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| ITU‑T Study Group 15 |
| Networks, Technologies and Infrastructures for Transport, Access and Home |
| Report of ITU-T SG15 to the World Telecommunication Standardization Assembly (WTSA-20), Part II: Questions proposed for study during the next study period (2022-2024) |

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| **Abstract:** | This contribution contains the text of the Study Group 15 Questions proposed for approval by the Assembly for the next study period. Revision 1 applies the mapping of Question numbers to letters, as customary for WTSA Part II reports. |
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Note by the TSB:

The report of Study Group 15 to the WTSA-20 is presented in the following documents:

Part I: **Document 15** – General

Part II: **Document 16** – Questions proposed for study during the study period 2022-2024

# 1 Introduction

This document contains the proposed updates to the Questions endorsed at the virtual TSAG meeting, 11-18 January 2021 as reflected in TSAG [R19](https://www.itu.int/md/meetingdoc.asp?lang=en&parent=T17-TSAG-R-0019), to be considered at WTSA-20. Table 1 lists the Questions and their relationships to the in-force set of Questions.

Table 1 – Map of proposed SG15 Questions (left) to those adopted January 2021 (right)

| New number | Proposed Question title | Status | Current number | Current Question title |
| --- | --- | --- | --- | --- |
| A/15 | Coordination of access and home network transport Standards | Continued | 1/15 | Coordination of access and home network transport standards |
| B/15 | Optical systems for fibre access networks | Continued | 2/15 | Optical systems for fibre access networks |
| C/15 | Technologies for in-premises networking and related access applications | Continued | 18/15 | Technologies for in-premises networking and related access applications |
| D/15 | Broadband access over metallic conductors | Continued | 4/15 | Broadband access over metallic conductors |
| E/15 | Characteristics and test methods of optical fibres and cables, and installation guidance | Continued | 5/15 | Characteristics and test methods of optical fibres and cables, and installation guidance |
| F/15 | Characteristics of optical components, subsystems and systems for optical transport networks | Continued | 6/15 | Characteristics of optical systems for terrestrial transport networks |
| G/15 | Connectivity, operation and maintenance of optical physical infrastructures | Continued | 16/15 | Connectivity, operation and maintenance of optical physical infrastructures |
| H/15 | Characteristics of optical fibre submarine cable systems | Continued | 8/15 | Characteristics of optical fibre submarine cable systems |
| I/15 | Interfaces, interworking, OAM, protection and equipment specifications for packet-based transport networks | Continued | 10/15 | Interfaces, interworking, operation, administration and maintenance (OAM) and equipment specifications for packet-based transport networks |
| J/15 | Signal structures, interfaces, equipment functions, protection and interworking for optical transport networks | Continued | 11/15 | Signal structures, interfaces, equipment functions, and interworking for optical transport networks |
| K/15 | Transport network architectures | Continued | 12/15 | Transport network architectures |
| L/15 | Network synchronization and time distribution performance | Continued | 13/15 | Network synchronization and time distribution performance |
| M/15 | Management and control of transport systems and equipment | Continued | 14/15 | Management and control of transport systems and equipment |

# 2 Wording of Questions

Question A/15

Coordination of access and home network transport standards

(Continuation of Question 1/15)

### A.1 Motivation

Within the ITU-T, transport technology in the Access Network is under study in a number of different study groups, e.g., SGs 9, 12, 13, and 15, with several Recommendations published, others in development, and other supportive activities conducted, such as workshops. Moreover, ITU-R, IEEE and other standards bodies, forums and consortia are also active in this area.

Recognizing 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, the latest WTSA assigned Study Group 15 as Lead Study Group on access network transport within ITU-T.

An access network transport (ANT) standards overview and an ANT standards work plan have been published.

The ANT standards overview describes various access network transport "scenarios" currently being developed and implemented and a list of associated Recommendations and Standards relating to defining those scenarios.

The ANT standards work plan lists a number of standardization bodies active in the ANT area with names and addresses for contact, communication and collaboration. It also lists possible "gaps", "overlaps" and conflicts of ongoing standardization activities. Both are published on the ITU-T Study Group 15 website.

As home networks become more sophisticated, and as their interactions with the access network become more complex, coordination between access network standards and home network standards becomes of increasing importance.

Using a process similar to the ANT standards coordination, a home network transport (HNT) standards overview and work plan have been published and is available on the SG15 webpage.

The access network is experiencing rapid technical change, historically high subscriber growth rates, a proliferation of new products and solutions, wide entry from new service providers and equipment suppliers who might be unfamiliar with general standards, and governments eager for deployment of advanced technologies in the access network. Access network standardization will see increased numbers of stakeholders who might be not industry experts or even members. These same concerns apply to home networks as they are increasingly connected to the access network and the WAN. The need for coordinated standardization in these portions of the network has not been greater than it is today.

### A.2 Question

– How can ITU-T Study Group 15 best fulfil its mission as Lead Study Group on access network transport within ITU-T?

– How can ITU-T Study Group 15 ensure smooth coordination for home network interactions with the access network?

– Study items to be considered include but are not limited to:

 Maintain and update the ANT standards overview together with other study groups and in conjunction with ITU-R and other relevant organizations.

 Maintain and update the ANT standards work plan, report ANT related standards activities underway by recognized standards developing organizations (SDOs), identify "gaps, overlaps and conflicts" by observing on-going standardization activities.

 Maintain and update the HNT standards overview and work plan together with other study groups and in conjunction with ITU-R and other relevant organizations. Report HNT related standards activities underway by recognized SDOs, identify "gaps, overlaps and conflicts" by observing on-going standardization activities. Maintain coordination across the relevant ITU-T study groups to ensure all available expertise is utilized to best advantage and in the establishment of priorities.

 Maintain and update the ANT and HNT standards web presentations.

 Serve as focal point to and provide coordination with other standards organizations, forums and consortia to ensure that the consolidation of work plans and priorities is based on a wide range of business, market and technological inputs.

 Contribute to ITU efforts to support developing countries by making pertinent information available such as ANT and HNT standards, documents and relevant information including indications of best practices on implementation of broadband.

 Contribute to ITU ANT and HNT standardization efforts that communicate, collaborate or otherwise work across industry and technical boundaries for technical standards of mutual benefit.

 Investigation of applications and higher-level discussion in focus groups and joint coordination activities in ITU-T for extraction of new requirements on transport technology in the access and home network.

### A.3 Tasks

Tasks include, but are not limited to:

– Update the ANT standards overview.

– Update the ANT standards work plan.

– Update the HNT standards overview and work plan.

– Maintain the living list of the conformance and interoperability testing (CIT) activities in other organizations related to technologies based on ITU-T Recommendations from WP1/15.

– Update the ANT and HNT web presentations corresponding to the revisions of the ANT and HNT standardization overviews and work plans in order to maintain easy access to the actual information.

– Respond to specific requests for information on ANT and HNT standards from other standards organizations and other interested entities.

– Contribute to the success of pertinent ITU-T activities.

– Communicate with other groups, inside and outside ITU-T as needed for coordination purposes.

As this Question is primarily for coordination, it does not normally develop Recommendations.

An up-to-date status of work under this Question is contained in the SG15 work programme (<https://www.itu.int/ITU-T/workprog/wp_search.aspx?sg=15>).

### A.4 Relationships

Recommendations:

– None.

Questions:

– QB/15, QC/15, QD/15, QE/15, QG/15

Study Groups:

– ITU-T SG5 – Environment and circular economy

– ITU-T SG9 – Broadband cable and TV

– ITU-T SG11 – Signalling requirements, protocols, test specifications and combating counterfeit products

– ITU-T SG12 – Performance, QoS and QoE

– ITU-T SG13 – Future networks, with focus on IMT-2020, cloud computing and trusted network infrastructures

– ITU-T SG16 – Multimedia coding, systems and applications

– ITU-T SG17 – Security

– ITU-T SG20 – Internet of things (IoT) and smart cities and communities

– ITU-R SGs 1, 4, 5 and 6 on Co-existence between wired telecommunication systems and radiocommunication services

– ITU-R WP1A – Spectrum engineering techniques

– ITU-R SG4 on Satellites in access network transport

– ITU-R WP 4B – Systems, air interfaces, performance and availability objectives for FSS, BSS and MSS, including IP-based applications and satellite news gathering

– ITU-R WP 5A – Land mobile service above 30 MHz (excluding IMT); wireless access in the fixed service; amateur and amateur-satellite services

– ITU-R WP 5C – Fixed wireless systems; HF and other systems below 30 MHz in the fixed and land mobile services

– ITU-R WP 5D – IMT Systems

– ITU-R WP6A – Terrestrial broadcasting delivery

– ITU-R WP6B – Broadcast service assembly and access

– ITU-D SG 1 and SG 2 on Broadband access technologies for developing countries

– Other ITU-T committees, e.g., joint coordination activity (JCA) when required.

Other bodies:

– Broadband Forum

– ATIS Committee STEP

– CENELEC CLC/TC205 on Home and Building Electronic Systems

– IEEE 802.3, 802.11 and 802.16

– IEEE 1904

– IEEE Power Line Communications Standards Committee

– CENELEC CLC/TC215 on Electro-technical aspects of telecommunications equipment

– IETF on access network management

– IEC TC86 and its sub-committees on fibre optics

– ETSI TC ATTM, TC CABLE, TC DECT, TC EE and ISG F5G

– ISO/IEC JTC1/SC25 on Interconnection of Information Technology Equipment

– TIA TR-41, TR-42

– HomeGrid Forum

– MoCA Multimedia over Coax Alliance

Question B/15

Optical systems for fibre access networks

(Continuation of Question 2/15)

### B.1 Motivation

Recommendations for point-to-point and point-to-multi point optical access systems, such as the G-PON (G.984 series), XG-PON (G.987 series), XGS-PON (G.9807 series), and NG-PON2 (G.989 series), have allowed telecommunications manufacturers to develop inter-operable optical access equipment, by which Fibre To The X (FTTx) has become reality. Practical experience with the design and deployment will necessitate revision of these Recommendations to include, for example, enhanced services, better interoperability, higher split ratios, longer reach, and increased capacity.

To provide new features in optical access, such as wavelength division multiple access (WDMA) and hybrid xDMA/yDMA systems, will necessitate the development of new Recommendations.

Fibre access systems need to support a range of service capabilities at the edge. Wireless, wireline and fibre (e.g., G.65x and Plastic Optical Fibre (POF)) will be needed. Economies are needed for fibre access deployment to become prevalent as a mass-market solution. Demand will be driven by factors such as: the ability to carry interactive and broadcast services (e.g. residential video, HDTV, AR, VR), managed bandwidth to multiple Internet Service Providers (ISPs), together with higher quality of service and improved resilience. Solutions are required for a wide range of market segments and situations including: business, small-to-medium-enterprise, small-office-home-office, residential, mobile backhaul and fronthaul, as well as green field and network upgrade.

To support current and/or future wireless/mobile services, optical access systems are expected to provide flexible broadband communication channels for plural base stations/remote units in some cases, and to support digital and/or analogue transmission of Radio Frequency signals for remote base stations/remote units in some other cases. Optical access systems are also expected to coordinate with external systems. This is to facilitate end-to-end service provisioning. Necessary information exchange between an optical access system and an external system should be considered to improve network performance. Such coordination and control are key to low-latency services in the IMT-2020/5G era.

The various optical access technologies are expected to serve a wider range of networking applications that are not access networks. In these new application areas, fibre technology brings many advantages compared to current means. By the same token, these new applications can present new requirements for the technology, such as revised loss budgets, fibre reach, topology, and media access control. Coordination with relevant other groups (e.g., QC/15) and joint projects can help to leverage the existing technology for these new applications. Demand for dedicated GbE, 10GbE, and higher-speed Ethernet services initially to business users is increasing. New techniques are needed to increase performance and reduce costs for both dedicated and shared bearer services. Both access and metro networks should be considered when offering such access services, because currently, access nodes are sometimes bypassed to minimize overall network cost. Both Point-to-point and point-to-multi-point solutions will be considered.

Integration of all services onto a single backhaul fibre network is an important economic consideration for network operators.

To be successful, QB/15 needs to harmonize with other bodies which have a strong optical access industry role, such as IEEE and IEC. The following major Recommendations in force fall under its responsibility: G.981, G.982, G.983 series, G.984 series, G.985, G.986, G.987 series, G.988, G.989 series, G.9801, G.9802, G.9803, G.9806, and G.9807 series.

### B.2 Question

– What new architecture, technologies and protocols are needed to:

 Enable next generation PON architecture and technology to offer broader bandwidth as well as improved services and economics in optical access networks?

 Integrate access and metro/backhaul networks into one seamless optical access and aggregation networks?

 Allow individual customers on a live legacy PON to be upgraded to higher capacity next generation systems without impacting on other users' traffic?

 Allow systems to evolve to higher split ratios physically and logically in optical access networks?

 Improve resiliency in optical access networks?

 Serve a mixture of optical, copper and radio (broadband) final customer connections to the same optical access system, with simplified remote electronics?

 Support digital and/or analogue transmission of radio frequency signals for current and future wireless/mobile services?

 Coordinate optical access systems and external systems in an end-to-end fashion for low-latency services?

 Support non-access applications of optical access technology through coordination with or joint projects with other groups?

– What enhancements to existing Recommendations are needed to improve interoperability between optical network unit (ONU) and optical line terminal (OLT)?

– What new or enhancements to existing Recommendations are needed to:

 Provide energy savings directly or indirectly in Information and Communication Technologies (ICTs) or in other industries?

 Realize mobile fronthaul/backhaul with optical access technologies?

 optical access network systems and services in the concept of software define network (SDN) / network function virtualization (NFV)?

 Secure information transmission over optical access systems?

– Study items to be considered include, but are not limited to:

 Next generation PON architecture and technology.

 New long-reach access system(s) for access/metro-integrated applications based on WDM access and/or enhanced TDM access technologies.

 How to specify ONUs for the consumer market?

 Impact of new component technology on optical access networks.

 How to ensure the optical systems contribute to the end-end QoS for packet services?

 How to ensure the maximum service capability for Ethernet and wireless local area network (WLAN) edge networks?

 How to provide for multimedia and low-latency services?

 Interoperability and physical interconnect conformance.

 The definition of access demarcation point, in the light of consumer-owned optical network terminations.

 Modulation schemes over fibre access.

 What is the service capacity and requirements outlook for access?

 How to ensure efficient inter-connection between fibre access systems and other technologies?

 How to manage wavelength channels in optical access?

 How to provide coexistence and migration of generations of optical access systems

 How to improve energy savings?

 How to mitigate rogue ONUs?

 How to coordinate with external systems and provide end-to-end services?

### B.3 Tasks

Tasks include, but are not limited to:

– Maintenance and enhancements of G.981, G.982, G.983 series, G.984 series, G.985, G.986, G.987 series, G.988, G.989 series, G.9801, G.9802, G.9803, G.9804, G.9806, and G.9807 series Recommendations and associated Supplements with regard to capacity, interoperability, management and control interfaces, survivability, spectral management, split ratios or other requirements

– Draft one or more new Recommendation series to describe the next generations of optical access systems

– Liaison and co-work with other groups to explore new applications of optical access systems

An up-to-date status of work under this Question is contained in the SG15 work programme (<https://www.itu.int/ITU-T/workprog/wp_search.aspx?sg=15>).

### B.4 Relationships

Recommendations:

– None.

Questions:

– All Questions in SG15.

Study Groups:

– ITU-T SG2 on management aspects

– ITU-T SG5 on energy consumption and efficiency

– ITU-T SG9 on television and sound transmission

– ITU-T SG13 on Multi-Protocol Label Switching (MPLS) layer characteristics

Other bodies:

– IEC TC86 and its sub-committees on devices and other topics

– Broadband Forum on network architectures, fibre access, and management

– IETF on MIB

– IEEE 802 on optical access systems, Ethernet and WLAN

– IEEE 1904.1 on service interoperability in ethernet passive optical networks

– ATIS Committee STEP

– O-RAN Alliance WG4

Question C/15

## Technologies for in-premises networking and related access applications

(Continuation of Question 18/15)

### C.1 Motivation

The continuing demand for an ever-increasing device connectivity to offer new services to the customer and to optimize the installation and management of infrastructure will require the development of new networking technologies. As an example,

– The continuing customer demand for ever higher bit rate data services, high-speed Internet access and other innovative services, and the ongoing needs of network operators to leverage in-premises connectivity for distributing within the home IPTV and other applications.

– There is a growing interest worldwide in providing support for the integration of new technologies and applications aimed at sustainably addressing energy independence and modernization of the aging power grid, e.g., utility scale renewable energy sources, distributed energy resources, Plug-in Electric Vehicles, and Demand-Side Management. For supporting the above technologies and applications, it is necessary to ensure the availability of a modern, flexible, and scalable communications network that will tie together the functions of "monitoring" and "control." Information and communication technologies will allow utilities to remotely locate, isolate, and restore power outages more quickly, thus increasing the stability of the grid. Information and communication technologies will also facilitate the integration of time-varying renewable energy sources into the grid, enable a better and more dynamic control of the load, and will also empower consumers with tools for optimizing their energy consumption.

Whilst the focus of the group is in-premises networking, some technical developments may be needed to adapt these technologies to other contexts (e.g., access, industrial).

These new technologies will require the development of new Recommendations and enhancements to existing Recommendations covering all requirements and implementation aspects of new deployments. These studies will include, but are not limited to physical layer transport, the transport of higher layer protocols, the management and testing of in-premises systems, security aspects, spectral management aspects and energy saving techniques as well as the definition of communication network architectures and requirements.

The following major Recommendations, in force at the time of approval of this Question, fall under its responsibility:

– J.190 through J.192,

– G.9951 through G.9954,

– G.9960 through G.9964, G.9972, G.9973, G.9976 through G.9980,

– G.999x series

– G.995x, and G.990x series

The target audience for this question are the technology suppliers, chipset vendors, equipment vendors, cable operators, service providers and utilities active in the domain of providing networking solutions for their users or infrastructures. A global audience will be targeted to facilitate a unified approach to support this broad scope of applications with a single technology, facilitating synergies across application fields.

### C.2 Question

Study items to be considered include, but are not limited to:

– What performance characteristics should heterogeneous networks possess in order to satisfactorily transport data streams associated with specific services as these streams are passed through the communication network to the terminal device?

– What enhancements are needed to Recommendations G.9951 through G.9954, G.9960 through G.9964, G.9991, G.995x and G.990x series, G.9972, G.9973, G.9976 through G.9980:

 in the light of design, network deployment experience, and evolving service requirements?

 to optimise the transport of IP-based services?

 to ensure efficiency and scalability in large networks?

 to support new smart applications?

– What new Recommendations or revisions to existing Recommendations are needed:

 for transceivers for heterogeneous networking over various mediums such as phone-line, coaxial, data (e.g. CAT5), power cables, optical fibre and wireless?

 for narrowband and broadband transceivers for networking using free space optical communication, including visible light communication (VLC)?

 to carry out line testing?

 to enable higher bit rates to be achieved by means of MIMO?

 to enable transport of higher layer protocols?

 to optimize the quality-of-experience to the end user?

 to provide secure admission to an in-premises network?

 to facilitate coexistence between various technologies sharing the same spectrum?

 to facilitate inter-domain communication between different mediums to optimize the choice of delivery path for data and ensure end-to-end QoS and QoE?

 to support timing synchronization mechanisms necessary for audio/video delivery?

* to support ultra-high-definition video service?

 for transceivers supporting Smart Grid application in the transmission, distribution and in-premises domains?

 What enhancements to existing and developing Recommendations are required to provide energy savings directly or indirectly?

 What new requirements should be developed to enhance existing Recommendations and allow them to support emerging energy related applications?

– What enhancements:

 to existing Recommendations are required to provide energy savings directly or indirectly in Information and Communication Technologies (ICTs) or in other industries?

 to developing or new Recommendations are required to provide such energy savings?

– What mechanisms for:

 network management should be employed to provision new network-based advanced services to devices connected to the heterogeneous networks?

 application management should be employed to provision advanced applications to devices connected to the heterogeneous networks?

 security should be employed to provide protection of the heterogeneous networks?

 seamless interconnection should be employed between multiple devices for advanced services in heterogeneous networks?

 mechanisms should be employed to support efficient, less cumbersome and low maintenance on heterogeneous networks?

– Study items include, but are not limited to:

 Requirements for advanced service capabilities over heterogeneous networks.

 Modulation, coding, digital signal processing, transport techniques, tools for spectrum management (including dynamic spectrum management), real noise environments over multiple communication media, handshaking procedures, testing procedures, physical layer management procedures, protocols for PLC coexistence, energy saving techniques and transport of higher layer protocols.

 These studies should take account of the different regulatory environments around the world.

 Transceiver to higher layer inter-connection techniques.

– These studies will include any specific requirements:

 To optimise the transport of IP-based services.

 To optimise the transport of Ethernet based services.

 To support the management of heterogeneous networking systems operating over various mediums.

### C.3 Tasks

Tasks include, but are not limited to:

– Maintenance and enhancements of existing Recommendations

 J.190 through J.192,

 G.9951 through G.9954,

 G.9960 through G.9964, G.9972, G.9973, G.9976 through G.9980,

 G.995x and G.990x series,

 G.999x series

– Production of new Recommendations in the G.990x, G.995x, G.996x, G.998x, and G.999x, series.

– Definition of requirements for advanced service delivery over heterogeneous networks.

An up-to-date status of work under this Question is contained in the SG15 work programme (<https://www.itu.int/ITU-T/workprog/wp_search.aspx?sg=15>).

### C.4 Relationships

Recommendations:

– None

Questions:

– QA/15, QB/15, QD/15, QE/15, QG/15

Study Groups:

– ITU-R SG1 and SG5

– ITU-T SG5 on EMC and various copper cable topics

– ITU-T SG9 on television and sound programme transport (in particular, QA/9, QB/9, QD/9, QE/9, QF/9, QG/9)

– ITU-T SG16 on multimedia aspects

– TSAG

Other bodies:

– ATIS Committee STEP

– Broadband Forum

– ETSI ATTM, EE

– HomeGrid Forum

– IEC CISPR I on EMC requirements

– IEC TC57 WG20 on power line communication

– IEC TC69 on power line communication for electric vehicles

– IEC on energy efficiency and smart grid communications related standards

– IEEE 802.1, 802.3, 802.11, 1901, 1905

– ISO/IEC JTC1/SC25 on interconnection of information technology equipment

– MoCA on multimedia over coax

– TIA TR-41 on spectral management considerations

– TTC (Japan)

– TTA (Korea)

– CCSA

– G3-PLC Alliance

– PRIME Alliance

– SAE on energy efficiency and smart grid communications related standards

– Cenelec TC210 WG11

Question D/15

Broadband access over metallic conductors

(Continuation of Question 4/15)

### D.1 Motivation

The continuing customer demand for ever higher bit rate data services, high-speed Internet access and other innovative services, and the on-going needs of network operators to fully exploit their installed base of metallic conductors (including copper pair and coaxial cables), will require the development of new Recommendations and enhancements to existing Recommendations covering all aspects of Transceivers operating over metallic conductors in the access part of the network, extending into the customer premises. These studies will include, but are not limited to, the transport of higher layer protocols, the management and test of the access systems, spectral management aspects and energy saving techniques.

G.fast has raised bit rates up to 2 Gbit/s, and beyond by combining the best aspects of optical, coaxial, and DSL technologies in hybrid systems with total wire length to the customers' transceiver up to 400 m, and by using 106MHz and 212MHz bandwidth profiles. Higher bit rates can be achieved by bonding. Functional and performance improvements are still under study.

MGfast will raise bit rates further to 5 Gbit/s and targets further enhancements to bit rates up to 10 Gbit/s and beyond by combining the best aspects of optical, coaxial, and DSL technologies in hybrid systems with total wire length to the customers' transceiver up to 200 m, and by using higher bandwidth profiles, and/or bonding. MGfast will also facilitate service distribution over the premises by using point-to-multipoint operation from the access node or distribution point to multiple end-user devices in the premises. MGfast will also introduce security and QoS-awareness (e.g., latency differentiation) in the physical layer. Functional and performance improvements are still under study.

The following major Recommendations, in force at the time of approval of this Question, fall under its responsibility: G.991.x series, G.992.x series, G.993.x series, G.994.1, G.996.x series, G.997.x, G.998.x series, G.999.1, G.970x, and G.971x series.

The target audience for this question are the technology suppliers, chipset vendors, equipment vendors, and service providers active in the domain of providing access to a high-speed network from the customer premises. A global audience is targeted to facilitate a unified approach to the broadband access over metallic conductors.

### D.2 Question

– What enhancements are needed to the G.99x and G.970x series of Recommendations:

 in the light of design, network deployment experience, and evolving service requirements?

 to optimise the transport of IP-based services?

 to optimize bit rates achieved by means of vectored groups of metallic pairs?

 to optimize time/frequency duplexing and multi-line operation?

 to increase the reach at high bit rates?

– What new Recommendations are needed:

 for transceivers for customer access over metallic conductors?

 to carry out line testing?

 to enable higher bit rates to be achieved by means of e.g., full duplex transmission, enhanced coding schemes, metallic pair bonding or coordination and/or vectoring over a group of metallic pairs?

 to enable transport of higher layer protocols?

 to optimize the quality-of-experience to the end user?

 to enable point-to-multipoint operation from the access node or distribution point to multiple end-user devices in the premises?

 to enable data slicing, multi-QoS and low latency data transport in the context of IMT-2020/5G?

 to enable cascading of access equipment supporting G.fast or MGfast (G.fastback) ?

 to enable security aspects in point-to-point and point-to-multipoint topologies?

 to enable medium access control across the binder in point-to-point and point-to-multipoint topologies?

 to improve co-existence of DSL and G.fast with other technologies, e.g., G.hn over powerline (joint with QC/15)?

 for reverse power feeding (RPF) of access equipment and sustaining minimum service in the absence of mains electrical power?

 for system (non-transceiver related) aspects of access network and customer premises equipment?

– What enhancements to existing Recommendations are required to provide energy savings directly or indirectly in Information and Communication Technologies (ICTs) or in other industries?

– What enhancements to developing or new Recommendations are required to provide such energy savings?

– Study items include, but are not limited to:

 Modulation and transport techniques, tools for spectrum management (including dynamic spectrum management), handshaking procedures, testing procedures, physical layer management procedures, energy saving techniques.

 Real noise environments and loop characteristics.

 Techniques for optimizing energy usage e.g., to adapt to actual user traffic on a pair, to mitigate power failures, and to support battery operation.

 Techniques for coordination of the transceivers in a group of metallic pairs as to operate within given limitations, e.g., limitations related to aggregate energy usage or aggregate data rate.

 Techniques for signal coordination in a group of metallic pairs to improve performance by use of vectoring (FEXT and NEXT cancellation, beamforming) and PSD control/shaping.

 Techniques for transport of time and synchronization over the copper access network, in collaboration with QL/15.

 Coordination within the digital access section between optical access and copper access to minimize complexity and optimize QoS.

 Techniques for inter-connection of transceivers with other physical layer and higher layer functionality.

 Techniques dealing with security aspects in point-to-point and point-to-multipoint topologies.

 Techniques dealing with medium access control across the binder in point-to-point and point-to-multipoint topologies.

 System (non-transceiver related) aspects of access network and customer premises equipment.

 Considerations of aspects of network function virtualization (NFV) and software defined networks (SDN) control.

– These studies should take account of the different regulatory environments around the world.

– These studies will include any specific requirements:

 to optimise the transport of IP-based services

 to optimise the transport of Ethernet based services

 to optimize for mobile fronthaul/backhaul (e.g., for low latency)

 to support the management of access systems operating over metallic conductors

### D.3 Tasks

Tasks include, but are not limited to:

– Maintenance and enhancements of existing Recommendations and production of new Recommendations in the G.99x (e.g., G.991.x series, G.992.x series, G.993.x series, G.994.1, G.996.x series, G.997.x, G.998.x series and G.999.1), G.970x, and G.971x series, and supporting Technical Papers and Supplements.

An up-to-date status of work under this Question is contained in the SG15 work programme (<https://www.itu.int/ITU-T/workprog/wp_search.aspx?sg=15>).

### D.4 Relationships

Recommendations:

– None.

Questions:

– QA/15, QB/15, QC/15, QL/15

Study Groups:

– ITU-R SG1 and SG5

– ITU-T SG5 on EMC, energy efficiency, and various copper cable topics

– ITU-T SG9 on television and sound programme transport

– ITU-T SG11 on testing and interoperability aspects

– ITU-T SG16 on multimedia aspects

Other bodies:

– IEC CISPR I on EMC requirements

– IEEE 802.1 and 802.3

– ISO/IEC JTC1/SC25 on interconnection of Information Technology equipment

– CENELEC TC210 on EMC requirements

– ETSI TC ATTM, EE and ERM on Reverse Power Feeding, Environmental Engineering and EMC matters.

– ATIS Committee STEP and its subcommittee on Telecom Energy Efficiency (TEE)

– CCSA on xDSL topics

– Broadband Forum on access network use cases, requirements, architecture, and management

– Broadband Forum on (certification) testing of the ITU-T G.99x, G.970x, and G.971x series

Question E/15

Characteristics and test methods of optical fibres and cables, and installation guidance

(Continuation of Question 5/15)

### E.1 Motivation

Optical fibre cables have been specified and deployed in telecommunication networks worldwide, finding wide application in access, intra/inter-office, metropolitan, long-haul, and submarine networks. New optical fibre technologies and new applications continue to drive the need for additional specifications. For example, the IoT, advanced mobile services, edge computing, cloud/distributed data management and so on requires new features and/or functions for optical fibre network. Moreover, increased transmission speeds and bandwidth requirements across the optical network supporting a variety of services requires a new class of optical fibre that can substantially expand the transmission capacity of a traditional single-mode fibre.

One important set of issues to be studied is related to the network infrastructure used to connect the customer. The choice of infrastructure type, cables and outside plant components is strictly dependent on the topology chosen as well as the installation conditions (presence of infrastructures or need to construct new ones). For this purpose, optical or optical/electrical cables and new cable constructions and installation techniques for outside plant construction and operation will be required.

Moreover, cable installation in existing buildings without specific available infrastructure for these new elements will be a challenge, and technical solutions for wiring customer premises with minimum disturbance to the customer need to be identified, such as in particular miniaturized cables and devices, pre-assembled solutions etc.

The responsibility under this Question includes the following areas of standardization:

– Description and testing of basic single- and multi-mode fibre types and associated with optical fibre cables, with parameter tables describing the variations within each of the basic types.

– Description of installation technique of cabled optical fibres in the network and user premises.

– Definitions of attributes and associated test methods for environmental, geometrical, transmission, mechanical and reliability characteristics.

– Descriptions of different possible fibres and/or cables solutions for OTN, access network and submarine network.

– Descriptions of relationships between the different attributes with other attributes and with variations in the environment.

– The following major Recommendations and Supplements, in force at the time of approval of this Question, fall under its responsibility:

 Optical fibres: G.650.1, G.650.2, G.650.3, G.651.1, G.652, G.653, G.654, G.655, G.656, G.657, G Suppl.40, G Suppl.47 and G Suppl.59.

 Optical fibre cables:

o L.100/L.10, L.102/L.26, L.101/L.43, L.106/L.58, L.103/L.59, L.109/L.60, L.104/L.67, L.107/L.78, L.108/L.79, L.105/L.87, L.110 for cable structure and characteristics,

o L.126/L.27 for cable evaluation, and

o L.151/L.34, L.150/L.35, L.152/L.38, L.161/L.46, L.153/L.48, L.154/L.49, L.158/L.56, L.156/L.57, L.157/L.61, L.159/L.77, L.160/L.82, L.155/L.83, L.162, L.163 for guidance and installation technique.

### E.2 Question

Study items to be considered include, but are not limited to:

– What fibre characteristics are needed to:

 Improve performance limits of optical fibres for next generation transmission systems such as beyond 100 Gbit/s per wavelength?

 Support coarse or dense wavelength division multiplexing (CWDM/DWDM) applications in access (including to and in home/building), metropolitan (including intra/inter office), long-haul and submarine networks?

 Support space- and/or mode-division multiplexing (SDM/MDM) applications?

 Open new spectral transmission regions as the additional passband?

NOTE − Some of these aspects are, at present, covered also in QB/15, QF/15 and QH/15 so coordination is necessary.

– What is needed to provide cost-effective optical access (including to and in home/building), mobile front/back-haul, metropolitan (including intra/inter office), long-haul and submarine networks? How can cohesive Recommendations on the optical cabling in these application eras be formulated? These could be divided by the main types of topology and could include aspects such as:

 Optical fibres.

o Impact of cable construction and cable installation on fibre characteristics.

o Impact of hardware, such as splicing trays, customer outlets, enclosures, connectors etc, on fibre and cable characteristics.

o Handleability and mechanical reliability of optical fibres.

o Testing and maintenance in field.

NOTE − Some of these aspects are, at present, covered also in QG/15 so coordination is necessary.

– Study items to be considered include, but are not limited to:

 Geometrical, mechanical, and optical properties of the glass, for single- and few-mode fibre applications.

 Mechanical and optical reliability of fibres and cables (lifetime and failure rate) under different installation and environmental conditions.

 Fibre requirements for high density cable structures.

o Modelling, and measurements of polarization mode dispersion (PMD) under advanced cable structure and/or particular environment.

o Impact of network deployment conditions on optical characteristics, e.g., multi path interference (MPI), PMD, cut off wavelength, distributed Raman amplification and so on.

 Possible additional fibre types, and additional parameter tables, within the existing Recommendations.

 Other types of single-mode silica fibres optimized for higher bitrates (e.g., beyond 100 Gbit/s) DWDM systems.

 Other types of single-mode silica fibres for opening new spectral transmission regions.

 Other types of single-mode silica fibres for reducing non-linearity effects.

 Fibre damage from high power and small bend radii.

 Fibre and cable requirements for parallel transmissions on either CWDM or SDM on single- or few-mode fibres.

 Fibre and cable requirements for SDM transmission beyond 100 Tbit/s per fibre.

 Fibre and cable requirements for supporting the advanced access and mobile network.

 Define a "degree of compatibility" between the different types of fibres installed in the same link in order to estimate the transmission characteristics.

 Fibre parameters for the monitoring wavelength region.

 Aspects and/or guidance of measurements in the field related to point-to-point and point-to-multipoint topology.

 What are the optimal methods to enter the user premises and for installing optical fibre cables and other network elements in common parts of the buildings?

 What are the desirable optical fibre cable construction types for wireless, indoor and outdoor cabling application?

 What are the desirable hybrid/composite cable construction types?

 What are the suitable techniques to connect the OTN, access network, and customer premises inside a building?

 What are the suitable techniques to construct the fibre network inside an apartment?

 What are the suitable technologies to connect "smart city" physical infrastructure?

 What are the suitable technologies for smart manufacturing?

### E.3 Tasks

Tasks include, but are not limited to:

– Maintenance and enhancements of G.65x-series including modifying parameters in Recommendations G.651.1, G.652, G.653, G.654, G.655, G.656, and G.657.

– Update the text of G Suppl.40, G Suppl.47 and G Suppl.59, as required.

– Develop new Recommendations or parameter tables within existing Recommendations for possible additional fibre and cable types.

– Develop definitions of new parameters, and corresponding factory and field test methods, RTMs and ATMs, for G.650.1, G.650.2, and G.650.3.

– Maintain and enhance L.100 series including modifying parameters in existing Recommendations L.100-L.199.

– Develop guidelines for users of optical fibres and cables.

– Develop cohesive Recommendations on the cabling.

– Optical fibre and cable aspects related to installation of OTN, access and wireless networks.

– Installation of cables inside home/building and intra/inter office.

– Solutions for connection between external and internal networks.

– Characteristics and test methods for vertical cabling in buildings.

– Impact of optical fibre cable installation on the city environment.

An up-to-date status of work under this Question is contained in the SG15 work programme (<https://www.itu.int/ITU-T/workprog/wp_search.aspx?sg=15>).

### E.4 Relationships

Recommendations:

– G.67x-, G.69x-, G.95x-, G.97x-, G.98x-, L.200-series, L.300-series, and L.400-series Recommendations

Questions:

– QA/15, QB/15, QF/15, QG/15, QH/15

Study Groups:

– None

Other bodies:

– ISO/IEC JTC1/SC25 on multimedia cabling for customer premises

– IEC SC86A on fibres and cables

– IEC SC86B on connectors and components

– IEC SC86C on system testing and active devices

– IEC SC46C JWG8 on hybrid cables

– CENELEC TC86A on fibres and cables

– CENELEC TC86BXA on connectors and components

– IEEE 802.3

Question F/15

Characteristics of optical components, subsystems and systems for optical transport networks

(Continuation of Question 6/15)

### F.1 Motivation

Optical fibre networks are deployed in telecommunication systems worldwide. Structural reforms leading to increased privatisation of telecommunications networks create an operating environment requiring optical networking and interconnection among different carriers.

Developments are being fuelled by the need for improved network efficiency, customer demand for ever higher bit rate data services, high-speed Internet access, and other innovative services.

This leads to a push for higher bit-rate (Terabit/s) optical transport systems in the intra-office, inter-office, metro and long-distance networks of the various network operators.

The Question defines specifications needed for physical layer interfaces of point-to-point and WDM systems, to enable the evolution of optical networks to support the ubiquitous availability of next-generation high-bandwidth services. To the greatest extent possible, these specifications should enable transverse compatibility (black-box and/or black-link) in a multi-vendor, multi-network-operator environment.

Furthermore, the increasing complexity of optical networks has brought about an increasing diversity of active, passive and hybrid or dynamic/adaptive optical components and subsystems with functions differing with the application. This Question also addresses the high-level need for specifications expressed by the system Recommendations and network operators. It serves as an interface to the component level standards generated outside of ITU-T in organizations such as IEC.

The following major Recommendations, in force at the time of approval of this Question, fall under its responsibility: G.640, G.661, G.662, G.663, G.664, G.665, G.666, G.667, G.671, G.672, G.680, G.691, G.692, G.693, G.694.1, G.694.2, G.695, G.696.1, G.697, G.698.1, G.698.2, G.698.3, G.698.4, G.955, G.957, G.959.1 and G.911.

### F.2 Question

– What system aspects and physical layer characteristics are necessary to enable longitudinally compatible and transversely compatible optical systems in intra-office, inter-office, metro and long-distance networks?

– What components aspects and desirable characteristics need to be specified to support intra-office, inter-office, metro and long-distance networks, and additionally, local access networks and submarine networks?

– What enhancements to existing draft or published Recommendations and what new Recommendations are necessary to specify interfaces for optical transport systems, employing both direct detect and coherent technologies, with bit rates at 25 Gbit/s and above, and, if necessary, taking account of the flexible DWDM grid?

– What systems and physical layer considerations are necessary for optical transport systems optimized for new applications for example metro applications, including mobile fronthaul and backhaul?

– What enhancements should be made to existing draft or published Recommendations to reflect technological developments, further reduce the cost and power consumption of optical fibre communication systems?

Study items to be considered include, but are not limited to:

– General considerations for optical systems used to transport OTN, Ethernet, CPRI and other protocols using several types of single-mode fibre. Statistical and semi-statistical power budget approaches:

 Specifications to enable transverse and longitudinal compatibility in single-channel and multichannel optical systems.

 System models, reference configurations and reference points to support optical interface specification methodologies.

 Specifications of interfaces inside a DWDM link, taking the flexible grid into account.

 Evaluation of the quality of an optical channel end-to end enabling routing decisions in all optical networks (e.g., transmitter's quality metric, such as error vector magnitude, accumulated effects of degradations, transients, etc.).

 Physical layer architectures including new technologies to increase optical transmission systems capacity.

 Linear and nonlinear propagation effects.

 Performance monitoring.

 Application of forward error correction (FEC) techniques to terrestrial optical transmission systems (e.g., to enhance system margin or to relax optical parameter specifications).

 Enhanced statistical design approaches.

 Availability/reliability aspects of optical systems.

– Further study items:

 Active devices and sub-systems such as optical amplifiers (OAs), including parameter definitions and measurement, classification of devices and sub-systems, optical nonlinearities, polarization, dispersion, noise and transients.

 Passive components such as splices and connectors, attenuators and terminators, M-by-N branching components (such as splitters and combiners), wavelength optical multiplexers and demultiplexers, optical filters, optical isolators and circulators and dispersion compensators.

 Worst-case transmission parameter values (for all environments and to end-of-life) for passive components in digital applications.

 Components and subsystems for use in bi-directional transmission systems on a single fibre.

 Specification of fixed optical add/drop multiplexers (OADMs) and re-configurable optical add/drop multiplexers (ROADMs) and optical cross-connects (OXCs).

 Safety aspects of considered components, including aspects of operation at high optical power levels.

### F.3 Tasks

Tasks include, but are not limited to:

– Enhance Recommendations G.640, G.661, G.662, G.663, G.664, G.665, G.666, G.667, G.671, G.672, G.680, G.691, G.692, G.693, G.694.1, G.694.2, G.695, G.696.1, G.697, G.698.1, G.698.2, G.698.3, G.698.4, G.955, G.957 and G.959.1.

– Develop new Recommendations, Supplements and/or combine existing Recommendations from progress on the above study points.

– Enhance the text of G Suppl.39.

An up-to-date status of work under this Question is contained in the SG15 work programme (<https://www.itu.int/ITU-T/workprog/wp_search.aspx?sg=15>).

### F.4 Relationships

Recommendations:

– G.6xx and G.9xx Series

Questions:

– QB/15, QE/15, QG/15, QH/15, QI/15, QJ/15, QK/15, QL/15, QM/15

Study Groups:

– ITU-T SG5

– ITU-T SG13

– ITU-T SG12 network performance objectives

Other bodies:

– IEC SC86B on optical passive components

– IEC SC86C on active components and dynamic components including all types of optical amplifiers, on system measurement test methods and on optical amplifier test methods

– IEC TC76 on laser safety and aspects of safe laser operation

– OIF on optical systems interfaces

– IEEE 802.3 on optical systems interfaces

– IETF CCAMP working group

Question G/15

Connectivity, operation and maintenance of optical physical infrastructures

(Continuation of Question 16/15)

### G.1 Motivation

The rapid development of telecommunications networks around the world is based on the installation of optical fibres cables both in long-distance and access networks. Especially fifth-generation wireless networks (IMT-2020/5G) are possible only if supported by an optical fibre backbone network. Today the development stages of the networks may be different from country to country, but they have in common the need of high reliability in order to guarantee all the broadband services currently used, such as data and video communications. Moreover, the different geographical conditions must be taken into account in the network design and implementation.

The Question defines specifications needed for physical infrastructures, to enable the evolution of optical networks to support the ubiquitous availability of next-generation high-bandwidth services. It represents a natural interface to other organizations, such as IEC, that work on the same topics.

Passive optical network (PON) topology is used in many countries for FTTx applications and suitable configurations must be considered, taking into account network installation, maintenance, operation and administration, as well as the evolution towards WDM PON. Moreover, it is important to consider appropriate optical access network planning for urban areas with concentrated optical fibre demand, as well as for rural areas, which disperse the optical fibre demand across a wide region.

The progress in the miniaturization of optical cables will lead to studies on its impact on existing networks and on accessories such as splice closures, cabinets, terminal boxes, novel high-count small footprint optical connectors, etc.

Emerging topics related to the Internet of Things (IoT), IMT-2020/5G and "Smart Cities" require the analysis of their impact on existing networks and studies on new potential needs related to deployment in indoor and outside plant environments.

Large/hyper scale data centres are built to support data services and ICT technologies such as cloud computing, big data and artificial intelligence. Study on infrastructures for long-haul and city range Data Centre interconnecting are required.

Finally, telecommunication infrastructures including optical fibre cables and their supporting infrastructures such as poles, holes, tunnels and so on, continue to deteriorate from aging. In order to guarantee the continuity of the service, effective and safe management of infrastructures is essential. It is also important to improve network resilience and recovery against disasters if we are to realize sustainable telecommunication services.

With the increase of number of customers connected with FTTx techniques it becomes mandatory to develop methods of fibre testing and fibre identification in order to ease the connection of new customers, as well as to identify faults in the field without service interruption.

Regulatory scenarios should be also taken into consideration for the design of fibre access networks, for IMT-2020/5G technology deployment, smart city physical infrastructures, factories, vertical industry applications and other new scenarios.

The following major Recommendations, in force at the time of approval of this Question, fall under its responsibility: L.200/L.51, L.201/L.13, L.202/L.50, L.203/L.44, L.204/L.70, L.205/L.11, L.206, L.207, L.208, L.250/L.90, L.251/L.72, L.252/L.86, L.253/L.47, L.254/L.62, L.256/L.45, L.257/L.39, L.258/L.63, L.259/L.73, L.260/L.84, L.261/L.89, L.262/L.94, L.300/L.25, L.301/L.41, L.302/L.40, L.310, L.311/L.93, L.312/L.68, L.313/L.66, L.314, L.315, L.340/L.74, L.341/L.88, L.360/L.80, L.361/L.64, L.362/L.69, L.390/L.92, L.391/L.81, L.392, L.400/L.12, L.401/L.31, L.402/L.36, L.403/L.37, and L.404.

### G.2 Question

Study items to be considered include, but are not limited to:

– What is the impact of different geographical conditions on optical network infrastructures?

– What are the appropriate optical access network topologies for urban areas and rural areas taking into consideration the optical fibre demand and the size of the area?

– What are the key considerations for indoor and outdoor network design taking into account planning and growth, including fibre needs for IMT-2020/5G deployment?

– What are the relevant characteristics of optical access networks for supporting the evolution of PON technologies?

– What are the optimal methods for installing network elements in common parts of the buildings?

– What are the features needed for building distribution point (BDP)?

– What are the key accessories and their features for the cabling in the building?

– What are the mechanical and environmental characteristics of the optical infrastructure, including:

· Optical distribution frames.

· Outdoor closures and cabinets.

· Indoor and outdoor distribution terminals.

· Optical fibre connectivity, including splices, optical and/or optical/electrical hybrid connectors, field mountable connectors, splitters and other passive components.

· Customer terminals and pre-terminated drop cables.

· Indoor cabling solutions.

– What methods can be envisaged for storage, protection and thermal management of active electronics in outside plant locations taking into account energy efficiency requirements?

– Which technical issues should be taken into account when splicing different kinds of single mode fibres?

– What are the optimal strategies for constructing new infrastructure and expansion of existing infrastructure, taking into consideration integrity of installation, maintenance and growth issues?

– What are the key issues when the existing infrastructures of other service providers and utilities (for example, public lighting and sewers) are shared to accommodate a new fibre cable in order to minimize civil works?

– What are the suitable techniques to investigate and/or map the existing infrastructures to avoid excavation and/or damage to the facilities?

– What is the impact of the fibre/cable miniaturization progress on the existing networks?

– What are the suitable techniques for urban areas and rural areas network design, taking into account the optical fibre demand and the size and future expansion of an area?

– What are the regulatory issues to be considered for fibre deployment?

– What is the impact of IoT on the infrastructure needs for "Smart Cities" and existing urban networks?

– What are the suitable techniques to connect "smart city" physical infrastructures such as smart light poles, or further on, smart light poles carrying IMT-2020/5G antennas?

– What are the suitable infrastructures for "inter-office" applications?

– What are the functional requirements for optical fibre line testing without any deterioration in optical communication signals in access networks?

– What procedures and methods can be employed for optical fibre line testing without interrupting optical services and/or during maintenance work on optical access networks?

– What test functions are needed to realize a highly reliable optical network?

– What kinds of optical devices for testing are needed to maintain an optical cable network effectively?

– What are the functional requirements for an optical fibre line testing system for access and trunk networks without any deterioration in optical communication signals?

– What kinds of parameters and/or information are needed for network operation systems for PON and optical fibre line testing systems in order to find a fault location in an optical fibre cable?

– What kinds of reliable technologies can be used to preserve and protect outside plant facilities?

– Study new solutions for monitoring critical network elements using sensor networks.

– Do the existing ITU-T Recommendations and handbooks provide an up-to-date coverage of the techniques needed to maintain the optical fibre cable infrastructure?

– Assess optical infrastructure security issues in the context of operation and maintenance.

– Study appropriate ways to improve network resilience and recovery against disasters.

– What are the functional requirements and/or suitable techniques for inspection, maintenance and repair of supporting infrastructures such as telephone poles, tunnels, ducts and manholes/handholes?

### G.3 Tasks

Tasks include, but are not limited to, develop Recommendations and/or technical documents on:

– Aspects related to planning, installation, activation and acceptance of optical networks.

– Technical aspects concerning regulations related to optical access networks.

– Technical aspects regarding the sharing of infrastructures of other operators and utilities.

– Advanced solutions for investigating the existing buried infrastructures.

– Characteristics and installation methods for BDP (building distribution point).

– Characteristics and installation methods for cabling accessories needed inside home/buildings.

– Characteristics and installation methods of cabinets for FTTx.

– Customer end distribution boxes and terminals, taking also into account of multi operator access.

– Outdoor optical cross-connect cabinets.

– Transmission parameter values for components with respect to statistical values, such as mean and standard deviation, short-term variations with environment, long-term degradation with aging, use of these in system calculations.

– Components for construction, installation and protection of cables and other elements of outside plant (optical fibre splices, optical fibre attenuators, single mode fibre optic connectors, optical branching components as well as field mountable optical connectors).

– New families of high count, small footprint optical connectors, optical/electrical hybrid connectors.

– Impact of the new fibre types with reduced coating thickness on the outside plant components (i.e., splice closures).

– Pre-terminated fibre drop cables & hardened connectors.

– Splicing of different kinds of single-mode fibres and splice measurement method solutions in outside plant and indoor network cabling and construction.

– New network solutions to support the needs of "Smart Cities", for example, technologies for fibre to the smart city physical infrastructures such as smart light poles.

– Optical physical infrastructures for backhaul/fronthaul networks for emerging applications such as data centre interconnections, advanced mobile services, smart manufacturing, etc.

– Revising existing Recommendations as needed.

An up-to-date status of work under this Question is contained in the SG15 work programme (<https://www.itu.int/ITU-T/workprog/wp_search.aspx?sg=15>).

### G.4 Relationships

Recommendations:

– ITU-T L-series and G.65x series

Questions:

– QA/15, QB/15, QE/15, and QF/15

Study Groups:

– ITU-T Study Group 5

– ITU-T Study Group 20

– ITU-R SGs

– ITU-D

Other bodies:

– IEC SC86A

– IEC SC86B

– IEC SC86C

– IEC TC86/WG4

– FTTH Council

– Broadband Forum

– CENELEC TC 86 BXA

Question H/15

Characteristics of optical fibre submarine cable systems

(Continuation of Question 8/15)

### H.1 Motivation

The transmission capacity within each country and/or between countries has been rapidly growing due to the evolution of Internet services on a global scale. Optical fibre submarine cable systems at the heart of global networks are affected by such an increase in transmission capacity. In such a seamless global network, connectivity also becomes more important than ever for telecommunication carriers and providers. Multi-vendor operability has also become important to realize cost-effective system construction and upgrade. Optical fibre submarine cable systems include two types of system, repeaterless systems and repeatered systems. Repeaterless submarine cable systems are used for network extensions (e.g., for linking to islands just offshore) because of lower cost for installation and OAM. Repeatered systems are used for long haul transmission (e.g., for linking different continents through the oceans) by introducing line optical amplifiers.

This Question has responsibility for the following areas of standardization related to:

– Specifications of terminal equipment and optical fibre submarine cables in optical fibre repeatered submarine cable systems with various optical amplifiers such as erbium-doped fibre amplifiers (EDFAs) and Raman amplifiers.

– Specifications of terminal equipment and optical fibre submarine cables in optical fibre repeaterless submarine cable systems, including systems with power amplifiers, pre-amplifiers and/or remotely pumped optical amplifiers.

– Specifications of optical interface and interface parameters to support longitudinal/transverse compatibility of the repeatered/repeaterless submarine system.

– Specifications of test methods concerning the terminal equipment, optical fibre submarine cables (including marinized terrestrial cables) and other equipment relevant to the submarine cable systems.

– Specifications of forward error correction (FEC) for optical fibre submarine cable systems.

– Specifications of monitoring systems for optical fibre submarine cable systems.

The following major Recommendations, in force at the time of approval of this Question, fall under its responsibility: G.971, G.972, G.973, G.973.1, G.973.2, G.974, G.975, G.975.1, G.976, G.977, G.978, G.979, L.430, L.431, L.432, L.433 and L.434. The following Supplement also falls under its responsibility: G Suppl.41.

### H.2 Question

– Study items to be considered include, but are not limited to:

 How should Recommendations G.971, G.972, G.973, G.973.1, G.973.2, G.975.1, G.976, G.977, G.978 and G.979 be amended from a viewpoint of techno-economics?

 What new transmission techniques should be recommended to increase transmission capabilities of optical fibre submarine cable systems?

 What new components and subsystems (fibre, component, etc.) should be utilized to improve system capacity and reliability?

 What new test methods are necessary for the submarine cable systems?

 What mechanical protection and system protection mechanisms should be recommended for high-capacity submarine cable systems to improve systems reliability/availability?

 What terrestrial and submarine integration should be recommended for the effective network systems?

 What kind of optical submarine system should be standardized to support longitudinal/transversal compatibility?

 What kind of optical fibre and/or cable is needed as a transmission line for optical fibre submarine cable systems to support the increasing transmission capacity and distance?

 What kind of optical submarine system should be recommended for cable with increased fibre count while satisfying the power supply limit through the cable for the repeaters.

 What kind of optical fibre and/or cable is needed for optical fibre submarine cable systems to improve the space multiplicity within the cable to support the increasing transmission capacity or cost-effective cable system deployment?

 What enhancement can be made to existing published Recommendations to further reduce power consumption of optical fibre submarine cable systems?

 What kind of technologies should be recommended to support the effective network maintenance and operation of submarine cable systems?

 What new Recommendations are needed to support interoperability of submarine aspects of software defined networks in terms of standard system parameters and acceptance criteria?

 What new Recommendation are needed to support the use of submarine cables and systems for ocean and climate monitoring and disaster warning?

 What new Recommendations are necessary?

– Study items to be considered include, but are not limited to:

 Transmission characteristics of optical fibre submarine cable systems.

 Interface characteristics of optical fibre submarine cable systems.

 Mechanical characteristics of the submarine portion of optical fibre submarine cable systems.

 Test methods.

 Evolution of submarine systems to higher bit rates, including the effects of chromatic dispersion, polarization mode dispersion, and optical fibre nonlinearities.

 Adoption of wavelength-division multiplexing/demultiplexing techniques.

 Introduction of other types of fibre amplifiers, Raman amplifiers, distributed Raman amplifiers or semiconductor optical amplifiers operating at different wavelengths.

 Flexibility for partial network upgrades.

 Repeaters with optical amplifiers.

 Use of branching devices in submarine networks.

 New specifications and test methods for submarine systems in accordance with the objective of longitudinal / transversal compatibility.

 Submarine systems with higher bit rates of beyond 100 Gbit/s, including the effects of chromatic dispersion, polarization mode dispersion, and optical fibre nonlinearities.

 New dispersion accommodation techniques including dispersion management transmission lines, unmanaged dispersion transmission lines and/or hybrid transmission lines for high-speed optical fibre submarine cable systems.

 Advanced FECs for high bit rate DWDM submarine systems.

 New types of amplifiers operating at different wavelength bands.

 Availability and reliability.

 Engineering, Operations and Maintenance.

 Interface compatibility of submarine and terrestrial systems.

 Terrestrial and submarine integrated networks.

 Mechanical and systems level protection mechanisms.

 System and cable repair procedures.

 Use of submarine systems for marine supervision.

 Terminal independent submarine cable commissioning parameters.

### H.3 Tasks

Tasks include, but are not limited to:

– Revisions to Recommendations G. 971, G. 972, G.973, G.973.1, G.973.2, G. 975.1, G. 976, G.977, G.978, G.979, L.430, L.431, L.432, L.433 and L.434, as required

– Update the text of G Suppl.41, as required

– Update the data on cable ships and submersible equipment (as required)

– Develop additional Recommendations from progress on the above study items

An up-to-date status of work under this Question is contained in the SG15 work programme (<https://www.itu.int/ITU-T/workprog/wp_search.aspx?sg=15>).

### H.4 Relationships

Recommendations:

– G.65x series, G.66x series, G.69x series and G.95x series

Questions:

– QE/15, QF/15, QJ/15

Study Groups:

– None

Other bodies:

– ITU/WMO/UNESCO IOC JTF

– IEC SC86A

– IEC SC86C

Question I/15

Interfaces, interworking, OAM, protection and equipment specifications for packet-based transport networks

(Continuation of Question 10/15)

### I.1 Motivation

The continued explosive growth of the Internet, the standardisation of Ethernet rates beyond 400G, the standardisation of additional Ethernet rates below 100 Gbit/s, accommodation of other packet‑based traffic, and the range of logical interfaces provided by FlexE that may or may not correspond to any existing Ethernet PHY rate, are key forces for packet transport network evolution. In order to ensure that packet-based transport networks maintain carrier-class performance, it is essential that network protection techniques continue to evolve, and relevant Recommendations are updated. Packet-based transport networks must also continue to provide the operation, administration and maintenance (OAM) capabilities that are essential to enabling carrier-class performance. Such networks are expected to support an increasingly wide variety of highly reliable and high-quality services, which also require effective network control and management. Such factors will drive the need for the revision of existing Recommendations as well as the development of new Recommendations for packet-based transport interfaces and equipment.

Under the responsibility of this Question, Recommendations will be developed to provide the specifications for packet-based equipment, OAM mechanisms, protection switching mechanisms, network interfaces, services, and domain interworking in packet transport networks. This activity will be conducted in close co-operation with related ITU-T Study Groups, IEEE, MEF, IETF and other SDOs, as necessary.

Existing Recommendations may need to be enhanced to take into account transport network control and management paradigms, such as Automatically Switched Optical Network (ASON) and SDN control of transport networks.

The area of responsibility under this Question includes the specification of:

– Equipment functions related to packet layer networks, including equipment functions related to access networks.

– Equipment functions for transport of data/packet traffic (e.g., Ethernet, IP, ATM, MPLS, MPLS-TP, Data Centre traffic).

– Power saving mechanisms for packet transport network equipment in the wider context of ICTs (Information and Communications Technologies).

– Packet transport OAM structures and methods.

– Specification of all protection switching processes related to packet transport networks.

– Network interface characteristics for the packet transport network.

– Packet data transport supervision.

– A framework for defining network-oriented characteristics of Ethernet services in alignment with industry requirements.

Recommendations related to packet transport technologies used in the access environment and not covered by other Questions of ITU-T SG15, are also covered by this Question.

The following major Recommendations in force at the time of approval of this Question, fall under its responsibility: G.8001/Y.1354, G.8011/Y.1307, G.8012/Y.1308, G.8012.1/‌Y.1308.1, G.8013/‌Y.1731, G.8021/Y.1341, G.8021.1/Y.1341.1, G.8031/Y.1342, G.8032/Y.1344, G.8101/Y.1355, G.8112/‌Y.1371, G.8113.1/Y.1372.1, G.8113.2/Y.1372.2, G.8121/Y.1381, G.8121.1/G.1381.1, G.8121.2/‌G.1381.2, G.8131/Y.1382, G.8132/Y.1383, G.8133, I.610, I.630, Y.1710, Y.1711, Y.1712, Y.1713, Y.1714, Y.1720 and Y.1730.

### I.2 Question

– Study items to be considered include, but are not limited to:

 What packet transport interfaces and equipment functions must be specified to enable compatible packet transport equipment in metro and long-distance networks, including considerations regarding protection mechanisms and evolution of the optical transport network?

 What characteristics should be recommended for equipment for the transport of packet-based traffic such as Ethernet, MPLS-TP, MPLS, Data Centre traffic?

– Study items to be considered include, but are not limited to:

 Specifications of Equipment functions necessary for the transport of packet-based traffic such as Ethernet services, MPLS-TP, and Data Centre traffic.

 Enhancements required to the packet transport equipment and network protection Recommendations in order to meet the needs, including support for disaster recovery of:

o Access networks.

o Data Centre networks.

o Cloud computing.

o Mobile networks including IMT-2020/5G.

o CBR clients.

o Future networks.

 Network protection Recommendations to provide enhanced survivability capabilities.

 Clarification and resolution of technical issues in published and draft Recommendations.

 What equipment functions should be specified to allow power savings within packet transport networks?

 Clarification of requirements and mechanisms of OAM for packet transport networks. This includes study on end-to-end OAM support for packet-based ubiquitous networks. The OAM functions provide the capability for defect detection, defect localization, topology management and performance management. OAM functions should be able to be applied to point-to-point, point-to-multipoint and multipoint-to-multipoint networks.

 Clarification of generic OAM principles for connection-oriented packet-switched and connectionless packet switched networks.

 Clarification of generic OAM principles under interworking of different network technologies. This includes network interworking and service interworking scenarios.

 Continuation of work on the transport Ethernet equipment Recommendation G.8021/Y.1341 in cooperation with IEEE and MEF.

 Continuation of work on the transport Ethernet OAM Recommendation G.8013/Y.1731 in cooperation with IEEE and MEF.

 Continuation of work on the MPLS-TP OAM Recommendations in cooperation with IETF.

 Continuation of work on the Ethernet services and Network Interfaces Recommendations in cooperation with MEF.

### I.3 Tasks

Tasks include, but are not limited to:

– Enhancements to, and refinements of, existing Recommendations on characteristics of packet transport network equipment functional blocks (G.8021/‌Y.1341, G.8021.1/‌Y.1341.1, G.8121/‌Y.1381, G.8121.1/G.1381.1, G.8121.2/G.1381.2).

– Enhancements to, and refinements of, existing Recommendations on OAM mechanisms for packet transport networks (G.8013/Y.1731, G.8113.1/Y.1371.1, G.8113.2/Y.1371.2).

– Preparation of Recommendations on OAM mechanisms including defect localization functions and performance measurement functions.

– Enhancement and improvement of linear and ring protection switching Recommendations for packet-based technologies.

– Further development of Ethernet service characteristics (G.8011/Y.1307).

– Further development of packet transport network interface specifications (G.8012/Y.1308, G.8112/Y.1371).

An up-to-date status of work under this Question is contained in the SG15 work programme (<https://www.itu.int/ITU-T/workprog/wp_search.aspx?sg=15>).

### I.4 Relationships

Recommendations:

– G.800, G.805, G.806, G.808, G.808.1, G.808.2, G.808.3, G.809, G.872, G.8010, G.8023, G.8051, G.8052, G.8052.1, G.8052.2, G.8110.1, G.8151, G.8152, G.8152.1, G.8152.2, G.7710, G.7711

Questions:

– QD/15, QJ/15, QK/15, QL/15, QM/15

Study Groups:

– ITU-T SG2 responsible for operational aspects

– ITU-T SG12 responsible for Ethernet and MPLS performance, QoS and QoE

– ITU-T SG13 responsible for future networks, with focus on IMT-2020, cloud computing and trusted network infrastructure

Other bodies:

– MEF on Ethernet services and network interfaces issues

– IEEE 802.1, 802.3 on Ethernet

– IETF working groups on OAM, MPLS transport, PW transport

– Broadband Forum on Ethernet and MPLS

– OIF on Flex Ethernet

Question J/15

Signal structures, interfaces, equipment functions, protection and interworking for optical transport networks

(Continuation of Question 11/15)

### J.1 Motivation

The explosive growth of the Internet and other packet-based traffic including data centre connectivity, wireless networks such as IMT-2020/5G and new high-definition video formats are the key drivers for the development of new transport network equipment and network node interface (NNI) related standards for optical networks. This rapidly growing traffic will be supported by the anticipated standardization of new Ethernet interfaces for rates beyond 400 Gbit/s, including the range of logical interfaces provided by FlexE. In addition, the development of optical transport network (OTN) specifications provides the ability to dramatically increase the bandwidth, and thus traffic carrying capacity, of optical networks. Furthermore, ODUflex has enabled efficient data traffic transport over OTN, and flexible OTN interfaces with FlexO have enabled more efficient use of physical interfaces for higher bit rate clients. Circuit-based transport networks must also continue to provide the operation, administration and maintenance (OAM) capabilities that are essential to enabling carrier-class performance. Moreover, information security is a growing concern, and transport networks must be enhanced in order to support this application need. In order to ensure that circuit-based transport networks based on these new technologies maintain carrier-class performance, it is essential that network protection techniques continue to evolve and relevant Recommendations are updated. These and other enhanced capabilities, as well as the need to support any new management capabilities, have resulted in a need for the revision of existing equipment Recommendations as well as the development of new Recommendations for transport equipment. Increased utilization of OTN technology for a wider set of applications has driven the demand for support of new client signals, including high speed Ethernet, storage area network (SAN) interfaces (such as fibre channel flows), as well as finer granularity channelization. Further work is expected to enhance the OTN Recommendations to carry future Ethernet and other data client interfaces. Further work to define new transport technology related to IMT-2020/5G is also expected.

The area of responsibility under this Question includes:

– Specification of transport signal structures, (including any forward error correction codes used with those signal structures), such as OTN (including SyncO and FlexO) and metro transport network (MTN).

– Specification of adaptations of client signals into server transport layers.

– Specification of interface characteristics for the transport and supervision of client signals.

– Specification of all protection switching processes related to OTN and MTN networks.

– Specification of all equipment functions, supervision related to the OTN and MTN networks including equipment functions related to access networks

– Specification of fundamental transmission parameters and determination of the effect of various transmission impairments. This includes transmission error and availability performance objectives and allocation methods for efficient design of digital networks and associated transmission equipment.

– Specification of survivability capabilities and development of a strategy for multi-domain and/or multi-layer survivability interactions (including those where different transport technologies are used at different layers).

– Investigation of IMT-2020/5G mobile front haul and backhaul transport network requirements.

– Investigation of power saving mechanisms for transport network equipment in the wider context of ICTs (Information and Communications Technologies).

– Investigation of how transport networks can be enhanced to support security

The following major Recommendations, in force at the time of approval of this Question, fall under its responsibility: G.703, G.704, G.707/Y.1322, G.709/Y.1331, G.709.1/Y.1331.1, G.709.2/‌Y.1331.2, G.709.3/Y.1331.3, G.709.4, G.7041/Y.1303, G.7042/Y.1305, G.7043/Y.1343, G.7044/‌Y.1347, G.8023, G.8040/Y.1340, X.85/Y.1321, X.86/Y.1323, G.705, G.783, G.798, G.798.1, G.806, G.808, G.808.1, G.808.2, G.808.3, G.841, G.842, G.873.1, G.873.2, G.873.3, G.821, G.826, G.827, G.828, G.829, G.8201, and G.8312.

### J.2 Question

– Study items to be considered include, but are not limited to:

 What enhancements should be made to the existing NNI related Recommendations or what new Recommendations should be developed:

o for the networks employing Optical Transport Network (OTN) to accommodate new Ethernet clients?

o to enable OTN interfaces at rates beyond 400 Gbit/s such that they can be carried over single or multiple wavelength interfaces?

o to enable OTN interfaces with optical lane rates of 100 Gbit/s in 100G, 200G, 400G and (future) B400G FlexO interfaces?

o for OTN and MTN support of the radio fronthaul / backhaul networks in line with IMT2020/5G mobile, network virtualization, high-definition video (4K, etc.)?

o to reflect additional transport network applications and interworking scenarios?

o for networks optimized for transport of packet data?

o for WAN transport of Optical Interworking Forum (OIF) flexible Ethernet (FlexE) over OTN for data centre connectivity and other applications?

 Clarification of generic OAM principles for circuit-switched networks.

 Clarification of generic OAM principles under interworking of different network technologies. This includes network interworking and service interworking scenarios.

 What additional protection mechanisms for transport equipment should be recommended to provide enhanced survivability capabilities and a cohesive strategy for multi-domain and/or multi-layer survivability interactions?

o Network protection Recommendations to provide enhanced survivability capabilities and a cohesive strategy for multi-layer survivability interactions.

o Enhancements required to the network protection Recommendations in order to meet the needs, including support of disaster recovery, of:

 - Access networks
- Data Centre networks
- Cloud computing
- Mobile networks including IMT-2020/5G
- Future networks

 What transport equipment functions must be specified to enable compatible transport equipment in inter-office and long-distance networks, including evolution to the optical transport network?

 What transmission error performance parameters and objectives need to be recommended?

 What enhancements should be made to the existing equipment function Recommendations or what new Recommendations should be developed in order to meet the needs, including synchronization of:

o Data Centre networks

o Cloud computing

o IMT-2020/5G

o Future networks

 What should be specified for the definition of new transport networks, while ensuring transverse compatibility and interworking with previously specified technologies?

 What enhancements to existing Recommendations are required to provide energy savings directly or indirectly in Information and Communication Technologies (ICTs) or in other industries? What enhancements to developing or new Recommendations are required to provide such energy savings?

 What new Recommendations or enhancements to existing Recommendations are required to provide secure transport networks?

### J.3 Tasks

Tasks include, but are not limited to:

– Development of relevant Recommendations related to IMT-2020/5G transport (including G.8312, G.8321, and G.8331)

– Enhancement to relevant Recommendations for transport networks (including G.709, G.709.x, G.798, and G.8023) to increase network transport capacity and accommodate greater than 400 Gbit/s Ethernet services.

– Enhancement to Recommendations for transport networks to support access applications, including IMT-2020/5G mobile radio fronthaul / backhaul applications.

– Enhancements to OTN protection mechanisms.

– Clarification of relationships between survivability function of circuit-based transport and survivability function in other layers or other transport technologies (e.g., SDH, OTN, etc.).

– Clarification of interworking between different protection schemes within a layer network (e.g., interworking linear and ring protection).

– Maintain and update, as necessary, the error performance Recommendations G.821, G.826, G.827, G.828, G.829 and G.8201.

– Maintain and update, as necessary, PDH, SDH, OTN, FlexO and LAPS Recommendations.

– Maintain and update, as necessary, GFP, LCAS, and HAO related Recommendations.

– Development of new Recommendation G.osu

– Further development of the OTN Interface Recommendations (including selection of new forward error correction codes based on emerging application needs).

An up-to-date status of work under this Question is contained in the SG15 work programme (<https://www.itu.int/ITU-T/workprog/wp_search.aspx?sg=15>).

### J.4 Relationships

Recommendations:

– G.693, G.694, G.695, G.698.x, G.784, G.800, G.805, G.807, G.825, G.872, G.874, G.957, G.959.1, G.993.x, G.7710, G.7712, G.8010, G.8021, G.8080, G.8110, G.8110.1, G.8121, G.8251, G.8261, G.8262, G.8264, G.8310, and G.8350

Questions:

– QB/15, QD/15, QF/15, QI/15, QK/15, QL/15, and QM/15

Study Groups:

– ITU-T SG2 on network maintenance

– ITU-T SG13 responsible for future networks, with focus on IMT-2020, cloud computing and trusted network infrastructure

– ITU-T SG17 on security

Other bodies:

– MEF on Ethernet services and Ethernet interfaces, Layer 1 services

– IEEE 802.1, 802.3 on Ethernet

– T11 on SAN flows transport

– Optical Interworking Forum (OIF) on flexible Ethernet (FlexE) and optical interfaces that leverage FlexO frame formats

– Broadband Forum (BBF)

Question K/15

Transport network architectures

(Continuation of Question 12/15)

### K.1 Motivation

Transport network architecture Recommendations (G.800, G.805, G.807, and G.809) and technology specific network architecture Recommendations (G.803, G.872, G.8310, G.8010, G.8110, G.8110.1 and I.326) have been established and are widely used. As operating experience is gained with employing current transport network technologies and new technologies evolve (e.g., variable size packets, high-speed transport networks), new Recommendations, or enhancements to existing Recommendations need to be developed, in close cooperation with the standardization activities on transport network systems and equipment. The operational aspects of networks, including the use of ASON or SDN for restoration, are becoming more important. The operational aspects of combined packet and circuit switched optical networks should be considered to ensure that they are addressed in a way that is architecturally sound and minimizes divergent approaches.

Software defined networking (SDN) is an architectural approach to managing transport network resources. Its architecture needs to be understood in the context of the management control continuum that includes the architecture of the automatically switched optical network (G.7703). Commonality and differences with existing architectures requires study as it is applied to various transport layers. Requirements for enhanced control interfaces to and within the transport network, for example to support network slicing, need to be studied. Interfaces to configure and control programmable hardware are needed. Interfaces that enable clients to request network services beyond basic connectivity are needed.

Artificial intelligence (AI) and machine learning (ML) are emerging technologies that may benefit transport network operators by increasing the degree of automation, the operating efficiency and the flexibility of transport network operation and resource utilization. Work on AI/ML is ongoing in many other organizations with whom we collaborate, we should provide analysis and guidance on the applicability of AI/ML to the transport network for use in SG15 and in other organizations. There are two broadly distinct aspects to this work: the potential benefits AI/ML technologies might provide to the transport network; and the support (i.e., the interfaces) that those applications may need from the transport network.

As compute and storage capabilities evolve, they may impact network architecture and that should be studied (e.g., a distributed SDN controller, data centre connectivity, the use of computing hardware to flexibly provide network functions such as forwarding and adaptation).

The continued evolution of transport networks and the services they support such as, the Internet, IMT-2020/5G, datacentre-based services, and higher definition video, have resulted in drastic changes in the demands placed on transport networks. The services supported by the transport network are critical to modern society; as a key component of society's infrastructure the security of the transport network is an important consideration. Transport networks need to continuously evolve to meet these changing demands and provide a converged transport network. This rapidly evolving situation led us to recognise the need for a coordination and communication activity among the involved Questions (primarily Questions B, F, I, J, K, L, and M/15) in order to avoid duplication of work and facilitate the most efficient completion of the work. Also, a standardization work plan for new optical transport network activities (the optical transport networks and technology standardization work plan, OTNT SWP) needs to be maintained. In addition, some general aspects such as terminology, need to be captured.

The following major Recommendations, in force at the time of approval of his Question, fall under its responsibility: G.800, G.803, G.805, G.809, G.807, G.872, G.8310, G.7701, G.7702, G.7703, G.8010/Y.1306, G.8110/Y.1370, G.8110.1/Y.1370.1 and I.326.

### K.2 Question

– Study items to be considered include, but are not limited to:

 refine and enhance the specification of transport network architecture, including enhancements to G.800, G.872, G.8310, G.7701, G.7702, G.7703, G.8010, G.8110 and G.8110.1, including use of ASON or SDN for network restoration, operational aspects and implications of the evolution of photonic technologies to support additional flexibility within the transport network?

 study architectures that use G.7701 components

 explore the relationship between the transport network architecture and applications such as computing and storage?

* explore the relationship between the architecture of MC systems and the evolving compute and storage environment?

 explore the implications of multi-technology and multi-layer integration, the potential for network simplification and the consequent impact on the network architecture and existing standards?

 develop the architecture of media networks as the manner in which information layers use them is evolving?

 explore the relationship among functional architectures developed in QK/15 and the information models developed in QM/15?

 explore enhancements to the architecture of transport networks to address emerging requirements of IMT-2020?

 Specify requirements for enhanced control interfaces to and within the transport network. Interfaces to configure and control programmable hardware are needed. Consider impacts of AI and ML on those interfaces. For example, are new parameters to existing interfaces required to support AI/ML applications; are new interfaces required to support them?

 What, if anything, needs to be changed architecturally to allow AI/ML applications to be used in the operation of the transport network?

 Define interfaces that enable clients to request network services beyond basic connectivity?

 Reflect synchronization (as studied in QL/15) in architecture Recommendations?

 Architecture to support the interaction between transport network management and IMT‑2020/5G network management?

 Explore the security aspects of the control components of the transport network's control and management architecture

 The security aspects of management and control, and applications using it including resource allocation aspects

– Study items include, but are not limited to:

 Transport networks that offer circuit switching capability including photonic switching technology.

 Transport networks that offer packet switching capability

 Converged multi-technology and multi-layer transport networks.

 The architecture of the media network and new ways that information layers can be supported over media.

 Support of point-to-multipoint and multipoint-to-multipoint transport services.

 The dynamic behaviour of resources in the network (e.g., link speed change).

 The SDN architectural approach and its role in providing more flexible control.

 The architectural implications, if any, of providing support for the use of AI/ML technology for operational enhancements to the transport network, excluding AI/ML algorithm development.

 Use of ASON or SDN for network restoration

 What enhancements to OTNT SWP or what new Recommendation(s) or mechanisms are necessary to capture, within this framework, new or evolving aspects of optical transport networks, their general terminology, and reliability/availability characteristics?

### K.3 Tasks

Tasks include, but are not limited to:

– Maintenance of Recommendations I.326, G.803, G.805, G.8010, G.8110, and G.8110.1.

– Refinement and enhancement of Recommendations G.800, G.807, G.8310, G.872, G.7701, G.7702, and G.7703.

– Investigate the use of ASON or SDN for network restoration and clarify the relationship between protection switching and restoration techniques.

– Use of AI and ML in the transport network.

– Facilitate discussion among questions during SG15 meetings to coordinate work on optical transport, including the harmonization of terminology.

– Develop, maintain, and regularly distribute a work plan that documents the work and time schedules of all major new optical transport network activities (OTNT SWP).

– Examine the application of existing SG17 security related Recommendations to transport network with a focus on architectural aspects.

– Facilitate discussion among questions during SG15 meetings to coordinate work on security.

– Exploring the relationship between the architecture of MC systems and the evolving compute and storage environment

An up-to-date status of work under this Question is contained in the SG15 work programme (<https://www.itu.int/ITU-T/workprog/wp_search.aspx?sg=15>).

### K.4 Relationships

Recommendations:

– AI and ML application Recommendations (e.g., Y.3172)

Questions:

– QB/15, QF/15, QI/15, QJ/15, QL/15 and QM/15

Study Groups:

– ITU-T SG2 on telecommunication management

– ITU-T SG13 working on SDN, AI & ML, and IMT-2020/5G

– JCA-IMT-2020 on 5G

– ITU-T SG20 requirements from IoT

– ITU-T SG17

Other bodies:

– IETF on Control Plane and security Issues

– IEEE 802 on Ethernet Issues

– OIF on optical control plane and flex Ethernet and security

– ONF on SDN and security

– ETSI ISG NFV, ISG ENI, ISG SAI

– 3GPP on IMT-2020/5G

– BBF on IMT-2020/5G

Question L/15

Network synchronization and time distribution performance

(Continuation of Question 13/15)

### L.1 Motivation

Network synchronization performance specifications are essential for successful operation of digital transmission networks including the support of, for example, mobile networks. Network timing performance standards are necessary to define the feasibility and most effective means of implementing a time reference distribution service. This includes the distribution of both precision time and frequency.

Continuing effort needs to be put into the study of synchronization issues in packet-based and new TDM networks.

Requirements for the related OAM and Management functions need to be further studied.

Requirements from new network architectures and applications should be considered (e.g., as related to the IoT, IMT2020/5G, IMT-2020/5G evolution, new emerging applications that may require accurate timing such as support for enhanced security solutions, etc.). New applications with particularly stringent timing requirements may need to be considered (e.g., quantum key distribution (QKD) related applications).

Robust and reliable network synchronization solutions (e.g., as related to global navigation satellite system (GNSS) backup synchronization references) need to be addressed.

There is increased need to provide timing to support the needs of other industries (e.g., industrial automation) that may rely on the transport and synchronization solutions defined within this study group. SDN/NFV implications on the synchronization networks should also be studied. Enhancements drawing on and looking to enable artificial intelligence (AI) and machine learning (ML) should be studied.

The advances in network synchronization related technologies should be addressed.

New transmission technologies, services and facilities are regularly being introduced. Inter-operator links need to be efficiently installed, commissioned, brought into service and maintained. Test and measurement instrumentation is required for the installation, commissioning, bringing into service and maintenance of telecommunications equipment and networks. The measurement of the same parameter made with different measuring instruments should give reliable, repeatable and comparable results. Test equipment specification needs continuous review to take account of technology changes and improvements of jitter, wander and precision time measurement.

The following major Recommendations, in force at the time of approval of this Question, fall under its responsibility:

– Definitions and Architecture: G.781, G.810, G.8260, G.8264, G.8265, G.8275

– PTP Profiles: G.8265.1, G.8275.1, G.8275.2

– Network Performance: G.8251, G.822, G.823, G.824, G.825, G.8261, G.8261.1, G.8271, G.8271.1, G.8271.2

– Clocks: G.811, G.811.1, G.812, G.813, G.8262, G.8262.1, G.8263, G.8272, G.8272.1, G.8273, G.8273.2, G.8273.3, G.8273.4

– Test equipment: O.171, O.172, O.173, O.174 and O.182

– Supplements: G Suppl.65, G Suppl.68

– Technical Reports: GSTR‑GNSS

### L.2 Question

– Study items to be considered include, but are not limited to:

 What are the requirements for jitter and wander for the future OTN interfaces, e.g., beyond 100 Gbit/s?

 What is the network functionality required to provide real-time distribution of absolute time-of-day reference services and/or phase synchronization? What network capabilities are required to support the performance levels necessary to satisfy a selected set of time-of-day and/or phase synchronization user applications?

 How can network synchronization performance be enhanced through the use of synchronization status messages or other techniques?

 What network synchronization characteristics, for both normal and degraded mode, should be recommended for services carried over packet networks? What is the dependence on synchronization of performance of various methods of service clock recovery with respect to service requirements (e.g., jitter, wander, time error, etc.)?

 How can robust and reliable network synchronization solutions be provided (e.g., as related to GNSS back-up) the "coherent PRTC" concept is one option that may be considered: how can high-accuracy time synchronization be used in this context to back-up GNSS?

 What advances of the synchronization technologies (e.g., new type of clocks) should be considered in the overall network synchronization solutions?

 What network synchronization characteristics should be recommended for services carried over packet-based networks?

 What network synchronization characteristics should be recommended for services carried over Metro Transport Network (MTN) based networks?

 What jitter and wander requirements are needed for wireless network applications (e.g., radio relay, satellite)?

 Synchronization aspects related to supporting mobile network operations: what synchronization requirements are related to supporting the operation of the mobile network (e.g., backhaul and fronthaul) and of the related applications (e.g., LTE, LTE-A, IMT2020/5G)? What solutions are suitable to meet these requirements? How can the accuracy be improved?

 What jitter and wander requirements are needed for access networks (e.g., DSL, PON, Microwave)?

 What jitter and wander specification requirements are needed in the evolution of OTN and in MTN?

 Synchronization aspects (frequency, phase and time) of packet networks, e.g., Ethernet, MPLS, IP networks.

 What mechanism can be used to add security to the transport of timing?

 Synchronization aspects related to new applications, e.g., as related to the Internet of things (IoT) and security mechanisms that depend on accurate timing?

 Synchronization aspects with regard to transport via satellite networks?

 What are the synchronization related requirements for OAM and Management functions?

 What is the implication of SDN/NFV concepts to the synchronization network architectures and requirements?

 Use of AI and ML in synchronization networks?

 What manual and automatic test and measurement instrumentation and techniques to assess transmission performance need to be specified by ITU-T and what should be the specifications?

– The following are examples of instrumentation and techniques which may be studied:

 measurement and evaluation of error performance parameters and objectives;

 test instrumentation and techniques associated with various technologies (e.g., PON, OTN PNT, submarine systems and beyond 100 Gbit/s);

 test instrumentation and techniques associated with Layer 1 Transmission technologies for metallic and optical media like 1G access, beyond 100 Gbit/s;

 jitter and wander test instrumentation and techniques associated with various technologies (e.g., PON, OTN, PNT and beyond 100 Gbit/s);

 test instrumentation and techniques associated with optical phase modulations (e.g., ODB, DQPSK and DP-QPSK);

 keeping O-Series Recommendations up to date.

### L.3 Tasks

Tasks include, but are not limited to:

– Continue development of recommendations related to the transport of frequency through packet networks, G.826x-series including G.8260, G.8261, G.8261.1, G.8262, G.8262.1, G.8263, G.8264, G.8265, G.8265.1, and G.8266.

– Continue development of recommendations related to the transport of phase and time through packet networks, G.826x- and G.827x-series including G.8260, G.8271, G.8271.1, G.8271.2, G.8272, G.8272.1, G.8273, G.8273.1, G.8273.2, G.8273.3, G.8273.4, G.8275, G.8275.1, G.8275.2.

– Revision and enhancements of the related supplements and technical reports: G Suppl.65, G Suppl.68, GSTR‑GNSS.

– Revisions and enhancements to Recommendations G.825 and G.8251.

– Maintenance and enhancement of G.81X-series.

– Continue work on the transport of clients through OTN (e.g., PTP, etc.).

– Consider need for new Recommendation on jitter and wander instrumentation for packet‑based networks (O-series), e.g., O.175.

– Consider need for new Recommendation on physical layer test instrumentation associated with Optical Phase modulations (ODB, DQPSK and DP-QPSK).

– Work on Recommendation for frequency and time synchronization layer functions (G.781, G.781.1).

– Work on sync in metro transport network (G.sync-mtn).

An up-to-date status of work under this Question is contained in the SG15 work programme (<https://www.itu.int/ITU-T/workprog/wp_search.aspx?sg=15>).

### L.4 Relationships

Recommendations:

– Q.551, G.703, G.709, G.783, G.798, G.800, G.805, G.80XX series, G.81XX series, G.83XX series

– G.783

Questions:

– QB/15, QC/15, QD/15, QF/15, QH/15, QI/15, QJ/15, QK/15, and QM/15

Study Groups:

– ITU-T SG2 on telecommunication management

– ITU-T SG13 responsible for future networks, with focus on IMT-2020, cloud computing and trusted network infrastructure

– ITU-T SG9 on broadband cable and tv

– ITU-T SG17 on security

– ITU-T SG20 on IoT, smart cities and communities

– ITU-R SG4 on satellites

– ITU-R SG5 on terrestrial services

– ITU-R SG6 on broadcasting service

– ITU-R SG7 on science services

Other bodies:

– ATIS SYNC

– IETF TICTOC

– IETF NTP

– MEF on circuit emulation over Ethernet and frame delay measurements

– MEF mobile backhaul/fronthaul

– MEF on transport services for mobile networks

– IEEE 1588

– IEEE 802.3

– IEEE 802.1

– IEEE 802.16 (Wireless MAN)

– 3GPP RAN, SA

– Broadband Forum

– IEC TC86

– Optical Interworking Forum (OIF)

– ETSI

– ONF

– O-RAN WG4, WG5, WG9

– CPRI

Question M/15

Management and control of transport systems and equipment

(Continuation of Question 14/15)

### M.1 Motivation

Demands for ever increasing levels of desired transport networking functionality and responsiveness to its range of users' needs continue to rise. This has triggered both evolution, and introduction of new, control and management paradigms (e.g., application of software defined networking (SDN), artificial intelligence/machine learning (AI/ML), virtual network (VN), security, and quantum information technology), with a corresponding increase in variety of control/management interface protocol solutions that may be deployed in transport networks. Transport networks may be vast and complex (e.g., multi-technology/layer, multi-protocol, multi-vendor) and co-existence among control and management paradigms is essential to enable large scale operational integration. Given the underlying transport resources remain the same, independent of the paradigm(s) employed, it is increasingly essential to provide a coherent information model of transport resources to enable interoperability between the different management/control paradigms and solution data models. Such factors will drive the need for the revision of existing Recommendations as well as the development of new Recommendations relevant to the control and management of transport network resources.

Building upon the foundation architectures of transport data plane, including media, and control-management (e.g., automatically switched optical networks (ASON) and SDN) of QK/15 (transport network architectures), QI/15 (packet-based transport), QJ/15 (optical transport), and QL/15 (synchronization), this Question is responsible to develop the specifications for the control and management of transport network resources, encompassing requirements, protocol-neutral Information Models (IM) and protocol-specific Data Model (DM) solutions for common transport functionality and transport technology-specific functionality (e.g., metro transport network (MTN), optical transport network (OTN), Ethernet transport, and MPLS-TP). To ensure coherent specifications and interoperability among the protocol-specific solutions, this Question is also responsible to develop guidelines for deriving protocol-specific solution DMs through pruning and refactoring of the protocol-neutral IMs to ensure coherent DM specifications and their traceability to the protocol-neutral IM. This Question is also responsible to develop the specifications of the architecture and requirements for the data communications network (DCN) encompassing control and management paradigms. These activities will be conducted in close co-operation with related ITU-T Study Groups, TM Forum, IEEE, IETF, ONF, MEF, BBF, and other SDOs as necessary.

Development and propagation of model driven tooling and the adoption of software development methodologies to enhance the creation of recommendations that include information and data models.

The following major Recommendations, in force at the time of approval of this Question, fall under its responsibility: G.774-series, G.784, G.874, G.875, G.7710/Y.1701, G.7711/Y.1702, G.7712/‌Y.1703, G.7713/Y.1704-series, G.7714/Y.1705-series, G.7715/Y.1706-series, G.7716/Y.1707, G.7718/‌Y.1709, G.7718.1/Y.1709.1, G.7721 series, G.8051/Y.1345, G.8052/Y.1346 series, G.8151/‌Y.1374, G.8152/Y.1375 series, and I.752.

### M.2 Question

– What requirements, information models, and data models must be specified to enable control and management of transport technology specific resources including support for OTN, MTN, Ethernet, MPLS-TP, support management of transport network using the various control and management paradigms?

– How can the management of the transport network make best use of cloud computing?

– What requirements, information models, and data models must be specified to support efficient and optimized control and management of multi-technology/layer and multi-domain transport network resources, including synchronization, abstraction and virtualization.

– What requirements, information models, and data models must be specified to enable the use of AI/ML techniques applied to the management and control of the transport network?

– What requirements, information models, and data models must be specified to enable the management and control of security techniques applied to the transport network?

– What requirements, information models, and data models must be specified to enable the management and control of quantum information technology as applied to the transport network?

– What requirements, information models, and data models must be specified to use Quantum Information Technology to manage and control the transport network?

– What requirements, information models, and data models must be specified to manage the management and control (MC) components?

– What is the interaction of the transport network management and IMT-2020/5G network management?

– What management and control requirements and protocol-neutral and protocol-specific solutions should be specified to enable power efficiency of the transport equipment in the network without decreasing the reliability and availability of the network?

– What control requirements and protocol-neutral solutions must be specified to enable efficient and effective signalling, routing, and automatic discovery of transport networks?

– Study items include, but are not limited to:

 ASON and SDN control component architecture-based protocol-neutral requirements and associated protocol-neutral and protocol-specific solutions (encompassing both technology-neutral and technology-specific aspects).

 Management aspects of control planes, including interaction between a control plane and a management plane.

 Management aspects of transport planes, including management support of the additional flexibility within the evolving transport network.

 Generic control and management aspects for transport resources.

 Multi-layer transport network, including synchronization.

 Management of AI/ML techniques as applied to a transport network.

 Management of security as applied to a transport network.

 Management and use of Quantum Information Technology in transport networks.

 Use of cloud computing infrastructure to support a management and control system (MCS)

 Control and management aspects for specific technologies and their applications (such as protection); e.g.:

o Optical transport network resources (encompassing photonic networking evolution).

o Ethernet transport resources.

o MPLS-TP transport network resources.

o Frequency synchronization and precision time synchronization network resources.

o Management of data communication capability.

o Power management of the equipment for energy saving.

o MTN

### M.3 Tasks

Tasks include, but are not limited to:

– Active list:

 Revise Recommendation G.874.

 Revise Recommendation G.875 (ex. G.874.1) OTN management requirements and protocol-neutral information model.

 New Recommendation G.875.x "OTN Data Model".

 New Recommendation G.876 "Media management".

 Revise Recommendation G.7710/Y.1701, Common Management Requirements, including requirements for power saving modes and synchronization.

 Revise Recommendation G.7711/Y.1702, Generic Protocol-Neutral Information Model for Transport Resources.

 New Recommendation G.7711.x/Y.1702.x "Generic Data Model".

 Revise Recommendation G.7712/Y.1703, Data Communication Network.

 Revise Recommendations G.7714/Y.1705 and G.7714.1/Y.1705.1, Auto Discovery.

 Revise Recommendations G.7716/Y.1707, Architecture of control plane operations.

 Revise Recommendations G.7718/Y.1709 and G.7719 (ex. G.7718.1/Y.1709.1) Management requirements and information model for MC components and functions.

 Revise Recommendation G.8051/Y.1345 "Management aspects of the Ethernet transport network element".

 Revise Recommendation G.8052/Y.1346 "Protocol-neutral management information model for the Ethernet transport network element".

 New Recommendation G.8052.x/Y.1346.x "Management data model for the Ethernet transport network element".

 Revise Recommendation G.8151/Y.1374 "Management aspects of the MPLS-TP network element".

 Revise Recommendation G.8152/Y.1375 "Protocol-neutral management information model for the MPLS-TP network element".

 New Recommendation G.8152.x/Y.1375.x "Management data model for the MPLS-TP network element".

 Revise Recommendations G.7721 "Requirement and information model for synchronization management"

 New Recommendation G.7721.1 "Data model for synchronization management"

 New Recommendation G.8350 "Management requirement and information model for MTN"

– Maintenance list:

 Recommendations in the G.774 series

 Recommendation G.784

 Recommendations G.7713/Y.1704 and G.7713.x/Y.1704.x series, Distributed Connection Management

 Recommendations G.7715/Y.1706 and G.7715.x series, ASON Routing Requirements

An up-to-date status of work under this Question is contained in the SG15 work programme (<https://www.itu.int/ITU-T/workprog/wp_search.aspx?sg=15>).

### M.4 Relationships

Recommendations:

– M series (ITU-T SG2), G.800, G.805, G.806, G.808 series, G.783, G.798, G.807, G.872, G.873 series, G.7044, G.7701, G.7702, G.7703, G.8010, G.8013, G.8021, G.8023, G.8031, G.8032, G.8110.1, G.8113.1, G.8113.2, G.8121 series, G.8131, G.8132, G.8310, G.8312, G.8321, G.8331, and Y.1563, AI/ML, and Quantum recommendations.

Questions:

– QB/15, QD/15, QF/15, QI/15, QJ/15, QK/15 and QL/15

Study Groups:

– ITU-T SG2 on telecommunication management, including AI/ML

– ITU-T SG12 for performance, QoS, and QoE

– ITU-T SG13 on SDN, IMT-2020, and AI/ML

– ITU-T SG17 on security, including Quantum

– ITU-T SG20 on IoT

– ITU-R on transport management related issues

Other bodies:

– Broadband Forum (BBF)

– ETSI ISGs, including but not limited to, NFV, SAI, ENI, ZSM

– IEEE 802 on Ethernet management

– IEEE 1588 on synchronization management

– IETF Working Groups in operations and management, transport, and routing

– MEF on Ethernet management

– OIF (Networking & Operations and Carrier WGs)

– OMG on UML

– ONF on SDN and generic information model

– TM Forum on network-level management interface specifications (MTNM, MTOSI, TIP, and ZOOM aspects)

– W3C on XML

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