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ITU-T

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G.709/Y.1331

Amendment 1

(11/2001)

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

Interfaces for the Optical Transport Network (OTN)

Amendment 1

ITU-T Recommendation G.709/Y.1331 – Amendment 1

ITU-T G-SERIES RECOMMENDATIONS

TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

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

ITU-T Recommendation G.709/Y.1331

Interfaces for the Optical Transport Network (OTN)

Amendment 1

Summary

This amendment includes the following extensions to ITU-T Rec. G.709/Y.1331 (2001)

– Backward IAE;

– ODUk multiplexing;

– ODUk virtual concatenation.

Source

Amendment 1 to ITU-T Recommendation G.709/Y.1331 was prepared by ITU-T Study Group 15 (2001-2004) and approved under the WTSA Resolution 1 procedure on 29 November 2001.

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.

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NOTE

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ITU-T Recommendation G.709/Y.1331

Interfaces for the Optical Transport Network (OTN)

Amendment 1

1 Introduction

This amendment contains extensions to the first version (02/2001) of ITU-T Rec. G.709/Y.1331, related to the addition of:

– Backward Incoming Alignment Error (see 2.3, 2.8, 2.9, 2.10, 2.11, 2.12, 2.13, 2.14);

– ODUk virtual concatenation (see 2.2, 2.8, 2.15, 2.16, 2.17, 2.18, 2.19, 2.26);

– ODUk multiplexing (see 2.4, 2.5, 2.6, 2.7, 2.15, 2.16, 2.17, 2.18, 2.19, 2.27).

Clauses 2.18 and 2.20 to 2.25 describe the necessary move of the specification in 15.9.2.1.2 of ITU-T Rec. G.709/Y.1331 to the subclauses in clause 17 of ITU-T Rec. G.709/Y.1331. This is a consequence of the decision to reallocate the PSI[1..255] bytes to mapping and concatenation specific overhead. Note that there is no change of specification associated with this move.

2 Additions

2.1 Clause 2

Add the following reference:

– ITU-T Recommendation G.7042 (2001), *Link capacity adjustment scheme (LCAS) for virtual concatenated signals*.

2.2 Clause 3

Add the following definition:

3.36 link capacity adjustment scheme (LCAS): LCAS in the virtual concatenation source and sink adaptation functions provides a control mechanism to smoothly increase or decrease the capacity of a link to meet the bandwidth needs of the application. It also provides a means of removing member links that have experienced failure. The LCAS assumes that in cases of capacity initiation, increases or decreases, the construction or destruction of the end-to-end path is the responsibility of the Network and Element Management Systems.

2.3 Clause 4

Add the following abbreviations:

BIAE Backward Incoming Alignment Error

CRC Cyclic Redundancy Check

CTRL Control word sent from source to sink

DNU Do Not Use

EOS End of Sequence

GID Group Identification

JOH Justification Overhead

LCAS	Link Capacity Adjustment Scheme
MFI	Multiframe Indicator
MSI	Multiplex Structure Identifier
MST	Member Status
NORM	Normal Operating Mode
ODTUjk	Optical channel Data Tributary Unit j into k
ODTUG	Optical channel Data Tributary Unit Group
ODUk-Xv	X virtually concatenated ODUks
OPUk-Xv	X virtually concatenated OPUks
RS-Ack	Re-sequence acknowledge
SQ	Sequence Indicator
TS	Tributary Slot
VCG	Virtual Concatenation Group
VCOH	Virtual Concatenation Overhead
vcPT	virtual concatenated Payload Type

2.4 Clause 7

Replace the 1st paragraph and Figure 7-1 with the following paragraph and figure in which time division multiplexing is added:

Figure 7-1 shows the relationship between various information structure elements and illustrates the multiplexing structure (including wavelength and time division multiplexing) and mappings for the OTM-n.

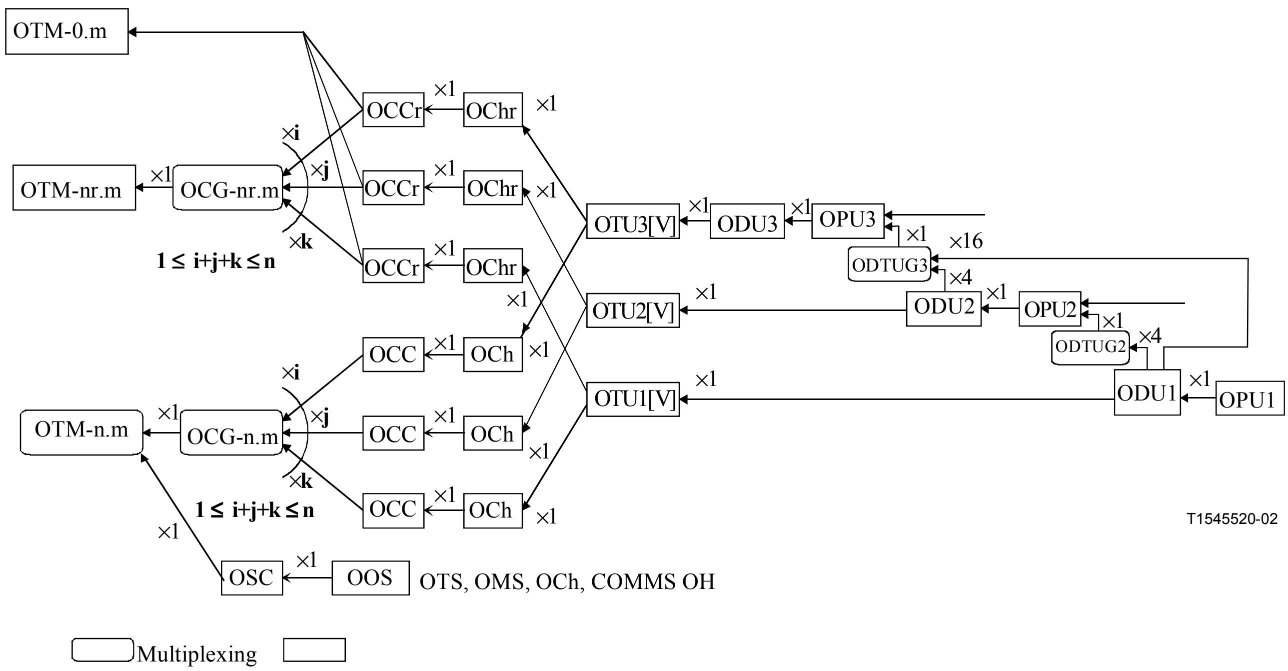


Figure 7-1/G.709/Y.1331 – OTM multiplexing and mapping structures

2.5 Clause 7.1

Replace the text with the following text in which the ODTUGk is added:

The client signal or an Optical channel Data unit Tributary Unit Group (ODTUGk) is mapped into the OPUk. The OPUk is mapped into an ODUk and the ODUk is mapped into an OTUk[V]. The OTUk[V] is mapped into an OCh[r] and the OCh[r] is then modulated onto an OCC[r].

2.6 Clause 7.3

Replace the 3rd and 4th sentences with the following sentences, which include OPUk-Xv:

The bit rates and capacity of the OPUk and OPUk-Xv Payload are defined in Table 7-3.

The OTUk/ODUk/OPUk/OPUk-Xv frame periods are defined in Table 7-4.

Replace Tables 7-3 and 7-4 with the following tables, which include OPUk-Xv:

Table 7-3/G.709/Y.1331 – OPU types and capacity

OPU type	OPU Payload nominal bit rate	OPU Payload bit rate tolerance
OPU1	2 488 320 kbit/s	± 20 ppm
OPU2	238/237 × 9 953 280 kbit/s	
OPU3	238/236 × 39 813 120 kbit/s	
OPU1-Xv	X × 2 488 320 kbit/s	± 20 ppm
OPU2-Xv	X × 238/237 × 9 953 280 kbit/s	
OPU3-Xv	X × 238/236 × 39 813 120 kbit/s	
NOTE – The nominal OPUk Payload rates are approximately: 2 488 320.000 kbit/s (OPU1 Payload), 9 995 276.962 kbit/s (OPU2 Payload) and 40 150 519.322 kbit/s (OPU3 Payload). The nominal OPUk-Xv Payload rates are approximately: X × 2 488 320.000 kbit/s (OPU1-Xv Payload), X × 9 995 276.962 kbit/s (OPU2-Xv Payload) and X × 40 150 519.322 kbit/s (OPU3-Xv Payload).		

Table 7-4/G.709/Y.1331 – OTUk/ODUk/OPUk/OPUk-Xv frame periods

OTU/ODU/OPU type	Period (Note)
OTU1/ODU1/OPU1/OPU1-Xv	48.971 μs
OTU2/ODU2/OPU2/OPU2-Xv	12.191 μs
OTU3/ODU3/OPU3/OPU3-Xv	3.035 μs
NOTE – The period is an approximated value, rounded to 3 digits.	

2.7 New clause 7.4

Add the following text:

7.4 ODUk time-division multiplex

Figure 7-1 shows the relationship between various time-division multiplexing elements that are defined below, and illustrates possible multiplexing structures. Up to 4 ODU1 signals are multiplexed into an ODTUG2 using time-division multiplexing. The ODTUG2 is mapped into the OPU2. A mixture of j (j ≤ 4) ODU2 and 16-4j ODU1 signals can be multiplexed into an ODTUG3 using time-division multiplexing. The ODTUG3 is mapped into the OPU3.

Figures 7-2 and 7-3 show how various signals are multiplexed using these multiplexing elements. Figure 7-2 presents the multiplexing of four ODU1 signals into the OPU2 signal. An ODU1 signal is extended with frame alignment overhead and asynchronously mapped into the Optical channel Data Tributary Unit 1 into 2 (ODTU12) using the justification overhead (JOH). The four ODTU12 signals are time-division multiplexed into the Optical channel Data unit Tributary Unit Group 2 (ODTUG2), after which this signal is mapped into the OPU2.

Figure 7-3 presents the multiplexing of up to 16 ODU1 signals and/or up to 4 ODU2 signals into the OPU3 signal. An ODU1 signal is extended with frame alignment overhead and asynchronously mapped into the Optical channel Data Tributary Unit 1 into 3 (ODTU13) using the justification overhead (JOH). An ODU2 signal is extended with frame alignment overhead and asynchronously mapped into the Optical channel Data Tributary Unit 2 into 3 (ODTU23) using the justification overhead (JOH). "x" ODTU23 (0 ≤ x ≤ 4) signals and "16-4x" ODTU13 signals are time-division multiplexed into the Optical channel Data unit Tributary Unit Group 3 (ODTUG3), after which this signal is mapped into the OPU3.

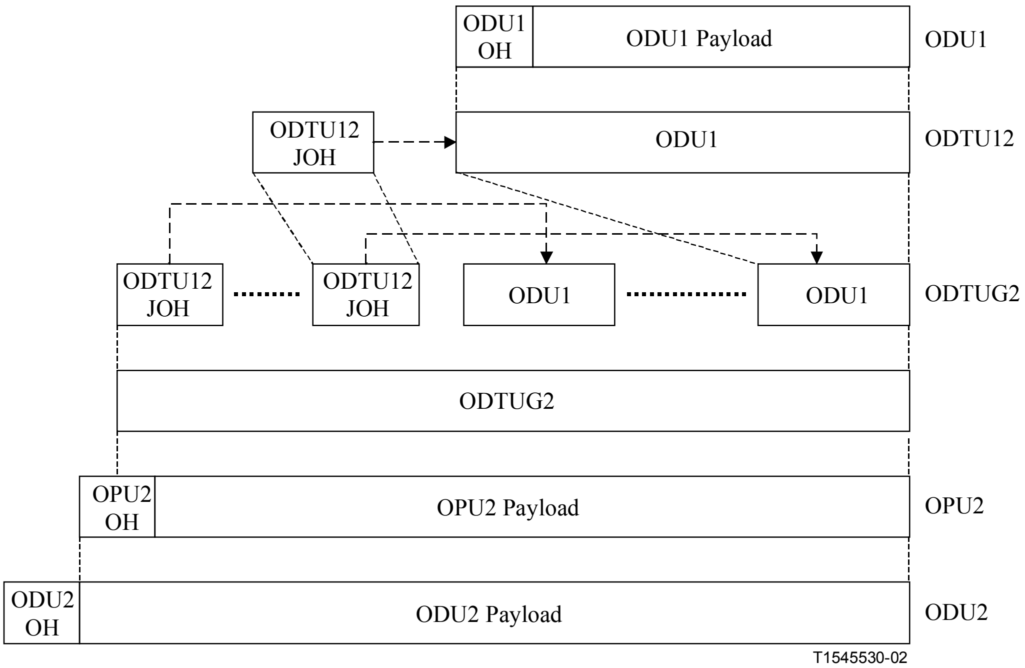


Figure 7-2/G.709/Y.1331 – ODU1 into ODU2 multiplexing method

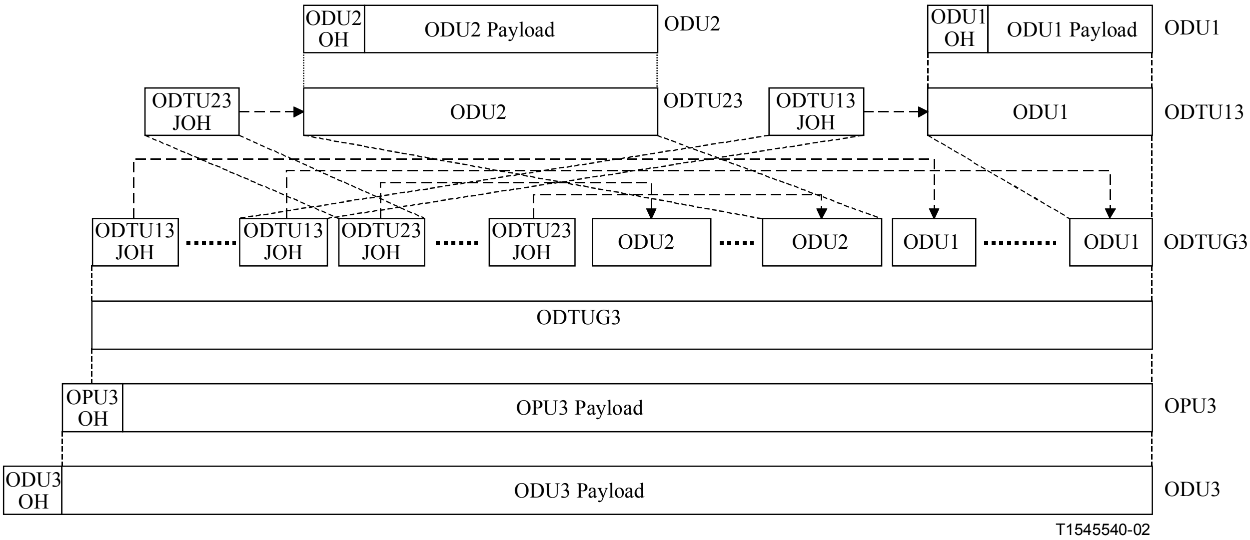


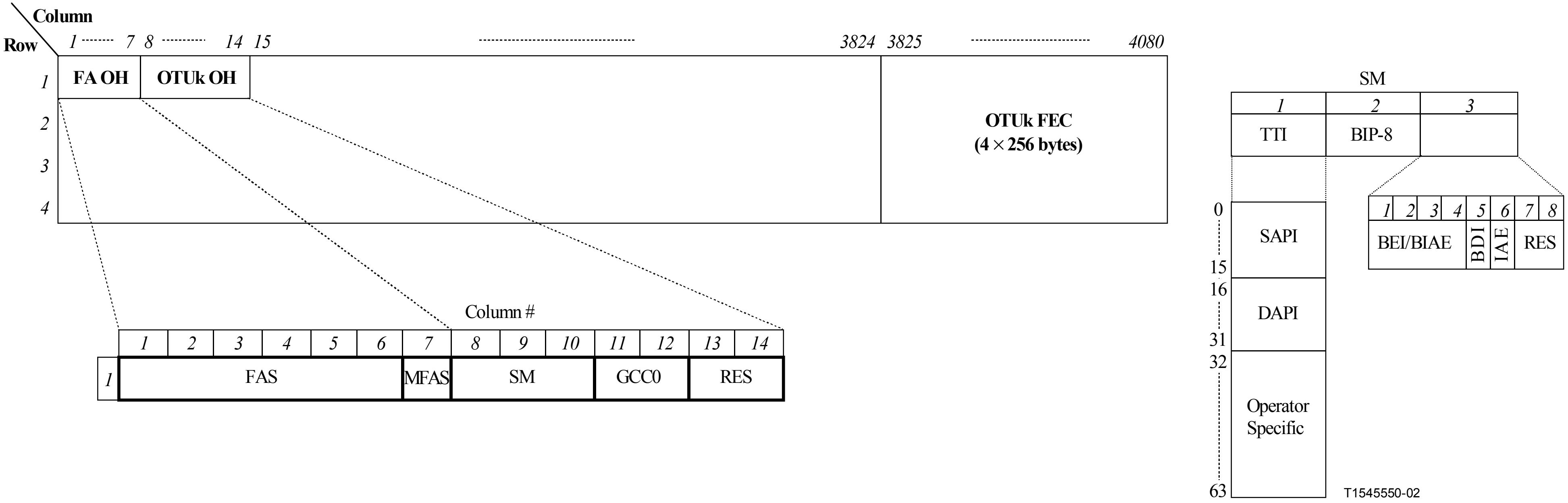
Figure 7-3/G.709/Y.1331 – ODU1 and ODU2 into ODU3 multiplexing method

Details of the multiplexing method and mappings are given in clause 19.

An example illustrating the multiplexing of 4 ODU1 signals into an ODU2 is presented in Appendix III.

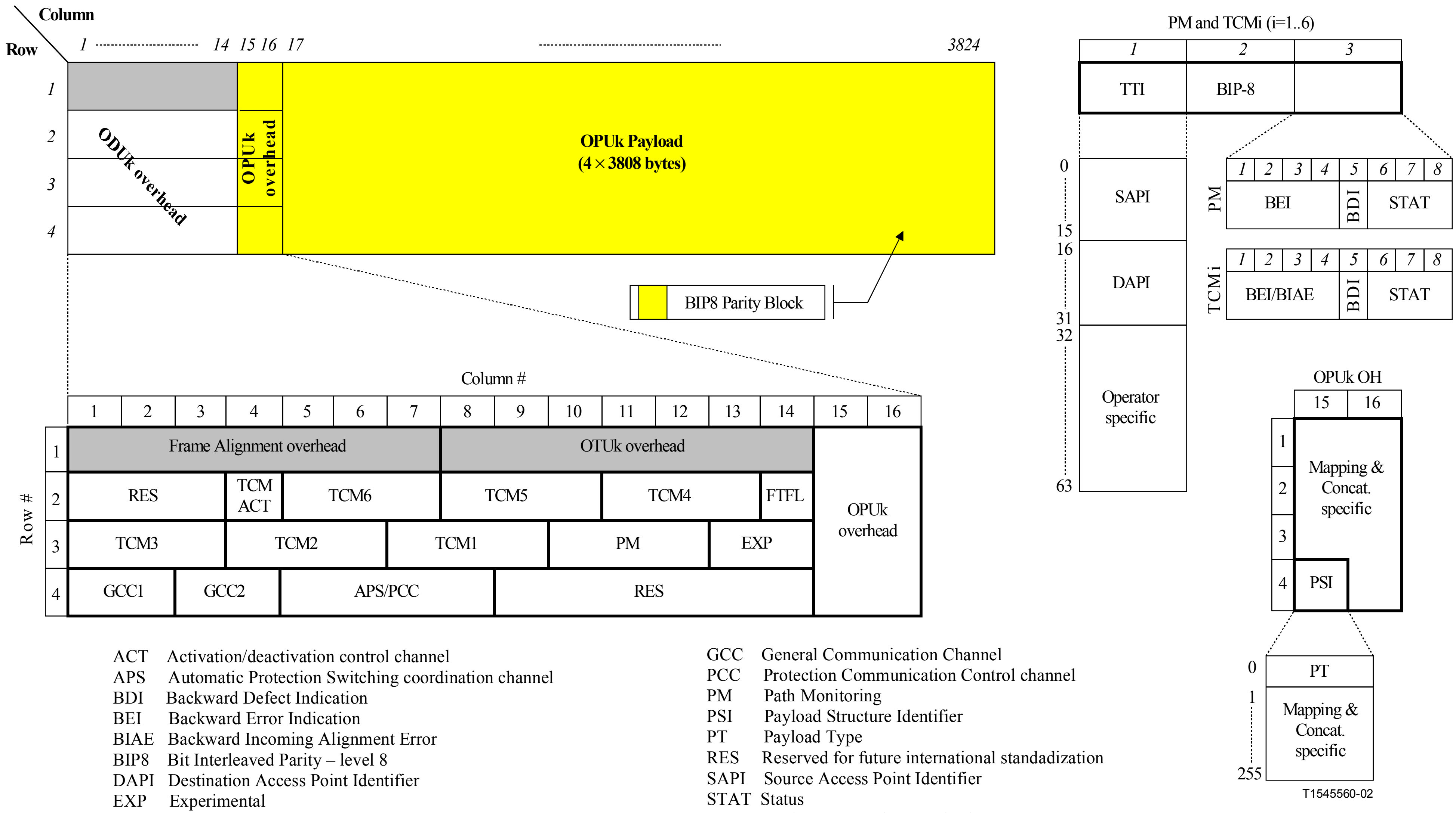
2.8 Clause 15

Replace Figures 15-2 and 15-3 with the following figures, in which BIAE is added, PSI[1..255] field is changed into mapping and concatenation specific as well as other 7 OPUk OH bytes:



BDI Backward Defect Indication
BEI Backward Error Indication
BIAE Backward Incoming Alignment Error
BIP8 Bit Interleaved Parity – level 8
DAPI Destination Access Point Identifier
FA Frame Alignment
FAS Frame Alignment Signal
GCC General Communication Channel
IAE Incoming Alignment Error
MFAS MultiFrame Alignment Signal
RES Reserved for future International standardization
SAPI Source Access Point Identifier
SM Section Monitoring
TTI Trail Trace Identifier

Figure 15-2/G.709/Y.1331 – OTUk frame structure, frame alignment, and OTUk overhead



ACT Activation/deactivation control channel
APS Automatic Protection Switching coordination channel
BDI Backward Defect Indication
BEI Backward Error Indication
BIAE Backward Incoming Alignment Error
BIP8 Bit Interleaved Parity – level 8
DAPI Destination Access Point Identifier
EXP Experimental
FTFL Fault Type and Fault Locatiom reporting channel
GCC General Communication Channel
PCC Protection Communication Control channel
PM Path Monitoring
PSI Payload Structure Identifier
PT Payload Type
RES Reserved for future international standadization
SAPI Source Access Point Identifier
STAT Status
TCM Tandem Connection Monitoring
TTI Trail Trace Identifier

Figure 15-3/G.709/Y.1331 – ODUk frame structure, ODUk, and OPUk overhead

2.9 Clause 15.7.1

Replace Figure 15-10 with the following figure in which BIAE is added:

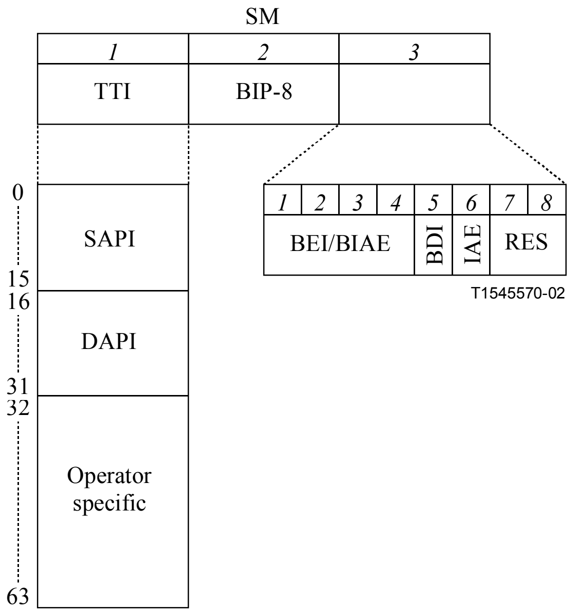


Figure 15-10/G.709/Y.1331 – OTUk Section Monitoring overhead

2.10 Clause 15.7.2.1

Replace the 4th dash item:

– Backward Error Indication (BEI);

with:

– Backward Error Indication and Backward Incoming Alignment Error (BEI/BIAE);

2.11 Clause 15.7.2.1.4

Replace the clause with the following text in which BIAE is added:

15.7.2.1.4 OTUk SM Backward Error Indication and Backward Incoming Alignment Error (BEI/BIAE)

For section monitoring, a four-bit Backward Error Indication (BEI) and Backward Incoming Alignment Error (BIAE) signal is defined. This signal is used to convey in the upstream direction the count of interleaved-bit blocks that have been detected in error by the corresponding OTUk section monitoring sink using the BIP-8 code. It is also used to convey in the upstream direction an incoming alignment error (IAE) condition that is detected in the corresponding OTUk section monitoring sink in the IAE overhead.

During a IAE condition the code "1011" is inserted into the BEI/BIAE field and the error count is ignored. Otherwise the error count (0-8) is inserted into the BEI/BIAE field. The remaining six possible values represented by these four bits can only result from some unrelated condition and shall be interpreted as zero errors (Table 15-1) and BIAE not active.

Table 15-1/G.709/Y.1331 – OTUk SM BEI/BIAE interpretation

OTUk SM BEI/BIAE bits 1234	BIAE	BIP violations
0000	false	0
0001	false	1
0010	false	2
0011	false	3
0100	false	4
0101	false	5
0110	false	6
0111	false	7
1000	false	8
1001, 1010	false	0
1011	true	0
1100 to 1111	false	0

2.12 Clause 15.8.1

Replace Figure 15-14 with the following figure in which BIAE is added:

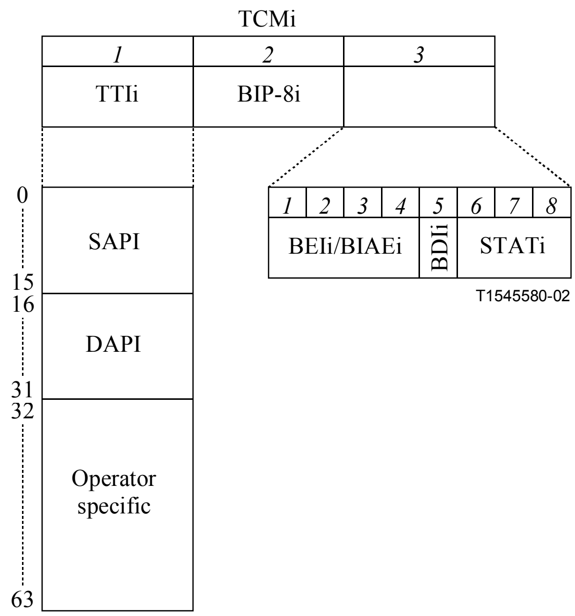


Figure 15-14/G.709/Y.1331 – ODUk Tandem Connection Monitoring #i overhead

2.13 Clause 15.8.2.2

Replace the 10th dash item:

– Backward Error Indication (BEI);

with:

– Backward Error Indication and Backward Incoming Alignment Error (BEI/BIAE);

2.14 Clause 15.8.2.2.4

Replace the clause with the following text in which BIAE is added:

15.8.2.2.4 ODUk TCM Backward Error Indication and Backward Incoming Alignment Error (BEI/BIAE)

For each tandem connection monitoring field, a four-bit Backward Error Indication (BEI) and Backward Incoming Alignment Error (BIAE) signal is defined. This signal is used to convey in the upstream direction the count of interleaved-bit blocks that have been detected in error by the corresponding ODUk tandem connection monitoring sink using the BIP-8 code. It is also used to convey in the upstream direction an incoming alignment error (IAE) condition that is detected in the corresponding ODUk tandem connection monitoring sink in the IAE overhead.

During a IAE condition the code "1011" is inserted into the BEI/BIAE field and the error count is ignored. Otherwise the error count (0-8) is inserted into the BEI/BIAE field. The remaining six possible values represented by these four bits can only result from some unrelated condition and shall be interpreted as zero errors (Table 15-4) and BIAE not active.

Table 15-4/G.709/Y.1331 – ODUk TCM BEI/BIAE interpretation

ODUk TCM BEI/BIAE bits 1234	BIAE	BIP violations
0000	false	0
0001	false	1
0010	false	2
0011	false	3
0100	false	4
0101	false	5
0110	false	6
0111	false	7
1000	false	8
1001, 1010	false	0
1011	true	0
1100 to 1111	false	0

2.15 Clause 15.9.1

Replace the text and figure with the following text and figure in which PSI[1..255] field is changed into a mapping and concatenation specific field:

The OPUk overhead consists of: Payload Structure Identifier (PSI) including the Payload Type (PT), overhead associated with concatenation and overhead (e.g. justification control and opportunity bits) associated with the mapping of client signals into the OPUk payload. The OPUk PSI and PT overhead locations are shown in Figure 15-23.

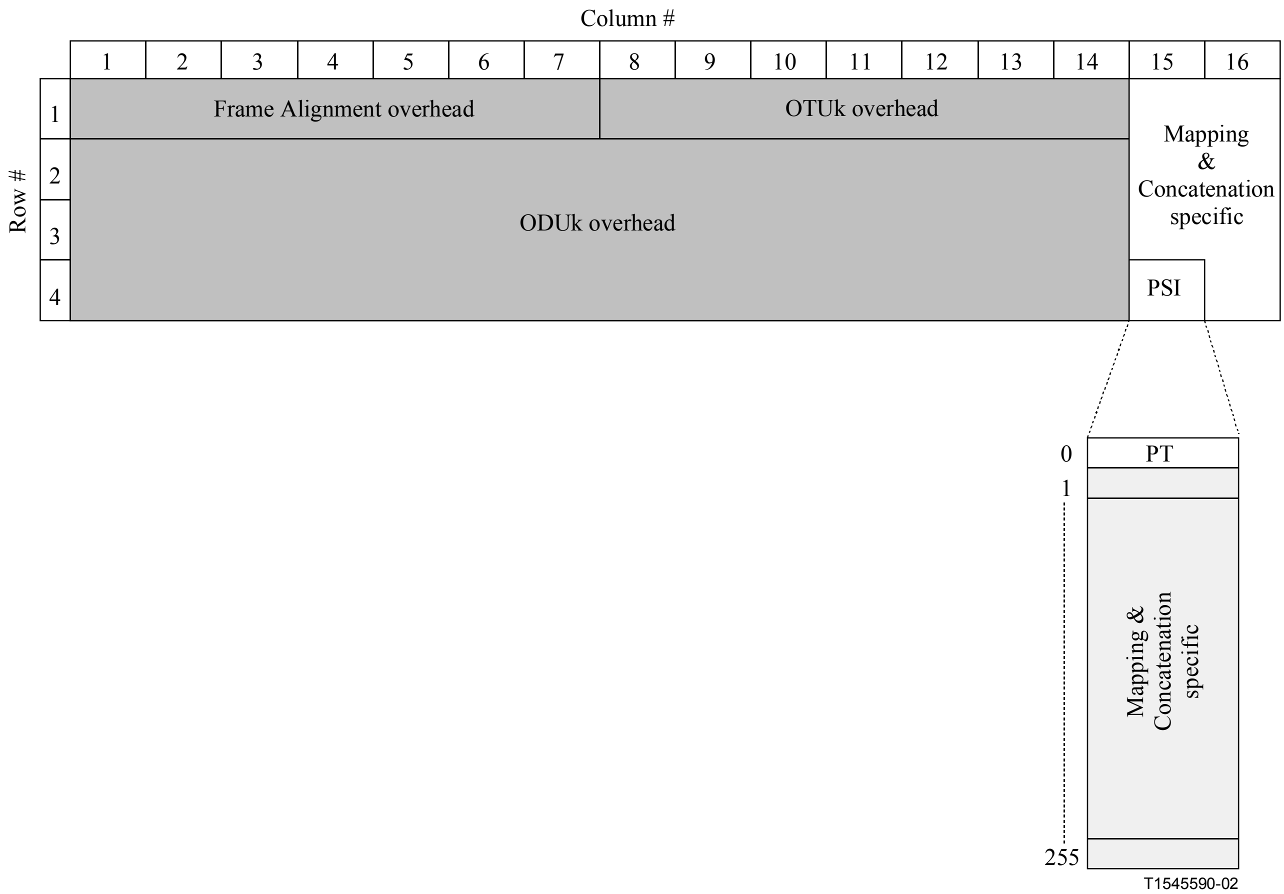


Figure 15-23/G.709/Y.1331 – OPUk overhead

2.16 Clause 15.9.2.1

Replace the 3rd paragraph with the following text in which PSI[1..255] field is changed into a mapping and concatenation specific field:

PSI[0] contains a one-byte Payload Type. PSI[1] to PSI[255] are mapping and concatenation specific, except for PT 0x01 (experimental mapping) and PTs 0x80-0x8F (for proprietary use).

2.17 Clause 15.9.2.1.1

Replace Table 15-7 with the following table in which code points 06 (Hex) and 20 (Hex) are added:

Table 15-7/G.709/Y.1331 – Payload Type code points

MSB 1 2 3 4	LSB 5 6 7 8	Hex code (Note 1)	Interpretation
0 0 0 0	0 0 0 1	01	Experimental mapping (Note 3)
0 0 0 0	0 0 1 0	02	Asynchronous CBR mapping, see 17.1
0 0 0 0	0 0 1 1	03	Bit synchronous CBR mapping, see 17.1
0 0 0 0	0 1 0 0	04	ATM mapping, see 17.2
0 0 0 0	0 1 0 1	05	GFP mapping, see 17.3
0 0 0 0	0 1 1 0	06	Virtual concatenated signal, see clause 18 (Note 5)
0 0 0 1	0 0 0 0	10	Bit stream with octet timing mapping, see 17.5.1
0 0 0 1	0 0 0 1	11	Bit stream without octet timing mapping, see 17.5.2

Table 15-7/G.709/Y.1331 – Payload Type code points

MSB 1 2 3 4	LSB 5 6 7 8	Hex code (Note 1)	Interpretation
0 0 1 0	0 0 0 0	20	ODU multiplex structure, see clause 19
0 1 0 1	0 1 0 1	55	Not available (Note 2)
0 1 1 0	0 1 1 0	66	Not available (Note 2)
1 0 0 0	x x x x	80-8F	reserved codes for proprietary use (Note 4)
1 1 1 1	1 1 0 1	FD	NULL test signal mapping, see 17.4.1
1 1 1 1	1 1 1 0	FE	PRBS test signal mapping, see 17.4.2
1 1 1 1	1 1 1 1	FF	Not available (Note 2)

NOTE 1 – There are 226 spare codes left for future international standardization.

NOTE 2 – These values are excluded from the set of available code points. These bit patterns are present in ODUk maintenance signals.

NOTE 3 – Value "01" is only to be used in cases where a mapping code is not defined in this table. By using this code, the development (experimental) activities do not impact the OTN network. There is no forward compatibility if a specific payload type is assigned later. If a new code is assigned, equipment using this code shall be reconfigured to use the new code.

NOTE 4 – These 16 code values will not be subject to standardization.

NOTE 5 – For the payload type of the virtual concatenated signal, a dedicated payload type overhead (vcPT) is used, see clause 18.

2.18 Clause 15.9.2.1.2

Delete the clause; the bytes are changed into mapping and concatenation specific overhead. Consequently, the original specification text is to be added to the client signal mapping subclauses in clause 17. See 2.20 to 2.25.

2.19 Clause 15.9.2.2

Replace the clause with the following text in which concatenation is added:

15.9.2.2 OPUk mapping and concatenation specific overhead

Seven bytes are reserved in the OPUk overhead for mapping and concatenation specific overhead. These bytes are located in rows 1 to 3 columns 15 and 16 and row 4 column 16. In addition, 255 bytes in the PSI are reserved for mapping and concatenation specific purposes.

The use of these bytes depends on the specific client signal mapping (defined in 17 and 19) and the use of concatenation (see clause 18).

2.20 Clause 17.1

Replace the 4th paragraph with the following paragraph in which a specification for the other 255 bytes in the PSI is added:

The OPUk overhead for these mappings consists of a Payload Structure Identifier (PSI) including the Payload Type (PT) and 255 bytes reserved for future international standardization (RES), three Justification Control (JC) bytes, one negative justification opportunity (NJO) byte, and three bytes reserved for future international standardization (RES). The JC bytes consist of two bits for justification control and six bits reserved for future international standardization.

2.21 Clause 17.2

Replace the 6th paragraph with the following paragraph in which a specification for the other 255 bytes in the PSI is added:

The OPUk overhead for the ATM mapping consists of a Payload Structure Identifier (PSI) including the Payload Type (PT) and 255 bytes reserved for future international standardization (RES), and seven bytes reserved for future international standardization (RES).

2.22 Clause 17.3

Replace the 4th paragraph with the following paragraph in which a specification for the other 255 bytes in the PSI is added:

The OPUk overhead for the GFP mapping consists of a Payload Structure Identifier (PSI) including the Payload Type (PT) and 255 bytes reserved for future international standardization (RES), and seven bytes reserved for future international standardization (RES).

2.23 Clause 17.4.1

Replace the 2nd paragraph with the following paragraph in which a specification for the other 255 bytes in the PSI is added:

The OPUk overhead for the NULL mapping consists of a Payload Structure Identifier (PSI) including the Payload Type (PT) and 255 bytes reserved for future international standardization (RES), and seven bytes reserved for future international standardization (RES).

2.24 Clause 17.4.2

Replace the 2nd paragraph with the following paragraph in which a specification for the other 255 bytes in the PSI is added:

The OPUk overhead for the PRBS mapping consists of a Payload Structure Identifier (PSI) including the Payload Type (PT) and 255 bytes reserved for future international standardization (RES), and seven bytes reserved for future international standardization (RES).

2.25 Clause 17.5

Replace the 2nd paragraph with the following paragraph in which a specification for the other 255 bytes in the PSI is added:

The OPUk overhead for the mapping consists of a Payload Structure Identifier (PSI) including the Payload Type (PT) and 255 bytes reserved for future international standardization (RES), and seven bytes for client-specific (CS) purposes. The definition of these CS overhead bytes is performed within the encapsulation process specification.

2.26 New clause 18

Add the following text in which concatenation is defined:

18 Concatenation

Concatenation in the OTN is realized by means of virtual concatenation of OPUk signals

18.1 Virtual concatenation of OPUk

18.1.1 Virtual concatenated OPUk (OPUk-Xv, k = 1 .. 3, X = 1 .. 256)

The OPUk-Xv (k = 1,2,3) frame structure is shown in Figure 18-1. It is organized in an octet-based block frame structure with 4 rows and X × 3810 columns.

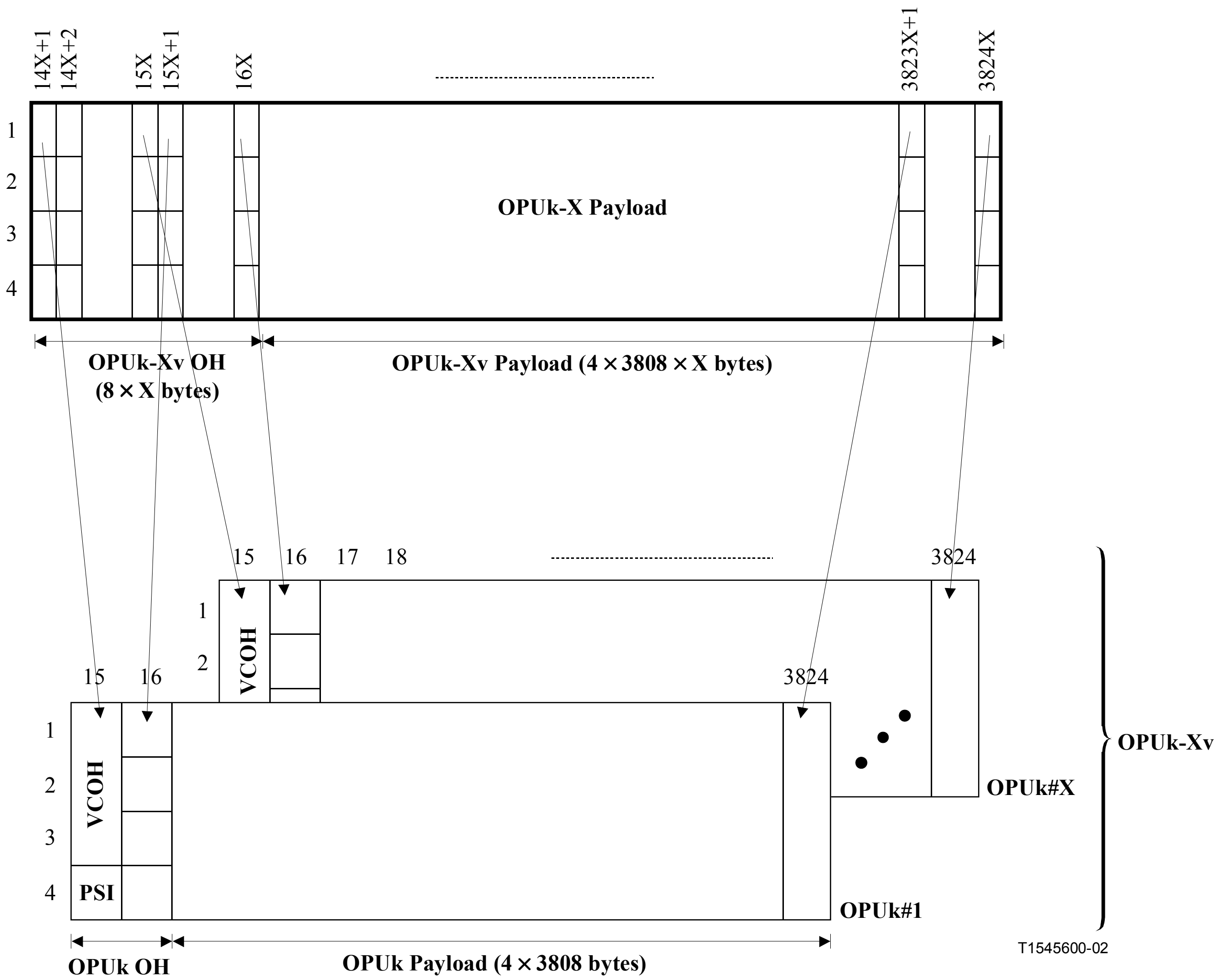


Figure 18-1/G.709/Y.1331 – OPUk-Xv structure

The two main areas of the OPUk-Xv frame are:

– OPUk-Xv Overhead area;

– OPUk-Xv Payload area.

Columns 14X+1 to 16X of the OPUk-Xv are dedicated to OPUk-Xv Overhead area.

Columns 16X+1 to 3824X of the OPUk-Xv are dedicated to OPUk-Xv Payload area.

NOTE – OPUk-Xv column numbers are derived from the OPUk columns in the ODUk frame.

A OPUk-Xv provides a contiguous payload area of X OPUk payload areas (OPUk-X-PLD) with a payload capacity of $X \times 238/(239 - k) \times 4^{(k-1)} \times 2\ 488\ 320$ kbit/s ± 20 ppm as shown in Figure 18-1. The OPUk-X-PLD is mapped in X individual OPUks which form the OPUk-Xv.

Each OPUk in the OPUk-Xv is transported in an ODUk and the X ODUks form the ODUk-Xv.

Each ODUk of the ODUk-Xv is transported individually through the network. Due to different propagation delay of the ODUks a differential delay will occur between the individual ODUks and thus OPUks. This differential delay has to be compensated and the individual OPUks have to be realigned for access to the contiguous payload area.

18.1.2 OPUk-Xv OH description

18.1.2.1 OPUk-Xv OH location

The OPUk-Xv overhead consists of: X times a Payload Structure Identifier (PSI) including the Payload Type (PT), X times virtual concatenation (VCOH) overhead used for a virtual concatenation-specific sequence and multiframe indication, and overhead (e.g. justification control and opportunity bits) associated with the mapping of client signals into the OPUk payload as shown in Figure 18-1. The PSI and VCOH overhead is specific for each individual OPUk of the OPUk-Xv, while the mapping-specific overhead is related to the concatenated signal

The OPUk-Xv VCOH consists of a 3-byte VCOH per OPUk. The VCOH bytes in each OPUk are used as defined below.

18.1.2.2 OPUk-Xv OH definition

18.1.2.2.1 OPUk-Xv Payload Structure Identifier (PSI)

In each OPUk of the OPUk-Xv, one byte is allocated in row 4, column 15 (Figure 18-2) to transport a 256-byte Payload Structure Identifier (PSI) signal as defined in 15.9.2.

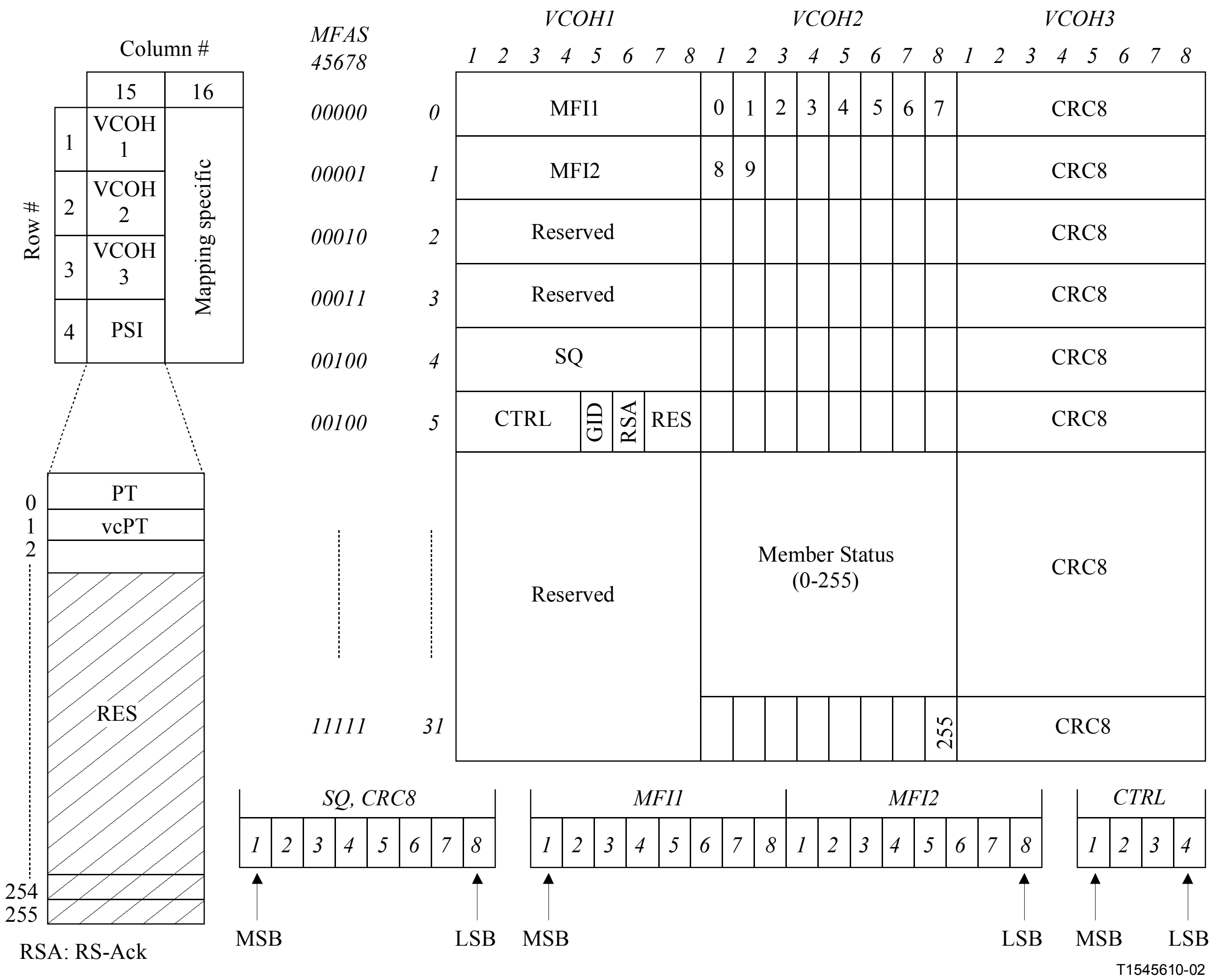


Figure 18-2/G.709/Y.1331 – OPUk-Xv Virtual Concatenation Overhead

PSI[1]is used for a virtual concatenation specific payload type identifier (vcPT).

The PSI content is identical for each OPUk of the OPUk-Xv.

18.1.2.2.1.1 OPUk-Xv Payload Type (vcPT)

A one-byte OPUk-Xv Payload Type signal is defined in the PSI[1] byte of the Payload Structure Identifier to indicate the composition of the OPUk-Xv signal. The code points are defined in Table 18-1.

Table 18-1/G.709/Y.1331 – Payload Type (vcPT) code points for virtual concatenated OPUk (OPUk-Xv) signals

MSB 1 2 3 4	LSB 5 6 7 8	Hex code (Note 1)	Interpretation
0 0 0 0	0 0 0 1	01	Experimental mapping (Note 3)
0 0 0 0	0 0 1 0	02	Asynchronous CBR mapping, see 18.2.1 and 18.2.2
0 0 0 0	0 0 1 1	03	Bit synchronous CBR mapping, see 18.2.1 and 18.2.2
0 0 0 0	0 1 0 0	04	ATM mapping, see 18.2.3
0 0 0 0	0 1 0 1	05	GFP mapping, see 18.2.4
0 0 0 1	0 0 0 0	10	Bit stream with octet timing mapping, see 18.2.6
0 0 0 1	0 0 0 1	11	Bit stream without octet timing mapping, see 18.2.6
0 1 0 1	0 1 0 1	55	Not available (Note 2)
0 1 1 0	0 1 1 0	66	Not available (Note 2)
1 0 0 0	x x x x	80-8F	Reserved codes for proprietary use (Note 4)
1 1 1 1	1 1 0 1	FD	NULL test signal mapping, see 18.2.5.1
1 1 1 1	1 1 1 0	FE	PRBS test signal mapping, see 18.2.5.2
1 1 1 1	1 1 1 1	FF	Not available (Note 2)
NOTE 1 – There are 228 spare codes left for future international standardization. NOTE 2 – These values are excluded from the set of available code points. These bit patterns are present in ODUk maintenance signals. NOTE 3 – Value "01" is only to be used in cases where a mapping code is not defined in this table. By using this code, the development (experimental) activities do not impact the OTN network. There is no forward compatibility if a specific payload type is assigned later. If a new code is assigned, equipment using this code shall be reconfigured to use the new code. NOTE 4 – These 16 code values will not be subject to standardization.			

18.1.2.2.1.2 OPUk-Xv Payload Structure Identifier Reserved overhead (RES)

254 bytes are reserved in the OPUk PSI for future international standardization. These bytes are located in PSI[2] to [PSI255] of the OPUk overhead. These bytes are set to all ZEROs.

18.1.2.2.2 OPUk-Xv Virtual Concatenation Overhead (VCOH1/2/3)

Three bytes per individual OPUk of the OPUk-Xv are used to transport a 8 × 3 byte × 32 frame structure for virtual concatenation specific overhead. These bytes are located in rows 1, 2 and 3 of column 15 as shown in Figure 18-2.

The structure is aligned with the ODUk multiframe and locked to bits 4, 5, 6, 7 and 8 of the MFAS. The structure is repeated 8 times in the 256 frame multiframe.

The structure is used to transport multiframe, sequences an LCAS control overhead.

18.1.2.2.2.1 OPUk-Xv Virtual Concatenation MultiFrame Indicator (MFI1, MFI2)

A two-stage multiframe is introduced to cover differential delay measurement (between the member signals within the virtual concatenated group) and compensation (of those differential delays) by the realignment process within the receiver.

The first stage uses MFAS in the Frame Alignment overhead area for the 8-bit multiframe indicator. MFAS is incremented every ODUk frame and counts from 0 to 255.

The second stage uses the MFI1 and MFI2 overhead bytes in the VCOH. They form a 16-bit multiframe counter with the MSBs in MFI1 and the LSBs in MFI2.

MFI1 is located in VCOH1[0] and MFI2 in VCOH1[1].

The multiframe counter of the second stage counts from 0 to 65535 and is incremented at the start of each multiframe of the first stage (MFAS = 0).

The resulting overall multiframe (a combination of 1st multi-frame and 2nd multi-frame counter) is 16 777 216 ODUk frames long.

At the start of the OPUk-Xv the multiframe sequence of all individual OPUks of the OPUk-Xv is identical.

The realignment process has to be able to compensate a differential delay of at least 125 µs.

18.1.2.2.2.2 OPUk-Xv Sequence Indicator (SQ)

The sequence indicator SQ identifies the sequence/order in which the individual OPUks of the OPUk-Xv are combined to form the contiguous OPUk-X-PLD as shown in Figure 18-1.

The 8-bit sequence number SQ (which supports values of X up to 256) is transported in VCOH1[4]. Bit 1 of VCOH1[4] is the MSB, bit 8 is the LSB.

Each OPUk of an OPUk-Xv has a fixed unique sequence number in the range of 0 to (X - 1). The OPUk transporting the first time slot of the OPUk-Xv has the sequence number 0, the OPUk transporting the second time slot the sequence number 1 and so on up to the OPUk transporting time slot X of the OPUk-Xv with the sequence number (X – 1).

For applications requiring fixed bandwidth, the sequence number is fixed assigned and not configurable. This allows the constitution of the OPUk-Xv either to be checked without using the trace, or to be transported via a number of ODUk signals which have their trail termination functions being part of an ODUk trail termination function resource group.

Refer to ITU-T Rec. G.7042 for the use and operation.

18.1.2.2.2.3 OPUk-Xv LCAS Control Words (CTRL)

The LCAS control word (CTRL) is located in bits 1 to 4 of VCOH1[5]. Bit 1 of VCOH1[5] is the MSB, bit 4 is the LSB.

Refer to ITU-T Rec. G.7042 for the LCAS control commands, their coding and operation.

18.1.2.2.2.4 OPUk-Xv LCAS Member Status (MST) Field

The LCA Member Status (MST) field reports the status of the individual OPUks of the OPUk-Xv.

One bit is used per OPUk to report the status from sink to source. VCOH2[0] to VCOH2[31] are used as shown in Figure 18-2. Refer to ITU-T Rec. G.7042 for coding and operation.

The status of all members (256) is transferred in 1567 µs (k = 1), 390 µs (k = 2) and 97 µs (k = 3).

18.1.2.2.2.5 OPUk-Xv LCAS Group Identification (GID)

The LCAS Group Identification (GID) provides the receiver with a means of verifying that all the arriving channels originated from one transmitter. Refer to ITU-T Rec. G.7042 for coding and operation.

Bit 5 of VCOH1[5] is used for the GID.

18.1.2.2.2.6 OPUk-Xv LCAS Re-Sequence Acknowledge (RS-Ack)

Re-Sequence Acknowledge, an indication from sink to source that a re-sequence, a sequence increase or a sequence decrease has been detected. Refer to ITU-T Rec. G.7042 for coding and operation.

Bit 6 of VCOH1[5] is used for the RS-Ack.

18.1.2.2.2.7 OPUk-Xv LCAS Cyclic Redundancy Check (CRC)

A 8-bit CRC check for fast acceptance of VirtConc LCAS OH is provided. The CRC-8 is calculated over VCOH1 and VCOH2 on a frame per frame based and inserted into VCOH3. The CRC_8 polynomial is $x^8 + x^2 + x + 1$. Refer to ITU-T Rec. G.7042 for operation.

18.1.2.2.2.8 OPUk-Xv VCOH Reserved Overhead

The reserved VCOH is set to all-0s.

18.1.2.2.3 OPUk Mapping Specific Overhead

X times four bytes are reserved in the OPUk overhead for mapping specific overhead. These bytes are located in columns 15X+1 to 16X.

The use of these bytes depends on the specific client signal mapping (defined in 18.2).

18.2 Mapping of client signals

18.2.1 Mapping of CBR signals (e.g. STM-64/256) into OPUk-4v

Mapping of a CBR signal (with up to ±20 ppm bit-rate tolerance) into an OPUk-4v may be performed according two different modes (asynchronous and bit synchronous) based on one generic OPUk-4v frame structure (Figure 18-3).

NOTE 1 – Examples of such signals are STM-64 and STM-256.

NOTE 2 – The maximum bit-rate tolerance between OPUk-4v and the client signal clock, which can be accommodated by this mapping scheme, is ±65 ppm. With a bit-rate tolerance of ±20 ppm for the OPUk-4v clock, the client signal's bit-rate tolerance can be ±45 ppm.

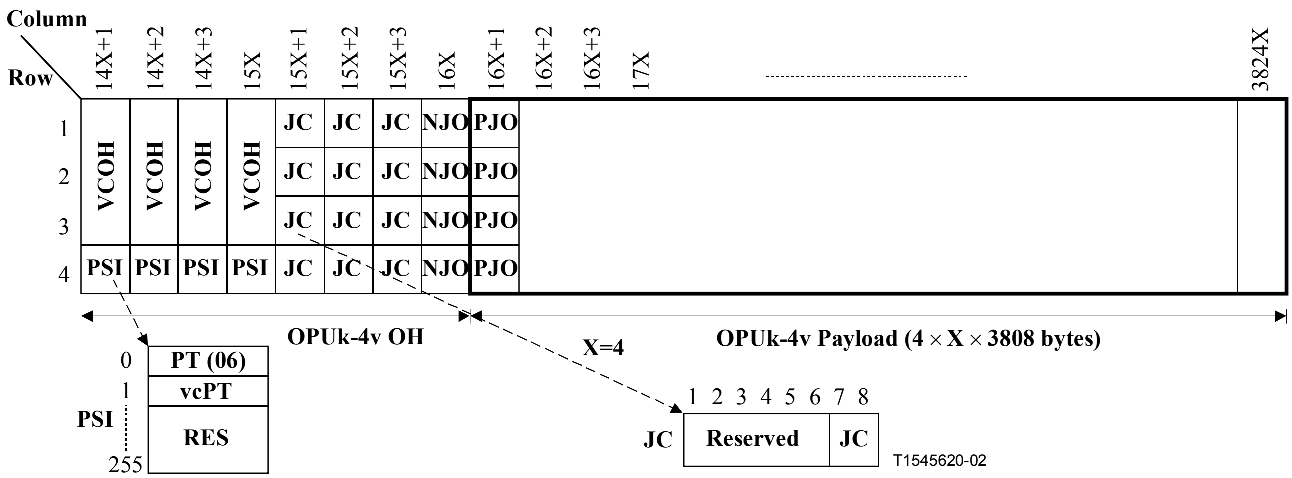


Figure 18-3/G.709/Y.1331 – OPUk-4v frame structure for the mapping of a CBR10G or CBR40G signal

The OPUk-4v overhead for these mappings consists of a X (X = 4) times a Payload Structure Identifier (PSI), which includes the Payload Type (PT) and virtual concatenation payload type (vcPT), X times Virtual Concatenation Overhead (VCOH), three Justification Control (JC) bytes and one Negative Justification Opportunity (NJO) byte per row. The JC bytes consist of two bits for justification control and six bits reserved for future international standardization.

The OPUk-4v payload for these mappings consists of X (X = 4) times 4 × 3808 bytes, including one Positive Justification Opportunity (PJO) byte per row.

The Justification Control (JC) signals, which are located in columns 15X+1 (61), 15X+2 (62) and 15X+3 (63) of each row, bits 7 and 8, are used to control the two justification opportunity fields NJO and PJO that follow in column 16X (64) and 16X+1 (65) of each row.

The asynchronous and bit synchronous mapping processes generate the JC, NJO and PJO according to Tables 17-1 and 17-2, respectively. The demapping process interprets JC, NJO and PJO according to Table 17-3. Majority vote (two out of three) shall be used to make the justification decision in the demapping process to protect against an error in one of the three JC signals.

The value contained in NJO and PJO when they are used as justification bytes is all-0s. The receiver is required to ignore the value contained in these bytes whenever they are used as justification bytes.

During a signal fail condition of the incoming CBR client signal (e.g. in the case of a loss of input signal), this failed incoming signal is replaced by the generic-AIS signal as specified in 16.6.1, and is then mapped into the OPUk-4v.

During signal fail condition of the incoming ODUk/OPUk-4v signal (e.g. in the case of an ODUk-AIS, ODUk-LCK, ODUk-OCI condition) the generic-AIS pattern as specified in 16.6.1 is generated as a replacement signal for the lost CBR signal.

Asynchronous mapping

The OPUk-4v signal for the asynchronous mapping is created from a locally generated clock (within the limits specified in Table 7-3), which is independent of the CBR (i.e. $4^{(k)}$ × 2 488 320 kbit/s) client signal.

The CBR (i.e. $4^{(k)}$ × 2 488 320 kbit/s) signal is mapped into the OPUk-4v using a positive/negative/zero (pnz) justification scheme.

Bit synchronous mapping

The OPUk-4v clock for the bit synchronous mapping is derived from the CBR (i.e. $4^{(k)} \times 2\,488\,320$ kbit/s) client signal. During signal fail conditions of the incoming CBR signal (e.g. in the case of loss of input signal), the OPUk-4v payload signal bit rate shall be within the limits specified in Table 7-3 and neither a frequency nor frame phase discontinuity shall be introduced. The resynchronization on the incoming CBR signal shall be done without introducing a frequency or frame phase discontinuity.

The CBR (i.e. $4^{(k)} \times 2\,488\,320$ kbit/s) signal is mapped into the OPUk-4v without using the justification capability within the OPUk-Xv frame: NJO contains four justification bytes, PJO contains four data bytes, and the JC signal is fixed to 00.

18.2.1.1 Mapping a CBR10G signal (e.g. STM-64) into OPU1-4v

Groups of 8 successive bits (not necessarily being a byte) of the CBR10G signal are mapped into a Data (D) byte of the OPU1-4v (Figure 18-4). Once per OPU1-4v row (and thus four times per OPU1-4v frame), it is possible to perform either a positive or a negative justification action.

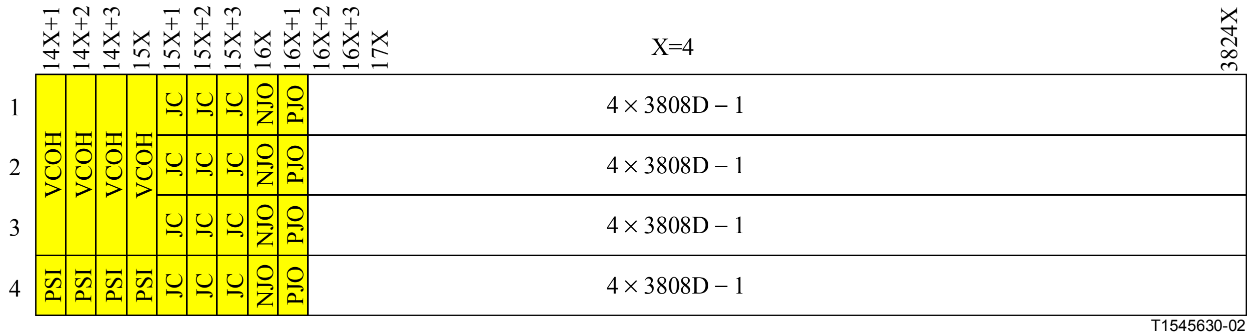


Figure 18-4/G.709/Y.1331 – Mapping of a CBR10G signal into OPU1-4v

18.2.1.2 Mapping a CBR40G signal (e.g. STM-256) into OPU2-4v

Groups of 8 successive bits (not necessarily being a byte) of the CBR40G signal are mapped into a Data (D) byte of the OPU2-4v (Figure 18-5). X times 64 Fixed Stuff (FS) bytes are added in columns 1904X+1 to 1920X. Once per OPU2-Xv row (and thus four times per OPU2-4v frame), it is possible to perform either a positive or a negative justification action.

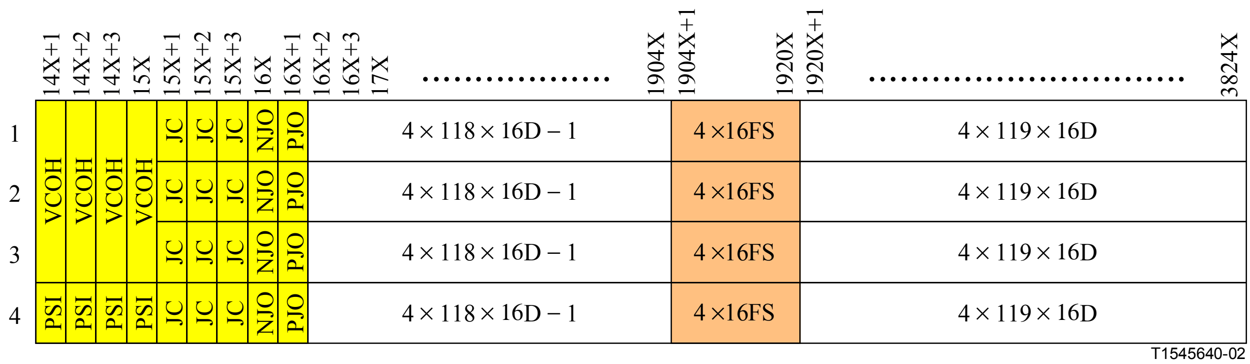


Figure 18-5/G.709/Y.1331 – Mapping of a CBR40G signal into OPU2-4v

18.2.2 Mapping of CBR signals (e.g. STM-256) into OPUk-16v

Mapping of a CBR signal (with up to ±20 ppm bit-rate tolerance) into an OPUk-16v may be performed according two different modes (asynchronous and bit synchronous) based on one generic modified OPUk-16v frame structure (Figure 18-6). This modified OPUk-16v frame structure has part of its OPUk-16v OH distributed over the frame; consequently, columns 15X+5 to 16X are now within the OPUk-16v payload area.

NOTE 1 – Examples of such signals are STM-256.

NOTE 2 – The maximum bit-rate tolerance between OPUk-16v and the client signal clock, which can be accommodated by this mapping scheme, is ±65 ppm. With a bit-rate tolerance of ±20 ppm for the OPUk-16v clock, the client signal's bit-rate tolerance can be ±45 ppm.

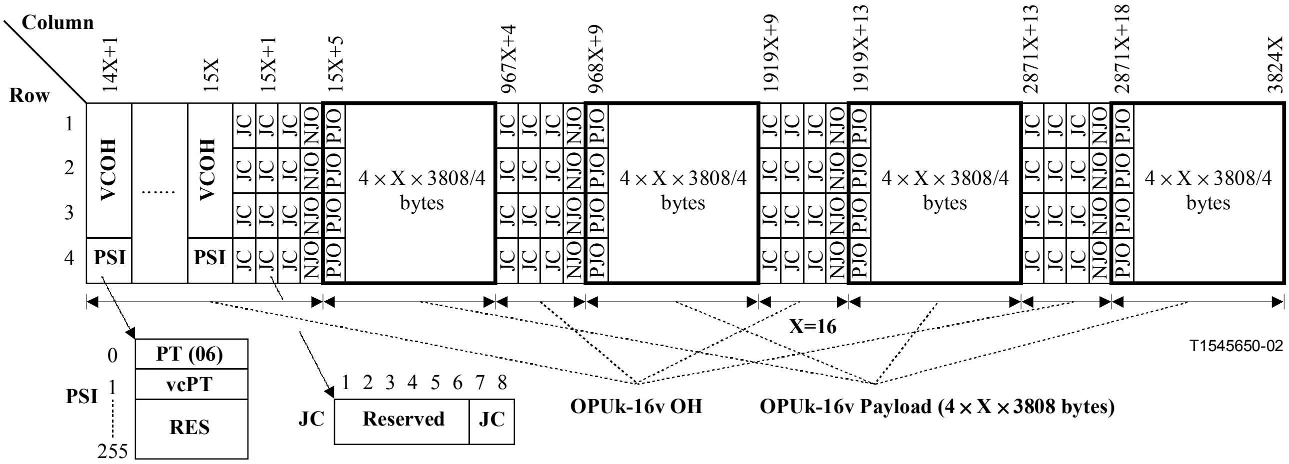


Figure 18-6/G.709/Y.1331 – OPUk-16v frame structure for the mapping of a CBR signal

The OPUk-16v overhead for these mappings consists of a X (X = 16) times a Payload Structure Identifier (PSI), which includes the Payload Type (PT) and virtual concatenation payload type (vcPT), X times Virtual Concatenation Overhead (VCOH), 4 × 3 Justification Control (JC) bytes and 4 × 1 Negative Justification Opportunity (NJO) bytes per row. The JC bytes consist of two bits for justification control and six bits reserved for future international standardization.

The OPUk-16v payload for these mappings consists of 4 blocks of 4 × 15232 bytes, including 4x1 Positive Justification Opportunity (PJO) bytes per row.

The Justification Control (JC) signals, which are located in the locations indicated in Figure 18-3, bits 7 and 8, are used to control the two justification opportunity fields NJO and PJO that follow in the next two columns of each row.

The asynchronous and bit synchronous mapping processes generate the JC, NJO and PJO according to Tables 17-1 and 17-2, respectively. The demapping process interprets JC, NJO and PJO according to Table 17-3. Majority vote (two out of three) shall be used to make the justification decision in the demapping process to protect against an error in one of the three JC signals.

The value contained in NJO and PJO when they are used as justification bytes is all-0s. The receiver is required to ignore the value contained in these bytes whenever they are used as justification bytes.

During a signal fail condition of the incoming CBR client signal (e.g. in the case of a loss of input signal), this failed incoming signal is replaced by the generic-AIS signal as specified in 16.6.1, and is then mapped into the OPUk-16v.

During signal fail condition of the incoming ODUk/OPUk-16v signal (e.g. in the case of an ODUk-AIS, ODUk-LCK, ODUk-OCI condition) the generic-AIS pattern as specified in 16.6.1 is generated as a replacement signal for the lost CBR signal.

Asynchronous mapping

The OPUk-16v signal for the asynchronous mapping is created from a locally generated clock (within the limits specified in Table 7-3), which is independent of the CBR (i.e. $4^{(k+1)} \times 2\,488\,320$ kbit/s) client signal.

The CBR (i.e. $4^{(k+1)} \times 2\,488\,320$ kbit/s) signal is mapped into the OPUk-16v using a positive/negative/zero (pnz) justification scheme.

Bit synchronous mapping

The OPUk-16v clock for the bit synchronous mapping is derived from the CBR client signal. During signal fail conditions of the incoming CBR signal (e.g. in the case of loss of input signal), the OPUk-16v payload signal bit rate shall be within the limits specified in Table 7-3 and neither a frequency nor frame phase discontinuity shall be introduced. The resynchronization on the incoming CBR signal shall be done without introducing a frequency or frame phase discontinuity.

The CBR (i.e. $4^{(k+1)} \times 2\,488\,320$ kbit/s) signal is mapped into the OPUk-16v without using the justification capability within the OPUk-16v frame: NJO contains four justification bytes, PJO contains four data bytes, and the JC signal is fixed to 00.

18.2.2.1 Mapping a CBR40G signal (e.g. STM-256) into OPU1-16v

Groups of 8 successive bits (not necessarily being a byte) of the CBR40G signal are mapped into a Data (D) byte of the OPU1-16v (Figure 18-7). Four times per OPU1-16v row (and thus sixteen times per OPU1-16v frame), it is possible to perform either a positive or a negative justification action.

Figure 18-7/G.709/Y.1331 – Mapping of a CBR40G signal into OPU1-16v

18.2.3 Mapping of ATM cell stream into OPUk-Xv

A constant bit rate ATM cell stream with a capacity that is identical to the OPUk-Xv payload area is created by multiplexing the ATM cells of a set of ATM VP signals. Rate adaptation is performed as part of this cell stream creation process by either inserting idle cells or by discarding cells. Refer to I.432.1. The ATM cell stream is mapped into the OPUk-Xv payload area with the ATM cell byte structure aligned to the OPUk-Xv payload byte structure (Figure 18-8). The ATM cell boundaries are thus aligned with the OPUk-Xv payload byte boundaries. Since the OPUk-Xv payload capacity (X × 15232 bytes) is not an integer multiple of the cell length (53 bytes), a cell may cross an OPUk-Xv frame boundary.

The ATM cell information field (48 bytes) shall be scrambled before mapping into the OPUk-Xv. In the reverse operation, following termination of the OPUk-Xv signal, the ATM cell information field will be descrambled before being passed to the ATM layer. A self-synchronizing scrambler with generator polynomial $x^{43} + 1$ shall be used (as specified in ITU-T Rec. I.432.1). The scrambler operates for the duration of the cell information field. During the 5-byte header the scrambler operation is suspended and the scrambler state retained. The first cell transmitted on start-up will be corrupted because the descrambler at the receiving end will not be synchronized to the transmitter scrambler. Cell information field scrambling is required to provide security against false cell delineation and cell information field replicating the OTUk and ODUk frame alignment signal.

When extracting the ATM cell stream from the OPUk-Xv payload area after the ODUk terminations, the ATM cells must be recovered. The ATM cell header contains a Header Error Control (HEC) field, which may be used in a similar way to a frame alignment word to achieve cell delineation. This HEC method uses the correlation between the header bits to be protected by the HEC (32 bits) and the control bit of the HEC (8 bits) introduced in the header after computation with a shortened cyclic code with generating polynomial $g(x) = x^8 + x^2 + x + 1$.

The remainder from this polynomial is then added to the fixed pattern "01010101" in order to improve the cell delineation performance. This method is similar to conventional frame alignment recovery where the alignment signal is not fixed but varies from cell to cell.

More information on HEC cell delineation is given in ITU-T Rec. I.432.1.

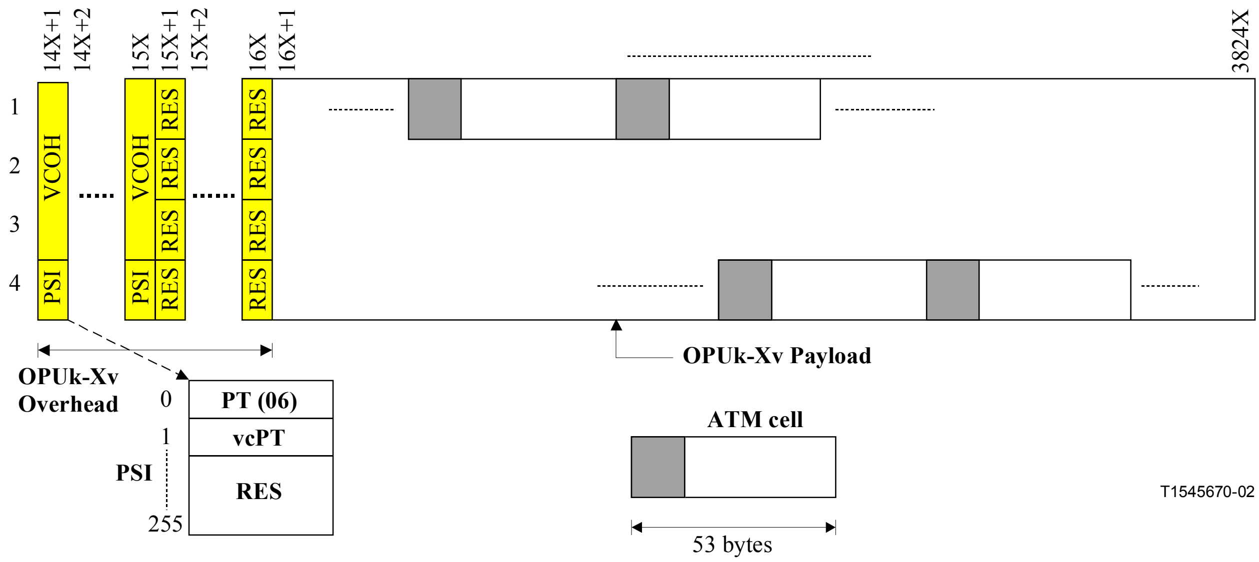


Figure 18-8/G.709/Y.1331 – OPUk-Xv frame structure and mapping of ATM cells into OPUk-Xv

The OPUk-Xv overhead for the ATM mapping consists of X times a Payload Structure Identifier (PSI), which includes the Payload Type (PT) and virtual concatenation payload type (vcPT), X times three Virtual Concatenation Overhead (VCOH) bytes and X times four bytes reserved for future international standardization (RES).

The OPUk-Xv payload for the ATM mapping consists of $4X \times 3808$ bytes.

18.2.4 Mapping of GFP frames into OPUk-Xv

The mapping of Generic Framing Procedure (GFP) frames is performed by aligning the byte structure of every GFP frame with the byte structure of the OPUk-Xv Payload (Figure 18-9). Since the GFP frames are of variable length (the mapping does not impose any restrictions on the maximum frame length), a GFP frame may cross the OPUk frame boundary. A GFP frame consists of a GFP header and a GFP payload area.

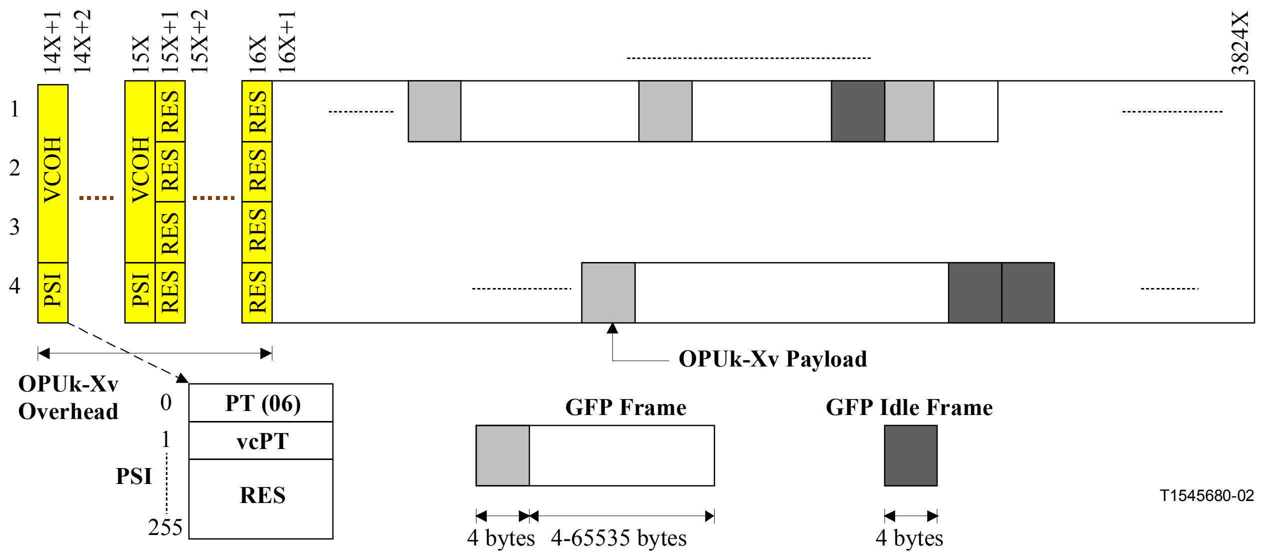


Figure 18-9/G.709/Y.1331 – OPUk-Xv frame structure and mapping of GFP frames into OPUk-Xv

GFP frames arrive as a continuous bit stream with a capacity that is identical to the OPUk-Xv payload area, due to the insertion of GFP Idles at the GFP encapsulation stage. The GFP frame stream is scrambled during encapsulation.

NOTE – There is no rate adaptation or scrambling required at the mapping stage; this is performed by the GFP encapsulation process.

The OPUk-Xv overhead for the GFP mapping consists of X times a Payload Structure Identifier (PSI), which includes the Payload Type (PT) and virtual concatenation payload type (vcPT), X times three Virtual Concatenation Overhead (VCOH) bytes and X times four bytes reserved for future international standardization (RES).

The OPUk-Xv payload for the GFP mapping consists of 4X × 3808 bytes.

18.2.5 Mapping of test signal into OPUk-Xv

18.2.5.1 Mapping of a NULL client into OPUk-Xv

An OPUk-Xv payload signal with an all-0s pattern (Figure 18-10) is defined for test purposes. This is referred to as the NULL client.

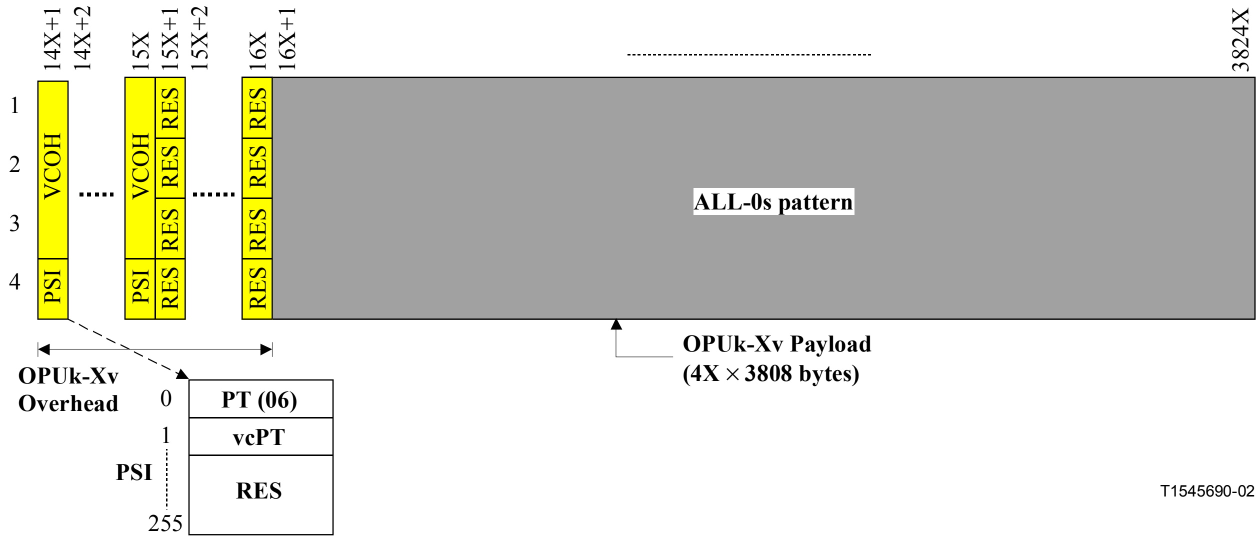


Figure 18-10/G.709/Y.1331 – OPUk-Xv frame structure and mapping of NULL client into OPUk-Xv

The OPUk-Xv overhead for the NULL mapping consists of X times a Payload Structure Identifier (PSI), which includes the Payload Type (PT) and virtual concatenation payload type (vcPT), X times three Virtual Concatenation Overhead (VCOH) bytes and X times four bytes reserved for future international standardization (RES).

The OPUk-Xv payload for the NULL mapping consists of 4X × 3808 bytes.

18.2.5.2 Mapping of PRBS test signal into OPUk-Xv

For test purposes a 2 147 483 647-bit pseudo-random test sequence ($2^{31} - 1$) as specified in 5.8/O.150 can be mapped into the OPUk-Xv Payload. Groups of 8 successive bits of the 2 147 483 647-bit pseudo-random test sequence signal are mapped into 8 Data bits (8D) (i.e. one byte) of the ODU3 Payload (Figure 18-11).

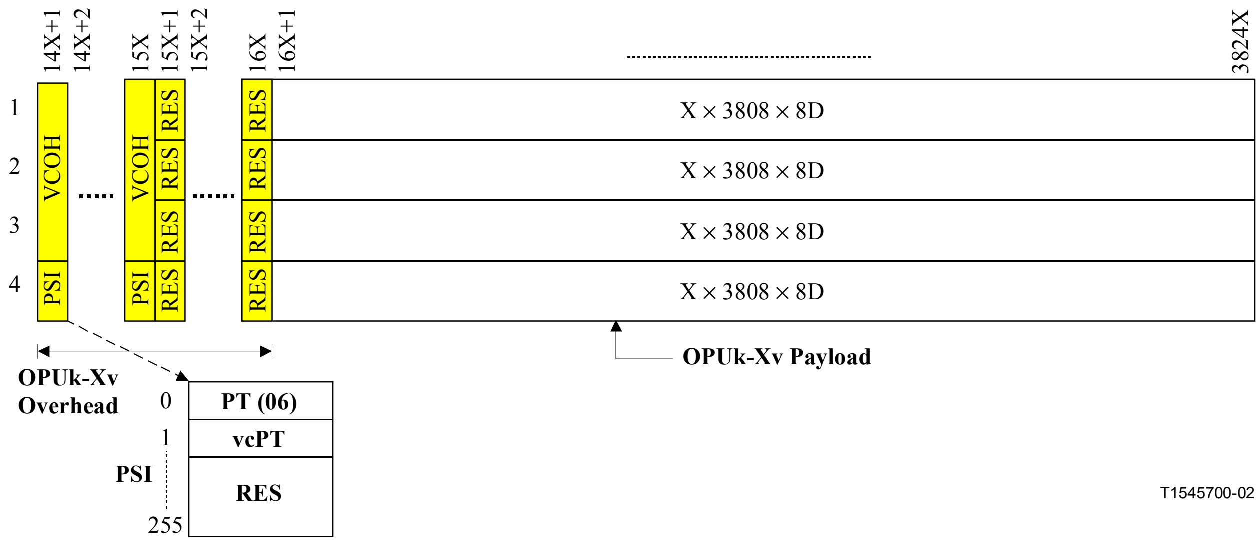


Figure 18-11/G.709/Y.1331 – OPUk-Xv frame structure and mapping of 2 147 483 647-bit pseudo-random test sequence into OPUk-Xv

The OPUk-Xv overhead for the PRBS mapping consists of X times a Payload Structure Identifier (PSI), which includes the Payload Type (PT) and virtual concatenation payload type (vcPT), X times three Virtual Concatenation Overhead (VCOH) bytes and X times four bytes reserved for future international standardization (RES).

The OPUk-Xv payload for the PRBS mapping consists of 4X × 3808 bytes.

18.2.6 Mapping of a non-specific client bit stream into OPUk-Xv

In addition to the mappings of specific client signals as specified in the other subclauses of this clause, a non-specific client mapping into OPUk-Xv is specified. Any (set of) client signal(s), which after encapsulation into a continuous bit stream with a bit rate of the OPUk-Xv Payload, can be mapped into the OPUk-Xv Payload (Figure 18-12). The bit stream must be synchronous with the OPUk-Xv signal. Any justification must be included in the continuous bit stream creation process. The continuous bit stream must be scrambled before mapping into the OPUk-Xv Payload.

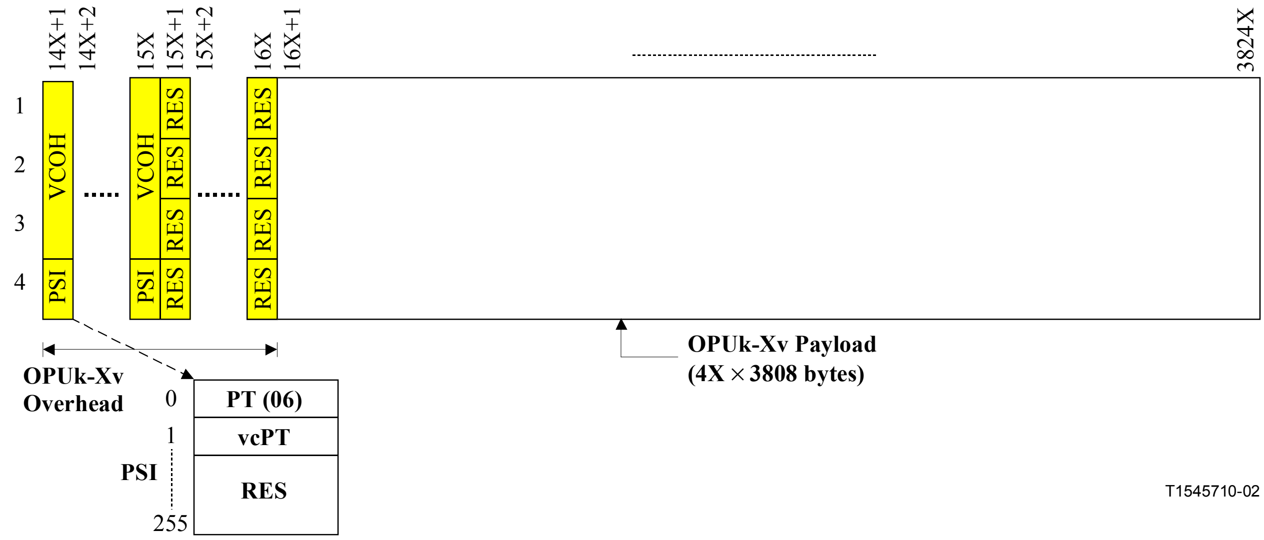


Figure 18-12/G.709/Y.1331 – OPUk-Xv frame structure for the mapping of a synchronous constant bit stream

The OPUk-Xv overhead for the mapping consists of X times a Payload Structure Identifier (PSI), which includes the Payload Type (PT) and virtual concatenation payload type (vcPT), X times three Virtual Concatenation Overhead (VCOH) bytes and X times four bytes for client specific purposes (CS). The definition of these CS overhead bytes is performed within the encapsulation process specification.

The OPUk-Xv payload for this non-specific mapping consists of 4X × 3808 bytes.

18.2.6.1 Mapping bit stream with octet timing into OPUk-Xv

If octet timing is available, each octet of the incoming data stream will be mapped into a data byte (octet) of the OPUk-Xv payload.

18.2.6.2 Mapping bit stream without octet timing into OPUk-Xv

If octet timing is not available, groups of 8 successive bits (not necessarily an octet) of the incoming data stream will be mapped into a data byte (octet) of the OPUk-Xv payload.

18.3 LCAS for virtual concatenation

Refer to ITU-T Rec. G.7042.

2.27 New clause 19

Add the following text in which ODUk multiplexing is defined:

19 Mapping ODUk signals into the ODTUjk signal

19.1 OPUk tributary slot definition

The OPUk is divided in a number of Tributary Slots (TS) and these Tributary Slots are interleaved within the OPUk. A Tributary Slot includes a part of the OPUk OH area and a part of the OPUk payload area. The bytes of the ODUj frame are mapped into the OPUk payload area of the Tributary Slot. The bytes of the ODTUjk Justification Overhead are mapped into the OPUk OH area.

19.1.1 OPU2 tributary slot allocation

Figure 19-1 presents the OPU2 tributary slot allocation. An OPU2 tributary slot occupies 25% of the OPU2 Payload area. It is a structure with 952 columns by 4 rows (Figure 19-3). The four OPU2 TSs are byte interleaved in the OPU2 Payload area.

In addition, the Justification Overhead (JOH) consisting of Justification Control (JC) and Negative Justification Opportunity (NJO) signals of the 4 OPU2 TSs are located in the overhead area, column 16 of rows 1 to 4. The JOH is assigned to the related tributary slots on a per frame base. JOH for a tributary slot is available once every 4 frames. A 4-frame multiframe structure is used for this assignment. This multiframe structure is locked to bits 7 and 8 of the MFAS byte as shown in Table 19-1.

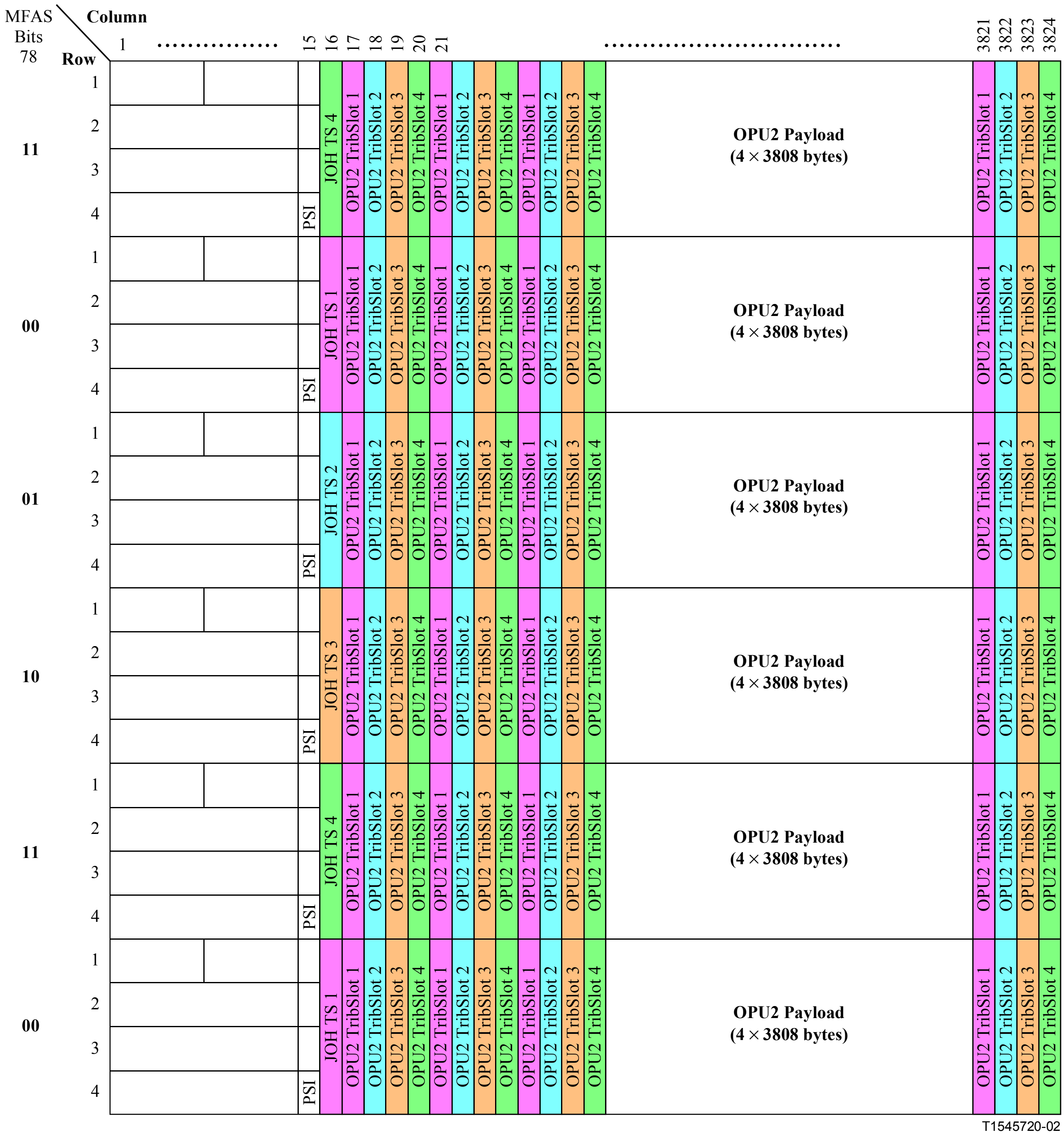


Figure 19-1/G.709/Y.1331 – OPU2 tributary slot allocation

Table 19-1/G.709/Y.1331 – OPU2 Justification OH tributary slots

MFAS bits 78	JOH TS
00	1
01	2
10	3
11	4

19.1.2 OPU3 tributary slot allocation

Figure 19-2 presents the OPU3 tributary slot allocation. An OPU3 tributary slot occupies 6.25% of the OPU3 Payload area. It is a structure with 238 columns by 4 rows (Figure 19-4). The sixteen OPU3 TS's are byte interleaved in the OPU3 Payload area.

In addition, the Justification Overhead (JOH) consisting of Justification Control (JC) and Negative Justification Opportunity (NJO) signals of the 16 OPU3 TSs are located in the overhead area, column 16 of rows 1 to 4. The JOH is assigned to the related tributary slots on a per frame base. JOH for a tributary slot is available once every 16 frames. A 16-frame multiframe structure is used for this assignment. This multiframe structure is locked to bits 5, 6, 7 and 8 of the MFAS byte as shown in Table 19-2.

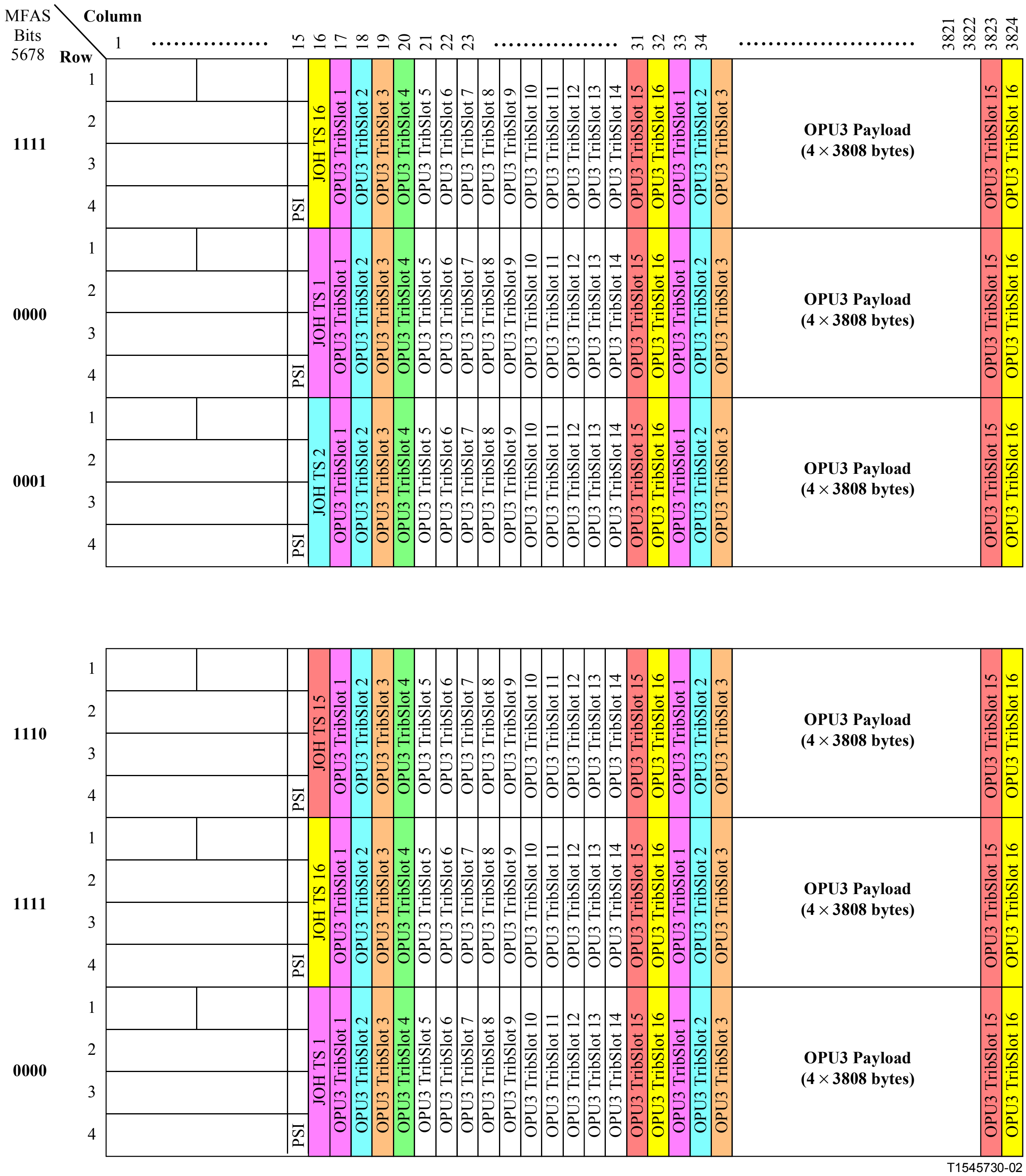


Figure 19-2/G.709/Y.1331 – OPU3 tributary slot allocation

Table 19-2/G.709/Y.1331 – OPU3 Justification OH tributary slots

MFAS bits 5678	JOH TS
0000	1
0001	2
0010	3
0011	4
0100	5
0101	6
0110	7
0111	8

MFAS bits 5678	JOH TS
1000	9
1001	10
1010	11
1011	12
1100	13
1101	14
1110	15
1111	16

19.2 ODTUjk definition

19.2.1 ODTU12

The Optical channel Data Tributary Unit 12 (ODTU12) is a structure with 952 columns by 4 times 4 rows plus 1 column of Justification Overhead (JOH). It carries a justified ODU1 signal. The location of the JOH column depends on the OPU2 tributary slot used when multiplexing the ODTU12 in the OPU2 (see 19.1.1).

19.2.2 ODTU13

The Optical channel Data Tributary Unit 13 (ODTU13) is a structure with 238 columns by 16 times 4 rows plus 1 column of Justification Overhead (JOH). It carries a justified ODU1 signal. The location of the JOH column depends on the OPU3 tributary slot used when multiplexing the ODTU13 in the OPU3 (see 19.1.2).

19.2.3 ODTU23

The Optical channel Data Tributary Unit 23 (ODTU23) is a structure with 952 columns by 16 times 4 rows plus 4 times 1 column of Justification Overhead (JOH). It carries a justified ODU2 signal. The location of the JOH column depends on the OPU3 tributary slot used when multiplexing the ODTU23 in the OPU3 (see 19.1.2). They might not be equally distributed.

19.3 Multiplexing ODTUjk signals into the OPUk

Multiplexing an ODTU12 signal into an OPU2 is realized by means of the mapping of the ODTU12 signal in one of the four OPU2 tributary slots.

Multiplexing an ODTU13 signal into an OPU3 is realized by means of the mapping of the ODTU13 signal in one of the sixteen OPU3 tributary slots.

Multiplexing an ODTU23 signal into an OPU3 is realized by means of the mapping of the ODTU23 signal in four (of the sixteen) arbitrary OPU3 tributary slots: OPU3 TSa, TSb, TSc and TSd with $1 \leq a < b < c < d \leq 16$.

NOTE – a, b, c and d do not have to be sequential ($a = i$, $b = i + 1$, $c = i + 2$, $d = i + 3$); the values can be arbitrarily selected to prevent bandwidth fragmentation.

The OPUk overhead for these multiplexed signals consists of a Payload Structure Identifier (PSI), which includes the Payload Type (PT) and the Multiplex Structure Identifier (MSI), three Justification Control (JC) bytes, one Negative Justification Opportunity (NJO) byte, and three bytes reserved for future international standardization (RES). The JC bytes consist of two bits for justification control and six bits reserved for future international standardization.

The 3-byte Justification Control (JC) signal, which is located in rows/columns/frames indicated in Figures 19-1 and 19-2, is used to control the three justification opportunity bytes NJO, PJO1 and PJO2 that follow in row 4.

19.3.1 ODTU12 mapping into one OPU2 Tributary Slot

A byte of the ODTU12 signal is mapped into a byte of an OPU2 TS #i (i = 1,2,3,4), as indicated in Figure 19-3 for a group of 4 rows out of the ODTU12.

A byte of the ODTU12 JOH is mapped into a JOH byte within the OPU2 OH allocated to OPU2 TS #i.

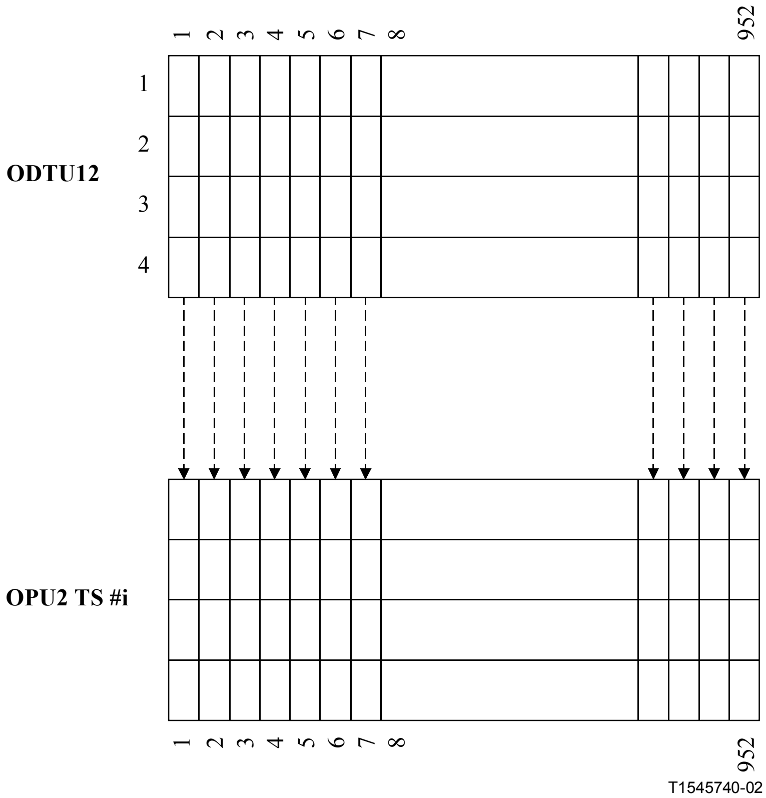


Figure 19-3/G.709/Y.1331 – Mapping of ODTU12 (excluding JOH) into OPU2 TribSlot

19.3.2 ODTU13 mapping into one OPU3 Tributary Slot

A byte of the ODTU13 signal is mapped into a byte of an OPU3 TS #i (i = 1,2,..,16), as indicated in Figure 19-4 for a group of 4 rows out of the ODTU13.

A byte of the ODTU13 JOH is mapped into a JOH byte within the OPU3 OH allocated to OPU3 TS #i.

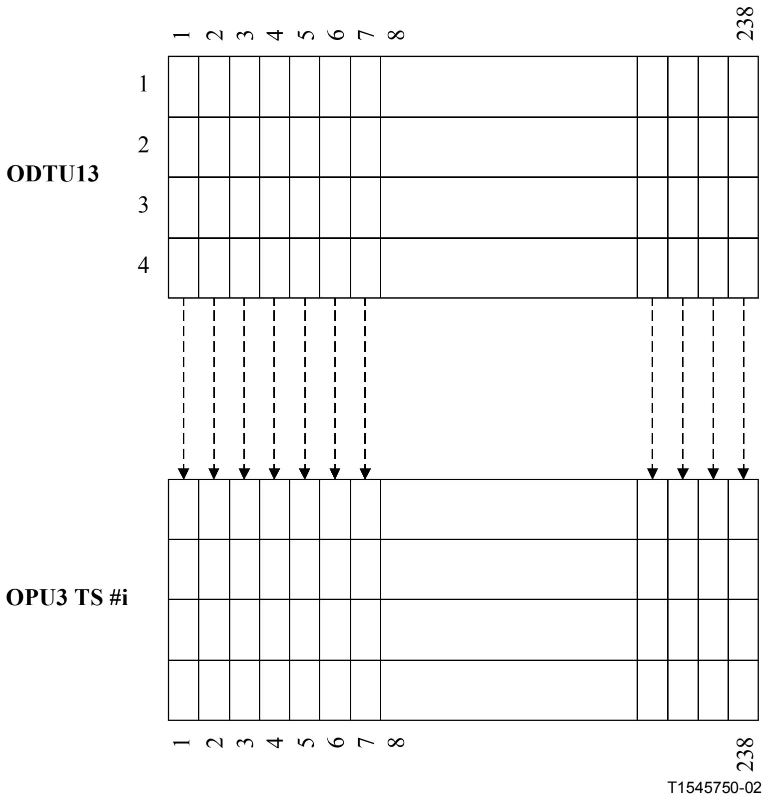


Figure 19-4/G.709/Y.1331 – Mapping of ODTU13 (excluding JOH) into OPU3 TribSlot

19.3.3 ODTU23 mapping into four OPU3 tributary slots

A byte of the ODTU23 signal is mapped into a byte of one of four OPU3 TS #A,B,C,D (A,B,C,D = 1,2,..,16), as indicated in Figure 19-5 for a group of 4 rows out of the ODTU13.

A byte of the ODTU23 JOH is mapped into a JOH byte within the OPU3 OH allocated to OPU3 TS #a,b,c,d.

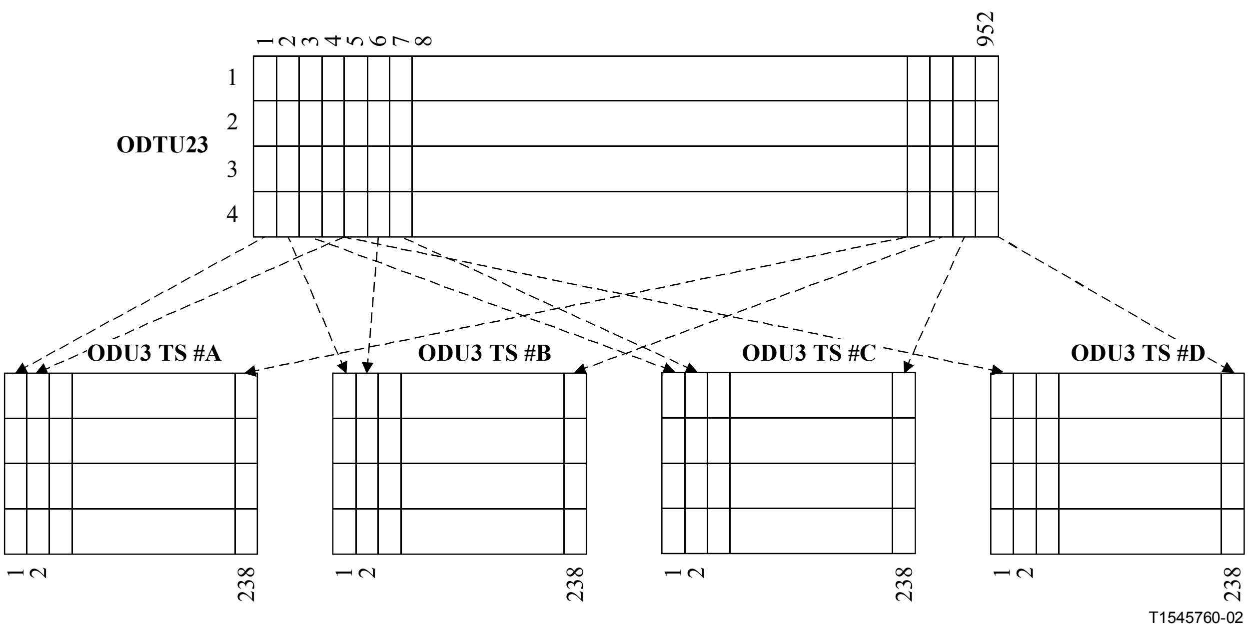


Figure 19-5/G.709/Y.1331 – Mapping of ODTU23 (excluding JOH) into 4 OPU3 TribSlots (#A, #B, #C, #D with A<B<C<D)

19.4 OPUk Multiplex Overhead

The OPUk multiplex overhead consists of Multiplex Structure Identifier (MSI), Justification Control (JC) and Negative Justification Opportunity (NJO) overhead. The OPUk MSI, JC and NJO overhead locations are shown in Figure 19-6. In addition, two Positive Justification Overhead bytes (PJO1, PJO2) are located in the OPUk payload. Note that the PJO1 and PJO2 locations are multiframe dependent.

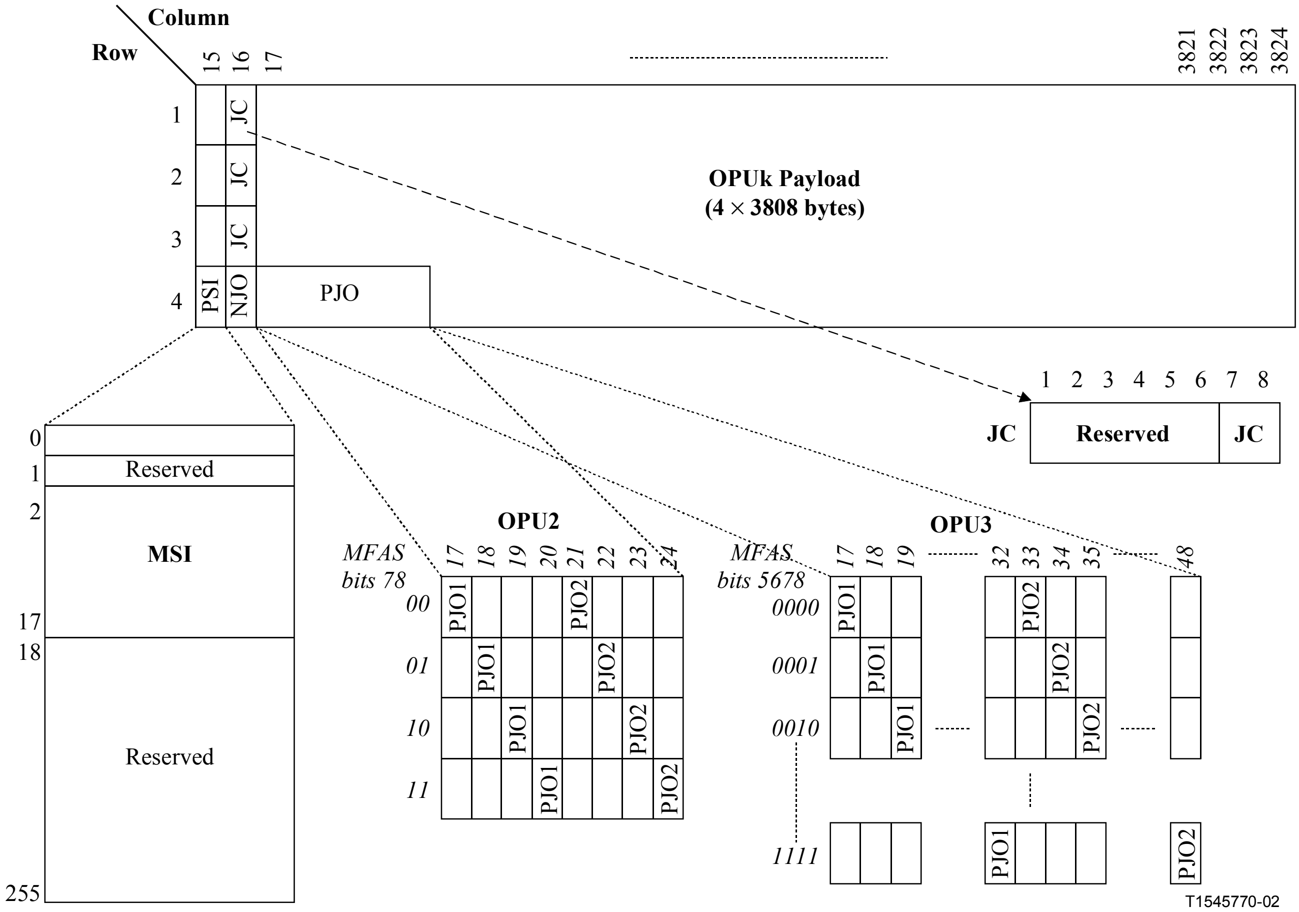


Figure 19-6/G.709/Y.1331 – OPUk Multiplex Overhead

19.4.1 OPUk Multiplex Structure Identifier (MSI)

The multiplex structure identifier (MSI) overhead, which encodes the ODU multiplex structure in the OPU, is located in the mapping specific area of the PSI signal (PSI[2] .. PSI[17]). The MSI indicates the content of each tributary slot (TS) of an OPU. The generic coding for each TS is shown in Figure 19-7. One byte is used for each TS.

Bits 1 and 2 indicate the ODU type transported in the TS.

Bits 3 to 8 indicate the tributary port of the ODU transported. This is of interest in case of flexible assignment of ODUs to tributary slots (e.g. ODU2 into OPU3). In case of fixed assignment the tributary port number corresponds to the tributary slot number.

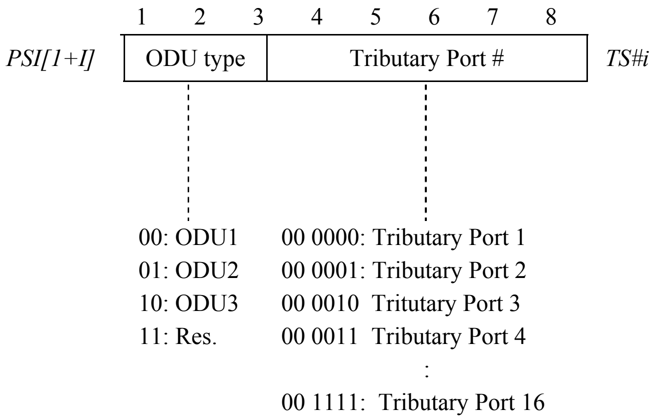


Figure 19-7/G.709/Y.1331 – Generic MSI coding

19.4.1.1 OPU2 Multiplex Structure Identifier (MSI)

For the 4 OPU2 tributary slots 4 bytes of the PSI are used as shown in Figure 19-8.

The ODU type is fixed ODU1.

The tributary port # indicates the port number of the ODU1 that is being transported in this TS; the assignment of ports to tributary slots is fixed, the port number equals the tributary slot number.

The remaining 12 bytes of the MSI field (PSI[6] to PSI[17]) are unused. They are set to 0 and ignored by the receiver.

	1 2	3 4 5 6 7 8	
PSI[2]	00	00 0000	*TS1*
PSI[3]	00	00 0001	*TS2*
PSI[4]	00	00 0010	*TS3*
PSI[5]	00	00 0011	*TS4*

Figure 19-8/G.709/Y.1331 – OPU2-MSI coding

19.4.1.2 OPU3 Multiplex Structure Identifier (MSI)

For the 16 OPU3 tributary slots 16 bytes of the PSI are used as shown in Figure 19-9.

The ODU type indicates if the OPU3 TS is carrying ODU1 or ODU2.

The tributary port # indicates the port number of the ODU1/2 that is being transported in this TS; for the case of ODU2 a flexible assignment of tributary ports to tributary slots is possible, for the case of ODU1 this assignment is fixed, the port number equals the slot number. ODU2 tributary ports are numbered 1 to 4.

	1 2	3 4 5 6 7 8	
PSI[2]	ODU type	Tributary Port #	*TS1*
PSI[3]	ODU type	Tributary Port #	*TS2*
PSI[4]	ODU type	Tributary Port #	*TS3*
PSI[5]	ODU type	Tributary Port #	*TS4*
PSI[6]	ODU type	Tributary Port #	*TS5*
PSI[7]	ODU type	Tributary Port #	*TS6*
PSI[8]	ODU type	Tributary Port #	*TS7*
PSI[9]	ODU type	Tributary Port #	*TS8*
PSI[10]	ODU type	Tributary Port #	*TS9*
PSI[11]	ODU type	Tributary Port #	*TS10*
PSI[12]	ODU type	Tributary Port #	*TS11*
PSI[13]	ODU type	Tributary Port #	*TS12*
PSI[14]	ODU type	Tributary Port #	*TS13*
PSI[15]	ODU type	Tributary Port #	*TS14*
PSI[16]	ODU type	Tributary Port #	*TS15*
PSI[17]	ODU type	Tributary Port #	*TS16*

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Figure 19-9/G.709/Y.1331 – OPU3-MSI coding

19.4.2 OPUk Payload Structure Identifier Reserved overhead (RES)

239 bytes are reserved in the OPUk PSI for future international standardization. These bytes are located in PSI[1] and PSI[18] to [PSI255] of the OPUk overhead. These bytes are set to all ZEROs.

19.4.3 OPUk Multiplex Justification Overhead (JOH)

The justification overhead (JOH) located in column 16 of the OPUk as indicated in Figure 19-6 consists of 3 Justification Control (JC) bytes and one Negative Justification Opportunity (NJO) byte. The 3 JC bytes are located in rows 1, 2 and 3. The NJO byte is located in row 4.

Bits 7 and 8 of each JC byte are used for justification control. The other six bits are reserved for future international standardization.

19.5 Mapping ODUj into ODTUjk

The mapping of ODUj signals (with up to ±20 ppm bit-rate tolerance) into the ODTUjk signal (j = 1,2; k = 2,3) is performed as an asynchronous mapping.

NOTE – The maximum bit-rate tolerance between OPUk and the ODUj signal clock, which can be accommodated by this mapping scheme, is – 113 to +83 ppm (ODU1 into OPU2), – 96 to +101 ppm (ODU1 into OPU3) and – 95 to +101 ppm (ODU2 into OPU3).

The ODUj signal is extended with Frame Alignment Overhead as specified in 15.6.2.1 and 15.6.2.2 and an all-0s pattern in the OTUj Overhead field (Figure 19-10);

The OPUk signal for the multiplexed ODUj structure is created from a locally generated clock (within the limits specified in Table 7-3), which is independent of the ODUj (j = 1,2)) client signals.

The extended ODUj signal is adapted to the locally generated ODUk clock by means of an asynchronous mapping with –1/0/+1/+2 positive/negative/zero (pnz) justification scheme.

An ODUj byte is mapped into an ODTUjk byte.

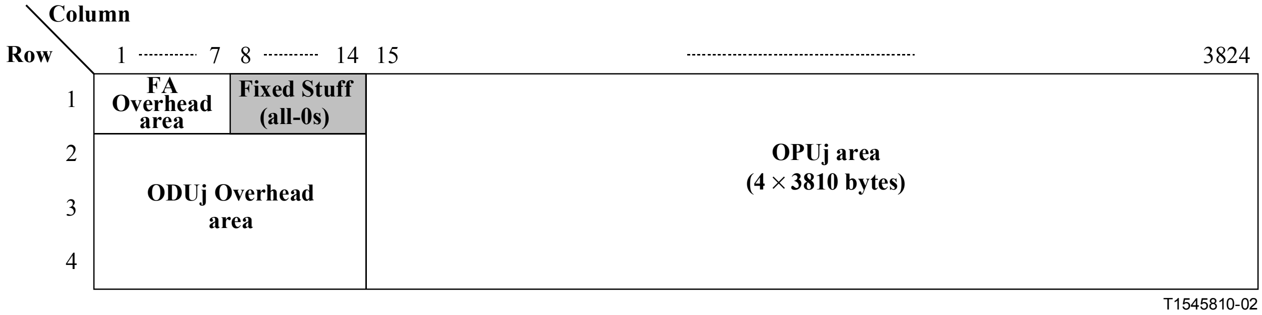


Figure 19-10/G.709/Y.1331 – Extended ODUj frame structure (FA OH included, OTUj OH area contains Fixed Stuff)

The asynchronous mapping process generates the JC, NJO, PJO1 and PJO2 according to Table 19-3. The demapping process interprets JC, NJO, PJO1 and PJO2 according to Table 19-3. Majority vote (two out of three) shall be used to make the justification decision in the demapping process to protect against an error in one of the three JC signals.

Table 19-3/G.709/Y.1331 – JC, NJO, PJO1 and PJO2 generation and interpretation

JC [78]	NJO	PJO1	PJO2	Interpretation
00	justification byte	data byte	data byte	no justification (0)
01	data byte	data byte	data byte	negative justification (−1)
10	justification byte	justification byte	justification byte	double positive justification (+2)
11	justification byte	justification byte	data byte	positive justification (+1)

The value contained in NJO, PJO1 and PJO2 when they are used as justification bytes is all-0s. The receiver is required to ignore the value contained in these bytes whenever they are used as justification bytes.

During a signal fail condition of the incoming ODUj client signal (e.g. OTUj-LOF), this failed incoming signal will contain the ODUj-AIS signal as specified in 16.5.1. This ODUj-AIS is then mapped into the ODTUjk.

For the case the ODUj is received from the output of a fabric (ODUj connection function), the incoming signal may contain (case of open matrix connection) the ODUj-OCI signal as specified in 16.5.2. This ODUj-OCI signal is then mapped into the ODTUjk.

NOTE – Not all equipment will have a real connection function (i.e. switch fabric) implemented; instead the presence/absence of tributary interface port units represents the presence/absence of a matrix connection. If such unit is intentionally absent (i.e. not installed), the associated ODTUjk signals should carry an ODUj-OCI signal. If such unit is installed but temporarily removed as part of a repair action, the associated ODTUjk signal should carry an ODUj-AIS signal.

The OPUk and therefore the ODTUjk (k = 2,3) signals are created from a locally generated clock (within the limits specified in Table 7-3), which is independent of the ODUj (j = 1,2)) client signal.

The ODUj (j = 1,2) signal is mapped into the ODTUjk (k = 2,3) using a −1/0/+1/+2 positive/negative/zero (pnz) justification scheme.

The demapping of ODUj signals from the ODTUjk signal (j = 1,2; k = 2,3) is performed by extracting the extended ODUj signal from the OPUk under control of its justification overhead (JC, NJO, PJO1, PJO2).

NOTE – Where the ODUj signal is output as an OTUj signal, frame alignment of the extracted extended ODUj signal is to be recovered to allow frame synchronous mapping of the ODUj into the OTUj signal.

During signal fail condition of the incoming ODUk/OPUk signal (e.g. in the case of an ODUk-AIS, ODUk-LCK, ODUk-OCI condition) the ODUj-AIS pattern as specified in 16.5.1 is generated as a replacement signal for the lost ODUj signal.

19.5.1 Mapping ODU1 into ODTU12

A byte of the ODU1 signal is mapped into an information byte of the ODTU12 (Figure 19-11). Once per 4 OPU2 frames, it is possible to perform either a positive or a negative justification action.

The frame in which justification can be performed is related to the JOH of the OPU2 TS in which the ODTU12 is mapped (Figure 19-1). Figure 19-11 shows the case with mapping in OPU2 TS1.

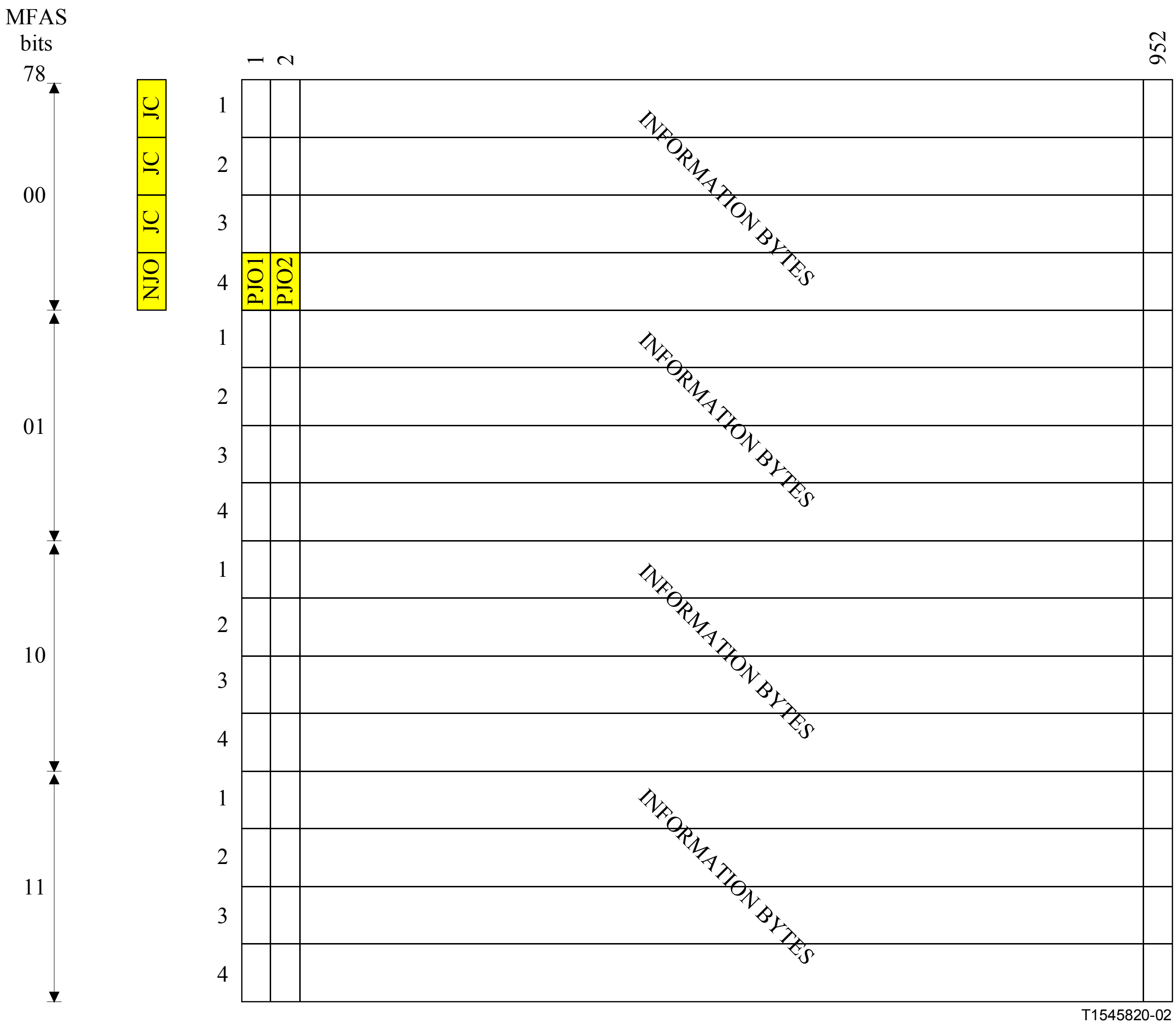


Figure 19-11/G.709/Y.1331 – ODTU12 frame format and mapping of ODU1 (case of mapping in TS1)

19.5.2 Mapping ODU1 into ODTU13

A byte of the ODU1 signal is mapped into an information byte of the ODTU13 (Figure 19-12). Column 119 of the ODTU13 is fixed stuff. An all-0s pattern is inserted in the fixed stuff bytes. Once per 16 OPU3 frames, it is possible to perform either a positive or a negative justification action.

The frame in which justification can be performed is related to the JOH of the OPU3 TS in which the ODTU13 is mapped (Figure 19-2). Figure 19-12 shows the case with mapping in OPU3 TS3.

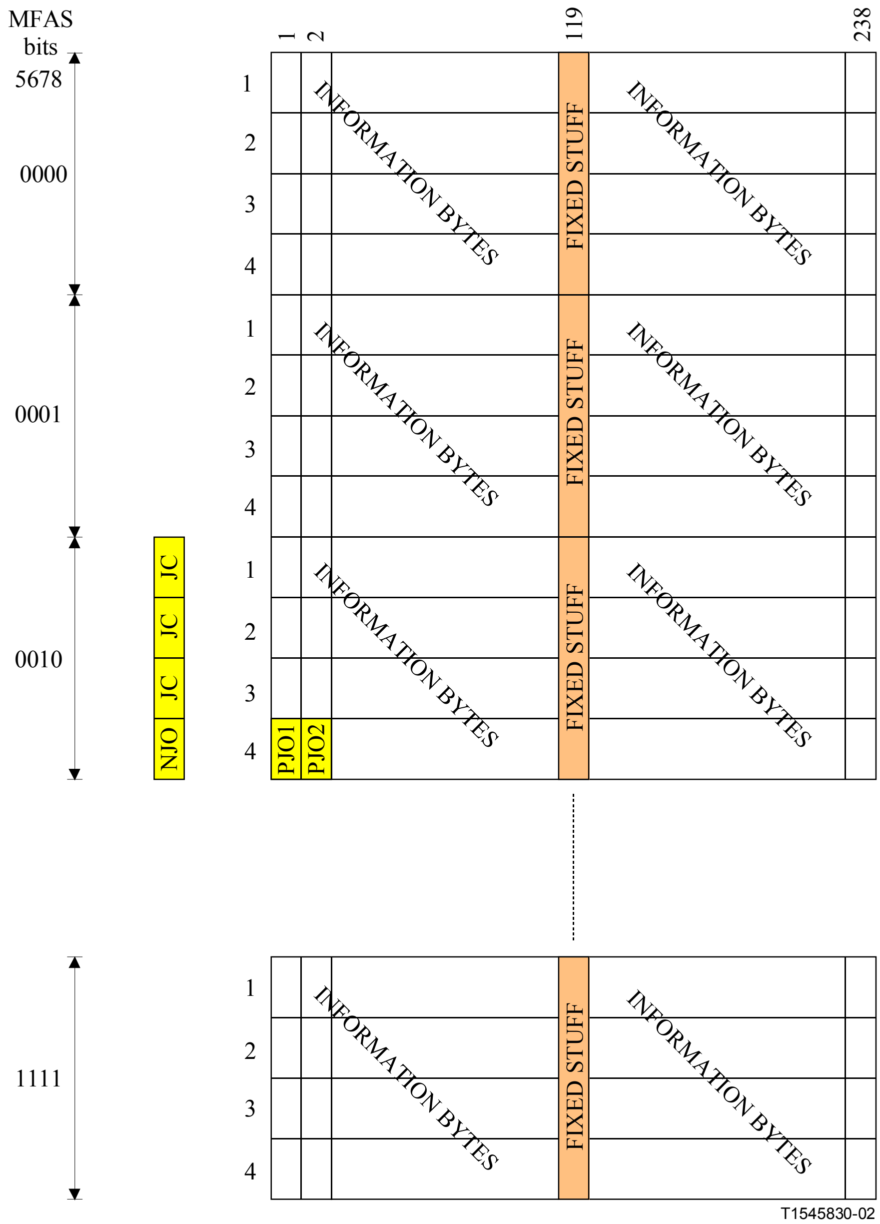


Figure 19-12/G.709/Y.1331 – ODTU13 frame format and mapping of ODU1 (case of mapping in TS3)

19.5.3 Mapping ODU2 into ODTU23

A byte of the ODU2 signal is mapped into an information byte of the ODTU23 (Figure 19-13). Four times per sixteen OPU3 frames, it is possible to perform either a positive or a negative justification action.

The four frames in which justification can be performed are related to the JOH of the OPU3 TSs in which the ODTU23 is mapped (Figure 19-2). Figure 19-13 shows the case with mapping in OPU3 TS1, TS5, TS9 and TS10.

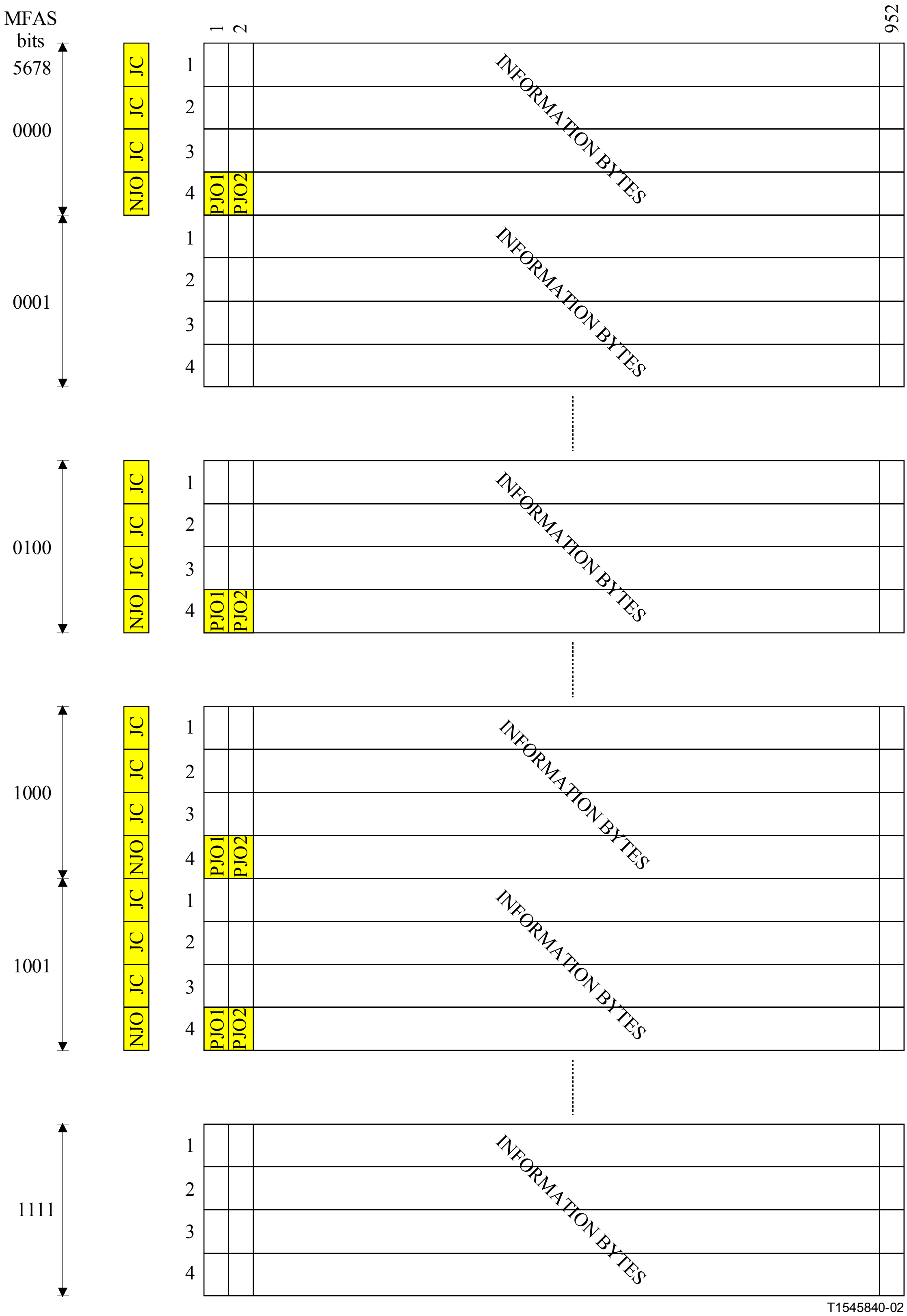


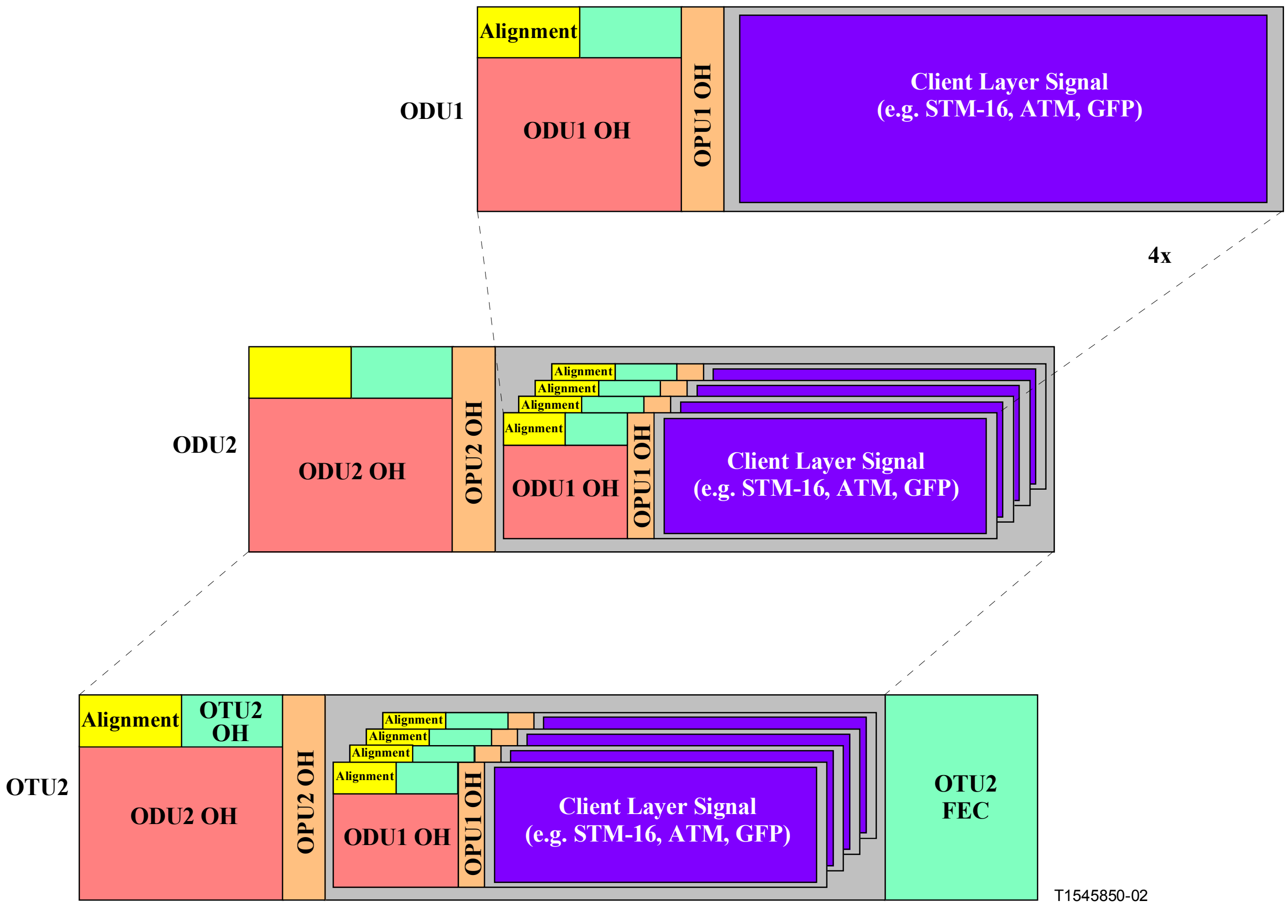
Figure 19-13/G.709/Y.1331 – ODTU23 frame format and mapping of ODU2 (case of mapping in TS1,5,9,10)

Appendix III

Example of ODUk multiplexing

Figure III.1 illustrates the multiplexing of four ODU1 signals into an ODU2. The ODU1 signals including the Frame Alignment Overhead and an all-0s pattern in the OTUk Overhead locations are adapted to the ODU2 clock via justification (asynchronous mapping). These adapted ODU1 signals are byte interleaved into the OPU2 Payload area, and their justification control and opportunity signals (JC, NJO) are frame interleaved into the OPU2 Overhead area.

ODU2 Overhead is added after which the ODU2 is mapped into the OTU2 [or OTU2V]. OTU2 [or OTU2V] Overhead and Frame Alignment Overhead are added to complete the signal for transport via an OTM signal.



NOTE – The ODU1 floats in $^1/_4$ of the OPU2 Payload area. An ODU1 frame will cross multiple ODU2 frame boundaries. A complete ODU1 frame (15 296 bytes) requires the bandwidth of (15 296/3808 =) 4.017 ODU2 frames. This is not illustrated.

Figure III.1/G.709/Y.1331 – Example of multiplexing 4 ODU1 signals into an ODU2 (artist impression)

2.29 Appendix IV

Appendix IV

Example of Fixed Stuff in OPUk with multiplex of lower order ODUk signals

When an OPU3 transports 16 ODU1 signals, columns 1905 to 1920 of the OPU3 contain fixed stuff; one fixed stuff column for each of the 16 ODU1 signals.

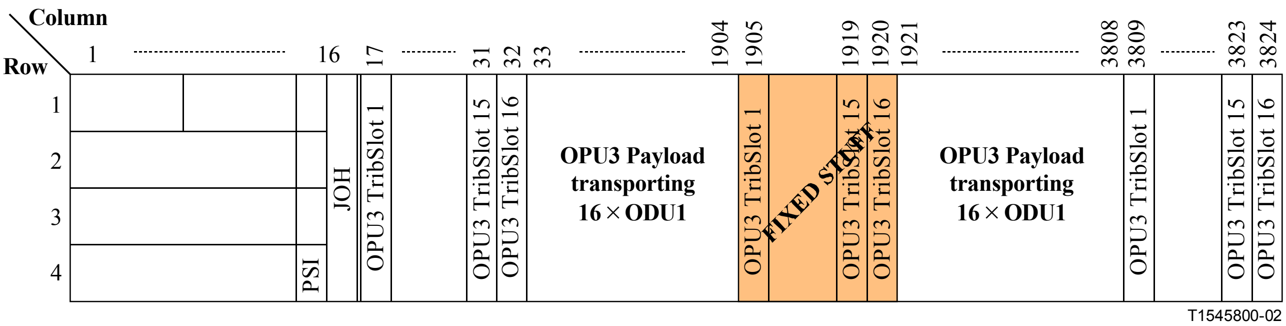


Figure IV.1/G.709/Y.1331 – Fixed Stuff locations when mapping 16 × ODU1 into OPU3

2.30 Appendix V

Appendix V

Range of stuff ratios for asynchronous multiplexing of ODUj into ODUk (k > j)

Appendix I derives a relation between client rate, server frame time, amount of fixed stuff, and stuff ratio, for the asynchronous mapping of CBR (STM-N) clients into ODUk. In this appendix the result of Equation (I-2) is generalized to apply also to the asynchronous multiplexing of ODUj into ODUk (k > j). The more general result is used to evaluate the range of stuff ratio for the multiplexing of ODU1 into ODU2, ODU1 into ODU3, and ODU2 into ODU3, assuming all ODU clocks have ±20 ppm frequency tolerance.

The asynchronous mapping of an STM-N client into ODUk is asynchronous, and uses a +1/0/−1 byte stuffing scheme. The asynchronous mapping of an ODUj client into ODUk (k > j) is asynchronous, and uses a +2/+1/0/−1 byte stuffing scheme. For the case of multiplexing, the ODUj being mapped will get only a fraction of the full payload capacity of the ODUk. There can be, in general, a number of fixed stuff bytes per ODUj or STM-N client. The magnitude of the justification ratio, α, is the long-run average fraction of stuff opportunities for the client in question where a stuff is actually done. The justification ratio takes on both positive and negative values. For consistency, the sign convention of Appendix I is followed, where positive α corresponds to negative stuffing and negative α corresponds to positive stuffing. It is explained in Appendix I that this convention is used so that α appears with a positive sign in the main result (Equation (I-2) and Equation (V-3)). Note that there is one stuff opportunity every ODUk frame. For mapping of STM-N into ODUk, the STM-N client is allowed to use all the stuff opportunities (because only one STM-N signal is mapped into an ODUk). However, for mapping ODUj into ODUk (k > j), the ODUj can only use 1/4 or 1/16 of the stuff opportunities (the former for mapping ODU1 into ODU2 or ODU2 into ODU3; the latter for mapping ODU1 into ODU3). The other stuff opportunities are needed for the other clients being multiplexed into the ODUk. The stuff ratio α is defined relative to the stuff opportunities available for the client in question; the range of α is therefore −1 to +2 in all cases of ODU multiplexing.

Following Appendix I, define the following notation (the index j is used to refer to the possible ODUj client being mapped, and the index k is used to refer to the ODUk server layer into which the ODUj or STM-N client is mapped):

- N number of fixed stuff bytes in the OPUk payload area associated with the client in question (note that this is not the total number of fixed stuff bytes if multiple clients are being multiplexed)
- S nominal STM-N or ODUj client rate (bytes/s)
- T nominal ODUk frame period (s)
- y_c client frequency offset (fraction)
- y_s server frequency offset (fraction)
- p fraction of OPUk payload area available to this client
- N_f average number of client bytes mapped into an ODUk frame, for the particular frequency offsets(averaged over a large number of frames)

Then N_f is given by:

$$N_f = ST\frac{1+y_c}{1+y_s} \tag{V-1}$$

For frequency offsets small compared to 1, this may be approximated

$$N_f = ST(1+y_c-y_s) \equiv ST\beta \tag{V-2}$$

The quantity β − 1 is the net frequency offset due to client and server frequency offset.

Now, the average number of client bytes mapped into an ODUk frame is also equal to the total number of bytes in the payload area available to this client (which is 4 × 3808 × p = 15232p), minus the number of fixed stuff bytes for this client (N), plus the average number of bytes stuffed for this client over a very large number of frames. The latter is equal to the justification ratio α multiplied by the fraction of frames p corresponding to justification opportunities for this client. Combining this with Equation (V-1) produces:

$$ST\beta = \alpha p + 15232p - N \tag{V-3}$$

In Equation (V-3), a positive α corresponds to more client bytes mapped into the ODUk, on average. As indicated above, this corresponds to negative justification. This sign convention is used so that α enters in Equation (V-2) with a positive sign (for convenience).

Equation (V-3) is the main result, and is a generalization of Equation (I-2). For mapping STM-N into ODUk, the quantity p is 1, and Equation (V-3) reduces to Equation (I-2).

The range of stuff ratio may now be determined for mapping ODUj into ODUk, using Equation (V-3). In what follows, let R_{16} be the STM-16 rate, i.e. 2.48832 Gbit/s.

ODU1 into ODU2 multiplexing

The ODU1 nominal client rate is (see 7.3):

$$S = \frac{239}{238}R_{16} \tag{V-4}$$

The ODU2 nominal frame time is:

$$T = \frac{(3824)(4)}{\frac{239}{237}(4R_{16})} \qquad \text{(V-5)}$$

The fraction p is 0.25. Inserting into Equation (V-3) produces:

$$\frac{239}{238} R_{16} \frac{(3824)(4)}{\frac{239}{237}(4R_{16})} \beta = \frac{\alpha}{4} + 3808 - N \qquad \text{(V-6)}$$

Simplifying and solving for α produces:

$$\alpha = \frac{237}{238}(15296)\beta + 4N - 15232 \qquad \text{(V-7)}$$

Now let β = 1 + y, where y is the net frequency offset (and is very nearly equal to $y_c - y_s$ for client and server frequency offset small compared to 1). Then:

$$\begin{aligned} \alpha &= \frac{237}{238}(15296) - 15232 + 4N + \frac{237}{238}(15296)y \\ &= 4N - 0.2689076 + 15231.731092y \end{aligned} \qquad \text{(V-8)}$$

The number of fixed stuff bytes N is zero, as given in 19.5.1. The client and mapper frequency offsets are in the range ±20 ppm, as given in 7.3. Then, the net frequency offset y is in the range ±40 ppm. Inserting these values into Equation (V-8) gives for the range for α:

$$\begin{array}{lll} \alpha = 0.340362 & \text{for} & y = +40\,\text{ppm} \\ \alpha = -0.268908 & \text{for} & y = 0\,\text{ppm} \\ \alpha = -0.878177 & \text{for} & y = -40\,\text{ppm} \end{array} \qquad \text{(V-9)}$$

In addition, stuff ratios of −1 and +2 are obtained for frequency offsets of −47.998 ppm and 148.96 ppm, respectively. The range of frequency offset that can be accommodated is approximately 197 ppm. This is 50% larger than the range that can be accommodated by a +1/0/−1 justification scheme (see Appendix I), and is due to the additional positive stuff byte.

ODU2 into ODU3 multiplexing

The ODU2 nominal client rate is (see 7.3):

$$S = \frac{239}{237}(4R_{16}) \qquad \text{(V-10)}$$

The ODU3 nominal frame time is:

$$T = \frac{(3824)(4)}{\frac{239}{236}(16R_{16})} \qquad \text{(V-11)}$$

The fraction p is 0.25. Inserting into Equation (V-3) produces:

$$\frac{239}{237} 4R_{16} \frac{(3824)(4)}{\frac{239}{236}(16R_{16})} \beta = \frac{\alpha}{4} + 3808 - N \qquad \text{(V-12)}$$

Simplifying and solving for α produces:

$$\alpha = \frac{236}{237}(15296)\beta + 4N - 15232 \quad \text{(V-13)}$$

As before, let β = 1 + y, where y is the net frequency offset (and is very nearly equal to $y_c - y_s$ for client and server frequency offset small compared to 1). Then:

$$\begin{aligned}\alpha &= \frac{236}{237}(15296) - 15232 + 4N + \frac{236}{237}(15296)y \\ &= 4N - 0.5400844 + 15231.459916y\end{aligned} \quad \text{(V-14)}$$

The number of fixed stuff bytes N is zero, as given in 19.5.3. The client and mapper frequency offsets are in the range ±20 ppm, as given in 7.3. Then, the net frequency offset y is in the range ±40 ppm. Inserting these values into Equation (V-14) gives for the range for α:

$$\begin{array}{lll}\alpha = 0.0691740 & \text{for} & y = +40\,\text{ppm} \\ \alpha = -0.5400844 & \text{for} & y = 0\,\text{ppm} \\ \alpha = -1.149343 & \text{for} & y = -40\,\text{ppm}\end{array} \quad \text{(V-15)}$$

In addition, stuff ratios of −1 and +2 are obtained for frequency offsets of −30.195 ppm and 166.77 ppm, respectively. As above, the range of frequency offset that can be accommodated is approximately 197 ppm, which is 50% larger than the range that can be accommodated by a +1/0/−1 justification scheme (see Appendix I) due to the additional positive stuff byte.

ODU1 into ODU3 multiplexing

The ODU1 nominal client rate is (see 7.3):

$$S = \frac{239}{238}(R_{16}) \quad \text{(V-16)}$$

The ODU3 nominal frame time is:

$$T = \frac{(3824)(4)}{\frac{239}{236}(16R_{16})} \quad \text{(V-17)}$$

The fraction p is 0.0625. Inserting into Equation (V-3) produces:

$$\frac{239}{238}R_{16}\frac{(3824)(4)}{\frac{239}{236}(16R_{16})}\beta = \frac{\alpha}{16} + 952 - N \quad \text{(V-18)}$$

Simplifying and solving for α produces:

$$\alpha = \frac{236}{238}(15296)\beta + 16N - 15232 \quad \text{(V-19)}$$

As before, let β = 1 + y, where y is the net frequency offset (and is very nearly equal to $y_c - y_s$ for client and server frequency offset small compared to 1). Then:

$$\begin{aligned}\alpha &= \frac{236}{238}(15296) - 15232 + 16N + \frac{236}{238}(15296)y \\ &= 16N - 64.5378151 + 15167.4612185y\end{aligned} \quad \text{(V-20)}$$

The total number of fixed stuff bytes in the ODU3 payload is 64, as given in 19.5.2; the number for one ODU1 client, N, is therefore 4. The client and mapper frequency offsets are in the range ±20 ppm, as given in 7.3. Then, the net frequency offset y is in the range ±40 ppm. Inserting these values into Equation (V-20) gives for the range for α:

$$\begin{aligned} \alpha &= 0.0688834 && \text{for} \quad y = +40\,\text{ppm} \\ \alpha &= -0.5378151 && \text{for} \quad y = 0\,\text{ppm} \\ \alpha &= -1.144514 && \text{for} \quad y = -40\,\text{ppm} \end{aligned} \tag{V-21}$$

In addition, stuff ratios of −1 and +2 are obtained for frequency offsets of −30.472 ppm and 167.32 ppm, respectively. As above, the range of frequency offset that can be accommodated is approximately 197 ppm, which is 50% larger than the range that can be accommodated by a +1/0/−1 justification scheme (see Appendix I) due to the additional positive stuff byte.

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