INTERNATIONAL TELECOMMUNICATION UNION

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

G.7041/Y.1303

(12/2001)

SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Digital terminal equipments – General

SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE AND INTERNET PROTOCOL ASPECTS

Internet protocol aspects – Transport

Generic framing procedure (GFP)

ITU-T Recommendation G.7041/Y.1303

ITU-T G-SERIES RECOMMENDATIONS

TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

INTERNATIONAL TELEPHONE CONNECTIONS AND CIRCUITS	G.100–G.199
GENERAL CHARACTERISTICS COMMON TO ALL ANALOGUE CARRIER-TRANSMISSION SYSTEMS	G.200–G.299
GENERAL CHARACTERISTICS OF INTERNATIONAL CARRIER TELEPHONE SYSTEMS ON RADIO-RELAY OR SATELLITE LINKS AND INTERCONNECTION WITH METALLIC LINES	G.400–G.449
COORDINATION OF RADIOTELEPHONY AND LINE TELEPHONY	G.450–G.499
TESTING EQUIPMENTS	G.500–G.599
TRANSMISSION MEDIA CHARACTERISTICS	G.600–G.699
DIGITAL TERMINAL EQUIPMENTS	G.700–G.799
DIGITAL NETWORKS	G.800–G.899
DIGITAL SECTIONS AND DIGITAL LINE SYSTEM	G.900–G.999
QUALITY OF SERVICE AND PERFORMANCE	G.1000–G.1999
TRANSMISSION MEDIA CHARACTERISTICS	G.6000–G.6999
DIGITAL TERMINAL EQUIPMENTS	G.7000–G.7999
General	**G.7000–G.7099**
Coding of analogue signals by pulse code modulation	G.7100–G.7199
Coding of analogue signals by methods other than PCM	G.7200–G.7299
Principal characteristics of primary multiplex equipment	G.7300–G.7399
Principal characteristics of second order multiplex equipment	G.7400–G.7499
Principal characteristics of higher order multiplex equipment	G.7500–G.7599
Principal characteristics of transcoder and digital multiplication equipment	G.7600–G.7699
Operations, administration and maintenance features of transmission equipment	G.7700–G.7799
Principal characteristics of multiplexing equipment for the synchronous digital hierarchy	G.7800–G.7899
Other terminal equipment	G.7900–G.7999
DIGITAL NETWORKS	G.8000–G.8999

For further details, please refer to the list of ITU-T Recommendations.

ITU-T Recommendation G.7041/Y.1303

Generic framing procedure (GFP)

Summary

This Recommendation defines a generic framing procedure (GFP) to delineate octet-aligned, variable-length payloads from higher-level client signals for subsequent mapping into octet-synchronous paths such as those defined in ITU-T Recs G.707/Y.1322 and G.709/Y.1331. The Recommendation definitions include the:

- frame formats for protocol data units (PDUs) transferred between GFP initiation and termination points;
- mapping procedure for the client signals into GFP.

Source

ITU-T Recommendation G.7041/Y.1303 was prepared by ITU-T Study Group 15 (2001-2004) and approved under the WTSA Resolution 1 procedure on 14 December 2001.

Keywords

Generic Framing Procedure, Optical Transport Network, Synchronous Digital Hierarchy.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications. The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

INTELLECTUAL PROPERTY RIGHTS

ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the Recommendation development process.

As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementors are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database.

CONTENTS

Page

Page

Introduction

GFP provides a generic mechanism to adapt traffic from higher-layer client signals over a transport network. Client signals may be PDU-oriented (such as IP/PPP or Ethernet MAC), block-code oriented constant bit rate stream (such as Fibre Channel or ESCON/SBCON).

This Recommendation consists of both common and client-specific aspects. Common aspects of GFP apply to all GFP-adapted traffic and they are specified in clause 6. Client-specific aspects of GFP are specified in clauses 7 and 8. Currently, two modes of client signal adaptation are defined for GFP.

- A PDU-oriented adaptation mode, referred to as Frame-Mapped GFP (GFP-F), is specified in clause 7.
- A block-code oriented adaptation mode, referred to as Transparent GFP (GFP-T), is specified in clause 8.

Figure 1 illustrates the relationship between the higher-layer client signals, GFP, and its transport paths.

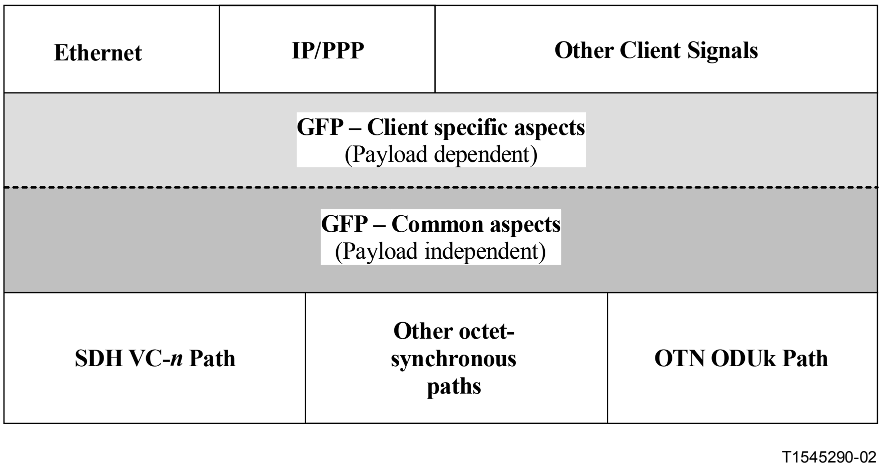


Figure 1/G.7041/Y.1303 – GFP relationship to Client Signals and Transport Paths

Figure 2 illustrates the environment in which GFP operates.

In the Frame-Mapped adaptation mode, the Client/GFP adaptation function may operate at the data link layer (or higher layer) of the client signal. Client PDU visibility is required. This visibility is obtained when the client PDUs are received from either the data layer network (e.g. IP router fabric or Ethernet switch fabric (C/C' in Figure 2)), or e.g. a bridge, switch or router function in a transport network element (TNE). In the latter case, the client PDUs are received via e.g. an Ethernet interface (A/A' in Figure 2).

For the Transparent adaptation mode, the Client/GFP adaptation function operates on the coded character stream, rather than on the incoming client PDUs. Thus, processing of the incoming codeword space for the client signal is required (B/B' in Figure 2).

Typically, interconnections can be set up between ports A and A', B and B', C and C', A and C' and C and A'. Note that the physical port type of B and B' must be the same to support an interconnection, while the physical port type of A and A' may be different.

Some high level functional models associated with the above GFP processing can be found in Appendix I.

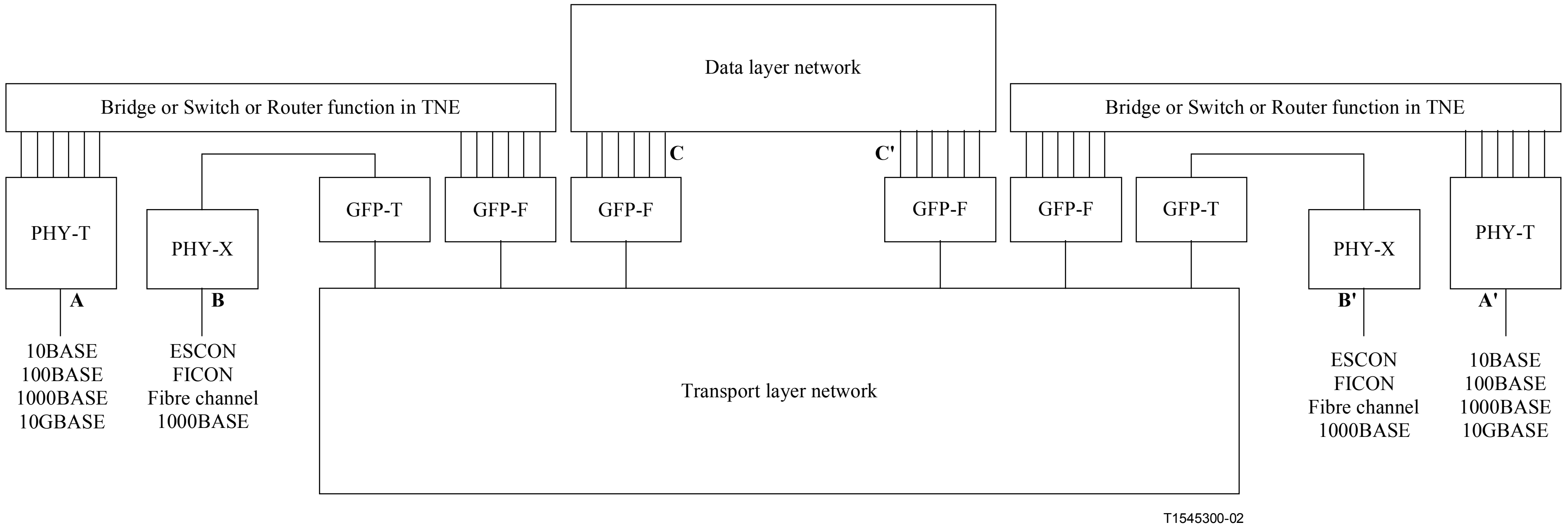


Figure 2/G.7041/Y.1303 – GFP Functional Model (Single Client)

ITU-T Recommendation G.7041/Y.1303

Generic framing procedure (GFP)

1 Scope

This Recommendation defines a generic framing procedure (GFP) to encapsulate variable length payload of various client signals for subsequent transport over SDH and OTN networks as defined in ITU-T Recs G.707/Y.1322 and G.709/Y.1331. The Recommendation definitions include the:

- frame formats for protocol data units (PDUs) transferred between GFP initiation and termination points;
- mapping procedure for the client signals into GFP.

The framing procedure described in this Recommendation can be applied to both the encapsulation of entire client frames (frame mapped GFP), in which a single client frame is mapped into a single GFP frame, and to character mapped transport (transparent GFP) in which a number of client data characters are mapped into efficient block codes for transport within a GFP frame.

2 References

The following ITU-T Recommendations, and other references contain provisions which, through referenced in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published.

- ITU-T Recommendation G.707/Y.1322 (2000), *Network node interface for the synchronous digital hierarchy*.
- ITU-T Recommendation G.709/Y.1331 (2001), *Interfaces for the optical transport network (OTN)*.
- ITU-T Recommendation G.783 (2000), *Characteristics of synchronous digital hierarchy (SDH) equipment functional blocks*.
- ITU-T Recommendation G.798 (2002), *Characteristics of optical transport networks hierarchy equipment functional blocks*.
- ITU-T Recommendation I.432 (1993), *B-ISDN user-network interface – Physical layer specification*.
- ISO/IEC 3309:1993, *Information Technology – Telecommunications and information exchange between systems – High-level data link control (HDLC) procedures – Frame structure*.
- IEEE 802.3 (1998), Part 3: *Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications*.
- ANSI X3.230 (1994), *Information Technology – Fibre Channel − Physical and Signaling Interface (FC-PH)*.
- ANSI X3.296 (1997), *Information Technology − Single-Byte Command Code Sets CONnection (SBCON) Architecture*.
- IETF RFC 1661 (1994), *The Point-to-Point Protocol (PPP)*.
- IETF RFC 1662 (1994), *PPP in HDLC-like Framing*.

3 Terms and definitions

This Recommendation defines the following terms:

3.1 frame-mapped GFP: A type of GFP mapping in which a client signal frame is received and mapped in its entirety into one GFP frame.

3.2 channel ID: The CID is an 8-bit binary number used to indicate one of 256 communications channels at a GFP initiation/termination point.

3.3 client data frame: A client data frame is a GFP frame that contains payload data from a client signal.

3.4 client management frame: A client management frame is a GFP frame containing information associated with the management of the GFP connection between the GFP source and sink.

3.5 control frame: A control frame is a GFP frame used to control the GFP connection. The only control defined at this time is the Idle frame.

3.6 Maximum Transmission Unit (MTU): Maximum size of the GFP Payload Area, in octets.

3.7 running disparity: A procedure used by block line codes, such as 8B/10B, to balance the total of number of ones and zeros transmitted over time. The running disparity at the end of a line code subblock is positive if more ones than zeros have been sent up to that point, and negative if more zeros than ones have been sent. The encoder uses the running disparity value to choose which of the two possible codes to transmit for the next character mapping in order to balance the number of transmitted ones and zeros.

3.8 Source/Destination Port (SP/DP): A logical addressable entity on a physical interface.

3.9 superblock: A superblock refers to a Transparent GFP structure that combines multiple 64B/65B codes along with a CRC-16, for the purposes of providing payload octet alignment and error control over the bits in the superblock. See Figure 8-3.

3.10 transparent GFP: A type of GFP mapping in which block-coded client characters are decoded and then mapped into a fixed-length GFP frame and may be transmitted immediately without waiting for the reception of an entire client data frame.

4 Abbreviations

This Recommendation uses the following abbreviations:

ANSI	American National Standards Institute
ATM	Asynchronous Transfer Mode
cHEC	Core HEC
CID	Channel ID
CoS	Class of Service
CRC	Cyclic Redundancy Check
CSF	Client Signal Fail
DE	Discard Eligibility
DP	Destination Port
DST	Destination
eHEC	Extension HEC
EOF	End Of Frame

ESCON	Enterprise Systems Connection
EXI	Extension Header Identifier
FC	Fibre Channel
FCS	Frame-Check Sequence
FICON	Fibre Connection
GFP	Generic Framing Procedure
GFP-F	Frame-mapped GFP
GFP-T	Transparent GFP
HDLC	High-level Data Link Control
HEC	Header Error Check
IEEE	Institute of Electrical and Electronic Engineers
IFG	Inter-Frame Gap
IP	Internet Protocol
IPG	Inter-Packet Gap
ISDN	Integrated Services Digital Network
ISO	International Organization for Standardization
ITU-T	International Telecommunication Union – Telecommunication Standardization Sector
LCC	Last Control Character
LOL	Loss Of Light
LOS	Loss Of Signal
LSB	Least Significant Bit
MAC	Media Access Control
MAPOS	Multiple Access Protocol Over SONET/SDH
MSB	Most Significant Bit
MTU	Maximum Transmission Unit
NE	Network Element
OA&M	Operations, Administration & Maintenance
ODU	Optical Data Unit
OTN	Optical Transport Network
PDU	Protocol Data Unit
PFI	Payload FCS Identifier
PLI	Payload Length Indicator
PPP	Point-to-Point Protocol
PTI	Payload Type Identifier
RD	Running Disparity
SBCON	Single-Byte Command Code Sets Connection
SDH	Synchronous Digital Hierarchy

SOF	Start of Frame
SONET	Synchronous Optical Network
SP	Source Port
SPE	Synchronous Payload Envelope
Src	Source
SSF	Server Signal Failure
STS	Synchronous Transport Signal
tHEC	Type HEC
TSF	Trail Signal Fail
TTL	Time To Live
UPI	User Payload Identifier

5 Conventions

Transmission order: The order of transmission of information in all the diagrams in this Recommendation is first from left to right and then from top to bottom. Within each byte the most significant bit is transmitted first. The most significant bit is illustrated at the left of all the diagrams.

Undefined field values: The default value for any undefined header fields is 0 unless otherwise stated.

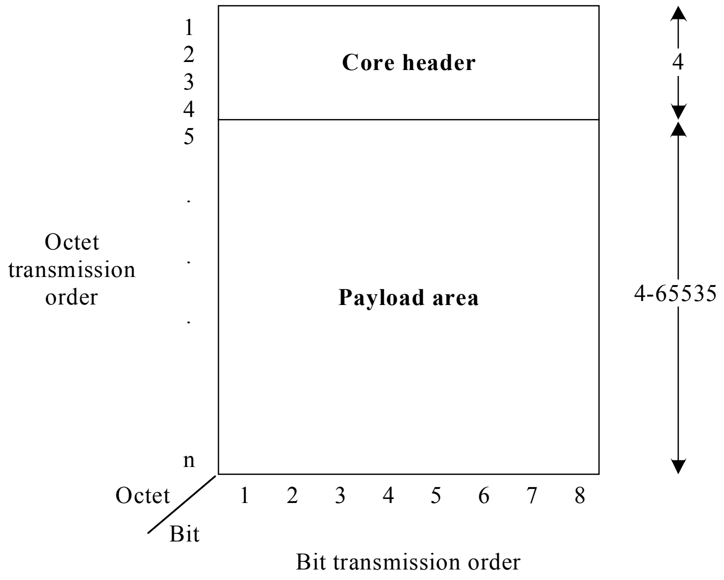
6 Common aspects of GFP

This clause discusses the common (protocol independent) aspects of GFP for octet-aligned payloads. The mapping of the framed payloads into an SDH VC-*n* is specified in ITU-T Rec. G.707/Y.1322. The mapping of the framed payloads into an OTN ODUk payload is specified in ITU-T Rec. G.709/Y.1331.

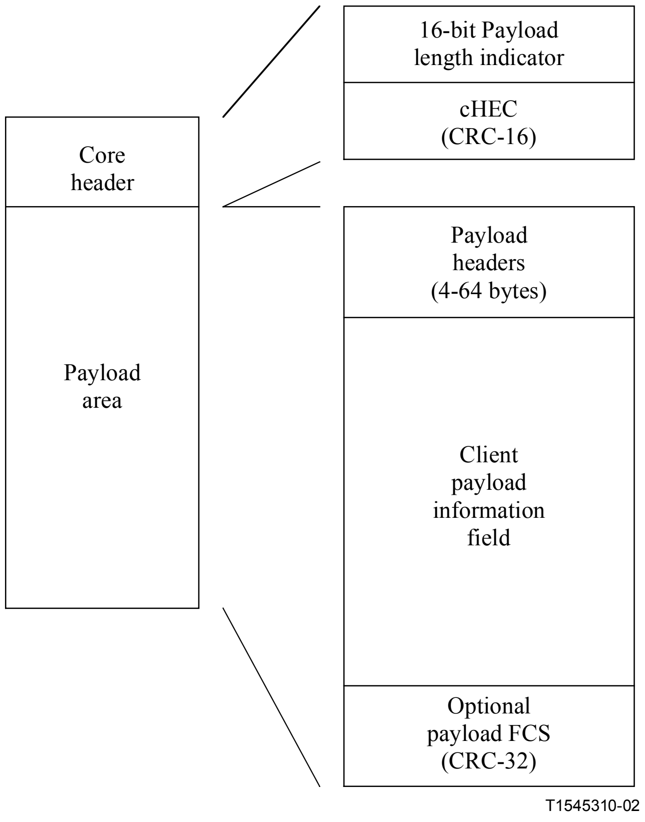
GFP uses a variation of the HEC-based frame delineation mechanism defined for Asynchronous Transfer Mode (ATM) (see ITU-T Rec. I.432.1). Two kinds of GFP frames are defined: GFP client frames and GFP control frames. Frame formats for GFP client and control frames are defined in 6.1 and 6.2. GFP also supports a flexible (payload) header extension mechanism to facilitate the adaptation of GFP for use with diverse transport mechanisms.Currently defined payload extension header types are specified in 6.1.2.3.

6.1 Basic signal structure for GFP client frames

The format for GFP frames is shown in Figure 6-1. GFP frames are octet-aligned and consist of a GFP Core Header and, except for GFP Idle frames, a GFP Payload Area.



a) Frame size and transmission order



b) Fields constituting a GFP client frame

Figure 6-1/G.7041/Y.1303 – Frame format for GFP client frames

6.1.1 GFP Core Header

The GFP Core Header format is shown in Figure 6-2. The four octets of the GFP Core Header consist of a 16-bit PDU Length Indicator field and a 16-bit Core Header Error Check (cHEC) field. This header allows GFP frame delineation independent of the content of the higher layer PDUs.

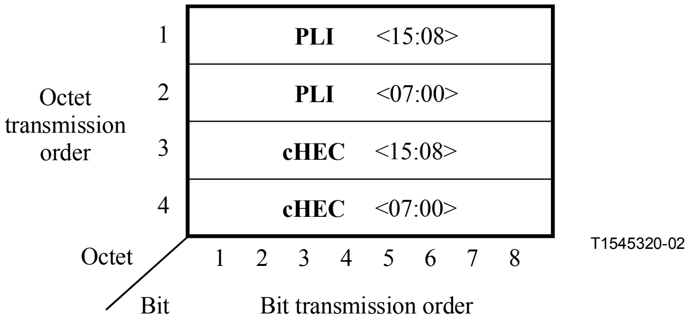


Figure 6-2/G.7041/Y.1303 – GFP Core Header format

6.1.1.1 PDU Length Indicator (PLI) field

The two-octet PLI field contains a binary number representing the number of octets in the GFP Payload Area. The absolute minimum value of the PLI field in a GFP client frame is 4 octets. PLI values 0-3 are reserved for GFP control frame usage (see 6.2).

6.1.1.2 Core HEC (cHEC) field

The two-octet Core Header Error Control field contains a CRC-16 error control code that protects the integrity of the contents of the Core Header by enabling both single-bit error correction and multi-bit error detection. The cHEC sequence is calculated over the octets of the Core Header as defined in 6.1.1.2.1.

6.1.1.2.1 HEC processing

The HEC generating polynomial is $G(x) = x^{16} + x^{12} + x^5 + 1$, with an initialization value of zero, where x^{16} corresponds to the MSB and x^0 corresponds to the LSB.

The cHEC field is generated by the source adaptation process using the following steps (see Appendix I/V.41):

1) The first two octets of the GFP frame are taken in network octet order, most significant bit first, to form a 16-bit pattern representing the coefficients of a polynomial $M(x)$ of degree 15.
2) $M(x)$ is multiplied by x^{16} and divided (modulo 2) by $G(x)$, producing a remainder $R(x)$ of degree 15 or less.
3) The coefficients of $R(x)$ are considered to be a 16-bit sequence, where x^{15} is the most significant bit.
4) This 16-bit sequence is the CRC-16 where the first bit of the CRC-16 to be transmitted is the coefficient of x^{15} and the last bit transmitted is the coefficient of x^0.

The sink adaptation process performs steps 1-3 in the same manner as the source adaptation process. In the absence of bit errors, the remainder shall be 0000 0000 0000 0000.

This single error correction shall be performed on the Core Header. The GFP sink adaptation process shall discard any of those GFP frames where multi-bit errors are detected. The sink adaptation process also updates any relevant system records for performance monitoring purposes.

6.1.1.3 Core header scrambling

The Core Header is scrambled for DC balanced by an exclusive-OR operation (modulo 2 addition) with the hexadecimal number B6AB31E0. This number is the maximum transition, minimum side-lobe, Barker-like sequence of length 32. The scrambling of the GFP Core Header improves the robustness of the GFP frame delineation procedure and provides a sufficient number of 0-1 and 1-0 transitions during idle transmission periods.

6.1.2 GFP Payload Area

The GFP Payload Area, which consists of all octets in the GFP frame after the GFP Core Header, is used to convey higher layer specific protocol information. This variable length area may include from 4 to 65 535 octets. As shown in Figure 6-3, the GFP Payload Area consists of two common components: a Payload Header and a Payload Information field. An optional Payload FCS (pFCS) field is also supported.

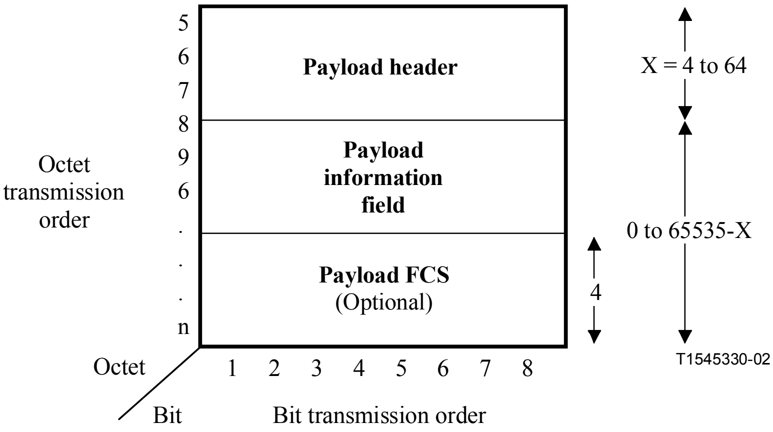


Figure 6-3/G.7041/Y.1303 – GFP Payload Area format

Practical GFP MTU sizes for the GFP Payload Area are application specific. An implementation should support transmission and reception of GFP frames with GFP Payload Areas of at least 1600 octets. By prior arrangement, consenting GFP implementations may use other MTU values.

6.1.2.1 Payload Header

The Payload Header is a variable-length area, 4 to 64 octets long, intended to support data link management procedures specific to the higher-layer client signal. The structure of the GFP Payload Header is illustrated in Figure 6-4. The area contains two mandatory fields, the Type and the tHEC fields, and a variable number of additional payload header fields. This group of additional payload header fields are referred to as the Extension Header. The presence of the Extension Header, and its format, and the presence of the optional Payload FCS are specified by the Type field. The tHEC protects the integrity of the Type field.

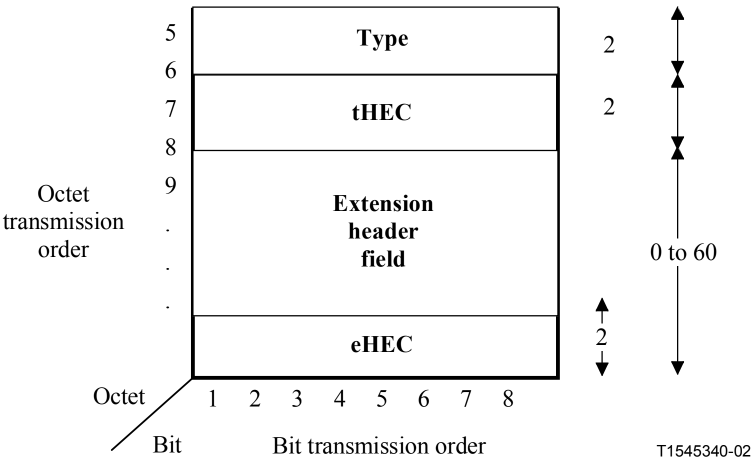


Figure 6-4/G.7041/Y.1303 – GFP Payload Header format

An implementation shall support reception of a GFP frame with a Payload Header of any length in the range 4 to 64 octets.

6.1.2.1.1 GFP Type field

The GFP Type field is a mandatory two-octet field of the Payload Header that indicates the content and format of the GFP Payload Information field (see 6.1.2.2). The Type field distinguishes between GFP frame types and between different services in a multi-service environment. As shown in Figure 6-5, the Type field consists of a Payload Type Identifier (PTI), a Payload FCS Indicator (PFI), a Extension Header Identifier (EXI) and a User Payload Identifier (UPI).

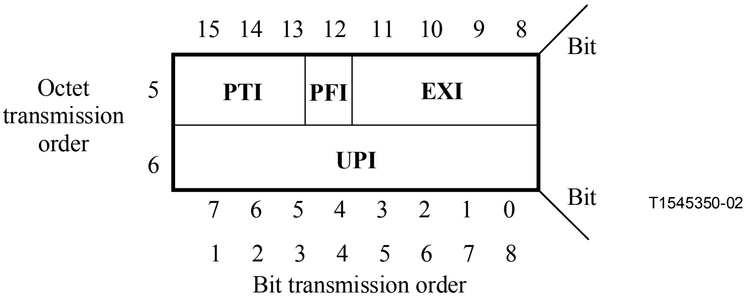


Figure 6-5/G.7041/Y.1303 – GFP Type Field format

The interpretation of the UPI field for PTI values different from 000 or 100 is for further study. Sample Type field values are illustrated in Appendix II.

6.1.2.1.1.1 Payload Type Identifier

A 3-bit subfield of the Type field identifying the type of GFP client frame. Two kinds of client frames are currently defined, User Data frames (PTI = 000) and Client Management frames (PTI = 100). PTI codepoints are given in Table 6-1.

Table 6-1/G.7041/Y.1303 – GFP Payload Type Identifiers

Payload Type Identifiers Type Bits <15:13>	Usage
000	Client Data
100	Client Management
Others	Reserved

6.1.2.1.1.2 Payload FCS Indicator (PFI)

A one bit subfield of the Type field indicating the presence (PFI = 1) or absence (PFI = 0) of the Payload FCS field.

6.1.2.1.1.3 Extension Header Identifier (EXI)

A 4-bit subfield of the Type field identifying the type of Extension Header GFP. Three kinds of Extension Headers are currently defined, a Null Extension Header, a Linear Extension Header, and a Ring Extension Header. EXI codepoints are given in Table 6-2.

Table 6-2/G.7041/Y.1303 – GFP Extension Header Identifiers

Extension Header Identifiers Type Bits <11:8>	Usage
0000	Null Extension Header
0001	Linear Frame
0010	Ring Frame
Others	Reserved

6.1.2.1.1.4 User Payload Identifier (UPI)

An 8-bit field identifying the type of payload conveyed in the GFP Payload Information field. Interpretation of the UPI field is relative to the type of GFP client frame as indicated by the PTI subfield. UPI values for client data frames are specified in 6.1.3.1 and UPI values for Client Management frames are specified in 6.1.3.2.

6.1.2.1.2 Type HEC (tHEC) field

The two-octet Type Header Error Control field contains a CRC-16 error control code that protects the integrity of the contents of the Type Field by enabling both single-bit error correction and multi-bit error detection.

The contents of the tHEC field is generated using the same steps as the cHEC (see 6.1.1.2.1) with the following exception:

– For the tHEC step 1) is modified such that *M(x)* is formed from all the octets in the Type field, but excluding the tHEC field itself.

The GFP sink adaptation process may perform single-bit error correction on all of the fields protected by a tHEC field. This single error correction shall be performed for the Type Header. The GFP sink adaptation process shall discard any of those GFP frames where multi-bit errors are detected, or where any error occurs in a header field that does not make use of single error correction. The sink adaptation process also updates any relevant system records for performance monitoring purposes.

6.1.2.1.3 GFP Extension Headers

The payload Extension Header is a 0-to-60 octet extended field (including the eHEC) that supports technology specific data link headers such as virtual link identifiers, source/destination addresses, port numbers, Class of Service, extension header error control, etc. The type of the extension header is indicated by the content of the EXI bits in the Type Field of the payload header.

Three Extension Header variants are currently defined to support client specific data over a logical Ring or logical Point-to-Point (Linear) configurations.

This clause describes the various fields in each Extension Header. The default value for any undefined fields is 0 unless otherwise stated.

6.1.2.1.3.1 Null Extension Header

The Payload header for a frame with a Null Extension Header is shown in Figure 6-6. This Extension Header applies to a logical point-to-point configuration. It is intended for scenarios where the transport path is dedicated to one client signal.

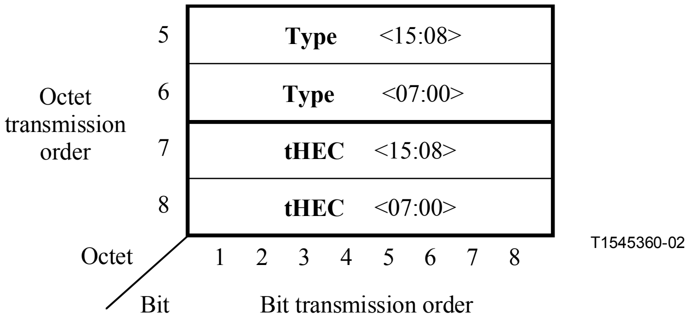


Figure 6-6/G.7041/Y.1303 – Payload Header for a GFP frame with a Null Extension Header

6.1.2.1.3.2 Extension Header for a linear frame

The Payload Header for a Linear (Point-to-Point) frame with an Extension Header, shown in Figure 6-7, is intended for scenarios where there are several independent links requiring aggregation onto a single transport path.

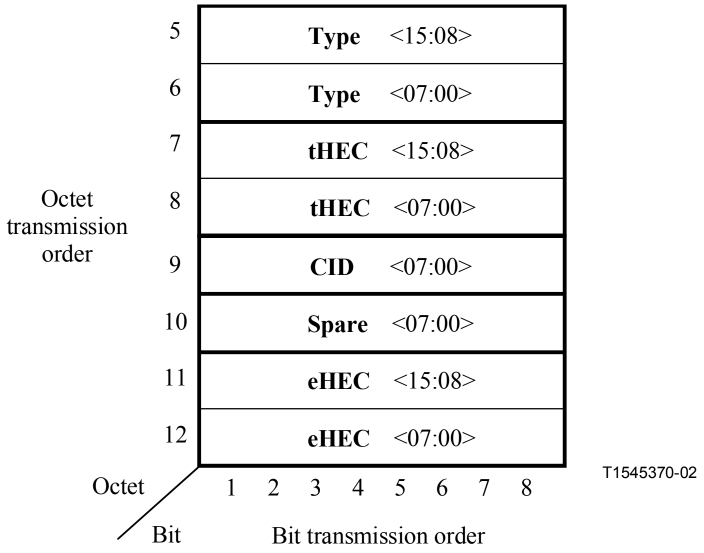


Figure 6-7/G.7041/Y.1303 – Payload Header for a Linear (Point-to-Point) Frame including the Extension Header

6.1.2.1.3.2.1 Channel ID (CID) field

The CID is an 8-bit binary number used to indicate one of 256 communications channels at a GFP termination point.

6.1.2.1.3.2.2 Spare field

The 8-bit spare field is reserved for future use.

6.1.2.1.3.2.3 Extension HEC (eHEC) field

See 6.1.2.1.4.

6.1.2.1.3.3 Extension Header for a ring frame

For further study.

6.1.2.1.4 Extension HEC (eHEC) field

The two-octet Extension Header Error Control field contains a CRC-16 error control code that protects the integrity of the contents of the extension headers by enabling both single-bit error correction (optional) and multi-bit error detection.

The contents of the eHEC field is generated using the same steps as the cHEC (see 6.1.1.2.1) with the following exception:

– For the eHEC step 1) is modified such that *M(x)* is formed from all the octets in the Extension Header, but excluding the eHEC field itself.

The GFP sink adaptation process may perform single-bit error correction on all of the fields protected by a tHEC field. Single error correction is optional for the Extension Header. The GFP sink adaptation process shall discard any of those GFP frames where multi-bit errors are detected, or where any error occurs in a header field that does not make use of single error correction. The sink adaptation process also updates any relevant system records for performance monitoring purposes.

6.1.2.2 Payload Information Field

The Payload Information field contains the framed PDU for frame-mapped GFP or, in the case of transparent GFP, a group of client signal characters. This variable length field may include from 0 to 65,535-*X* octets, where *X* is the size of the Payload Header. This field may include an optional Payload FCS field. The client PDU/signal is always transferred into the GFP Payload Information field as an octet-aligned packet stream.

6.1.2.2.1 Payload Frame Check Sequence (pFCS) field

The GFP Payload FCS, as shown in Figure 6-8, is an optional, four-octet long, frame check sequence. It contains a CRC-32 sequence that protects the contents of the GFP Payload Information field. The FCS generation process is defined in 6.1.2.2.1.1. A value of 1 in the PFI bit within the Type field identifies the presence of the payload FCS field.

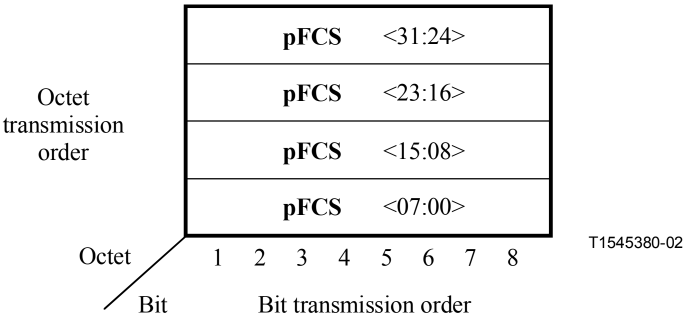


Figure 6-8/G.7041/Y.1303 – GFP Payload Frame Check Sequence format

6.1.2.2.1.1 Payload FCS generation

The Payload FCS is generated using the CRC-32 generating polynomial (ISO/IEC 3309) $G(x) = x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^{8} + x^{7} + x^{5} + x^{4} + x^{2} + x^{1} + 1$ where x^{32} corresponds to the MSB and x^{0} corresponds to the LSB.

The Payload FCS field is generated using the following steps:

1) The *N* octets from the GFP Payload Information field, excluding the FCS are taken in network octet order, most significant bit first, to form a 8*N*-bit pattern representing the coefficients of a polynomial $M'(x)$ of degree $8N - 1$.

2) $M'(x)$ is multiplied by x^{32}, added to the all-ones polynomial $U(x) = 1 + x^{1} + x^{2} + \ldots + x^{31}$, and divided (modulo 2) by $G(x)$, producing a remainder $R(x)$ of degree 31 or less.

   NOTE – The addition of $x^{8N} [1 + x^{1} + x^{2} + \ldots + x^{31}]$ is equivalent to presetting the shift register to all 1s for typical shift register implementations using presets.

3) The coefficients of $R(x)$ are considered to be a 32-bit sequence, where x^{31} is the most significant bit.

4) The complement of this 32-bit sequence is the CRC-32.

The sink adaptation process performs steps 1)-3) in the same manner as the source adaptation process. In the absence of errors, the remainder shall be 11000111_00000100_11011101_01111011, in the order x^{31} to x^{0}.

6.1.2.3 Payload area scrambling

Scrambling of the GFP Payload Area is required to provide security against payload information replicating scrambling word (or its inverse) from a frame synchronous scrambler such as those used in the SDH RS layer or in an OTN OPUk channel). Figure 6-9 illustrates the scrambler and descrambler processes.

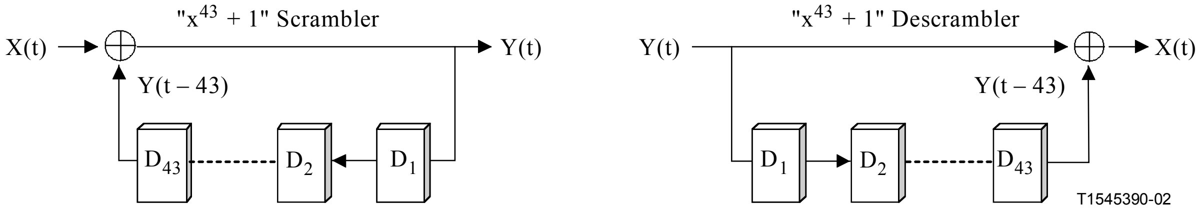


Figure 6-9/G.7041/Y.1303 – x^{43}+1 Scrambler and descrambler processes for GFP

All octets in the GFP Payload Area are scrambled using a $1 + x^{43}$ self-synchronous scrambler. Scrambling is done in network bit order.

At the source adaptation process, scrambling is enabled starting at the first transmitted octet after the cHEC field, and is disabled after the last transmitted octet of the GFP frame. When the scrambler or descrambler is disabled, its state is retained. Hence, the scrambler or descrambler state at the beginning of a GFP frame Payload Area will thus be the last 43 Payload Area bits of the GFP frame transmitted in that channel immediately prior to the current GFP frame.

The activation of the sink adaptation process descrambler also depends on the present state of the cHEC check algorithm:

a) In the HUNT and PRESYNC states, the descrambler is disabled.

b) In the SYNC state, the descrambler is enabled only for the octets between the cHEC field and the end of the candidate GFP frame.

NOTE – the GFP sink adaptation process can reliably forward GFP frames to the higher layer entity only when the sink adaptation process is in the SYNC state.

6.1.3 GFP client frames

Two types of GFP client frames are currently defined, Client Data and Client Management. GFP client data frames are used to transport data from the client signal. GFP Client Management Frames are used to transport information associated with the management of the client signal or GFP connection.

6.1.3.1 Client data frames

Client data is transported over GFP using client data frames. Client data frames are GFP client frames consisting of a Core Header and a Payload Area. The Type field of the client data frames uses the following Type subfield values:

- PTI = 000
- PFI = Payload specific
- EXI = Payload specific
- UPI = Payload specific

The Payload FCS Indicator (PFI) shall be set as required depending whether FCS is enabled or not. The Extension Header Identifier (EXI) shall be set consistently with the frame multiplexing and topology requirements for the GFP connection. The User Payload Identifier shall be set according to the transported client signal type. Defined UPI values for client data frames are given Table 6-3.

Table 6-3/G.7041/Y.1303 – User Payload Identifiers for GFP Client frames

PTI = 000	
User Payload Identifier (binary) TYPE Bits <7:0>	**GFP Frame Payload Area**
0000 0000 1111 1111	Reserved and not available
0000 0001	Frame-mapped Ethernet
0000 0010	Frame-mapped PPP
0000 0011	Transparent fiber channel
0000 0100	Transparent FICON
0000 0101	Transparent ESCON
0000 0110	Transparent Gb Ethernet
0000 0111	Reserved for future
0000 1000	Frame-mapped multiple access protocol over SDH (MAPOS)
0000 1001 through 1110 1111	Reserved for future standardization
1111 0000 through 1111 1110	Reserved for proprietary use

6.1.3.2 GFP Client Management frames

Client Management frames provide a generic mechanism for the GFP client specific source adaptation process to optionally send Client Management frames to the GFP client specific sink adaptation process. The frame consists of:

Client Management frames are GFP client frames consisting of a Core Header and a Payload Area. The Type field of the client data frames uses the following Type subfield values:

- PTI = 100
- PFI = Payload specific
- EXI = Payload specific
- UPI = Payload specific

For use as a GFP Client Management frame the Payload FCS Indicator (PFI) shall be set as required depending whether FCS is enabled or not. (Note that the use of FCS in GFP Client management frames reduces the amount of 'spare' bandwidth that can be used for such frames.) The Extension Header Indicator (EXI) shall be set as required depending on whether the extension header is employed or not. (Note that the use of Extension Header in GFP Client Management frame will significantly reduce the amount of 'spare' bandwidth that can be used for such frames.)

The UPI defines the use of the GFP Client Management frame payload. In this way the GFP Client management frame may be used for multiple purposes. Table 6-4 defines the GFP Client Management frame payload uses.

Table 6-4/G.7041/Y.1303 – GFP Client Management frame User Payload Identifier

PTI = 100	
UPI value	**Usage**
0000 0000 and 1111 1111	Reserved
0000 0001	Client signal fail (Loss of client signal)
0000 0010	Client signal fail (Loss of character synchronization)
0000 0011 thru 1111 1110	Reserved for future use

6.2 GFP Control frames

GFP control frames are used in the management of the GFP connection. The only control frame specified at this time is the GFP Idle frame.

6.2.1 GFP Idle frames

The GFP Idle frame is a special four-octet GFP control frame consisting of only a GFP Core Header with the PLI and cHEC fields (see 6.1.1) set to 0, and no Payload Area. The Idle frame is intended for use as a filler frame for the GFP source adaptation process to facilitate the adaptation of the GFP octet stream to any given transport medium where the transport medium channel has a higher capacity than required by the client signal. The GFP Idle frame format is shown in Figure 6-10, with the parenthetical values indicating the values after the Barker-like scrambling has been performed.

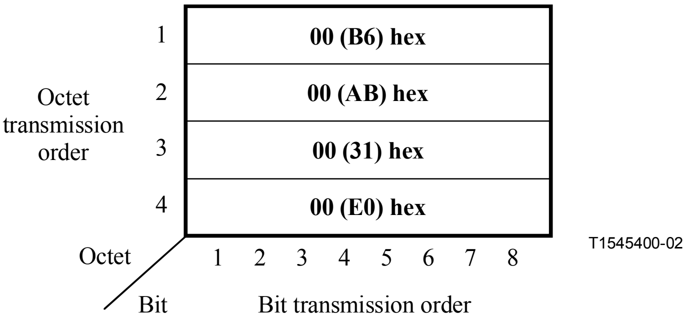


Figure 6-10/G.7041/Y.1303 – GFP Idle frame (Barker-like scrambled frame)

6.2.2 Other control frames

Control frames with PLI = 1, 2, or 3 are for further study.

6.3 GFP frame-level functions

This clause discusses frame-level processes common to all payloads that are framed via GFP. Processes specific to particular payloads are discussed in clauses 7 and 8. The relationships among these processes are illustrated in Figure 6-11.

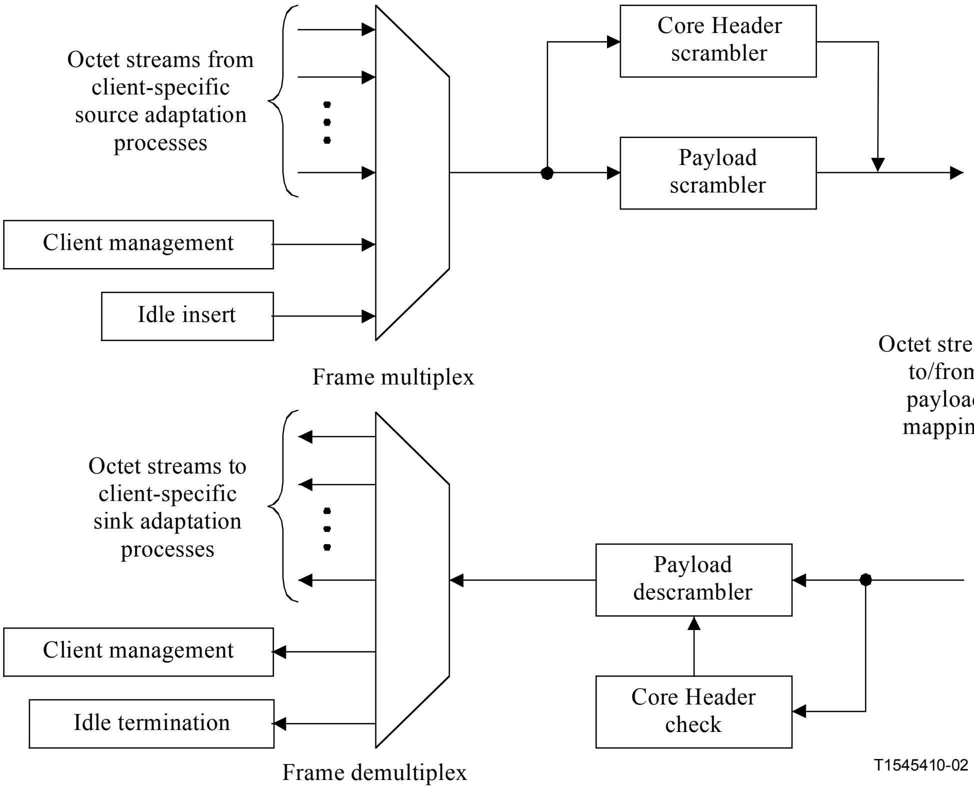


Figure 6-11/G.7041/Y.1303 – GFP common (Protocol Independent) procedures

6.3.1 GFP frame delineation algorithm

GFP uses a modified version of the HEC check algorithm specified in 4.5.1.1/I.432, to provide GFP frame delineation. The frame delineation algorithm used in GFP differs from that in ITU-T Rec. I.432 in two basic ways:

a) The algorithm uses the PDU Length Indicator field of the GFP Core Header to find the end of the GFP frame; and

b) HEC field calculation uses a 16-bit polynomial and, consequently, generates a two-octet cHEC field.

GFP frame delineation is performed based on the correlation between the first two octets of the GFP frame and the embedded two-octet cHEC field. Figure 6-12 shows the state diagram for the GFP frame delineation method.

The state diagram works as follows:

1) In the HUNT state, the GFP process performs frame delineation by searching, octet by octet, for a correctly formatted Core Header over the last received sequence of four octets. The Core Header single error correction is disabled while in this state. Once a correct cHEC match is detected in the candidate PLI and cHEC fields, a candidate GFP frame is identified and the receive process enters the PRESYNC state.

2) In the PRESYNC state, the GFP process performs frame delineation by checking, frame by frame, for a correct cHEC match in the presumed Core Header of the next candidate GFP frame. The PLI field in the Core Header of the preceding GFP frame is used to find the beginning of the next candidate GFP frame. Core Header single error correction remains disabled while in this state. The process repeats until DELTA consecutive correct cHECs are confirmed, at which point the process enters the SYNC state. If an incorrect cHEC is detected, the process returns to the HUNT state. The total number of consecutive correct cHECs required to move from the HUNT state to the SYNC state is therefore DELTA + 1.

3) In the SYNC state, the GFP process performs frame delineation by checking for a correct cHEC match on the next candidate GFP frame. The PLI field in the Core Header of the preceding GFP frame is used to find the beginning of the next candidate GFP frame. Single-bit Core Header error correction is enabled while in this state. Frame delineation is lost whenever multiple bit errors are detected in the Core Header by the cHEC. In this case, a GFP Loss of Frame Delineation event is declared, the framing process returns to the HUNT state, and a client Server Signal Failure (SSF) is indicated to the client adaptation process.

4) Idle GFP frames participate in the delineation process and are then discarded.

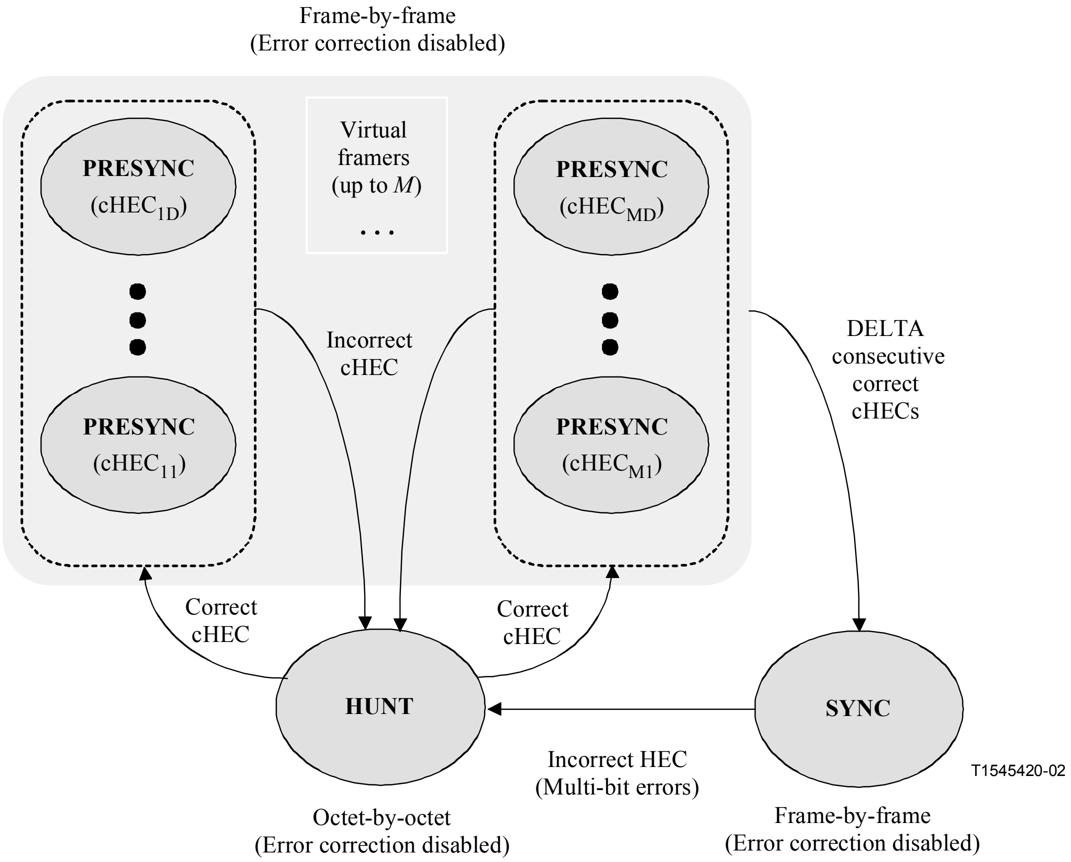


Figure 6-12/G.7041/Y.1303 – GFP Frame Delineation state diagram

Robustness against false delineation in the resynchronization process depends on the value of DELTA. A value of DELTA = 1 is suggested.

Frame delineation acquisition speed can be improved by the implementation of multiple "virtual framers", whereby the GFP process remains in the HUNT state and a separate PRESYNC substate is spawned for each candidate GFP frame detected in the incoming octet stream, as depicted in Figure 6-12.

6.3.2 Frame multiplexing

GFP frames from multiple ports and multiple client types are multiplexed on a frame-by-frame basis. The choice of scheduling algorithms is outside the scope of this Recommendation.

When there are no other GFP frames available for transmission, GFP Idle frames shall be inserted, thus providing a continuous stream of frames for mapping into an octet aligned physical layer.

6.3.3 Client Signal Fail indication

GFP provides a generic mechanism for a GFP client-specific source adaptation process to propagate a Client Signal Fail (CSF) indication to the far-end GFP client-specific sink-adaptation process on detection of failure defect in the ingress client signal.

Detection rules for client signal fail events is, by definition, client-specific (see clauses 7 and 8). Upon detection, a GFP source adaptation process should generate a Client Management frame (PTI = 100). The PFI subfield is set to 0 (no Payload Information field FCS), and the EXI subfield is set to the appropriate Extension Header type as applicable. The two types of CSF, use the following UPI field values:

– Loss of Client Signal (UPI = 0000 0001).

– Loss of Client Character Synchronization (UPI = 0000 0010).

Upon detection of the CSF condition, the GFP client-specific source adaptation process should send CSF indications to the far end GFP client-specific sink adaptation process once every 100 ms ≤ T ≤ 1000 ms, beginning at the next GFP frame. Interim frames shall be GFP Idle frames.

Upon reception of the CSF indication, the GFP client sink adaptation process declares a sink client signal failure. Defect handling is discussed in 6.3.4.

The GFP client-specific sink adaptation process should clear the defect condition either:

1) after failing to receive *N* CSF indications in *N* × 1000 ms, (a value of 3 is suggested for *N*); or

2) upon receiving a valid GFP client data frame.

Handling of incomplete GFP frames at the onset of a CSF event should be consistent with the error handling procedures specified in 7.3 for Frame-mapped GFP and 8.5 for Transparent-mapped GFP.

6.3.4 Defect handling in GFP

Figure 6-13 depicts the causal relationship between various defects detected or indicated by the GFP process. Trail Signal Fail (TSF) events refer to failure events detected in the SDH or OTN transport network as defined in ITU-T Recs G.783 and G.798. GFP Server Signal Fail events refer to GFP Loss of Frame Delineation events as defined in the GFP state machine (see 6.3.1) or propagation of TSF events to the GFP clients. CSF events refer to failure events detected in the client signal on ingress (communicated to far-end by a CSF client management frame) or egress (client-specific mapping defects such as payload errors, see clauses 7 and 8).

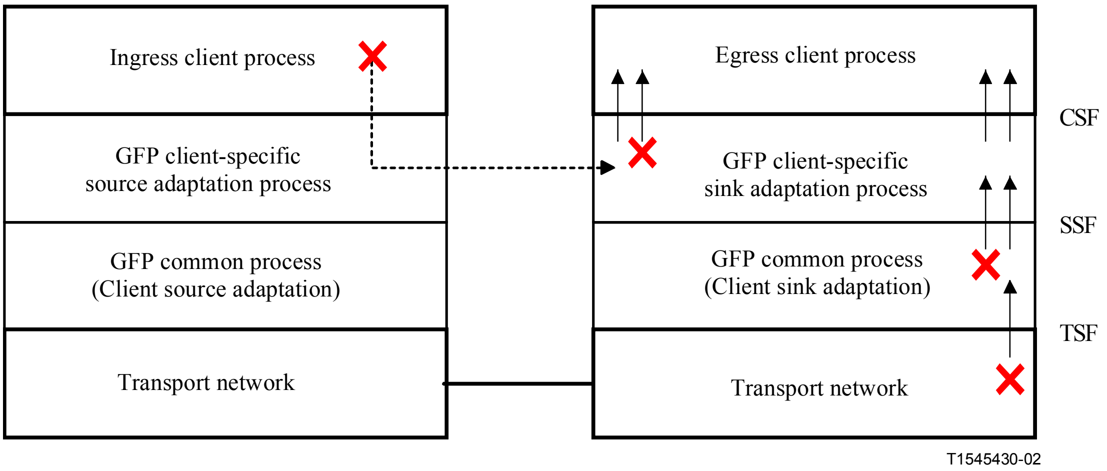


Figure 6-13/G.7041/Y.1303 – Defect Signal Propagation in GFP

Upon detection of a TSF event or a GFP Loss of Frame Delineation event, the GFP sink adaptation process generates a GFP SSF indication to its client-specific sink adaptation processes. These failure events are cleared as soon as the GFP process regains link synchronization.

Upon detection of CSF events other than a far-end CSF indication, the GFP client-specific sink adaptation processes should take client-specific (as well as server-specific) actions to deal with those failure events.

7 Payload specific aspects for frame-mapped GFP

This clause describes those aspects of the generic encapsulation specific to the adaptation of client signals using a frame-by-frame mapping of the client payload into GFP.

7.1 Ethernet MAC payload

The format of Ethernet MAC frames is defined in IEEE 802.3, section 3.1. There is a one-to-one mapping between a higher-layer PDU and a GFP PDU. Specifically, the boundaries of the GFP PDU are aligned with boundaries of the framed higher layer PDUs. This relationship between Ethernet MAC frames and GFP frames is illustrated in Figure 7-1.

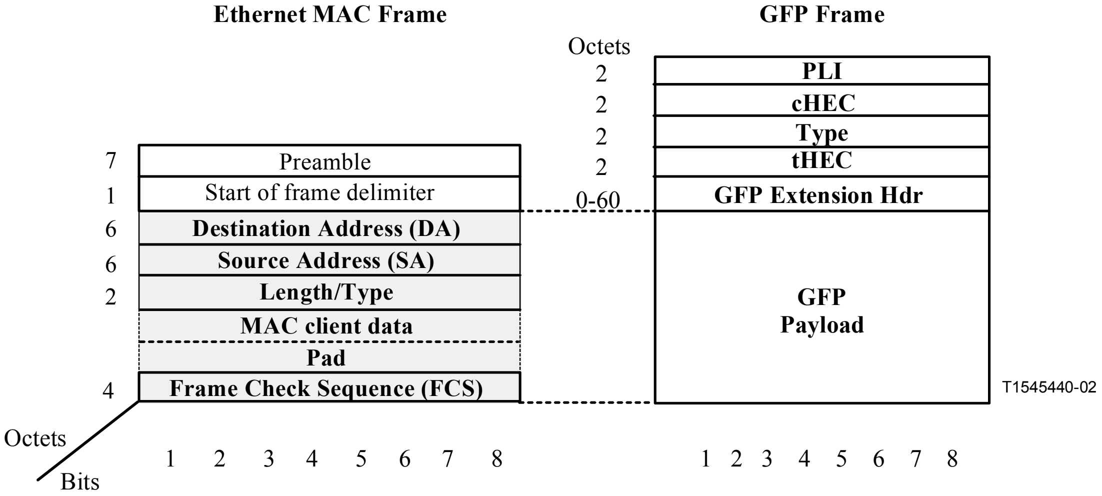


Figure 7-1/G.7041/Y.1303 – Ethernet and GFP frame relationships

7.1.1 Ethernet MAC encapsulation

The Ethernet MAC octets from Destination Address through Frame Check Sequence, inclusive, are placed in the GFP Payload Information field. Octet-alignment is maintained and bit identification within octets is maintained. Specifically, on an octet-by-octet basis, bits 0 and 7 in clause 3 of IEEE 802.3 correspond to bits 8 and 1, respectively, in this GFP Recommendation.

7.1.2 Ethernet Inter-Packet Gap (IPG) deletion and restoring

The following rules apply to the deletion and restoration of Ethernet IPGs when the client is not a native frame-mapped GFP client:

1) IPGs are deleted before the Ethernet MAC frame is processed by the GFP source adaptation process and restored after the GFP frame is processed by the GFP sink adaptation process.
2) IPGs are deleted as the Ethernet MAC frame is extracted from the client bit-stream. The extracted (decoded) Ethernet MAC frame is then forwarded to the GFP source adaptation process for subsequent encapsulation into a GFP frame.

3) IPGs are restored after the Ethernet MAC frame is extracted from the GFP frame by the GFP termination element. The extracted (uncoded) Ethernet MAC frame is then forwarded to the client layer for subsequent processing. IPGs are restored by ensuring that sufficient octets containing an idle pattern of 00 hex are present between consecutive received Ethernet MAC frames to meet the minimum receiver IFG requirements. Minimum receiver IFG requirements are stated in IEEE 802.3, section 4.4.

7.2 IP/PPP payload

IP/PPP payloads are first encapsulated in an HDLC-like frame. The format of a PPP frame is defined in IETF RFC 1661, section 2. The format of the HDLC-like frame is defined in IETF RFC 1662, section 3. Unlike IETF RFC 1662, no octet stuffing procedure is performed on flag or control escape characters. There is a one-to-one mapping between a higher-layer PPP/HDLC PDU and a GFP PDU. Specifically, the boundaries of the GFP PDU are aligned with boundaries of the framed higher layer PPP/HDLC PDUs. This relationship between PPP/HDLC frame and the GFP frame is illustrated in Figure 7-2.

Similar clients, such as MAPOS, are mapped in the same manner as PPP frames.

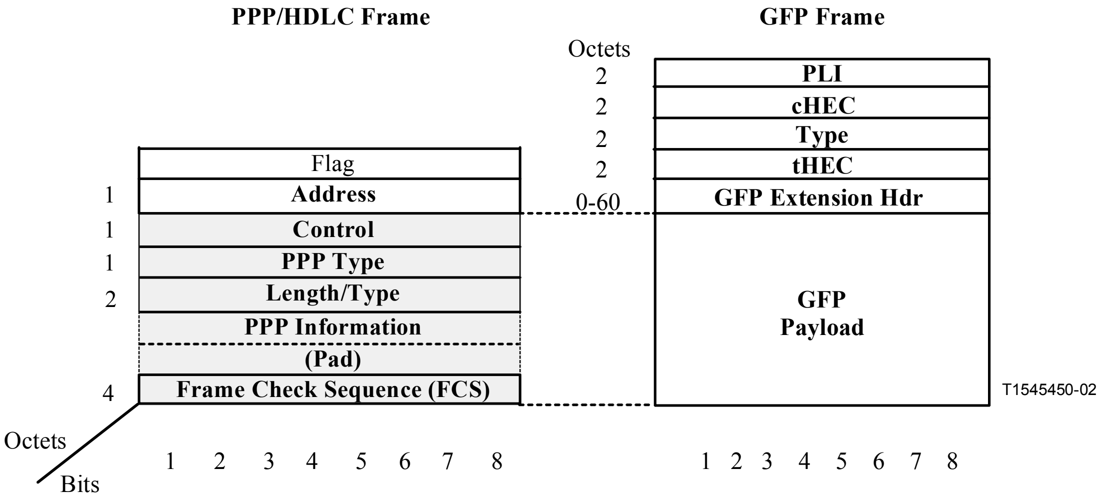


Figure 7-2/G.7041/Y.1303 – PPP/HDLC and GFP frame relationships

7.2.1 PPP frame encapsulation

All octets from the PPP/HDLC frame, including any optional PPP Information field padding, are placed in the Payload Information field of a GFP frame. Octet alignment is maintained and bit identification within octets is also maintained.

7.2.2 GFP/HDLC delineation interworking

GFP does not rely on flag characters, and associated control escape octet, for frame delineation purposes. The following rules apply to the processing of Octet-Synchronous HDLC frames by a GFP/HDLC interworking function:

1) Flags and associated control escape octets are removed (as specified in IETF RFC 1662, section 4.2) as the PPP/HDLC frame is extracted from the incoming client octet stream. The extracted (decoded) PPP/HDLC frame is then forwarded to the GFP source adaptation process for subsequent encapsulation into a GFP frame.

2) The GFP extracts the PPP/HDLC frame from the GFP frame. The extracted (uncoded) PPP/HDLC frame is then forwarded to the client layer for subsequent processing. Flags and control escape characters are then restored by inserting flag characters (e.g. hexadecimal 0x7e) and escape control characters (e.g. hexadecimal 0x7d) as specified in IETF RFC 1662, section 4.

7.2.3 PPP payload configuration options

Modifications to the PPP/HDLC-like frame format may be negotiated using the Link Configuration Protocol (LCP) Configuration Options procedures as defined in IETF RFC 1661, section 6. For example, the format of the GFP frame after a successful negotiation of the Address-and-Control-Field-Compression (ACFC) Configuration Option is illustrated in Figure 7-3. Such configuration procedures are client-specific and transparent to GFP process.

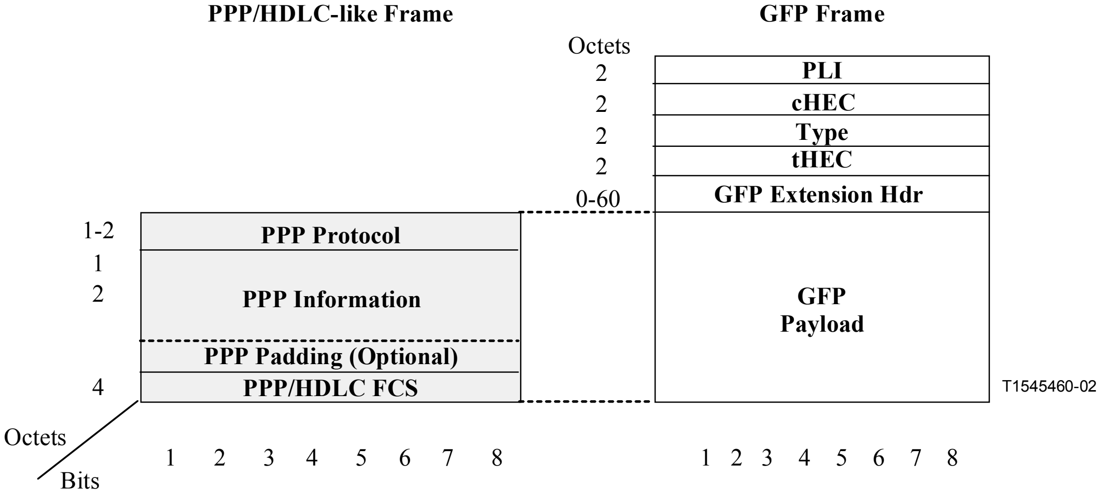


Figure 7-3/G.7041/Y.1303 – PPP/HDLC/HDLC and GFP frame relationships (with PPP's ACFC configuration option)

7.3 Error handling in frame-mapped GFP

On ingress, PDUs detected in error before transmission by the client source adaptation process should be discarded. PDUs detected in error while in transmission by the client source adaptation process should be padded up with an all ones bit sequence, and transmitted with a Payload FCS which has all 32-bits complemented, when present. These actions ensure that the termination GFP process, or the client end, will drop the errored PDU.

8 Payload-specific aspects for transparent mapping of 8B/10B clients into GFP

Transparent mapping of 8B/10B payloads into GFP is intended to facilitate the transport of 8B/10B block-coded client signals for scenarios that require very low transmission latency. Examples of such client signals include Fibre Channel, ESCON, FICON, and Gigabit Ethernet. Rather than buffering an entire frame of the client data into its own GFP frame, the individual characters of the client signal are demapped from the client block codes and then mapped into periodic, fixed-length GFP frames. The mapping occurs regardless of whether the client character is a data or a control character, which thus preserves the client 8B/10B control codes. Frame multiplexing is not precluded with transparent GFP.

The transparent GFP frame uses the same frame structure as the frame-mapped GFP, including the required Payload Header. The Payload FCS is optional. The transparent GFP frame format is depicted in Figure 8-1.

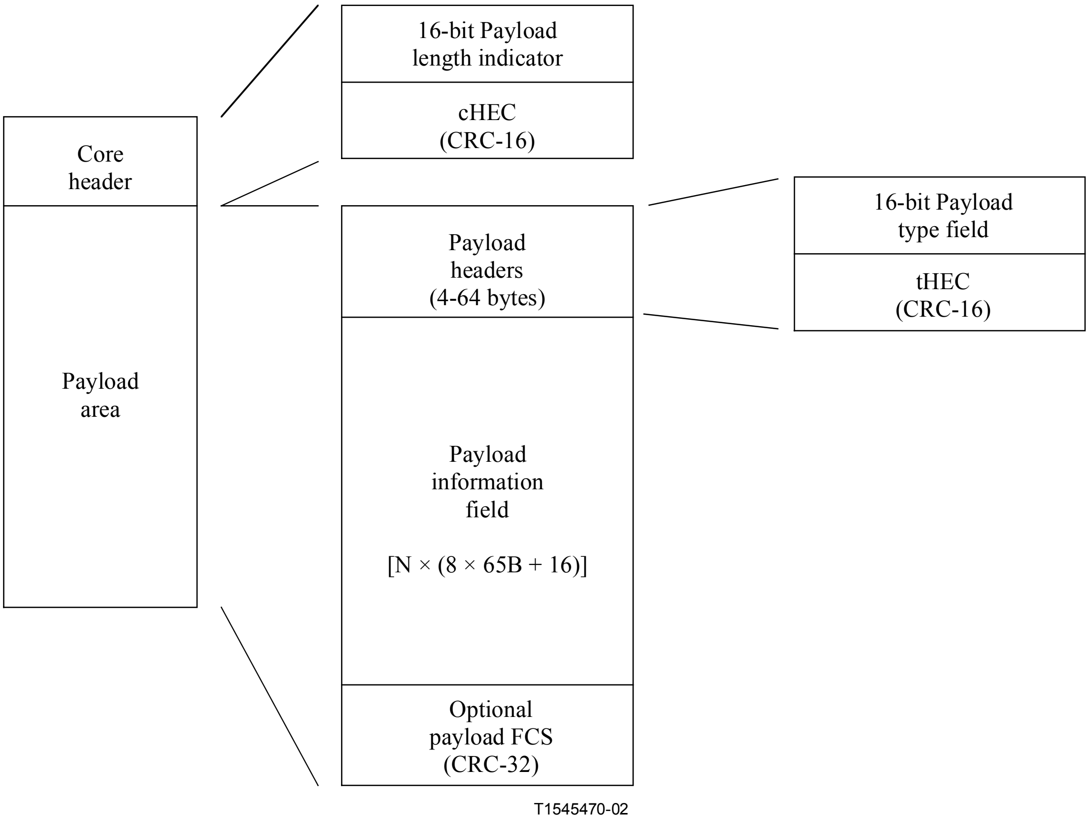


Figure 8-1/G.7041/Y.1303 – Transparent GFP frame format

8.1 Adapting 8B/10B client signals via 64B/65B block codes

As depicted in the Functional Model in Figure 2, the first step in the client adaptation process is decoding the physical layer of the client signal. For 8B/10B line codes, the received 10-bit character is decoded into its original 8-bit value, if it is an 8B/10B data codeword, or into a control character if it is an 8B/10B control codeword. The 8B/10B control codewords are mapped into one of the 16 possible 4-bit Control Code Indicators for the 8-bit control characters available in transparent GFP. (See Table 8-1.)

Table 8-1/G.7041/Y.1303 – Mapping between 8B/10B Control Characters and the 64B/65B Control Code Indicators

Name	Octet Value	10B Codeword (RD–) abcdei fghj	10B Codeword (RD+) abcdei fghj	64B/65B 4-bit Mapping
/K28.0/	1C	001111 0100	110000 1011	0000
/K28.1/	3C	001111 1001	110000 0110	0001
/K28.2/	5C	001111 0101	110000 1010	0010
/K28.3/	7C	001111 0011	110000 1100	0011
/K28.4/	9C	001111 0010	110000 1101	0100
/K28.5/	BC	001111 1010	110000 0101	0101
/K28.6/	DC	001111 0110	110000 1001	0110
/K28.7/	FC	001111 1000	110000 0111	0111
/K23.7/	F7	111010 1000	000101 0111	1000
/K27.7/	FB	110110 1000	001001 0111	1001

Table 8-1/G.7041/Y.1303 – Mapping between 8B/10B Control Characters and the 64B/65B Control Code Indicators

Name	Octet Value	10B Codeword (RD–) abcdei fghj	10B Codeword (RD+) abcdei fghj	64B/65B 4-bit Mapping
/K29.7/	FD	101110 1000	010001 0111	1010
/K30.7/	FE	011110 1000	100001 0111	1011
10B_ERR	N/A	Unrecognized RD–	Unrecognized RD+	1100
65B_PAD	N/A	N/A	N/A	1101
Spare	N/A	N/A	N/A	1110
Spare	N/A	N/A	N/A	1111

NOTE 1 – While all 256 data characters must be supported, only 12 special 8B/10B control codewords are recognized and used for 64B/65B control characters in Gigabit Ethernet, Fibre Channel, FICON, and ESCON. Hence, the compression of special 8B/10B control codewords into 4-bit values is possible without restricting client signals, or providing protocol-specific handling of 8B/10B control codewords.

NOTE 2 – The recoding process is entirely unaware of the meaning of control words or ordered sets. It simply generically recodes data and control words into 65B blocks. No knowledge of start-of-frame, end-of-frame, errors, idles, control codes, ordered sets, etc. is required.

The decoded 8B/10B characters are then mapped into a 64-bit/65-bit (64B/65B) block code. The structure of the 64B/65B block code is shown in Figure 8-2. The leading bit of the 65-bit block, the Flag bit, indicates whether that block contains only 64B/65B 8-bit data characters or whether client control characters are also present in that block. (Flag bit = 0 indicates data octets only and Flag bit = 1 indicates at least one control octet in the block). Client control characters, which are mapped into 8-bit 64B/65B control characters, are located at the beginning of the 64-bit block payload if they are present in that block. The first bit of the 64B/65B control character contains a Last Control Character (LCC) flag bit which indicates whether this control character is the last one in this block (LCC = 0), or whether there is another control character in the next octet (LCC = 1). The next three bits contain the Control Code Locator, which indicates the original location of the 8B/10B control code character within sequence of the eight client characters contained in the block. The last 4 bits, the Control Code Indicator, give the 4-bit representation of the 8B/10B control code character. The explicit mapping of 8B/10B control code characters into the 4-bit Control Codes is defined in Table 8-1. The control codes are mapped into the payload bytes of the 64B/65B code in the order in which they were received. Note that, as a result, the control code addresses aaa-hhh in Figure 8-2 will be in ascending order.

Input Client Characters	Flag Bit	64-Bit (8-Octet) Field							
All data	0	D1	D2	D3	D4	D5	D6	D7	D8
7 data, 1 control	1	0 aaa C1	D1	D2	D3	D4	D5	D6	D7
6 data, 2 control	1	1 aaa C1	0 bbb C2	D1	D2	D3	D4	D5	D6
5 data, 3 control	1	1 aaa C1	1 bbb C2	0 ccc C3	D1	D2	D3	D4	D5
4 data, 4 control	1	1 aaa C1	1 bbb C2	1 ccc C3	0 ddd C4	D1	D2	D3	D4
3 data, 5 control	1	1 aaa C1	1 bbb C2	1 ccc C3	1 ddd C4	0 eee C5	D1	D2	D3
2 data, 6 control	1	1 aaa C1	1 bbb C2	1 ccc C3	1 ddd C4	1 eee C5	0 fff C6	D1	D2
1 data, 7 control	1	1 aaa C1	1 bbb C2	1 ccc C3	1 ddd C4	1 eee C5	1 fff C6	0 ggg C7	D1
8 control	1	1 aaa C1	1 bbb C2	1 ccc C3	1 ddd C4	1 eee C5	1 fff C6	1 ggg C7	0 hhh C8

– Leading bit in a control octet (LCC) = 1 if there are more control octets and = 0 if this payload octet contains the last control octet in that block.
– aaa = 3-bit representation of the 1st control code's original position (1st Control Code Locator).
– bbb = 3-bit representation of the 2nd control code's original position (2nd Control Code Locator).
…
– hhh = 3-bit representation of the 8th control code's original position (8th Control Code Locator).
– Ci = 4-bit representation of the ith control code (Control Code Indicator).
– Di = 8-bit representation of the ith data value in order of transmission.

Figure 8-2/G.7041/Y.1303 – Transparent GFP 64B/65B code components (see Figure 8.3 for actual superblock structure)

For example, if there is a single 64B/65B control character in a block and it was originally located between 8B/10B data codewords D2 and D3, the first octet of the 64B/65B block will contain 0.010.C1. The LCC value of 0 indicates that this 64B/65B control character is the last one in that block and the value of aaa = 010 indicates C1's location between D2 and D3. At the demapper, the 64B/65B data characters are remapped as 8-bit data octets and then encoded back into the 8B/10B data codewords. For 64B/65B control characters, the four-bit Control Code Indicators are remapped into the appropriate 8B/10B control codewords with their positions within the original character stream restored based on the three-bit Control Code Locator.

8.1.1 10B_ERR code

Certain client signal defects may produce 8B/10B codewords on ingress to the GFP source adaptation process that cannot be recognized by the 64B/65B adaptation process (e.g. a client signal failure, an illegal 8/10B codeword or a legal codeword with a running disparity error, see 8.3). A special 64B/65B control character, the 10B_ERR code, is provided to convey such "unrecognized 8B/10B codeword" client signal defects.

When reconstructing the client signal on egress from the transport network, received 10B_ERR code are typically recoded by the demapper into either 001111 0001 (RD–) or 110000 1110 (RD+) (fixed illegal 8B/10B codewords with neutral disparity), depending on running disparity (see 8.3 for other client-specific running disparity considerations). Although the actual value of the unrecognized 8B/10B codeword is not retained, the occurrence and location of the client signal defect are preserved.

8.1.2 Insertion of 65B_PAD code and GFP Client Management frames

Since the Transparent GFP application requires that the available path (channel) capacity is at least that of the client signal base (pre-encoding) data rate, the input receive (ingress) buffer at the mapper will regularly approach underflow. For rate adaptation purposes, if a transparent GFP frame is currently being transmitted, and if there are no client characters ready for transmission by the transparent GFP mapper, the mapper shall insert a 65B_PAD padding character. The pad character is mapped into the GFP frame in the same manner as a control character and is recognized and removed by the GFP demapper. Client-specific considerations for 65B_PAD code handling are given in 8.4.

Client data frames are transmitted with priority over Client Management frames. If a GFP Client Management frame is available to transmit, and the ingress buffer is nearly empty (e.g. if a 65B_PAD character has been sent during the current client data frame), then the Client Management frame may be sent after the current client data frame. In order to maintain low latency, it is recommended that, for a right-sized channel only, a single Client Management frame be sent between client data frames. It is also recommended that Client Management frames used with Transparent GFP be limited to a Payload Information Field of eight bytes or less. Note that low latency may also be maintained by increasing the channel size to allow the exchange of additional Client Management frames.

8.2 Adapting 64B/65B code blocks into GFP

To preserve the octet alignment of the Transparent GFP signal with the transport SDH/ODUk frame, the first step in the adaptation process is to group eight 64B/65B codes into a superblock as shown in Figure 8-3. The leading (Flag) bits of each of the eight 64B/65B codes are grouped together into a first trailing octet. The sixteen bits of the last two trailing octets are used for a CRC-16 error check over the bits of this superblock.

<table>
<tr><td colspan="8">Octet 1, 1</td></tr>
<tr><td colspan="8">Octet 1, 2</td></tr>
<tr><td colspan="8">Octet 1, 3</td></tr>
<tr><td colspan="8">.
.
.</td></tr>
<tr><td colspan="8">Octet 8, 7</td></tr>
<tr><td colspan="8">Octet 8, 8</td></tr>
<tr><td>L1</td><td>L2</td><td>L3</td><td>L4</td><td>L5</td><td>L6</td><td>L7</td><td>L8</td></tr>
<tr><td>CRC1</td><td>CRC2</td><td>CRC3</td><td>CRC4</td><td>CRC5</td><td>CRC6</td><td>CRC7</td><td>CRC8</td></tr>
<tr><td>CRC9</td><td>CRC10</td><td>CRC11</td><td>CRC12</td><td>CRC13</td><td>CRC14</td><td>CRC15</td><td>CRC16</td></tr>
</table>

where: Octet j, k is the kth octet of the jth 64B/65B code in the superblock
Lj is the leading (Flag) bit jth 64B/65B code in the superblock
CRCi is the ith error control bit where CRC1 is the MSB of the CRC

Figure 8-3/G.7041/Y.1303 – Superblock structure for mapping 64B/65B code components into the GFP frame

NOTE – To minimize latency, the transparent GFP mapper can begin transmitting data as soon as the first 64B/65B code in the group has been formed rather than waiting for the entire superblock to be formed.

Assuming no Payload FCS and a Null Extension header, the resulting GFP frame is $[(N \times ((65 \times 8) + 16) + (8 \times 8)]$ bits long, where N is the number of superblocks in the GFP frame. The value of N depends on the base, uncoded, rate of the client signal and on the transport channel capacity. Suggested SDH virtually concatenated channel capacities and the associated minimum values for N are shown in Appendix IV. Suggested channel capacities for other transport paths are for further study. The minimum value of N depends on the data rate of the client signal, the number of GFP frame overhead octets (e.g. 8 with no optional Payload FCS and a Null Extension Header), and the size of the payload envelope, as shown in Appendix IV. Specifically, N_{min} must be chosen such that for the fastest tolerance client clock rate and slowest tolerance SDH/OTN clock rate, the time required to transmit the GFP frame containing the $N \times 8 \times 8$ client characters is less than the time in which the client can deliver these $N \times 8 \times 8$ characters to the GFP mapper.

Note that N may be optionally configurable according to spare bandwidth requirements for the transport of Client Management frames. See Appendix IV.

8.2.1 Error control with Transparent GFP

The 16 error control bits in a superblock (see Figure 8-3) contain a CRC-16 error check code over the 536 bits in that superblock. If the demapper detects an error, it should output either 10B error characters or unrecognized 10B characters in place of all of the client characters contained in that superblock. The 10B error and unrecognized characters are described for disparity errors in the client-specific aspects (see 8.4). This replacement guarantees that the client receiver will be able to detect the presence of the error.

The generator polynomial for the CRC-16 is $G(x) = x^{16} + x^{15} + x^{12} + x^{10} + x^{4} + x^{3} + x^{2} + x + 1$ with an initialization value of zero, where x^{16} corresponds to the MSB and x^{0} to the LSB. The superblock CRC is generated by the source adaptation process using the following steps:

1) The first 65 octets of the superblock are taken in network octet order (see Figure 8-3), most significant bit first, to form a 520-bit pattern representing the coefficients of a polynomial $M(x)$ of degree 519.

2) $M(x)$ is multiplied by x^{16} and divided (modulo 2) by $G(x)$, producing a remainder $R(x)$ of degree 15 or less.

3) The coefficients of $R(x)$ are considered to be a 16-bit sequence, where x^{15} is the most significant bit.

4) This 16-bit sequence is the CRC-16.

NOTE – Single error correction is also possible with this CRC-16. However, since the sink adaptation process performs the CRC-16 check after the payload descrambling is performed, the error correction circuit should account for single bit errors as well as double errors spaced 43 bits apart coming out of the descrambler.

The sink adaptation process performs steps 1)-3) in the same manner as the source adaptation process. In the absence of bit errors, the remainder shall be 0000 0000 0000 0000.

8.3 Running disparity in 64B/65B codes

8B/10B codewords are designed to facilitate error-free transmission by maintaining DC balance, providing significant transitions for clock recovery, and limiting run-length of consecutive 1s or 0s. DC balance is measured on a codeword by codeword basis by keeping track of "running disparity." Running disparity is either positive (indicating more 1s than 0s have been sent), or negative (more 0s than 1s sent).

In order to maintain DC balance in 8B/10B codewords, each 8-bit data character and each of the 12 recognized "special control characters" have two 10-bit encodings. Depending on current running disparity, the 8B/10B encoder will select which of the two encodings to transmit for next data or control character in order to either flip the running disparity, or to maintain the current running disparity. Specifically, the new codeword flips the running disparity from negative to positive if there have been more 0s than 1s transmitted, from positive to negative if there have been more 1s than 0s transmitted, or maintains the running disparity if there has been an equal number of 1s and 0s.

Transmission bit errors may cause a received 8B/10B codeword to have the wrong disparity for the current beginning running disparity state. In these cases, a running disparity error is detected. Independent of the received character's validity, the received transmission character shall be used to calculate a new value of running disparity. The new value shall be used as the receiver's current running disparity for the next received transmission character.

NOTE – Transmission bit errors may also result in the errored codeword being received with correct disparity and a corrupted but legal 8B/10B codeword that results in some later non-errored codeword being detected with a running disparity error. In some cases, protocol-specific running disparity rules have been created to ensure each data packet begins or ends with defined disparity so that errors will not be propagated across data packets.

8.3.1 Handling of running disparity on ingress

On ingress, the initial running disparity, upon power-on, reset, or transition from a loss of signal or loss of codeword synchronization phase, may be assumed either positive or negative.

A match to the received 10B character is searched for in the appropriate RD+ or RD– column of the 8B/10B valid codeword lookup table, depending on the current beginning running disparity. If no match is found, either an illegal codeword or a legal codeword with a running disparity error has been detected. Both are treated as 8B/10B code violations, and are replaced with the 10B_ERR code in the 64B/65B mapping process.

8.3.2 Handling of running disparity on egress

On egress, the initial running disparity upon power-on, reset, or transition from a loss of signal or loss of codeword synchronization phase, shall be assumed to be negative.

Transparent transport implementations must generate correct running disparity using any applicable protocol-specific rules. References are provided in 8.3.3 to the standard(s) that define each currently applicable protocol's disparity rules.

10B_ERR codes are recoded into client signals either as an unrecognized codeword with valid running disparity, or as a protocol-specific error, depending on the protocol, as described in 8.3.3.

8.3.3 Client-specific running disparity aspects

This clause describes the client-specific running disparity rules for each of the identified, supported 8B/10B client protocols.

8.3.3.1 Fibre Channel payload

Running disparity rules for Fibre Channel are found in ANSI X3.230, Fibre Channel Physical and Signaling Interface (FC-PH), Rev 4.3, section 11. In addition to the "generic" running disparity rules specified in section 11.2, Fibre Channel specific rules in section 11.4 provide two versions of each EOF ordered set, and dictate their use to ensure that negative running disparity will result after processing of the final character of the EOF ordered set. Ordered sets defined for the primitive signals and primitive sequences preserve this negative disparity, ensuring that the ordered sets associated with SOF delimiters, primitive signals, and primitive signals will also always be transmitted with negative beginning running disparity. This restriction allows Fibre Channel Idle words to be removed and added from an encoded bit stream one word at a time without altering the beginning running disparity.

To prevent subsequent valid Fibre Channel frames from being declared invalid, the K28.5 character associated with all ordered sets except EOF should be generated assuming beginning negative running disparity. In the event that a previous transmission error results in an incorrect EOF for the current running disparity, the next ordered set will be generated with RD− K28.5, forcing ending running disparity to be negative. As a result, transmission errors will not cause a running disparity error to be propagated across frames.

For "transparent transport" of Fibre Channel payloads, 10B_ERR shall be recoded into one of the following unrecognized 10B neutral disparity codewords, depending on beginning running disparity: 001111 0001 (RD–) or 110000 1110 (RD+).

8.3.3.2 ESCON payload

Running disparity rules for ESCON are found in ANSI X3.296, Information Technology – Single-Byte Command Code Sets Connection (SBCON) Architecture, section 6.2.2. Since ESCON does not define an error code to substitute for code violations, on egress, 10B_ERR shall be recoded into one of the following unrecognized 10B neutral disparity codewords, depending on beginning running disparity: 001111 0001 (RD–) or 110000 1110 (RD+).

8.3.3.3 FICON payload

For purposes of mapping into transparent GFP, the running disparity rules for FICON are identical to those specified for Fibre Channel in ANSI X3.230, Rev 4.3.

8.3.3.4 Gigabit Ethernet payload

Running disparity rules for Gigabit Ethernet are found in IEEE 802.3, section 36.2.4. Two Idle encodings are provided, indicated as /I1/ and /I2/. The first /I/ following a packet or Configuration ordered set restores the current running disparity to a negative value. All subsequent /I/s are /I2/ to ensure negative ending running disparity. This restriction allows single /I2/s to be inserted/removed for rate adaptation without altering the beginning running disparity associated with the code-group subsequent to the inserted or removed /I2/.

In order to ensure beginning negative running disparity for each SOF, all /I2/ Idles should be generated with RD− K28.5, insuring beginning negative running disparity for the next Idle or SOF.

Per section 36.2.4.16 of IEEE 802.3, running disparity errors detected on ingress (and replaced with 10B_ERR codeword in 64B/65B encoding process), should be replaced with /V/ codeword (K30.7) having correct disparity on egress. As an option, it is also permissible to recode received 10B_ERR into one of the following unrecognized 10B neutral disparity codewords, depending on beginning running disparity: 001111 0001 (RD–) or 110000 1110 (RD+).

8.4 Rate adaptation in 64B/65B codes

On ingress, rate adaptation to the output payload data rate occurs in the 64B/65B encoding process. If there is not an 8B/10B codeword available for the mapper to recode into 64B/65B block code the mapper inserts a 65B_PAD as described in 8.1.2. Essentially, this 65B_PAD is a non-client-idle that is used to pad 64/65B blocks for rate adaptation purposes. On egress, the demapper removes these non-client-idle signals. Since fixed length GFP frames are used, and frames may be padded with 65B_PADs for rate adaptation, there is no need to buffer an entire GFP frame prior to inserting it into the payload of the outgoing transport signal, thus reducing buffering and delay in the mapping process.

8.4.1 Egress rate adaptation procedures

There are two approaches for generating the client egress data interface clock at the GFP client-specific sink-adaptation process. One approach is to adapt the client signal to a clock source that is local to the GFP sink adaptation process. The other approach is to generate the client signal egress block by deriving it from the received GFP signal and transport clock.

Should a failure occur in either the ingress client signal, or during SDH/OTN transport, a protocol-specific local reference clock is still required at the client data egress point if the client expects a client rate link failure signal to replace the failed client.

8.4.1.1 Rate adaptation to a local reference clock

The currently supported 8B/10B client signals specify operating frequencies with clock-offset requirements of ±100 ppm to ±200 ppm, which are significantly relaxed compared to SDH or OTN. Each of these client signals is designed to allow rate adaptation to a local reference clock, either at repeaters or at the far-end, through client Idle (or fill-word) insertion or removal. To facilitate this rate adaptation, each of these client signals impose minimum Inter-Packet Gap (IPG) rules, which specify the minimum number of Idle codewords which must be inserted between data packets. Each of these client signals also specifies the maximum data packet size. Minimum IPG rules have been established to insure that where rate adaptation to a local clock is required, even under the worst case condition where a fast input clock and slow output clock require some IPG Idles to be deleted, sufficient IPG will remain between packets for successful client frame delineation.

This scheme may be employed equally well when reconstructing transparent-mapped client data on egress. With this approach, a local reference clock is supplied at the GFP sink adaptation process. As client data is demapped from GFP frames and recoded into 8B/10B codewords, it is rate adapted to the local reference clock through idle insertion/removal. Client-specific processing is required to recognize legal opportunities to insert/remove idle codewords, generate proper idle codes, and insert such codes in the egress bit-stream. An example of a client specific parameter is the minimum and maximum number of idles that are allowed to be inserted or removed.

Even in links containing multiple repeaters, if all "local" clocks meet the accuracy requirements for the specific protocol, sufficient opportunities for idle insertion or removal will occur, since aggregate timing offsets through cascaded repeaters cannot exceed worst-case clock offset requirements.

With this approach, timing characteristics such as the jitter and wander of the reconstructed client signal depend primarily on the quality of the local reference clock. The local reference clock is protocol rate specific (e.g. Gigabit Ethernet, Fibre Channel, and ESCON do not share common frequencies).

8.4.1.2 Rate adaptation from the transported client signal

Client signals are provided at a smooth protocol-specific clock rate on ingress. While there may be gaps in the client data packets themselves, these are filled with inter-packet gap (IPG) at a constant clock rate. Transparent mapping preserves all of the client data, control, and IPG information when recoding it using 64B/65B (assuming no client Loss of Signal or Loss of Character Synchronization occurs). However, the recoded data is then mapped into GFP frames with 65B_PAD stuffing to rate-adapt to the higher bandwidth transport payload channel. GFP Client Management or control frames may also be inserted periodically or opportunistically between GFP client data frames. Transport frames add their own overhead (Section and Path Overhead plus fixed stuff bytes in the case of SDH). No alignment between client data, stuffing bytes or blocks, GFP frames, transport overhead is maintained.

On egress, clock recovery is expected to require a FIFO and desynchronizer, where the desynchronizer would require a reference clock, PLL, and filter. Recovered clock timing would depend on some filtered version of the FIFO fill level. The FIFO itself would be subject to fairly dramatic changes in level under normal operating conditions due to the occurrence of large blocks of section/transport overhead, GFP frame overhead, and GFP Client Management frames. Under worst-case conditions, it is possible that all of the client data "gapping" mechanisms will align into one contiguous "no client data" block. The relatively non-periodic nature of some of the gaps combined with the relative large client data source clock frequency tolerance complicate the FIFO and PLL design.

The advantage of this desynchronizer approach is that no protocol-specific knowledge is required to recover client clock on egress.

The jitter and wander timing characteristics of the reconstructed client signal depend primarily on the design of the clock recovery system. With a more complex design, a wide range of client rates may be supported with a single design.

8.4.2 Client-specific rate adaptation aspects

On egress, transparently transported client signals must be reconstructed and output in a manner that is compliant with the physical interface requirements specific to each protocol. Regardless of the selected client egress timing approach, protocol-specific timing requirements must be met, as defined in applicable standards for each client protocol. The following clauses identify key applicable requirements, but other protocol-specific requirements may apply.

8.4.2.1 Fibre Channel payload

Fibre Channel full rate output data rate (after 8B/10B encoding) shall be 1062.5 Mbit/s ± 100 ppm, as specified in ANSI X3.230, Fibre Channel Physical and Signaling Interface (FC-PH), Rev 4.3, section 5.1. Output signal timing requirements are further specified in ANSI X3.230, sections 6.1.1 (Single-mode optical output interface), 6.2.1 (Multi-mode optical output interface), and 7 (Electrical cable interface). Output signals will normally be generated with a minimum of six Primitive Signals (Idles and R_RDY) between frames, as specified in ANSI X3.230, section 17.1. If rate adaptation is performed using Fibre Channel Idle insert/removal, rate adaptation shall be applied such that the receiving destination receives at least two Idles preceding each frame, as specified in ANSI X3.230, section 17.1.

Rate adaptation may also be required when a continuous stream of Fibre Channel primitive sequences is received, where primitive sequences are defined in Table 26 of ANSI X3.230. Since a minimum of three consecutive identical primitive sequences are required to be received before the sequence is recognized (per section 16.4.1 of ANSI X3.230), rate adaptation by inserting one replica of the received four-character sequence, or deleting a received sequence, shall only occur after three consecutive identical sequences have been received and retransmitted.

Depending on implementation, a continuous stream of 10B_ERR neutral disparity characters could be generated at egress, although rate adaptation is still required here. In this case, rate adaptation may be performed by removing or inserting a 10B_ERR neutral disparity character after 12 consecutive 10B_ERR characters have been received and retransmitted.

8.4.2.2 ESCON payload

ESCON output data rate (after 8B/10B encoding) shall be 200 Mbit/s ± 0.04 Mbit/s, as specified in ANSI X3.296, Information Technology – Single-Byte Command Code Sets Connection (SBCON) Architecture, section 5.1.2. Output signal timing requirements are further specified in ANSI X3.296, sections 5.2.1 (Multi-mode output interface) and 5.3.1 (Single-mode output interface). Output signals will normally be generated with a minimum of four idle characters (K28.5) between data frames, as specified in ANSI X3.296, section 6.3. If rate adaptation is performed using ESCON Idle insert/removal, either one or two idle characters may be added or removed between frames, according to the rules of ANSI X3.296, section 7.2.

Rate adaptation may also be required when a continuous stream of ordered set sequences is received, where ordered set sequences are defined in Table 15 of ANSI X3.296. Since a minimum of eight consecutive sequences are required to be received before the sequence is recognized (per section 6.3 of ANSI X3.296), rate adaptation by inserting a replica of the received two-character sequence, or deleting a received sequence shall only occur after eight consecutive identical sequences have been received and retransmitted.

Depending on implementation, a continuous stream of 10B_ERR neutral disparity characters could be generated at egress, although rate adaptation is still required here. In this case, rate adaptation may be performed by removing or inserting a 10B_ERR neutral disparity character after 12 consecutive 10B_ERR characters have been received and retransmitted.

8.4.2.3 FICON payload

The timing requirements for FICON are the same as those specified for Fibre Channel in ANSI X3.230, Rev 4.3.

8.4.2.4 Full-duplex Gigabit Ethernet payload

Gigabit Ethernet (GbE) output data rate (after 8B/10B encoding) shall be 1250 Mbit/s ± 100 ppm, as specified in IEEE 802.3. Output signal timing requirements are further specified in IEEE 802.3, sections 38.5 and 38.6 (1000BASE-LX optical fiber interfaces), and 39.3.1 and 39.3.3 (1000BASE-CX (short-haul copper interface). Output signals will normally be generated with a minimum IPG of 12 octets, per IEEE 802.3, section 4.4.2.3. GbE Idle characters are two octets, as defined in IEEE 802.3, section 36.2.4.12. If rate adaptation is performed using full-duplex GbE Idle insert/removal, only a single /I2/ should be removed in any IPG, and only when its removal shall not result in no /I/ and not less than 8 octets including /T/, /R/, and /I/ remaining between frames, for successful frame delineation according to IEEE 802.3, Figures 36-7a and 36-7b.

Rate adaptation may also be required when a continuous stream of eight-character Configuration ordered sets (consisting of alternating /C1/C2/) is received. Since a minimum of three consecutive /C1/C2/ Configuration ordered sets are required to be received before the Configuration set is recognized, rate adaptation by inserting a replica of the received /C1/C2/ sequence, or deleting a received /C1/C2/ sequence shall only occur after three consecutive identical /C1/C2/ sequences have been received and retransmitted.

Depending on implementation, a continuous stream of 10B_ERR neutral disparity or transmission error (/V/) characters could be generated at egress, which still requires rate adaptation. In this case, rate adaptation may be performed by removing or replicating a 10B_ERR or /V/ character after 12 consecutive 10B_ERR or /V/ characters have been received and retransmitted.

8.5 Client-specific Signal Fail aspects

When transparent GFP mapping detects a client signal failure at ingress, it may send a "Client Signal Fail" indication as described in 6.3.3. Client signal fail conditions include, as a minimum, loss of 8B/10B synchronization and, in some cases, loss of signal. Other implementation-dependent indications of a failed client signal (e.g. loss-of-clock from an interface between integrated circuits) may be encoded as Client Signal Fail.

Since client signals are provided as a continuous serial stream of 10-bit characters, it is necessary to find codeword alignment. Special characters containing the "comma" delimiter provide the information necessary to achieve and maintain codeword alignment. While all 8B/10B client signals employ the same bit alignment technique, conditions for detecting and clearing loss of 8B/10B synchronization are protocol-specific, and are identified in following protocol-specific clauses.

Server layer failures, in the GFP process itself, in the 64B/65B adaptation process, or in the transport network, may induce a CSF indication to the client adaptation process.

If the onset of CSF occurs within a GFP client data frame, the remainder of the 64B/65B blocks of that GFP frame shall be filled with 10B_ERR codes. At the far-end these shall be decoded as errors.

At the far-end of a transport network, transparently transported client signals must still be reconstructed and output in a manner that is compliant with the physical and coding interface requirements specific to each protocol. The following client-specific clauses define what action should be taken at client signal egress in response to a received far-end Client Signal Fail indication, or any adaptation or transport defects that make it impossible to extract a client signal.

8.5.1 Fibre Channel payload

8.5.1.1 Fibre Channel Loss of Light (LOL)

Fibre Channel Loss of Signal is an implementation-dependent option. When supported, applicable Loss of Light and Signal Detect requirements are found in sections 5.6, 6.2.3.2 and H.10 of ANSI X3.230, Fibre Channel Physical and Signaling Interface (FC-PH), Rev 4.3.

Other implementation-dependent indications of a failed client signal (e.g. loss-of-clock from a SerDes) may be encoded as Client Signal Fail.

8.5.1.2 Fibre Channel 8B/10B Loss of Synchronization

Fibre Channel conditions for declaring in/out of 8B/10B codeword synchronization are specified in section 12.1 of ANSI X3.230.

8.5.1.3 Fibre Channel output due to ingress or transport Signal Fail

Since the goal of Transparent GFP Mapping is to transport client signals as transparently as possible, it is not appropriate to initiate link initialization or link recovery procedures on egress due to Client Signal Fail or transport failures. It is recommended that the egress Fibre Channel transmitter continuously output the neutral disparity decoding for 10B_ERR, forcing Loss-of-Synchronization detection and the associated action at the downstream Fibre Channel receiver. Alternatively, the egress transmitter may generate the Not_Operational primitive per section 16.4.2 of ANSI X3.230.

If the CSF condition persists, the client adaptation process may transmit nothing, forcing LOS detection and associated action at the downstream Fibre Channel receiver.

8.5.2 ESCON Payload

8.5.2.1 ESCON Loss of Signal (LOS)

Optical Loss of Signal detection requirements are specified in ANSI X3.296, Information Technology – Single-Byte Command Code Sets Connection (SBCON) Architecture, sections 5.2 and 5.3 for multi-mode and single-mode interfaces, respectively.

8.5.2.2 ESCON 8B/10B Loss of Synchronization

ESCON conditions for declaring being in or out of 8B/10B codeword synchronization are specified in ANSI X3.296, section 7.1.

8.5.2.3 ESCON output due to ingress or transport Signal Fail

Since the goal of Transparent GFP Mapping is to transport client signals as transparently as possible, it is not appropriate to initiate link initialization or link recovery procedures on egress due to Client Signal Fail or transport failures. It is recommended that the egress ESCON transmitter continuously output the neutral disparity decoding for 10B_ERR, forcing Loss-of-Synchronization detection and the associated action at the downstream ESCON receiver. Alternatively, the egress transmitter may generate the Not-operational sequence per section 7.4.2 of ANSI X3.296.

If the CSF condition persists, the client adaptation process may transmit nothing, forcing LOS detection and associated action at the downstream ESCON receiver.

8.5.3 FICON Payload

The CSF handling requirements for FICON are identical to those for Fibre Channel, as specified in ANSI X3.230, Rev 4.3.

8.5.4 Full-duplex Gigabit Ethernet payload

8.5.4.1 Gigabit Ethernet Loss of Signal

Gigabit Ethernet Physical Media Dependent (PMD) Signal Detect requirements are specified in sections 38.2.4 and 39.2.3 of IEEE 802.3 for fiber and copper interfaces, respectively.

8.5.4.2 Gigabit Ethernet 8B/10B Loss of Synchronization

Gigabit Ethernet conditions for declaring being in or out of 8B/10B codeword synchronization are specified in IEEE 802.3, section 36.2.5.2.6 and Figure 36-9.

8.5.4.3 Gigabit Ethernet output due to ingress or transport Signal Fail

Since the goal of Transparent GFP Mapping is to transport client signals as transparently as possible, it is not appropriate to initiate link initialization or link recovery procedures on egress due to Client Signal Fail or transport failures. It is recommended that the egress GbE transmitter continuously output the /V/ ordered set per section 36.2.4.16 of IEEE 802.3, forcing Loss-of-Synchronization detection and the associated action at the downstream GbE receiver.

If the CSF condition persists, the client adaptation process may transmit nothing, forcing LOS detection and associated action at the downstream GbE receiver.

Appendix I

Examples of functional models for GFP applications

This appendix presents some examples of functional models for GFP applications. In the absence of layer network architectures for data layer networks (e.g. IP and Ethernet), the models presented are for illustration purposes only.

GFP can be deployed in transport network elements (e.g. SDH) and in data network elements (e.g. IP, Ethernet).

In the former case, a physical data interface (Ethernet or Storage Area Network type) is provided as a tributary interface port on the transport network element. For the case where the physical data signal is an 8B/10B coded signal, it can be transported through the transport network as a transparent stream using GFP-T mapping (Figure I.1). For the case where only a part of the physical interface bandwidth is carrying traffic, and only this traffic is to be transported through the transport network, the physical data interface signal is terminated, data PDUs are extracted and forwarded via GFP-F mapping over aVC-*m*-*X*v, VC-*n*, VC-*n*-*X*c, or VC-*n*-*X*v signal (Figure I.2).

In the latter case, GFP processing is performed inbetween the IP Router [Ethernet Switch] fabric and the e.g. STM-N interface port functions (Figures I.3 and I.4).

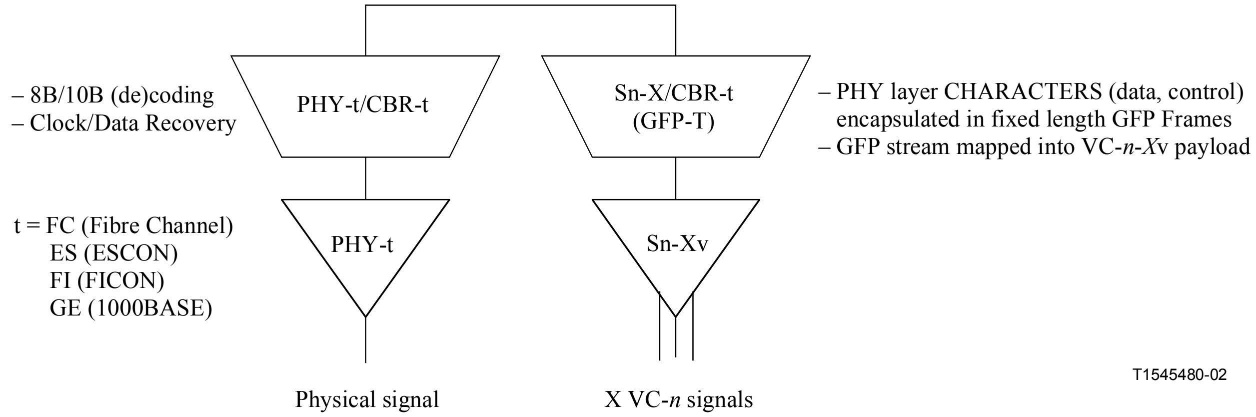


Figure I.1/G.7041/Y.1303 – FC/ES/FI/GE tributary interface port using GFP-T mapping in SDH network element

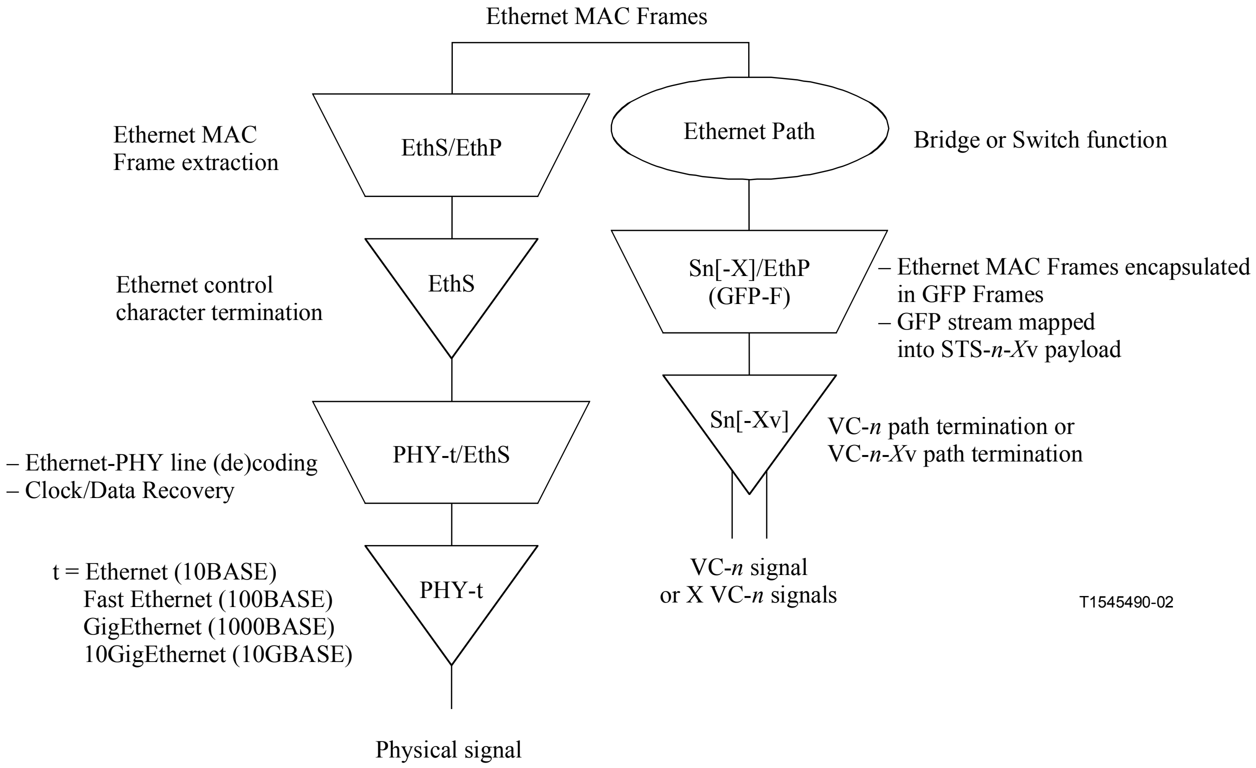


Figure I.2/G.7041/Y.1303 – Ethernet tributary interface port using GFP-F mapping in SDH network element

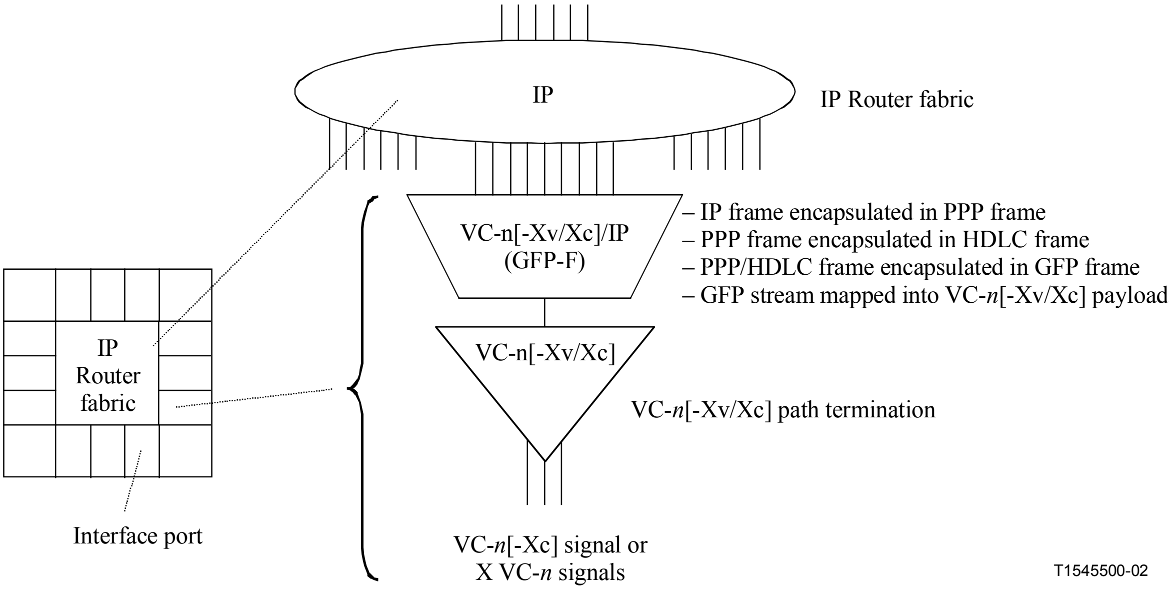


Figure I.3/G.7041/Y.1303 – VC-n/VC-n-Xv/VC-n-Xc port on IP router, or IP router function embedded in hybrid SDH/IP equipment

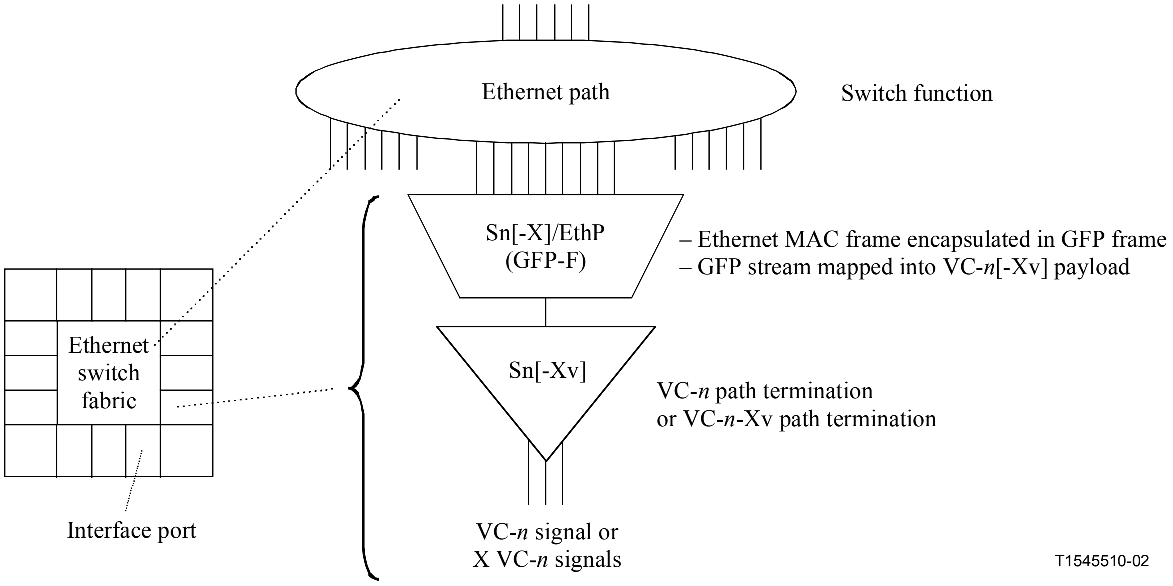


Figure I.4/G.7041/Y.1303 – VC-n-Xv port on Ethernet switch, or Ethernet switch function embedded in hybrid SDH/Ethernet equipment

Appendix II

Sample GFP payload types

Table II.1/G.7041/Y.1303 – GFP Payload Types

Payload Type Identifier (BIN) TYPE Bits <15:13>	Payload FCS Identifier (BIN) TYPE Bit <12>	Extension Header Identifier (BIN) TYPE Bits <11:8>	User Payload Identifier (BIN) TYPE Bits <7:0>	TYPE (HEX)	GFP Frame Payload Area	Length of Extension Headers (# Octets)
000	0	xxxx	0000 0000	0x00	Reserved	
000	1	xxxx	0000 0000	1x00	Reserved	
000	0	0000	0000 0001	0001	Ethernet with Null Extension Header & no Payload FCS	0
000	0	0000	0000 0010	0002	PPP with Null Extension Header & no Payload FCS	0
000	0	0001	0000 0001	0101	Ethernet with Linear Extension Header & no Payload FCS	4
000	0	0001	0000 0010	0102	PPP with Linear Extension Header & no Payload FCS	4
000	0	0010	0000 0001	0201	Ethernet with Ring Extension Header & no Payload FCS	18
000	0	0010	0000 0010	0202	PPP with Ring Extension Header & no Payload FCS	18
000	0	0000	0000 0011	1003	Transparent Fiber Channel with Null Extension Header & no Payload FCS	0
000	0	0000	0000 0100	1004	Transparent FICON with Null Extension Header & no Payload FCS	0
000	0	0000	0000 0101	1005	Transparent ESCON with Null Extension Header & no Payload FCS	0

Table II.1/G.7041/Y.1303 – GFP Payload Types

Payload Type Identifier (BIN) **TYPE Bits <15:13>**	**Payload FCS Identifier (BIN)** **TYPE Bit <12>**	**Extension Header Identifier (BIN)** **TYPE Bits <11:8>**	**User Payload Identifier (BIN)** **TYPE Bits <7:0>**	**TYPE** **(HEX)**	**GFP Frame** **Payload Area**	**Length of Extension Headers** **(# Octets)**
000	0	0000	0000 0110	1006	Transparent Gb Ethernet with Null Extension Header & no Payload FCS	0
1xx	x	xxxx	xxxx xxxx	–	Reserved	–
x1x	x	xxxx	xxxx xxxx	–	Reserved	–
xx1	x	xxxx	xxxx xxxx	–	Reserved	–

Appendix III

GFP frame example illustrating transmission order and CRC calculation

Worked Example

Transmit:

User_data → GFP_source adaptation → scramble and DC_balance → SDH

Receive:

SDH → un_DC_balance and unscramble → GFP_sink decapsulation → client data

The following worked example shows the encapsulation of a 64-byte Ethernet frame with linear header and FCS, before DC balancing and self-synchronous scrambling. The Ethernet data octets are mapped to GFP octet according to Transmission Bit Order (bit 0 in IEEE 802.3, clause 3 corresponds to GFP octet bit 8, and bit 7 in IEEE 802.3, clause 3 corresponds to GFP octet bit 1).

Byte	**Field**	**Value(hex)**	**Comment**
1	PLI[15:8]	00	; PLI = Length { Payload Header + Payload Information Field + Payload FCS } ; = 8 + 64 + 4 = 76 bytes
2	PLI[7:0]	4C	
3	cHEC[15:8]	89	;
4	cHEC[7:0]	48	;
5	TYPE[15:8]	11	; [15:13] = '000' (client data)
6	TYPE[7:0]	01	; [12] = '1' (payload FCS enabled)
7	tHEC[15:8]	20	; [11:8] = '0001' (linear header)

```
8     tHEC[7:0]       63        ; [7:0] = '00000001' (Ethernet)
9     EHDR[15:8]       80       ; CID[07:00] = 0x8000 the value is just an example
10    EHDR [7:0]      00        ; SPARE[7:0]
11    eHEC[15:8]      1B        ; eHEC calculated over CID,SPARE
12    eHEC[7:0]       98        ; End extension header
13    DATA            FF        ; 1d Ethernet DA = 0xFFFFFFFFFFFF
14    DATA            FF        ; 2d
15    DATA            FF        ; 3d
16    DATA            FF        ; 4d
17    DATA            FF        ; 5d
18    DATA            FF        ; 6d
19    DATA            06        ; 7d Ethernet SA = 0x060504030201
20    DATA            05        ; 8d
21    DATA            04        ; 9d
22    DATA            03        ; 10d
23    DATA            02        ; 11d
24    DATA            01        ; 12d
25    DATA            00        ; 13d Ethernet TYPE/LENGTH
26    DATA            2E        ; 14d
27    DATA            00        ; 15d Ethernet payload
28    DATA            01        ; 16d
29    DATA            02        ; 17d
30    DATA            03        ; 18d
31    DATA            04        ; 19d
32    DATA            05        ; 20d
33    DATA            06        ; 21d
34    DATA            07        ; 22d
35    DATA            08        ; 23d
36    DATA            09        ; 24d
37    DATA            0A        ; 25d
38    DATA            0B        ; 26d
39    DATA            0C        ; 27d
40    DATA            0D        ; 28d
41    DATA            0E        ; 29d
42    DATA            0F        ; 30d
43    DATA            10        ; 31d
44    DATA            11        ; 32d
45    DATA            12        ; 33d
46    DATA            13        ; 34d
47    DATA            14        ; 35d
48    DATA            15        ; 36d
```

49	DATA	16	; 37d
50	DATA	17	; 38d
51	DATA	18	; 39d
52	DATA	19	; 40d
53	DATA	1A	; 41d
54	DATA	1B	; 42d
55	DATA	1C	; 43d
56	DATA	1D	; 44d
57	DATA	1E	; 45d
58	DATA	1F	; 46d
59	DATA	20	; 47d
60	DATA	21	; 48d
61	DATA	22	; 49d
62	DATA	23	; 50d
63	DATA	24	; 51d
64	DATA	25	; 52d
65	DATA	26	; 53d
66	DATA	27	; 54d
67	DATA	28	; 55d
68	DATA	29	; 56d
69	DATA	2A	; 57d
70	DATA	2B	; 58d
71	DATA	2C	; 59d
72	DATA	2D	; 60d
73	DATA	DE	; 61d Ethernet FCS computed over 60 bytes
74	DATA	E1	; 62d
75	DATA	90	; 63d
76	DATA	D0	; 64d
77	FCS[31:24]	56	; First byte of optional GFP payload FCS
78	FCS[23:16]	CF	; Covers only payload information field, excludes
79	FCS[15:8]	2B	; the extension header (i.e. 64 bytes)
80	FCS[7:0]	B0	; Last byte of optional GFP FCS

The core header is XORed with the DC Barker code, the rest of the GFP frame is unchanged.

Byte	**Field**	**Value(hex)**	**Comment**
1	PLI[15:8]	B6	; 00 xor B6
2	PLI[7:0]	E7	; 4C xor AB
3	cHEC[15:8]	B8	; 89 xor 31
4	cHEC[7:0]	A8	; 48 xor E0
5	...		

The following example shows the calculation of the cHEC for PLI[15:0] = 0x004C. The polynomial is $G(x) = x^{16} + x^{12} + x^{5} + 1$. The PLI is shifted into the CRC-16 calculator with PLI[15:8] first, then PLI[7:0], most significant bit first for each octet.

		x^{15} … x^{0}
		0000000000000000 <- CRC-16 initial state
Input bit	1	0001000000100001 <- CRC-16 after input bit
	0	0010000001000010
	0	0100000010000100
	1	1001000100101001
	1	0010001001010010
	0	0100010010100100
	0	1000100101001000

Transmit the CRC-16 starting from x^{15} gives the GFP octets cHEC[15:0] = 0x8948.

The GFP frame is input to the $x^{43} + 1$ scrambler in network bit order (most significant bit first). Starting with the first byte of the TYPE field (the core header is not scrambled):

Bit #1	TYPE[15]
Bit #2	TYPE[14]
Bit #3	TYPE[13]
...	

Appendix IV

Number of superblocks used in Transparent GFP

This appendix is intended to provide guidance for choosing the minimum number of superblocks to be used in a Transparent GFP frame ($N_{\min}$). The minimum values of N for several known client bit rates in their minimum-sized SDH channels is given in Table IV.1. The formula for determining $N_{\min}$ is as follows:

$$N_{\min} = [(CSBW_{\max})(GFPOH)/(512)(ChR_{\min}) - (536)(CSBW_{\max})]$$

where:

$CSBW_{\max}$ = the worst case client signal bandwidth (i.e. fastest clock tolerance).

GFPOH = the number of overhead bits in the GFP frame.

$CMFBW$ is the bandwidth available for sending client management frames.

$ChR_{\min}$ is the worst case channel rate (i.e. slowest channel clock tolerance).

Client data frame length = (GFP overhead) + (N)(536 bits)

Table IV.1/G.7041/Y.1303 – SDH Path capacity and number of superblocks per Transparent GFP frame

Client un-encoded data rate	**Example client signal**	**VC Path Size**	**Min. number of 65B blocks/GFP frame**
160 Mbit/s	ESCON	VC-3-4v	1
425 Mbit/s	Fibre Channel	VC-4-3v	13
850 Mbit/s	Fibre Channel / FICON	VC-4-6v	13
1000 Mbit/s	Gbit Ethernet	VC-4-7v	95
1700 Mbit/s	Fibre Channel	VC-4-12v	13

NOTE – The minimum number of superblocks shown here assumes a Null Extension Header and no optional payload FCS.

ITU-T Y-SERIES RECOMMENDATIONS

GLOBAL INFORMATION INFRASTRUCTURE AND INTERNET PROTOCOL ASPECTS

GLOBAL INFORMATION INFRASTRUCTURE	
General	Y.100–Y.199
Services, applications and middleware	Y.200–Y.299
Network aspects	Y.300–Y.399
Interfaces and protocols	Y.400–Y.499
Numbering, addressing and naming	Y.500–Y.599
Operation, administration and maintenance	Y.600–Y.699
Security	Y.700–Y.799
Performances	Y.800–Y.899
INTERNET PROTOCOL ASPECTS	
General	Y.1000–Y.1099
Services and applications	Y.1100–Y.1199
Architecture, access, network capabilities and resource management	Y.1200–Y.1299
Transport	**Y.1300–Y.1399**
Interworking	Y.1400–Y.1499
Quality of service and network performance	Y.1500–Y.1599
Signalling	Y.1600–Y.1699
Operation, administration and maintenance	Y.1700–Y.1799
Charging	Y.1800–Y.1899

For further details, please refer to the list of ITU-T Recommendations.

SERIES OF ITU-T RECOMMENDATIONS

Series A	Organization of the work of ITU-T
Series B	Means of expression: definitions, symbols, classification
Series C	General telecommunication statistics
Series D	General tariff principles
Series E	Overall network operation, telephone service, service operation and human factors
Series F	Non-telephone telecommunication services
Series G	**Transmission systems and media, digital systems and networks**
Series H	Audiovisual and multimedia systems
Series I	Integrated services digital network
Series J	Cable networks and transmission of television, sound programme and other multimedia signals
Series K	Protection against interference
Series L	Construction, installation and protection of cables and other elements of outside plant
Series M	TMN and network maintenance: international transmission systems, telephone circuits, telegraphy, facsimile and leased circuits
Series N	Maintenance: international sound programme and television transmission circuits
Series O	Specifications of measuring equipment
Series P	Telephone transmission quality, telephone installations, local line networks
Series Q	Switching and signalling
Series R	Telegraph transmission
Series S	Telegraph services terminal equipment
Series T	Terminals for telematic services
Series U	Telegraph switching
Series V	Data communication over the telephone network
Series X	Data networks and open system communications
Series Y	**Global information infrastructure and Internet protocol aspects**
Series Z	Languages and general software aspects for telecommunication systems

Printed in Switzerland
Geneva, 2002