DWDM Fundamentals

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Acknowledgement:

This document is produced from the operational experience of the author with the help of knowledge based documents from vendors and tried to keep it universal. Many diagrams are used from open public sources and vendor's technical papers for better understanding and illustration. Also thanks to my teammates for helping me to produce this document.

Course Topics:

1. Introduction to Fiber
2. Fiber Characteristics
3. Introduction to WDM
4. DWDM
5. DWDM for Advanced Network

What we will cover in Part-2

1. 100G & Beyond
2. Planning Aspects
3. Operational Aspects
4. Case Study-1
5. Case Study-2

DWDM Fundamentals

Topic 1: Introduction to Fiber

a. Light Transmit Mechanism

b. Type of Fiber

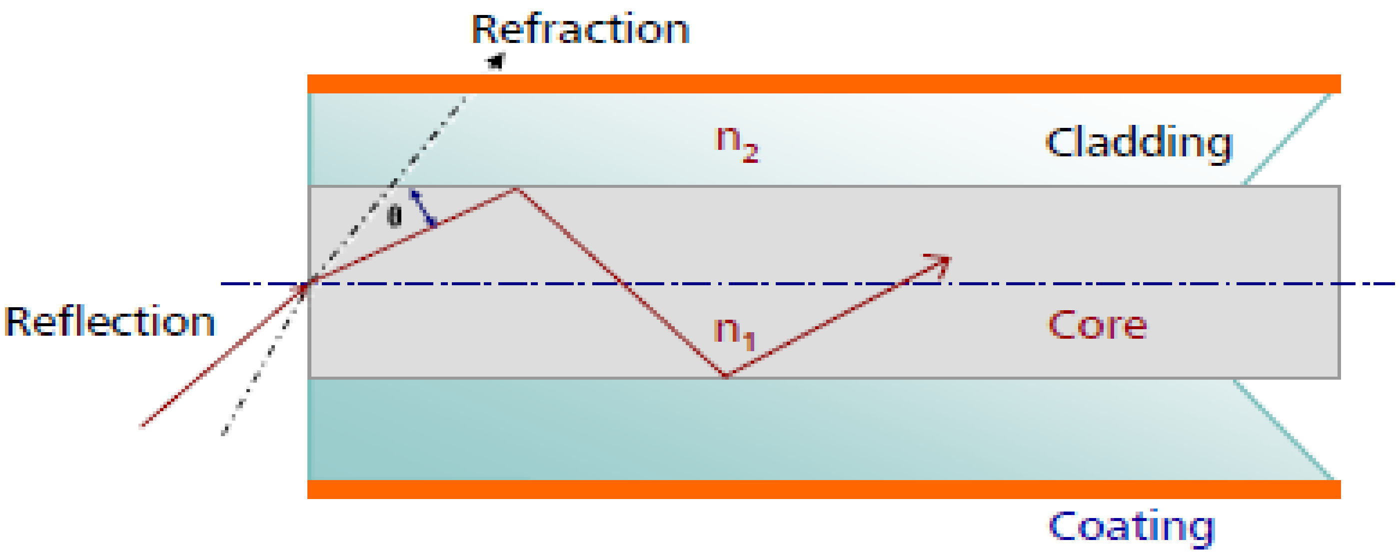
c. Peripherals - Connector, Patch Chords, ODF

Light Transmit Mechanism

The optical fiber transmits light by taking advantage of a phenomenon called **total internal reflection.**

Optical fiber is transparent glass and the **core** of the fiber has a higher refractive index than the **cladding**. The difference of refractive index cause the light to bounce of the cladding and stay within the core.

So, light entering the fiber with the proper angle gets totally reflected from the core/cladding interface. The light is then totally contained within the core and zigzags down the fiber.



Light Transmit Mechanism

Light propagation in an optical fiber is affected in many ways.
It also depends on the properties of the light entering the fiber, primarily its **wavelength** (but also its **intensity**, **polarization** and **bandwidth**).

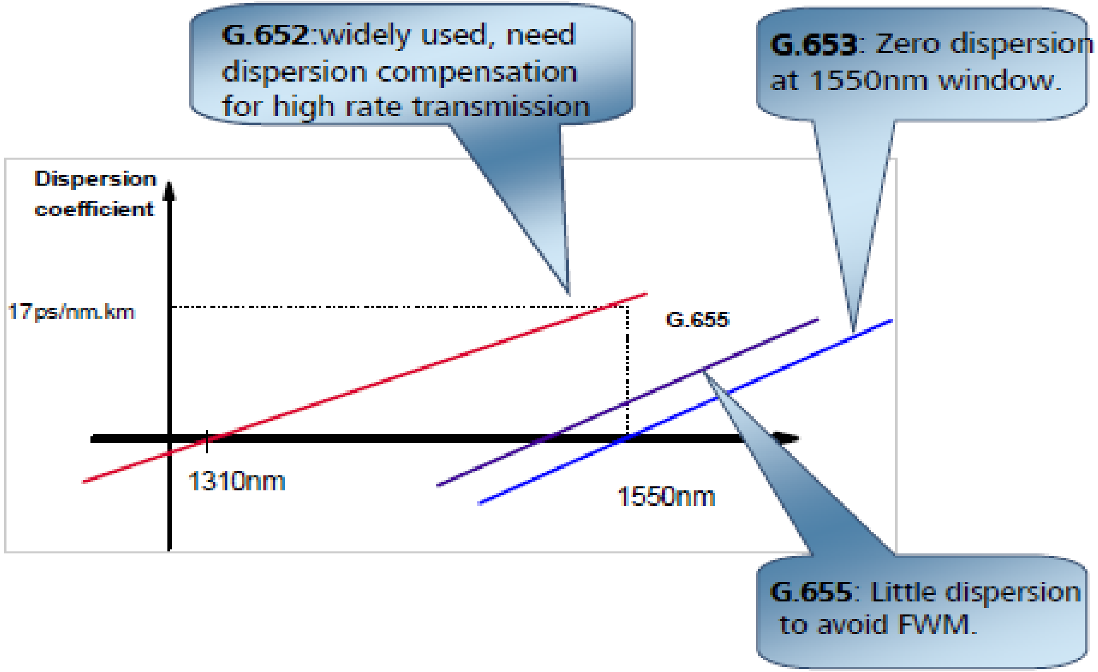
So, here are the main mechanisms that transform the light in the fiber –

1. Attenuation
2. Dispersion
3. Polarization
4. Nonlinearity

Type of Fiber

There are some fiber types which are used in DWDM transmission system.
G.652, G.654, G.655, G.657 A2

G.652 fiber is currently a
single mode fiber for widely use.
Though there is dispersion coefficient
But it effective than G.653 and G.655
Because of Non linear effect and
Four Wave mixing (FWM).



G.653 is zero dispersion fiber
but it needs regeneration after each
300km.

G.655 is nonzero dispersion shifted fiber.

G.657-A2 low attenuation 0.21 dB/km, low PMD for long-distance transmission, low bending loss.

Peripherals

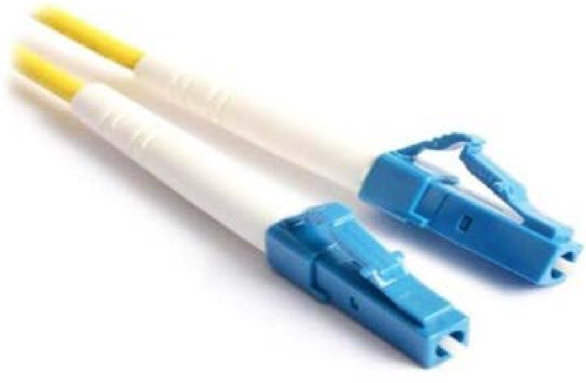
1. Connector
2. Patch Cords
3. ODF

FC Connector

SC Connector

The are 3 types of Connectors-

a) FC (Fiber Channel)
b) SC (Subscriber Connector)
c) LC (Lucent Connector)



LC Connector

Peripherals

Patch Cord

The are various types of Patch Cord -

a) FC- FC
b) FC- LC
c) LC-LC
d) SC- SC
e) SC- LC
f) FC- SC

FC-LC

LC-LC

SC-SC

FC-FC

SC-LC

FC-SC

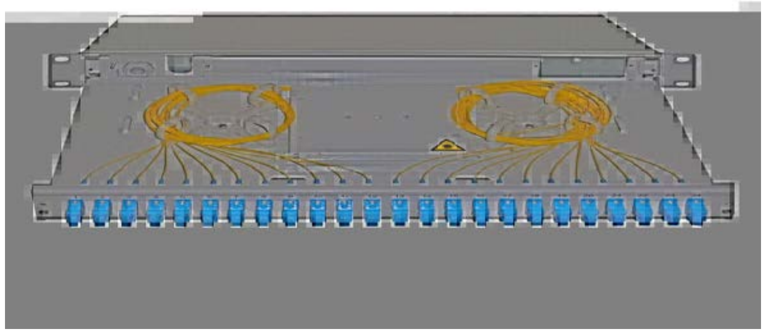
Peripherals

ODF- Optical Distribution Frame

There are number of FC or SC ports in ODF.
There ports are used to connect patch cord.

An ODF may consists of number of trays,
Each tray has 12 FC or SC ports.

A fiber tube is entered from behind of a ODF.
Each fiber core of that tube is spliced with a connector.



Topic 2: Fiber Characteristics

a. Wavelength Bands

b. Optical Power

c. Dispersion

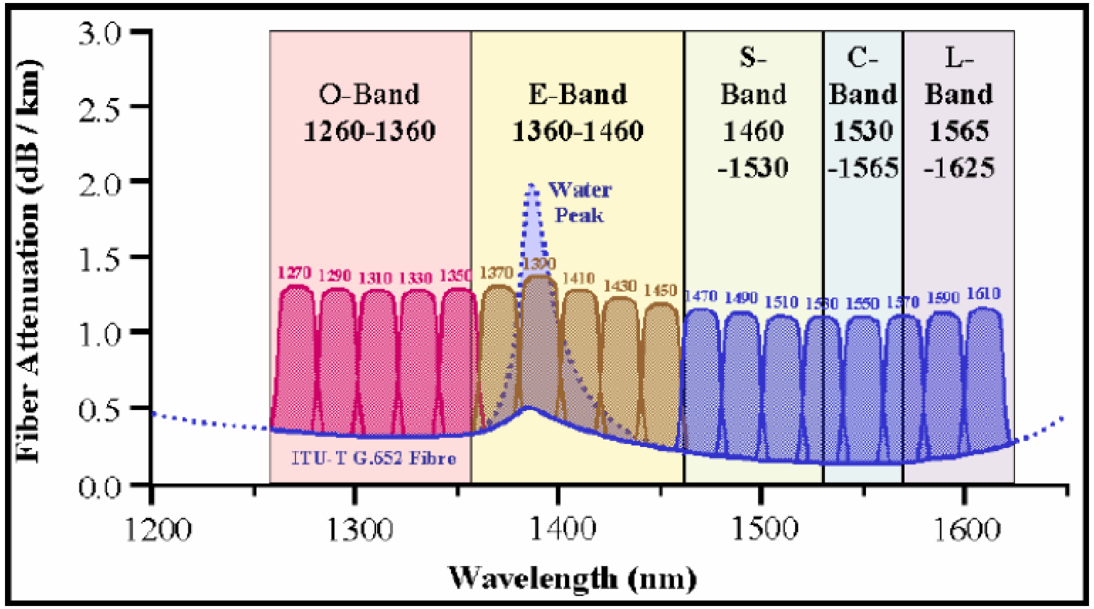
d. OSNR

Wavelength Bands

There are total 6 bands in fiber optic wavelength transmission system.

‘O’-band, ‘E’-band, ‘S’-band, ‘C’-band, ‘L’-band, and ‘U’-band

‘O’- band was developed for 850nm Laser with wavelength range 1260 to 1360 nm. Used in GPON network.
‘E’- band not popular due to high cost.



The “C-band” is developed to use 1550 nm wavelengths with lowest loss. “C-band” has increased after repeaters were replaced with fiber amplifiers. With DWDM (dense wavelength-division multiplexing) the impact of “C-band” became greater for ability to share single fiber using multiple wavelengths.

Wavelength Bands

- To take advantage of the lower loss at 1550 nm, fiber was developed for the C-band.

Band Name	Wavelengths	Description
O-band	1260 – 1360 nm	Original band, PON upstream
E-band	1360 – 1460 nm	Water peak band
S-band	1460 – 1530 nm	PON downstream
C-band	1530 – 1565 nm	Lowest attenuation, original WDM band, compatible with fiber amplifiers, CATV
L-band	1565 – 1625 nm	Low attenuation, expanded DWDM band
U-band	1625 – 1675 nm	Ultra-long wavelength

Optical Power

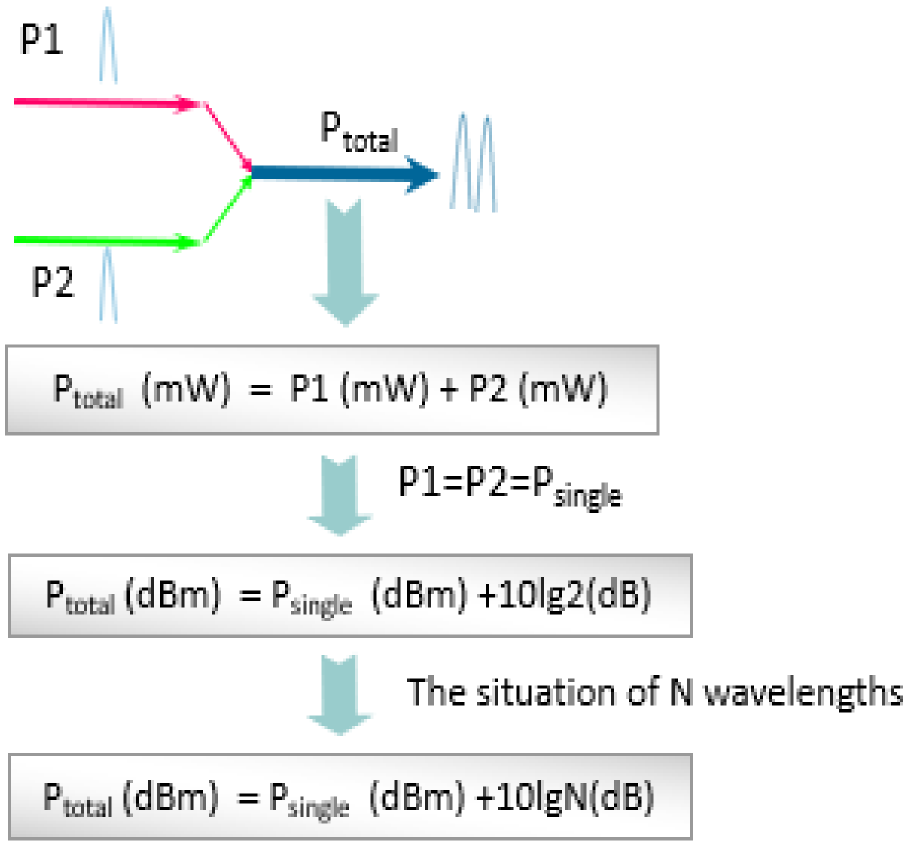
mW and dBm are the absolute value for optical power;
dB is the relative value for optical power.
When we describe the values of gain and attenuation, it is used.

0dBm = 1 mW
10dBm = 10 mW
20dBm = 100 mW

$$P\ (dBm) = 10\log\frac{P(mW)}{1(mW)}$$

So to convert mW to dBm suppose, for 100mW
P (dBm) = 10 log (100)= 2x 10 = 20 dBm

Another formula is to calculate optical power of each single wavelength. Here,
P_{total} means total wavelength power.
P1/P2 means single wavelength power.

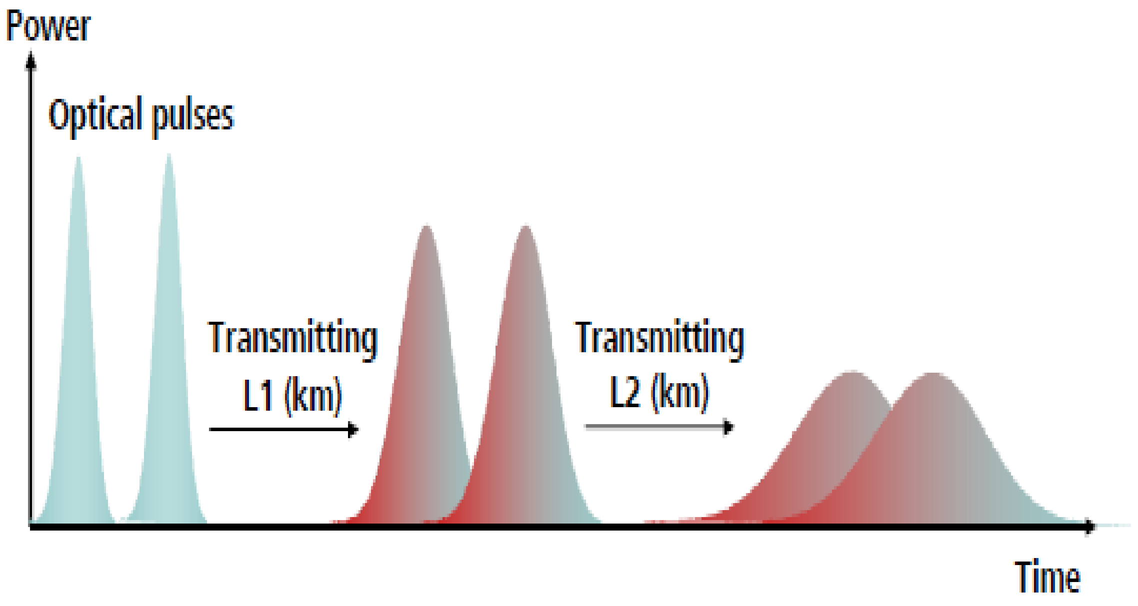


Dispersion

Dispersion in fiber refers to a physical phenomenon of signal distortion caused when various modes carrying signal energy or different frequencies of the signal have different group velocity and disperse or scatters or distracts from each other during propagation.

Two major types of Dispersion-

1. Chromatic Dispersion
2. Polarization Mode Dispersion



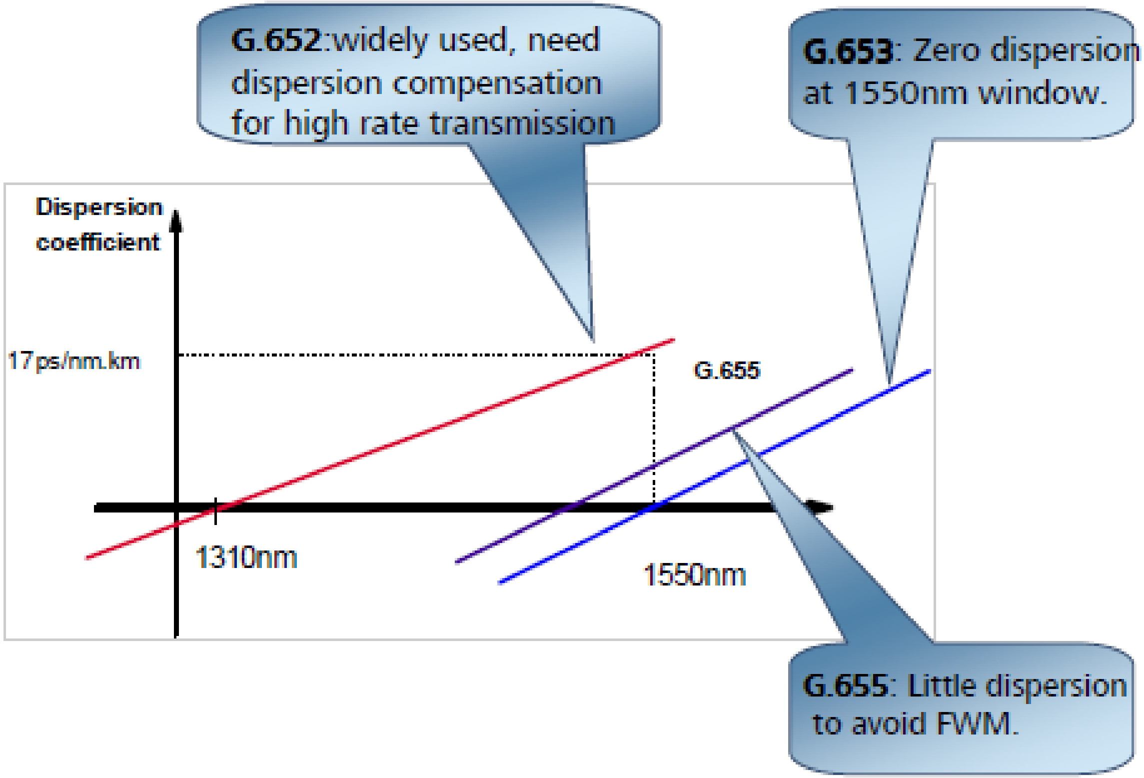
Chromatic Dispersion

Chromatic dispersion is measured in ps/nm/km, meaning that for every km of fiber traveled through, a pulse with a 1 nm spread of wavelengths will disperse by 1 ps for a dispersion of 1 ps/nm/km.

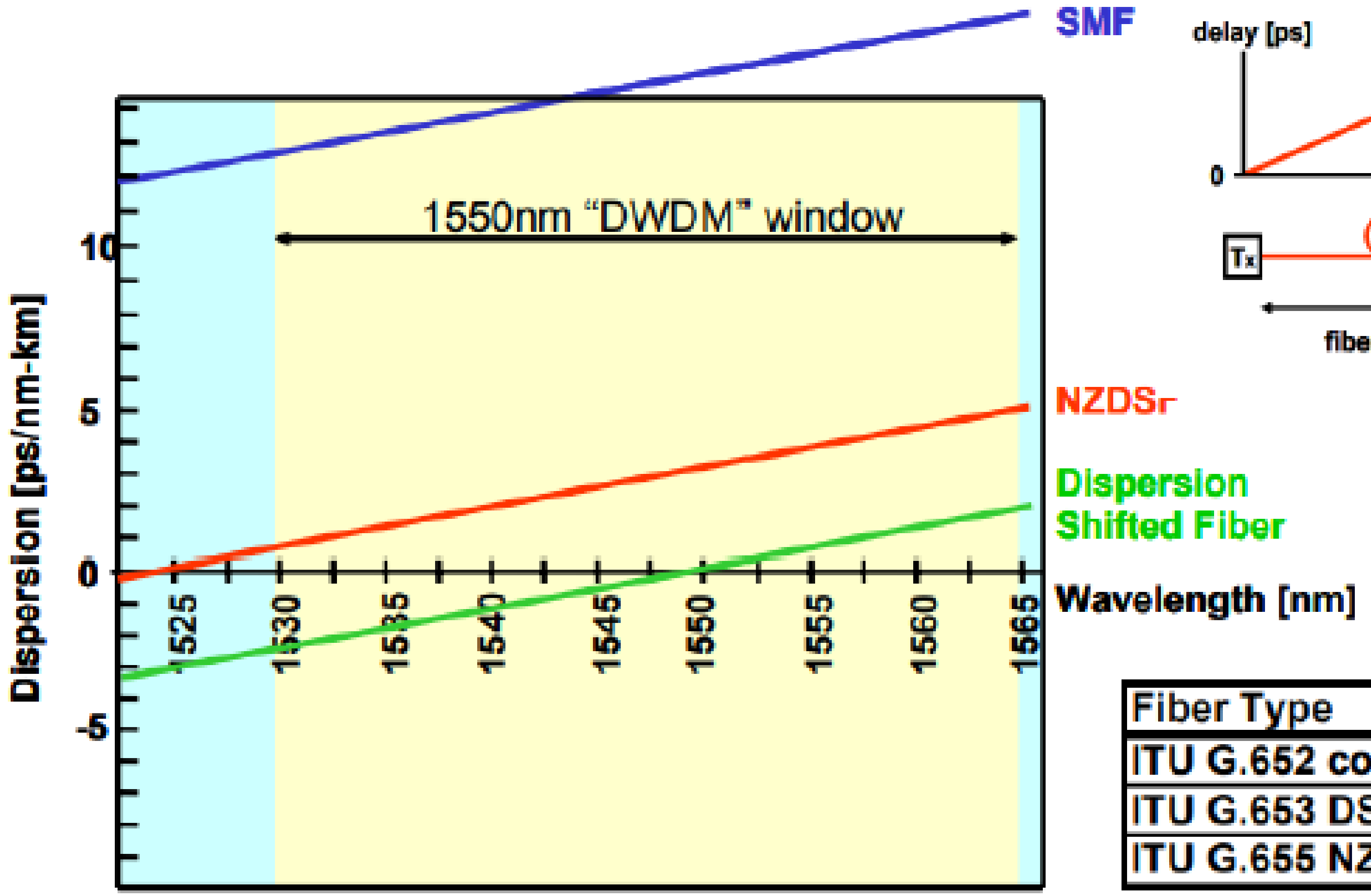
With a 1 ps/nm/km chromatic dispersion, a 10-Gbit/s pulse with a 0.2nm spectral width will have spread by a whole bit period (100 ps) after 500 km of fiber.

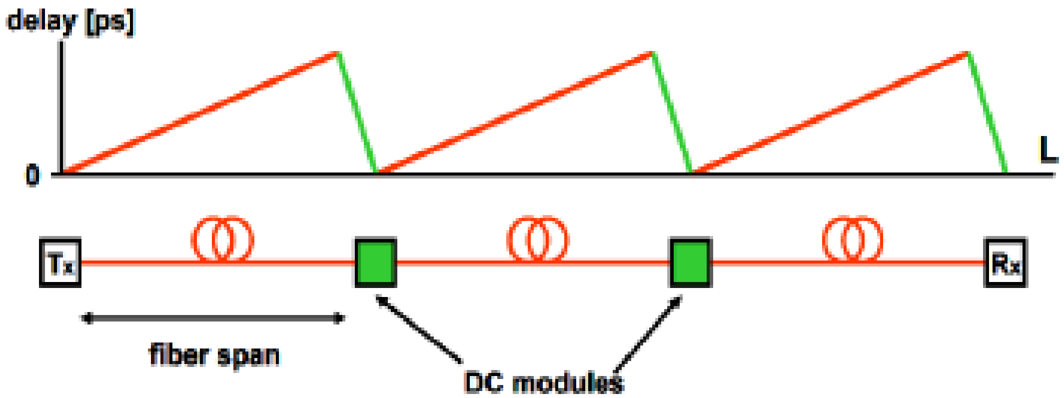
G.652 widely used, need dispersion compensation for high rate transmission

The dispersion coefficient of G.652 at 1550 nm is 17 ps/nm.km
And for G.655 it is 1 to 6 ps/nm.km



Dispersion Compensation Fiber (DCF)

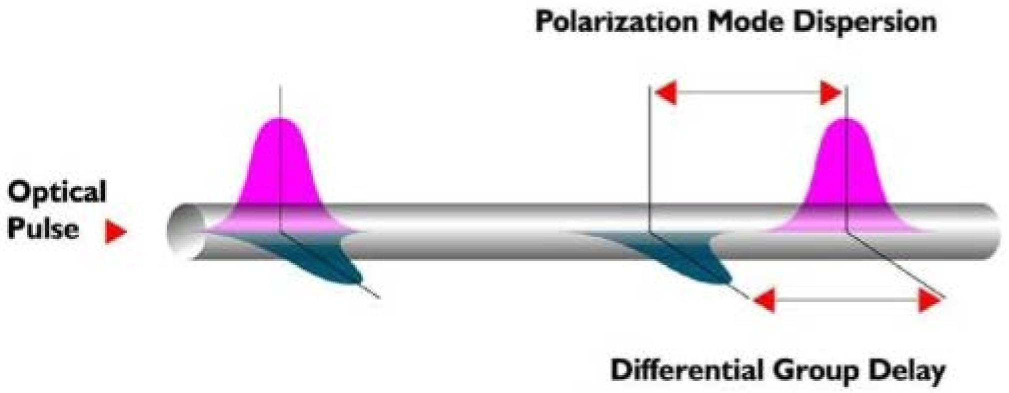




Fiber Type	Chromatic Dispersion ps / (nm * km) 1310 nm	1550 nm
ITU G.652 conventional	0	17
ITU G.653 DSF	-15	0
ITU G.655 NZDSF	-12	3

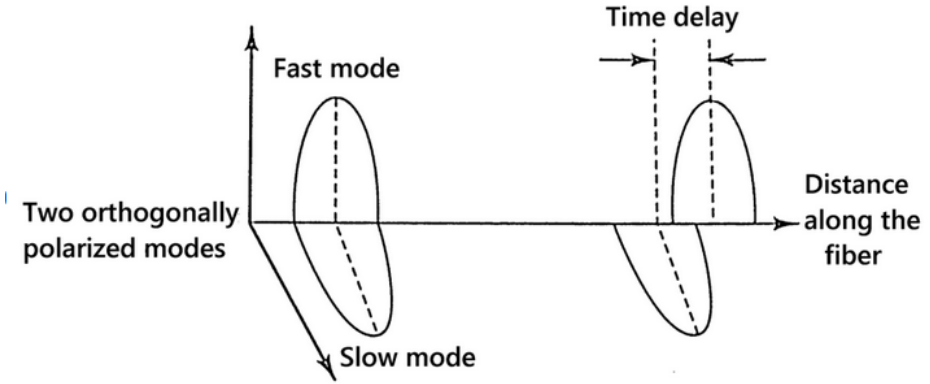
Polarization Mode Dispersion

In optical fiber, there is usually some slight difference in the propagation characteristics of light waves with different polarization states.



In a fiber, the cross section of fiber core may take **shape of ellipse** due to manufacturing Technology.

And the anisotropic stress of cross section of core resulting from **inhomogeneous thermal expansion coefficient** of material may lead to anisotropy of refractive index.



Both these circumstances cause the difference In two polarization mode propagation velocities and **different group delays** which lead to Polarization Mode Dispersion.

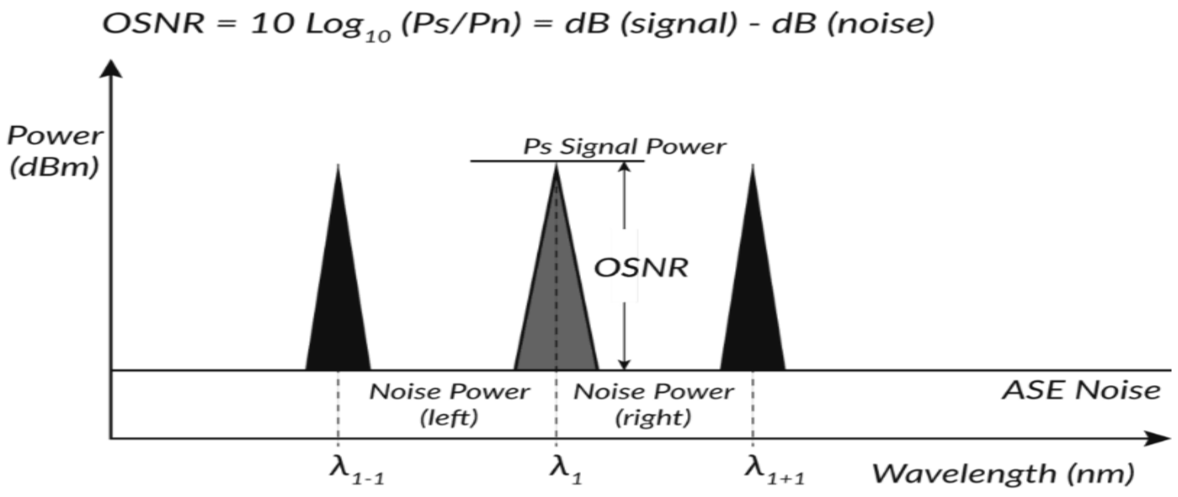
OSNR

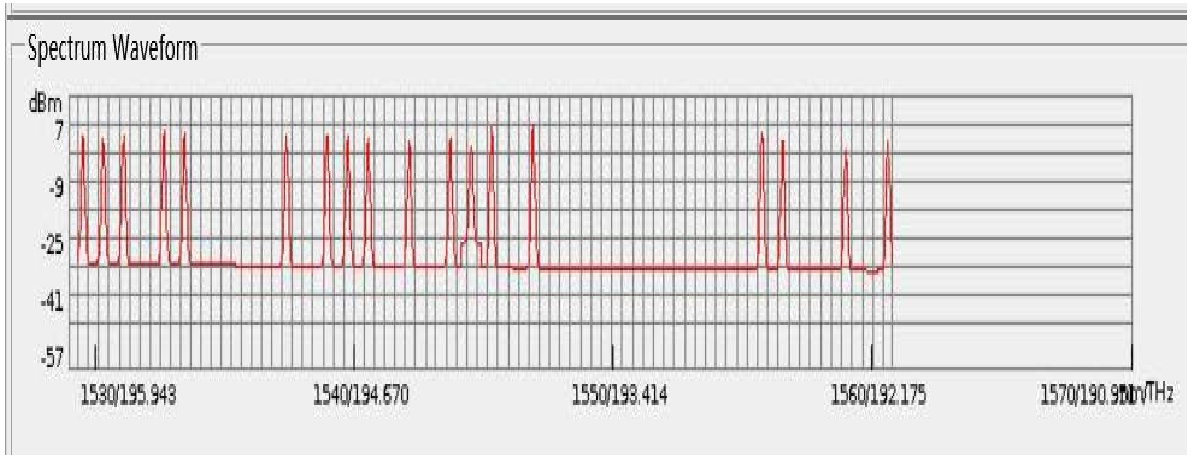
OSNR is Optical Signal to Noise Ratio.
It is used to quantify degree of optical noise interference on optical signals. It is the ratio of signal power to noise power within valid bandwidth.

The OSNR values that matter the most are at the receiver, because a low OSNR value means that the receiver will probably not detect or recover the signal.

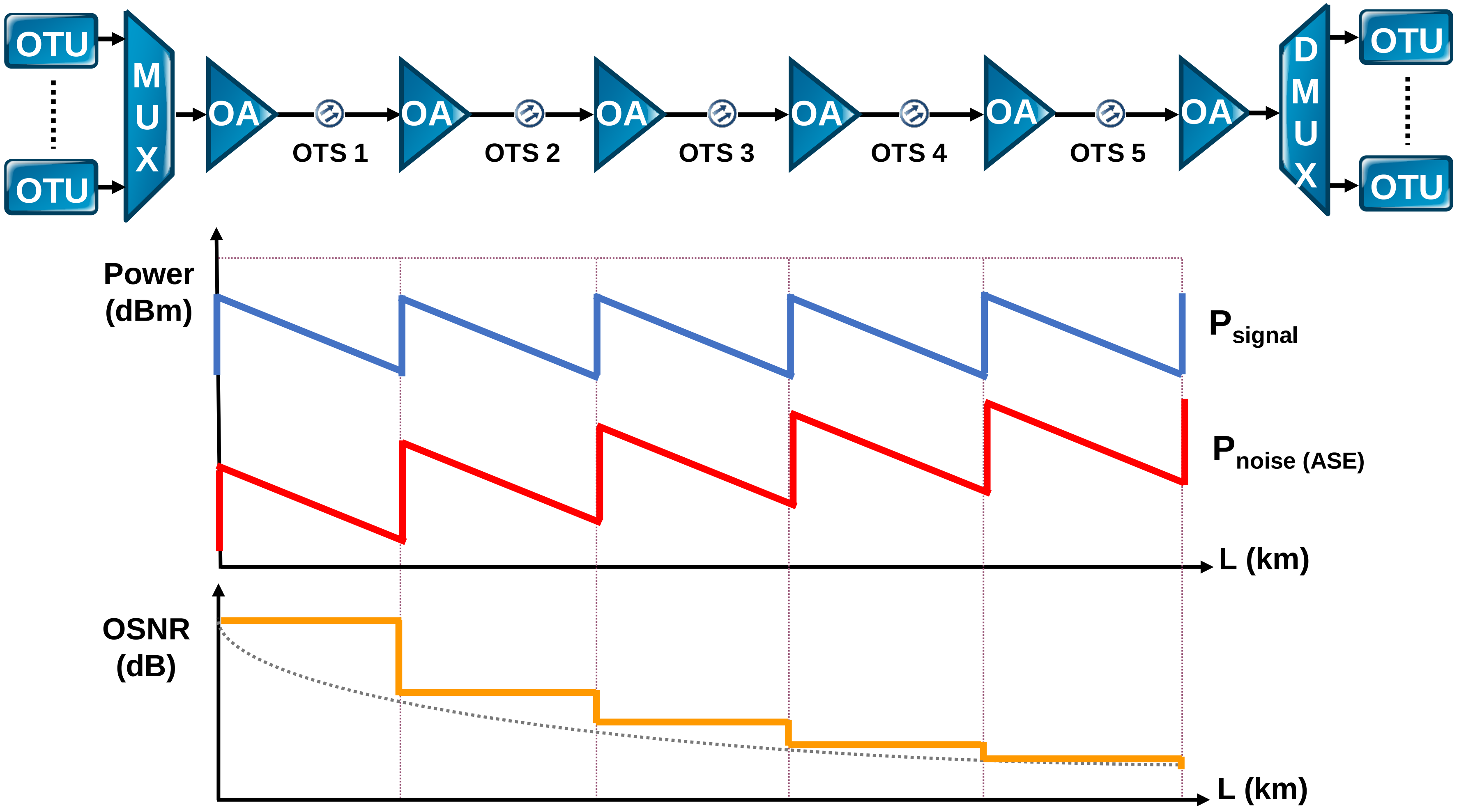
There exists a direct relationship between OSNR and bit error rate (BER), where BER is the ultimate value to measure the signal quality of long distance fiber transmission.

At receiving end minimum OSNR value required to recover or detect a signal.





OSNR



OTU
OTU
M U X
OA
OTS 1
OA
OTS 2
OA
OTS 3
OA
OTS 4
OA
OTS 5
OA
D M U X
OTU
OTU
Power (dBm)
P_{signal}
$P_{noise\ (ASE)}$
L (km)
OSNR (dB)
L (km)

DWDM Fundamentals

Topic 3: Introduction to WDM

a. Optical Splitting

b. CWDM vs DWDM

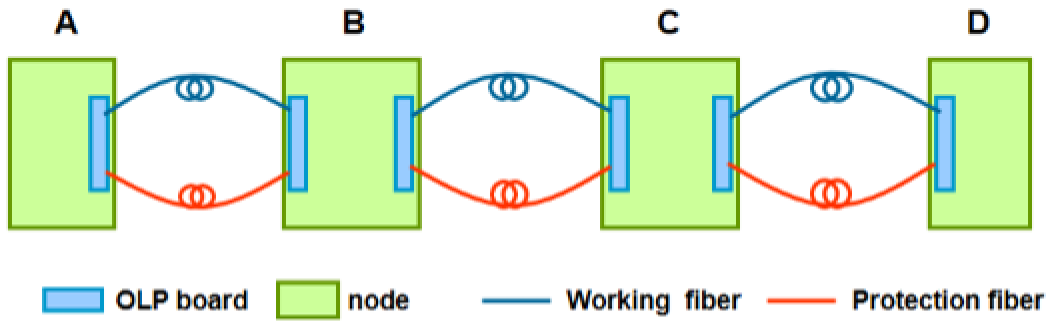
c. WDM in GPON - Triple Play

Optical Splitting

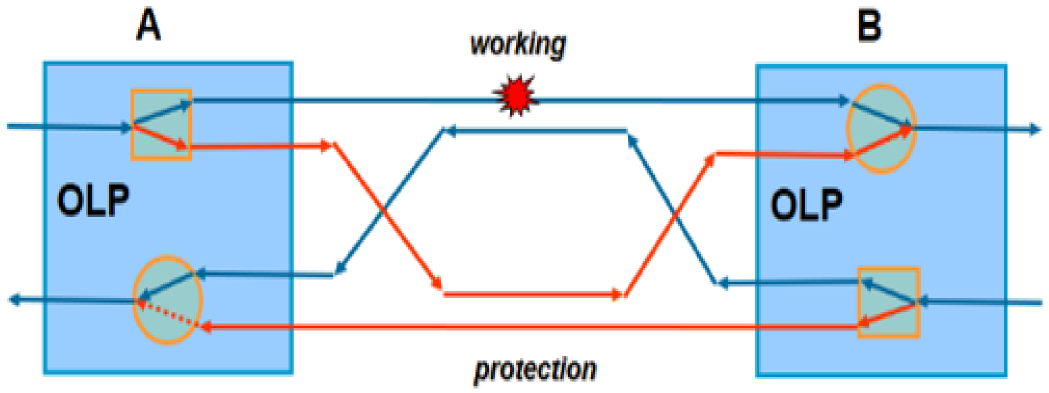
Common type of optical splitting -
Example OLP- Optical Line Protection
Used in DWDM to protect lambda signal.

OLP is port level protection.
OLP board performs concurrent sending
And selective receiving of signals.

Concurrent Sending --- splitter
Selective Receiving– optical switching



- Switching & restoration



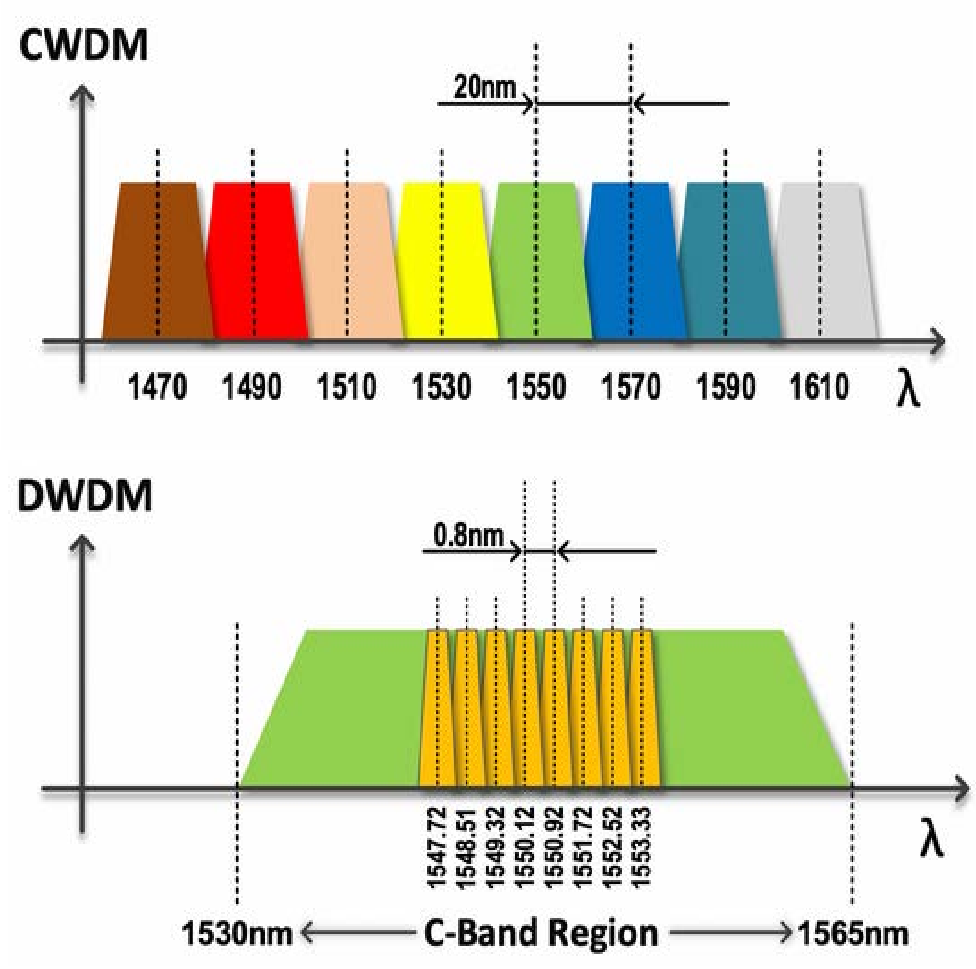
CWDM vs DWDM

CWDM- Coarse wavelength division multiplexing
DWDM- Dense wavelength division multiplexing

	Channel spacing	Wavelength (nm)	capacity	Application
CWDM	20 nm	1470~1611	40G	100 km
DWDM	0.8 nm	C –band 1529~1561	>4.8T	2000 km

Generally, CWDM is used for lower cost, lower capacity (sub-10G) and shorter distance applications where cost is an important factor.

DWDM supports 120 km long transmission span. provide up to 400G per lambda, amplify whole C- band with EDFA and supports 96 channels at 0.8 nm apart.



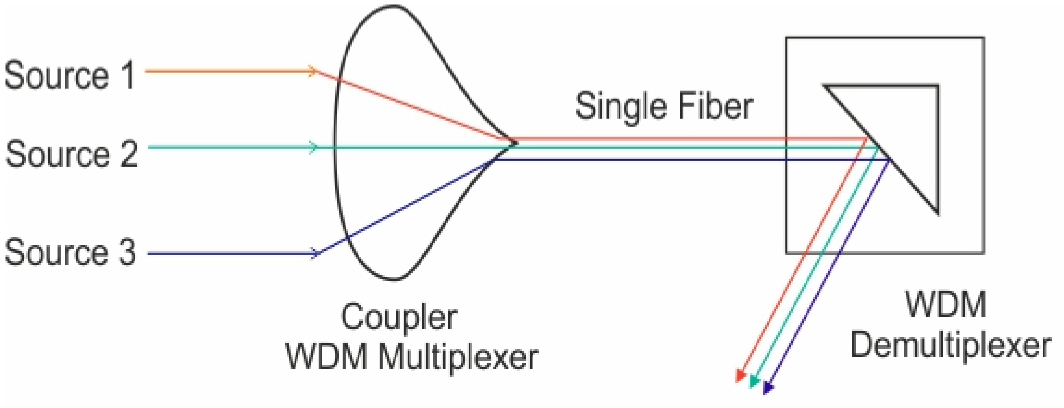
WDM in GPON

The phenomena of WDM is based on coupler and Prism(WDM Demultiplexer).

Different colors of light goes into the coupler, Coupler combines the colors and gives a single Fiber output.

At receiving end a prism is installed which gets signal input by single fiber and reflects white light into different color at different angle.

Here different colors are different data streams.

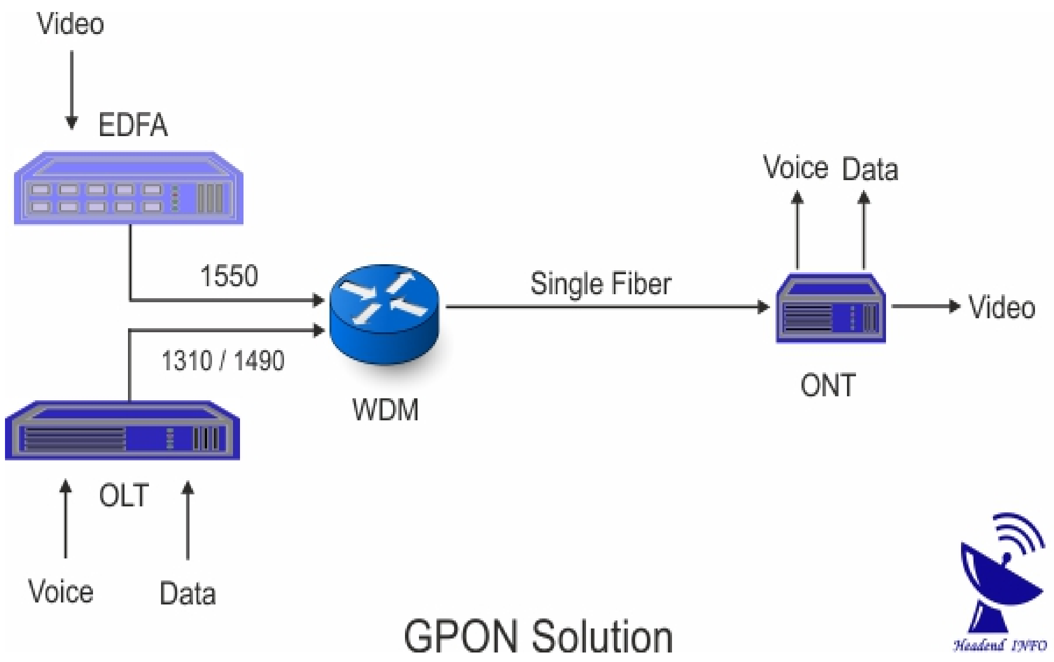


WDM in GPON

WDM plays very important role in GPON solution.

In the figure WDM is installed after EDFA and OLT.
Where EDFA gives CATV input at **1550** nm to WDM.
OLT gives Data/Voice input to WDM at **1310** nm.

Now WDM combines the different wavelength of
Data stream and provides the single output of
Optical fiber.



At the receiving the ONT takes these combined data
streams and provide different output wavelengths
For different application like Data, Voice and CATV.

The **benefit of WDM**, it reduces cost and complexity of fiber,
Maintenance of fiber as well.

WDM in GPON - Triple Play

In the network of integration of three networks, the FTTH CATV system’s signal is transmitted in the same fiber with the upstream and downstream optical signals of the PON system by adopting WDM technology.

There are two kinds of downstream signals:

CATV PON data signal with an optical wavelength of 1490nm
and CATV broadcast signal with an optical wavelength of 1550nm.

In upstream, there is a CATV PON data signal with a wavelength of 1310nm.

The main components of PON system are-

1. EDFA
2. OLT
3. WDM Passive device
4. ONU
5. ODN

WDM in GPON - Triple Play

OLT at local side is the core of the CATV PON system. It provides uplink for information accessing, including voice, data, for passive optical distribution network.

OLT is control center of CATV PON system by which the network management system performs operations, management, maintenance of the CATV PON system.

EDFA amplifies the received CATV front signal then transmits it. Its uplink interface connects the FTTH CATV front-end optical transmitter, and the downlink interface connects the input port of the WDM device.

WDM is passive device between OLT/EDFA and ODN with function of multiplexing CATV downstream signal and PON signal of upstream and downstream together.

WDM in GPON - Triple Play

ODN network between OLT and ONU, which is passive optical distribution network consisting of optical splitter and optical fiber, distributes and converges optical signals.

ODN network forwards downstream data to each ONU terminal and aggregates upstream data into the OLT.

The integration of three networks is mainly for the construction of broadcast television networks and provides fiber access the “last mile”.

DWDM Fundamentals

Topic 4: DWDM

a. Wavelength & Channel Spacing

b. MUX/DMUX

c. Generic System Structure

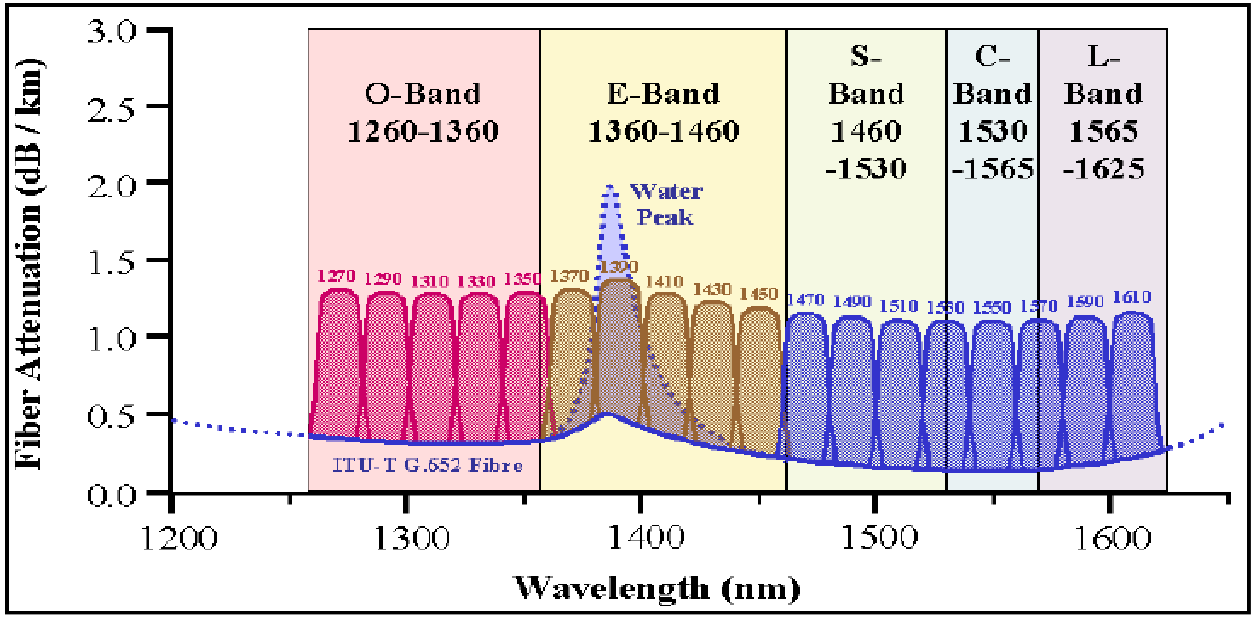
d. Amplifiers - EDFA & RAMAN

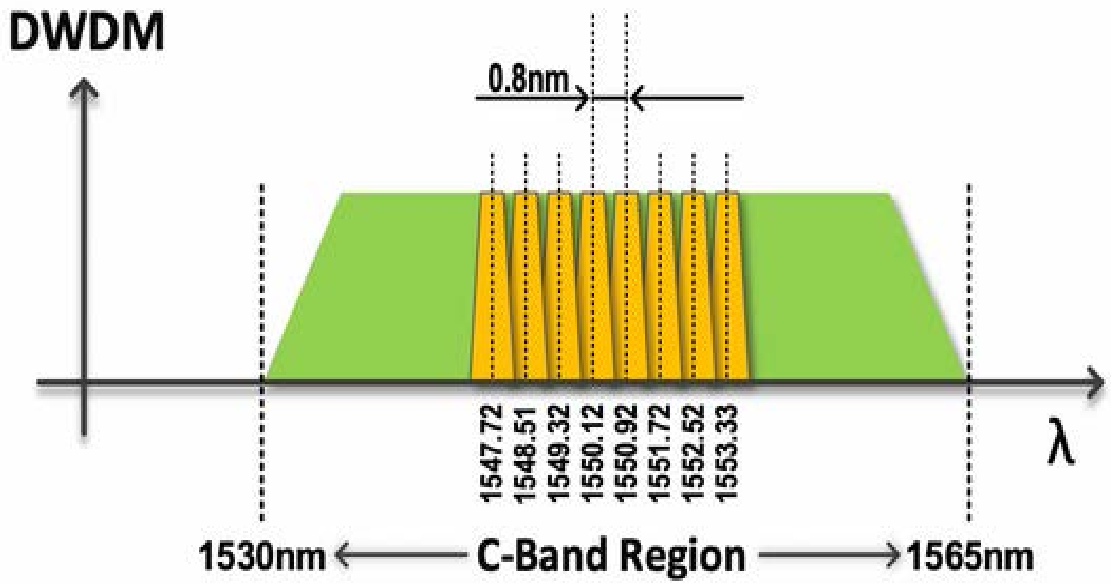
f. OTN Architecture

g. Transponder

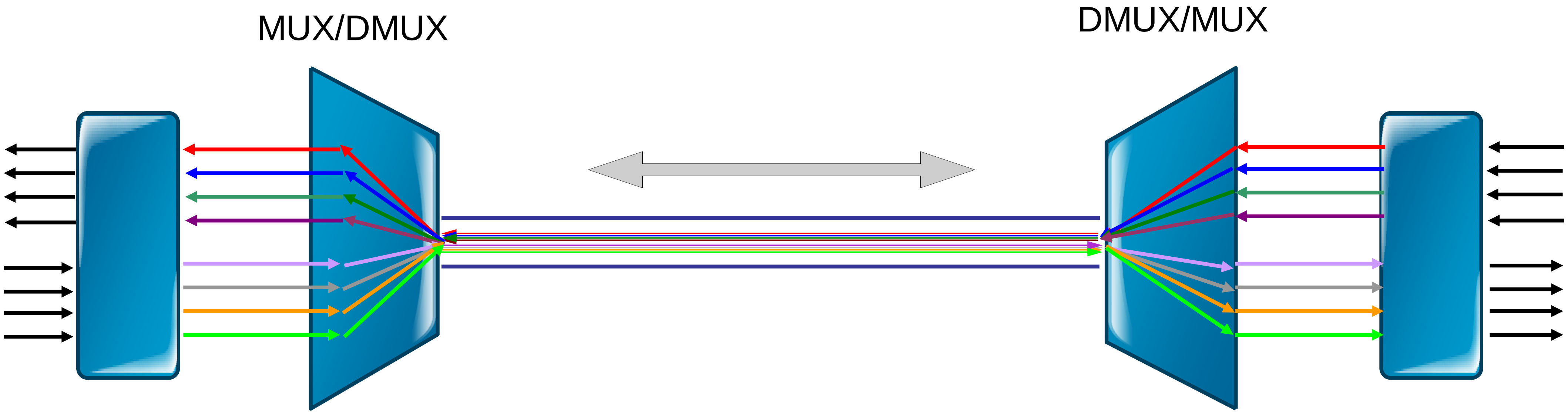
h. Muxponder

Wavelength & Channel Spacing





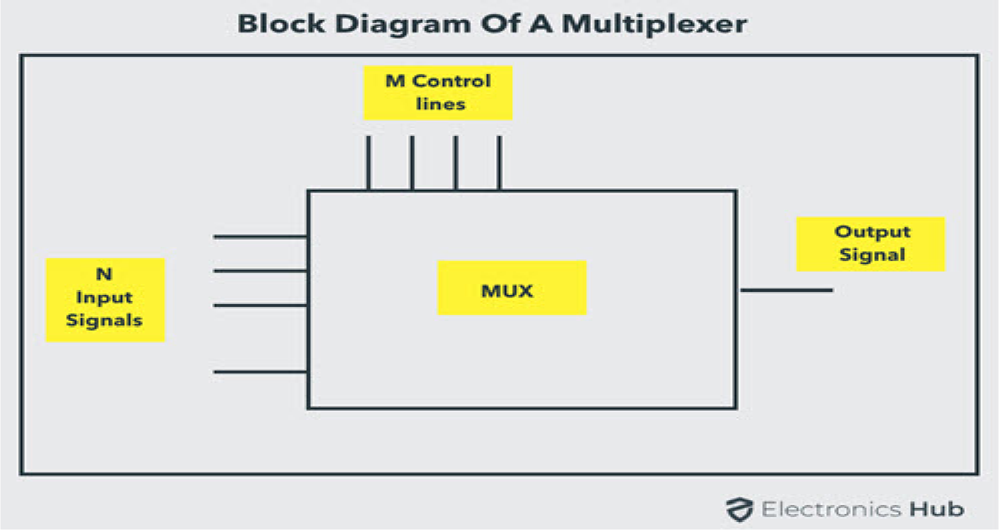
Wavelength & Channel Spacing



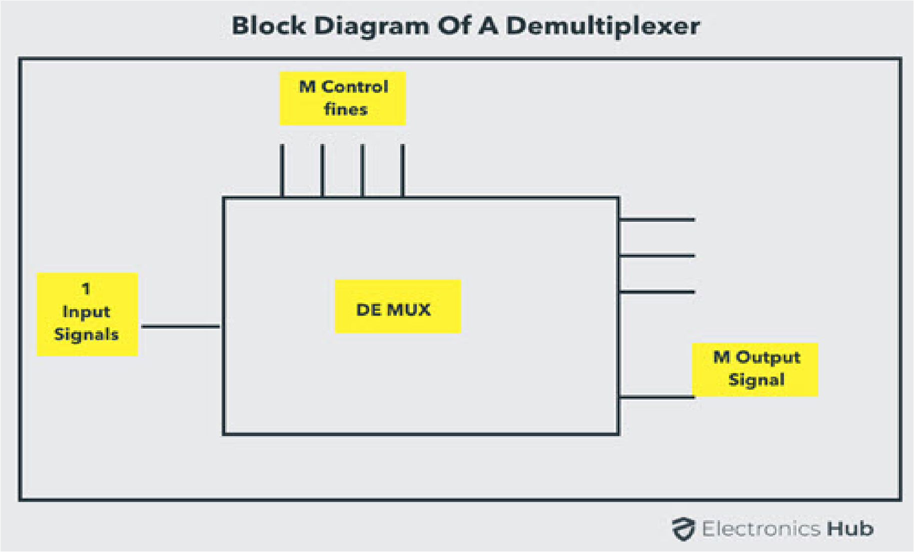
DWDM highlights

- Up to 96 DWDM wavelength over one pair of fiber
- DWDM channel spacing 0.8 nm (100 GHz grid) or 0.4 nm (50 GHz grid)
- Distances over 2,000 km can be achieved with the use of optical amplifier
- DWDM wavelength: 1528 nm to 1563 nm

MUX-DEMUX



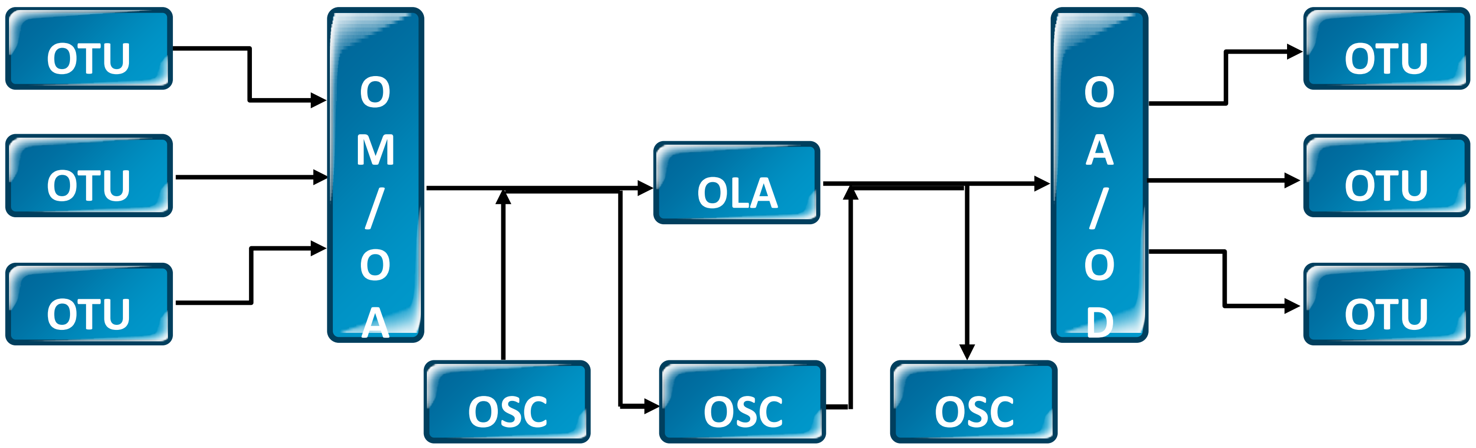
Multiplexer means many into one. A multiplexer is a circuit used to select and route any one of the several input signals to a single output.



Demultiplexer means one to many. A demultiplexer is a circuit with one input and many outputs. By applying control signal, we can steer any input to the output.

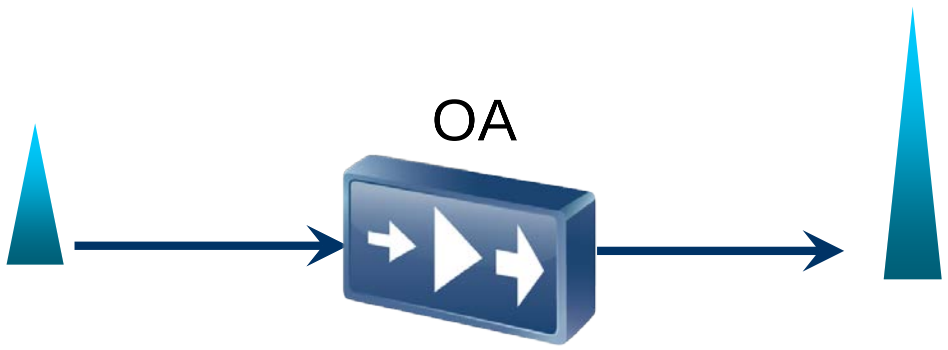
System Structure

- The overall structure of the WDM system of N-path wavelength:
  - Optical Transponder Unit (OTU)
  - Optical Multiplexer Unit / Optical De-multiplexer Unit (OMU/ODU)
  - Optical Amplifier (OA)
  - Supervisory Channel (OSC/ESC)

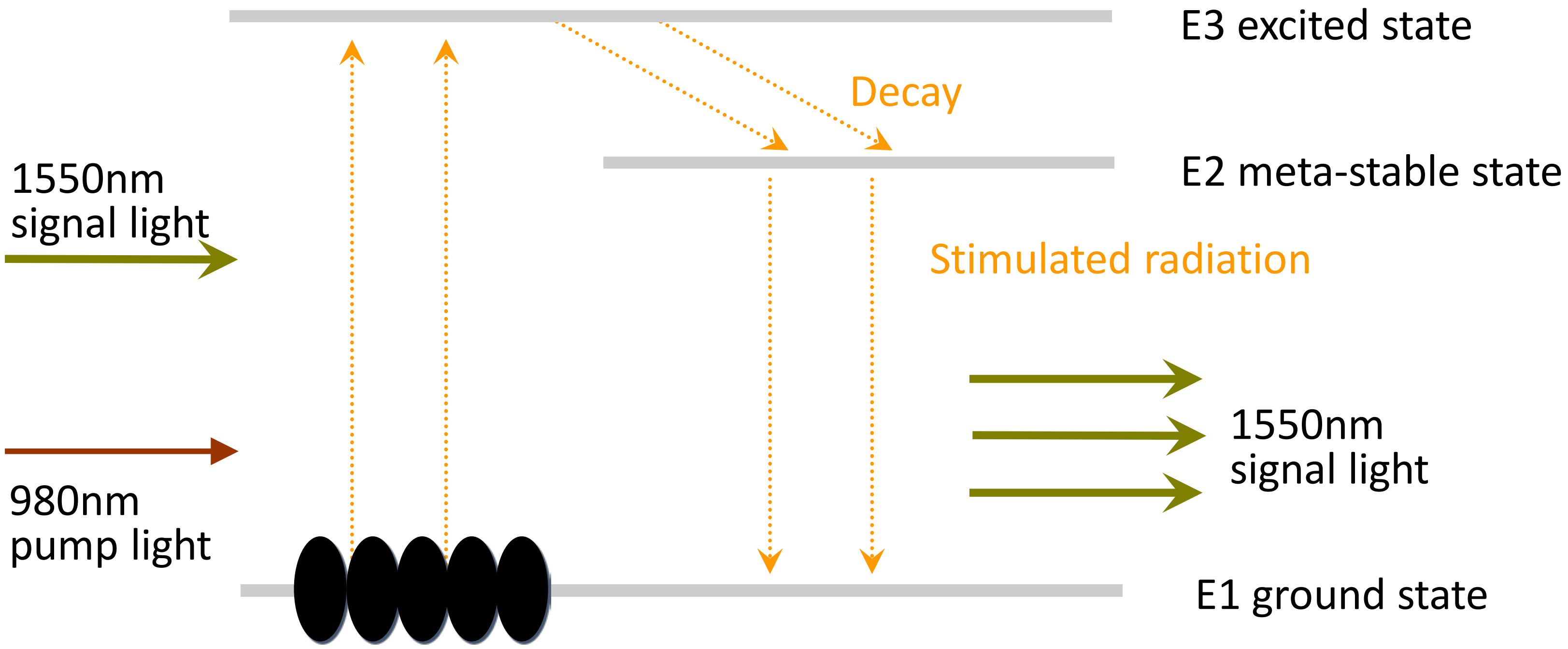


Optical Amplifiers

EDFA	Erbium Doped Fiber Amplifier
RFA	Raman Fiber Amplifier

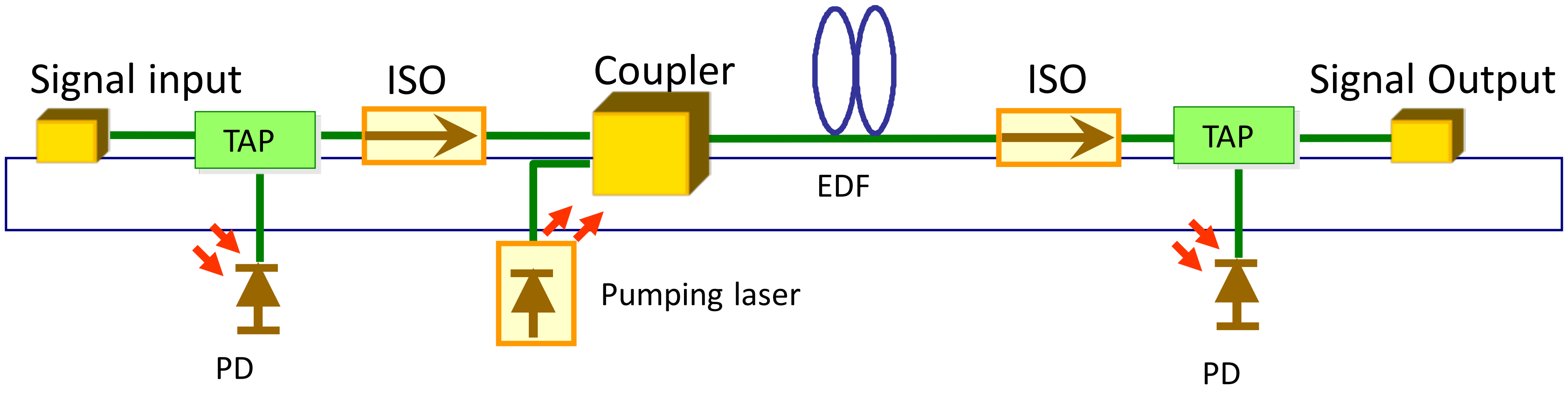


Erbium Doped Fiber Amplifier



- Er^{3+} energy level diagram

Structure of EDFA



ISO: Isolator

PD: Photon Detector

Features of EDFA

Advantages

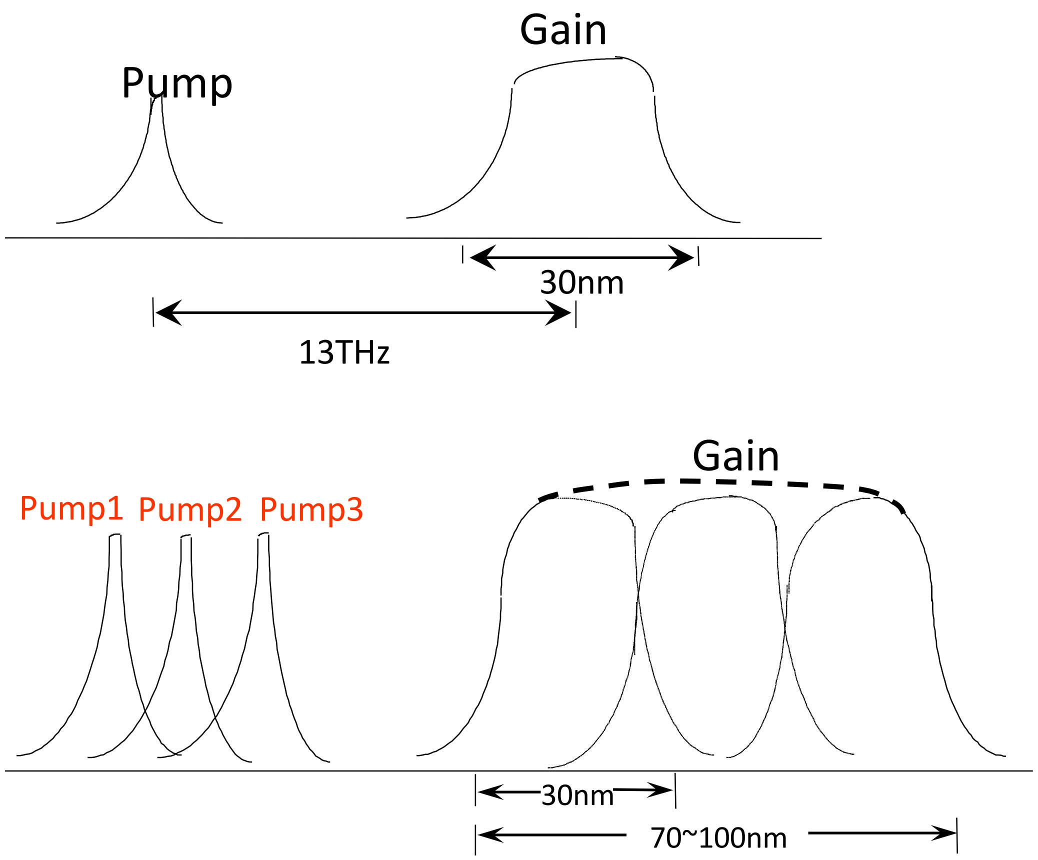
- Consistent with the low attenuation window
- High energy conversion efficiency
- High gain with little cross-talk
- Good gain stability

Disadvantages

- Fixed gain range
- Gain un-flatness
- Optical surge problem

Raman Fiber Amplifier

- Stimulated Raman Scattering



Features of Raman

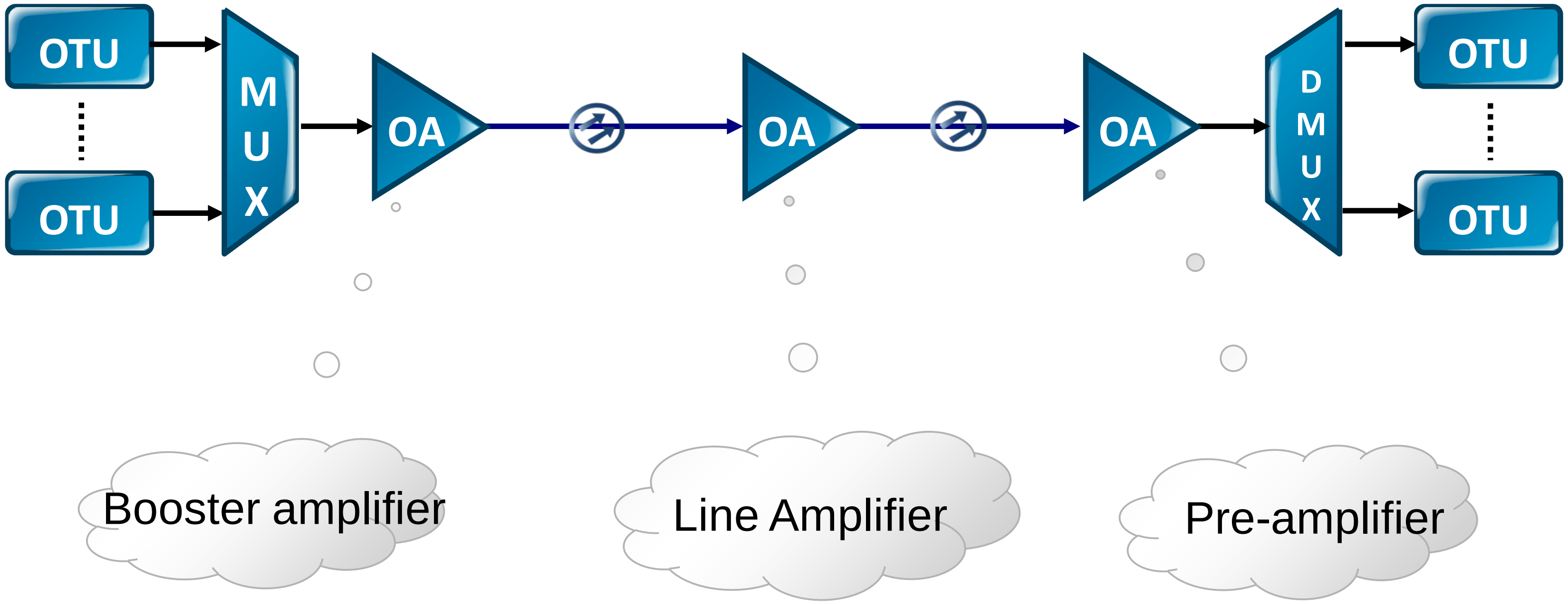
Advantages

- Flexible gain wavelength
- Simple structure
- Nonlinear effect can be reduced;
- Low noise

Disadvantages

- High pump power, low efficiency and high cost;
- Components & fiber undertake the high power;

Application of OA



OTN

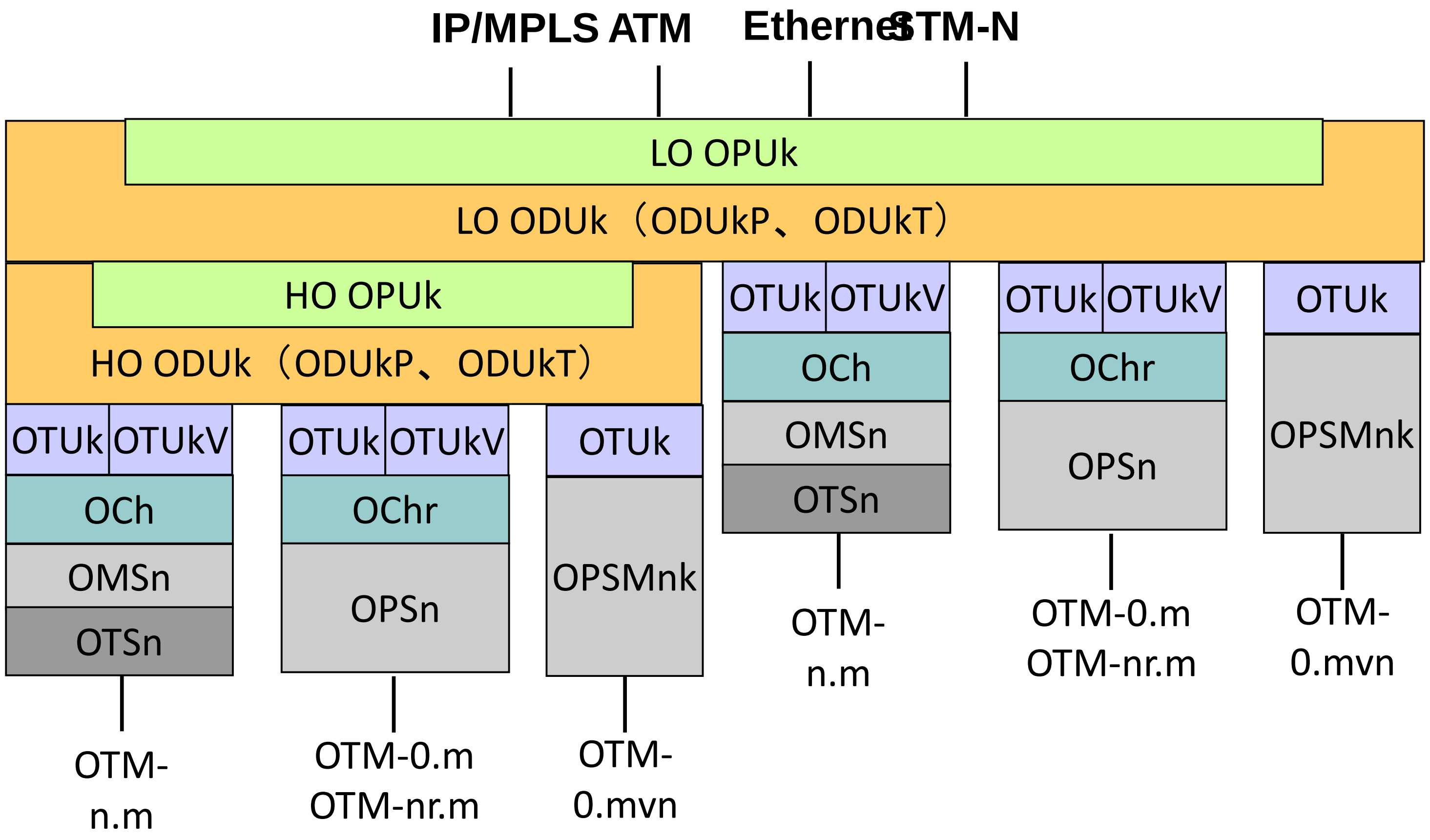
- OTN（Optical Transport Network）
  - An Optical Transport Network (OTN) is composed of a set of Optical Network Elements connected by optical fiber links, able to provide functionality of transport, multiplexing, routing, management, supervision and survivability of client signals.

Features of OTN

- **Compared with SDH and SONET ：**
  - Ultra capacity with high accuracy, Terabit/second per fiber via DWDM lines
  - Service transparency for client signals
  - Asynchronous mapping, powerful FEC function, predigest network design and reduce the cost

- **Compared with traditional WDM**
  - Enhanced OAM & networking functionality for all services
  - Dynamically electrical/optical layer grooming

OTN network layers and interface structure



OPUk: Optical channel Payload Unit-k

ODUk: Optical channel Data Unit-k

OTUk: completely standardized Optical channel Transport Unit-k

OTUkV: functionally standardized Optical channel Transport Unit-k

OCh: Optical Channel with full functionality

OChr: Optical Channel with reduced functionality

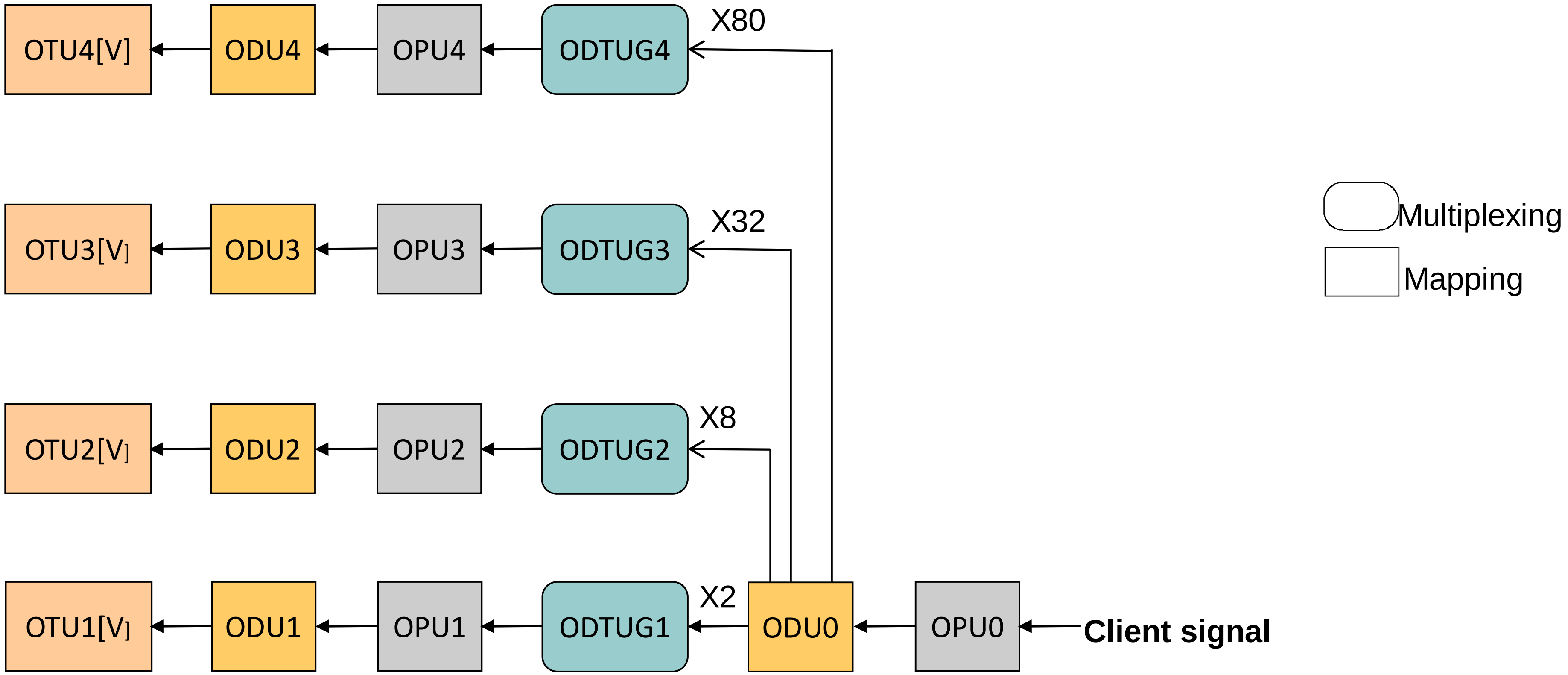
OMS: Optical Multiplex Section

OTS: Optical Transmission Section

OPS: Optical Physical Section

OTM: Optical Transport Module

ODUk multiplexing and mapping structure

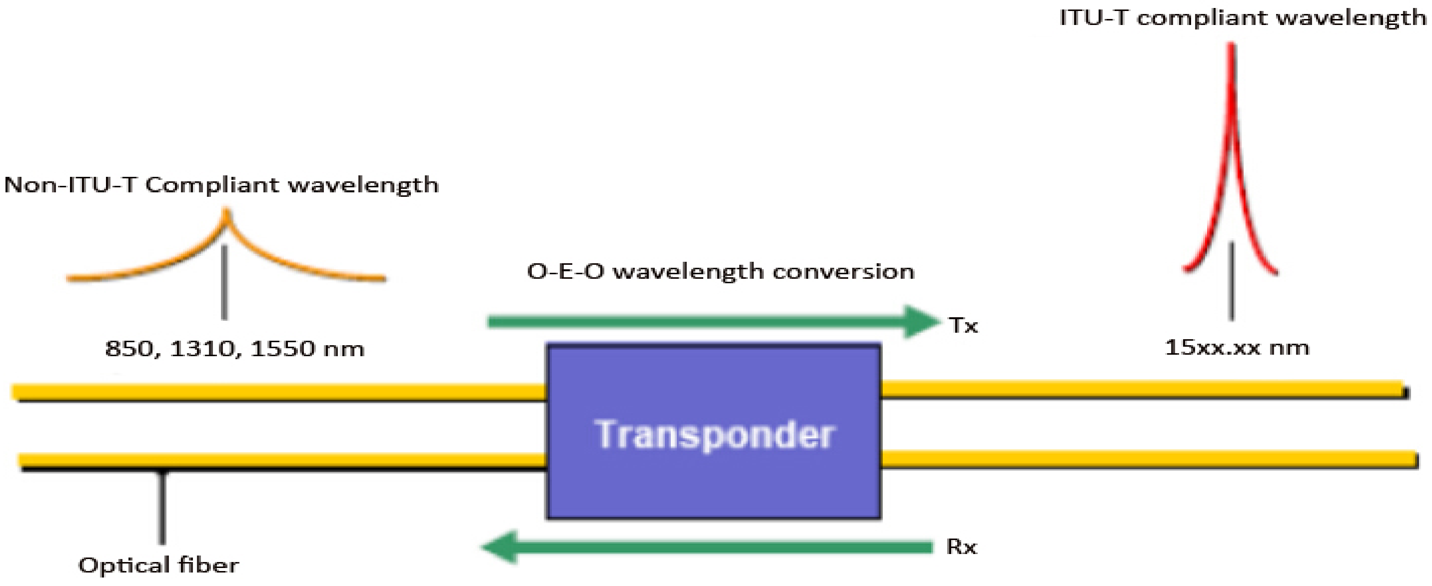


ODUk multiplexing and mapping structure

Signal	Data Rate (Gbit/s)	Typical Applications
ODU0	1.24416	Transport of a timing transparent transcoded (compressed) 1000BASE-X signal[3] or a stream of packets (such as Ethernet, MPLS or IP) using Generic Framing Procedure
ODU1	2.498775126	Transport of two ODU0 signals or a STS-48/STM-16 signal or a stream of packets (such as Ethernet, MPLS or IP) using Generic Framing Procedure.
ODU2	10.03727392	Transport of up to eight ODU0 signals or up to four ODU1 signals or a STS-192/STM-64 signal or a WAN PHY (10GBASE-W) or a stream of packets (such as Ethernet, MPLS or IP) using Generic Framing Procedure
ODU3	40.31921898	Transport of up to 32 ODU0 signals or up to 16 ODU1 signals or up to four ODU2 signals or a STS-768/STM-256 signal or a timing transparent transcoded 40 Gigabit Ethernet signal or a stream of packets (such as Ethernet, MPLS or IP) using Generic Framing Procedure
ODU4	104.7944458	Transport of up to 80 ODU0 signals or up to 40 ODU1 signals or up to ten ODU2 signals or up to two ODU3 signals or a 100 Gigabit Ethernet signal

Transponder

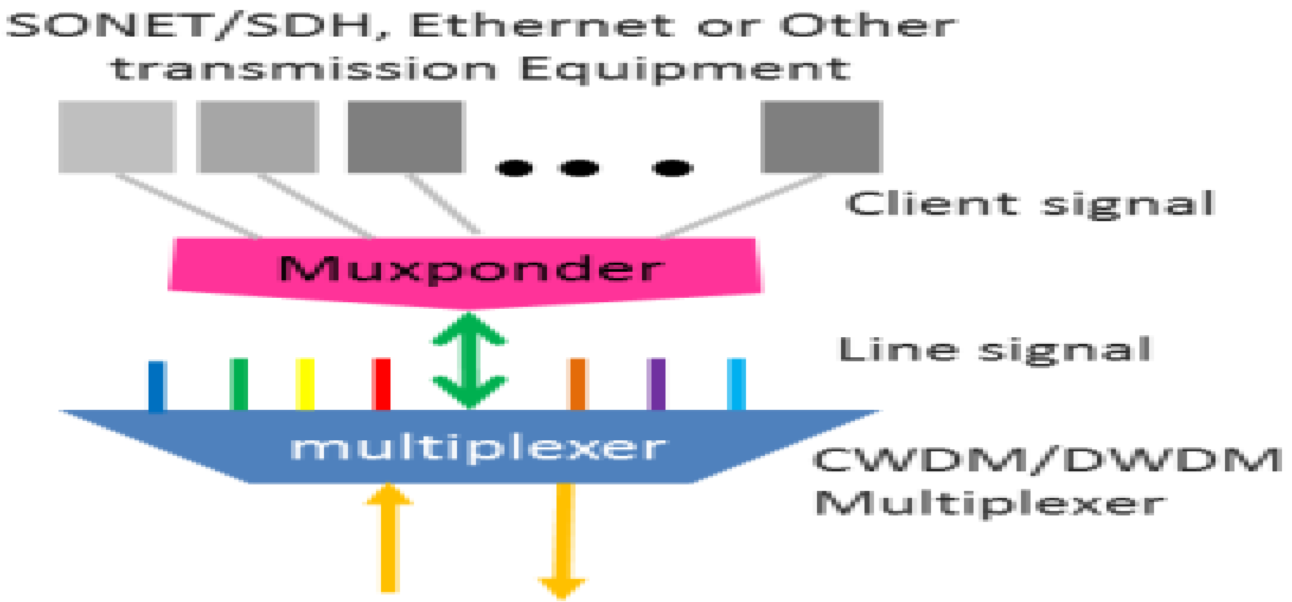
WDM transponder is an optical-electrical-optical (O-E-O) wavelength converters that are designed to perform an O-E-O operation to convert wavelengths of light. Figure shows bidirectional transponder operation (the transponder is located between a client device and a DWDM system). From left to right, the transponder receives an optical bit stream operating at one particular wavelength (1310 nm). And then it converts the operating wavelength of the incoming bitstream to an ITU-compliant wavelength and transmits its output into a DWDM system. On the receive side (right to left), the process is reversed. The transponder receives an ITU-compliant bit stream and converts the signals back to the wavelength used by the client device.



Muxponder

The muxponder are a great way to support many lower data rate services with a single fiber or fiber pair. The main feature of muxponder is being aggregation and Ethernet switching.

Muxponders use pluggable transceivers (SFPs on the client side and XFPs on the line side) so they can be used in a wide variety of applications. Clients can be electrical or optical (1310 or 1550 nm), co-located or some distance away. Line side interfaces can be fiber, CWDM or DWDM with a variety of reaches supported.



Topic 5: DWDM for Advanced Network

a. Protection Scheme

b. FOADM & ROADM

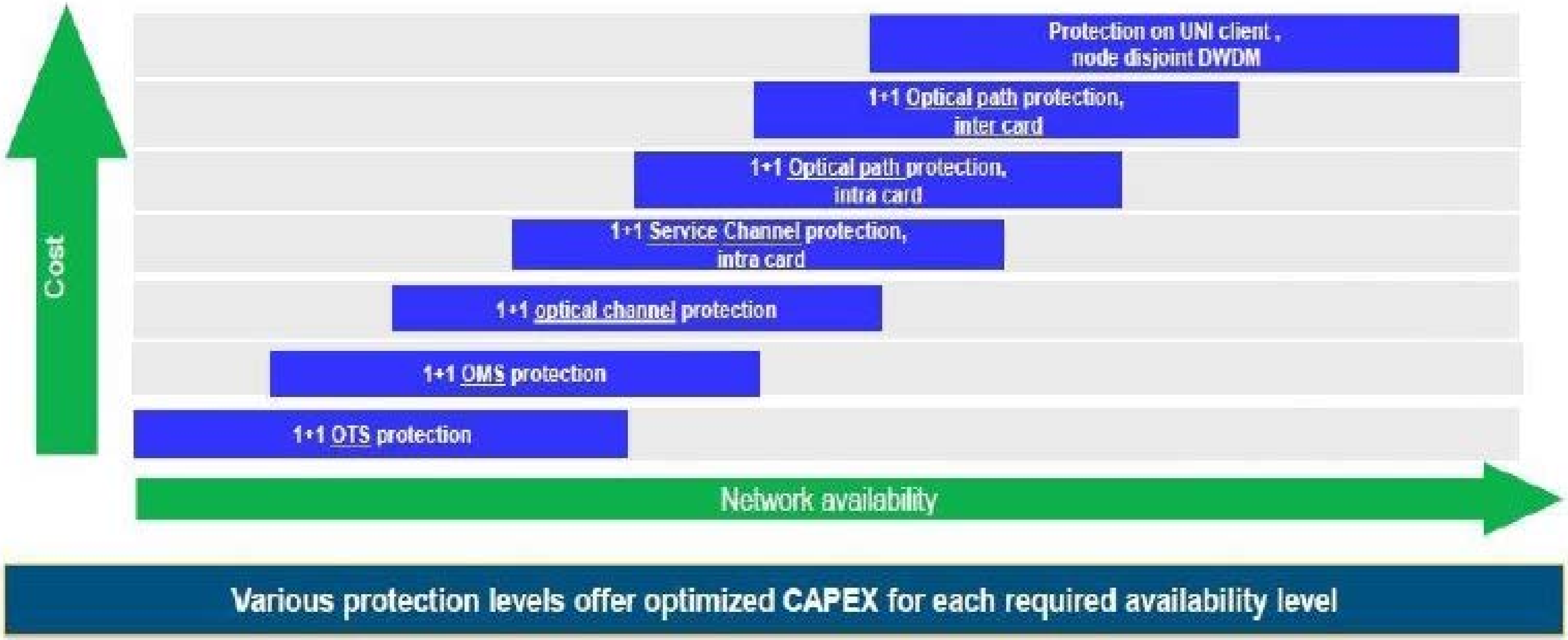
c. Protection Maintained by Client over FOADM

d. ASON

e. Optical vs Electrical

f. FEC

Protection Scheme



1. Equipment Level Protection

- 1.1 Power Protection
- 1.2 Board 1+1 Protection

2. Optical Layer Protection

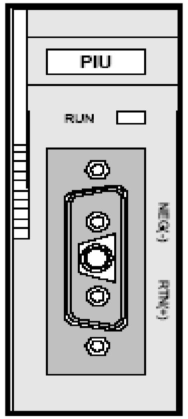
- 2.1 Optical Line Protection
- 2.2 OTU Intra-Board 1+1 Protection
- 3.3 Client 1+1 Protection

3. Electrical Layer Protection

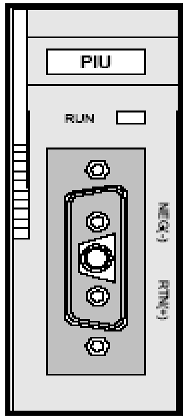
- 3.1 ODUk SNCP Protection
- 3.2 SW SNCP Protection
- 3.3 Tributary SNCP Protection
- 3.4 ODUk SPRing Protection

Power Protection

- **DC input protection**



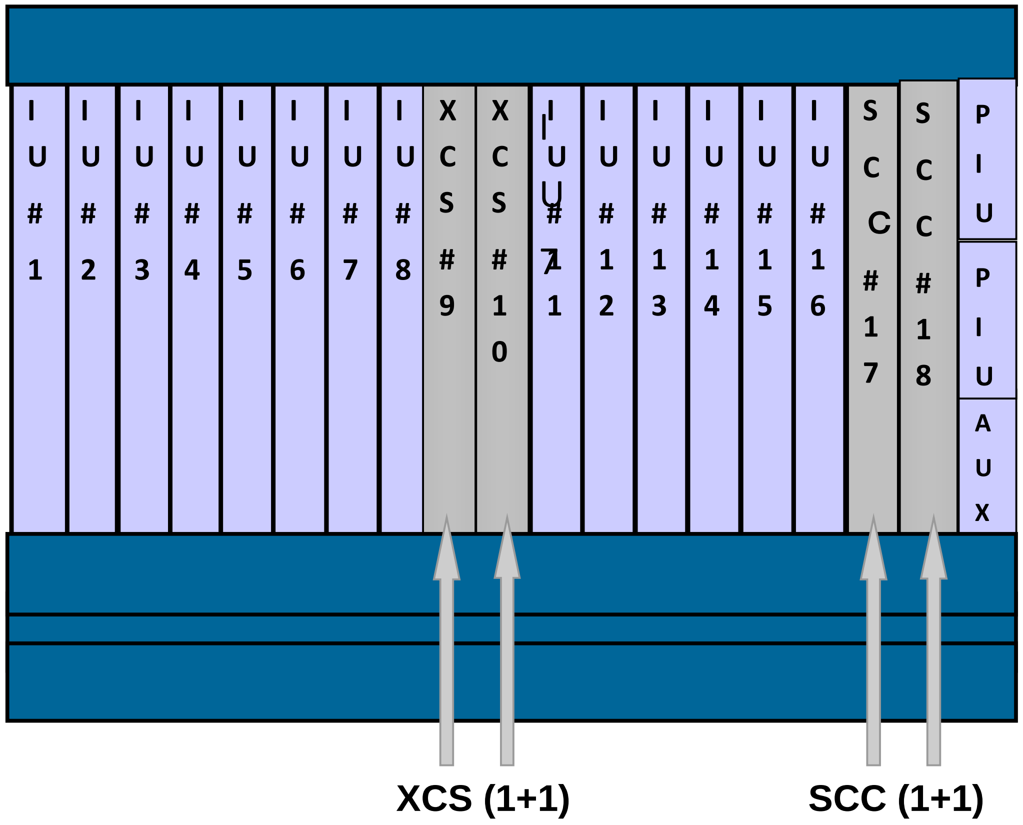
PIU



PIU

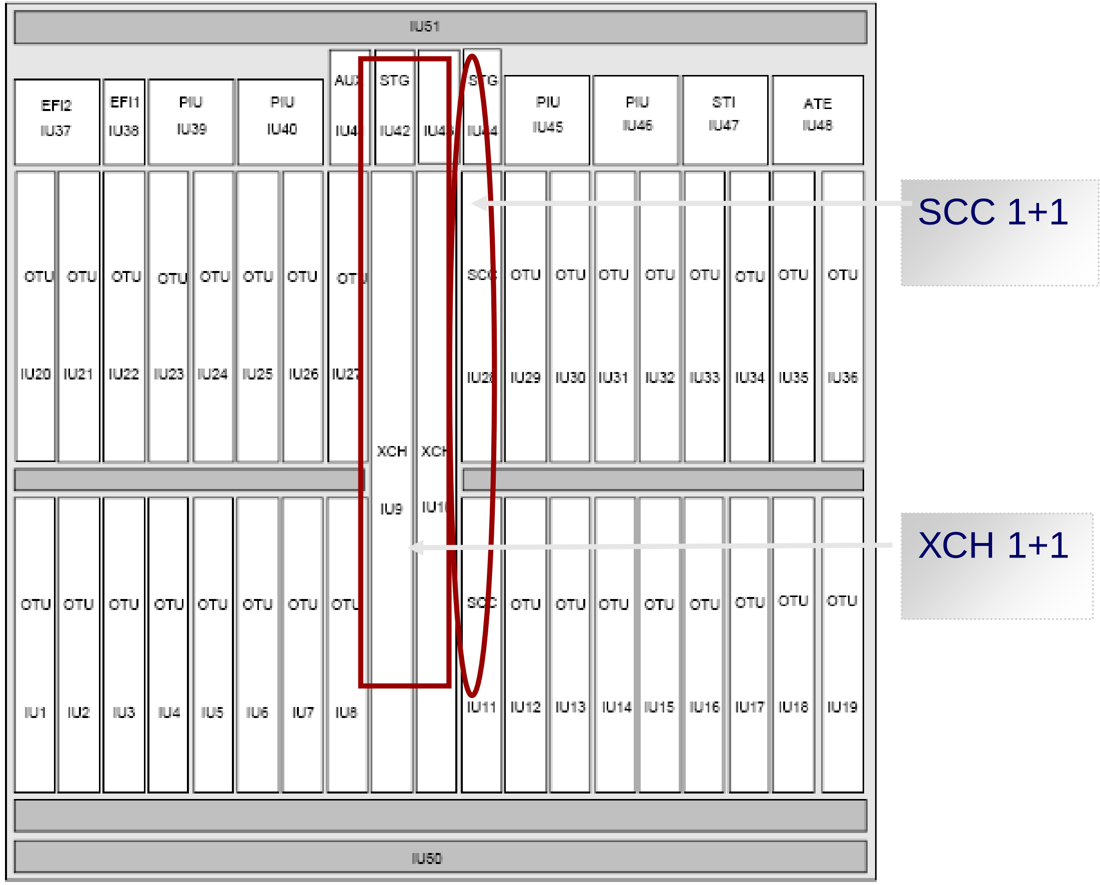
Board 1+1 Protection

- SCC & XCS board 1+1 protection--OSN 6800



Board 1+1 Protection

- SCC & XCH board 1+1 protection--OSN 8800



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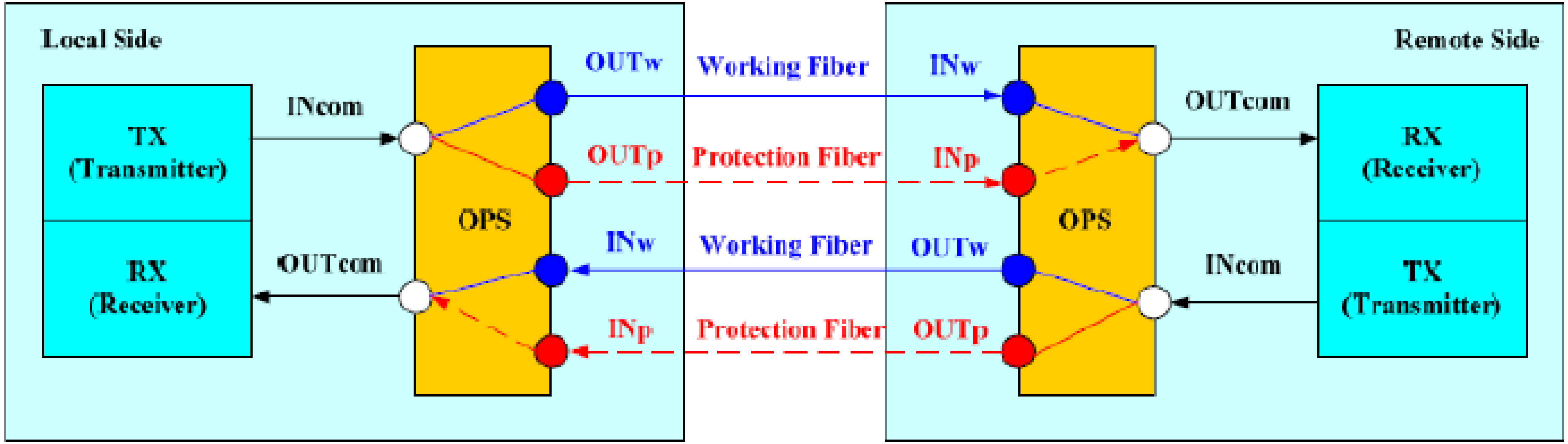
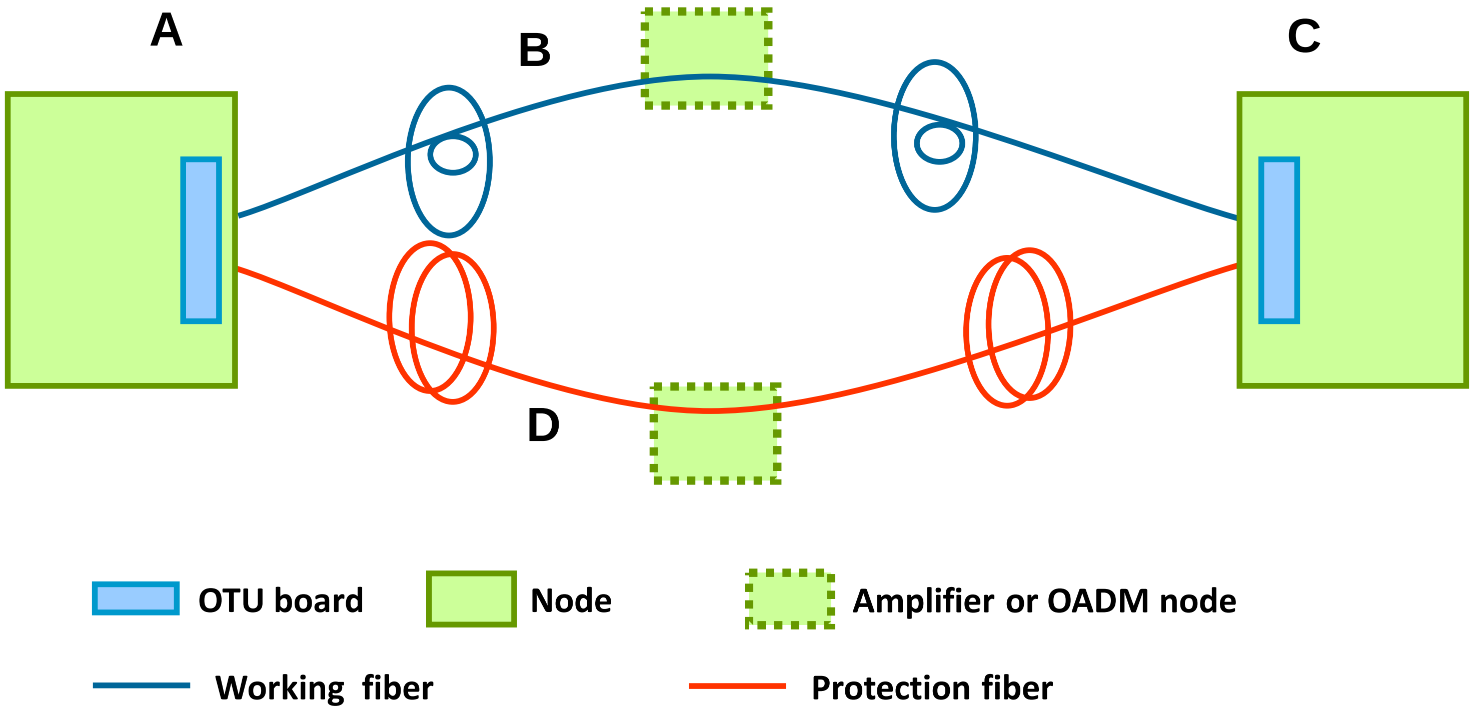
Optical Line Protection (OLP)



- OLP board performs concurrent sending and selective receiving.
- OLP protection is performed segmentally and use the diverse route between the adjacent sites.
- OLP usually used in chain topology and configured at line side of each node.

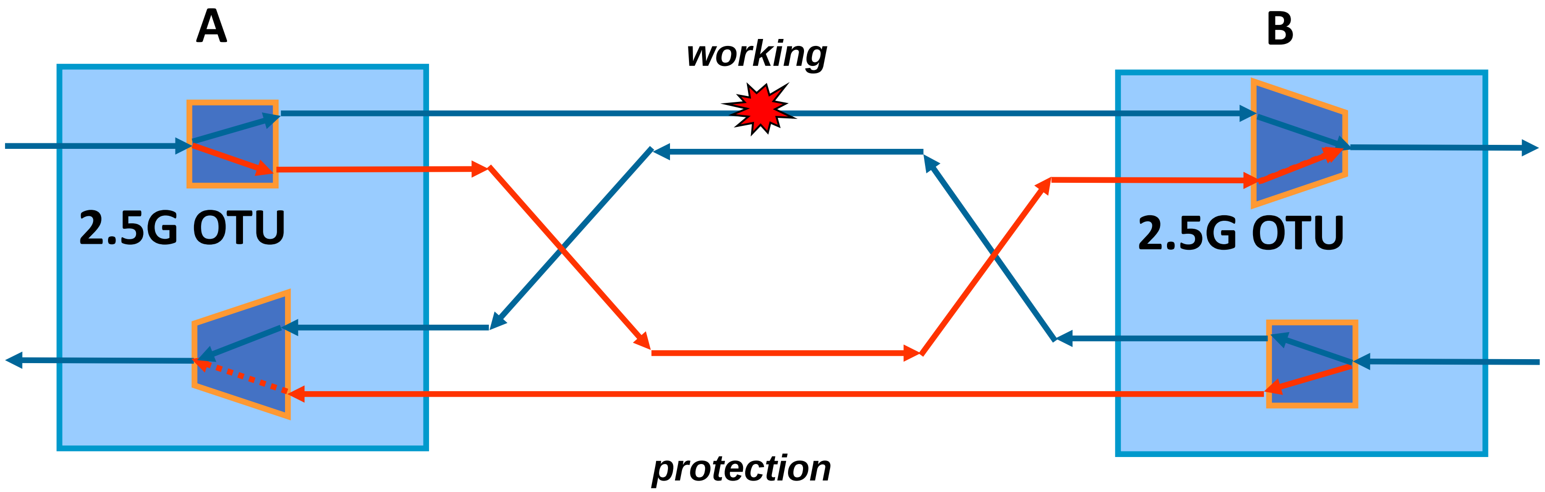
OTU Intra-board 1+1 Protection



- Protect the boards and fibers after OTU board by the concurrent sending and selective receiving of OTU board.
- Usually used in the ring topology, adopt separate route to get protection.

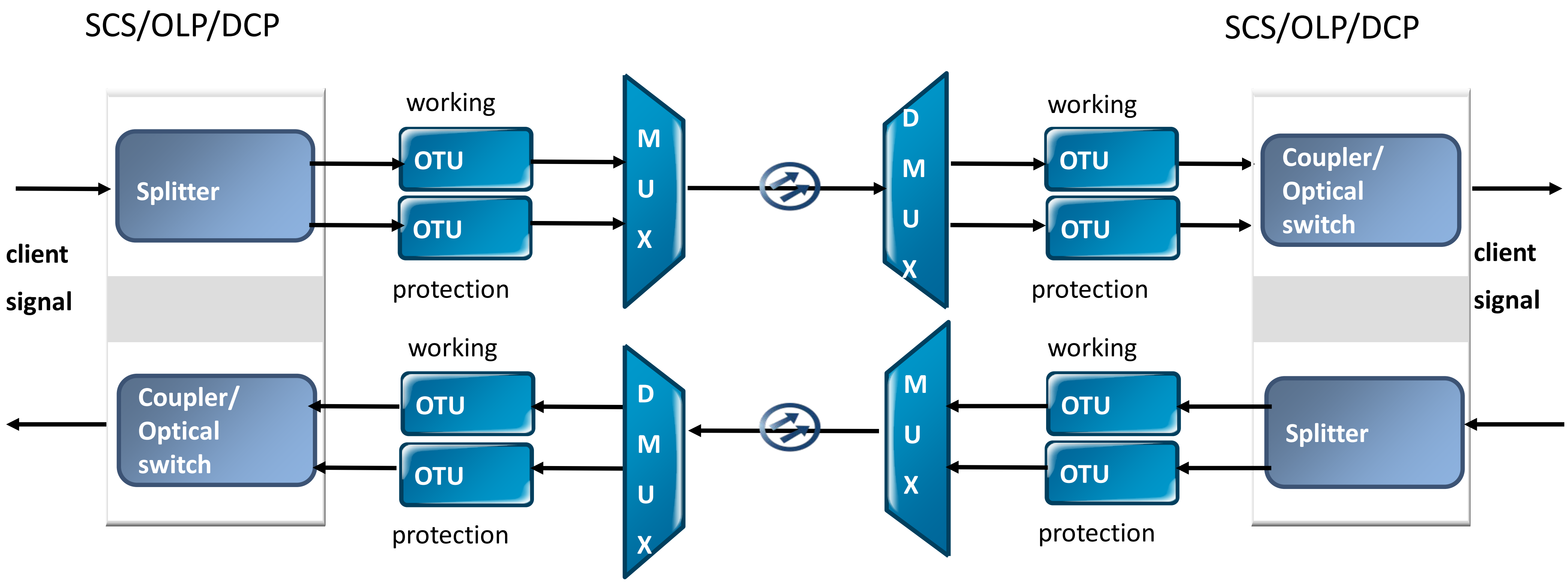
OTU Intra-board 1+1 Protection

- Switching & restoration



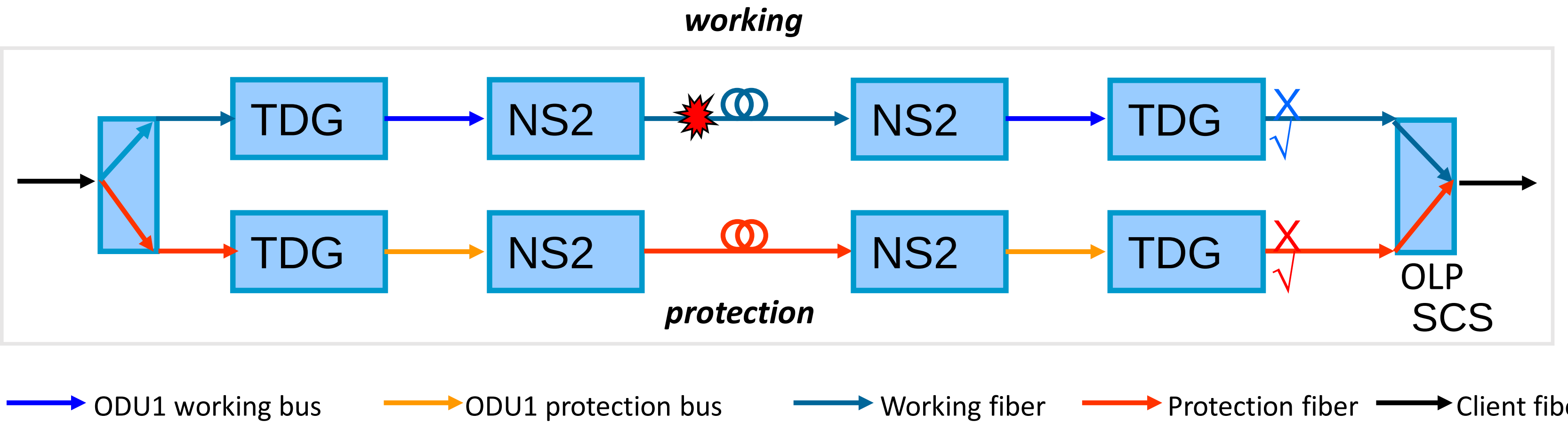
- Protection mechanism: concurrent sending and selective receiving, switching at the receive end.

Client-side Protection of OTU Board



Client-side Protection of OTU Board

- Switching & restoration



- Protection mechanism: concurrent sending and selective receiving, switching at the receive end.

1. **Equipment Level Protection**
   - 1.1 Power Protection
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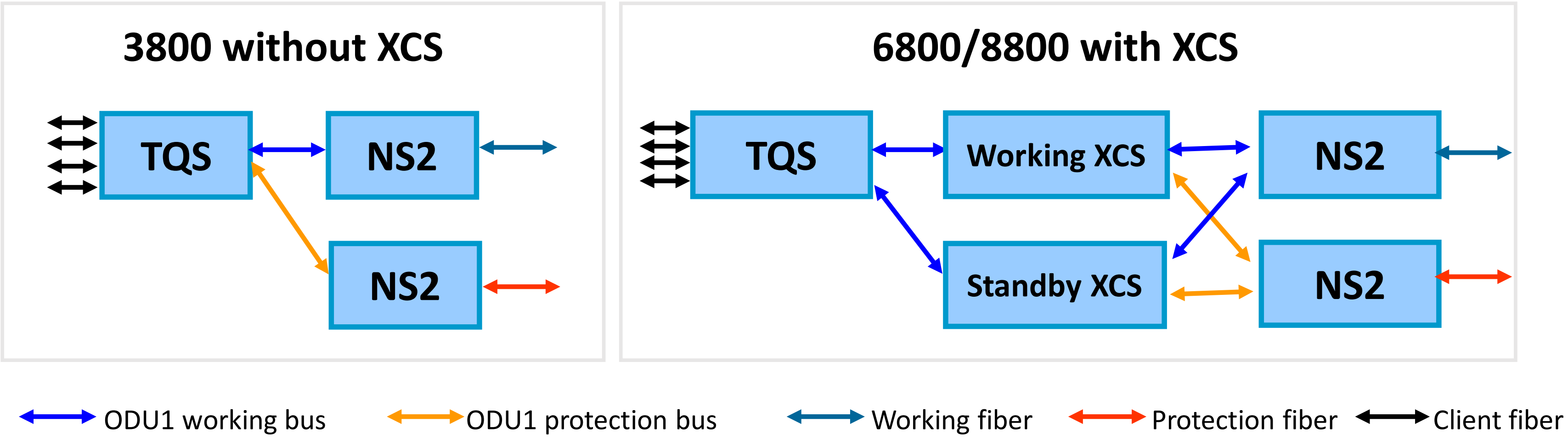
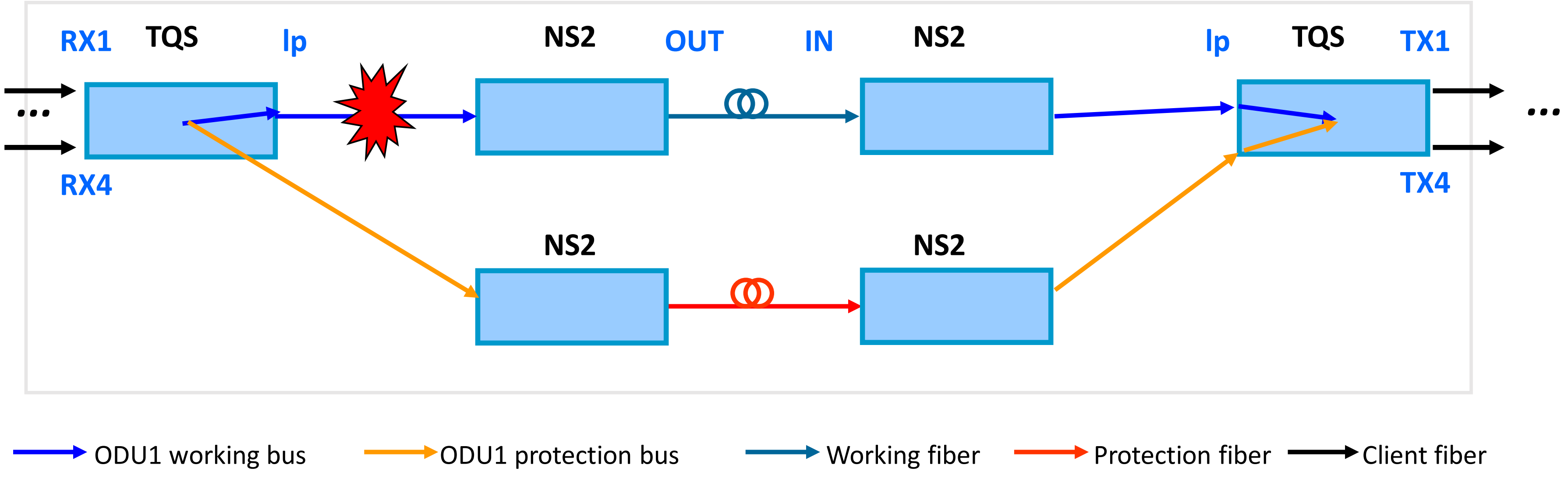
ODUk SNCP Protection



- Protect the line board and OCh fiber.

ODUk SNCP Protection

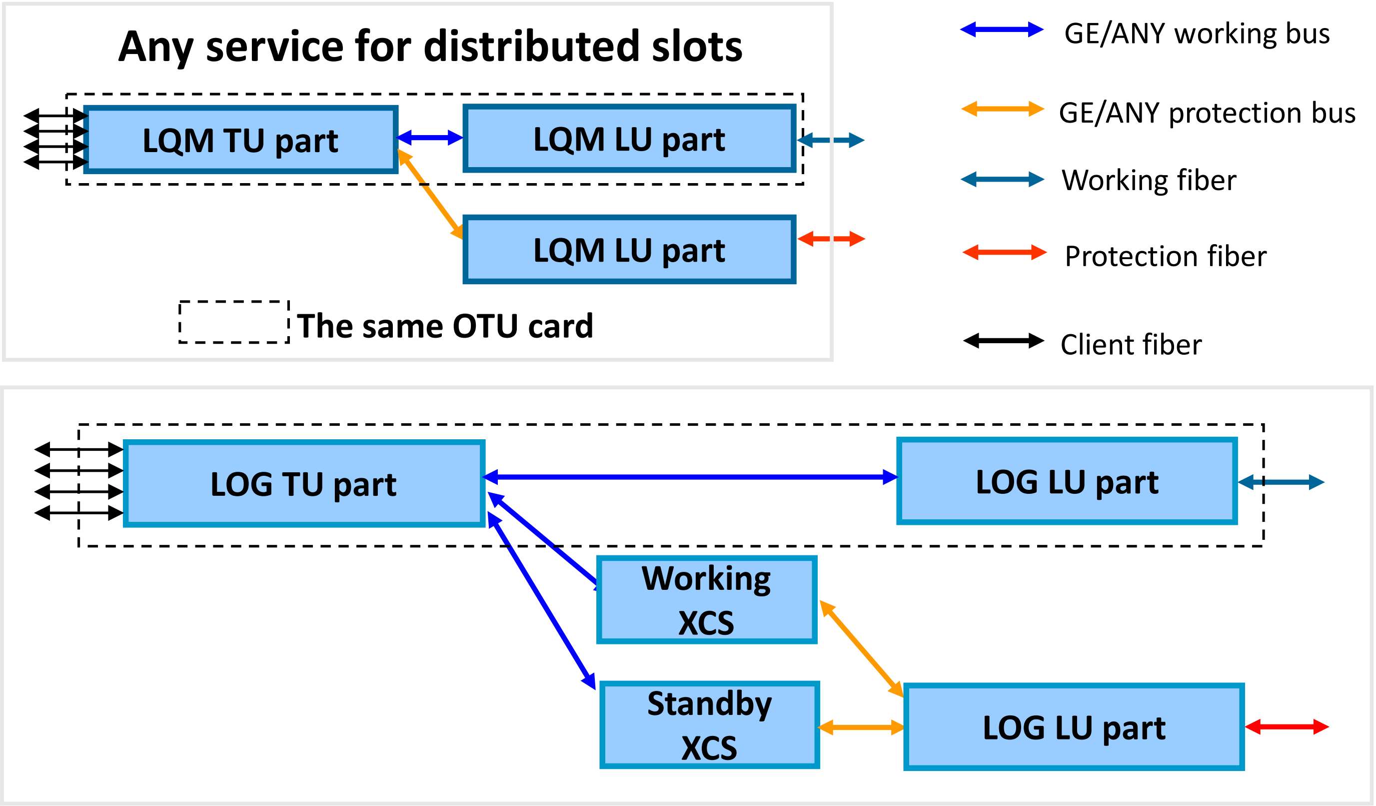
- Switching & restoration



- Working principle: Concurrent sending, selective receiving.

SW-SNCP Protection

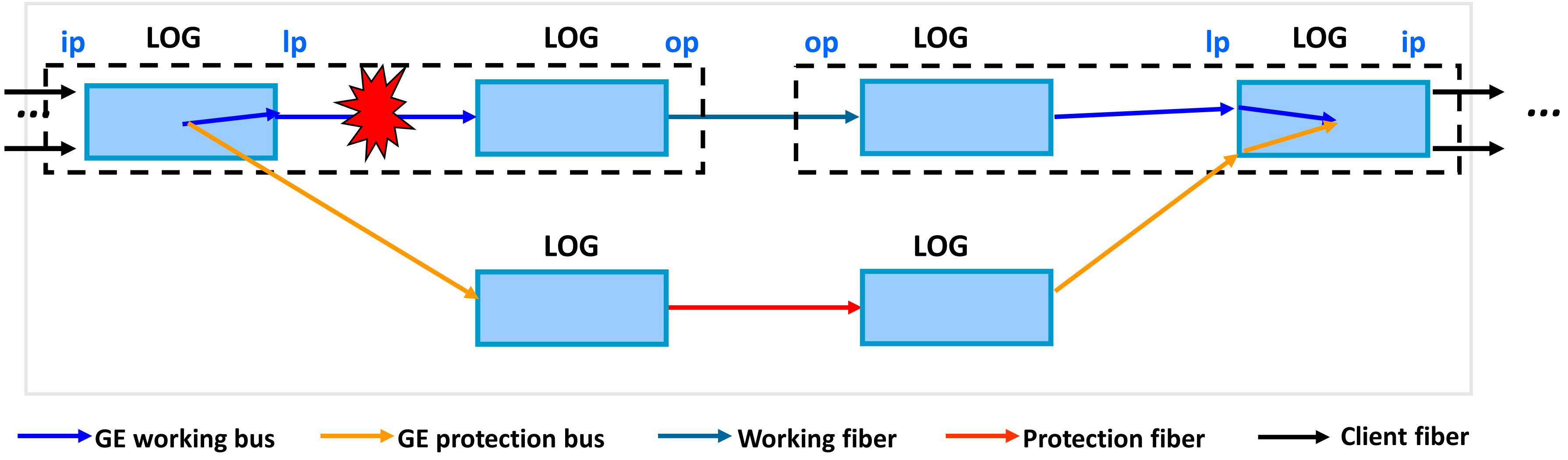
- Implementation



GE service for centralized XC

SW-SNCP Protection

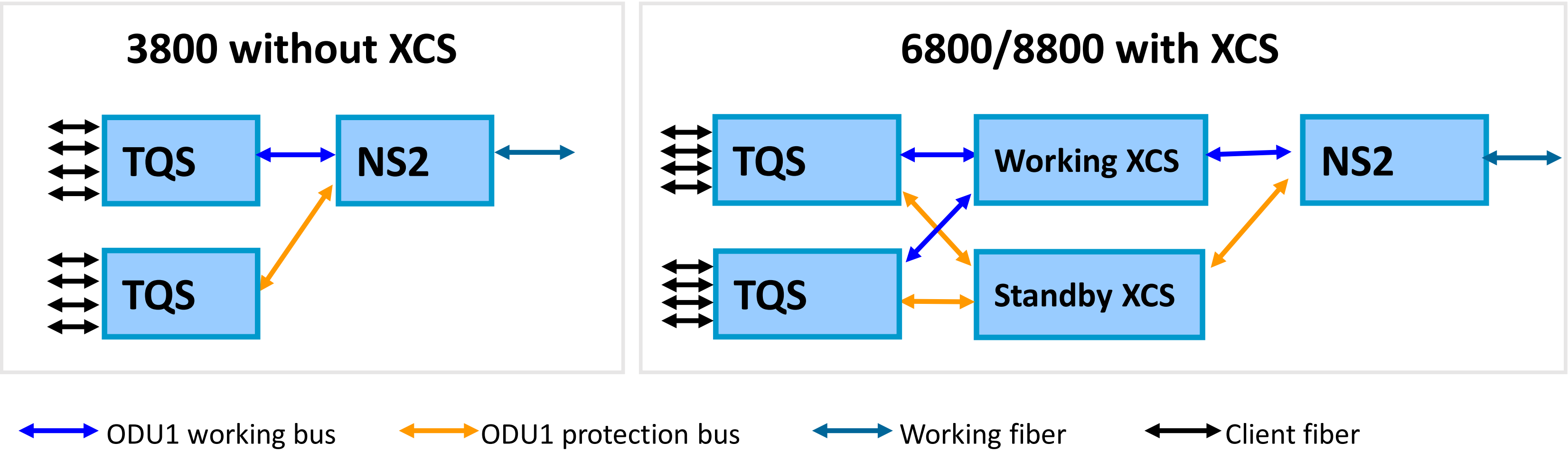
- Switching & restoration



- Working principle: Concurrent sending, selective receiving.
- Trigger condition: Board is offline, SF/SD.

Tributary SNCP Protection

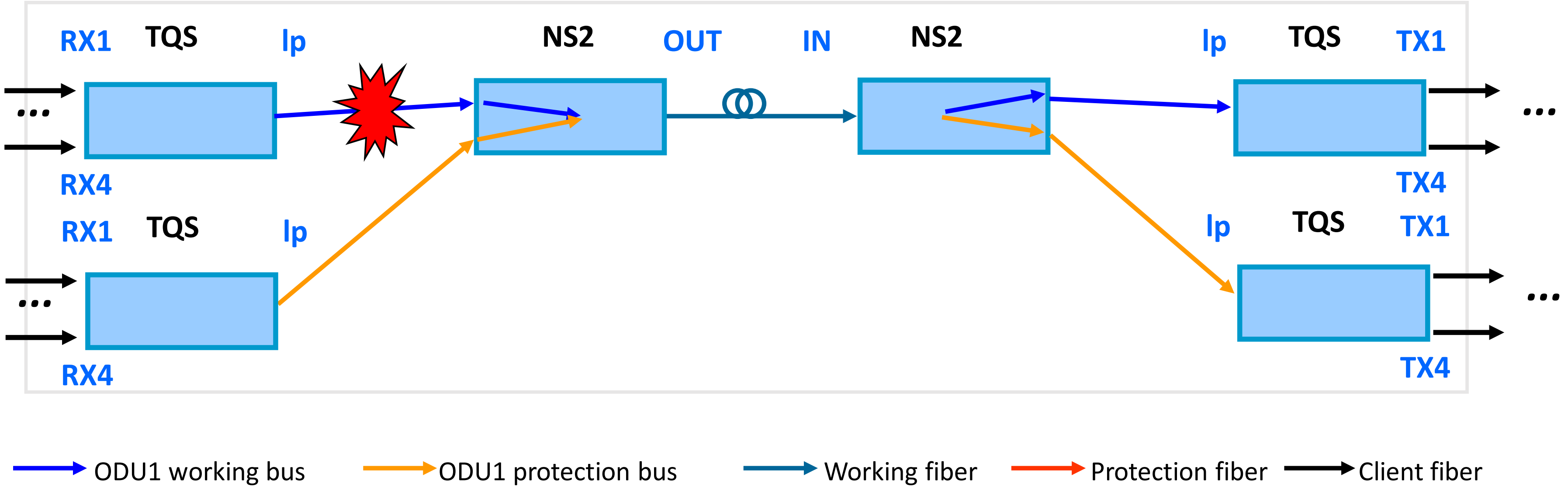
- Implementation



- Protect the tributary board and SDH/SONET or OTN services received on the client side.
- The granularity is ODUk services.

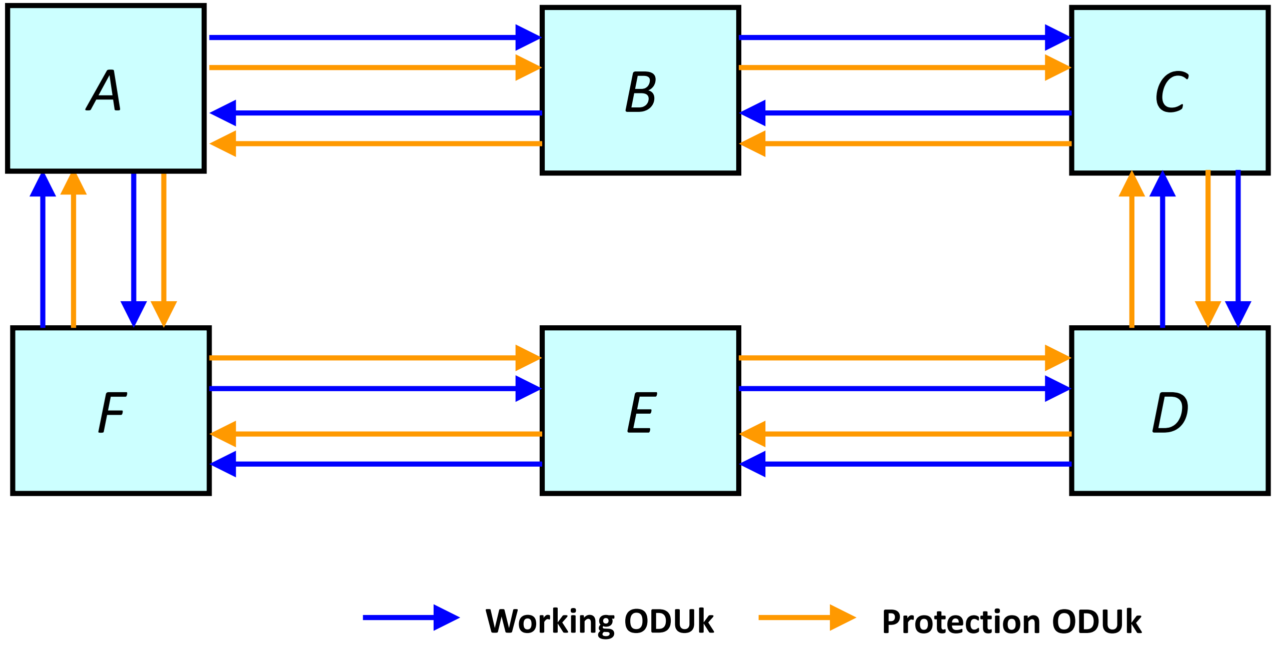
Tributary SNCP Protection

- Switching & restoration



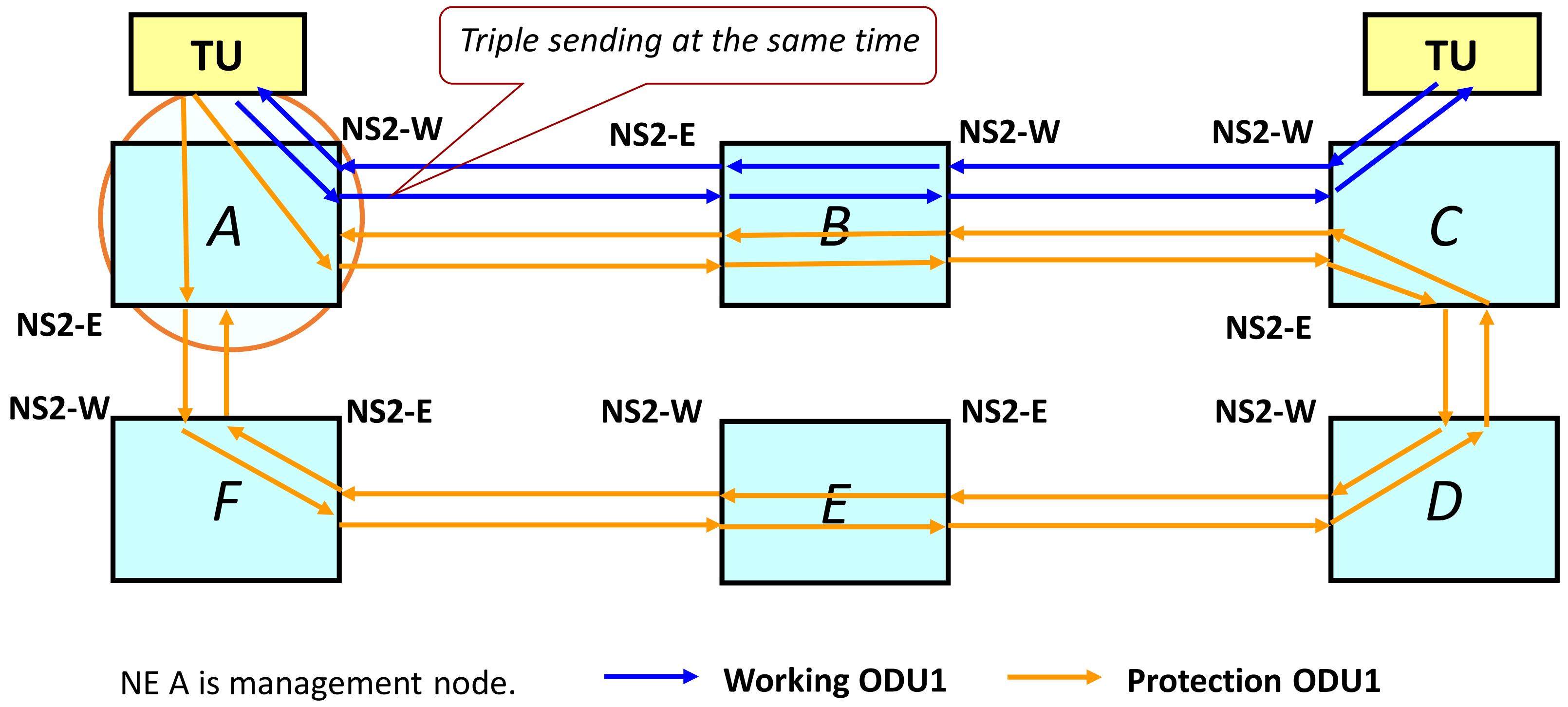
- Working principle: Concurrent sending, selective receiving.
- switching : no APS protocol.
- Trigger condition: Board is offline, SF/SD.

ODUk SPRing Protection



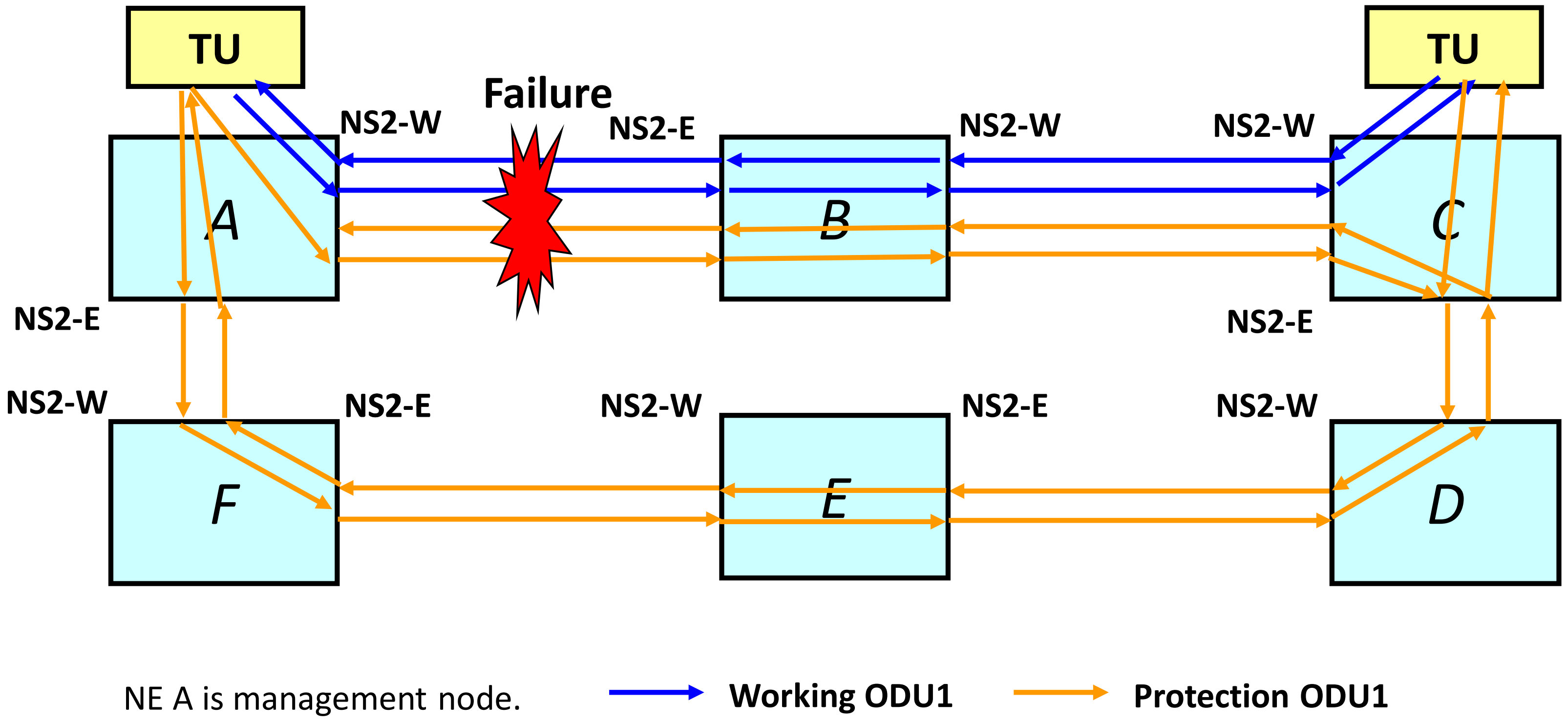
ODUk SPRing Protection

- Normal traffic flow between NE A & NE C



ODUk SPRing Protection

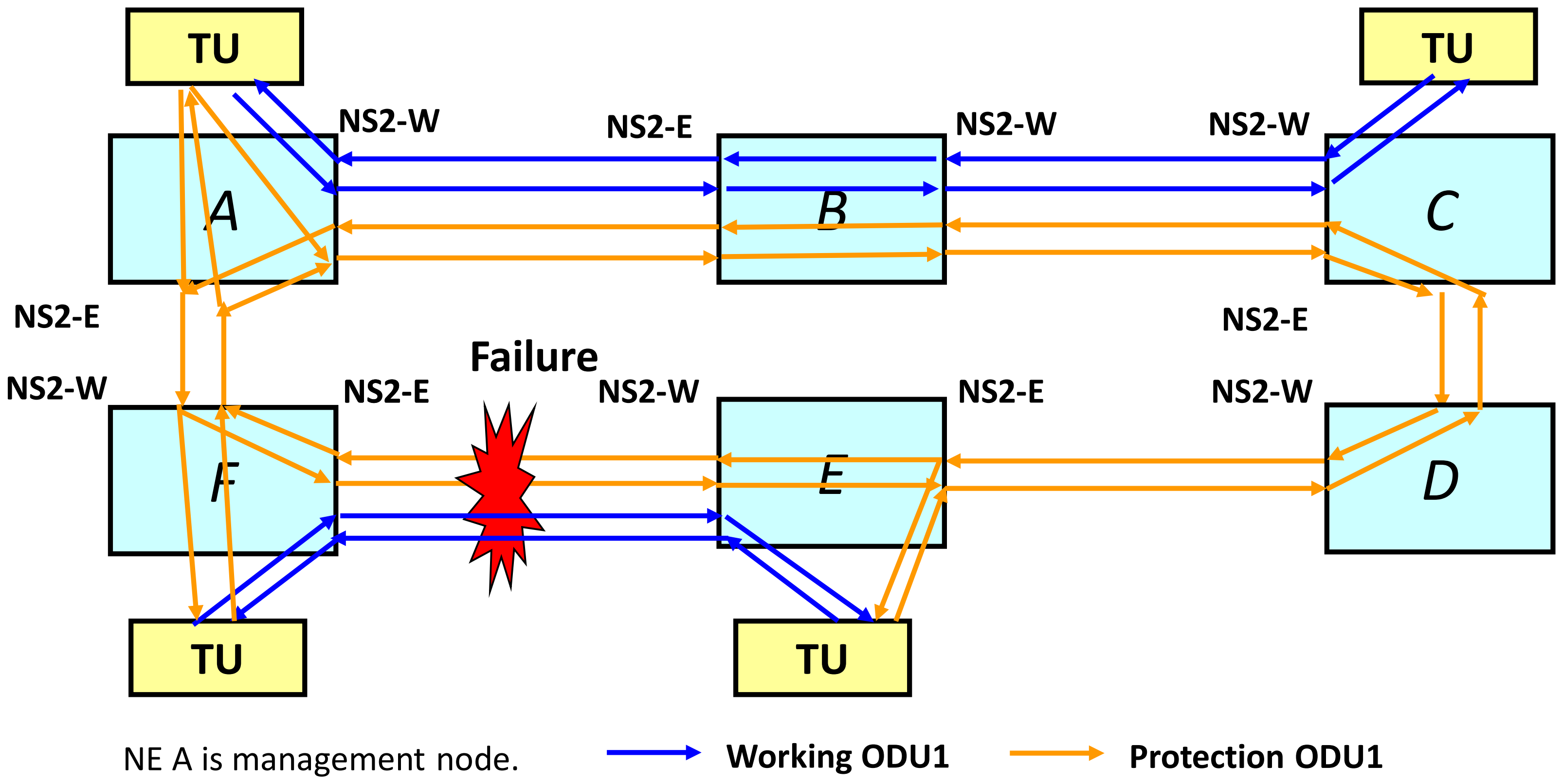
- Switched traffic flow between NE A & NE C



Both NE A&NE B bridged and switched.

ODUk SPRing Protection

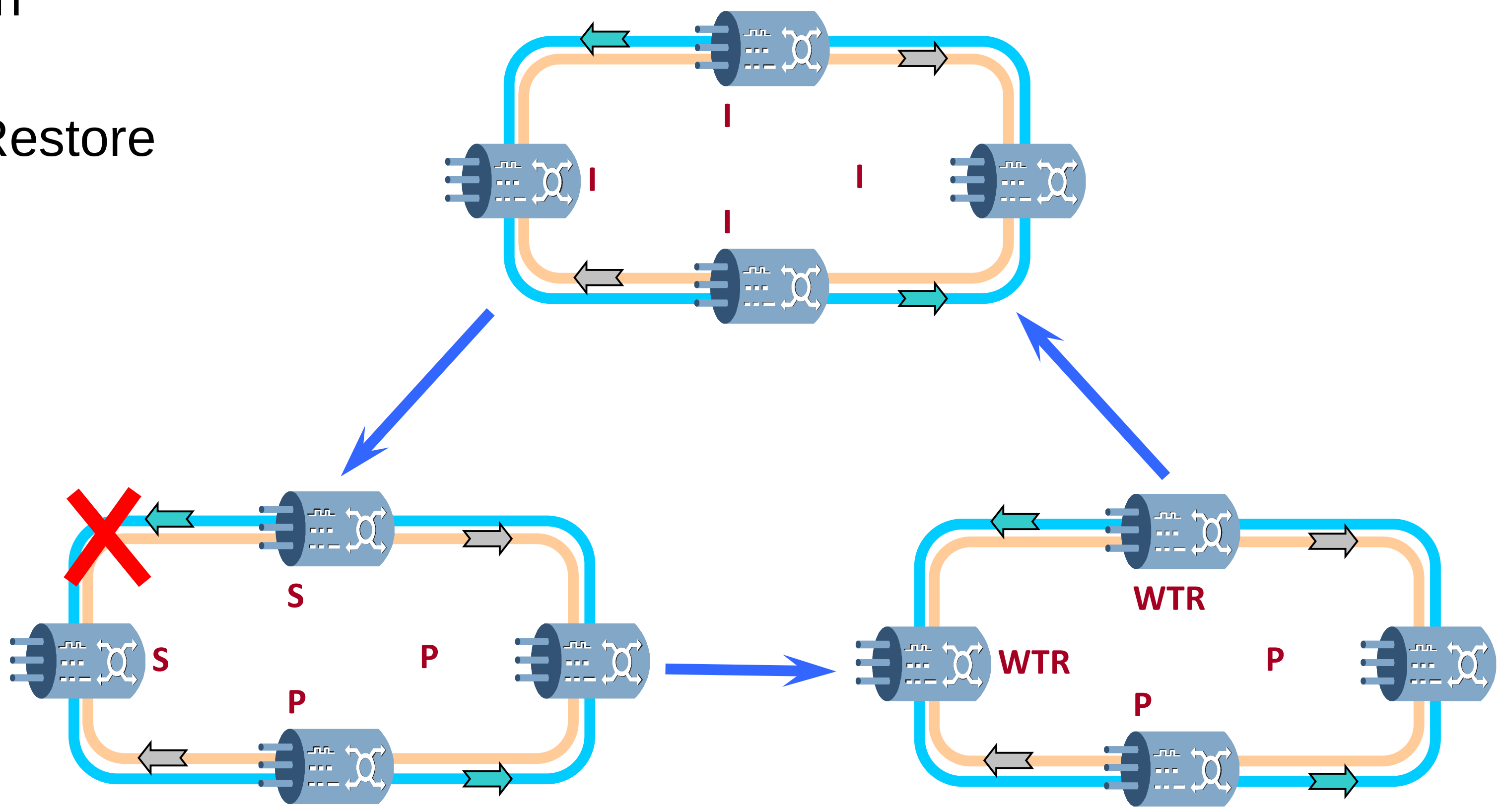
- Switched traffic flow between NE E & NE F



Both NE E&NE F bridged and switched.

ODUk SPRing Protection

- **Transition of APS controller status**
  - I = Idle
  - P = Pass-through
  - S = Switching
  - WTR = Wait to Restore



Comparison

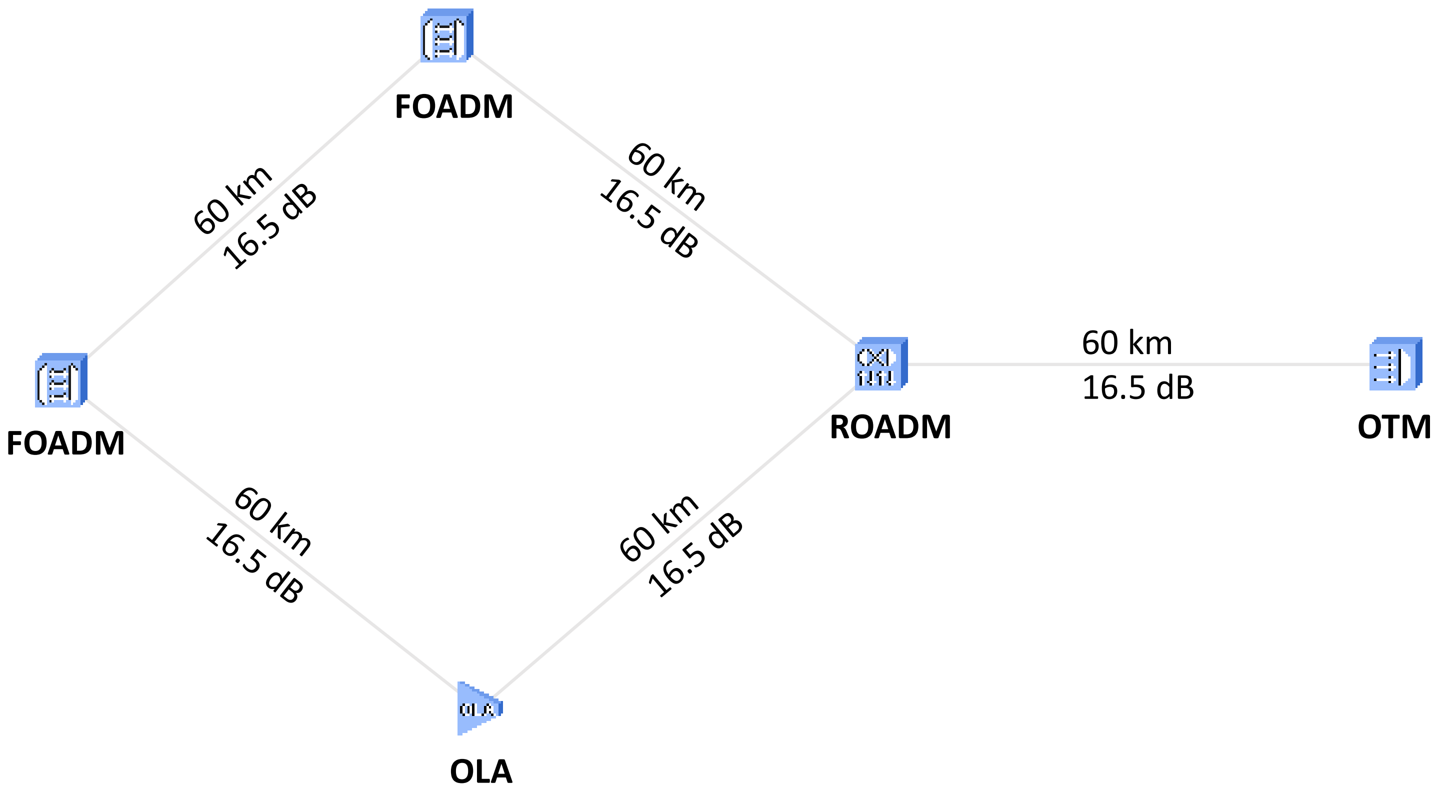
Type	Feature	Remark
OLP	splitter	Protect the line cable failure, simple and stable
Intra-board protection	OTU board optical layer	Protect the line cable and intra-fiber failure, cheap, for 5/10G OTU board needs external OLP
Client side 1+1	Client side optical layer of OTU	Extends the protection to the client side and has the greatest protection range
ODUk SNCP	ODU1/ODU2 electrical layer	Protect the line fiber and the LU part
SW SNCP	GE/ANY electrical layer	Protect the line fiber and the LU part
Tributary SNCP	ODUk electrical layer	Protect the client services and the TU part
ODUk SPRing	ODU1/ODU2 electrical layer	Ring topology, distributed service, share the protection channel, need protocol.

WDM Network Element

The WDM NE can be configured as four types:

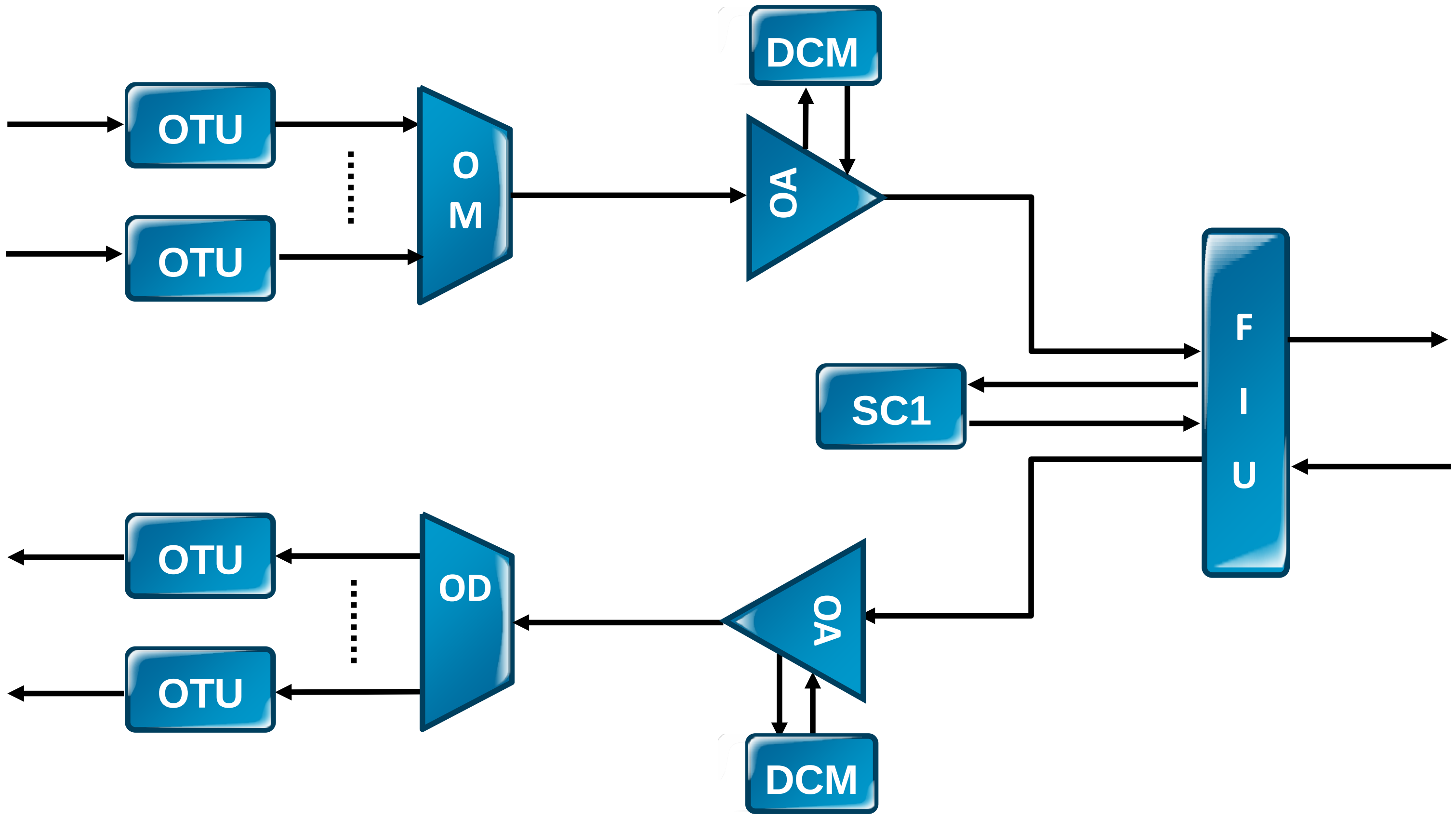
- Optical Terminal Multiplexer (OTM)
- Optical Line Amplifier (OLA)
- Optical Add/Drop Multiplexer (OADM)
    - Fixed optical add or drop multiplexer (FOADM)
    - Reconfigurable optical add or drop multiplexer (ROADM)
- Regenerator (REG)

WDM Network Element



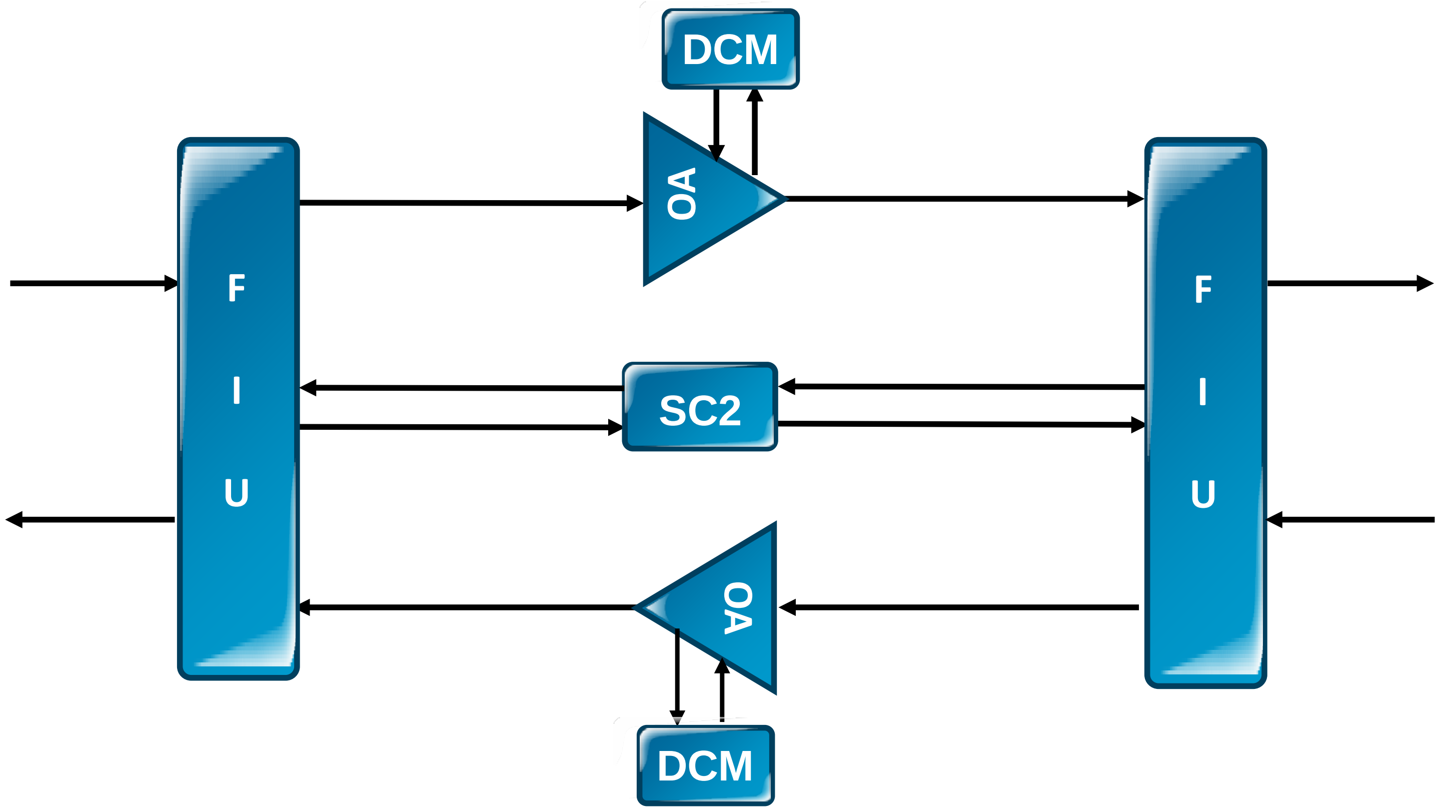
Signal Flow

- OTM (40-wavelength):



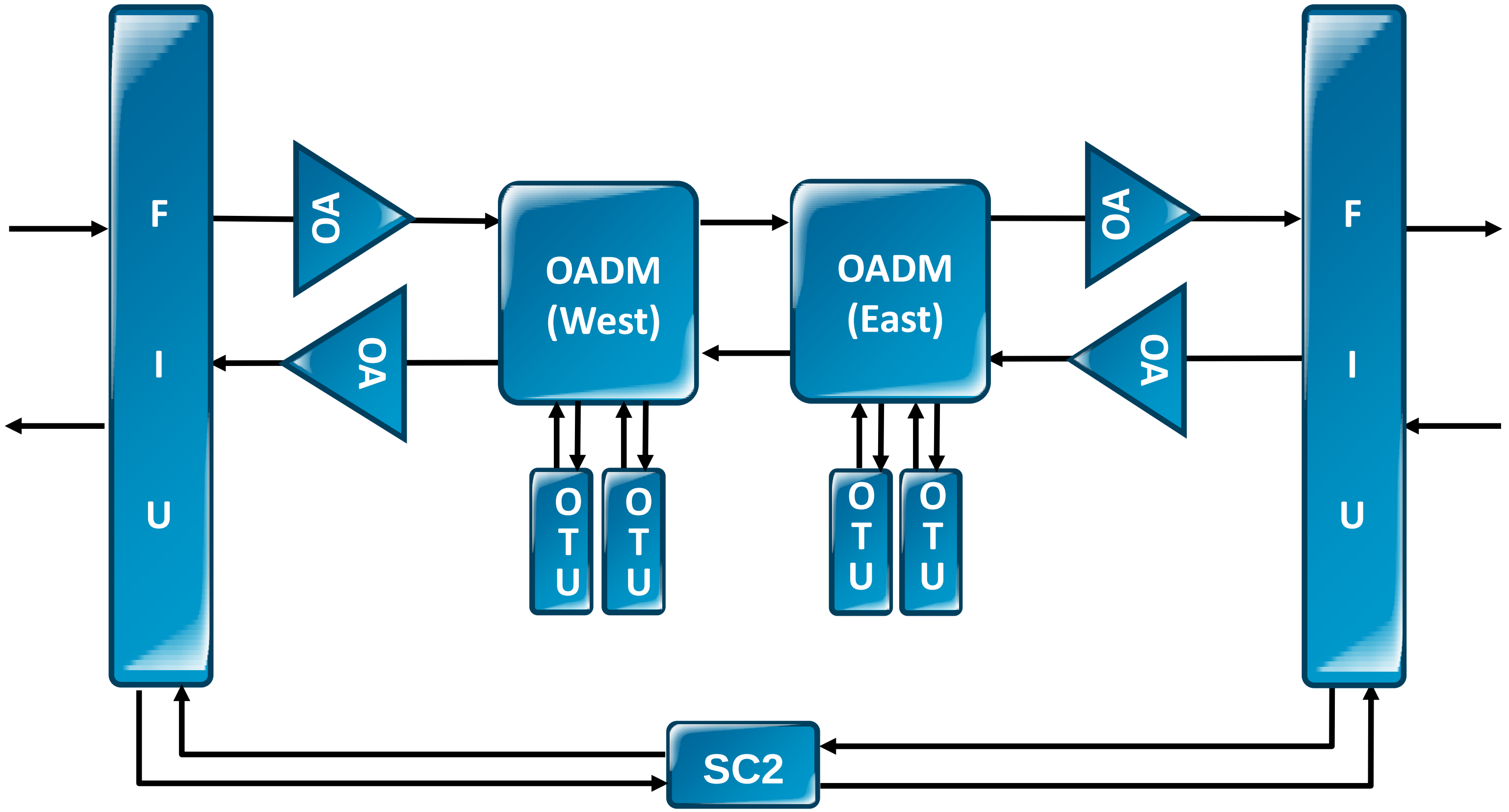
Signal Flow

- OLA:



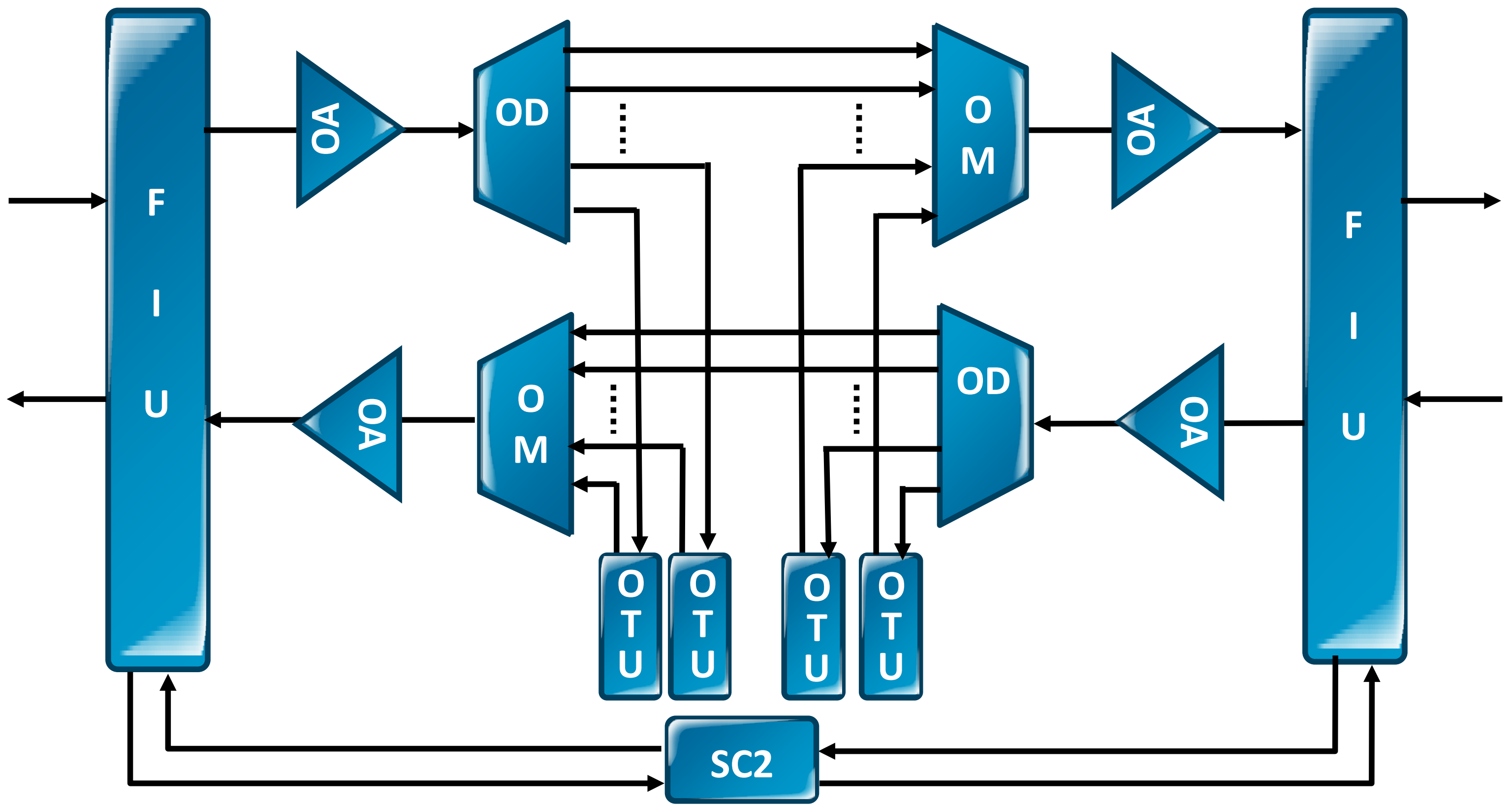
Signal Flow

- FOADM: (Serial FOADM)



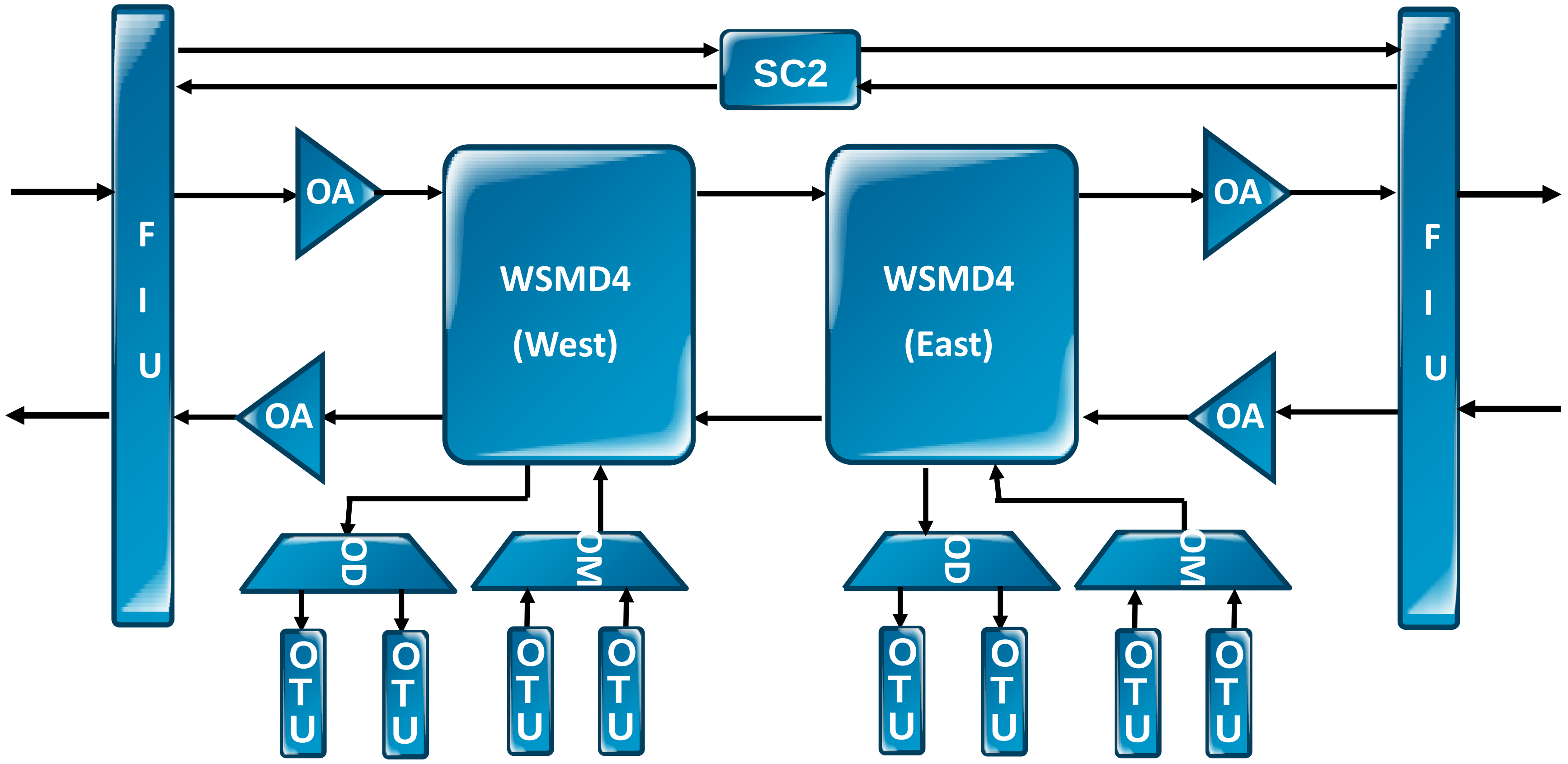
Signal Flow

- FOADM: (Parallel FOADM)



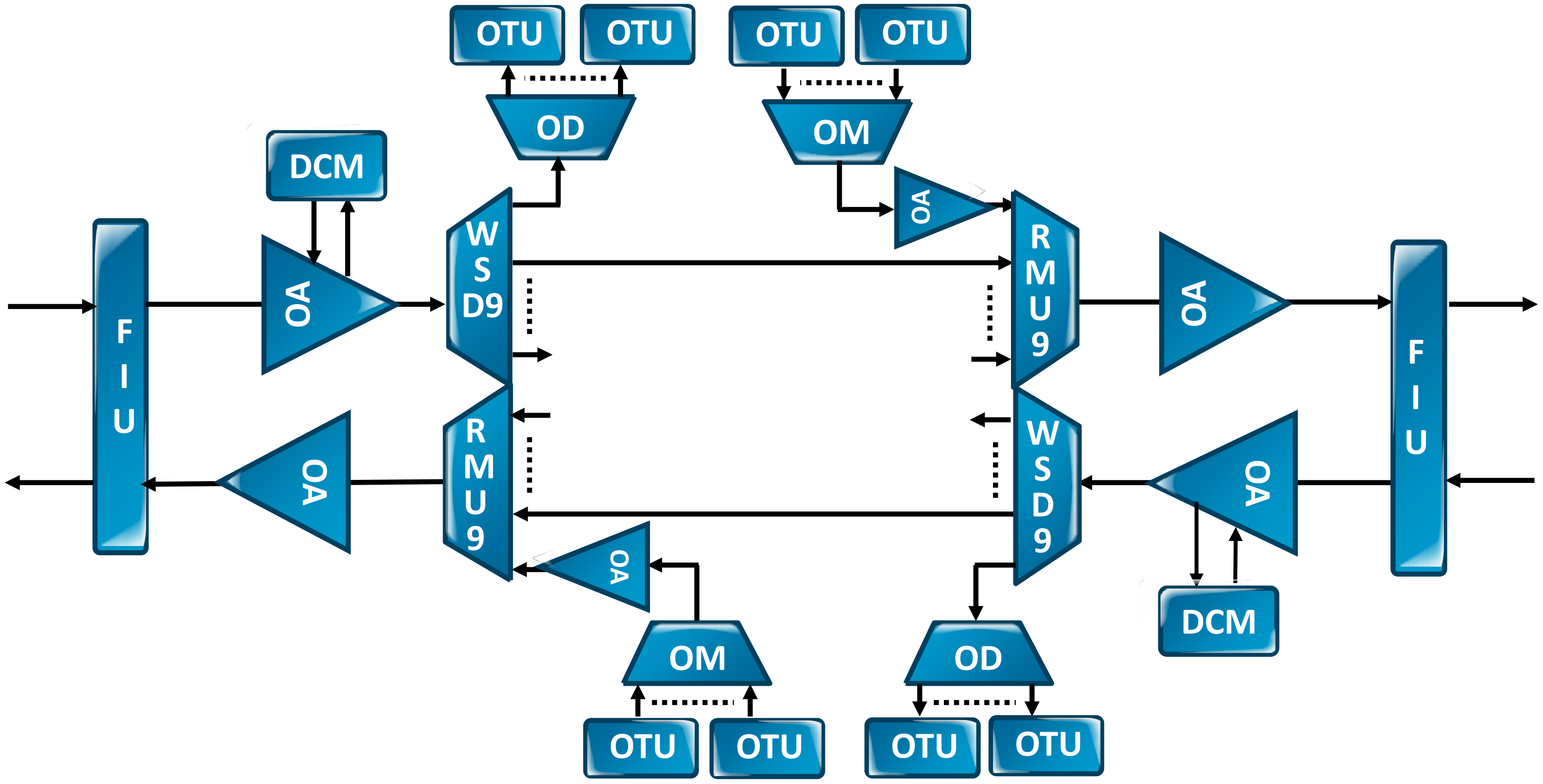
Signal Flow

- ROADM: (WSMD4+WSMD4)



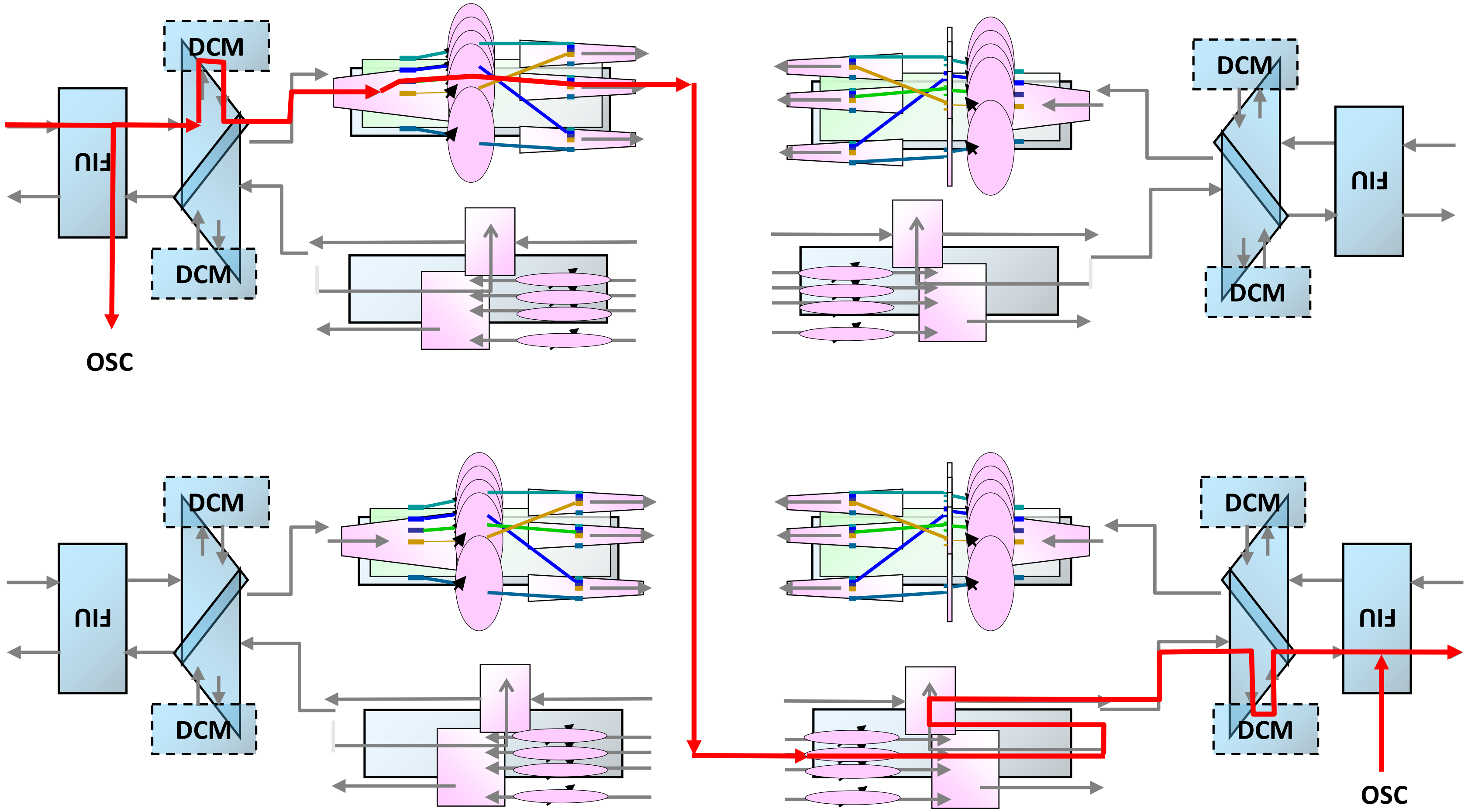
Signal Flow

- ROADM: (WSD9+RMU9, 2degrees)



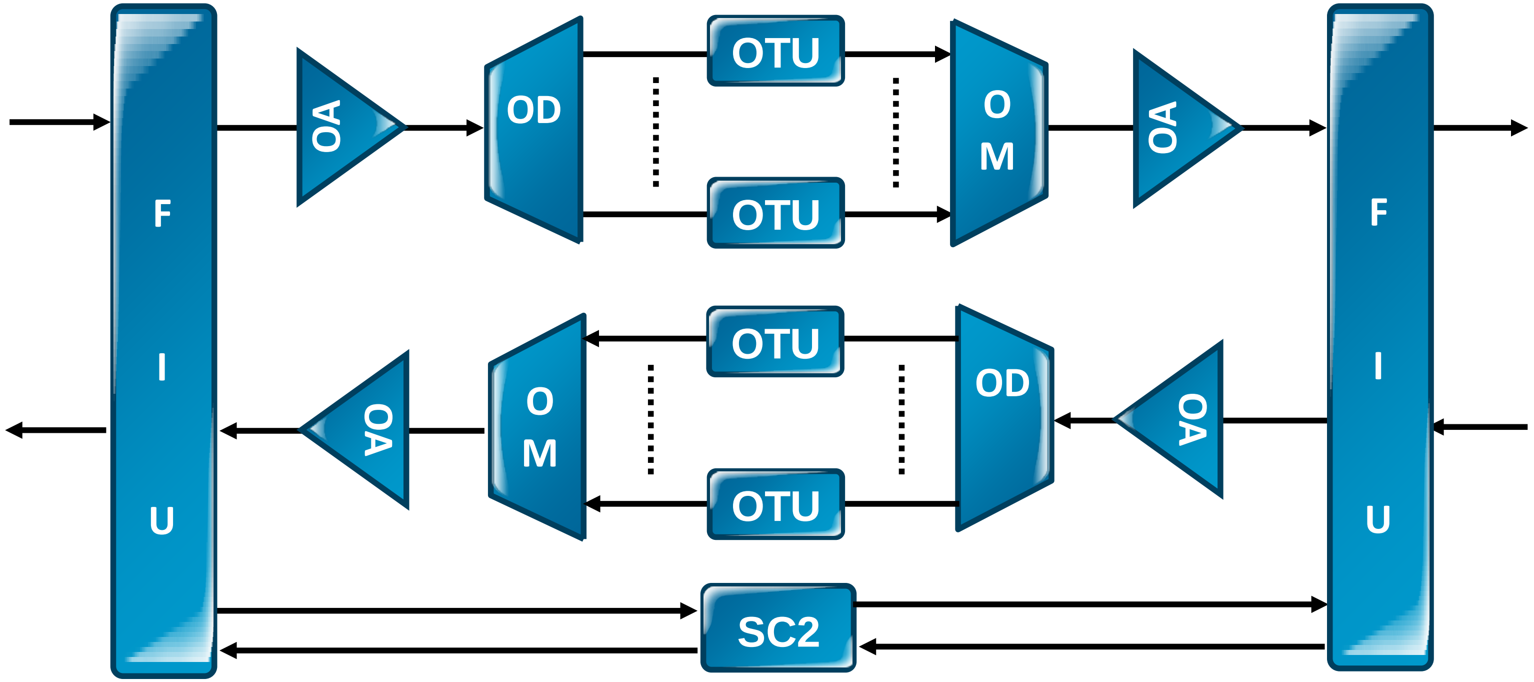
Signal Flow

- ROADM: (WSD9+RMU9, 4 degrees)



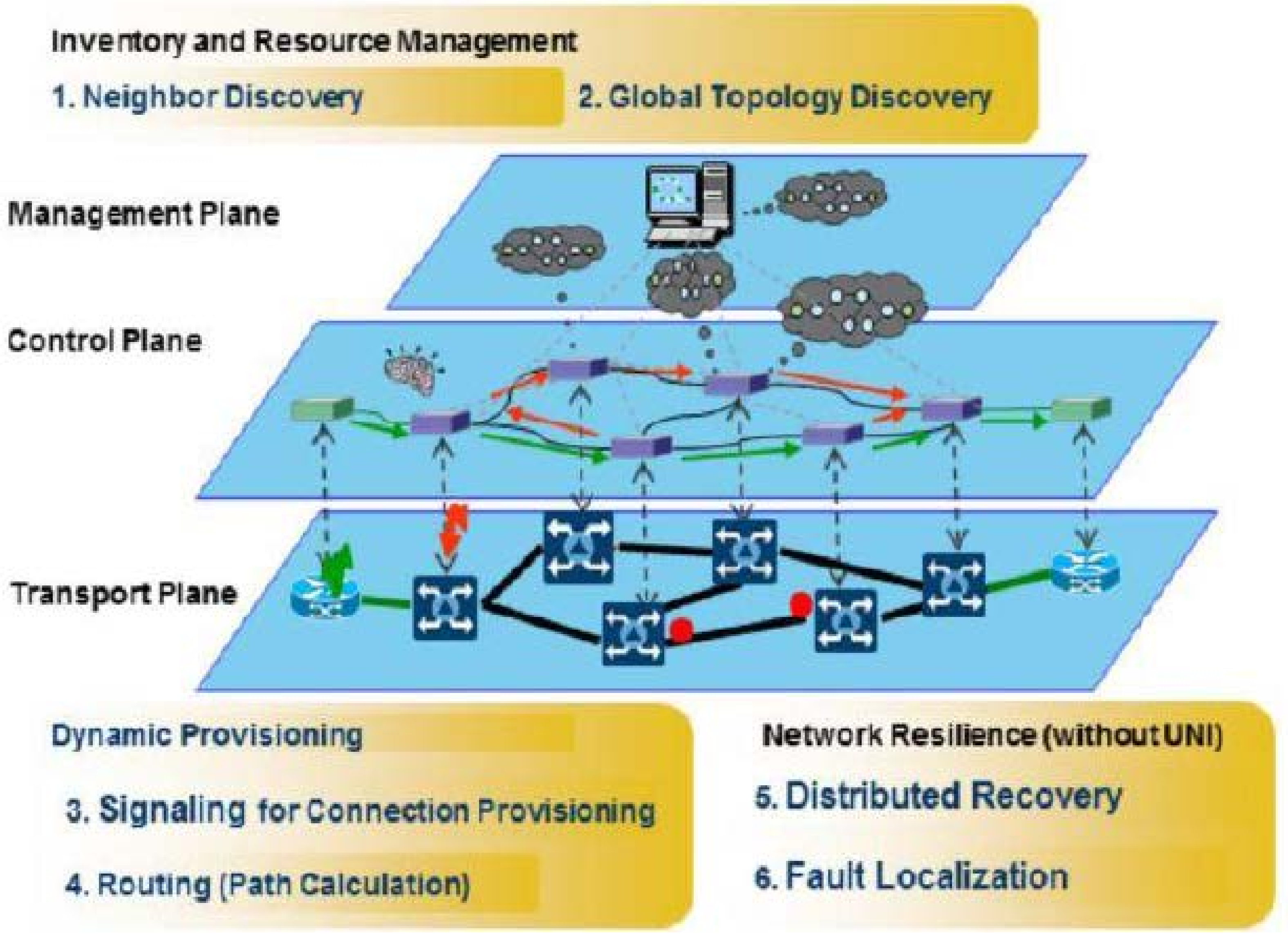
Signal Flow

- REG:



Note: Signals are regenerated through the regenerating OTU.

Automatically Switched Optical Network (ASON)



Protocols:
1: LMP
2: OSPF-TE
3: RSVP-TE
4: CSPF
5: all
6: LMP

Automatically Switched Optical Network (ASON)

LMP: Link management protocol
Manage and maintain the health of control and data planes between two neighboring nodes

OSPF-TE: Open shortest path first-Traffic Engineering
Routing protocols for the auto-discovery of network topology, advertise resource availability (e.g bandwidth or protection type)

CSPF: Constraint Shortest Path First
Based on OSPF route information, calculated the path for tunnel

RSVP-TE: Resource reservation protocol for traffic engineering
Based on CSPF’s result, send message to create the tunnel hop-by-hop.

Automatically Switched Optical Network (ASON)

Electrical ASON	Optical ASON
Electrical ASON is based on ODUk switching at electrical layer of an OTN cross-connect board. So OTN switches and ROADM boards need to be used.	Optical-layer ASON requires the ROADM system for hardware support
Focus on tributary and line boards and use electrical-layer cross-connect ODUk logical ports	Optical-layer ASON: Focus only on the FIU and OTU boards. Based on optical-layer ROADM
Electrical layer ASON are applicable to large-scale long-haul scenarios.	optical-layer ASON applies only to small- and medium-scale scenarios.
For electrical ASON this scenario is different because multiple lambda paths needs to be pre-set from the beginning and, for sure multiple transponders are needed.	Due to optical ASON is based on lambda switching, the protection and re-route is more flexible and save in transponder resources because the same transponder can change on direction and color
High cost solution	More cheaper solution

FEC – Forward Error Correction

- Forward error correction (FEC) is a digital signal processing technique used to enhance data reliability. It does this by introducing redundant data, called error correcting code, prior to data transmission or storage. FEC provides the receiver with the ability to correct errors without a reverse channel to request the retransmission of data.

- The first FEC code, called a Hamming code, was introduced in the early 1950s. It is a method adopted to obtain error control in data transmission where the transmitter sends redundant data. Only a portion of the data without apparent errors is recognized by the receiver. This allows broadcasting data to be sent to multiple destinations from a single source.

Automatically Switched Optical Network (ASON)

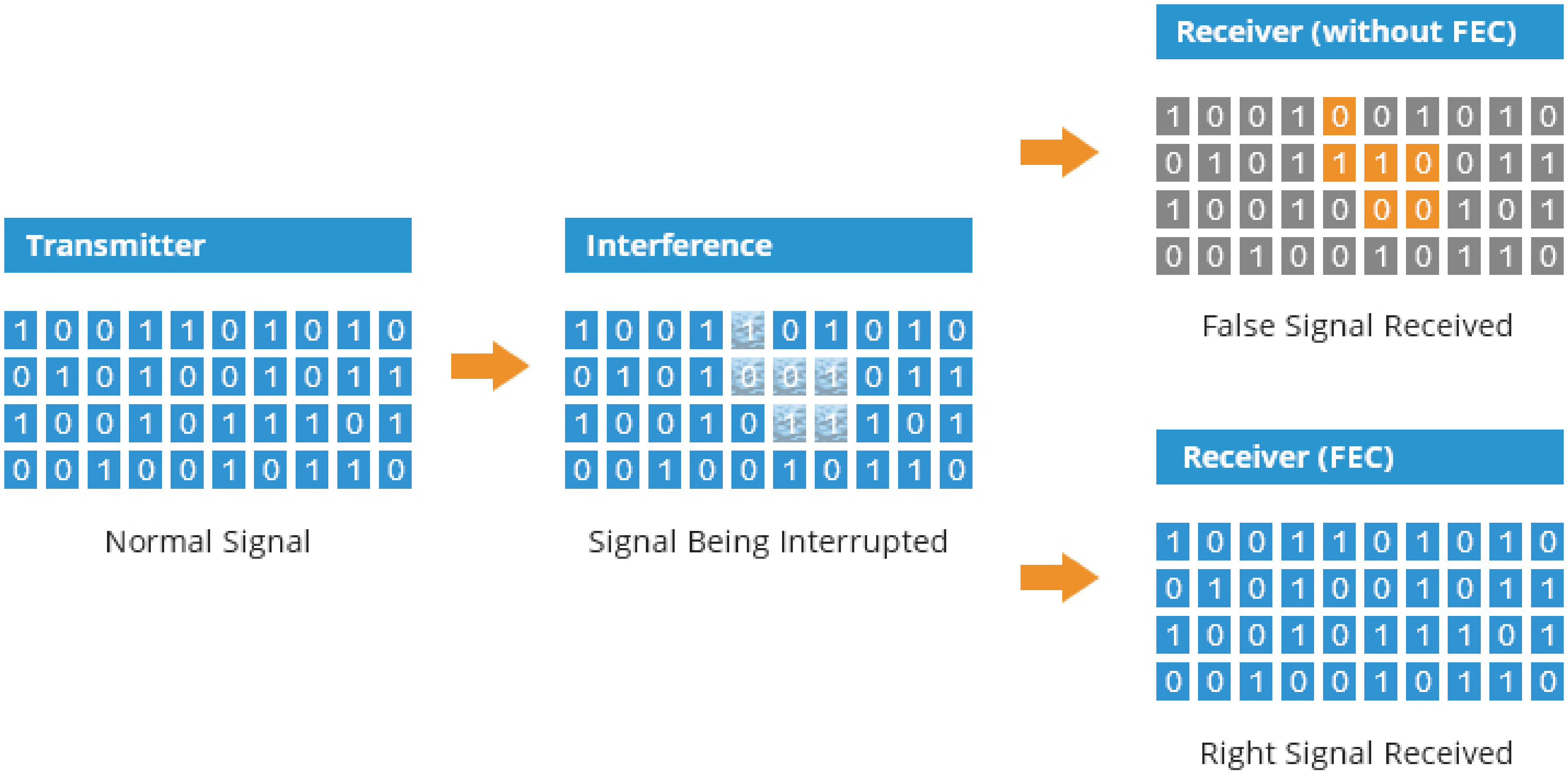


Figure : The Working Principle of FEC

Appendix

DWDM- Dense Wavelength Division Multiplexing
MUT_LOS- Multiplexer Loss of Signal
OAU- Optical Amplifier Unit
OTU- Optical Transponder Unit
OADM- Optical Add-Drop Multiplexing
OSC- Optical Supervisory Channel
FIU- Fiber Interface Unit
QPSK- Quadrature Phase shift Keying
QAM- Quadrature Amplitude Modulation
ROADM- Reconfigurable Optical Add-Drop Multiplexers
ASON- Automatically Switched Optical Network
FOADM- Fixed Optical Add-Drop Multiplexers
OTN- Optical Transport Network
OTM- Optical Transport Module
EDFA - Erbium Doped Fiber Amplifier
WSMD4- Wavelength Selective Multiplexing Demultiplexing
RMU9- Reconfigurable Multiplexing Unit

Reference

- ❖ OTC000003 WDM principle
- ❖ ITU-T G.694.1 and G.694.2 (about the wavelength distribution)
- ❖ https://optiwave.com/

- ❖ http://www.fiber-optic-transceiver-module.com/

- ❖ ITU-T G.671 (about the optical passive components)

- ❖ ITU-T G.652 , G.653 and G.655 (about the fiber)
- ❖ Optix OSN 8800 Hardware description
- ❖ Optix OSN 8800 Product description
- ❖ Practical experience on Huawei OSN 1800, OSN 8800 operation and maintenance