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OAB: Optical transport networks
Online course specification

Course aim:
This online course explains the operation and possible architectures of, and services provided by, optical transport networks as employed by telecommunications operators with emphasis on national and regional networks based on the ITU G.709 recommendation.

Target audience:
Those involved in designing, implementing, and maintaining optical transport networks.

Course level: Advanced
An explanation of PTT course levels is given at the end of this document

Pre-requisites:
An understanding of time division multiplexing, connection oriented packet switching, and wavelength division multiplexing. It is recommended that the following PTT online courses are studied before attempting this course: “Modulation and multiplexing” and “Introduction to wide area networks” . A prior appreciation of legacy SDH networks will also be beneficial; this subject is covered by the PTT course “SDH principles”.

Course structure:
The course consists of the following 5 modules:

1. Network topology and services
2. OTN principles
3. Network operation
4. Service provision
5. Network architectures

Module 1: Network topology and services

Module aim: To describe typical structures, facilities, protocols, and capabilities of telecoms national networks and the case for employing an ITU specified optical transport network (OTN) as a replacement for the SDH.

After completing this module, a trainee will be able to:

- explain that telecommunications networks must be reliable, resilient, secure and have enough resources to provide the required quality of service at the busiest periods.
- describe the type and range of services provided by telecoms networks including those to business and residential customers.
- explain that telecommunications networks provide high-capacity connections with low error rates, low delay, guaranteed bit rates, and high security.
- explain the factors that influence the capacity of optical links with reference to DWDM, optical amplifier bandwidth, error correction, and coherent detection.
- describe and compare the typical topologies and roles of core, aggregation, and access networks with reference to the role of ring and mesh topologies in providing resilience.
- Explain the transition from TDM to IP-based service provision and the challenges involved in providing a comparable service with reference to characteristics such as latency, timing distribution, resilience, and quality of service.

- describe and compare the various transport technologies that may be employed in a telecoms network with reference to their position in the OSIRM.
- explain the role of MPLS and Ethernet in providing the transport of IP-based traffic with quality of service guarantees.
- describe the requirement for supervisory data collection to ensure network resilience and confirmation of adherence to service level agreements.
- describe the role of network management systems.
- explain the need to transition from networks based on the synchronous digital hierarchy (SDH) to those based on ITU recommendations relating to an optical transport network (OTN).

Module 2: OTN principles

Module aim: To describe the operation and advantages of optical switching, the concept of optical channels, the ability of those channels to transport various types of client signal, and methods of monitoring channel performance.

After completing this module, a trainee will be able to:

- describe the advantages of an OTN with reference to the provision of optical, switchable optical channels providing high capacity connections for a variety of service types.
- explain the principles of a MOEMS optical cross-connect.
- describe the role of the basic components of an all-optical network including optical add/drop multiplexers and cross-connect equipment.
- describe the structure and capabilities of an optical transport network (OTN).
- describe the capabilities of a reconfigurable optical add-drop multiplexer (ROADM) with reference to the terms “directionless”, “colourless”, “contentionless” and “gridless”
- explain the concept of optical channels and their ability to transport various types of synchronous and asynchronous traffic.
- describe the role of an optical transport unit (OTU), optical data unit (ODU), and optical payload unit.
- explain that several lower order ODUs each carrying a client signal can be multiplexed together for transport by a single OTU.
- describe the provision and features of optical supervisory channels in an OTN.
- explain the advantages of the forward error correction (FEC) facility offered by an OTN.
- describe the transport capabilities of the hierarchy of OTUs giving examples of the types of client signal that can be transported at each of the four OTU levels.

Module 3: Network operation

Module aim: To describe the operations, administration, maintenance (OAM) and automatic protection facilities of an optical transport network (OTN).

After completing this module, a trainee will be able to:

- explain the role of an operations, administration, maintenance (OAM) system.
- describe the OAM facilities offered by an ITU recommended OTN.
- describe and compare the role of, and facilities provided by, the overheads included at the OTU and ODU levels.
- explain and compare the concepts of optical multiplex section (OMS) and optical transport section (OTS).
- explain that an optical supervisory channel carries information that allows the monitoring of individual optical channels, OMS, and OTS.
- explain the relationship between defect and maintenance indications giving examples of the type of alarm that can be raised by network elements in an OTN.

- explain the requirement for automatic protection systems with protection switching occurring in less than 50 milliseconds.
- explain that the degree of protection provided is a balance between network resilience and the efficient use of bandwidth with reference to 1+1 protection, 1:1 protection, and 1:n protection.
- compare the operation and advantages of unidirectional, bidirectional and revertive protection switching.
- compare the role and operation of trail, subnetwork connection (SNC), ring, and mesh protection.
- explain the role of tandem connection monitoring including its use in SNCs.
- explain and compare the operation of various types of SNC as specified by the ITU.
- explain and compare the provision of two fibre and four fibre shared ring protection in an OTN.

Module 4: Service provision

Module aim: To describe the techniques employed to provide services to customers that meet the requirements of those customers while ensuring the efficient use of optical transport network traffic capacity.

After completing this module, a trainee will be able to:

- explain that a telecoms network must provide interfaces that are compatible with the requirements of business customers.
- describe the optical interfaces commonly offered to businesses for point to point connections over an OTN.
- explain that special techniques are required to adapt ITU specified OTN transport channels for the flexible provision of high-speed IP and Ethernet services.
- describe and compare methods of mapping client signals into the payload of OTN transport signals with reference to bit synchronous mapping, asynchronous mapping, and generic mapping procedures.
- explain the role and operation of ODUflex in making more efficient use of link capacity when transporting IP traffic over an OTN.
- describe the characteristics and typical applications of fine grain OTN (fgOTN) services that provide low bit rate, ultra-low latency connections with stable timing distribution.
- explain the provision of an OSUflex service with reference to mapping client signals into optical service units (OSUs) and the multiplexing of OSUs.
- describe and compare the facilities offered by an OSUflex service with that of an fgODUflex service including hitless capacity adjustment.

Module 5: Network architecture

Module aim: To describe the role and facilities of, and relationship between, the various protocols employed in aggregation and core networks and compare the advantages of certain protocol combinations and network architectures.

After completing this module, a trainee will be able to:

- describe the required characteristics and facilities of telecommunications networks.
- explain the role of, and relationship between, the optical transport layer, the connection oriented layer, and packet layer of a telecommunications network.
- compare methods of achieving the most efficient use of link capacity while avoiding congestion.
- compare various methods of providing a connection oriented service.
- compare the various MPLS variants and Carrier Ethernet in terms of providing quality of service guarantees for virtual circuits, and OAM and traffic restoration facilities.

- describe, and compare the role of, the protocols typically employed in legacy networks that employ the synchronous digital hierarchy (SDH).
- compare the benefits and facilities of OTN “hop by hop” and ROADM based architectures for core networks
- compare the roles and benefits of the use of TDM (OTN) and MPLS based switching in an optical transport network.
- Describe the principles, facilities, functional elements, and possible applications of an OTN-based distributed architecture in access and metro networks.
- describe and compare the benefits of possible protocol combinations in aggregation and core networks including those using OTN switching and transport.

Course access requirements:
To access the course, a computer/tablet running a browser such as Chrome, Safari, Edge etc is required. The device should have an active Internet connection and a screen resolution of at least 1024x768.

Learning facilities:
This online course employs interactive simulations, hypertext links to an online glossary and multiple-choice question sessions to fully involve the trainee in the learning experience. Each module provides revision links to previously studied, relevant topics. A record of progress and level of achievement is recorded for each trainee. Once studied as a structured, assessed course, the content can be browsed for revision or reference.

PTT course levels:
PTT online courses are categorised by one of three levels according to the depth of treatment they provide:

1. **Introductory:**

   PTT Introductory courses are designed for those with no previous experience or knowledge of telecommunications. These courses provide an overview of telecommunications or discuss the fundamentals of electronic communications. The study of general science at secondary (high) school is a typical pre-requisite for PTT Introductory courses.
   PTT Introductory courses are suitable for those joining the telecommunications sector particularly those in an apprenticeship programme.

2. **Intermediate:**

   PTT Intermediate courses are designed for technicians and engineers requiring an understanding of a certain aspect of digital technology. Those planning to study an Intermediate course should understand the basic principles of computing or electronic communications.
   The depth of treatment provided by Intermediate courses is typically equivalent to level 3 of a UK national vocational qualification (NVQ).
   PTT Intermediate courses can be used to support level 3 digital apprenticeships.

3. **Advanced:**

   PTT Advanced courses are designed for those who require an in-depth treatment of a certain aspect of telecommunications. Such courses are suitable for system designers as well as those who will be responsible for the maintenance of the system described in the course.
   Those planning to study a PTT Advanced course should have a background in telecommunications, and an understanding of telecommunications fundamentals and the principles of the type of telecommunications system described in the course.

PTT
February 2025