Optical Transport Networks & Technologies Standardization Work Plan
Issue 34, July 2024

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General

This is a living document and may be updated even between meetings. The latest version can be found at the following URL.

https://www.itu.int/en/ITU-T/studygroups/com15/Pages/otn.aspx Proposed modifications and comments should be sent to: ITU-T TSB.

From the Issue 22, the document is split into two parts to separate the up-to-date snapshot-type information and comprehensive database-type information.

- Part 1 provides highlights of relevant SDOs' activity.
- Part 2 updated.

Editor of the document thanks continuous support of the SDOs and their information regularly provided.

Splitting the document and its information into the two parts is one of the attempts to make this kind of information useful and attractive to the potential readers. ITU-T SG15 is considering more effective way to provide the information and efficient way to maintain and update it. Regarding Part 1, setting up the common template for reporting is one idea. For Part 2, automated database representation is under consideration in ITU.

Any comments, not only the correction and update of the information but also the ways to provide the information are highly appreciated.

Part 1: Status reports as of July 2024

1 Highlight of ITU-T SG15

Highlights from the most recent SG15 Plenary meeting can be found here:
https://www.itu.int/en/ITU-T/studygroups/2017-2020/15/Pages/exec-sum.aspx

2 Reports from other organizations

The table below highlights the latest status reports received from the relevant organizations. ITU-T members can see the details of the reports by accessing ITU-T SG15 temporary documents for plenary. Some TDs may be from earlier SG15 plenaries.

Table 1 – Summary of status reports from relevant organizations

ID	Organization	Summary	Reference
1	Broadband Forum	Liaison Report for Broadband Forum Related to WP3/15. The liaison report highlights some key initiatives and particular activities of interest to WP3. Initiatives: Open Broadband; 5G; Common YANG. Specific areas of interest: 5G Transport; TR-350 Ethernet Services using BGP MPLS-based Ethernet VPNs; FlexE in IP/MPLS Networks for 5G; YANG for Ethernet OAM/CFM and Alarm Models; Deterministic Transport; Network Slicing.	[219-GEN]
2	IEEE 802.1	IEEE 802.1 liaison report The 802.1 working group has three active task groups: Maintenance, Time-Sensitive Networking (TSN), and Security. In addition, a coordination subgroup exists to explore IEEE 802 Network Enhancements for the Next Decade. This activity will assess emerging requirements for IEEE 802-based communication infrastructures, identify commonalities, gaps, and trends not currently addressed by IEEE 802 standards and projects, and facilitate building industry consensus towards proposals to initiate new standards development efforts. A second subgroup, YANGsters, is responsible for discussing common practice and tooling for YANG models supporting IEEE 802 protocols. The 802.1 working group has over 23 active projects ranging from revisions of existing work (like time synchronization), addition of new bridging features (like asynchronous traffic shaping), support of YANG modelling and application to new verticals (like fronthaul, automotive or industrial automation). See section 4.6.1.12	[348-GEN]
3	IEEE 802.3	See section 4.6.1.13	[333-GEN]
4	MEF	MEF liaison report	[349-GEN]

		With over 200 member companies, including many of the world's largest service providers and technology vendors, MEF is an industry forum leading the development of a global federation of network, cloud, and technology providers to establish dynamic, assured, and certified services that empower enterprise digital transformation. MEF 3.0 services are delivered over automated, virtualized, and interconnected networks powered by LSO (Lifecycle Service Orchestration), SDN, and NFV. MEF produces service standards, LSO frameworks, LSO APIs, MEF 3.0 Proof of Concept Showcases, and certification programs for services, technologies, and professionals. MEF 3.0 work will enable automated delivery of standardized Carrier Ethernet, Optical Transport, IP, SD-WAN, cybersecurity, SASE, and other Layer 4-7 services across multiple provider networks.	
5	OIF (PLL)	Liaison report for OIF Physical and Link Layer (PLL) Working Group OIF-CEI-05.0 was published in May 2022 OIF-CEI-05.1 was published Dec. 2022 CEI-04.0 Maintenance was published in OIF-CEI-05.0 CEI-224G framework white paper was revised accordingly and published as OIF-FD-CEI-224G-01.0 – Next Generation CEI-224G Framework (February 2022). CEI (Common Electrical I-O) – OIF-CEI-05.2 was published in January 2024 The following CEI (Common Electrical I-O) projects are active: • CEI-112G-Linear • CEI-112G-XSR+ PAM4 • CEI-224G-LR-PAM4 • CEI-224G-MR-PAM4 • CEI-224G-VSR-PAM4 • CEI-224G-PAM4 Protocol Agnostic Link Training • CEI-224G-Linear • E-SGMII • 1600ZR • 1600ZR+ 400ZR interop maintenance completed principal ballot comments. An 800G Coherent project is developing 800ZR and 800LR specifications	[346-GEN]

		FlexE 2.2 IA is now published as https://www.oiforum.com/wp-content/uploads/OIF-FLEXE-02.2.pdf FlexE Neighbor Discovery is now published as http://www.oiforum.com/wp-content/uploads/OIF-FLEXE-ND-01.0-.pdf (publicly available). CFP2 Digital Coherent Optics (CFP2-DCO) is now published as http://www.oiforum.com/wp-content/uploads/OIF-CFP2-DCO-01.0.pdf (publicly available). Energy Efficient Interfaces (formerly Co-Packaging) • Retimed Transmitter Linear Receiver Project • System Vendor Requirements Document for Energy Efficient Interfaces	
6	IETF	Transport related IETF work includes activities in the working groups ccamp, mpls, teas, and pce.	TD342/GEN
7	JCA IMT2020	Incoming liaison from JCA IMT2020 is in TD240/G JCA IMT2020 has updated their Standardisation Activity Roadmap which is available at JCA-IMT2020 website.	[40-GEN]
8	IEEE P1588	Liaison report for IEEE 1588. The P1588 WG has finalized in 2019 a new edition of the IEEE1588 standard, (IEEE1588-2019) (based on the 2008 version of the standard, IEEE1588-2008). This has been published on the 2020-06-16 (IEEE1588-2019). Work has started to address some aspects to be covered by future amendments of the IEEE 1588. The work is structured into several sub-committees addressing the various topics. A number of PARs have been recently approved to address these updates (see Active Projects - IEEE P1588 Working Group): - **P1588a**: Enhancements for Best Master Clock Algorithm (BMCA) mechanisms - **P1588b**: Addition of PTP mapping for transport over Optical Transport Network (OTN) - **P1588c**: Clarification of Terminology - **P1588d**: Guidelines for selecting and operating a Key Management System - **P1588e**: MIB and YANG Data Models - **P1588f**: Enhancements for latency and/or asymmetry calibration - **P1588g**: Master-slave optional alternative terminology" -	[464-GEN]

Additional information on the WG can be found on its website:
https://ieee-sa.centraldesktop.com/1588public/

Part 2: Standard work plan

1 Introduction to Part 2

Today's global communications world has many different definitions for Optical and other Transport networks, which are supported by different technologies. This resulted in a number of different Study Groups within the ITU-T, e.g., SG 11, 12, 13, and 15 developing Recommendations related to Optical and other Transport Networks and Technologies. Moreover, other standards developing organizations (SDOs), forums and consortia are also active in this area.

Recognising that without a strong coordination effort there is the danger of duplication of work as well as the development of incompatible and non-interoperable standards, WTSA-08 (held in 2008) designated Study Group 15 as the Lead Study Group on Optical and other Transport Networks and Technologies, with the mandate to:

- study the appropriate core Questions (Question 6, 10, 11, 12, 13, 14),
- define and maintain overall (standards) framework, in collaboration with other SGs and SDOs,
- coordinate, assign and prioritise the studies done by the Study Groups (recognising their mandates) to ensure the development of consistent, complete and timely Recommendations.

Study Group 15 entrusted WP 3/15, under Question 12/15, with the task to manage and carry out the Lead Study Group activities on Optical and other Transport Networks and Technologies. To avoid misunderstanding that the mandate above is only applied to G.872-based Optical Transport Network (OTN), this Lead Study Group Activity is titled Optical and other Transport Networks & Technologies (OTNT) that encompass all the related networks, technologies and infrastructures for transport as defined in clause 4.

2 Scope

As the mandate of this Lead Study Group role implies, the standards area covered relates to Optical and other Transport networks and technologies. The Optical and other Transport functions include:

- client adaptation functions
- multiplexing functions
- cross connect and switching functions, including grooming and configuration
- management and control functions
- physical media functions
- network synchronization and distribution functions
- test and measurement functions.

Apart from taking the Lead Study Group role within the ITU-T, Study Group 15 will also endeavour to cooperate with other relevant organizations, including ATIS, ETSI, ISO/IEC, IETF, IEEE, MEF, OIF and TIA.

3 Abbreviations

ANSI	American National Standards Institute
ASON	Automatically Switched Optical Network
ATIS	Alliance for Telecommunications Industry Solutions
EoT	Ethernet frames over Transport
ETSI	European Telecommunications Standards Institute
IEC	International Electrotechnical Commission

IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
ISO	International Organization for Standardization
MON	Metropolitan Optical Network
MPLS	Multiprotocol Label Switching
MPLS-TP	MPLS Transport Profile
MTN	Metro Transport Network
OIF	Optical Internetworking Forum
OTN	Optical Transport Network
OTNT	Optical and other Transport Networks & Technologies
SDH	Synchronous Digital Hierarchy
SONET	Synchronous Optical NETwork
TIA	Telecommunications Industry Association
TMF	TeleManagement Forum
WSON	Wavelength Switched Optical Network
WTSA	World Telecommunications Standardization Assembly

4 Definitions and descriptions

One of the most complicated factors in coordination work among multiple organizations in the area of OTNT is differing terminology. Often multiple different groups are utilising the same terms with different definitions. This clause includes definitions relevant to this document. See Annex A for more information on how common terms are used in different organizations.

4.1 Optical and other Transport Networks & Technologies (OTNT)

The transmission of information over optical media in a systematic manner is an optical transport network. The optical transport network consists of the networking capabilities/functionalities and the technologies required to support them. For the purposes of this standardization and work plan, all *new* optical transport networking functionalities and the related other transport technologies will be considered as part of the OTNT standardization work plan. The focus will be the transport and networking of digital client payloads over fibre optic cables. Though established optical transport mechanisms in transport plane (such as Synchronous Digital Hierarchy (SDH), Optical Transport Network (OTN), Ethernet frames over Transport (EoT), Multi-protocol label switching-transport profile (MPLS-TP)) fall within this broad definition, only standardization efforts relating to *new* networking functionalities of OTN, EoT and MPLS-TP will be actively considered as part of this Lead Study Group activity. Control plane and related equipment management aspects including ASON and SDN are also within the scope. Synchronization and time distribution aspects in the above transport network technologies are also included in the definition of OTNT.

4.2 Optical Transport Network (OTN)

ITU-T Recommendation G.709 (Interfaces for the optical transport network) with its amendement defines that an optical transport network (OTN) is composed of a set of optical network elements connected by optical fibres, that provide functionality to encapsulate, transport, multiplex, route, manage, supervise and provide survivability of client signals.
The 6th edition of Recommendation ITU-T G.709 “Interfaces for the Optical Transport Network”, published in June 2020, adds 25 and 50 Gbit/s OTU, ODU and OPU frame formats and

multiplexing of lower rate ODUk/flex signals into these two OPUs. Edition *6.0* clarifies that the ODUflex(GFP) bit rate can be any rate and is not limited to the recommended bit rates, updates the OTN interface terminology, corrects the replacement signal definitions for some of the Ethernet client signals and restricts the FlexE aware sub-rate granularity to 25 Gbit/s.

ITU-T G.709 describes a flexible n x 100G frame format (OTUCn) designed for use at beyond 100G line-side and client-side interfaces, where the "C" corresponds to the Roman numeral for 100. The OTUCn format can be used for line-side interfaces up to 25.6 Tbit/s, giving system vendors the ability to develop higher-rate OTUCn line-side interfaces at their own pace over the coming 15 to 20 years, in line with market demand and technology availability and independently of progress in standardization.

OTUCn client-side interfaces will use the new, flexible n × 100G FlexO frame format and forward error correction (FEC) combined with the available client optical modules. The initial n × 100G FlexO standard, ITU-T G.709.1, was published in the beginning of 2017. Future n × 200G and n × 400G FlexO standards will be available when next-generation 200G or 400G client optical modules become available.

ITU-T G.709 provides the necessary support for 200G and 400G Ethernet under development within IEEE. OTN can support the FlexE-unaware, FlexE-aware subrate and FlexE Client services developed by OIF; in addition introducing the capability to transport frequency and time synchronization information, complementing the similar capability in packet transport networks.

The majority of OTUCn applications to be enabled by ITU-T G.709 will relate to line-side interfaces. Examples of initial OTUCn applications are likely to include:

- Interconnecting 10+ Tbit/s OTN cross connects via 200G, 300G, 400G, 500G, etc. OTUCn line ports
- Interconnecting 200G and 400G transponders, which support the 200GE and 400GE services in the IEEE Std 802.3-2022, as well as the emerging subrated n×100G FlexE-Aware services developed by OIF's FlexE Implementation Agreement project
- Interconnecting n × 100GE muxponders with 200G, 300G, 400G, 500G, etc. tunnels

ITU-T Recommendations for OTN include:

- [ITU-T G.709] provides the rates and formats used in the OTN
- [ITU-T G.709.1] specifies Flexible OTN common elements
- [ITU-T G.709.2] specifies OTU4 long-reach interface
- [ITU-T G.709.3] specifies Flexible OTN long-reach interfaces
- [ITU-T G.709.4] specifies OTU25 and OTU50 short-reach interfaces
- [ITU-T G.709.5] specifies Flexible OTN short-reach interfaces
- [ITU-T G.709.6] specifies Flexible OTN B400G long-reach interfaces
- [ITU-T G.709.20] is the Overview of fine grain OTN
- [ITU-T G.798] defines the equipment functional blocks
- [ITU-T G.872] defines OTN architecture
- [ITU-T G.807] defines optical media network architecture
- [ITU-T G.873.1] and [ITU-T G.873.2] describes linear and ring protection
- [ITU-T G.874] and [ITU-T G.875] define the management interface
- [ITU-T G.698.1], [ITU-T G.698.2] and [ITU-T G.959.1] define the physical interfaces.

According to G.872, the OTN is decomposed into the following layer structure.

Ethernet clients	Digital Clients of the OTN (including Ethernet clients)

<table>
<tr><td rowspan="4">FlexO</td><td colspan="2" rowspan="2">ODU
(ODUj/ODUk/ODUCn)</td><td>fgODUflex</td><td colspan="2" rowspan="4">OTN digital layers</td></tr>
<tr><td></td></tr>
<tr><td>OTUCn</td><td colspan="2" rowspan="2">OTU/OTUCn</td></tr>
<tr><td></td></tr>
<tr><td colspan="4">OTSiA</td><td>OTN optical media signals</td><td rowspan="2">OTN optical media layer</td></tr>
<tr><td colspan="4">Media constructs, OMS/OTS optical signal maintenance entities non-associated overhead information</td><td>OTN optical media network</td></tr>
</table>

Figure 6-1/G.872 – Overview of the OTN

The digital layers of the OTN (optical data unit (ODU), optical transport unit (OTU)) provide for the multiplexing and maintenance of digital clients. There is one-to-one mapping between an OTU and an optical tributary signal assembly (OTSiA). The OTSiA represents the optical tributary signal group (OTSiG) and the non associated overhead (OTSiG-O), which is used for management for OTSiG. The OTSiG, represents one or more optical tributary signals (OTSi) that are each characterized by their central frequency and an application identifier. This approach allows the OTU (in particular for bit rates higher than 100Gb/s) to be distributed across multiple optical tributary signals (OTSi). An interface may be created by bonding standard-rate interfaces (e.g., m * 100G), over which the OTUCn ($n \geq 1$) signal is adapted. This is known as a FlexO group and is used in G.709.1 and G.709.3. FlexO enables ODUflex services >100Gbit/s to be supported across multiple interfaces.
Below the OTSi are the media constructs (optical devices) that provide the ability to configure the media channels. A media channel is characterized by its frequency slot (i.e., nominal central frequency and width as defined in [ITU T G.694.1]). Each OTSi is guided to its destination by an independent network media channel. This is now described in G.807 and is not OTN specific.

4.2.1 400ZR Interop

The OIF 400ZR IA was approved and published 2020-March-10. It is available at https://www.oiforum.com/wp-content/uploads/OIF-400ZR-01.0_reduced2.pdf. From the IA Introduction, "This Implementation Agreement (IA) specifies a Digital Coherent 400ZR interface for two applications:

- 120 km or less, amplified, point-to-point, DWDM noise limited links.
- Unamplified, single wavelength, loss limited links."

The most recent liaison received was TD68/GEN.

In TD50/G, it is reported that updates to the OIF 400ZR IA Maintenance baseline were agreed and a motion passed to conduct a Principal Member Ballot on "OIF-400ZR-01.0 Maintenance". The 400ZR, 75 GHz DWDM amplified - Application Code (0x03) parameters can be found in Section 13.3. The EVM updates are included in section 14.4 and any new or updated optical parameter definitions can be found in Section 13.4.

4.3 Subscriber and Operator Layer 1 Services

In late 2016 the MEF launched a new project to define both Subscriber (UNI-to-UNI) and Operator (wholesale) L1 Services. The first specification defines the attributes of a Subscriber L1 service for Ethernet and Fibre Channel client protocols, used in LAN and SAN extension for data centre interconnect, as well as SONET and SDH client protocols for legacy WAN services. It was published as MEF 63 in August 2018. A parallel project has concluded on a partner specification defining Operator L1 services between a UNI and OTN ENNI (access) and between OTN ENNIs (transit). This provides the basis for streamlining the interconnection of multi-domain L1 services. It was published as MEF 64 in February 2020.

4.4 Support for mobile networks

MEF 22.3 Implementation Agreement (IA) Transport Services for Mobile Networks identifies the requirements for MEF Ethernet Services (EVC) and MEF External Interfaces (EIs such as UNIs) for use in mobile networks. It includes an amendment for small cells, support for multi-operator networks and time synchronization. It also aligns with revised MEF service definitions and attributes in MEF 6.2 and MEF 10.3. A new MEF project was launched in 2017 on Transport Services for Mobile Networks to include 5G requirements for fronthaul and the description of network slicing applicability. That amendment to MEF 22.3 was published as MEF 22.3.1 in April 2020.

SG 15 is responsible for developing Recommendations for transport networks, access networks, and home networking, including standard architectures of optical transport networks as well as physical and operational characteristics of their constituent technologies. These technologies may be used to support the backhaul, midhaul and fronthaul for mobile networks depending on the performance requirements of each.

4.5 Ethernet frames over transport

Ethernet is today the dominant LAN technology in private and enterprise sectors. It is defined by a set of IEEE 802 standards. Emerging multi-protocol/multi-service Ethernet services are also offered over public transport networks. Public Ethernet services and Ethernet frames over transport standards and implementation agreements continue being developed in the ITU-T and other organizations. Specifically, the ITU-T SG15 focuses on developing Recommendations related to the support and definition of Ethernet services over traditional telecommunications transport, such as PDH, SDH, and OTN. Ethernet can be described in the context of three major components: *services aspects*, *network layer*, and *physical layer*. The following description is meant to provide a brief overview of Public Ethernet considering each of the above aspects.

The Public Ethernet *services aspects* (for service providers) include different service markets, topology options, and ownership models. Public Ethernet services are defined to a large extent by the type(s) of topologies used and ownership models employed. The topology options can be categorized by the four types of services they support: Line services, LAN services, Tree services, and Access services. Line services are point-to-point in nature and include services like Ethernet private and virtual lines. LAN services are multi-point-to-multi-point (such as virtual LAN services). Tree services are rooted multi-point. Access services are of hub-and-spoke nature and enable single ISP/ASP to serve multiple, distinct, customers. (Due to the similar aspects from a public network perspective, Line and Access services may be essentially the same.)

The services can be provided with different service qualities. A circuit switched technology like SDH always provides a guaranteed bit rate service while a packet switched technology like MPLS can provide various service qualities from best effort traffic to a guaranteed bit rate service. Ethernet services can be provided for the Ethernet MAC layer or Ethernet physical layer.

The Ethernet *network layer* is the Ethernet MAC layer that provides end-to-end transmission of Ethernet MAC frames between Ethernet end-points of individual services, identified by their MAC addresses. Ethernet MAC layer services can be provided as Line, LAN, Tree and Access services over circuit switched technologies like SDH VCs and OTN ODUs or over packet switched technologies like MPLS. For the Ethernet LAN service Ethernet MAC bridging might be performed within the public transport network in order to forward the MAC frames to the correct destination. Ethernet MAC services can be provided at any bit rate. They are not bound to the physical data rates (i.e., 10 Mbit/s, 100 Mbit/s, 1 Gbit/s, 2.5 Gb/s, 5 Gb/s, 10 Gbit/s, 25 Gb/s, 40 Gbit/s, 50 Gb/s, 100 Gbit/s, 200 Gb/s, and 400 Gb/s) defined by IEEE.
IEEE has defined a distinct set of *physical layer* data rates for Ethernet with a set of interface options (electrical or optical). An Ethernet physical layer service transports such signals transparently over a public transport network. Examples are the transport of a 10 Gbit/s Ethernet WAN signal over an OTN or the transport of a 1 Gbit/s Ethernet signal over SDH using transparent GFP mapping. Ethernet physical layer services are point-to-point only and are always at the standardized data rates. They are less flexible compared to Ethernet MAC layer services, but offer lower latencies.

4.5.1 FlexE in OIF

OIF specified a Flex Ethernet 1.0 implementation agreement in June 2016, additional features in FlexE 2.0 in 2018, FlexE 2.1 in 2019, and FlexE 2.2 in2021.
This implementation agreement provides a bonding mechanism to create higher-rate interfaces out of multiple Ethernet PHYs, a mechanism to support smaller clients (Ethernet flows with lower effective MAC rates) over Ethernet PHYs, and a mechanism to multiplex multiple lower rate flows across a group of Ethernet PHYs. The first version of this implementation agreement is based on the bonding of 100GBASE-R Ethernet PHYs into a FlexE group.
FlexE 2.0 adds:

- Support for FlexE groups composed of 200 Gb/s and 400 Gb/s Ethernet PHYs
- More detail on use of FlexE management channels
- Consider coarser calendar granularity to reduce gate count for high bandwidth devices
- Management of skew for specific applications
- Transport of frequency or time by the FlexE group

FlexE 2.1 adds support for FlexE groups composed of 50GBASE-R PHYs. FlexE 2.2 adds support for 50 GbE PHYs.

FlexE Neighbor Discovery Implementation Agreement was published 2018-Sept-12 and specifies OIF extensions to the 802.1AB Link Layer Discovery Protocol (LLDP) for FlexE neighbor discovery.

The OIF is aware that ITU-T Rec. G.8023 captures certain behaviours of the OIF FlexE IAs.

4.6 Overview of the standardization of carrier class Ethernet

4.6.1 Evolution of "carrier-class" Ethernet

Ethernet became to be used widely in network operator's backbone or metro area networks. Although Ethernet was originally designed for LAN environment, it has been enhanced in several aspects so that it can be used in network operators' environment. In addition, Ethernet can easily realize multipoint-to-multipoint connectivity, which would require n*(n-1)/2 connections if an existing point to point transport technology is used. The following subclauses explain enhancements which have been adopted in Ethernet networks thus far.

4.6.1.1 High bit rate and long reach interfaces

IEEE Std 802.3-2022 and IEEE Std 802.3db-2022 include 100G, 200G, and 400G interfaces supporting a variety of reaches and using a variety of signalling formats. Additional high bit rate interfaces are under development by the currently active IEEE P802.3cw, IEEE P802.3df, and IEEE P802.3dj task forces.

4.6.1.2 Ethernet-based access networks

Various PON interfaces exist in IEEE Std 802.3-2022 and IEEE Std 802.3cs-2022 that may be used as Ethernet access networks.

4.6.1.3 Enhancement of scalability

VLAN technology is widely used to provide customers with logically independent networks while sharing network resource physically. However, since the 12-bit VLAN ID must be a unique value throughout the network, the customer accommodation is limited to 4094 (2 values, 0 and 4095, are reserved for other purposes).

To relax this limitation, a method which uses two VLAN IDs in a frame was standardized by IEEE Std 802.1ad (Provider Bridges) in October 2005. This method allows the network to provide up to 4094 Service VLANs, each of which can accommodate up to 4094 Customer VLANs.

4.6.1.4 Scalable Ethernet-based backbone

In order to realize further scalable networks, IEEE Std 802.1ah (Provider Backbone Bridges) specified a method which uses B-Tag, I-Tag and C-Tag. B-Tag and C-Tag include a 12-bit VLAN ID. I-Tag includes a 20-bit Service ID. One VLAN ID identifies a Customer VLAN. The Service ID identifies a service in a provider network. Another VLAN ID identifies a Backbone VLAN. This allows the network to use 12-bit VLAN ID and 20-bit service ID spaces as well as its own MAC address space. IEEE Std 802.1ah was approved in June 2008 and has since been incorporated in IEEE Std 802.1Q-2018.

4.6.1.5 The number of MAC addresses to be learned by bridges

Bridges in a network automatically learn the source MAC addresses of incoming frames. When the number of stations is large, this learning process consumes a lot of resources in each bridge. To alleviate this burden, IEEE Std 802.1ah (Provider Backbone Bridges) standardized a method which encapsulates MAC addresses of user stations by backbone MAC addresses so that bridges inside the backbone network need not learn the MAC addresses of user stations.

4.6.1.6 Network level OAM

To enable network operators to detect, localize and verify defects easily and efficiently, network-level Ethernet OAM functions were standardized in ITU-T SG13 (Q5/13) and IEEE Std 802.1ag under a close collaboration.

Recommendation ITU-T G.8013 was approved in May 2006. It was last revised in August 2015 and has had an amendment and two corrigenda since. IEEE Std 802.1ag was approved in September 2007 and has since been incorporated in IEEE Std 802.1Q as revised. IEEE Std 802.1ag covers fault management functions only while ITU-T G.8013 covers both fault management and performance monitoring. Guidance for Ethernet OAM performance monitoring was provided in G.Suppl. 53 in December 2014. Recommendation ITU-T G.8021 specifies Ethernet transport equipment processes related in particular to Ethernet OAM in support of ITU-T G.8013/Y.1731 specification. ITU-T G.8021 was last revised in December 2021.

Ethernet services performance parameters were standardized by ITU-T SG12 (Q17/12) in Recommendation Y.1563, approved in January 2009. Service OAM Framework (MEF17), Service OAM Fault Management Implementation Agreement (MEF 30.1) and Service OAM Performance Monitoring Implementation Agreement (MEF 35.1) are specified in MEF.

In October 2008, WTSA-08 transferred Q5/13 (OAM) to SG15 and ITU-T work on Ethernet OAM is now conducted in SG15.

4.6.1.7 Fast survivability technologies

To realize fast and simple protection switching in addition to Link Aggregation and Rapid Spanning Tree Protocol, Recommendation on Ethernet linear protection switching mechanism (ITU-T G.8031) was approved in June 2006. Recommendation on Ethernet ring protection (ITU-T G.8032) was approved in June 2008. In March 2010, the revised ITU-T G.8032v2 covered interconnected and multiple rings, operator commands and non-revertive mode. ITU-T G.8032 was later revised to effect refinements not impacting the protocol behavior or its state machines. In September 2016, a supplement on Ethernet linear protection switching with dual node interconnection (G.sup60) was approved. This is based on ITU-T G.8031.

In March 2012, the IEEE 802.1 Working Group (WG) developed a standard on Shortest Path Bridging (IEEE Std 802.1aq) to optimize restoration capabilities. In June 2009, they completed a standard on Provider Backbone Bridge Traffic Engineering (IEEE Std 802.1Qay), which includes linear protection switching.

In 2014, the IEEE 802.1 WG completed a revision of the IEEE 802.1AX Link Aggregation standard, introducing the Distributed Resilient Network Interface. This standard incorporates technology sometimes known as multi-chassis link aggregation, and allows the construction of multi-vendor protected network-to-network interfaces. The aims included preventing changes in one attached network from affecting the other attached network, where possible. This standard was revised in 2020 in the light of implementation experience and to ensure interoperability and proper operation.

IEEE Std 802.1CB "Frame Replication and Elimination for Reliability" was approved in 2017 as a standard with applications in the area of protection. It specifies procedures, managed objects and protocols for bridges and end stations that provide:

- Identification and replication of frames, for redundant transmission;
- Identification of duplicate frames;
- Elimination of duplicate frames;
- Stream identification.

4.6.1.8 QoS/traffic control/traffic conditioning

QoS, traffic control, and traffic conditioning issues are being studied in ITU-T (SG12 and SG13), IEEE 802.3, and MEF. IEEE 802.1 completed work in June 2009 on Provider Backbone Bridge Traffic Engineering (IEEE Std 802.1Qay).

4.6.1.9 Subscriber and Operator Ethernet Services

MEF developed MEF 10.4 Subscriber Ethernet Service Attributes, published in December 2018. MEF 6.2 EVC Ethernet Services Definitions Phase 3, published in August 2014, defines six Ethernet Services. It was updated, in particular to align with MEF 10.4, resulting in revised MEF 6.3, published in November 2019. MEF 26.2 External Network Network Interfaces (ENNI) and Operator Service Attributes was published in August 2016 and specifies Service Attributes which can be used to realize Operator Services. MEF 51.1 Operator Ethernet Service Definitions, published in December 2018, specifies Operator Virtual Connection (OVC) Services based on the Service Attributes defined in MEF 26.2. In 2018 a revision of Carrier Ethernet Services for Cloud MEF 47 was initiated to align with the updated MEF 6.3, 10.4, 26.2 and include MEF 51.1 OVC services. The revision MEF 47.1, renamed as Elastic Ethernet Services & Cloud Connectivity, was published in early 2021.

4.6.1.10 Service Activation Testing (SAT)

Recommendation Y.1564, "Ethernet service activation test methodology" was approved in SG12 in March, 2011. MEF completed MEF 48 Service Activation Testing in October 2014. An updated version MEF 48.1 was published in February 2020 to encompass the requirements and test methodologies applicable to E-Line, Access E-Line and Transit E-Line services defined in MEF 6.2 and MEF 51.1.

4.6.1.11 Time-Sensitive Networking and Deterministic Networking

Following on from the development of Audio-Video Bridging (AVB) in IEEE 802.1, itself based upon advances in time synchronisation in IEEE 1588, IEEE 802.1 renamed the AVB Task Group to Time-Sensitive Networking Task Group. This Task Group completed the Stream Reservation Protocol (IEEE Std 802.1Qat) and the Credit-based Shaper (IEEE Std 802.1Qav) to provide lossless guaranteed bandwidth over Ethernet. This was followed by the Frame Preemption (IEEE Std 802.1Qbu) project and clause 99 of IEEE 802.3-2018 (was the "Interspersing Express Traffic" project), which create an express lane for high-priority traffic. Together with the strict priority scheduling capabilities of IEEE Std 802.1Q, these technologies underpin the IEEE Std 802.1CM TSN Profile for Fronthaul. For other applications of time-sensitive streams, a combination of Enhancements for Scheduled Traffic (IEEE Std 802.1Qbv), Per-Stream Filtering and Policing (IEEE Std 802.1Qci), Cyclic Queuing and Forwarding (IEEE Std 802.1Qch) and Asychronous Traffic Shaping (IEEE Std 802.1Qcr) provide bounded latency, guaranteed bandwidth and zero congestion loss, on a network which can support best-effort traffic at the same time. An active project to define a TSN Profile for Service Provider Networks (P802.1DF) is on-going.

4.6.1.12 Status of IEEE 802.1 (updated 03/2024)

The 802.1 Working Group currently has three active Task Groups: Maintenance, Time-Sensitive Networking (TSN), and Security. In addition, a coordination subgroup exists to explore IEEE 802 Network Enhancements for the Next Decade. This activity assesses emerging requirements for IEEE 802-based communication infrastructures, identify commonalities, gaps, and trends not currently addressed by IEEE 802 standards and projects, and facilitate building industry consensus towards proposals to initiate new standards development efforts. Another subgroup, YANGsters, is responsible for discussing common practice and tooling for YANG models supporting IEEE 802 protocols.
The IEEE 802.1 Working Group has 23 active projects (not including proposed projects) ranging from revisions of existing work (like time synchronization), addition of new bridging features (like enhancements to cyclic queuing and forwarding), support of YANG modelling and application to new verticals (like industrial automation, automotive, or aerospace).

NOTE: in a liaison TD441/G from 2020-Nov-10, the IEEE 802.1 Working Group advised of their plans to withdraw IEEE Std 802.1D-2004 *IEEE Standard for Local and metropolitan area networks—Media Access Control (MAC) Bridges* by the end of 2021. It has been superseded by IEEE 802.1Q-2014. IEEE Std 802.1Q-2014 has since been revised as IEEE Std 802.1Q-2022.

Within each TG there are several active projects as shown below.

<u>Security</u>

- P802.1Qdt – Bridges and Bridges Networks–Amendment: Priority-based Flow Control Enhancements

Time-Sensitive Networking

- Standalone (specifying new base standards):
  - IEC/IEEE 60802 TSN Profile for Industrial Automation
  - P802.1CQ – Multicast and Local Address Assignment
  - P802.1DC – Quality of Service Provision by Network Systems
  - P802.1DG – TSN Profile for Automotive In-Vehicle Ethernet Communications
  - P802.1DP/SAE AS6675 – TSN Profile for Aerospace
  - P802.1DU – Cut-Through Forwarding Bridges and Bridged Networks

- 802.1Q amendments (amending IEEE Std 802.1Q-2022):
  - P802.1Qdd – Resource Allocation Protocol
  - P802.1Qdj – Configuration Enhancements for Time-Sensitive Networking
  - P802.1Qdq - Shaper Parameter Settings for Bursty Traffic requiring Bounded Latency
  - P802.1Qdv – Enhancements to Cyclic Queuing and Forwarding
  - P802.1Qdw – Source Flow Control
  - P802.1Qdx – YANG Data Model for Credit Based Shaper
  - P802.1Qdy - YANG for the Multiple Spanning Tree Protocol

- 802.1AS amendments (amending IEEE Std 802.1AS-2020):
  - P802.1ASdm – Hot Standby
  - P802.1ASdn – Time Synch YANG

- 802.1AS amendment (amending IEEE P802.1AS-2020-REV):
  - P802.1ASds – Support for the IEEE Std 802.3 Clause 4 Media Access Control (MAC) operating in half-duplex

- 802.1AX amendments (amending IEEE Std 802.1AX-2020):
  - P802.1AXdz – YANG for Link Aggregation

Maintenance

- P802-REVc – Revision to IEEE Standard 802-2014
- P802.1Q-2022-Rev – Revision of IEEE Std 802.1Q-2022 (roll-up of amendments)
- P802.1AS-2020-Rev – Revision of IEEE Std 802.1AS-2020 (roll-up of amendments)
- P802.1CS-2020/Cor1 – Corrigendum to IEEE Std 802.1CS-2020
- P802.1ACea – MAC Service Definition Amendment: Support for IEEE Std 802.15.6
- P802.1CB-2017/Cor1 – Corrigendum to IEEE Std 802.1CB-2017

Ongoing projects related to OTNT

Time-Sensitive Networking (TSN)
This task group is home to a group of standards projects:

P802.1Q-2022-Rev – Bridges and Bridged Networks

This project is a maintenance roll-up of IEEE Std 802.1Q-2022 with the amendments IEEE P802.1Qcz, IEEE P802.1Qcw and IEEE P802.1Qcj. Depending on their progress to approval, other amendments in progress may also be included.

P802.1DC – Quality of Service Provision by Network Systems

This new standard will specify procedures and managed objects for Quality of Service (QoS) features specified in IEEE Std 802.1Q, such as per-stream filtering and policing, queuing, transmission selection, flow control and preemption, in a network system which is not a bridge. IEEE Std 802.1Q specifies Quality of Service (QoS) features for bridges. These features are perfectly applicable to other devices, e.g. end stations, routers, or firewall appliances. In IEEE Std 802.1Q, the specifications of these features are scattered, and coupled tightly to the operation of a bridge. There is a need for simple reference points to these QoS specifications that are usable for non-bridge systems, and for managed objects for these features that are not specific to bridges.

P802.1ASdm – Timing and Synchronization for Time-Sensitive Applications – Amendment: Hot Standby

This amendment specifies protocols, procedures, and managed objects for hot standby without use of the Best Master Clock Algorithm (BMCA), for time-aware systems, including:

- A function that transforms the synchronized times of two generalized Precision Time Protocol (gPTP) domains into one synchronized time for use by applications;
- A function that directs the synchronized time of one gPTP domain into a different gPTP domain; and
- Mechanisms that determine whether a gPTP domain has sufficient quality to be used for hot standby.

P802.1Qdq – Shaper Parameter Settings for Bursty Traffic Requiring Bounded Latency

This amendment adds an informative annex that describes recommended shaper parameter settings for bursty traffic requiring bounded latency.

P802.1Qdt – PFC Enhancements

This amendment specifies procedures and managed objects for automated Priority-based Flow Control (PFC) headroom calculation and Media Access Control Security (MACsec) protection of PFC frames, using the existing Precision Time Protocol (PTP) and enhancements to the Data Center Bridging Capability Exchange protocol (DCBX). The proposed amendment places emphasis on the requirements for low latency and lossless transmission in large-scale and geographically dispersed data centers.

P802.1Qdv – Enhancements to Cyclic Queuing and Forwarding

This amendment specifies procedures, protocols and managed objects to enhance Cyclic Queuing and Forwarding, comprising: a transmission selection procedure that organizes frames in a traffic class output queue into logical bins that are output in strict rotation at a constant frequency; a procedure for storing received frames into bins based on the time of reception of the frame; a procedure for storing received frames into bins based on per-flow octet counters; a protocol for determining the phase relationship between a transmitter's and a receiver's bin boundaries in time; managed objects, Management Information Base (MIB), and YANG modules for controlling these procedures; and an informative annex to provide guidance for applying these procedures.

P802.1Qdw – Source Flow Control

This amendment specifies procedures, managed objects, and a YANG data model for the signaling and remote invocation of flow control at the source of transmission in a data center network. This amendment specifies enhancements to the Data Center Bridging Capability (DCBX) protocol to advertise the new capability. This amendment specifies the optional use of existing stream filters to allow bridges at the edge of the network to intercept and convert signaling messages to existing Priority-based Flow Control (PFC) frames.

YANGsters – IEEE 802 YANG editors' coordination

This subgroup is responsible for discussing common practice for YANG models supporting IEEE 802 protocols. This common practice includes, but is not limited to, URN root, style, structure, tooling and process. While the primary attendees are expected to be editors of existing IEEE 802 YANG projects, other experts interested in YANG are welcome.

P802.1ASdn - Timing and Synchronization for Time-Sensitive Applications - Amendment: YANG Data Model

This amendment specifies a YANG data model that allows configuring and state reporting for all managed objects of the base standard. This amendment specifies a Unified Modeling Language (UML)-based figure to explain the managed objects and the associated YANG data model.

P802.1Qdy - YANG for the Multiple Spanning Tree Protocol

This amendment specifies YANG modules that enable configuration and status reporting for bridges and bridge components for the Multiple Spanning Tree Protocol (MSTP). This amendment addresses MSTP requirements arising from industrial automation networks, updating existing managed objects and updating the existing Management Information Base (MIB) to match the capabilities of the YANG modules.

802 Network Enhancements for the next decade

The goal of this activity is to document emerging requirements and directions for IEEE 802 networks, identify commonalities, gaps, and trends not currently addressed by IEEE 802 standards and projects, and facilitate building industry consensus towards proposals to initiate new standards development efforts. Encouraged topics include enhancements of IEEE 802 communication networks and vertical networks as well as enhanced cooperative functionality among existing IEEE standards in support of network integration. Topics concerning higher-layer applications related to new standards development in the IEEE 802.1 Working Group are also specifically expected and encouraged. Findings related to existing IEEE 802 standards and projects are forwarded to the responsible working groups for further considerations.

Stakeholders identified to date include but are not limited to users and producers of systems and components for networking systems, data center networks, high performance computing, cloud computing, telecommunications carriers, automotive, intelligent transport systems, Internet of Things (IoT), factory automation, and industrial applications. External standardization bodies and industry organizations, such as the Internet Engineering Task Force (IETF), North American Network Operators Group (NANOG), and Telecommunications Industry Association (TIA), International Telecommunication Union (ITU), have been engaged with Nendica activities and will be encouraged to participate in enhanced cooperation.

Published IEEE 802 standards are available free of charge six months after publication from the following website: http://standards.ieee.org/getieee802/
For the first six months, they are available for sale from the following website (note that corrigenda are free of charge): http://www.techstreet.com/ieee/subgroups/38361

4.6.1.13 Status of IEEE 802.3 (Updated in 07/2024)

The following are the IEEE 802.3 standards currently in force:

- The base standard, IEEE Std 802.3-2022 was approved on 13 May 2022 and published 29 July 2022. It supersedes IEEE Std 802.3-2018.

There are eight approved and published amendment to IEEE Std 802.3-2022:

- Amendment 1: IEEE Std 802.3dd-2022, Power over Data Lines of Single Pair Ethernet, was approved by the Standards Board on 16 June 2022 and published on 31 August 2022.
- Amendment 2: IEEE Std 802.3cs-2022, Physical Layers and Management Parameters for Increased-Reach Point-to-Multipoint Ethernet Optical Subscriber Access (Super-PON), was approved by the Standards Board on 21 September 2022 and published on 18 November 2022.
- Amendment 3: IEEE Std 802.3db-2022, Physical Layer Specifications and Management Parameters for 100 Gb/s, 200 Gb/s, and 400 Gb/s Operation over Optical Fiber Using 100 Gb/s Signaling, was approved by the Standards Board on 21 September 2022 and published on 20 December 2022.
- Amendment 4: IEEE Std 802.3ck-2022, Physical Layer Specifications and Management Parameters for 100 Gb/s, 200 Gb/s, and 400 Gb/s Electrical Interfaces Based on 100 Gb/s Signaling, was approved by the Standards Board on 21 September 2022 and published on 28 December 2022.
- Amendment 5: IEEE Std 802.3de-2022, Enhancements to MAC Merge and Time Synchronization Service Interface for Point-to-Point 10 Mb/s Single-Pair Ethernet, was approved by the Standards Board on 21 September 2022 and published on 30 December 2022.
- Amendment 6: IEEE Std 802.3cx-2023, Media Access Control (MAC) Service Interface and Management Parameters to Support Improved Precision Time Protocol (PTP) Timestamping Accuracy, was approved by the Standards Board on 30 March 2023 and published on 21 April 2023.

- Amendment 7: IEEE Std 802.3cz-2023, Physical Layer Specifications and Management Parameters for Multi-Gigabit Optical Automotive Ethernet, was approved by the Standards Board on 30 March 2023 and published on 28 April 2023.
- Amendment 8, IEEE Std 802.3cy-2023, Physical Layer Specifications and Management Parameters for 25 Gb/s Electrical Automotive Ethernet was approved by the Standards Board on 29 June 2023 and published on 11 August 2023.
- Amendment 9: IEEE Std 802.3df-2024, Media Access Control Parameters for 800 Gb/s and Physical Layers and Management Parameters for 400 Gb/s and 800 Gb/s Operation, was approved by the Standards Board on 15 February 2024 and published on 15 March 2024.

The current version of the Ethernet MIBs standard is published as IEEE Std 802.3.1-2013. A maintenance project (IEEE 802.3.1b) to update this SNMP MIB document to cover the new features present in IEEE Std 802.3-2022 is in the Working Group Ballot phase.

The current version of the Ethernet YANG models is published as IEEE Std 802.3.2-2019. A maintenance project (IEEE 802.3.2a) to update this YANG model to cover the new features present in IEEE Std 802.3-2022 is in the Working Group Ballot phase.

The following Task Forces, Study Groups, and ad hoc groups are currently active within the IEEE 802.3 Working Group:

- The IEEE P802.3da 10 Mb/s Single Pair Multidrop Segments Enhancement Task Force is in the the Task Force Review phase.
- The IEEE P802.3df 400 Gb/s and 800Gb/s Ethernet Task Force is nearing completion of the Standards Association ballot phase and is expected to be approved in the first quarter of 2024.
- IEEE P802.3dg Physical Layer Specifications and Management Parameters for 100Mb/s Operation and Associated Power Delivery over a Single Balanced Pair of Conductors Task Force is in the proposal selection phase.
- IEEE P802.3dh Multi-Gigabit Optical Automotive Ethernet using Graded-Index Plastic Optical Fiber Task Force is in the proposal selection phase.
- The IEEE P802.3dj 200 Gb/s, 400Gb/s, 800Gb/s, and 1.6Tb/s Ethernet Task Force was split out of the original P802.3df task force. The final baselines were adopted in March 2024, and the editorial team is in the process of resolving comments on the draft. We anticipate sharing a draft with you when the project reaches the working group ballot phase.
- The IEEE P802.3dk Greater than 50 Gb/s Bidirectional Access PHYs Task Force is in the proposal selection phase.
- The IEEE 802.3 Ethernet for Automotive Imaging Sensors Study Group has concluded its work, and the IEEE P802.3dm Asymmetrical Electrical Automotive Ethernet Task Force has been formed.
- The IEEE P802.3dn Multi-Gigabit Automotive MDI Return Loss Task Force, which is creating Corrigendum 1 to IEEE Std 802.3-2022, is about to progress to the Standards Association Ballot phase. This corrigendum corrects errors in some PMD specifications related to automotive Ethernet PHYs.

At present there are no active Study Groups, which are study activities that have not yet reached the stage of an approved Project Authorization Request (PAR), Criteria for Standardization Development (CSD), or project objectives.

4.6.2 Standardization activities on Ethernet

Standardization work on "carrier-class" Ethernet is conducted within ITU-T SG12, ITU-T SG15, IEEE 802.1 WG, IEEE 802.3 WG, IETF, and MEF. The table below summarizes the current standardization responsibilities on "carrier-class" Ethernet. Table lists the current status of individual Ethernet-related ITU-T Recommendations.

Table 2 – Standardization on "carrier-class" Ethernet

#	Standard bodies	Q/SG or WG	Study items
1	ITU-T SG12	Q17/12	Ethernet services performance
	ITU-T SG15	Q10/15	Interfaces, Interworking, Ethernet OAM mechanisms and equipment functional architecture, Ethernet protection/restoration
		Q11/15	Ethernet Service description and frame mapping (GFP)
		Q12/15	Ethernet architecture
		Q13/15	Synchronous Ethernet
		Q14/15	Management aspects of Ethernet
3	IEEE 802	802.1	Higher layers above the MAC (including Network level Ethernet OAM mechanisms, Provider bridges, Provider backbone bridges, and quality of service)
		802.3	Standard for Ethernet
4	IETF	CCAMP WG	common control plane and measurement plane solutions and GMPLS mechanisms/protocol extensions to support source-controlled and explicitly-routed Ethernet data paths for Ethernet data planes
		MPLS WG	many elements of the support of Ethernet "carrier-class" pseudowires over MPLS and MPLS-TP networks
		L2VPN WG	Layer 2 Virtual Private Networks
		PWE3 WG	encapsulation, transport, control, management, interworking and security of Ethernet services emulated over MPLS enabled IP packet switched networks
		TEAS	Traffic Engineering Architecture and Signaling
		PCE WG	Path computation architecture for GMPLS paths
5	MEF	Digital Services Committee	Service attributes including traffic and performance parameters, Subscriber and Operator services definitions, aggregation and ENNI interfaces, management interfaces, performance, UNI monitoring, security aspects, fault management and test specifications.

4.6.3 Further details

Further details about standardization on Ethernet can be found on the following websites:
ITU-T SG12 : http://www.itu.int/ITU-T/studygroups/com12/index.asp
ITU-T SG13: http://www.itu.int/ITU-T/studygroups/com13/index.asp
ITU-T SG15: http://www.itu.int/ITU-T/studygroups/com15/index.asp
IEEE 802.1 WG: http://www.ieee802.org/1/

IEEE 802.3 WG: http://www.ieee802.org/3/
IETF: http://www.ietf.org/
MEF Forum: https://www.mef.net/

4.7 Metro Transport Network (MTN)

ITU-T SG15 has been developing a new network technology called “Metro Transport Network (MTN)” that leverages Flexible Ethernet capabilities defined in the OIF FlexE 2.1 IA. MTN consists of two non recursive layers, the MTN Path layer, and the MTN Section layer. The MTN Path layer uses the MTN Section layer as its server layer. The MTN Path layer provides configurable connection-oriented connectivity. The server layer for the MTN section layer is provided by 50GBASE-R, 100GBASE-R, 200GBASE-R, 400GBASE-R Ethernet interfaces. Ethernet clients are supported by the MTN Path layer.

As of September 2022 MTN Recommendations published are:

- G.8310 “Architecture of the metro transport network”
- G.8312 “Interfaces for metro transport networks”
- G.8331 “MTN Linear Protection”
- G.8321 “Characteristics of metro transport network equipment functional blocks”
- G.8350 “Management and control for metro transport network”

In December 2023, fine grain MTN (fgMTN) was included in:

- G.8312.20 “Overview of fine-grain MTN”
- G.8310 “Architecture of the metro transport network”

5 OTNT correspondence and Liaison tracking

5.1 OTNT related contacts

The International Telecommunication Union - Telecommunications Sector (ITU-T) maintains a strong focus on global OTNT standardization. It is supported by other organizations that contribute to specific areas of the work at both the regional and global levels. Below is a list of the most notable organizations recognised by the ITU-T and their URL for further information.

- ATIS - Alliance for Telecommunications Industry Solutions: http://www.atis.org
- TIA - Telecommunications Industry Association: http://www.tiaonline.org
- IEC - International Electrotechnical Commission: http://www.iec.ch/
- IETF - Internet Engineering Task Force: http://www.ietf.org
- IEEE 802 LAN/MAN Standards Committee: http://www.ieee802.org/
- Optical Internetworking Forum (OIF) Technical Committee: http://www.oiforum.com/public/techcommittee.html
- Broadband (ex. IP/MPLS) Forum: http://www.broadband-forum.org/
- MEF Forum: https://www.mef.net/
- TMF- TeleManagement Forum: http://www.tmforum.org/browse.aspx

6 Overview of existing standards and activity

With the rapid progress on standards and implementation agreements on OTNT, it is often difficult to find a complete list of the relevant new and revised documents. It is also sometimes difficult to find a concise representation of related documents across the different organizations that produce them. This clause attempts to satisfy both of those objectives by providing concise tables of the relevant documents.

6.1 New or revised OTNT standards or implementation agreements

Many documents, at different stages of completion, address the different aspect of the OTNT space. The table below lists the known drafts and completed documents under revision that fit into this area. The table does not list all established documents which might be under review for slight changes or addition of features.

Three major families of documents (and more) are represented by fields in the following table, SDH/SONET, OTN Transport Plane, and ASON/SDN Control. All of the Recommendations and standards of the three families are included in tables in the later clauses of this document that provide context for the topic they relate to ITU-T Recommendations may be obtained at https://www.itu.int/rec/T-REC/e.

Table 3 – OTNT Related Standards and Industry Agreements (IEEE 802 standards)

Organisation (Subgroup responsible)	Number	Title	Publication Date
IEEE 802.1	IEEE Std. 802.1AS-2020	IEEE Standard for Local and Metropolitan Area Networks - Timing and Synchronization for Time-Sensitive Applications in Bridged Local Area Networks	2020
IEEE 802.1	IEEE Std. 802.1AS-2020/Cor1-2021	Timing and Synchronization for Time-Sensitive Applications - Corrigendum 1: Technical and Editorial Corrections	2021
IEEE 802.1	IEEE Std. 802.1AB-2016	Station and Media Access Control Connectivity Discovery	2016
IEEE 802.1	IEEE Std 802.1ABdh-2021	Station and Media Access Control Connectivity Discovery Amendment 2: Support for Multiframe Protocol Data Units	2021
IEEE 802.1	IEEE Std 802.1ABcu-2021	Station and Media Access Control Connectivity Discovery Amendment 1: YANG Data Model	2021
IEEE 802.1	IEEE Std. 802.1AX-2020	Link Aggregation	2020
IEEE 802.1	IEEE Std. 802.1CB-2017	Frame Replication and Elimination for Reliability	2017
IEEE 802.1	IEEE Std 802.1CBdb-2021	Frame Replication and Elimination for Reliability Amendment 2: Extended Stream Identification Functions	2021
IEEE 802.1	IEEE Std 802.1CBcv-2021	Frame Replication and Elimination for Reliability - Amendment 1: Information Model, YANG Data Model, and Management Information Base Module	2021
IEEE 802.1	IEEE Std. 802.1Q-2022	Bridges and Bridged Networks—Revision	2022
IEEE 802.1	IEEE Std 802.1CM-2018	Time-Sensitive Networking for Fronthaul	2018
IEEE 802.1	IEEE Std 802.1CMde-2020	Time-Sensitive Networking for Fronthaul - Amendment 1: Enhancements to Fronthaul Profiles to Support New Fronthaul Interface, Synchronization, and Syntonization Standards	2020
IEEE 802.3	IEEE Std 802.3-2022	IEEE Standard for Ethernet	09/2022
IEEE 802.3	IEEE Std 802.3db-2022	Physical Layer Specifications and Management Parameters for 100 Gb/s, 200 Gb/s, and 400 Gb/s Operation over Optical Fiber Using 100 Gb/s Signaling	12/2022
IEEE 802.3	IEEE Std 802.3ck-2022	Physical Layer Specifications and Management Parameters for 100 Gb/s, 200 Gb/s, and 400 Gb/s Electrical Interfaces Based on 100 Gb/s Signaling	12/2022

IEEE 802.3	IEEE Std 802.3cx-2023	Media Access Control (MAC) Service Interface and Management Parameters to Support Improved Precision Time Protocol (PTP) Timestamping Accuracy	04/2023
IEEE 802.3	IEEE Std 802.3.1-2013	IEEE Standard for Management Information Base (MIB) Definitions for Ethernet	08/2013
IEEE 802.3	IEEE Std 802.3.2-2013	IEEE Standard for Ethernet YANG Data Model Definitions	03/2019
IEEE 802.3	IEEE Std 802.3df-2024	Media Access Control Parameters for 800 Gb/s and Physical Layers and Management Parameters for 400 Gb/s and 800 Gb/s Operation	02/2024

Table 4 – OTNT Related Standards and Industry Agreements (MEF documents)

Category	Number	Title
Service Definitions	6.3	Subscriber Ethernet Services Definitions
Service Definitions	8	Implementation Agreement for the Emulation of PDH Circuits over Metro Ethernet Networks
Service Definitions	22.3	Implementation Agreement – Transport Services for Mobile Networks
Service Definitions	22.3.1	Amendment to MEF 22.3: Transport Services for Mobile Networks
Service Definitions	43	Virtual NID (vNID) Functionality for E-Access Services
Service Definitions	47.1	Elastic Ethernet Services & Cloud Connectivity
Service Definitions	51.1	Operator Ethernet Service Definitions
Service Definitions	62	Managed Access E-Line Service Implementation Agreement
Service Definitions	65	Simplified Transit E-Line Service
Service Definitions	69.1	Subscriber IP Service Definitions
Service Definitions	118	Zero Trust Framework for MEF Services
Service Attributes	10.4	Subscriber Ethernet Service Attributes
Service Attributes	23.2	Class of Service Phase 3 Implementation Agreement
Service Attributes	23.2.1	Models for Bandwidth Profiles with Token Sharing
Service Attributes	23.2.2	Satellite Performance Tier
Service Attributes	26.2	External Network Network Interface (ENNI) and Operator Service Attributes
Service Attributes	41	Generic Token Bucket Algorithm
Service Attributes	41.0.1	Amendment to MEF 41: Clarification of Generic Token Bucket Algorithm (GTBA) Behavior
Service Attributes	45.1	Layer 2 Control Protocols in Ethernet Services
Service Attributes	61.1	IP Service Attributes
Service Attributes	61.1.1	UNI Access Link Trunks, IP Addresses, and Mean Time to Repair Performance Metric
Service Attributes	63	Subscriber Layer 1 Service Attributes
Service Attributes	64	Operator Layer 1 Service Attributes and Services
Service Attributes	70.1	SD-WAN Service Attributes and Service Framework
Service Attributes	74	Commercial Affecting Attributes
Service Attributes	88	Application Flow Security for SD-WAN Services
Service Attributes	117	SASE Service Attributes and Service Framework
Service Attributes	130	Device Physical and Environmental Service Attributes
Service Attributes	126	Network Slice Performance Profiles
Architecture	2	Requirements and Framework for Ethernet Service Protection
Architecture	3	Circuit Emulation Service Definitions, Framework and Requirements in Metro Ethernet Networks
Architecture	4	Metro Ethernet Network Architecture Framework Part 1: Generic Framework
Architecture	11	User Network Interface (UNI) Requirements and Framework
Architecture	12.2	Carrier Ethernet Network Architecture Framework Part 2: Ethernet Services Layer
Architecture	13	User Network Interface (UNI) Type 1 Implementation Agreement
Architecture	20	UNI Type 2 Implementation Agreement
Architecture	29	Ethernet Services Constructs
Architecture	32	Requirements for Service Protection Across External Interfaces
Architecture	68	Cloud Services Architecture
Architecture	114	DLT-Based Commercial and Operational Services Framework – Billing
Information and Data Models	7.4	MEF Services Model: Information Model for Carrier Ethernet Services
Information and Data Models	31	Service OAM Fault Management Definition of Managed Objects (SNMP)
Information and Data Models	31.0.1	Amendment to Service OAM SNMP MIB for Fault Management
Information and Data Models	36.1	Service OAM SNMP MIB for Performance Monitoring
Information and Data Models	38	Service OAM Fault Management YANG Modules
Information and Data Models	39	Service OAM Performance Monitoring YANG Module
Information and Data Models	40	UNI and EVC Definition of Managed Objects (SNMP)

Category	Number	Title
Information and Data Models	42	ENNI and OVC Definition of Managed Objects (SNMP)
Information and Data Models	44	Virtual NID (vNID) Definition of Managed Objects (SNMP)
Information and Data Models	56	Interface Profile Specification – Service Configuration and Activation
Information and Data Models	58	Legato - EVC Services YANG - Service Configuration and Activation
Information and Data Models	59	Network Resource Management - Information Model: Connectivity
Information and Data Models	60	Network Resource Provisioning - Interface Profile Specification
Information and Data Models	72.1	Network Resource Model – Subscriber & Operator Layer 1
Information and Data Models	78.1	MEF Core Model (MCM)
Information and Data Models	82	MEF Services Model – Information Model for SD-WAN Services
Information and Data Models	83	Network Resource Model – OAM
Information and Data Models	86	Presto Service OAM Interface Profile Specification
Information and Data Models	89	Resource Model - Common
Information and Data Models	95	MEF Policy Driven Orchestration
Information and Data Models	95.0.1	Amendment to MEF 95: Policy Driven Orchestration
Information and Data Models	111	MEF Services Model: Information Model for Layer 1 Connectivity Service
Information and Data Models	112	MEF Services Model: Information Model for IP/IP VPN
Information and Data Models	125	LSO Cantata and LSO Sonata Subscriber Ethernet Product Schemas and Developer Guide
Information and Data Models	106	LSO Sonata Access E-Line Product Schemas and Developer Guide
Service Activation and Test	46	Latching Loopback Protocol and Functionality
Service Activation and Test	48.1	Ethernet Service Activation Testing
Service Activation and Test	49	Service Activation Testing Control Protocol and PDU Formats
Service Activation and Test	49.0.1	Amendment to Service Activation Testing Control Protocol and PDU Formats
Service Activation and Test	67	Service Activation Testing for IP Services
SOAM Fault and Performance Management	17	Service OAM Framework and Requirements
SOAM Fault and Performance Management	30.1	Service OAM Fault Management Implementation Agreement Phase 2
SOAM Fault and Performance Management	30.1.1	Amendment to MEF 30.1 - Correction to Requirement
SOAM Fault and Performance Management	35.1	Service OAM Performance Monitoring Implementation Agreement
SOAM Fault and Performance Management	66	SOAM for IP Services
SOAM Fault and Performance Management	133	Allegro, Interlude and Legato Fault Management and Performance Monitoring BR&UC
Element Management	15	Requirements for Management of Metro Ethernet Phase 1 Network Elements
Element Management	16	Ethernet Local Management Interface
MEF Service Lifecycle	50.1	MEF Services Lifecycle Process Flows
MEF Service Lifecycle	52	Carrier Ethernet Performance Reporting Framework
MEF Service Lifecycle	53	Ethernet Services Qualification Questionnaire
MEF Service Lifecycle	54	Ethernet Interconnection Point (EIP): An ENNI Implementation Agreement
MEF Service Lifecycle	55.1	Lifecycle Service Orchestration (LSO): Reference Architecture and Framework
MEF Service Lifecycle	57.1	Ethernet Ordering Technical Standard - Business Requirements and Use Cases
MEF Service Lifecycle	57.2	Product Order Management Business Requirements and Use Cases
MEF Service Lifecycle	76	Service Control Business Requirements and Use Cases
MEF Service Lifecycle	79	Address, Service Site, and Product Offering Qualification Management - Requirements and Use Cases
MEF Service Lifecycle	79.0.1	Amendment to MEF 79: Address, Service Site, and Product Offering Qualification Management Requirements and Use Cases
MEF Service Lifecycle	79.0.2	Amendment to MEF 79: Address Validation

Category	Number	Title
MEF Service Lifecycle	80	Quote Management Requirements and Use Cases
MEF Service Lifecycle	81	Product Inventory Management - Requirements and Use Cases
MEF Service Lifecycle	81.0.1	Amendment to MEF 81: Product Inventory Management
MEF Service Lifecycle	87	LSO Cantata and LSO Sonata Product Offering Qualification API – Developer Guide
MEF Service Lifecycle	113	Trouble Ticketing Requirements and Use Cases
MEF Service Lifecycle	137	LSO Cantata and LSO Sonata Appointment and Work Order Management API – Developer Guide
MEF Service Lifecycle	124	LSO Cantata and LSO Sonata Trouble Ticket and Incident Management API – Developer Guide
MEF Service Lifecycle	115	LSO Cantata and LSO Sonata Quote Management API – Developer Guide
MEF Service Lifecycle	116	LSO Cantata and LSO Sonata Product Inventory API – Developer Guide
MEF Service Lifecycle	120	Lean NFV Overview and Framework
MEF Service Lifecycle	121	LSO Cantata and LSO Sonata Address Management API – Developer Guide
MEF Service Lifecycle	122	LSO Cantata and LSO Sonata Site Management API – Developer Guide
MEF Service Lifecycle	128	LSO API Security Profile
MEF Service Lifecycle	134	Draft Release 1 Invoice Business Requirements and Use Cases
Test Requirements & Abstract Test Suites	9	Abstract Test Suite for Ethernet Services at the UNI
Test Requirements & Abstract Test Suites	14	Abstract Test Suite for Traffic Management Phase 1
Test Requirements & Abstract Test Suites	18	Abstract Test Suite for Circuit Emulation Services
Test Requirements & Abstract Test Suites	19	Abstract Test Suite for UNI Type 1
Test Requirements & Abstract Test Suites	21	Abstract Test Suite for UNI Type 2 Part 1 Link OAM
Test Requirements & Abstract Test Suites	24	Abstract Test Suite for UNI Type 2 Part 2 E-LMI
Test Requirements & Abstract Test Suites	25	Abstract Test Suite for UNI Type 2 Part 3 Service OAM
Test Requirements & Abstract Test Suites	27	Abstract Test Suite For UNI Type 2 Part 5: Enhanced UNI Attributes & Part 6: L2CP Handling
Test Requirements & Abstract Test Suites	34	ATS for Ethernet Access Services
Test Requirements & Abstract Test Suites	37	Abstract Test Suite for ENNI
Test Requirements & Abstract Test Suites	90	SD-WAN Certification Test Requirements
Test Requirements & Abstract Test Suites	90.1	SD-WAN Phase 2 Test and Certification Requirements
Test Requirements & Abstract Test Suites	91	Carrier Ethernet Test Requirements
Test Requirements & Abstract Test Suites	91.0.1	Amendment to MEF 91: Satellite Performance Tier
Test Requirements & Abstract Test Suites	131	MEF Secure SD-WAN Certification Test Requirements

The current set of MEF technical specifications is at:
https://www.mef.net/learn/mef-technical-standards-sdks/standard-type-view/

6.2 SDH & SONET Related Recommendations and Standards

Refer to Issue 21 of this standard work plan document.

6.3 ITU-T Recommendations on the OTN Transport Plane

The following table lists all the known ITU-T Recommendations specifically related to the OTN Transport Plane. Many also apply to other types of optical networks.

Table 5 – ITU-T Recommendations on the OTN Transport Plane

	ITU-T Published Recommendations
Definitions	**G.870** Definitions and Terminology for Optical Transport Networks (OTN)
Architectural Aspects	**G.800** Unified functional architecture of transport networks **G.805** Generic functional architecture of transport networks **G.807** Generic functional architecture of the optical media network **G.872** Architecture of Optical Transport Networks
Management and Control	See section 6.4.
Structures & Mapping	**G.709**Interfaces for the Optical Transport Network (OTN)
	G.709.1 Flexible OTN common elements
	G.709.2 OTU4 long-reach interface
	G.709.3 Flexible OTN long-reach interfaces
	G.709.4 OTU25 and OTU50 short-reach interfaces
	G.709.5 Flexible OTN short-reach interfaces
	G.709.6 Flexible OTN B400G long-reach interfaces
	G.709.20 Overview of fine grain OTN
	G.703 Physical/electrical characteristics of hierarchical digital interfaces
	G.975 Forward Error Correction
	G.798 Characteristics of optical transport network (OTN) equipment functional blocks
	G.798.1 Types and characteristics of optical transport network equipment
	G.806 Characteristics of transport equipment - Description Methodology and Generic Functionality
	G.7041 Generic Framing Procedure
	G.7042 Link capacity adjustment scheme (LCAS) for virtual concatenated signals
	G.Sup43 Transport of IEEE 10GBASE-R in optical transport networks (OTN)
	G.Sup58 Optical transport network module framer interfaces
	G.Sup67 Application of OTN to 5G Transport
	G.Sup70 Sub 1 Gbit/s services transport over OTN
	G.Sup76 OTN security
Protection Switching	**G.873.1** Optical Transport network (OTN) - Linear Protection
	G.873.2 ODUk shared ring protection
	G.873.3 OTN shared mesh protection
Management Aspects	**G.874** Management aspects of the optical transport network element
	G.Imp874 Implementer's Guide
	G.875 Optical Transport Network (OTN) Protocol-Neutral Management Information Model For The Network Element View
	G.876 Management Requirement and Information/Data Model for Media
	G.Imp874.1 Implementer's Guide
	G.7710 Common Equipment Management Requirements
	G.7711 Generic protocol-neutral information model for transport resources
	G.7714 Generalized automatic discovery for transport entities
	G.7714.1 Protocol for automatic discovery in SDH and OTN networks
Data Communication Network (DCN)	**G.7712** Architecture and specification of data communication network
Error Performance	**G.8201** Error performance parameters and objectives for multi-operator international paths within the Optical Transport Network (OTN)
	M.2401 Error Performance Limits and Procedures for Bringing-Into-Service and Maintenance of multi-operator international paths and sections within Optical Transport Networks

	ITU-T Published Recommendations
Jitter & Wander Performance	**G.8251** The control of jitter and wander within the optical transport network (OTN)
Physical-Layer Aspects	**G.664** General Automatic Power Shut-Down Procedures for Optical Transport Systems
	G.691 Optical Interfaces for single-channel STM-64 and other SDH systems with Optical Amplifiers,
	G.692 Optical Interfaces for Multichannel Systems with Optical Amplifiers
	G.693 Optical interfaces for intra-office systems
	G.694.1 Spectral grids for WDM applications: DWDM frequency grid
	G.694.2 Spectral grids for WDM applications: CWDM wavelength grid
	G.695 Optical interfaces for Coarse Wavelength Division Multiplexing applications
	G.696.1 Intra-Domain DWDM applications
	G.697 Optical monitoring for DWDM system
	G.698.1 Multichannel DWDM applications with single-channel optical interfaces
	G.698.2 Amplified multichannel DWDM applications with single channel optical interfaces
	G.698.3 Multichannel seeded DWDM applications with single-channel optical interfaces
	G.698.4 Multichannel bi-directional DWDM applications with port agnostic single-channel optical interfaces
	G.959.1 Optical Transport Networking Physical Layer Interfaces
	G.Sup.39 Optical System Design and Engineering Considerations
Fibres	**G.651.1** Characteristics of a 50/125 µm multimode graded index optical fibre cable for the optical access network
	G.652 Characteristics of a single-mode optical fibre and cable
	G.653 Characteristics of a dispersion-shifted single mode optical fibre and cable
	G.654 Characteristics of a cut-off shifted single-mode fibre and cable
	G.655 Characteristics of a non-zero dispersion shifted single-mode optical fibre and cable
	G.656 Characteristics of a fibre and cable with non-zero dispersion for wideband optical transport
	G.657 Characteristics of a bending loss insensitive single mode optical fibre and cable for the access network
	G.Sup40 Optical fibre and cable Recommendations and standards guideline
Components & Sub-systems	**G.661** Definition and test methods for the relevant generic parameters of optical amplifier devices and subsystems
	G.662 Generic characteristics of optical amplifier devices and subsystems
	G.663 Application related aspects of optical amplifier devices and subsystems
	G.665 Generic characteristics of Raman amplifiers and Raman amplified subsystems
	G.666 Characteristics of PMD compensators and PMD compensating receivers
	G.667 Characteristics of Adaptive Chromatic Dispersion Compensators
	G.671 Transmission characteristics of optical components and subsystems
	G.672 Characteristics of multi-degree reconfigurable optical add/drop multiplexers

6.4 Standards on Architectural approaches to Management and Control

The following table lists ITU-T Recommendations specifically related to ASON and SDN Control.

Table 6 – Standards on the ASON/SDN Control Plane

Topic	Title
Definitions	**G.8081** Definitions and Terminology for Automatically Switched Optical Networks (ASON)
Architecture	**G.7701** Common Control Aspects
	G.7702 Architecture for SDN control of transport networks
	G.7703 Architecture for the Automatic Switched Optical Network (ASON)
Protocol Neutral Specifications for key signalling elements	**G.7713** Distributed Call and Connection Management (DCM)
	G.Imp7713 Implementer's Guide
	G.7713.1 Distributed Call and Connection Management based on PNNI
	G.Imp7713.1 Implementer's Guide

Topic	Title
	G.7713.2 Distributed Call and Connection Management: Signalling mechanism using GMPLS RSVP-TE
	G.7713.3 Distributed Call and Connection Management : Signalling mechanism using GMPLS CR-LDP
	G.Imp7713.3 Implementer's Guide
	G.7714 Generalised automatic discovery for transport entities
	G.7714.1 Protocol for automatic discovery in SDH and OTN networks
	G.Imp7714.1 Implementer's Guide
	G.7715 Architecture and requirements for routing in the automatically switched optical network
	G.Imp7715 Implementer's Guide
	G.7715.1 ASON routing architecture and requirements for link state protocols
	G.Imp7715.1 Implementer's Guide
	G.7715.2ASON routing architecture and requirements for remote route query
	G.7716 Architecture of management and control operations
	G.7718 Framework for the management of management-control components and functions
	G.7718 Framework for the management of management-control components and functions
	G.7719 Management information model for management-control components and functions
	G. 7712 Architecture and specification of data communication network
Data Communication Network (DCN)	

The following table lists IETF RFCs related to Management and Control domain of OTN.

Table 7 – IETF work related to Control Plane

RFC	**Title**	**Working Group**
RFC8282	Extensions to the Path Computation Element Communication Protocol (PCEP) for Inter-Layer MPLS and GMPLS Traffic Engineeringhttps://datatracker.ietf.org/doc/rfc8282/	
RFC8283	An Architecture for Use of PCE and the PCE Communication Protocol (PCEP) in a Network with Central Control	
RFC8363	GMPLS OSPF-TE Extensions in Support of Flexi-Grid Dense Wavelength Division Multiplexing (DWDM) Networks https://datatracker.ietf.org/doc/rfc8363/	
RFC8413	Framework for Scheduled Use of Resources https://datatracker.ietf.org/doc/rfc8413/	
RFC 8453	Framework for Abstraction and Control of TE Networks (ACTN) https://datatracker.ietf.org/doc/rfc8453/	
RFC 8469	Recommendation to Use the Ethernet Control Word https://datatracker.ietf.org/doc/rfc8469/	
RFC8632	A YANG Data Model for Alarm Management https://datatracker.ietf.org/doc/rfc8632/	
RFC 8780	PCEP Extension for WSON Routing and Wavelength Assignment https://datatracker.ietf.org/doc/rfc8780/	
RFC 8779	PCEP extensions for GMPLS https://datatracker.ietf.org/doc/rfc8779/	
RFC 8776	Common YANG Data Types for Traffic Engineering	

	https://datatracker.ietf.org/doc/rfc8776/	
RFC 8795	YANG Data Model for Traffic Engineering (TE) Topologies https://datatracker.ietf.org/doc/rfc8795/	
RFC9093	A YANG Data Model for Layer 0 Types https://datatracker.ietf.org/doc/rfc9093/	
RFC9094	A YANG Data Model for WSON (Wavelength Switched Optical Networks) https://datatracker.ietf.org/doc/rfc9094/	
RFC9376	Applicability of GMPLS for B100G Optical Transport Network https://datatracker.ietf.org/doc/rfc9376/	
RFC9504	Path Computation Element (PCE) Protocol Extensions for Stateful PCE Usage in GMPLS-controlled Networks https://datatracker.ietf.org/doc/rfc9504/	
RFC9543	A Framework for Network Slices in Networks Built from IETF Technologies https://datatracker.ietf.org/doc/rfc9543/	
	YANG Data Model for FlexE Management https://datatracker.ietf.org/doc/draft-ietf-ccamp-flexe-yang-cm/	CCAMP
	Extension to the Link Management Protocol (LMP/DWDM -rfc4209) for Dense Wavelength Division Multiplexing (DWDM) Optical Line Systems to manage the application code of optical interface parameters in DWDM application https://datatracker.ietf.org/doc/draft-ietf-ccamp-dwdm-if-lmp/	CCAMP
	A YANG Data Model for Transport Network Client Signals https://datatracker.ietf.org/doc/draft-ietf-ccamp-client-signal-yang/	CCAMP
	A YANG Data Model for Ethernet TE Topology https://datatracker.ietf.org/doc/draft-ietf-ccamp-eth-client-te-topo-yang/	CCAMP
	A YANG Data Model for Layer 0 Types https://datatracker.ietf.org/doc/draft-ietf-ccamp-rfc9093-bis/	CCAMP
	A YANG Data Model for requesting Path Computation in an Optical Transport Network (OTN) https://datatracker.ietf.org/doc/draft-ietf-ccamp-otn-path-computation-yang/	CCAMP
	A YANG model to manage the optical interface parameters for an external transponder in a WDM network https://datatracker.ietf.org/doc/draft-ietf-ccamp-dwdm-if-param-yang/	CCAMP
	YANG Data Models for requesting Path Computation in Optical Networks https://datatracker.ietf.org/doc/draft-ietf-ccamp-optical-path-computation-yang/	CCAMP
	Framework and Data Model for OTN Network Slicing https://datatracker.ietf.org/doc/draft-ietf-ccamp-yang-otn-slicing/	CCAMP
	A YANG Data Model for Optical Impairment-aware Topology https://datatracker.ietf.org/doc/draft-ietf-ccamp-optical-impairment-topology-yang/	CCAMP
	A framework for Management and Control of DWDM optical interface Parameters https://datatracker.ietf.org/doc/draft-ietf-ccamp-dwdm-if-mng-ctrl-fwk/	CCAMP
	A YANG Data Model for WDM Tunnels https://datatracker.ietf.org/doc/draft-ietf-ccamp-wdm-tunnel-yang/	CCAMP

	YANG data model for Flexi-Grid Optical Networks https://datatracker.ietf.org/doc/draft-ietf-ccamp-flexigrid-yang/	CCAMP
	A YANG Data Model for L1 Connectivity Service Model (L1CSM) https://datatracker.ietf.org/doc/draft-ietf-ccamp-l1csm-yang/	CCAMP
	A YANG Data Model for Layer 1 Types https://datatracker.ietf.org/doc/draft-ietf-ccamp-layer1-types/	CCAMP
	A YANG Data Model for Optical Transport Network Topology https://datatracker.ietf.org/doc/draft-ietf-ccamp-otn-topo-yang/	CCAMP
	OTN Tunnel YANG Model https://datatracker.ietf.org/doc/draft-ietf-ccamp-otn-tunnel-model/	CCAMP
	Information Encoding for WSON with Impairments Validation https://datatracker.ietf.org/doc/draft-ietf-ccamp-wson-iv-encode/	CCAMP
	Information Model for Wavelength Switched Optical Networks (WSONs) with Impairments Validation https://datatracker.ietf.org/doc/draft-ietf-ccamp-wson-iv-info/	CCAMP
	A YANG Data Model for Interface Reference Topology https://datatracker.ietf.org/doc/draft-ietf-ccamp-if-ref-topo-yang/	CCAMP
	Conveying Transceiver-Related Information within RSVP-TE Signaling https://datatracker.ietf.org/doc/draft-ietf-ccamp-tsvmode-signaling/	CCAMP
	Interworking of GMPLS Control and Centralized Controller System https://datatracker.ietf.org/doc/draft-ietf-teas-gmpls-controller-inter-work/	TEAS
	Applicability of Abstraction and Control of Traffic Engineered Networks (ACTN) to Packet Optical Integration (POI) https://datatracker.ietf.org/doc/draft-ietf-teas-actn-poi-applicability/	TEAS
	A YANG Data Model for requesting path computation https://datatracker.ietf.org/doc/draft-ietf-teas-yang-path-computation/	TEAS
	IETF Network Slice Controller and its associated data models https://datatracker.ietf.org/doc/draft-ietf-teas-ns-controller-models/	TEAS
	PCEP Extension for Flexible Grid Networks https://datatracker.ietf.org/doc/draft-ietf-pce-flexible-grid/	PCE
	Updates for PCEPS: TLS Connection Establishment Restrictions https://datatracker.ietf.org/doc/draft-ietf-pce-pceps-tls13/02/	PCE
	PCEP Extension for Stateful Inter-Domain Tunnels https://datatracker.ietf.org/doc/draft-ietf-pce-stateful-interdomain/	PCE
	Path Computation Element Protocol (PCEP) Extension for Color https://datatracker.ietf.org/doc/draft-ietf-pce-pcep-color/	PCE
	A YANG Data Model for Network Inventory	IVY

	https://datatracker.ietf.org/doc/draft-ietf-ivy-network-inventory-yang/	
	Some Key Terms for Network Incident and Problem Management https://datatracker.ietf.org/doc/draft-ietf-nmop-network-incident-yang/	NMOP
	A YANG Data Model for Network Incident Management https://datatracker.ietf.org/doc/draft-ietf-nmop-network-incident-yang/	NMOP

6.5 Standards on the Ethernet Frames, MPLS, and MPLS-TP

The following tables list ITU-T Recommendations specifically related to Ethernet, MPLS and MPLS-TP.

Table 8 – Ethernet related Recommendations

Organisation (Subgroup responsible)	Number	Title
SG12 (Q17/12)	G.1563	Ethernet frame transfer and availability performance
SG13(Q7/13)	Y.1415	Ethernet-MPLS network interworking - User plane interworking
SG15(Q10/15)	Y.1730	Requirements for OAM functions in Ethernet-based networks and Ethernet services
SG15(Q10/15)	Y.1731	OAM functions and mechanisms for Ethernet based networks
SG15(Q12/15)	G.8010	Architecture of Ethernet Layer Networks
SG15(Q10/15)	G.8011	Ethernet service characteristics
SG15(Q10/15)	G.8012	Ethernet UNI and Ethernet NNI
SG15(Q10/15)	G.8013/Y.1731	OAM functions and mechanisms for Ethernet based networks
SG15(Q10/15)	G.8021	Characteristics of Ethernet transport network equipment functional blocks
SG15(Q11/15)	G.8023	Characteristics of equipment functional blocks supporting Ethernet physical layer and Flex Ethernet interfaces
SG15(Q10/15)	G.8031	Ethernet linear protection switching
SG15(Q10/15)	G.8032	Ethernet ring protection switching
SG15(Q14/15)	G.8051	Management aspects of the Ethernet-over-Transport (EoT) capable network element
SG15(Q14/15)	G.8052	Protocol-neutral management information model for the Ethernet Transport capable network element
SG15(Q14/15)	G.8052.1	Transport OAM Management Information/Data Models for Ethernet Transport Network Element
SG15(Q13/15)	G.8262	Timing characteristics of synchronous Ethernet equipment slave clock (EEC)
SG15(Q13/15)	G.8262.1	Timing characteristics of enhanced synchronous equipment slave clock

Table 9 – MPLS related Recommendations

Organisation (Subgroup responsible)	Number	Title
SG13(Q3/13)	Y.1311.1	Network-based IP VPN over MPLS architecture
SG12 (Q17/12)	Y.1561	Performance and availability parameters for MPLS networks
SG13(Q4/13)	Y.2174	Distributed RACF architecture for MPLS networks
SG13(Q4/13)	Y.2175	Centralized RACF architecture for MPLS core networks
SG13(Q12/13)	Y.1411	ATM-MPLS network interworking - Cell mode user plane interworking
SG13(Q12/13)	Y.1412	ATM-MPLS network interworking - Frame mode user plane interworking
SG13(Q12/13)	Y.1413	TDM-MPLS network interworking - User plane interworking
SG13(Q12/13)	Y.1414	Voice services - MPLS network interworking

Organisation (Subgroup responsible)	Number	Title
SG13(Q12/13)	Y.1415	Ethernet-MPLS network interworking - User plane interworking
SG13(Q12/13)	Y.1416	Use of virtual trunks for ATM/MPLS client/server control plane interworking
SG13(Q12/13)	Y.1417	ATM and frame relay/MPLS control plane interworking: Client-server
SG15(Q10/15)	Y.1710	Requirements for OAM functionality for MPLS networks
SG15(Q10/15)	Y.1711	Operation & Maintenance mechanism for MPLS networks
SG15(Q10/15)	Y.1712	OAM functionality for ATM-MPLS interworking
SG15(Q10/15)	Y.1713	Misbranching detection for MPLS networks
SG15(Q10/15)	Y.1714	MPLS management and OAM framework
SG15(Q10/15)	Y.1720	Protection switching for MPLS networks
SG15(Q12/15)	G.8110	MPLS Layer Network Architecture

Table10 – MPLS-TP-related Recommendations

Organisation (Subgroup responsible)	Number	Title
SG15(Q12/15)	G.8110.1	Architecture of the Multi-Protocol Label Switching transport profile layer network
SG15(Q10/15)	G.8112	Interfaces for the MPLS Transport Profile layer network
SG15(Q10/15)	G.8113.1	Operations, administration and maintenance mechanism for MPLS-TP in packet transport networks
SG15(Q10/15)	G.8113.2	Operations, administration and maintenance mechanisms for MPLS-TP networks using the tools defined for MPLS
SG15(Q10/15)	G.8121	Characteristics of MPLS-TP equipment functional blocks
SG15(Q10/15)	G.8121.1	Characteristics of MPLS-TP equipment functional blocks supporting ITU-T G.8113.1 OAM mechanisms
SG15(Q10/15)	G.8121.2	Characteristics of MPLS-TP equipment functional blocks supporting ITU-T G.8113.2 OAM mechanisms
SG15(Q10/15)	G.8131	Linear protection switching for MPLS transport profile
SG15(Q10/15)	G.8132	MPLS-TP shared ring protection
SG15(Q10/15)	G.8133	Dual Homing Protection for MPLS-TP Pseudowires
SG15(Q14/15)	G.8151	Management aspects of the MPLS-TP network element
SG15(Q14/15)	G.8152	Protocol-neutral management information model for the MPLS-TP network element
SG15(Q14/15)	G.8152.1	MPLS-TP NE OAM Information Model & Data Model
SG15(Q14/15)	G.8152.2	MPLS-TP NE Resilience Information Model & Data Model

Table 11 – MTN-related Recommendations

Organisation (Subgroup responsible)	Number	Title
SG15(Q12/15)	G.8310	Architecture of metro transport network
SG15(Q11/15)	G.8312	Interfaces for a metro transport network
SG15(Q11/15)	G.8312.20	Overview of fine-grain MTN
SG15(Q11/15)	G.8331	Metro transport network (MTN) linear protection
SG15(Q11/15)	G.8321	Characteristics of metro transport network equipment functional blocks
SG15(Q11/15)	G.8350	Management and control for metro transport network

6.6 Standards on Synchronization

The series of G.8200-G.8299 ITU-T Recommendations are dedicated for Synchronization, quality and availability targets. Other synchronization related Recommendations can be found into the series G.810-G.819 (Design objectives for digital networks) and into the G.780-G.789 series (Principal characteristics of multiplexing equipment for the synchronous digital hierarchy).

Common aspects:

- G.8201: Error performance parameters and objectives for multi-operator international paths within optical transport networks
- G.810: Definitions and terminology for synchronization networks
- G.8260: Definitions and terminology for synchronization in packet networks
- G.781: Synchronization Layer Functions
- G.781.1: Synchronization Layer Functions for packet-based networks

Supplements and Technical Reports:

- GNSS-TR: Considerations on the Use of GNSS as a Primary Time Reference in Telecommunications
- G.Suppl.65: Simulations of transport of time over packet networks
- G.Suppl.68: Synchronization OAM requirements
- G.Supp.FTS: Supplement on the use of options in PTP profile with full timing Support from the network

ATIS report:

ATIS published a Technical Report "GPS Vulnerability" (ATIS-0900005) on 2017 September 7. From the abstract: "This technical report provides a North American telecom sector perspective on the impact of GPS vulnerabilities to telecom networks, synchronization in particular, and provides a series of comments and recommendations for consideration by the larger timing community."

IEEE P1952

The IEEE 1952 working group has been initiated in September 2021 to study resilient positioning, navigation, and timing. The project title is "Standard for Resilient Positioning, Navigation and Timing (PNT) User Equipment".

Table 12– Synchronization-related Recommendations

<table>
<tr><th></th><th>Frequency</th><th>Time and phase</th></tr>
<tr><td rowspan="2">Network Requirements</td><td>G.8261: Timing and synchronization aspects in packet networks
G.8261.1: Packet delay variation network limits applicable to packet-based methods (Frequency synchronization)</td><td>G.8271: Time and phase synchronization aspects of telecommunication networks
G.8271.1: Network limits for time synchronization in packet networks with full timing support from the network
G.8271.2: Network limits for time synchronization in packet networks with partial timing support from the network</td></tr>
<tr><td colspan="2">G.mtn-sync: Synchronization aspects of metro transport network</td></tr>
<tr><td>Clock</td><td>G.811: Timing characteristics of primary reference clocks
G.811.1: Timing characteristics of enhanced primary reference clocks</td><td>G.8273: Framework of phase and time clocks</td></tr>
</table>

	G.812: Timing requirements of slave clocks suitable for use as node clocks in synchronization networks G.813: Timing characteristics of SDH equipment slave clocks (SEC) G.8262: Timing characteristics of synchronous equipment slave clock G.8262.1: Timing characteristics of enhanced synchronous equipment slave clock G.8263: Timing characteristics of packet-based equipment clocks G.8251: The control of jitter and wander within the optical transport network (OTN) G.8266: Timing characteristics of telecom grandmaster clocks for frequency synchronization	G.8273.1: Timing characteristics of telecom grandmaster clocks for time synchronization (in progress) G.8273.2: Timing characteristics of telecom boundary clocks and telecom time slave clocks for use with full timing support from the network G.8273.3: Timing characteristics of telecom transparent clocks for use with full timing support from the network G.8273.4: Timing characteristics of partial timing support telecom boundary clocks and telecom time slave clocks
	G.8272: Timing characteristics of primary reference time clocks G.8272.1: Timing characteristics of enhanced primary reference time clocks G.8272.2: Timing characteristics of coherent network primary reference time clocks	
Distribution	G.8264: Distribution of timing information through packet networks G.8265: Architecture and requirements for packet-based frequency delivery G.8265.1: Precision time protocol telecom profile for frequency synchronization	G.8275: Architecture and requirements for packet-based time and phase distribution G.8275.1: Precision time protocol telecom profile for phase/time synchronization with full timing support from the network G.8275.2: Precision time protocol telecom profile for time/phase synchronization with partial timing support from the network
Management	G.7721 Management requirement and information model for synchronization G.7721.1 Data model of synchronization management	

6.7 ITU-T Recommendation Relationships

For a given layer technology studied in WP3 of SG15, there are a set of Recommendations that cover interface, architecture, and management/control aspects. Table 12 shows how the relationships between sets of Recommendations. Parallels between Recommendations in the same category but for different layers become evident when arranged as in the table. Should a new layer technology be studied, it would be natural to expect Recommendations to cover interface(s), architecture, equipment, protection, management requirements, and information model.

Table 12 Recommendation Relationships

	Control/Management Continuum	**Transport technology**					**Common technology**
Common Arch	G.7701	G.800, G.805, G.807					
Arch	G.7702 G.7703	OTN (incl. fgOTN): G.872	ETH: G.8010	MT: G.8110.1	MTN (incl. fgMTN): G.8310	Media G.807	
Interface		G.709 G.709.x G.709.20	IEEE802.3 G.8013	G.8113.1 G.8113.2 G.8112	G.8312 G.8312.20	G.698.1-.4	
Protection		G.873.x	G.8031 G.8032	G.8131 G.8132	G.8331		G.808 G.808.1 G.808.2 G.808.3 G.808.4 (fgOTN/fgMTN)
Equipment		G.798 G.798.x	G.8021 G.8023	G.8121 G.8121.x	G.8321		G.806
Protocol Requirements	G.7713.x G.7714.x G.7715.x						
Synchronization		G.8251			G.mtn-sync		G.8260 G.826x G.827x G.781 G.781.1 G.810 G.811 G.811.1 G.812
DCN	G.7712						
Common Mgmt IM	G.7711						

Common Mgmt Requirement	G.7718	G.7710					
Mgmt Requirement		G.874	G.8051	G.8151	G.8350	G.876	G.7721 (sync)
Mgmt protocol-neutral IM	G.7719	G.875	G.8052	G.8152			
MC operations	G.7716						
Purpose-specific information model (in UML) & data models (e.g., in Yang)			G.8052.1 G.8052.2	G.8152.1 G.8152.2			G.7721.1 (sync)

See Tables 6, 7, 10, & 11 for titles of the Recommendations referenced in Table 12.