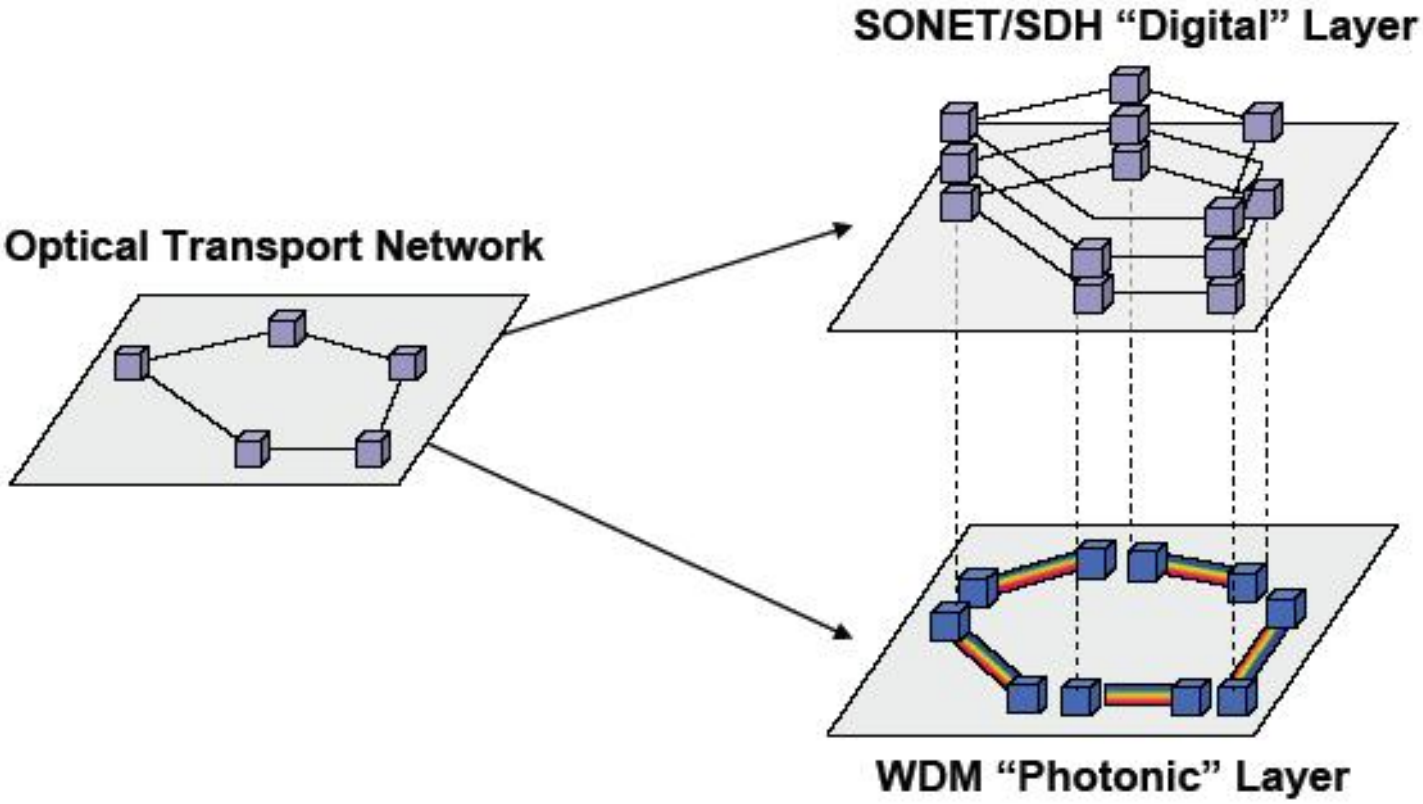
Αστικά δίκτυα και δίκτυα κορμού

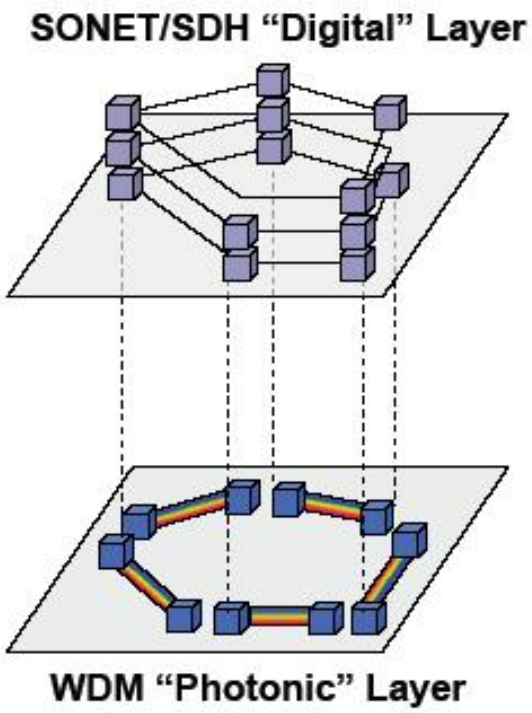
Αλέξανδρος Σταυδάς
Πρώτος Κύκλος

Optical Transport Architecture Today-1



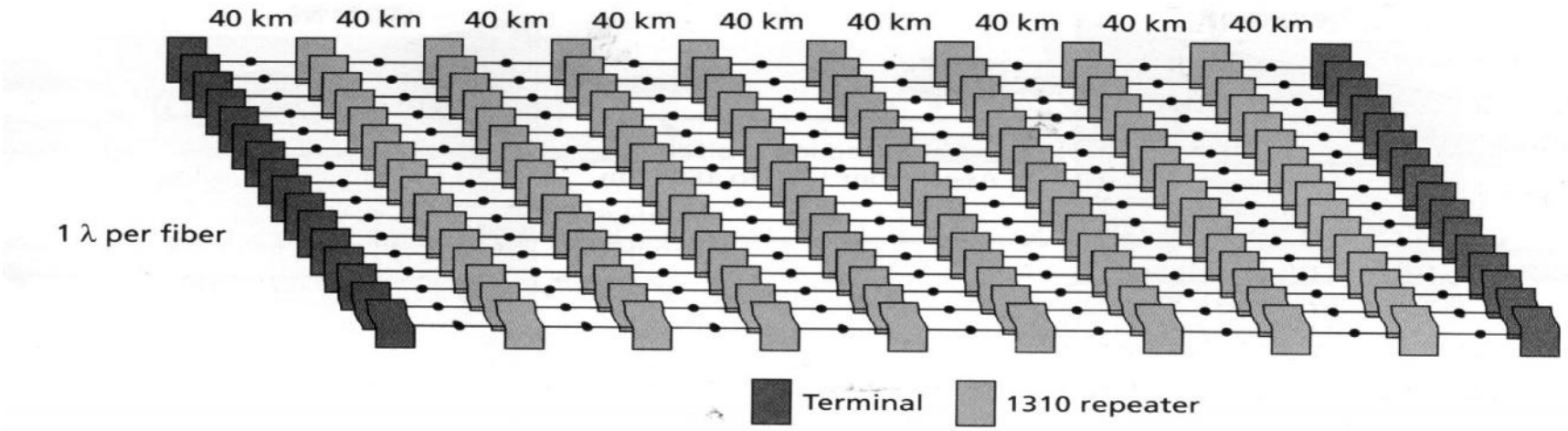
- Το Optical Transport περιλαμβάνει ένα SONET/SDH "digital" layer και ένα "photonic" layer με WDM

Optical Transport Architecture Today-2

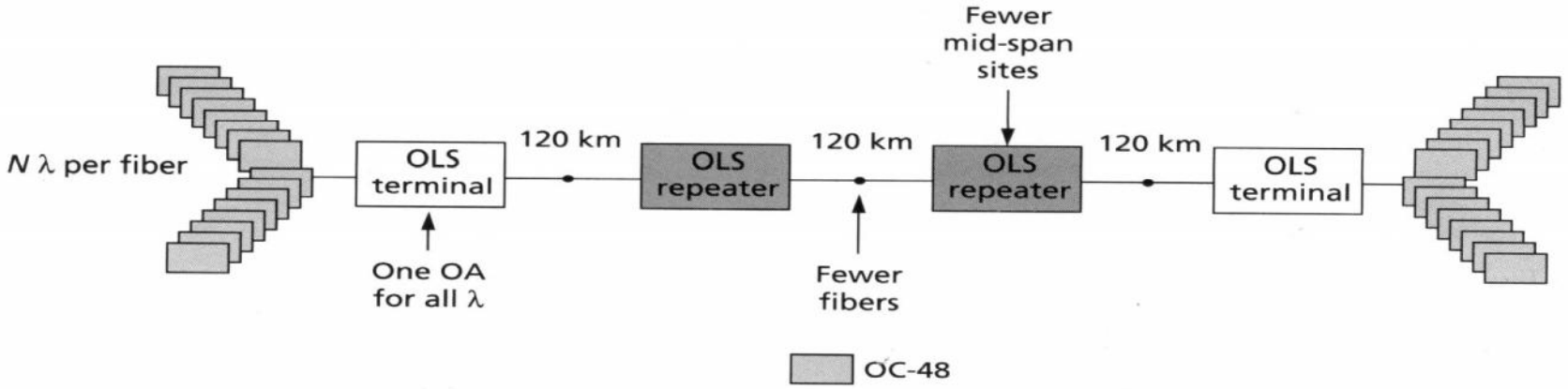


- Sub-λ grooming & switching (STM-1, etc...)
- Sub-λ muxing & add/drop
- <50ms protection
- Path Monitoring (SONET/SDH overhead)
- Χωρητικότητα 10Gb/s ανα μήκος κύματος
- Οπτική μετάδοση μεταξύ "ηλεκτρονικών" κόμβων
- Low transport cost ($ per bit-km)
- Transparency for "wavelength" services

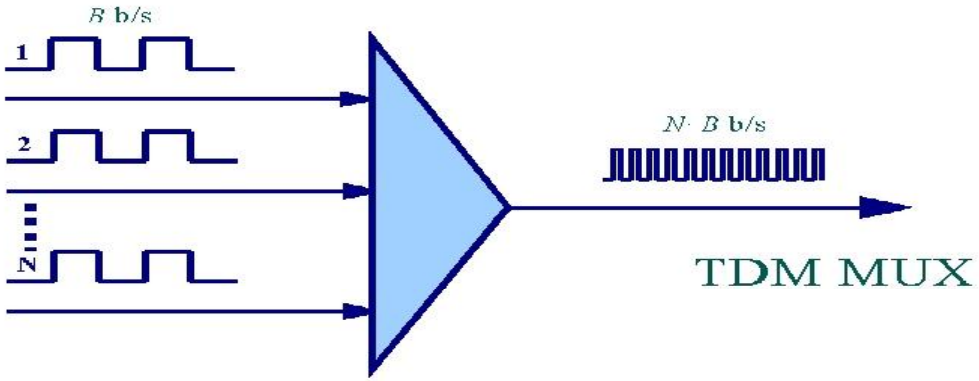
Οπτική μετάδοση

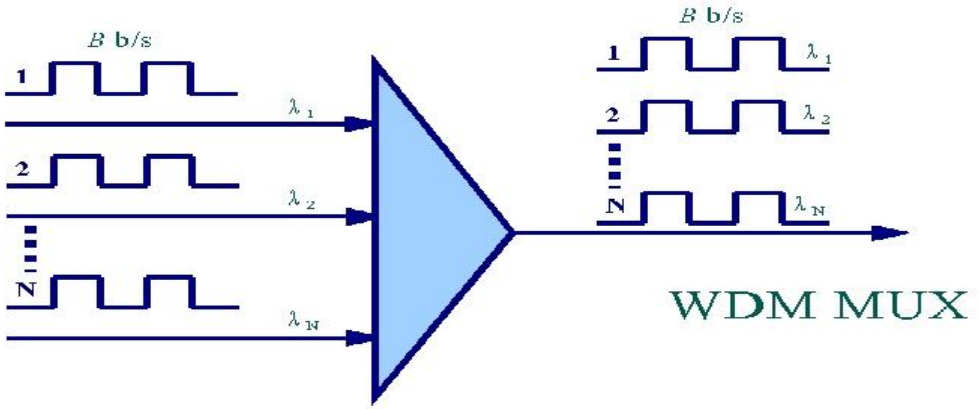


(a) Conventional high-speed transport (40 Gb/s)



TDM vs. WDM





Number of channels:

Example: 40 Gb/s at 1 Mb/s
▷ 40.000 channels

160 Gb/s is on the research level.

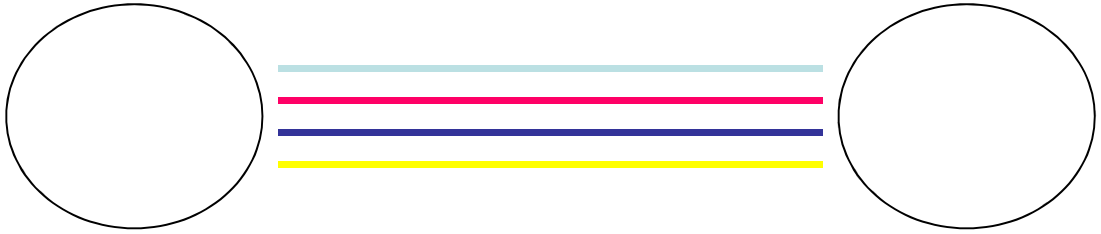
1.000 channels reported (difficult)
e.g. 5 GHz channel separation.

Potential still unexplored.

Maximum aggregate rate

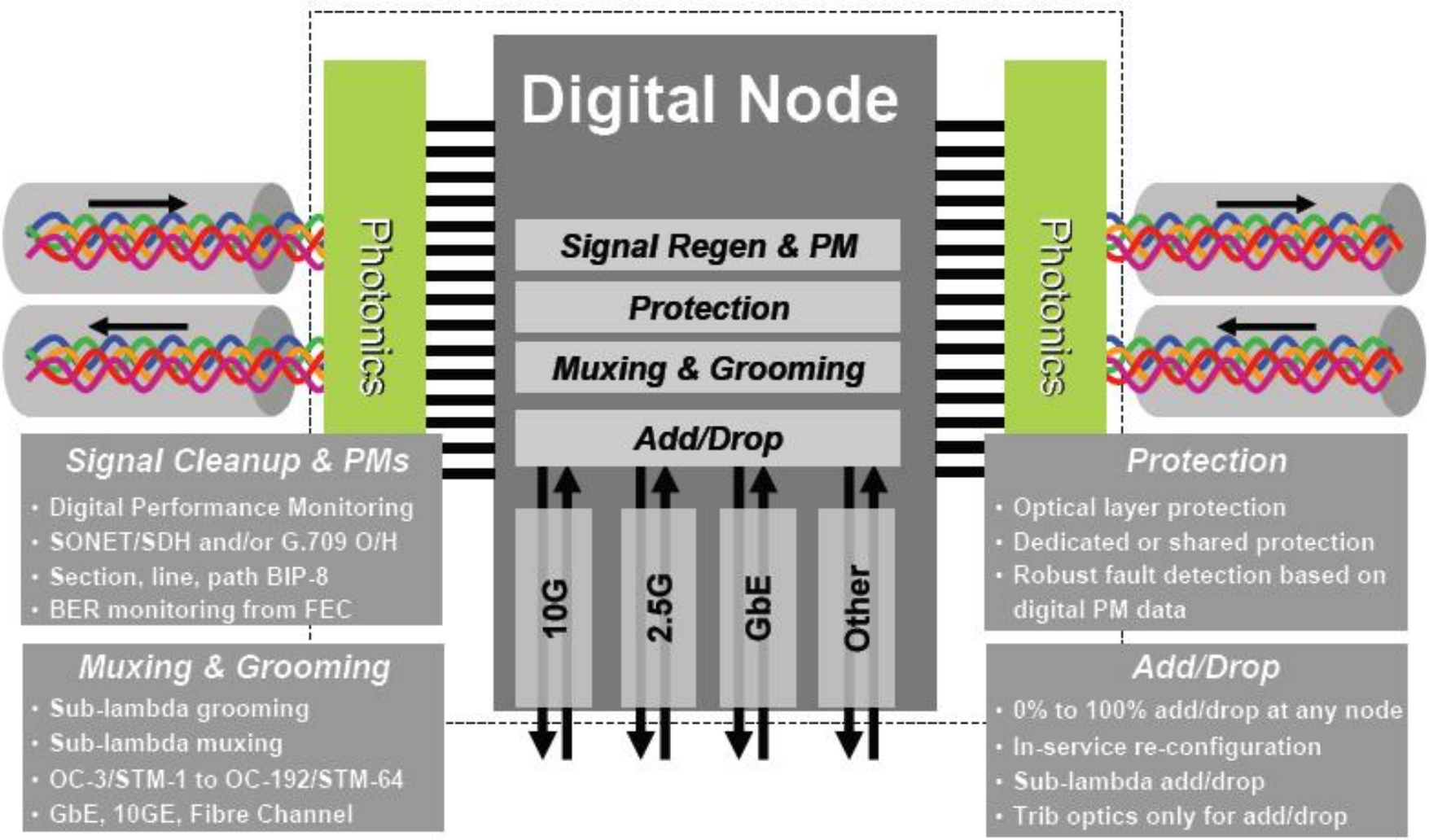
$(N \cdot B)_{max} = 20$ THz.

Point-to-point WDM



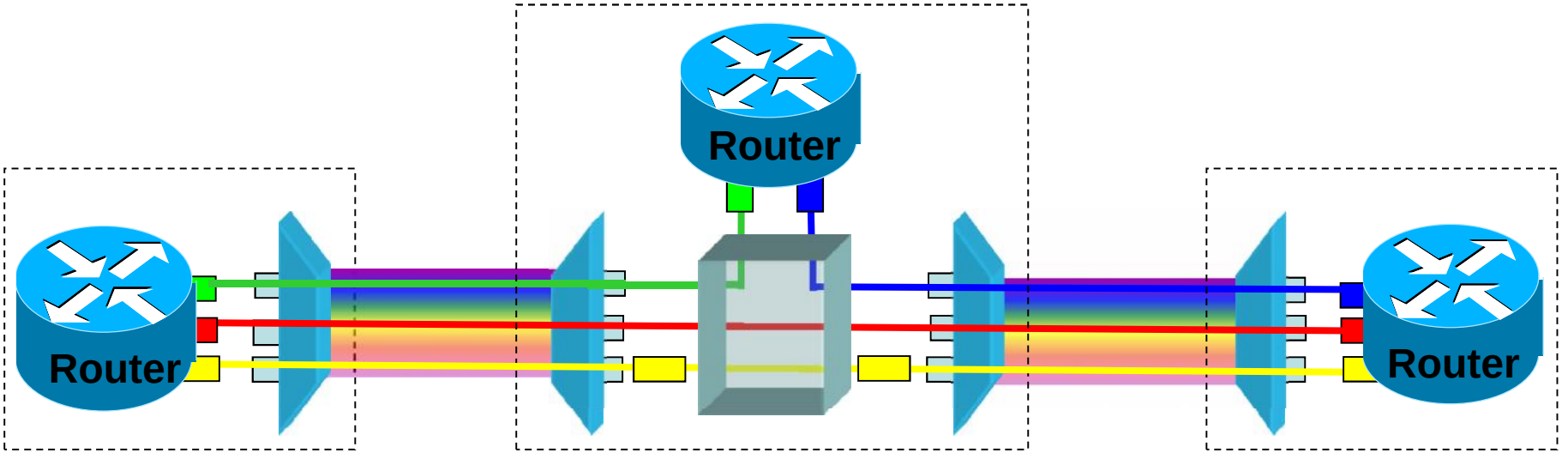
- Increase point-to-point capacity
- Single-hop. All traffic is terminated at the receiving end
- Onward progress is decided either locally via a centrally controlled mechanism

Η σημερινή αρχιτεκτονική των κόμβων



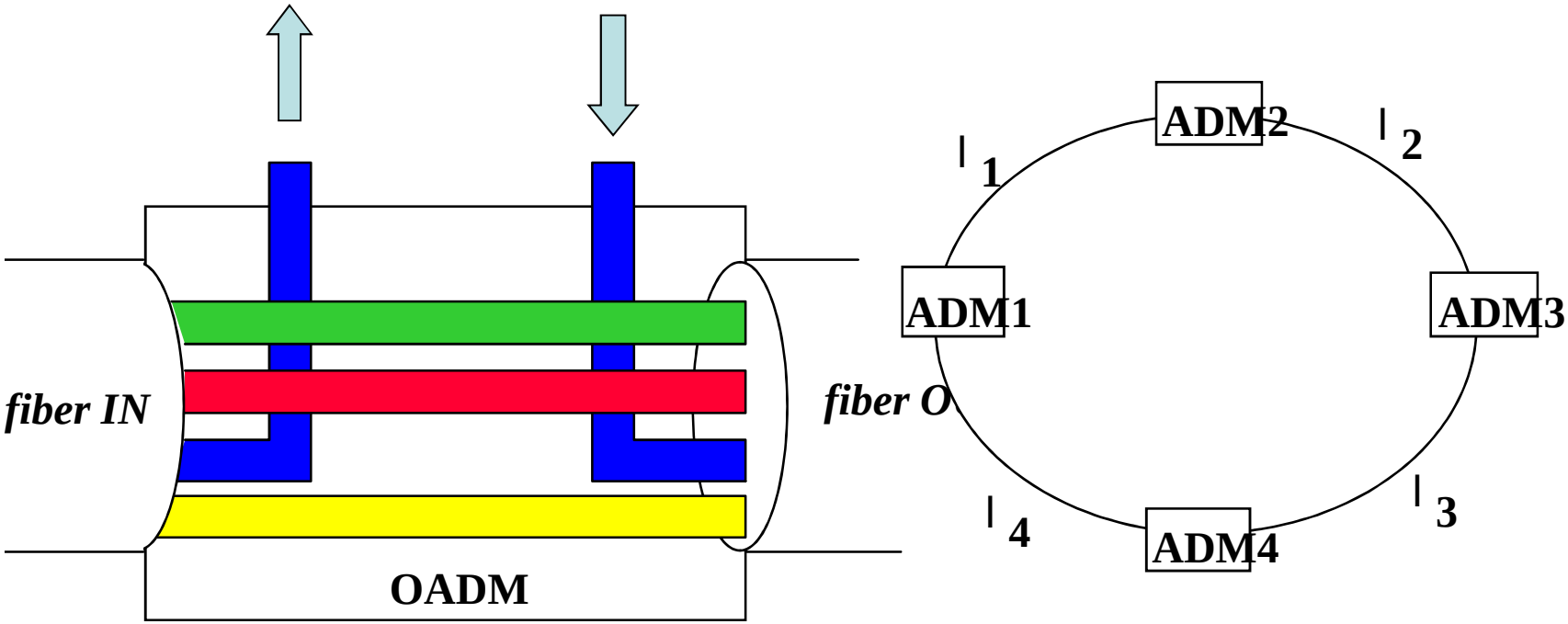
Έτσι θα είναι και στο μέλλον?

Optical Bypassing



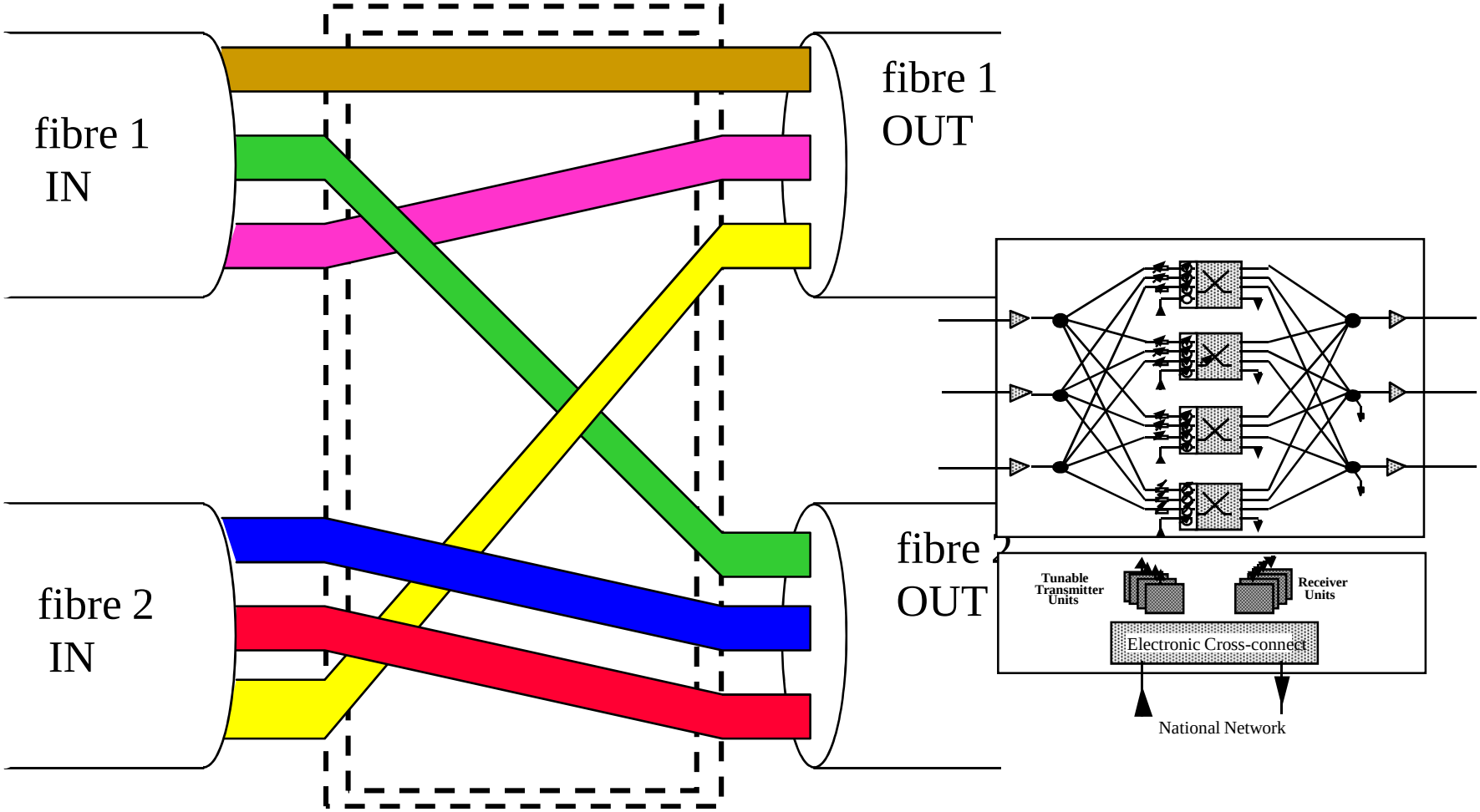
- Reconfigurable optical WDM layer with optical bypass
  - O/E/O minimized---capex/opex reduction
  - Switching for automated connection provisioning
  - SDH/SONET-like look and feel
- Direct connections between routers
- Framing remains from SDH/SONET

OADM

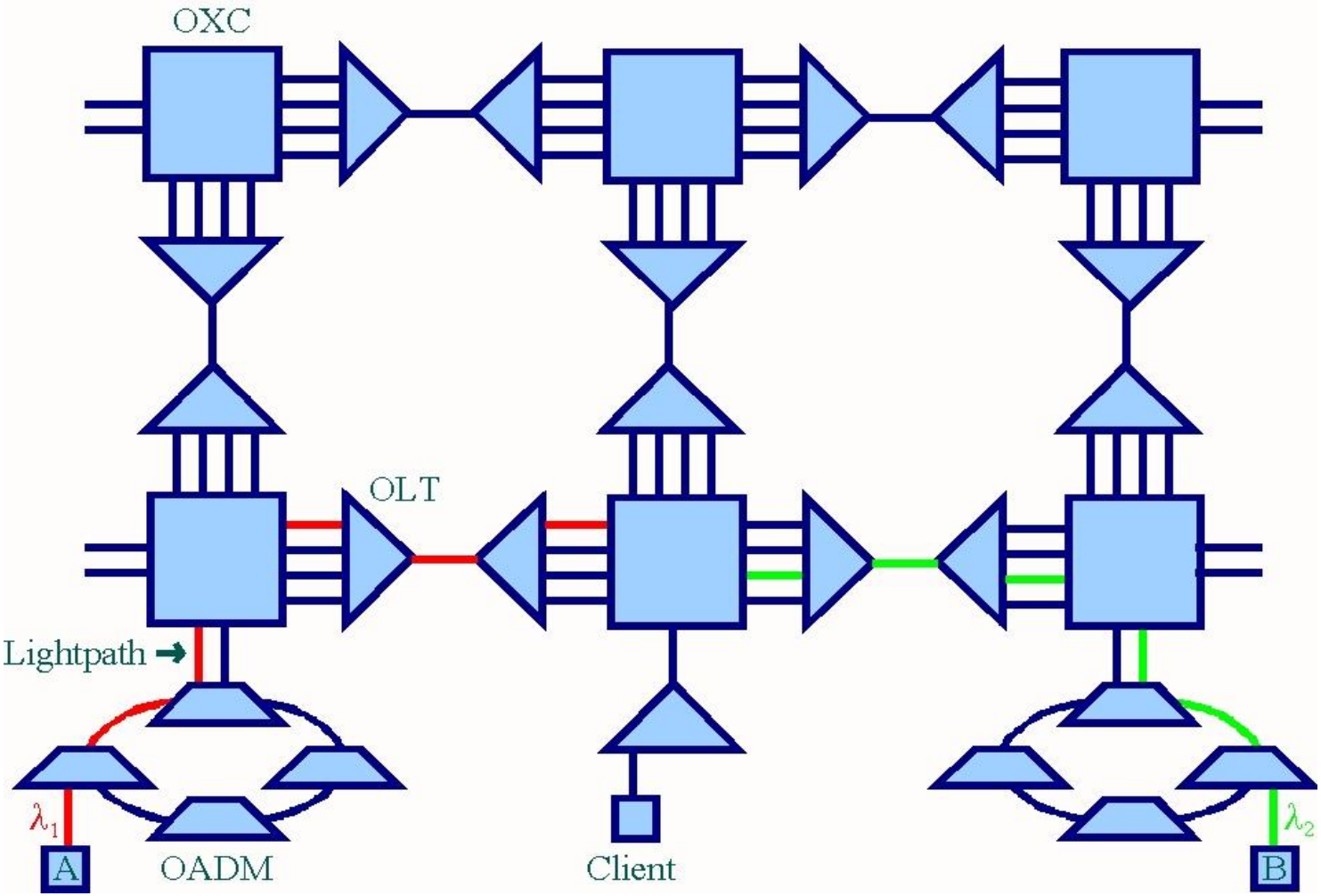


The principle of operation is the same with SDH networks. Rings are constructed with A/D filters

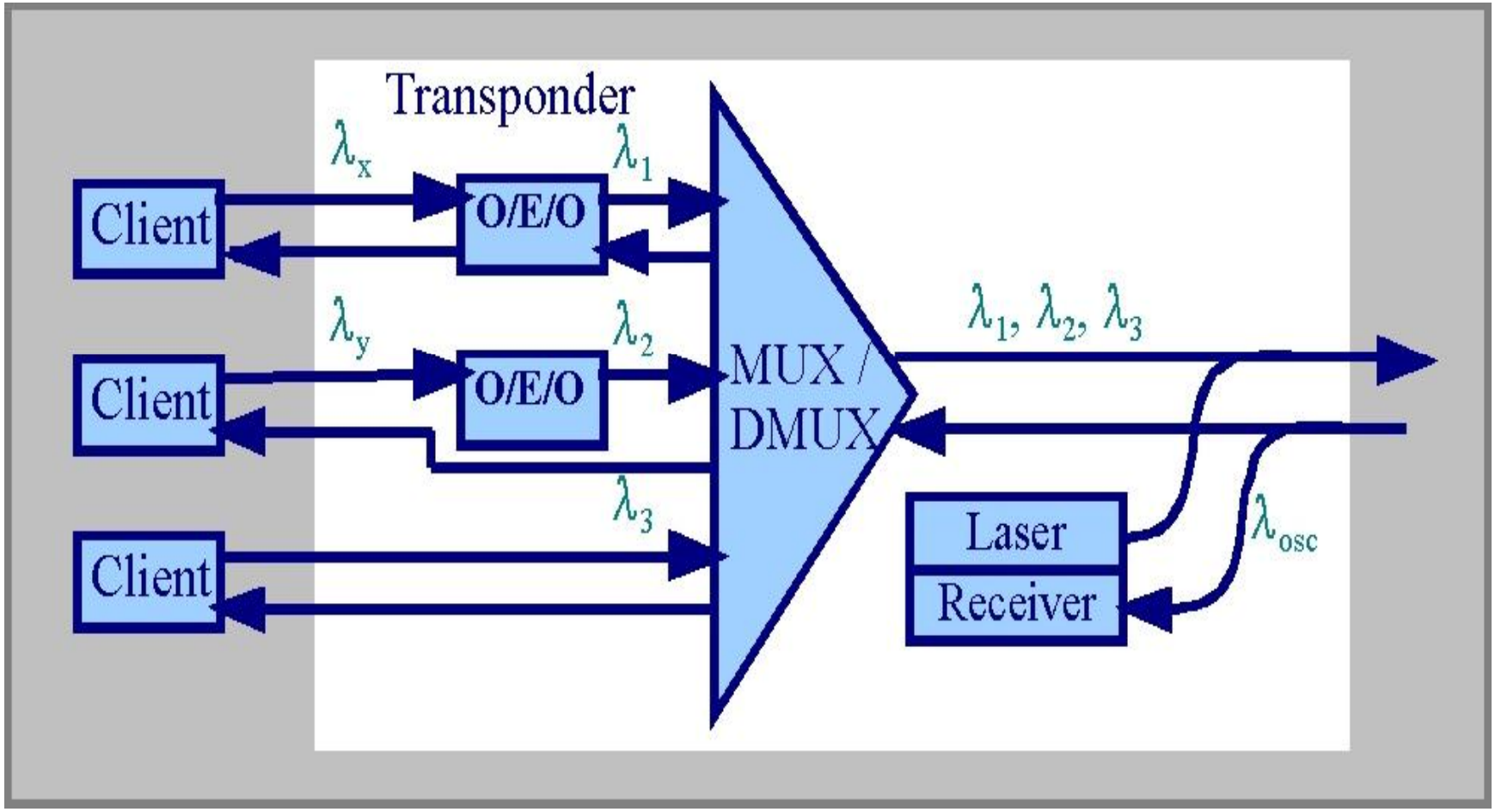
OXC


fibre 1
IN
fibre 2
IN
fibre 1
OUT
fibre 2
OUT
Tunable
Transmitter
Units
Receiver
Units
Electronic Cross-connect
National Network

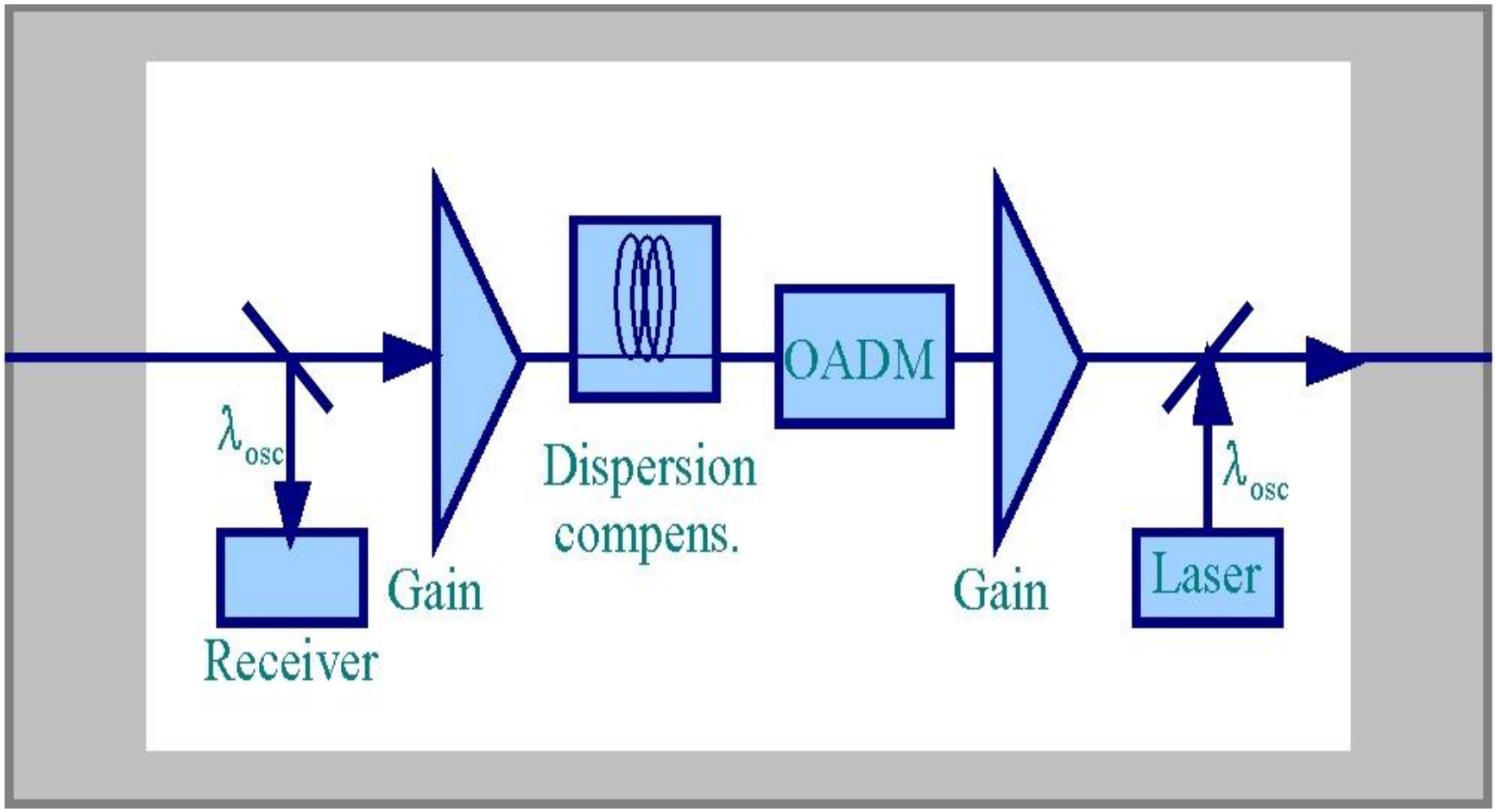
Optical network elements



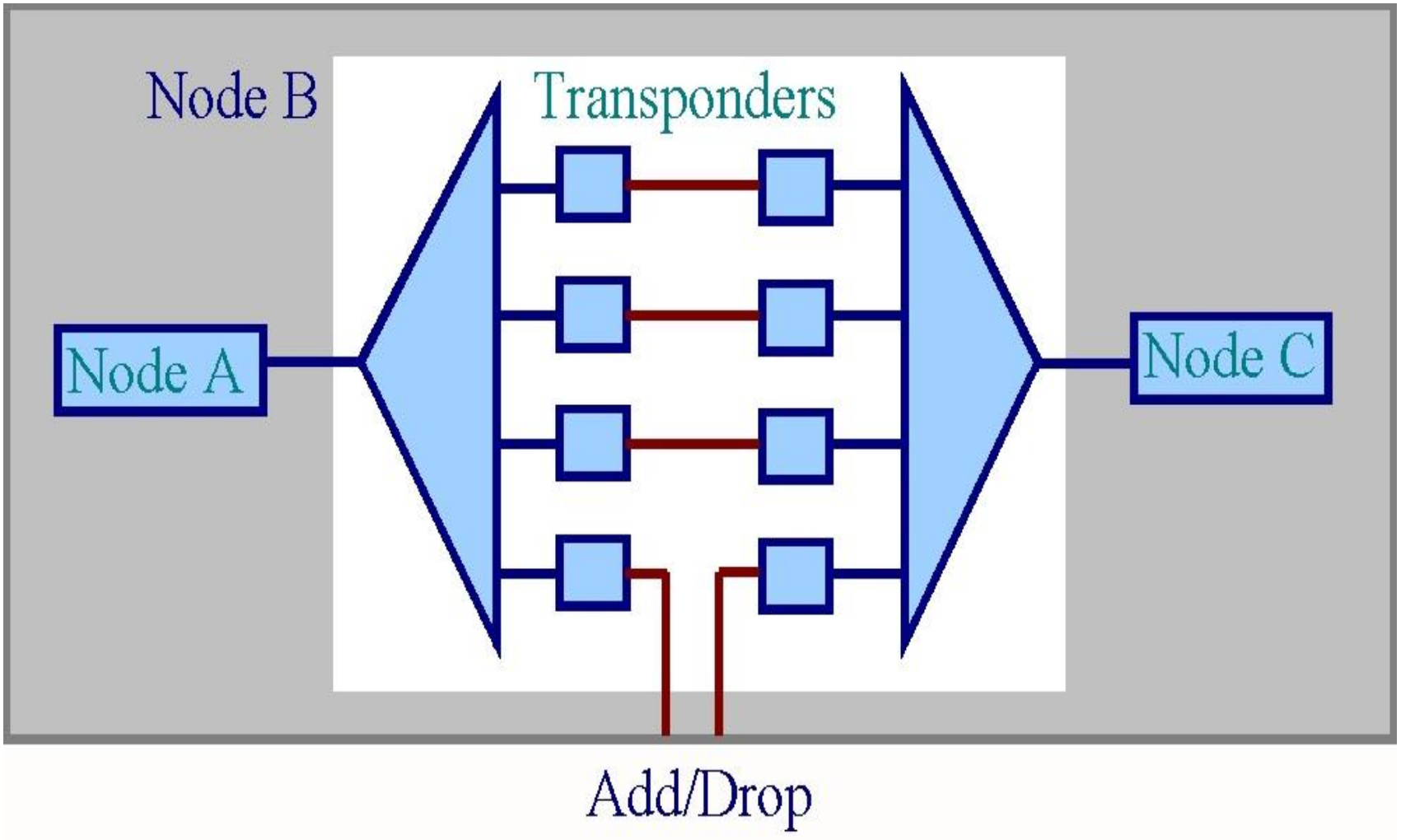
Optical Line Terminal (OLT)



Optical Line Amplifier (OLA)



Optical Add/Drop Multiplexer



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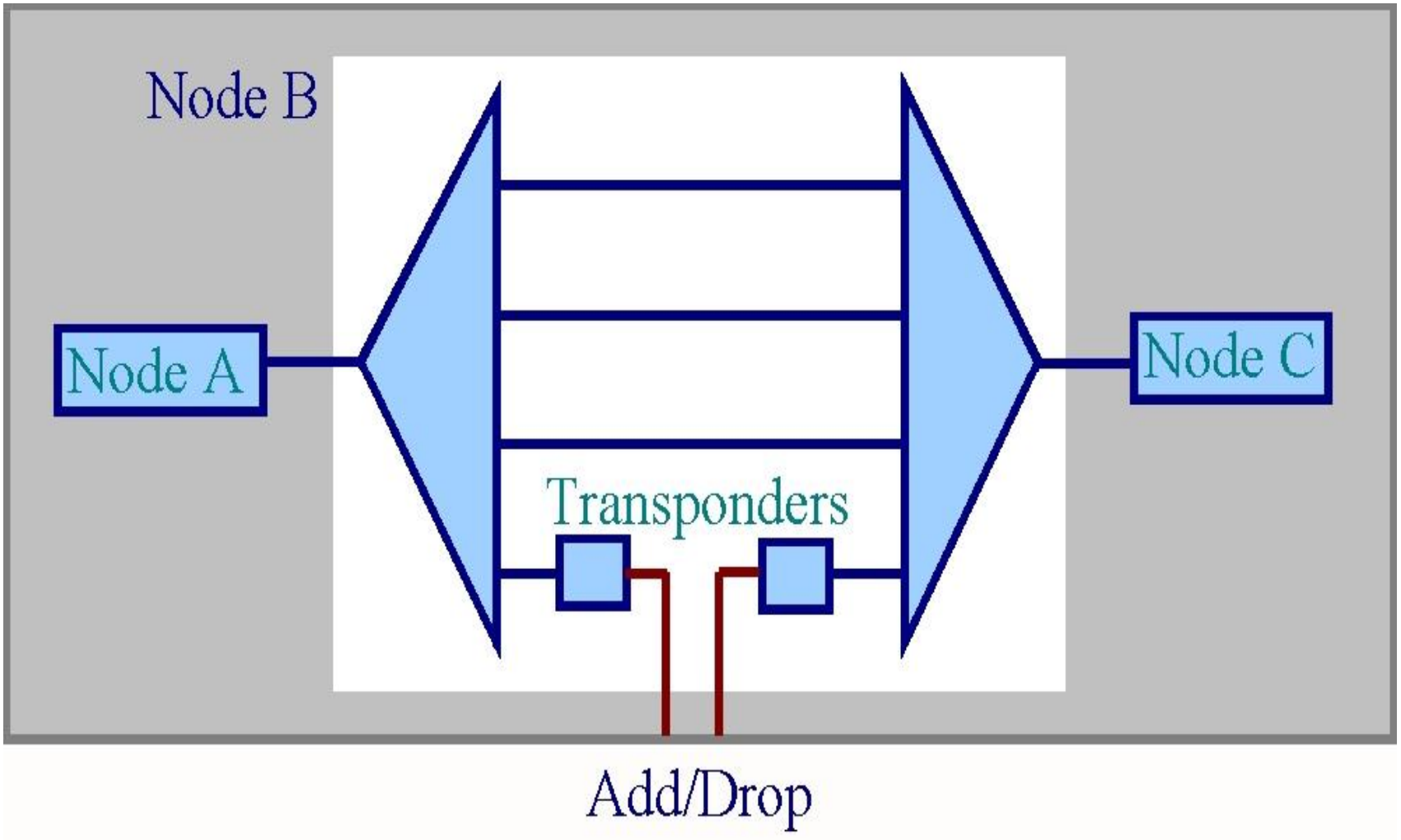
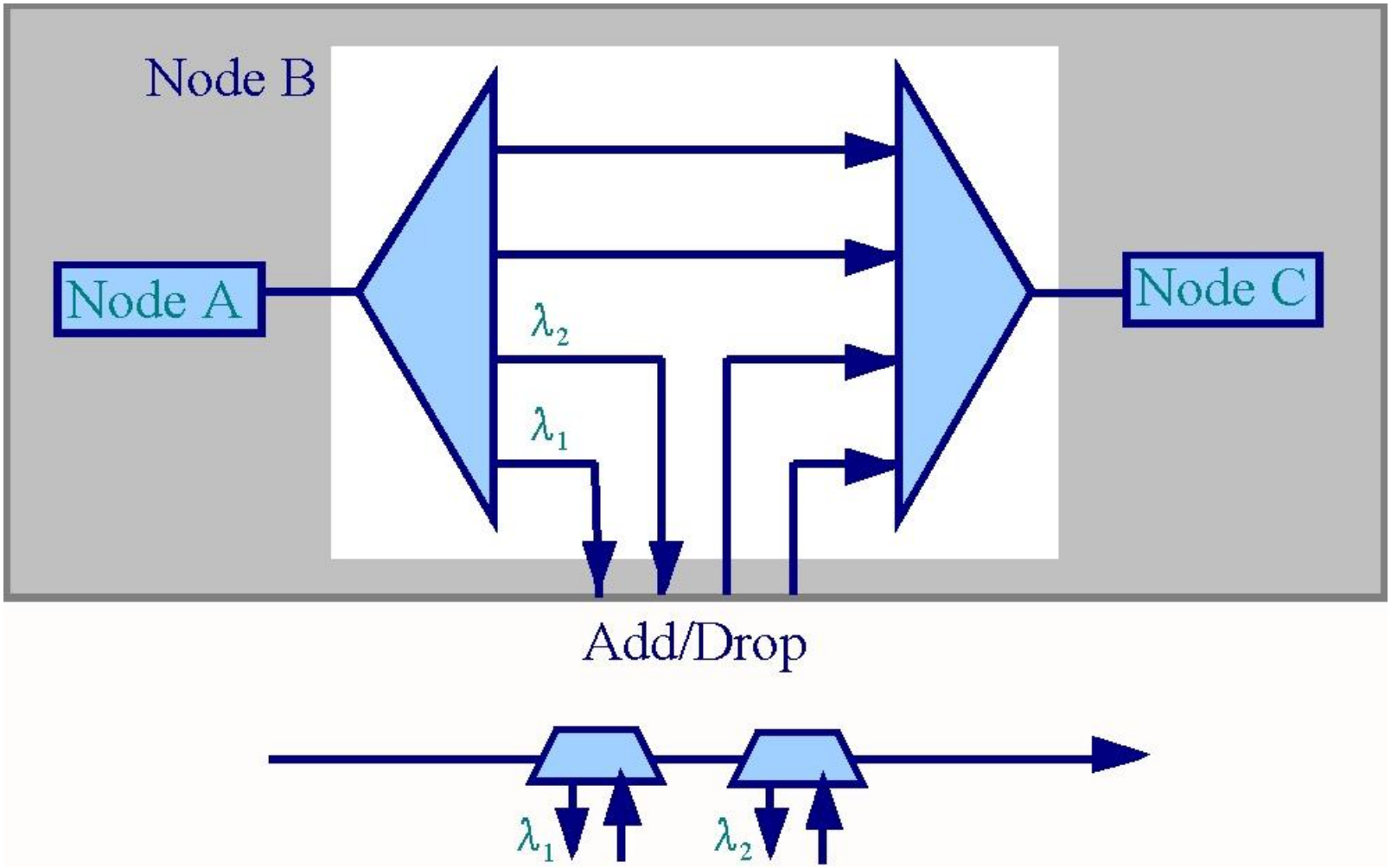
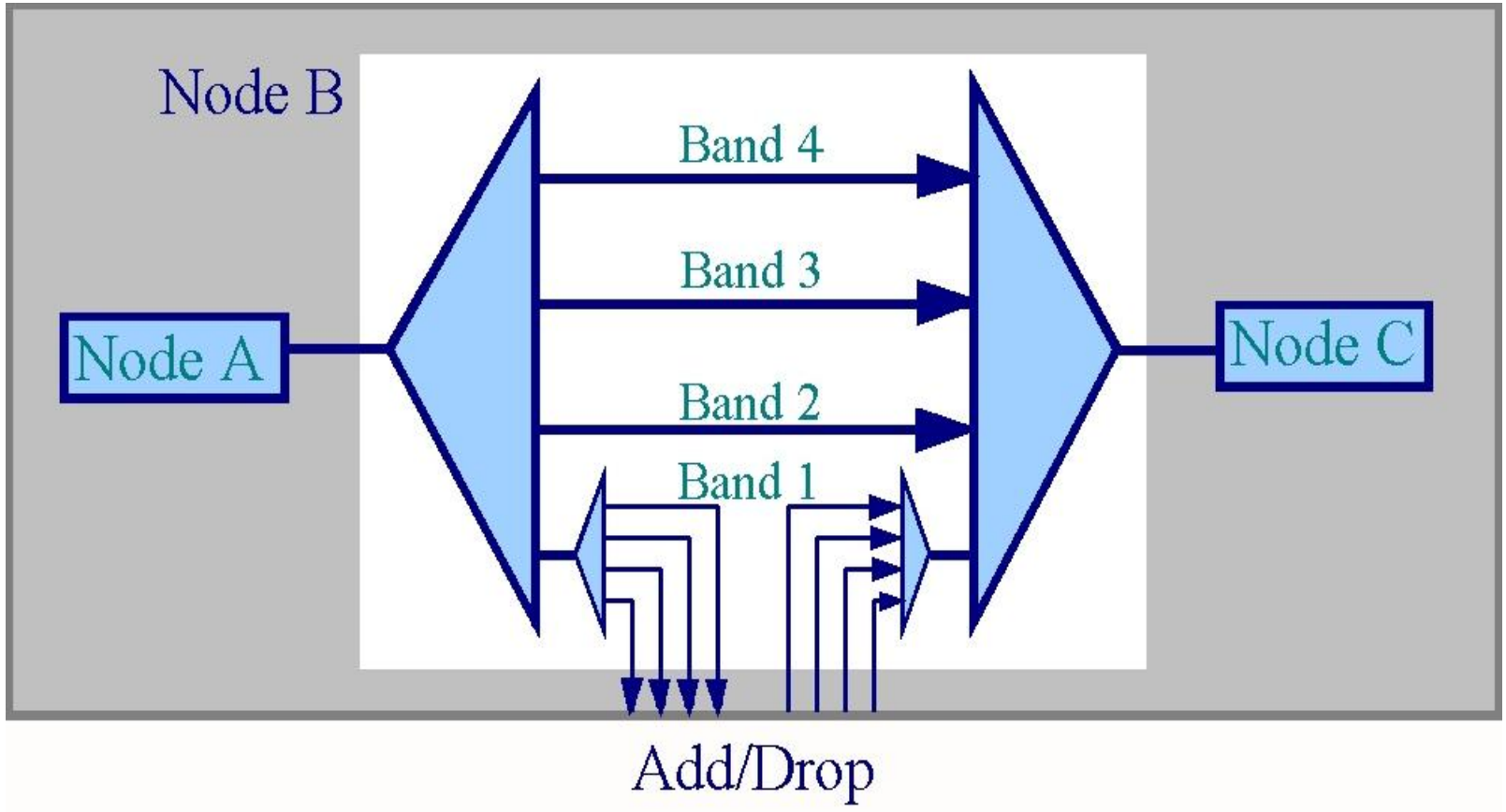


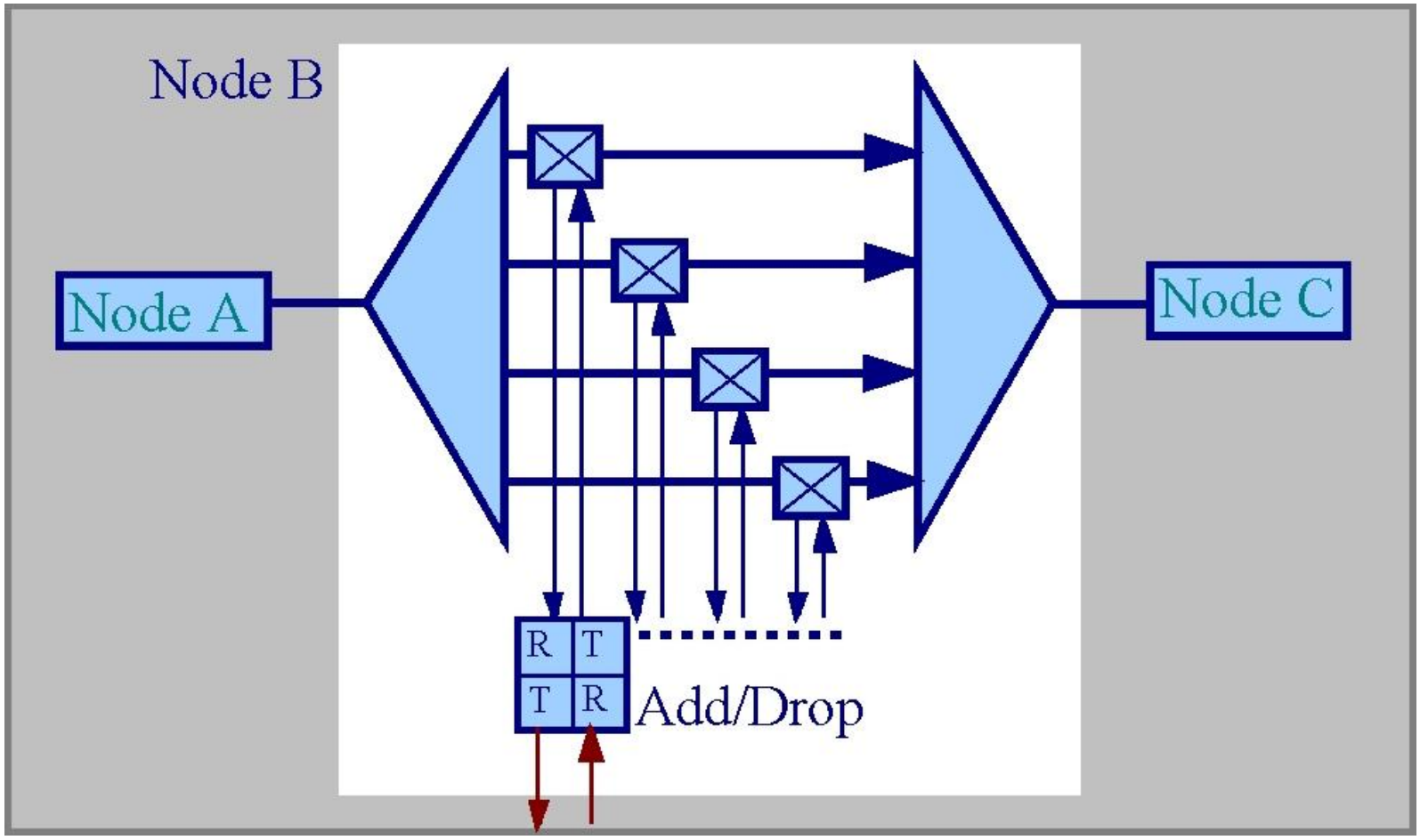
Optical Add/Drop Multiplexer



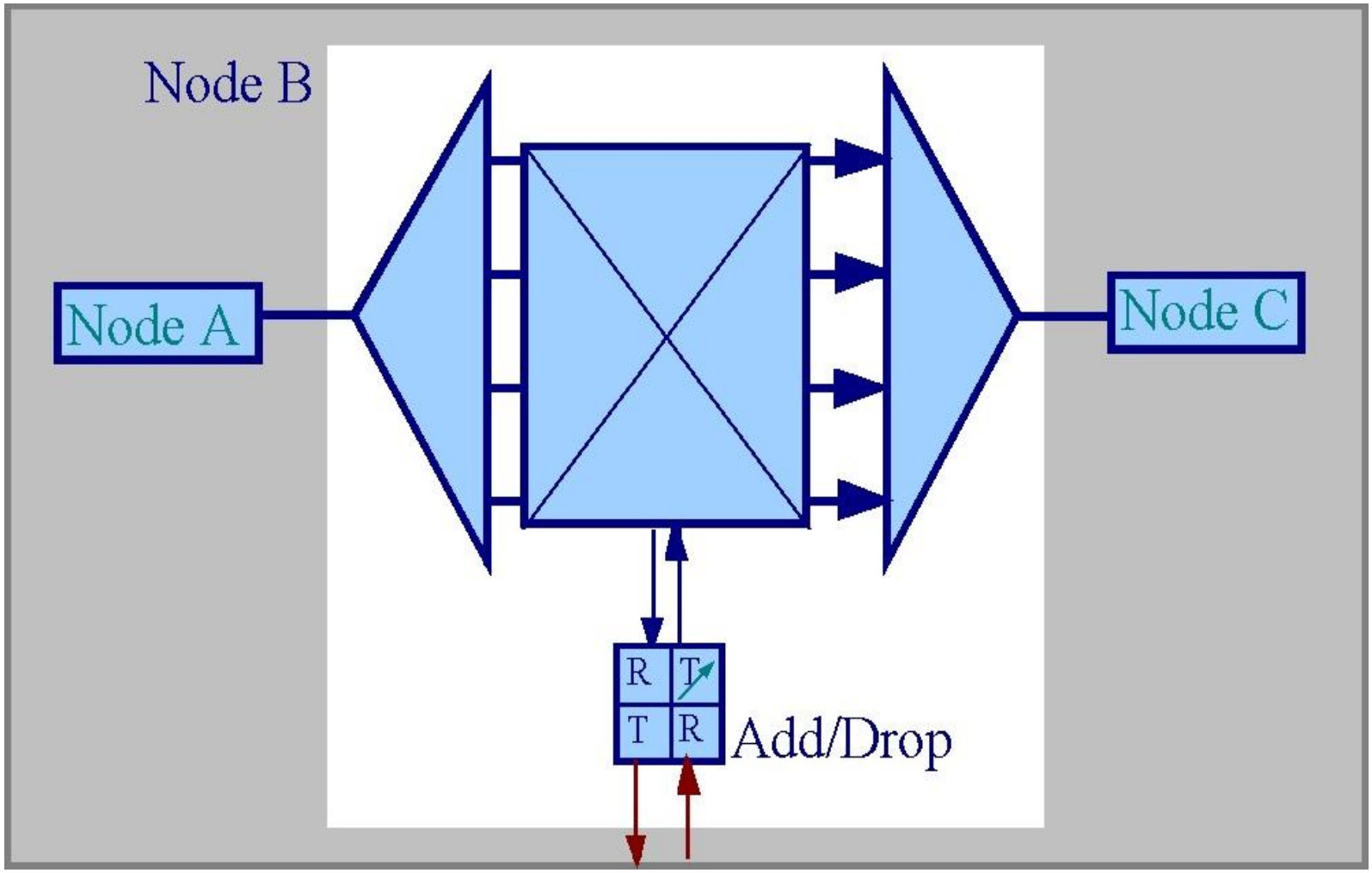
Optical Add/Drop Multiplexer



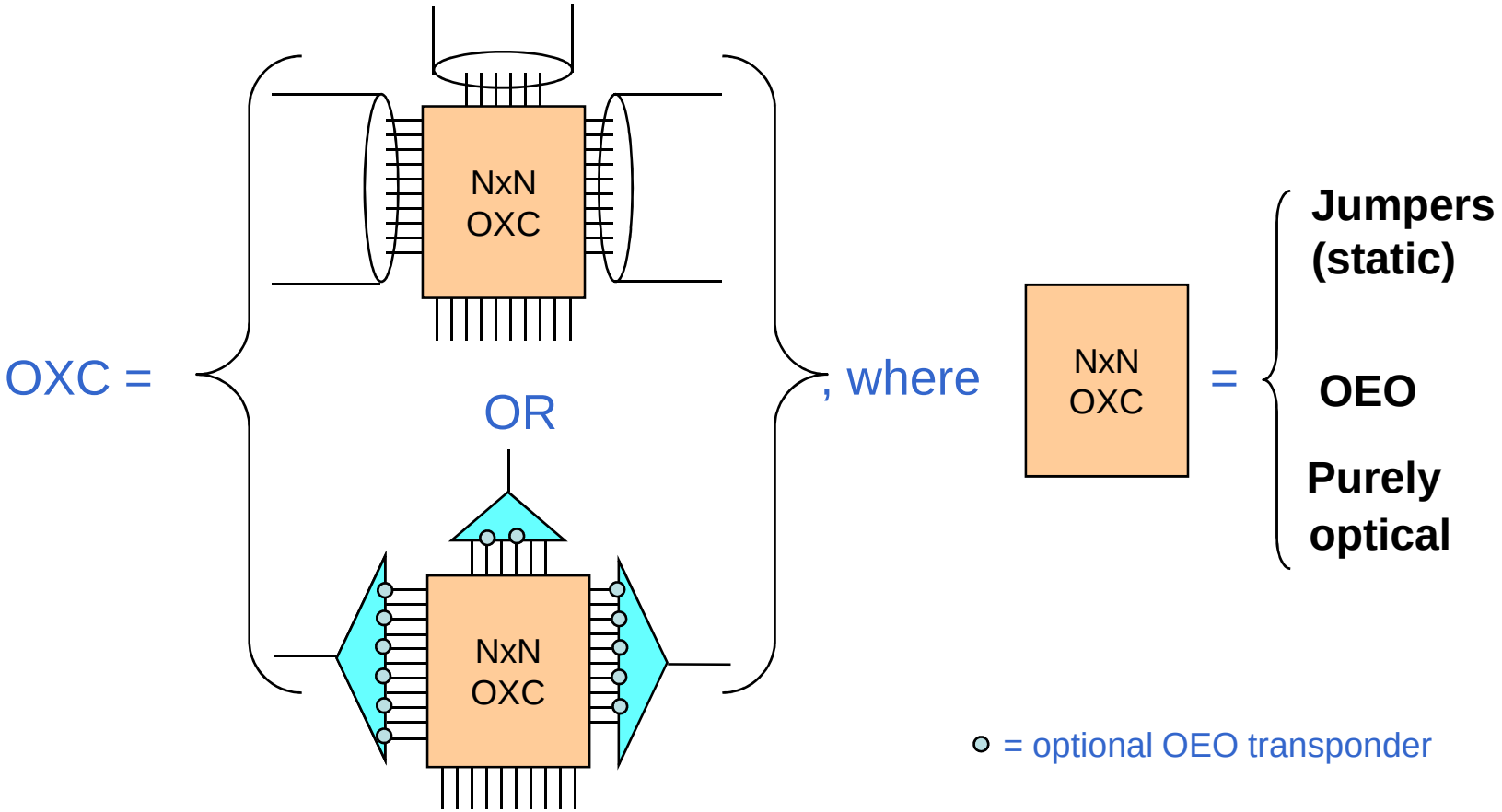
Optical Add/Drop Multiplexer



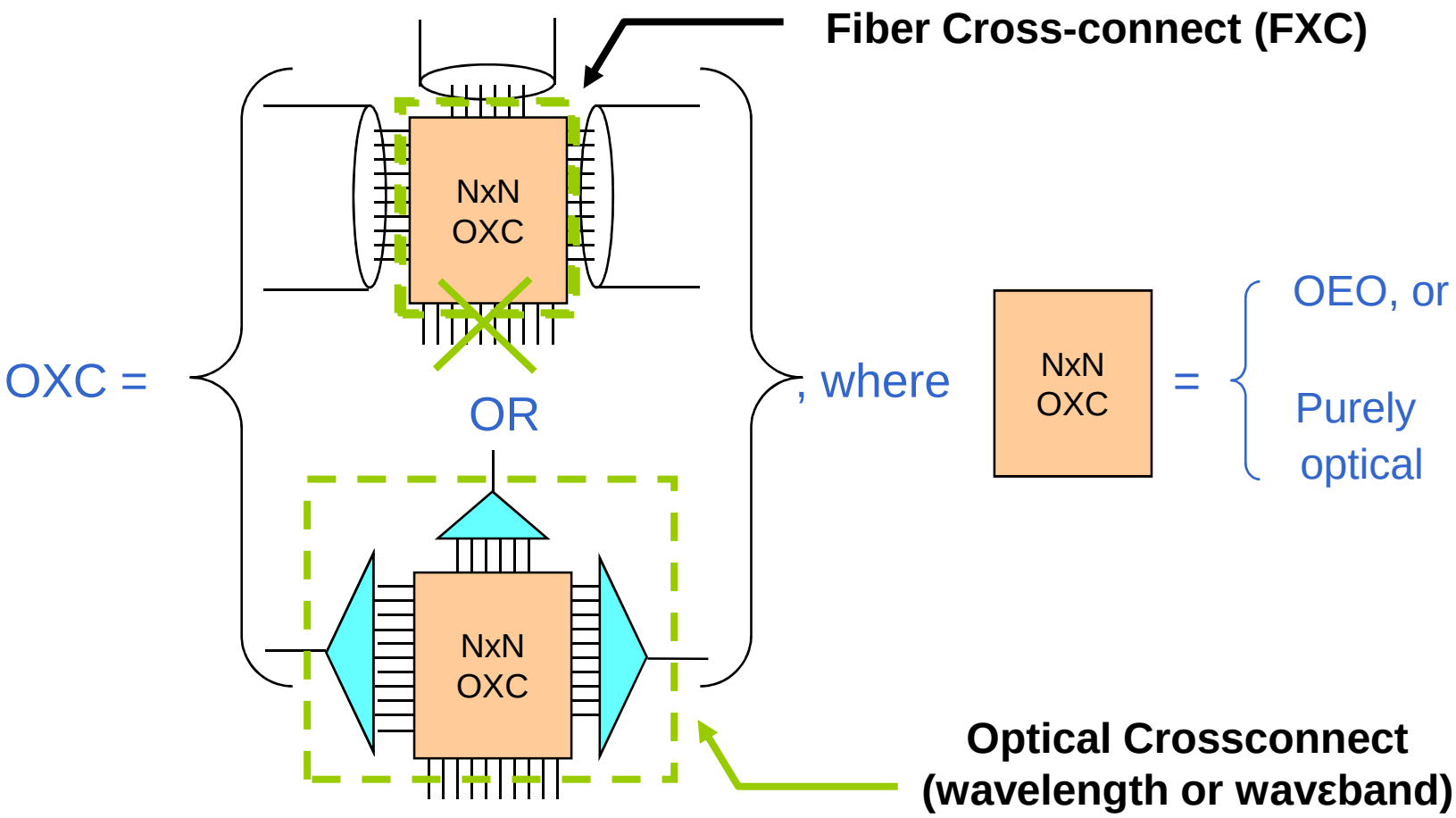
Optical Add/Drop Multiplexer



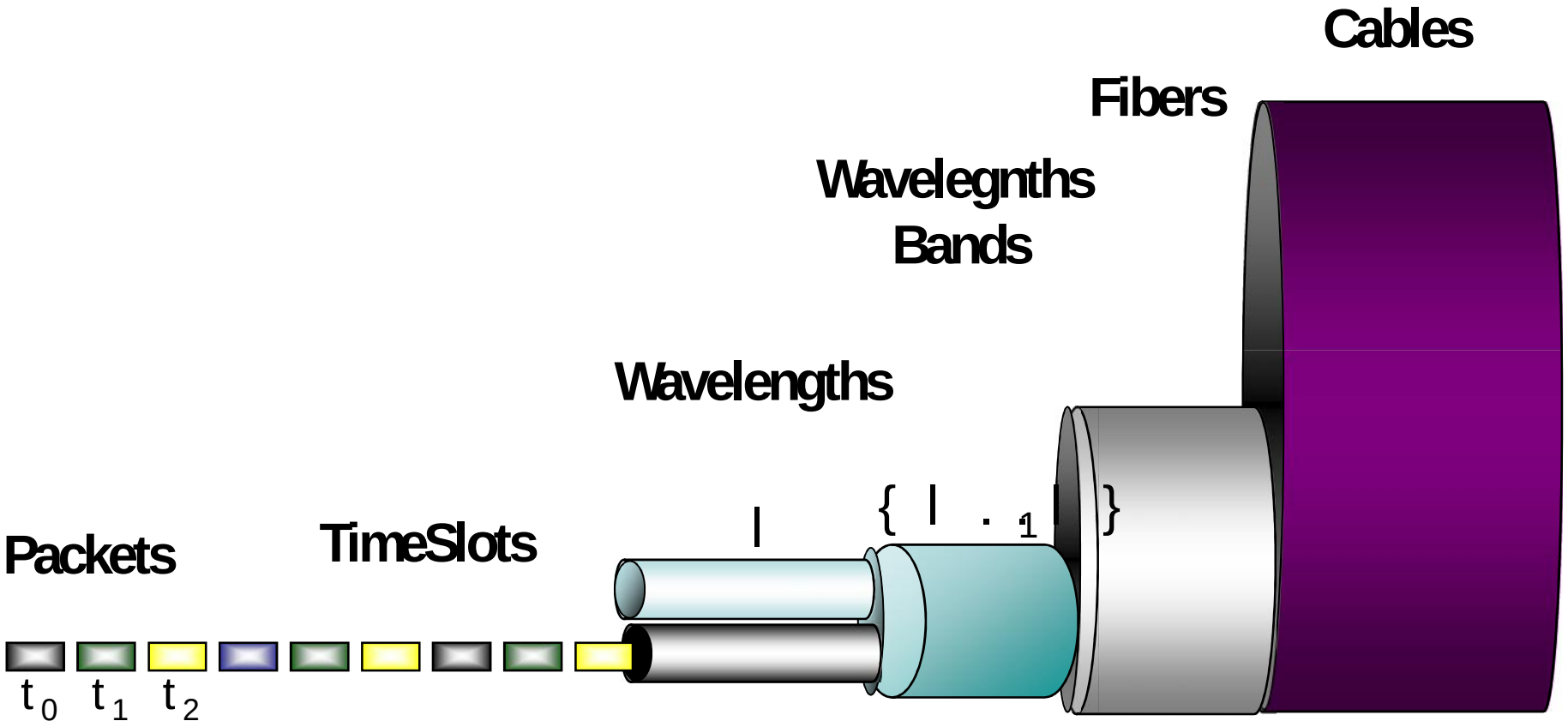
Generic OXC functionality



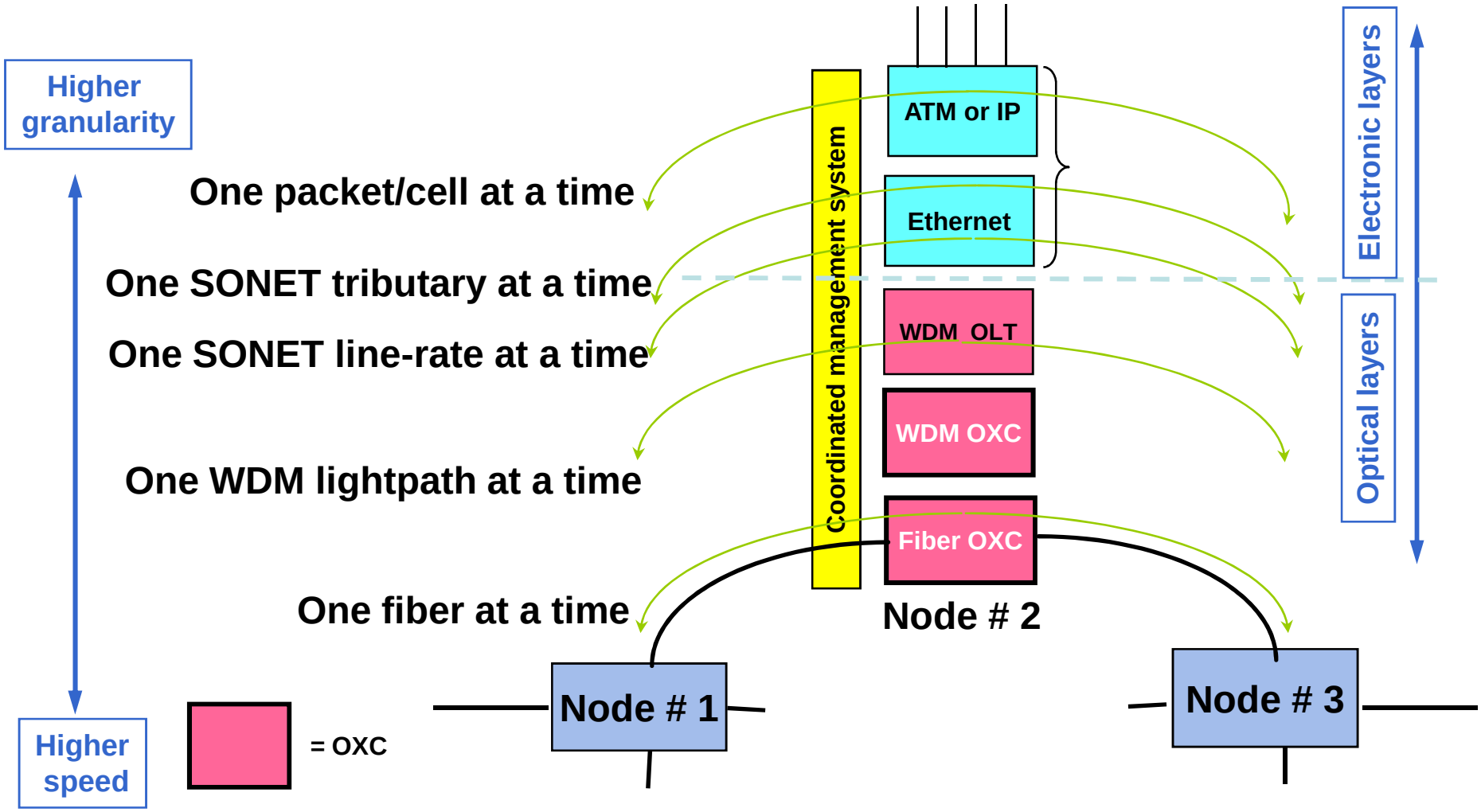
Generic OXC functionality-2



Various Bandwidth Granularities



Granularity management



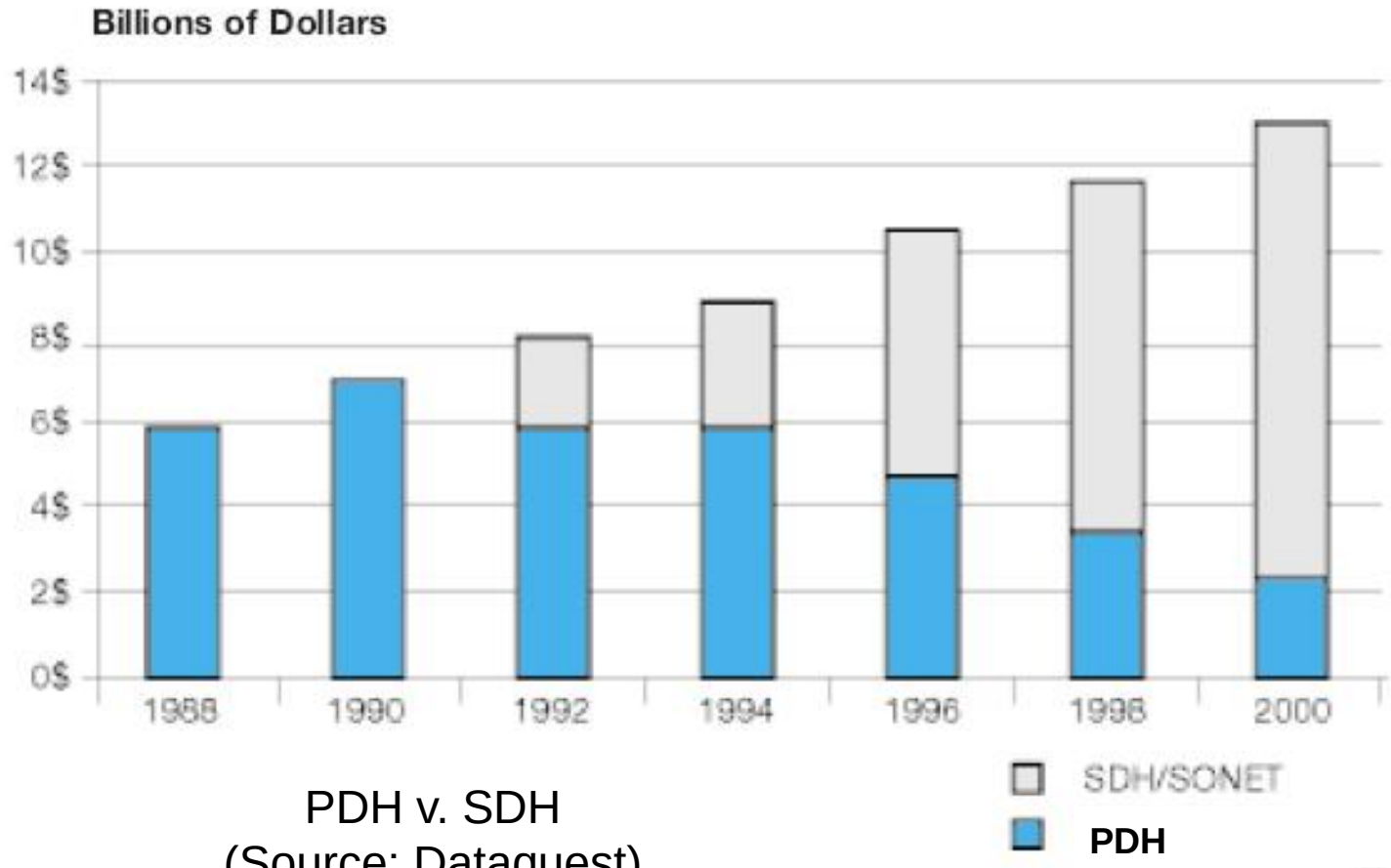
SONET/SDH

Synchronous Networking
Synchronous Digital Hierarchy

Η Ιστορία του SONET/SDH-1

- 1988- Έγκριση της πρότασης από παγκόσμια κοινότητα
  - Καθορισμός του βασικού ρυθμού του SDH στα 155.52 Mb/s
- 1990 - Λειτουργία του πρώτου (Multi-vendor) SONET δικτύου στα OC-1 and OC-3
- Three Phase process
  - Phase I: Addressed issue of passing bits between two equipment (1988)
  - Phase II: Addressed issue of multivendor interoperability (1990/91)
  - Phase III: Addressed issue of OAM&P (still ongoing)

Η Ιστορία του SONET/SDH-2



PDH v. SDH
(Source: Dataquest)

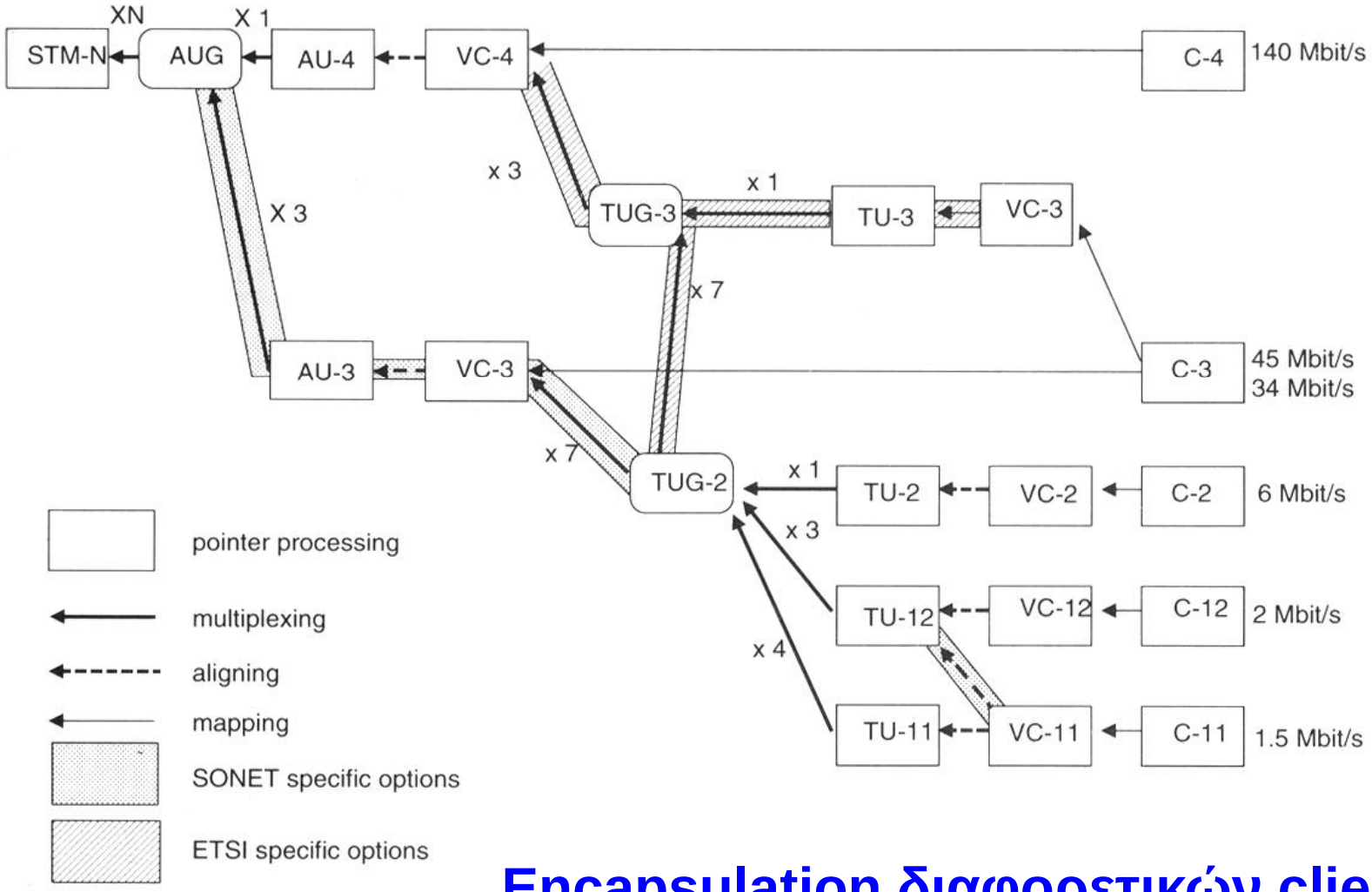
Κυριαρχία του SDH/SONET σε διάστημα μιας δεκαετίας

Το SONET/SDH σήμερα

- Η SONET/SDH τεχνολογία στο 95% των Service Provider παγκόσμια
- Multiple, global equipment makers
  - Alcatel-Lucent, Siemens-Nokia, Cisco, Fujitsu, Ericsson, Nortel, etc.
- Υψηλοί ρυθμοί
  - STM-64 κυριαρχεί = 10 Gb/s.
  - Εμφανίζεται το STM-256 = 40 Gb/s

Οι ιδιότητες ενός δικτύου SONET/SDH

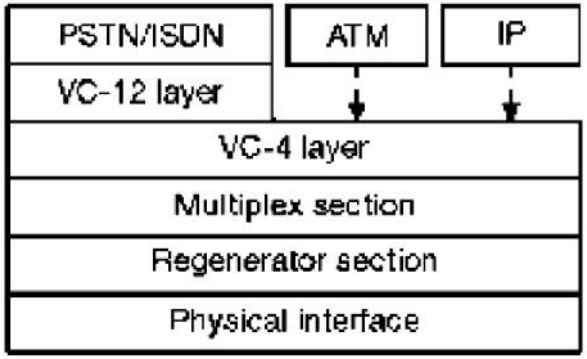
SDH - Transparency

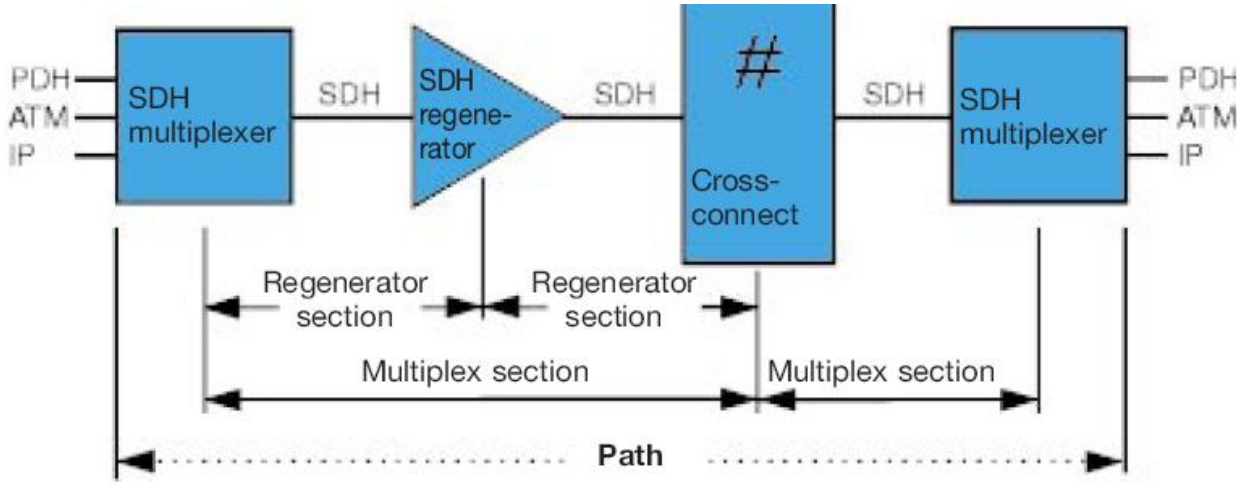


Encapsulation διαφορετικών clients

SDH transport network

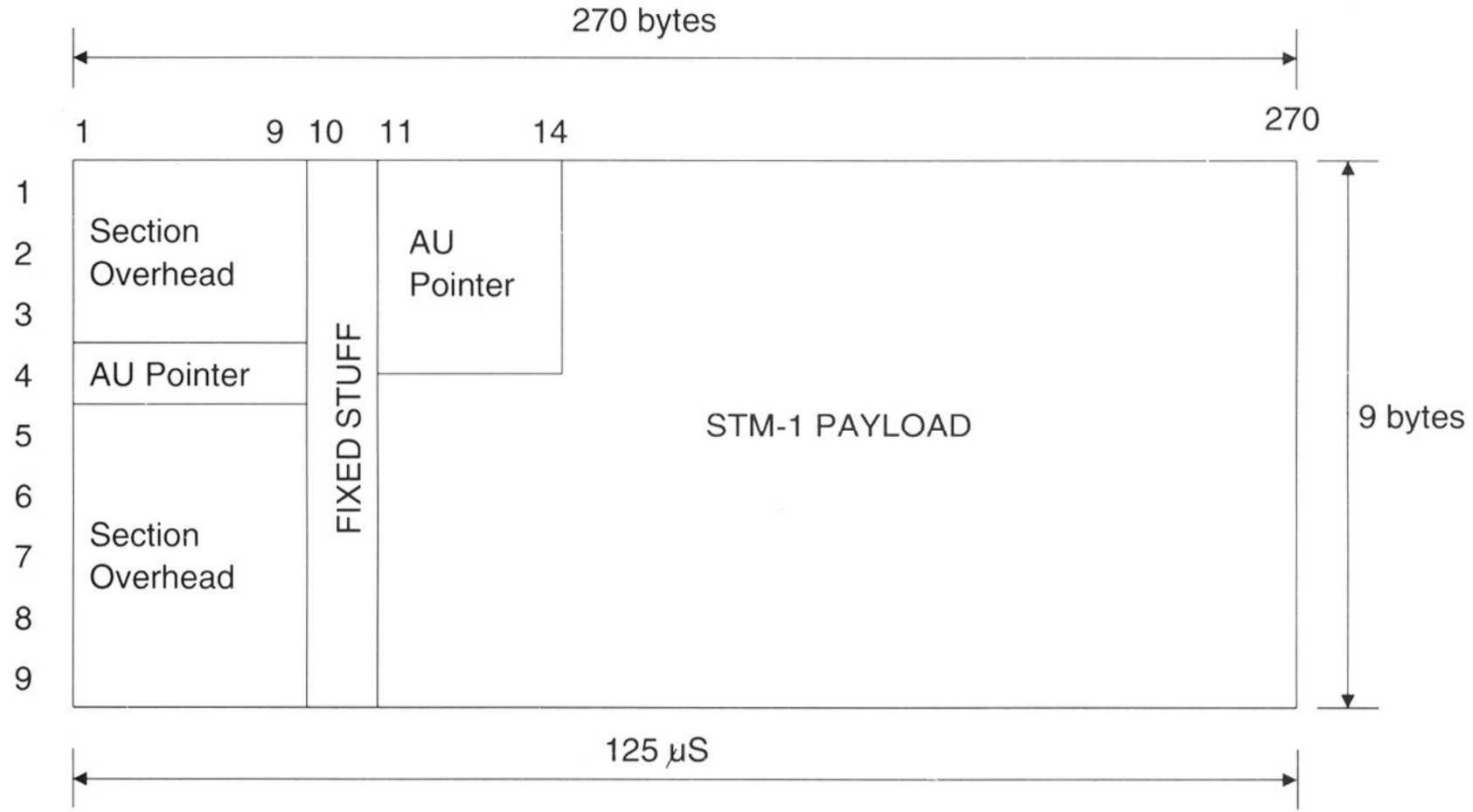
❑ The SDH layer model





❑ Path section designations

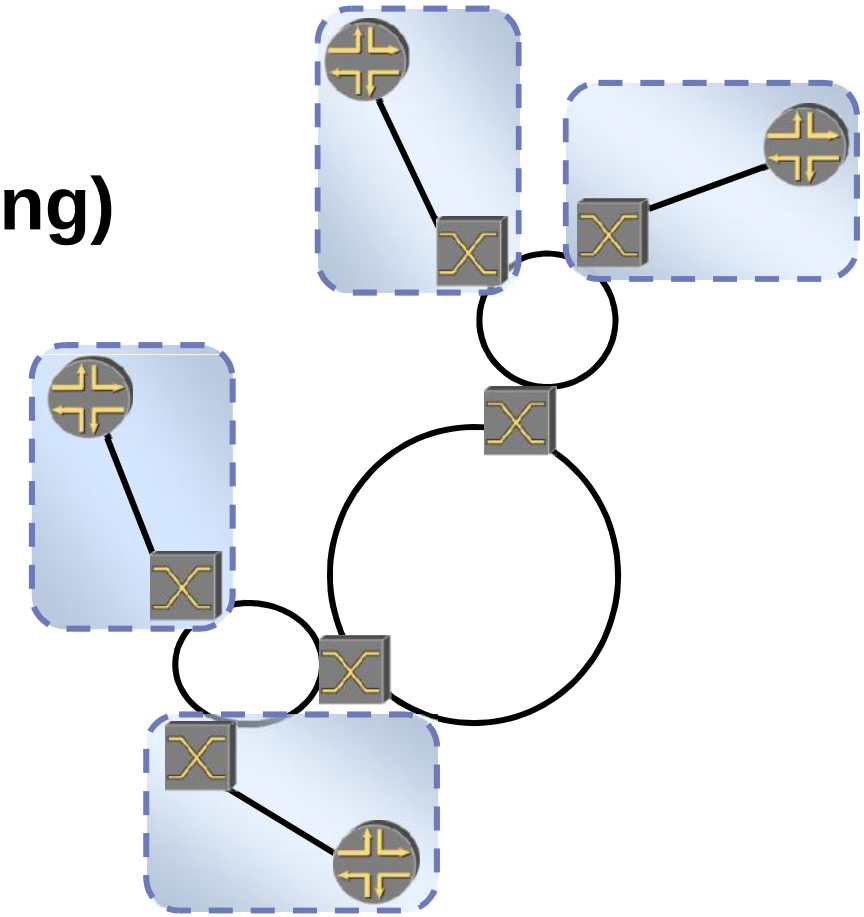
SDH - OA&M



- ❑ **Performance monitoring,**
- ❑ **Bandwidth management**
- ❑ **Network management**

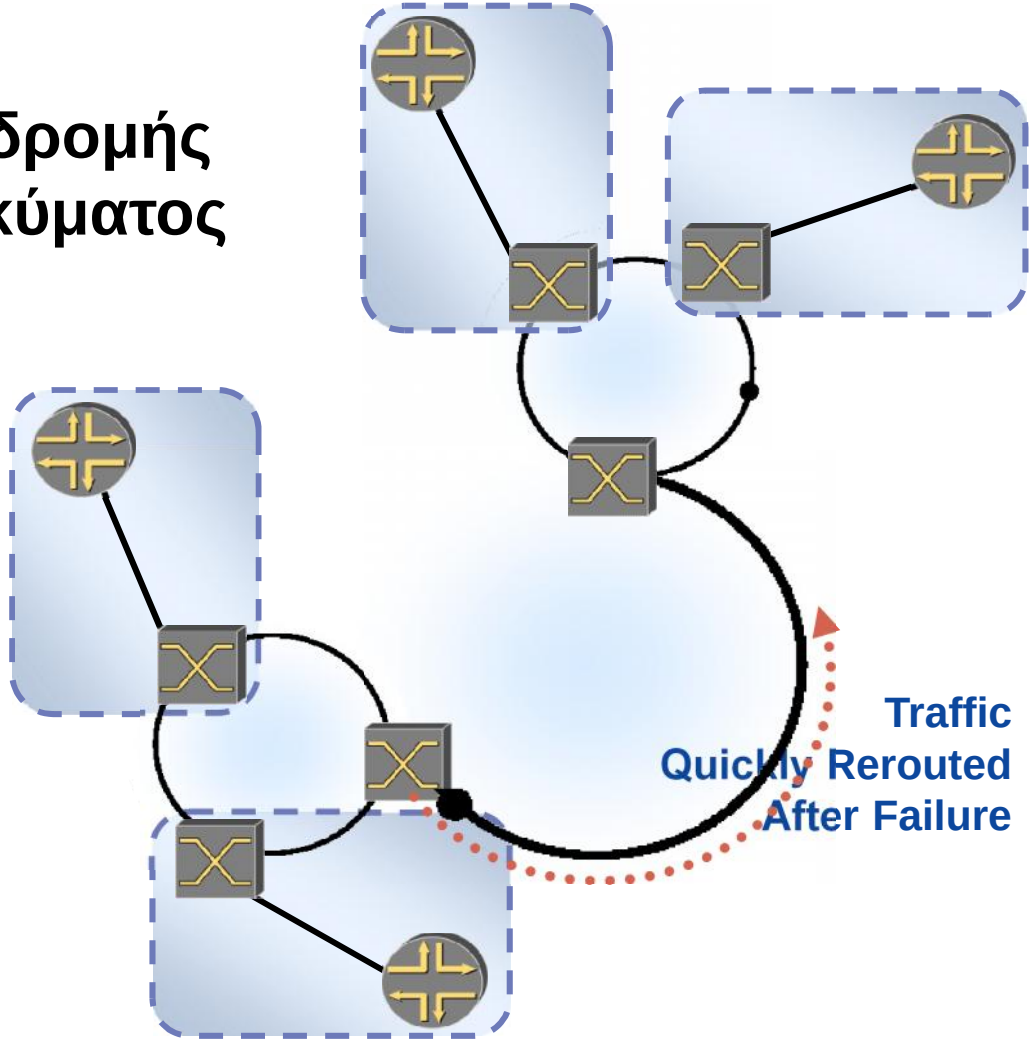
Η επιβιωσιμότητα του SDH

- **10s of ms protection**
- **Simple restoration**
- **Δύο ίνες (dual fiber ring)**

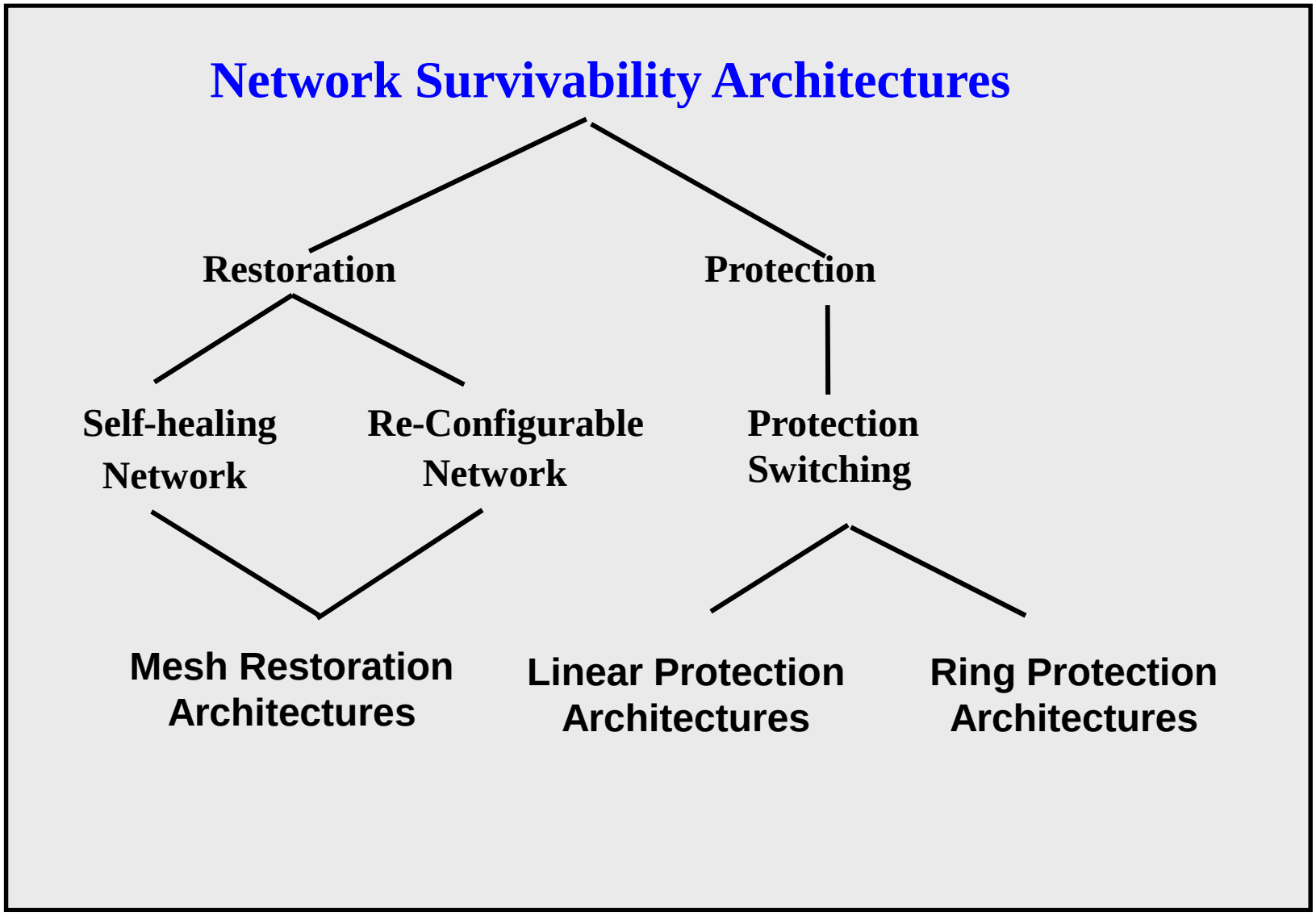


Η επιβιωσιμότητα του SDH

Χρήση της μίας διαδρομής με πρόσθετα μήκη κύματος



Αρχιτεκτονικές για επιβιωσιμότητα



Network Availability & Survivability

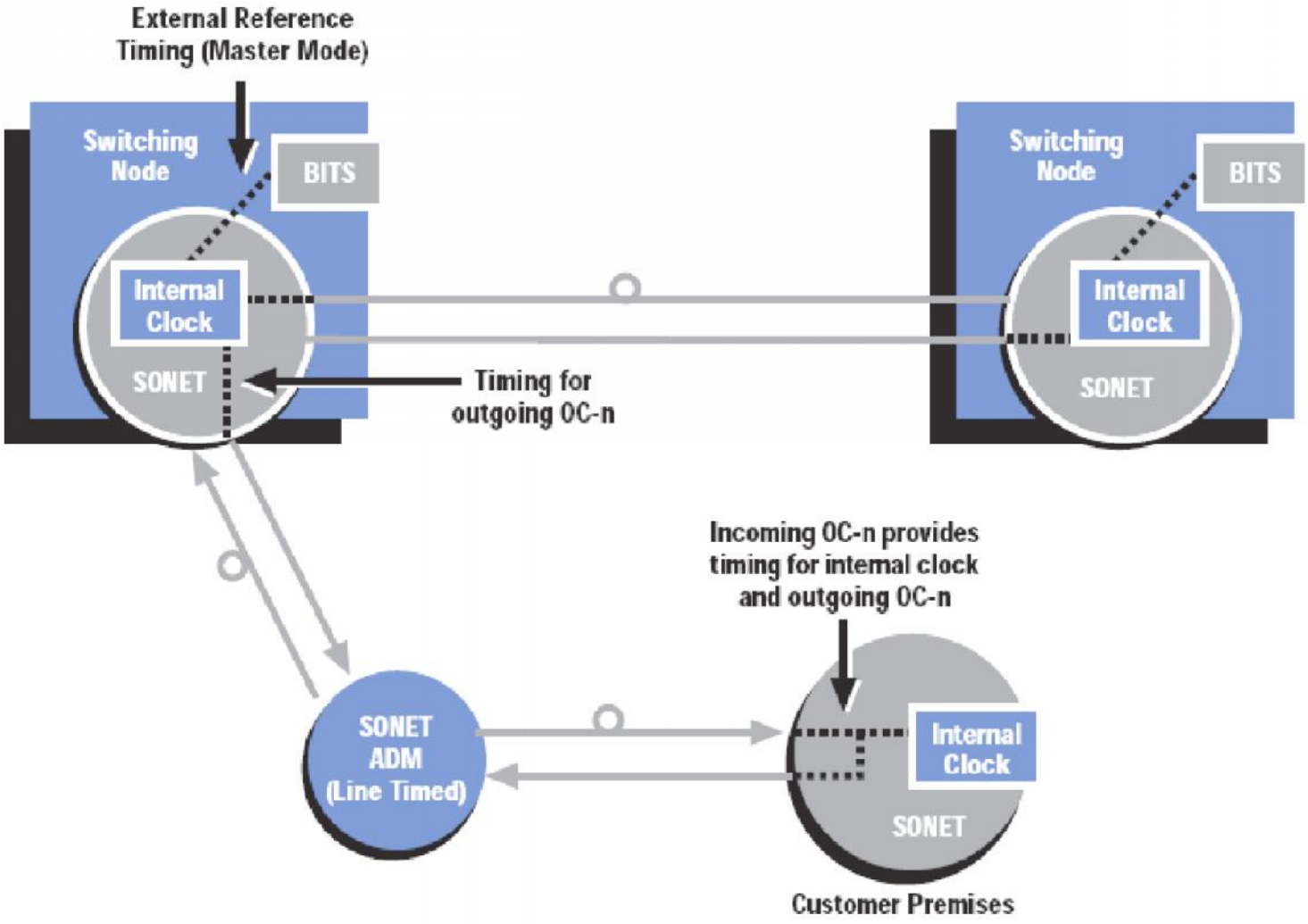
Διαθεσιμότητα (availability) ονομάζεται η πιθανότητα ενός συστήματος να εκτελέσει την λειτουργία του με το απαιτούμενο επίπεδο απόδοσης, στις συγκεκριμένες συνθήκες και το συγκεκριμένο περιβάλλον που απαιτείται να λειτουργήσει. Δηλαδή

$$\text{Availability} = \frac{\text{Reliability}}{\text{Reliability + Recovery}}$$

Ποσοτικοποίηση της Διαθεσιμότητας

Percent Availability	N-Nines	Downtime Time Minutes/Year
99%	2-Nines	5,000 Min/Yr
99.9%	3-Nines	500 Min/Yr
99.99%	4-Nines	50 Min/Yr
99.999%	5-Nines	5 Min/Yr
99.9999%	6-Nines	.5 Min/Yr

SDH - Synchronization



Άλλες σημαντικές ιδιότητες

- Εξαιρετική επίδοση ως προς το jitter
- Απλή διαδικασία σε Add/Drop Multiplexing Digital Crossconnect (DCS)
- Standardization

Λόγοι αντικατάστασης SONET/SDH

- Κυριαρχία των δεδομένων. Δύο φορές περισσότερα από την συνολική κυκλοφορία της φωνής
- Μεγάλος αριθμός από διαφορετικά συστήματα για διαφορετικά clients: ADM, DCS, Ethernet switch, ATM switch, IP switch/router, DWDM transport terminal
- Οι Carriers ψάχνουν μιαν απάντηση στα πιο πάνω προβλήματα κρατώντας όμως τα θετικά του synchronous networking

SONET/SDH Limitations-1

- With SDH DCS, the node has to process the aggregate capacity. Apparently, every node has to cope with both domestic AND transit traffic.

- Despite the fact that the transmission cost is going down, the cost of switching is very high because SDH allows granularity down eventually to 64Kb/s (more likely 45 Mb/s). High speed electronics are used

- Engineered for voice, not data. SDH needed to provide grooming for all possible clients i.e. to accommodate dissimilar types of traffic. Planning and grooming complexity. Delivery measured in weeks

SONET/SDH Limitations-2

- **Άκαμπτο**
  - **Static not dynamic bandwidth**
  - **Granularity – γιατί όχι 5.5 Gb/s ?**

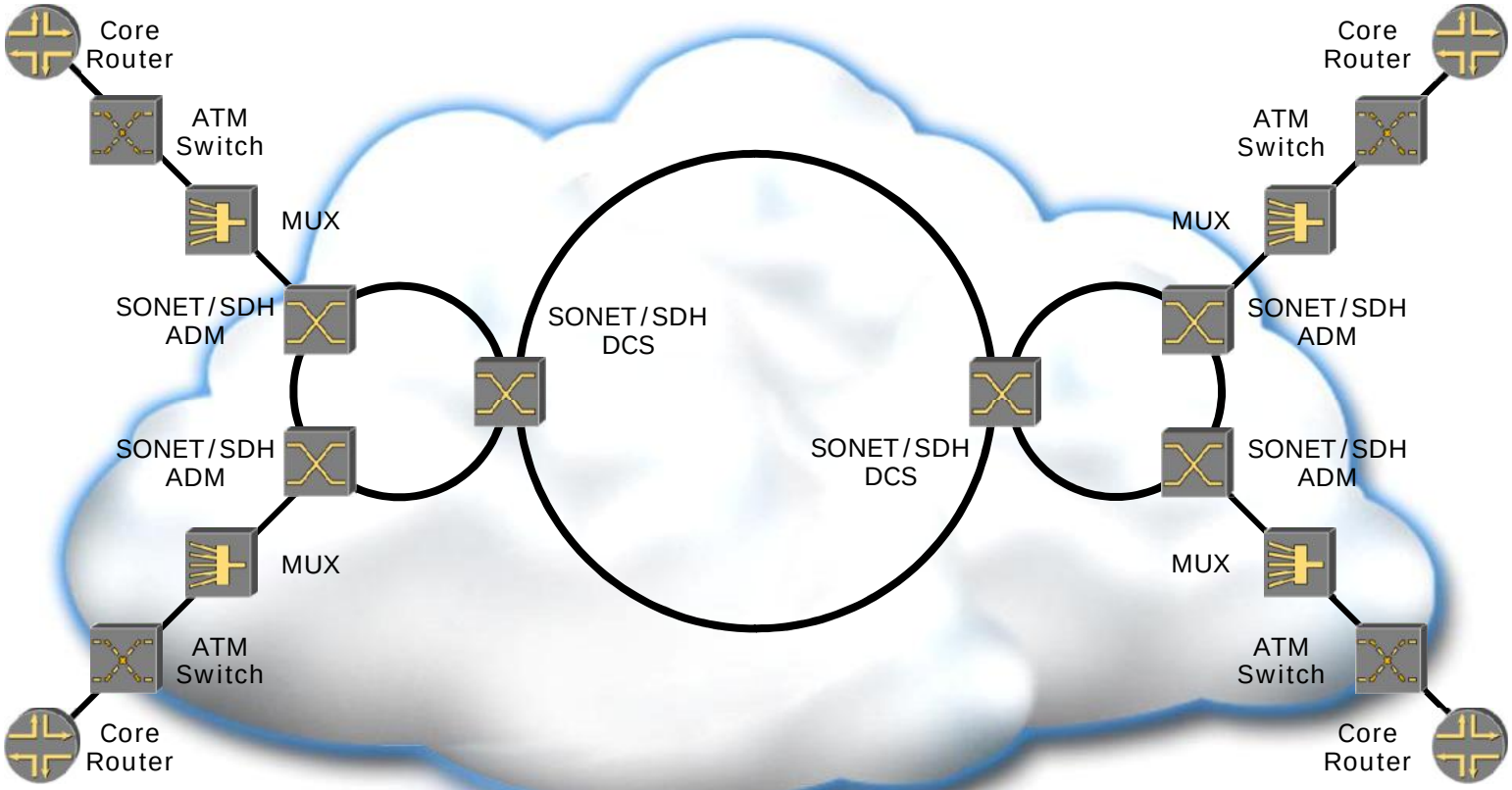
- **Little interoperability at “control plane”(επίπεδο ελέγχου)**
  - **Οι operators είναι αναγκασμένοι να αγοράζουν από μία φίρμα**
  - **Αποτρέπει την δυνατότητα να αγοράσουν τα καλύτερα υπο-συστημάτα από διαφορετικές εταιρίες.**

Το μέλλον του SONET/SDH

- Χρειάζονται μεγαλύτερες ταχύτητες από τα υπάρχοντα SONET συστήματα
  - Το STM-256 εμφαωνίζεται
- Κυριαρχεί σε MAN και WAN
- Multi-Service Provisioning Platforms (MSPP)
  - Τα MSPPs είναι SONET/SDH συστήματα προσαρμοσμένα για δεδομένα
  - To combine various functionalities into one chassis ADM and DCS + non-TDM functionality (IP + Layer 2 switching, DWDM). This is the “digital wrapper” called NG-SONET. IP + SONET/SDH Integration (RPR, GFP, VCAT). Data & SAN interfaces.

Αλλάζει ο τύπος του Networking

Typical IP Backbone (Late 1990's)



- Data packed over traditional voice/TDM transport

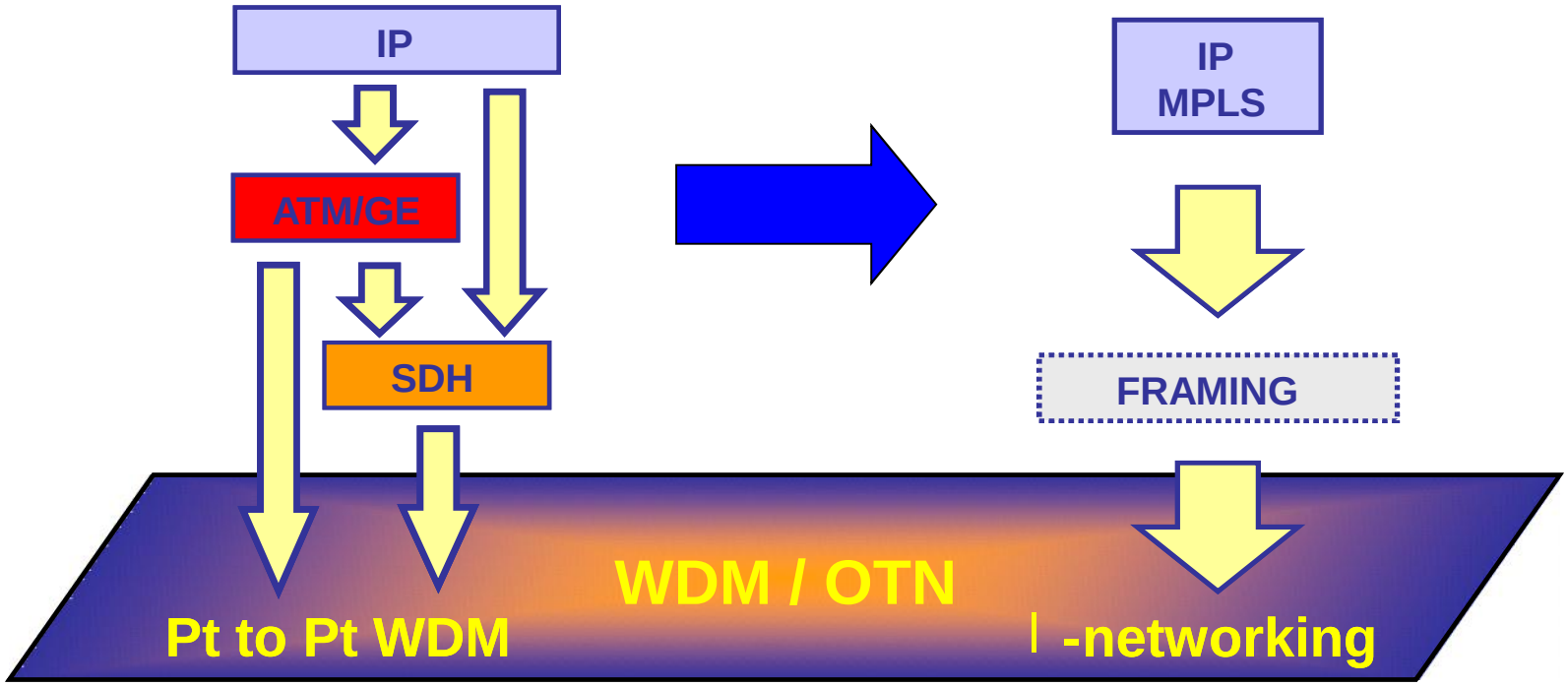
Why So Many Layers?

- Router
  - Packet switching
  - Mux and statistical gain
  - Any-to-any connectivity
  - Restoration (several seconds)
- ATM/Frame switches
  - forwarding
  - Traffic engineering
  - Restoration (sub-second)
- MUX
  - Speed match router/ switch interfaces to transmission network
- SONET/SDH
  - TDM oriented
  - **Aggregation**-grooming
  - Standardized Transportation
  - Restoration (50msec)
- DWDM
  - Raw bandwidth
  - Defer new construction
- Result
  - Duplication of functionalities
  - Multiple Network Management Systems
  - Increased capital and operational costs

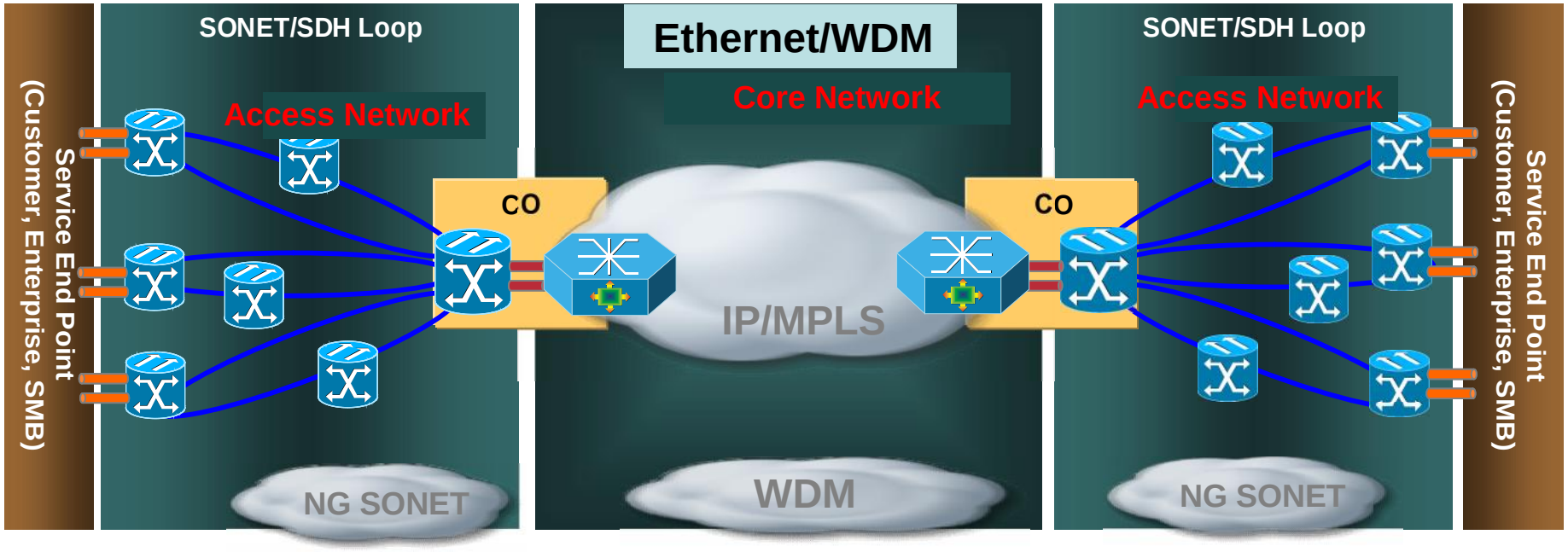
SDH - WDM duplication

- **P-t-P Links**
  - **One SDH connection between Terminals**
  - **Many fiber or WDM lightpaths between Terminals**
- **Rings**
  - **SONET/SDH ADMs, vs. Bare fiber or WDM**
  - **equivalents (OADNs)**
- **Mesh, interconnected rings, etc.**
  - **SONET/SDH DCSs**
  - **Bare fiber or WDM OXCs**

Network De-Layering

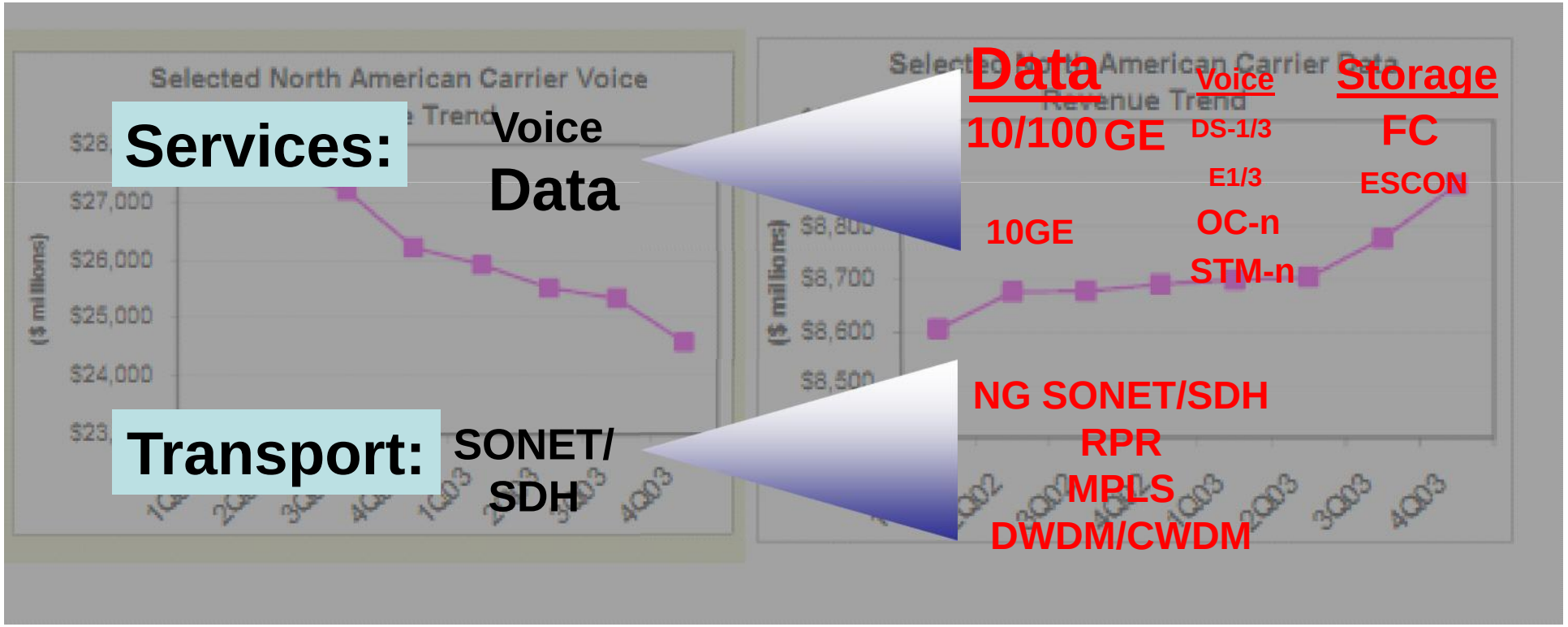


End-End Data Delivery



- Core networks: Ethernet (L2) + WDM (+ optical technology in the switch)
- Access Networks: NG SONET/SDH for PoS
- Boundaries between packet and optical networks are blurring…
- Consistent interworking across optical and packet layers

Η εξέλιξη των Metro/Access Δικτύων



Summary

Yesterday

- Optical and IP separate
- NG SONET with L1 Ethernet
- Manually intensive WDM

Tomorrow

- Ethernet into optical
- WDM into routers
- NG SONET with L2 Ethernet, SAN, RPR, WDM
- Plug and play, reconfigurable WDM