# The Target

- Design a MAN* like fiber network for high data transmission rates.
  The network is partial below sea level and difficult to install and to maintain.
- Such a fiber network demands an optimized minimum of cables, connections and a minimum of active (electronic) components c.q. modules. (simplicity)
- What to achieve:
  - High data rates
  - Reliability (Low failure rates)
  - Decrease of power needs
  - Long-term stability
  - Maintainability
  - Low volume mechanics
  - Openness (easy to provide)
  - adorable Costs
- Conclusions

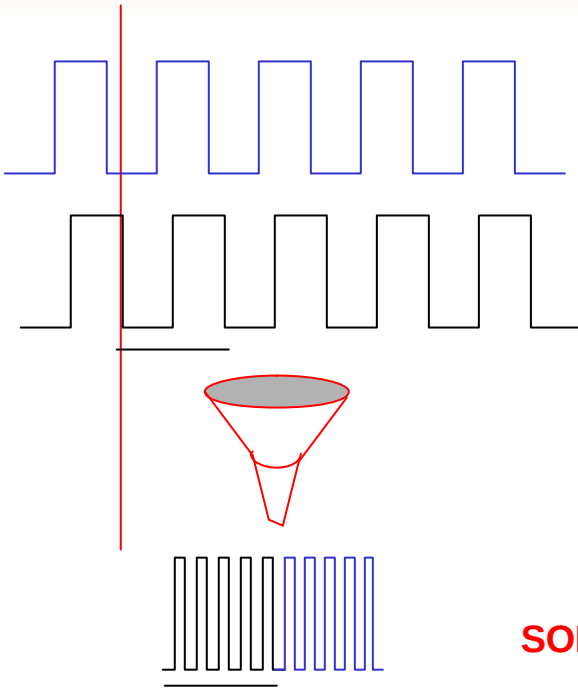
*Metropolitan Area Network

# Methods to increase data rates
## on one carrier

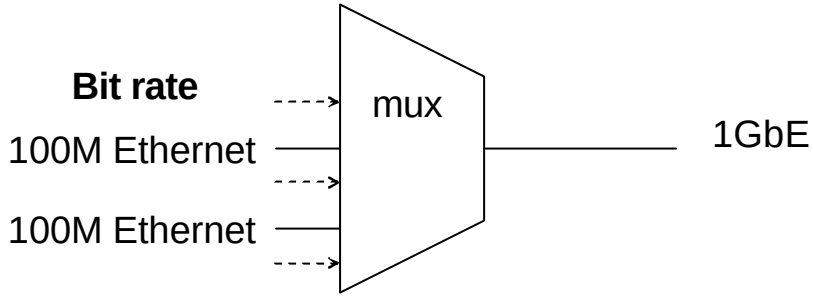
- Increase the bit rate (transfer 10 Mbps to 100 Mbps etc.)
- SDM space domain multiplexing (parallel cabling)
- FDM frequency domain multiplexing
- (O)TDM time domain multiplexing (data share time slots)
- WDM wave length division multiplexing

# Wavelength Multiplexing

## TDM/FDM



### Ethernet switch

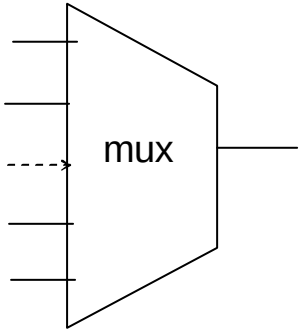



### SONET/SDH* original optical transport of TDM data

**TELCO (telephone)**

DS0 64 Kbps
DS1 1.544 Mbps
DS2 6.312 Mbps
DS3 44.736 Mbps

| Bit rate | | |
|---|---|---|
| **OC-12 | 622 Mbps | STS-12/STM4 |
| OC-48 | 2488 Mbps | STS-48/STM-16 |
| OC-3 | 1.55 Mbps | STS-3/STM-1 |
| OC-3 | 1.55 Mbps | |




OC-192 9953 Mbps

(OC-768 40 Gbps)

*** Synchronous Optical NETwork/Synchronous Digital Hierarchy**
**** Optical Carrier**

# Carrier Efficiency and WDM

**Bandwidth efficiency**

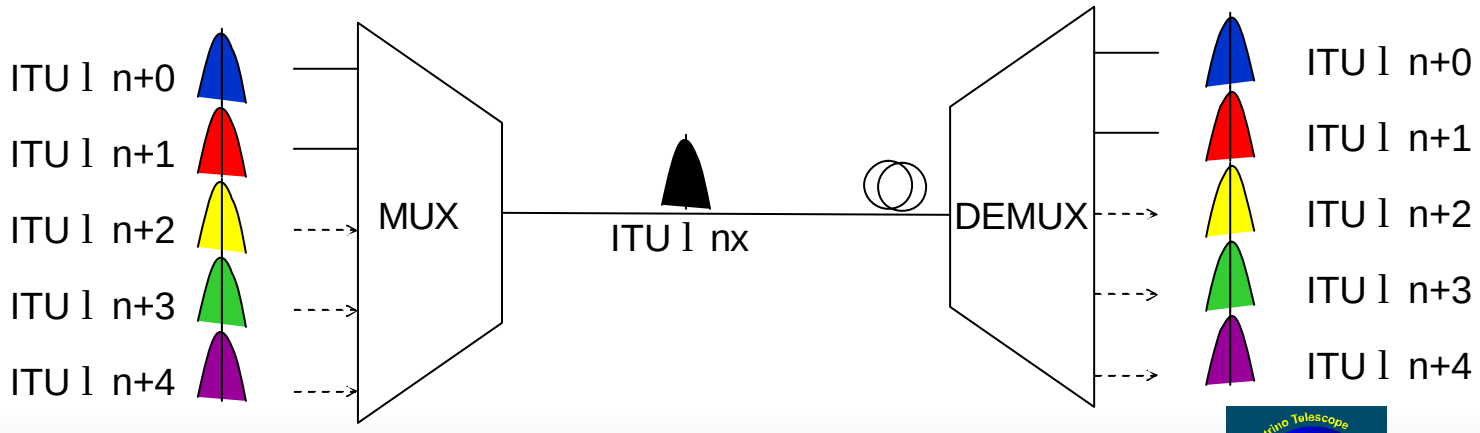
| Ethernet | SONET/SDH | ~bit rate Mbps | **used bandwidth** |
|---|---|---|---|
| 10BASE-T | STS-1 | 51 | **20%** |
| 100BASE-T | STS-3/STM-1 | 155 | **64%** |
| 1000BASE-T | STS-48/STM-16 | 2488 | **40%** |

(Figures from CISCO)

**WDM 100% bandwidth (excluding redundancy channels):**

**WDM assigns different optical signals to different specific wavelength.**
**The specific wavelength are multiplexed and injected in one fiber.**

**Any optical input signal**
**with sufficient S/N ratio**



# Standarisation on DWDM and CDWM channels

International Telecommunication Union –T (standardization) (was CCITT)

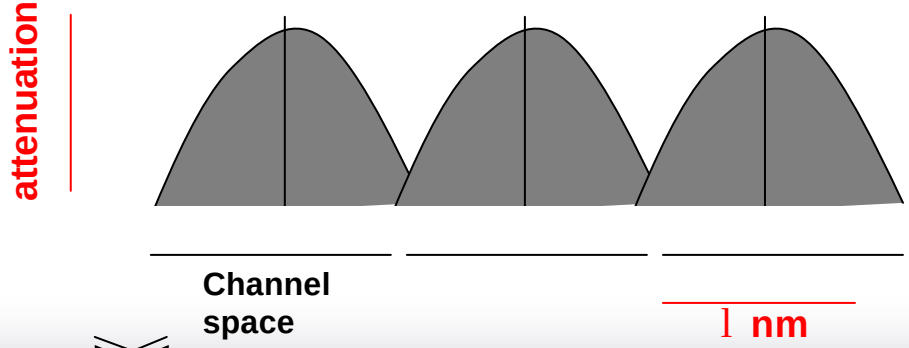
| Bit Rate (Gbs) | Channel Spacing (GHz) | *Spectral Efficiency η (%) |
|---|---|---|
| 2.5 | 100/50 | 2.5/5.0 |
| 10 | 200/100/50 | 5/10/20 |
| 40 | 100 | 40 |

**ITU channel specification for DWDM (1491.88 nm to 1611.79 nm)**

For 50 GHz offset: 300 channels -> in OA range: 150 channels
For 100 GHz offset: 150 channels -> in OA range: 75 channels

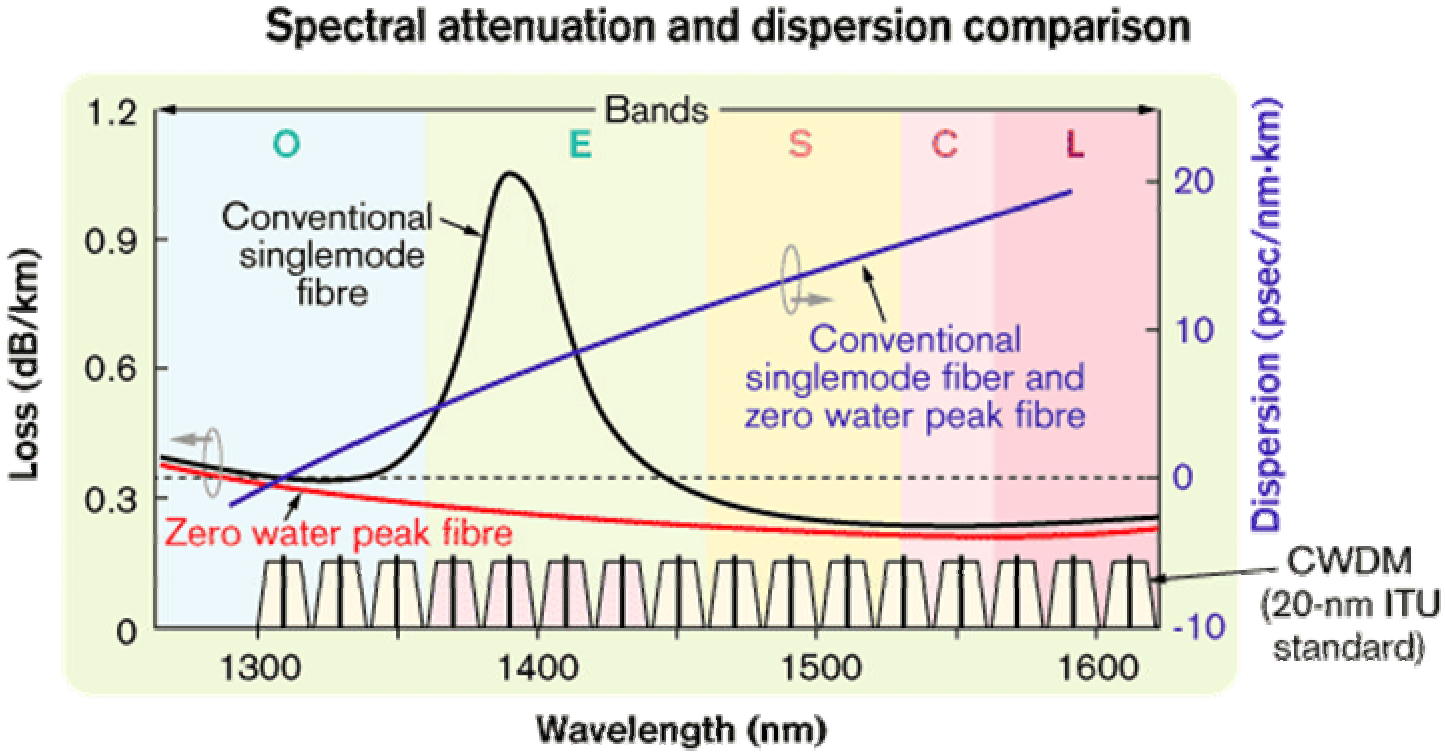
**ITU channel specification for CWDM (1214 nm to 1610 nm)**

For ~ 2.5 THz offsets: 18 channels -> in OA range: 4 channels

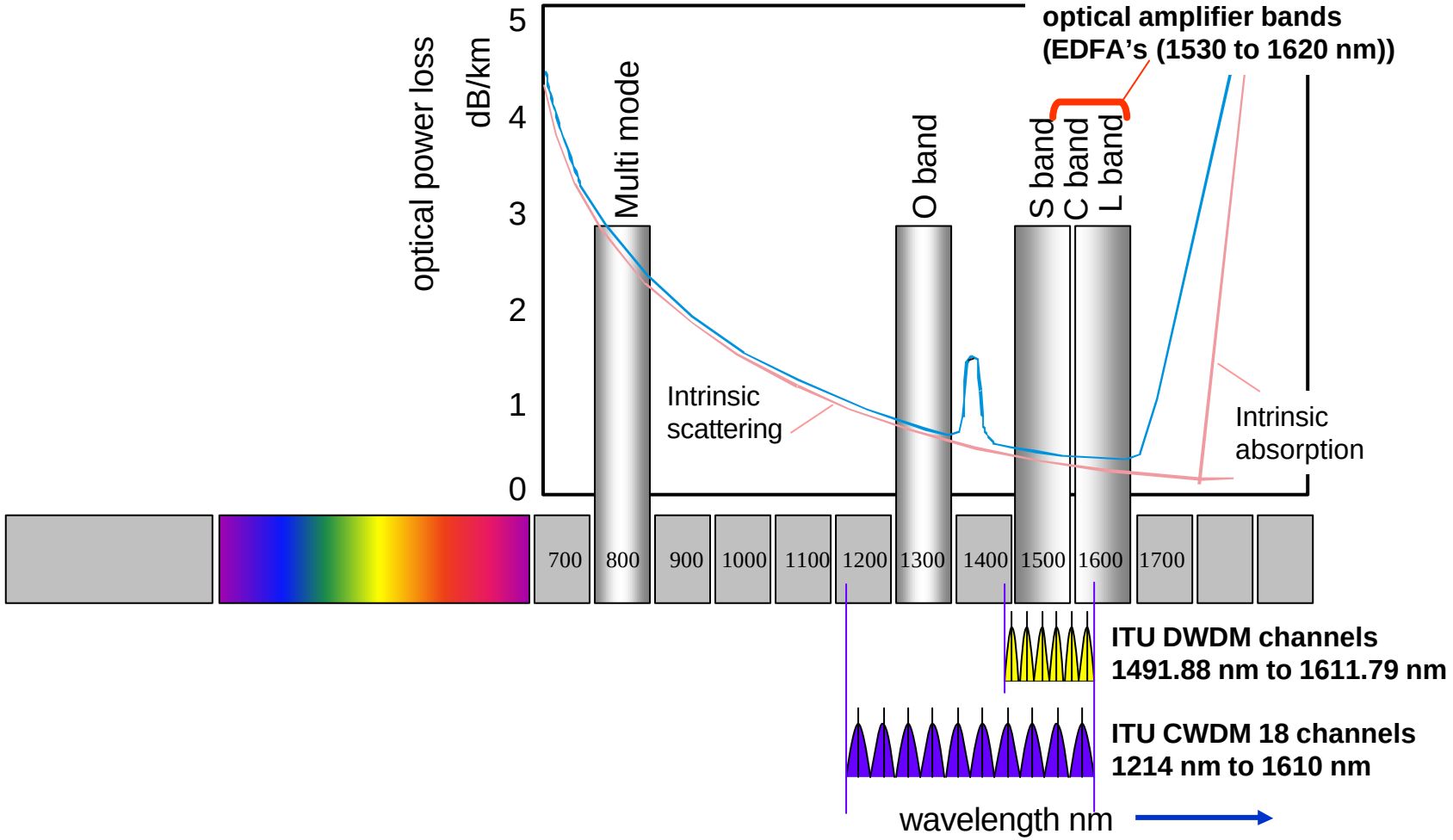



*Depends on digital bit format
RZ, NRZ,optical SSB
analog signals calculation

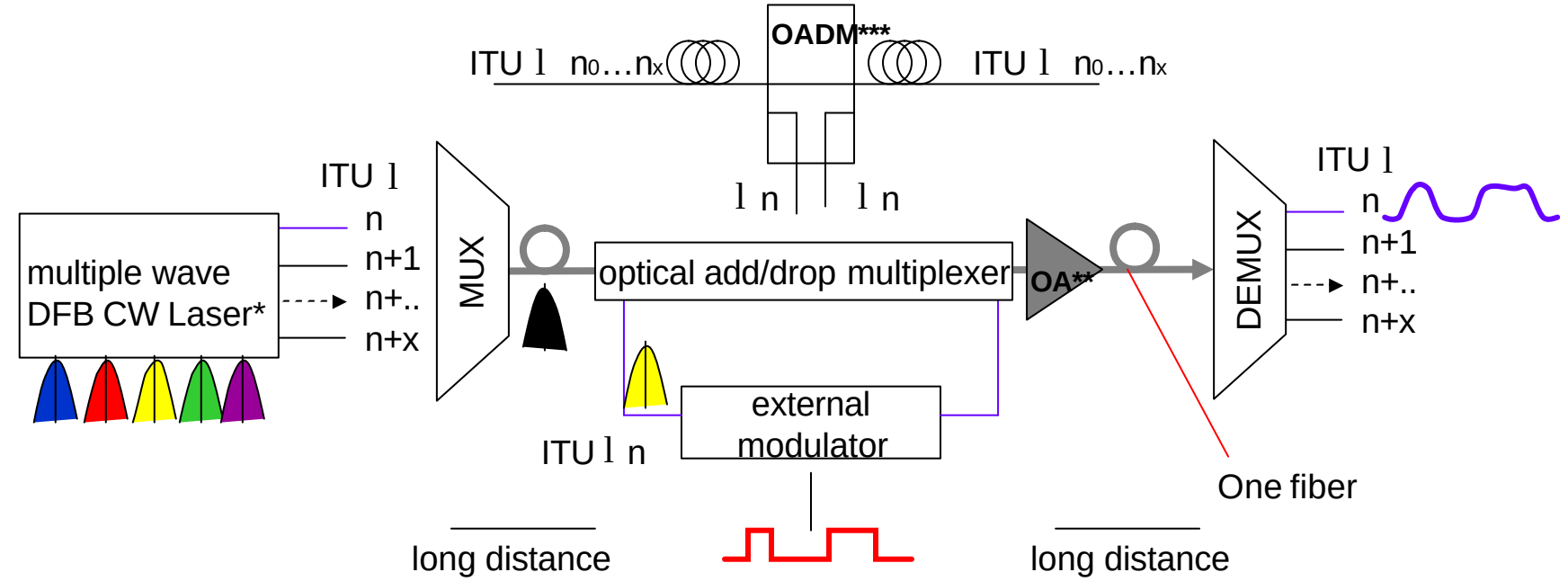
# Close view CDWM channels

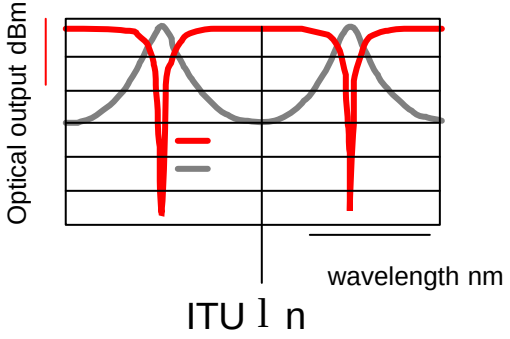


# Spectral Overview

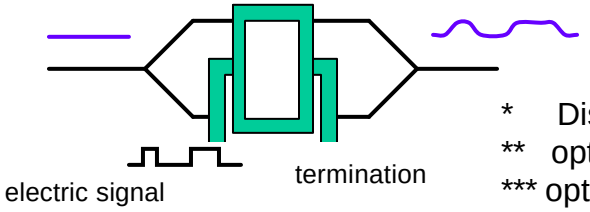


# Simple path for data requirement and transport



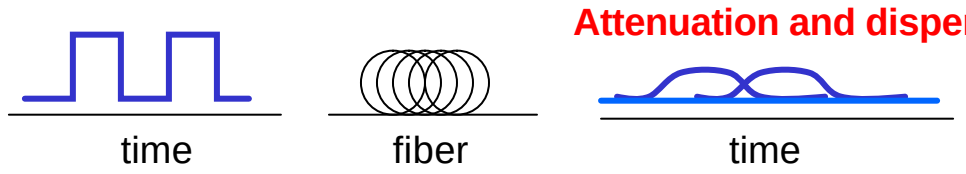

e.g. Mach-Zehnder mod.

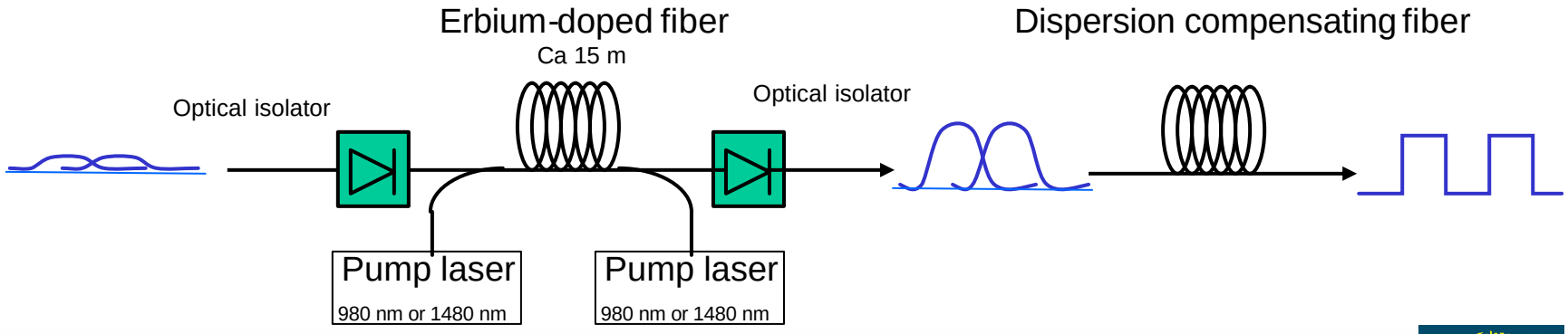



* Distributed Feed Back Continuous Wave Laser
** optional Optical Amplifier (EDFA or SOA)
*** optical add/drop multiplexer

# Some technical aspects on fiber

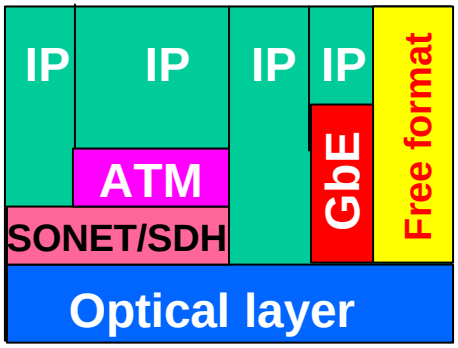
**Many optical parts are passive and bi-directional (No optical to electric to optical needed)**
**All optical switching**
**Care for dispersion compensation**
**Restoration optical power if necessary**
**Many manufactures**



# Data Transport technologies

## transport layer to physical layer examples




IP
ATM

- SONET/SDH
- Gigabit Ethernet
- 1GbE / 10GbE
- Fiber Channel
- FDDI

IP
ATM (Async. Transfer Mode)

Free format

- Dedicated slow control
- Clock signal
- (Any analog signal?)

DWDM

- SONET/SDH
- Gigabit Ethernet
- 1GbE/10GbE
- Fiber Channel
- FDDI

IP
ATM

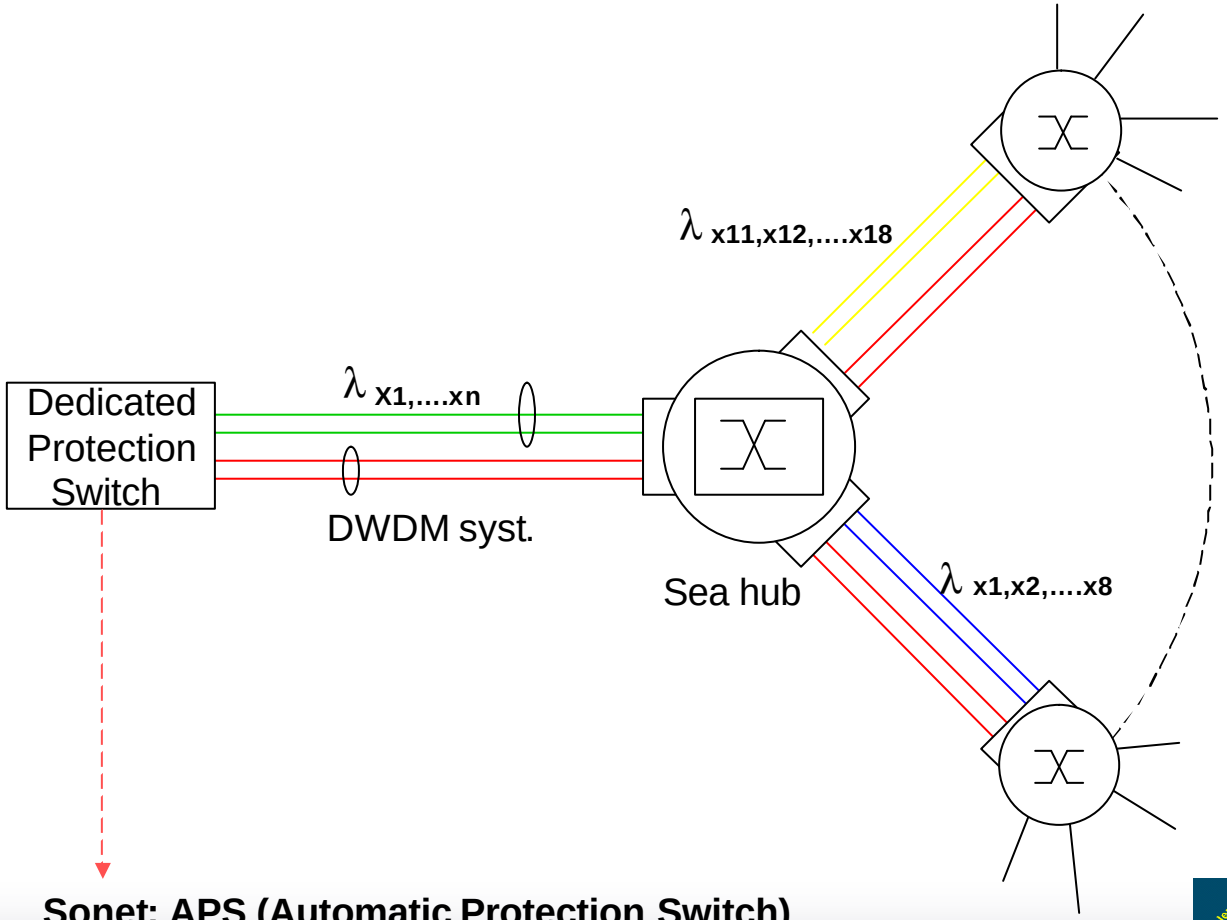
IP
ATM

- Dedicated slow control
- Clock signal
- (Any analog signal?)

Free format

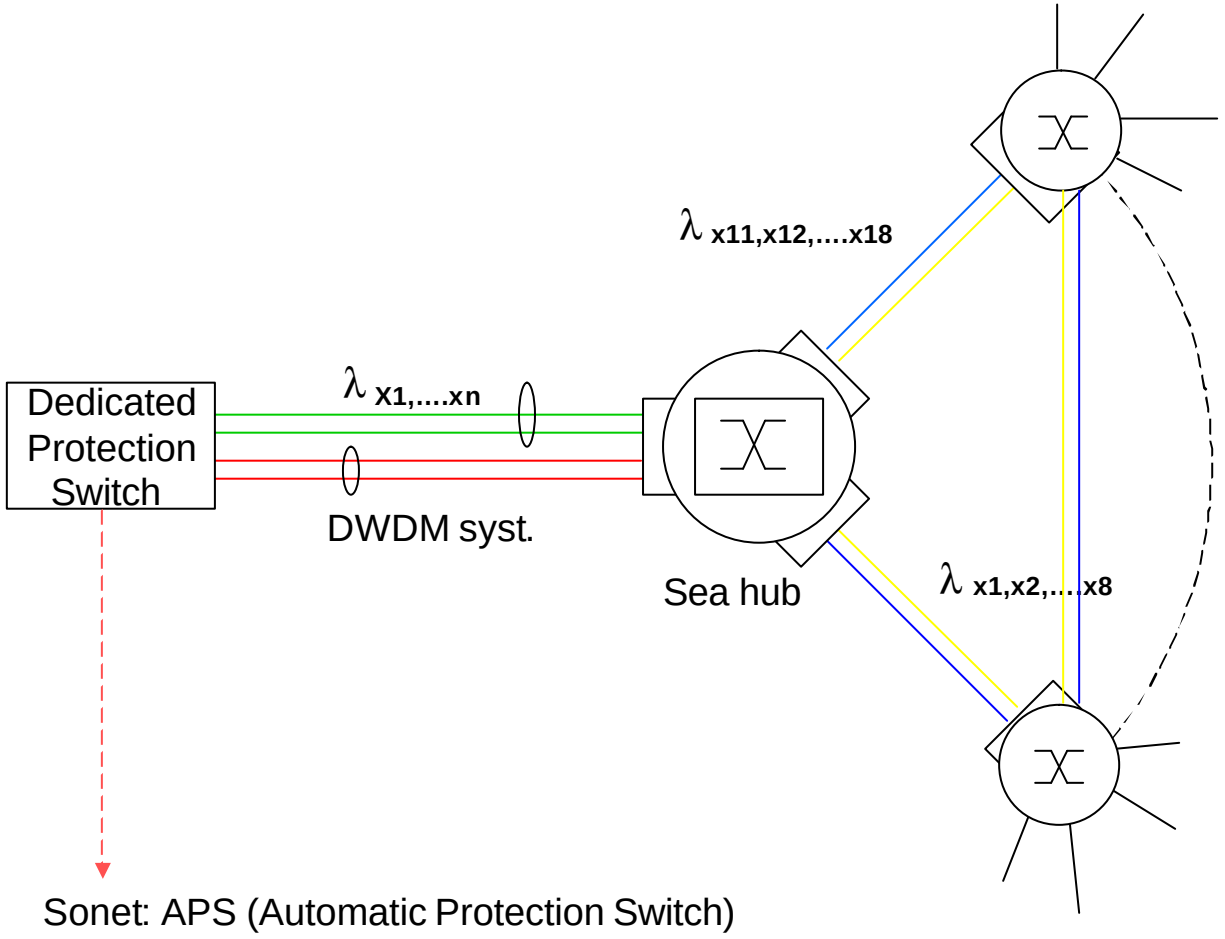
# Protection System

**A DWDM system needs an protection system also.**
**e.g.redundant fiber routing**

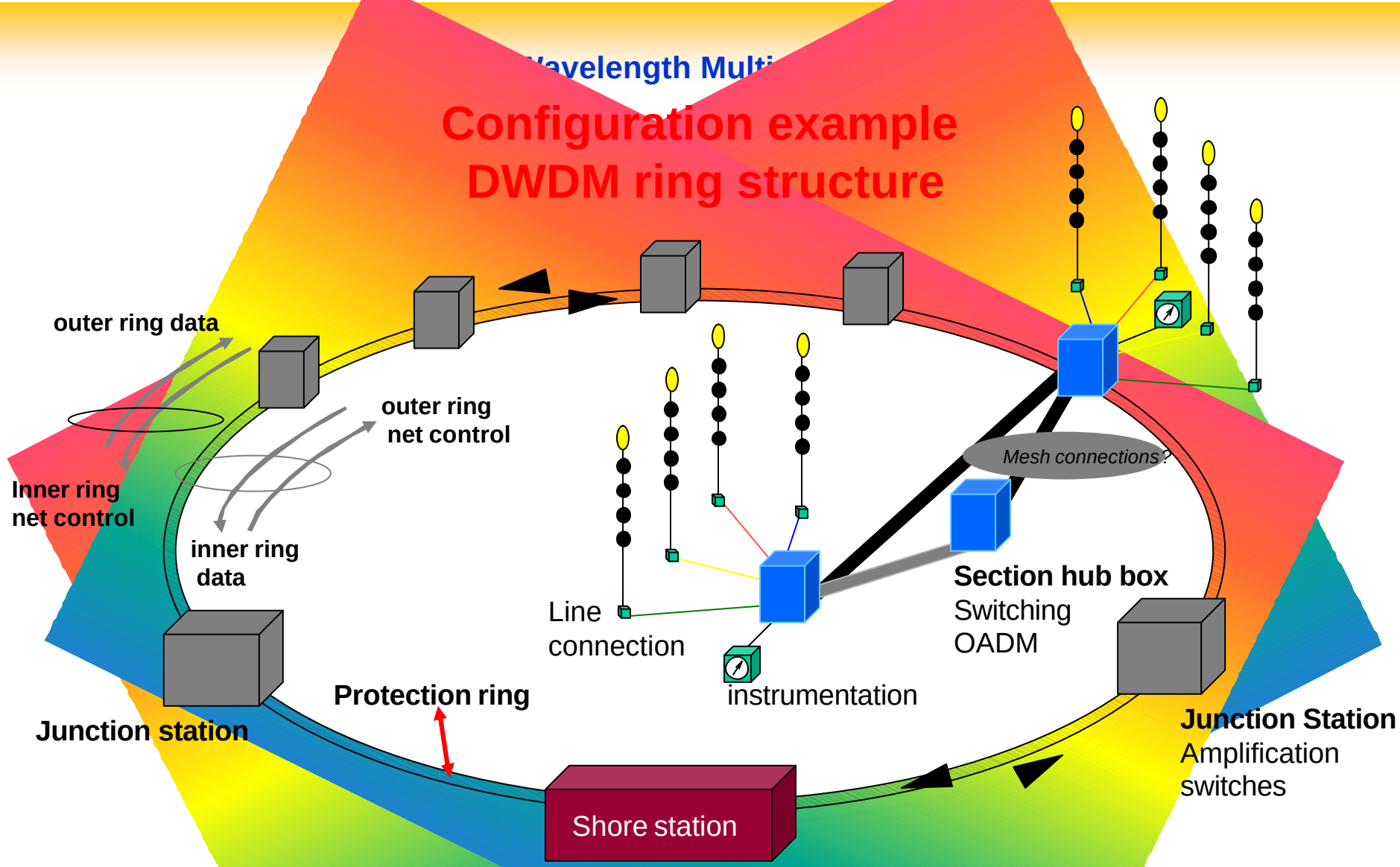



**Sonet: APS (Automatic Protection Switch)**

# Protection System



# Configuration example
# DWDM ring structure




**2 DWDM rings for data and protection**
**In both rings optical survey system**

# Available optical components
## (our box of bricks)

- Direct modulated laser
- Optical modulator with CW laser
- Wavelength converter
- Optical add/drop converter
- Wavelength Multiplexer / demultiplexer (and bi-directional types)
- Broadband amplifier (SOA, EDFA, Raman types)
- Splitter
- All Optical Switch
- Circulator
- Detectors (light sensitive diode´s)
- (All optical delay line, all optical flip-flop and more)

# Conclusions

**Design a whole optical DWDM network.**
**It is the physical layer of the data and control system**

## Advantages:

**We can start from scratch**
**Many point to point connections can be established (fixed or switched)**
**No dedicated optical-electrical-optical repeaters are needed.**
**Many transport protocols and dedicated signals possible.**
**All signals on one fiber are amplified with a single optical amplifier**
**Many components are passive and don´t need electrical power.**
**Less connectivity**
**A providing network with transparent point to point connections makes it easy to implement various hardware and software designs.**

## Disadvantages

**A special optical network surveyor and server has to be implemented so,**
**Redundant network add-ins must be implemented to avoid catastrophes**

## Costs to be calculated:

**less electrical power**
**cheaper cables (less fiber)**
**expensive connections**
**less electronic circuits (e.g. Sonet every up speed of data is an opt.-elec.-opt. issue)**
**expensive amplifiers**

The question is not:

Weather we will have Gigabit networks in the future

The question is:

When we will have Gigabit networks in the future available

Saying From:
1. National coordination office for HPCC (High performance Computing and Communication)
2. The Corporation for National Research Initiatives
3. IEEE communications Society Technical Committee on Gigabit Networking