**Optical Transport Networks & Technologies Standardization Work Plan**

**Issue 25, December 2018**

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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 December 2018

# 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>

# 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 the October 2018 meeting as indicated in the reference: https://www.itu.int/md/T17-SG15-181008-TD/en

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 reportThe 802.1 working group has four active task groups: Maintenance, Time Sensitive Networking (TSN), Security, and OmniRAN. In addition, an Industry Connections activity exists to explore IEEE 802 Network Enhancements For the Next Decade the Interworking.. 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. The 802.1 working group has over 20 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).The liaison highlights the following projects to be noted in SG15: 1) 802 Network Enhancements for the next decade (e.g., 5G), 2) all projects in TSN, 3) P802.1 AX-Rev – Link Aggregation revision, 4) P802.1Qcx – CFM YANG data model, 5) P802.1ABcu – LLDP YANG data model P802.1Xck – YANG data model, 6) YANGsters – IEEE 802 YANG Editors’ coordination P802.1Qcp – YANG data model, 7) P802.1CBcv – Frame Replication and Elimination for Reliability Amendment: Information Model, YANG Data Model and MIB Module, and 8) P802.1DC – Quality of Service Provision by Network Systems  | [ 200-GEN ] |
| 3 | IEEE 802.3  | Relevant recent projects: * IEEE P802.3cd 50 Gb/s, 100 Gb/s, and 200 Gb/s Ethernet Task Force
* IEEE P802.3ca 25 Gb/s, 50 Gb/s, and 100 Gb/s Ethernet Passive Optical Networks Task Force
* IEEE P802.3cb 2.5 Gb/s and 5 Gb/s Backplane Task Force.
* IEEE P802.3cf YANG data models Task Force
* IEEE P802.3cn Beyond 10 km optical PHYs Task Force
* IEEE P802.3ck 100 Gb/s, 200 Gb/s, and 400 Gb/s Electrical Interfaces Task Force
* IEEE P802.3cm 400 Gb/s over Multimode Fiber Task Force
* IEEE 802.3 Bidirectional 10 Gb/s and 25 Gb/s Optical Access PHYs Study Group
* IEEE 802.3 Physical Layers for increased-reach Ethernet optical subscriber access (Super-PON) Study Group

The IEEE 802.3 standards currently in force are:1) the base standard, IEEE Std 802.3-2018, was approved by the Standards Board on 14 June 2018 and published on 31 August 2018. It incorporates and supersedes the following amendments:* IEEE Std 802.3bw-2015
* IEEE Std 802.3by-2016
* IEEE Std 802.3bq-2016
* IEEE Std 802.3bp-2016
* IEEE Std 802.3br-2016
* IEEE Std 802.3bn-2016
* IEEE Std 802.3bz-2016
* IEEE Std 802.3bu-2016
* IEEE Std 802.3bv-2017
* IEEE Std 802.3-2015/Cor 1-2017
* IEEE Std 802.3bs-2017
* IEEE Std 802.3cc-2017

2) the base MIB standard, IEEE Std 802.3.1-2013 | [ 214-GEN] [324-WP3] |
| 4 | MEF | MEF liaison reportWith over 200 leading member companies, including 130 service providers, the MEF is the enabling force for the development and implementation of agile, assured and orchestrated Third Network services for the digital economy and the hyper-connected world. Third Network services are delivered over automated, virtualized, and interconnected networks globally powered by Carrier Ethernet 2.0 (CE 2.0), Lifecycle Service Orchestration (LSO), SDN, and NFV.CE 2.0 is MEF’s globally adopted services framework and the foundation for new services innovation. The current annual market for Carrier Ethernet products and services is approximately $80B. The MEF is also facilitating industry neutral implementation environments for service orchestration (OpenLSO) and L2-L7 connectivity services (OpenCS) based on Open Source, SDN and NFV.MEF 3.0 is a transformational framework for defining, delivering, and certifying agile, assured, and orchestrated communication services across a global ecosystem of automated networks.MEF Active projects:* Lifecycle Service Orchestration: 13 projects
* Services: 10 projects and 2 ad-hocs
* Applications: 6 projects
 | [ 201-GEN], [259-WP3] |
| 5 | OIF (PLL) | Liaison report for OIF Physical and Link Layer (PLL) Working Group The following 56G CEI (Common Electrical I-O) projects are active; CEI-56G-XSR, CEI-56G-VSR.FlexE 2.0 IA is now published as <http://www.oiforum.com/wp-content/uploads/OIF-FLEXE-02.0.pdf> (publicly available).  | [ 202-GEN ] |
| 6 | IETF | Liaison report for IETFThe meeting schedule for 2018 - 2020 was provided. One liaison on YANG Alarm Module from CCAMP was highlighted. |  [ 218-GEN ] |
| 7 | JCA SDN | Incoming liaison from JCA SDN [JCA-SDN - LS 5 -E](http://handle.itu.int/11.1002/ls/sp16-jca-sdn-oLS-00005.docx).JCA SDN has updated their SDN Standardisation Activity Roadmap which is available at [http://www.itu.int/en/ITU-T/jca/sdn/](http://www.itu.int/en/ITU-T/jca/sdn). JCA SDN concluded at its November 2017 meeting. | [ 119-GEN ] |
| 8 | IEEE P1588 | Liaison report for IEEE 1588.IEEE 1588-v3 is expected to be completed in 2018. The most recent draft, which is in working group ballot, addresses:* High Accuracy: improved time sync performance (assuming Layer 1 frequency synchronization and asymmetry calibrations).
* Management: performance monitoring; future of the native IEEE1588 management protocol, PTP networks configurations; data information models; 1588 MIB.
* Upkeep-Architecture: various points requiring clarifications; solution for profile isolation; PTP redundancy (including definition of solutions for multi paths multi-masters); restructuring of the standard to separate the “media-dependent” functions from the “media- independent” functions.
* Security: various options to provide security to the protocol.
 | [ 127-GEN ] |

# Part 2: Standard work plan

# 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, 7, 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 3.

# 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.

# Abbreviations

|  |  |
| --- | --- |
| ANSI | American National Standards Institute |
| ASON | Automatically Switched Optical Network |
| ASTN | Automatically Switched Transport 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 |
| 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 |

# 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.

## 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.

## Optical Transport Network (OTN) (largely revised in 09/2016 reflecting B100G)

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 5th edition of Recommendation ITU-T G.709/Y.1331 “Interfaces for the Optical Transport Network”, published in June 2016, enables optical transport at rates higher than 100 Gbit/s (the code name is beyond 100 Gbit/s or B100G).

The revised ITU-T G.709/Y.1331 extends OTN with a new, 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.

The revised ITU-T G.709/Y.1331 provides the necessary support for 200G and 400G Ethernet under development within IEEE. The revision also extends OTN to 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 the initial OTUCn applications to be enabled by ITU-T G.709/Y.1331 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 802.3-2018, 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

In sync with the introduction to the B100G support, a number of ITU‑T Recommendations are updating information on the implementation of the OTN for example:

* [ITU‑T G.709] provides the rates and formats used in the OTN
* [ITU-T G.709.1] specifies Flexible OTN short-reach interface
* [ITU-T G.709.2] specifies OTU4 long-reach interface
* [ITU-T G.709.3] specifies Flexible OTN long-reach interfaces
* [ITU‑T G.798] defines the equipment functional blocks
* [ITU-T G.872] defines OTN 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 the revised G.872, the OTN is decomposed into the following layer structure.

|  |  |
| --- | --- |
|  | Digital |
|  | ODU |  |
|  |
|  | OTU |  |
|  |
| OTSiA | Optical signals |
| Media constructs | OMS/OTS Optical signal maintenance entities | Media  |
| Fibre |

Figure 6‑1/G.872 – Overview of the OTN covering beyond 100 Gbit/s

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 ≥ 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.

### FlexE in OIF (updated in Dec-2018)

OIF specified a Flex Ethernet 1.0 implementation agreement in June 2016 and additional features in FlexE 2.0 in 2018.

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

At the November 2018 Sydney meeting, it was agreed to start a new project as FlexE 2.1 that adds support for FlexE groups composed of 50 Gb/s Ethernet PHYs.

**400ZR Interop**

Discussion continues on this project (start in [oif2016.400.04](http://www.oiforum.com/bin/c5i?mid=4&rid=5&gid=0&k1=48077&tid=1483452969)) to specify optical interfaces with the following characteristics:

* Short-reach DWDM (amplified) as a priority over single channel ZR (passive). Both applications have a minimum distance of 80km
* DP-16QAM modulation format
* System-side interface support for IEEE Std 802.3bs

At the Nuremberg meeting, this project updated the baseline in [oif2017.245.08](https://www.oiforum.com/bin/c5i?mid=4&rid=5&gid=0&k1=49180&tid=1516364616) with optical parameters. At the Vancouver meeting a third application code (unamplified link up to 10 km) was firstly added and then removed again and the draft in [oif2017.245.09](https://www.oiforum.com/bin/c5i?mid=4&rid=5&gid=0&k1=49180) was sent to straw ballot..

The most recent liaison concerning this project is in [TD 181 (GEN)](https://www.itu.int/md/meetingdoc.asp?lang=en&parent=T17-SG15-181008-TD-GEN-0181).

## 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 is expected to be published as MEF 63 later in 2018. In parallel, work is underway on a partner specification defining Operator L1 services between a UNI and OTN ENNI (access) and between OTN ENNIs (transit). This will provide the basis for streamlining the interconnection of multi-domain L1 services. It is expected to be published in late 2019.

## Subscriber and Operator IP Services

In early 2016 the MEF launched a new project to define the service attributes to describe Subscriber (retail) and Operator (wholesale) IP services. The first of these, IP Service Attributes for Subscriber IP Services Technical Specification (MEF 61), was published in early 2018. It specifies a standard set of service attributes for describing IP VPNs and Internet access services offered to end-users. MEF 61 is currently being used as the starting point for defining attributes for Operator IP services. It is expected to be published as a revision to MEF 61 in mid-2019. Two related projects were started in early 2018: Service OAM for IP Services and Service Activation Testing for IP Services. The first phase of both of these projects is expected to complete in 2019.

## Support for mobile networks (reference to ITU-R M2375 added in 09/2016)

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 for 5G Mobile Networks to include 5G requirements for fronthaul, midhaul and network slicing.

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.

## 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 three types of services they support: Line services, LAN 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). 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 and Access services over circuit switched technologies like SDH VCs and OTN ODUs or over packet switched technologies like MPLS and RPR. 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.

## Overview of the standardization of carrier class Ethernet

### 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.

#### High bit rate and long reach interfaces

The IEEE Std 802.3-2018 includes 200GBASE-DR4/FR4/LR4 and 400GBASE-SR16/DR4/FR8/LR8.

#### Ethernet-based access networks

Various PON interfaces exist in IEEE802.3-2018 that may be used as Ethernet access networks. Additional optical PON PHY types are under development by the currently active IEEE P802.3ca project.

#### Enhancement of scalability

VLAN technology is widely used to provide customers with logically independent networks while sharing network resource physically. However, since 12bit 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 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.

#### Scalable Ethernet-based backbone

In order to realize further scalable networks, IEEE 802.1ah (Backbone Provider Bridges) specifies a method which uses B-Tag, I-Tag and C-Tag. B-Tag and C-Tag include 12 bit VLAN ID. I-Tag includes 20bit Service ID (note: the size of the Service ID under study). One VLAN ID identifies a Customer VLAN. Service ID identifies a service in a provider network. Another VLAN ID identifies a Backbone VLAN. This allows the network to use 12bit VLAN ID space and 20 bit service ID space as well as its own MAC address space. IEEE 802.1ah was approved in June 2008.

#### 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 of each bridge. To alleviate this burden, IEEE 802.1ah (Backbone Provider Bridges) standardized a method which encapsulates MAC addresses of user stations by backbone MAC addresses so that bridges inside the backbone network do not learn MAC addresses of user stations.

#### 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 802.1ag under a close collaboration.

ITU-T Recommendation Y.1731 was approved in May 2006 and revised in February 2008. IEEE 802.1ag was approved in September 2007. IEEE 802.1ag covers fault management functions only while Y.1731 covers both fault management and performance management.

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 now Ethernet OAM work is conducted in SG15.

#### 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 (G.8031) was approved in June 2006. Recommendation on Ethernet ring protection (G.8032) was approved in June 2008. In March 2010, the revised G.8032v2 covered interconnected and multiple rings, operator commands and non-revertive mode. In September 2016, a supplement on Ethernet linear protection switching with dual node interconnection (G.sup60) was approved. This is based on G.8031.

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

In 2014, IEEE 802.1 WG completed a revision of the 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 construnction 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 again revised starting in 2017 in the light of implementation experience to ensure interoperability and proper operation.

IEEE 802.1CB “Frame Replication and Elimination for Reliability” is 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.

#### 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 802.1Qay). MEF developed MEF 10.3: " Ethernet Services Attributes", in October 2013, together with further amendments on “Composite Performance Metric” (MEF 10.3.1, February 2015) and “UNI Resiliency” (MEF 10.3.2, October 2015). An updated version MEF 10.4 which also incorporates the amendments is planned for 2018. MEF 6.2 EVC Ethernet Services Definitions Phase 3, published in August 2014, defines six Ethernet Services with Service Attributes and parameters as specified in MEF 10.3. 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 OVC Services Definitions, published in August 2015, specifies Operator Virtual Connection (OVC) Services based on the Service Attributes defined in MEF 26.1. An updated version MEF 51.1 is planned for late 2018.

#### 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 is planned for 2019.

#### Time-Sensitive Networking and Deterministic Networking

Following on from the development of Audio-Video Bridging in IEEE 802.1, itself based upon advances in time synchronisation in IEEE 1588, IEEE 802.1 formed the Time-Sensitive Networking task force. This group completed the Stream Reservation Protocol (802.1Qat) and the Credit-based Shaper (802.1Qav) to provide lossless guaranteed bandwidth over Ethernet. This was followed by the Frame Pre-emption (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 802.1Q, these technologies underpin the P802.1CM Profile for Fronthaul. For more demanding time-sensitive streams, a combination of Enhancements for Scheduled Traffic (802.1Qbv), Per-Stream Filtering and Policing (802.1Qci) and Cyclic Queuing and Forwarding (802.1Qch) provide bounded latency, guaranteed bandwidth and zero congestion loss, on a network which can support best-effort traffic at the same time.

#### Status of IEEE 802.1 (Updated in 11/2018)

The 802.1 working group has four active task groups: Maintenance, Time-Sensitive Networking (TSN), Security, and OmniRAN. In addition, an Industry Connections activity exists to explore IEEE 802 Network Enhancements For the Next Decade the Interworking. 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.

The 802.1 working group has over 20 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).

Within each TG there are a number of active projects as shown below:

[Security](https://1.ieee802.org/security/)

* [P802E: Recommended Practice for Privacy Considerations for IEEE Technologies](http://1.ieee802.org/security/802e/)
* [P802.1X-Rev: Port-Based Network Access Control](http://1.ieee802.org/security/802-1x-rev/)*[(Revision)](http://1.ieee802.org/security/802-1x-rev/)*

[Time Sensitive Networking](https://1.ieee802.org/tsn/)

* Standalone (specifying new base standards):
	+ [IEC/IEEE 60802 TSN Profile for Industrial Automation](https://1.ieee802.org/iec-ieee-60802-tsn-profile-for-industrial-automation/)
	+ [P802.1CS – Link-local Registration Protocol](https://1.ieee802.org/tsn/802-1cs/)
	+ [P802.1DC – Quality of Service Provision by Network Systems](https://1.ieee802.org/tsn/802-1dc/)
* Revisions (of a base standard):
	+ [P802.1AS-Rev – Timing and Synchronization for Time-Sensitive Applications](http://www.ieee802.org/1/pages/802.1AS-rev.html)
	+ [P802.1AX-Rev – Link Aggregation Revision](https://1.ieee802.org/tsn/802-1ax-rev/)
* 802.1Q amendments (amending [IEEE Std 802.1Q-2018](https://standards.ieee.org/standard/802_1Q-2018.html)):
	+ [P802.1Qcj – Automatic Attachment to Provider Backbone Bridging (PBB) services](https://1.ieee802.org/tsn/802-1qcj/)
	+ [P802.1Qcr](https://1.ieee802.org/tsn/802-1qcr/) – Bridges and Bridged Networks Amendment: Asynchronous Traffic Shaping
	+ [P802.1Qcw – YANG Data Models for Scheduled Traffic, Frame Preemption, and Per-Stream Filtering and Policing](https://1.ieee802.org/tsn/802-1qcw/)
	+ [P802.1Qcx – YANG Data Model for Connectivity Fault Management](https://1.ieee802.org/tsn/802-1qcx/)
	+ P802.1Qcz – Congestion Isolation
* 802.1AB amendments (amending [IEEE Std 802.1AB-2016](https://standards.ieee.org/findstds/standard/802.1AB-2016.html)):
	+ [P802.1ABcu – LLDP YANG Data Model](https://1.ieee802.org/tsn/802-1abcu/)
* 802.1CB amendments (amending [IEEE Std 802.1CB-2017](https://standards.ieee.org/findstds/standard/802.1CB-2017.html)):
	+ [P802.1CBcv – FRER YANG Data Model and Management Information Base Module](https://1.ieee802.org/tsn/802-1cbcv/)
	+ [P802.1CBdb – FRER Extended Stream Identification Functions](https://1.ieee802.org/tsn/802-1cbdb/)

[OmniRAN](https://1.ieee802.org/omniran/)

* [P802.1CF](https://1.ieee802.org/omniran/802-1cf/) – Network Reference Model and Functional Description of IEEE 802 Access Network
* [P802.1CQ](https://1.ieee802.org/dcb/p802-1cq-multicast-and-local-address-assignment/) – Multicast and Local Address Assignment

[Maintenance](https://1.ieee802.org/maintenance/)

* [802.1ACct](https://1.ieee802.org/maintenance/802-1acct/) – Support for IEEE Std 802.15.3

The following projects are currently in Task Group (TG) ballot:

* [P802E – Recommended Practice for Privacy Considerations for IEEE Technologies](http://1.ieee802.org/security/802e/)
* [P802.1AX-Rev – Link Aggregation Revision](https://1.ieee802.org/tsn/802-1ax-rev/)
* [P802.1Qcr – Bridges and Bridged Networks Amendment: Asynchronous Traffic Shaping](https://1.ieee802.org/tsn/802-1qcr/)
* [P802.1CS – Link-local Registration Protocol](https://1.ieee802.org/tsn/802-1cs/)
* [P802.1Qcx – YANG Data Model for Connectivity Fault Management](https://1.ieee802.org/tsn/802-1qcx/)

The following are currently in Working Group (WG) ballot:

* [P802.1AS-Rev – Timing and Synchronization for Time-Sensitive Applications](http://www.ieee802.org/1/pages/802.1AS-rev.html)

There following documents are currently in Sponsor ballot

* [P802.1CF](https://1.ieee802.org/omniran/802-1cf/) – Network Reference Model and Functional Description of IEEE 802 Access Network

The following projects have been approved by the Standards Board but have not yet been published:

* [P802.1Qcc](https://1.ieee802.org/tsn/802-1qcc/) – Stream Reservation Protocol (SRP) Enhancements and Performance Improvements
* [P802.1Qcy](https://1.ieee802.org/dcb/802-1qcy/) – Bridges and Bridged Networks Amendment: VDP Extension to Support NVO3
* [P802.1Xck: Port-Based Network Access Control—Amendment 2: YANG Data Model](http://1.ieee802.org/security/802-1xck/)
* [P802.1AE-Rev: MAC Security (MACsec) *(Revision)*](http://1.ieee802.org/security/802-1ae-rev/)
* [802.1AC-2016/Cor-1](https://1.ieee802.org/maintenance/802-1ac-2016-cor-1/) – LLC Encapsulation Ethertype

The following are the current new projects under development:

[P802.1CMde](http://www.ieee802.org/1/files/public/docs2018/de-draft-PAR-0918-v01.pdf) – Time-Sensitive Networking for Fronthaul Amendment: Enhancements for Fronthaul Interface, Synchronization, and Syntonization Standards

This amendment defines enhancements to the base standard's features, options, configurations, defaults, protocols and procedures of bridges, stations, and LANs in order to address new developments in fronthaul interface standards, and related synchronization and syntonization standards. This amendment also addresses errors and omissions in existing content.

The purpose of this standard is to specify defaults and profiles that enable the transport of time-sensitive fronthaul streams in Ethernet bridged networks.

The fronthaul interfaces supported by the base standard have been further developed. The synchronization and syntonization standards that the base standard relies on are being enhanced. These developments need to be addressed by enhancing the fronthaul profiles.

Some background on the 802.1CM activity can be seen in a recent [press release](http://www.ieee802.org/1/files/public/docs2018/cm-draft-press-release-0718-v01.pdf) and [summary presentation](http://www.ieee802.org/1/files/public/docs2018/cm-farkas-overview-0718-v01.pdf).

[P802.1DF](http://www.ieee802.org/1/files/public/docs2018/df-draft-PAR-0918-v01.pdf) – Time-Sensitive Networking Profile for Service Provider Networks

This standard defines profiles that select features, options, configurations, defaults, protocols, and procedures of bridges and end-stations defined in IEEE Std 802.1Q and IEEE Std 802.1CB that are necessary to provide Time-Sensitive Networking (TSN) quality of service features for non-fronthaul shared service provider networks. The standard also provides use cases, and informative guidance for network operators on how to configure their networks for those use cases.

This standard provides guidance for equipment vendors, designers, and operators of service provider networks that are shared by multiple users and applications, and that need the TSN Quality of Service (QoS) features offered by IEEE Std 802.1Q bridges. These networks have links with a very large bandwidth-delay product. The TSN features include dependable bandwidth and bounded latency.

[P802.1DG](http://www.ieee802.org/1/files/public/docs2018/dg-draft-PAR-0918-v01.pdf) – Time-Sensitive Networking Profile for Automotive In-Vehicle Ethernet Communications

This standard specifies profiles for secure, highly reliable, deterministic latency, automotive in-vehicle bridged IEEE 802.3 Ethernet networks based on IEEE 802.1 Time-Sensitive Networking (TSN) and security standards.

This standard provides guidance for designers and implementers of IEEE 802.3 Ethernet networks that support the entire range of in-vehicle applications including those requiring security, high availability and reliability, maintainability, and bounded latency.

**Ongoing projects related to OTNT**

[802 Network Enhancements for the next decade](http://standards.ieee.org/about/sasb/iccom/IC17-001-01_IE.pdf) (e.g., 5G)

As a result of the IEEE 802 5G standing committee, the 802.1 OmniRAN TG agreed to create an Industry Connections activity to develop requirements for 802 network enhancements (including those related to 5G). This would effectively be an architectural description of all 802 technologies (wired and wireless) and would comprise an access network with appropriate interfaces that could be applicable for some 5G use cases. Several verticals including automotive, industrial and the cable industry have been noted as potential beneficiaries of enhancements for 802 networks. This activity will identify requirements that could result in new standards projects.

Currently a single area is developing a report: Flexible Factory IoT.

[Time-Sensitive Networking](http://www.ieee802.org/1/pages/tsn.html)

This task group is home to a group of standards projects and can be [summarized](http://www.ieee802.org/1/files/public/docs2017/tsn-farkas-def-0317-v04.pptx) in the following diagram:



[P802.1AX-rev](http://www.ieee802.org/1/pages/802.1AX-rev.html) – Link Aggregation

Link Aggregation (LAG) allows the establishment of full-duplex point-to-point links that have a higher aggregate bandwidth than the individual links that form the aggregation, and the use of multiple systems at each end of the aggregation. This allows improved utilization of available links in bridged local area network (LAN) environments, along with improved resilience in the face of failure of individual links or systems.

This revision will correct and clarify Link Aggregation specifications in the light of implementation experience to ensure interoperability and ensure proper operation. In addition, a LAG YANG module is in scope of the revision.

[P802.1Qcx](https://1.ieee802.org/tsn/802-1qcx/) – CFM YANG data model

This amendment specifies a Unified Modeling Language (UML)-based information model and a YANG data model that allows configuration and status reporting for bridges and bridge components for Connectivity Fault Management (CFM) as specified in 802.1Q It further defines the relationship between the information and data model and models for the other management capabilities.

This project will require coordination with ITU-T SG15 as well as MEF.

The draft is in task group ballot, and 802.1Q YANG modules are also deposited in GitHub in the IEEE branch (<https://github.com/YangModels/yang>)

[P802.1ABcu](https://1.ieee802.org/tsn/802-1abcu/) – LLDP YANG data model

This amendment specifies a Unified Modeling Language (UML)-based information model and a YANG data model that allows configuration and status reporting for bridges and bridge components with regards to topology discovery with the capabilities currently specified in clauses 10 (LLDP management) and 11 (LLDP MIB definitions) of 802.1AB.

[YANGsters](https://1.ieee802.org/yangsters/) – IEEE 802 YANG editors’ coordination

This group 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.

[P802.1CBcv](https://1.ieee802.org/tsn/802-1cbcv/) – Frame Replication and Elimination for Reliability Amendment: Information Model, YANG Data Model and MIB Module

This amendment specifies a Unified Modeling Language (UML) based information model for the capabilities currently specified in clauses 9 and 10 of 802.1CB. A YANG data model and a MIB module both based on that UML model support configuration and status reporting.

[P802.1DC](https://1.ieee802.org/tsn/802-1dc/) – 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.

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>

#### Status of IEEE 802.3 (Updated in 11/2018)

The following are the IEEE 802.3 standards currently in force:

* The base standard, IEEE Std 802.3-2018, was approved by the Standards Board on 14 June 2018 and published on 31 August 2018. It incorporates and supersedes the following amendments:
* IEEE Std 802.3bw-2015
* IEEE Std 802.3by-2016
* IEEE Std 802.3bq-2016
* IEEE Std 802.3bp-2016
* IEEE Std 802.3br-2016
* IEEE Std 802.3bn-2016
* IEEE Std 802.3bz-2016
* IEEE Std 802.3bu-2016
* IEEE Std 802.3bv-2017
* IEEE Std 802.3-2015/Cor 1-2017
* IEEE Std 802.3bs-2017
* IEEE Std 802.3cc-2017
* The current version of the Ethernet MIBs standard is published as IEEE Std 802.3.1-2013.

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

* The IEEE P802.3bt Power via MDI over 4-Pair Task Force has completed the sponsor ballot process and the draft was approved by the Standards Board on 27th September 2018.
* The IEEE P802.3ca 25 Gb/s, 50 Gb/s, and 100 Gb/s Passive Optical Networks Task Force is in the Task Force review phase. The IEEE 802.3 working group has agreed to modification of the objectives to remove 100 Gb/s from the scope of the project, and corresponding PAR modifications are pending approval by the Standards Board.
* The IEEE P802.3cb 2.5 Gb/s and 5 Gb/s Backplane Task Force has completed the Sponsor ballot process and the draft was approved by the Standards Board on 27th September 2018.
* The IEEE P802.3cd 50 Gb/s, 100 Gb/s, and 200 Gb/s Ethernet Task Force is in the Sponsor ballot phase, and is seeking conditional approval to proceed to RevCom for approval after the sponsor ballot process is complete.
* The IEEE P802.3cg 10 Mb/s Single Pair Ethernet Task Force is in the Working Group ballot phase.
* The IEEE P802.3ch Multi-Gig Automotive PHY Task Force is in the proposal selection phase.
* The IEEE P802.3.2 (IEEE 802.3cf) YANG Data Model Definition Task Force has just initiated the Sponsor ballot phase.
* The IEEE P802.3ck 100 Gb/s, 200 Gb/s, and 400 Gb/s Electrical Interfaces Task Force is in the proposal selection phase.
* The IEEE P802.3cm 400 Gb/s over Multimode Fiber Task Force has begun the Task Force Review phase.
* The IEEE P802.3cn Beyond 10km Optical PHYs Task Force is in the proposal selection phase.

There are two 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.

* The IEEE 802.3 Bidirectional 10 Gb/s, 25 Gb/s, and 50 Gb/s Optical Access PHYs Study Group is studying proposed new PHY types at the indicated rates of operation using signaling in both directions over a single fiber.
* The IEEE 802.3 Physical Layers for increased-reach Ethernet optical subscriber access Study Group is studying possible new access architectures to support larger reach and split ratios of current PON systems using a combination of WDM and power splitters, while using only passive components between the CO and the subscriber.

### 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 12 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 | 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(Refer to Annex B on organization restructuring) | CCAMP WG | common control plane and measurement plane solutions and GMPLS mechanisms/protocol extensions to support source-controlled and explicitly-routedEthernet 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, interworkingand security of Ethernet services emulated over MPLS enabled IP packet switched networks |
| 5 | MEF | Services Committee | Service attributes including traffic and performance parameters, Subscriber and Operator services definitions, aggregation and ENNI interfaces, management interfaces, performance monitoring, fault management and test specifications. |

### 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/>

# OTNT correspondence and Liaison tracking

## 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: http:// <https://www.mef.net/>
* TMF- TeleManagement Forum: <http://www.tmforum.org/browse.aspx>

# 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.

## 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.

Table 4 – OTNT Related Standards and Industry Agreements (ITU-T Recomendations)

| **Organization (Subgroup responsible)** | **Number** | **Title** |
| --- | --- | --- |
| ITU-T (SG2) | M.2401 (12/2003) | Error performance limits and procedures for bringing-into-service and maintenance of multi-operator international paths and sections within an optical transport network |
| ITU-T (Q17/12) | Y.1563 (01/2009) | Ethernet frame transfer and availability performance |
| ITU-T (Q2/15) | G.983.1 (01/2005) | Broadband optical access systems based on Passive Optical Networks (PON) |
| ITU-T (Q2/15) | G.983.2 (07/2005) | ONT management and control interface specification for B-PON |
| ITU-T (Q2/15) | G.983.3 (03/2001) | A broadband optical access system with increased service capability by wavelength allocation |
| ITU-T (Q2/15) | G.983.4 (11/2001) | A broadband optical access system with increased service capability using dynamic bandwidth assignment |
| ITU-T (Q2/15) | G.983.5 (01/2002) | A broadband optical access system with enhanced survivability |
| ITU-T (Q2/15) | G.984.1 (03/2008) | Gigabit-capable passive optical networks (GPON): General characteristics |
| ITU-T (Q2/15) | G.984.2 (03/2003) | Gigabit-capable Passive Optical Networks (G-PON): Physical Media Dependent (PMD) layer specification |
| ITU-T (Q2/15) | G.984.3 (01/2014) | Gigabit-capable passive optical networks (G-PON): Transmission convergence layer specification |
| ITU-T (Q2/15) | G.984.4 (02/2008) | Gigabit-capable passive optical networks (G-PON): ONT management and control interface specification |
| ITU-T (Q2/15) | G.984.5 (05/2014) | Gigabit-capable passive optical networks (G-PON): Enhancement band |
| ITU-T (Q2/15) | G.984.6 (03/2008) | Gigabit-capable passive optical networks (GPON): Reach extension |
| ITU-T (Q2/15) | G.984.7 (07/2010) | Gigabit-capable passive optical networks (GPON): Long reach |
| ITU-T (Q2/15) | G.985 (03/2003) | 100 Mbit/s point-to-point Ethernet based optical access system |
| ITU-T (Q2/15) | G.986 (01/2010) | 1 Gbit/s point-to-point Ethernet-based optical access system |
| ITU-T (Q2/15) | G.987 (06/2012) | 10-Gigabit-capable passive optical network (XG-PON) systems: Definitions, abbreviations and acronyms |
| ITU-T (Q2/15) | G.987.1 (03/2016) | 10-Gigabit-capable passive optical networks (XG-PON): General requirements |
| ITU-T (Q2/15) | G.987.2 (02/2016) | 10-Gigabit-capable passive optical networks (XG-PON): Physical media dependent (PMD) layer specification |
| ITU-T (Q2/15) | G.987.3 (01/2014) | 10-Gigabit-capable passive optical networks (XG-PON): Transmission convergence (TC) layer specification |
| ITU-T (Q2/15) | G.987.4 (06/2012) | 10-Gigabit-capable passive optical networks (XG-PON): Reach extension |
| ITU-T (Q2/15) | G.988 (2018) | ONU management and control interface (OMCI) specification |
| ITU-T (Q2/15) | G.989 (10/2015) | 40-Gigabit-capable passive optical networks (NG-PON2): Definitions, abbreviations and acronyms  |
| ITU-T (Q2/15) | G.989.1 (03/2013) | 40-Gigabit-capable passive optical networks (NG-PON2): General requirements |
| ITU-T (Q2/15) | G.989.2 (2018) | 40-Gigabit-capable passive optical networks 2 (NG-PON2): Physical media dependent (PMD) layer specification |
| ITU-T (Q2/15) | G.989.3 (2018) | 40-Gigabit-capable passive optical networks (NG-PON2): Transmission convergence layer specification |
| ITU-T (Q2/15) | G.9801 (08/2013) | Ethernet passive optical networks using OMCI |
| ITU-T (Q2/15) | G.9802 (2018) | Multiple-wavelength passive optical networks (MW-PONs) |
| ITU-T (Q2/15) | G.9803 (04/2015) | Radio over Fiber systems |
| ITU-T (Q2/15) | G.9807.1 (06/2016) | 10-Gigabit-capable symmetric passive optical network (XGS-PON) |
| ITU-T (Q2/15) | G.9807.2 (2018) | 10 Gigabit-capable symmetrical passive optical networks (XG(S)-PON): Reach extension |
| ITU-T (Q11/15) | G.780/Y.1351 (07/2010) | Terms and definitions for synchronous digital hierarchy (SDH) networks |
| ITU-T (Q11/15) | G.870/Y.1352 (11/2016) | Terms and definitions for optical transport networks |
| ITU-T (Q10/15) | G.8001/Y.1354 (04/2016) | Terms and definitions for Ethernet frames over transport |
| ITU-T (Q12/15) | G.8081/Y.1353 (02/2012) | Terms and definitions for automatically switched optical networks |
| ITU-T (Q10/15) | G.8101/Y.1355 (11/2016) | Terms and definitions for MPLS transport profile |
| ITU-T (Q5/15) | G.650.1 (07/2010) | Definitions and test methods for linear, deterministic attributes of single-mode fibre and cable |
| ITU-T (Q5/15) | G.650.2 (07/2007) | Definitions and test methods for statistical and non-linear related attributes of single-mode fibre and cable |
| ITU-T (Q5/15) | G.650.3 (03/2008) | Test methods for installed single-mode optical fibre cable links |
| ITU-T (Q5/15) | G.651.1 (2018) | Characteristics of a 50/125 µm multimode graded index optical fibre cable for the optical access network |
| ITU-T (Q5/15) | G.652 (11/2016) | Characteristics of a single-mode optical fibre and cable |
| ITU-T (Q5/15) | G.653 (07/2010) | Characteristics of a dispersion-shifted, single-mode optical fibre and cable |
| ITU-T (Q5/15) | G.654 (11/2016) | Characteristics of a cut-off shifted single-mode optical fibre and cable |
| ITU-T (Q5/15) | G.655 (11/2009) | Characteristics of a non-zero dispersion-shifted single-mode optical fibre and cable |
| ITU-T (Q5/15) | G.656 (07/2010) | Characteristics of a fibre and cable with non-zero dispersion for wideband optical transport |
| ITU-T (Q5/15) | G.657 (11/2016) | Characteristics of a bending-loss insensitive single-mode optical fibre and cable for the access network |
| ITU-T (Q6/15) | G.664 (10/2012) | Optical safety procedures and requirements for optical transmission systems |
| ITU-T (Q6/15) | G.680 (07/2007) | Physical transfer functions of optical network elements |
| ITU-T (Q6/15) | G.691 (03/2006) | Optical interfaces for single channel STM-64 and other SDH systems with optical amplifiers |
| ITU-T (Q6/15) | G.692 (10/1998) | Optical interfaces for multichannel systems with optical amplifiers |
| ITU-T (Q6/15) | G.693 (11/2009) | Optical interfaces for intra-office systems |
| ITU-T (Q6/15) | G.694.1 (02/2012) | Spectral grids for WDM applications: DWDM frequency grid |
| ITU-T (Q6/15) | G.694.2 (12/2003) | Spectral grids for WDM applications: CWDM wavelength grid |
| ITU-T (Q6/15) | G.695 (01/2015) | Optical interfaces for coarse wavelength division multiplexing applications |
| ITU-T (Q6/15) | G.696.1 (07/2010) | Longitudinally compatible intra-domain DWDM applications |
| ITU-T (Q6/15) | G.697 (11/2016) | Optical monitoring for dense wavelength division multiplexing systems |
| ITU-T (Q6/15) | G.698.1 (11/2009) | Multichannel DWDM applications with single-channel optical interfaces |
| ITU-T (Q6/15) | G.698.2 (11/2018) | Amplified multichannel dense wavelength division multiplexing applications with single channel optical interfaces |
| ITU-T (Q6/15) | G.698.3 (02/2012) | Multichannel seeded DWDM applications with single-channel optical interfaces |
| ITU-T (Q6/15) | G.698.4 (2018) | Multichannel bi-directional DWDM applications with port agnostic single-channel optical interfaces |
| ITU-T (Q6/15) | G.911 (04/1997) | Parameters and calculation methodologies for reliability and availability of fibre optic systems |
| ITU-T (Q6/15) | G.957 (03/2006) | Optical interfaces for equipment and systems relating to the synchronous digital hierarchy |
| ITU-T (Q6/15) | G.959.1 (04/2016) | Optical transport network physical layer interfaces |
| ITU-T (Q7/15) | G.671 (02/2012) | Transmission characteristics of optical components and subsystems |
| ITU-T (Q7/15) | G.672 (2018) | Characteristics of multi-degree reconfigurable optical add/drop multiplexers |
| ITU-T (Q11/15) | G.781 (09/2008) | Synchronization layer functions |
| ITU-T (Q11/15) | G.783 (03/2006) | Characteristics of synchronous digital hierarchy (SDH) equipment functional blocks |
| ITU-T (Q11/15) | G.798 (12/2012) | Characteristics of optical transport network hierarchy equipment functional blocks |
| ITU-T (Q11/15) | G.806 (02/2012) | Characteristics of transport equipment – Description methodology and generic functionality |
| ITU-T (Q11/15) | G.871/Y.1301 (10/2000) | Framework of Optical Transport Network Recommendations |
| ITU-T (Q11/15) | G.808 (11/2016) | Terminology for protection and restoration |
| ITU-T (Q11/15) | G.808.1 (05/2014) | Generic protection switching – Linear trail and subnetwork protection |
| ITU-T (Q11/15) | G.808.2 (11/2013) | Generic protection switching – Ring protection |
| ITU-T (Q11/15) | G.808.3 (10/2012) | Generic protection switching – Shared mesh protection |
| ITU-T (Q11/15) | G.841 (10/1998) | Types and characteristics of SDH network protection architectures |
| ITU-T (Q11/15) | G.842 (04/1997) | Interworking of SDH network protection architectures |
| ITU-T (Q11/15) | G.873.1 (10/2017) | Optical transport network (OTN): Linear protection |
| ITU-T (Q11/15) | G.873.2 (07/2015) | ODUk shared ring protection |
| ITU-T (Q11/15) | G.873.3 (09/2017) | OTN Shared Mesh Protection |
| ITU-T (Q10/15) | G.8021/Y.1341 (11/2016) | Characteristics of Ethernet transport network equipment functional blocks |
| ITU-T (Q10/15) | G.8021.1/Y.1341.1 (10/2012) | Types and characteristics of Ethernet transport network equipment |
| ITU-T (Q10/15) | G.8031/Y.1342 (01/2015) | Ethernet linear protection switching |
| ITU-T (Q10/15) | G.8032/Y.1344 (02/2012) | Ethernet ring protection switching |
| ITU-T (Q10/15) | G.8131/Y.1382 (07/2014) | Linear protection switching for MPLS transport profile |
| ITU-T (Q10/15) | G.8132/Y.1383 (08/2017) | MPLS-TP shared ring protection |
| ITU-T (Q10/15) | Y.1720 (12/2006) | Protection switching for MPLS networks |
| ITU-T (Q10/15) | G.8011/Y.1307 (11/2016) | Ethernet service characteristics |
| ITU-T (Q10/15) | G.8012/Y.1308 (08/2004) | Ethernet UNI and Ethernet NNI |
| ITU-T (Q10/15) | G.8012.1/Y.1308.1 (12/2012) | Interfaces for the Ethernet transport network |
| ITU-T (Q10/15) | G.8013/Y.1731 (11/2013) | OAM functions and mechanisms for Ethernet based networks |
| ITU-T (Q10/15) | G.8112/Y.1371 (10/2012) | Interfaces for the MPLS Transport Profile layer network |
| ITU-T (Q10/15) | G.8113.1/Y.1372.1 (04/2016) | Operations, administration and maintenance mechanism for MPLS-TP in packet transport networks |
| ITU-T (Q10/15) | G.8113.2/Y.1372.2 (11/2012) | Operations, administration and maintenance mechanisms for MPLS-TP networks using the tools defined for MPLS |
| ITU-T (Q10/15) | G.8121/Y.1381 (04/2016) | Characteristics of MPLS-TP equipment functional blocks |
| ITU-T (Q10/15) | G.8121.1/Y.1381.1 (04/2016) | Characteristics of MPLS-TP equipment functional blocks supporting ITU-T G.8113.1/Y.1372.1 OAM mechanisms |
| ITU-T (Q10/15) | G.8121.2/Y.1381.2 (04/2016) | Characteristics of MPLS-TP equipment functional blocks supporting ITU-T G.8113.2/Y.1372.2 OAM mechanisms |
| ITU-T (Q10/15) | Y.1710 (11/2002) | Requirements for Operation & Maintenance functionality in MPLS networks |
| ITU-T (Q10/15) | Y.1711 (02/2004) | Operation & Maintenance mechanism for MPLS networks |
| ITU-T (Q10/15) | Y.1712 (01/2004) | OAM functionality for ATM-MPLS interworking |
| ITU-T (Q10/15) | Y.1713 (03/2004) | Misbranching detection for MPLS networks |
| ITU-T (Q10/15) | Y.1714 (01/2009) | MPLS management and OAM framework |
| ITU-T (Q10/15) | Y.1730 (01/2004) | Requirements for OAM functions in Ethernet-based networks and Ethernet services |
| ITU-T (Q11/15) | G.707/Y.1322 (01/2007) | Network node interface for the synchronous digital hierarchy (SDH) |
| ITU-T (Q11/15) | G.709/Y.1331 (2018) | Interfaces for the optical transport network (OTN) |
| ITU-T (Q11/15) | G.709.1/Y.1331.1 (02018) | Flexible OTN short-reach interface  |
| ITU-T (Q11/15) | G.709.2/Y.1331.2 (07/2018) | OTU4 long-reach interface |
| ITU-T (Q11/15) | G.709.3/Y.1331.3 (2018) | Flexible OTN long-reach interfaces |
| ITU-T (Q11/15) | G.798.1 (01/2013) | Types and characteristics of optical transport network equipment |
| ITU-T (Q11/15) | G.7041/Y.1303 (08/2016) | Generic framing procedure |
| ITU-T (Q11/15) | G.7042/Y.1305 (03/2006) | Link capacity adjustment scheme (LCAS) for virtual concatenated signals |
| ITU-T (Q11/15) | G.7043/Y.1343 (07/2004) | Virtual concatenation of plesiochronous digital hierarchy (PDH) signals |
| ITU-T (Q11/15) | G.7044/Y.1347 (10/2011) | Hitless adjustment of ODUflex(GFP) |
| ITU-T (Q11/15) | G.8201 (04/2011) | Error performance parameters and objectives for multi-operator international paths within optical transport networks |
| ITU-T (Q12/15) | G.800 (04/2016) | Unified functional architecture of transport networks |
| ITU-T (Q12/15) | G.805 (03/2000) | Generic functional architecture of transport networks |
| ITU-T (Q12/15) | G.872 (01/2017) | Architecture of optical transport networks |
| ITU-T (Q12/15) | G.7701 (11/2016) | Common Control Aspects |
| ITU-T (Q12/15) | G.7702 (03/2018) | Architecture for SDN control of transport networks |
| ITU-T (Q12/15) | G.8010/Y.1306 (02/2004) | Architecture of Ethernet layer networks |
| ITU-T (Q12/15) | G.8080/Y.1304 (02/2012) | Architecture for the automatically switched optical network |
| ITU-T (Q12/15) | G.8110/Y.1370 (01/2005) | MPLS layer network architecture |
| ITU-T (Q12/15) | G.8110.1/Y.1370.1 (12/2011) | Architecture of the Multi-Protocol Label Switching transport profile layer network |
| ITU-T (Q13/15) | G.813 (03/2003) | Timing characteristics of SDH equipment slave clocks (SEC) |
| ITU-T (Q13/15) | G.8251 (09/2010) | The control of jitter and wander within the optical transport network (OTN) |
| ITU-T (Q13/15) | G.8260 (02/2012) | Definitions and terminology for synchronization in packet networks |
| ITU-T (Q13/15) | G.8261/Y.1361 (08/2013) | Timing and synchronization aspects in packet networks |
| ITU-T (Q13/15) | G.8261.1/Y.1361.1 (02/2012) | Packet delay variation network limits applicable to packet-based methods (Frequency synchronization) |
| ITU-T (Q13/15) | G.8262/Y.1362 (01/2015) | Timing characteristics of a synchronous Ethernet equipment slave clock |
| ITU-T (Q13/15) | G.8264/Y.1364 (05/2014) | Distribution of timing information through packet networks |
| ITU-T (Q13/15) | G.8265/Y.1365 (10/2010) | Architecture and requirements for packet-based frequency delivery |
| ITU-T (Q13/15) | G.8265.1/Y.1365.1 (07/2014) | Precision time protocol telecom profile for frequency synchronization |
| ITU-T (Q13/15) | G.8266/Y.1376 (11/2016) | Timing characteristics of telecom grandmaster clocks for frequency synchronization |
| ITU-T (Q13/15) | G.8271/Y.1366 (07/2016) | Time and phase synchronization aspects of packet networks |
| ITU-T (Q13/15) | G.8271.1/Y.1366.1 (08/2013) | Network limits for time synchronization in packet networks |
| ITU-T (Q13/15)  | G.8272/Y.1367 (01/2015) | Timing characteristics of primary reference time clocks |
| ITU-T (Q13/15) | G.8272.1/Y.1367.1 (11/2016) | Timing characteristics of enhanced primary reference time clocks |
| ITU-T (Q13/15) | G.8273/Y.1368 (08/2013) | Framework of phase and time clocks |
| ITU-T (Q13/15) | G.8273.2/Y.1368.2 (01/2017) | Timing characteristics of telecom boundary clocks and telecom time slave clocks |
| ITU-T (Q13/15) | G.8275/Y.1369 (11/2013) | Architecture and requirements for packet-based time and phase distribution |
| ITU-T (Q13/15) | G.8275.1/Y.1369.1 (06/2014) | Precision time protocol telecom profile for phase/time synchronization with full timing support from the network |
| ITU-T (Q13/15) | G.8275.2/Y.1369.2 (06/2016) | Precision time Protocol Telecom Profile for time/phase synchronization with partial timing support from the network |
| ITU-T (Q14/15) | G.784 (03/2008) | Management aspects of synchronous digital hierarchy (SDH) transport network elements |
| ITU-T (Q14/15) | G.874 (08/2017) | Management aspects of optical transport network elements |
| ITU-T (Q14/15) | G.875 (ex. G.874.1) (11/2016) | Optical transport network: Protocol-neutral management information model for the network element view |
| ITU-T (Q14/15) | G.7710/Y.1701 (02/2012) | Common equipment management function requirements |
| ITU-T (Q14/15) | G.7711/Y.1702 (03/2018) | Generic protocol-neutral information model for transport resources |
| ITU-T (Q14/15) | G.7712/Y.1703 (09/2010) | Architecture and specification of data communication network |
| ITU-T (Q14/15) | G.7713/Y.1704 (11/2009) | Distributed call and connection management (DCM) |
| ITU-T (Q14/15) | G.7713.1/Y.1704.1 (03/2003) | Distributed Call and Connection Management (DCM) based on PNNI |
| ITU-T (Q14/15) | G.7713.2/Y.1704.2 (03/2003) | Distributed Call and Connection Management: Signalling mechanism using GMPLS RSVP-TE |
| ITU-T (Q14/15) | G.7713.3/Y.1704.3 (03/2003) | Distributed Call and Connection Management: Signalling mechanism using GMPLS CR-LDP |
| ITU-T (Q14/15) | G.7714/Y.1705 (08/2005) | Generalized automatic discovery for transport entities |
| ITU-T (Q14/15) | G.7714.1/Y.1705.1 (08/2017) | Protocol for automatic discovery in SDH and OTN networks |
| ITU-T (Q14/15) | G.7715/Y.1706 (06/2002) | Architecture and requirements for routing in the automatically switched optical networks |
| ITU-T (Q14/15) | G.7715.1/Y.1706.1 (02/2004) | ASON routing architecture and requirements for link state protocols |
| ITU-T (Q14/15) | G.7715.2/Y.1706.2 (02/2007) | ASON routing architecture and requirements for remote route query |
| ITU-T (Q14/15) | G.7716/Y.1707 (01/2010) | Architecture of control plane operations |
| ITU-T (Q14/15) | G.7718/Y.1709 (07/2010) | Framework for ASON management |
| ITU-T (Q14/15) | G.7719 (ex. G.7718.1/Y.1709.1) (12/2006) | Protocol-neutral management information model for the control plane view |
| ITU-T (Q14/15) | G.8051/Y.1345 (03/32018) | Management aspects of the Ethernet Transport (ET) capable network element |
| ITU-T (Q14/15) | G.8052/Y.1346 (11/2016) | Protocol-neutral management information model for the Ethernet Transport capable network element |
| ITU-T (Q14/15) | G.8151/Y.1374 (08/2017) | Management aspects of the MPLS-TP network element |
| ITU-T (Q14/15) | G.8152/Y.1375 (12/2016) | Protocol-neutral management information model for the MPLS-TP network element |
| ITU-T (Q15/15) | O.172 (04/2005) | Jitter and wander measuring equipment for digital systems which are based on the synchronous digital hierarchy (SDH) |
| ITU-T (Q15/15) | O.173 (02/2012) | Jitter measuring equipment for digital systems which are based on the optical transport network |
| ITU-T (Q15/15) | O.174 (11/2009) | Jitter and wander measuring equipment for digital systems which are based on synchronous Ethernet technology |
| ITU-T (Q15/15) | O.175 (10/2012) | Jitter measuring equipment for digital systems based on XG-PON |
| ITU-T (Q15/15) | O.182 (07/2007) | Equipment to assess error performance on Optical Transport Network interfaces |
| ITU-T (Q15/15) | O.201 (07/2003) | Q-factor test equipment to estimate the transmission performance of optical channels |

Table 6 – OTNT Related Standards and Industry Agreements (IEEE 802 standards)

|  |  |  |  |
| --- | --- | --- | --- |
| **Organisation (Subgroup responsible)** | **Number** | **Title** | **Publication Date** |
| IEEE 802.1 | IEEE Std. 802-2014 | IEEE Standard for Local and Metropolitan Area Networks: Overview and Architecture | 2014 |
| IEEE 802.1 | IEEE Std. 802.1AS-2011 | IEEE Standard for Local and Metropolitan Area Networks - Timing and Synchronization for Time-Sensitive Applications in Bridged Local Area Networks | 2011 |
| IEEE 802.1 | IEEE Std. 802.1AS-2011/Cor 1-2013 | IEEE Standard for Local and metropolitan area networks— Timing and Synchronization for Time-Sensitive Applications in Bridged Local Area Networks— Corrigendum 1: Technical and Editorial Corrections | 2013 |
| IEEE 802.1 | IEEE Std. 802.1AS-2011/Cor 2-2015 | IEEE Standard for Local and metropolitan area networks— Timing and Synchronization for Time-Sensitive Applications in Bridged Local Area Networks— Corrigendum 2: Technical and Editorial Corrections | 2015 |
| IEEE 802.1 | IEEE Std. 802.1AX-2014 | Link Aggregation | 2008 |
| IEEE 802.1 | IEEE 802.1AX-2014/Cor 1-2017 | Link Aggregation – Corrigendum 1 | 2017 |
| IEEE 802.1 | IEEE Std. 802.1D-2004 | Media access control (MAC) Bridges (Incorporates IEEE 802.1t-2001 and IEEE 802.1w) | 2004 |
| IEEE 802.1 | IEEE Std. 802.1Q-2014 | Virtual Bridged Local Area Networks—Revision | 2011 |
| IEEE 802.1 | IEEE Std. 802.1Qcd-2015 | Application Virtual Local Area Network (VLAN) Type, Length, Value (TLV) | 2015 |
| IEEE 802.1 | IEEE Std 802.1Qca-2015 | Path Control and Reservation | 2015 |
|  | IEEE Std 802.1Q-2014 Cor 1-2015 | Technical and editorial corrections | 2015 |
|  | IEEE Std 802.1Qbv-2015 | Enhancements for scheduled traffic | 2015 |
|  | IEEE Std 802.1Qbu-2016 | Frame preemption | 2016 |
|  | IEEE Std 802.1Qbz-2016 | Enhancements to Bridging of IEEE 802.11 Media | 2016 |
|  | IEEE Std 802.1Qci-2017 | Per-Stream Filtering and Policing | 2017 |
| IEEE 802.3 | IEEE Std 802.3-2018 | IEEE Standard for Ethernet | 08/2018 |
| IEEE 802.3 | IEEE Std 802.3.1-2013 | IEEE Standard for Management Information Base (MIB) Definitions for Ethernet | 08/2013 |

Table 8 – OTNT Related Standards and Industry Agreements (MEF documents)

| **Category** | **Number** | **Title** |
| --- | --- | --- |
| Service Definitions | 6.2 | Metro Ethernet Services Definitions Phase 3 |
| 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 | 33 | Ethernet Access Services Definition |
| Service Definitions | 43 | Virtual NID (vNID) Functionality for E-Access Services |
| Service Definitions | 47 | Carrier Ethernet Services for Cloud Implementation Agreement |
| Service Definitions | 51 | OVC Services Definitions |
| Service Definitions | 62 | Managed Access E-Line Service Implementation Agreement |
| Service Attributes | 10.3 | Ethernet Services Attributes Phase 3 |
| Service Attributes | 10.3.1 | Composite Performance Metric (CPM) Amendment to MEF 10.3 |
| Service Attributes | 10.3.2 | UNI Resiliency Enhancement Amendment to MEF 10.3 |
| 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 | 26.2 | External Network Network Interface (ENNI) and Operator Service Attributes |
| Service Attributes | 41 | Generic Token Bucket Algorithm |
| Service Attributes | 45 | Multi-CEN L2CP |
| Service Attributes | 45.0.1 | Amendment to MEF 45: OVC Services Requirement for L2CP |
| Service Attributes | 61 | IP Service Attributes for Subscriber IP Services |
| Service Attributes | 63 | Subscriber Layer 1 Service Attributes |
| 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 |
| Information and Data Models | 7.3 | Carrier Ethernet Management Information Model |
| 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) |
| 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 |
| Service Activation and Test  | 46 | Latching Loopback Protocol and Functionality |
| Service Activation and Test | 48 | 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 |
| 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 | SOAM PM Implementation Agreement Amendment |
| 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 | Lifecycle Service Orchestration (LSO): Reference Architecture and Framework |
| MEF Service Lifecycle | 55.0.1 | Amendment to MEF 55 - Operational Threads |
| MEF Service Lifecycle | 55.0.2 | Amendment to MEF 55 - TOSCA Service Templates |
| MEF Service Lifecycle | 57 | Ethernet Ordering Technical Specification - Business Requirements and Use Cases |
| Abstract Test Suites | 9 | Abstract Test Suite for Ethernet Services at the UNI |
| Abstract Test Suites | 14 | Abstract Test Suite for Traffic Management Phase 1 |
| Abstract Test Suites | 18 | Abstract Test Suite for Circuit Emulation Services |
| Abstract Test Suites | 19 | Abstract Test Suite for UNI Type 1 |
| Abstract Test Suites | 21 | Abstract Test Suite for UNI Type 2 Part 1 Link OAM |
| Abstract Test Suites | 24 | Abstract Test Suite for UNI Type 2 Part 2 E-LMI |
| Abstract Test Suites | 25 | Abstract Test Suite for UNI Type 2 Part 3 Service OAM |
| Abstract Test Suites | 27 | Abstract Test Suite For UNI Type 2 Part 5: Enhanced UNI Attributes & Part 6: L2CP Handling |
| Abstract Test Suites | 34 | ATS for Ethernet Access Services |
| Abstract Test Suites | 37 | Abstract Test Suite for ENNI |

The current set of MEF technical specifications is at: https://www.mef.net/resources/technical-specifications

## SDH & SONET Related Recommendations and Standards

Refer to Issue 21 of this standard work plan document.

## ITU-T Recommendations on the OTN Transport Plane

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

Table 9 – 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.872** Architecture of Optical Transport Networks |
| Control Plane  | ASON recommendations are moved to specific ASON/SDN standards page.  |
| Structures & Mapping | **G.709/Y.1331** Interfaces for the Optical Transport Network (OTN) |
|  | **G.709.1/Y.1331.1** Flexible OTN short-reach interface |
|  | **G.709.2/Y.1331.2** OTU4 long-reach interface |
|  | **G.709.3/Y.1331.3** Flexible OTN long-reach interfaces |
|  | **G.975** Forward Error Correction |
|  | **G.798** Characteristics of optical transport network (OTN) equipment functional blocks |
|  | **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 |
| 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.Imp874.1** Implementer's Guide |
| **G.7710/Y.1701** Common Equipment Management Requirements |
| **G.7711/Y.1702** Generic protocol-neutral information model for transport resources |
| **G.7714/Y.1705** Generalized automatic discovery for transport entities |
| **G.7714.1/Y.1705.1** Protocol for automatic discovery in SDH and OTN networks |
| Data Communication Network (DCN)  | **G.7712/Y.1703** 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  |
| 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.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 |

## Standards on ASON and SDN Architectural approaches to Control

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

Table 10 – Standards on the ASTN/ASON Control Plane

| **Topic**  | **Title**  |
| --- | --- |
| Definitions | **G.8081/Y.1353** Definitions and Terminology for Automatically Switched Optical Networks (ASON) |
| Architecture  | **G.8080/Y.1304** Architecture for the Automatic Switched Optical Network (ASON) |
| **G.7701** Common Control Aspects |
| **G.7702** Architecture for SDN control of transport networks |
| Protocol Neutral Specifications for key signalling elements  | **G.7713/Y.1704** Distributed Call and Connection Management (DCM) |
| **G.Imp7713/Y.1704 Implementer's Guide** |
| **G.7713.1/Y.1704** Distributed Call and Connection Management based on PNNI |
| **G.Imp7713.1/Y.1704** Implementer's Guide |
| **G.7713.2/Y.1704** Distributed Call and Connection Management: Signalling mechanism using GMPLS RSVP-TE  |
| **G.Imp7713.2/Y.1704** Implementer's Guide |
| **G.7713.3/Y.1704** Distributed Call and Connection Management : Signalling mechanism using GMPLS CR-LDP  |
| **G.Imp7713.3/Y.1704** Implementer's Guide |
| **G.7714/Y.1705** Generalised automatic discovery for transport entities  |
| **G.7714.1/Y.1705.1** Protocol for automatic discovery in SDH and OTN networks |
| **G.Imp7714.1** Implementer's Guide |
| **G.7715/Y.1706** Architecture and requirements for routing in automatically switched optical networks |
| **G.Imp7715** Implementer's Guide |
| **G.7715.1/Y.1706.1** ASON routing architecture and requirements for link state protocols  |
| **G.Imp7715.1** Implementer's Guide |
| **G.7715.2/Y.1706.2** ASON routing architecture and requirements for remote route query  |
| **G.7716/Y.1707** Architecture of control plane operations |
| **G.7718/Y.1709** Framework for ASON Management |
| **G.7719 (ex. G.7718.1/Y.1709.1)** Protocol-neutral management information model for the control plane view |
| Data Communication Network (DCN)  | **G. 7712/Y.1703** Architecture and specification of data communication network  |

## 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 12 – 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(Q10/15) | G.8001 | Terms and definitions for Ethernet frames over transport |
| SG15(Q12/15) | G.8010/Y.1306 | Architecture of Ethernet Layer Networks |
| SG15(Q10/15) | G.8011/Y.1307 | Ethernet service characteristics |
| SG15(Q10/15) | G.8012/Y.1308 | Ethernet UNI and Ethernet NNI |
| SG15(Q10/15) | G.8012.1/Y.1308.1 | Interfaces for the Ethernet transport network |
| SG15(Q10/15) | G.8013/Y.1731 | OAM functions and mechanisms for Ethernet based networks |
| SG15(Q10/15) | G.8021/Y.1341 | Characteristics of Ethernet transport network equipment functional blocks |
| SG15(Q10/15) | G.8021.1/Y.1341.1 | Types and characteristics of Ethernet transport network equipment |
| SG15(Q10/15) | G.8031/Y.1342 | Ethernet linear protection switching |
| SG15(Q10/15) | G.8032/Y.1344 | Ethernet ring protection switching |
| SG15(Q10/15) | G.8131/Y.1382 | Linear protection switching for MPLS transport profile |
| SG15(Q10/15) | G.8132/Y.1383 | MPLS-TP shared ring protection |
| SG15(Q14/15) | G.8051/Y.1345 | Management aspects of the Ethernet-over-Transport (EoT) capable network element  |
| SG15(Q14/15) | G.8052/Y.1346 | Protocol-neutral management information model for the Ethernet Transport capable network element |
| SG15(Q13/15) | G.8262/Y.1362 | Timing characteristics of synchronous Ethernet equipment slave clock (EEC) |

Table 13 – 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 |
| 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/Y.1370 | MPLS Layer Network Architecture |

Table 14 – MPLS-TP-related Recommendations

| **Organisation (Subgroup responsible)** | **Number** | **Title** |
| --- | --- | --- |
| SG15(Q10/15) | G.8101/Y.1355 | Terms and definitions for MPLS transport profile |
| SG15(Q12/15) | G.8110.1/Y.1370.1 | Architecture of the Multi-Protocol Label Switching transport profile layer network |
| SG15(Q10/15) | G.8112/Y.1371 | Interfaces for the MPLS Transport Profile layer network |
| SG15(Q10/15) | G.8113.1/Y1372.1 | Operations, administration and maintenance mechanism for MPLS-TP in packet transport networks |
| SG15(Q10/15) | G.8113.2/Y.1372.2 | Operations, administration and maintenance mechanisms for MPLS-TP networks using the tools defined for MPLS |
| SG15(Q10/15) | G.8121/Y.1381 | Characteristics of MPLS-TP equipment functional blocks |
| SG15(Q10/15) | G.8121.1/Y.1381.1 | Characteristics of MPLS-TP equipment functional blocks supporting ITU-T G.8113.1/Y.1372.1 OAM mechanisms |
| SG15(Q10/15) | G.8121.2/Y.1381.2 | Characteristics of MPLS-TP equipment functional blocks supporting ITU-T G.8113.2/Y.1372.2 OAM mechanisms |
| SG15(Q10/15) | G.8131/Y.1382 | Linear protection switching for MPLS transport profile |
| SG15(Q10/15) | G.8132/Y.1383 | MPLS-TP shared ring protection |
| SG15(Q14/15) | G.8151/Y.1374 | Management aspects of the MPLS-TP network element |
| SG15(Q14/15) | G.8152/Y.1375 | Protocol-neutral management information model for the MPLS-TP network element |

## Standards on Synchronization

The series of G.8200-G.8299 ITU-T Recommendations are dedicated for Synchronization, quality and availability targets.

Common aspects:

G.8201: Error performance parameters and objectives for multi-operator international paths within optical transport networks

G.8251: The control of jitter and wander within the optical transport network (OTN)

G.8260: Definitions and terminology for synchronization in packet networks

Table 15 – Synchronization-related Recommendations

|  |  |  |
| --- | --- | --- |
|  | **Frequency** | **Time and phase** |
| Network Requirements | G.8261/Y.1361: Timing and synchronization aspects in packet networks G.8261.1/Y.1361.1: Packet delay variation network limits applicable to packet-based methods (Frequency synchronization) | G.8271/Y.1366: Time and phase synchronization aspects of packet networks G.8271.1/Y.1366.1: Network limits for time synchronization in packet networksG.8271.2/Y.1366.2: Network limits for time synchronization in packet networks with partial timing support from the network |
| Clock | G.811: Timing characteristics of primary reference clocks G.811.1: Timing characteristics of enhanced primary reference clocks G.812: Timing requirements of slave clocks suitable for use as node clocks in synchronization networksG.813: Timing characteristics of SDH equipment slave clocks (SEC)G.8262/Y.1362: Timing characteristics of a synchronous Ethernet equipment slave clockG.8262.1/Y.1362.1G.8263/Y.1363: Timing characteristics of packet-based equipment clocksG.8251: The control of jitter and wander within the optical transport network (OTN)G.8266/Y.1376: Timing characteristics of telecom grandmaster clocks for frequency synchronization | G.8273/Y.1368: Framework of phase and time clocksG.8273.1/Y.1368.1: Timing characteristics of telecom grandmaster clocks for time synchronization (in progress)G.8273.2/Y.1368.2: Timing characteristics of telecom boundary clocks and telecom time slave clocksG.8273.3/Y.1368.3: Timing characteristics of telecom transparent clocksG.8273.4/Y.1368.4: Timing characteristics of partial timing support telecom boundary clocksand telecom time slave clocks (in progress) |
| G.8272/Y.1367: Timing characteristics of primary reference time clocksG.8272.1/Y.1367.1: Timing characteristics of enhanced primary reference time clocks |
| Distribution | G.8264/Y.1364: Distribution of timing information through packet networksG.8265: Architecture and requirements for packet-based frequency delivery G.8265.1: Precision time protocol telecom profile for frequency synchronization | G.8275/Y.1369: Architecture and requirements for packet-based time and phase distributionG.8275.1/Y.1369.1: Precision time protocol telecom profile for phase/time synchronization with full timing support from the networkG.8275.2/Y.1369.2: Precision time protocol telecom profile for time/phase synchronization with partial timing support from the network |

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