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# Transport of IEEE 10G base-R in optical transport networks (OTN)

ITU-T G-series Recommendations – Supplement 43

ITU-T

ITU-T G-SERIES RECOMMENDATIONS

**TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS**



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## Supplement 43 to ITU-T G-series Recommendations

# Transport of IEEE 10G base-R in optical transport networks (OTN)


### Summary

This Supplement describes several approaches for transport of 10G LAN PHY over SDH and OTN transport networks. As some of these approaches use rates, formats and mappings that are not defined in ITU-T Recommendations, this Supplement analyses various attributes of the different approaches to provide guidance regarding their applicability to different network contexts.

This Supplement relates to [ITU-T G.872], [ITU-T G.709/Y.1331], [ITU-T G.798], [ITU-T G.707/Y.1322], [ITU-T G.8010/Y.1306], [ITU-T G.8012/Y.1308], [ITU-T G.959.1] and [ITU-T G.696.1].



### Source

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## Supplement 43 to ITU-T G-series Recommendations

# Transport of IEEE 10G base-R in optical transport networks (OTN)

## 1 Scope

This Supplement describes different approaches for transport of 10G base-R signals in optical transport networks via an ODU2 or non-standard ODU2-like frame format (i.e., rates, formats and mappings that are not defined in ITU-T Recommendations). Different attributes of the varying solutions are described to help provide guidance on which approaches are appropriate to which network contexts.

Including a currently non-standard mapping in this supplement does not preclude considering that mapping for standardization at a future date.

## 2 References


[ITU-T G.694.1] ITU-T Recommendation G.694.1 (2002), *Spectral grids for WDM applications: DWDM frequency grid*.

[ITU-T G.696.1] ITU-T Recommendation G.696.1 (2005), *Longitudinally compatible intra-domain DWDM applications*.

[ITU-T G.707/Y.1322] ITU-T Recommendation G.707/Y.1322 (2003), *Network node interface for the synchronous digital hierarchy (SDH).*

[ITU-T G.709/Y.1331] ITU-T Recommendation G.709/Y.1331 (2003), *Interfaces for the optical transport network (OTN).*

[ITU-T G.798] ITU-T Recommendation G.798 (2006), *Characteristics of optical transport network hierarchy equipment functional blocks*.

[ITU-T G.870/Y.1352] ITU-T Recommendation G.870/Y.1352 (2004), *Terms and definitions for optical transport networks (OTN).*

[ITU-T G.872] ITU-T Recommendation G.872 (2001), *Architecture of optical transport networks*, plus Corrigendum 1 (2005).

[ITU-T G.959.1] ITU-T Recommendation G.959.1 (2006), *Optical transport network physical layer interfaces*.

[ITU-T G.8001/Y.1354] ITU-T Recommendation G.8001/Y.1354 (2006), *Terms and definitions for Ethernet frames over Transport (EoT).*

[ITU-T G.8010/Y.1306] ITU-T Recommendation G.8010/Y.1306 (2004), *Architecture of Ethernet layer networks,* plus Amendment 1 (2006).

[ITU-T G.8012/Y.1308] ITU-T Recommendation G.8012/Y.1308 (2004), *Ethernet UNI and Ethernet NNI*, plus Amendment 1 (2006).

[ITU-T G.8251] ITU-T Recommendation G.8251 (2001), *The control of jitter and wander within the optical transport network (OTN).*

[IEEE 802.3] IEEE 802.3 (2005), *IEEE Standard for Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications*.

## 3 Definitions

### 3.1 Terms defined elsewhere

This Supplement uses the following terms defined elsewhere:

**3.1.1 preamble**: See [IEEE 802.3]. 7 octets that precede the SFD prior to an Ethernet packet/traffic unit. Originally used for collision detection for half-duplex Ethernet interfaces operating at speeds of 100 Mbit/s and lower.

**3.1.2 inter-packet gap (IPG)**: See [IEEE 802.3]. A delay or time gap between CSMA/CD packets intended to provide interframe recovery time for other CSMA/CD sublayers and for the physical medium.

**3.1.3 start of frame delimiter (SFD)**: See [IEEE 802.3]. The SFD field is the sequence 10101011. It immediately follows the preamble pattern and indicates the start of a frame.

### 3.2 Terms defined in this Supplement

*None.*

## 4 Abbreviations and acronyms

This Supplement uses the following abbreviations:

CBR10G: See [ITU-T G.870/Y.1352].

CBR2.5G: See [ITU-T G.870/Y.1352].

IaDI: See [ITU-T G.870/Y.1352].

IrDI: See [ITU-T G.870/Y.1352].

OCC, OCCr: See [ITU-T G.870/Y.1352].

## 5 Conventions

*None.*

## 6 Standard mappings

### 6.1 10G base-W (WAN PHY) via STM-64

[IEEE 802.3] has defined a WAN interface for compatibility with SDH/SONET transport. In the Ethernet domain, this interface is supported via a WAN interface sub-layer (clause 50 of [IEEE 802.3]) that limits the effective data rate of the XGMII from 10 Gbit/s to 9.95328 Gbit/s prior to 64B/66B coding and insertion in an SDH/SONET format frame. The mapping of this data into the frame of an SDH STM-64 (VC-4-64c) is illustrated in Annex F of [ITU-T G.707/Y.1322].

Even if the interface provides only the ±20 ppm clock accuracy required by clause 50 of [IEEE 802.3] rather than SDH clock tolerances (±4.6 ppm), this can be transported via ODU2 according to the mapping specified in clause 17.1.2 of [ITU-T G.709/Y.1331].

## 6.2 GFP-F mapping of 10G base-R (LAN PHY) payload only into OPU2

A payload information transparent mapping can be performed according to clause 7.3 of [ITU-T G.709/Y.1331] using the following process:

- Terminate (sink) the 64B/66B line code, the preamble, SFD, and IPG as per [IEEE 802.3].
- Apply GFP-F framing.
- Encode into an OPU2 according to clause 7.3 of [ITU-T G.709/Y.1331].

On the assumption that MAC frames do not on average exceed the maximum size specified by [IEEE 802.3] (1518 octets excluding the preamble, SFD and IPG), the bit rate required is for a signal that is +100 ppm from the nominal bit rate approximately 9'922'968.791 kbit/s.

If maximum size jumbo frames are used, the bit rate required for a signal that is +100 ppm from the nominal bit rate is approximately 9'995'002.399 kbit/s.

Note that in the mapping of GFP frames into OPUk specified in clause 7.3 of [ITU-T G.709/Y.1331], the entire OPU2 payload area of 9'995'277 kbit/s is available (i.e., the fixed stuff bytes of the CBR10G mapping are not present). For an OPU2 that is running at the minimum rate of –20 ppm from the nominal value, this is reduced to 9'995'077.058 kbit/s.

With standard 802.3 termination, this mapping can fully transport every ETH_CI traffic unit from a 10G base-R signal over an OPU2. Refer to Table V.4 of [ITU-T G.7041/Y.1303], where a characterization is given of the MAC rate throughput (not counting overhead) of 10G base-R signals vs. GFP mappings. The MAC rate throughput of a 10G base-R interface assuming a worst-case situation of 9618 byte jumbo-frames is 9'986'502 bit/s. The MAC rate throughput of GFP mapping of the same MAC frames into ODU2 is 9'986'970 bit/s, which is greater than what is required to carry the entire MAC payload from a 10G base-R signal.

# 7 Non-standard mappings

This means rates, formats and mappings that are not fully defined in ITU-T Recommendations.

## 7.1 Bit-transparent mapping of 10G base-R signal into OPU2e

It uses the mapping scheme of CBR10G signal into OPU2, defined in clause 17.1.2 of [ITU-T G.709/Y.1331]. The client signal, 10GbE LAN PHY, with fixed stuff bytes is accommodated into an OPU-like signal, further into an ODU-like signal, and then further into an OTU-like signal. These signals are denoted as OPU2e, ODU2e and OTU2e, respectively. With this mapping, the OTU2e signal must be clocked at a nominal bit rate of 11.0957 Gbit/s, as opposed to the standard OTU2 nominal bit rate of 10.709225316 Gbit/s. Further, since the signal is formed by wrapping a signal with the clock tolerance of the underlying Ethernet signal (±100 ppm) rather than that of a standard OTU2 signal (±20 ppm), standard methods for control of jitter and wander according to [ITU-T G.8251] do not apply.

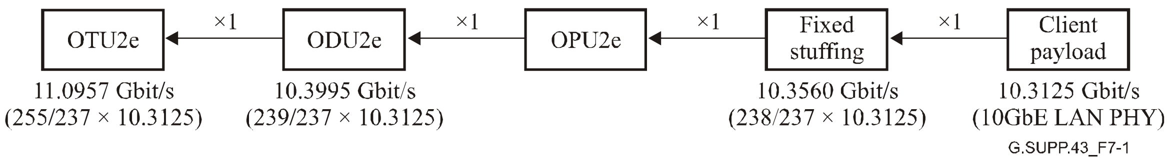


**Figure 7-1 – Mapping structure with fixed stuffing**

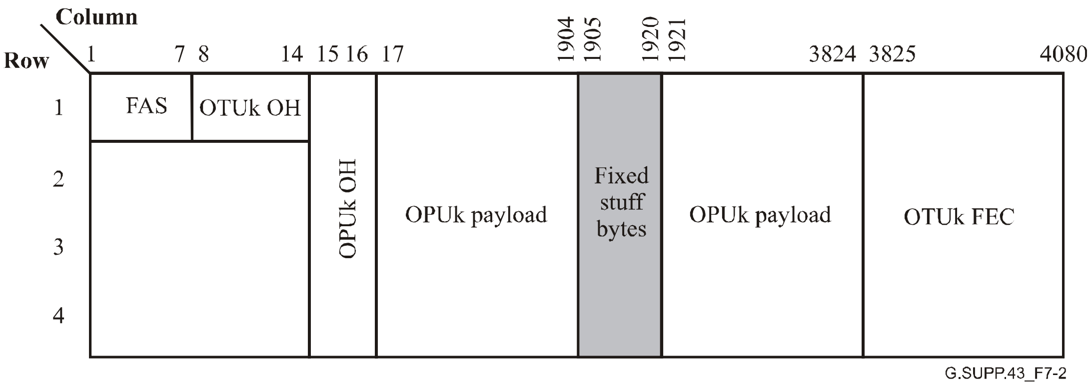


**Figure 7-2 – Mapping frame with fixed stuff bytes**

## 7.2 Bit-transparent mapping of 10G base-R signal into OPU1e

This mapping uses the mapping of CBR2G5 signal into OPU1, defined in clause 17.1.1 of [ITU-T G.709/Y.1331]. It has the same attributes as the clause 7.1 mapping above, but since the fixed stuff bytes of the CBR10G mapping are not left free, the overall data rate is somewhat less (11.0491 Gbit/s rather than 11.0957 Gbit/s). As with the clause 7.1 option, the clock tolerance of the underlying Ethernet signal (±100 ppm) rather than that of a standard OTU2 signal (±20 ppm), standard methods for control of jitter and wander according to [ITU-T G.8251] do not apply.

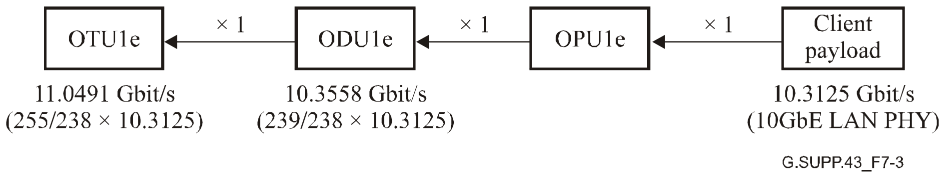


**Figure 7-3 – Mapping structure without fixed stuffing**

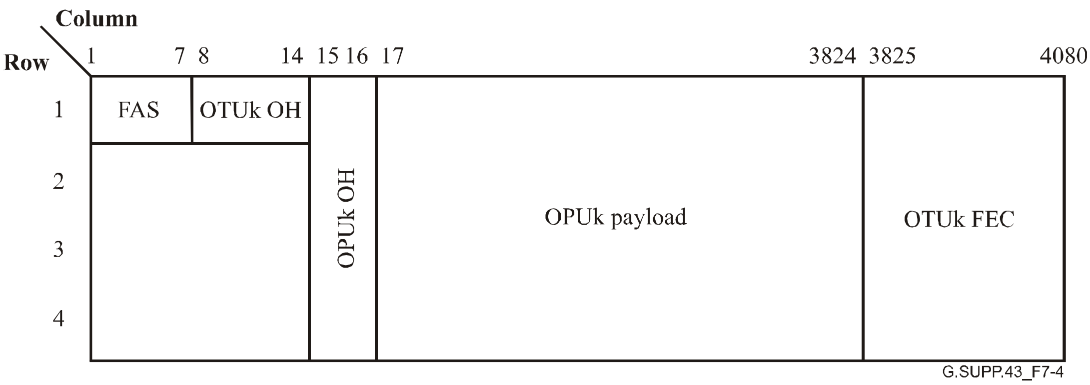


**Figure 7-4 – Mapping frame without fixed stuff bytes**

### 7.3 G.709 bit rate compliant information transparent transport of payload and preamble

*Using 64B/66B information to delimit data and ordered sets*

A 10 GbE LAN signal is made up of several layers as shown in Figure 7-5:

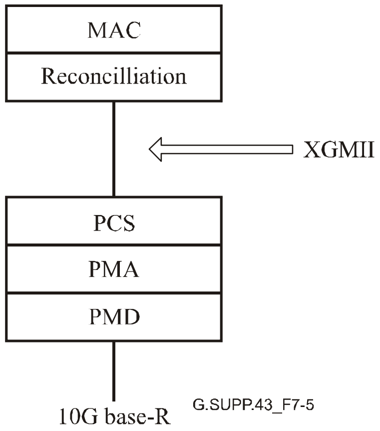


**Figure 7-5 – 10 GbE LAN model**

The PCS sublayer is described in clause 49 of [IEEE 802.3].

*GFP-F encapsulation*

User data is encapsulated using an 8-byte GFP-F header.

Ordered sets are encapsulated using an 8-byte GFP-F header. The first byte of the ordered set has the four most significant bits set to all zero and the four least significant bits equal to the O Code. This way both Sequence and Signal Ordered Sets can be transferred. The next three bytes contain the three Data bytes of the Ordered Set.

The 8-byte header includes:

- 2 bytes – PDU length indicator (PLI);
- 2 bytes – cHEC;
- 2 bytes – GFP type;
- 2 bytes – tHEC.

The GFP Type field is shown in Figure 6-5 of [G.7041/Y.1303].

The UPI field indicates data or ordered sets. The rest of the fields are static.

- PTI = 000 (Client Data);
- PFI = 0 (No FCS);
- EXI = 0000 (Null Extension Header);
- UPI = proprietary (1111 1101 preferred (New code for 64B/66B Encoded Data for 10GbE));

  = proprietary (1111 1110 preferred (New code for 64B/66B Ordered Sets for 10GbE)).

NOTE – The control codes such as Idle, Error and the reserved codes, are not transferred. The UPI codepoints are from the range reserved for proprietary use as per [ITU-T G.7041/Y.1303].

*Mapping to OPU2*

The 10GbE LAN signal does not transmit timing or synchronization information, so there is no need to do stuffing. The "Mapping & Concatenation Specific" Bits of the OPU Overhead (Bytes 1, 2, and 3 of column 15 and all of column 16) are used to carry data.

The Payload Type (proprietary, 1000 0111 preferred) called "64B/66B Mapping of GFP-F frames" from the range of proprietary use codes allocated by [ITU-T G.709/Y.1331] is used to distinguish this mapping from the standard GFP-F framing described in clause 6.2.

## 8 Characteristics of alternative mappings

Table 8-1 provides a summary of the characteristics and applicability of each of the different mappings. Further discussion of each of these characteristics is provided in the indicated clauses of this Supplement.

**Table 8-1 – Characteristics of alternative mappings**

| Mapping | Clause 6.1 | Clause 6.2 | Clause 7.1 | Clause 7.2 | Clause 7.3 |
|---|---|---|---|---|---|
| G.709 bit rate compliant (see 8.1) | Yes | Yes | No | No | Yes |
| IrDI/IaDI (see 8.2) | Both | Both | IaDI only | IaDI only | Both |
| Clock Tolerance of client Ethernet signal (see 8.3) | ±20 ppm (Note 1) | ±100 ppm | ±100 ppm | ±100 ppm | ±100 ppm |
| Clock Tolerance of ODUxx signal (see 8.3) | ±20 ppm | ±20 ppm | ±100 ppm | ±100 ppm | ±20 ppm |
| Jitter/Wander according to [ITU-T G.8251] (see 8.3) | Yes | Yes | No | No | Yes |
| G.959.1 optical tributary class (see 8.4) | NRZ/RZ 10G | NRZ/RZ 10G | NRZ/RZ 40G | NRZ/RZ 40G | NRZ/RZ 10G |
| G.696.1 Client Class (see 8.4) | 10G | 10G | 40G | 40G | 10G |
| Multiplex to 40G according to [ITU-T G.709/Y.1331] (see 8.5) | Yes | Yes | No | No | Yes |
| Transport Full Rate Payload (see 8.6) | No | Yes | Yes | Yes | Yes |
| Transport Full Rate Preamble and Payload (see 8.6) | Yes | No | Yes | Yes | Yes |
| Transport IPG (see 8.6) | Yes | No | Yes | Yes | No |
| Full bit transparency (see 8.6) | Yes | No | Yes | Yes | No |

**Table 8-1 – Characteristics of alternative mappings**

| Mapping | Clause 6.1 | Clause 6.2 | Clause 7.1 | Clause 7.2 | Clause 7.3 |
|---|---|---|---|---|---|
| Support undisclosed proprietary usage of MAC or PCS sublayer (see 8.6) | Yes | No | Yes | Yes | Yes (Note 2) |
| BER monitoring based on PCS (see 8.7) | Yes | No | Yes | Yes | No |
| NOTE 1 – [IEEE 802.3] specifies ±20 ppm for the clock tolerance for a 10G base-W interface. [ITU-T G.707/Y.1322] indicates that 10G base-W signals that meet the stricter clock tolerance of ±4.6 ppm may be transported as STM-64 in an SDH network. However, the mapping into ODU2 supports any CBR10G signal including STM-64 and 10G base-W that has a clock tolerance of ±20 ppm.<br>NOTE 2 – Proprietary usage of the preamble is supported. Proprietary usage of the IPG is not. | | | | | |

## 8.1 G.709 bit rate compliant

The G.709 bit rate that is generally used to transport signals of approximately 10 Gbit/s is OPU2. The nominal bit rate for an OPU2 payload is 9'995'276.962 kbit/s. This may transport signals directly via mappings such as GFP-F, or via STM-64 using the CBR10G mapping specified in clause 17.1.2 of [ITU-T G.709/Y.1331]. Mappings that comply with the G.709 bit rate are networkable signals according to the OTN architecture specified in [ITU-T G.872].

## 8.2 Inter-domain/intra-domain interfaces

[ITU-T G.872] specifies two different types of interfaces to be used in the optical transport network. Inter-domain interfaces (IrDI) are standardized interfaces that may be used at handoff points between operators or between equipment from different vendors within an operator's environment. Intra-domain interfaces (IaDI) are generally applicable only within a single vendor island within an operator's network to enable the use of unique optical technology, dispersion management, etc., in the context of long-haul optical line systems.

The mappings of 10G base-R signals via OPU2e and OPU1e according to clauses 7.1 and 7.2 are inherently intra-domain interfaces. They are not standard G.709 bit rate signals. They do not interwork with standard mappings of Ethernet, e.g., using GFP-F. The two over-clocked mechanisms do not interwork with each other. As a result, such signals are generally only deployed in a point-to-point configuration between equipment that implements the same mapping.

## 8.3 Timing and synchronization

The timing tolerance for G.709 signals is ±20 ppm. The timing tolerance for 10G base-R Ethernet signals is ±100 ppm. Mappings that simply wrap the Ethernet signal in a G.709-like frame (e.g., those described in clauses 7.1 and 7.2) derive their timing from the Ethernet signal, and hence have a timing accuracy of ±100 ppm.

The control of jitter and wander for G.709 signals having a timing accuracy of ±20 ppm has been extensively analysed in [ITU-T G.8251]. No such analysis has been done for Ethernet-based signals with a timing accuracy of ±100 ppm. Signals with a timing accuracy of ±100 ppm should generally only be deployed in point-to-point situations where jitter and wander accumulation is not an issue.

## 8.4 Optical characteristics

[ITU-T G.959.1] specifies optical tributary classes for 10G operation that are applicable to signals from 2.4 Gbit/s to 10.71 Gbit/s. Signals above 10.71 Gbit/s, including the two over-clocked mappings only fall within the 40G range of 9.9 Gbit/s to 43.02 Gbit/s. [ITU-T G.696.1] specifies a similar set of ranges for client classes of 10G and 40G. Since the signals according to 7.1 and 7.2

exceed the 10G ranges, the spectral characteristics are beyond that of a standard 10G channel, which should be taken into account in selecting the appropriate frequency grid for transport of these signals.

### 8.5 Multiplexing, multi-service

[ITU-T G.709/Y.1331] provides for multiplexing of 10-Gbit/s signals via ODU2 into ODU3. This multiplexing hierarchy allows for optimizing fibre capacity by carrying the largest number of bits per wavelength.

As long as standard bit-rate signals are used in the network, multiplexing to 40 Gbit/s as specified in clause 19 of [ITU-T G.709/Y.1331] is straightforward. Multi-service networking is possible: it is not necessary that all 10-Gbit/s ODU2s be transporting the same type of signal. ODU2 signals carrying diverse payloads including STM-64, GFP-F mapped Ethernet, or in turn multiplexing four 2.5-Gbit/s ODU1 signals can be combined in the same 40-Gbit/s wavelength.

But this multiplexing mechanism relies on ODU2 signals of a standard bit rate (10'037'273.924 kbit/s) and timing tolerance (±20 ppm). This multiplexing mechanism is not specified for non-standard bit rates (e.g., the ODU2e (10.3995 Gbit/s) and ODU1e (10.3558 Gbit/s) signals described in clauses 7.1 and 7.2, respectively. These two non-standard bit-rates cannot be multiplexed with any standard bit-rate signals or with each other. The stuff opportunities of the G.709 multiplexing mechanism are also designed based on an assumption of ±20-ppm timing tolerance.

### 8.6 Transparency

Ethernet is a packet technology. Clause 6 of [ITU-T G.8010/Y.1306] defines the characteristic information of an Ethernet layer network as being a non-contiguous flow of ETH_CI traffic units, each consisting of a destination address, a source address, and a MAC service data unit, delimited by headers and trailers that are link specific.

#### 8.6.1 Information transparency

All of the mappings discussed in this Supplement carry the flow of ETH_CI traffic units, and hence are transparent to the Ethernet layer network characteristic information.

#### 8.6.2 MAC frame transparency

The link specific headers and trailers used for ETH_CI traffic units carried using the mappings described in this Supplement are summarized in Table 8-2.

**Table 8-2 – ETH_CI header and trailer used in different mappings**

| Mapping (Clause) | Header format | Trailer format | Inter-frame filler |
|---|---|---|---|
| 6.1 | Preamble + SFD | MAC FCS | IPG |
| 6.2 | GFP Header | MAC FCS | GFP Idle |
| 7.1 | Preamble + SFD | MAC FCS | IPG |
| 7.2 | Preamble + SFD | MAC FCS | IPG |
| 7.3 | GFP header + Preamble + SFD | MAC FCS | GFP Idle |

In [IEEE 802.3], preambles, SFD, and IPG are considered as overhead – not as payload. They do not transit a bridge or a repeater in any standardized full-duplex Ethernet technology. They were originally put into the frame format to support collision detection for half-duplex Ethernet interfaces at 100 Mbit/s, and lower rates. As this is effectively "free space" for full-duplex interfaces, there have been cases where the preamble and IPG have been used to transmit data for undisclosed proprietary purposes.

There are cases where a requirement has been expressed that the preamble and IPG should be carried intact over a transport network. To satisfy this requirement for transport of non-standard Ethernet, it is occasionally necessary to use non-standard mappings in the transport network.

### 8.6.3 Full-rate transparency

As described above, Ethernet is a packet technology. Ethernet interfaces exist at a variety of rates. Multiple different rates of interfaces can be utilized in the same Ethernet network, with packet flows being routed at bridges in the network to their destinations.

Since Ethernet is a packet technology rather than a circuit technology, there is no guarantee that there is enough bandwidth to transport all of the packets routed over any specific link. This may occur because a variety of link speeds are used in the network, or simply because packets may arrive at a bridge over many different links that are routed to the same link, exceeding the capacity of that link. Congestion of this sort can result in delays and discarded packets when the buffer capacity at the bridge is exceeded. This is all part of normal Ethernet operation.

Nevertheless, there are cases where it is deemed important to transport every packet from a 10G base-R Ethernet interface over a transport network.

The mapping described in clause 6.1 is accomplished via a 10G base-W (10G WAN PHY) interface on an Ethernet bridge. Normal Ethernet bridge operation will result in a maximum packet flow over that link that is approximately 3% less than the maximum possible using a 10G base-R (10G LAN PHY) interface.

The mapping described in clause 6.2 is capable of transporting the full packet rate of a 10G base-R interface even though the serial bit rate available in the OPU2 is lower. The reasons that the same packet flow can be supported over a lower bit rate include:

- the use of the OTN scrambler (clause 11.2 of [ITU-T G.709/Y.1331]) rather than 64B/66B coding to ensure the transitions required for framing the received signal;
- the use of GFP to delimit packets rather than MAC framing. The GFP header uses the same number of octets as the preamble and SFD, but for MAC framing an IPG is required (minimum 12 octets) following the MAC FCS.

The use of non-standard mappings (clauses 7.1 and 7.2) is only necessary to achieve both the full 10G base-R packet rate and the MAC frame transparency (see clause 8.6.2) that would permit non-standard use of the preamble and IPG or PCS sublayer.

## 8.7 BER monitoring

[ITU-T G.709/Y.1331] provides in the ODUk frame structure for BER monitoring independent of the transmitted client signal using a BIP-8 parity check. This is available at the path (ODUk) and section (OTUk) layer, plus up to six layers of tandem connection monitoring.

In addition, mappings that transport the 64B/66B coding of the PCS sublayer can perform BER monitoring from MAC termination to MAC termination within the client layer itself through the detection of invalid 66B codewords.

Mappings that decode 64B/66B before transmitting the packets (e.g., clause 6.2 using GFP-F framing) can still utilize this coding for BER monitoring across the segments of the path using a 10G base-R physical interface, but would use the BIP-8 within the ODU2 overhead to monitor BER for OTN segments of the path.

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