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622.08 Mbps Physical Layer Specification

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TABLE OF CONTENTS

SECTION PAGE NUMBER

LIST OF FIGURES

LIST OF TABLES

1. 622.08 MBPS PHYSICAL LAYER SPECIFICATION

The 622.08 Mbps physical layer specification is based on the Synchronous Optical Network (SONET) and the Synchronous Digital Hierarchy (SDH) standards. These standards provide, through a framing structure, the payload envelope necessary for the transport of ATM cells as well as overhead bytes for the carriage of OAM information. The SONET/SDH OAM functions residing in the physical layer management (M-plane) are covered in section 4. The functions of the physical layer (U-plane) are grouped into the physical media dependent (PMD) sublayer (covered in section 2) and the transmission convergence (TC) sublayer (covered in section 3).

This specification shall apply for 622.08 Mbps interfaces at the public UNI, the private UNI and the private NNI.

2. PHYSICAL MEDIUM DEPENDENT (PMD) SUBLAYER

Currently, three fiber-based PMDs are defined for the 622.08 Mbps interface. Other PMD types are for further study.

2.1 Fiber Specification

A single-mode fiber interface and two multi-mode fiber interfaces are defined. The support of either longer link distances or other fiber types is based on the chosen implementation.

(**R**) The public UNI shall use the single-mode interface.

(**O**) The private UNI and the private NNI may use the single-mode interface.

(**O**) The private UNI and the private NNI may use either multi-mode interface.

The physical media consists of two fiber links, one for each direction of transmission. The optional implementation of automatic protection switching (see description of the K1, K2 bytes in the Transmission Convergence Sublayer section) requires an additional, separate fiber for each transmission direction.

2.1.1 Single-Mode Fiber Interface

The single-mode fiber interface is specified in G.957, and in T1.646. An intermediate reach interface and a short reach interface are defined. The intermediate reach interface is intended for link lengths up to 15 km. The short reach interface is intended for link lengths up to 2 km.

The optical parameters considered in this standard are based on the spectral characteristics of single-mode fibers specified in IEC 793-2 and ANSI/TIA/EIA-492CAAA.

2.1.1.1 Line Code

(**R**) The optical line coding is binary NRZ.

2.1.1.2 System Budget

Proper system performance is ensured by considering the attenuation, reflection and dispersion characteristics of the optical path.

Attenuation Range: The intermediate reach interface has an attenuation range of 0 to 12 dB. The short reach interface has an attenuation range of 0 to 7 dB. These ranges are consistent with G.957 and T1.646. This specification is assumed to represent worst-case values including losses due to splices, connectors, optical attenuators (if used), or other passive optical devices, and additional cable margin to cover allowances for the following.

1. Future modifications to the cable configuration (additional splices, increased cable lengths, etc.)

2. Fiber cable performance variations due to environmental factors

3. Degradation of any connector, optical attenuator (if used), or other passive optical device when provided.

(**R**) The short and intermediate reach attenuation ranges shall be as specified in T1.646 and G.957.

Dispersion: Intermediate reach systems, when operating in the 1293 to 1334 wavelength range, shall have a maximum dispersion of 46 ps/nm. An optional configuration of this interface, which operates in the 1274 to 1356 nm wavelength range (see Table 1), shall have a maximum dispersion of 74 ps/nm. Short reach systems shall have a maximum dispersion of 13 ps/nm. These ranges are consistent with G.957 and T1.646.

(**R**) The maximum dispersion shall be as specified in T1.646 and G.957.

2.1.1.3 Transmitter Characteristics

(**R**) The intermediate reach transmitter characteristics shall be as defined in T1.646 and G.957.

(**R**) The short reach transmitter characteristics shall be as defined in T1.646 and G.957.

2.1.1.4 Receiver Characteristics

(**R**) The intermediate reach receiver characteristics shall be as defined T1.646 and G.957.

(**R**) The short reach receiver characteristics shall be as defined in T1.646 and G.957.

The single-mode fiber interface parameters, as contained in G.957 and T1.646, are summarized in Table 1.

Parameter	Intermediate Reach	Short Reach	Units
Transmitter Characteristics			
Wavelength (Note 1)	1293-1334 (1274-1356)	1261-1360	nm
Spectral Width:			
Maximum RMS Width	4 (2.5)	14.5, 35 (Note 2)	nm
Mean Launched Power	-15 to -8	-15 to -8	dBm
Minimum Extinction Ratio	8.2	8.2	dB
Eye Pattern Mask	see T1.646	see T1.646	
Receiver Characteristics			
Minimum Sensitivity	-28	-23	dBm
Minimum Overload	-8	-8	dBm
Optical Path Power Penalty (Note 3)	1	1	dB

Table 1 Optical Parameters for 622.08 Mbps Single-mode Fiber Interface

Note 1: The parenthetical values for the intermediate reach wavelength range, spectral width and dispersion (see Note 3) correspond to an optional configuration operating in the referenced wavelength range of 1274 to 1356 nm.

Note 2: For the short reach interface, the maximum RMS width of 14.5 nm applies to MLM lasers, while the width of 35 nm applies to LEDs.

Note 3: The intermediate reach interface is assumed to have a maximum dispersion of 46 (74)ps/nm. The short reach interface is assumed to have a maximum dispersion of 13 ps/nm for MLM laser applications and 14 ps/nm for LED applications.

2.1.1.4 Jitter

The following jitter specifications apply for single-mode fiber interfaces at the public UNI, the private UNI and the private NNI.

(**R**) The interface jitter shall be as defined in T1.646.

(**R**) The receiver jitter tolerance shall exceed the jitter tolerance template specified in T1.646 and G.958.

(**R**) When the interface is synchronized to the recovered clock, the jitter transfer shall exceed the requirements of T1.646 and G.958.

2.1.2 Multi-Mode Fiber Interface

A light emitting diode (LED) based MMF interface and a short wavelength (SW) laser based MMF interface are specified. Either MMF interface may be used; however, the two MMF interfaces are not inter-operable. Both MMF interfaces support the two types of multi-mode fiber specified below and are intended for a minimum link length of 300 m.

The optical parameters referenced in this standard are defined in ANSI/TIA/EIA-568-A and in ISO/IEC 11801.

2.1.2.1 Optical Fiber

(**R**) The optical fiber shall be 62.5/125 um multi-mode, graded index optical fiber as specified in IEC 793-2 Type A1b and TIA/EIA-492AAAA-A or 50/125 um multi-mode, graded index optical fiber as specified in IEC 793-2 Type A1a.

2.1.2.2 Line Code

(**R**) The optical line coding binary NRZ.

2.1.2.3 Error Rate

(**R**) An LED-based MMF interface receiver shall operate with a bit error rate not to exceed 10^{-10} when presented with a transmitter signal as specified in section 2.1.2.4.2 transmitted through a multi-mode fiber link subject to the system budget constraints specified in 2.1.2.4.1.

(**R**) A SW laser-based MMF interface receiver shall operate with a bit error rate not to exceed 10^{-10} when presented with a transmitter signal as specified in section 2.1.2.5.2 transmitted through a multi-mode fiber link subject to the system budget constraints specified in 2.1.2.5.1.

2.1.2.4 LED-based MMF Interface

2.1.2.4.1 System Budget

Proper system performance is ensured by considering the attenuation, reflection and dispersion characteristics of the optical path and including them as part of the link budget. In addition to these cable plant characteristics, a system power penalty is normally included in the link budget. The power penalty includes the effects of eye closure due to transmitter characteristics (finite rise and fall times, random and systematic jitter). This system power penalty is accounted for in the receiver sensitivity specification; therefore, the system budget is composed entirely of losses due to the cable plant.

Attenuation Range: The attenuation range specification for 62.5 um optical fiber was defined based on the use of components meeting the requirements of ANSI/TIA/EIA-568-A and ISO/IEC 11801 and operating up to 500 meters. The attenuation range for 50 um fiber is also intended for operation up to 500 m. The static attenuation in the optical path includes worst case loss values for the fiber media , connectors, splices, attenuators and any other passive optical devices. The attenuation range is 0 to 6 dB for 62.5 um fiber and 0 to 2 dB for 50 um fiber.

(**R**) Each 62.5 um optical fiber link shall have an end-to-end attenuation of 6.0 dB or less at 1300 nm when measured in accordance with Annex H of ANSI/TIA/EIA-568-A.

(**R**) Each 50 um optical fiber link shall have an end-to-end attenuation of 2.0 dB or less at 1300 nm when measured in accordance with Annex H of ANSI/TIA/EIA-568-A.

Dispersion: The specifications for fiber dispersion for broad spectral width sources account for the effect of modal and chromatic dispersion to ensure correct system operation.

(**R**) Each optical fiber shall have a minimum modal bandwidth of 500 MHz-km at 1300 nm when measured in accordance with IEC 793-1-C2A (ANSI/TIA/EIA-455-51A) or IEC 793-1-C2B (ANSI/TIA/EIA-455-30B).

(**R**) Each optical fiber shall meet the zero dispersion wavelength and maximum dispersion slope as specified in IEC 793-2 and ANSI/TIA/EIA-492AAAA-A.

Reflections: The attenuation parameters include loss due to reflections in the connector forward loss. The effects on the transmitter due to reflections are assumed to be small for these data rates and for the devices intended for use by this standard and are, therefore, ignored.

2.1.2.4.2 Transmitter Characteristics

The values prescribed are for worst case operating conditions and end of life; they are to be met over the full range of standard operating conditions, (i.e., voltage, temperature and humidity) and include aging effects. The limits for the rise and fall times specified below are 10%-90%. The following parameters are specified for the transmitter.

(**R**) The wavelength range shall be from 1270 to 1380 nm.

(**R**) The maximum full width half-maximum (FWHM) spectral width shall be 200 nm.

(**R**) The mean launched power into 62.5 um fiber shall be between -14 and -20 dBm.

(**R**) The mean launched power into 50 um fiber shall be between -14 and -24 dBm.

(**R**) The minimum extinction ratio shall be 10 dB.

(**R**) The transmitter exit Rise (Fall) time shall be less than 1.25 ns.

(**R**) The maximum transmitter overshoot shall be 25%.

(**R**) The systematic interface jitter at the transmitter output shall be less than 0.40 ns peak-to-peak.

(**R**) The random interface jitter at the transmitter output shall be less than 0.15 ns peak-to-peak.

2.1.2.4.3 Receiver Characteristics

The values prescribed are for worst case end of life; they are to be met over the full range of standard operating conditions, (i.e., voltage, temperature and humidity) and include aging effects. The limits for the rise and fall times specified below are 10%-90%. The following characteristics are specified for the receiver.

(**R**) The minimum receiver sensitivity shall be -26 dBm.

(**R**) The minimum receiver overload shall be -14 dBm.

(**R**) The receiver optical input rise (fall) time shall be less than 1.6 ns.

(**R**) The systematic interface jitter at the receiver input shall be less than 0.50 ns peak-to-peak.

(**R**) The random interface jitter at the receiver input shall be less than 0.15 ns peak-to-peak.

(**R**) The minimum receiver eye opening at a $1x10^{-10}$ BER shall be 0.31 ns.

The LED-based multi-mode interface parameters are summarized in Table 2.

LED-based MMF Interface Parameter	62.5 um MMF	50 um MMF	Units
Transmitter Interface Characteristics			
Wavelength	1270 - 1380	1270 - 1380	nm
Maximum Spectral Width	200	200	nm
Mean Launched Power (Note 2)	-20 to -14	-24 to -14	dBm
Minimum Extinction Ratio	10	10	dB
Maximum Rise (Fall) Time, (10-90%)	1.25	1.25	ns
Maximum Overshoot	25	25	%
Maximum Systematic Interface Peak-to-Peak Jitter	0.4	0.4	ns
Maximum Random Interface Peak-to-Peak Jitter	0.15	0.15	ns
Receiver Interface Characteristics			
Minimum Sensitivity (Note 2)	-26	-26	dBm
Minimum Overload	-14	-14	dBm
Maximum Rise (Fall) Time, (10-90%)	1.6	1.6	ns
Maximum Systematic Interface Peak-to-Peak Jitter	0.5	0.5	ns
Maximum Random Interface Peak-to-Peak Jitter	0.15	0.15	ns
Minimum Receiver Eye Opening (Note 1)	0.31	0.31	ns

Table 2 LED-based Optical Parameters for MMF Interface

Note 1: The receiver eye opening represents the eye opening allocated for the clock recovery function after the optical to electrical conversion at the receiver.

Note 2: A 6 dB system budget is specified for 62.5 um fiber and a 2 dB system budget is specified for 50 um fiber. The entire system budget is allocated for cable plant losses as described in section 2.1.2.4.1.

2.1.2.4.4 Jitter

The following jitter specifications apply for the LED-based multi-mode fiber interface at the private UNI and the private NNI.

(**R**) The transmit interface jitter shall be as specified in section 2.1.2.4.2.

(**R**) The receive interface jitter shall be as specified in section 2.1.2.4.3.

The receiver jitter tolerance and the jitter transfer through the interface are for further study. Note that the jitter transfer specification is only applicable when the interface is synchronized to the recovered clock.

2.1.2.5 SW laser-based MMF Interface

2.1.2.5.1 System Budget

Proper system performance is ensured by considering the attenuation, reflection, and dispersion characteristics of the optical path and including them as part of the link budget. In addition to these cable plant characteristics, a system power penalty must also be included in the link budget. The power penalty includes the effects of eye closure due to transmitter characteristics (finite rise and fall times, random and systematic jitter) and modal noise.

(**R**) The total system budget shall be 6 dB, of which 4 dB is allocated for cable plant characteristics and 2 dB for system power penalties.

Attenuation Range: An attenuation range specification of 4 dB is defined based on typical premises wiring layouts as described in ANSI/TIA/EIA-568-A and ISO/IEC 11801 and operating up to 300 m. The static attenuation in the optical path includes worst case loss values for the fiber media, connectors, splices, attenuators and any other passive optical devices. The attenuation range is 0 to 4 dB for both 62.5 um fiber and 50 um fiber.

(**R**) Each optical fiber link of 300 m shall have an end-to-end attenuation not exceeding 4.0 dB at 780 nm.

Dispersion: The specifications for fiber dispersion for SW laser-based sources account for the effect of modal dispersion to ensure correct system operation. SW laser-based sources are not limited by chromatic dispersion.

(**R**) Each optical fiber shall have a minimum modal bandwidth of 160 MHz-km at 850 nm when measured in accordance with IEC 793-1-C2A (ANSI/TIA/EIA-455-51A) or IEC 793-1-C2B (ANSI/TIA/EIA-455-30B).

Note: the bandwidth specified meets the performance requirements for 780 nm laser operation.

Reflections: The effects on the transmitter due to reflections are assumed to be small for these data rates. A specification of a maximum Relative Intensity Noise under worst case reflection conditions is included to assure that reflections do not impact system performance.

(**R**) The source shall not exceed a RIN of -116 dB/Hz with a minimum fiber return loss of 12 dB.

Modal Noise: A portion of the system power penalty is reserved for performance degradation due to modal noise. A methodology for the measurement of modal noise is for further study; however, modal noise can be kept within acceptable limits by controlling the connector loss in the link and by proper transmitter design.

(**R**) The system power penalty due to modal noise shall not exceed 0.5 dB for 62.5 um fiber and 1.0 dB for 50 um fiber.

The modal noise system power penalty above assumes that the connector loss is distributed across the link and that the maximum connector loss for any single connector does not exceed 0.56 dB.

2.1.2.5.2 Transmitter Characteristics

The values prescribed are for worst case operating conditions and end of life; they are to be met over the full range of standard operating conditions, (i.e., voltage, temperature and humidity) and include aging effects. The limits for the rise and fall times specified below are 10%-90%. The following parameters are specified for the transmitter.

(**R**) The wavelength range shall be from 770 to 860 nm.

(**R**) The maximum full width half-maximum (FWHM) spectral width shall be 9 nm.

The maximum coupled power limit is set by eye safety requirements as specified in IEC 825-1 (11/93). In the event that these limits change, the maximum coupled power may be increased to the maximum level set by the minimum receiver overload.

(**R**) The mean launched power shall be between -4 and -10 dBm at 860 nm and -5 to -10 dBm at 770nm. At wavelengths between these limits, the maximum power is specified in IEC 825-1 (11/93).

(**R**) The minimum extinction ratio shall be 9 dB.

(**R**) The transmitter exit Rise (Fall) time shall be less than 0.75 ns.

(**R**) The maximum transmitter overshoot shall be 25% when measured into the filter specified in G.957. This filter is intended to represent the effective receiver bandwidth.

(**R**) The total interface jitter at the transmitter output shall be less than 0.35 ns peak-to-peak.

(**R**) The systematic interface jitter at the transmitter output is for further study.

(**R**) The random interface jitter at the transmitter output is for further study.

2.1.2.5.3 Receiver Characteristics

The values prescribed are for worst case end of life; they are to be met over the full range of standard operating conditions, (i.e., voltage, temperature and humidity) and include aging effects. The limits for the rise and fall times specified below are 10%-90%. The following characteristics are specified for the receiver.

(**R**) The minimum receiver sensitivity shall be -16 dBm.

(**R**) The minimum receiver overload shall be 0 dBm.

(**R**) The receiver optical input rise (fall) time shall be less than 1.2 ns.

(**R**) The total interface jitter at the receiver input shall be less than 0.55 ns peak-to-peak.

(**R**) The systematic interface jitter at the receiver input is for further study.

(**R**) The random interface jitter at the receiver input is for further study.

(**R**) The minimum receiver eye opening at a 1×10^{-10} BER shall be 0.31 ns.

The SW laser-based multi-mode interface parameters are summarized in Table 3.

SW laser-based MMF Interface Parameter	62.5 um MMF	50 um MMF	Units
Transmitter Interface Characteristics			
Wavelength	770 - 860	770 - 860	nm
Maximum Spectral Width	9	9	nm
Mean Launched Power (Note 2)	-10 to -4	-10 to -4	dBm
Minimum Extinction Ratio	9	9	dB
Maximum Rise (Fall) Time, (10-90%)	0.75	0.75	ns
Maximum Overshoot	25	25	%
Maximum Interface Peak-to Peak Jitter	0.35	0.35	ns
Receiver Interface Characteristics			
Minimum Sensitivity (Note 2)	-16	-16	dBm
Minimum Overload	0	0	dBm
Maximum Rise (Fall) Time, (10-90%)	1.2	1.2	ns
Maximum Interface Peak-to-Peak Jitter	0.55	0.55	ns
Minimum Receiver Eye Opening (Note 1)	0.31	0.31	ns

Table 3 SW laser-based Optical Parameters for MMF Interface

Note 1: The receiver eye opening represents the eye opening allocated for the clock recovery function after the optical to electrical conversion at the receiver.

Note 2: A 6 dB system budget is specified for both 62.5 um fiber and 50 um fiber. Of this 6 dB budget, 4 dB is allocated for cable plant losses and 2 dB is allocated for a system power penalty as described in section 2.1.2.5.1.

2.1.2.5.4 Jitter

The following jitter specifications apply for the SW laser-based multi-mode fiber interface at the private UNI and the private NNI.

(**R**) The transmit interface jitter shall be as specified in section 2.1.2.5.2.

(**R**) The receive interface jitter shall be as specified in section 2.1.2.5.3.

The receiver jitter tolerance and the jitter transfer through the interface are for further study. Note that the jitter transfer specification is only applicable when the interface is synchronized to the recovered clock.

2.1.3 Synchronization

The public UNI must be synchronized to a primary reference source as described below. The private UNI and the private NNI typically do not require synchronization. In private UNI or private NNI applications where synchronization is required, it shall be provided as described for the public UNI below.

(**R**) In normal asynchronous operation, the transmit timing at the private UNI or the private NNI in both directions of transmission shall be within ±100 ppm of 622.08 Mbps.

(**R**) In normal synchronous operation, the transmit timing at the public UNI in the direction of the network to the customer shall be traceable to a Primary Reference Source (PRS) per T1.101.

(**R**) In normal synchronous operation, the transmit timing at the public UNI in the direction of the customer to the network shall be traceable to a PRS.

(**R**) When in a maintenance state, the timing of the signals from the network side may lack traceability to a PRS; in that case, the signals at the public UNI in the direction from the network to the customer shall be within ±20 ppm of 622.08 Mbps.

(**R**) When in a maintenance state, the timing of the signals from the customer interface may lack traceability to a PRS; in that case, the signals at the public UNI in the direction from the customer to the network shall be within ±20 ppm of 622.08 Mbps.

2.1.4 Media Interface Connector

(**R**) The optical fiber interface shall be the Duplex SC and shall meet the dimension and interface specifications of IEC 874-14. The connector shall meet the performance specifications as specified in ISO/IEC 11801.

It is recommended that the network polarity (transmit and receive) be managed in accordance with ANSI/TIA/EIA-568-A

Users having an installed base of BFOC/2.5 connectors and adapters (commonly referred to as ST) may remain with the BFOC connector and adapter for both existing and future additions to their optical network in accordance with ANSI/TIA/EIA-568-A.

3. TRANSMISSION CONVERGENCE (TC) SUBLAYER

A SONET/SDH based TC is specified for the 622.08 Mbps interface. The SONET STS-12c (T1.646) and SDH STM-4 (G.708, G.709) frame formats are used to transport ATM cells (see figure 1). These two frame formats are largely identical except for the usage of certain overhead bytes.

Mapping of ATM cells into the SONET/SDH frame is accomplished by scrambling the ATM cell payload and mapping the resulting cell stream into a synchronous payload envelope (SPE) or equivalently a VC-4-4c, mapping the SPE into the SONET/SDH frame using the H1-H2 pointer, and finally applying the SONET/SDH frame synchronous scrambler to the resulting frame.

ATM cell extraction operates in the analogous reverse procedure, i.e. by descrambling the SONET/SDH frame, reading the H1-H2 pointer to locate the SPE, performing cell delineation, and finally descrambling the ATM cell payload.

The defined overhead bytes, along with the coding differences between SONET and SDH are summarized in Table 4.

3.1 SONET/SDH Overhead Functions

Overhead Byte	Function	SONET Coding	SDH Coding
A1	Frame Alignment	11110110	11110110
A2	Frame Alignment	00101000	00101000
C1	Identification (Note 1)	00000001-00001100 (Bytes 1 - 12)	00000001-00000100 (Bytes 1 - 4)
B1	Section Error Monitoring	BIP-8	BIP-8
B2	Line Error Monitoring	BIP-96	BIP-96
H1 (bits 1-4)	NDF, Path AIS (Notes 2, 3)	0110 or 1001	0110 or 1001
H1 (bits 5-6)	SS bits, Path AIS (Notes 2, 3)	00	10
H1 (bits 7-8), H2	Pointer, Path AIS (Notes 2, 3)	0000000000 - 1100001110	0000000000 - 1100001110
H1*	Concatenation	10010011	10010011
H2*	Concatenation	11111111	11111111
K1,K2	APS	Per T1.105	Per G.783
K2 (bits 6-8)	Line AIS, Line RDI	111, 110	111, 110
Z2	Line FEBE	B2 Error Count	B2 Error Count
J1	Path Trace	Note 4	Note 5
B3	Path Error Monitoring	BIP-8	BIP-8
C2	Path Signal Label	00010011	00010011
G1 (bits 1-4)	Path FEBE	B3 Error Count	B3 Error Count
G1 (bit 5)	Path RDI	1 (Note 6)	1 (Note 6)

Table 4 SONET/SDH Overhead

Note 1: Receivers should not use this pattern for frame alignment identification because new functions may be defined for these bytes in the future. For SDH interfaces, bytes 5 to 12 are unused. These bytes are not scrambled and should be set to a balanced value (i.e. 11001100).

Note 2: H1 and H2 are the first of twelve H1 and H2 bytes. H1* and H2* are the 2nd through 12th H1 and H2 bytes. The asterix indicates concatenation.

Note 3: Path AIS is indicated by an all 1's condition in H1, H2, H1* and H2*.

Note 4: A 64 ASCII COMMON LANGUAGE® Location Identifier (CLLI) (8-bit) code, padded with ASCII NULL characters and terminated with CR/LF, is a suitable trace message for SONET interfaces. If no message has been loaded, then 64 NULL characters shall be transmitted. - COMMON LANGUAGE is a registered trademark and CLLI is a trademark of Bellcore.

Note 5: SDH interfaces may use a 64 byte free format string (see Note 4) or the 16 byte E.164 format as described in G.709.

Note 6: The assertion of path RDI in response to loss of pointer (LOP), path AIS and loss of cell delineation (LCD) is specified in I.432. The additional treatment of path trace mismatch, path unequipped and signal label mismatch are for further study for the public UNI. Alternate methods of including the LCD defect in path RDI is also for further study.

3.2 Active Overhead Bytes

The functionality of certain overhead bytes is optional at the public UNI, the private UNI and the private NNI.

(**R**) The active overhead bytes at the public UNI shall be as specified in T1.646 and I.432.

(**R**) Unassigned overhead bytes (see figure 1) are specifically not active across the public UNI, the private UNI or the private NNI and shall be ignored by the receiver.

(**R**) Unassigned overhead bytes shall be set to 00000000 by the transmitter (before frame synchronous scrambling).

The required and optional overhead bytes at the private UNI and the private NNI are specified in sections 3.2.1 - 3.2.12

3.2.1 Framing Bytes: A1, A2

(**R**) Transmitting equipment supporting the private UNI or the private NNI shall insert the values indicated in Table 4.

(**R**) Receiving equipment supporting the private UNI or the private NNI shall use the A1 and A2 bytes for frame alignment as specified in T1.105 and G.783.

3.2.2 Identification: C1,

(**R**) Transmitting equipment supporting the private UNI or the private NNI shall insert the values indicated in Table 4.

3.2.3 Section Error Monitoring: B1

(**R**) Transmitting equipment supporting the private UNI or the private NNI shall generate and insert the B1 byte as specified in T1.105 and G.708 .

(**O**) Receiving equipment supporting the private UNI or the private NNI may detect and accumulate section BIP errors as specified in T1.105 and G.708.

3.2.4 New Data Flag, Pointer Value and Pointer Action: H1, H2, H3

(**R**) Transmitting equipment supporting the private UNI or the private NNI shall generate a valid pointer in these bytes as specified in T1.105 and G.709.

(**R**) Receiving equipment supporting the private UNI or the private NNI shall interpret the pointer as specified in T1.105 and G.709.

3.2.5 Concatenation Indication H1, H2**

(**R**) Transmitting equipment supporting the private UNI or the private NNI shall insert the values indicated in Table 4

(**R**) Receiving equipment supporting the private UNI or the private NNI shall check for the concatenation indication when interpreting the pointer as specified in T1.105 and G.709.

3.2.6 Line Error Monitoring: B2

(**R**) Transmitting equipment supporting the private UNI or the private NNI shall generate and insert the B2 byte as specified in T1.105 and G.708.

(**O**) Receiving equipment supporting the private UNI or the private NNI may detect and accumulate line BIP errors as specified in T1.105 and G.708.

3.2.7 Automatic Protection Switching, Line Status: K1, K2

(**O**) Transmitting equipment supporting the private UNI or the private NNI may generate and insert line AIS and line RDI indication in the K2 byte (bits 6-8) using the values indicated in Table 4.

(**O**) Receiving equipment supporting the private UNI or the private NNI may detect line AIS and line RDI in the K2 byte (bits 6-8) as specified in T1.105 and G.783.

(**O**) In addition to the above listed line status functions, the K1 and K2 bytes may be utilized to provision a 1+1 Automatic Protection Switch (APS) capability across the public UNI, the private UNI or the private NNI. The K1 byte shall indicate a request for switch action according to the APS channel protocol specified in T1.105 and G.783. The K2 byte shall also be coded according to the generation rules in T1.105 and G.783. Line AIS and line RDI on bits 6 to 8 of the K2 byte shall take precedence over the APS indication on these same bits.

(**CR**) If these bytes are not used, they must be set to an all zeros pattern before scrambling.

3.2.8 Line Far End Block Error (FEBE): Z2
(**O**) Transmitting equipment supporting the private UNI or the private NNI may insert these bits as specified in T1.646 and I.432.

(**O**) Receiving equipment supporting the private UNI or the private NNI may accumulate line FEBE as specified in T1.646 and I.432.

(**CR**) If this byte is not used, it must be set to an all zeros pattern before scrambling.

3.2.9 Path Trace: J1
(**O**) Equipment supporting the private UNI or the private NNI may perform facility testing by repetitively inserting the appropriate 64 byte or 16 byte code as indicated in Table 4.

(**CR**) If this byte is not used, it must be set to an all zeros pattern before scrambling.

3.2.10 Path Error Monitoring: B3
(**R**) Transmitting equipment supporting the private UNI or the private NNI shall generate and insert the B3 byte as specified in T1.105 and G.709.

(**R**) Receiving equipment supporting the private UNI or the private NNI shall detect and accumulate path BIP errors as specified in T1.105 and G.709.

3.2.11 Path Signal Label: C2
(**R**) Transmitting equipment supporting the private UNI or the private NNI shall insert the value indicated in Table 4

(**O**) Receiving equipment supporting the private UNI or the private NNI may check for the correct path signal label as specified in T1.105 and G.709.

3.2.12 Path Status: G1
(**R**) Transmitting equipment supporting the private UNI or the private NNI shall generate and insert path RDI in bit 5 as specified in T1.646 and I.432

(**R**) Transmitting equipment supporting the private UNI or the private NNI shall generate and insert the path FEBE value into bits 1-4 as specified in T1.105 and G.709.

(**R**) Receiving equipment supporting the private UNI or the private NNI shall detect path RDI as specified in T1.105 and G.783.

(**R**) Receiving equipment supporting the private UNI or the private NNI shall accumulate path FEBE as specified in T1.105 and G.709.

3.3 Cell Mapping

ATM cell mapping is performed by aligning by row, the byte structure of every cell with the byte structure of the SPE. The bit rate available for user information cells, signaling cells and OAM cells (excluding unassigned bytes and physical layer related maintenance information transported in SONET/SDH overhead bytes) is nominally 599.04 Mbps (refer to “Payload ” depicted in figure 1).

(**R**) ATM cells shall be mapped into the SPE, or equivalently the VC-4-4c, in accordance with I.432 and T1.646.

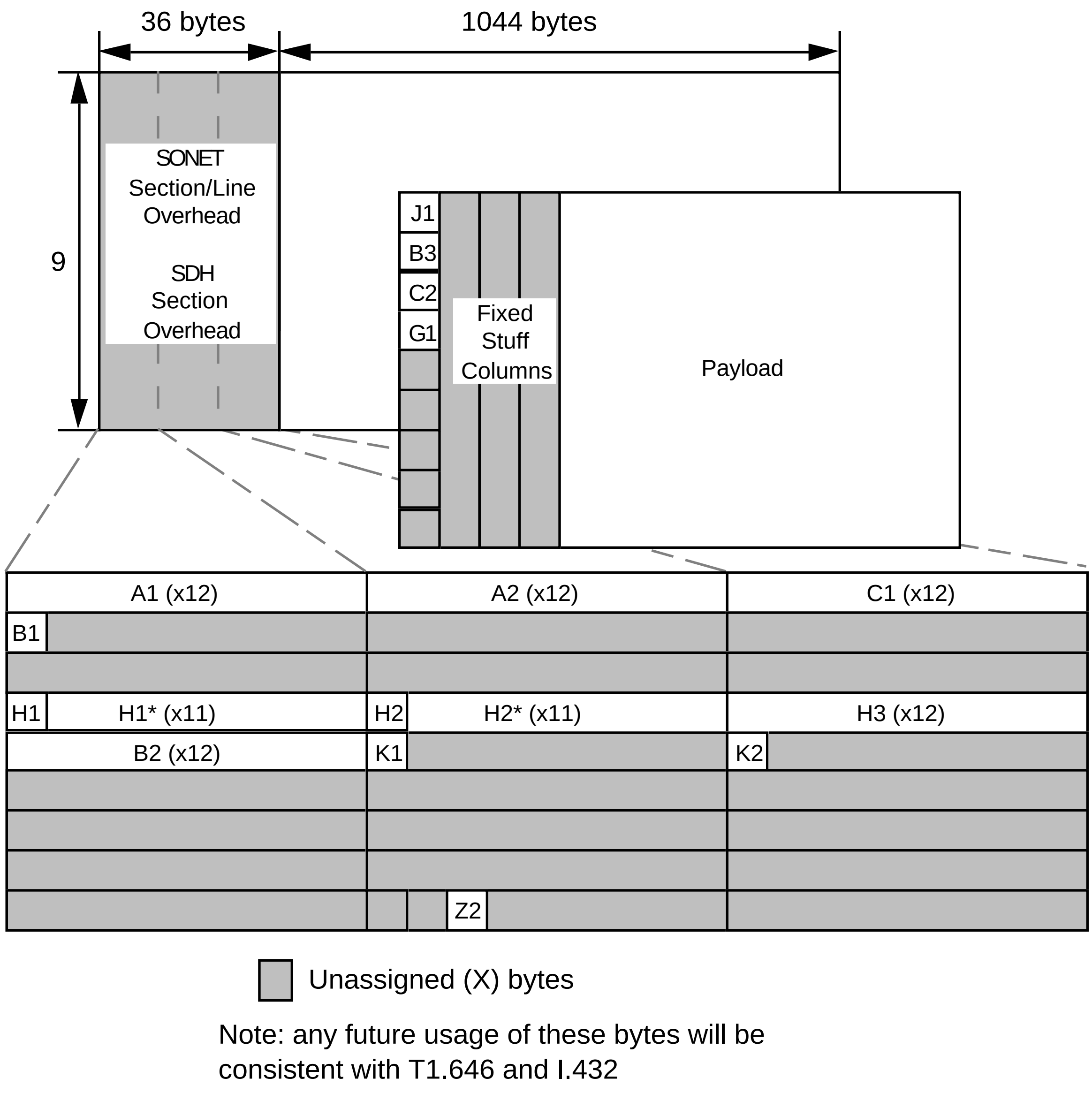

Figure 1 SONET STS-12c/STM-4 Frame Format

3.4 HEC Functions

The entire cell header is protected by the Header Error Check (HEC) sequence. This sequence is used by the receiver to determine cell boundaries (cell delineation), and to provide header error detection and error correction functionality.

3.4.1 HEC Generation

(**R**) The HEC byte shall be generated as specified in I.432, including the recommended modulo 2 addition (XOR) of the pattern 01010101 to the HEC bits.

3.4.2 HEC Verification

(**R**) HEC sequence error detection shall be performed as specified in I.432.

(**O**) In addition to HEC error detection, single bit HEC error correction may also be implemented. In this case, the two modes of operation shall interact as specified in I.432.

3.4.3 Cell Delineation

(**R**) Cell delineation shall be performed in accordance with the HEC-based algorithm specified in I.432.

3.5 Cell Payload Scrambling

Cell payload scrambling permits the randomization of the cell payload to avoid continuous non-variable bit patterns and improves the efficiency of the cell delineation algorithm.

(**R**) The self synchronizing scrambler polynomial ($x^{43} + 1$) shall be used to scramble and descramble the cell payloads in accordance with the procedure defined in I.432 and T1.646.

3.6 Cell Rate Decoupling

(**R**) The physical layer shall adapt the cell rate arriving from the ATM layer to the payload capacity of the SPE by inserting idle cells when assigned cells are not available from the ATM layer.

Idle cells are identified by the cell header pattern shown in Table 5. The cell payload content of an idle cell is “01101010” repeated 48 times. Note, however, that cell rate decoupling may be performed at the ATM layer, in which case “unassigned” cells are used and not idle cells. See T1.627 for further information regarding unassigned and assigned cells. The idle cell as defined in this document is identified as having an “invalid” cell header pattern in T1.627. When used for cell rate decoupling, however, the idle cells are not passed to the ATM layer and are, therefore, not detected as invalid.

	Octet 1	Octet 2	Octet 3	Octet 4	Octet 5
Header Pattern	00000000	00000000	00000000	00000001	Correct HEC

Table 5 Header Pattern for Idle Cell Identification

4. MAINTENANCE

Physical layer maintenance is accomplished by monitoring the received signal. The monitored parameters are used both by the layer management entity and for failure and performance monitoring.. The monitored parameters are based on Near-End (NE) events, in terms of anomalies and defects, and Far-End (FE) reports, in terms of anomalies, defects and failures.

SONET/SDH interfaces terminate at three hierarchical levels: Section, Line, and Path. Maintenance capabilities are performed by equipment contained within network elements, and are made possible by maintenance tools built into the overhead fields of the framing structure.

(**R**) Performance monitoring functionality at the public UNI shall be as specified in T1.646.

(**R**) Failure alarm monitoring functionality at the public UNI shall be as specified in T1.646.

The required and optional performance monitoring and failure alarm monitoring functionality at the private UNI and the private NNI is specified in sections 4.1 - 4.11.

4.1 Loss-Of-Signal (LOS)

(**R**) Equipment supporting the private UNI or the private NNI shall detect the LOS defect as specified in T1.646 and I.432.

4.2 Section BIP-8 Error

(**O**) Equipment supporting the private UNI or the private NNI may monitor section BIP-8 errors.

4.3 Loss-Of-Frame (LOF)

(**R**) Equipment supporting the private UNI or the private NNI shall detect the LOF defect as specified in T1.646 and I.432.

4.4 Line BIP-96 Error

(**O**) Equipment supporting the private UNI or the private NNI may monitor line BIP-96 errors.

4.5 Line FEBE

(**O**) Equipment supporting the private UNI or the private NNI may monitor line FEBE.

4.6 Line AIS

(**O**) Equipment supporting the private UNI or the private NNI may detect the line AIS defect as specified in T1.646 and I.432.

4.7 Line RDI

(**O**) Equipment supporting the private UNI or the private NNI may detect the line RDI defect as specified in T1.646 and I.432.

4.8 Path BIP-8 Error

(**R**) Equipment supporting the private UNI or the private NNI shall monitor and accumulate path BIP-8 errors.

4.8 Path FEBE

(**R**) Equipment supporting the private UNI or the private NNI shall monitor and accumulate path FEBE.

4.9 Loss-Of-Pointer (LOP)

(**R**) Equipment supporting the private UNI or the private NNI shall detect the LOP defect as specified in T1.646 and I.432.

4.9 Path AIS

(**R**) Equipment supporting the private UNI or the private NNI shall detect the Path AIS defect as specified in T1.646 and I.432.

4.10 Path RDI

(**R**) Equipment supporting the private UNI or the private NNI shall detect the Path RDI defect as specified in T1.646 and I.432.

4.11 Loss-Of-Cell-Delineation (LCD)

(**R**) Equipment supporting the private UNI or the private NNI shall detect the LCD defect as specified in T1.646 and I.432.

5. ACRONYM LIST

AIS	Alarm Indication Signal
APS	Automatic Protection Switching
ATM	Asynchronous Transfer Mode
BER	Bit Error Ratio
BFOC	Bayonet Fibre Optic Connector
BIP	Bit Interleaved Parity
CLLI	Common Language Location Identifier
CR/LF	Carriage Return / Line Feed
FE	Far End
FEBE	Far End Block Error
FWHM	Full Width, Half Maximum
HEC	Header Error Check
LCD	Loss of Cell Delineation
LED	Light Emitting Diode
LOF	Loss of Frame
LOP	Loss of Pointer
LOS	Loss of Signal
MLM	Multi-Longitudinal Mode
MMF	Multi-Mode Fiber
NDF	New Data Flag
NE	Near End
NNI	Network-Network Interface
NRZ	Non-Return to Zero
OAM	Operations and Maintenance
PMD	Physical Medium Dependent
PRS	Primary Reference Source
RDI	Remote Defect Indication
RIN	Relative Intensity Noise
RMS	Root Mean Square
SC	Subscriber Connector (Optical Fibre Connector)
SDH	Synchronous Digital Hierarchy
SONET	Synchrounous Optical Network
SPE	Synchronous Payload Envelope
STM-4	Synchronous Transfer Module - level 4
STS-12c	Concatenated Synchronous Transport Signal level 12
SW	Short Wavelength
TC	Transmission Convergence
UNI	User-Network Interface
VC-4-4c	Virtual Container - level 4 concatenated

6. NORMATIVE REFERENCES

The following references contain provisions which, through reference in this text, constitute provisions of this specification. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this specification are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. When the referenced standard is superseded by a revision approved by the issuing standards body, the revision shall apply.

6.1 Referenced American National Standards

ANSI T1.101-1994, Telecommunications - Synchronization Interface Standard for Digital Networks

ANSI T1.105-1991, Telecommunications - Digital Hierarchy - Optical Interface Rates and Formats Specifications (SONET)

ANSI T1.627-1993, Telecommunications - Broadband ISDN - ATM Layer Functionality and Specification.

ANSI T1.646-1995, Telecommunications - Broadband ISDN and DS1/ATM User-Network Interfaces: Physical Layer Specification

ANSI/TIA/EIA-455-51A Pulse Distortion Measurement of Multimode Optical Fiber Information Transmission Capacity

ANSI/TIA/EIA-455-30B Frequency Domain Measurement of Multimode Optical Fiber Information Transmission Capacity

ANSI/TIA/EIA-492AAAA-A Detail Specification for 62.5 um Core Diameter/125 um Cladding Diameter Class Ia Graded-Index Multimode Optical Fibers

ANSI/TIA/EIA-492CAAA Detail Specification for Class IVa Dispersion-Unshifted Single Mode Fibers

ANSI/TIA/EIA-568-A Commercial Building Telecommunications Cabling Standard

6.2 Referenced ITU and ISO Standards

ITU-T Recommendation G.708, Network Node Interface for the Synchronous Digital Hierarchy, 1993.

ITU-T Recommendation G.709, Synchronous Multiplexing Structure, 1993.

ITU-T Recommendation G.783, Characteristics of SDH Multiplexing Equipment Functional Blocks, 1993.

ITU-T Recommendation G.957, Optical Interfaces for Equipments and Systems Relating to the SDH, 1993

ITU-T Recommendation G.958, Digital Line Systems Based on SDH for use on Optical Fibre Cables.

ITU-T Recommendation I.432, B-ISDN User-Network Interface - Physical Layer Specification

ISO / IEC 11801 Generic Cabling for Customer Premises, 1995

IEC 793-1 Optical Fibres, Part 1: Generic Specification

IEC 793-2 Optical Fibres, Part 2: Product Specifications

IEC 825-1 Safety of Laser Products, First Edition, November 1993

Method IEC 793-1-C2A Impulse Response

Method IEC 793-1-C2B Frequency Response

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