater than 0.

**(R-89)** $P_{Tx}$ and $P_{Rx}$ shall be set to an equal value if the IMA unit is configured in the Symmetrical Configuration and Operation mode.

**(O-15)** The values of $P_{Tx}$ and $P_{Rx}$ may be configurable.

Table 12 on page 58 lists and describes the local events causing GSM state transitions.

**Table 12 Local Events Driving the GSM**

| Event | Description |
|---|---|
| Group Setup | The establishment of the IMA Group by the UM. |
| Group Removed | Removal of the IMA Group by the UM. |
| Acceptance of FE Group Parameters | All the FE group parameters are acceptable while the FE GSM is the Start-up or Start-up-Ack state. |
| Rejection of FE Group Parameters | One or more of the FE group parameters are unacceptable. For example, the proposed M value is not supported or the requested group symmetries are different. |
| Inhibiting | An implementation specific shut down of the group for a reason other than insufficient links (e.g., by the UM). |
| No longer inhibiting | Removal of the inhibiting condition. |
| Sufficient Links | See the description of the Insufficient-Links state in Table 11 on page 57. |
| Not Sufficient Links | See the description of the Insufficient-Links state in Table 11 on page 57. |
| Events that cause a new startup attempt from Config-Aborted | This can be driven by many causes, a new local configuration, a realization that the FE is attempting start-up with a different configuration, or simply a timeout to retry. These are implementation specific. |

**(R-90)** If the requested configuration is unacceptable, the IMA unit shall indicate this using the Config Aborted state for at least 1 second.

The previous requirement is to allow for at least one round trip of communication between the NE and FE (4*M cells plus round trip time).

**(R-91)** The IMA unit shall support the GSM state transitions as defined in Table 13 on page 60.

Table 13 on page 60 shows the state transition of the GSM. The first row lists the current state, and the first column indicates the event triggering state change. Two categories of events (NE events and FE states) are defined. If events occur simultaneously, they shall be treated sequentially. The order is implementation specific.

## Table 13 Group State Machine (GSM) State Transitions

| | **Not Configured (see note 1)** | **Start-up** | **Start-up-Ack** | **Config-Aborted** | **Insufficient-Links** | **Blocked** | **Operational** |
|---|---|---|---|---|---|---|---|
| **NE Rx Events** | | | | | | | |
| Group Set-up | Start-up | -- | -- | -- | -- | -- | -- |
| Group Removed | -- (see note 2) | Not Configured | Not Configured | Not Configured | Not Configured | Not Configured | Not Configured |
| Acceptance of FE Group Parameters | -- | Start-up or Start-up-Ack (see note 3) | N/A (see note 4) | N/A | N/A | N/A | N/A |
| Rejection of FE Group Parameters | -- | Config-Aborted | Config-Aborted (see note 5) | -- | N/A | N/A | N/A |
| Inhibiting | -- | -- | -- | -- | -- | -- | Blocked |
| Not inhibiting | -- | -- | -- | -- | -- | Operational (see note 6) | -- |
| Sufficient links | -- | -- | -- | -- | Blocked or Operational (see notes 6,7) | -- | -- |
| Not Sufficient links | -- | -- | -- | -- | -- | Insufficient-Links | Insufficient-Links |
| Local Restart | -- | Start-up | Start-up | Start-up | Start-up | Start-up | Start-up (see note 8) |
| Time-out (see note 9) | -- | -- | Start-up (see note 10) | Start-up (see note 11) | -- | | -- |
| **FE State signaled via ICP cell** | | | | | | | |
| Start-up | -- | Start-up, Start-up-Ack, or Config-Aborted (see note 12) | -- | Start-up or Config-Aborted (see note 13) | Start-up | Start-up | Start-up |
| Start-up-Ack | -- | Start-up, Start-up-Ack, or Config-Aborted (see note 12) | Insufficient-Links | -- | -- | -- | -- |
| Config-Aborted | -- | -- | -- | -- | -- | | -- |
| Insufficient-Links | -- | -- | Insufficient-Links | -- | -- | | -- |
| Blocked | -- | -- | Insufficient-Links | -- | -- | | -- |
| Operational | -- | -- | Insufficient-Links | -- | -- | | -- (see note 6) |

1 Starting state.
2 "--" means the event is ignored in this state.
3 Proceed to Start-up-Ack if FE=(Start-up-Ack or Start-up), otherwise remain in Start-up.
4 N/A (Not Applicable) indicates that this event should not happen, but may be ignored otherwise.
5 Reporting “Rejection of FE Group Parameters” is not expected when GSM is in Start-up-Ack state, since the FE group parameters had to be accepted to allow GSM to move into the Start-up-Ack state.
6 The GTSM shall be only Up when both the NE and FE GSMs are operational.
7 If inhibiting go to Blocked state, otherwise to Operational state.
8 To perform a graceful group restart, the group may be blocked or all the links inhibited before restarting.
9 Time-outs are only meaningful for Start-up-Ack (see note 10) and Config-Aborted (see note 11).
10 This time-out shall be at least one second. This will provide enough time for the FE GSM to notice that the NE GSM is in Start-up-Ack and to change to Start-up-Ack itself.
11 When the GSM aborts due to unacceptable configuration, it shall remain in the Config-Aborted state for at least one second (at least one round trip delay between both ends).
12 If the new parameters are acceptable proceed to Start-up-Ack, if rejected proceed to Config-Aborted or remain Start-up if the IMA has not yet decided to accept the parameters.
13 If receiving FE-Start-up with new group parameters, then proceed to Start-up, otherwise remain in Config-Aborted.

**(R-92)** Each IMA interface shall independently determine whether the group is up or down with respect to carrying traffic as in Figure 14 on page 57 and report the result according to Table 14 on page 61.

**(R-93)** The IMA unit shall report the entrance of the GTSM into the Down state to the UM and ATM Layer Management. This shall be the only notification to the ATM Layer Management about Physical Layer defects or failures (other notifications to the UM are possible).

**(R-94)** The IMA unit shall report the return of the GTSM to the Up state to the UM and ATM Layer Management.

**Table 14 GTSM States and Corresponding Report Priority**

| GTSM State | Reasons | Report Priority (see note 1) |
|---|---|---|
| Up | | |
| Down | FE Start-up | 1 (Most important) |
| Down | NE Aborted (with given reason) | 2 |
| Down | FE Aborted (with given reason) | 3 |
| Down | NE Insufficient Links | 4 |
| Down | FE Insufficient Links | 5 |
| Down | NE Blocked | 6 |
| Down | FE Blocked | 7 (Least important) |

1. The report priority applies only when reporting that the GTSM has moved to the down state.

**(R-95)** The IMA interface shall not drop any ATM layer cells when adding or recovering links while the GSM is maintained in the Operational state.

**(R-96)** The IMA interface shall not drop any ATM layer cells when deleting or inhibiting links while the GSM is maintained in the Operational state.

When links are being deactivated due to link failure or link deletion, the bandwidth of the IMA group decreases. Appendix C.1 on page 157 explains the possible actions to be performed in this case.

### 10.2.1.3 Synchronized Link Activation during Group Start-up Procedure

This section defines extra requirements to synchronize the activation of the links during the Group Start-up procedure.

To minimize the number of bandwidth changes on the IMA virtual link, as a result of group start-up, it is important to activate as many links as possible at the same time. The following requirements ensure that as many links as possible (i.e., that are acceptable in terms of delay) are activated at the same time.

**(R-97)** The group start-up procedure shall ensure that all accepted links have their states changed to Tx=Usable in the same update of the ICP cell.

**(R-98)** The group start-up procedure shall ensure that all accepted links have their states changed to Rx=Active in the same update of the ICP cell after the Tx state of the accepted links has been reported Usable in a previous update of the ICP cell.

**(R-99)** The group start-up procedure shall ensure that all accepted links have their states changed to Tx=Active in the same update of the ICP cell after the Rx state of the accepted links has been reported Active in a previous update of the ICP cell.

**(R-100)** The group start-up procedure shall wait a minimum of one second before reporting links Rx=Active, unless all the configured links are being reported Tx=Usable by the FE.

**(R-101)** The group start-up procedure shall wait a minimum of one second before reporting links Tx=Active, unless all the configured links are being reported Rx=Active by the FE.

Figure 15 on page 63 provides an example of the detailed behavior at each end of the IMA virtual link during group start-up.

An example of the flow of the start-up procedure over time is shown in Figure 16 on page 64. The figure highlights the essential checkpoints required to be passed before moving further in the process. The links become part of the sequencing round-robin (RR) when the transmitting end has allocated them a LID and the receiving end has started synchronizing them (delay compensation for accommodating longest propagation delay links).

Appendix D on page 168 details the start-up procedure when using a different value for $P_{Tx}$ and $P_{Rx}$ in the case of optional asymmetrical operations.

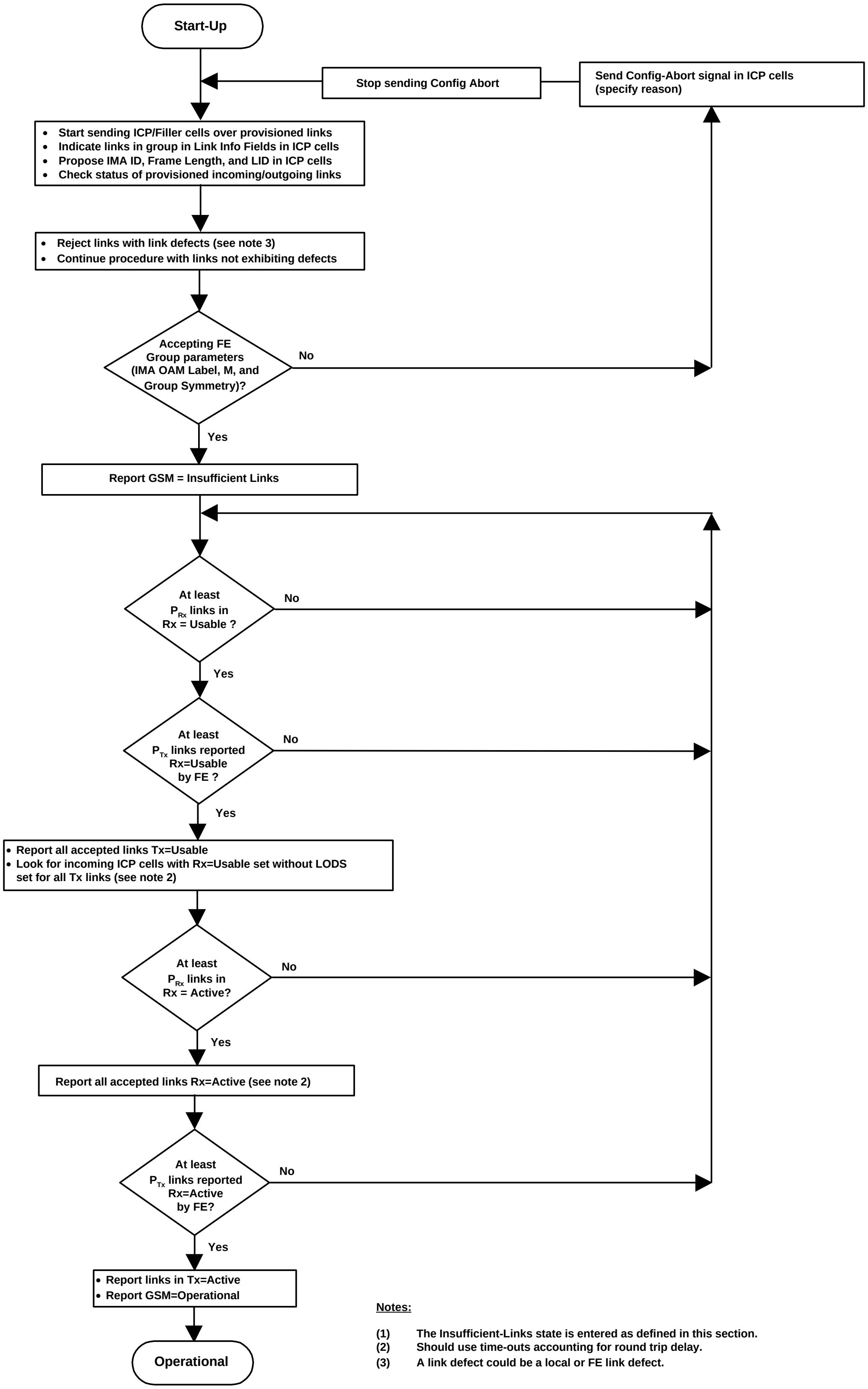
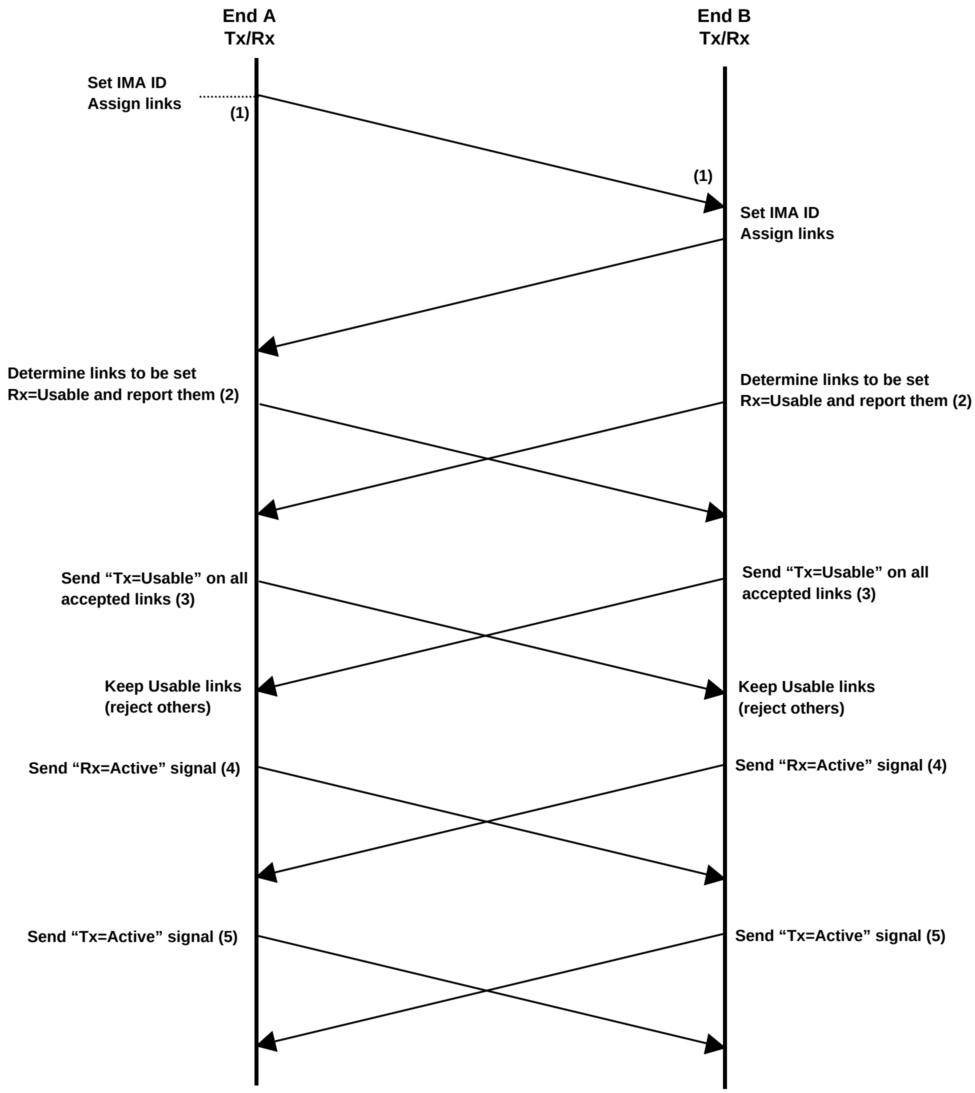



**Figure 15 Example of Synchronized Link Activation during Group Start-up**




**Notes**

(1) Each link is assigned a LID.
(2) At this point, links reported Rx=Usable are those that have been recognized within the IMA group, that do not exhibit any defects and that exhibit proper link differential delay.
(3) All links are reported Tx=Usable at the same time.
(4) All links are reported Rx=Active at the same time.
(5) The transmit links can be activated once they all have been recognized Active in the receive direction or after some time-out has expired and P out of N of the receive links have been recognized Active. Links are reported Tx=Active at the same time.

**Figure 16 Example of Synchronized Link Activation during Group Start-up over Time**

### 10.2.2 Link Addition and Slow Recovery (LASR) Procedure

The Link Addition and Slow Recovery (LASR) procedure is defined to synchronize the insertion of new or recovered links within the IMA RR. Figure 17 on page 66 gives an example of the group and link actions at each end of the IMA virtual link. It is required that each end of the IMA virtual link process the LASR procedure in order to complete the insertion and activation of the newly inserted links. Links being inserted can be removed during the execution of the LASR procedure.

**(R-102)** The LASR procedure shall be used to synchronize the insertion of new links or recovered links added using the slow recovery mechanism, defined in Section 12.1.3.1 on page 74, within the IMA RR.

**(R-103)** Only one LASR procedure per IMA group shall be executed at any time. The link addition shall be used to insert one or more than one link at the same time.

**(R-104)** If the LASR procedure is in progress, the insertion of one or more new links triggered by the UM or a possible slow link recovery (as defined in Section 12.1.3.1 on page 74) shall be delayed until the link addition procedure is completed or aborted (link addition capability is enabled once again as shown in Figure 17 on page 66).

**(R-105)** The LASR procedure shall ensure that all the links being inserted have their states changed to Tx=Usable in the same update of the ICP cell.

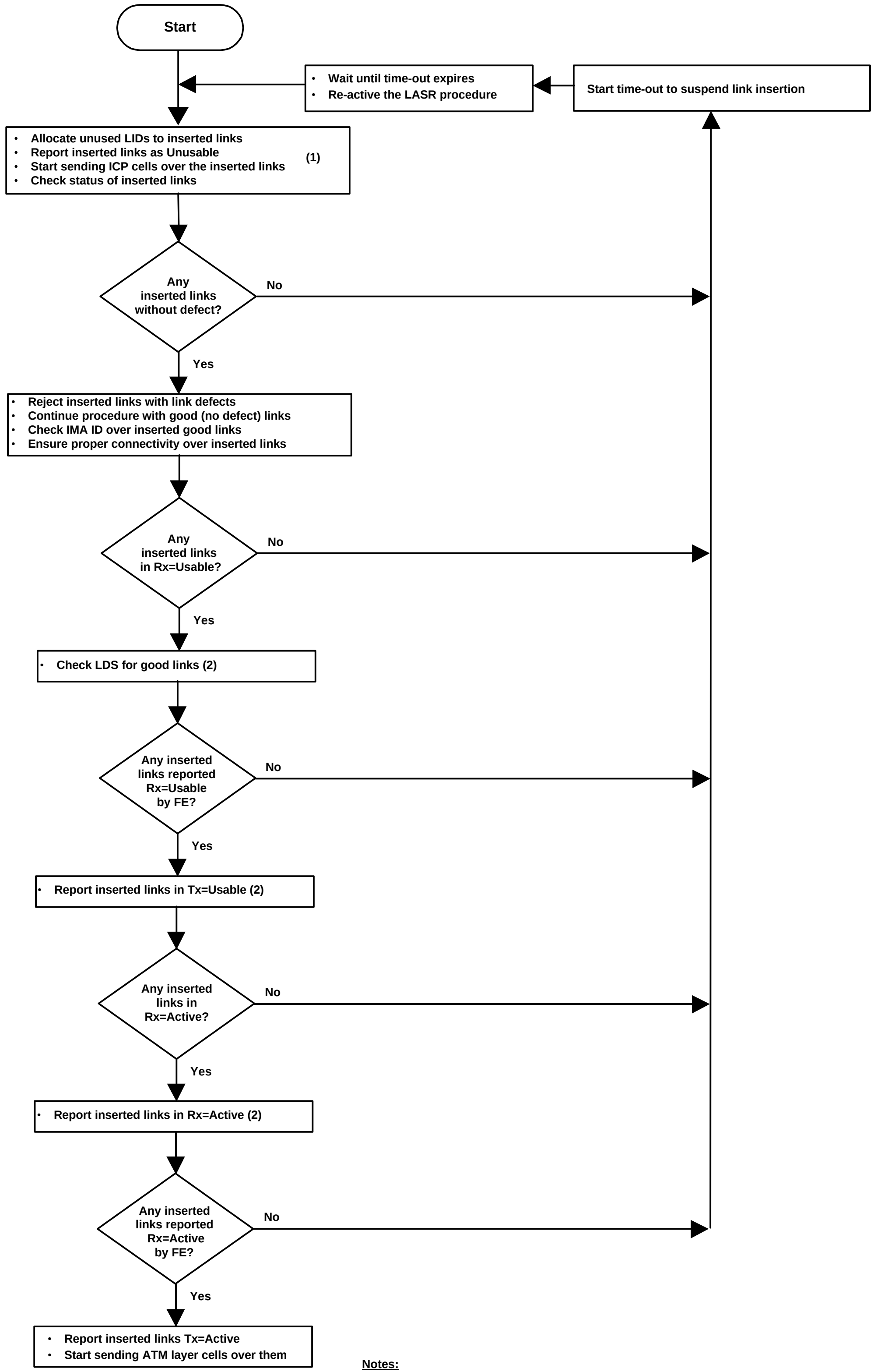
**(R-106)** The LASR procedure shall ensure that all the links being inserted have their states changed to Rx=Active in the same update of the ICP cell after the Tx state of the accepted links has been reported Usable in a previous update of the ICP cell.

**(R-107)** The LASR procedure shall ensure that all the links being inserted have their states changed to Tx=Active in the same update of the ICP cell after the Rx state of the accepted links has been reported Active in a previous update of the ICP cell.

**(R-108)** The LASR procedure shall wait a minimum of one second before reporting links Rx=Active, unless all the links being inserted are being reported Tx=Usable by the FE.

**(R-109)** The LASR procedure shall wait a minimum of one second before reporting links Tx=Active, unless all the links being inserted are being reported Rx=Active by the FE.

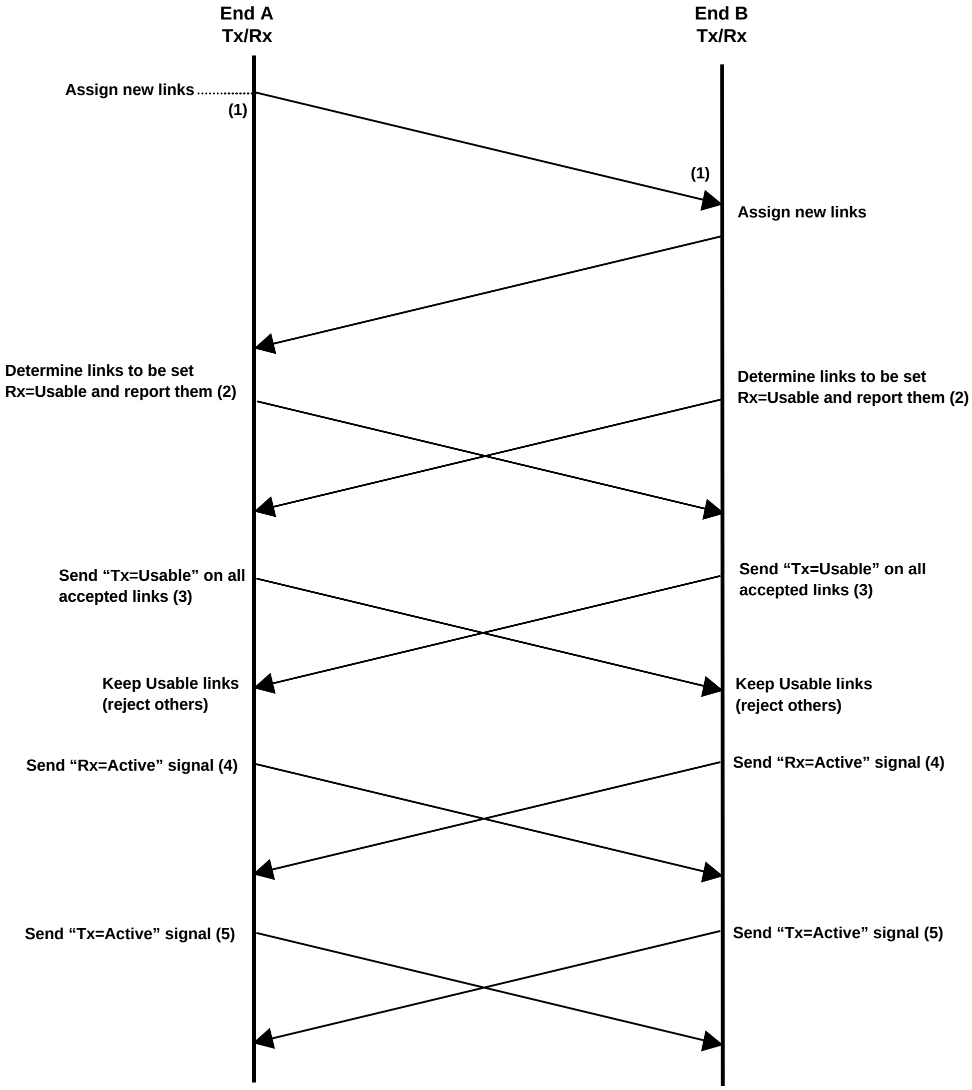
An example of the execution of the LASR procedure over time is shown in Figure 18 on page 67.




Notes:

(1) Only applied when inserting new links (not for link slow recovery)
(2) Should have time-outs accounting for round trip delay

**Figure 17 Link Addition and Slow Recovery (LASR) Procedure**




**Notes**

(1) Each link is assigned a LID.
(2) At this point, new links are those that are Usable at both ends.
(3) All links are reported Tx=Usable at the same time.
(4) All links are reported Rx=Active at the same time.
(5) The new links can be activated in the transmit direction once they all have been recognized Active in the receive direction or after some time-out has expired and some of the links have been recognized Active in the receive direction. All new links should be reported Tx=Active at the same time.

**Figure 18 Example of Link Addition Procedure over Time**

# 11. IMA Frame Synchronization Mechanism

This section defines the IMA Frame Synchronization Mechanism (IFSM). It is based on the cell delineation mechanism in ITU-T Recommendation I.432[30] and ANSI T1.646[6].

**(R-110)** Each IMA link in the group shall provide the IFSM as shown in Figure 19 on page 69 and Table 16 on page 69.

In the standards for the Physical Layer specification like ITU-T Recommendation I.432 or ANSI T1.646 the synchronization mechanism is specified independent of error/maintenance handling. The synchronization states form a basis for the different error and maintenance states. The same applies for this specification.

The IFSM consists of the IMA Hunt, IMA PreSync, and IMA Sync states. By analogy with ITU-T Recommendation I.432 and ANSI T1.646, the checking scheme should be Cell-by-Cell in the IMA Hunt state and Frame-by-Frame in the IMA Sync and IMA PreSync states.

**(R-111)** The IFSM (implemented for each link separately) shall operate independently of any link defects and link delay compensation.

**(R-112)** The default value of Alpha($\alpha$), Beta($\beta$) and Gamma($\gamma$), variables appearing in Figure 19 on page 69, shall be supported as specified in Table 15 on page 68.

**(O-16)** The support of values of Alpha($\alpha$), Beta($\beta$) and Gamma($\gamma$) other than the default values, such as specified in Table 15 on page 68, is optional.

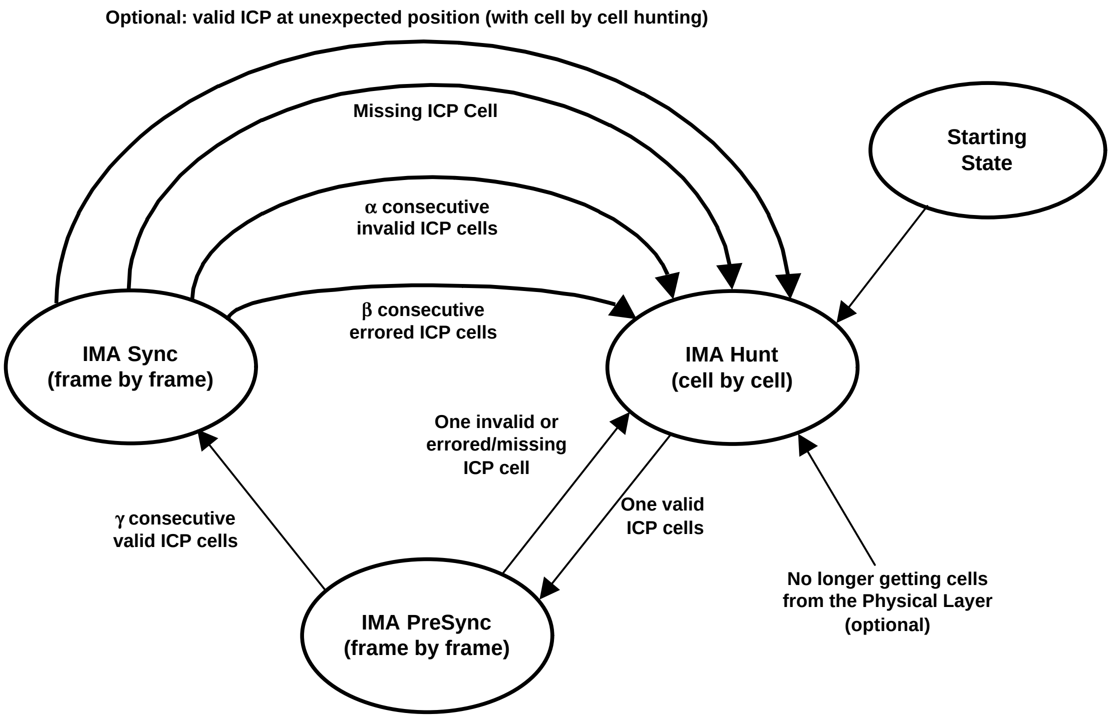
**Table 15 Alpha, Beta, and Gamma values**

| Setting | Range | Default (Required support) |
|---|---|---|
| Alpha($\alpha$)<br>(consecutive invalid ICP cells) | 1-2 | 2 |
| Beta($\beta$)<br>(consecutive errored ICP cells) | 1-5 | 2 |
| Gamma($\gamma$)<br>(consecutive valid ICP cells) | 1-5 | 1 |

**(R-113)** Upon the occurrence of a HEC/CRC errored cell in the ICP position, the receiving end shall ignore the cell content but shall assume that it was an ICP cell.

**(O-17)** The IFSM may also go into the Hunt state from any other state when cells are no longer being received from the physical layer.

Table 16 on page 69 provides the definitions of the terms appearing in Figure 19 on page 69.




<u>Notes:</u>

- **The value of α, β, and γ are settable as specified in this section.**
- **In brackets: checking scheme in each state (cell by cell or frame by frame checking)**
- **See next table for definition of terms.**

**Figure 19 IMA Frame Synchronization Mechanism (IFSM)**

**Table 16 Definitions for IMA Synchronization Mechanism**

| Term | Definitions |
|---|---|
| Invalid ICP Cell<br>(see notes 1, 2, 3, and 4) | Cell with good HEC & CRC and CID = ICP at expected frame position with<br>(unexpected IMA OAM Label) <u>or</u><br>(unexpected LID) <u>or</u><br>(unexpected IMA ID) <u>or</u><br>(received M not equal to expected M of the IMA group) <u>or</u><br>(unexpected IMA frame number) <u>or</u><br>(unexpected ICP cell offset) |
| Errored ICP Cell<br>(see note 5) | A cell with a HEC or CRC error at expected ICP cell position if it is not a Missing cell. |
| Valid ICP Cell | (Cell with CID field equal to ICP) <u>and</u><br>(No IMA OAM header, HEC, or CRC error), <u>and</u><br>(expected IMA OAM Label) <u>and</u><br>(expected LID) <u>and</u><br>(expected IMA ID) <u>and</u><br>(received M equal to expected M of the IMA group) <u>and</u><br>(expected IMA frame number) <u>and</u><br>(expected ICP cell offset) |
| Expected/unexpected<br>(see notes 1, 2, and 3) | IMA OAM Label, LID, IMA ID, M, ICP cell offset expected/unexpected related to value fixed during group start-up or link addition: when in Start-up, any value is to be expected.<br>IMA frame number, stuff indication: to separate reference counting at Rx side (see note 5). |

| Term | Definitions |
|---|---|
| Missing ICP Cell | (Cell located at ICP cell location without HEC error and without IMA OAM cell header) or<br><br>(Cell located at ICP cell location without HEC error, with IMA OAM cell header, and without CID field equal to ICP) |
| Consecutive ICP Cells<br>(see notes 5, 6, 7) | ICP cells sent on the same links in consecutive IMA frames (excepting the SICP cell in a stuff event, and regardless of offset). Thus one consecutive ICP cell is an ICP cell on one link in one IMA frame, two consecutive ICP cells are the cells on the same link in two consecutive IMA frames, etc. |

1. Unexpected IMA OAM Label means that the IMA OAM Label no longer matches the IMA OAM Label that had been previously validated at group start-up.
2. Unexpected IMA ID means that the IMA ID is no longer matching the IMA ID that has been previously validated. If the reception of the unexpected IMA ID persists, the Rx IMA has to re-evaluate the new IMA ID to determine if it shall accept or reject the new IMA ID for the given IMA group.
3. Unexpected LID means that the incoming LID is no longer matching the LID that has been previously validated. If the reception of the unexpected LID persists, the IMA receiver has to re-evaluate the new LID to determine if it shall accept or reject the new LID for the given link.
4. Invalid stuff sequence appearing in consecutive ICP cells may also be used as a parameter to detect and report an invalid ICP cell.
5. Only applicable to “frame by frame” checking.
6. The IFSM shall only reset the counting of "Invalid ICP cells" when a valid ICP cell is detected. The fact that an errored ICP cell arrived before Beta(β) ICP cells shall not cause the counting of "Invalid ICP cells" to be reset.
7. The IFSM shall reset the counting of "Errored ICP cells" when receiving Valid or Invalid ICP cells (both types are received with a good HEC and CRC value).

## 11.1 IMA Frame Synchronization with Stuff Events

The IMA receiver should preserve the IMA frame synchronization while receiving stuff events subjected to HEC or CRC errors.

Figure 20 on page 71 shows cases when one or more of the ICP cells preceding and comprising the stuff event are HEC or CRC errored. The reader should note that since the two ICP cells comprising the stuff event are supposed to be identical, and in fact represent the same ICP cell position, shown in Figure 20 as “ICP n+1”, the IFSM should consider only one of the two ICP cells of each stuff event when making its various transitions.

**(R-114)** The IMA receiver shall maintain synchronization for cases 1, 2, 3, and 6 represented in Figure 20 on page 71 when Alpha(α) or Beta(β) is greater than one.

**(O-18)** The IMA receiver may optionally maintain synchronization for cases 4 or 5 in Figure 20 on page 71.

Case 4 requires the use of cell-by-cell hunting as described in Section 11 on page 68.

**(O-19)** The IMA receiver may optionally maintain synchronization for case 7 in Figure 20 on page 71, when passing stuff indication over more than one of the previous ICP cells and when β, as defined in Section 11 on page 68, is greater than 2.

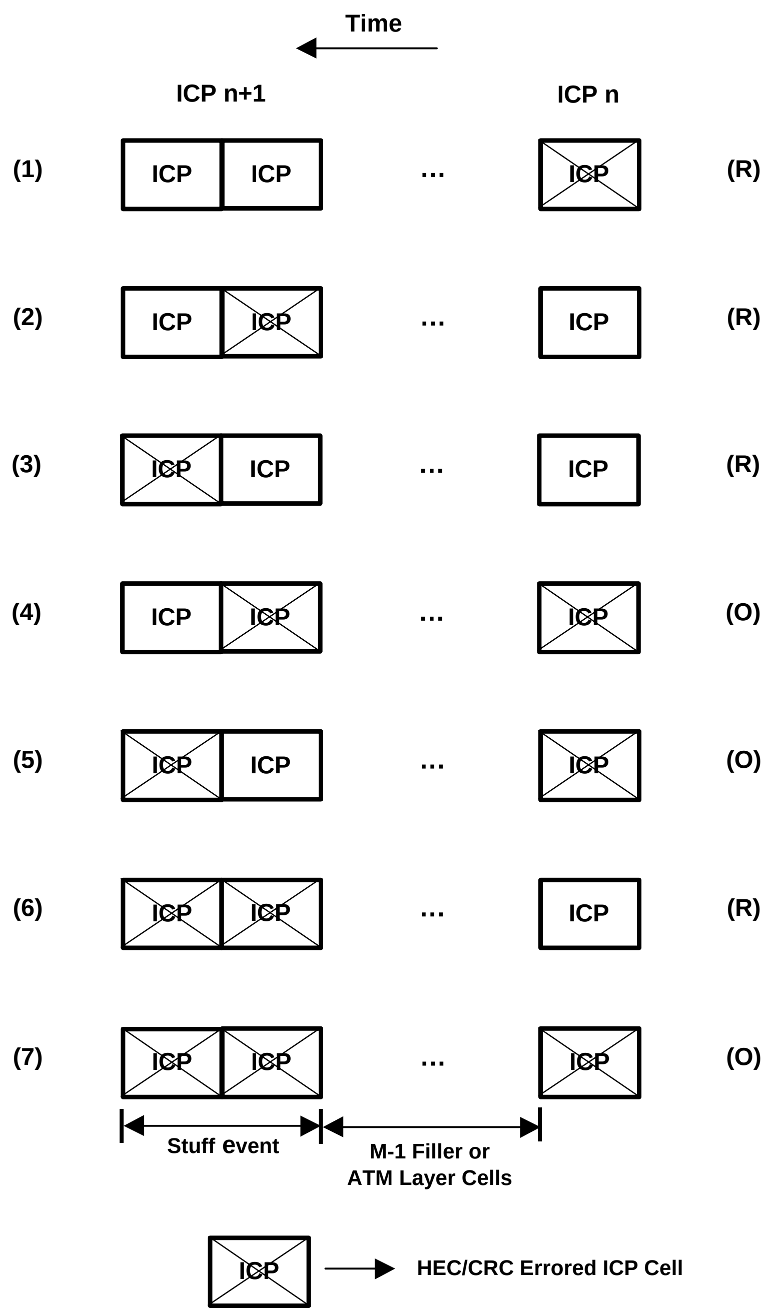



**Figure 20 Error on ICP Cells Preceding and Comprising a Stuff Event**

# 12. IMA Interface OAM Implementation

This section specifies the physical layer OAM functions and procedures required on the IMA interface.

## 12.1 IMA OAM Functions

### 12.1.1 IMA Group Maintenance Signals

Section 10.2.1 on page 55 specifies the signals to be used for reporting the actual state of the GSM and GTSM.

### 12.1.2 IMA Link Maintenance Signals

Section 10.1.6 on page 54 specifies the signals to be used for reporting the actual transmit and receive link states to the FE.

**(R-115)** The following link remote defect indicators shall be used to report local IMA defects:

- Link defects: indicates that a link defect has been detected at the local end (i.e., LOS, OOF/LOF, AIS, or LCD).
- LIF: indicates that a LIF defect has been detected at the local end.
- LODS indicates that a LODS defect has been detected at the local end.

**(R-116)** If several defects are detected at the same time, the defect with the highest priority, as listed in Table 17 on page 72, shall be reported.

**Table 17 Priorities of Defect Reports**

| **Priority** | **Rx Defect** |
|---|---|
| 1 (highest) | Link defect (e.g., LOS, OOF/LOF, AIS or LCD) |
| 2 | LIF |
| 3 | LODS |

The IMA defects (LIF or LODS) are defined in Table 18 on page 77.

**(R-117)** The IMA receiver shall report any Rx defect to the far-end IMA within the next 2*M cells to be transmitted after the defect state has been entered as specified in Section 12.1.3 on page 72 (where M is the M used by the IMA transmitter).

There is no immediate relationship between any defect reporting and the Tx and Rx link states.

### 12.1.3 IMA Link Error Handling

This section defines the procedures to handle IMA link errors.

**(R-118)** Error handling of IMA links shall be as specified Figure 21 on page 73 and Figure 22 on page 74.

Error handling regarding anomalies, defects, and failures are specified based on the IMA Frame

Synchronization Mechanism (IFSM) defined in Figure 19 on page 69. Figure 21 on page 73 shows the relationship between the states of the IFSM and the error/maintenance states derived from the cell delineation procedure defined in ITU-T Recommendation I.432[30] and ANSI T1.646[6]. The IMA Working state corresponds to the case where the IFSM has been in the IMA Sync state. The IMA "OIF Anomaly" state corresponds to the cases when the IMA frame synchronization mechanism has exited the IMA Sync state. The IMA LIF defect corresponds to the case where the OIF anomaly has persisted for at least "Gamma(γ)+2" IMA frames. The choice of "Gamma(γ) + 2" has been made to minimize possible racing between the transition of the IMA Error State Machine (IESM) into either the IMA Working or LIF state. In the case where no cell/frame is transferred from the PHY layer to the IMA sub-layer such as covered by option (O-17), the transition from OIF to LIF may also be triggered when OIF persists for "Gamma(γ) + 2" IMA Frame times.

The "IMA LIF Defect" state is exited when the IMA frame synchronization mechanism has been in the IMA Sync state for at least two IMA frames.

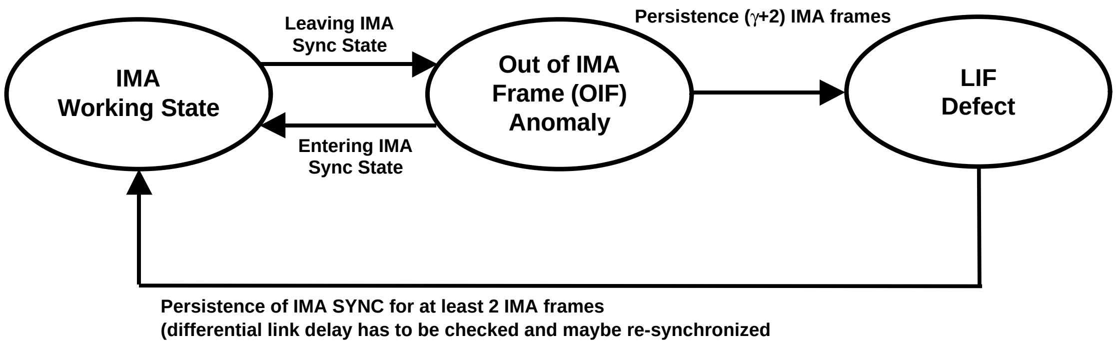



**Figure 21 IMA Error/Maintenance state Diagram**

Appendix C.7 on page 165 provides three examples of interactions between the IFSM and IESM.

**(R-119)** On a given link, the IMA receiver shall pass to the ATM layer from the IMA sublayer any cells accumulated before the occurrence of an OCD or OIF anomaly on that link.

**(R-120)** The IMA receiver shall pass from the IMA sublayer to the ATM layer no cells received on a link during an OCD or OIF anomaly condition reported on that link.

**(R-121)** The IMA receiver shall replace with Filler cells all ATM layer cells received on a link after an OCD or OIF anomaly condition has been detected on that link.

**(R-122)** The IMA unit shall not report an Rx defect to the FE until the LIF or LODS defect state is entered.

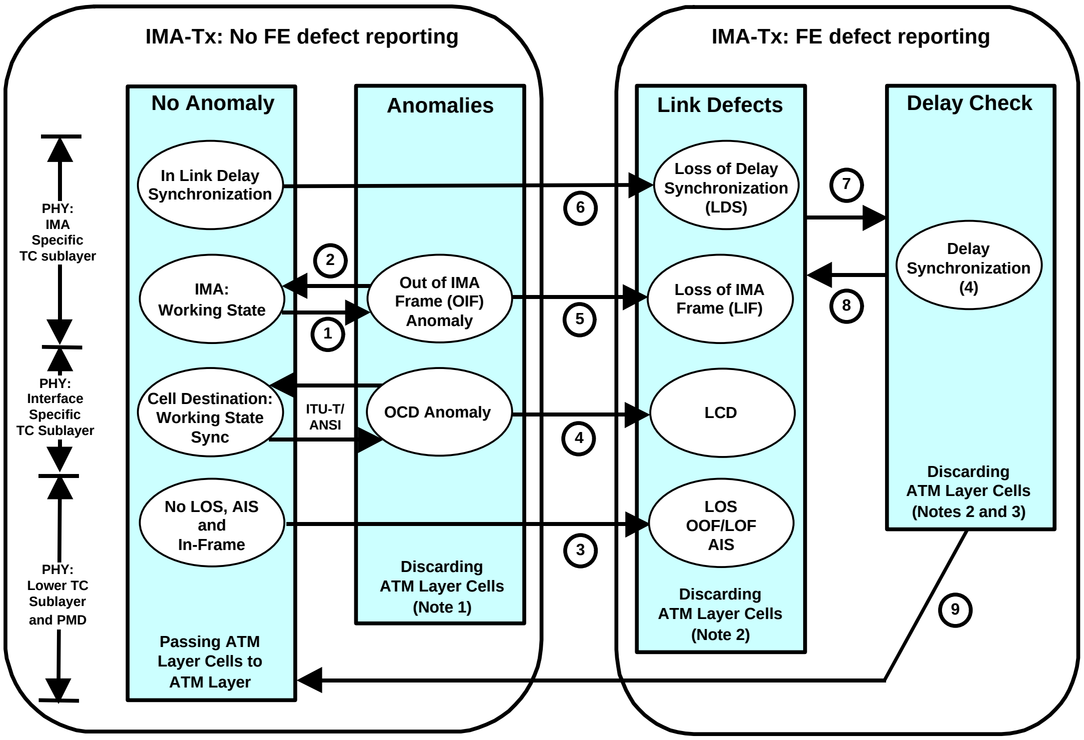
**(R-123)** The reporting of the LIF or LODS defect shall be as specified in Section 12.1.2 on page 72.

The two major states shown as largest boxes in Figure 22 on page 74 are distinguished by whether or not the FE is informed during the error handling. In the case where the FE is not informed, the sub-states are distinguished by whether cells received in the sub-state are passed to the ATM layer or discarded.

In general, the detection of failures is based on the persistence of defects and received "FE defect reporting" and is implementation specific. The same applies for the detection of the Rx Failed condition defined in Section 10.1.4 on page 50.

The action of maintaining synchronization also means that the IMA receiver passes valid incoming cells to the ATM layer as if the bad link was simply receiving Filler cells.

It should be noted that there is only one state in which incoming ATM layer cells can be passed to the ATM layer.




**State Transitions:**

1. Transition according to IFSM for leaving IMA SYNC.
2. Entering SYNC state according to IFSM. Entering the IMA Sync state triggers a new delay synchronization for that link.
3. LOS, LOF (DS1)/LOF(E1), or AIS or other lower layer notification is reported at the physical layer.
4. LCD notification is reported at the physical layer.
5. Persistence: “Gamma(γ) + 2” IMA Frame times.
6. Loss of Delay Synchronization (LODS).
7. No LOS, OOF/LOF, AIS, LCD, or LOF condition detected.
8. LOS, LOF, AIS, LCD, LIF, or LODS.
9. No error reporting by IMA protocol, recovery of the link.

**Notes:**

(1) Fast recovery: ATM layer cells that are received are discarded. When Rx=On, the IMA receiver shall emulate the reception of ATM layer cells by substituting Filler cells.

(2) Medium recovery: the IMA receiver is waiting for persistent defect. The Rx=On action is performed until the persistence leads to the entrance of the RX Failed state. When Rx=On, the IMA receiver shall emulate the reception of ATM layer cells by substituting Filler cells.

(3) Slow recovery: RX Failed occurs. When Rx=On, the IMA receiver shall emulate the reception of ATM layer cells by substituting Filler cells.

(4) Differential delay synchronization should be checked and re-synchronized.

**Figure 22 IMA Error Handling Overview**

#### 12.1.3.1 IMA Link Recovery Mechanisms

According to Figure 22 on page 74, three types of link recovery are possible:

1. Fast recovery without entering the defect zone (e.g., going directly from "IMA Out of Frame" anomaly

to the IMA Working state as described in Figure 21 on page 73); the FE is not aware of the anomaly and the fast recovery.

2. Medium recovery: a defect is reported and the FE defect reporting is initiated; the FE is aware of the defect and the medium recovery.

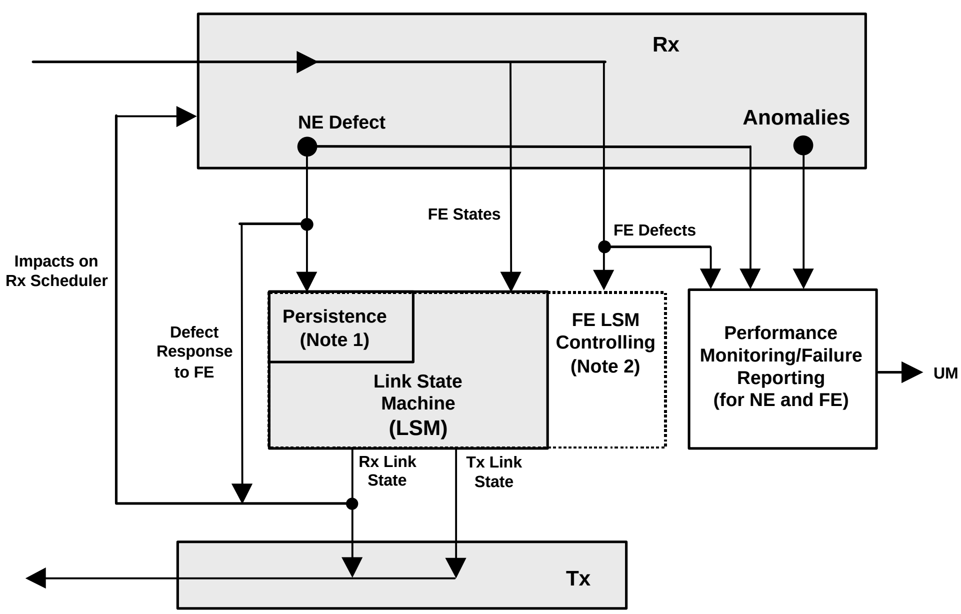
3. Slow recovery: a Rx Failed condition is entered due to the persistence of a defect; this triggers the deactivation of that link and the recovery by the IMA protocol as specified in Section 10.1.5 on page 50; the FE is aware of the deactivation of the link and the slow recovery. Examples of the slow recovery are shown in Figure 46 on page 175 and Figure 47 on page 176.

The slow recovery mechanism using the IMA protocol is is dependent on how the local end processes the defect and declares the Rx Failed condition. The occurrence of the Rx Failed condition will cause the LSM to move the Unusable state (see Section 10.1.5 on page 50).

## 12.2 IMA Performance and Failure Alarm Monitoring

This section describes the requirements for IMA performance and failure alarm monitoring.

Figure 23 on page 75 illustrates the way monitored parameters are used by both the layer management entities, for driving the LSM, and for failure and performance monitoring. NE events (in terms of anomalies, signals, and defects) and FE reports (in terms of anomalies, signals, defects and error conditions) are defined to provide performance monitoring parameters. NE events and (processed) failures are also defined to make up FE reports for the transmitted signal.




Note 1. Results in Rx Failed as a result of the persistence check and triggers the LSM (to go to Rx Unusable (Failed) state).
Note 2. Optional: the FE can observe the NE persistence behavior and force the NE behavior by changing Tx state to Unusable, thereby forcing the NE out of Active. The FE may do this if, in its estimation, the NE persistence processing is unacceptable.

**Figure 23 Structure of Anomaly and Defect Processing**

### 12.2.1 Performance Monitoring Objectives

Performance monitoring is the process of continuous collection, analysis and reporting of performance data associated with a transmission entity (such as described in ANSI Tl.231[3]). Similar to ITU-T Recommendation G.826[26], the following process is defined:

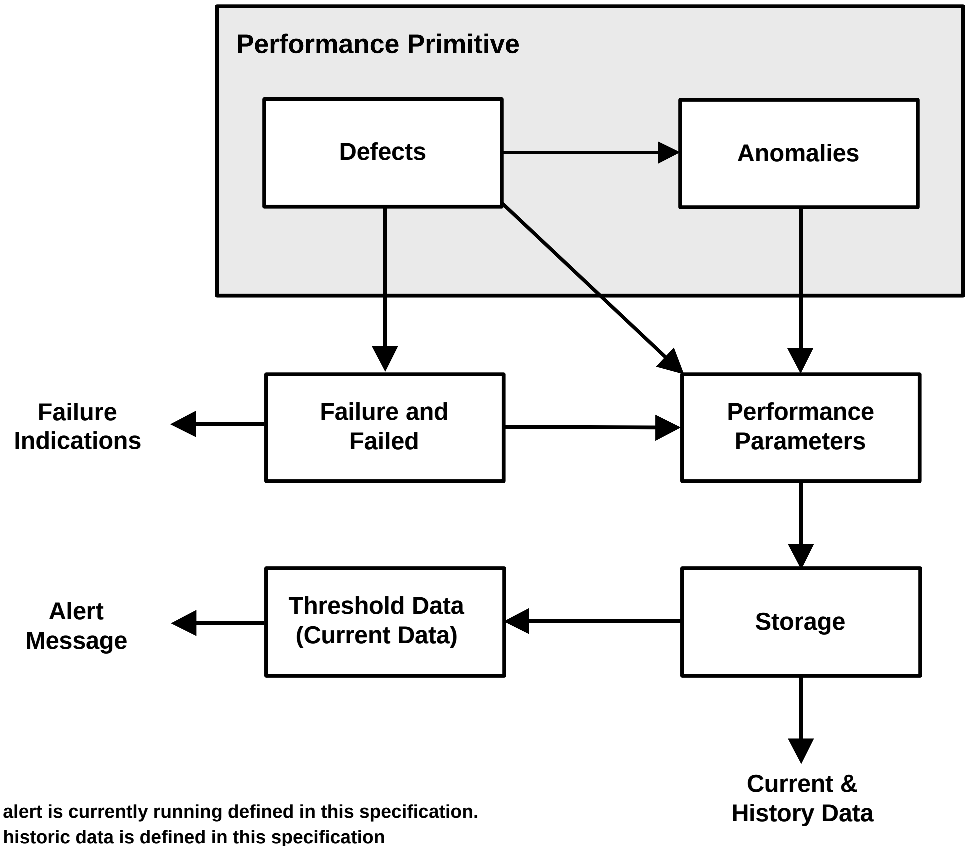



**Figure 24 Performance Monitoring Process (based on ANSI Tl.231, Figure 4)**

The IMA Performance Primitives consist of

- Anomalies with
  - Bit error related events (e.g., errored ICP cells)
  - Synchronization related events (e.g., OIF)
- Defects with
  - IMA Frame error events (e.g., LIF)
  - Other defect events (e.g., LODS)
- *Failure alarm*: a failure alarm is the termination of the ability of an item to perform a required function (ANSI Tl.231). A failure alarm is declared when the defect (or response FE defect) persists for x seconds (default: 2.5 ± 0.5 seconds). The failure alarm is different that the Failed condition defined in Section 10.1.4 on page 50.
- *Performance Parameters* specified for each sublayer or OAM level separately are based on performance primitives and failures. IMA performance parameters are inhibited during seconds when the unavailability of the link or the group has been reported and when the counting of anomaly events is inhibited during defect detection [1].

[1] The IMA performance parameters could optionally be accumulated over 15 minutes and 24 hours accumulation periods.

- The Intermittent defect handling like the hit integration (refer to Appendix C.2 on page 157) is only used for special applications and is not required in ANSI T1.231[3].

Based on ANSI T1.231[3], the following performance data variables are also defined:

- Current data: data currently accumulated during predetermined accumulation period (normally 15 minutes and one day),
- Previous data: data saved from the current data storage at the end of every accumulation period,
- Recent data: additional data registers provided to maintain a recent history of the collected data

## 12.2.2 Performance Monitoring Parameters

### 12.2.2.1 IMA Performance Primitives

**(R-124)** Table 18 on page 77 indicates the performance primitives that shall be detected or reported by the IMA interface.

**Table 18 IMA Link and Group Anomalies and Defects**

| Performance Primitives | Events | Definition |
|---|---|---|
| Anomalies<br>(IMA Specific) | Errored ICP cell | Same definition as in Figure 19 on page 69. |
| | Invalid ICP cell | Same definition as in Figure 19 on page 69. |
| | Missing ICP cell | Same definition as in Figure 19 on page 69. |
| | OIF events | Leaving the IMA Sync state. |
| Defects<br>(IMA Specific) | LIF | Definition as provided in Section 12.1.3 on page 72. |
| | LODS | A LODS defect is reported when the link differential delay between the link and the other links in the group is over the tolerable link differential delay. |
| | RDI-IMA | One of the available remote defect indicators (including IMA link specific defect) is indicated in the link related "Link Information" field. |

### 12.2.2.2 IMA Performance Parameters

The IMA performance parameters are based on principles for the sub-layers of DS1 and El, e.g., ANSI T.231[3], ANSI T1.646[6], and ITU-T Recommendation G.826[26].

**Table 19 IMA Performance Parameters**

| | Link/ Group | Performance Parameter | Definition |
|---|---|---|---|
| **(R-125)** | Link | IV-IMA | ICP Violations: count of errored, invalid or missing ICP cells, except during seconds where a SES-IMA or UAS-IMA condition is reported. |
| **(O-20)** | Link | OIF-IMA | Count OIF anomalies, except during SES-IMA or UAS-IMA conditions. |
| **(R-126)** | Link | SES-IMA | Count of one second intervals containing ≥ 30% of the ICP cells counted as IV-IMAs (see note l) or one or more link defects (e.g., LOS, OOF/LOF, AIS, or LCD), LIF, or LODS defects, except during UAS-IMA conditions. |
| **(R-127)** | Link | SES-IMA-FE | Count of one second intervals containing one or more RDI-IMA defects, except during UAS-IMA-FE conditions. |

| | Link/ Group | Performance Parameter | Definition |
|---|---|---|---|
| **(R-128)** | Link | UAS-IMA | Unavailable seconds at NE: NE unavailability begins at the onset of 10 contiguous SES-IMA including the first 10 seconds to enter the UAS-IMA condition, and ends at the onset of 10 contiguous seconds with no SES-IMA, excluding the last 10 seconds to exit the UAS-IMA condition. See note 3 for details about the effects of other performance parameters. |
| **(R-129)** | Link | UAS-IMA-FE | Unavailable seconds at FE: FE unavailability begins at the onset of 10 contiguous SES-IMA-FE including the first 10 seconds to enter the UAS-IMA-FE condition, and ends at the onset of 10 contiguous seconds with no SES-IMA-FE, excluding the last 10 seconds to exit the UAS-IMA-FE condition. See note 3 for details about the effects of other performance parameters. |
| **(R-130)** | Link | Tx-UUS-IMA | Tx Unusable seconds: count of Tx Unusable seconds at the Tx NE LSM. |
| **(R-131)** | Link | Rx-UUS-IMA | Rx Unusable seconds: count of Rx Unusable seconds at the Rx NE LSM. |
| **(R-132)** | Link | Tx-UUS-IMA-FE | Tx Unusable seconds at FE: count seconds with Tx Unusable indications from the Tx FE LSM |
| **(R-133)** | Link | Rx-UUS-IMA-FE | Rx Unusable seconds at FE: count of seconds with Rx Unusable indications from the Rx FE LSM |
| **(R-134)** | Link | Tx-FC | NE Tx link failure count: count of NE Tx link failure alarm condition entrances. The possible NE Tx link failure alarm conditions are: Tx-Mis-Connected and Tx-Fault. Refer to Table 20 on page 79 for the definition of these alarm conditions. |
| **(R-135)** | Link | Rx-FC | NE Rx link failure count: count of NE Rx link failure alarm condition entrances. The possible NE Rx link failure alarm conditions are: LIF, LODS, Rx-Mis-Connected and Rx-Fault. Refer to Table 20 on page 79 for the definition of these alarm conditions. |
| **(O-21)** | Link | Tx-FC-FE | FE Tx link failure count: count of FE Tx link failure alarm condition entrances. The only possible link failure alarm condition is Tx-Unusable-FE. Refer to Table 20 on page 79 for the definition of these alarm conditions. |
| **(O-22)** | Link | Rx-FC-FE | FE Rx link failure count: count of FE Rx link failure alarm condition entrances. The possible FE Rx link failure alarm conditions are: RFI-IMA, and Rx-Unusable-FE. Refer to Table 20 on page 79 for the definition of these alarm conditions. |
| **(O-23)** | Link | Tx-Stuff-IMA | Count of stuff events inserted in the transmit direction (see note 2). |
| **(O-24)** | Link | Rx-Stuff-IMA | Count of stuff events inserted in the receive direction, except during SES-IMA or UAS-IMA conditions (see note 2). |
| **(R-136)** | Group | GR-UAS-IMA | Count of one second intervals where the GTSM is Down. |
| **(R-137)** | Group | GR-FC | NE Group Failure count: count of NE group failure condition entrances. The possible NE group failure alarm conditions are: Config-Aborted and Insufficient-Links. Refer to Table 20 on page 79 for the definition of these alarm conditions. |
| **(O-25)** | Group | GR-FC-FE | FE Group Failure count: count of FE group failure condition entrances. The possible FE group failure alarm conditions are: Start-up-FE, Config-Aborted-FE, Insufficient-Links-FE, and Blocked-FE. Refer to Table 20 on page 79 for the definition of these alarm conditions. |

Note 1: See Appendix G on page 178 for more detail about the selection of 30%.

Note 2. The Tx-Stuff-IMA and Rx-Stuff-IMA performance parameters indicate the count of all stuff events appearing on the given link. They do not necessarily indicate if the transmit clock of the link is running faster than the other links in the IMA group.

Note 3. The performance parameters that are inhibited during seconds where the UAS-IMA or UAS-IMA-FE performance parameters are incremented shall also be adjusted when the UAS-IMA or UAS-IMA-FE performance parameters are adjusted at the entrance or exit of the UAS-IMA or UAS-IMA-FE condition.

**(O-26)** The accumulation of IMA performance parameters over 15 minute intervals is optional.

**(O-27)** The accumulation of IMA performance parameters over 24 hour intervals is optional.

**(CR-7)** If (O-26) is used, the current/previous and recent data shall be kept.

**(CR-8)** If (O-26) is used, the current data set shall be used for threshold crossing.

**(CR-9)** If (O-27) is used, the current/previous and recent data shall be kept.

**(CR-10)** If (O-27) is used, the current data set shall be used for threshold crossing.

### 12.2.3 IMA Failure Alarms

Table 20 on page 79 presents the IMA failure alarm definitions reported to the UM.

**Table 20 IMA Failure Alarms**

| (R)/(0) | Link/ Group | Failure Alarm | Definition |
|---|---|---|---|
| **(R-138)** | Link | LIF | Persistence of a LIF defect at the NE (see note 1). |
| **(R-139)** | Link | LODS | Persistence of a LODS defect at the NE (see note 1). |
| **(R-140)** | Link | RFI-IMA | Persistence of an RDI-IMA defect at the NE (see note 1). |
| **(R-141)** | Link | Tx-Mis-Connected | When the Tx link is detected as mis-connected.<br>This is reported when the IMA unit has determined that the Tx link is not connected to the same FE IMA unit as the other Tx links in the group. The detection is implementation specific. |
| **(R-142)** | Link | Rx-Mis-Connected | When the Rx link is detected as mis-connected.<br>This is reported when the IMA unit has determined that the Rx link is not connected to the same FE IMA unit as the other Rx links in the group. The detection is implementation specific. |
| **(O-28)** | Link | Tx-Fault | Implementation specific Tx fault declared at the NE (see note 1). |
| **(O-29)** | Link | Rx-Fault | Implementation specific Rx fault declared at the NE (see note 1). |
| **(R-143)** | Link | Tx-Unusable-FE | When the FE reports Tx-Unusable. |
| **(R-144)** | Link | Rx-Unusable-FE | When the FE reports Rx-Unusable. |
| **(R-145)** | Group | Start-up-FE | When the FE is starting-up (the declaration of this failure alarm may be delayed to ensure the FE remains in Start-up). |
| **(R-146)** | Group | Config-Aborted | When the FE tries to use unacceptable configuration parameters. |
| **(R-147)** | Group | Config-Aborted-FE | When the FE reports unacceptable configuration parameters. |
| **(R-148)** | Group | Insufficient-Links | When less than $P_{Tx}$ transmit or $P_{Rx}$ receive links are Active. |
| **(R-149)** | Group | Insufficient-Links-FE | When the FE reports that less than $P_{Tx}$ transmit or $P_{Rx}$ receive links are Active. |
| **(R-150)** | Group | Blocked-FE | When the FE reports that it is blocked. |
| **(R-151)** | Group | GR-Timing-Mis-match | When the FE transmit clock mode is different than the NE transmit clock mode. |

Note 1. The persistence relevant for the failure detection and the failure clearance of these alarms is specified in (R-152) on page 80 and (O-30) on page 80.

Appendix C.2 on page 157 suggests a state machine to be used for processing error conditions.

**(R-152)** In the case of the LIF, LODS, RFI-IMA and Fault failure alarms, the IMA shall support $2.5 \pm 0.5$ seconds as a default persistence checking time to enter a failure alarm condition, and $10 \pm 0.5$ seconds as a default persistence clearing time to exit the same failure alarm condition.

**(O-30)** In the case of the LIF, LODS, RFI-IMA and Fault failure alarms, the IMA may allow configuration of other values for default persistence checking time to enter a failure alarm condition, and for default persistence clearing time to exit the same failure alarm condition.

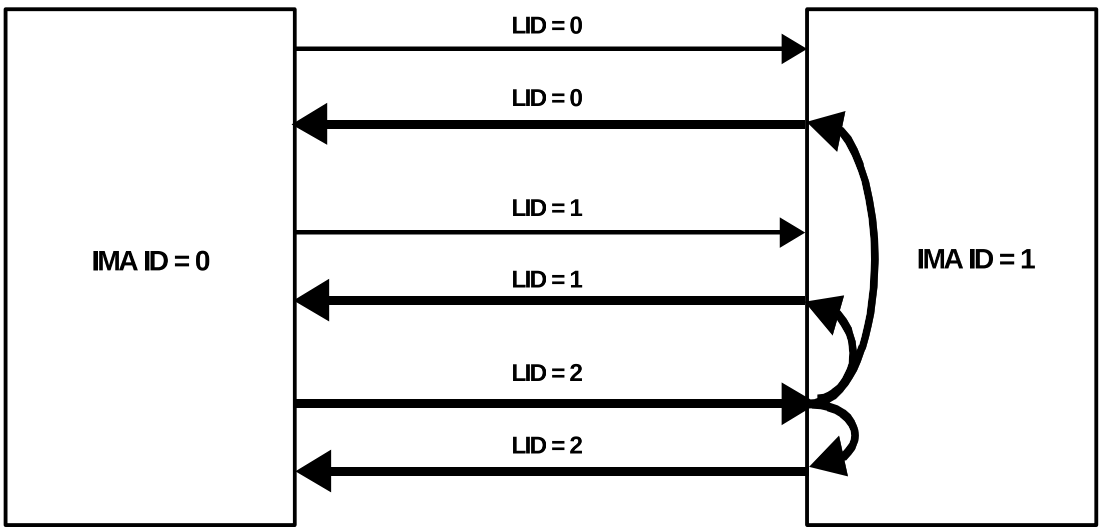
**(CR-11)** If (O-28) is used, the IMA unit shall not clear the Tx-Fault failure alarm, defined in (O-28) on page 79, until the fault that led to the declaration of the alarm is no longer present for the duration specified to clear the alarm in (R-152) on page 80.

**(CR-12)** If (O-29) is used, the IMA unit shall not clear the Rx-Fault failure alarm, defined in (O-29) on page 79, until the fault that led to the declaration of the alarm is no longer present for the duration specified to clear the alarm in (R-152) on page 80.

# 13. Test Pattern Procedure

The test pattern procedure is defined to provide extra support to verify the connectivity of a link within an IMA group. It is based on the use of a test pattern sent over one link for which verification of the connectivity to the rest of the group is desired. The test pattern is expected to be looped over all the other links in the group at the FE. The procedure is performed using fields carried over ICP cells exchanged between both ends of the IMA virtual links. These fields are the Tx Test Control, Tx Test Pattern, and Rx Test Pattern fields and their internal structures as defined in Table 2 on page 31.

Figure 25 on page 81 shows an example where a test pattern is originated at one end (IMA identified as IMA ID = 0) to verify the connectivity of the link identified as LID = 2 with the other links already in the group.




Notes

- IMA with ID = 0 performing Test Pattern procedure over the link identified as LID = 2 in the Tx direction.
- The emphasized lines indicates the links where the test pattern originally transmitted from IMA ID=0 over LID=2 link are carried over.

**Figure 25 Example of Looped Test Pattern**

**(O-31)** The IMA unit may activate the Test Pattern procedure in the transmit direction.

The test pattern procedure is made available to ensure proper link connectivity. The following requirements shall be followed in order to exercise the Test Pattern procedure.

**(CR-13)** If (O-31) is used, the IMA transmitter shall use the Test Link Command field in the ICP cell (as defined in the Tx Test Control field in Table 2 on page 31) to request the FE to activate the loop back of the test pattern contained in the Tx Test Pattern field.

**(CR-14)** If (O-31) is used, the IMA transmitter shall use the Tx LID field defined in the Tx Test Control field in Table 2 on page 31 to identify to the FE which transmit link the FE should extract the Tx Test Pattern from the received ICP cells.

**(CR-15)** If (O-31) is used, the IMA transmitter shall send any changed values of the Test Link Command, Tx LID and Tx Test Pattern fields in ICP cells for at least 2 consecutive IMA frames over each link within the IMA group.

**(CR-16)** If (O-31) is used, the IMA transmitter shall continue to send the same values of the Test Link Command, Tx LID and Tx Test Pattern fields as long as the IMA transmitter wants the FE IMA unit to loop back the test pattern.

**(R-153)** The IMA receiver shall monitor the incoming ICP cells on the links already recognized in the group to detect a change of the Test Link Command field.

**(R-154)** If the Test Link Command field is detected as active over the links already recognized in the group and over the test link, the IMA receiver shall copy the value of the Tx Test Pattern field received from the test link, indicated over the Tx LID field, into the Rx Test Pattern field on every subsequent ICP cell sent over all outgoing links in the group.

**(R-155)** The IMA transmitter shall continue sending the same value over the Rx Test Pattern field until the IMA transmitter has received an indication to stop looping the pattern, to loop a new pattern received from the same link over the Tx Test Pattern, or to loop the test pattern received from another link (indicated over the Tx LID field).

**(R-156)** The IMA transmitter shall return the 0xFF pattern over the Rx Test Pattern field when the incoming test command is not active or the test link is not detected.

**(R-157)** The IMA unit shall only handle one test pattern per IMA group at any given time.

The following text suggests behaviors at the transmit and receive ends.

- Once sending the new value of the Tx LID (of the test link) and Tx Test Pattern fields, the IMA unit might have to wait some time in order to let the pattern be detected by the receive end and to be looped back. The IMA unit should verify that the test pattern is returned in the Rx Test Pattern field over ICP cells received on any other links that have already been recognized part of the group on both ends.

- Loopback configuration on a given link can be detected by verifying that the received Tx Test Pattern value read from the incoming ICP cells is the same as the one inserted in the outgoing ICP cells.

- The IMA unit should try several values randomly chosen to ensure that the FE has not been trying the same value at the same time. It is not recommended to use 0xFF as a test pattern since this value is used by the IMA receiver to report that the incoming link Tx Test Command is inactive or that the test link is not currently detected (see (R-156) on page 82).

- At start-up time, the IMA transmitter sends the 0xFF pattern until receiving ICP cells indicating the first Test Link Command.

Figure 26 on page 83 shows the Test Pattern procedure execution over time.

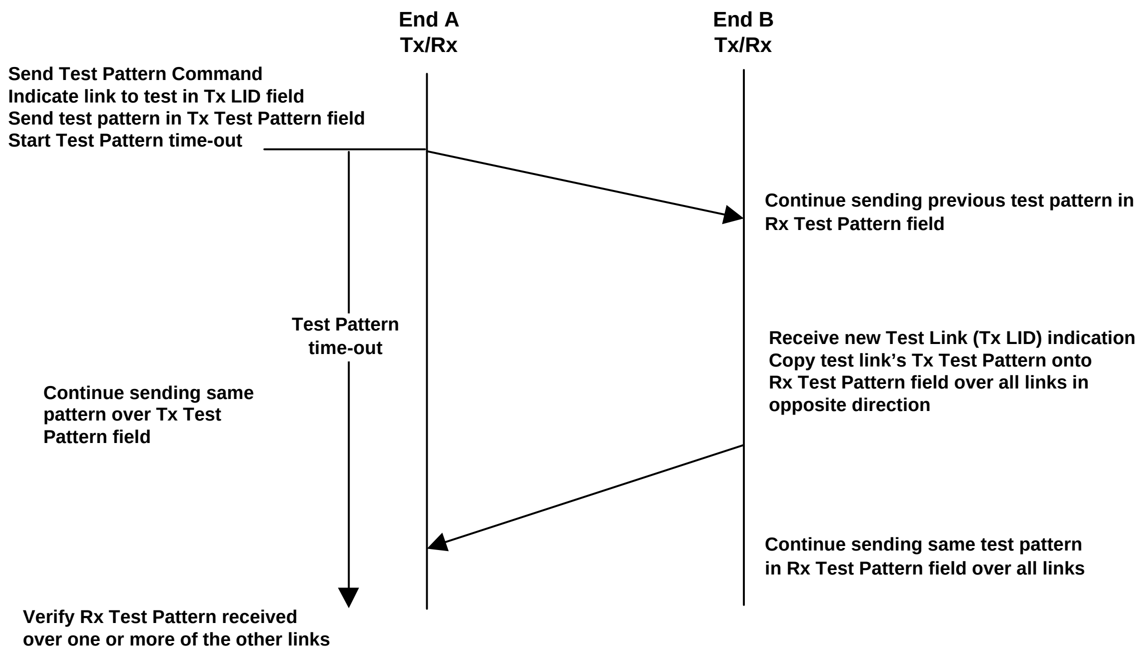



**Figure 26 Test Pattern Procedure over Time**

# 14. IMA Interaction with Plane Management

**(R-158)** The IMA unit shall process the following indications from/to the Plane Management:

- *IMA group configuration*: this indication is received by the IMA unit from the Plane Management and indicates which links are to be assigned to the IMA group.
- *Link addition/deletion:* this indication is received by the IMA unit from the Plane Management and indicates that a link is to be added to or deleted from the IMA group.
- *IMA service operational status change:* this indication is sent by the IMA unit to the Plane Management to indicate a change of the operational status of the IMA group (e.g., GTSM moving to Down state).
- *Tx/Rx cell rate change*: this indication is sent by the IMA unit to the Plane Management to indicate that the cell rate has changed in the transmit and/or receive directions (a link has been added to or deleted from the IMA group, a link has been de-activated due to a defect, or a link has been recovered from a defect condition).

# 15. Management Information Base

**(O-32)** The Unit Management (UM) may be SNMP based.

**(CR-17)** If (O-32) is used, the IMA unit shall implement the mandatory objects in the IMA MIBs defined in Appendix A on page 106.

**(O-33)** If (O-32) is used, the IMA unit may implement the optional objects in the IMA MIBs defined in Appendix A on page 106.

# 16. References


[1] ANSI T1.101-1987, "Synchronization Interface Standards for Digital Networks".

[2] ANSI T1.102-1993, "Digital Hierarchy - Electrical Interfaces".

[3] ANSI T1.231-1993, "Digital Hierarchy - Layer 1 In-Service Digital Transmission Performance

[4] ANSI T1.403-1995, "Network-to-Customer Installation-DS1 Metallic Interface".

[5] ANSI T1.408-1990, "Integrated Services Digital Network (ISDN) Primary Rate - Customer Installation Metallic Interfaces Layer 1 Specification.

[6] ANSI T1.646-1995, Broadband-ISDN - Physical Layer Specification for User-Network Interfaces Including DS1/ATM, 1995.

[7] ATM Forum AF-BICI-0013.003, "B-ISDN Inter Carrier Interface (B-ICI) Specification Version 2.0

[8] ATM Forum AF-PHY-0016.000, "DS1 Physical Layer Specification", September, 1994.

[9] ATM Forum AF-PHY-0064.000, "E1 Physical Layer Interface Specification", July 1996.

[10] ATM Forum AF-PHY-0086.000, "Inverse Multiplexing for ATM (IMA) Specification Version 1.0", July 1997.

[11] ATM Forum AF-PNNI-0055.000, "Private Network-Network Interface Specification Version 1.0", March 1996.

[12] ATM Forum User-Network Interface Specification, Version 3.1, May 1994.

[13] Harel, D., 1987, "State Charts: A visual formalism for complex systems", Science of Computer Programming, Volume 8.

[14] IETF RFC 1157, "A Simple Network Management Protocol (SNMP)", May 1990.

[15] IETF RFC 1213, "Management Information Base for Network Management of TCP/IP-based

[16] IETF RFC 1406, "Definitions of Managed Objects for the DS1 and E1 interface types", January 1993.

[17] IETF RFC 1902, "Structure of Management Information for Version 2 of the Simple Network Management Protocol, January 1996.

[18] IETF RFC 1905, "Protocol Operations for Version 2 of the Simple Network Management Protocol

[19] IETF RFC 2233, "The Interfaces Group MIB using SMIv2", November 1997.

[20] ISO/IEC 11573.1994(E), "Information technology - Telecommunications and information exchange between systems - Synchronization methods and technical requirements for Private Integrated Service Networks".

[21] ITU-T Recommendation G.703, "Physical/Electrical Characteristics of Hierarchical Digital

[22] ITU-T Recommendation G.810, "Considerations on Timing and Synchronization Issues", 1988.

[23] ITU-T Recommendation G.811, "Timing Requirements at the Outputs of Primary Reference Clocks Suitable for Plesiochronous Operation of International Digital Links", 1988.

[24] ITU-T Recommendation G.823, "The control of jitter and wander within digital networks which are

based on the 2048 kbit/s hierarchy, 1988.

[25] ITU-T Recommendation G.824, “The control of jitter and wander within digital networks which are based on the 1544 kbit/s hierarchy, 1988.

[26] ITU-T Recommendation G.826, “Error performance parameters and objectives for international constant bit rate digital paths at or above the primary rate, 1993.

[27] ITU-T Recommendation I.321, “B-ISDN Protocol Reference Model and its applications”, March 1993.

[28] ITU-T Recommendation I.361, “B-ISDN ATM Layer Specification”, March 1993.

[29] ITU-T Recommendation I.431, “Primary Rate User-Network Interface - Layer 1 specification”, March 1993.

[30] ITU-T Recommendation I.432 Series, “B-ISDN User-Network Interface - Physical Layer

[31] ITU-T Recommendation I.610, “B-ISDN Operation and Maintenance Principles and Functions”, 1995.

# Annex I IMA Version 1.1 PICS Proforma[1]

## I.1 Introduction

To evaluate conformance of a particular implementation, it is necessary to have a statement of which capabilities and options have been implemented for a given protocol. Such a statement is called a Protocol Implementation Conformance Statement (PICS).

### I.1.1 Scope

This annex provides the PICS proforma for the Inverse Multiplexing for ATM (IMA) Version 1.1 Specification as described in AF-PHY-0086.001[A-1] in compliance with the relevant requirements, and in accordance with the relevant guidelines, given in ISO/IEC 9646-2[A-3].

### I.1.2 Definitions

This document uses the following terms defined in ISO/IEC 9646-1[A-2]:

- a Protocol Implementation Conformance Statement (PICS) is a statement made by the supplier of an implementation or a system, stating which capabilities have been implemented for a given protocol,
- a PICS Proforma is a document in the form of a questionnaire, designed by the protocol specifier or the conformance test suite specifier, which when completed for an implementation or a system, becomes the PICS, and
- a static conformance review is a review of the extent to which the static conformance requirements are met by the implementation, accomplished by comparing the PICS with the static conformance requirements expressed in the relevant protocol specification.

### I.1.3 Symbols and Conventions

M Mandatory

O Option (may be selected to suit the implementation, provided that any requirements applicable to the options are observed)

### I.1.4 Conformance

The supplier of a protocol implementation, which is claimed to conform to AF-PHY-0086.001[A-1], is required to complete a copy of the PICS proforma provided in the following sections of this annex and is required to provide the information necessary to identify both the supplier and the implementation.

[1] Copyright release for PICS: this annex may be freely reproduced, so that it may be used for its intended purpose.

## I.2 Identification of the Implementation

**Implementation Identification**

Implementation Name: ____________________

Implementation Version: ____________________

**System Under Test**

SUT Name: ____________________

Hardware Configuration: ____________________

Operating System: ____________________

**Product Supplier**

Name: ____________________

Address: ____________________

Telephone Number: ____________________

Facsimile Number: ____________________

Email: ____________________

Additional Information: ____________________

**Client**

Name: ____________________

Address: ____________________

Telephone Number: ____________________

Facsimile Number: ____________________

Email: ____________________

Additional Information: ____________________

**PICS Contact Person**

Name: ____________________

Address: ____________________

Telephone Number: ____________________

Facsimile Number: ____________________

Email: ____________________

Additional Information: ___________________________________________________________

## I.3 IMA PICS Proforma

### I.3.1 Global Statement of Conformance

The implementation described in this PICS Proforma meets all of the mandatory requirements of the protocol specification.

Yes__

No__

Note: Answering “No” indicates non-conformance to the protocol specification. Non-supported mandatory capabilities are to be identified in the following tables, with an explanation in the “Comments” section of each table as to why the implementation is “non conforming”.

### I.3.2 Instructions for Completing the PICS Proforma

Each question in this section refers to a major function of the protocol. Answering “Yes” to a particular question states that the implementation supports all of the mandatory procedures for that function, as defined in the referenced section of AF-PHY-0086.001[A-1]. Answering “No” to a particular question in this section states that the implementation does not support that function of the protocol.

A supplier may also provide additional information, categorized as exceptional (X) or supplementary information. This additional information should be provided in the Support column as items labeled X<I> for exceptional or S<I> for supplementary information, respectively for cross-reference purposes, where <I> is any unambiguous number.

### I.3.3 IMA Protocol Functions

**Table 21 Basic IMA Protocol (BIP) Definition Functions**

| Item | Protocol feature | Cond. for Status | Status Pred. | Ref. | Support |
|---|---|---|---|---|---|
| **BIP.1** | Does the implementation support a number N ($1 \leq N \leq 32$) of transmission links within an IMA group operating at the same nominal link cell rate (LCR)? | | M | (R-1) | Yes__ No__ |
| **BIP.2** | Does the implementation support the IMA interface connected to another interface over clear channel facilities (implies cells generated by transmit IMA shall only be terminated at the receive IMA)? | | M | (R-2) | Yes__ No__ |
| **BIP.3** | Does the interface specific TC sublayer of the implementation pass all cells to the IMA sublayer or provide an indication that a cell was received (this includes HEC errored cells)? | | M | (R-3) | Yes__ No__ |
| **BIP.4** | Does the implementation prohibit cell rate decoupling at the interface specific TC sublayer? | | M | (R-4) | Yes__ No__ |
| **BIP.5** | Does the implementation assign a LID unique within the IMA group to each Tx IMA link on each physical link? | | M | (R-5) | Yes__ No__ |
| **BIP.6** | Does the implementation ensure that the LID does not change while the link is a member of the IMA group? | | M | (R-6) | Yes__ No__ |
| **BIP.7** | Does the implementation distribute ATM cells arriving from the ATM layer over the N links in a cyclic round-robin fashion, and on a cell-by-cell basis? | | M | (R-7) | Yes__ No__ |
| **BIP.8** | Does the implementation distribute ATM cells over the links using an ascending order based on the LID assigned to each link within the IMA group? | | M | (R-8) | Yes__ No__ |

| Item | Protocol feature | Cond. for Status | Status Pred. | Ref. | Support |
|---|---|---|---|---|---|
| **BIP.9** | Does the implementation support the ICP cell format defined in Table 2 on page 31 to convey IMA configuration, synchronization, status, and defect information to the far-end? | | M | (R-9) | Yes__ No__ |
| **BIP.10** | Does the implementation perform cell rate decoupling by inserting IMA Filler cells in place of ATM cells when there is no cell available at the ATM layer? | | M | (R-10) | Yes__ No__ |
| **BIP.11** | Does the implementation accept, on receive, ATM cells from the N links according to ascending order based on the LID received in the ICP cells on the incoming link? | | M | (R-11) | Yes__ No__ |
| **BIP.12** | Does the implementation, on receive, compensate for link differential delays and rebuild the original ATM cell stream? | | M | (R-11) | Yes__ No__ |
| **BIP.13** | Does the implementation discard received Filler cells and cells with bad HEC? | | M | (R-11) | Yes__ No__ |
| **BIP.14** | Does the implementation process and discard incoming ICP cells? | | M | (R-11) | Yes__ No__ |
| **BIP.15** | Does the implementation aggregate, on receive, the ATM cell stream to the ATM layer? | | M | (R-11) | Yes__ No__ |
| **BIP.16** | Does the implementation preserve the order of incoming cells? | | M | (R-11) | Yes__ No__ |
| **BIP.17** | Does the implementation use the ICP cell to maintain IMA protocol synchronization? | | M | (R-12) | Yes__ No__ |
| **BIP.18** | Does the implementation use the ICP cell to maintain link delay synchronization? | | M | (R-12) | Yes__ No__ |
| **BIP.19** | Does the implementation transmit first the most significant bit of each octet of the IMA OAM cell? | | M | (R-13) | Yes__ No__ |
| **BIP.20** | Does the implementation support the same cell header for both the Filler and ICP cell formats as defined in Table 1 on page 28 and Table 2 on page 31? | | M | (R-14) | Yes__ No__ |
| **BIP.21** | Does the implementation use bit 7 of octet 7 (CID field) of the Filler and ICP cells to identify the IMA OAM cell as an ICP or Filler cell? | | M | (R-15) | Yes__ No__ |
| **BIP.22** | Does the implementation use octets 52-53 as specified in ITU-T Recommendation I.610 [A-5] for octets 52-53 of the OAM cells of the F1/F3 flows? | | M | (R-16) | Yes__ No__ |
| **BIP.23** | Does the implementation support the Filler cell format defined in Table 1 on page 28? | | M | (R-17) | Yes__ No__ |
| **BIP.24** | Does the implementation support the ICP cell format defined in Table 2 on page 31? | | M | (R-18) | Yes__ No__ |
| **BIP.25** | Does the implementation transmit the content of the link specific fields appearing in class A over the link for which these fields apply? | | M | (R-19) | Yes__ No__ |
| **BIP.26** | Does the implementation transmit the same content of fields appearing in classes B and C of the ICP cell over all links within an IMA group? | | M | (R-20) | Yes__ No__ |
| **BIP.27** | Does the implementation use the LID bits (bits 4-0 of octet 7) in the ICP cell to identify the Link ID (range being 0 to 31)? | | M | (R-21) | Yes__ No__ |
| **BIP.28** | Does the implementation use the "Tx State" field, located in the Link "x" Information field in an ICP cell, to report the transmit state of the IMA link on which the NE IMA is transmitting ICP cells carrying LID = "x" ("x" being a value between 0 and 31)? | | M | (R-22) | Yes__ No__ |
| **BIP.29** | Does the implementation use the "Rx State", located in the Link "x" Information field in an ICP cell, to report the receive state of the incoming IMA link on which the FE IMA is transmitting ICP cells carrying LID = "x" ("x" being a value between 0 and 31)? | | M | (R-23) | Yes__ No__ |
| **BIP.30** | Does the implementation use the "Rx Defect Indicators" field, located in the Link "x" Information field in an ICP cell, to report the Rx defect indicators corresponding to the incoming IMA link on which the FE IMA is transmitting ICP cells carrying LID = "x" ("x" being a value between 0 and 31)? | | M | (R-24) | Yes__ No__ |

| Item | Protocol feature | Cond. for Status | Status Pred. | Ref. | Support |
|---|---|---|---|---|---|
| **BIP.31** | Does the implementation always transmit ICP cells with Octet 50 unused and set to “0x6A” as defined in ITU-T Recommendation I.432 [A-4]? | | M | (R-25) | Yes__ No__ |
| **BIP.32** | Does the implementation reserve the End-to-End Channel field (Octet 51) as a proprietary channel? | | M | (R-26) | Yes__ No__ |
| **BIP.33** | Does the implementation set the End-to-End Channel field (Octet 51) to “0” when not using this field? | | M | (R-27) | Yes__ No__ |
| **BIP.34** | Does the implementation not rely on the processing of the End-to-End Channel field for any IMA functionality? | | M | (R-28) | Yes__ No__ |
| **BIP.35** | Does the implementation only consider the information within ICP cells exhibiting neither a HEC nor a CRC-10 error? | | M | (R-29) | Yes__ No__ |
| **BIP.36** | Does the implementation always transmit "0x03" over the OAM Label in the Filler and ICP cells? | | M | (R-30) | Yes__ No__ |
| **BIP.37** | If the implementation does not support the IMA version proposed by the OAM Label received from the far-end IMA unit, does the implementation report the "Config-Aborted - Unsupported IMA Version" state over the "Group Status and Control" field? | | M | (R-31) | Yes__ No__ |
| **BIP.38** | Does the implementation transmit IMA frames, composed of M consecutive cells, on each link within the IMA group? | | M | (R-32) | Yes__ No__ |
| **BIP.39** | Does the implementation send ICP cells on each link once per IMA frame, hence every M cells? | | M | (R-33) | Yes__ No__ |
| **BIP.40** | Does the implementation use the IFSN field in the ICP cell to indicate the sequence number of the IMA frame? | | M | (R-34) | Yes__ No__ |
| **BIP.41** | Does the implementation increment the IFSN field in the ICP cell from 0 to 255 and repeat the sequence? | | M | (R-35) | Yes__ No__ |
| **BIP.42** | Does the implementation increment the IFSN field in the ICP cell with each IMA frame on a per-link basis? | | M | (R-36) | Yes__ No__ |
| **BIP.43** | Within an IMA frame, does the implementation place identical IFSN values in the ICP cells sent on each link? | | M | (R-36) | Yes__ No__ |
| **BIP.44** | Does the implementation align the transmission of the IMA frame on all links within an IMA group? | | M | (R-37) | Yes__ No__ |
| **BIP.45** | Does the implementation use the ICP Cell Offset field (octet 9) to indicate the location of the ICP cell within the IMA frame of length M cells? | | M | (R-38) | Yes__ No__ |
| **BIP.46** | Does the implementation always set the value of the ICP cell offset between 0 and M-1 where M is the IMA frame length in cells? | | M | (R-39) | Yes__ No__ |
| **BIP.47** | Does the implementation distribute the ICP cells, from link to link within the IMA group, in an uniform fashion across the IMA frame? | | O | (O-1) | Yes__ No__ |
| **BIP.48** | Does the implementation select the offset of the ICP cell sent of any link when the link is assigned a LID? | | M | (R-40) | Yes__ No__ |
| **BIP.49** | Does the implementation retain the offset of the ICP cell sent on a given link until the link is no longer part of the group? | | M | (R-40) | Yes__ No__ |
| **BIP.50** | Does the implementation always use the Frame Length field in the ICP cell to indicate the value of M? | | M | (R-41) | Yes__ No__ |
| **BIP.51** | Does the implementation support M = 128? | | M | (R-42) | Yes__ No__ |
| **BIP.52** | Does the implementation support M = 32? | | O | (O-2) | Yes__ No__ |
| **BIP.53** | Does the implementation support M = 64? | | O | (O-2) | Yes__ No__ |
| **BIP.54** | Does the implementation support M = 256? | | O | (O-2) | Yes__ No__ |
| **BIP.55** | Does the implementation only change the value M at group start-up time? | | M | (R-43) | Yes__ No__ |
| **BIP.56** | Does the implementation use on transmit the value configured by the UM? | (O-2) | M | (CR-1) | Yes__ No__ |
| **BIP.57** | Does the implementation allow different values of M in both Tx and Rx directions? | (O-2) | M | (CR-2) | Yes__ No__ |

| Item | Protocol feature | Cond. for Status | Status Pred. | Ref. | Support |
|---|---|---|---|---|---|
| **BIP.58** | Does the implementation synchronize its incoming links using the received M value for IMA frame synchronization? | (O-2) | M | (CR-3) | Yes__ No__ |
| **BIP.59** | Does the implementation abort the start-up procedure using the corresponding code in the Group Status and Control field of the ICP cell when it does not support the received M? | | M | (R-44) | Yes__ No__ |
| **BIP.60** | Does the implementation allow to configure the value M? | | O | (O-3) | Yes__ No__ |
| **BIP.61** | Does the implementation set the SCCI field to the previously transmitted SCCI field value, incremented modulo 256, to indicate a change on at least one of the fields appearing in octets 12 through 49 in the transmitted ICP cell? | | M | (R-45) | Yes__ No__ |
| **BIP.62** | Does the implementation use the SCCI field to identify received ICP cells for processing when ICP cells are monitored on more than one link, or when the monitored link has changed? | | M | (R-46) | Yes__ No__ |
| **BIP.63** | Does the implementation process the fields in octets 12 through 49 if the SCCI field has advanced beyond the SCCI value of the last processed ICP cell? | | M | (R-46) | Yes__ No__ |
| **BIP.64** | Does the implementation select the IMA ID at group start-up time? | | M | (R-47) | Yes__ No__ |
| **BIP.65** | Does the implementation transmit the IMA ID in the IMA ID field? | | M | (R-48) | Yes__ No__ |
| **BIP.66** | Does the implementation allow to configure the value of IMA ID? | | O | (O-4) | Yes__ No__ |
| **BIP.67** | Does the implementation use the "Group Symmetry Mode" field, specified in Table 2 on page 31, to indicate the symmetry of the IMA group? | | M | (R-49) | Yes__ No__ |
| **BIP.68** | Does the implementation ensure that the symmetry of the group is only established or changed at group start-up time? | | M | (R-50) | Yes__ No__ |
| **BIP.69** | Does the implementation support the Symmetrical Configuration and Operation mode? | | M | (R-51) | Yes__ No__ |
| **BIP.70** | Does the implementation support the Symmetrical Configuration and Asymmetrical Operation mode? | | O | (O-5) | Yes__ No__ |
| **BIP.71** | Does the implementation support the Asymmetrical Configuration and Operation mode? | | O | (O-6) | Yes__ No__ |
| **BIP.72** | Does the implementation abort the start-up procedure using the appropriate code defined in the “Group Status and Control” field of the ICP cell (as specified in Table 2 on page 31) if the NE does not support the symmetry mode proposed by the FE? | | M | (R-52) | Yes__ No__ |
| **BIP.73** | Does the implementation abort the start-up procedure using the appropriate code defined in the “Group Status and Control” field of the ICP cell (as specified in Table 2 on page 31) if the symmetry mode proposed by the FE and the configured symmetry mode of the NE do not match? | | M | (R-52) | Yes__ No__ |
| **BIP.74** | In order to allow a fast recovery when (O-5) or (O-6) is used at the NE and when the FE IMA unit can only be configured to the "Symmetrical Configuration and Operation" mode, does the implementation adjust to “Symmetrical Configuration and | | O | (O-7) | Yes__ No__ |
| **BIP.75** | Does the implementation support only the valid combinations of group symmetry modes at each end of the IMA virtual link as specified in Table 4 on page 36? | | M | (R-53) | Yes__ No__ |
| **BIP.76** | Does the implementation allow configuration of the group mode? | | O | (O-8) | Yes__ No__ |
| Comments: | | | | | |

**Table 22 QoS Requirements Functions**

| Item | Protocol feature | Cond. for Status | Status Pred. | Ref. | Support |
|---|---|---|---|---|---|

| Item | Protocol feature | Cond. for Status | Status Pred. | Ref. | Support |
|---|---|---|---|---|---|
| QOS.1 | Does the implementation support all ATM traffic/QoS classes supported by the ATM layer? | | M | (R-54) | Yes__ No__ |
| Comments: | | | | | |

**Table 23 CTC and ITC Operation Functions**

| Item | Protocol feature | Cond. for Status | Status Pred. | Ref. | Support |
|---|---|---|---|---|---|
| CIT.1 | Does the implementation indicate to the FE in which transmit clock mode it is running in the “Transmit Clock Mode” field in the ICP cell? | | M | (R-55) | Yes__ No__ |
| CIT.2 | Does the implementation support the CTC mode in the transmit direction? | | M | (R-56) | Yes__ No__ |
| CIT.3 | Does the implementation only indicate to the FE that it is in the CTC mode when all the “transmit” clocks of the links in the group are derived from the same source? | | M | (R-57) | Yes__ No__ |
| CIT.4 | Does the implementation support the ITC mode in the transmit direction? | | O | (O-9) | Yes__ No__ |
| CIT.5 | Does the implementation indicate that it is in the ITC mode even if all the transmit clocks of the links in the group are derived from the same source? | | O | (O-10) | Yes__ No__ |
| CIT.6 | Does the implementation use the cell stuffing procedure to prevent link transmit buffer under-run or over-run? | (O-9) | M | (CR-4) | Yes__ No__ |
| CIT.7 | Does the implementation indicate a stuff event in the ICP cell preceding a stuff event using the mandatory LSI codes specified in Table 2 on page 30? | | M | (R-58) | Yes__ No__ |
| CIT.8 | Does the implementation perform stuffing by repeating the ICP cell containing the LSI code indicating that “this cell is 1 out of 2 ICP cells comprising the stuff event”? | | M | (R-59) | Yes__ No__ |
| CIT.9 | Does the implementation also indicate an incoming stuff event in the fourth, third, and second ICP preceding the stuff event using the optional LSI codes? | | O | (O-11) | Yes__ No__ |
| CIT.10 | At any given link, does the implementation ensure it does not introduce a stuff event more than once every 5*M ICP, Filler and ATM layer cells? | | M | (R-60) | Yes__ No__ |
| CIT.11 | Does the implementation remove one of any two consecutive ICP cells with LSI code indicating “this cell is 1 out of the 2 ICP cells | | M | (R-61) | Yes__ No__ |
| CIT.12 | Does the implementation ensure that the SICP cell is not counted as a cell for the purposes of determining the IMA round-robin sequence? | | M | (R-61) | Yes__ No__ |
| CIT.13 | Does the implementation support CTC and ITC modes on receive? | | M | (R-62) | Yes__ No__ |
| CIT.14 | Does the implementation inform the UM of a mismatch between the FE and NE IMA transmit clock modes? | | M | (R-63) | Yes__ No__ |
| CIT.15 | Does the implementation ensure that a restart is not caused if the implementation detects a mismatch between the FE and NE Transmit clock modes? | | M | (R-63) | Yes__ No__ |
| CIT.16 | Does the implementation rely on at least one ICP cell with a correct CRC-10 in order to process the incoming stuff cell indication code (this is recommended)? | | O | (O-12) | Yes__ No__ |
| Comments: | | | | | |

### Table 24 IMA Data Cell (IDC) Rate Implementation Functions

| Item | Protocol feature | Cond. for Status | Status Pred. | Ref. | Support |
|---|---|---|---|---|---|
| IDC.1 | Does the implementation ensure on transmit that a Filler cell is not injected if an ATM layer cell is available for scheduling? | | M | (R-64) | Yes__ No__ |
| IDC.2 | Does the implementation only check on transmit that an ATM layer cell is available and accept that cell only when the Tx IDCC ticks? | | M | (R-64) | Yes__ No__ |
| IDC.3 | Does the implementation only select the TRL from the set of links whose transmit state is Active? | | M | (R-65) | Yes__ No__ |
| IDC.4 | If there is no link in the Active state, does the implementation select one of the links in the Usable state, if any, or one of the links in the Unusable state otherwise? | | M | (R-66) | Yes__ No__ |
| IDC.5 | Does the implementation only select or change the TRL during the following situations:<br>• during group start-up,<br>• when the previously selected TRL's transmit state changes from Active to any other state (e.g., Usable, Unusable, or Not In Group) while another link’s transmit state is Active, or<br>• when the previously selected TRL’s transmit state changes from Usable to Unusable or Not In Group while another link’s transmit state is Active or Usable? | | M | (R-67) | Yes__ No__ |
| IDC.6 | Does the implementation indicate the selected or changed TRL to the FE over the “Transmit Timing Information” field in the ICP cell? | | M | (R-68) | Yes__ No__ |
| IDC.7 | Does the implementation derive the Tx IDCC from the selected TRL according to Equation 1 on page 40? | | M | (R-69) | Yes__ No__ |
| IDC.8 | When running in the CTC mode, does the implementation introduce a stuff event every 2048 ICP, Filler and ATM layer cells on all links? | | M | (R-70) | Yes__ No__ |
| IDC.9 | Does the implementation introduce a stuff event every 2048 ICP, Filler and ATM layer cells on the TRL? | (O-9) | M | (CR-5) | Yes__ No__ |
| IDC.10 | Does the implementation introduce stuff events on links other than the TRL in order to compensate for the timing difference between the TRL and the other links? | (O-9) | M | (CR-6) | Yes__ No__ |
| IDC.11 | Does the implementation remove CDV attributed to the presence of ICP cells by a mechanism equivalent to providing a small smoothing buffer into which cells are placed after reordering and after removing ICP cells? | | M | (R-71) | Yes__ No__ |
| IDC.12 | If the TRL is in the Working state and the FE has, for at least 100 milliseconds, identified a given link as the TRL, does the implementation derive the Rx IDCR using the incoming link indicated by the FE as the TRL? | | M | (R-72) | Yes__ No__ |
| IDC.13 | Does the implementation have an equivalent behavior to the following: when the IMA data cell clock at the receiver ticks, one cell is removed from the smoothing buffer; if the cell is a Filler cell, then the Filler cell is discarded and nothing passed to the ATM layer; if the cell is not a Filler cell, then it is passed to the ATM layer? | | M | (R-73) | Yes__ No__ |
| Comments: | | | | | |

### Table 25 Link Differential Delay (LDD) Functions

| Item | Protocol feature | Cond. for Status | Status Pred. | Ref. | Support |
|---|---|---|---|---|---|
| LDD.1 | Does the implementation introduce a differential delay among the constituent links of a maximum of 2.5 cell times at the physical link rate? | | M | (R-74) | Yes__ No__ |

| Item | Protocol feature | Cond. for Status | Status Pred. | Ref. | Support |
|---|---|---|---|---|---|
| **LDD.2** | Does the implementation tolerate up to at least 25 milliseconds of link differential delay on receive? | | M | (R-75) | Yes__ No__ |
| **LDD.3** | Does the implementation allow configuring the link differential delay tolerance? | | O | (O-13) | Yes__ No__ |
| Comments: | | | | | |

**Table 26 IMA Interface Operation (IIO) Functions**

| Item | Protocol feature | Cond. for Status | Status Pred. | Ref. | Support |
|---|---|---|---|---|---|
| **IIO.1** | Does the implementation support the Tx LSM defined in Table 8 on page 52? | | M | (R-76) | Yes__ No__ |
| **IIO.2** | Does the implementation support the Rx LSM defined in Table 9 on page 53? | | M | (R-77) | Yes__ No__ |
| **IIO.3** | Does the implementation signal the current state of the Tx LSM to the FE IMA unit via the ICP cells? | | M | (R-78) | Yes__ No__ |
| **IIO.4** | Does the implementation perform the actions corresponding to the Tx LSM sub-states? | | M | (R-78) | Yes__ No__ |
| **IIO.5** | Does the implementation update the Tx LSM according the occurrence of the events listed in Table 8 on page 52? | | M | (R-78) | Yes__ No__ |
| **IIO.6** | Does the implementation treat sequentially the incoming events that trigger the Tx LSM, although the order of treatment is implementation specific if these events appear simultaneously? | | M | (R-78) | Yes__ No__ |
| **IIO.7** | Does the implementation signal the current state of the Rx LSM to the FE IMA unit via the ICP cells? | | M | (R-78) | Yes__ No__ |
| **IIO.8** | Does the implementation perform the actions corresponding to the Rx LSM sub-states? | | M | (R-78) | Yes__ No__ |
| **IIO.9** | Does the implementation update the Rx LSM according the occurrence of the events listed in Table 9 on page 53? | | M | (R-78) | Yes__ No__ |
| **IIO.10** | Does the implementation treat sequentially the incoming events that trigger the Rx LSM, although the order of treatment is implementation specific if these events appear simultaneously? | | M | (R-78) | Yes__ No__ |
| **IIO.11** | Does the implementation report any change of the Tx and Rx LSMs within the next 2*M (where M is the M used by the IMA transmitter) cells on that link over the “Tx State" and "Rx State" fields of the Link Information field (refer to Table 3 on page 32)? | | M | (R-79) | Yes__ No__ |
| **IIO.12** | Does the implementation use one of the Unusable encodings when reporting the Unusable state? | | M | (R-80) | Yes__ No__ |
| **IIO.13** | Does the implementation use “Inhibited”, “Failed”, “Fault” or “Mis-connected” as a reason when reporting the Unusable state? | | O | (O-14) | Yes__ No__ |
| **IIO.14** | Does the implementation re-evaluate the TX and Rx LSMs state upon each incoming ICP cell with new state indication? | | M | (R-81) | Yes__ No__ |
| **IIO.15** | Does the implementation allow the valid combinations of Tx and Rx LSM states and disallow the invalid combinations when running in the Symmetrical Configuration and Operation mode? | | M | (R-82) | Yes__ No__ |
| **IIO.16** | Does the implementation allow the valid combinations of Tx and Rx LSM states and disallow the invalid combinations when running in the Symmetrical Configuration and Asymmetrical Operation mode? | | M | (R-82) | Yes__ No__ |
| **IIO.17** | Does the implementation allow all combinations of Tx and Rx LSM states when running in the Asymmetrical Configuration and Operation mode? | | M | (R-82) | Yes__ No__ |
| **IIO.18** | Does the implementation report any GSM states, with the exception of the Not Configured state, to the FE group using the corresponding value defined in the “Group Status and Control” field? | | M | (R-83) | Yes__ No__ |

| Item | Protocol feature | Cond. for Status | Status Pred. | Ref. | Support |
|---|---|---|---|---|---|
| **IIO.19** | Does the implementation always send over each link the same value in the "Group Status and Control" field for at least 2 consecutive IMA frames? | | M | (R-84) | Yes__ No__ |
| **IIO.20** | Does the implementation validate the Rx OAM Label, Rx M, and Rx IMA ID over at least one link before moving into the Start-up-Ack state? | | M | (R-85) | Yes__ No__ |
| **IIO.21** | Does the implementation use the validated Rx OAM Label, Rx M, and Rx IMA ID to achieve IMA frame synchronization as defined in Section 11 on page 68? | | M | (R-86) | Yes__ No__ |
| **IIO.22** | Does the implementation ensure that at least $P_{Tx}$ links in the transmit direction and $P_{RX}$ links in the received direction can be moved into the Active state before moving the GSM into the Operational state? | | M | (R-87) | Yes__ No__ |
| **IIO.23** | Does the implementation ensure that $P_{Tx}$ is greater than zero? | | M | (R-88) | Yes__ No__ |
| **IIO.24** | Does the implementation ensure that $P_{Rx}$ is greater than zero? | | M | (R-88) | Yes__ No__ |
| **IIO.25** | Does the implementation ensure that $P_{Tx}$ and $P_{Rx}$ are equal when the configured in the Symmetrical Configuration and Operation mode? | | M | (R-89) | Yes__ No__ |
| **IIO.26** | Does the implementation allow configuration of the value of $P_{Tx}$? | | O | (O-15) | Yes__ No__ |
| **IIO.27** | Does the implementation allow configuration of the value of $P_{RX}$? | | O | (O-15) | Yes__ No__ |
| **IIO.28** | Does the implementation report the Config-Aborted state for at least one second when the configuration requested by the FE is unacceptable? | | M | (R-90) | Yes__ No__ |
| **IIO.29** | Does the implementation support the GSM state transitions as defined in Table 13 on page 60? | | M | (R-91) | Yes__ No__ |
| **IIO.30** | Does the implementation determine and report that the group is up when both the local and remote GSMs are Operational? | | M | (R-92) | Yes__ No__ |
| **IIO.31** | Does the implementation determine and report that the group is down when either the local or the remote GSM is not operational? | | M | (R-92) | Yes__ No__ |
| **IIO.32** | Does the implementation report the proper reasons why the GSM is not operational? | | M | (R-92) | Yes__ No__ |
| **IIO.33** | Does the implementation report the highest priority reason according to Table 14 on page 61? | | M | (R-92) | Yes__ No__ |
| **IIO.34** | Does the implementation report the entrance of the GTSM into the Down state to the UM and ATM Layer Management? | | M | (R-93) | Yes__ No__ |
| **IIO.35** | Is the report of the entrance of the GTSM into the Down state the only notification to the ATM Layer Management about Physical Layer defects or failures? | | M | (R-93) | Yes__ No__ |
| **IIO.36** | Does the implementation report the return of the GTSM to the Up state to the UM and ATM Layer Management? | | M | (R-94) | Yes__ No__ |
| **IIO.37** | Does the implementation ensure it does not drop any ATM layer cells when adding or recovering links while the GSM is maintained in the Operational state? | | M | (R-95) | Yes__ No__ |
| **IIO.38** | Does the implementation ensure that it does not drop any ATM layer cells when deleting or inhibiting links while the GSM is maintained in the Operational state? | | M | (R-96) | Yes__ No__ |
| **IIO.39** | When running the group start-up procedure, does the implementation ensure that all accepted links have their states changed to Tx=Usable in the same update of the ICP cell? | | M | (R-97) | Yes__ No__ |
| **IIO.40** | When running the group start-up procedure and after the Tx state of all accepted links has been reported in a previous update of the ICP cell, does the implementation ensure that all accepted links have their states changed to Rx=Active in the same update of the ICP cell? | | M | (R-98) | Yes__ No__ |

| Item | Protocol feature | Cond. for Status | Status Pred. | Ref. | Support |
|---|---|---|---|---|---|
| **IIO.41** | When running the group start-up procedure and after the Rx state of all accepted links has been reported in a previous update of the ICP cell, does the implementation ensure that all accepted links have their states changed to Tx=Active in the same update of the ICP cell? | | M | (R-99) | Yes__ No__ |
| **IIO.42** | When running the group start-up procedure, does the implementation wait a minimum of one second, unless all the configured links are being reported Tx=Usable by FE, before reporting links Rx=Active? | | M | (R-100) | Yes__ No__ |
| **IIO.43** | When running the group start-up procedure, does the implementation wait a minimum of one second, unless all the configured links are being reported Rx=Active by FE, before reporting links Tx=Active? | | M | (R-101) | Yes__ No__ |
| **IIO.44** | Does the implementation synchronize the insertion of new links or recovered links added using the slow recovery mechanism, defined in Section 12.1.3.1 on page 74, within the IMA RR? | | M | (R-102) | Yes__ No__ |
| **IIO.45** | Does the implementation execute only one LASR procedure per IMA group at any time (even if more than one link is inserted at the same time)? | | M | (R-103) | Yes__ No__ |
| **IIO.46** | Does the implementation delay the insertion of one or more new links or a possible slow link recovery when the LASR is in progress until the link addition procedure is completed or aborted? | | M | (R-104) | Yes__ No__ |
| **IIO.47** | When running the LASR procedure, does the implementation ensure that all the inserted links have their states changed to Tx=Usable in the same update of the ICP? | | M | (R-105) | Yes__ No__ |
| **IIO.48** | When running the LASR procedure and after the Tx state of all accepted links has been reported Usable in a previous update of the ICP cell, does the implementation ensure that all the inserted links have their states changed to Rx=Active in the same update of the ICP cell? | | M | (R-106) | Yes__ No__ |
| **IIO.49** | When running the LASR procedure and after the Rx state of all accepted links has been reported Active in a previous update of the ICP cell, does the implementation ensure that all the inserted links have their states changed to Tx=Active in the same update of the ICP cell? | | M | (R-107) | Yes__ No__ |
| **IIO.50** | When running the LASR procedure, does the implementation wait a minimum of one second, unless all the inserted links are being reported Tx=Usable by FE, before reporting links Rx=Active? | | M | (R-108) | Yes__ No__ |
| **IIO.51** | When running the LASR procedure, does the implementation wait a minimum of one second, unless the inserted links are being reported Rx=Active by FE, before reporting links Tx=Active? | | M | (R-109) | Yes__ No__ |
| Comments: | | | | | |

**Table 27 IMA Frame Synchronization (IFS) Mechanism Functions**

| Item | Protocol feature | Cond. for Status | Status Pred. | Ref. | Support |
|---|---|---|---|---|---|
| **IFS.1** | Does the implementation perform IMA frame synchronization on each link, based on the IFSM defined in Figure 19 on page 69 and Table 16 on page 69? | | M | (R-110) | Yes__ No__ |
| **IFS.2** | Does the implementation operate the IFSM for each link independently of any link defects and link delay compensation? | | M | (R-111) | Yes__ No__ |
| **IFS.3** | Does the implementation support the default value 2 for Alpha($\alpha$)? | | M | (R-112) | Yes__ No__ |
| **IFS.4** | Does the implementation support the default value 2 for Beta($\beta$)? | | M | (R-112) | Yes__ No__ |

| Item | Protocol feature | Cond. for Status | Status Pred. | Ref. | Support |
|---|---|---|---|---|---|
| **IFS.5** | Does the implementation support the default value 1 for Gamma(γ)? | | M | (R-112) | Yes__ No__ |
| **IFS.6** | Does the implementation support the value 1 for Alpha(α)? | | O | (O-16) | Yes__ No__ |
| **IFS.7** | Does the implementation support the value 1 for Beta(β)? | | O | (O-16) | Yes__ No__ |
| **IFS.8** | Does the implementation support the value 3 for Beta(β)? | | O | (O-16) | Yes__ No__ |
| **IFS.9** | Does the implementation support the value 4 for Beta(β)? | | O | (O-16) | Yes__ No__ |
| **IFS.10** | Does the implementation support the value 5 for Beta(β)? | | O | (O-16) | Yes__ No__ |
| **IFS.11** | Does the implementation support the value 2 for Gamma(γ)? | | O | (O-16) | Yes__ No__ |
| **IFS.12** | Does the implementation support the value 3 for Gamma(γ)? | | O | (O-16) | Yes__ No__ |
| **IFS.13** | Does the implementation support the value 4 for Gamma(γ)? | | O | (O-16) | Yes__ No__ |
| **IFS.14** | Does the implementation support the value 5 for Gamma(γ)? | | O | (O-16) | Yes__ No__ |
| **IFS.15** | Does the implementation assume that any occurrence of HEC/CRC errored cell in the ICP cell position was an ICP cell? | | M | (R-113) | Yes__ No__ |
| **IFS.16** | Does the implementation ignore the cell content of a HEC/CRC errored cell in the ICP cell position? | | M | (R-113) | Yes__ No__ |
| **IFS.17** | Does the implementation go into the Hunt state from any other state when no longer getting cells from the physical layer? | | O | (O-17) | Yes__ No__ |
| **IFS.18** | Does the implementation maintain IMA frame synchronization for cases 1, 2, 3, and 6 identified in Figure 20 on page 71? | | M | (R-114) | Yes__ No__ |
| **IFS.19** | Does the implementation maintain IMA frame synchronization for case 4 identified in Figure 20 on page 71? | | O | (O-18) | Yes__ No__ |
| **IFS.20** | Does the implementation maintain IMA frame synchronization for case 5 identified in Figure 20 on page 71? | | O | (O-18) | Yes__ No__ |
| **IFS.21** | Does the implementation maintain IMA frame synchronization for case 7 identified in Figure 20 on page 71 when passing stuff indication over more than one of the previous ICP cells and when Beta(β) is greater than 2? | | O | (O-19) | Yes__ No__ |
| Comments: | | | | | |

### Table 28 IMA Interface OAM Operation Functions

| Item | Protocol feature | Cond. for Status | Status Pred. | Ref. | Support |
|---|---|---|---|---|---|
| **OAM.1** | Does the implementation report the following link remote defect indicators: link defects, LIF, and LODS? | | M | (R-115) | Yes__ No__ |
| **OAM.2** | If several defects are detected at the same time, does the implementation report the defect with the highest priority, as listed in Table 17 on page 72? | | M | (R-116) | Yes__ No__ |
| **OAM.3** | Does the implementation report any Rx defect to the far-end IMA within the next 2*M cells to be transmitted after the defect state has been entered as specified in Section 12.1.3 on page 72 (where M is the M used by the IMA transmitter)? | | M | (R-117) | Yes__ No__ |
| **OAM.4** | Does the implementation perform error handling as specified in Figure 21 on page 73 and Figure 22 on page 74? | | M | (R-118) | Yes__ No__ |
| **OAM.5** | On a given link, does the implementation pass to the ATM layer from the IMA sublayer any cells accumulated before the occurrence of an OCD or OIF anomaly on that link? | | M | (R-119) | Yes__ No__ |
| **OAM.6** | Does the implementation inhibit the passing from the IMA sublayer to the ATM layer of any cells received on a link during an OCD or OIF anomaly condition reported on that link? | | M | (R-120) | Yes__ No__ |
| **OAM.7** | Does the implementation replace with Filler cells all ATM layer cells received on a link after an OCD or OIF anomaly condition has been detected on that link? | | M | (R-121) | Yes__ No__ |
| **OAM.8** | Does the implementation only report an Rx defect in the backward direction after LIF or LODS defect state is entered? | | M | (R-122) | Yes__ No__ |

| Item | Protocol feature | Cond. for Status | Status Pred. | Ref. | Support |
|---|---|---|---|---|---|
| **OAM.9** | Does the implementation report the LIF or LODS defect as specified in Section 12.1.2 on page 72? | | M | (R-123) | Yes__ No__ |
| **OAM.10** | Does the implementation detect errored ICP cells as indicated in Table 18 on page 77? | | M | (R-124) | Yes__ No__ |
| **OAM.11** | Does the implementation detect invalid ICP cells as indicated in Table 18 on page 77? | | M | (R-124) | Yes__ No__ |
| **OAM.12** | Does the implementation detect missing ICP cells as indicated in Table 18 on page 77? | | M | (R-124) | Yes__ No__ |
| **OAM.13** | Does the implementation report OIF events as indicated in Table 18 on page 77? | | M | (R-124) | Yes__ No__ |
| **OAM.14** | Does the implementation report LIF defects as indicated in Table 18 on page 77? | | M | (R-124) | Yes__ No__ |
| **OAM.15** | Does the implementation report LODS defects as indicated in Table 18 on page 77? | | M | (R-124) | Yes__ No__ |
| **OAM.16** | Does the implementation report RDI-IMA defects as indicated in Table 18 on page 77? | | M | (R-124) | Yes__ No__ |
| **OAM.17** | Does the implementation increment IV-IMA for every detected errored, invalid or missing ICP cell, except during seconds when a SES-IMA or UAS-IMA condition is reported, as indicated in Table 19 on page 77? | | M | (R-125) | Yes__ No__ |
| **OAM.18** | Does the implementation increment OIF-IMA for each reported OIF anomaly, except during seconds when a SES-IMA or UAS-IMA condition is reported, as indicated in Table 19 on page 77? | | O | (O-20) | Yes__ No__ |
| **OAM.19** | Does the implementation increment SES-IMA for every one second interval containing ≥ 30 % of the ICP cells counted as IV-IMA, as indicated in Table 19 on page 77? | | M | (R-126) | Yes__ No__ |
| **OAM.20** | Does the implementation increment SES-IMA for every one interval of one second containing one or more link defects (e.g., LOS, OOF/LOF, AIS, and LCD), except during seconds when an UAS-IMA condition is reported, as indicated in Table 19 on page 77? | | M | (R-126) | Yes__ No__ |
| **OAM.21** | Does the implementation increment SES-IMA for every one second interval containing one or more LIF link defects, except during seconds when an UAS-IMA condition is reported, as indicated in Table 19 on page 77? | | M | (R-126) | Yes__ No__ |
| **OAM.22** | Does the implementation increment SES-IMA for every one second interval containing one or more LODS link defects, except during seconds when a UAS-IMA condition is reported, as indicated in Table 19 on page 77? | | M | (R-126) | Yes__ No__ |
| **OAM.23** | Does the implementation increment SES-IMA-FE for every one second interval containing one or more RDI-IMA defect, except during seconds when a UAS-IMA-FE condition is reported, as indicated in Table 19 on page 77? | | M | (R-127) | Yes__ No__ |
| **OAM.24** | Does the period of NE unavailability begin at the onset of 10 contiguous SES-IMA (including the first 10 seconds to enter the UAS-IMA condition), as indicated in Table 19 on page 77? | | M | (R-128) | Yes__ No__ |
| **OAM.25** | Does the period of NE unavailability end at the onset of 10 contiguous seconds with no SES-IMA (excluding the last 10 seconds to exit the UAS-IMA condition), as indicated in Table 19 on page 77? | | M | (R-128) | Yes__ No__ |
| **OAM.26** | Does the implementation increment UAS-IMA for each one second interval when the UAS-IMA condition is reported, as indicated in Table 19 on page 77? | | M | (R-128) | Yes__ No__ |
| **OAM.27** | Does the period of FE unavailability begin at the onset of 10 contiguous SES-IMA (including the first 10 seconds to enter the UAS-IMA condition), as indicated in Table 19 on page 77? | | M | (R-129) | Yes__ No__ |

| Item | Protocol feature | Cond. for Status | Status Pred. | Ref. | Support |
|---|---|---|---|---|---|
| **OAM.28** | Does the period of FE unavailability end at the onset of 10 contiguous seconds with no SES-IMA-FE (excluding the last 10 seconds to exit the UAS-IMA-FE condition), as indicated in Table 19 on page 77? | | M | (R-129) | Yes__ No__ |
| **OAM.29** | Does the implementation increment UAS-IMA-FE for each one second interval when the UAS-IMA-FE condition is reported, as indicated in Table 19 on page 77? | | M | (R-129) | Yes__ No__ |
| **OAM.30** | Does the implementation increment Tx-UUS-IMA for each second when the NE Tx LSM is Unusable, as indicated in Table 19 on page 77? | | M | (R-130) | Yes__ No__ |
| **OAM.31** | Does the implementation increment Rx-UUS-IMA for each second when the NE Rx LSM is Unusable, as indicated in Table 19 on page 77? | | M | (R-131) | Yes__ No__ |
| **OAM.32** | Does the implementation increment Tx-UUS-IMA-FE for each second when the FE Tx LSM is reported Unusable, as indicated in Table 19 on page 77? | | M | (R-132) | Yes__ No__ |
| **OAM.33** | Does the implementation increment Rx-UUS-IMA-FE for each second when the FE Rx LSM is reported Unusable, as indicated in Table 19 on page 77? | | M | (R-133) | Yes__ No__ |
| **OAM.34** | Does the implementation increment Tx-FC each time the Tx-Mis-Connected link failure condition is entered, as indicated in Table 19 on page 77? | | M | (R-134) | Yes__ No__ |
| **OAM.35** | Does the implementation increment Tx-FC each time the Tx-Fault link failure condition is entered, as indicated in Table 19 on page 77? | | M | (R-134) | Yes__ No__ |
| **OAM.36** | Does the implementation increment Rx-FC each time the LIF link failure condition is entered, as indicated in Table 19 on page 77? | | M | (R-135) | Yes__ No__ |
| **OAM.37** | Does the implementation increment Rx-FC each time the LODS link failure condition is entered, as indicated in Table 19 on page 77? | | M | (R-135) | Yes__ No__ |
| **OAM.38** | Does the implementation increment Rx-FC each time the Rx-Mis-Connected link failure condition is entered, as indicated in Table 19 on page 77? | | M | (R-135) | Yes__ No__ |
| **OAM.39** | Does the implementation increment Rx-FC each time the Rx-Fault link failure condition is entered, as indicated in Table 19 on page 77? | | M | (R-135) | Yes__ No__ |
| **OAM.40** | Does the implementation increment Tx-FC-FE each time the Tx-Unusable-FE link failure condition is entered, as indicated in Table 19 on page 77? | | O | (O-21) | Yes__ No__ |
| **OAM.41** | Does the implementation increment Rx-FC-FE each time the RFI-IMA link failure condition is entered, as indicated in Table 19 on page 77? | | O | (O-22) | Yes__ No__ |
| **OAM.42** | Does the implementation increment Rx-FC-FE each time the Rx-Unusable-FE link failure condition is entered, as indicated in Table 19 on page 77? | | O | (O-22) | Yes__ No__ |
| **OAM.43** | Does the implementation increment Tx-Stuff-IMA for each stuff event inserted in the transmit direction, as indicated in Table 19 on page 77? | | O | (O-23) | Yes__ No__ |
| **OAM.44** | Does the implementation increment Rx-Stuff-IMA for each stuff event detected in the receive direction, except during seconds when a SES-IMA or UAS-IMA condition is reported, as indicated in Table 19 on page 77? | | O | (O-24) | Yes__ No__ |
| **OAM.45** | Does the implementation increment GR-UAS-IMA for each second when the GTSM is down, as indicated in Table 19 on page 77? | | M | (R-136) | Yes__ No__ |
| **OAM.46** | Does the implementation increment GR-FC each time the Config-Aborted group failure condition is entered, as indicated in Table 19 on page 77? | | M | (R-137) | Yes__ No__ |

| Item | Protocol feature | Cond. for Status | Status Pred. | Ref. | Support |
|---|---|---|---|---|---|
| **OAM.47** | Does the implementation increment GR-FC each time the Insufficient-Links group failure condition is entered, as indicated in Table 19 on page 77? | | M | (R-137) | Yes__ No__ |
| **OAM.48** | Does the implementation increment GR-FC-FE each time the Start-up-FE group failure condition is entered, as indicated in Table 19 on page 77? | | O | (O-25) | Yes__ No__ |
| **OAM.49** | Does the implementation increment GR-FC-FE each time the Config-Aborted-FE group failure condition is entered, as indicated in Table 19 on page 77? | | O | (O-25) | Yes__ No__ |
| **OAM.50** | Does the implementation increment GR-FC-FE each time the Insufficient-Links-FE group failure condition is entered, as indicated in Table 19 on page 77? | | O | (O-25) | Yes__ No__ |
| **OAM.51** | Does the implementation increment GR-FC-FE each the Blocked-FE group failure condition is entered, as indicated in Table 19 on page 77? | | O | (O-25) | Yes__ No__ |
| **OAM.52** | Does the implementation accumulate IMA performance parameters over 15 minute intervals? | | O | (O-26) | Yes__ No__ |
| **OAM.53** | Does the implementation accumulate IMA performance parameters over 24 hour intervals? | | O | (O-27) | Yes__ No__ |
| **OAM.54** | Does the implementation keep the current/previous and recent data? | (O-26) | M | (CR-7) | Yes__ No__ |
| **OAM.55** | Does the implementation use the current data for threshold crossing? | (O-26) | M | (CR-8) | Yes__ No__ |
| **OAM.56** | Does the implementation keep the current/previous and recent data? | (O-27) | M | (CR-9) | Yes__ No__ |
| **OAM.57** | Does the implementation use the current data for threshold crossing? | (O-27) | M | (CR-10) | Yes__ No__ |
| **OAM.58** | Does the implementation report a LIF failure alarm for the persistence of a LIF defect at the NE? | | M | (R-138) | Yes__ No__ |
| **OAM.59** | Does the implementation report a LODS failure alarm for the persistence of a LODS defect at the NE? | | M | (R-139) | Yes__ No__ |
| **OAM.60** | Does the implementation report a RFI-IMA failure alarm for the persistence of a RDI-IMA defect at the NE? | | M | (R-140) | Yes__ No__ |
| **OAM.61** | Does the implementation report Tx-Mis-Connected failure alarm when the Tx link is detected as mis-connected? | | M | (R-141) | Yes__ No__ |
| **OAM.62** | Does the implementation report Rx-Mis-Connected failure alarm when the Rx link is detected as mis-connected? | | M | (R-142) | Yes__ No__ |
| **OAM.63** | Does the implementation report a Tx Fault failure alarm for any implementation specific Tx fault declared at the NE? | | O | (O-28) | Yes__ No__ |
| **OAM.64** | Does the implementation report a Rx Fault failure alarm for any implementation specific Rx fault declared at the NE? | | O | (O-29) | Yes__ No__ |
| **OAM.65** | Does the implementation report a Tx-Unusable-FE failure alarm when it receives Tx-Unusable from FE? | | M | (R-143) | Yes__ No__ |
| **OAM.66** | Does the implementation report a Rx-Unusable-FE failure alarm when it receives Rx-Unusable from FE? | | M | (R-144) | Yes__ No__ |
| **OAM.67** | Does the implementation report a Start-up-FE failure alarm when it receives this signal from FE (the declaration of this failure alarm may be delayed to ensure the FE remains in Start-up)? | | M | (R-145) | Yes__ No__ |
| **OAM.68** | Does the implementation report a Config-Aborted failure alarm when the FE tries to use unacceptable configuration parameters? | | M | (R-146) | Yes__ No__ |
| **OAM.69** | Does the implementation report a Config-Aborted-FE failure alarm when the FE reports unacceptable configuration parameters? | | M | (R-147) | Yes__ No__ |
| **OAM.70** | Does the implementation report an Insufficient-Links failure alarm when less than $P_{Tx}$ transmit links or $P_{Rx}$ receive links are active? | | M | (R-148) | Yes__ No__ |
| **OAM.71** | Does the implementation report an Insufficient-Links-FE failure alarm when the FE reports that less than $P_{Tx}$ transmit links or $P_{Rx}$ receive links are active? | | M | (R-149) | Yes__ No__ |

| Item | Protocol feature | Cond. for Status | Status Pred. | Ref. | Support |
|---|---|---|---|---|---|
| OAM.72 | Does the implementation report a Blocked-FE failure alarm when the FE reports that it is blocked? | | M | (R-150) | Yes__ No__ |
| OAM.73 | Does the implementation report GR-Timing-Mismatch when the FE transmit clock mode is different than the NE transmit clock mode? | | M | (R-151) | Yes__ No__ |
| OAM.74 | In the case of the LIF, LODS, RFI-IMA and Fault failure alarms, does the implementation support 2.5 ± 0.5 seconds as a default persistence checking time to enter a failure alarm condition? | | M | (R-152) | Yes__ No__ |
| OAM.75 | In the case of the LIF, LODS, RFI-IMA and Fault failure alarms, does the implementation support 10 ± 0.5 seconds as a default persistence clearing time to exit the failure alarm condition? | | M | (R-152) | Yes__ No__ |
| OAM.76 | In the case of the LIF, LODS, RFI-IMA and Fault failure alarms, does the IMA allow configuration of other values for default persistence checking time to enter a failure alarm condition? | | O | (O-30) | Yes__ No__ |
| OAM.77 | In the case of the LIF, LODS, RFI-IMA and Fault failure alarms, does the IMA allow configuration of other values for default persistence checking time to exit the same failure alarm condition? | | O | (O-30) | Yes__ No__ |
| OAM.78 | Does the implementation ensure that the Tx-Fault failure alarm, as defined in (O-28) on page 79, is not cleared until the fault that led to the declaration of the alarm is no longer present for the duration specified to clear the alarm in (R-152) on page 80? | (O-28) | M | (CR-11) | Yes__ No__ |
| OAM.79 | Does the implementation ensure that the Rx-Fault failure alarm, as defined in (O-29) on page 79, is not cleared until the fault that led to the declaration of the alarm is no longer present for the duration specified to clear the alarm in (R-152) on page 80? | (O-29) | M | (CR-12) | Yes__ No__ |
| Comments: | | | | | |

**Table 29 Test Pattern Procedure (TPP) Functions**

| Item | Protocol feature | Cond. for Status | Status Pred. | Ref. | Support |
|---|---|---|---|---|---|
| TPP.1 | Does the implementation activate the Test Pattern procedure in the transmit direction? | | O | (O-31) | Yes__ No__ |
| TPP.2 | Does the implementation use the Test Link Command field in the ICP cell (as defined in the Tx Test Control field in Table 2 on page 31) to request the FE to activate the loop back of the test pattern contained in the Tx Test Pattern field? | (O-31) | M | (CR-13) | Yes__ No__ |
| TPP.3 | Does the implementation use the Tx LID field defined in the Tx Test Control field in Table 2 on page 31 to identify to the FE which transmit link the FE should extract the Tx Test Pattern from in the received ICP cells? | (O-31) | M | (CR-14) | Yes__ No__ |
| TPP.4 | Does the implementation send any changed values of the Test Link Command, Tx LID and Tx Test Pattern fields in ICP cells for at least 2 consecutive IMA frames over each link within the IMA group? | (O-31) | M | (CR-15) | Yes__ No__ |
| TPP.5 | Does the implementation continue to send the same values of the Test Link Command, Tx LID and Tx Test Pattern fields as long as the IMA transmitter wants the FE IMA unit to loop back the test pattern? | (O-31) | M | (CR-16) | Yes__ No__ |
| TPP.6 | Does the implementation monitor the incoming ICP cells on the links already recognized in the group to detect a change of the Test Link Command? | | M | (R-153) | Yes__ No__ |

| Item | Protocol feature | Cond. for Status | Status Pred. | Ref. | Support |
|---|---|---|---|---|---|
| **TPP.7** | If the Test Link Command field is detected as active over the links already recognized in the group and over the test link, does the implementation copy the value of the Tx Test Pattern field received from the test link, indicated over the Tx LID field, into the Rx Test Pattern field on every subsequent ICP cell sent over all outgoing links in the group? | | M | (R-154) | Yes__ No__ |
| **TPP.8** | Does the implementation continue sending the same value over the Rx Test Pattern field until the IMA transmitter has received an indication to stop looping the pattern, to loop a new pattern received from the same link over the Tx Test Pattern, or to loop the test pattern received from another link (indicated over the Tx LID field)? | | M | (R-155) | Yes__ No__ |
| **TPP.9** | Does the implementation return the “0xFF” pattern over the Rx Test Pattern field when the incoming test command is inactive or the test link is not detected? | | M | (R-156) | Yes__ No__ |
| **TPP.10** | Does the implementation only handle one test pattern per IMA group at any given time? | | M | (R-157) | Yes__ No__ |
| Comments: | | | | | |

**Table 30 IMA Interaction with Plane Management Functions**

| Item | Protocol feature | Cond. for Status | Status Pred. | Ref. | Support |
|---|---|---|---|---|---|
| **IPM.1** | Does the implementation process IMA group configuration indications received from the Plane Management? | | M | (R-158) | Yes__ No__ |
| **IPM.2** | Does the implementation process IMA link addition/deletion indications received from the Plane Management? | | M | (R-158) | Yes__ No__ |
| **IPM.3** | Does the implementation send IMA service operational status change indications to the Plane Management? | | M | (R-158) | Yes__ No__ |
| **IPM.4** | Does the implementation send Tx/Rx cell rate change indications to the Plane Management? | | M | (R-158) | Yes__ No__ |
| Comments: | | | | | |

**Table 31 Management Information Base (MIB) Functions**

| Item | Protocol feature | Cond. for Status | Status Pred. | Ref. | Support |
|---|---|---|---|---|---|
| **MIB.1** | Does the implementation support a UM based on SNMP? | | O | (O-32) | Yes__ No__ |
| **MIB.2** | Does the implementation implement the mandatory objects in the IMA-MIBs defined in Appendix A on page 106? | (O-32) | M | (CR-17) | Yes__ No__ |
| **MIB.3** | Does the implementation implement the optional objects in the IMA MIBs defined in Appendix A on page 106? | (O-32) | O | (O-33) | Yes__ No__ |
| Comments: | | | | | |

## I.4 PICS Proforma References

[A-1] The ATM Forum, AF-PHY-0086.001, Inverse Multiplexing for ATM (IMA) Specification Version 1.1.

[A-2] ISO/IEC 9646-1: 1990, Information technology - Open systems interconnection - Conformance testing methodology and framework - Part 1: General concepts (See also ITU-T Recommendation X.290 (1991)).

[A-3] ISO/IEC 9646-2: 1990, Information technology - Open systems interconnection - Conformance testing methodology and framework - Part 2: Abstract test suite specification (See also ITU-T Recommendation X.291 (1991)).

[A-4] ITU-T Recommendation I.432 Series, “B-ISDN User-Network Interface - Physical Layer

[A-5] ITU-T Recommendation I.610, “B-ISDN Operation and Maintenance Principles and Functions”, 1995.

# Appendix A IMA SNMP MIBs

## A.1 The Network Management Framework

The IMA unit management is defined using SNMP MIBs. SNMP [14] is an Internet standard network management framework.

The Request For Comment (RFC) documents which are relevant here are:

- RFC 1213 [15] which defines MIB-II, the core set of manager objects for the Internet suite of protocols,
- RFC 1902 [17] which defines the Structure of Management Information (SMI), the mechanisms used for describing and naming objects for the purpose of management,
- RFCs 1157 [14] which defined SNMPv1 and RFC 1905 [18] which defines SNMPv2,
- RFC 2233 [19] which defines the evolution of the Interfaces group of MIB-II,
- RFC 1406 [16] which defines managed objects for DS1 and E1 interfaces.

## A.2 Overview

This MIB provides the objects necessary for configuration, performance, and fault management of the IMA physical layer.

If the IMA protocol is used over DS1/E1 links, this MIB specification requires the implementation of the DS1 MIB defined in RFC 1406 [16] with a separate instance created for each DS1/E1 used by the IMA interface.

## A.3 IMA Terminology

The errors/defects/failures listed in this document pertain to the IMA functionality only.

### A.3.1 Error events

See Section 12.2.2.1 on page 77.

### A.3.2 Defects

See Section 12.2.2.1 on page 77.

### A.3.3 Performance Monitoring Parameters

See Section 12.2.2 on page 77.

### A.3.4 Failure Alarm States

See Section 12.2.3 on page 79.

## A.4 MIB-II and RFC 2233 Support

All SNMP agents that support the IMA protocol must implement MIB-II and the mandatory groups of RFC 2233 [19]. The purpose of IMA protocol is to present the illusion that a group of one or more links can be treated as a single physical interface of aggregate bandwidth. Real physical interfaces have entries in the MIB-II Interfaces have entries in the MIB-II Interfaces Table. To preserve a consistent management framework, it is highly desirable for each IMA Group to have entries in this table as well.

To identify an interface as belonging to an IMA Group, it must be tagged with an ifType constant: atm ima(107). This constant lets a network management application knows that additional information about the interface is available via the IMA MIB.

IMA Groups are created and destroyed by network management. So that agents can control IMA ifIndex allocation, IMA Group tables define an object imaGroupIfIndex that represents the ifIndex associated with the IMA interface. Both values are available through table entries:

- an imaGroupMappingTable entry converts the IMA Group ifIndex to an imaGroupIndex, and
- an imaGroupTable entry contains an imaGroupIfIndex object that identifies the IMA Group ifIndex.

The MIB-II interfaces associated with physical links exist independently of the IMA link definition. A physical link is designated to be an IMA link by the creation of a row in the IMA Link Table. The ifStackTable

The following depicts a typical use of the ifStackTable for atmIma(107) interfaces, in this case when stacked below an atm(37) interface and stacked above a number of ds1(18) interfaces representing individual DS1 or E1 physical IMA links:

```
+-------------------------------------+
|                 atm                 |
+-------------------------------------+
                  |
+-------------------------------------+
|               atmIma                |
+-------------------------------------+
    |          |                 |
+-------+  +-------+        +-------+
|  ds1  |  |  ds1  |  . . . |  ds1  |
+-------+  +-------+        +-------+
```

Note that:

- There is a one-to-one correspondence between a higher layer ATM layer interface and a lower layer IMA Group interface.
- The IMA Group may perform inverse multiplexing over multiple physical interfaces.

### A.4.1 Interpretations of Interface Table Entries for IMA Groups

The following items defined in the ifTable of RFC 2233 [19] have IMA specific definitions:

ifIndex IMA Interface index.

ifType atmIma(107)

ifSpeed The interface speed is represents by the following equation (where Non represents, in the transmit direction, the number of links which currently transmit cells passed from the ATM layer, and in the receive direction, the number of links which currently receive ATM layer cells to be passed to the ATM layer; where TRLCR is the TRL cell rate providing by the TRL in the transmit and receive direction respectively; M is the IMA frame length in cell units):

$$\text{ifSpeed} = N_{on} \times \text{TRLCR} \times \left(\frac{M-1}{M}\right) \times \left(\frac{2048}{2049}\right)$$

ifPhysAddress A zero-length octet string

ifOperStatus This reflects the state of the Group Traffic State Machine.

RFC 2233 [19] provides the full descriptions of the status values.

For conformance to RFC 2233 [19], the ifGeneralInformationGroup, ifStackGroup2 and ifCounterDiscountinuityGroup are the only mandatory groups.

### A.4.2 Interaction with ifAdminStatus

Setting the ifAdminStatus of the IMA Group interface to “down” or “testing” will cause the inhibiting condition which affects the Group State Machine.

Setting the ifAdminStatus of a link interface to ‘down’ or ‘testing’ will cause the inhibiting condition which affects the link’s Transmit and Receive State Machines.

## A.5 MIB Definition

```
IMA-MIB DEFINITIONS ::= BEGIN

IMPORTS
      MODULE-IDENTITY, OBJECT-TYPE, Integer32, Counter32, Gauge32,
      NOTIFICATION-TYPE, enterprises
        FROM SNMPv2-SMI
      MODULE-COMPLIANCE, OBJECT-GROUP, NOTIFICATION-GROUP
        FROM SNMPv2-CONF
      TEXTUAL-CONVENTION, DateAndTime, RowStatus
        FROM SNMPv2-TC
      InterfaceIndex, InterfaceIndexOrZero, ifIndex
        FROM IF-MIB;

atmfImaMib MODULE-IDENTITY
      LAST-UPDATED "9902111830Z"
      ORGANIZATION "The ATM Forum"
      CONTACT-INFO
        "ATM Forum
        World Headquarters
        2570 West El Camino Real
        Suite 304
        Mountain View, CA 94040-1313
        USA
        Phone: +1 415 949 6700
        Fax: +1 415 949 6705
        email: info@atmforum.com"
      DESCRIPTION
        "The MIB module for managing ATM Forum Inverse Multiplexing
        for ATM (IMA) interfaces."
      REVISION     "9902111830Z"
      DESCRIPTION
        "Updated and repaired version of the IMA-MIB released with the
        IMA v1.1 specification (af-phy-0086.001)."
      REVISION     "9701092245Z"
      DESCRIPTION
        "Initial incomplete version of the IMA-MIB as published in the
        IMA v1.0 specification (af-phy-0086.000)."
      ::= { atmfIma 1 }

-- The object identifier subtree for the IMA-MIB.
```

```
atmForum OBJECT IDENTIFIER ::= { enterprises 353 }
atmForumNetworkManagement OBJECT IDENTIFIER ::= { atmForum 5 }
atmfIma OBJECT IDENTIFIER ::= { atmForumNetworkManagement 7 }

atmfImaMibObjects OBJECT IDENTIFIER ::= { atmfImaMib 1 }
atmfImaMibTraps OBJECT IDENTIFIER ::= { atmfImaMib 2 }
atmfImaMibTrapPrefix OBJECT IDENTIFIER ::= { atmfImaMibTraps 0 }
atmfImaMibConformance OBJECT IDENTIFIER ::= { atmfImaMib 3 }

-- Textual conventions

MilliSeconds ::= TEXTUAL-CONVENTION
      STATUS      current
      DESCRIPTION
        "Time in milliseconds"
      SYNTAX      Integer32

ImaGroupState ::= TEXTUAL-CONVENTION
      STATUS      current
      DESCRIPTION
        "State of the IMA group."
      REFERENCE
        "ATM Forum IMA v1.1, Section 10.2.1 on page 55"
      SYNTAX      INTEGER {
        notConfigured(1),
        startUp(2),
        startUpAck(3),
        configAbortUnsupportedM(4),
        configAbortIncompatibleSymmetry(5),
        configAbortOther(6),
        insufficientLinks(7),
        blocked(8),
        operational(9),
        configAbortUnsupportedImaVersion(10) }

ImaGroupFailureStatus ::= TEXTUAL-CONVENTION
      STATUS      current
      DESCRIPTION
        "Failure reason of an IMA group."
      REFERENCE
        "ATM Forum IMA v1.1, Section 10.2.1, page 55"
      SYNTAX      INTEGER {
        noFailure(1), -- unit is up
        startUpNe(2),
        startUpFe(3),
        invalidMValueNe(4),
        invalidMValueFe(5),
        failedAssymetricNe(6),
        failedAssymetricFe(7),
        insufficientLinksNe(8),
        insufficientLinksFe(9),
        blockedNe(10),
        blockedFe(11),
        otherFailure(12),
        invalidImaVersionNe(13),
        invalidImaVersionFe(14) }

ImaAlarmStatus ::= TEXTUAL-CONVENTION
      STATUS      current
      DESCRIPTION
        "A qualification of the IMA trap which indicates if the
        condition causing the trap has been detected (declared)
        or is no longer present (cleared)."
      SYNTAX      INTEGER {
        cleared(1),
```

```
        declared(2) }

ImaAlarmType ::= TEXTUAL-CONVENTION
      STATUS      current
      DESCRIPTION
        "An identification of the event that caused the generation
        of the IMA trap."
      REFERENCE
        "ATM Forum IMA v1.1, Section 12.2.3 on page 79"
      SYNTAX      INTEGER {
        imaAlarmLinkLif(1),
        imaAlarmLinkLods(2),
        imaAlarmLinkRfi(3),
        imaAlarmLinkTxMisConnect(4),
        imaAlarmLinkRxMisConnect(5),
        imaAlarmLinkTxFault(6),
        imaAlarmLinkRxFault(7),
        imaAlarmLinkTxUnusableFe(8),
        imaAlarmLinkRxUnusableFe(9),
        imaAlarmGroupStartupFe(10),
        imaAlarmGroupCfgAbort(11),
        imaAlarmGroupCfgAbortFe(12),
        imaAlarmGroupInsuffLinks(13),
        imaAlarmGroupInsuffLinksFe(14),
        imaAlarmGroupBlockedFe(15),
        imaAlarmGroupTimingSynch(16) }

ImaGroupTxClkMode  ::= TEXTUAL-CONVENTION
      STATUS      current
      DESCRIPTION
        "Indicate the transmit clock mode of the IMA group.
        There are two possible modes: the Common Transmit
        Clock (CTC) and the Independent Transmit Clock (ITC).
        The CTC mode corresponds to the case when the transmit clock
        of all IMA links are derived from the same source.  The ITC
        configuration corresponds to the case where there is at least
        one IMA link whose transmit clock is derived from a source
        different than at least another link transmit clock."
      REFERENCE
        "ATM Forum IMA v1.1, Section 7 on page 38"
      SYNTAX      INTEGER {
        ctc(1),
        itc(2) }

ImaGroupSymmetry ::= TEXTUAL-CONVENTION
      STATUS      current
      DESCRIPTION
        "The group symmetry mode adjusted during the group start-up."
      REFERENCE
        "ATM Forum IMA v1.1, Section 5.2.2.7 on page 35"
      SYNTAX      INTEGER {
        symmetricOperation(1),
        asymmetricOperation(2),
        asymmetricConfiguration(3) }

ImaFrameLength ::= TEXTUAL-CONVENTION
      STATUS      current
      DESCRIPTION
        "Length of the IMA frames."
      REFERENCE
        "ATM Forum IMA v1.1, Section 5.2.2.4.2 on page 34"
      SYNTAX      INTEGER {
        m32(32),
        m64(64),
        m128(128),
```

```
        m256(256) }

ImaLinkState ::= TEXTUAL-CONVENTION
      STATUS      current
      DESCRIPTION
        "State of a link belonging to an IMA group."
      REFERENCE
        "ATM Forum IMA v1.1, Section 10.1.2 on page 48"
      SYNTAX      INTEGER {
        notInGroup(1),
        unusableNoGivenReason(2),
        unusableFault(3),
        unusableMisconnected(4),
        unusableInhibited(5),
        unusableFailed(6),
        usable(7),
        active(8) }

ImaLinkFailureStatus ::= TEXTUAL-CONVENTION
      STATUS      current
      DESCRIPTION
        "Local failure status of a link belonging to an IMA group."
      REFERENCE
        "ATM Forum IMA v1.1, Section 10.1.2 on page 48"
      SYNTAX      INTEGER {
        noFailure(1),
        imaLinkFailure(2),
        lifFailure(3),
        lodsFailure(4),
        misConnected(5),
        blocked(6),
        fault(7),
        farEndTxLinkUnusable(8),
        farEndRxLinkUnusable(9) }

ImaTestProcStatus ::= TEXTUAL-CONVENTION
      STATUS      current
      DESCRIPTION
        "States of the Test Pattern Procedure."
      REFERENCE
        "ATM Forum IMA v1.1, Section 13 on page 81"
      SYNTAX      INTEGER {
        disabled(1),
        operating(2),
        linkFail(3) }

--
-- The IMA Group subtree
--
-- The IMA Group subtree consists of the number of IMA groups and a
-- table of IMA groups.  Each entry in the table of IMA groups contains
-- information (configuration and status) specific to each group.
--

imaGroupNumber OBJECT-TYPE
      SYNTAX      INTEGER (0..2147483647)
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of IMA groups configured on this system."
      ::= { atmfImaMibObjects 1 }

imaGroupTable OBJECT-TYPE
      SYNTAX      SEQUENCE OF ImaGroupEntry
      MAX-ACCESS  not-accessible
```

```
      STATUS      current
      DESCRIPTION
        "The IMA Group Configuration table."
      ::= { atmfImaMibObjects 2 }

imaGroupEntry OBJECT-TYPE
      SYNTAX      ImaGroupEntry
      MAX-ACCESS  not-accessible
      STATUS      current
      DESCRIPTION
        "An entry in the IMA Group table."
      INDEX       { imaGroupIndex }
      ::= { imaGroupTable 1 }

ImaGroupEntry ::= SEQUENCE {
      imaGroupIndex               INTEGER (1..2147483647),
      imaGroupRowStatus           RowStatus,
      imaGroupIfIndex             InterfaceIndex,
      imaGroupNeState             ImaGroupState,
      imaGroupFeState             ImaGroupState,
      imaGroupFailureStatus       ImaGroupFailureStatus,
      imaGroupSymmetry            ImaGroupSymmetry,
      imaGroupMinNumTxLinks       INTEGER (1..32),
      imaGroupMinNumRxLinks       INTEGER (1..32),
      imaGroupNeTxClkMode         ImaGroupTxClkMode,
      imaGroupFeTxClkMode         ImaGroupTxClkMode,
      imaGroupTxTimingRefLink     InterfaceIndexOrZero,
      imaGroupRxTimingRefLink     InterfaceIndexOrZero,
      imaGroupLastChange          DateAndTime,
      imaGroupTxImaId             INTEGER (0..255),
      imaGroupRxImaId             INTEGER (0..255),
      imaGroupTxFrameLength       ImaFrameLength,
      imaGroupRxFrameLength       ImaFrameLength,
      imaGroupDiffDelayMax        MilliSeconds,
      imaGroupLeastDelayLink      InterfaceIndexOrZero,
      imaGroupDiffDelayMaxObs     MilliSeconds,
      imaGroupAlphaValue          INTEGER (1..2),
      imaGroupBetaValue           INTEGER (1..5),
      imaGroupGammaValue          INTEGER (1..5),
      imaGroupRunningSecs         Gauge32,
      imaGroupUnavailSecs         Counter32,
      imaGroupNeNumFailures       Counter32,
      imaGroupFeNumFailures       Counter32,
      imaGroupTxAvailCellRate     Gauge32,
      imaGroupRxAvailCellRate     Gauge32,
      imaGroupNumTxCfgLinks       Gauge32,
      imaGroupNumRxCfgLinks       Gauge32,
      imaGroupNumTxActLinks       Gauge32,
      imaGroupNumRxActLinks       Gauge32,
      imaGroupTestLinkIfIndex     InterfaceIndexOrZero,
      imaGroupTestPattern         INTEGER (-1..255),
      imaGroupTestProcStatus      ImaTestProcStatus,
      imaGroupValidIntervals      INTEGER (0..96),
      imaGroupInvalidIntervals    INTEGER (0..96),
      imaGroupTimeElapsed         INTEGER (0..899),
      imaGroupTxOamLabelValue     INTEGER (1..255),
      imaGroupRxOamLabelValue     INTEGER (0..255) }

imaGroupIndex OBJECT-TYPE
      SYNTAX      INTEGER (1..2147483647)
      MAX-ACCESS  not-accessible
      STATUS      current
      DESCRIPTION
        "A unique value for the IMA Group."
      ::= { imaGroupEntry 1 }
```

```
imaGroupRowStatus OBJECT-TYPE
      SYNTAX      RowStatus
      MAX-ACCESS  read-create
      STATUS      current
      DESCRIPTION
        "The imaGroupRowStatus object allows create, change, and delete
        operations on imaGroupTable entries.

        To create a new conceptual row (or instance) of the imaGroupTable,
        imaGroupRowStatus must be set to 'createAndWait' or 'createAndGo'.
        If settable, a successful set of the following objects must be
        performed before the imaGroupRowStatus of a new conceptual row can
        be set to 'active':

          imaGroupMinNumTxLinks
          imaGroupMinNumRxLinks
          imaGroupTxImaId

        Some objects in the imaGroupTable control settings which can only
        be established or changed at group start-up time.  These objects
        include:

          imaGroupTxImaId
          imaGroupSymmetry
          imaGroupTxFrameLength

        To change (modify) the imaGroupTxImaId object, the manager must
        first set imaGroupRowStatus to 'notInService'.  However, changes
        to the following two objects can be optionally allowed while the
        imaGroupRowStatus is 'active':

          imaGroupSymmetry
          imaGroupTxFrameLength

        These two objects can be changed when the imaGroupRowStatus is
        'active' in order to allow the far-end to recover from its
        Config-Aborted state without having to force the near-end Group
        State machine to go to the 'Not Configured' state.  Changing
        these object values after group start-up has completed causes a
        restart of the IMA group.

        Alternatively, as noted above, the agent implementation may
        simply require the imaGroupRowStatus object to first be set to
        'notInService' before allowing changes to either of these two
        objects.

        To remove (delete) an imaGroupTable entry from this table, set
        imaGroupRowStatus to 'destroy'.

        Setting the imaGroupRowStatus to 'active' has the effect of
        activating the Group Startup Procedure.  The Group Startup
        Procedure uses provisioned links that have imaLinkRowStatus set
        to 'active' and imaLinkGroupIndex set to the imaGroupIndex in
        this conceptual row.

        When the imaGroupRowStatus is not in 'active' state, the Group
        State machine is in its 'Not Configured' state."
      ::= { imaGroupEntry 2 }

imaGroupIfIndex OBJECT-TYPE
      SYNTAX      InterfaceIndex
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
```

```
        "This object identifies the logical interface number ('ifIndex')
        assigned to this IMA group, and is used to identify corresponding
        rows in the Interfaces MIB.

        Note that re-initialization of the management agent may cause
        a client's 'imaGroupIfIndex' to change."
      ::= { imaGroupEntry 3 }

imaGroupNeState OBJECT-TYPE
      SYNTAX      ImaGroupState
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The current operational state of the near-end IMA Group State
        Machine."
      REFERENCE
        "ATM Forum IMA v1.1, Section 10.2.1 on page 55"
      ::= { imaGroupEntry 4 }

imaGroupFeState OBJECT-TYPE
      SYNTAX      ImaGroupState
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The current operational state of the far-end IMA Group State
        Machine."
      REFERENCE
        "ATM Forum IMA v1.1, Section 10.2.1 on page 55"
      ::= { imaGroupEntry 5 }

imaGroupFailureStatus OBJECT-TYPE
      SYNTAX      ImaGroupFailureStatus
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The current failure status of the IMA group (the reason why
        the GTSM is in the down state)."
      REFERENCE
        "ATM Forum IMA v1.1, Section 10.2.1 on page 55"
      ::= { imaGroupEntry 6 }

imaGroupSymmetry OBJECT-TYPE
      SYNTAX      ImaGroupSymmetry
      MAX-ACCESS  read-create
      STATUS      current
      DESCRIPTION
        "Symmetry of the IMA group."
      REFERENCE
        "ATM Forum IMA v1.1, Section 5.2.2.7 on page 35"
      DEFVAL { symmetricOperation }
      ::= { imaGroupEntry 7 }

imaGroupMinNumTxLinks OBJECT-TYPE
      SYNTAX      INTEGER (1..32)
      MAX-ACCESS  read-create
      STATUS      current
      DESCRIPTION
        "Minimum number of transmit links required to be Active for
        the IMA group to be in the Operational state."
      REFERENCE
        "ATM Forum IMA v1.1, Section 10.2.1.1 on page 55"
      ::= { imaGroupEntry 8 }

imaGroupMinNumRxLinks OBJECT-TYPE
      SYNTAX      INTEGER (1..32)
```

```
      MAX-ACCESS  read-create
      STATUS      current
      DESCRIPTION
        "Minimum number of receive links required to be Active for
        the IMA group to be in the Operational state."
      REFERENCE
        "ATM Forum IMA v1.1, Section 10.2.1.1 on page 55"
      ::= { imaGroupEntry 9 }

imaGroupNeTxClkMode OBJECT-TYPE
      SYNTAX      ImaGroupTxClkMode
      MAX-ACCESS  read-create
      STATUS      current
      DESCRIPTION
        "Transmit clocking mode used by the near-end IMA group."
      REFERENCE
        "ATM Forum IMA v1.1, Section 7 on page 38"
      DEFVAL { ctc }
      ::= { imaGroupEntry 10 }

imaGroupFeTxClkMode OBJECT-TYPE
      SYNTAX      ImaGroupTxClkMode
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Transmit clocking mode used by the far-end IMA group."
      REFERENCE
        "ATM Forum IMA v1.1, Section 7 on page 38"
      ::= { imaGroupEntry 11 }

imaGroupTxTimingRefLink OBJECT-TYPE
      SYNTAX      InterfaceIndexOrZero
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The ifIndex of the transmit timing reference link to be
        used by the near-end for IMA data cell clock recovery from
        the ATM layer.  The distinguished value of zero may be used
        if no link has been configured in the IMA group, or if the
        transmit timing reference link has not yet been selected."
      REFERENCE
        "ATM Forum IMA v1.1, Section 8.1.1 on page 41"
      ::= { imaGroupEntry 12 }

imaGroupRxTimingRefLink OBJECT-TYPE
      SYNTAX      InterfaceIndexOrZero
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The ifIndex of the receive timing reference link to be
        used by near-end for IMA data cell clock recovery toward
        the ATM layer.  The distinguished value of zero may be used
        if no link has been configured in the IMA group, or if the
        receive timing reference link has not yet been detected."
      REFERENCE
        "ATM Forum IMA v1.1, Section 8.1.1 on page 41"
      ::= { imaGroupEntry 13 }

imaGroupLastChange OBJECT-TYPE
      SYNTAX      DateAndTime
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The time-of-day the IMA group last changed operational
        state (i.e., value of imaGroupNeState changed)."
```

```
      ::= { imaGroupEntry 14 }

imaGroupTxImaId OBJECT-TYPE
      SYNTAX      INTEGER (0..255)
      MAX-ACCESS  read-create
      STATUS      current
      DESCRIPTION
        "The IMA ID currently in use by the near-end IMA function."
      REFERENCE
        "ATM Forum IMA v1.1, Section 5.2.2.6 on page 35"
      ::= { imaGroupEntry 15 }

imaGroupRxImaId OBJECT-TYPE
      SYNTAX      INTEGER (0..255)
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The IMA ID currently in use by the far-end IMA function."
      REFERENCE
        "ATM Forum IMA v1.1, Section 5.2.2.6 on page 35"
      ::= { imaGroupEntry 16 }

imaGroupTxFrameLength OBJECT-TYPE
      SYNTAX      ImaFrameLength
      MAX-ACCESS  read-create
      STATUS      current
      DESCRIPTION
        "The frame length to be used by the IMA group in the transmit
        direction.  Can only be set when the IMA group is startup."
      REFERENCE
        "ATM Forum IMA v1.1, Section 5.2.2.4.2 on page 34"
      DEFVAL { m128 }
      ::= { imaGroupEntry 17 }

imaGroupRxFrameLength OBJECT-TYPE
      SYNTAX      ImaFrameLength
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Value of IMA frame length as received from remote IMA function."
      REFERENCE
        "ATM Forum IMA v1.1, Section 5.2.2.4.2 on page 34"
      ::= { imaGroupEntry 18 }

imaGroupDiffDelayMax OBJECT-TYPE
      SYNTAX      MilliSeconds
      MAX-ACCESS  read-create
      STATUS      current
      DESCRIPTION
        "The maximum number of milliseconds of differential delay among
        the links that will be tolerated on this interface."
      REFERENCE
        "ATM Forum IMA v1.1, Section 9.2 on page 45"
      DEFVAL { 25 }
      ::= { imaGroupEntry 19 }

imaGroupLeastDelayLink OBJECT-TYPE
      SYNTAX      InterfaceIndexOrZero
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The ifIndex of the link configured in the IMA group which has
        the smallest link propagation delay.  The distinguished value of
        zero may be used if no link has been configured in the IMA group,
        or if the link with the smallest link propagation delay has not
```

```
        yet been determined."
      REFERENCE
        "ATM Forum IMA v1.1, Section 9.2 on page 45"
      ::= { imaGroupEntry 20 }

imaGroupDiffDelayMaxObs OBJECT-TYPE
      SYNTAX      MilliSeconds
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The latest maximum differential delay observed (in milliseconds)
        between the links having the least and most link propagation delay,
        among the receive links that are currently configured in the IMA
        group."
      REFERENCE
        "ATM Forum IMA v1.1, Section 9.2 on page 45"
      ::= { imaGroupEntry 21 }

imaGroupAlphaValue OBJECT-TYPE
      SYNTAX      INTEGER (1..2)
      MAX-ACCESS  read-create
      STATUS      current
      DESCRIPTION
        "This indicates the 'alpha' value used to specify the number
        of consecutive invalid ICP cells to be detected before moving
        to the IMA Hunt state from the IMA Sync state."
      REFERENCE
        "ATM Forum IMA v1.1, Section 11 on page 68"
      DEFVAL { 2 }
      ::= { imaGroupEntry 22 }

imaGroupBetaValue OBJECT-TYPE
      SYNTAX      INTEGER (1..5)
      MAX-ACCESS  read-create
      STATUS      current
      DESCRIPTION
        "This indicates the 'beta' value used to specify the number
        of consecutive errored ICP cells to be detected before moving
        to the IMA Hunt state from the IMA Sync state."
      REFERENCE
        "ATM Forum IMA v1.1, Section 11 on page 68"
      DEFVAL { 2 }
      ::= { imaGroupEntry 23 }

imaGroupGammaValue OBJECT-TYPE
      SYNTAX      INTEGER (1..5)
      MAX-ACCESS  read-create
      STATUS      current
      DESCRIPTION
        "This indicates the 'gamma' value used to specify the number
        of consecutive valid ICP cells to be detected before moving
        to the IMA Sync state from the IMA PreSync state."
      REFERENCE
        "ATM Forum IMA v1.1, Section 11 on page 68"
      DEFVAL { 1 }
      ::= { imaGroupEntry 24 }

imaGroupRunningSecs OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The amount of time (in seconds) since this IMA group has
        been in the Operational state."
      REFERENCE
```

```
        "ATM Forum IMA v1.1, Section 10.2.1 on page 55"
      ::= { imaGroupEntry 25 }

imaGroupUnavailSecs OBJECT-TYPE
      SYNTAX      Counter32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Count of one second intervals where the IMA Group Traffic
        State Machine is Down."
      REFERENCE
        "ATM Forum IMA v1.1, Section 10.2.1 on page 55 and (R-136) in Section
        12.2.2.2 on page 77"
      ::= { imaGroupEntry 26 }

imaGroupNeNumFailures OBJECT-TYPE
      SYNTAX      Counter32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of times a near-end group failure (Config-Aborted,
        Insufficient-Links) has been reported since power-up or reboot."
      REFERENCE
        "ATM Forum IMA v1.1, (R-137) in Section 12.2.2.2 on page 77"
      ::= { imaGroupEntry 27 }

imaGroupFeNumFailures OBJECT-TYPE
      SYNTAX      Counter32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of times a far-end group failure (Config-Aborted-FE,
        Insufficient-Links-FE, Blocked-FE) has been reported since
        power-up or reboot.  This is an optional attribute."
      REFERENCE
        "ATM Forum IMA v1.1, (O-25) in Section 12.2.2.2 on page 77"
      ::= { imaGroupEntry 28 }

imaGroupTxAvailCellRate OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The current cell rate (truncated value in cells per second)
        provided by this IMA group in the transmit direction,
        considering all the transmit links in the Active state."
      ::= { imaGroupEntry 29 }

imaGroupRxAvailCellRate OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The current cell rate (truncated value in cells per second)
        provided by this IMA group in the receive direction,
        considering all the receive links in the Active state."
      ::= { imaGroupEntry 30 }

-- imaGroupNumTxCfgLinks is used by a network operator to tell how many
-- links are configured for transmit in the IMA group.

imaGroupNumTxCfgLinks OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
```

```
      DESCRIPTION
        "The number of links that are configured to transmit in this IMA
        group. This attribute overwrites the value of the
        imaGroupNumRxActLinks attribute when the IMA group is configured
        in the Symmetrical Configuration group symmetry mode."
      ::= { imaGroupEntry 31 }

-- imaGroupNumRxCfgLinks is used by a network operator to tell how many
-- links are configured for receive in the IMA group.

imaGroupNumRxCfgLinks OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of links that are configured to receive in this IMA
        group. This attribute is overwritten by the value of the
        imaGroupNumTxActLinks attribute when the IMA group is configured
        in the Symmetrical Configuration group symmetry mode."
      ::= { imaGroupEntry 32 }

-- imaGroupNumTxActLinks is used by a network operator to tell how many
-- links which are configured for transmit are also Active.

imaGroupNumTxActLinks OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of links which are configured to transmit and are
        currently Active in this IMA group."
      ::= { imaGroupEntry 33 }

-- imaGroupNumRxActLinks is used by a network operator to tell how many
-- links which are configured for receive are also Active.

imaGroupNumRxActLinks OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of links which are configured to receive and are
        currently Active in this IMA group."
      ::= { imaGroupEntry 34 }

--
-- Test Pattern Procedure control objects.  These objects are implemented
-- if the IMA implements the Test Pattern Procedure.  In this case all
-- test pattern procedure related objects must be implemented.  Specifically,
-- these objects are:
--
--   imaGroupTestLinkIfIndex
--   imaGroupTestPattern
--   imaGroupTestProcStatus
--   imaLinkRxTestPattern
--   imaLinkTestProcStatus
--

imaGroupTestLinkIfIndex OBJECT-TYPE
      SYNTAX      InterfaceIndexOrZero
      MAX-ACCESS  read-create
      STATUS      current
      DESCRIPTION
        "This object is used to designate an interface as the test link
        for use in the Test Pattern Procedure.  The distinguished value of
```

```
        zero specifies that the implementation may choose the Test Link,
        in which case, the implementation may also choose the value of
        'imaGroupTestPattern'.  The value zero may also be used if no link
        has yet been added to the group.

        Note that this value is NOT the same as the Tx LID value, but
        instead either identifies the ifIndex value of the test link to be
        used by the Test Pattern Procedure (i.e., the link whose LID value
        is inserted in the Tx LID field of the transmitted ICP cells),
        or identifies that the implementation may choose the test link (if
        the value is zero)."
      REFERENCE
        "ATM Forum IMA v1.1, Section 13 on page 81"
      DEFVAL { 0 }
      ::= { imaGroupEntry 35 }

imaGroupTestPattern OBJECT-TYPE
      SYNTAX      INTEGER (-1..255)
      MAX-ACCESS  read-create
      STATUS      current
      DESCRIPTION
        "The value of this object is used to specify the Tx Test Pattern
        in an IMA group loopback operation.  A value in the range 0 to
        255 designates a specific pattern.  The distinguished value of
        -1 specifies that the implementation may choose the value.  In
        this case, the implementation may also choose the value of
        'imaGroupTestLinkIfIndex'.

        It is recommended that the specific value 255 not be used for
        testing, since by (R-137) the IMA interface is required to
        transmit 0xFF (i.e., 255) when the incoming test command is
        inactive or the test link is not detected, and thus it cannot
        be established for certain whether 255 was received due to an
        actual loopback operation or due to the normal operation of an
        IMA that is not performing (or else cannot perform) the test
        pattern procedure."
      REFERENCE
        "ATM Forum IMA v1.1, Section 13 on page 81"
      DEFVAL { -1 }
      ::= { imaGroupEntry 36 }

imaGroupTestProcStatus OBJECT-TYPE
      SYNTAX      ImaTestProcStatus
      MAX-ACCESS  read-create
      STATUS      current
      DESCRIPTION
        "This object is used to enable or disable the
        Test Pattern Procedure, and to note whether at least one
        link failed the test.

        The test is started by setting operating(2) status.  If any
        link should fail the test, the IMA will set the status to
        linkFail(3).  The linkFail(3) state will persist until
        either the disabled(1) state is set or until no instance
        of imaLinkTestProcStatus has the value linkFail(3).

        Only the values disabled(1) and operating(2) may be written.
        Writing the operating(2) value will not cause clearing of
        the linkFail(3) state."
      REFERENCE
        "ATM Forum IMA v1.1, Section 13 on page 81"
      DEFVAL { disabled }
      ::= { imaGroupEntry 37 }

--
```

```
-- Objects for use with the IMA Group Current Table, the IMA Group
-- Interval Table, and the IMA Group Total Table.
--
-- Implementation of these objects is optional, dependent on whether
-- the tables mentioned above are implemented.
--

imaGroupValidIntervals OBJECT-TYPE
      SYNTAX      INTEGER (0..96)
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of previous 15 minute intervals for which valid data
        was collected.  The value will be 96 unless the IMA group table
        entry was created within the last 24 hours, in which case the value
        will be the number of complete 15 minute intervals since the IMA
        group table entry was created.  In the case where the agent is a
        proxy, it is possible that some intervals are unavailable.  In this
        case, this value is the maximum interval number for which valid
        data is available.  This attribute is only mandatory when the IMA
        Group Interval Statistics and/or IMA Group Total Statistics objects
        are implemented."
      REFERENCE
        "ATM Forum IMA v1.1, (O-26) in Section 12.2.2.2 on page 77"
      ::= { imaGroupEntry 38 }

imaGroupInvalidIntervals OBJECT-TYPE
      SYNTAX      INTEGER (0..96)
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of intervals for which no valid data is available.
        This attribute is only mandatory when the IMA Group Interval
        Statistics and/or IMA Group Total Statistics objects are
        implemented."
      REFERENCE
        "ATM Forum IMA v1.1, (O-26) in Section 12.2.2.2 on page 77"
      ::= { imaGroupEntry 39 }

imaGroupTimeElapsed OBJECT-TYPE
      SYNTAX      INTEGER (0..899)
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of seconds that have elapsed since the beginning of
        the current measurement period.  This attribute is only mandatory
        when the IMA Group Current Statistics are implemented."
      REFERENCE
        "ATM Forum IMA v1.1, (O-26) in Section 12.2.2.2 on page 77"
      ::= { imaGroupEntry 40 }

--
-- Objects to report the IMA OAM Label values transmitted and
-- received by the IMA group.
--

imaGroupTxOamLabelValue OBJECT-TYPE
      SYNTAX      INTEGER (1..255)
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "IMA OAM Label value transmitted by the NE IMA unit."
      REFERENCE
        "ATM Forum IMA v1.1, Section 5.2.2.3 on page 32"
      ::= { imaGroupEntry 41 }
```

```
imaGroupRxOamLabelValue OBJECT-TYPE
      SYNTAX      INTEGER (0..255)
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "IMA OAM Label value transmitted by the FE IMA unit.  The value 0
        likely means that the IMA unit has not received an OAM Label
        from the FE IMA unit at this time."
      REFERENCE
        "ATM Forum IMA v1.1, Section 5.2.2.3 on page 32"
      ::= { imaGroupEntry 42 }

--
-- The IMA Group Mapping Table subtree
--
-- The IMA Group Mapping Table subtree consists of a table of mappings
-- from 'ifIndex' values of IMA groups to their 'imaGroupIndex' values.
-- This table allows the Unit Management to perform easy look-ups (no
-- searches and sorts).
--
-- Note that the Group Index is different than the ifIndex.
--

imaGroupMappingTable OBJECT-TYPE
      SYNTAX      SEQUENCE OF ImaGroupMappingEntry
      MAX-ACCESS  not-accessible
      STATUS      current
      DESCRIPTION
        "A table mapping the 'ifIndex' values of 'imaGroupIfIndex'
        to the 'imaGroupIndex' values of the corresponding IMA group."
      ::= { atmfImaMibObjects 3 }

imaGroupMappingEntry OBJECT-TYPE
      SYNTAX      ImaGroupMappingEntry
      MAX-ACCESS  not-accessible
      STATUS      current
      DESCRIPTION
        "Each row describes one ifIndex to imaGroupIndex mapping."
      INDEX       { ifIndex }
      ::= { imaGroupMappingTable 1 }

ImaGroupMappingEntry ::= SEQUENCE {
      imaGroupMappingIndex    Integer32 }

imaGroupMappingIndex OBJECT-TYPE
      SYNTAX      Integer32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The imaGroupIndex of the IMA Group which implements the
        specified interface."
      ::= { imaGroupMappingEntry 1 }

--
-- The IMA Link subtree
--
-- The IMA Link subtree consists of a table of IMA links.  Each entry
-- in the table contains status information about a link which is part
-- of an IMA group, and also contains a configuration object to select
-- to which IMA group the link belongs.
--

imaLinkTable OBJECT-TYPE
      SYNTAX      SEQUENCE OF ImaLinkEntry
```

```
      MAX-ACCESS  not-accessible
      STATUS      current
      DESCRIPTION
        "The IMA group Link Status and Configuration table."
      ::= { atmfImaMibObjects 4 }

imaLinkEntry OBJECT-TYPE
      SYNTAX      ImaLinkEntry
      MAX-ACCESS  not-accessible
      STATUS      current
      DESCRIPTION
        "An entry in the IMA Group Link table."
      INDEX       { imaLinkIfIndex }
      ::= { imaLinkTable 1 }

ImaLinkEntry ::= SEQUENCE {
      imaLinkIfIndex              InterfaceIndex,
      imaLinkRowStatus            RowStatus,
      imaLinkGroupIndex           Integer32,
      imaLinkNeTxState            ImaLinkState,
      imaLinkNeRxState            ImaLinkState,
      imaLinkFeTxState            ImaLinkState,
      imaLinkFeRxState            ImaLinkState,
      imaLinkNeRxFailureStatus    ImaLinkFailureStatus,
      imaLinkFeRxFailureStatus    ImaLinkFailureStatus,
      imaLinkTxLid                INTEGER (0..31),
      imaLinkRxLid                INTEGER (0..31),
      imaLinkRelDelay             MilliSeconds,
      imaLinkImaViolations        Counter32,
      imaLinkOifAnomalies         Counter32,
      imaLinkNeSevErroredSecs     Counter32,
      imaLinkFeSevErroredSecs     Counter32,
      imaLinkNeUnavailSecs        Counter32,
      imaLinkFeUnavailSecs        Counter32,
      imaLinkNeTxUnusableSecs     Counter32,
      imaLinkNeRxUnusableSecs     Counter32,
      imaLinkFeTxUnusableSecs     Counter32,
      imaLinkFeRxUnusableSecs     Counter32,
      imaLinkNeTxNumFailures      Counter32,
      imaLinkNeRxNumFailures      Counter32,
      imaLinkFeTxNumFailures      Counter32,
      imaLinkFeRxNumFailures      Counter32,
      imaLinkTxStuffs             Counter32,
      imaLinkRxStuffs             Counter32,
      imaLinkRxTestPattern        INTEGER (0..255),
      imaLinkTestProcStatus       ImaTestProcStatus,
      imaLinkValidIntervals       INTEGER (0..96),
      imaLinkInvalidIntervals     INTEGER (0..96),
      imaLinkTimeElapsed          INTEGER (0..899) }

imaLinkIfIndex OBJECT-TYPE
      SYNTAX      InterfaceIndex
      MAX-ACCESS  not-accessible
      STATUS      current
      DESCRIPTION
        "This corresponds to the 'ifIndex' of the MIB-II interface
        on which this link is established.  This object also
        corresponds to the logical number ('ifIndex') assigned to
        this IMA link."
      ::= { imaLinkEntry 1 }

imaLinkRowStatus OBJECT-TYPE
      SYNTAX      RowStatus
      MAX-ACCESS  read-create
      STATUS      current
```

```
      DESCRIPTION
        "The imaLinkRowStatus object allows create, change, and delete
        operations on imaLinkTable entries.

        To create a new conceptual row (or instance) of the imaLinkTable,
        imaLinkRowStatus must be set to 'createAndWait' or 'createAndGo'.
        A successful set of the imaLinkGroupIndex object must be performed
        before the imaLinkRowStatus of a new conceptual row can be set to
        'active'.

        To change (modify) the imaLinkGroupIndex in an imaLinkTable entry,
        the imaLinkRowStatus object must first be set to 'notInService'.
        Only then can this object in the conceptual row be modified.
        This is due to the fact that the imaLinkGroupIndex object provides
        the association between a physical IMA link and the IMA group to
        which it belongs, and setting the imaLinkGroupIndex object to a
        different value has the effect of changing the association between
        a physical IMA link and an IMA group.  To place the link 'in group',
        the imaLinkRowStatus object is set to 'active'.  While the row is
        not in 'active' state, both the Transmit and Receive IMA link state
        machines are in the 'Not In Group' state.

        To remove (delete) an imaLinkTable entry from this table, set
        this object to 'destroy'."
      ::= { imaLinkEntry 2 }

imaLinkGroupIndex OBJECT-TYPE
      SYNTAX      Integer32
      MAX-ACCESS  read-create
      STATUS      current
      DESCRIPTION
        "The value which identifies the IMA group (imaGroupIndex)
        of which this link is a member."
      ::= { imaLinkEntry 3 }

imaLinkNeTxState OBJECT-TYPE
      SYNTAX      ImaLinkState
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The current state of the near-end transmit link."
      REFERENCE
        "ATM Forum IMA v1.1, Section 10.1.2 on page 48"
      ::= { imaLinkEntry 4 }

imaLinkNeRxState OBJECT-TYPE
      SYNTAX      ImaLinkState
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The current state of the near-end receive link."
      REFERENCE
        "ATM Forum IMA v1.1, Section 10.1.2 on page 48"
      ::= { imaLinkEntry 5 }

imaLinkFeTxState OBJECT-TYPE
      SYNTAX      ImaLinkState
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The current state of the far-end transmit link as reported
        via ICP cells."
      REFERENCE
        "ATM Forum IMA v1.1, Section 10.1.2 on page 48"
      ::= { imaLinkEntry 6 }
```

```
imaLinkFeRxState OBJECT-TYPE
      SYNTAX      ImaLinkState
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The current state of the far-end receive link as reported
        via ICP cells."
      REFERENCE
        "ATM Forum IMA v1.1, Section 10.1.2 on page 48"
      ::= { imaLinkEntry 7 }

imaLinkNeRxFailureStatus OBJECT-TYPE
      SYNTAX      ImaLinkFailureStatus
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The current link failure status of the near-end receive link."
      REFERENCE
        "ATM Forum IMA v1.1, Section 10.1.2 on page 48"
      ::= { imaLinkEntry 8 }

imaLinkFeRxFailureStatus OBJECT-TYPE
      SYNTAX      ImaLinkFailureStatus
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The current link failure status of the far-end receive link
        as reported via ICP cells."
      REFERENCE
        "ATM Forum IMA v1.1, Section 10.1.2 on page 48"
      ::= { imaLinkEntry 9 }

imaLinkTxLid OBJECT-TYPE
      SYNTAX      INTEGER (0..31)
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The outgoing LID used currently on the link by the local end.
        This value has meaning only if the link belongs to an IMA group."
      REFERENCE
        "ATM Forum IMA v1.1, Section 5.2.2.1 on page 26"
      ::= { imaLinkEntry 10 }

imaLinkRxLid OBJECT-TYPE
      SYNTAX      INTEGER (0..31)
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The incoming LID used currently on the link by the remote
        end as reported via ICP cells.  This value has meaning only
        if the link belongs to an IMA group."
      REFERENCE
        "ATM Forum IMA v1.1, Section 5.2.2.1 on page 26"
      ::= { imaLinkEntry 11 }

imaLinkRelDelay OBJECT-TYPE
      SYNTAX      MilliSeconds
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The latest measured delay on this link relative to the link, in
        the same IMA group, with the least delay."
      REFERENCE
        "ATM Forum IMA v1.1, Section 9.2 on page 45"
```

```
      ::= { imaLinkEntry 12 }

imaLinkImaViolations OBJECT-TYPE
      SYNTAX      Counter32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "ICP violations: count of errored, invalid or missing ICP cells,
        except during SES-IMA or UAS-IMA conditions."
      REFERENCE
        "ATM Forum IMA v1.1, (R-125) in Section 12.2.2.2 on page 77"
      ::= { imaLinkEntry 13 }

imaLinkOifAnomalies OBJECT-TYPE
      SYNTAX      Counter32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of OIF anomalies, except during SES-IMA or UAS-IMA
        conditions, at the near-end.  This is an optional attribute."
      REFERENCE
        "ATM Forum IMA v1.1, (O-20) in Section 12.2.2.2 on page 77"
      ::= { imaLinkEntry 14 }

imaLinkNeSevErroredSecs OBJECT-TYPE
      SYNTAX      Counter32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Count of one second intervals containing >= 30% of the ICP cells
        counted as IV-IMAs, or one or more link defects (e.g., LOS, OOF/LOF,
        AIS, or LCD), LIF defects, or LODS defects, except during UAS-IMA
        condition."
      REFERENCE
        "ATM Forum IMA v1.1, (R-126) in Section 12.2.2.2 on page 77"
      ::= { imaLinkEntry 15 }

imaLinkFeSevErroredSecs OBJECT-TYPE
      SYNTAX      Counter32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Count of one second intervals containing one or more RDI-IMA
        defects, except during UAS-IMA-FE condition."
      REFERENCE
        "ATM Forum IMA v1.1, (R-127) in Section 12.2.2.2 on page 77"
      ::= { imaLinkEntry 16 }

imaLinkNeUnavailSecs OBJECT-TYPE
      SYNTAX      Counter32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Count of unavailable seconds at near-end: unavailability begins
        at the onset of 10 contiguous SES-IMA and ends at the onset
        of 10 contiguous seconds with no SES-IMA."
      REFERENCE
        "ATM Forum IMA v1.1, (R-128) in Section 12.2.2.2 on page 77"
      ::= { imaLinkEntry 17 }

imaLinkFeUnavailSecs OBJECT-TYPE
      SYNTAX      Counter32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
```

```
        "Count of unavailable seconds at far-end: unavailability begins
        at the onset of 10 contiguous SES-IMA-FE and ends at the onset of
        10 contiguous seconds with no SES-IMA-FE."
      REFERENCE
        "ATM Forum IMA v1.1, (R-129) in Section 12.2.2.2 on page 77"
      ::= { imaLinkEntry 18 }

imaLinkNeTxUnusableSecs OBJECT-TYPE
      SYNTAX      Counter32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Tx Unusable seconds: count of Tx Unusable seconds at the near-end
        Tx LSM."
      REFERENCE
        "ATM Forum IMA v1.1, (R-130) in Section 12.2.2.2 on page 77"
      ::= { imaLinkEntry 19 }

imaLinkNeRxUnusableSecs OBJECT-TYPE
      SYNTAX      Counter32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Rx Unusable seconds: count of Rx Unusable seconds at the near-end
        Rx LSM."
      REFERENCE
        "ATM Forum IMA v1.1, (R-131) in Section 12.2.2.2 on page 77"
      ::= { imaLinkEntry 20 }

imaLinkFeTxUnusableSecs OBJECT-TYPE
      SYNTAX      Counter32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Tx Unusable seconds at far-end: count of seconds with Tx Unusable
        indications from the far-end Tx LSM."
      REFERENCE
        "ATM Forum IMA v1.1, (R-132) in Section 12.2.2.2 on page 77"
      ::= { imaLinkEntry 21 }

imaLinkFeRxUnusableSecs OBJECT-TYPE
      SYNTAX      Counter32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Rx Unusable seconds at far-end: count of seconds with Rx Unusable
        indications from the far-end Rx LSM."
      REFERENCE
        "ATM Forum IMA v1.1, (R-133) in Section 12.2.2.2 on page 77"
      ::= { imaLinkEntry 22 }

imaLinkNeTxNumFailures OBJECT-TYPE
      SYNTAX      Counter32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of times a near-end transmit failure alarm condition
        has been entered on this link (i.e., some form of implementation
        specific transmit fault)."
      REFERENCE
        "ATM Forum IMA v1.1, (R-134) in Section 12.2.2.2 on page 77"
      ::= { imaLinkEntry 23 }

imaLinkNeRxNumFailures OBJECT-TYPE
      SYNTAX      Counter32
```

```
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of times a near-end receive failure alarm condition
        has been entered on this link (i.e., LIF, LODS,
        RFI-IMA, Mis-Connected or some form of implementation specific receive
        fault)."
      REFERENCE
        "ATM Forum IMA v1.1, (R-135) in Section 12.2.2.2 on page 77"
      ::= { imaLinkEntry 24 }

imaLinkFeTxNumFailures OBJECT-TYPE
      SYNTAX      Counter32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of times a far-end transmit failure alarm condition
        has been entered on this link (i.e., Tx-Unusable-FE).  This is an
        optional attribute."
      REFERENCE
        "ATM Forum IMA v1.1, (O-21) in Section 12.2.2.2 on page 77"
      ::= { imaLinkEntry 25 }

imaLinkFeRxNumFailures OBJECT-TYPE
      SYNTAX      Counter32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of times a far-end receive failure alarm condition
        has been entered on this link (i.e., Rx-Unusable-FE).  This is an
        optional attribute."
      REFERENCE
        "ATM Forum IMA v1.1, (O-22) in Section 12.2.2.2 on page 77"
      ::= { imaLinkEntry 26 }

imaLinkTxStuffs OBJECT-TYPE
      SYNTAX      Counter32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Count of stuff events inserted in the transmit direction.
        This is an optional attribute."
      REFERENCE
        "ATM Forum IMA v1.1, (O-23) in Section 12.2.2.2 on page 77"
      ::= { imaLinkEntry 27 }

imaLinkRxStuffs OBJECT-TYPE
      SYNTAX      Counter32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Count of stuff events detected in the receive direction.
        This is an optional attribute."
      REFERENCE
        "ATM Forum IMA v1.1, (O-24) in Section 12.2.2.2 on page 77"
      ::= { imaLinkEntry 28 }

--
-- Test Pattern Procedure control objects.  These objects are implemented
-- if the IMA implements the Test Pattern Procedure.  In this case all
-- test pattern procedure related objects must be implemented.  Specifically,
-- these objects are:
--
--   imaGroupTestLinkIfIndex
--   imaGroupTestPattern
```

```
--   imaGroupTestProcStatus
--   imaLinkRxTestPattern
--   imaLinkTestProcStatus
--

imaLinkRxTestPattern OBJECT-TYPE
      SYNTAX      INTEGER (0..255)
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "This object identifies the test pattern received in the
        ICP Cell (octet 17) on the link during the IMA Test Pattern
        Procedure.  This value may then be compared to the transmitted
        test pattern."
      ::= { imaLinkEntry 29 }

imaLinkTestProcStatus OBJECT-TYPE
      SYNTAX      ImaTestProcStatus
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "This value indicates the current state of the Test Pattern
        Procedure.  If the value is disabled(1), the test is not
        running.  A value of operating(2) means the test is running
        and no error has been found on this interface.  A value of
        linkFail(3) means an error has been detected on this link
        during the test.

        Once an error is detected, the linkFail(3) value is latched until
        either this object is read or until the imaGroupTestProcStatus
        is moved to disabled(1).  Once read, if the error no longer
        persists, a subsequent read will report the value operating(2)."
      ::= { imaLinkEntry 30 }

--
-- Objects for use with the IMA Link Current Table, the IMA Link
-- Interval Table, and the IMA Link Total Table.
--
-- Implementation of these objects is optional, dependent on whether
-- the tables mentioned above are implemented.
--

imaLinkValidIntervals OBJECT-TYPE
      SYNTAX      INTEGER (0..96)
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of previous 15 minute intervals for which valid data
        was collected.  The value will be 96 unless the IMA group table
        entry was created within the last 24 hours, in which case the value
        will be the number of complete 15 minute intervals since the IMA
        group table entry was created.  In the case where the agent is a
        proxy, it is possible that some intervals are unavailable.  In this
        case, this value is the maximum interval number for which valid
        data is available.  This attribute is only mandatory when the IMA
        Link Interval Statistics and/or IMA Link Total Statistics objects
        are implemented."
      REFERENCE
        "ATM Forum IMA v1.1, (O-26) in Section 12.2.2.2 on page 77"
      ::= { imaLinkEntry 31 }

imaLinkInvalidIntervals OBJECT-TYPE
      SYNTAX      INTEGER (0..96)
      MAX-ACCESS  read-only
      STATUS      current
```

```
      DESCRIPTION
        "The number of intervals for which no valid data is available.
        This attribute is only mandatory when the IMA Link Interval
        Statistics and/or IMA Link Total Statistics objects are
        implemented."
      REFERENCE
        "ATM Forum IMA v1.1, (O-26) in Section 12.2.2.2
         on page 77"
      ::= { imaLinkEntry 32 }

imaLinkTimeElapsed OBJECT-TYPE
      SYNTAX      INTEGER (0..899)
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of seconds that have elapsed since the beginning of
        the current measurement period.  This attribute is only mandatory
        when the IMA Link Current Statistics are implemented."
      REFERENCE
        "ATM Forum IMA v1.1, (O-26) in Section 12.2.2.2
         on page 77"
      ::= { imaLinkEntry 33 }

--
-- IMA Failure Alarms
--
-- Implementation of the imaFailureAlarm Trap is optional.
--

imaAlarmStatus OBJECT-TYPE
      SYNTAX      ImaAlarmStatus
      MAX-ACCESS  accessible-for-notify
      STATUS      current
      DESCRIPTION
        "Status of the IMA alarm."
       ::= { atmfImaMibObjects 5 }

imaAlarmType OBJECT-TYPE
      SYNTAX      ImaAlarmType
      MAX-ACCESS  accessible-for-notify
      STATUS      current
      DESCRIPTION
        "The Type of IMA alarm declared or cleared.  The value of
        ImaAlarmType identifies the type of alarm according to the
        definitions in the IMA specification."
      REFERENCE
        "ATM Forum IMA v1.1, Section 12.2.3 on page 79"
       ::= { atmfImaMibObjects 6 }

imaFailureAlarm NOTIFICATION-TYPE
      OBJECTS {
        ifIndex,
        imaAlarmStatus,
        imaAlarmType }
      STATUS      current
      DESCRIPTION
        "The imaFailureAlarm provides a method for an agent implementing IMA
        to notify an NMS of an alarm condition."
      REFERENCE
        "ATM Forum IMA v1.1, Section 12.2.3 on page 79"
      ::= { atmfImaMibTrapPrefix 1 }

--
-- The IMA Group Current Statistics subtree
--
```

```
-- The IMA Group Current Statistics subtree consists of a single table:
-- the IMA Group Current Table.  This table contains various statistics
-- collected by each IMA group for the current 15 minute interval.
--
-- Implementation of IMA Group Current Table is optional.
--

imaGroupCurrentTable OBJECT-TYPE
      SYNTAX      SEQUENCE OF ImaGroupCurrentEntry
      MAX-ACCESS  not-accessible
      STATUS      current
      DESCRIPTION
        "The IMA Group Current table."
      ::= { atmfImaMibObjects 7 }

imaGroupCurrentEntry OBJECT-TYPE
      SYNTAX      ImaGroupCurrentEntry
      MAX-ACCESS  not-accessible
      STATUS      current
      DESCRIPTION
        "An entry in the IMA Group Current table."
      INDEX       { imaGroupIndex }
      ::= { imaGroupCurrentTable 1 }

ImaGroupCurrentEntry ::= SEQUENCE {
      imaGroupCurrentUnavailSecs     Gauge32,
      imaGroupCurrentNeNumFailures   Gauge32,
      imaGroupCurrentFeNumFailures   Gauge32 }

imaGroupCurrentUnavailSecs OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Count of one second intervals where the IMA Group Traffic
        State Machine is Down in the current 15 minutes interval."
      REFERENCE
        "ATM Forum IMA v1.1, Section 10.2.1 on page 55, (R-136) and
        (O-26) in Section 12.2.2.2 on page 77"
      ::= { imaGroupCurrentEntry 1 }

imaGroupCurrentNeNumFailures OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of times a near-end group failure (Config-Aborted,
        Insufficient-Links) has been reported in the current 15
        minutes interval."
      REFERENCE
        "ATM Forum IMA v1.1, (R-137) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaGroupCurrentEntry 2 }

imaGroupCurrentFeNumFailures OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of times a far-end group failure (Config-Aborted-FE,
        Insufficient-Links-FE, Blocked-FE) has been reported in the
        current 15 minutes interval.  This is an optional attribute."
      REFERENCE
        "ATM Forum IMA v1.1, (O-25) and (O-26) in Section 12.2.2.2
        on page 77"
```

```
      ::= { imaGroupCurrentEntry 3 }

--
-- The IMA Group Interval Statistics subtree
--
-- The IMA Group Interval Statistics subtree consists of a single table:
-- the IMA Group Interval Table.  This table contains various statistics
-- collected by each IMA group over the previous 24 hours of operation.
-- The past 24 hours are broken into 96 completed 15 minute intervals.
--
-- Implementation of IMA Group Interval Table is optional.
--

imaGroupIntervalTable OBJECT-TYPE
      SYNTAX      SEQUENCE OF ImaGroupIntervalEntry
      MAX-ACCESS  not-accessible
      STATUS      current
      DESCRIPTION
        "The IMA Group Interval table."
      ::= { atmfImaMibObjects 8 }

imaGroupIntervalEntry OBJECT-TYPE
      SYNTAX      ImaGroupIntervalEntry
      MAX-ACCESS  not-accessible
      STATUS      current
      DESCRIPTION
        "An entry in the IMA Group Interval table."
      INDEX       { imaGroupIndex, imaGroupIntervalNumber }
      ::= { imaGroupIntervalTable 1 }

ImaGroupIntervalEntry ::= SEQUENCE {
      imaGroupIntervalNumber          INTEGER (1..96),
      imaGroupIntervalUnavailSecs     Gauge32,
      imaGroupIntervalNeNumFailures   Gauge32,
      imaGroupIntervalFeNumFailures   Gauge32 }

imaGroupIntervalNumber OBJECT-TYPE
      SYNTAX      INTEGER (1..96)
      MAX-ACCESS  not-accessible
      STATUS      current
      DESCRIPTION
        "A number between 1 and 96, where 1 is the most
         recently completed 15 minute interval and 96 is the least
         recently completed 15 minutes interval (assuming that all
         96 intervals are valid)."
      ::= { imaGroupIntervalEntry 1 }

imaGroupIntervalUnavailSecs OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Count of one second intervals where the IMA Group Traffic
        State Machine is Down in one of the previous 96, individual 15
        minute, intervals."
      REFERENCE
        "ATM Forum IMA v1.1, Section 10.2.1 on page 55, (R-136) and
        (O-26) in Section 12.2.2.2 on page 77"
      ::= { imaGroupIntervalEntry 2 }

imaGroupIntervalNeNumFailures OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
```

```
        "The number of times a near-end group failure (Config-Aborted,
        Insufficient-Links) has been reported in one of the previous
        96, individual 15 minute, intervals."
      REFERENCE
        "ATM Forum IMA v1.1, (R-137) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaGroupIntervalEntry 3 }

imaGroupIntervalFeNumFailures OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of times a far-end group failure (Config-Aborted-FE,
        Insufficient-Links-FE, Blocked-FE) has been reported in one of
        the previous 96, individual 15 minute, intervals.  This is an
        optional attribute."
      REFERENCE
        "ATM Forum IMA v1.1, (O-25) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaGroupIntervalEntry 4 }

--
-- The IMA Group Total Statistics subtree
--
-- The IMA Group Total Statistics subtree consists of a single table:
-- the IMA Group Total Table.  This table contains the cumulative sum
-- of the various statistics collected by each IMA group for the 24 hour
-- period preceding the current interval.
--
-- Implementation of IMA Group Total Table is optional.
--

imaGroupTotalTable OBJECT-TYPE
      SYNTAX      SEQUENCE OF ImaGroupTotalEntry
      MAX-ACCESS  not-accessible
      STATUS      current
      DESCRIPTION
        "The IMA Group Total table."
      ::= { atmfImaMibObjects 9 }

imaGroupTotalEntry OBJECT-TYPE
      SYNTAX      ImaGroupTotalEntry
      MAX-ACCESS  not-accessible
      STATUS      current
      DESCRIPTION
        "An entry in the IMA Group Total table."
      INDEX       { imaGroupIndex }
      ::= { imaGroupTotalTable 1 }

ImaGroupTotalEntry ::= SEQUENCE {
      imaGroupTotalUnavailSecs     Gauge32,
      imaGroupTotalNeNumFailures   Gauge32,
      imaGroupTotalFeNumFailures   Gauge32 }

imaGroupTotalUnavailSecs OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Count of one second intervals where the IMA Group Traffic
        State Machine is Down in the previous 24 hour interval.
        Invalid 15 minute intervals count as 0."
      REFERENCE
        "ATM Forum IMA v1.1, Section 10.2.1 on page 55, (R-136) and
```

```
        (O-27) in Section 12.2.2.2 on page 77"
      ::= { imaGroupTotalEntry 1 }

imaGroupTotalNeNumFailures OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of times a near-end group failure (Config-Aborted,
        Insufficient-Links) has been reported in the previous 24 hour
        interval.  Invalid 15 minute intervals count as 0."
      REFERENCE
        "ATM Forum IMA v1.1, (R-137) and (O-27) in Section 12.2.2.2
        on page 77"
      ::= { imaGroupTotalEntry 2 }

imaGroupTotalFeNumFailures OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of times a far-end group failure (Config-Aborted-FE,
        Insufficient-Links-FE, Blocked-FE) has been reported in the
        previous 24 hour interval.  Invalid 15 minute intervals count
        as 0.  This is an optional attribute."
      REFERENCE
        "ATM Forum IMA v1.1, (O-25) and (O-27) in Section 12.2.2.2
        on page 77"
      ::= { imaGroupTotalEntry 3 }

--
-- The IMA Link Current Statistics subtree
--
-- The IMA Link Current Statistics subtree consists of a single table:
-- the IMA Link Current Table.  This table contains various statistics
-- collected by each IMA link for the current 15 minute interval.
--
-- Implementation of IMA Link Current Table is optional.
--

imaLinkCurrentTable OBJECT-TYPE
      SYNTAX      SEQUENCE OF ImaLinkCurrentEntry
      MAX-ACCESS  not-accessible
      STATUS      current
      DESCRIPTION
        "The IMA Link Current table."
      ::= { atmfImaMibObjects 10 }

imaLinkCurrentEntry OBJECT-TYPE
      SYNTAX      ImaLinkCurrentEntry
      MAX-ACCESS  not-accessible
      STATUS      current
      DESCRIPTION
        "An entry in the IMA Link Current table."
      INDEX       { ifIndex }
      ::= { imaLinkCurrentTable 1 }

ImaLinkCurrentEntry ::= SEQUENCE {
      imaLinkCurrentImaViolations     Gauge32,
      imaLinkCurrentOifAnomalies      Gauge32,
      imaLinkCurrentNeSevErroredSecs  Gauge32,
      imaLinkCurrentFeSevErroredSecs  Gauge32,
      imaLinkCurrentNeUnavailSecs     Gauge32,
      imaLinkCurrentFeUnavailSecs     Gauge32,
      imaLinkCurrentNeTxUnusableSecs  Gauge32,
```

```
      imaLinkCurrentNeRxUnusableSecs  Gauge32,
      imaLinkCurrentFeTxUnusableSecs  Gauge32,
      imaLinkCurrentFeRxUnusableSecs  Gauge32,
      imaLinkCurrentNeTxNumFailures   Gauge32,
      imaLinkCurrentNeRxNumFailures   Gauge32,
      imaLinkCurrentFeTxNumFailures   Gauge32,
      imaLinkCurrentFeRxNumFailures   Gauge32,
      imaLinkCurrentTxStuffs          Gauge32,
      imaLinkCurrentRxStuffs          Gauge32 }

imaLinkCurrentImaViolations OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "ICP violations: count of errored, invalid or missing ICP cells,
        except during SES-IMA or UAS-IMA conditions, in the current
        15 minute interval."
      REFERENCE
        "ATM Forum IMA v1.1, (R-125) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkCurrentEntry 1 }

imaLinkCurrentOifAnomalies OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of OIF anomalies, except during SES-IMA or UAS-IMA
        conditions, at the near-end in the current 15 minute interval.
        This is an optional attribute."
      REFERENCE
        "ATM Forum IMA v1.1, (O-20) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkCurrentEntry 2 }

imaLinkCurrentNeSevErroredSecs OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Count of one second intervals containing >= 30% of the ICP cells
        counted as IV-IMAs, or one or more link defects (e.g., LOS, OOF/LOF,
        AIS, or LCD), LIF defects, or LODS defects, except during UAS-IMA
        condition, in the current 15 minute interval."
      REFERENCE
        "ATM Forum IMA v1.1, (R-126) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkCurrentEntry 3 }

imaLinkCurrentFeSevErroredSecs OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Count of one second intervals containing one or more RDI-IMA
        defects, except during UAS-IMA-FE condition, in the current 15
        minute interval."
      REFERENCE
        "ATM Forum IMA v1.1, (R-127) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkCurrentEntry 4 }

imaLinkCurrentNeUnavailSecs OBJECT-TYPE
      SYNTAX      Gauge32
```

```
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Count of unavailable seconds at near-end in the current 15 minute
        interval: unavailability begins at the onset of 10 contiguous
        SES-IMA and ends at the onset of 10 contiguous seconds with no
        SES-IMA."
      REFERENCE
        "ATM Forum IMA v1.1, (R-128) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkCurrentEntry 5 }

imaLinkCurrentFeUnavailSecs OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Count of unavailable seconds at far-end in the current 15 minute
        interval: unavailability begins at the onset of 10 contiguous
        SES-IMA-FE and ends at the onset of 10 contiguous seconds with no
        SES-IMA-FE."
      REFERENCE
        "ATM Forum IMA v1.1, (R-129) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkCurrentEntry 6 }

imaLinkCurrentNeTxUnusableSecs OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Tx Unusable seconds: count of Unusable seconds at the near-end
        Tx LSM in the current 15 minute interval."
      REFERENCE
        "ATM Forum IMA v1.1, (R-130) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkCurrentEntry 7 }

imaLinkCurrentNeRxUnusableSecs OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Rx Unusable seconds: count of Unusable seconds at the near-end
        Rx LSM in the current 15 minute interval."
      REFERENCE
        "ATM Forum IMA v1.1, (R-131) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkCurrentEntry 8 }

imaLinkCurrentFeTxUnusableSecs OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Tx Unusable seconds at far-end: count of seconds with Tx Unusable
        indications from the far-end Tx LSM in the current 15 minute
        interval."
      REFERENCE
        "ATM Forum IMA v1.1, (R-132) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkCurrentEntry 9 }

imaLinkCurrentFeRxUnusableSecs OBJECT-TYPE
      SYNTAX      Gauge32
```

```
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Rx Unusable seconds at far-end: count of seconds with Rx Unusable
        indications from the far-end Rx LSM in the current 15 minute
        interval."
      REFERENCE
        "ATM Forum IMA v1.1, (R-133) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkCurrentEntry 10 }

imaLinkCurrentNeTxNumFailures OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of times a near-end transmit failure alarm condition
        has been entered on this link (i.e., some form of implementation
        specific transmit fault) in the current 15 minute interval."
      REFERENCE
        "ATM Forum IMA v1.1, (R-134) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkCurrentEntry 11 }

imaLinkCurrentNeRxNumFailures OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of times a near-end receive failure alarm condition
        has been entered on this link (i.e., LIF, LODS, RFI-IMA, Mis-Connected,
        or some form of implementation specific receive fault)
        in the current 15 minute interval."
      REFERENCE
        "ATM Forum IMA v1.1, (R-135) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkCurrentEntry 12 }

imaLinkCurrentFeTxNumFailures OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of times a far-end transmit failure alarm condition
        has been entered on this link (i.e., Tx-Unusable-FE) in the
        current 15 minute interval.  This is an optional attribute."
      REFERENCE
        "ATM Forum IMA v1.1, (O-21) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkCurrentEntry 13 }

imaLinkCurrentFeRxNumFailures OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of times a far-end receive failure alarm condition
        has been entered on this link (i.e., Rx-Unusable-FE) in the
        current 15 minute interval.  This is an optional attribute."
      REFERENCE
        "ATM Forum IMA v1.1, (O-22) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkCurrentEntry 14 }

imaLinkCurrentTxStuffs OBJECT-TYPE
```

```
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Count of stuff events inserted in the transmit direction in
        the current 15 minute interval.  This is an optional attribute."
      REFERENCE
        "ATM Forum IMA v1.1, (O-23) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkCurrentEntry 15 }

imaLinkCurrentRxStuffs OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Count of stuff events detected in the receive direction in
        the current 15 minute interval.  This is an optional attribute."
      REFERENCE
        "ATM Forum IMA v1.1, (O-24) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkCurrentEntry 16 }

--
-- The IMA Link Interval Statistics subtree
--
-- The IMA Link Interval Statistics subtree consists of a single table:
-- the IMA Link Interval Table.  This table contains various statistics
-- collected by each IMA link over the previous 24 hours of operation.
-- The past 24 hours are broken into 96 completed 15 minute intervals.
--
-- Implementation of IMA Link Interval Table is optional.
--

imaLinkIntervalTable OBJECT-TYPE
      SYNTAX      SEQUENCE OF ImaLinkIntervalEntry
      MAX-ACCESS  not-accessible
      STATUS      current
      DESCRIPTION
        "The IMA Link Interval table."
      ::= { atmfImaMibObjects 11 }

imaLinkIntervalEntry OBJECT-TYPE
      SYNTAX      ImaLinkIntervalEntry
      MAX-ACCESS  not-accessible
      STATUS      current
      DESCRIPTION
        "An entry in the IMA Link Interval table."
      INDEX       { ifIndex, imaLinkIntervalNumber }
      ::= { imaLinkIntervalTable 1 }

ImaLinkIntervalEntry ::= SEQUENCE {
      imaLinkIntervalNumber            INTEGER (1..96),
      imaLinkIntervalImaViolations     Gauge32,
      imaLinkIntervalOifAnomalies      Gauge32,
      imaLinkIntervalNeSevErroredSecs  Gauge32,
      imaLinkIntervalFeSevErroredSecs  Gauge32,
      imaLinkIntervalNeUnavailSecs     Gauge32,
      imaLinkIntervalFeUnavailSecs     Gauge32,
      imaLinkIntervalNeTxUnusableSecs  Gauge32,
      imaLinkIntervalNeRxUnusableSecs  Gauge32,
      imaLinkIntervalFeTxUnusableSecs  Gauge32,
      imaLinkIntervalFeRxUnusableSecs  Gauge32,
      imaLinkIntervalNeTxNumFailures   Gauge32,
      imaLinkIntervalNeRxNumFailures   Gauge32,
```

```
      imaLinkIntervalFeTxNumFailures   Gauge32,
      imaLinkIntervalFeRxNumFailures   Gauge32,
      imaLinkIntervalTxStuffs          Gauge32,
      imaLinkIntervalRxStuffs          Gauge32 }

imaLinkIntervalNumber OBJECT-TYPE
      SYNTAX      INTEGER (1..96)
      MAX-ACCESS  not-accessible
      STATUS      current
      DESCRIPTION
        "A number between 1 and 96, where 1 is the most
         recently completed 15 minute interval and 96 is the least
         recently completed 15 minutes interval (assuming that all
         96 intervals are valid)."
      ::= { imaLinkIntervalEntry 1 }

imaLinkIntervalImaViolations OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "ICP violations: count of errored, invalid or missing ICP cells,
        except during SES-IMA or UAS-IMA conditions, in one of the
        previous 96, individual 15 minute, intervals."
      REFERENCE
        "ATM Forum IMA v1.1, (R-125) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkIntervalEntry 2 }

imaLinkIntervalOifAnomalies OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of OIF anomalies, except during SES-IMA or UAS-IMA
        conditions, at the near-end in one of the previous 96, individual
        15 minute, intervals.  This is an optional attribute."
      REFERENCE
        "ATM Forum IMA v1.1, (O-20) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkIntervalEntry 3 }

imaLinkIntervalNeSevErroredSecs OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Count of one second intervals containing >= 30% of the ICP cells
        counted as IV-IMAs, or one or more link defects (e.g., LOS, OOF/LOF,
        AIS, or LCD), LIF defects, or LODS defects, except during UAS-IMA
        condition, in one of the previous 96, individual 15 minute,
        intervals."
      REFERENCE
        "ATM Forum IMA v1.1, (R-126) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkIntervalEntry 4 }

imaLinkIntervalFeSevErroredSecs OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Count of one second intervals containing one or more RDI-IMA
        defects, except during UAS-IMA-FE condition, in one of the previous
        96, individual 15 minute, intervals."
```

```
      REFERENCE
        "ATM Forum IMA v1.1, (R-127) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkIntervalEntry 5 }

imaLinkIntervalNeUnavailSecs OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Count of unavailable seconds at near-end in one of the previous
        96, individual 15 minute, intervals: unavailability begins at the
        onset of 10 contiguous SES-IMA and ends at the onset of 10
        contiguous seconds with no SES-IMA."
      REFERENCE
        "ATM Forum IMA v1.1, (R-128) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkIntervalEntry 6 }

imaLinkIntervalFeUnavailSecs OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Count of unavailable seconds at far-end in one of the previous
        96, individual 15 minute, intervals: unavailability begins at the
        onset of 10 contiguous SES-IMA-FE and ends at the onset of 10
        contiguous seconds with no SES-IMA-FE."
      REFERENCE
        "ATM Forum IMA v1.1, (R-129) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkIntervalEntry 7 }

imaLinkIntervalNeTxUnusableSecs OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Tx Unusable seconds: count of Unusable seconds at the near-end
        Tx LSM in one of the previous 96, individual 15 minute, intervals."
      REFERENCE
        "ATM Forum IMA v1.1, (R-130) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkIntervalEntry 8 }

imaLinkIntervalNeRxUnusableSecs OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Rx Unusable seconds: count of Unusable seconds at the near-end
        Rx LSM in one of the previous 96, individual 15 minute, intervals."
      REFERENCE
        "ATM Forum IMA v1.1, (R-131) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkIntervalEntry 9 }

imaLinkIntervalFeTxUnusableSecs OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Tx Unusable seconds at far-end: count of seconds with Tx Unusable
        indications from the far-end Tx LSM in one of the previous 96,
        individual 15 minute, intervals."
```

```
      REFERENCE
        "ATM Forum IMA v1.1, (R-132) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkIntervalEntry 10 }

imaLinkIntervalFeRxUnusableSecs OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Rx Unusable seconds at far-end: count of seconds with Rx Unusable
        indications from the far-end Rx LSM in one of the previous 96,
        individual 15 minute, intervals."
      REFERENCE
        "ATM Forum IMA v1.1, (R-133) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkIntervalEntry 11 }

imaLinkIntervalNeTxNumFailures OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of times a near-end transmit failure alarm condition
        has been entered on this link (i.e., some form of implementation
        specific transmit fault) in one of the previous 96, individual
        15 minute, intervals."
      REFERENCE
        "ATM Forum IMA v1.1, (R-134) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkIntervalEntry 12 }

imaLinkIntervalNeRxNumFailures OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of times a near-end receive failure alarm condition
        has been entered on this link (i.e., LIF, LODS, RFI-IMA,
        Mis-Connected, or some form of implementation specific
        receive fault) in one of the previous 96, individual 15 minute,
        intervals."
      REFERENCE
        "ATM Forum IMA v1.1, (R-135) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkIntervalEntry 13 }

imaLinkIntervalFeTxNumFailures OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of times a far-end transmit failure alarm condition
        has been entered on this link (i.e., Tx-Unusable-FE) in one of the
        previous 96, individual 15 minute, intervals.  This is an optional
        attribute."
      REFERENCE
        "ATM Forum IMA v1.1, (O-21) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkIntervalEntry 14 }

imaLinkIntervalFeRxNumFailures OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
```

```
      DESCRIPTION
        "The number of times a far-end receive failure alarm condition
        has been entered on this link (i.e., Rx-Unusable-FE) in one of
        the previous 96, individual 15 minute, intervals.  This is an
        optional attribute."
      REFERENCE
        "ATM Forum IMA v1.1, (O-22) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkIntervalEntry 15 }

imaLinkIntervalTxStuffs OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Count of stuff events inserted in the transmit direction in
        one of the previous 96, individual 15 minute, intervals.  This
        is an optional attribute."
      REFERENCE
        "ATM Forum IMA v1.1, (O-23) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkIntervalEntry 16 }

imaLinkIntervalRxStuffs OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Count of stuff events detected in the receive direction in
        one of the previous 96, individual 15 minute, intervals.  This
        is an optional attribute."
      REFERENCE
        "ATM Forum IMA v1.1, (O-24) and (O-26) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkIntervalEntry 17 }

--
-- The IMA Link Total Statistics subtree
--
-- The IMA Link Total Statistics subtree consists of a single table:
-- the IMA Link Total Table.  This table contains the cumulative sum
-- of the various statistics collected by each IMA link for the 24 hour
-- period preceding the current interval.
--
-- Implementation of IMA Link Total Table is optional.
--

imaLinkTotalTable OBJECT-TYPE
      SYNTAX      SEQUENCE OF ImaLinkTotalEntry
      MAX-ACCESS  not-accessible
      STATUS      current
      DESCRIPTION
        "The IMA Link Total table."
      ::= { atmfImaMibObjects 12 }

imaLinkTotalEntry OBJECT-TYPE
      SYNTAX      ImaLinkTotalEntry
      MAX-ACCESS  not-accessible
      STATUS      current
      DESCRIPTION
        "An entry in the IMA Link Total table."
      INDEX       { ifIndex }
      ::= { imaLinkTotalTable 1 }

ImaLinkTotalEntry ::= SEQUENCE {
```

```
      imaLinkTotalImaViolations     Gauge32,
      imaLinkTotalOifAnomalies      Gauge32,
      imaLinkTotalNeSevErroredSecs  Gauge32,
      imaLinkTotalFeSevErroredSecs  Gauge32,
      imaLinkTotalNeUnavailSecs     Gauge32,
      imaLinkTotalFeUnavailSecs     Gauge32,
      imaLinkTotalNeTxUnusableSecs  Gauge32,
      imaLinkTotalNeRxUnusableSecs  Gauge32,
      imaLinkTotalFeTxUnusableSecs  Gauge32,
      imaLinkTotalFeRxUnusableSecs  Gauge32,
      imaLinkTotalNeTxNumFailures   Gauge32,
      imaLinkTotalNeRxNumFailures   Gauge32,
      imaLinkTotalFeTxNumFailures   Gauge32,
      imaLinkTotalFeRxNumFailures   Gauge32,
      imaLinkTotalTxStuffs          Gauge32,
      imaLinkTotalRxStuffs          Gauge32 }

imaLinkTotalImaViolations OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "ICP violations: count of errored, invalid or missing ICP cells,
        except during SES-IMA or UAS-IMA conditions, in the previous 24
        hour interval.  Invalid 15 minute intervals count as 0."
      REFERENCE
        "ATM Forum IMA v1.1, (R-125) and (O-27) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkTotalEntry 1 }

imaLinkTotalOifAnomalies OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of OIF anomalies, except during SES-IMA or UAS-IMA
        conditions, at the near-end in the previous 24 hour interval.
        Invalid 15 minute intervals count as 0.  This is an optional
        attribute."
      REFERENCE
        "ATM Forum IMA v1.1, (O-20) and (O-27) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkTotalEntry 2 }

imaLinkTotalNeSevErroredSecs OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Count of one second intervals containing >= 30% of the ICP cells
        counted as IV-IMAs, or one or more link defects (e.g., LOS, OOF/LOF,
        AIS, or LCD), LIF defects, or LODS defects, except during UAS-IMA
        condition, in the previous 24 hour interval.  Invalid 15 minute
        intervals count as 0."
      REFERENCE
        "ATM Forum IMA v1.1, (R-126) and (O-27) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkTotalEntry 3 }

imaLinkTotalFeSevErroredSecs OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Count of one second intervals containing one or more RDI-IMA
```

```
        defects, except during UAS-IMA-FE condition, in the previous 24
        hour interval.  Invalid 15 minute intervals count as 0."
      REFERENCE
        "ATM Forum IMA v1.1, (R-127) and (O-27) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkTotalEntry 4 }

imaLinkTotalNeUnavailSecs OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Count of unavailable seconds at near-end in the previous 24 hour
        interval: unavailability begins at the onset of 10 contiguous
        SES-IMA and ends at the onset of 10 contiguous seconds with no
        SES-IMA.  Invalid 15 minute intervals count as 0."
      REFERENCE
        "ATM Forum IMA v1.1, (R-128) and (O-27) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkTotalEntry 5 }

imaLinkTotalFeUnavailSecs OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Count of unavailable seconds at far-end in the previous 24 hour
        interval: unavailability begins at the onset of 10 contiguous
        SES-IMA-FE and ends at the onset of 10 contiguous seconds with no
        SES-IMA-FE.  Invalid 15 minute intervals count as 0."
      REFERENCE
        "ATM Forum IMA v1.1, (R-129) and (O-27) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkTotalEntry 6 }

imaLinkTotalNeTxUnusableSecs OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Tx Unusable seconds: count of Unusable seconds at the near-end
        Tx LSM in the previous 24 hour interval.  Invalid 15 minute
        intervals count as 0."
      REFERENCE
        "ATM Forum IMA v1.1, (R-130) and (O-27) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkTotalEntry 7 }

imaLinkTotalNeRxUnusableSecs OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Rx Unusable seconds: count of Unusable seconds at the near-end
        Rx LSM in the previous 24 hour interval.  Invalid 15 minute
        intervals count as 0."
      REFERENCE
        "ATM Forum IMA v1.1, (R-131) and (O-27) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkTotalEntry 8 }

imaLinkTotalFeTxUnusableSecs OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
```

```
      DESCRIPTION
        "Tx Unusable seconds at far-end: count of seconds with Tx Unusable
        indications from the far-end Tx LSM in the previous 24 hour
        interval.  Invalid 15 minute intervals count as 0."
      REFERENCE
        "ATM Forum IMA v1.1, (R-132) and (O-27) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkTotalEntry 9 }

imaLinkTotalFeRxUnusableSecs OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Rx Unusable seconds at far-end: count of seconds with Rx Unusable
        indications from the far-end Rx LSM in the previous 24 hour
        interval.  Invalid 15 minute intervals count as 0."
      REFERENCE
        "ATM Forum IMA v1.1, (R-133) and (O-27) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkTotalEntry 10 }

imaLinkTotalNeTxNumFailures OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of times a near-end transmit failure alarm condition
        has been entered on this link (i.e., some form of implementation
        specific transmit fault) in the previous 24 hour interval.
        Invalid 15 minute intervals count as 0."
      REFERENCE
        "ATM Forum IMA v1.1, (R-134) and (O-27) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkTotalEntry 11 }

imaLinkTotalNeRxNumFailures OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of times a near-end receive failure alarm condition
        has been entered on this link (i.e., LIF, LODS, RFI-IMA,
        Mis-Connected, or some form of implementation specific receive fault)
        in the previous 24 hour interval. Invalid 15 minute intervals
        count as 0."
      REFERENCE
        "ATM Forum IMA v1.1, (R-135) and (O-27) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkTotalEntry 12 }

imaLinkTotalFeTxNumFailures OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of times a far-end transmit failure alarm condition
        has been entered on this link (i.e., Tx-Unusable-FE) in the
        previous 24 hour interval.  Invalid 15 minute intervals count
        as 0.  This is an optional attribute."
      REFERENCE
        "ATM Forum IMA v1.1, (O-21) and (O-27) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkTotalEntry 13 }
```

```
imaLinkTotalFeRxNumFailures OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "The number of times a far-end receive failure alarm condition
        has been entered on this link (i.e., Rx-Unusable-FE) in the
        previous 24 hour interval.  Invalid 15 minute intervals count
        as 0.  This is an optional attribute."
      REFERENCE
        "ATM Forum IMA v1.1, (O-22) and (O-27) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkTotalEntry 14 }

imaLinkTotalTxStuffs OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Count of stuff events inserted in the transmit direction in
        the previous 24 hour interval.  Invalid 15 minute intervals
        count as 0.  This is an optional attribute."
      REFERENCE
        "ATM Forum IMA v1.1, (O-23) and (O-27) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkTotalEntry 15 }

imaLinkTotalRxStuffs OBJECT-TYPE
      SYNTAX      Gauge32
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
        "Count of stuff events detected in the receive direction in
        the previous 24 hour interval.  Invalid 15 minute intervals
        count as 0.  This is an optional attribute."
      REFERENCE
        "ATM Forum IMA v1.1, (O-24) and (O-27) in Section 12.2.2.2
        on page 77"
      ::= { imaLinkTotalEntry 16 }

-- Conformance Information

atmfImaMibGroups OBJECT IDENTIFIER ::= { atmfImaMibConformance 1 }
atmfImaMibCompliances OBJECT IDENTIFIER ::= { atmfImaMibConformance 2 }

-- Compliance Statements

atmfImaMibCompliance MODULE-COMPLIANCE
      STATUS      current
      DESCRIPTION
        "The compliance statement for network elements implementing
        ATM Forum Inverse Multiplexing for ATM (IMA) interfaces."
      MODULE -- this module

-- Mandatory Part

      MANDATORY-GROUPS {
        imaGroupGroup,
        imaLinkGroup,
        imaGroupMappingTableGroup,
        imaAlarmGroup,
        imaNotificationsGroup }

      GROUP imaTestPatternGroup
      DESCRIPTION
```

```
        "This group is mandatory only for implementations that support
        the Test Pattern Procedure."

      GROUP imaGroupIntervalGroup
      DESCRIPTION
        "This group is mandatory only for implementations that support
        interval statistics."

      GROUP imaLinkIntervalGroup
      DESCRIPTION
        "This group is mandatory only for implementations that support
        interval statistics."

-- Compliance Part

      OBJECT imaGroupSymmetry
      MIN-ACCESS read-only
      DESCRIPTION
        "Write access is not required."

      OBJECT imaGroupMinNumTxLinks
      MIN-ACCESS read-only
      DESCRIPTION
        "Write access is not required."

      OBJECT imaGroupMinNumRxLinks
      MIN-ACCESS read-only
      DESCRIPTION
        "Write access is not required."

      OBJECT imaGroupTxImaId
      MIN-ACCESS read-only
      DESCRIPTION
        "Write access is not required."

      OBJECT imaGroupTxFrameLength
      MIN-ACCESS read-only
      DESCRIPTION
        "Write access is not required."

      OBJECT imaGroupDiffDelayMax
      MIN-ACCESS read-only
      DESCRIPTION
        "Write access is not required."

      OBJECT imaGroupAlphaValue
      MIN-ACCESS read-only
      DESCRIPTION
        "Write access is not required."

      OBJECT imaGroupBetaValue
      MIN-ACCESS read-only
      DESCRIPTION
        "Write access is not required."

      OBJECT imaGroupGammaValue
      MIN-ACCESS read-only
      DESCRIPTION
        "Write access is not required."

      OBJECT imaGroupFeNumFailures
      MIN-ACCESS not-accessible
      DESCRIPTION
        "This is an optional attribute."
```

```
OBJECT imaGroupTestLinkIfIndex
MIN-ACCESS read-only
DESCRIPTION
  "Write access is not required."

OBJECT imaGroupTestPattern
MIN-ACCESS read-only
DESCRIPTION
  "Write access is not required."

OBJECT imaLinkOifAnomalies
MIN-ACCESS not-accessible
DESCRIPTION
  "This is an optional attribute."

OBJECT imaLinkFeTxNumFailures
MIN-ACCESS not-accessible
DESCRIPTION
  "This is an optional attribute."

OBJECT imaLinkFeRxNumFailures
MIN-ACCESS not-accessible
DESCRIPTION
  "This is an optional attribute."

OBJECT imaLinkTxStuffs
MIN-ACCESS not-accessible
DESCRIPTION
  "This is an optional attribute."

OBJECT imaLinkRxStuffs
MIN-ACCESS not-accessible
DESCRIPTION
  "This is an optional attribute."

OBJECT imaGroupCurrentFeNumFailures
MIN-ACCESS not-accessible
DESCRIPTION
  "This is an optional attribute."

OBJECT imaGroupIntervalFeNumFailures
MIN-ACCESS not-accessible
DESCRIPTION
  "This is an optional attribute."

OBJECT imaGroupTotalFeNumFailures
MIN-ACCESS not-accessible
DESCRIPTION
  "This is an optional attribute."

OBJECT imaLinkCurrentOifAnomalies
MIN-ACCESS not-accessible
DESCRIPTION
  "This is an optional attribute."

OBJECT imaLinkCurrentFeTxNumFailures
MIN-ACCESS not-accessible
DESCRIPTION
  "This is an optional attribute."

OBJECT imaLinkCurrentFeRxNumFailures
MIN-ACCESS not-accessible
DESCRIPTION
  "This is an optional attribute."
```

```
      OBJECT imaLinkCurrentTxStuffs
      MIN-ACCESS not-accessible
      DESCRIPTION
        "This is an optional attribute."

      OBJECT imaLinkCurrentRxStuffs
      MIN-ACCESS not-accessible
      DESCRIPTION
        "This is an optional attribute."

      OBJECT imaLinkIntervalOifAnomalies
      MIN-ACCESS not-accessible
      DESCRIPTION
        "This is an optional attribute."

      OBJECT imaLinkIntervalFeTxNumFailures
      MIN-ACCESS not-accessible
      DESCRIPTION
        "This is an optional attribute."

      OBJECT imaLinkIntervalFeRxNumFailures
      MIN-ACCESS not-accessible
      DESCRIPTION
        "This is an optional attribute."

      OBJECT imaLinkIntervalTxStuffs
      MIN-ACCESS not-accessible
      DESCRIPTION
        "This is an optional attribute."

      OBJECT imaLinkIntervalRxStuffs
      MIN-ACCESS not-accessible
      DESCRIPTION
        "This is an optional attribute."

      OBJECT imaLinkTotalOifAnomalies
      MIN-ACCESS not-accessible
      DESCRIPTION
        "This is an optional attribute."

      OBJECT imaLinkTotalFeTxNumFailures
      MIN-ACCESS not-accessible
      DESCRIPTION
        "This is an optional attribute."

      OBJECT imaLinkTotalFeRxNumFailures
      MIN-ACCESS not-accessible
      DESCRIPTION
        "This is an optional attribute."

      OBJECT imaLinkTotalTxStuffs
      MIN-ACCESS not-accessible
      DESCRIPTION
        "This is an optional attribute."

      OBJECT imaLinkTotalRxStuffs
      MIN-ACCESS not-accessible
      DESCRIPTION
        "This is an optional attribute."

   ::= { atmfImaMibCompliances 1 }

-- Units of Conformance

imaGroupGroup OBJECT-GROUP
```

```
      OBJECTS {
        imaGroupNumber,
        imaGroupRowStatus,
        imaGroupIfIndex,
        imaGroupNeState,
        imaGroupFeState,
        imaGroupFailureStatus,
        imaGroupSymmetry,
        imaGroupMinNumTxLinks,
        imaGroupMinNumRxLinks,
        imaGroupNeTxClkMode,
        imaGroupFeTxClkMode,
        imaGroupTxTimingRefLink,
        imaGroupRxTimingRefLink,
        imaGroupLastChange,
        imaGroupTxImaId,
        imaGroupRxImaId,
        imaGroupTxFrameLength,
        imaGroupRxFrameLength,
        imaGroupDiffDelayMax,
        imaGroupLeastDelayLink,
        imaGroupDiffDelayMaxObs,
        imaGroupAlphaValue,
        imaGroupBetaValue,
        imaGroupGammaValue,
        imaGroupRunningSecs,
        imaGroupUnavailSecs,
        imaGroupNeNumFailures,
        imaGroupFeNumFailures,
        imaGroupTxAvailCellRate,
        imaGroupRxAvailCellRate,
        imaGroupNumTxCfgLinks,
        imaGroupNumRxCfgLinks,
        imaGroupNumTxActLinks,
        imaGroupNumRxActLinks,
        imaGroupTxOamLabelValue,
        imaGroupRxOamLabelValue }
      STATUS     current
      DESCRIPTION
        "A set of objects providing configuration and status information for
        an IMA group definition."
      ::= { atmfImaMibGroups 1 }

imaLinkGroup OBJECT-GROUP
      OBJECTS {
        imaLinkRowStatus,
        imaLinkGroupIndex,
        imaLinkNeTxState,
        imaLinkNeRxState,
        imaLinkFeTxState,
        imaLinkFeRxState,
        imaLinkNeRxFailureStatus,
        imaLinkFeRxFailureStatus,
        imaLinkTxLid,
        imaLinkRxLid,
        imaLinkRelDelay,
        imaLinkImaViolations,
        imaLinkOifAnomalies,
        imaLinkNeSevErroredSecs,
        imaLinkFeSevErroredSecs,
        imaLinkNeUnavailSecs,
        imaLinkFeUnavailSecs,
        imaLinkNeTxUnusableSecs,
        imaLinkNeRxUnusableSecs,
        imaLinkFeTxUnusableSecs,
```

```
        imaLinkFeRxUnusableSecs,
        imaLinkNeTxNumFailures,
        imaLinkNeRxNumFailures,
        imaLinkFeTxNumFailures,
        imaLinkFeRxNumFailures,
        imaLinkTxStuffs,
        imaLinkRxStuffs }
      STATUS     current
      DESCRIPTION
        "A set of objects providing status information for an IMA link."
      ::= { atmfImaMibGroups 2 }

imaGroupMappingTableGroup OBJECT-GROUP
      OBJECTS {
        imaGroupMappingIndex }
      STATUS     current
      DESCRIPTION
        "A table mapping the 'ifIndex' values of 'imaGroupIfIndex'
        to the 'imaGroupIndex' values of the corresponding
        IMA group."
      ::= { atmfImaMibGroups 3 }

imaTestPatternGroup OBJECT-GROUP
      OBJECTS {
        imaGroupTestLinkIfIndex,
        imaGroupTestPattern,
        imaGroupTestProcStatus,
        imaLinkRxTestPattern,
        imaLinkTestProcStatus }
      STATUS     current
      DESCRIPTION
        "Objects in the imaGroupTable and imaLinkTable which control and
        report on the Test Pattern Procedure.  These objects must be
        implemented if the IMA Test Pattern Procedure is supported."
      ::= { atmfImaMibGroups 4 }

imaAlarmGroup OBJECT-GROUP
      OBJECTS {
        imaAlarmStatus,
        imaAlarmType }
      STATUS     current
      DESCRIPTION
        "Objects used in the imaFailureAlarm notification."
      ::= { atmfImaMibGroups 5 }

imaGroupIntervalGroup OBJECT-GROUP
      OBJECTS {
        imaGroupValidIntervals,
        imaGroupInvalidIntervals,
        imaGroupTimeElapsed,
        imaGroupCurrentUnavailSecs,
        imaGroupCurrentNeNumFailures,
        imaGroupCurrentFeNumFailures,
        imaGroupIntervalUnavailSecs,
        imaGroupIntervalNeNumFailures,
        imaGroupIntervalFeNumFailures,
        imaGroupTotalUnavailSecs,
        imaGroupTotalNeNumFailures,
        imaGroupTotalFeNumFailures }
      STATUS     current
      DESCRIPTION
        "Objects containing interval statistics for an IMA group."
      ::= { atmfImaMibGroups 6 }

imaLinkIntervalGroup OBJECT-GROUP
```

```
      OBJECTS {
        imaLinkValidIntervals,
        imaLinkInvalidIntervals,
        imaLinkTimeElapsed,
        imaLinkCurrentImaViolations,
        imaLinkCurrentOifAnomalies,
        imaLinkCurrentNeSevErroredSecs,
        imaLinkCurrentFeSevErroredSecs,
        imaLinkCurrentNeUnavailSecs,
        imaLinkCurrentFeUnavailSecs,
        imaLinkCurrentNeTxUnusableSecs,
        imaLinkCurrentNeRxUnusableSecs,
        imaLinkCurrentFeTxUnusableSecs,
        imaLinkCurrentFeRxUnusableSecs,
        imaLinkCurrentNeTxNumFailures,
        imaLinkCurrentNeRxNumFailures,
        imaLinkCurrentFeTxNumFailures,
        imaLinkCurrentFeRxNumFailures,
        imaLinkCurrentTxStuffs,
        imaLinkCurrentRxStuffs,
        imaLinkIntervalImaViolations,
        imaLinkIntervalOifAnomalies,
        imaLinkIntervalNeSevErroredSecs,
        imaLinkIntervalFeSevErroredSecs,
        imaLinkIntervalNeUnavailSecs,
        imaLinkIntervalFeUnavailSecs,
        imaLinkIntervalNeTxUnusableSecs,
        imaLinkIntervalNeRxUnusableSecs,
        imaLinkIntervalFeTxUnusableSecs,
        imaLinkIntervalFeRxUnusableSecs,
        imaLinkIntervalNeTxNumFailures,
        imaLinkIntervalNeRxNumFailures,
        imaLinkIntervalFeTxNumFailures,
        imaLinkIntervalFeRxNumFailures,
        imaLinkIntervalTxStuffs,
        imaLinkIntervalRxStuffs,
        imaLinkTotalImaViolations,
        imaLinkTotalOifAnomalies,
        imaLinkTotalNeSevErroredSecs,
        imaLinkTotalFeSevErroredSecs,
        imaLinkTotalNeUnavailSecs,
        imaLinkTotalFeUnavailSecs,
        imaLinkTotalNeTxUnusableSecs,
        imaLinkTotalNeRxUnusableSecs,
        imaLinkTotalFeTxUnusableSecs,
        imaLinkTotalFeRxUnusableSecs,
        imaLinkTotalNeTxNumFailures,
        imaLinkTotalNeRxNumFailures,
        imaLinkTotalFeTxNumFailures,
        imaLinkTotalFeRxNumFailures,
        imaLinkTotalTxStuffs,
        imaLinkTotalRxStuffs }
      STATUS     current
      DESCRIPTION
        "Objects containing interval statistics for an IMA link."
      ::= { atmfImaMibGroups 7 }

imaNotificationsGroup NOTIFICATION-GROUP
      NOTIFICATIONS {
        imaFailureAlarm }
      STATUS     current
      DESCRIPTION
        "Notifications that must be implemented for IMA groups and links."
      ::= { atmfImaMibGroups 8 }
END
```

# Appendix B Example of Link Delay Synchronization

This section describes an example on how link delay synchronization may be achieved.

The delay compensation at the receive end may be done using the IMA framing number and ICP cell offset contained in the incoming ICP cells.

Figure 27 on page 153 shows an IMA group with three links called Link 0, Link 1 and Link 2. The link multiplexing order is 0-> 1-> 2-> 0, etc. The ICP cells have been identified according to the LID of the link on which they are sent. The cells other than the ICP cells have been numbered in the order they are sent over the virtual link.

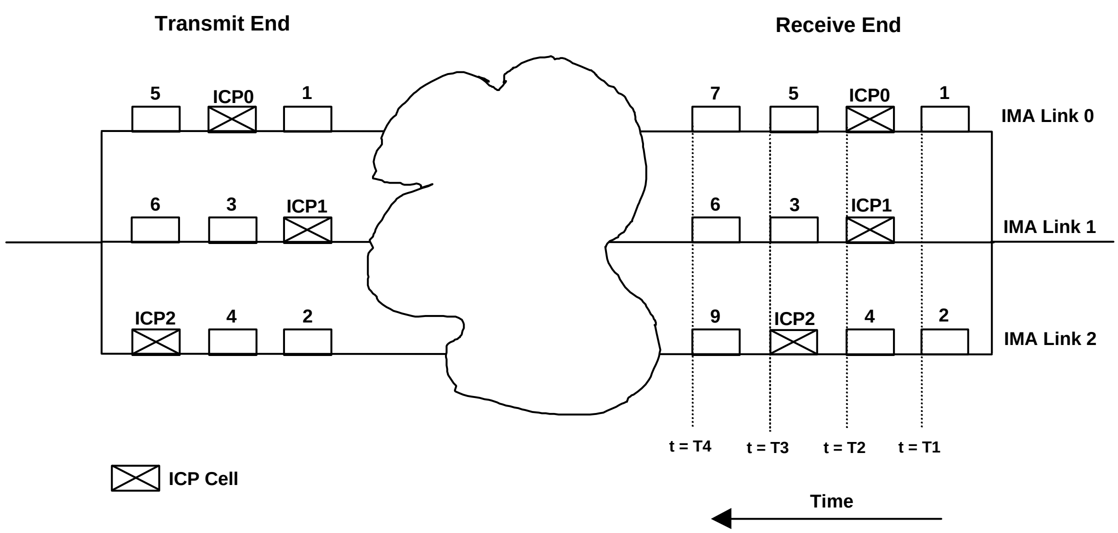



**Figure 27 Link Delay Compensation Example**

The transmit end has staggered the ICP cells giving them ICP Cell Offset of 1, 0 and 2 for links 0, 1 and 2 respectively. Again, these values are used for illustration purposes only. It is recommended that ICP cell position from link-to-link be spaced out as evenly as possible in an IMA frame. At the receive end, link 0 and link 2 have the same amount of propagation delay but link 1 has a delay one cell time longer than link 0 or link 2. At the receive end, each link has its own circular buffer which should be deep enough to tolerate the maximum link delay variation.

Figure 28 on page 154 through Figure 31 on page 156 show an example of the processing of the incoming cells at the receive end. One Delay Compensation Buffer (DCB) is defined per link. The shaded portions of DCBs on Figure 28 through Figure 31 represent unfilled portions of the buffer allocated for each link. Each section of the buffer represents a single cell buffer. The unshaded portion represents portions filled with cells.

Figure 28 on page 154 through Figure 31 on page 156 also shows the contents of the three Delay Compensation Buffers (DCB) on the receive end at time t = T1, T2, T3 and T6. The write pointer of each link shows the next location where a cell would be put when received from that link. At time T0, no ICP cells have been received yet on any links so no cells are written to the buffers. Whenever a cell is written into a buffer, the write pointer is incremented. A read (playback) pointer increments as cells are read out of the buffer. Both pointers wrap around when they reach the end of the buffer. Until the first ICP cell is received, no cell is written into the buffer. When the first ICP cell is received, the write pointer is initialized to the value of the IMA frame number plus ICP cell offset contained in that ICP cell. Every cell received after that ICP cell is written into the buffer.

All of the delay compensation is done with the adjustment of the write pointers. The read pointers are always aligned and the cells are read out of the buffers in the assigned link multiplexing order. The differential delay between any two links can be simply calculated using the difference between the write pointer values for those two links. Extending this idea to the entire set of links, the maximum differential delay for the link group is simply the difference between the minimum and maximum write pointer values for that group. If we assume the use of DS1 links and given a maximum allowable delay delta of 25 milliseconds, the maximum difference acceptable between the write pointers will be 91 cells. The accuracy of this technique is ± 1 cell time (e.g., 276 microseconds at DS1 rate) which is satisfactory for this application.

The process of reading from the buffer is controlled by the IMA cell clock. In round-robin order and at the IMA clock tick, a cell is removed from the DCB (the pointer is advanced). If the cell is an ICP cell, the next link in order is immediately selected (and so on until a cell is found that is not an ICP cell). If the cell is a Filler cell, it is discarded and nothing is passed to the ATM layer. It the cell is not a Filler cell, it is passed to the ATM layer.

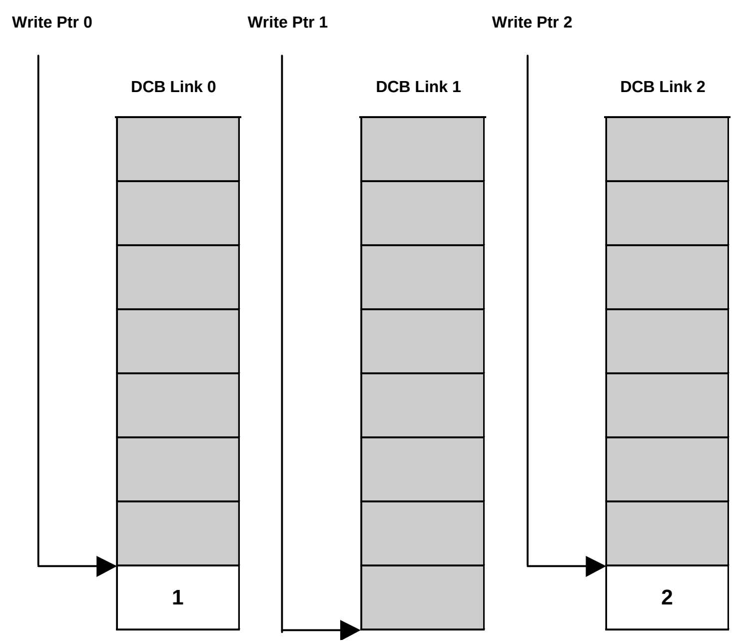



**Figure 28 Snapshot of Buffers at T1**

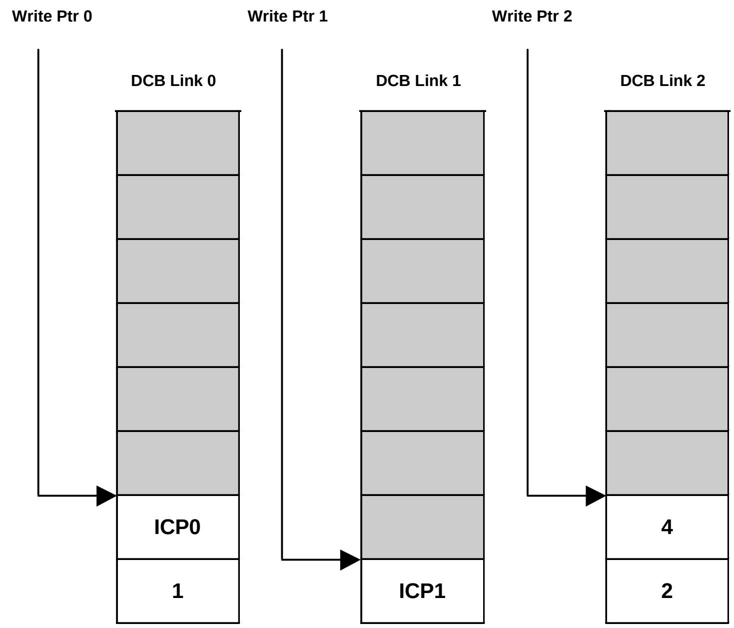



**Figure 29 Snapshot of Buffers at T2**

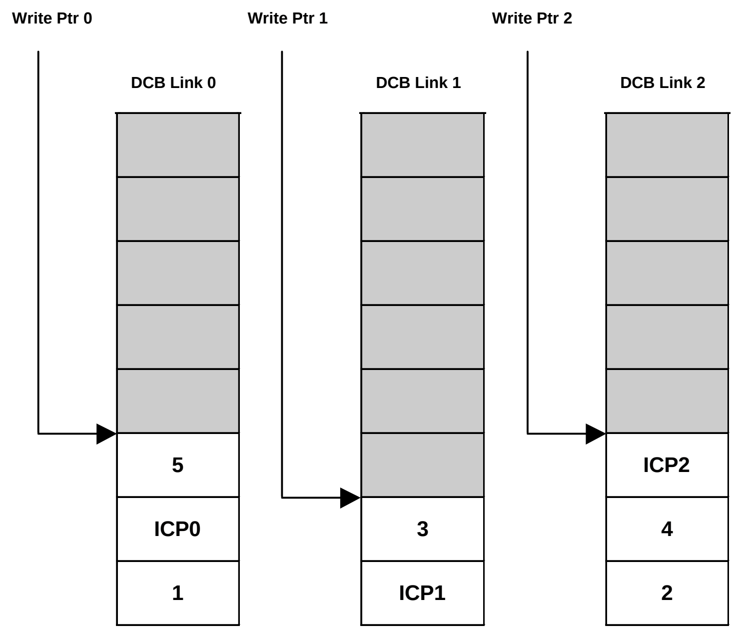



**Figure 30 Snapshot of Buffers at T3**

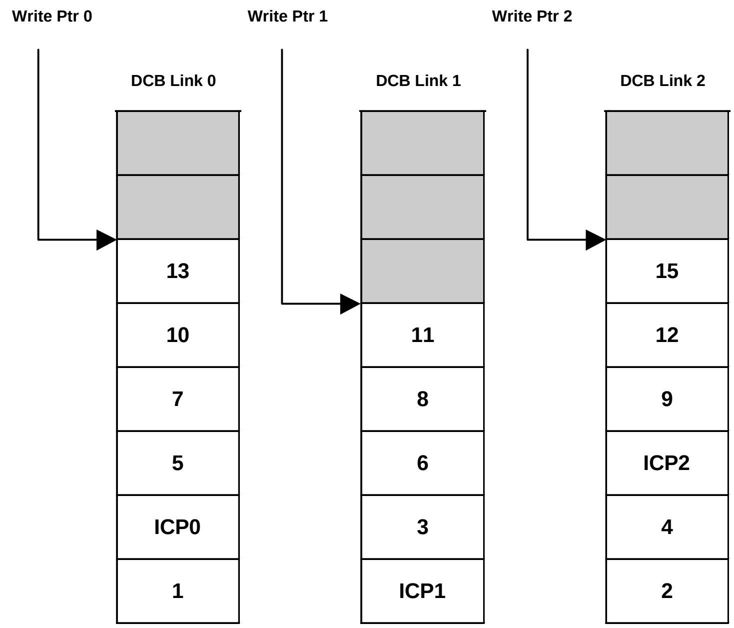



**Figure 31 Snapshot of Buffers at T6**

# Appendix C Implementation Consideration

This section may be used as guidelines for IMA implementers.

## C.1 Dynamic Changes in ATM Layer Cell Rate

This section provides some guidelines on handling dynamic changes of IMA data cell rate (IDCR). The ATM Layer needs to react to dynamic changes in the IDCR, particularly to decreases in the cell rate since decreases in the cell rate are problematic. Connections at the previous (larger) cell rate reserved some quantity of bandwidth (cell rate). If the interface cell rate drops (due to actions within the IMA unit), then the aggregate reserved cell rate of the connections may exceed the interface cell rate and result in higher Cell Loss Ratio (CLR) and delay than contracted. Dynamic changes can be reported in three types of circumstances: (1) a one or more links fail, (2) one or more link are removed administratively, and (3) one or more link are added administratively.

In case (1), the IMA interface may or may not experience an increase of CLR and delay on some or all connections due to a decrease of available bandwidth. In some cases, both ends of the virtual links may not release connections and let congestion control discard cells if a severe congestion is reported. In other cases, each end may release connections to preserve QoS on the most important connections. The handling of connections upon dynamic bandwidth decrease has been under consideration by several ATM Forum Working Groups (NM, TM, PNNI, and SIG Working Groups).

In case (2), the IMA unit is instructed by the management control plane to drop a link. In this case, the administrative plane function should have taken steps to ensure that the connections on the interface would still pass Connection Admission Control (CAC) at the reduced interface cell rate before instructing the IMA unit to drop the link. It is conceivable that the administrative function may even preempt connections so those remaining will fall within CAC limits. In any case, close coordination between the CAC and the control functions of the IMA unit is necessary if dynamic additions/deletions are to be performed.

In case (3), the IMA unit is instructed by the management control plane to add a link. In this case, the administrative plane function should have informed the CAC that additional bandwidth is present. Otherwise new connections will not be admitted, even though more bandwidth is available.

The treatment of CAC in the ATM Forum UNI and PNNI specifications [12][11] is implementation dependent. Thus the treatment of CAC under dynamic bandwidth changes is left to the discretion of the ATM interface implementers.

## C.2 State Machine for De-Bouncing Error Condition Report

The Rx Failed condition, described in Section 10.1.4 on page 50, and the link failure alarm, such as defined in Section 12.2.3 on page 79, may be a direct mapping of the defect state machine presented in Figure 21 on page 73, but this may cause lengthening of short errors. Repetitive bursts of errors will also affect the data path if links are brought back in too rapidly. Since there were disparate views as to integration times, a generic state model can be employed, with events loosely defined. Figure 32 on page 158 shows a simplified Rx Failed integration state machine. The integration times can be left as vendor-defined parameters.

Another standard technique is the weighted integration into the error condition (e.g., Rx Failed or failure condition). For each sampling period, if a defect is present, a value is added to an integration counter. If no defect is present, a smaller value is subtracted. In this way, errored samples are weighted more heavily. A typical ratio is 10:1.

The state machine could also be used for de-bouncing any other error condition report such as “Fault” condition report.

The model described above does not apply well to the IMA-specific checks such as IMA framing or link delay synchronization. These take longer to detect than defects, and more latitude may be required. This state machine can be used as an example, leaving X and Y and specific integration techniques to the implementers.

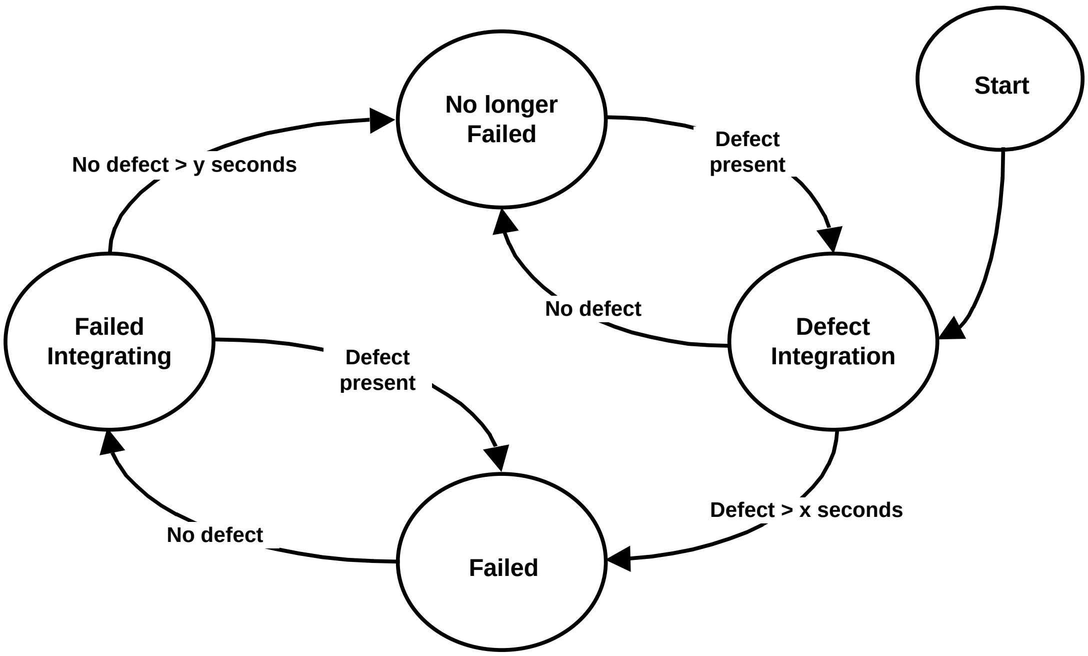



**Figure 32 Rx Failed State Machine**

## C.3 Interactions between GSM and Group Wide Procedures

This is an informative appendix to ease understanding of the GSM and its interactions with the Group Start-up and LASR wide procedures. Figure 33 on page 159 presents an auxiliary group state machine (Group Wide Procedure state machine) orthogonal to the Group State Machine (GSM) defined in Section 10.2.1 on page 55. The states of the Group Wide Procedure (GWP) state machine indicate when group-wide procedures are being executed.

Some requirements for LSM transitions, specifically (R-97) on page 61 through (R-109) on page 65, only apply when particular group-wide procedures are being executed. Therefore, the states in the GWP state machine below determine when these requirements are in effect.

This GWP state machine is only intended to help clarify when certain requirements apply. Table 32 on page 159 and Table 33 on page 159 provide the definitions of the GWP states and state transitions.

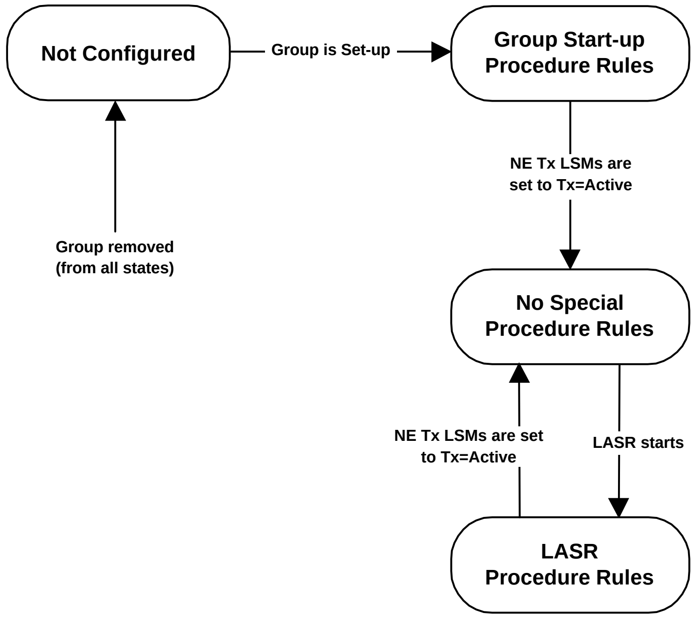



**Figure 33 Group Wide Procedure States**

**Table 32 Description of Group Wide Procedure States**

| State | Description |
|---|---|
| Not Configured | Same as the GSM “Not Configured” state. The group does not exist (refer to Table 11 on page 57). |
| Group Start-up Procedures Rules | LSM transitions are restricted by requirements (R-97) through (R-101) defined in Section 10.2.1.3 on page 61. |
| No Special Procedures Rules | LSM transitions operate normally with no restrictions for group start-up or LASR procedures. |
| LASR Procedure Rules | LSM transitions are restricted by requirements (R-102) through (R-109) defined in Section 10.2.2 on page 64. |

**Table 33 Description of Group Wide Procedure State Transitions**

| State | Description |
|---|---|
| Group is set-up | Corresponds with transition from “Not Configured” to “Start-Up” in the GSM (refer to Table 13 on page 60). |
| LASR starts | As defined by (R-102) on page 65. |
| NE Tx LSMs are set to Active | As defined in (R-99) on page 61 during Group Start-up and (R-107) on page 65 during execution of the LASR procedure. |
| Group removed | Corresponds with transition to “Not Configured” in the GSM (refer to Table 11 on page 57 and Table 13 on page 60). |

## C.4 Maximum Link Differential Delay Limitation

This section discusses the limitation of the maximum link differential delay that can be supported by the IMA protocol due to the size of the IMA frame. Having the following characteristic of the IMA frame and a newly defined IMA super-frame:

- IMA frame size: M cells (32, 64, 128 or 256)
- IMA frame sequence number (IFSN) range: 0 to 255
- IMA Super-Frame (ISF) definition: starts with IMA frame with sequence number 0 and ends with IMA frame with sequence number 255.

ISF length: 256*M

The ISF is defined to illustrate that the IFSN repeats every 256 IMA frames. The IFSN is used by the receiver to compensate for links with longer propagation delay. The receiver then always relies on the IFSN contained in the incoming ICP cells on each links. If the differential delay between the links with the shortest and longest propagation delay is larger than one half of the ISF transmission time, the receiver will not be able to determine which link has the shortest delay. The difference has to be modulo 256, which means that the receiver could think that the difference is either greater or smaller than one half of the ISF. The only way to avoid the confusion is to ensure that the link differential delay between the links with the shortest and the longest propagation delays is never greater than one half of the time to transmit the ISF.

Equation 2 on page 160 defines the maximum link differential delay based on the ISF size (256), M, the periodic stuffing on the TRL, the allowed CDV at the transmitter (see (R-74) on page 45) and the LCR.

$$\text{Delay} = \left(\left(\frac{256}{2}\right) \text{x M x} \left(\frac{2048}{2049}\right) - 2.5\right) \text{ x } \left(\frac{1}{\text{LCR}}\right) \qquad \textbf{Equation 2}$$

Table 34 on page 160 shows the maximum link differential delay that can be supported by the IMA interface in the case of various types of links are used to form an IMA virtual link.

**Table 34 Maximum Link Differential for Different M Values over various Links**

| M (cells per IMA Frame) | Maximum Link Differential delay (in milliseconds) | | | | |
|---|---|---|---|---|---|
| | DS1 | El | DS3 (Direct Mapping) | E3 (Direct Mapping) | OC-3 (Sonet/SDH) |
| 32 | 1130.5 | 904.4 | 39.26 | 51.19 | 11.59 |
| 64 | 2261.7 | 1809.4 | 78.55 | 102.4 | 23.20 |
| 128 | 4524.1 | 3619.3 | 157.1 | 204.9 | 46.40 |
| 256 | 9049.0 | 7239.2 | 314.3 | 409.8 | 92.80 |

Although the sizes of the delay listed above is extremely high, it is important to highlight this limitation of the IMA protocol. This would be particularly important if the IMA protocol is implemented over higher speed interfaces.

The information can also be expressed another way to give the maximum data rates that can be supported if the required maximum link differential delay is limited to 25 milliseconds. Table 35 on page 160 shows the maximum link rates that may be supported for different M. The data rate is the rate of the cell stream excluding any framing overhead.

**Table 35 Maximum Data Rate for a Maximum Link Differential Delay of 25 msec**

| M (cells per IMA Frame) | Maximum Data Rate for a delay (maximum link differential delay of 25) | |
|---|---|---|
| | Bit Rate (Mbps) | Cell Rate (kcell/sec) |
| 32 | 69.5 | 163.82 |
| 64 | 139 | 327.74 |
| 128 | 278 | 655.58 |
| 256 | 555 | 1311.26 |

## C.5 Clock Variation Tolerance for IMA

There are three aspects to be considered for determining the required clock variation tolerance for proper IMA operation:

- required number of consecutive ICP cells required for performing stuffing,
- periodically stuffing on the timing reference link every 2048 cells, and
- maximum insertion rate of stuff event insertion rate

### C.5.1 Tolerance Due to IMA Stuffing Procedure

The specification allows for indication of the stuff action over the previous 4 ICP cells (Section 7 on page 38). This excludes the two ICP cells that comprises the stuff event. This implies a maximum frequency of adjustment of once every 5 ICP cells, or every 5 IMA frames.

For an IMA frame with the default value of M=128, 5 IMA frames are 640 cells. This implies that links can have a total variance of 1 cell time out of 640 cell times, or 1/640. Converting this to ppm by multiplying by 106 gives 1562. The frequency variation is then 781 ppm. Table 36 on page 161 gives these calculations for various values of M.

**Table 36 M Implications on PPM**

| M (cells per IMA Frame) | 5*M (number of cells) | Total variance (ppm) | Frequency variation (± ppm) |
|---|---|---|---|
| 32 | 160 | 6250 | 3125 |
| 64 | 320 | 3125 | 1562 |
| 128 | 640 | 1562 | 781 |
| 256 | 1280 | 781 | 390 |

The smallest limit on ppm variation, ± 390 ppm, is substantially more than that for the one required on DS1/E1 links (± 32 ppm and ± 50 ppm respectively). Accordingly the IMA stuff procedure does not limit link selection further, and in fact can adjust for differences in link frequencies substantially more than are allowable.

Since there is the SICP cell itself, the adjustment period is (5*M)+1 cells.

### C.5.2 Tolerance Due to Periodically Stuffing on the Timing Reference Link

Equation 1 on page 40 requires the insertion of one cell every 2048 ICP, Filler and ATM layer cells transmitted over the timing reference link (TRL). This value, 2048, has been chosen because it is the next binary number ($2^{11}$) that allows to use the optional advanced stuff indication procedure for M equals to 256 (1280 is the minimum required as described in the previous section).

In the case the TRL is the faster link in the group, link frequency differences up to 488 ppm can be tolerated between the TRL and the slowest link in the group. This is assuming that this is no need to insert stuff events on the slowest link.

### C.5.3 Tolerance Due to Maximum Stuff Event Insertion Rate

The maximum stuff event insertion rate is defined to be one stuff event every 5*M ICP, Filler and ATM layer cells for accommodating configurations using the optional four advanced indications. Enforcing such value also allows to avoid cases where some implementations would not constantly regulate the insertion of the stuff events over time.

In the case where the TRL is the slowest link in the group, the choice of 5*M where M equals 128 allows link frequency differences up to 293 ppm between the TRL and the faster link in the group. This value is derived from the fact that there is a frequency difference of 781 ppm between a link on which a stuff event is inserted every 1280 ICP, Filler and ATM layer cells and another link on which there is no stuff event being inserted, and a frequency difference of 488 ppm between the TRL and a link on which there is no stuff event being inserted. The frequency difference between the TRL and the faster link, 293 ppm, is still much larger than the ppm requirement of most link interfaces. Table 37 on page 162 shows the maximum tolerated frequency difference between the TRL and the fastest link.

**Table 37 Maximum Tolerated Frequency difference between the TRL and the Fastest Link**

| M (cells per IMA Frame) | 5*M (number of cells) | Total variance (ppm) | Maximum tolerated frequency difference between TRL and faster link |
|---|---|---|---|
| 32 | 160 | 6250 | 5762 |
| 64 | 320 | 3125 | 2637 |
| 128 | 640 | 1562 | 1074 |
| 256 | 1280 | 781 | 293 |

## C.6 Example of IMA Data Cell Rate Recovery Implementation

This section describes an example of IMA Data Cell Rate (IDCR) recovery mechanism. It suggests that the IMA receiver to the ATM layer limit itself to specifying the cell order, the IMA data cell rate and aggregate CDV. The actual method to clock an individual cell from the IMA sublayer to the ATM layer is implementation and application specific.

Figure 34 on page 163 shows a partial block diagram of the IMA receiver. Portions shown are relevant to the IDCR recovery of the IMA group. It consists of the Delay Compensation Buffers (DCB), the IMA Data Cell Clock (IDCC), the Read Pointer Functional Block (RPFB) and the output interface to the ATM layer.

The shaded portions of the DCB, in Figure 34, signifies unfilled portions of the buffer allocated for each link. Each section of the buffer represents a single cell buffer. The unshaded portion represents portions filled with cells. The write pointer of each link shows the next location where a cell would be put when received from that link. The read pointer points to the next cell that would be queued to the ATM layer interface.

Figure 34 shows the DBC for an IMA group composed of three links 0, 1, 2 (therefore N=3) with M=8 cells. M equal to 8 is used to simplify the figure. Link 0 is the link with the greatest delay with 3 cells in its buffer. Links 0, 1, and 2 have a least 3 cells in their DCBs.

When encountering an ICP cell, the RPFB will ignore the cell and will immediately advance to the next link in order without having to wait for the next IDCC tick. When encountering a stuff event, the RPFB will ignore both ICP cells part of the stuff event and will immediately advance to the next link in order. The RPFB is not responsible to examine the ICP cell content. It can be assumed that incoming ICP cells are passed to another functional block of the IMA interface for further processing.

When encountering a Filler cell, the RPFB will ignore the cell and wait until the next IDCC tick to advance to the next link in order.

Figure 35 on page 164 shows the insertion of stuff cells every “Y” IMA frames on the TRL, where Y is 2048/M, or 256 if this example.

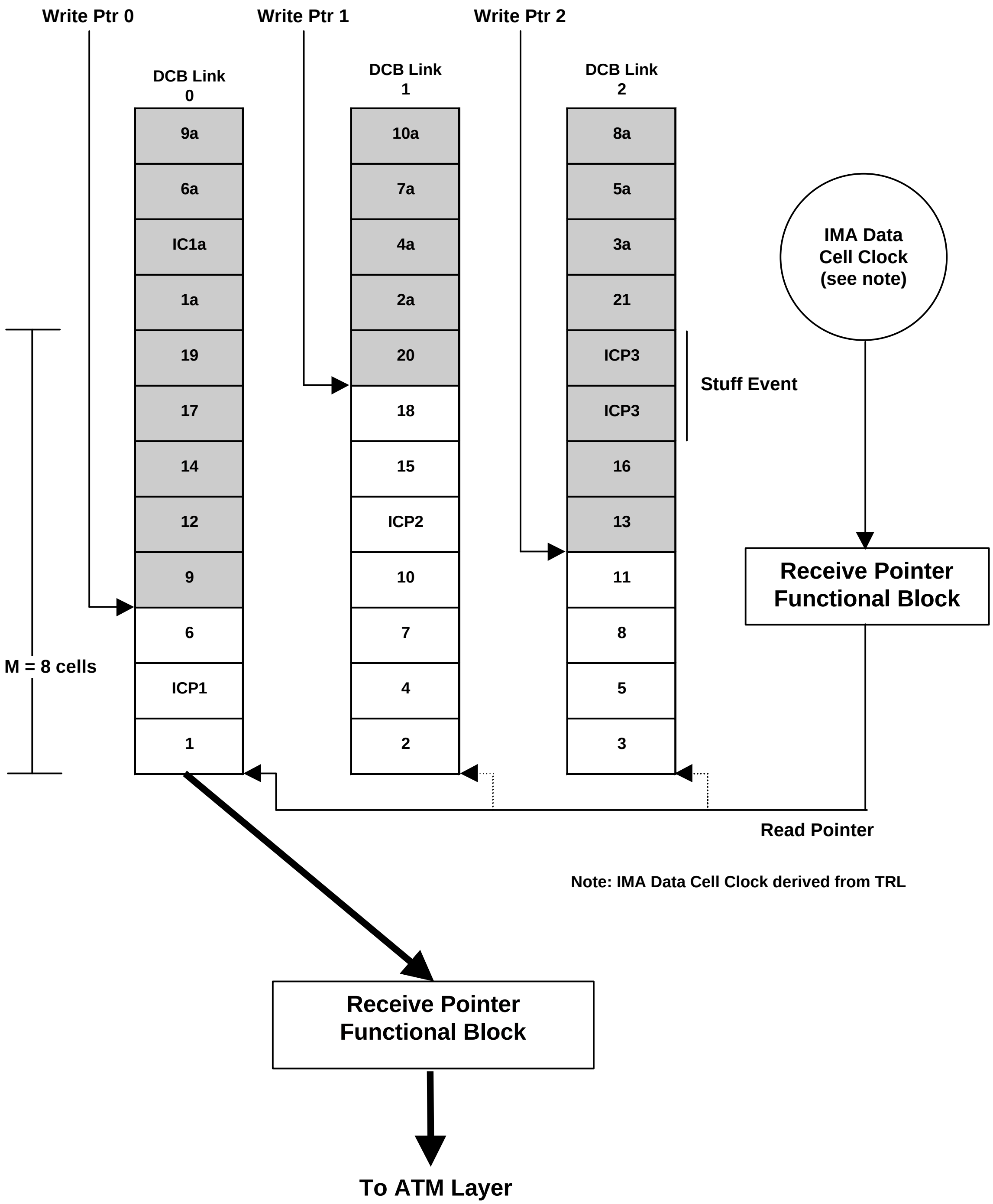



**Figure 34 Serving Delay Compensation Buffer**

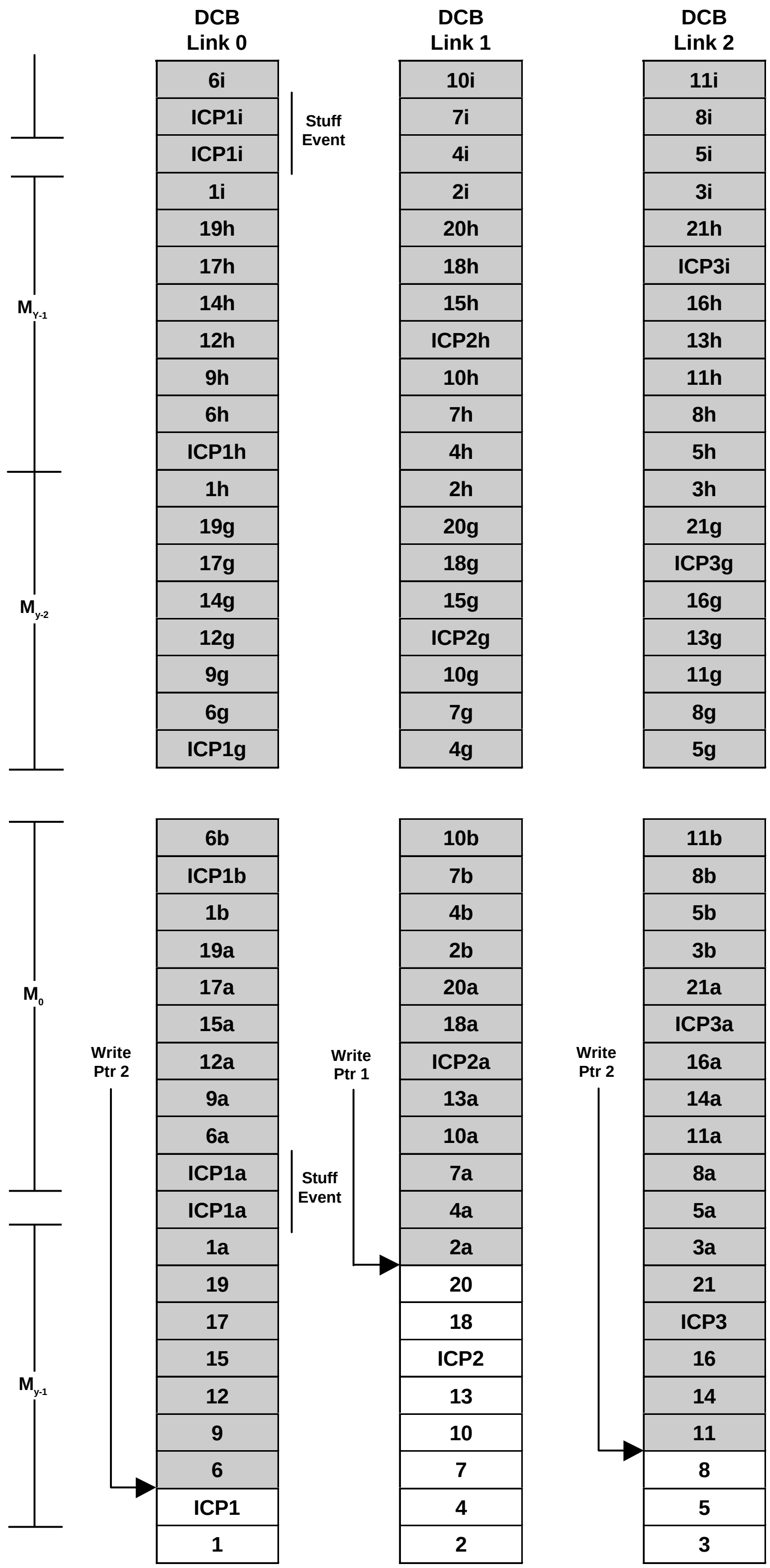



Figure 35 Insertion of Stuff Cell every Y*M Cells on the TRL

## C.7 Examples of Interactions between IFSM and IESM

This section provides three examples illustrating the interaction between the IFSM and IESM defined in Figure 19 on page 69 and Figure 21 on page 73.

**Example 1:**

- Having the IFSM in the “IMA Sync” state and the IMA Error State Machine (IESM) in the “IMA

  Getting “Beta(β)” consecutive errored ICP cells, the IFSM will proceed to “IMA Hunt”. At the same time, the IESM will proceed to OIF, and
- Getting “Gamma(γ) + 2” consecutive errored ICP cells will lead the IESM to proceed to LIF

**Example 2:**

- Having the IFSM in the “IMA Sync” state and the IESM in the “IMA Working State”,

  Getting “Beta(β)” consecutive errored ICP cells, the IFSM will proceed to “IMA Hunt”. At the same time, the IESM will proceed to OIF state,
- Getting a valid ICP cell will lead the IFSM to proceed to “IMA PreSync”, and

  Getting “Gamma(γ)” additional consecutive ICP cells will lead IFSM to proceed to “IMA Sync” which will cause IESM to proceed to “IMA Working State”.

**Example 3:**

- Having the IFSM in the “IMA Sync” state and the IESM in the “IMA Working State”,

  Getting “Beta(β)” consecutive errored ICP cells, the IFSM will proceed to “IMA Hunt”. At the same time, the IESM will proceed to OIF state,
- Getting one more errored ICP cell, no change to IFSM and IESM, and
- Getting “Gamma(γ) + 1” additional valid ICP cells will either cause the IFSM to proceed to “IMA Sync” before LIF is reported by IESM or LIF being reported by IESM before “IMA Sync” state is entered by IFSM.

## C.8 Use of Link Information Fields for Reporting Rx LSM and Defect Information

This is an informative appendix to ease understanding of the use of the Link Information fields in the ICP cells. This is illustrated in Figure 36 on page 166.

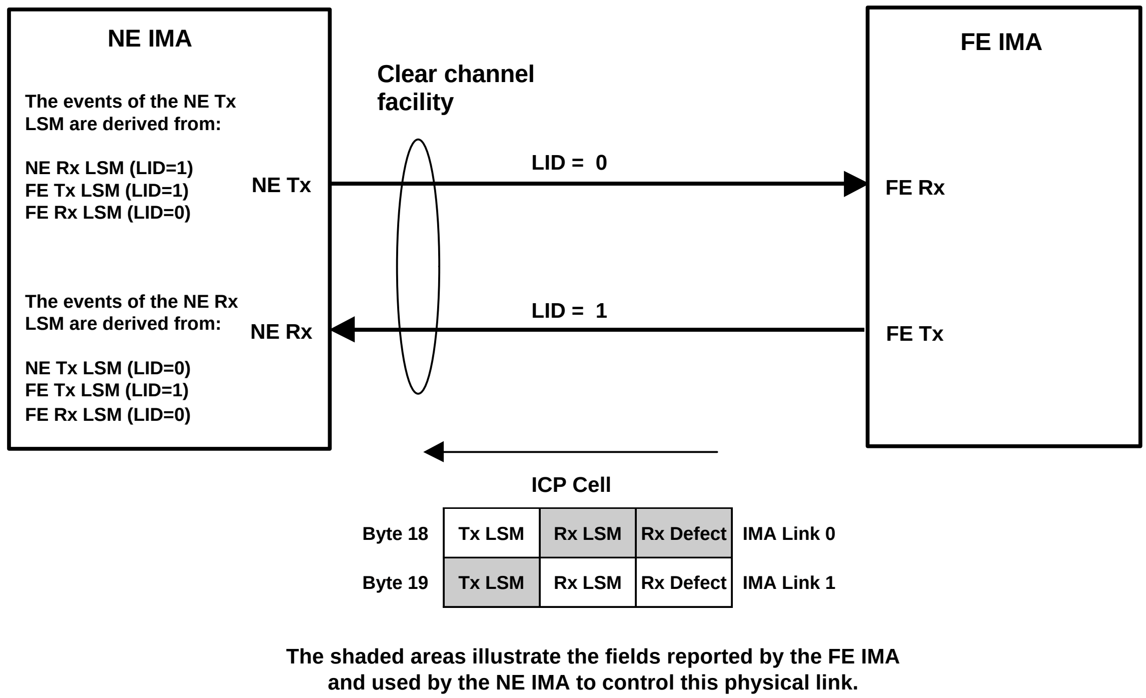
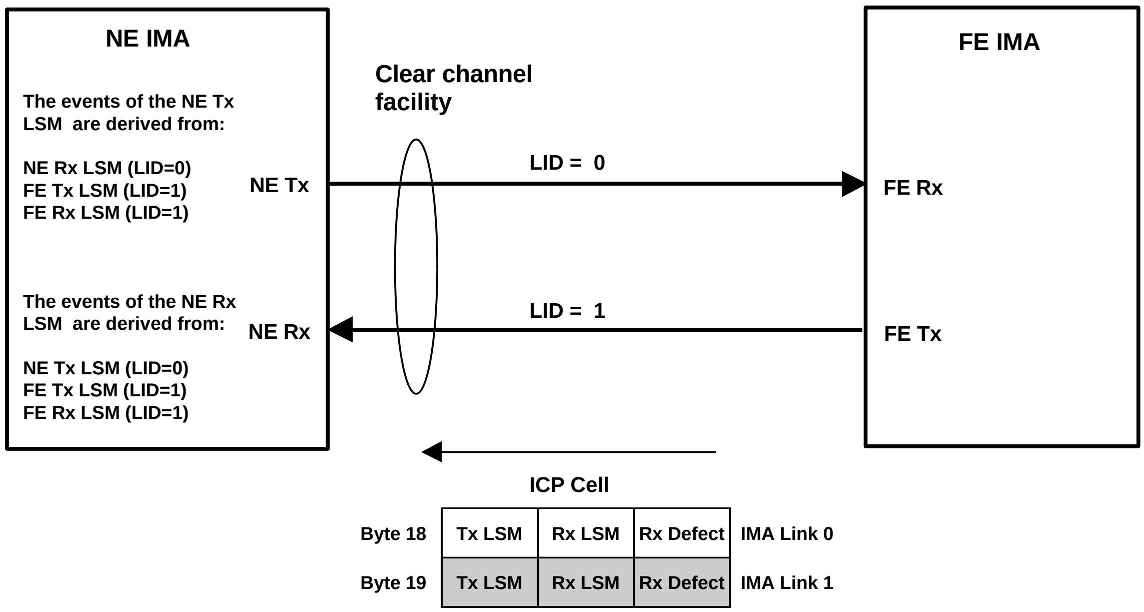



**Figure 36 Processing of the Link Information Field**

### C.8.1 Processing of Link Info field by IMA Version 1.0 Implementations

It should be noted that a significant number of IMA v1.0 implementations have used a different technique to report Rx information over the Link Information fields in the ICP cells when configuring the IMA unit in the Symmetrical Configuration and Operation mode. This technique is illustrated in Figure 37 on page 167 and differs from the technique clarified in IMA v1.1. This should be considered when there is a need to connect an IMA v1.1 implementation with an IMA v1.0 implementation.




The shaded areas illustrate the fields reported by the FE IMA and used by the NE IMA to control this physical link.

**Figure 37 Processing of the Link Info Field by IMA Version 1.0 Implementations**

# Appendix D Asymmetric Operation

## D.1 Introduction

This appendix covers extensions of the IMA specification to the operations and configuration to cover two aspects of asymmetric links.

Asymmetric configuration covers the configuration and static elements of IMA to allow the provision of asymmetric links, for example a group with 3 links in one direction and 2 in the other.

Asymmetric operation treats the operation of the links independently separating the transmit and receive behavior and allowing the IMA to continue to use a link in one direction that has failed in the other.

## D.2 Transmit and Receive Link State Transitions

The Transmit (Tx) and Receive (Rx) link state transitions should operate independently, with independent setting of the Link Information fields in the ICP cells for the Tx and Rx ends. An IMA group set in the asymmetric operation but not supporting asymmetric configuration would always expect the Tx and Rx links to be either both in a group or both out of a group.

The NE Tx state transition does not consider the NE Rx state or the FE Tx state when deciding on the state of the NE Tx link (i.e., see notes in Table 8 on page 52).

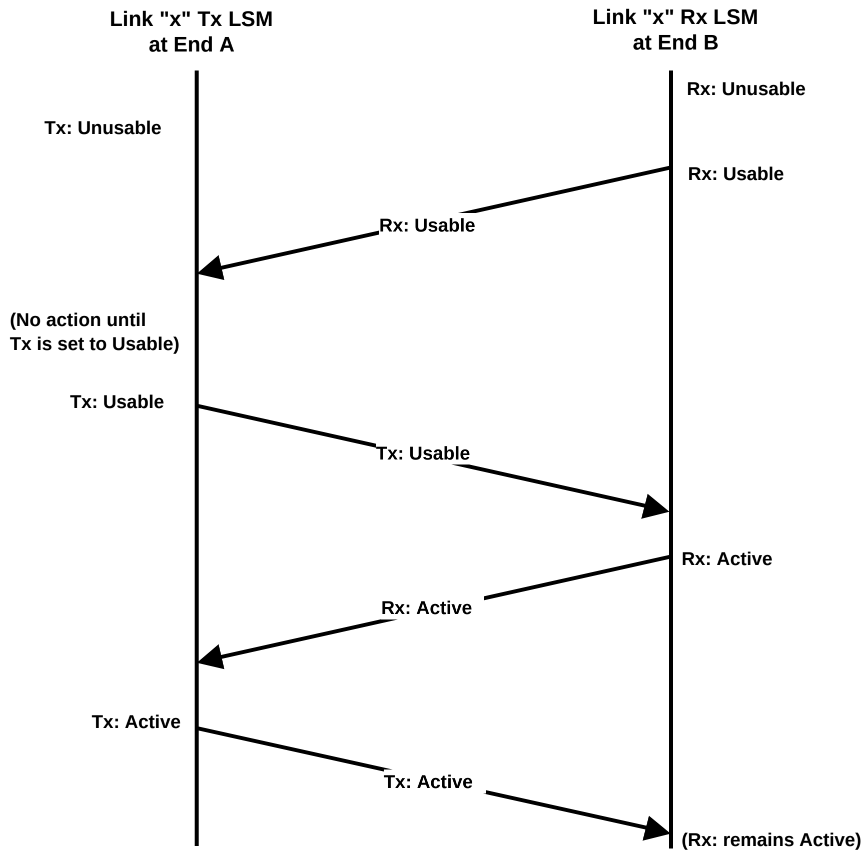
The NE Rx state transition does not consider the NE Tx state or the FE Rx state when deciding on the state of the NE Rx link (i.e., see notes in Table 9 on page 53).

## D.3 Link Start-up

There are two cases, one where the receive end is ready first, and a second where the transmit end is ready first. This is shown in Figure 38 on page 169 and Figure 39 on page 170.

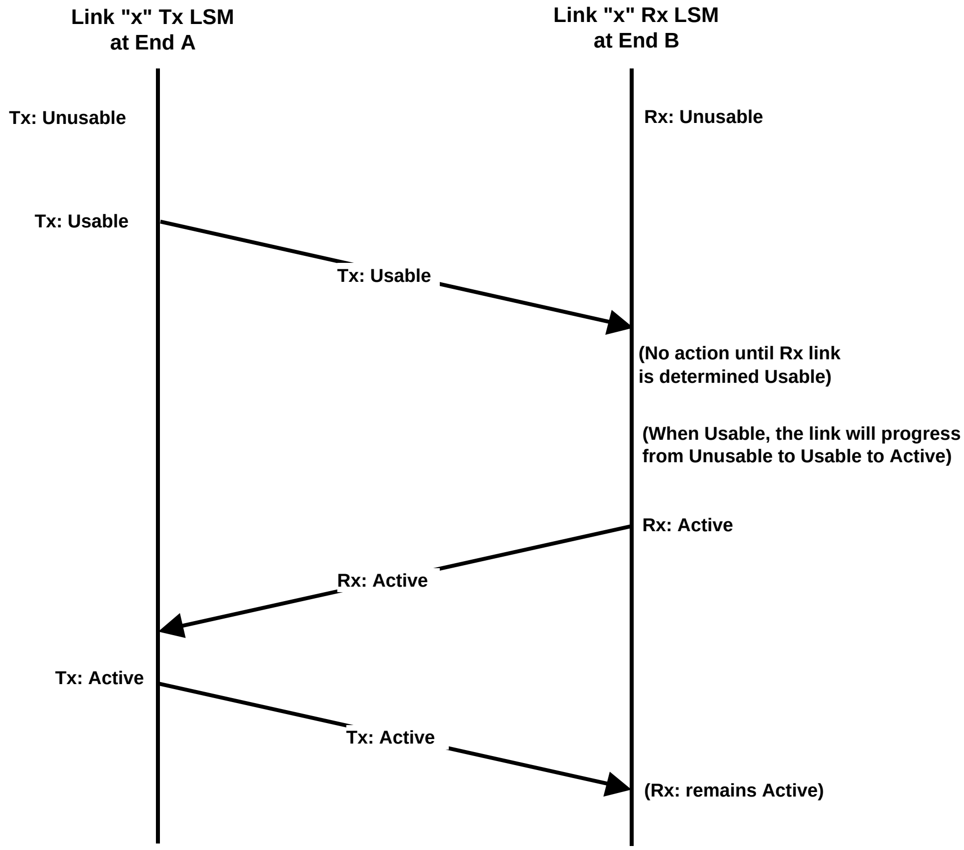
## D.4 Group Start-Up

For any group, two values will be provided, $P_{Tx}$ and $P_{Rx}$. $P_{Tx}$ and $P_{Rx,}$ as appearing in Figure 15 on page 63 may be different.




Note: Only the NE states newly entered and transmitted over the ICP cells are shown.

**Figure 38 Exchange of the NE Tx and Rx State during Link Start-up - Rx Ready First**



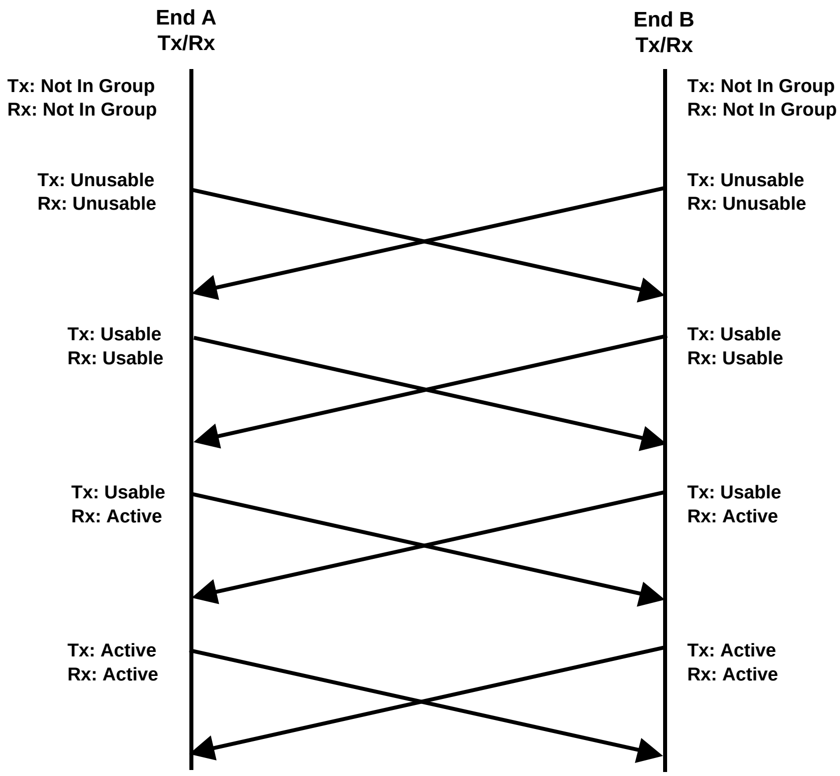

Note: Only the NE states newly entered and transmitted over the ICP cells are shown.

**Figure 39 Exchange of the NE Tx and Rx State during Link Start-up - Tx Ready First**

# Appendix E Examples of Link State Exchanges

This section presents examples of state exchanges between the two ends of the IMA virtual link based on the LSM defined in Section 10.1 on page 46. The link addition, activation, deletion and de-activation cases are covered. Both symmetrical and asymmetrical configurations are also considered.

Figure 40 on page 171 shows the case where a link is added and activated simultaneously at both ends. Overlapping identical handshakes are performed in both directions, controlling each direction independently.

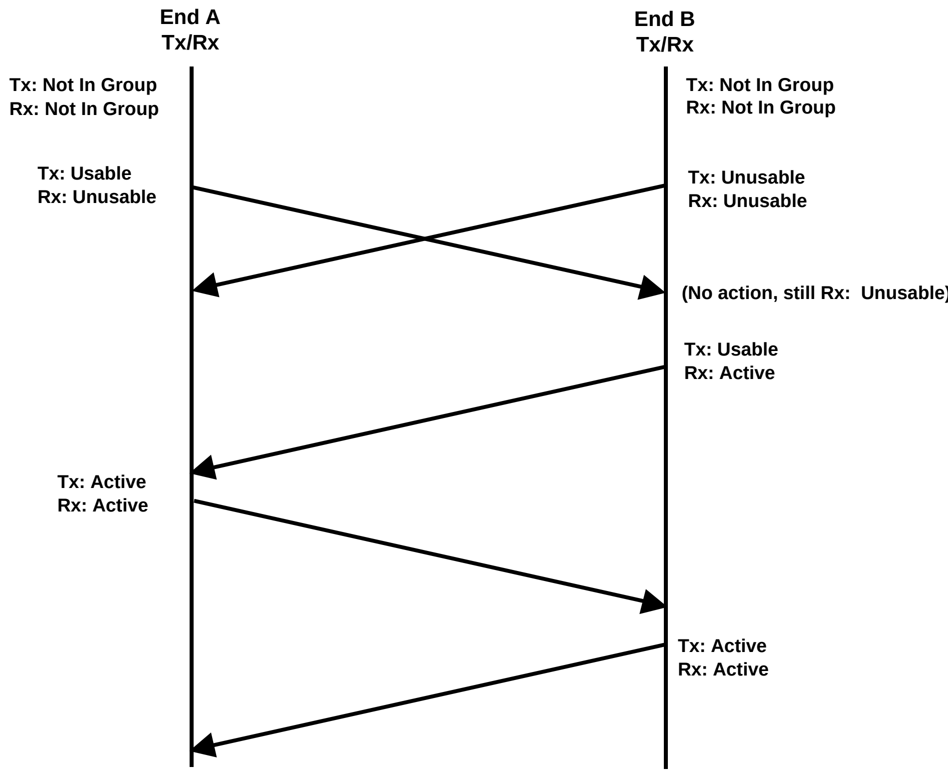



**Note:**

- **Only the NE states newly entered and transmitted over the ICP cells are shown.**
- **The transitions to Tx=Usable, Rx=Active and Tx=Active depend on the group wide synchronized addition/slow recovery procedure of links**

**Figure 40 Link Addition with Overlapping Sequence (Symmetrical Operation)**

Figure 41 on page 172 shows the case when both ends are not overlapping. One end is moving to Usable before the other end. End B may safely skip to the receive Unusable state, and the response is immediate transition to receive Active state at the local end. Full operation is established in a single round-trip.




Note:
- Only the NE states newly entered and transmitted over the ICP cells are shown.
- The transitions to Tx=Usable, Rx=Active and Tx=Active depend on the group wide synchronized addition/slow recovery procedure of links

**Figure 41 Link Addition with Non-Overlapping Sequence (Symmetrical Operation)**

Figure 42 on page 173 and Figure 43 on page 173 show the state exchange initiated by end A for deleting a link in the transmit direction for both the symmetrical and asymmetrical operations. Note that the receive link remains Active in the case where the groups are asymmetrically operated.

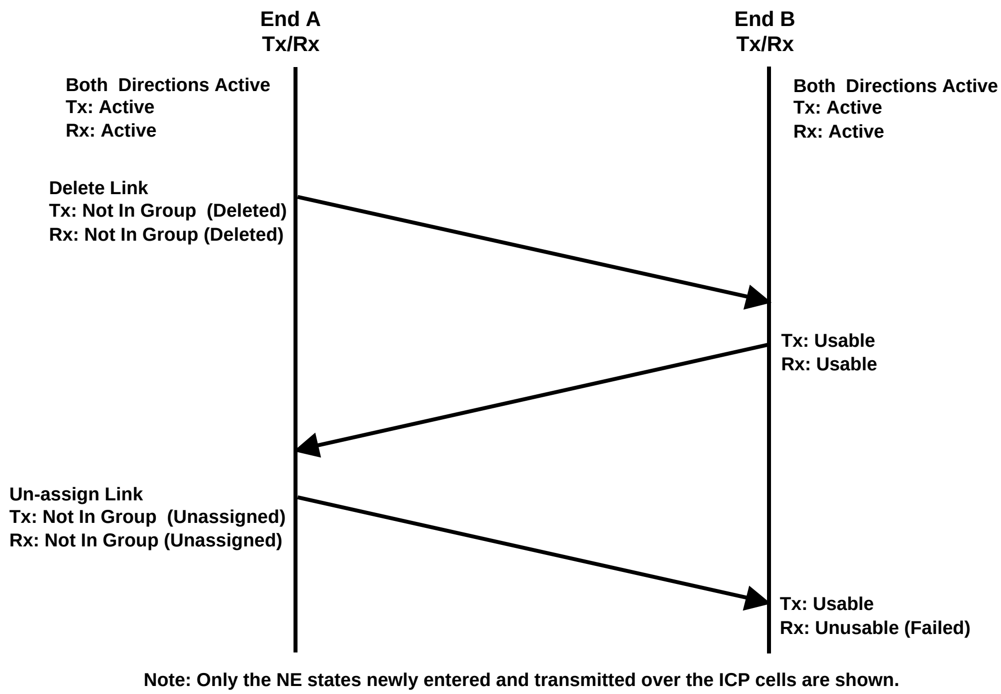



**Figure 42 Transmit Link Deletion at One End (Symmetrical Operational)**

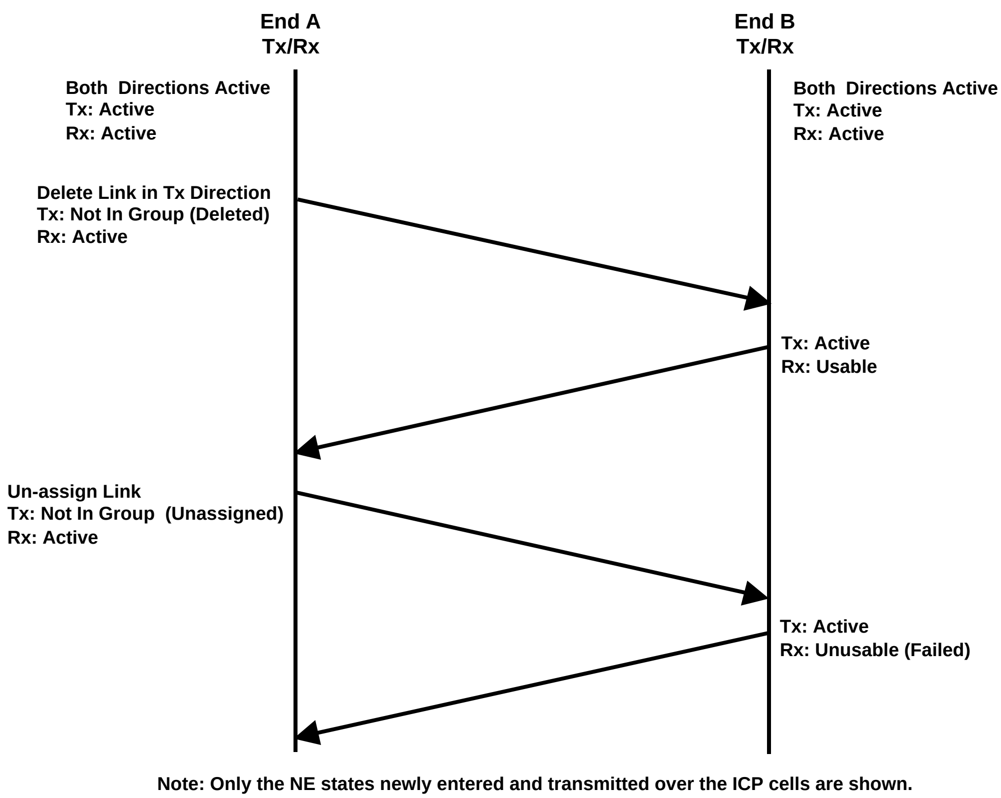



**Figure 43 Transmit Link Deletion at One End (Asymmetrical Operational)**

Figure 44 on page 174 shows the state exchange in the case of link de-activation in the case of a transmit failure in one direction under symmetrical configuration. Figure 45 on page 174 shows the scenario for the asymmetrical operation.

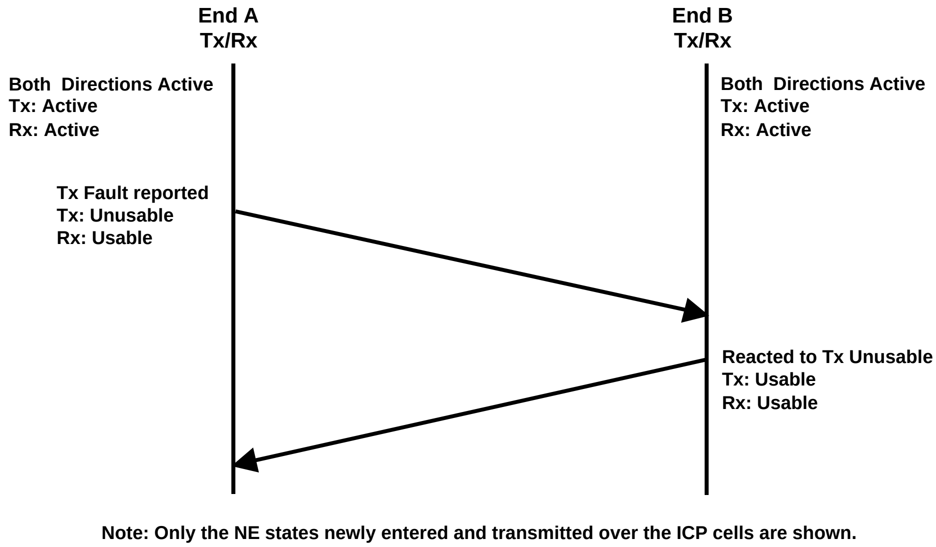



**Figure 44 Link De-activation Due to Tx Fault (Symmetrical Operational)**

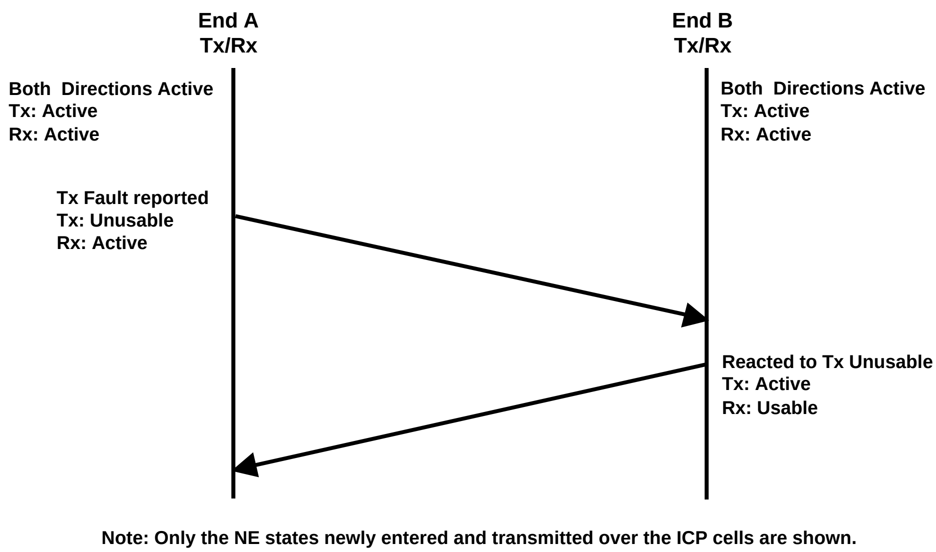
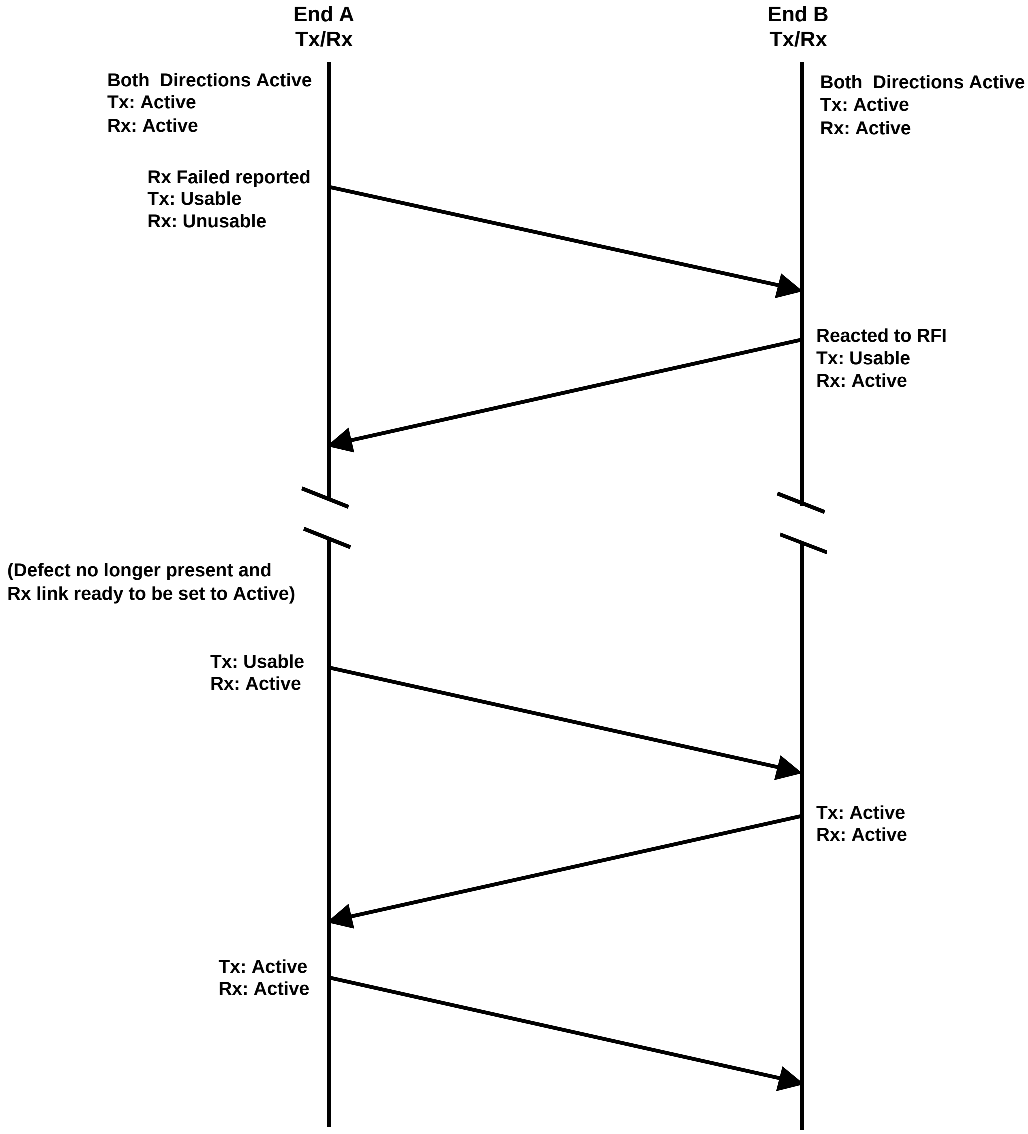


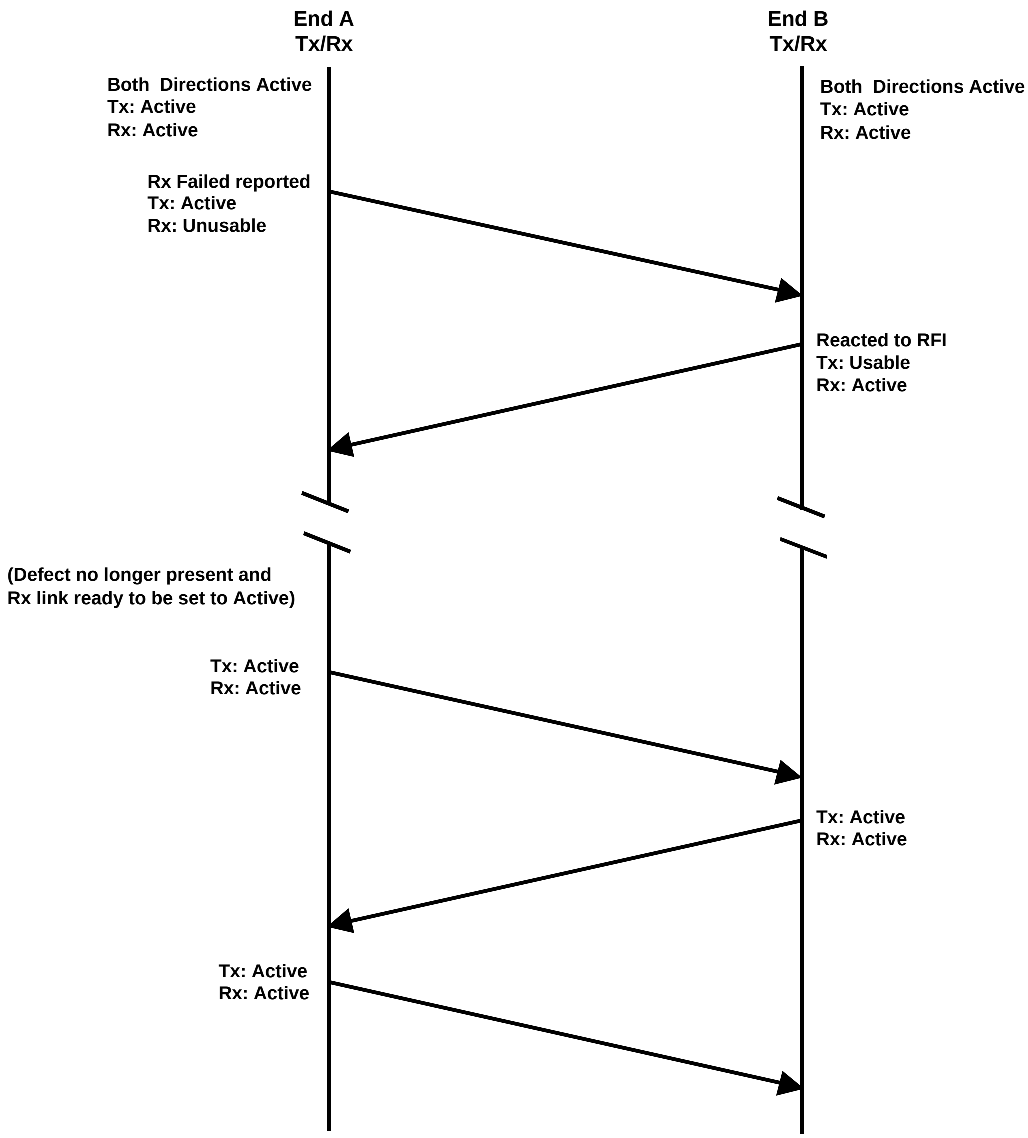

**Figure 45 Link De-activation Due to Tx Fault (Asymmetrical Operational)**

Figure 46 on page 175 and Figure 47 on page 176 show a link de-activation when the Rx Failed condition is entered and the later link re-activation after Rx Failed condition is exited, under symmetrical and asymmetrical operation respectively.




Note: Only the NE states newly entered and transmitted over the ICP cells are shown.

**Figure 46 Link De-activation/Recovery under Link Failed Condition (Symmetrical Operation)**




Note: Only the NE states newly entered and transmitted over the ICP cells are shown.

**Figure 47 Link De-activation/Recovery under Link Failed Condition (Asymmetrical Operation)**

# Appendix F IMA OAM Behaviors

This appendix provides information about the OAM behaviors of the IMA interface. Figure 48 on page 177 shows the OAM behaviors of a single link and an IMA interface. The following can be noted:

- A defect is reported once at a layer (F1, F2, F3, F4, or F5) upon detecting a defect at the same layer or when AIS is reported by the lower layer.
- Once a defect is detected at a layer, an RDI is reported in the opposite direction.
- Once a defect is detected at a layer, AIS is reported to the next upper layer.

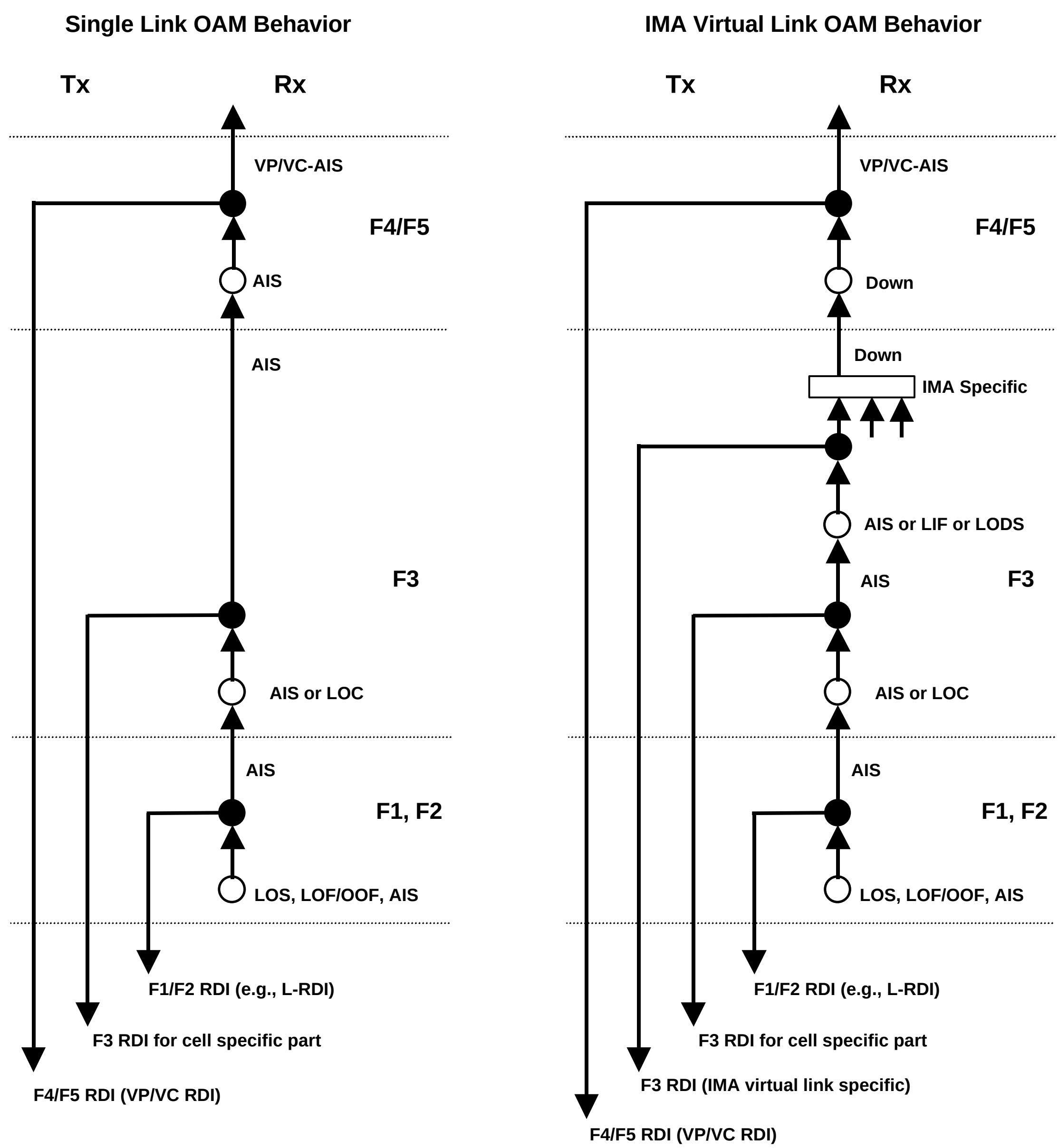



Figure 48 Single Link and IMA Virtual Link OAM Behaviors

# Appendix G Numbers of IV-IMAs to Trigger SES-IMA

ITU-T Recommendation G.826 [26] specifies that SES shall be reported for second periods that contain ≥ 30% errored blocks. This ITU recommendation also specifies that:

- that a lesser value may be used in the case where the system does not have the ability to detect as such,
- that a value different from 30% may be used, and
- that the value may vary with transmission rate.

Table 38 on page 178 shows the number of errored ICP cells that could be used to derive SES if we require ≥ 30% errored blocks to report SES. This is excluding the presence of Filler and ATM layer cells. The table shows that the values of the SES threshold depend of M and the available LCR.

**Table 38 Proposed Numbers of IV-IMAs to Trigger SES**

| | DS1 (LCR = 3622.6 cells/second) | | E1 (LCR = 4528.3 cells/second) | |
|---|---|---|---|---|
| **M** | **ICP cells/second** | **≥ 30%** | **ICP cells/second** | **≥ 30%** |
| 32 | 113 | 34 | 142 | 43 |
| 64 | 56 | 17 | 71 | 22 |
| 128 | 28 | 9 | 36 | 11 |
| 256 | 14 | 5 | 18 | 6 |

# Appendix H Detailed IMA Clocking Configurations

This appendix contains detailed information with respect to clocking options that are specific to various IMA link configurations, where the links are DS1 or E1 links. The information contained within this appendix builds upon the details as described within Section 4.3 on page 24 and addresses the scenarios where the transmit clocks of the links within the IMA group may or may not be derived from the same clock source (i.e., CTC or ITC mode), and where the IMA interface is used in public and private network configurations. The respective clocking configuration selected for an IMA application will be determined by the availability and provisioning of link services. It is suggested that, if possible, all the links within the IMA link group use a single source for transmit clock and, if possible, that source be traceable to a Primary Reference Source (PRS).

Throughout this appendix the terms Primary Reference Source (PRS)[5], Primary Reference Clock (PRC)[23], and Stratum 1 are synonymous.

## H.1 IMA Group in CTC Mode

This section describes clocking options applicable to the configuration where the IMA interface is running in the Common Transmit Clock (CTC) mode. These clocking options can be categorized into two main sections, namely non-transparent and transparent, as shown in Figure 49 on page 179. The link reference model illustrates the different timing domains [20].

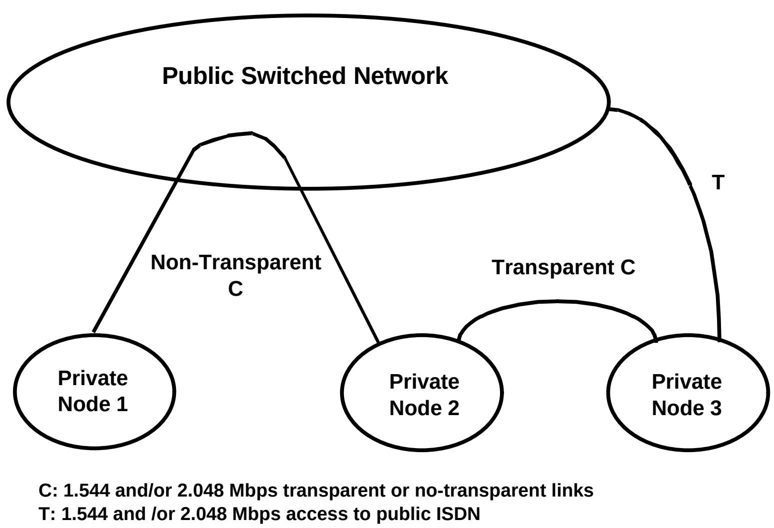



**Figure 49 Link Timing Reference Model**

Transparent is defined within reference [20] as: a link or group of links is transparent if the signal carried is not re-timed from a clock associated with the link(s). The timing of a signal passing across a transparent link may however be altered due to jitter, wander, filtering or error conditions.

### H.1.1 Non-Transparent Links

The following section will detail link configurations applicable to a non-transparent relationship. All these configurations are associated with the support of access to a synchronous public network.

#### H.1.1.1 Single Time Domain

The single-time domain clocking configuration is applicable to an application where all transmitters are within a single timing domain (e.g., all links from the same local area carrier). An example is given in Figure 50 on page 180.

The IMA units will derive their respective transmit clocks from one of their receive clock signals, which will normally be traceable to a Stratum 1.

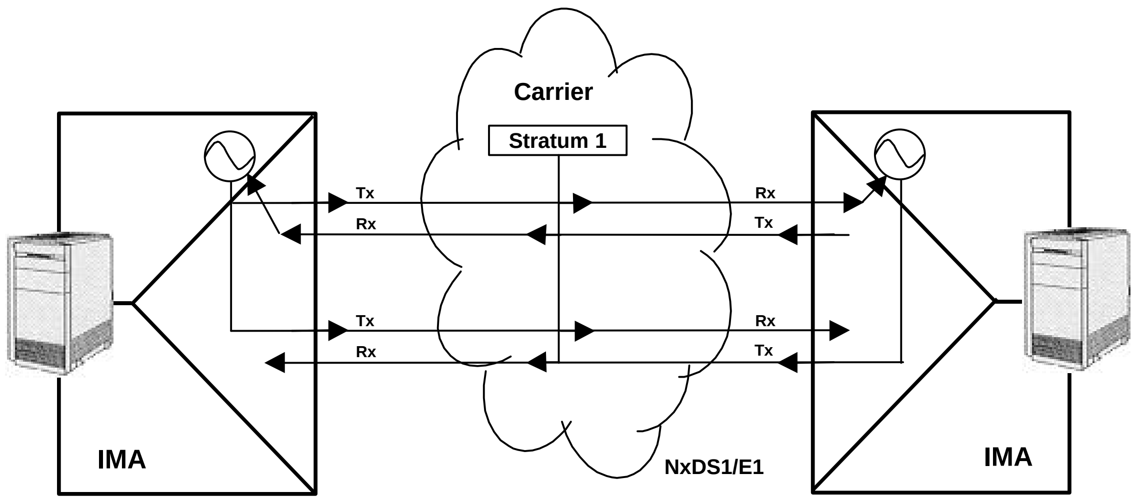



**Figure 50 Single Time Domain**

The DS1 interface will be expected to conform to the ANSI T1.408 [5] specification which imposes the following requirements:

The IMA received and transmitted bit streams must be synchronized to the carrier's clock.

In normal operation the bit stream is traceable to a Stratum 1 primary reference, which has a long term bit rate accuracy of $1x10^{-11}$. When synchronization by a Stratum 1 clock has been interrupted, the signal delivered by the network to the interface shall have a minimum accuracy of $4.6 \times 10^{-6}$, Stratum 3 accuracy, as specified in ANSI T1.408[5], Section 5.3.1.1.

For multiple network interfaces (as with an IMA interface with multiple links), the transmission rate is determined by the signal received across only one link interface, or is derived externally from the carrier's Stratum 1, so that all interfaces are synchronized to the same master clock source.

An E1 interface has similar requirements that are specified in ITU-T Recommendations G.703 [21] and I.431 [29].

### H.1.1.2 Two or More Timing Domains

The two or more timing domains clocking configuration addresses the scenario where the multiple IMA low speed links are obtained from a number of distinct and separate carriers, which have their own synchronization hierarchies (timing domains). This scenario may be quite common as it adds to the diversity and survivability of an IMA application. An example is shown in Figure 51 on page 176.

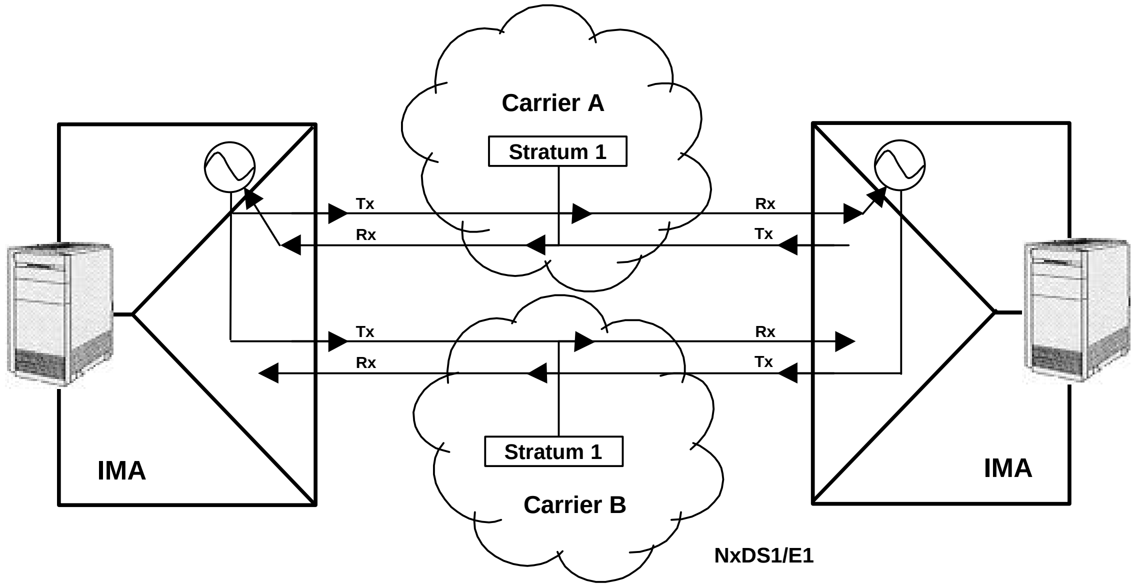



**Figure 51 Two or More Timing Domains**

The configuration will have each link or group of links synchronized to a separate master clock source, which again will normally be traceable to Stratum 1. In practice only one of the carrier master clocks will synchronize the IMA equipment for synchronization, e.g., Carrier A's Stratum 1 reference clock. This may result in virtually error-free traffic performance as the carriers are operating plesiochronously with each other, with average clock rate different by no more than 1 part per $10^{-11}$. In this configuration, it is recommended to ensure all carriers use Stratum 1 traceable clocks when subscribing.

### H.1.1.3 International or Inter Exchange Carrier (IEC) Timing Domains

The following configuration, shown in Figure 52 on page 182, can be referred to as the "Classic Plesiochronous" configuration with respect to a synchronous network. The scenario addressed is where the links traverse more than one timing domain. This is possible within international and inter-IEC topologies as well as within many larger networks. Each IMA interface's internal clock will synchronize to a DS1/E1 received from the host carrier and provide timing to the IMA transmitted signals, so that all the signals in the group of links are normally traceable to one of the carrier's Stratum 1. The inter-working and re-timing of the information stream across the different timing domains will be managed transparently to the application. If timing differences do accumulate then a controlled slip may be introduced by individual DS1/E1 receivers to compensate for the differences. Under fault free conditions the occurrence of a controlled slip will be rare, e.g. in a worst case scenario where the number of carriers (N) is 2, 1 controlled frame slip will occur every 72 days (per DS1/E1).

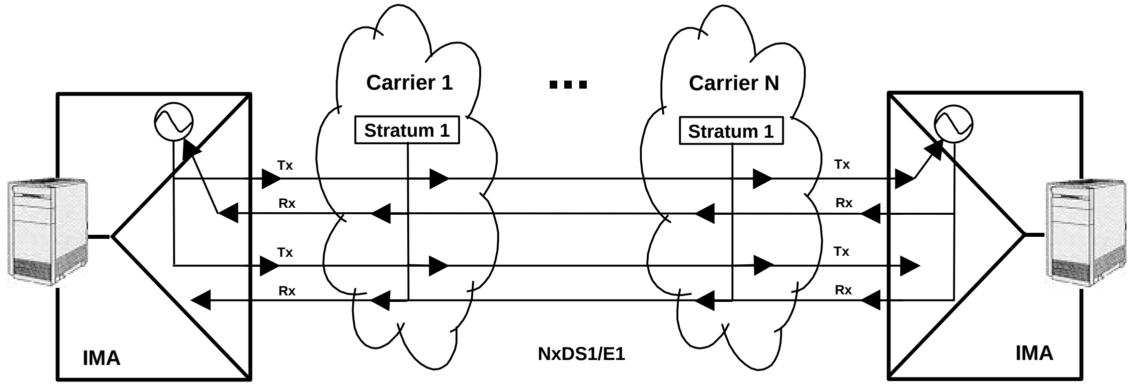



**Figure 52 International or Inter IEC Timing Domains**

### H.1.2 Transparent Links

The following section details link configurations applicable to a transparent relationship, e.g. private leased lines. These configurations will require the customer premise to provide or act as the master clock source for the transmitted signals. All these configurations should be termed as being asynchronous, which indicates that they are not synchronized to a network-wide clock source. Note that the respective local clock source may still be traceable to a network-wide PRS but this is not a requirement.

### H.1.3 Master/Master Configuration

The master/master configuration is applicable when addressing services which require the customer premise equipment to act as the clock source. In this configuration the transmit clock is not derived from the receive bit stream (see Figure 53 on page 182). The configuration may also be known as a “Transparent” or “Split timing” configuration [20]. The clocks are required to support an accuracy of 1.544 Mbps ± 32 ppm for DS1 configuration [2] and 2.048 Mbps ± 50 ppm for E1 configuration [21].

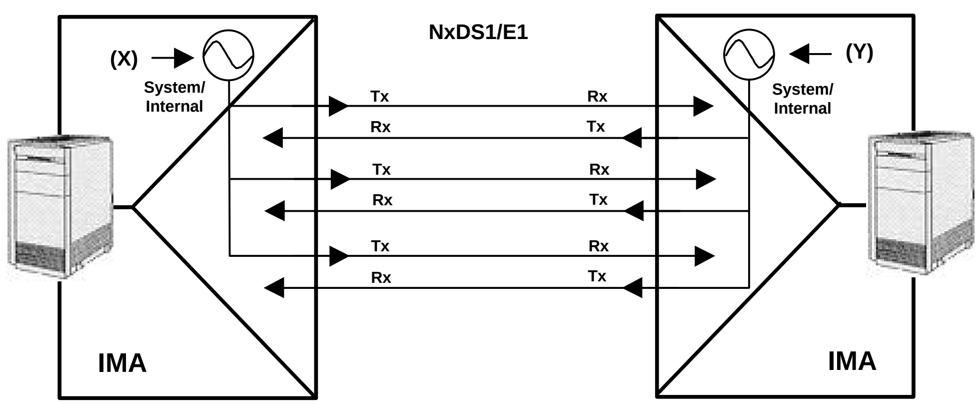



**Figure 53 Master/Master Configuration**

Practical configuration options with respect to the clock sources are detailed as follows, refer [20]. (x) and (y) are reference clocks. When (x) and (y) are providing a clock signal, two cases can occur, in addition to the free-running case:

1. (x) and (y) come from the same clock and are therefore synchronous and

2. (x) and (y) are from two different clock sources.

### H.1.3.1 Master/Slave Configuration

The Master/Slave configuration, also referred as looped timing configuration, is the most common configuration with respect to the support of private networking scenarios. An example is represented in Figure 54 on page 183.

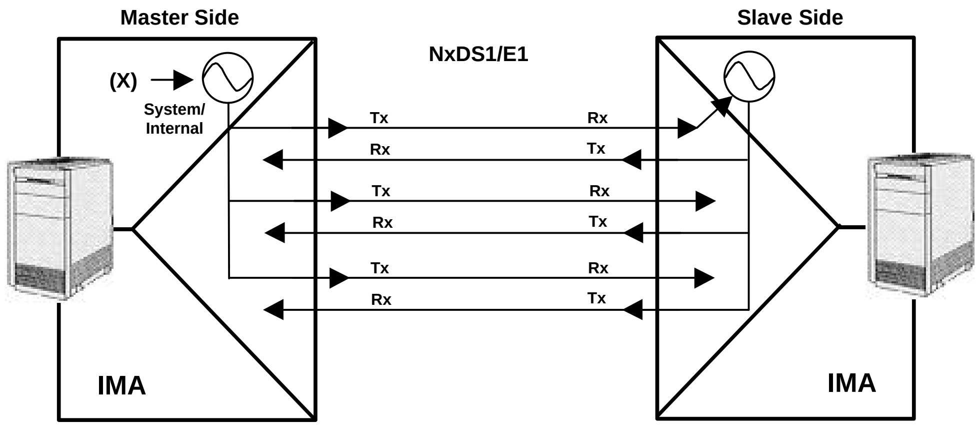



**Figure 54 Master/Slave Configuration**

As it can be determined from Figure 54, there is a single master clock source. The remote equipment (Slave) will synchronize to the master-provided transmitted signal. The accuracy of the master clock source is expected to be in the range of 1.544 Mbps ± 32 ppm for DS1 configurations [2], and 2.048 Mbps ± 50 ppm for E1 configurations [21].

## H.2 Connections to Public ISDN

The access to DS1/E1 links may be either transparent or non-transparent. The ATM switch in the public network will provide timing. The overall effect is as if the links were non-transparent. Figure 50 on page 180 illustrates this case.

### H.2.1 IMA Group in ITC Mode

Detailed within this section are clocking options applicable to the configuration where the IMA group is running in the Independent Transmit Clock (ITC) mode. This typically results in the scenario where some of the source clock signals are not traceable to a PRS.

### H.2.2 Two or More Timing Domains - Un-synchronized

The clocking configuration, as detailed within Figure 55 on page 184, is similar to the configuration contained within Section H.1.1.2 on page 180, where the multiple IMA low speed links are supported over a number of distinct and separate carriers in a non-transparent fashion. The main difference in this configuration is that each link within the IMA link group is synchronized via “looped” timing to each of the respective carriers’ reference clocks, whereas in the previous configuration (Section H.1.1.2) one of the carriers was selected as the reference. This configuration will result in virtually error-free performance as described in Section H.1.1.2.

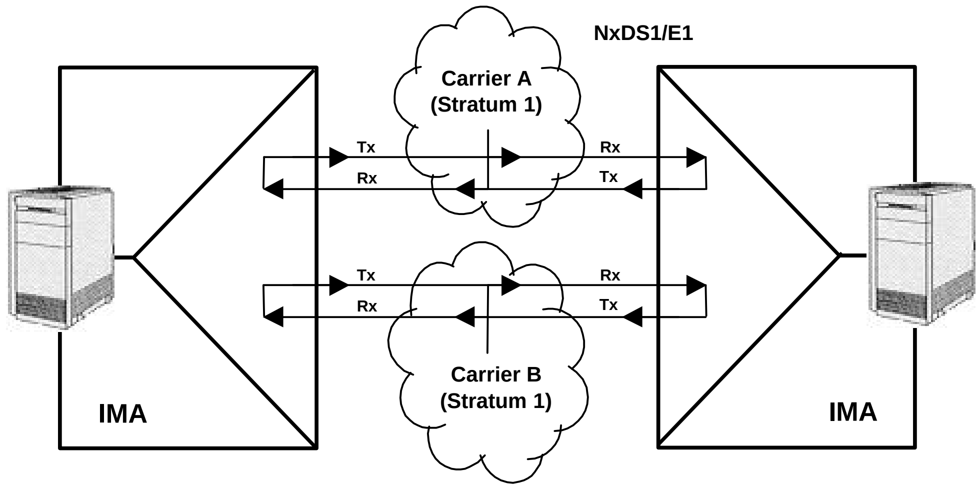



**Figure 55 Two or More Timing Domains - Un-synchronized**

### H.2.3 Non-Transparent/Transparent Mixed Configuration

The non-transparent/transparent mixed configuration addresses the scenario where the links within the IMA link group are supported over a combination of transparent and non-transparent facilities. This may be the result of the following conditions where the majority of the links are supported as private leased line connections and additional links are managed/deployed via an on-demand basis by utilizing dialup and/or ISDN facilities. The additional links may be established either as a result of a demand for additional bandwidth or alternatively to address a restoration/survivability scenario.

Figure 56 on page 185 shows an example of mixed of transparent/non-transparent configurations. It displays the following configuration mix:

- the private leased line links will be supported as transparent links, in this case a master/slave clocking configuration has been selected.
- the dialup and/or ISDN lines will be supported as non-transparent links, in this case a master/slave.

The non-transparent/transparent mixed configuration, therefore, creates the situation where the links within the IMA link group are supported in a non-synchronous fashion. The private leased line links will be synchronized to a locally derived timing source, which maybe asynchronous to the carrier clock source; and the links supported over the dialup and/or ISDN facilities will be synchronized to the carrier's master clock source.

If possible, the timing configuration represented in Figure 56 on page 185 should be avoided. In case this configuration is used, it is recommended to drive timing on the transparent links from one of the PRS traceable sources from a carrier(s) rather than from local sources. This changes the configuration to that covered in Section H.1.1.1 on page 179 Section H.1.1.2 on page 180 (depending on the number of independent Primary Reference Sources in the configuration).

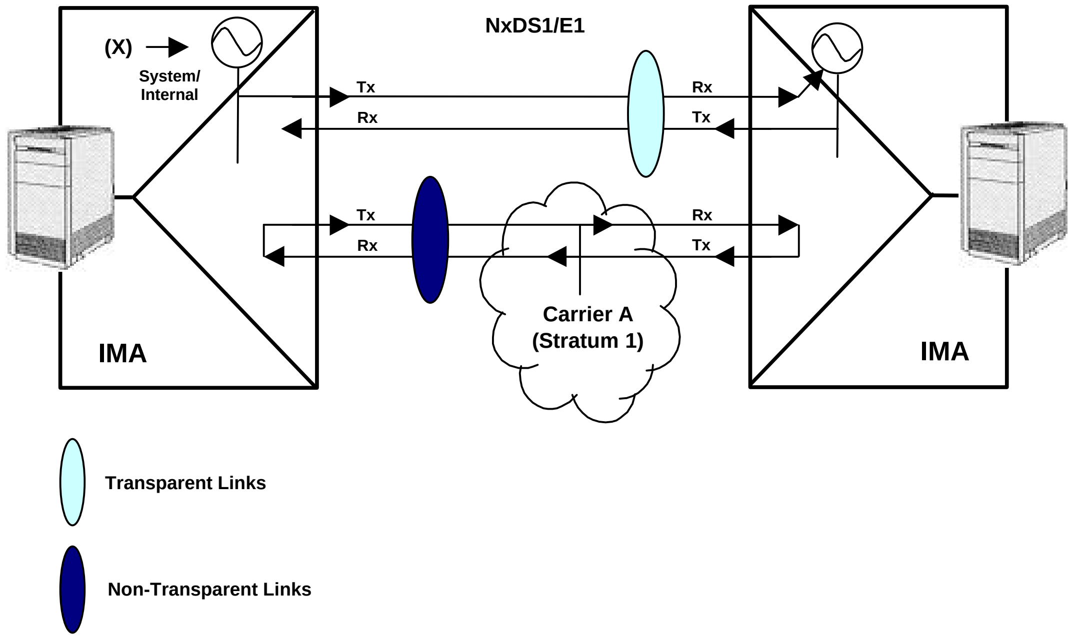



**Figure 56 Non-Transparent/Transparent Mixed Configuration**