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Recommendation

ITU-T G.709.20 (04/2024)

SERIES G: Transmission systems and media, digital systems and networks

Digital terminal equipments – General

Overview of fine grain OTN

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Recommendation ITU-T G.709.20

Overview of fine grain OTN

Summary

Recommendation ITU-T G.709.20 provides an overview of functions provided by the fine grain OTN (fgOTN) layer network and identifies Recommendations where the functions are defined.

History *

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1 Scope

This Recommendation provides an overview of functions provided by the fine grain OTN (fgOTN) layer network and identifies Recommendations where the functions are defined.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T G.709] Recommendation ITU-T G.709/Y.1331 (2020), *Interfaces for the optical transport network*.

[ITU-T G.823] Recommendation ITU-T G.823 (2000), *The control of jitter and wander within digital networks which are based on the 2048 kbit/s hierarchy*.

[ITU-T G.825] Recommendation ITU-T G.825 (2000), *The control of jitter and wander within digital networks which are based on the synchronous digital hierarchy (SDH)*.

[ITU-T G.872] Recommendation ITU-T G.872 (2024), *Architecture of the optical transport network*.

[IEEE 802.3] IEEE 802.3-2018, *IEEE Standard for Ethernet*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 Terms defined in [ITU-T G.709]

– optical transport network (OTN)

– optical data unit k (ODUk)

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

APS Automatic Protection Switching

CBR Constant Bit Rate

CPE Customer Premises Equipment

fgGMP Fine Grain Generic Mapping Procedure

fgODUflex	Fine Grain Flexible Optical Data Unit
fgOPU	Fine Grain Optical Payload Unit
fgOTN	Fine Grain Optical Transport Network
fgTS	Fine Grain Tributary Slot
HRM	Hypothetical Reference Model
LPF	Low Pass Filtering
NE	Network Element
ODUflex	Flexible Optical Data Unit
ODUk	Optical Data Unit-k
OTN	Optical Transport Network
PM	Path Monitoring
SDH	Synchronous Digital Hierarchy
TCM	Tandem Connection Monitoring
TDM	Time Division Multiplexing
TS	Tributary Slot
VC	Virtual Container

5 Conventions

This Recommendation uses the following conventions:

None.

6 Application scenario and hypothetical reference modes of fgOTN

6.1 Application scenario

As synchronous digital hierarchy (SDH) phases out in operators' networks, fine grain OTN (fgOTN) technology complementing the existing optical transport network (OTN) with an additional fgOTN path layer network is used as an alternative to carry private line services. Historically, SDH networks based on a time division multiplexing (TDM) mechanism are used to transport low-rate signals, while the minimal container of OTN defined in [ITU-T G.709] is ~1.25G which is inefficient to transport these low rate (e.g., sub1G) signals using existing methods. A new fine grain ODU layer network has been defined to carry these low rate signals across the OTN networks, to provide isolated, secure, reliable and TDM-based transport capabilities.

6.2 Hypothetical reference model (HRM) of fgOTN

A hypothetical reference network showing multiple sub1G clients using fgOTN connections is illustrated in Figure 6-1. The sub1G clients could be packet services or constant bit rate (CBR) services.

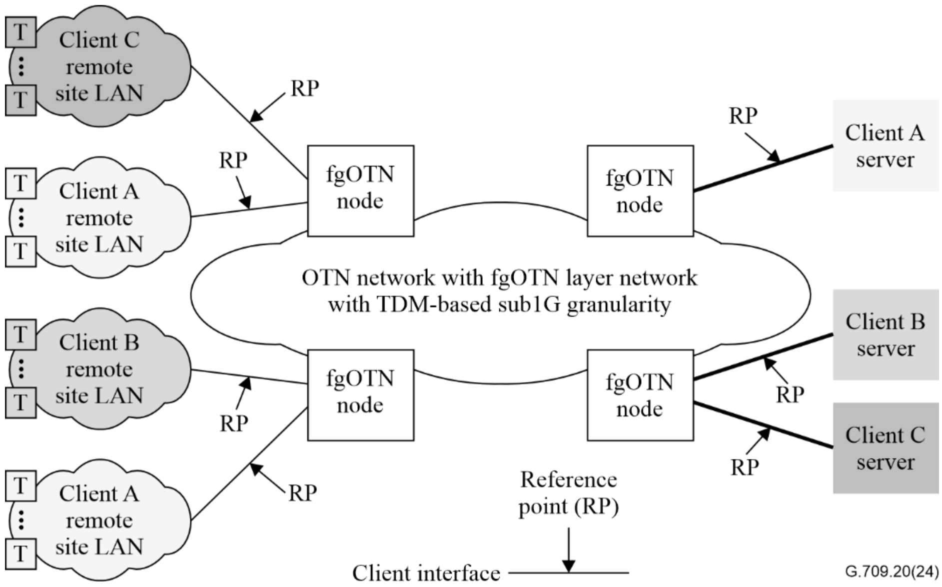

Figure 6-1 – HRM for sub1G clients over fgOTN network

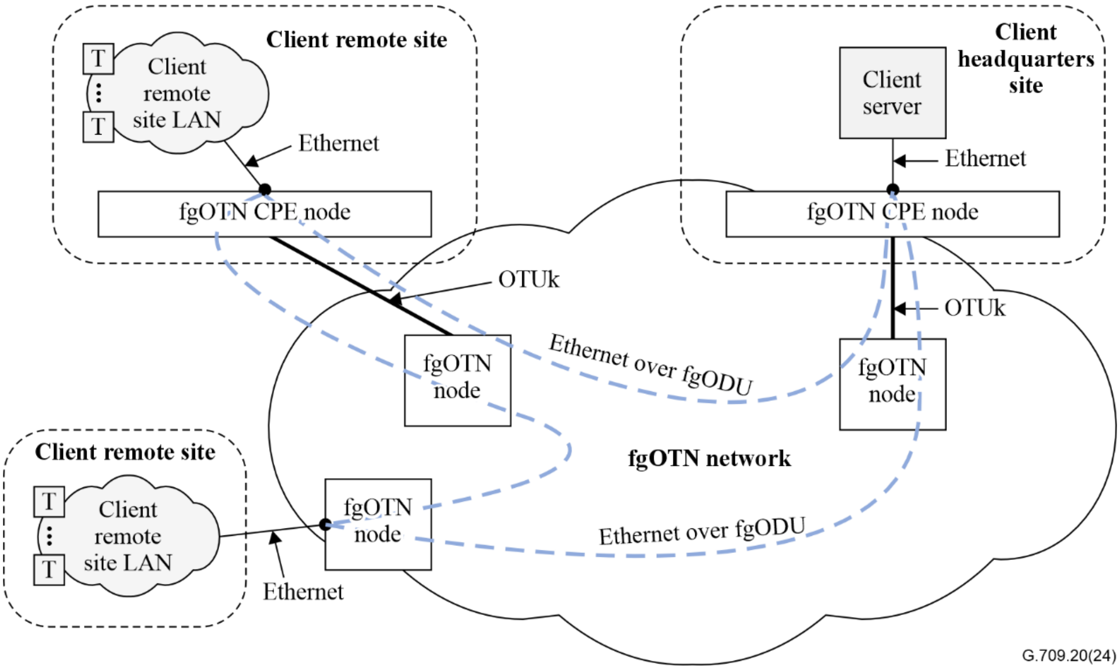

Figure 6-2 – Example of packet clients over fgOTN connections

Figure 6-2 shows an example of packet clients over fgOTN connections either between the remote sites and the headquarters or between the remote sites. The option of using customer premises equipment (CPE) to terminate the fgOTN connections is also illustrated. The packet client connections share the same type of interface at both the remote sites and at the headquarters site. Each Ethernet signal which contains the consolidated traffic of the remote site is encapsulated into a fgOTN container which is transported in the fgOTN networks. Ethernet signals could be connected to either fgOTN equipment which is within the operators' networks or fgOTN CPE equipment which is within the client remote sites.

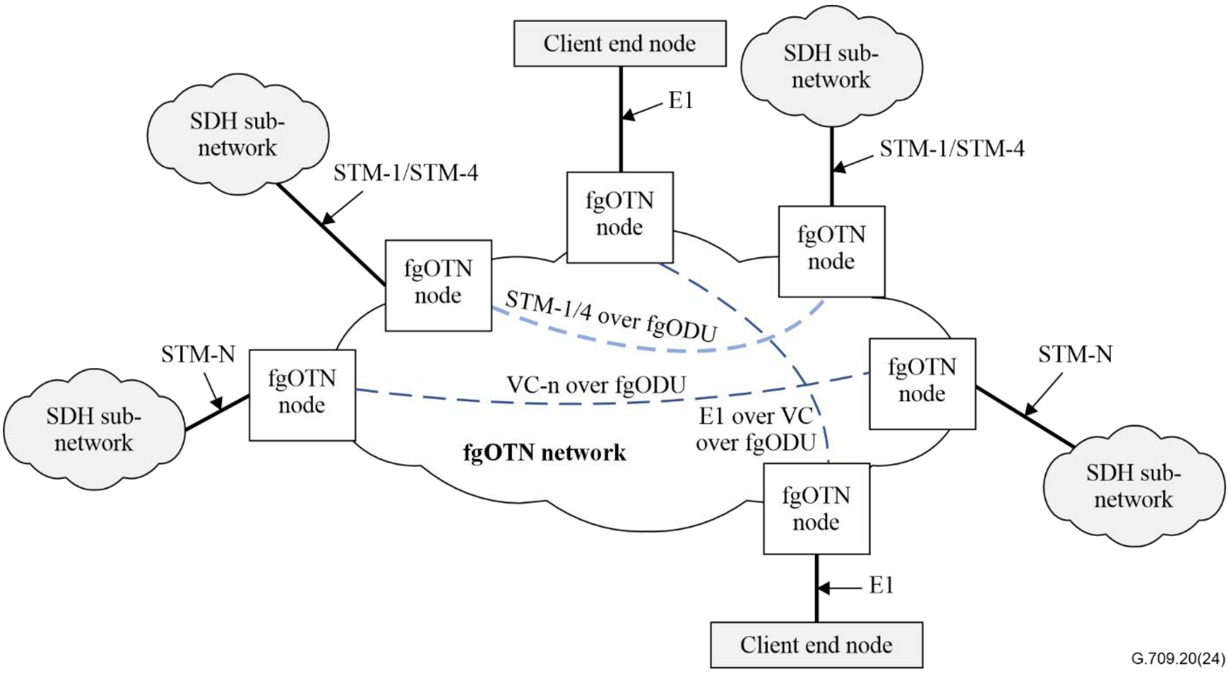

Figure 6-3 – Example of CBR clients over fgOTN connections

Figure 6-3 shows an example of CBR clients over fgOTN connections. fgOTN equipment could support STM-1, STM-4 and E1 interfaces, and fgOTN containers could carry CBR clients which include STM-1, STM-4, and VC-n/E1 (E1 signal from E1 interface is firstly mapped into VC-12 and subsequently mapped into a fgOTN container). Each CBR client is encapsulated into its own fgOTN container. CBR client signals could be connected to either fgOTN equipment which is within the operators' networks or fgOTN CPE equipment which is within the client remote sites.

Table 6-1 gives the fgOTN network topology considerations.

Table 6-1 – fgOTN network topology

Traffic pattern	Remote to headquarters	Y
	Between remote sites	Y
	Both	Y
Redundancy	Protection/restoration in transport network	Y
	Client interfaces	Y
	Physically diverse feeds to client locations	N
	Dual feed to redundant servers	Y
Network size	Number of fgOTN switching nodes	Max~20
	TCM levels	2
	Number of remotes connected to the headquarters	100 ~ 3,000
	Max connection length	~6,900 km

All connections provided by the fgOTN transport network are bidirectional point to point.

Table 6-2 gives the fgOTN connection characteristics.

Table 6-2 – fgOTN connection characteristics

Granularity of tributary slots	CBR service	K × 10 Mbit/s
	Packet service	N × 10 Mbit/s (Note)
Server capacity		ODU0/1/2/flex(fgTS,n) (where n = 3 to 7)
Maximum number of client connections		ODU0 ~ 119 ODU1 ~ 238 ODU2 ~ 952 ODUflex(fgTS,n) ~ n*119
Maximum client size	CBR service	STM-4
	Packet service	~1.19 Gbit/s
NOTE – A 10 Mbit/s tributary slot should support a full rate mapping of a 10 Mbit/s Ethernet service.		

7 General functional requirements of fgOTN

The general functional requirements of fgOTN are given as follows:

a) fgOTN should support TDM multiplexing. TDM multiplexing provides hard isolation for the client signals of fgOTN. fgOTN should support deterministic latency to guarantee the performance of OTN networks.

b) fgOTN should support mapping services into a fine grain flexible optical data unit (fgODUflex) path layer, including Ethernet services such as p*10M MAC data stream (p = 1 to 119), CBR services (STM-1/4, VC-n/E1) (E1 signal from E1 interface is encapsulated into VC-12 and subsequently encapsulated into the fgODUflex container).

c) fgOTN should support multiplexing multiple fgODUflex signals into ODU0/1/2/flex(fgTS,n) (where n = 3 to 7).

d) fgOTN should support fgODUflex SNCP 1+1 protection (for 50M services and above the switching time should be within 50 ms, while for 10M~50M services the switching time within 50 ms is recommended).

e) fgOTN should support the fgOTN equipment functions.

f) fgOTN should support timing transparent transport for CBR services. For VC-n services, fgOTN should share a common synchronization source on both the source network element (NE) and the sink NE.

g) fgOTN should support fgODUflex hitless bandwidth adjustment function for packet services.

8 Overview of fgOTN Rcommendation series

This clause provides an overview of the fgOTN Recommendations where the functions are defined.

8.1 fgOTN architecture

The information structure for fgODUflex is represented by information containment relationships and flows. The principal information containment relationship is described in Figure 8-1.

A client signal is mapped into the fgODUflex payload area and the generated justification control information is inserted into fgOPUflex overhead area. It generates the fgODUflex path connection monitoring information which is inserted into fgODUflex PM overhead. Furthermore, it generates the fgODUflex tandem connection monitoring information which is inserted into fgODUflex tandem connection monitoring (TCM) overhead. It supports two levels of fgODUflex tandem connection monitoring. The generated fgODUflex signal is mapped into one or multiple fine grain tributary slots of the server OPU.

The fgOTN layer architecture is defined in Annex A of [ITU-T G.872].

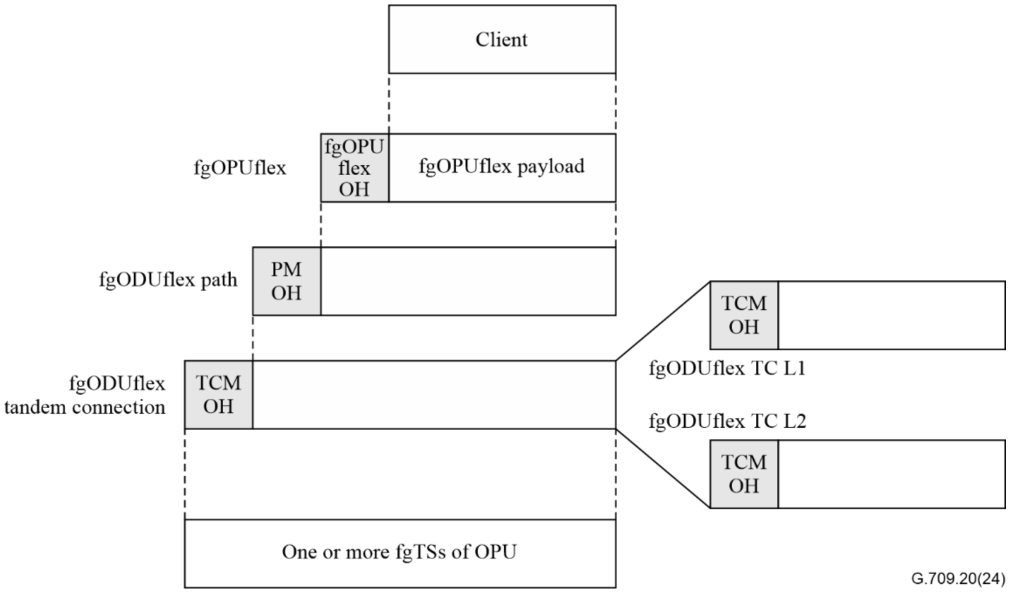

Figure 8-1 – fgODUflex principal information containment relationship

8.2 fgOTN interface

The fgOTN interface is defined in Annex M of [ITU-T G.709].

OPU server/fgODUflex adaptation is defined in Annex N of [ITU-T G.709].

Hitless bandwidth adjustment of fgODUflex is defined in Annex O of [ITU-T G.709].

8.3 Hitless resizing

The location of the hitless resizing specification(s) is given in Annex O of [ITU-T G.709].

Annex A

Reference network model example

(This annex forms an integral part of this Recommendation.)

An example of a reference network model for a multi-domain fgOTN application is shown in Figure A.1. There is one backbone OTN network, two metro OTN networks and two fgOTN CPEs in this model.

Figure A.1 – A reference network model for multi-domain fgOTN application

To support both fgOTN and optical data unit-k (ODUk) based services, metro OTN networks should support both fgODUflex and ODUk switching. At the boundary nodes (e.g., metro-core nodes) of the metro OTN networks, the fgODUflexes to other metro OTN networks are multiplexed into ODUk of backbone networks. Therefore, the backbone OTN network could only support ODUk switching.

The metro OTNs consist of metro-core, metro-aggregation and metro-access nodes. For a fgOTN that spans across the backbone network, the maximum number of fgOTN cross-connect nodes is 20.

Annex B

Detailed functional requirements of fgOTN

(This annex forms an integral part of this Recommendation.)

The detailed functional requirements of fgOTN are given as follows:

B.1 fgOTN layer architecture

The fgOTN complements the existing OTN with an additional fgOTN path layer network that provides bandwidth efficient TDM support for sub1G services. This fgOTN layer network is a service layer network of the OTN ODUk layer network.

B.2 fgOTN frame format

The fgOTN frame format is a byte-oriented fgODUflex frame structure, enhanced to support the overhead performance requirements. The fgODUflex overheads include FAS/MFAS, PM (TTI, BIP-8, BEI, BDI, STAT, APS, and DM), 2 levels of TCM (TTI, BIP-8, BEI/BIAE, BDI, STAT, APS, and DM), PT, CSF, DAi, and overheads related to hitless bandwidth resizing.

B.3 fgOTN/client adaptation functions

The requirements and functions defined for packet services and CBR services are given in clauses B.3.1 and B.3.2.

B.3.1 Packet services

The fgOTN should support packet services, and the packet services are assumed to be Ethernet.

1) The support for the MEF 6.3 Ethernet services is required:
   - Ethernet virtual private line (EVPL) service either between a pair of remote sites, or between a remote site and a headquarters site.
   - Ethernet private line (EPL) service between a pair of remote sites.

   NOTE – The EPL service is only supported when the physical interfaces at both sites are dedicated to the remote-to-remote connection.
2) Packet services that use a physical coding sublayer (PCS) codeword transparent mapping are not supported by fgOTN.
3) Packet services are mapped into the server layer which supports a granularity of ~10 Mbit/s.
4) Ethernet packet services will be encoded into 64B/66B blocks according to [IEEE 802.3] clause 82. Rate adaptation of encoded Ethernet packet stream into the fgOTN payload area is performed by IMP. Error marking is required for packet services.
5) Low pass filtering (LPF) function is not required at fgOTN intermediate switching nodes for fgODUflex carrying packet services.
6) Timing transparent transport is not required for packet services.
7) Hitless bandwidth adjustment should be supported for packet services.

B.3.2 CBR services

1) The main application for CBR services is to provide support for legacy SDH services after SDH equipment phases out.

The following CBR services could be mapped into fgODUflex containers:

- STM-1, STM-4, VC-n/E1.

The following CBR interfaces could be provided by a fgOTN edge node:

- STM-1, STM-4, E1.

VC-n signals could be from STM-N (N=1,4,16, etc.) interfaces.

E1 signal from E1 interfaces is encapsulated into VC-12 and subsequently encapsulated into fgODUflex containers.

2) Functional requirements include timing transparency, DM and automatic protection switching (APS).

3) CBR services that could be mapped over the fgOTN path: STM-1/STM-4, v_1*VC-12 (v_1 = 1, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55 and 60), v_2*VC-3 (v_2 = 1 and 2), and VC-4.

4) Rate adaptation of CBR clients into the fgODUflex payload area is performed by generic mapping procedure (GMP).

5) Timing transparency, i.e., transfer of client timing information is required for CBR services.

6) For VC-n clients, the fgOTN should share a common synchronization source on both the source NE and the sink NE. The CnD is not required when mapping VC-n into fgODUflex via GMP, i.e., VC-n synchronization is performed with an additional synchronization network outside, without needing to transport timing synchronization.

B.4 ODUk/fgOTN adaptation functions

FgGMP is used for adapting the fgODUflex path signal into the ODU server layer. The ODU server container is ~n*1.25 Gbit/s ODUflex/ODUk, and the maximum rate of an ODU server for direct mapping of fgODUflex path signals is ~10 Gbit/s (ODU2). The interleaving granularity of tributary slots for mapping fgODUflex path signals into ODUflex/ODUk is 16-byte. The tributary slot (TS) bandwidth granularity is slightly above 10 Mbit/s. An ODU0 consists of 119 TSs.

B.5 Protection

Unidirectional 1+1 protection and bidirectional 1+1 protection should be supported for fgOTN. For client rates which equal to or greater than 50 Mbit/s, 50 ms protection switch time is required. For client rate below 50 Mbit/s, protection switch time could be relaxed. The APS field encoding for bidirectional 1+1 protection could be different from the current ITU-T G.709 definition. One path monitoring (PM) level APS and two TCM level APS are needed.

B.6 Equipment

The equipment aspects of fgODUflex trail termination functions, fgODUflex connection function, fgODUflex/client adaptation functions and ODUP/fgODUflex adaption function should be supported.

FgOTN should support switching function based on fgODUflex. The PM/TCM monitoring of fgODUflex, PRBS testing and fgODUflex delay measurement are needed.

B.7 Synchronization

When STM-1, STM-4 or VC/E1 is carried as a client of the fgOTN network, the jitter and wander should be as defined in [ITU-T G.823] and [ITU-T G.825]. These mappings should provide timing transparency but do not need to transfer SDH network synchronization information. An E1 carried by a VC-12 across the fgOTN network should meet the jitter and wander requirements as defined in [ITU-T G.823].

B.8 Management

Management requirements of fgOTN are to be determined.

Protocol-neutral information model of fgOTN is to be determined.

B.9 Hitless resizing

Hitless adjustment of fgODUflex should be supported to hitlessly increase or decrease the bandwidth of fgODUflex connections in OTN networks. Hitless resizing should be with a completion time in the order of seconds or less. The resizing uses a single-step mechanism rather than a ramp. The granularity of bandwidth adjustment is ~10 Mbit/s. The need for low-pass filtering at intermediate nodes should be avoided.

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