Operational & Planning Aspects of DWDM

Tuesday, 22 March 2022 at 15:00 (UTC +10:00)

Simon Baroi, CT | Zobair Khan, CT

communitytrainers@apnic.net

Course Topics:

- 100G & Beyond.
- Planning Aspects.
- Operational Aspects.
- Case Study-1 (Planning)
- Case Study-2 (Operational)
- Case Study-3 (Operational)

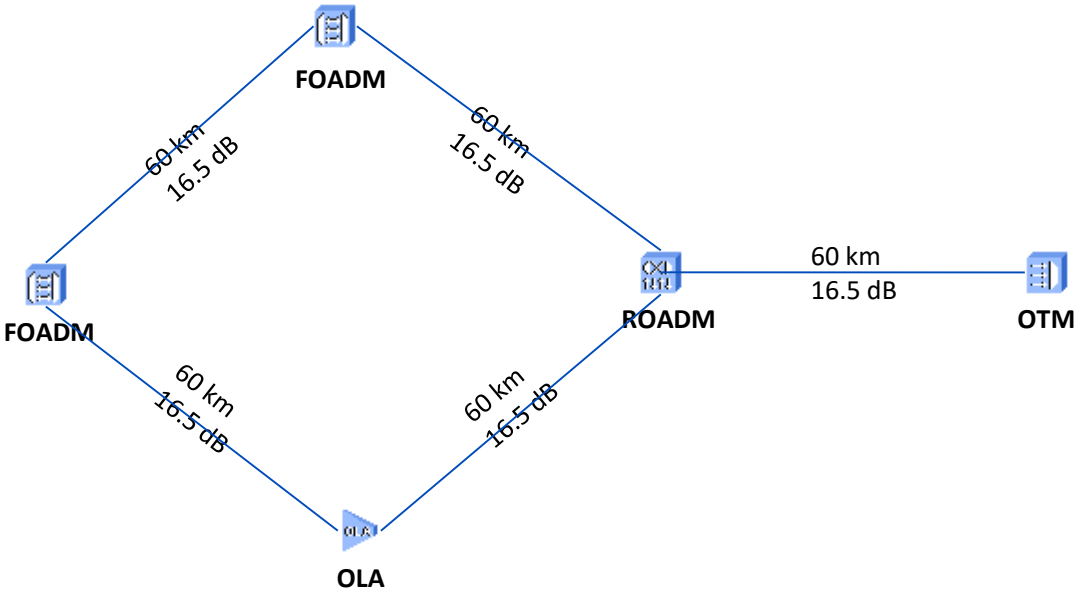
What we have learned in Part-1

- Introduction to Fiber
- Fiber Characteristics
- Introduction to WDM
- DWDM
- DWDM for Advanced Network

WDM Network Element

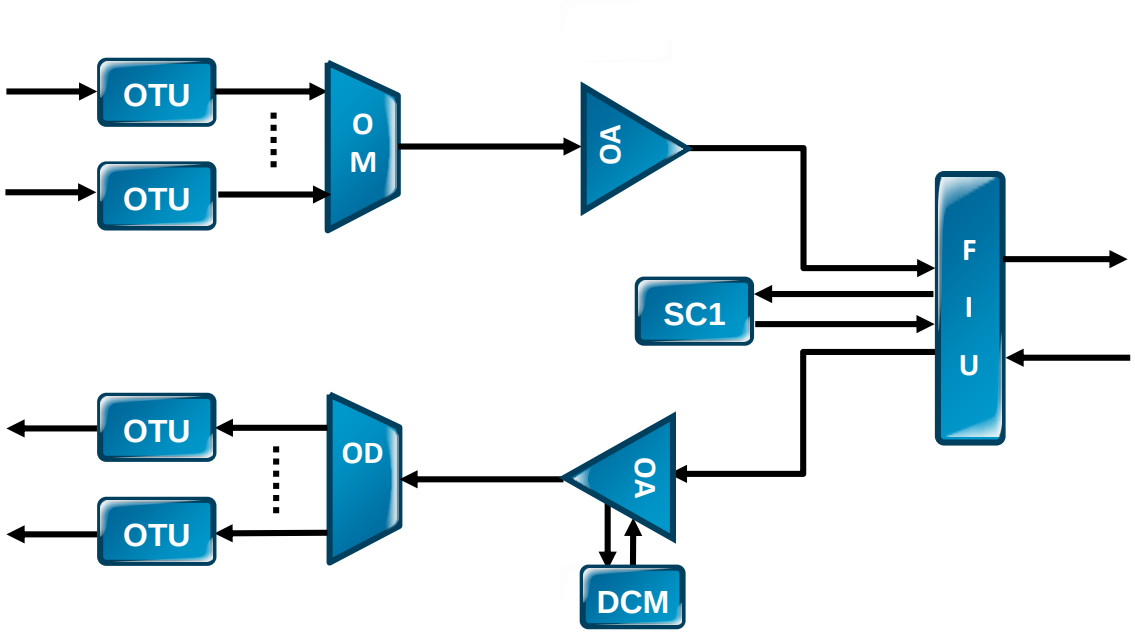
- The WDM can be configured as four types:
  - Optical Terminal Multiplexer (OTM)
  - Optical Line Amplifier (OLA)
  - Optical Add/Drop Multiplexer (OADM)
    - Fixed optical add or drop multiplexer (FOADM)
    - Reconfigurable optical add or drop multiplexer (ROADM)
  - Regenerator (REG)

WDM Network Element



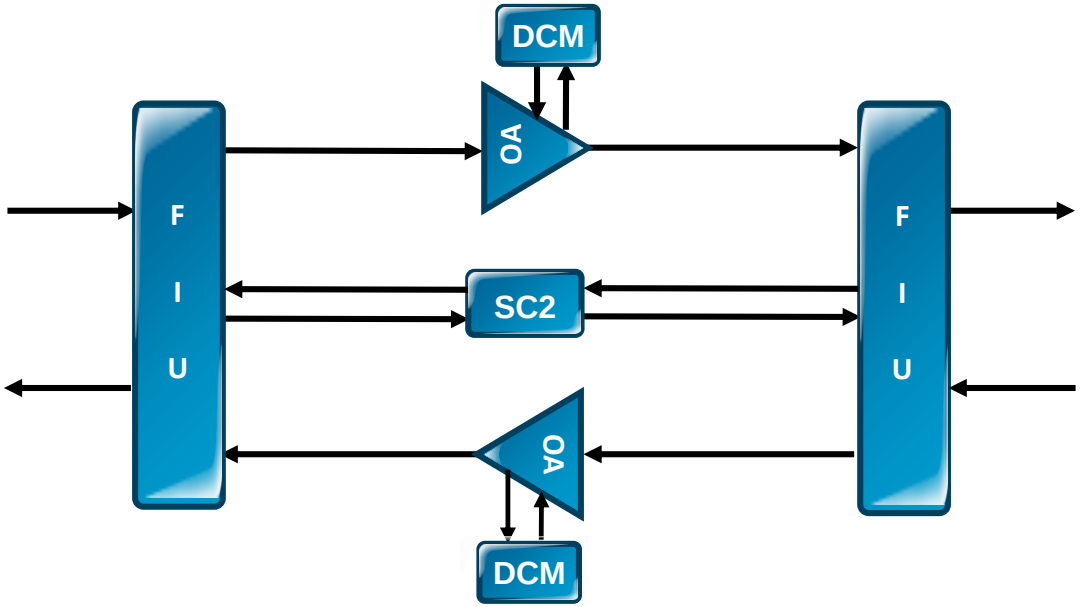
Signal Flow

- OTM (40-wavelength):



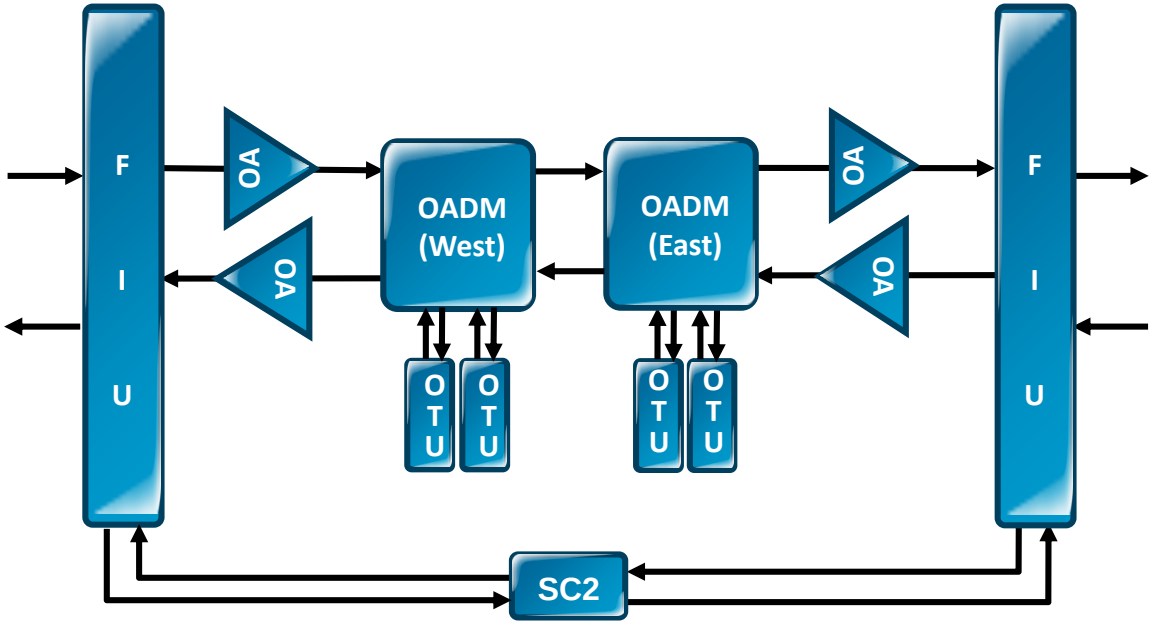
Signal Flow

- OLA:



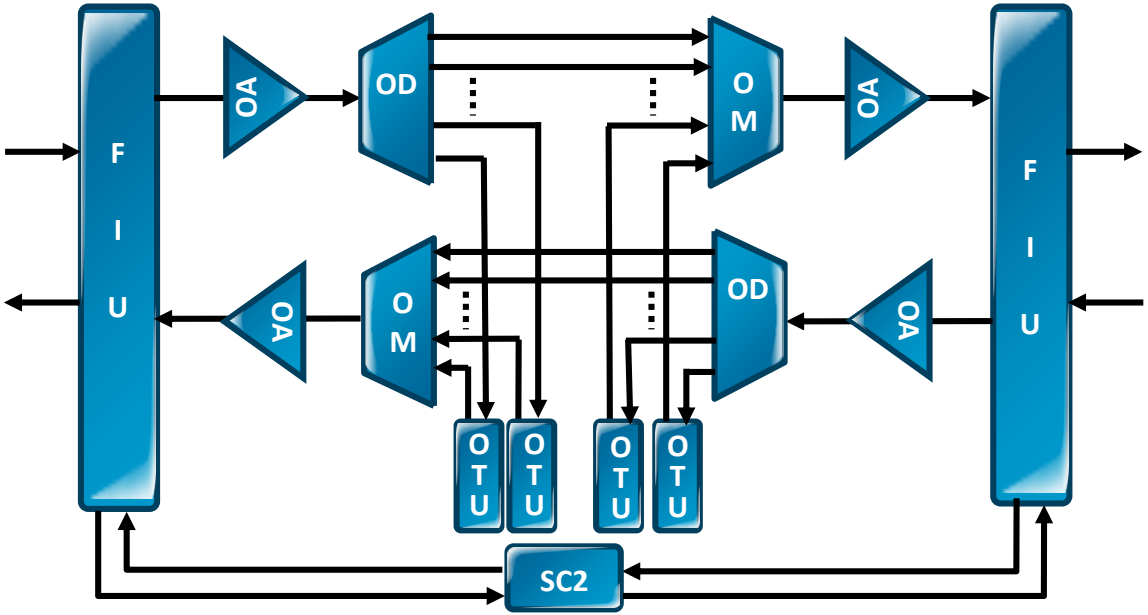
Signal Flow

- FOADM: (Serial FOADM)



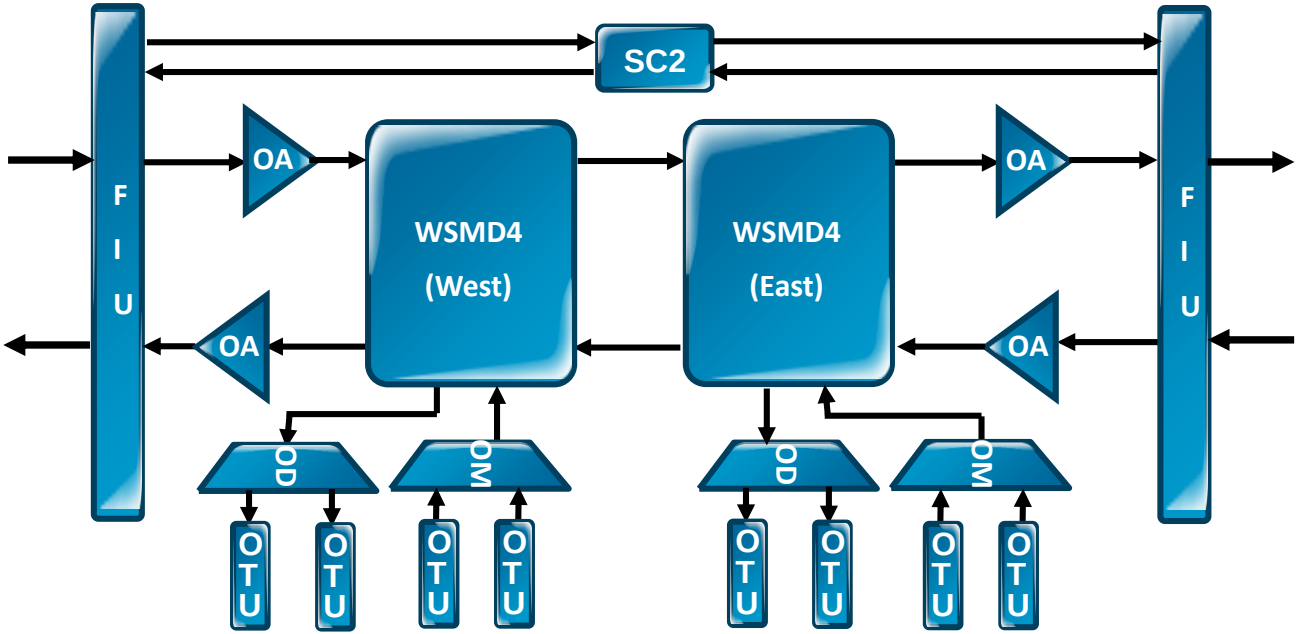
Signal Flow

- FOADM: (Parallel FOADM)



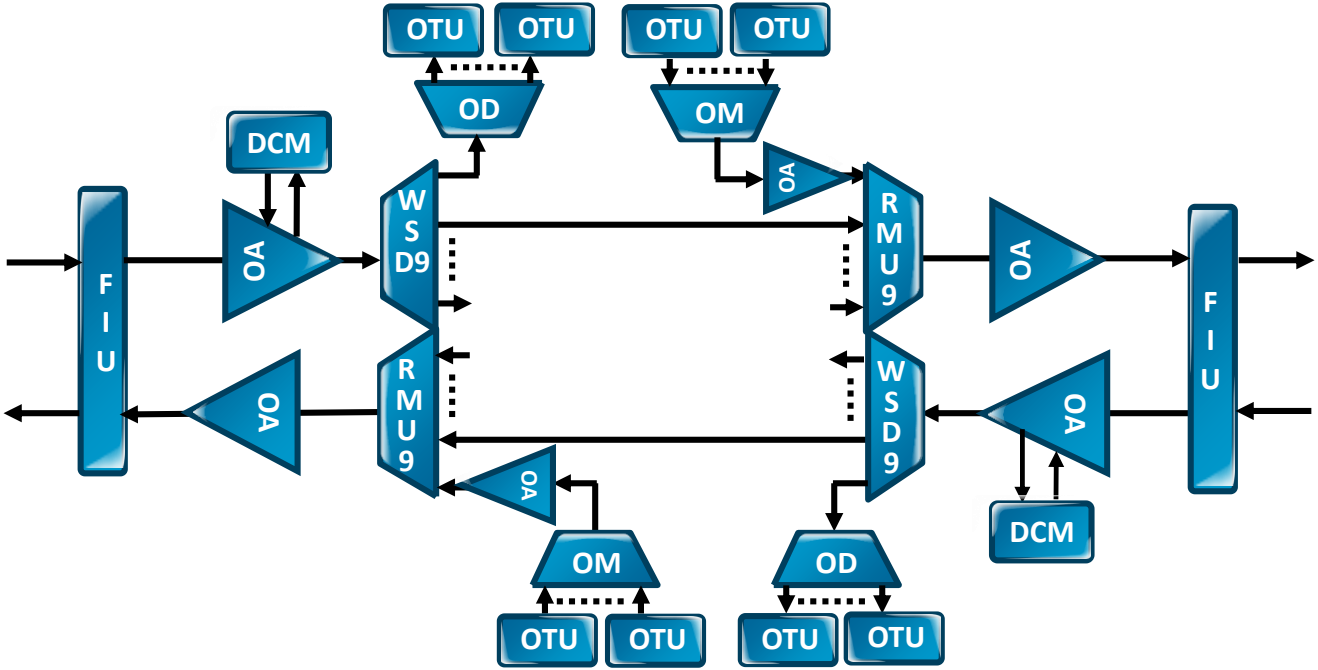
Signal Flow

- ROADM: (WSMD4+WSMD4)



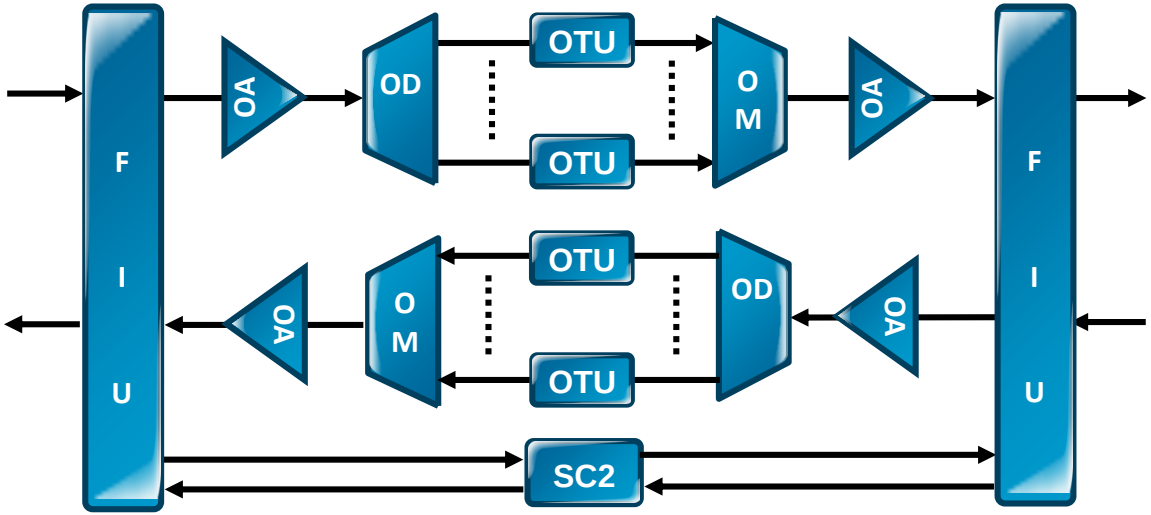
Signal Flow

- ROADM: (2degrees)



Signal Flow

- REG
  :



Note: Signals are regenerated through the regenerating OTU.

Operational & Planning Aspects of DWDM

Module 1: 100G and Beyond

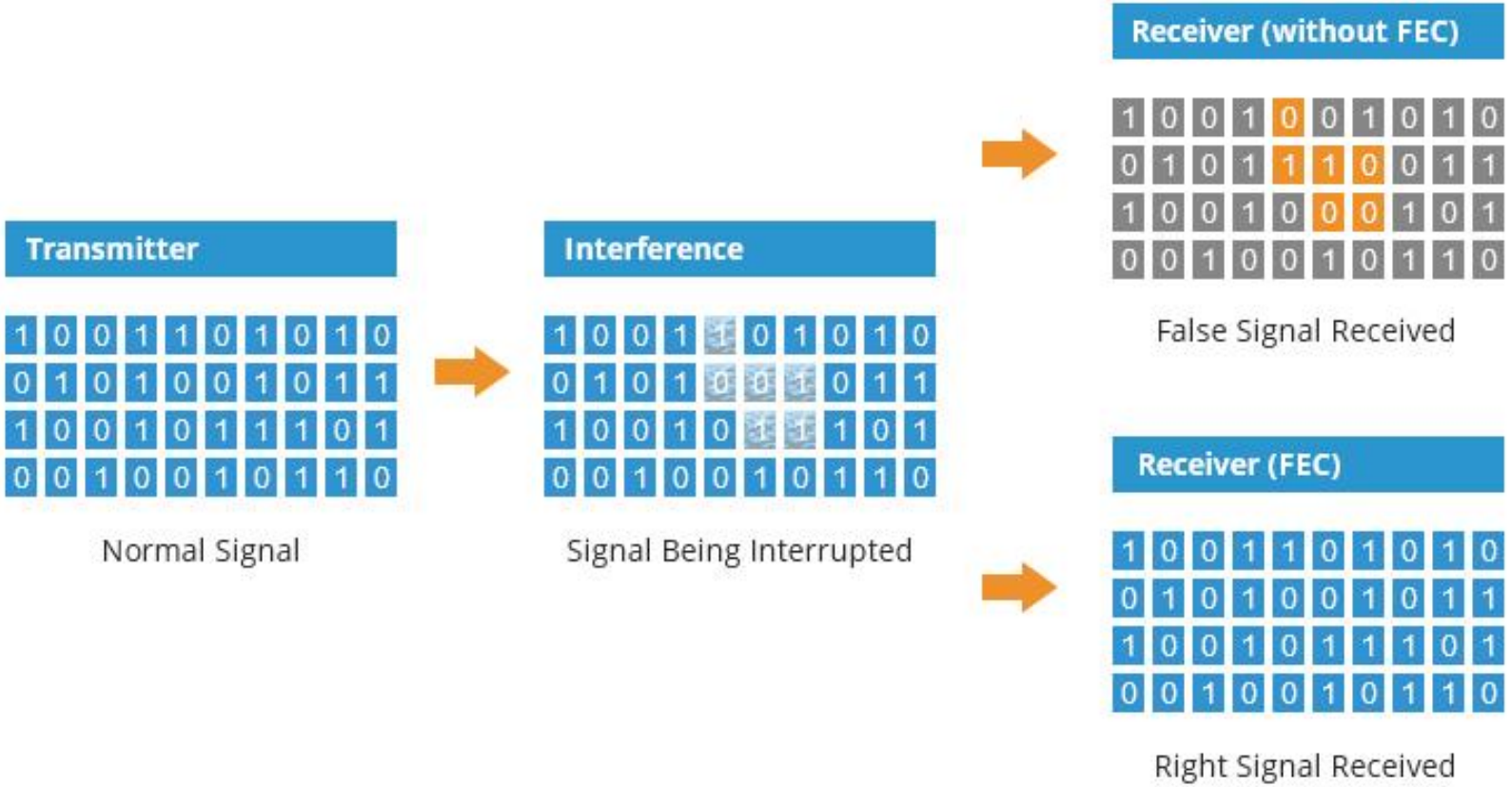
Coherent Network

- Coherent optical technology forms the foundation to achieve transport speeds of 100G and beyond, delivering Terabits of information across a single fiber pair.
- Digital signal processors electronically compensate for Chromatic and Polarization Mode Dispersion (CD and PMD) and eliminate the need for dispersion-sloped compensating modules from the photonic line.
- Coherent optics enables greater network flexibility and programmability by supporting different baud rates and modulation formats. This results in greater flexibility in line rates.
- High scalability from 100G to 400G and beyond per single signal carrier, delivering increased data throughput at a lower cost per bit.

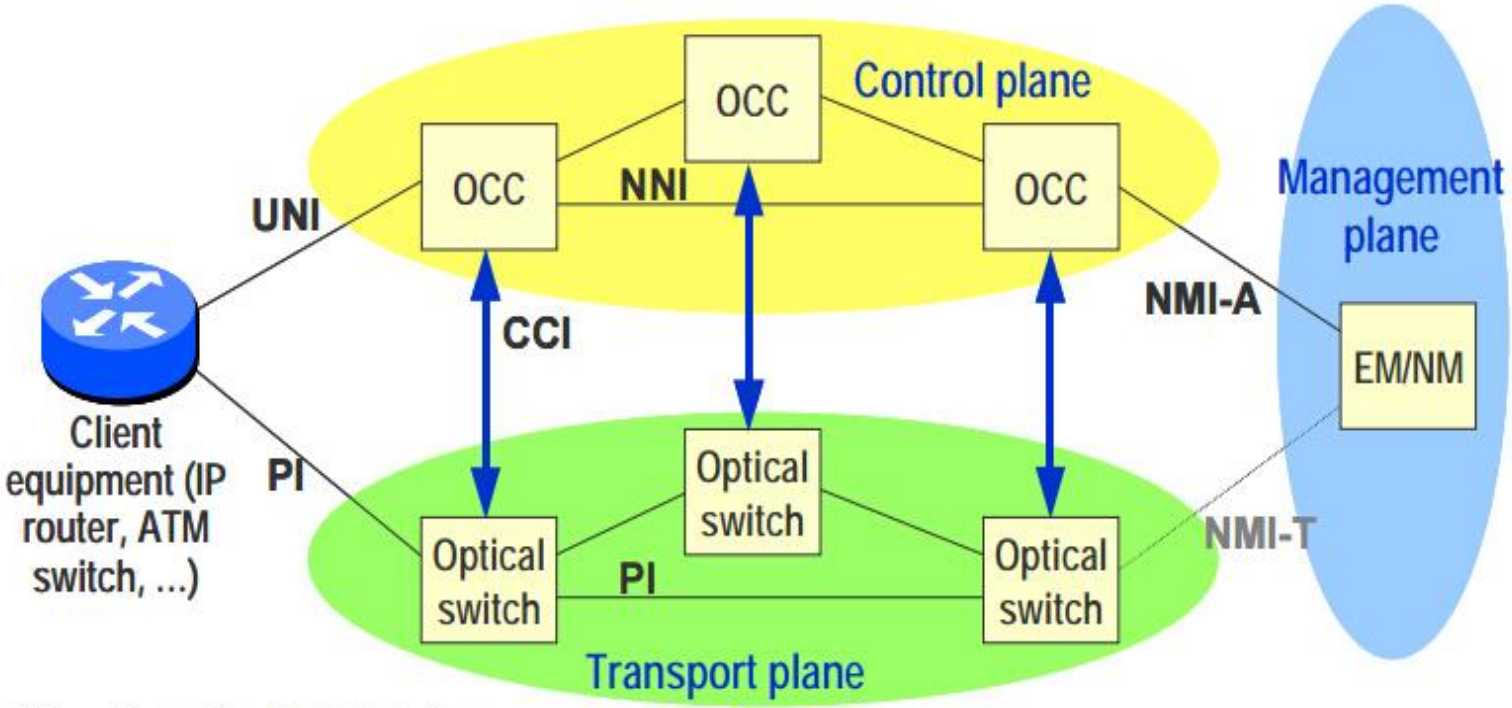
Benefits of Coherent Network :

- High-gain soft-decision Forward Error Correction (SD-FEC)
- Spectral shaping. (37.5 ghz, 75ghz)
- Programmability. (100G/200G/400G/600G)
- Strong mitigation to dispersion. (CD,PMD)

Forward Error Correction :



Automatically Switched Optical Network (ASON)

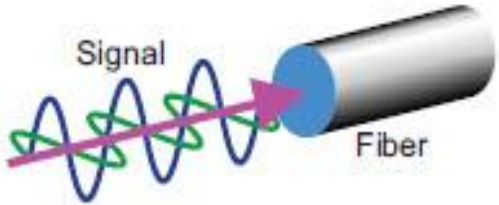


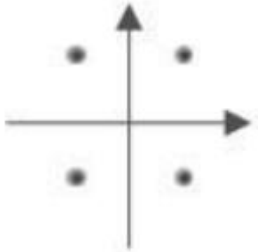
CCI: Connection Control Interface
NMI-A: Network Management Interface for the ASON Control Plane
NMI-T: Network Management Interface for the Transport Network
NNI: Network to Network Interface
OCC: Optical Connection Controller
PI: Physical Interface
UNI: User to Network Interface

Automatically Switched Optical Network (ASON)

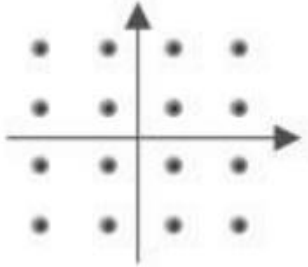
Electrical ASON	Optical ASON
Electrical ASON is based on ODUk switching at electrical layer of an OTN cross-connect board. So OTN Cross-Connect and ROADM boards need to be used.	Optical-layer ASON requires the ROADM system for hardware support
Focus on tributary and line boards and use electrical-layer cross-connect ODUk logical ports	Focus only on the FIU and OTU boards. Based on optical-layer ROADM
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

DSP and Modulation Technique :

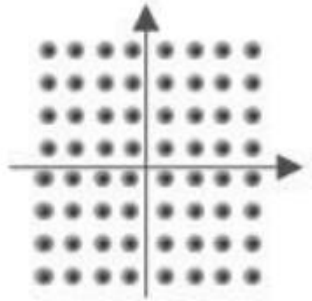




QPSK



16-QAM

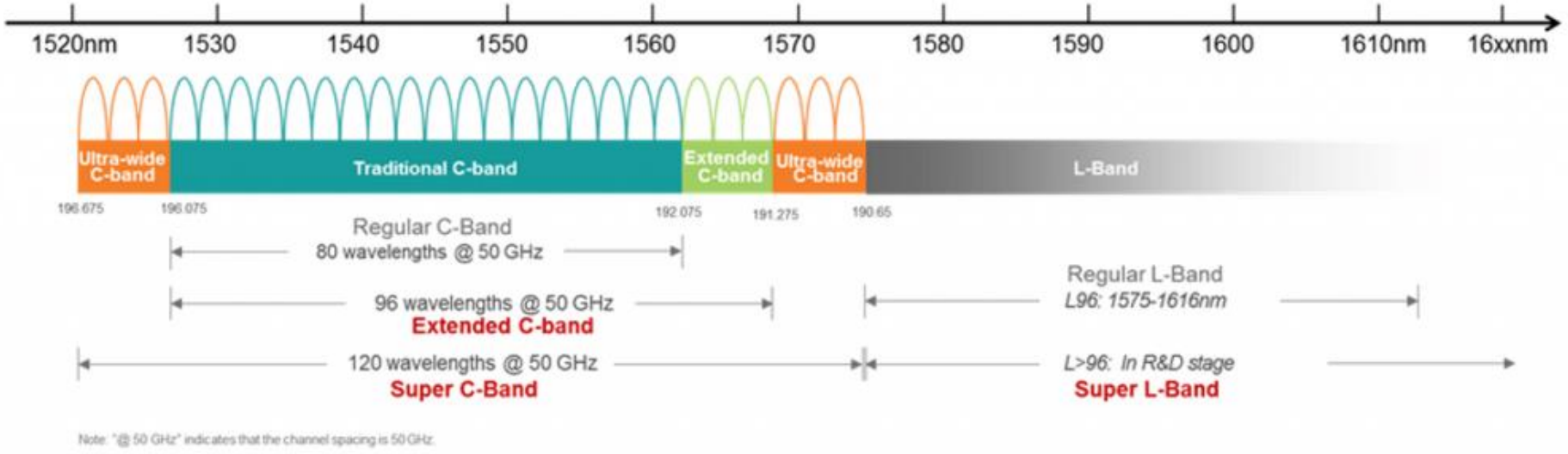


64-QAM

Bandwidth Vs. DSP:

Data Rate	Modulation	Bits/Symbol	Baud Rate	Polarization	Raw BW (G)	Channel Size	6.25GHz Slices
100 Gbps	QPSK	2	32 GigaBaud	2	128	37.5 GHz	6
150 Gbps	8QAM	3	32 GigaBaud	2	192	37.5 GHz	6
200 Gbps	16QAM	4	32 GigaBaud	2	256	37.5 GHz	6
200 Gbps	8QAM	3	56 GigaBaud	2	336	62.5 GHz	10
200 Gbps	QPSK	2	64 GigaBaud	2	256	75 GHz	12
400 Gbps	16QAM	4	64 GigaBaud	2	512	75 GHz	12
600 Gbps	64QAM	6	64 GigaBaud	2	768	75 GHz	12
800 Gbps	64QAM	6	96 GigaBaud	2	1152	112.5 GHz	18

Super C-band uses the **ultra-wide C** band (C120) beyond the traditional C-band (C80) and the extended C-band (C96). It increases the available wavelength range.



Super-C Band : 120 Lambda
L Band : 96 Lambda

Total : 216 Lambda

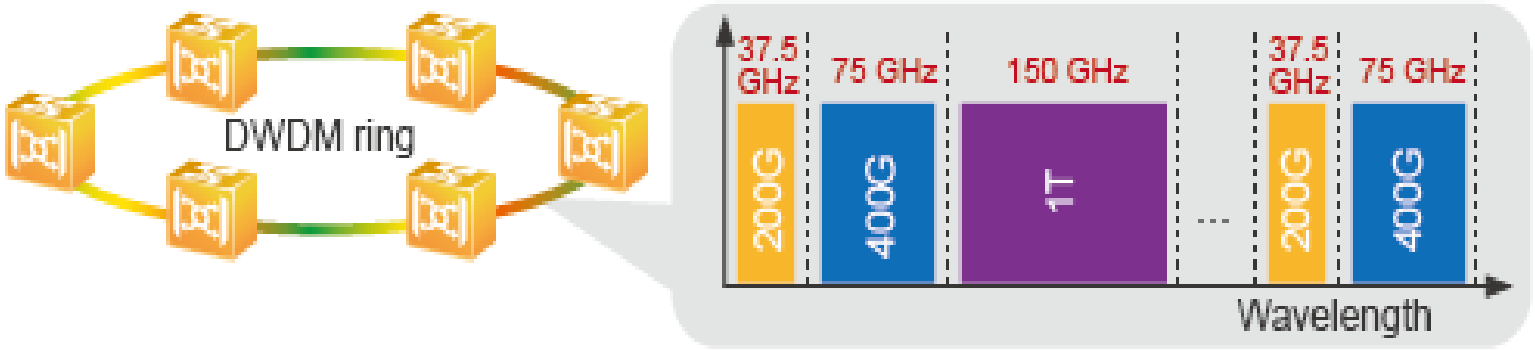
Fixed Grid

The traditional 40- or 80-wavelength DWDM system uses the Fixed Grid (fixed spectrum) mode, which features a fixed center frequency and fixed wavelength spacing of 50 GHz or 100 GHz.

However, in the Fixed Grid mode, bandwidths cannot be adjusted flexibly.

Flexible Grid (felxi-grid)

To implement flexible spectrum allocation and improve spectrum usage, the Flexible Grid technology is utilized. The Flexible Grid technology can provide 37.5 GHz to 400 GHz wavelength spacing.

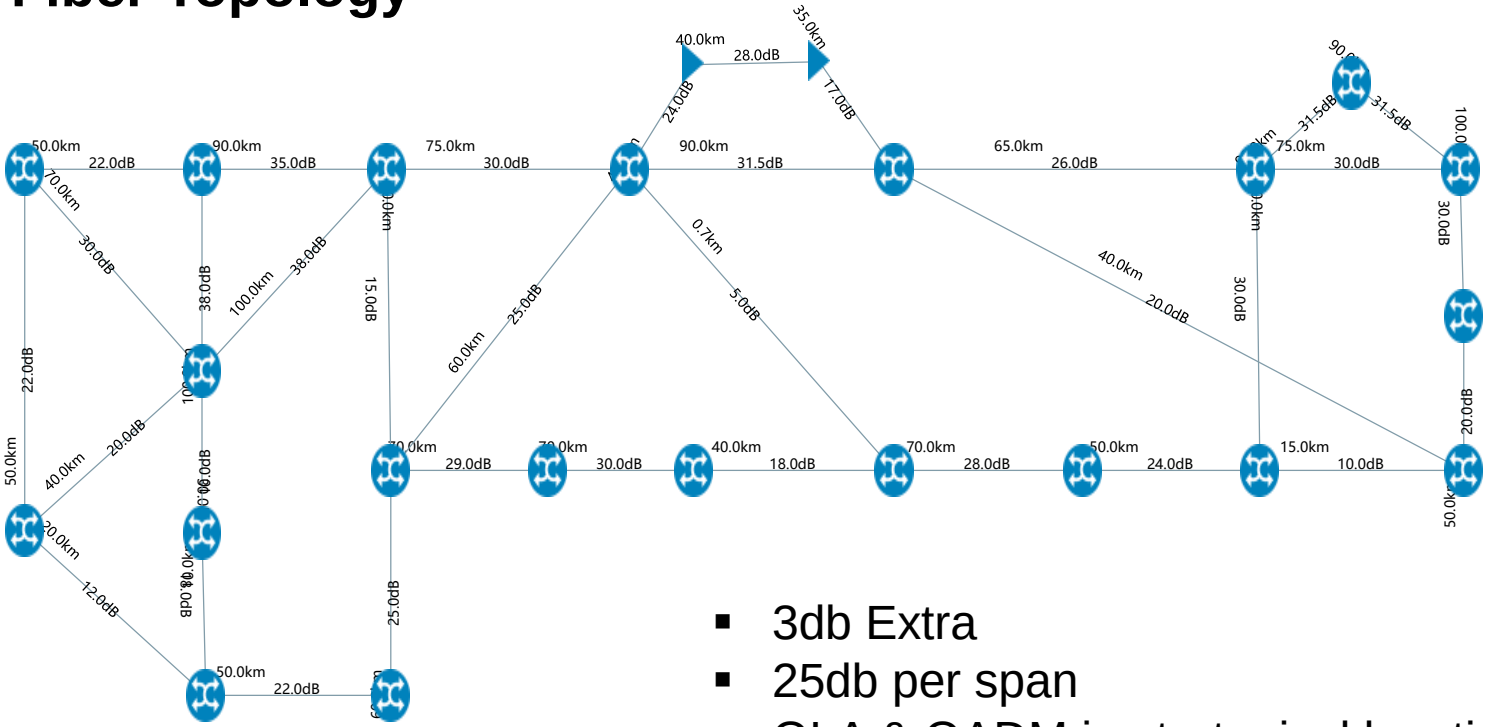


It divides spectrums into slices with smaller widths, such as 6.25 GHz slices or 12.5 GHz slices. A high-speed signal can occupy multiple spectrum slices, implementing flexible bandwidth adjustment and improving network-wide spectrum usage.

Operational & Planning Aspects of DWDM

Module 2: Planning Aspects

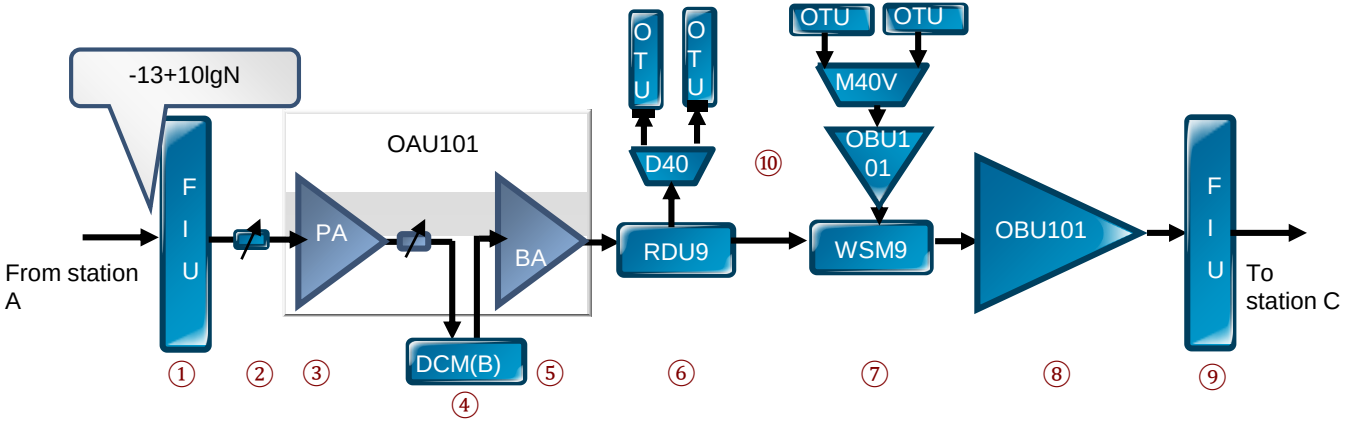
Fiber Topology



- 3db Extra
- 25db per span
- OLA & OADM in strategical location
- Avoid spof in terms of location-fiber-power

Power Calculation of all Path

- Typical optical power of the reference points from station A to station C



③⑤ OAU101 nominal individual channel input/output Power -16/+4dBm, gain range:20~31dB.

④ IL of DCM(B): 5dB. ①⑨ IL of FIU: 1dB. ⑩ IL of D40: 6dB, IL of M40V: 8dB.

⑥ IL of RDU9: 8dB(IN-DMx,IN-EXPO).

⑦ IL of WSM9: 8.5dB(EXPI-OUT), 12.5dB (AMx-TOA), 1.5 dB (ROA-OUT)

⑧ OBU101 nominal individual channel input/output Power -20/0dBm.

Traffic Matrix

SL	From	To	Line Capacity Gbps	Modulation	Protection Type	Service Type
1	A	B	200	100G QPSK	ASON	2x100G
2	X	Y	200	100G QPSK	ASON	1x100G & 10x10G
3	.	.	100	100G QPSK	ASON	1x100G
4	.	..	200	100G QPSK	ASON	20x10G
5	.	.	100	100G QPSK	ASON	10x10G
6	.	.	100	100G QPSK	ASON	1x100G
7		.	100	100G QPSK	ASON	1x100G
8	.	..	100	100G QPSK	ASON	1x100G
9	.	.	100	100G QPSK	ASON	1x100G
10	.	.	200	100G QPSK	ASON	1x100G & 10x10G
11	..	.	100	100G QPSK	ASON	10x10G
12	.	.	100	100G QPSK	ASON	1x100G
13	.	..	100	100G QPSK	ASON	1x100G
14	.	.	100	100G QPSK	ASON	1x100G
15	.	.	100	100G QPSK	ASON	1x100G
16	.	.	100	100G QPSK	ASON	1x100G
17	.	.	100	100G QPSK	ASON	10x10G
18	..	..	100	100G QPSK	ASON	1x100G
19	.	.	100	100G QPSK	ASON	1x100G
20	.	.	100	100G QPSK	ASON	1x100G
21	.	.	100	100G QPSK	ASON	1x100G
22	.	.	100	100G QPSK	ASON	1x100G
23	.	..	400	200G e16QAM	ASON	1x400G

Protection Mechanism

1. Equipment Level Protection

- ❑ Power Protection
- ❑ Board 1+1 Protection

2. Optical Layer Protection

- ❑ Optical Line Protection
- ❑ Intra-Board 1+1 Protection
- ❑ Client 1+1 Protection

3. Electrical Layer Protection

- ❑ ODUk SNCP Protection
- ❑ Tributary SNCP Protection
- ❑ ODUk Ring Protection

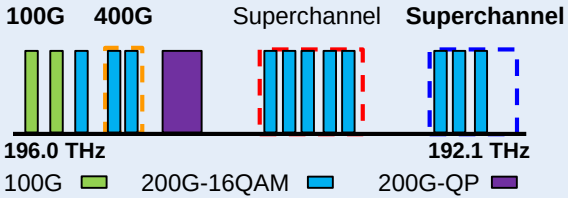
Future Scalability

- 96 lambda capacity with add/drop capability
  -save TCO , configuration flexible
- Optical – Electrical subracks separated solution
  -easy for maintenance ,higher reliability
- 100G/200G/400G Muxponder Board
  -unique card solution
- ROAD should support 6.25 Ghz channel spacing
- SDN ready
  - Save OPEX and CAPEX , future oriented

Technology Roadmap

		Channel Space	
	QPSK Capacity: 12.8T 64×200G		75GHz	3600km
+18%	8QAM Capacity: 15.2T 76×200G		62.5GHz	3400km
+50%	16QAM Capacity: 19.2T 96×200G		50GHz	2000km

Flex Grid management is an issue that needs to be considered in the application of 200G.



Various modulation formats supported by 200G will break the spectrum width limitations of traditional 50 GHz. Flex Grid is used for spectrum allocation.
Traditional wavelength management faces various difficulties. It is necessary to obtain real-time network-wide spectrum resource distribution information to visualize the Flex Grid network.

Spares & Warranty

Spare parts

- Spare parts are essential assets for maintaining high reliability and productivity. Having spare parts available right away allows you to meet your production goals.
- Some of the benefits of a spare parts inventory include:

  - Reduced downtime
  - No excessive expediting or shipping fees
  - 100% SLA

Warranty

- A warranty is a guarantee from a seller that a defective product will be repaired or replaced within a specific time. A guarantee is a seller's promise that a product will meet certain quality or performance standards. If not, it will be repaired or replaced.
- Standard Warranty means the assurance that the Products and/or Professional Services satisfy - for a limited period of time - the required quality or performance in accordance to the provisions

In-land RMA Vs. Overseas RMA

Operational & Planning Aspects of DWDM

Module 3 : Operational Aspects

Operational Aspects & Challenges

Fiber Loss Optimization

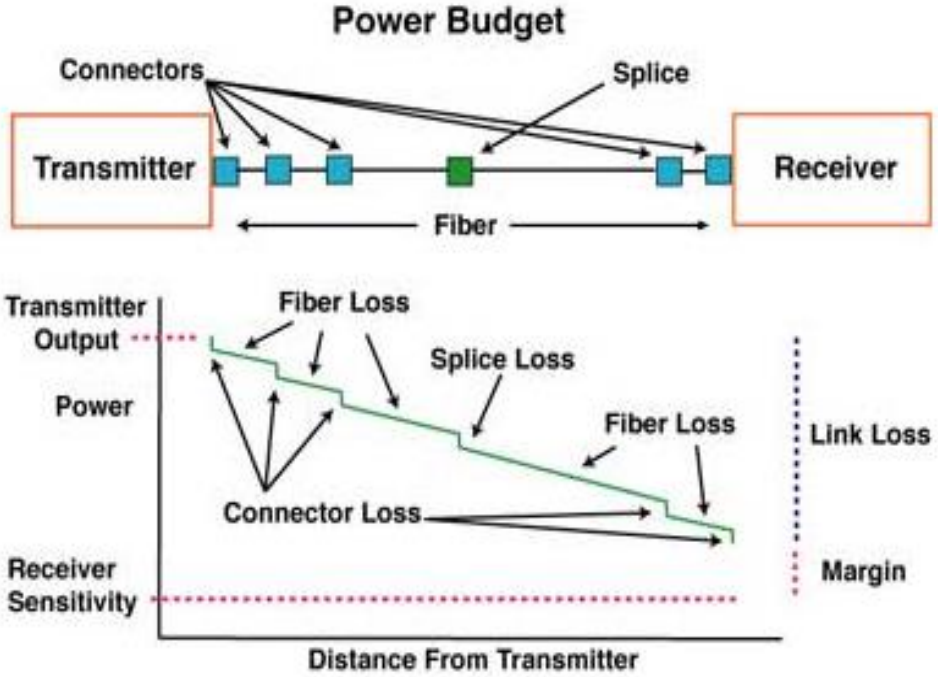
Fiber loss optimization is essential in optical transmission system.

To establish transmission backbone link the below parameters are followed :

- Fiber (backbone) Loss
- Connector Loss
- Splice Loss

For DWDM long distance transmission system of C band 1529nm to 1560 nm range wavelength,

G.652D fiber used for both coherent and non-coherent system.

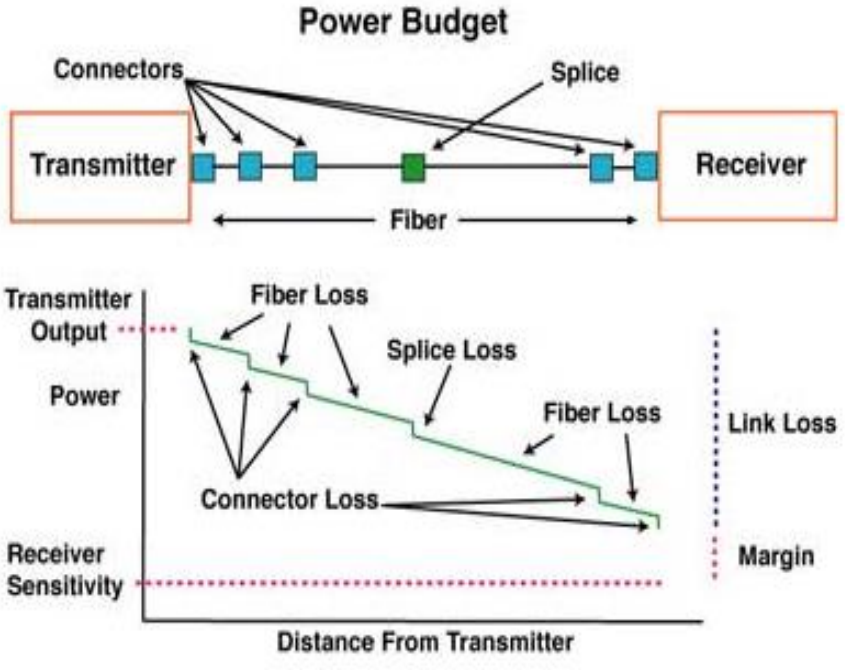


Fiber Loss Optimization

G652D: marginally lower attenuation and lower splicing losses, when splicing like fibers.

G657-A2 is better for patch cords provide an improved bend radius and flexibility.

- Fiber backbone loss 0.3 dB/km
- For connector, loss should be 0.5 dB
- For each hard patch loss should be 0.5 dB
- Per splice loss 0.03 dB
- Patch cord with connector, loss should be 1 dB



Optical Reporting

Optical Reporting is very much important for smooth operation and maintenance purpose.

Optical Reporting should include below parameters :

1. Each Backbone Loss (end to end)
2. Performance of each span (db)
3. Link Availability (SLA)
4. Reason for backbone outages (RFO)
5. Common Fiber removal
6. Frequent Outage Report
7. Always find alternate path
8. Road/Utility Extension Report

Environmental Hygiene

Environmental hygiene is essential for any optical transmission network.
For smooth and error free transmission clean environment is required.

Dust
Fiber optic networks work by carrying pulses of light between transmitters and receivers.
Dust and contamination block the signal and lead to light loss, reducing power and efficiency.
A 1-micrometer dust particle on a single-mode core can block up to 1 per cent of the light
(a 0.05dB loss)**.** Dirt can cause damage to system equipment also.

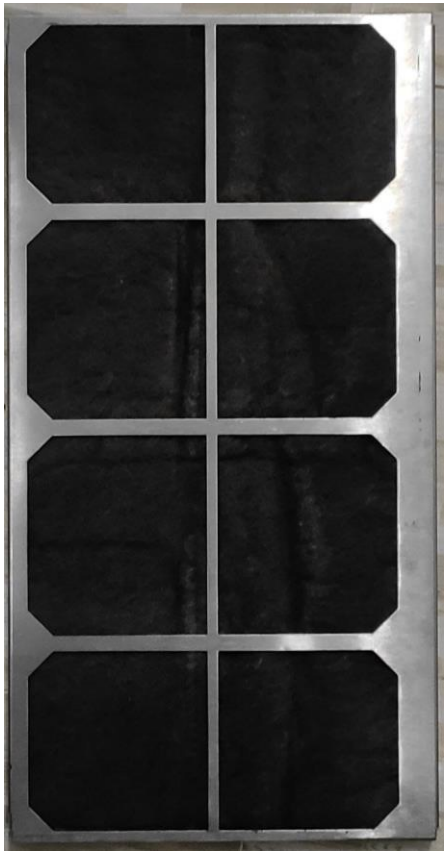
Path cord Laying--Improper Patch cord laying can cause hazard to signal transmission.

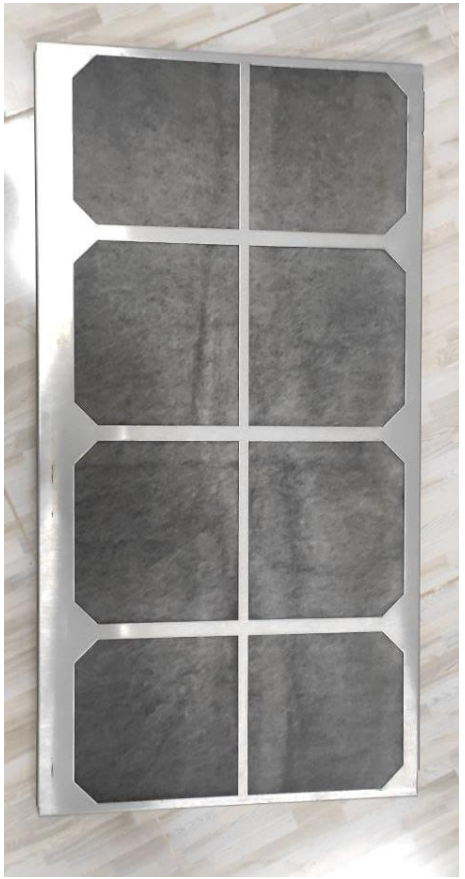
Connector CAP--Every unused connector head should capped.

Dummy for Unused Slot– Free slots must be filled with dummy.

Engineers should touch equipment after proper grounding using ESD Band to avoid (+ve) charge.

Equipment Cleaning :





Power :

- Good Power Backup as Per Location
  - GenSet
  - Battery

- **Grounding of Device**

Proper grounding of equipment is must to prevent thundering or voltage surge.

Temperature

- Temperature is one of the most important parameters for safety of fiber optic transmission device.
- Every Data Center or equipment room must be facilitated with adequate cooling system (AC).

- Without proper cooling system, devices become hot and it can cause signal degradation. It can even damage modules and equipment.

- DWDM transmission equipment has its own cooling system (FAN) but its not enough as the POPs are all in closed environment.
- Temperature within 22 to 25 degree Celsius is required for smooth performance and device safety.

Tools

OTDR:

Optical Time Domain Reflectometer
Used to inject a series of optical pulses into the fiber. Light pulses goes through the fiber core. Suppose a fi has length of 70km so OTDR will show the full length with intermediate event by event loss of hard patch, bend or splice points. If there is break after 45 km then OTDR result will show the break point at
45 km in display.

Power Meter :

Optical power meter is used to measure power level of optical signal at dBm unit and it has various Wavelength range like 1310nm, 1490nm, 1550 nm.

Different wavelength’s optical power can be measured easily. There is a FC connector On top of meter to connect patch cord.
It can sense normally from +20 dBm to – 50 dBm.

Fiber Cleaning Kit :

Fiber cleaning kit is used to clean patch cord connector.
There are 2 types of kit.

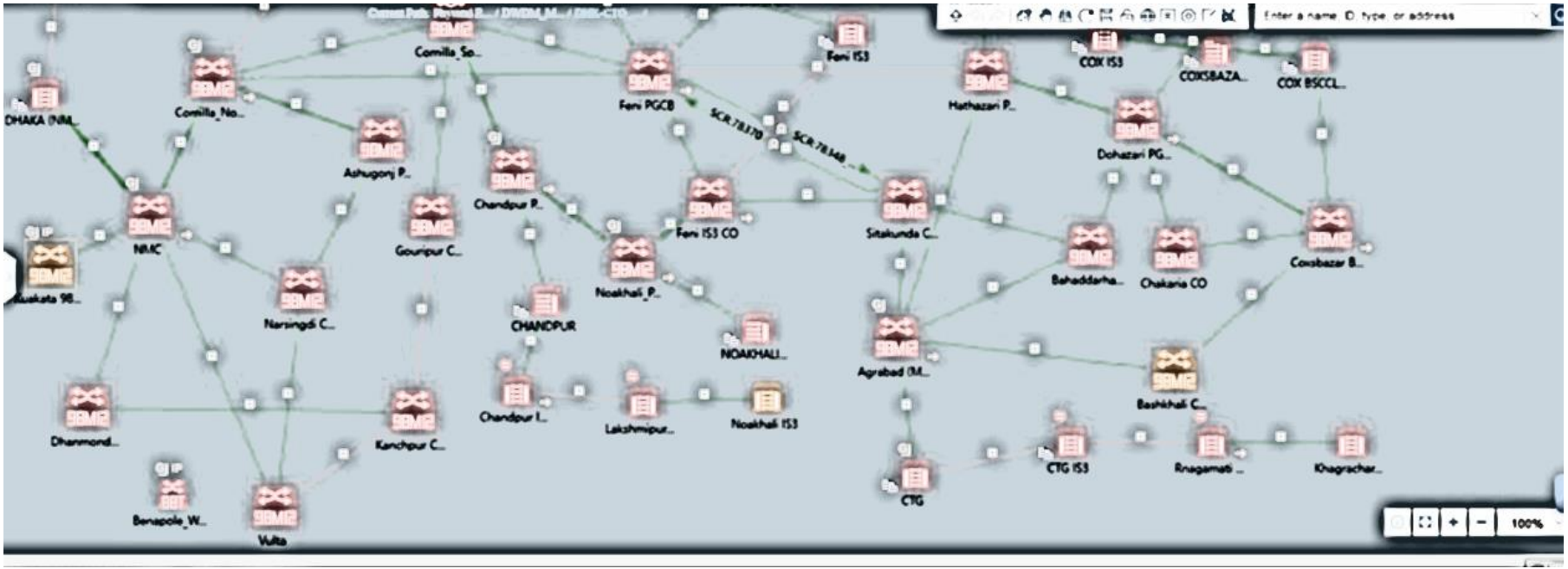
Pen Type cleaning kit
Rub type cleaning kit

Pen type is used for cleaning LC connector.
Need to connect LC head to pen and press gently.

With Rub type kit any connector can be cleaned.
Just need to rub connector head on the white portion of kit.

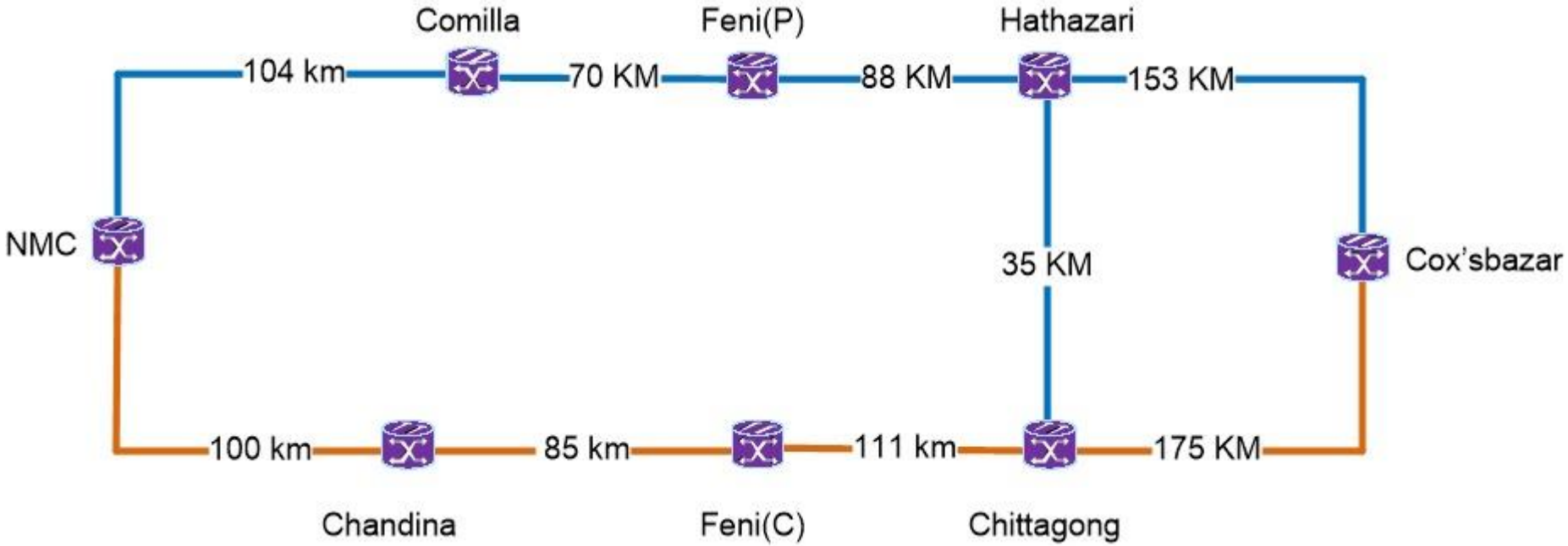
Trained NOC & Filed Engineer :

Network Management System:



Operational & Planning Aspects of DWDM

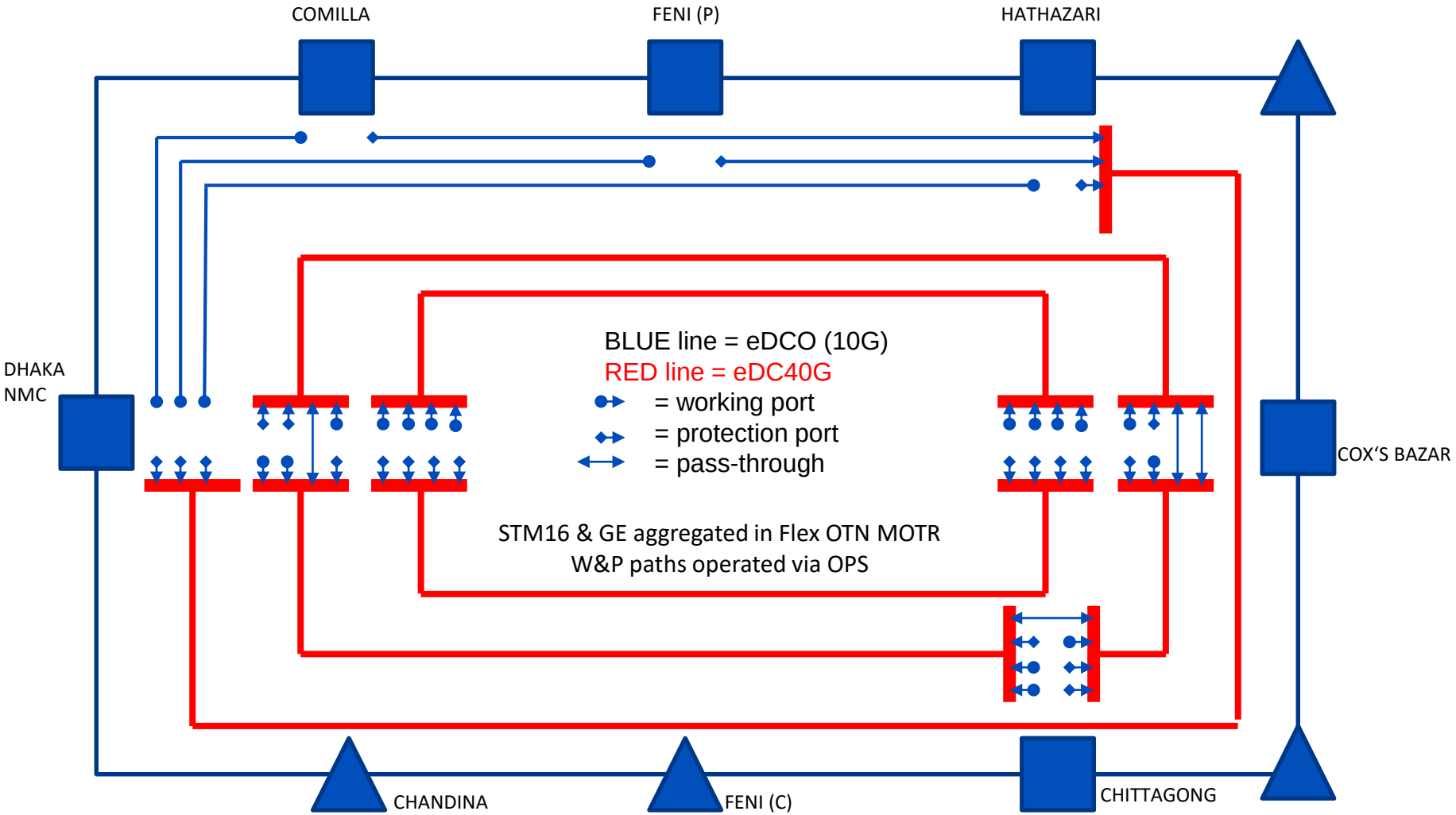
Module 4: Case Study 1 - Planning



- Area : Flat
- Fiber Characteristics
  - Underground : Yellow Line
  - Power Grid Cable : Blue Line
- Protection : Ring Network

	NMC	Comilla	Feni (P)	Chittagong	Hathazari	Cox's Bazar
NMC	0	4xSTM-16 2xGE	4xSTM-16 2xGE	4xSTM-16 1x10GE	4xSTM-16 2xGE	4 x STM-64 4xSTM-16 2xGE
Comilla	4xSTM-16 2xGE	0				
Feni (P)	4xSTM-16 2xGE		0			
Chittagong	4xSTM-16 1x10GE			0		4 x STM-16
Hathazari	4xSTM-16 2xGE				0	
Cox's Bazar	4 x STM-64 4xSTM-16 2xGE			4 x STM-16		0
Chandina	OLA Site		Fiber Loss 0.25 per km			
Feni (C)	OLA Site					

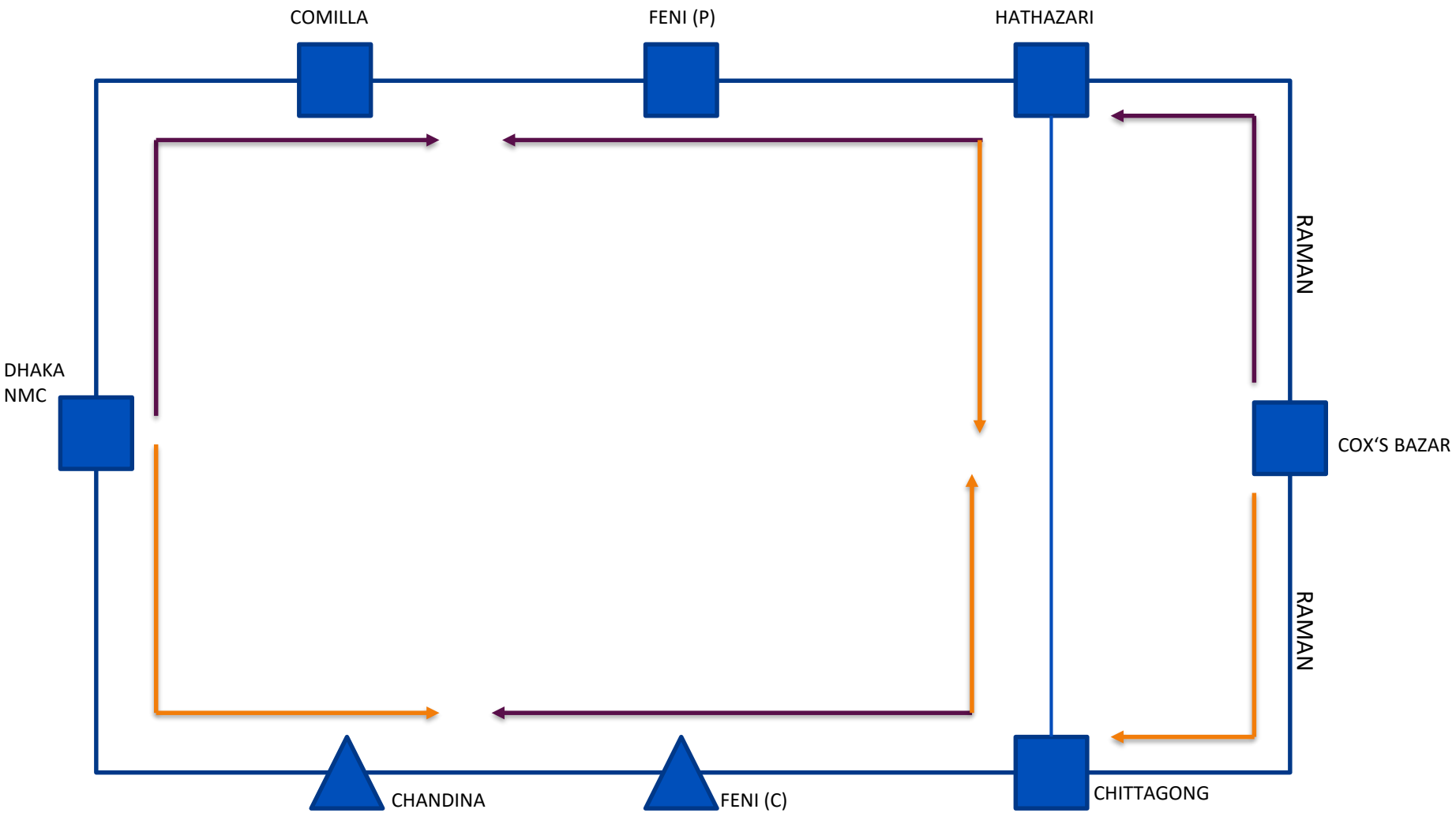
	NMC	Comilla	Feni (P)	Chittagong	Hathazari	Cox's Bazar
NMC	0	3xSTM-16 2xGE	3xSTM-16 2xGE	4xSTM-16 1x10GE	3xSTM-16 2xGE	4 x STM-64 3xSTM-16 2xGE
Comilla	3xSTM-16 2xGE	0				
Feni (P)	3xSTM-16 2xGE		0			
Chittagong	4xSTM-16 1x10GE			0		4 x STM-16
Hathazari	3xSTM-16 2xGE				0	
Cox's Bazar	4 x STM-64 3xSTM-16 2xGE			4 x STM-16		0
Chandina	OLA Site		Fiber Loss 0.25 per km			
Feni (C)	OLA Site					


COMILLA
FENI (P)
HATHAZARI
DHAKA
NMC
COX'S BAZAR
BLUE line = eDCO (10G)
RED line = eDC40G
= working port
= protection port
= pass-through
STM16 & GE aggregated in Flex OTN MOTR
W&P paths operated via OPS
CHANDINA
FENI (C)
CHITTAGONG

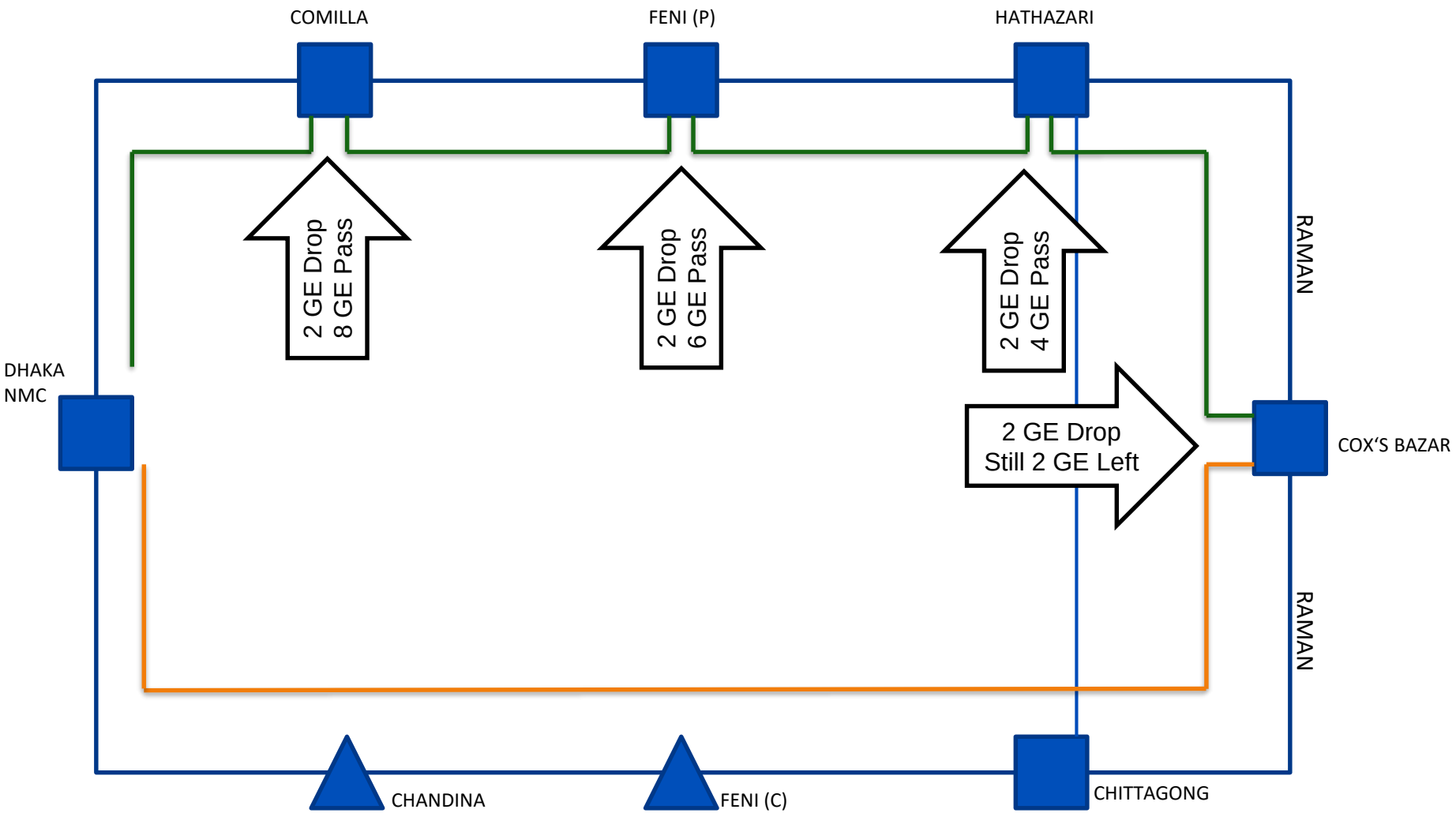
- Traffic Matrix
  - one 10G channel to every point
  - One STM-16 is reduced to make the use for one 10G.
    - 3 x 2.5 (STM-16) + 2 GE = 10 G *(hmm… Planning Problem)*

- To Reduce the cost Hathazari to Chittagong link was dropped *(hmm….. Investment Problem)*

- Transponder based services were used
- No Centralized cross connect board were used here


COMILLA
FENI (P)
HATHAZARI
RAMAN
DHAKA
NMC
COX'S BAZAR
RAMAN
CHANDINA
FENI (C)
CHITTAGONG

	NMC	Comilla	Feni (P)	Chittagong	Hathazari	Cox's Bazar
NMC	0	4xSTM-16 2xGE	4xSTM-16 2xGE	4xSTM-16 1x10GE	4xSTM-16 2xGE	4 x STM-64 4xSTM-16 2xGE
Comilla	4xSTM-16 2xGE	0				
Feni (P)	4xSTM-16 2xGE		0			
Chittagong	4xSTM-16 1x10GE			0		4 x STM-16
Hathazari	4xSTM-16 2xGE				0	
Cox's Bazar	4 x STM-64 4xSTM-16 2xGE			4 x STM-16		0


COMILLA
FENI (P)
HATHAZARI
2 GE Drop
8 GE Pass
2 GE Drop
6 GE Pass
2 GE Drop
4 GE Pass
RAMAN
DHAKA
NMC
2 GE Drop
Still 2 GE Left
COX'S BAZAR
RAMAN
CHANDINA
FENI (C)
CHITTAGONG

- Traffic Matrix
  - Full traffic was designed according to requirement
- Redundant link was crated between Hathazari and Chittagong.

- OTN Services were used in Centralized cross connect board.

  (hmmm…. Limited cross-connect)
- RAMAN Amplifier for long distance link, which is expensive and crucial to handle the power of that card.

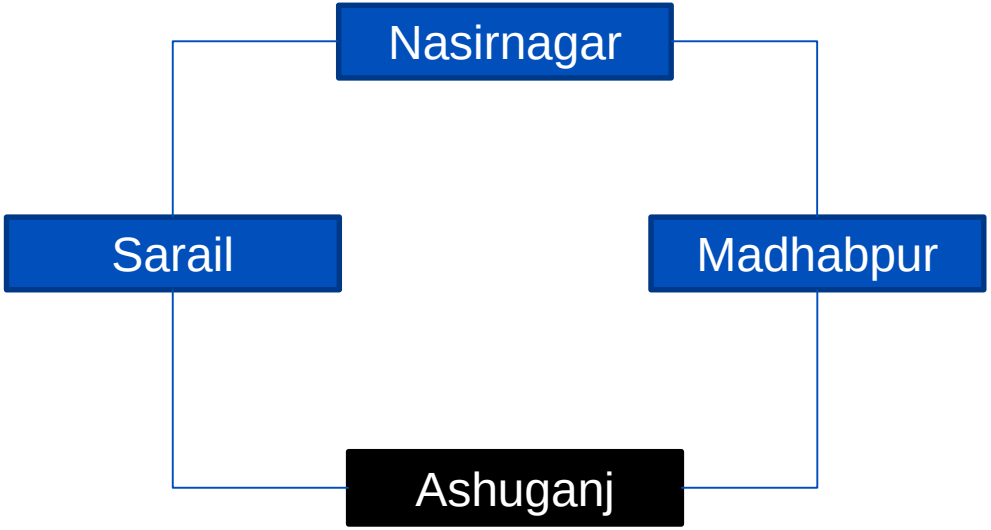
Operational & Planning Aspects of DWDM

Module 5 : Case Study-2 [Operational]

Optical Power Abnormity

Symptom

- ring network
- all stations are configured as OADM.
- Ashugonj is the aggregation node which is indicated with black.
- Sarail, Nasirnagar, Madhabpur has similar services that drop at Ashugonj.



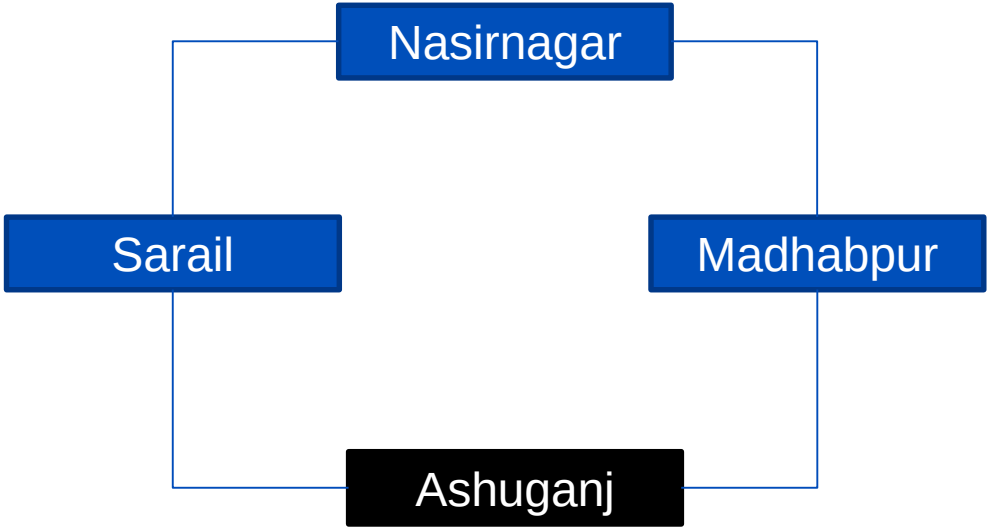
Cleare...	Severity	Name	Alarm Source
	Critical	IN_PWR_LOW	Madhabpur_7-72 / Madhabpur(7-72)

- One day all OTU at Madhabpur, Sarail and Nasirnagar reports IN_PWR_LOW alarm and Sarail reports LOF alarm.

- Traffic has not impacted

Possible Causes

- The OTU that reports alarm are at same direction that is Ashugonj to Madhabpur to Nasirnagar to Sarail.
- But in opposite direction no alarm found.



Analyze :

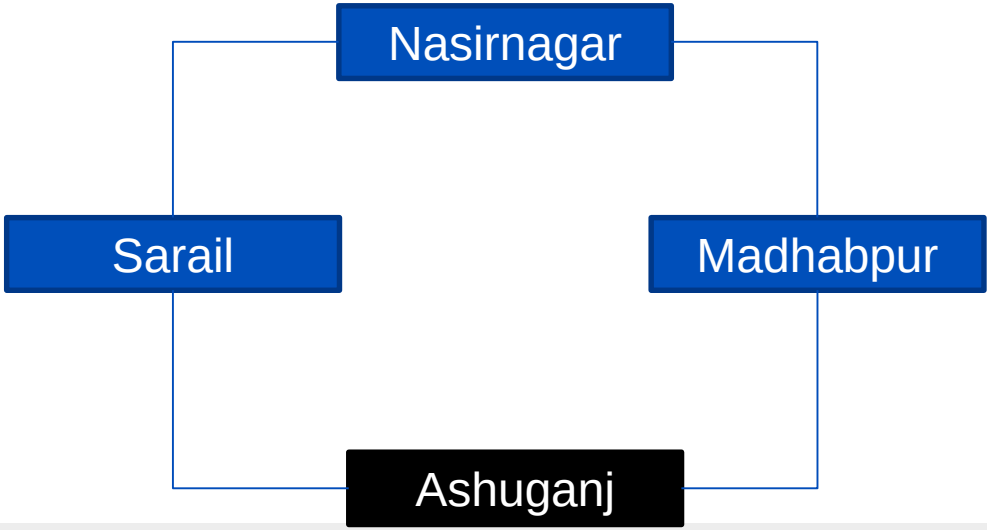
- So firstly we will analyze the signal flow from Ashugonj to Madhabpur.
- We logged in to Madhabpur node and it has 2 directions.
- One towards Ashugonj and another towards Nasirnagar.
- Alarm generates at OTU card that directly Connected with Ashugonj.

Possible Causes

Cause 1: The patch cord between Mux Unit to FIU Unit was abnormal on Ashugonj NE.

Cause 2: Backbone fiber loss between Ashuganj to Madhabpur.

Cause 3: FIU to AMP patch cord or Mux Unit to OTU patch cord abnormal.



Handling Procedure

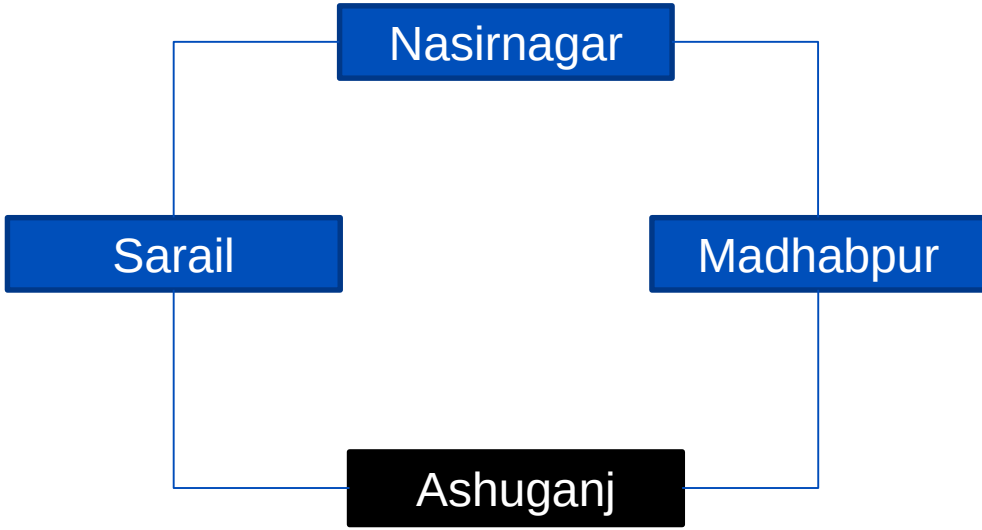
1. Check transmit power of Mux Unit on Ashugonj end and found +4 dBm towards Madhabpur.

2. Receive power at Madhabpur end
is -26 dBm. Distance of backbone is 50 km,
loss should be 20 dB but loss is 30 dB.
Historical power shows loss was 20 dB.
Loss was 20 dB.

3. So problem is here receive core of
Ashugonj to Madhabpur backbone link. (RX)

4. Need to work on this link and reduce
loss. Team found fiber bent and fix that.

After that loss reduced to 20 dB again.
And alarm at OTU board removed.



Summary and Suggestion

Multiple OTU boards generates IN_PWR_LOW alarm at a time.

First portion of the faulty section Checked.

Reason found that low optical power receiving at receiver end. As compare to distance loss is high.

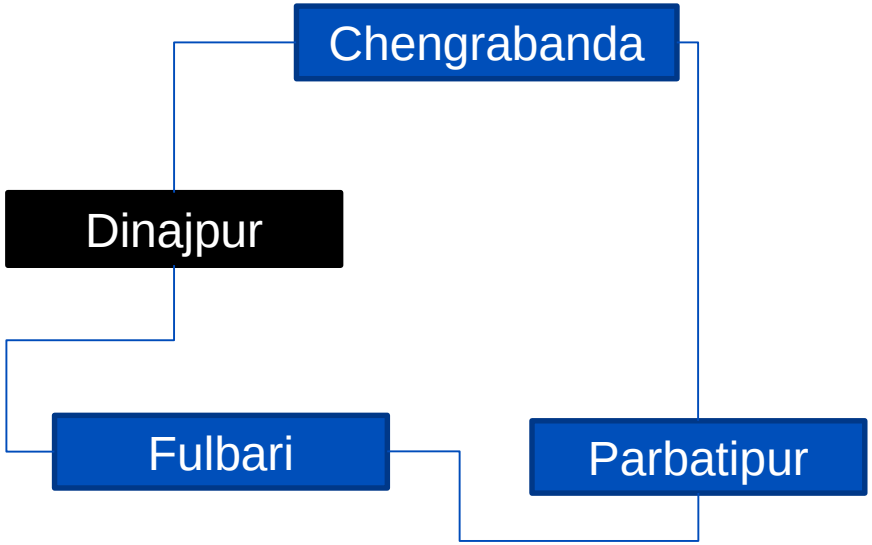
After fixing fiber bent problem solved and alarm cleared.

Operational & Planning Aspects of DWDM

Module 6: Case Study-3 [Operational]

Symptom

- A ring network – all are OADM.
- Dinajpur is the aggregation node .
- One day all nodes OTU card shows LOS of payload alarm
- Fulbari FIU cards shows MUT_LOS alarm, also OSC LOS alarm.
- Service interrupted.



Alarms

MUT_LOS : Loss of multiplexed signal. When Input multiplexed signal is lost.

OSC LOS : When optical supervisory channel Receives no optical power.

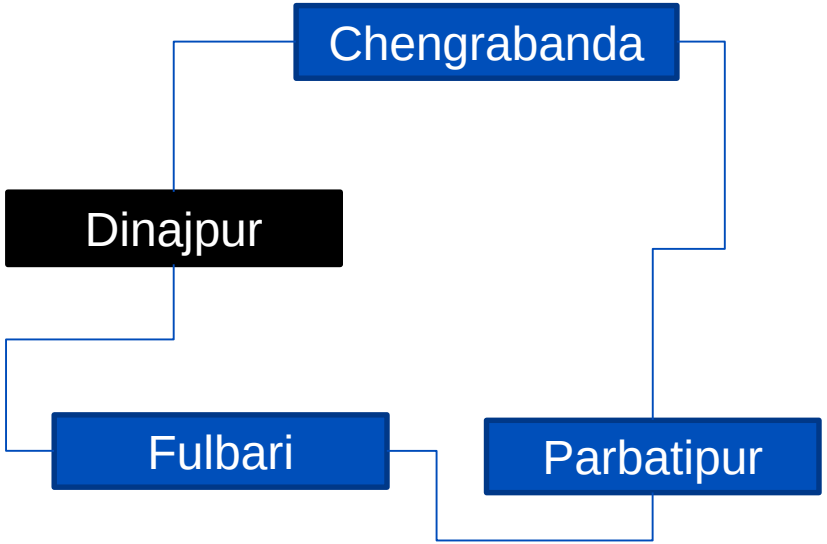
Possible Causes

- Multichannel signal faulty or single channel?
- Uni-direction or bi-directional?

Cause-1 : FIU to FIU backbone down

Cause-2 :
- Patch cord between Amp card to FIU faulty
- Mux Unit to Amp or AMP to Mux Unit faulty

Cause-3 :
AMP or FIU Card/Unit faulty.



Service Interruption

Handling Procedure

1. Check transmit power of Mux Unit on Dinajpur end.

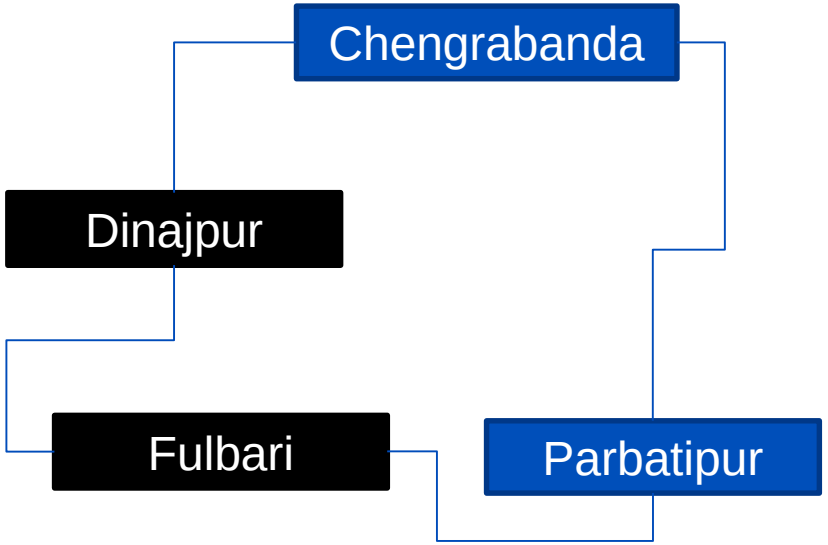
2. Check transmit power Dinajpur AMP

3. Check receive power at Fulbari end, *no Receive from Dinajpur*.

4. Check patch cord at Fulbari end at ODF.

5. No power found at ODF, team OTDR and Found fiber break.

6. So OSC LOS and MUT_LOS generates For backbone fiber cut issue.



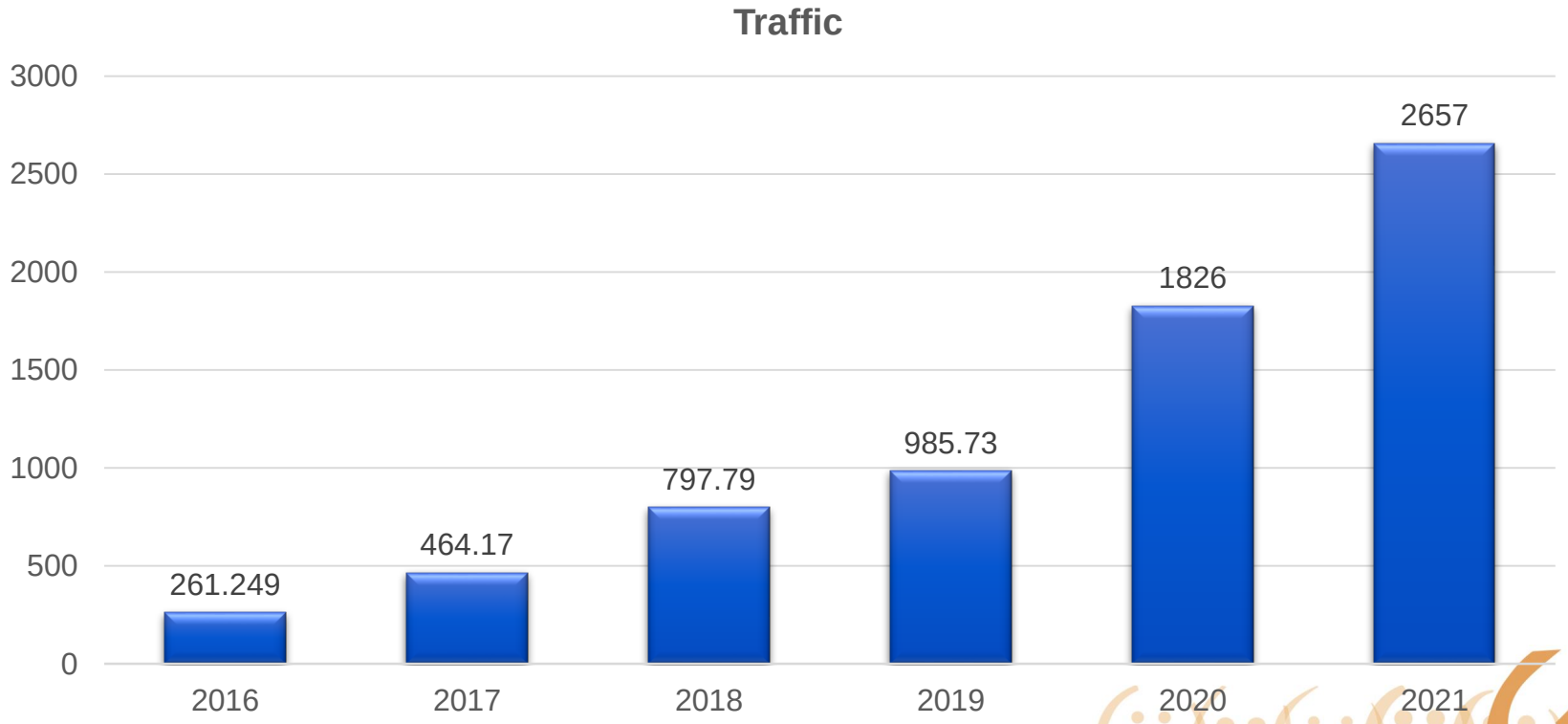
Suggestion

- Multiple OTU boards generates LOS of payload and one node reports OSC_LOS. alarm. Each portion patch cord section by section checked.

- Reason found that no optical power receiving at Fulbari receiver end. No power found at ODF, team OTDR and found fiber break.

Why DWDM ?

International Traffic Coming to Bangladesh :



Summary :

- Traffic Engineering & Traffic Steering should be done in Optical Level and its Easier.
- DWDM Backbone is Service Independent – So Future Prof.
- Less devices, so Reduce Capex.
- Less computation, so Reduce Opex.

Thank You!

communitytrainers@apnic.net

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