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

**Issue 23, June 2017**

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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.

http://www.itu.int/ITU-T/studygroups/com15/otn/

Proposed modifications and comments should be sent to:

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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 June 2017

# Highlight of ITU-T SG15

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). This revision 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.

OTUCn client-side interfaces 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 January 2017 as “Flexible OTN short-reach interface”. Future n × 200G and n × 400G FlexO standards will be available when next-generation 200G or 400G client optical modules become available.

As of June 2017, new work items "Flexible OTN (FlexO) frame formats for long-reach interface", "Frame format and HD FEC for OTU4 Long Reach metro applications" are ongoing.

In the area of network restoration and protection, G. Supplement 60 ""Ethernet Linear Protection Switching with Dual Node Interconnection" is avaialble. Additionally, the work on ODU shared mesh protection (ODU SMP) is being progressed.

In the area of packet-based technologies, a revised Recommendation G.8011 "Ethernet Service Characteristics", a revised G.8021 "Characteristics of Ethernet transport network equipment functional blocks "and an amendment to G.8012 "Ethernet UNI and Ethernet NNI" were published.

In the area of Interfaces for Optical Transport Network (OTN), an amendment to Recommendation G.798 "Characteristics of optical transport network hierarchy equipment functional blocks" was published. This amendament is part of reorganization of the funcational block represention of OTN equipment to support beyond 100 Gbps (i.e, OTUCn).

In the area of transport network architecture, a revised Recommendation G.872 "Architecture of optical transport networks" was published as its 4th edition. This revision updated the OTN architecurr to support the interfaces beyond 100 Gbps (i.e., OTUCn) with a new represntaion of an optical channel by Optical Tributary Signal(s) (OTSi), their grouping (OSTiG) and their assembly including maintenance (OTSiA). The optical part of the OTN architecture is repsernsetd by media and media channels. With regard to the transport control, a new Recommendation G.7701 "Common Control Aspects" gives the common control framework for both software defined networking (SDN) controller and automatically switched optical network (ASON) control approaches,

Significant progresses was also made on time and frequency synchronization with the publication of two new Recommendations, G.8266, (telecom grandmaster clocks for frequency synchronization), and G.8272.1 (Enhanced Primary Reference Time Clock) and the revision of G.8273.2 (telecom boundary clocks and telecom time slave clocks).

In the area of management and control of transport systems and equipment, a revised G.874.1 "Optical transport network (OTN): Protocol-neutral management information model for the network element view", a revised recommendation G.7711 "Generic protocol-neutral information model for transport resources" and G.8052 "Protocol-neutral management information model for the Ethernet Transport capable network element" , a new recommendation G.8152 "Protocol-neutral management information model for the MPLS-TP network element" were published during between the end of 2016 and the beginning of 2017.

Finally, June-2017 SG15 meeting received more than 30 contirbutions on the topic of IMT-2020/5G, in particular on their radio access networks (i.e., fronthaul, middlehaul and backhaul), by the support of OTN and some other transport technologies. Before discussing specific solutions, the meeting decided to confirm the design target by summarizing the requirements and possible architechtuer(s) of RAN.The initiation of this activity was informed to the relevant SDOs.

More information on ITU-T Study Group 15 can be found on the group’s homepage.

# 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 June 2017 meeting as indicated in the reference.

http://www.itu.int/md/T13-SG15-170619-TD/en

Table 1 – Summary of status reports from relevant organizations

|  |  |  |  |
| --- | --- | --- | --- |
| ID | Organization | Summary | Reference |
| 1 | Broadband Forum  | Liaison to SG15 ITU-T on Flex Ethernet for IP/MPLS NetworksAt their 2017Q2 meeting in Taipei, the Broadband Forum initiated a new project entitled “Applicability ofFlex Ethernet in IP/MPLS Networks”. This project addresses the architecture, requirements and use cases in IP/MPLS networks to deploy Flex Ethernet (a.k.a. FlexE) as a new type of nodal interface.The BBF project intends to use FlexE and its related aspects specified by that document including data plane characteristics and provisioning requirements in IP/MPLS networks, including:• Interconnection between routers on FlexE interfaces in IP/MPLS networks.• End-to-end MPLS LSPs on FlexE-based channels.• Control plane protocols (e.g. RSVP-TE, PCEP) including their extensions and their applicability aspects for managing FlexE based MPLS LSP.• Aspects of using FlexE interfaces and FlexE-based MPLS LSP as a network slicing instance.• Co-existence of FlexE-based and other data link based MPLS LSPs and their operation.• New services and applications that FlexE-capable IP/MPLS networks can enable. | [ 30-WP3 ] |
| 2 | IEEE 802.1 | IEEE 802.1 liaison reportThe 802.1 working group has five active task groups: Maintenance, Time Sensitive Networking (TSN), Security, Data Center Bridging (DCB) and OmniRAN. Note that last year, the Interworking (i.e., Ethernet Bridging) task group was merged with the TSN task group and the Local Address study group was merged with the DCB task group.The 802.1 working group has over 20 active projects ranging from revisions of existing work (like the MAC service definition), addition of new bridging features (like frame replication), support of YANG modelling and application to new verticals (like fronthaul).The liaison highlights the following projects to be noted in SG15: 1) all projects in TSN, 2) 802 Network Enhancements for the next decade (e.g., 5G), 3) P802.1CM – Profile for Fronthaul, 4) P802.1Xck – YANG data model, 5) P802.1Qcp – YANG data model, 6) P802c – Local Address space, and 7) P802.1AX-rev – Link Aggregation. | [ 59-GEN ] |
| 3 | IEEE 802.3  | LS/i on Liaison letter to ITU-T Study Group 15 [from IEEE 802.3 Working Group]Developing new projects: IEEE P802.3bs 200 Gb/s and 400 Gbs Ethernet Task Force and the IEEE P802.3cd 50 Gb/s, 100 Gb/s, and 200 Gb/s Ethernet Task Force.1. IEEE P802.3bs

The P802.3bs draft moved to the Sponsor ballot stage at the Huntington Beach meeting in January 2017 (one meeting ahead of schedule). This draft covers 200GBASE-DR4, 200GBASE-FR4, 200GBASE-LR4, 400GBASE-SR16, 400GBASE-DR4, 400GBASE-FR8, and 400GBASE-LR8.1. IEEE P802.3cd

The IEEE P802.3cd 50 Gb/s, 100 Gb/s, and 200 Gb/s Ethernet Task Force was formed after the March 2016 plenary meeting to develop 50 Gb/s Ethernet. In addition next generation 100 Gb/s Ethernet PHYs and 200 Gb/s Ethernet PHYs based on 4 lanes of 50G over backplane, copper cable and multimode fibre are under developement. The Draft3.0 was produced in January 2018.3) IEEE P802.3cc - 25 Gigabit/s Ethernet over single-mode fiber Task ForceThis Task Force is in the Sponsor ballot phase on their draft which covers 25GBASE-LR – 10 km over SMF using 1 x 25 Gb/s NRZ and 25GBASE-ER – 40 km over SMF using 1 x 25 Gb/s NRZ.The IEEE 802.3 standards currently in force are:1) the base standard, IEEE Std 802.3-2015, approved by the Standards Board on 3 September 2015 and published on 4 March 2016;2) nine amendments and one corrigendum. | [ 55-GEN ][ 115-WP3 ] |
| 4 | MEF | MEF liaison reportMEF Technical & Operations Committee Project Dashboard produced in May 2017 shows their ongoing activities in services, orchestration and operations areas.IP Service Attributes for Subscriber IP Services Technical Specification was approved recently.MEF has organized its Third Network Service Projects, environment platforms and collaboration under the MEF CTO Office. The Open Initiative - which includes OpenLSO (Lifecycle Service Orchestration) projects, OpenCS (connectivity services) projects, MEFnet and LSO Hackathon is focused on enabling service providers to create Third Network services. Examples of Third Network services are scoped out, developed, tested and documented. | [ 60-GEN ] |
| 5 | OIF (PLL) | Liaison report for OIF Physical and Link Layer (PLL) Working GroupRegarding CEI (Common Electrical I-O) projects for 56G, at May-2017 Ljubljana meeting, CEI-56G-USR-NRZ, CEI-56G-XSR-NRZ, and CEI-56G-LR-ENRZ were sent to Principal member ballot, while CEI-56G-XSR-PAM4, CEI-56G-VSR-NRZ, CEI-56G-VSR-PAM4, CEI-56G-MR-PAM4, and CEI-56G-LR-PAM4 were sent to Straw ballot.At Nov-2016 Auckland meeting, it was agreed to start a new project as FlexE 2.0 that include:* 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 Nov-2016 Auckland meeting, it was agreed to start a new project to specify optical interfaces with the following characteristics:* Passive single channel ZR and amplified short reach DWDM with distances up to 120 km
* Single-carrier 400G
* Coherent detection and advanced DSP/FEC
* Target loss budget 24 dB
 | [ 56-GEN ] |
| 6 | IETF | Liaison report for IETFThe meeting schedule for 2017 - 2019 was informaed. | [ 2-WP3 ][ 71-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, 9, 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 3/15, 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 emerging 200GE and 400GE services under development in the IEEE 802.3bs project, 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 syc 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.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.874.1] 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).

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 June-2017)

OIF specified a Flex Ethernet implementation agreement in June 2016.

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**

At Nov-2016 Auckland meeting, it was agreed to start a new project as FlexE 2.0 that include:

* 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

**400ZR Interop**

At Nov-2016 Auckland meeting, it was agreed to start a new project to specify optical interfaces with the following characteristics:

* Passive single channel ZR and amplified short reach DWDM with distances up to 120 km
* Single-carrier 400G
* Coherent detection and advanced DSP/FEC
* Target loss budget 24 dB

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

MEF 22.1 Mobile Backhaul Implementation Agreement (MBH IA) identifies the requirements for MEF Ethernet Services (EVC) and MEF External Interfaces (EIs such as UNIs) for use in mobile backhaul networks based on MEF specifications (referenced in ITU-T Rec. G.8011). MEF MBH IA, Phase 3 goals include small cells, multi-operator networks and time synchronization. As part of Phase 3, MEF has introduced some terms in draft MEF 22.1.1. These terms (backhaul, fronthaul and midhaul) may assist in describing how transport network technologies in SG15 may be applied in the international mobile telecommunications architecture.

Phase 3 of the Mobile Backhaul Implementation Agreement incorporates the Small Cell amendment in the base IA, aligns with revised MEF Service definitions and attributes in MEF 6.2 and MEF 10.3, as well as adding support for multi-operator networks.

The work on this deliverable MEF MBH Phase 3 is projected to complete in late-2015. The deliverable, MEF 22.2, will supersede MEF 22.1 and MEF 22.1.1 after it is approved by the MEF Board at that time.

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.

**ITU-R report on architecture and topology of IMT networks, M.2375 (06/2015)**

As traffic demand for mobile broadband communications represented by International Mobile Telecommunications (IMT), including both IMT-2000 and IMT-Advanced as defined in Resolution ITU-R 56 are increasing, the transport network in the mobile infrastructure is becoming an important application that requires special consideration.

The transport network supports the connections between one and the other of separated radio transceiver functions within one base station, between different base stations of the mobile broadband network, as well as the connections of one base station to other network elements of the mobile infrastructure.

The Report ITU-R M.2375, published in June 2015, offers an overview of the architecture and topology of IMT networks and a perspective on the dimensioning of the respective transport requirements in these topologies, in order to assist relevant studies on the transport network in the mobile infrastructure. The Report covers different architectural aspects in a general level of detail.

## 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, 10 Gbit/s, 40 Gbit/s and 100 Gbit/s) defined by IEEE. It should be noted that there are current IEEE 802.3 efforts aimed at introducing interfaces with new rates of operation at 2.5 Gb/s, 5 Gb/s, 25 Gb/s, 50 Gb/s, 200 Gb/s, and 400 Gb/s.

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

Up to 100Gbit/s for example 40GBASE-KR4/CR4/SR4/LR4/FR and 100GBASE-CR10/SR10/LR4/ER4 have been standardized by IEEE 802.3 WG.

The IEEE Std 802.3-2015 includes 100GBASE-CR4, 100GBASE-KR4, and 100GBASE-KP4, 100GBASE-SR4 and 40GBASE-ER4.

#### Ethernet-based access networks

One of the Ethernet capabilities as access networks regarding 10G-EPON was enhanced by IEEE 802.3 WG into IEEE Std 802.3-2015. Up to 10Gbit/s interfaces, 2BASE-TL, 10PASS-TS, 100BASE-LX10/BX10, 1000BASE-LX10/BX10, 1000BASE-PX10/PX20/PX30/PX40 (1G-EPON), and 10GBASE-PR10/PR20/PR30/PR40/PRX10/PRX20/PRX30/PRX40 (10G-EPON), are specified in IEEE 802.3-2015 as well.

#### 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) is standardizing 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 (Q.17/12) in Recommendation Y.1563, approved in January 2009. Service OAM Framework (MEF17), Service OAM Fault Management Implementation Agreement (MEF 30) and Service OAM Performance Monitoring Implementation Agreement (MEF 35) 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 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.

IEEE 802.17 WG is developing standards on Resilient Packet Ring (RPR). The latest 802.17 project has been IEEE P802.17c: "Protected Inter-Ring Connection". This project extends the property of fast restoration time (50 ms), associated with an individual RPR ring, to dual-interconnected rings.

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

#### 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 10.2: "Amendment to Ethernet Services Attributes Phase 2", in September 2009.

#### Service Activation Testing (SAT)

Recommendation Y.1564, “Ethernet service activation test methodology” was approved in SG12 in March, 2011.

#### Status of IEEE 802.1 (Updated in 06/2017)

As of 2017, the IEEE 802.1 working group has five active task groups: Maintenance, Time Sensitive Networking (TSN), Security, Data Center Bridging (DCB) and OmniRAN. Note that the Interworking (i.e., Ethernet Bridging) task group has been merged with TSN. In addition the Local Address study group has merged with the DCB task group.

The 802.1 working group has over 20 active projects ranging from revisions of existing work (like the MAC service definition), addition of new bridging features (like frame replication), 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

* + [802.1Xbx](http://www.ieee802.org/1/pages/802.1xbx.html) - MAC Security Key Agreement protocol (MKA) extensions
	+ [802.1ARce](http://www.ieee802.org/1/pages/802.1arce.html) - Secure Device Identity Amendment 1: SHA-384 and P-384 Elliptic Curve
	+ [802.1Xck](http://www.ieee802.org/1/pages/802.1ck.html) - Port-Based Network Access Control Amendment: YANG Data Model
	+ [802E](http://www.ieee802.org/1/pages/802e.html) - Recommended Practice for Privacy Considerations for IEEE 802 Technologies

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

* + [802.1AS-Rev](http://www.ieee802.org/1/pages/802.1AS-rev.html) - Timing and Synchronisation: Timing and Synchronisation for Time-Sensitive Applications - Revision
	+ [802.1CB](http://www.ieee802.org/1/pages/802.1cb.html) - 802.1CB - Frame Replication and Elimination for Reliabilty
	+ [802.1Qcc](http://www.ieee802.org/1/pages/802.1cc.html) - 802.1Qcc - Stream Reservation Protocol (SRP) Enhancements and Performance Improvements
	+ [802.1Qch](http://www.ieee802.org/1/pages/802.1ch.html) - 802.1Qch - Cyclic Queuing and Forwarding
	+ [802.1Qci](http://www.ieee802.org/1/pages/802.1ci.html) - 802.1Qci - Per-Stream Filtering and Policing
	+ [802.1Qcj](http://www.ieee802.org/1/pages/802.1cj.html) - 802.1Qcj - Automatic Attachment to Provider Backbone Bridging (PBB) services
	+ [802.1CM](http://www.ieee802.org/1/pages/802.1cm.html)- 802.1CM - Time-Sensitive Networking for Fronthaul
	+ [802.1Qcp](http://www.ieee802.org/1/pages/802.1cp.html) - 802.1Qcp - YANG Data Model
	+ [802.1Qcr](http://www.ieee802.org/1/pages/802.1cr.html) - 802.1Qcr - Asynchronous Traffic Shaping

[Data Center Bridging](http://www.ieee802.org/1/pages/dcbridges.html)

* + [802.1Qcn](http://www.ieee802.org/1/pages/802.1cn.html) - 802.1Qcn - Virtual Station Interface (VSI) Discovery and Configuration Protocol (VDP) Extension to Support Network Virtualization Overlays Over Layer 3 (NVO3)
	+ [802c](http://www.ieee802.org/1/pages/802c.html) - 802c - Local Medium Access Control (MAC) Address Usage
	+ 802.1CQ - Multicast and Local Addresses Assignment

OmniRAN

* + [802.1CF](http://www.ieee802.org/1/pages/802.1cf.html) - Network Reference Model and Functional Description of IEEE 802 Access Network

Maintenance

* + [802.1AX-Rev](http://www.ieee802.org/1/pages/802.1AX-rev.html) - Link Aggregation Revision
	+ [802.1Q-Rev](http://www.ieee802.org/1/pages/802.1Q-rev.html) - Bridges and Bridged Networks Revision

The following are the current new projects under development:

[P802.1ACct](http://www.ieee802.org/1/files/public/docs2017/ACct-draft-PAR-0517-v01.pdf) - MAC Service Definition - support for 802.15.3

IEEE Std 802.1AC defines the Media Access Control (MAC) Service provided by all IEEE 802 MACs, and the Internal Sublayer Service (ISS) provided within MAC Bridges, in abstract terms of the following: a) Their semantics, primitive actions, and events; and b) The parameters of, interrelationship between, and valid sequences of these actions and events. This amendment project adds support of the Internal Sublayer Service by the IEEE Std 802.15.3 MAC entity.

[P802.1ABcu](http://www.ieee802.org/1/files/public/docs2017/cu-draft-PAR-0517-v01.pdf) - LLDP YANG

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.

[P802.1CBcv](http://ieee802.org/1/files/public/docs2017/cv-draft-PAR-0517-v01.pdf) - 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.

[P802.1Qcw](http://ieee802.org/1/files/public/docs2017/cw-draft-PAR-0517-v01.pdf) - YANG Data Models for Scheduled Traffic, Frame Preemption, and Per-Stream Filtering and Policing

This amendment specifies a Unified Modeling Language (UML)-based information model and YANG data models that allow configuration and status reporting for bridges and bridge components with the capabilities currently specified in clauses 12.29 (scheduled traffic), 12.30 (frame preemption) and 12.31 (per-stream filtering and policing) of 802.1Q. It further defines the relationship between the information and data model and models for the other management capabilities.

[P802.1Qcx](http://ieee802.org/1/files/public/docs2017/cx-draft-PAR-0517-v01.pdf) - 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).

**Ongoing projects related to OTNT**

[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:



[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.

[P802.1CM](http://www.ieee802.org/1/pages/802.1cm.html) – Profile for Fronthaul

This standard defines profiles that select features, options, configurations, defaults, protocols and procedures of bridges, stations and LANs that are necessary to build networks that are capable of transporting fronthaul streams, which are time sensitive.

This project is being developed with the participation of the CPRI cooperation. There is a draft in task group ballot. This draft includes the requirements of CPRI 7.0 as Class 1 and contains a placeholder for eCPRI as Class 2 that is expected to be added after the next plenary. Class 1 is then described, including the limits of synchronization/syntonization accuracy, and subdivided into two profiles based on either strict priority queues or pre-emption.

A recent [tutorial](http://www.ieee802.org/1/files/public/docs2017/cm-farkas-overview-for-MEF-MBH-IA-0417.pptx) was provided to MEF Forum.

[P802.1Xck](http://www.ieee802.org/1/pages/802.1ck.html) – YANG data model

This standard specifies a YANG data model that allows configuration and status reporting for port-based network access control for IEEE Std. 802.1X and IEEE Std 802.1AE, using the information model already specified.

802.1Xck YANG model derived from IEEE Std 802.1Xbx, Figure 12-3 (PAE management information UML model)

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

[P802.1Qcp](http://www.ieee802.org/1/pages/802.1cp.html) – YANG data model

This standard specifies a UML-based information model and a YANG data model that allows configuration and status reporting for bridges and bridge components including TPMRs, MAC Bridges, Customer VLAN Bridges, and Provider Bridges. It further defines the relationship between the information and data model and models for the other management capabilities specified in this standard and for IEEE Std 802.1AX and IEEE Std 802.1X

802.1Qcp YANG model is derived from UML models that are based from IEEE Std 802.1Q, Clause 12 (Bridge management)

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

[P802c](http://www.ieee802.org/1/pages/802c.html) – Local Address space

The standard will provide an optional local address space structure to allow multiple administrations to coexist. Three are currently specified: a range of addresses for protocols using a Company ID assigned by the IEEE Registration Authority; a range of local addresses designated for assignment by an IEEE 802 Standard; and a range of local addresses designated for assignment by local administrators.

This project is expected to be approved in June by Standards Board.

[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.

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 06/2017)

The following are the IEEE 802.3 standards currently in force:

* The base standard, IEEE Std 802.3-2015, was approved by the Standards Board on 3 September 2015 and was published on 4 March 2016.
* Nine amendments and a corrigendum are currently in force:
	+ IEEE Std 802.3bz-2016 - *Media Access Control Parameters, Physical Layers, and Management Parameters for 2.5 Gb/s and 5 Gb/s Operation, Types 2.5GBASE-T and 5GBASE-T*, was approved on 22nd September 2016 and published on 18th October 2016.
	+ IEEE Std 802.3bn-2016 - *Physical Layer Specifications and Management Parameters for Ethernet Passive Optical Networks Protocol over Coax*, was approved on 22nd September 2016 and published on 7th December 2016.
	+ IEEE Std 802.3bu-2016 – *Physical Layer and Management Parameters for Power over Data Lines (PoDL) of Single Balanced Twisted-Pair Ethernet*, was approved on 7th December 2016 and published on 7th February 2017.
	+ IEEE Std 802.3bv-2017 - *Physical Layer Specifications and Management Parameters for 1000 Mb/s Operation Over Plastic Optical Fiber*, was approved on 14th February 2017 and published on 14th March 2017.
	+ IEEE Std 802.3-2015 Cor 1-2017 - *Multi-lane Timestamping*, was approved on 23rd March 2017 and published on 21st April 2017.
	+ IEEE Std 802.3bw-2015 - *Physical Layer Specifications and Management Parameters for 100 Mb/s Operation over a Single Balanced Twisted Pair Cable (100BASE-T1)* which was approved by the Standard Board on 26 October 2015 and published on 8 March 2016.
	+ IEEE Std 802.3by-2016 - *Media Access Control Parameters, Physical Layers, and Management Parameters for 25 Gb/s Operation*, which was approved on 30 June 2016 and published on 29 July 2016.
	+ IEEE Std 802.3bq-2016 - *Physical Layer and Management Parameters for 25 Gb/s and 40 Gb/s Operation, Types 25GBASE-T and 40GBASE-T* – which was approved on 30 June 2016 and published on 8 September 2016.
	+ IEEE Std 802.3bp-2016 - *Physical Layer Specifications and Management Parameters for 1 Gb/s Operation over a Single Twisted Pair Copper Cable* – which was approved on 30 June 2016 and published on 9 September 2016.
	+ IEEE Std 802.3br-2016 - *Specification and Management Parameters for Interspersing Express Traffic* – which was approved on 30 June 2016 and published on 14 October 2016.
* 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 P802.3bs 200 Gb/s and 400 Gb/s Ethernet Task Force is currently in the Sponsor ballot phase. A copy of Draft 3.1 has been sent to ITU-T Q6/15 and Q11/15 in a separate liaison communication.
* The IEEE P802.3bt DTE Power via MDI over 4-Pair Task Force is currently in the Working Group Ballot phase.
* The IEEE P802.3ca 25 Gb/s, 50 Gb/s, and 100 Gb/s Passive Optical Networks Task Force is in the proposal selection phase.
* The IEEE P802.3cb 2.5 Gb/s and 5 Gb/s Backplane Task Force is in the Working Group ballot phase. Note that copper cable objectives have been removed from this project since our last communication.
* The IEEE P802.3cc 25 Gb/s Ethernet over Single-Mode Fiber Task Force is in the Sponsor ballot phase.
* The IEEE P802.3cd 50 Gb/s, 100 Gb/s, and 200 Gb/s Ethernet Task Force has just begun the Working Group ballot phase.
* The IEEE P802.3cg 10 Mb/s Single Twisted Pair Ethernet Task Force is in the proposal selection phase.
* The IEEE P802.3ch Multi-Gig Automotive PHY Task Force is in the proposal selection phase.
* The IEEE P802.3.2 (802.3cf) YANG Data Model Definition Task Force is in the proposal selection phase.

In addition to the projects described above, a PAR has been approved for the next revision project, which is expected to become IEEE Std 802.3-2018 once completed. This is expected to update IEEE Std 802.3-2015 by including the nine approved amendments and corrigendum, and should work proceed as expected, also the amendments resulting from IEEE P802.3bs, IEEE P802.3cb, IEEE P802.3cc, and all ready-for-ballot maintenance requests. All other active projects are expected to become amendments to IEEE Std 802.3- 2018.

### 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 |
| 2 | ITU-T SG15 | Q3/15 | Coordination on OTN including optical Ethernet |
| Q9/15 | Ethernet protection/restoration |
| Q10/15 | Ethernet OAM mechanisms and equipment functional architecture |
| 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 | Technical Committee | Service attributes including traffic and performance parameters, service definitions, Aggregation and E-NNI interfaces, management interfaces, performance monitoring, 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: https://www.mef.net

## Standardization on MPLS and MPLS-TP

In order to make MPLS technology fully applicable to operators' networks, standardization for enhancing MPLS was started in ITU-T SG13 and SG15. In addition to “normal” MPLS, Transport MPLS was studied actively. In 2007-2008 timeframe, several meetings were held to discuss the working method on Transport MPLS between ITU-T (in particular, SG13 and SG15) and IETF. In February 2008, SG15 set up a Joint Work Team (JWT) to discuss this matter intensively. In December 2008, SG 15 agreed to use the term MPLS-TP to refer to the extensions to MPLS technology, which was being developed by the IETF to meet the requirements of the transport network. The meeting also agreed the plan to migrate the existing Trasnport MPLS Recommendations to MPLS-TP. In October 2009, MPLS-TP steering committee was established to provide MPLS-TP project management coordination between IETF and ITU-T. Figure 4-4 shows the structural relationship between IETF and ITU-T.



**Figure 4-4 Structure of the Joint Working Team (JWT) and related Sub-Groups**

The JWT recommended that:

* Jointly agree to work together and bring transport requirements into the IETF and extend IETF MPLS forwarding, OAM, survivability, network management and control plane protocols to meet those requirements through the IETF Standards Process
* The JWT believes this would fulfill the mutual goal of improving the functionality of the transport networks and the internet and guaranteeing complete interoperability and architectural soundness
* Refer to the technology as the Transport Profile for MPLS (MPLS-TP)
* Therefore, we recommend that future work should focus on:
	+ In the IETF: Definition of the MPLS-TP
	+ In the ITU-T:
		- Integration of the MPLS-TP into the transport network
		- Alignment of the current T-MPLS Recommendations with MPLS-TP and,
		- Terminate the work on current T-MPLS.

Further details can be found at:

<http://ties.itu.int/ftp/public/itu-t/ahtmpls/readandwrite/doc_exchange/overview/MPLS-TP_overview-22.ppt>

Table 3 below summarizes the current standardization responsibilities on MPLS-TP.

Table 3 – Standardization on MPLS-TP

|  |  |  |  |
| --- | --- | --- | --- |
| # | Standard body | Q/SG (WG) | Study items |
| 1 | ITU-T SG15 | Q3/15 | Terms and definitions for MPLS-TP |
| Q9/15 | MPLS-TP protection/survivability |
| Q10/15 | MPLS-TP interfaces, OAM architecture and mechanisms and equipment functional architecture |
| Q12/15 | MPLS-TP network architecture |
| Q14/15 | MPLS-TP network management and control |
| 2 | IETF(Refer to Annex B on organization restructuring and Annex C on transport network management) | BFD WG | Bidirectional Forwarding Detection (bfd) extensions for MPLS-TP |
| CCAMP WG | Common control plane and measurement plane solutions and GMPLS mechanisms/protocol extensions for MPLS transport profile (MPLS-TP), Automatically Switched Optical Networks (ASON) and Wavelength Switched Optical Networks (WSON) |
| L2VPN WG(concluded) | Extensions to L2VPN protocols and RFC's necessary to create anMPLS Transport Profile (MPLS-TP) |
| MPLS WG | Requirements, mechanisms, protocols and framework for MPLS-TP |
| OPSAWG | Definition of the OAM acronym  |
| PCE WG | Specification of Path Computation Element(PCE) based architecture for the computation of paths for MPLS and GMPLS LSPs |
| PWE3 WG(concluded) | Extensions to the PWE3 protocols and RFCsnecessary to create an MPLS Transport Profile (MPLS-TP) |

### OAM for MPLS and MPLS-TP

In ITU-T, SG13 (Q5/13) originally specified MPLS OAM, such as Recommendations on OAM requirements (Y.1710), mechanisms (Y.1711), OAM under ATM-MPLS interworking (Y.1712) and misbranch detection (Y.1713). IETF also specified MPLS OAM, such as the usage of the "OAM Alert label" in RFC3429, MPLS OAM requirements in RFC4377, MPLS OAM framework in RFC4378, methods for defect detection (LSP ping and traceroute) in RFC4379.

In October 2008, WTSA-08 transferred Q5/13 (OAM) with the work of MPLS/MPLS-TP OAM to SG15 (i.e., Q.10/15). Since then, SG15 determined a new Recommendation G.8113.1 (ex. G.tpoam) under TAP in February 2011 and sent it without modification to WTSA-12 for approval in December 2011. Another MPLS-TP OAM Recommendation G.8113.2 was also sent to WTSA-12 in September 2012.

In November 2012, the WTSA-12 approved both Recommendations on the first day. On the next day of the approval, IETF and IANA published RFC6671, which allocates pseudowire associated channel type 0x8902, and G.8113.1 became operational.

### MPLS/MPLS-TP protection switching

MPLS protection switching is standardized in ITU-T SG15 (Q.9/15). Recommendation on MPLS protection switching (Y.1720) was revised in December 2006. T‑MPLS linear protection switching (G.8131) was approved in December 2006. IETF is also standardizing MPLS survivability techniques. RFC3469 describes MPLS recovery framework. RFC4090 specifies Fast ReRoute (FRR).

Regarding MPLS-TP, MPLS-TP linear protection switching (revised G.8131) and MPLS-TP ring protection switching (new G.8132) were developed under the cooperation with IETF based on the agreement of JWT. Both Recommendations were planned to be consent in December 2011, but were deferred. In 2014, the revised G.8131 was published.

### MPLS interworking

Interworking with MPLS networks was studied in ITU-T SG13 (Q7/13). Recommendations on ATM-MPLS interworking (cell mode: Y.1411, frame mode: Y.1412), TDM-MPLS interworking (Y.1413), voice services – MPLS interworking (Y.1414) and Ethernet-MPLS network interworking (Y.1415) are available.

### MPLS-TP network architecture

MPLS layer network architecture (G.8110) was approved by ITU-T SG15 in January 2005. Transport MPLS network architecture (G.8110.1) was approved by ITU-T SG15 (Q.12/15) in November 2006. Regarding MPLS-TP, architecture of MPLS-TP Layer Network was approved in December 2011.

### MPLS-TP equipment functional architecture

Transpot MPLS equipment functional architecture (G.8121) was approved within ITU-T SG15 (Q.9/15) in March 2006 and amended October 2007. Its revision, MPLS-TP equipment functional architecture, was consented under AAP in December 2011 and was approved in September 2012. Further revision became available in November 2013.

### MPLS-TP equipment network management

Transport MPLS equipment network management (G.8151) was approved in ITU-T SG15 (Q14/15) in October 2007. MPLS-TP network management (revised G.8151) was consented in December 2011 and approved in July 2012.

### MPLS-TP interface

G.8112 (Interfaces for the Transpot MPLS hierarchy) was approved by ITU-T SG15 (Q.11/15) in October 2006. In December 2008, the packet transport work of Q.11/15 was transferred to a new Question 10/15 in order to balance the load among questions of Working Party 3/15. Since then, Q10/15 developed MPLS-TP interface (revised G.8112), which was consent in September 2012.

### Further details

Table 13 lists the current status of MPLS-related ITU-T Recommendations. Table 14 lists the current status of MPLS-TP-related IETF RFCs, internet drafts, and ITU-T Recommendations.

Further details about standardization of MPLS/MPLS-TP can be found in the following:

<http://www.itu.int/ITU-T/studygroups/com15/index.asp>

Further details about standardization of MPLS-TP can be found in the following:

http://www.itu.int/ITU-T/studygroups/com15/ahmpls-tp/

The dependency between the draft revised MPLS-TP Recommendations and the MPLS-TP drafts and RFCs can be found at

http://www.itu.int/oth/T0906000002/en

# 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://grouper.ieee.org/groups/802/index.shtml
* Optical Internetworking Forum (OIF) Technical Committee: http://www.oiforum.com/public/techcommittee.html
* Broadband (ex. IP/MPLS) Forum: http://www.broadband-forum.org/
* MEF Technical Committee: 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 Control Plane. 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 (10/2010) | 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 (10/2012) | ONU management and control interface (OMCI) specification |
| 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 (12/2014) | 40-Gigabit-capable passive optical networks 2 (NG-PON2): Physical media dependent (PMD) layer specification |
| ITU-T (Q3/15) | G.780/Y.1351 (07/2010) | Terms and definitions for synchronous digital hierarchy (SDH) networks |
| ITU-T (Q3/15) | G.870/Y.1352 (11/2016) | Terms and definitions for optical transport networks |
| ITU-T (Q3/15) | G.8001/Y.1354 (04/2016) | Terms and definitions for Ethernet frames over transport |
| ITU-T (Q3/15) | G.8081/Y.1353 (02/2012) | Terms and definitions for automatically switched optical networks |
| ITU-T (Q3/15) | 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 (07/2007) | 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 (11/2009) | 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.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 (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 (Q9/15) | G.808 (11/2016) | Terminology for protection and restoration |
| ITU-T (Q9/15) | G.808.1 (05/2014) | Generic protection switching – Linear trail and subnetwork protection |
| ITU-T (Q9/15) | G.808.2 (11/2013) | Generic protection switching – Ring protection |
| ITU-T (Q9/15) | G.808.3 (10/2012) | Generic protection switching – Shared mesh protection |
| ITU-T (Q9/15) | G.841 (10/1998) | Types and characteristics of SDH network protection architectures |
| ITU-T (Q9/15) | G.842 (04/1997) | Interworking of SDH network protection architectures |
| ITU-T (Q9/15) | G.873.1 (05/2014) | Optical transport network (OTN): Linear protection |
| ITU-T (Q9/15) | G.873.2 (04/2012) | ODUk shared ring 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 (Q9/15) | G.8031/Y.1342 (01/2015) | Ethernet linear protection switching |
| ITU-T (Q9/15) | G.8032/Y.1344 (02/2012) | Ethernet ring protection switching |
| ITU-T (Q9/15) | G.8131/Y.1382 (07/2014) | Linear protection switching for MPLS transport profile |
| ITU-T (Q9/15) | 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 (06/2016) | Interfaces for the optical transport network (OTN) |
| ITU-T (Q11/15) | G.709.1/Y.1331.1 (01/2017) | Flexible OTN short-reach interface  |
| 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.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 (08/2013) | Management aspects of optical transport network elements |
| ITU-T (Q14/15) | 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 (12/2016) | 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 (01/2015) | 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.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 (08/2013) | 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 (01/2015) | 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 5 lists IETF RFCs and Internet Drafts. It should be noted that all Internet-Drafts should be identified as "work in progress". This request is made, as standard, by the IETF in the following text at the head of every Internet-Draft:

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

Table 5 – OTNT Related Standards and Industry Agreements (IETF RFCs and Internet Drafts)

| **Organisation (Subgroup responsible)** | **Number** | **Title** | **Publication Date** |
| --- | --- | --- | --- |
| IETF (mpls) | RFC5317 | JWT Report on MPLS Architectural Considerations for a Transport Profile | 02/2009 |
| IETF (mpls) | RFC5586 | MPLS Generic Associated Channel | 06/2009 |
| IETF (mpls) | RFC5654 | MPLS-TP Requirements | 08/2009  |
| IETF (mpls) | RFC5718 | An Inband Data Communication Network For the MPLS Transport Profile | 08/2009 |
| IETF (mpls) | RFC5860 | Requirements for OAM in MPLS Transport Networks | 03/2010 |
| IETF (mpls) | RFC5921 | A Framework for MPLS in Transport Networks | 07/2010 |
| IETF (mpls) | RFC5950 | MPLS-TP Network Management Framework | 09/2010 |
| IETF (mpls) | RFC5951 | MPLS TP Network Management Requirements | 9/2010 |
| IETF (mpls) | RFC5960 | MPLS Transport Profile Data Plane Architecture | 08/2010 |
| IETF(mpls) | RFC6215 | MPLS Transport Profile User-to-Network and Network-to-Network Interfaces | 04/2011 |
| IETF (mpls) | RFC6291 | Guidelines for the use of the OAM acronym in the IETF | 06/2011 |
| IETF (mpls) | RFC6370 | MPLS-TP Identifiers | 9/2011 |
| IETF (mpls) | RFC6371 | MPLS-TP OAM Framework | 09/2011 |
| IETF (mpls) | RFC6372 | Multiprotocol Label Switching Transport Profile Survivability Framework | 09/2011 |
| IETF(ccamp) | RFC6373 | MPLS Transport Profile (MPLS-TP) Control Plane Framework | 09/2011 |
| IETF(mpls) | RFC6374 | Packet Loss and Delay Measurement for MPLS Networks | 09/2011 |
| IETF(mpls) | RFC6375 | A Packet Loss and Delay Measurement Profile for MPLS-Based Transport Networks | 09/2011 |
| IETF(mpls) | RFC6427 | MPLS Fault Management Operations, Administration, and Maintenance (OAM) | 11/2011 |
| IETF | RFC6428 | Proactive Connectivity Verification, Continuity Check, and Remote Defect Indication for the MPLS Transport Profile | 11/2011 |
| IETF | RFC6435 | MPLS Transport Profile Lock Instruct and Loopback Functions | 11/2011 |
| IETF (mpls) | RFC7054 | Addressing Requirements and Design Considerations for Per-Interface Maintenance Entity Group Intermediate Points (MIPs) | 2013 |
| IETF (mpls) | RFC7087 | A Thesaurus for the Interpretation of Terminology Used in MPLS Transport Profile (MPLS-TP) Internet-Drafts and RFCs in the Context of the ITU-T's Transport Network Recommendations | 2013 |
| IETF(mpls) | RFC6669 |  An Overview of the Operations, Administration, and Maintenance (OAM) Toolset for MPLS-Based Transport Networks | 07/2012 |
| IETF | RFC6671 | Allocation of a Generic Associated Channel Type for ITU-T MPLS Transport Profile Operation, Maintenance, and Administration (MPLS-TP OAM) | 11/2012 |
| IETF | RFC6923 | MPLS Transport Profile (MPLS-TP) Identifiers Following ITU-T Conventions | 05/2013 |
| IETF | RFC6941 | MPLS Transport Profile (MPLS-TP) Security Framework | 04/2013 |
| IETF (mpls) | [RFC 7271](http://datatracker.ietf.org/doc/rfc7271/) | MPLS Transport Profile (MPLS-TP) Linear Protection to Match the Operational Expectations of Synchronous Digital Hierarchy, Optical Transport Network, and Ethernet Transport Network Operators | 2014 |
| IETF (ccamp) | RFC 3468 | The Multiprotocol Label Switching (MPLS) Working Group decision on MPLS signaling protocols | 02/2003 |
| IETF (ccamp) | RFC 3609 | Tracing Requirements for Generic Tunnels  | 09/2003 |
| IETF (ccamp) | RFC 3945 | Generalized Multi-Protocol Label Switching Architecture | 10/2004 |
| IETF (ccamp) | RFC 4003 | GMPLS Signaling Procedure For Egress Control – updates RFC 3473 | 02/2005 |
| IETF (ccamp) | RFC 4139 | Requirements for Generalized MPLS (GMPLS) Signaling Usage and Extensions for Automatically Switched Optical Network (ASON) | 07/2005 |
| IETF (ccamp) | RFC 4201 | Link Bundling in MPLS Traffic Engineering (TE) | 10/2005 |
| IETF (ccamp) | RFC 4202 | Routing Extensions in Support of Generalized Multi-Protocol Label Switching (GMPLS) | 10/2005 |
| IETF (ccamp) | RFC 4203 | OSPF Extensions in Support of Generalized Multi-Protocol Label Switching – updates RFC 3630 | 10/2005 |
| IETF (ccamp) | RFC 4204 | Link Management Protocol (LMP) | 10/2005 |
| IETF (ccamp) | RFC 4207 | Synchronous Optical Network (SONET)/Synchronous Digital Hierarchy (SDH) Encoding for Link Management Protocol (LMP) Test Messages | 10/2005 |
| IETF (ccamp) | RFC4208 | Generalize Multiprotocol Label Switching(GMPLS) User-Network Interface (UNI): Resource ReserVation Protocol-Traffic Engineering (RSVP-TE) Support for the Overlay Model | 10/2005 |
| IETF (ccamp) | RFC4209 | Link Management Protocol (LMP) for Dense Wavelength Division Multiplexing (DWDM) Optical Line Systems | 10/2005 |
| IETF (ccamp) | RFC4258 | Requirements for Generalized Multi-Protocol Label Switching (GMPLS) Routing for the Automatically Switched Optical Network (ASON) | 11/2005 |
| IETF (ccamp) | RFC4257 | Framework for Generalized Multi-Protocol Label Switching (GMPLS)-based Control of Synchronous Digital Hierarchy/Synchronous Optical Networking (SDH/SONET) Networks | 12/2005 |
| IETF (ccamp) | RFC4328 | Generalized Multi-Protocol Label Switching (GMPLS) Signaling Extensions for G.709 Optical Transport Networks Control – updates RFC 3471 | 01/2006 |
| IETF (ccamp) | RFC4394 | A Transport Network View of the Link Management Protocol | 02/2006 |
| IETF (ccamp) | RFC4397 | A Lexicography for the Interpretation of Generalized Multiprotocol Label Switching (GMPLS) Terminology within The Context of the ITU-T's Automatically Switched Optical Network (ASON) Architecture | 02/2006 |
| IETF (ccamp) | RFC4426 | Generalized Multi-Protocol Label Switching (GMPLS) Recovery Functional Specification | 03/2006 |
| IETF (ccamp) | RFC4427 | Recovery (Protection and Restoration) Terminology for Generalized Multi-Protocol Label Switching (GMPLS) | 03/2006 |
| IETF (ccamp) | RFC4428 | Analysis of Generalized Multi-Protocol Label Switching (GMPLS)-based Recovery Mechanisms (including Protection and Restoration) | 03/2006 |
| IETF (ccamp) | RFC4558 | Node ID based RSVP Hello: A Clarification Statement | 06/2006 |
| IETF (ccamp) | RFC4606 | Generalized Multi-Protocol Label Switching (GMPLS) Extensions for Synchronous Optical Network (SONET) and Synchronous Digital Hierarchy (SDH) Control | 08/2006 |
| IETF (ccamp) | RFC4631 | Link Management Protocol (LMP) Management Information Base (MIB) – updates RFC4327 | 09/2006 |
| IETF (ccamp) | RFC4652 | Evaluation of existing Routing Protocols against ASON routing requirements | 10/2006 |
| IETF (ccamp) | RFC4726 | A Framework for Inter-Domain MPLS Traffic Engineering | 11/2006 |
| IETF (ccamp) | RFC4736 | Reoptimization of Multiprotocol Label Switching (MPLS) Traffic Engineering (TE) loosely routed Label Switch Path (LSP) | 11/2006 |
| IETF (ccamp) | RFC4783 | GMPLS – Communication of Alarm Information | 12/2006 |
| IETF (ccamp) | RFC4801 | Definitions of Textual Conventions for Generalized Multiprotocol Label Switching (GMPLS) Management | 02/2007 |
| IETF (ccamp) | RFC4802 | Generalized Multiprotocol Label Switching (GMPLS) Traffic Engineering Management Information Base | 02/2007 |
| IETF (ccamp) | RFC4803 | Generalized Multiprotocol Label Switching (GMPLS) Label Switching Router (LSR) Management Information Base | 02/2007 |
| IETF (ccamp) | RFC4872 | RSVP-TE Extensions in support of End-to-End Generalized Multi-Protocol Label Switching (GMPLS)-based Recovery | 05/2007 |
| IETF (ccamp) | RFC4873 | GMPLS Based Segment Recovery | 05/2007 |
| IETF (ccamp) | RFC4874 | Exclude Routes – Extension to RSVP-TE | 04/2007 |
| IETF (ccamp) | RFC4920 | Crankback Signaling Extensions for MPLS and GMPLS RSVP-TE | 07/2007 |
| IETF (ccamp) | RFC4972 | Routing extensions for discovery of Multiprotocol (MPLS) Label Switch Router (LSR) Traffic Engineering (TE) mesh membership | 07/2007 |
| IETF (ccamp) | RFC4974 | Generalized MPLS (GMPLS) RSVP-TE Signaling Extensions in support of Calls | 08/2007 |
| IETF (ccamp) | RFC4990 | Use of Addresses in Generalized Multi-Protocol Label Switching (GMPLS) Networks | 09/2007 |
| IETF (ccamp) | RFC5063 | Extensions to GMPLS RSVP Graceful Restart | 10/2007 |
| IETF (ccamp) | RFC5073 | IGP Routing Protocol Extensions for Discovery of Traffic Engineering Node Capabilities | 12/2007 |
| IETF (ccamp) | RFC5145 | Framework for MPLS-TE to GMPLS Migration | 03/2008 |
| IETF (ccamp) | RFC5146 | Interworking Requirements to Support Operation of MPLS-TE over GMPLS Networks | 03/2008 |
| IETF (ccamp) | RFC5150 | Label Switched Path Stitching with Generalized Multiprotocol Label Switching Traffic Engineering (GMPLS TE) | 02/2008 |
| IETF (ccamp) | RFC5151 | Inter-Domain MPLS and GMPLS Traffic Engineering -- Resource Reservation Protocol-Traffic Engineering (RSVP-TE) Extensions | 02/2008 |
| IETF (ccamp) | RFC5152 | A Per-Domain Path Computation Method for Establishing Inter-Domain Traffic Engineering (TE) Label Switched Paths (LSPs) | 02/2008 |
| IETF (ccamp) | RFC5212 | Requirements for GMPLS-Based Multi-Region and Multi-Layer Networks (MRN/MLN) | 07/2008 |
| IETF (ccamp) | RFC5298 | Analysis of Inter-Domain Label Switched Path (LSP) Recovery | 08/2008 |
| IETF (ccamp) | RFC5316 | ISIS Extensions in Support of Inter-Autonomous System (AS) MPLS and GMPLS Traffic Engineering | 12/2008 |
| IETF (ccamp) | RFC5339 | Evaluation of Existing GMPLS Protocols against Multi-Layer and Multi-Region Networks (MLN/MRN) | 09/2008 |
| IETF (ccamp) | RFC5392 | OSPF Extensions in Support of Inter-Autonomous System (AS) MPLS and GMPLS Traffic Engineering | 01/2009 |
| IETF (ccamp) | RFC5420 (replaces RFC4420) | Encoding of Attributes for MPLS LSP Establishment Using Resource Reservation Protocol Traffic Engineering (RSVP-TE) | 02/2009 |
| IETF (ccamp) | RFC5467 | GMPLS Asymmetric Bandwidth Bidirectional Label Switched Paths (LSPs) | 03/2009 |
| IETF (ccamp) | RFC5493 | Requirements for the Conversion between Permanent Connections and Switched Connections in a Generalized Multiprotocol Label Switching (GMPLS) Network | 04/2009 |
| IETF (ccamp) | RFC5495 | Description of the Resource Reservation Protocol - Traffic-Engineered (RSVP-TE) Graceful Restart Procedures | 03/2009 |
| IETF (ccamp) | RFC5553 | Resource Reservation Protocol (RSVP) Extensions for Path Key Support | 05/2009 |
| IETF (ccamp) | RFC5787 | OSPFv2 Routing Protocols Extensions for ASON Routing | 03/2010 |
| IETF (ccamp) | RFC 7260 | GMPLS RSVP-TE extensions for OAM Configuration | 2014 |
| IETF (ccamp) | RFC 7369 | GMPLS RSVP-TE Extensions for Ethernet OAM Configuration | 2014 |
| IETF (ccamp) | [draft-ietf-ccamp-gmpls-g-694-lambda-labels-04.txt](http://www.ietf.org/internet-drafts/draft-ietf-ccamp-gmpls-g-694-lambda-labels-02.txt) | Generalized Labels for G.694 Lambda-Switching Capable Label Switching Routers | 03/2009 |
| IETF (ccamp) | draft-ietf-ccamp-ethernet-traffic-parameters-08.txt | Ethernet Traffic Parameters | 04/2009 |
| IETF (ccamp) | draft-ietf-ccamp-wson-impairments-00.txt | A Framework for the Control of Wavelength Switched Optical Networks (WSON) with Impairments | 06/2009 |
| IETF (ccamp) | draft-ietf-ccamp-ethernet-gmpls-provider-reqs-02.txt | Service Provider Requirements for Ethernet control with GMPLS | 06/2009 |
| IETF (ccamp) | draft-ietf-ccamp-rwa-wson-encode-02.txt | Routing and Wavelength Assignment Information Encoding for Wavelength Switched Optical Networks | 07/2009 |
| IETF (ccamp) | draft-ietf-ccamp-pc-spc-rsvpte-ext-03.txt | RSVP-TE Signaling Extension For Management Plane To Control Plane LSP Handover In A GMPLS Enabled Transport Network | 07/2009 |
| IETF (ccamp) | draft-ietf-ccamp-gmpls-mln-extensions-07.txt | Generalized Multi-Protocol Label Switching (GMPLS) Protocol Extensions for Multi-Layer and Multi-Region Networks (MLN/MRN) | 08/2009 |
| IETF (ccamp) | draft-ietf-ccamp-confirm-data-channel-status-07.txt | Data Channel Status Confirmation Extensions for the Link Management Protocol | 09/2009 |
| IETF (ccamp) | draft-ietf-ccamp-rwa-wson-framework-03.txt | Framework for GMPLS and PCE Control of Wavelength Switched Optical Networks (WSON) | 09/2009 |
| IETF (ccamp) | draft-ietf-ccamp-lsp-dppm-08.txt | Label Switched Path (LSP) Dynamic Provisioning Performance Metrics in Generalized MPLS Networks | 09/2009 |
| IETF (ccamp) | draft-ietf-ccamp-rwa-info-04.txt | Routing and Wavelength Assignment Information Model for Wavelength Switched Optical Networks | 09/2009 |
| IETF (ccamp) | draft-ietf-ccamp-gmpls-ethernet-arch-05.txt | Generalized Multi-Protocol Label Switching (GMPLS) Ethernet Label Switching Architecture and Framework | 09/2009 |
| IETF (ccamp) | draft-ietf-ccamp-mpls-graceful-shutdown-10.txt | Graceful Shutdown in MPLS and Generalized MPLS Traffic Engineering Networks | 09/2009 |
| IETF (ccamp) | draft-ietf-ccamp-gmpls-vcat-lcas-08.txt | Operating Virtual Concatenation (VCAT) and the Link Capacity Adjustment Scheme (LCAS) with Generalized Multi-Protocol Label Switching (GMPLS) | 07/2009 |
| IETF (ccamp) | draft-ietf-ccamp-gmpls-ted-mib-05.txt | Traffic Engineering Database Management Information Base in support of GMPLS | 01/2009 |
| IETF (ccamp) | [draft-ietf-ccamp-rwa-info-04.txt](http://www.ietf.org/internet-drafts/draft-ietf-ccamp-rwa-info-00.txt) | Routing and Wavelength Assignment Information Model for Wavelength Switched Optical Networks | 09/2009 |
| IETF (ccamp) | draft-ietf-ccamp-oam-configuration-fwk-03 | OAM Configuration Framework and Requirements for GMPLS RSVP-TE | 01/2010 |
| IETF (pce) | RFC 4655 | A Path Computation Element (PCE) Based Architecture | 08/2006 |
| IETF (pce) | RFC 4657 | Path Computation Element (PCE) Communication Protocol Generic Requirements | 09/2006 |
| IETF (pce) | RFC 4674 | Requirements for Path Computation Element (PCE) Discovery | 10/2006 |
| IETF (pce) | RFC4927 | PCE Communication Protocol (PCECP) Specific Requirements for Inter-Area Multi Protocol Label Switching (MPLS) and Generalized MPLS (GMPLS) Traffic Engineering | 07/2007 |
| IETF (pce) | RFC 5088 | OSPF Protocol Extensions for Path Computation Element (PCE) Discovery | 01/2008 |
| IETF (pce) | RFC 5089 | IS-IS Protocol Extensions for Path Computation Element (PCE) Discovery | 01/2008 |
| IETF (pce) | RFC 5376 | Inter-AS Requirements for the Path Computation Element Communication Protocol (PCECP) | 11/2008 |
| IETF (pce) | RFC 5394 | Policy-Enabled Path Computation Framework | 12/2008 |
| IETF (pce) | RFC 5440 | Path Computation Element (PCE) Communication Protocol (PCEP) | 03/2009 |
| IETF (pce) | RFC 5441 | A Backward-Recursive PCE-Based Computation (BRPC) Procedure to Compute Shortest Constrained Inter-Domain Traffic Engineering Label Switched Paths | 04/2009 |
| IETF (pce) | RFC 5455 | Diffserv-Aware Class-Type Object for the Path Computation Element Communication Protocol | 03/2009 |
| IETF (pce) | draft-ietf-pce-vpn-req-00.txt | PCC-PCE Communication Requirements for VPNs | 03/2009 |
| IETF (pce) | RFC 5520 | Preserving Topology Confidentiality in Inter-Domain Path Computation Using a Path-Key-Based Mechanism | 04/2009 |
| IETF (pce) | RFC 5521 | Extensions to the Path Computation Element Communication Protocol (PCEP) for Route Exclusions | 04/2009 |
| IETF (pce) | RFC 5541 | Encoding of Objective Functions in the Path Computation Element Communication Protocol (PCEP) | 06/2009 |
| IETF (pce) | draft-ietf-pce-monitoring-05.txt | A set of monitoring tools for Path Computation Element based Architecture | 06/2009 |
| IETF (pce) | RFC 5557 | Path Computation Element Communication Protocol (PCEP) Requirements and Protocol Extensions in Support of Global Concurrent Optimization | 07/2009 |
| IETF (pce) | draft-ietf-pce-gmpls-aps-req-01.txt | Requirements for GMPLS applications of PCE | 07/2009 |
| IETF (pce) | draft-ietf-pce-manageability-requirements-07.txt | Inclusion of Manageability Sections in PCE Working Group Drafts | 07/2009 |
| IETF (pce) | draft-ietf-pce-vendor-constraints-00.txt | Conveying Vendor-Specific Constraints in the Path Computation Element Protocol | 07/2009 |
| IETF (pce) | draft-ietf-pce-pcep-svec-list-02.txt | The use of SVEC (Synchronization VECtor) list for Synchronized dependent path computations | 08/2009 |
| IETF (pce) | draft-ietf-pce-inter-layer-req-10.txt | PCC-PCE Communication Requirements for Inter-Layer Traffic Engineering | 08/2009 |
| IETF (pce) | draft-ietf-pce-inter-layer-frwk-10.txt | Framework for PCE-Based Inter-Layer MPLS and GMPLS Traffic Engineering | 03/2009 (awaiting RFC #) |
| IETF(opsawg) | draft-ietf-opsawg-mpls-tp-oam-def-05.txt | "The OAM Acronym Soup" | 05/2010 |

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

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| --- | --- | --- | --- |
| **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 | 2011 |
| IEEE 802.1 | IEEE Std. 802.1AX-2014 | Link Aggregation | 2008 |
| 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. 802.16k-2007 | Media Access Control (MAC) Bridges - Amendment 2: Bridging of IEEE 802.16 | 2007 |
| IEEE 802.1 | IEEE Std. 802.1Q-2014 | Virtual Bridged Local Area Networks—Revision | 2011 |
| IEEE 802.3 | IEEE Std 802.3-2015 | IEEE Standard for Ethernet | 03/2016 |
| IEEE 802.3 | IEEE Std 802.3bw-2015 | Amendment 1: Physical Layer Specifications and Management Parameters for 100 Mb/s Operation over a Single Balanced Twisted Pair Cable (100BASE-T1)) | 03/2016 |
| IEEE 802.3 | IEEE Std 802.3bz-2016 | Media Access Control Parameters, Physical Layers, and Management Parameters for 2.5 Gb/s and 5 Gb/s Operation, Types 2.5GBASE-T and 5GBASE-T,  | 10/2016. |
| IEEE 802.3 | IEEE Std 802.3bn-2016 | Physical Layer Specifications and Management Parameters for Ethernet Passive Optical Networks Protocol over Coax,  | 12/2016 |
| IEEE 802.3 | IEEE Std 802.3bu-2016  | Physical Layer and Management Parameters for Power over Data Lines (PoDL) of Single Balanced Twisted-Pair Ethernet | 02/2017 |
| IEEE 802.3 | IEEE Std 802.3bv-2017 | Physical Layer Specifications and Management Parameters for 1000 Mb/s Operation Over Plastic Optical Fiber,  | 03/2017. |
| IEEE 802.3 | IEEE Std 802.3-2015 Cor 1-2017 | Multi-lane Timestamping,  | 04/2017. |
| IEEE 802.3 | IEEE Std 802.3by-2016 | Media Access Control Parameters, Physical Layers, and Management Parameters for 25 Gb/s Operation,  | 07/2016 |
| IEEE 802.3 | IEEE Std 802.3bq-2016 | Physical Layer and Management Parameters for 25 Gb/s and 40 Gb/s Operation, Types 25GBASE-T and 40GBASE-T | 09/2016 |
| IEEE 802.3 | IEEE Std 802.3bp-2016 | Physical Layer Specifications and Management Parameters for 1 Gb/s Operation over a Single Twisted Pair Copper Cable | 09/2016 |
| IEEE 802.3 | IEEE Std 802.3br-2016 | Specification and Management Parameters for Interspersing Express Traffic | 10/2016 |
| IEEE 802.3 | IEEE Std 802.3bz-2016 | Media Access Control Parameters, Physical Layers, and Management Parameters for 2.5 Gb/s and 5 Gb/s Operation, Types 2.5GBASE-T and 5GBASE-T,  | 10/2016. |
| IEEE 802.3 | IEEE Std 802.3.1-2013 | IEEE Standard for Management Information Base (MIB) Definitions for Ethernet | 08/2013 |
| IEEE 802.17 | IEEE Std. 802.17-2011 | Resilient packet ring (RPR) access method and physical layer specifications | 09/2011 |
| IEEE 802.17 | IEEE Std. 802.17a-2004 | Media Access Control (MAC) Bridges - Amendment 1: Bridging of IEEE Std 802.17 | 102004 |
| IEEE 802.17 | IEEE Std. 802.17b-2007 | Resilient packet ring (RPR) access method and physical layer specifications - Amendment 2: Spatially aware sublayer | 07/2007 |
| IEEE 802.17 | IEEE Std. 802.17c-2010 | Resilient Packet Ring (RPR) Access Method and Physical Layer Specifications - Amendment 3 - Protected Inter-Ring Connection | 05/2010 |

Table 7 – OTNT Related Standards and Industry Agreements (OIF documents)

| **Organisation (Subgroup responsible)** | **Number** | **Title** | **Publication Date** |
| --- | --- | --- | --- |
| OIF | OIF-TL-01.1 | Implementation Agreement for Common Software Protocol, Control Syntax, and Physical (Electrical and Mechanical) Interfaces for Tunable Laser Modules.  | 11/2002 |
| OIF | OIF-TLMSA-01.0 | Multi-Source Agreement for CW Tunable Lasers.  | 05/2003 |
| OIF | OIF-ITLA-MSA-01.0 | Integratable Tunable Laser Assembly Multi-Source Agreement.  | 06/2004 |
| OIF | OIF-ITLA-MSA-01.1 | Integrable Tunable Laser Assembly Multi Source Agreement  | 11/2005 |
| OIF | OIF-ITLA-MSA-01.2 | Integrable Tunable Laser Assembly Multi Source Agreement | 06/2008 |
| OIF | OIF-ITTA-MSA-01.0 | Integrable Tunable Transmitter Assembly Multi Source Agreement | 11/2008 |
| OIF | OIF-UNI-01.0 | User Network Interface (UNI) 1.0 Signaling Specification | 10/2001 |
| OIF | OIF-UNI-01.0-R2-Common | User Network Interface (UNI) 1.0 Signaling Specification, Release 2: Common Part  | 02/2004 |
| OIF | OIF-UNI-01.0-R2-RSVP | RSVP Extensions for User Network Interface (UNI) 1.0 Signaling, Release 2 | 02/2004 |
| OIF | OIF-UNI-02.0-Common | User Network Interface (UNI) 2.0 Signaling Specification: Common Part | 02/2008 |
| OIF | OIF-UNI-02.0-RSVP | User Network Interface (UNI) 2.0 Signaling Specification: RSVP Extensions for User Network Interface (UNI) 2.0 | 02/2008 |
| OIF | OIF-CDR-01.0 | Call Detail Records for OIF UNI 1.0 Billing | 04/2002 |
| OIF | OIF-SEP-01.0 | Security Extension for UNI and NNI  | 05/2003 |
| OIF | OIF-SEP-02.1 | Addendum to the Security Extension for UNI and NNI  | 03/2006 |
| OIF | OIF-SLG-01.0 | OIF Control Plane Logging and Auditing with Syslog | 11/2007 |
| OIF | OIF-E-NNI-Sig-01.0 | Intra-Carrier E-NNI Signaling Specification  | 02/2004 |
| OIF | OIF-E-NNI-Sig-02.0 | E-NNI Signaling Specification | 04/2009 |
| OIF | OIF-ENNI-OSPF-01.0 | External Network-Network Interface (E-NNI) OSPF-based Routing - 1.0 (Intra-Carrier) Implementation Agreement | 01/2007 |
| OIF | OIF-G-Sig-IW-01.0 | OIF Guideline Document: Signaling Protocol Interworking of ASON/GMPLS Network Domains | 06/2008 |
| OIF | OIF-SMI-01.0 | Security Management Interfaces to Network Elements  | 09/2003 |
| OIF | OIF-SMI-02.1 | Addendum to the Security for Management Interfaces to Network Elements  | 03/2006 |
| OIF | OIF-VSR4-01.0 | Very Short Reach (VSR) OC-192 Interface for Parallel Optics | 12/2000 |
| OIF | OIF-VSR4-03.0 | Very Short Reach (VSR) OC-192 Four Fiber Interface Based on Parallel Optics | 07/2003 |
| OIF | OIF-VSR4-04.0 | Serial Shortwave Very Short Reach (VSR) OC-192 Interface for Multimode Fiber | 01/2001 |
| OIF | OIF-VSR4-05.0 | Very Short Reach (VSR) OC-192 Interface Using 1310 Wavelength and 4 and 11 dB Link Budgets | 10/2002 |
| OIF | OIF-VSR5-01.0 | Very Short Reach Interface Level 5 (VSR-5): SONET/SDH OC-768 Interface for Very Short Reach (VSR) Applications | 09/2002 |
| OIF | OIF-LRI-02.0 | Interoperability for Long Reach and Extended Reach 10 Gb/s Transponders and Transceivers | 07/2006 |
| OIF | OIF-FD-100G-DWDM-01.0 | 100G Ultra Long Haul DWDM Framework Document | 06/2009 |

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

| **Organisation (Subgroup responsible)** | **Number** | **Title** | **Publication Date** |
| --- | --- | --- | --- |
| Carrier Ethernet Service Definitions | 6.2 | Metro Ethernet Services Definitions Phase 3 |  |
| Carrier Ethernet Service Definitions | 8 | Implementation Agreement for the Emulation of PDH Circuits over Metro Ethernet Networks |  |
| Carrier Ethernet Service Definitions | 22.2 | Mobile Backhaul Phase 3 Implementation Agreement |  |
| Carrier Ethernet Service Definitions | 28 | External Network Network Interface (ENNI) Support for UNI Tunnel Access and Virtual UNI |  |
| Carrier Ethernet Service Definitions | 33 | Ethernet Access Services Definition |  |
| Carrier Ethernet Service Definitions | 43 | Virtual NID (vNID) Functionality for E-Access Services |  |
| Carrier Ethernet Service Definitions | 47 | Carrier Ethernet Services for Cloud implementation Agreement |  |
| Carrier Ethernet Service Attributes | 10.3 | Ethernet Services Attributes Phase 3 |  |
| Carrier Ethernet Service Attributes | 10.3.1 | Composite Performance Metric (CPM) Amendment to MEF 10.3 |  |
| Carrier Ethernet Service Attributes | 23.1 | Class of Service Phase 2 Implementation Agreement |  |
| Carrier Ethernet Service Attributes | 26.1 | External Network Network Interface (ENNI) Phase 2 |  |
| Carrier Ethernet Service Attributes | 41 | Generic Token Bucket Algorithm |  |
| Carrier Ethernet Service Definitions | 45 | Multi-CEN L2CP |  |
| 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 | 7.2 | 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 | 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) |  |
| 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 |  |
| 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 |  |
| Management | 15 | Requirements for Management of Metro Ethernet Phase 1 Network Elements |  |
| Management | 16 | Ethernet Local Management Interface |  |
| MEF Service Lifecycle | 50 | Service Operations GuidelinesA process model for the generic Carrier Ethernet service lifecycle, including Service Operations Lifecycle management and Product Lifecycle management. It establishes a foundation for specifications developed by the MEF Service Operations Committee. |  |
| 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 |  |

## 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  | ASTN/ASON recommendations are moved to specific ASTN/ASON 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.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) |
| Protection Switching  | **G.808.1** Generic protection switching - Linear trail and subnetwork protection  |
| **G.873.1** Optical Transport network (OTN) - Linear Protection |
| **G.Imp873.1** Implementer's Guide |
| **G.873.2** ODUk shared ring protection |
| Management Aspects  | **G.874** Management aspects of the optical transport network element  |
| **G.Imp874** Implementer's Guide |
| **G.874.1** 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.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.671** Transmission characteristics of optical components and subsystems |

## Standards on the ASTN/ASON Control Plane

The following table lists ITU-T Recommendations specifically related to the ASTN/ASON Control Plane.

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.Imp8080** Implementer's Guide |
| Protocol Neutral Specifications for key signalling elements  | **G.7713/Y.1704** Distributed Call and Connection Management (DCM) |
| **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.7718/Y.1709** Framework for ASON Management |
|  **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  |

Table 11 shows the mapping of existing protocol-specific documents between ITU-T Recommendations and ones that were received from other organizations.

Table 11 – Estimated mapping of protocol-specific documents in ITU-T ASON Recommendations



## Standards on the Ethernet Frames, MPLS, Transport 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 (Q.17/12) | G.1563 | Ethernet frame transfer and availability performance  |
| SG13(Q7/13) | Y.1415 | Ethernet-MPLS network interworking - User plane interworking |
| SG15(Q.10/15) | Y.1730 | Requirements for OAM functions in Ethernet-based networks and Ethernet services |
| SG15(Q.10/15) | Y.1731  | OAM functions and mechanisms for Ethernet based networks |
| SG15(Q.3/15) | G.8001 | Terms and definitions for Ethernet frames over transport |
| SG15(Q.12/15) | G.8010/Y.1306 | Architecture of Ethernet Layer Networks |
| SG15(Q.10/15) | G.8011/Y.1307 | Ethernet service characteristics |
| SG15(Q.10/15) | G.8012/Y.1308 | Ethernet UNI and Ethernet NNI |
| SG15(Q.10/15) | G.8012.1/Y.1308.1 | Interfaces for the Ethernet transport network |
| SG15(Q.10/15) | G.8013/Y.1731 | OAM functions and mechanisms for Ethernet based networks |
| SG15(Q.9/15) | G.8021/Y.1341 | Characteristics of Ethernet transport network equipment functional blocks |
| SG15(Q.9/15) | G.8021.1/Y.1341.1 | Types and characteristics of Ethernet transport network equipment |
| SG15(Q.9/15) | G.8031/Y.1342 | Ethernet linear protection switching |
| SG15(Q.9/15) | G.8032/Y.1344 | Ethernet ring protection switching |
| 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(Q.13/15) | G.8262/Y.1362 | Timing characteristics of synchronous Ethernet equipment slave clock (EEC) |

Table 13 – MPLS related Recommendations

| **Organisation (Subgroup responsible)** | **Number** | **Title** |
| --- | --- | --- |
| SG13(Q.3/13) | Y.1311.1 | Network-based IP VPN over MPLS architecture |
| SG12 (Q.17/12) | 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(Q.12/13) | Y.1411 | ATM-MPLS network interworking - Cell mode user plane interworking |
| SG13(Q.12/13) | Y.1412 | ATM-MPLS network interworking - Frame mode user plane interworking |
| SG13(Q.12/13) | Y.1413 | TDM-MPLS network interworking - User plane interworking |
| SG13(Q.12/13) | Y.1414 | Voice services - MPLS network interworking |
| SG13(Q.12/13) | Y.1415 | Ethernet-MPLS network interworking - User plane interworking |
| SG13(Q.12/13) | Y.1416 | Use of virtual trunks for ATM/MPLS client/server control plane interworking |
| SG13(Q.12/13) | Y.1417 | ATM and frame relay/MPLS control plane interworking: Client-server  |
| SG15(Q.10/15) | Y.1710 | Requirements for OAM functionality for MPLS networks |
| SG15(Q.10/15) | Y.1711 | Operation & Maintenance mechanism for MPLS networks |
| SG15(Q.10/15) | Y.1712 | OAM functionality for ATM-MPLS interworking |
| SG15(Q.10/15) | Y.1713 | Misbranching detection for MPLS networks |
| SG15(Q.10/15) | Y.1714 | MPLS management and OAM framework |
| SG15(Q.9/15) | Y.1720 | Protection switching for MPLS networks |
| SG15(Q.12/15) | G.8110/Y.1370 | MPLS Layer Network Architecture |

Table 14 – MPLS-TP-related Recommendations

| **Organisation (Subgroup responsible)** | **Number** | **Title** |
| --- | --- | --- |
| SG15(Q3/15) | 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(Q9/15) | G.8131/Y.1382 | Linear protection switching for MPLS transport profile |
| SG15(Q14/15) | G.8151/Y.1374 | Management aspects of the MPLS-TP network element |

## Standards on Synchronization [Newly introduced in 09/2016]

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 – Synchorozaion-related Recommendations

|  |  |  |
| --- | --- | --- |
|  | Frequency | Time and phase |
| Network | 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 networks |
| Clock | G.8262/Y.1362: Timing characteristics of a synchronous Ethernet equipment slave clock G.8263/Y.1363: Timing characteristics of packet-based equipment clocks | G.8272/Y.1367: Timing characteristics of primary reference time clocksG.8273/Y.1368: Framework of phase and time clocksG.8273.2/Y.1368.2: Timing characteristics of telecom boundary clocks and telecom time slave 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 |

# Overview of existing holes, overlaps, and conflicts

Considering the number and diversity of different organizations working on standardising aspects of OTNT, it is inevitable that some areas will be missed. For the same reasons, some aspects will be addressed in multiple groups, resulting in possible conflicts based on different applications, priorities, or technical expertise. These items need to be identified and addressed as appropriate. The following table lists those that have been identified, the recommended action, and the status of that action.

Table 16 – Known OTNT standardization holes, overlaps, conflicts (as of 07/2015)

| **No** | **Issue** | **Action** | **Status** |
| --- | --- | --- | --- |
| 1. | WSON (wavelength switched optical network) is now under discussion between IETF ccamp and ITU-T SG15. While ITU-T SG15 is specifying architecture and transport plane aspects, IETF ccamp is specifying control plane standard | Liaisons to and from the IETF ccamp, continuing work by Q6 & 12/15 | Resolved  |
| 2 | **Interconnection of core & access transport of time & SSM issues**Timing distribution method over access technologies such as GPON/xPON and XDSL for directly passing time and phase information from the ONU to the base stations are requested and investigated. Both frequency synchronization aspect and time synchronization aspect are discussed.  | Possible proposals should be considered in Q2/15, Q4/15 and Q13/15 | On-going |
| 3 | Ethernet over OTN (E-OTN) issuesThe use of Ethernet technology in PTN requires an extension of the tagging option defined in 802.1Q to support VC, VP, VS stacking in single and multi-domain scenarios. The necessity of the new transport tag option, PTN Layer Hierarchy (the 3 packet layer) and the role of each layer are still under discussion. PB and PBB models are also need to be considered. | Liaisons to and from the IEEE 802.1, continuing work by Q.9/15 and Q12/15 | Resolved |
| 4 | **Transport of CPRI interface over OTN**Transport of CPRI over OTN is proposed. A definition of the applicable OTN hypothetical reference model (HRM) is required. Further clarifications of the requirements are undergoing discussion. | Contribution is invited in Q11 and Q13G.SupCPRI was produced in July 2015. | On-going |
| 5 | **OTN beyond 100G**Possible additions to G.709 for standardization of interfaces at rates beyond 100G are being developed. Proposals are being considered and working assumptions are being collected in preparation for standardization. Final specification of an interoperable inter-domain interface is awaiting stability in the definition of 400GbE by the IEEE. Other SG15 Questions are being consulted, but the current work is focused in Q11. | Contribution is invited in Q11 | On-going |
| 6 | **Software Defined Networking in transport networks**SG15 has responsibility for transport aspects of SDN. Two Recommendations have started in jointly in Q12 and Q14, and there is ongoing coordination with JCA-SDN and ONF. | Contributions are invited in Q12 and Q14Representatives from SG15 participate in JCA-SDN. | On-going |
| 7 | **Terminology update on OTN and refinement of modelling**OTN terminology is being updated to be more precise and consistent across multiple Recommendations under the scopes of Q6, Q11, Q12, and Q14/15.The SG15 Questions are collaborating to select new terms that are consistent with the scopes of the Questions defining them and the Recommendations where they are used. The new terms and revisions to incorporate them should make OTN Recommendations easier to read while possibly reducing overlap across the document scopes. | Contributions are invited in Q11, Q12, and Q14/15. | Identified in Nov. 2014.On-going |
| 8 | **Management of synchronization network** * Configuration of the synchronization network
* Performance monitoring and related OAM tools
* Information modelling
* SDN control of synchronization network.
 | Q10, 13, 14 | Identified in Nov. 2014.On-going. |

# Annex A - Terminology Mapping

The terminology used by different organizations working on similar or overlapping technical areas of standardization has complicated attempts to co-ordinate work between different groups. The same terms are often used, with different meanings by multiple organizations. Question 3 of ITU-T Study Group 15 is responsible for maintaining “Terms and definitions” Recommendations on a number of established major categories of optical networks and technologies, as listed in Table 7‑1‑1. Readers are warned to verify the definitions before assuming a common understanding of the terms. Specific appendices have been included in ITU-T Recommendations G.7713.x to assist the reader in mapping signalling protocol terminology used in those document to the similar terms used in other well know references. Documents for terminology mapping in IETF such as RFC4397 and draft-ietf-mpls-tp-rosetta-stone can also be referred.

# Annex B – Routing Area Reorganization in IETF (as of Nov. 2014)

The IETF’s Routing Area Directors have proposed and received agreement to reorganize the Routing area. This directly impacts a number of the working groups that have liaised with ITU-T in the past.

A summary of the restructuring is as follows:

L2VPN, L3VPN and PWE3 are closed, with active work shuffled based on topic into two new working groups:

BESS: BGP Enabled Services
PALS: Pseudo-wire and LDP-enabled Services

NVO3’s charter will be adjusted with some of the work moving to BESS and PALS.

Traffic Engineering aspects in CCAMP, MPLS and PCE are moved into a new working group:

TEAS: Traffic Engineering Architecture and Signaling

Charters for the BESS and PALS working groups have been completed and are found on the IETF list of working groups found here: <http://datatracker.ietf.org/wg/>

A charter for TEAS as well as revised charters for CCAMP, MPLS and PCE are under development.

No changes are made to the remaining Routing Area working Groups (BFD, FORCES, I2RS, IDR, ISIS, MANET, OSPF, PIM, ROLL, RTWG, SFC, SIDR, SPRING).

The restructuring is scheduled to take effect after the IETF91 (Nov. 2014).

# Annex C – IETF transport network management (as of July 2015)

This Annex reports on the status of the transport management related activities in IETF.

## Layer Independent OAM Management in the Multi-Layer Environment (lime)

The LIME working group will concentrate on the operational challenges in consistent handling of end-to-end OAM and coordination of OAM within underlying network layers. This work will enable consistent configuration, reporting, and presentation for the OAM mechanisms used to manage the network, regardless of the layers and technologies, including management mechanisms to facilitate better mapping between information reported from OAM mechanisms that operate in different network layers. It will also produce architectural guidelines for the development of new OAM tools and protocols in both management plane and data plane so that they may be coherent with these mechanisms and more easily integrated from operational points of view. The charter of the Working Group can be found at <http://datatracker.ietf.org/wg/lime/charter/>.

## Network Configuration Protocol (netconf)

The NETCONF protocol (RFC 6241) provides mechanisms to install, manipulate, and delete the configuration of network devices. NETCONF is based on the secure transport (SSH is mandatory to implement while TLS is an optional transport) and uses an XML-based data representation. The NETCONF protocol is data modeling language independent, but YANG (RFC 6020) is the recommended NETCONF modeling language, which introduces advanced language features for configuration management.

In the current phase of the incremental development of NETCONF the WG will focus on following items:

Develop the call home mechanism for the mandatory SSH binding (Reverse SSH) providing a server-initiated session establishment.

Develop a zero touch configuration document (a technique to establish a secure network management relationship between a newly delivered network device configured with just its factory default settings, and the Network Management System), specific to the NETCONF use case.

Advance NETCONF over TLS to be in-line with NETCONF 1.1 (i.e., update RFC 5539) and add the call home mechanism to provide a server-initiated session establishment.

Combine the server configuration data models from Reverse SSH and RFC5539bis drafts in a separate call home YANG module.

Develop RESTCONF, a protocol based on NETCONF in terms of capabilities, but over HTTP and with some REST characteristics, for accessing YANG data using the datastores defined in NETCONF. An "ordered edit list" approach is needed (the YANG patch) to provide client developers with a simpler edit request format that can be more efficient and also allow more precise client control of the transaction procedure than existing mechanisms. The YANG patch operation, based on the HTTP PATCH method, will be prepared in a separate draft. RESTCONF should not deviate from the NETCONF capabilities unless proper justification is provided and documented. The RESTCONF work will consider requirements suggested by the other working groups (for example I2RS).

RFC published since December 2014:

[RFC7589](http://datatracker.ietf.org/doc/rfc7589/) (Proposed Standard 2015.06) Using the NETCONF Protocol over Transport Layer Security (TLS) with Mutual X.509 Authentication (former title: NETCONF Over Transport Layer Security (TLS)). This document describes how to use the Transport Layer Security (TLS) protocol to secure the exchange of NETCONF messages. This document obsoletes RFC 5539.

Full details of the work of the Network Configuration (netconf) WG, including the published RFCs and Internet-Drafts, can be found at <http://www.ietf.org/dyn/wg/charter/netconf-charter.html> and <http://datatracker.ietf.org/wg/netconf/>.

## Network Configuration Data Modeling Language (netmod)

The Network ConfigurationData Modeling Language (netmod) WG is chartered to define a modeling language or accompanying rules that can be used to model the management information that is to be configured using NETCONF, including defining the semantics of operational data, configuration data, notifications, and operations. This language will be used to serve as the normative description of NETCONF data models.

The most recently published RFC is:

[RFC-7407](http://datatracker.ietf.org/doc/rfc7407/) A YANG Data Model for SNMP Configuration: This document defines a collection of YANG definitions for configuring SNMP engines. (2014.12).

Full details of the work of the NETCONF Data Modeling Language (netmod) WG, including the published RFCs and Internet-Drafts, can be found at <http://www.ietf.org/dyn/wg/charter/netmod-charter.html> and <http://datatracker.ietf.org/wg/netmod/>.

## Traffic Engineering Architecture and Signaling-related work (TEAS)

The Traffic Engineering Architecture and Signaling (TEAS) Working Group, recently transitioning in charter work from the MPLS and CCAMP WGs, is responsible for defining MPLS and GMPLS traffic engineering architecture, standardizing the RSVP-TE signaling protocol, and identifying required related control-protocol functions, i.e., routing and path computation element functions. Traffic Engineering (TE) is the term used to refer to techniques that enable operators to control how specific traffic flows are treated within their networks. TE is applied to packet networks via MPLS TE tunnels and LSPs. The MPLS-TE control plane was generalized to additionally support non-packet technologies via GMPLS. RSVP-TE is the signaling protocol used for both MPLS-TE and GMPLS.

The TEAS WG has recently published the following RFC:

[RFC 7551](http://datatracker.ietf.org/doc/rfc7551/) (Proposed Standard) RSVP-TE Extensions for Associated Bidirectional Label Switched Paths (LSPs): This document describes Resource Reservation Protocol (RSVP) extensions to bind two point-to-point unidirectional Label Switched Paths (LSPs) into an associated bidirectional LSP. The association is achieved by defining new Association Types for use in ASSOCIATION and in Extended ASSOCIATION Objects. One of these types enables independent provisioning of the associated bidirectional LSPs on both sides, while the other enables single-sided provisioning. The REVERSE\_LSP Object is also defined to enable a single endpoint to trigger creation of the reverse LSP and to specify parameters of the reverse LSP in the single-sided provisioning case. (2015.05)

Full details of the work of the Traffic Engineering Architecture and Signaling (TEAS) WG, including the published RFCs and individual Internet-Drafts, can be found at <http://datatracker.ietf.org/wg/teas/charter/>.

## GMPLS management-related work (CCAMP)

The CCAMP working group is responsible for standardizing a common control plane and a separate common measurement plane for non-packet technologies found in the Internet and in the networks of telecom service providers (ISPs and SPs). Examples of the devices in such networks include photonic cross-connects, OEO switches, ROADMs, TDM switches, microwave links, and Ethernet switches.

The CCAMP WG has recently published the following management-related RFC:

[RFC 7446](http://datatracker.ietf.org/doc/rfc7446/) (Proposed Standard) Routing and Wavelength Assignment Information Model for Wavelength Switched Optical Networks: This document provides a model of information needed by the Routing and Wavelength Assignment (RWA) process in Wavelength Switched Optical Networks (WSONs). The purpose of the information described in this model is to facilitate constrained optical path computation in WSONs. This model takes into account compatibility constraints between WSON signal attributes and network elements but does not include constraints due to optical impairments. Aspects of this information that may be of use to other technologies utilizing a GMPLS control plane are discussed.(2015.02)

[RFC 7487](http://datatracker.ietf.org/doc/rfc7487/) (Proposed Standard) Configuration of pro-active MPLS-TP Operations, Administration, and Maintenance (OAM) Functions for MPLS-based Transport Network Using RSVP-TE: This specification describes the configuration of pro-active MPLS-TP OAM Functions for a given LSP using a common set of TLVs that can be carried on RSVP-TE protocol. (2015.03)

Full details of the work of the Common Control and Measurement Plane (ccamp) WG, including the published RFCs and individual Internet-Drafts, can be found at <http://www.ietf.org/dyn/wg/charter/ccamp-charter.html> and <http://datatracker.ietf.org/wg/ccamp/>

## MPLS management-related work (MPLS)

The MPLS working group is responsible for standardizing technology for label switching and for the implementation of label-switched paths over packet based link-level technologies.

The MPLS WG has recently published the following management-related RFC:

[RFC 7506](http://datatracker.ietf.org/doc/rfc7506/) (Proposed Standard) IPv6 Router Alert Option for MPLS Operations, Administration, and Maintenance (OAM). (2015.04).

[RFC-7453](http://datatracker.ietf.org/doc/rfc7453/) (Proposed Standard) MPLS Transport Profile (MPLS-TP) Traffic Engineering (TE) Management Information Base (MIB): This memo defines a portion of the Management Information Base (MIB) for use with network management protocols in the Internet community. In particular, it describes additional managed objects and textual conventions for tunnels, identifiers, and Label Switching Routers to support multiprotocol Label Switching (MPLS) MIB modules for transport networks.(2015.02)

[RFC-7412](http://datatracker.ietf.org/doc/rfc7412/) (Proposed Standard) Requirements for MPLS Transport Profile (MPLS-TP) Shared Mesh Protection: This document presents the basic network objectives for the behavior of Shared Mesh Protection (SMP) that are not based on control-plane support. This document provides an expansion of the basic requirements presented in RFC 5654 ("Requirements of an MPLS Transport Profile") and RFC 6372 ("MPLS Transport Profile (MPLS-TP) Survivability Framework"). This document provides requirements for any mechanism that would be used to implement SMP for MPLS-TP data paths, in networks that delegate protection switch coordination to the data plane. (2014.12)

Full details of the work of the MPLS (mpls) WG, including the published RFCs and Internet-Drafts, can be found at <http://www.ietf.org/dyn/wg/charter/mpls-charter.html> and <http://datatracker.ietf.org/wg/mpls/>.

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