08 - Optical networks - Control and management

Functionality of Control and Management plane
- Introduction
- How establish a connection
- **OCH (Optical Channel):**
- Quiz

Management
- Monitoring and Configuration task
- Survivability
- Quiz
- Quiz

Monitoring

Functionality of Control and Management plane

Introduction

In networking, the
Control Plane and **Management Plane** play distinct roles in ensuring proper functionality and monitoring of the network:

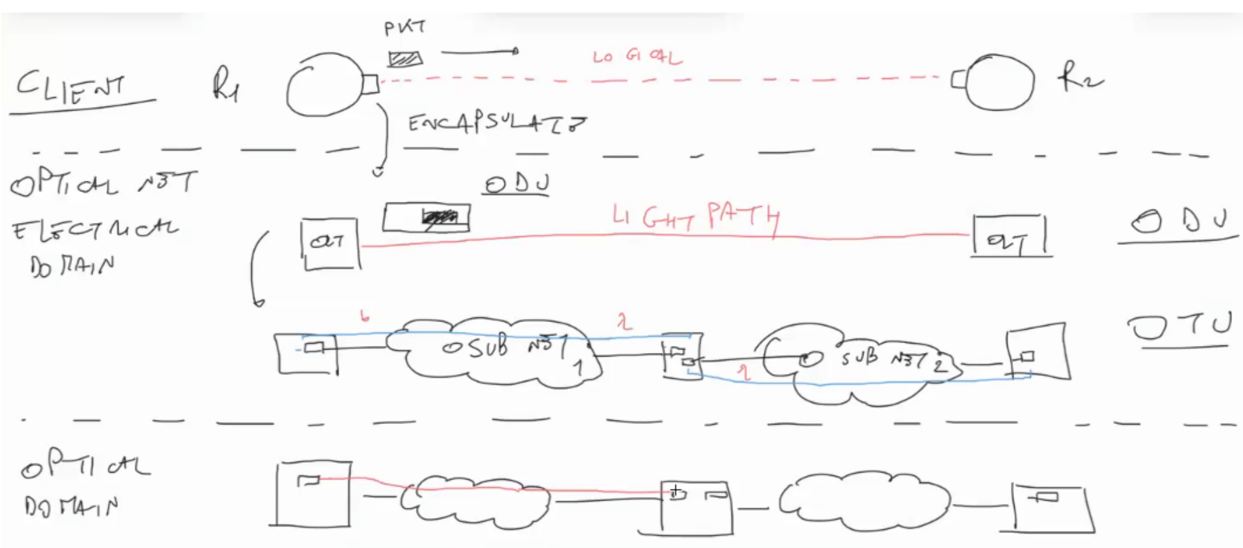
- **Control Plane**: In IP networks, the control plane is responsible for routing. Its main function is to establish the connection by finding a lightpath and an available ray, essentially solving a network graph problem. (Control = Routing)
- **Management Plane**: The management plane is the part of the network used for configuration tasks. This includes assigning IP addresses to interfaces, setting static routes, configuring routing protocols, and monitoring the network's behavior to ensure the health of the infrastructure.

The processes of network control and management can be performed in two ways: manually by a physical operator or through automated systems. When performed manually, tasks are executed via Command Line Interface (CLI). For instance, finding a lightpath was initially done manually by an operator, a process that could take several hours. In contrast, automation significantly accelerates these processes, making them much faster and more efficient.

How establish a connection

In optical networks, operations were originally managed by a centralized element referred to as the "Control and Management Element." This component was responsible for centrally controlling the optical network, which consists of various devices such as OADMs (Optical Add-Drop Multiplexers), OXCs (Optical Cross-Connects), and OLTs (Optical Line Terminals). It communicated and configured the optical network using specific protocols.

When a client requests a connection, they can specify several parameters, such as the required bandwidth, targeted Bit Error Rate (BER), level of protection, and maximum jitter (e.g., the length of the lightpath). These parameters are directly tied to solving an optimization problem, ensuring the network meets the performance requirements of the user.



When two clients are logically connected, their packets do not directly traverse the logical connection. Instead, the packets are encapsulated into a lower layer, such as the optical or electrical domain, passing through the OLT (Optical Line Terminal).

Within the OLT, a transponder performs the necessary adaptations, such as adding overhead data and ensuring compatibility. The OLT generates a new packet, known as an ODU (Optical Data Unit), which includes the optical network's header. The OLTs on either side are connected via a lightpath.

In general, a lightpath passes through multiple optical subnetworks. As it traverses these networks, the lightpath is divided into different sub-lightpaths, which are created by transponders. At this stage, we operate in the OTU (Optical Transport Unit) layer. Each sub-lightpath is associated with a specific wavelength, ensuring efficient and precise transmission across the optical network

OCH (Optical Channel):

An Optical Channel (OCH) represents a point-to-point connection between transponders within the same optical network. The concatenation of multiple OCHs forms a logical lightpath.

When transitioning from OCH to OMS (Optical Multiplex Section), the OCH level only handles a single wavelength ("one color") and cannot distinguish individual client signals. The OMS, on the other hand, creates an aggregate signal that contains all possible signals, enabling the transport of multiple client signals over the same optical infrastructure.

Quiz

it represents the logical connection between the client's interfaces	1	A	ODU
at this layer we have visibility of Optical Amplifiers	2	B	OCh
it is the portion of the network between two mutliplexers	3	C	OTS
it is the only layer in the optical domain where we have access at the single wavelengths	4	D	OTU
it represents a logical connection between two end points in an optical subnetwork	5	E	OMS

1. **Where the client delivers packets to the optical network**: This process involves the creation of an **ODU (Optical Data Unit)**, which encapsulates the client data for transport within the optical network.
2. **Amplifier usage between transmitter and receiver**: Amplifiers are generally used between any pair of devices to boost the optical signal. This process takes place at the **OTS (Optical Transmission Section)**, the lowest layer in the optical hierarchy.
3. **Between two multiplexers**: The connection between two multiplexers operates at the **OMS (Optical Multiplex Section)**, where multiple signals are aggregated for efficient transmission.
4. **Access to a single wavelength**: If only a single wavelength is accessed without multiplexing, we are in the layer above multiplexing, referred to as **OCh (Optical Channels)**.
5. **Not necessarily connecting clients and endpoints**: The **OTU (Optical Transport Unit)** operates in cases involving multiple optical subnetworks, ensuring the end-to-end transport of optical signals even when direct client-to-endpoint connections are not involved.

Management

Monitoring and Configuration task

Two main task of management plane are:

- **Monitoring**: involves checking the health status of the network, identifying possible component failures, and reacting accordingly. It also includes monitoring client traffic flows to ensure that the network meets the required Quality of Service (QoS) parameters, such as Bit Error Rate (BER) and speed (**configuration task**).

- **Configuration task:** these include setting up and managing the network infrastructure. Specific tasks involve assigning IP addresses to interfaces, configuring static routes and dynamic routing protocols, and ensuring the appropriate allocation of resources to meet client demands.

In the **electrical domain**, monitoring typically involves checking the BER since we have access to binary information. However, in the **optical domain**, where binary information is inaccessible, monitoring relies on metrics like the Signal-to-Noise Ratio (SNR).

Optical Trace: when examining a single fiber, it often carries multiple wavelengths associated with different client communications (different lightpaths). To map each wavelength to its corresponding logical connection, an identifier—referred to as an optical trace—is used. The optical trace functions like an IP address and consists of a binary string containing details such as the identities of the two clients and the transponders on either side. This allows operators to recognize the ownership and destination of specific traffic within the network.

Survivability

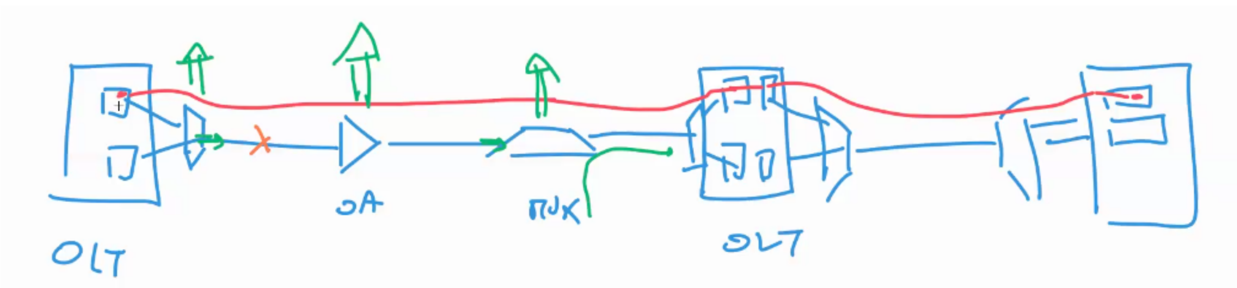
Survivability refers to the network's ability to restore service when a failure occurs.

Failures are detected through alarms. In large networks, a single event can generate thousands of alarms, making it crucial to identify the root cause of the problem. For example, in a network with 32 lightpaths traversing a link with two intermediate nodes, the failure of a single link could trigger a total of 129 alarms (32 lightpaths passing through 4 nodes, plus 1 transponder warning of a fiber loss).

To manage this, **alarm suppression techniques** are used to minimize the number of redundant alarms. These techniques rely on a set of signals called the **Forward**

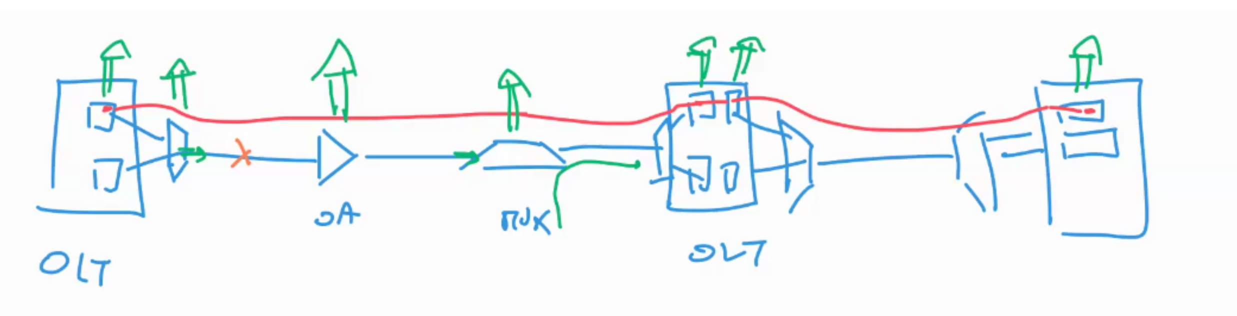
Defect Indicator (FDI) and the **Backward Defect Indicator (BDI)**. When a defect indicator is received, the system stops sending additional alarms. This ensures that only one component sends a continuous alarm, simplifying fault management.

Because networks operate across different layers, the defect indicator (DI) signal varies depending on the layer it represents



- **Optical Amplifier**: Raises an alarm when no signal is received, indicating a potential issue upstream in the transmission path.
- **Multiplexer/Demultiplexer**: Raises an alarm when no signal is entering or exiting, signaling a problem in the corresponding input or output connections.
- **OLT (Optical Line Terminal)**: May not raise an alarm in some cases, as the signal could still be arriving from an alternate path, making it less sensitive to specific failures in the network.

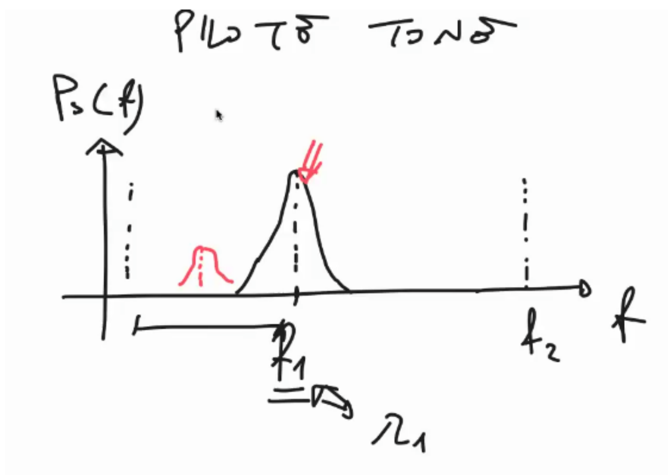
We have to notify all other component that there is a problem



To send a Defect Indicator (DI):

- **In the electrical domain**, the DI is added to the header of the signal, incorporating the necessary information directly into the transmitted data.
- **In the optical domain**, a pilot tone is used as the "header." This involves adding a low-power, small-bandwidth signal in front of the target frequency. The assumption is that there is sufficient spacing between all transmitted frequencies to accommodate the pilot tone without interference.

The pilot tone is inserted and terminated in conjunction with the optical channel. At intermediate points in the network, the pilot tone can be monitored to check the signal integrity, but it is not regenerated at these points. This ensures that the pilot tone remains a reliable identifier throughout the optical channel.

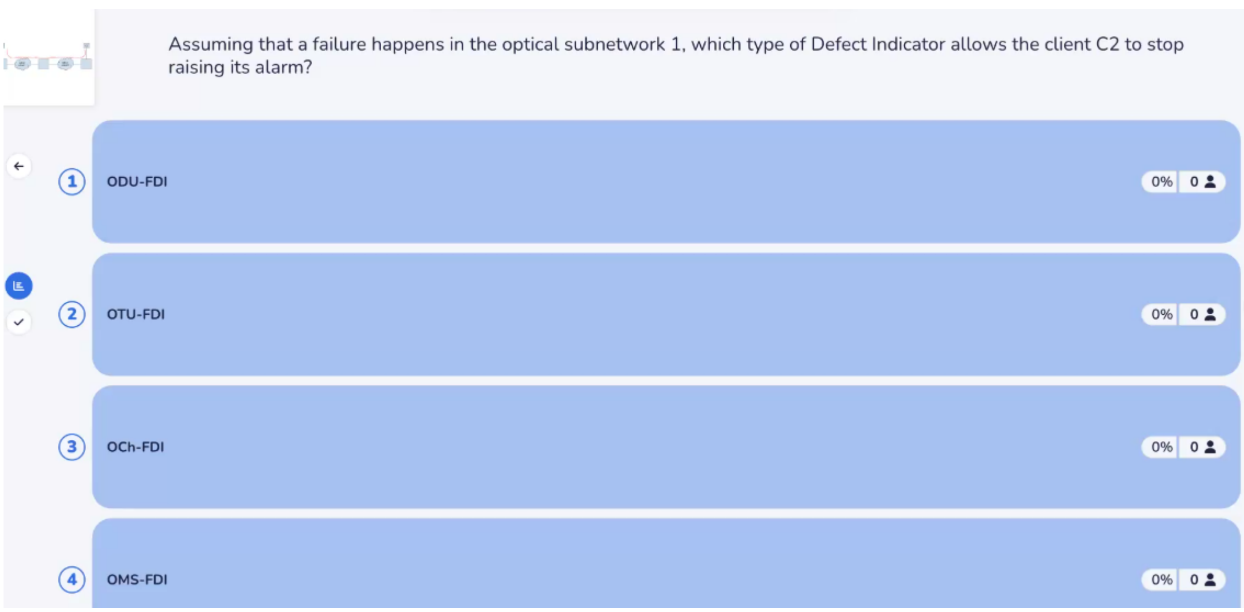


Another way to add a "header" in the optical domain is by using a **dedicated wavelength** on the transponder, known as the **Optical Supervisory Channel (OSC)**. This channel is specifically used for monitoring purposes and operates independently of the data wavelengths. The OSC is inserted at the fiber level, allowing it to provide information about the optical signal and system health without interfering with the primary data transmission.

Quiz

- 1C
- 2A
- 3B

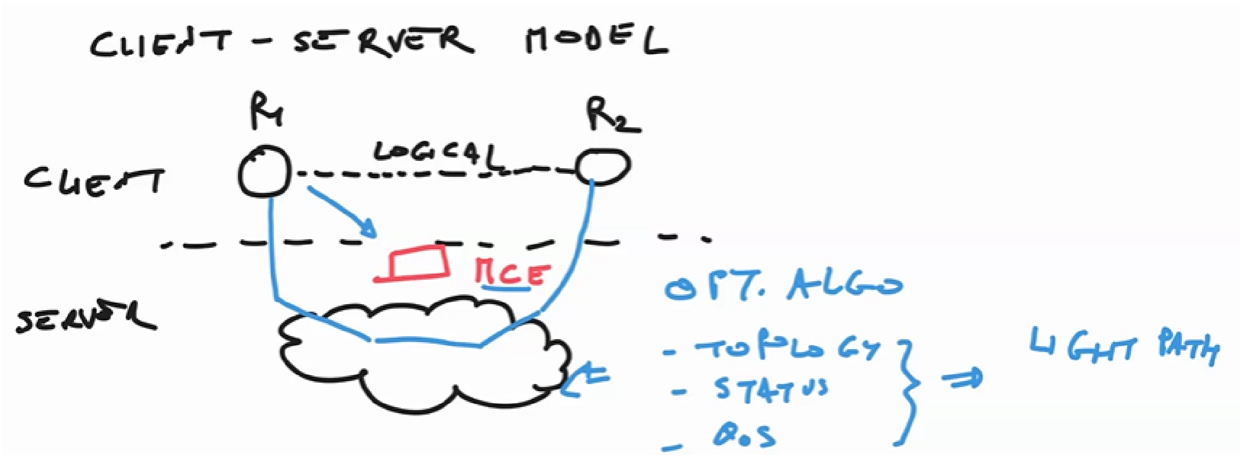
Quiz



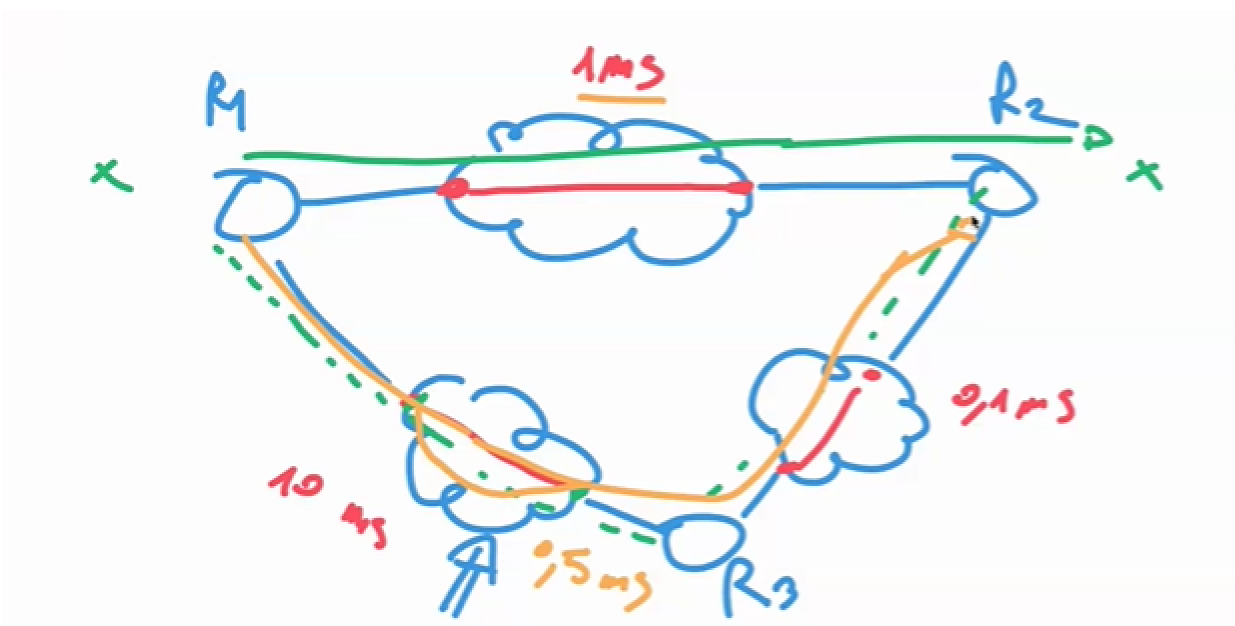
Correct andwer is ODU-FDI, to be sure the client is notified about the failer the correct layer is the ODU layer (between client and ODU)

Monitoring

There are two main paradigms in network design: **Client-Server Model** and **Peer Model**.



Client-Server Model: in this paradigm, the client requests the creation of a connection. The controller takes full responsibility for determining the path and assigning the wavelength (e.g., the one in red). This allocation is finalized only after the controller verifies all the required information, such as Bit Error Rate (BER), bandwidth, and other performance metrics, to ensure the connection meets the client’s specified requirements.



Peer Model: in the peer model, the client actively collaborates with the controller in the process of creating the lightpath. This cooperation allows for distributed decision-making, where both the client and the controller share information and contribute to determining the optimal path and wavelength for the connection.

The difference between the two models is that in the
Client-Server Model, once a lightpath is assigned, it remains fixed and is not changed, whereas in the **Peer Model**, if a lightpath becomes available (e.g., after being freed), the control plane dynamically updates the routing table to follow this new optical path.