How much is time saving of 3 milliseconds worth?


CHICAGO
NEW YORK


CHICAGO
DETROIT
CLEVELAND
PITTSBURGH
PHILADELPHIA
NEW YORK
0
50 MILES


Aurora, IL
Cermak
Wawaka, IN
Clyde, OH
Greenville, PA
Mahanoy City, PA
Mahwah, NJ
300 Blvd East
Brookville, PA
Secaucus, NJ
111 8th Avenue
165 Halsey
LaPorte, IN
Wauseon, OH
Cleveland, OH
State College, PA
Sunbury, PA
Allentown, PA
Carteret, NJ
Piscataway, NJ
ILLINOIS
INDIANA
MICHIGAN
OHIO
PENNSYLVANIA
NEW YORK
NEW JERSEY

How much is time saving of 3 milliseconds worth?

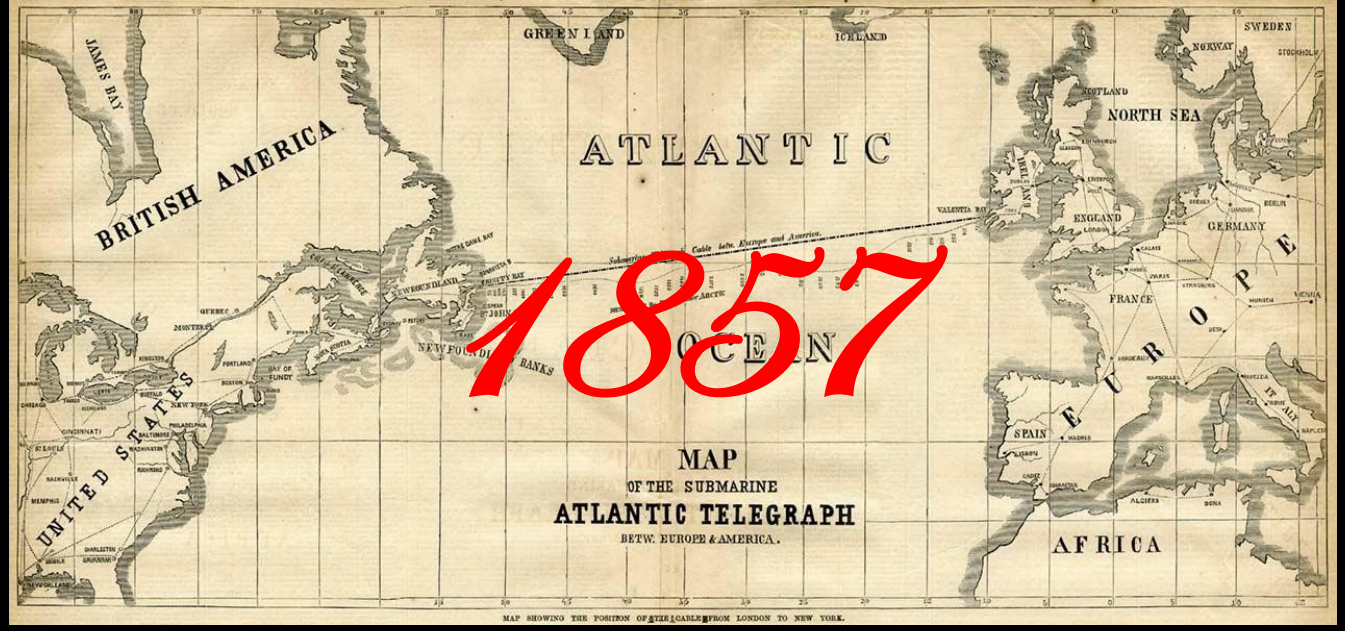
$300 millions

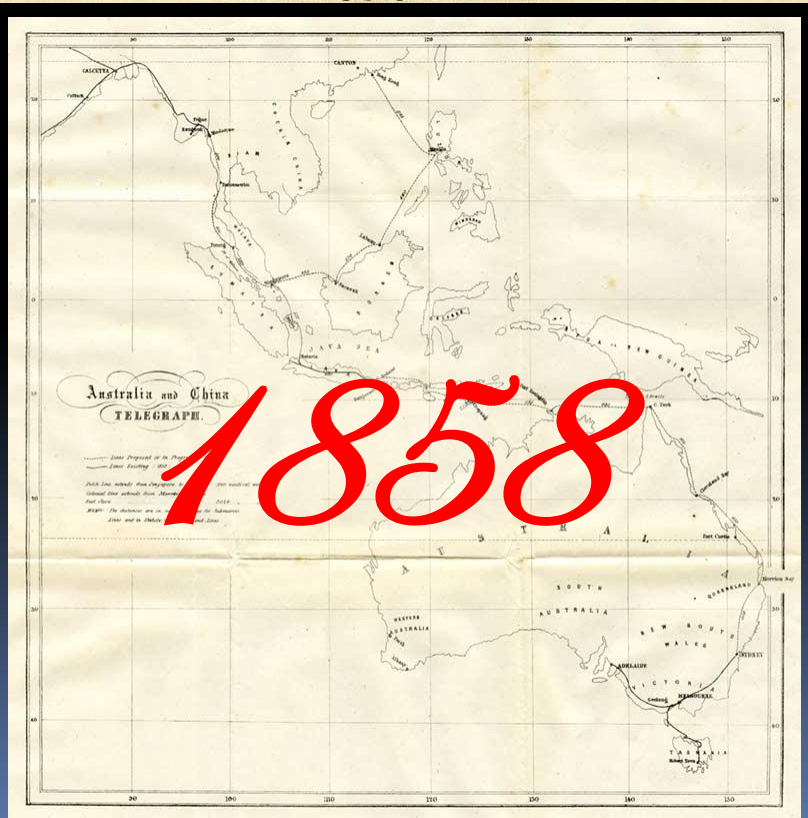
ECE 6323

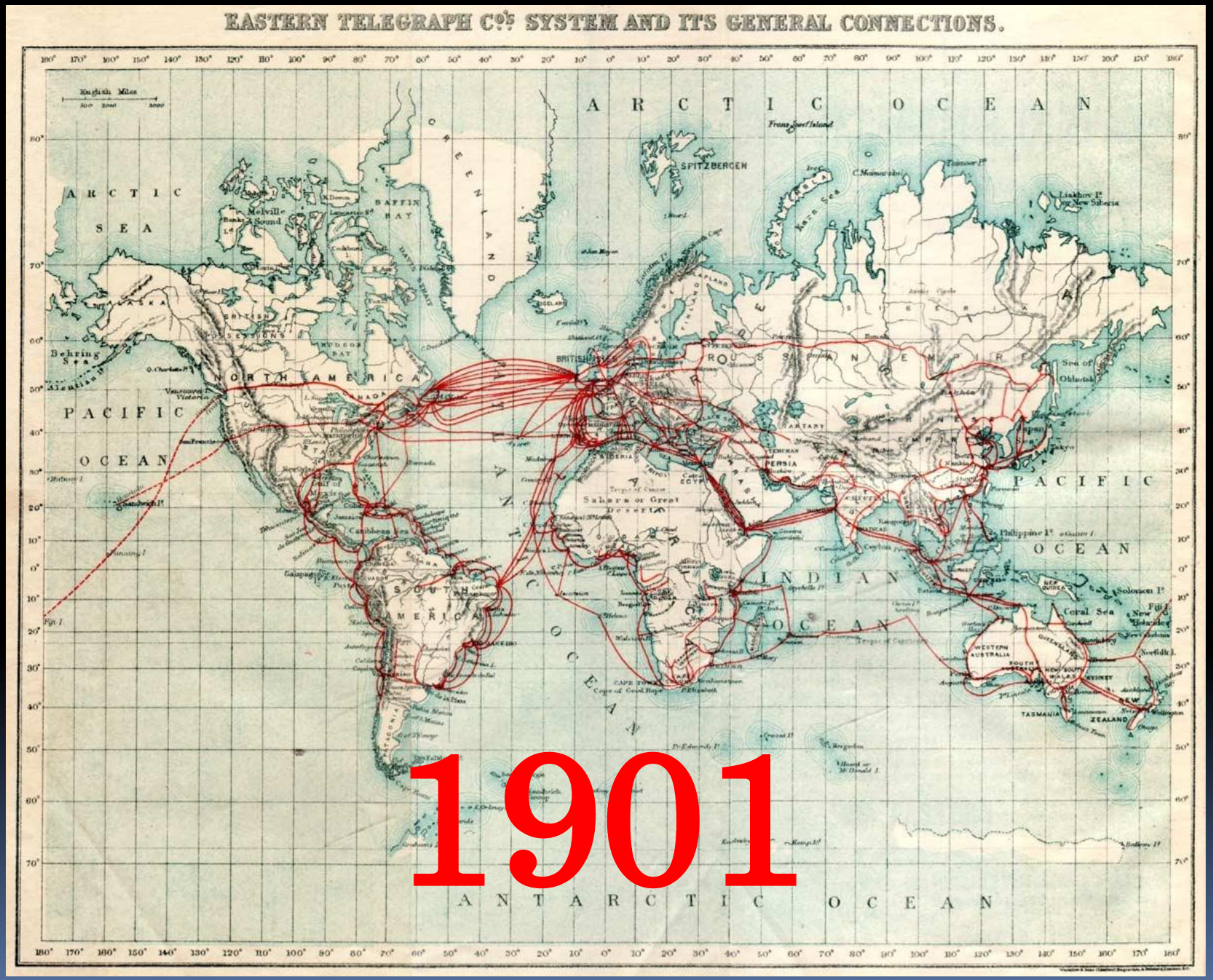
OPTICAL COMMUNICATION NETWORK: INTRODUCTION

Outline

- Introduction
- Telecom/datacom network concept
- Optical network concepts and architecture
  - Overview
  - Layers and protocol
  - (D)WDM network and wavelength routing
  - Optical switching
- Optical network deployment
  - Global
  - Fiber to the premise (home, business,…)
- Summary

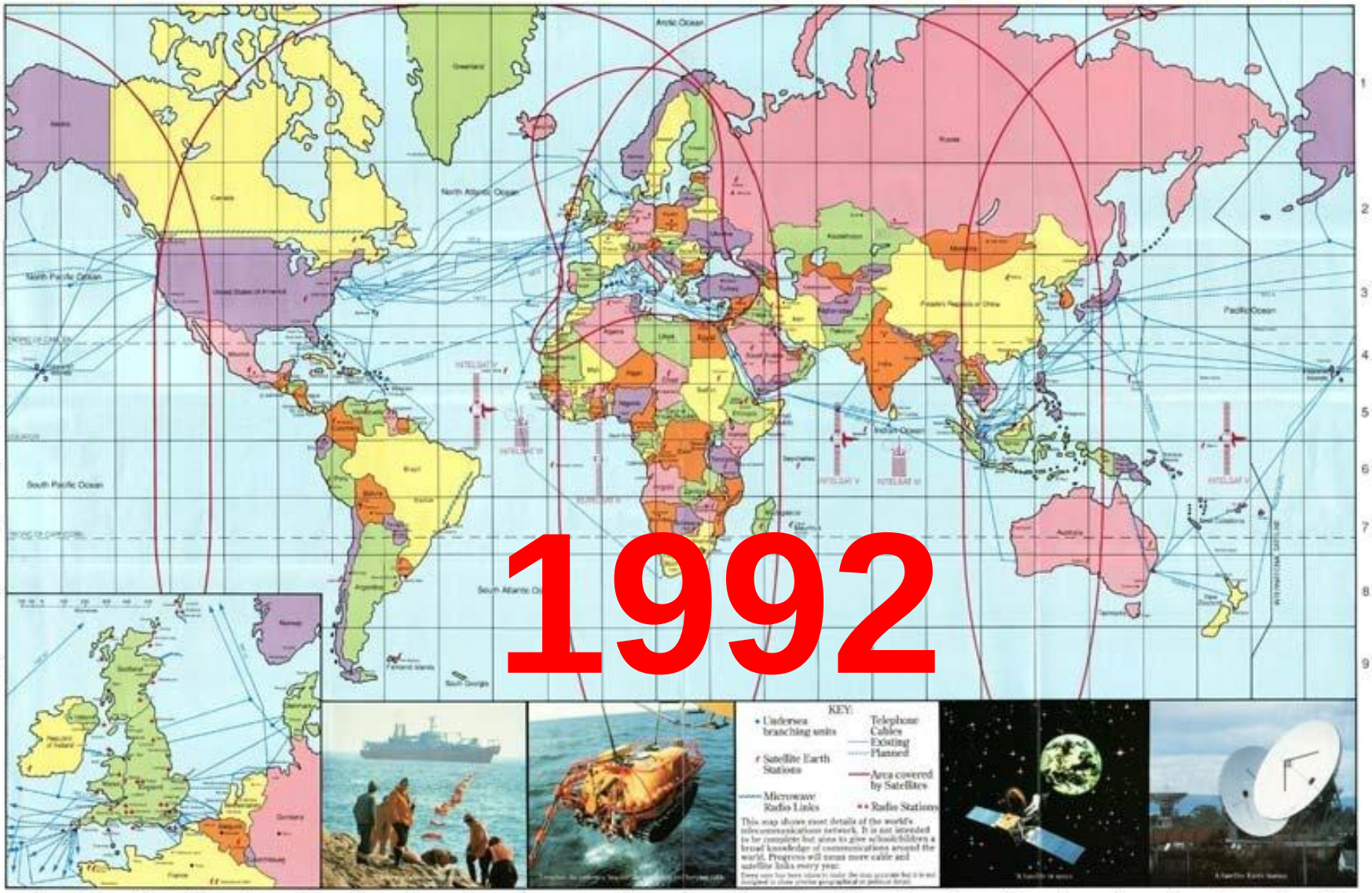

GREEN LAND
ICELAND
SWEDEN
NORWAY
STOCKHOLM
JAMES BAY
BRITISH AMERICA
ATLANTIC
NORTH SEA
SCOTLAND
ENGLAND
LONDON
GERMANY
BERLIN
FRANCE
PARIS
EUROPE
1857
OCEAN
NEWFOUNDLAND
BANKS
BAY OF FUNDY
MONTREAL
QUEBEC
PORTLAND
BOSTON
NEW YORK
PHILADELPHIA
BALTIMORE
WASHINGTON
CHICAGO
CINCINNATI
ST LOUIS
MEMPHIS
NASHVILLE
CHARLESTON
SAVANNAH
MOBILE
NEW ORLEANS
UNITED STATES
SPAIN
MADRID
LISBON
CADIZ
GIBRALTAR
ALGIERS
BONA
AFRICA
MAP
OF THE SUBMARINE
ATLANTIC TELEGRAPH
BETW. EUROPE & AMERICA.
MAP SHOWING THE POSITON OF THE CABLE FROM LONDON TO NEW YORK.


CALCUTTA
CANTON
JAVA SEA
Australia and China
TELEGRAPH.
1858
AUSTRALIA
SOUTH
AUSTRALIA
NEW SOUTH
WALES
QUEENSLAND
ADELAIDE
VICTORIA
MELBOURNE
TASMANIA
Port Curtis
Moreton Bay


EASTERN TELEGRAPH Co's SYSTEM AND ITS GENERAL CONNECTIONS.
ARCTIC OCEAN
ARCTIC SEA
PACIFIC OCEAN
INDIAN OCEAN
ATLANTIC OCEAN
ANTARCTIC OCEAN
NORTH AMERICA
SOUTH AMERICA
SPITZBERGEN
GREENLAND
BAFFIN BAY
Melville Sound
Behring Sea
Sahara or Great Desert
PERSIA
Coral Sea
TASMANIA
NEW ZEALAND
1901

Communications – Around the World

BT

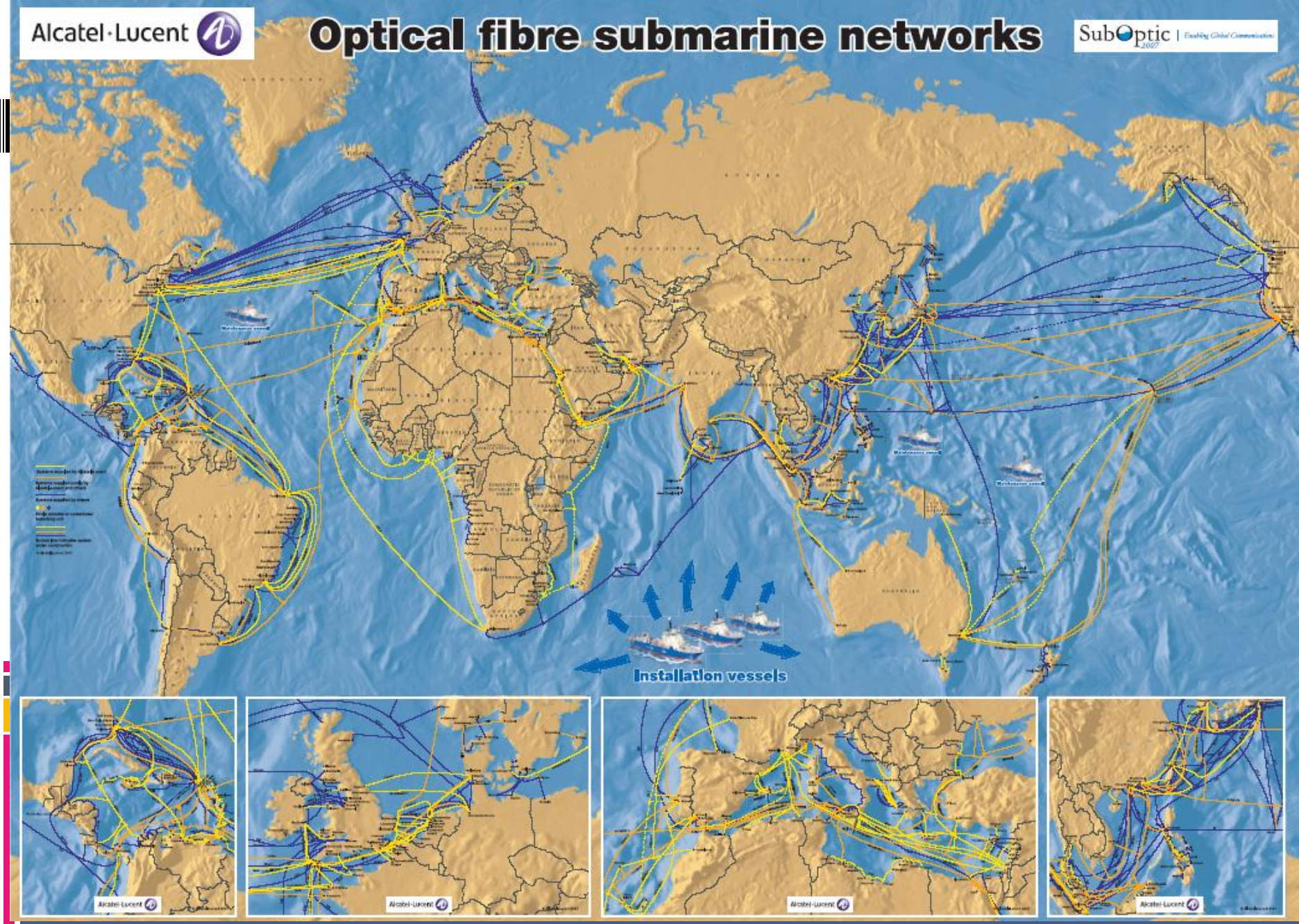


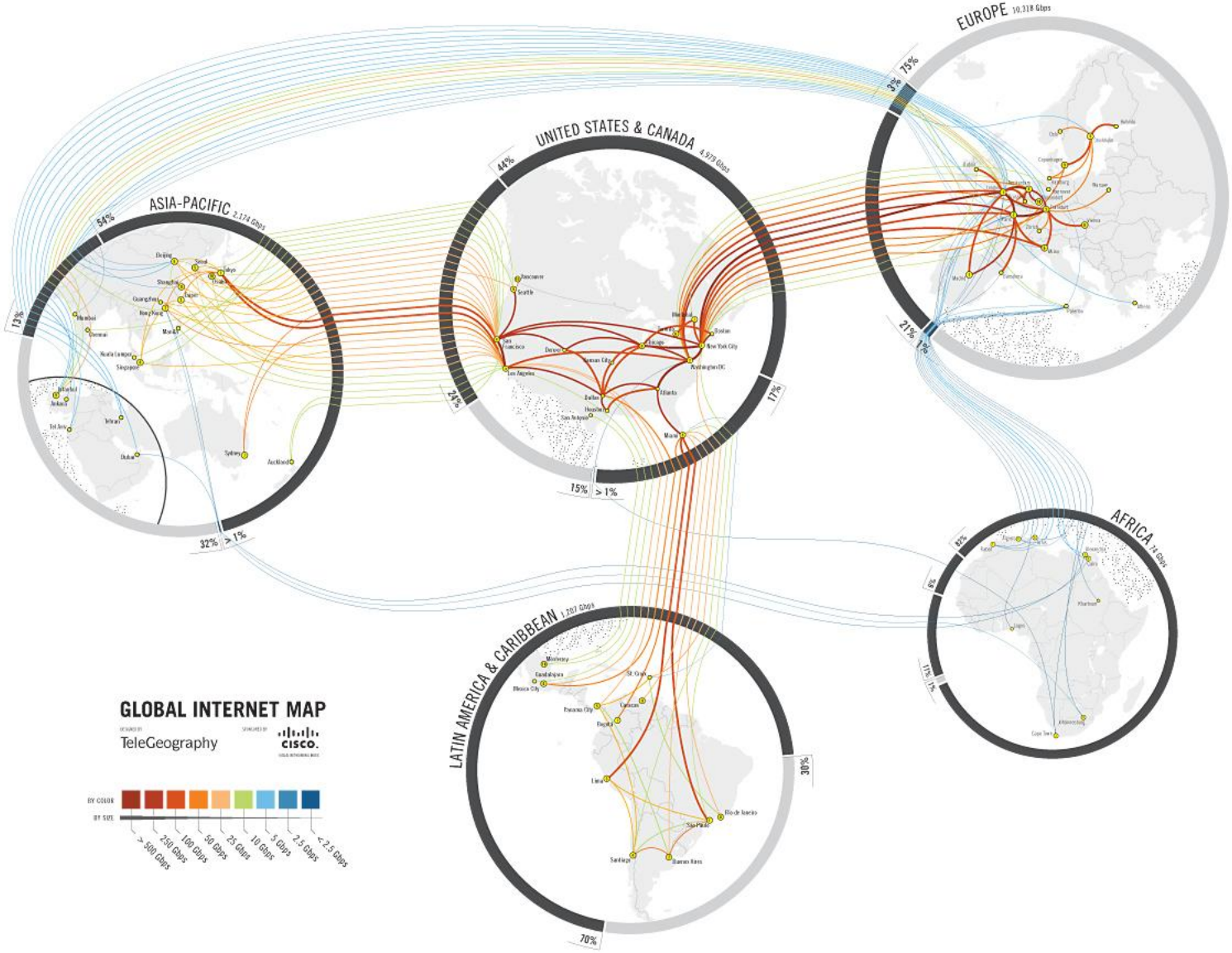
1992

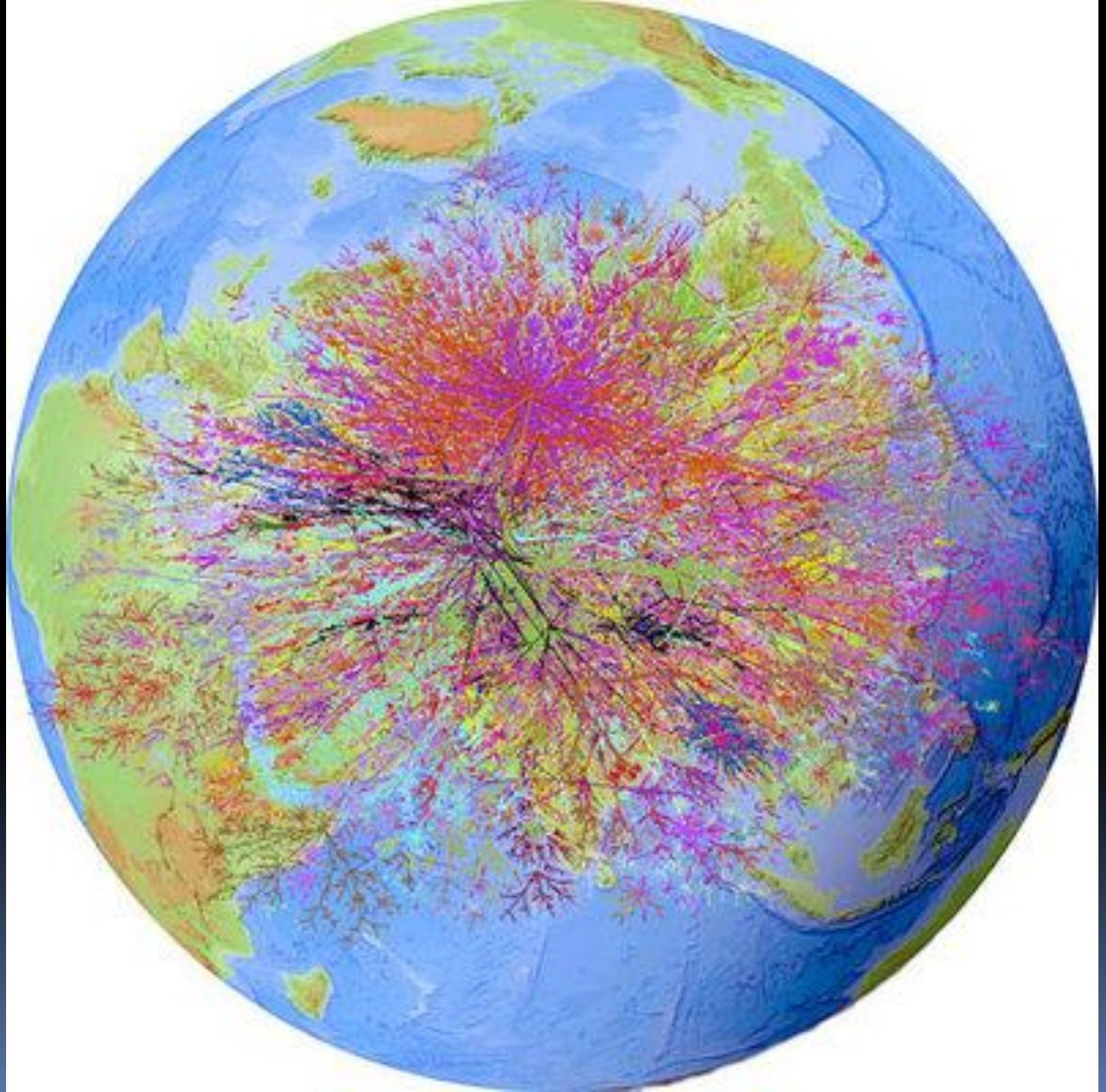
A B C D E F G H J K L M N O P Q R S T U V W X Y Z

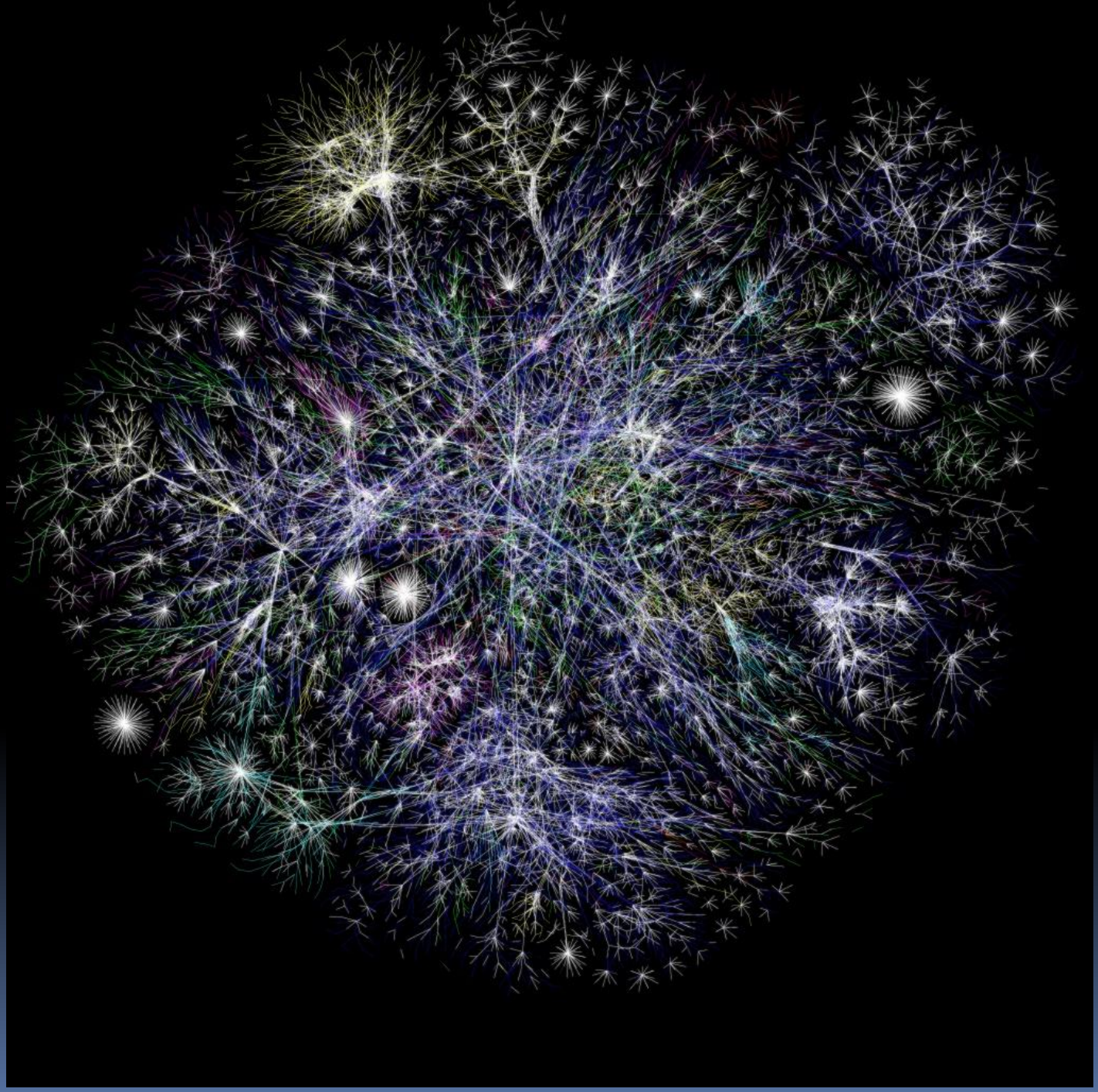
That was then…

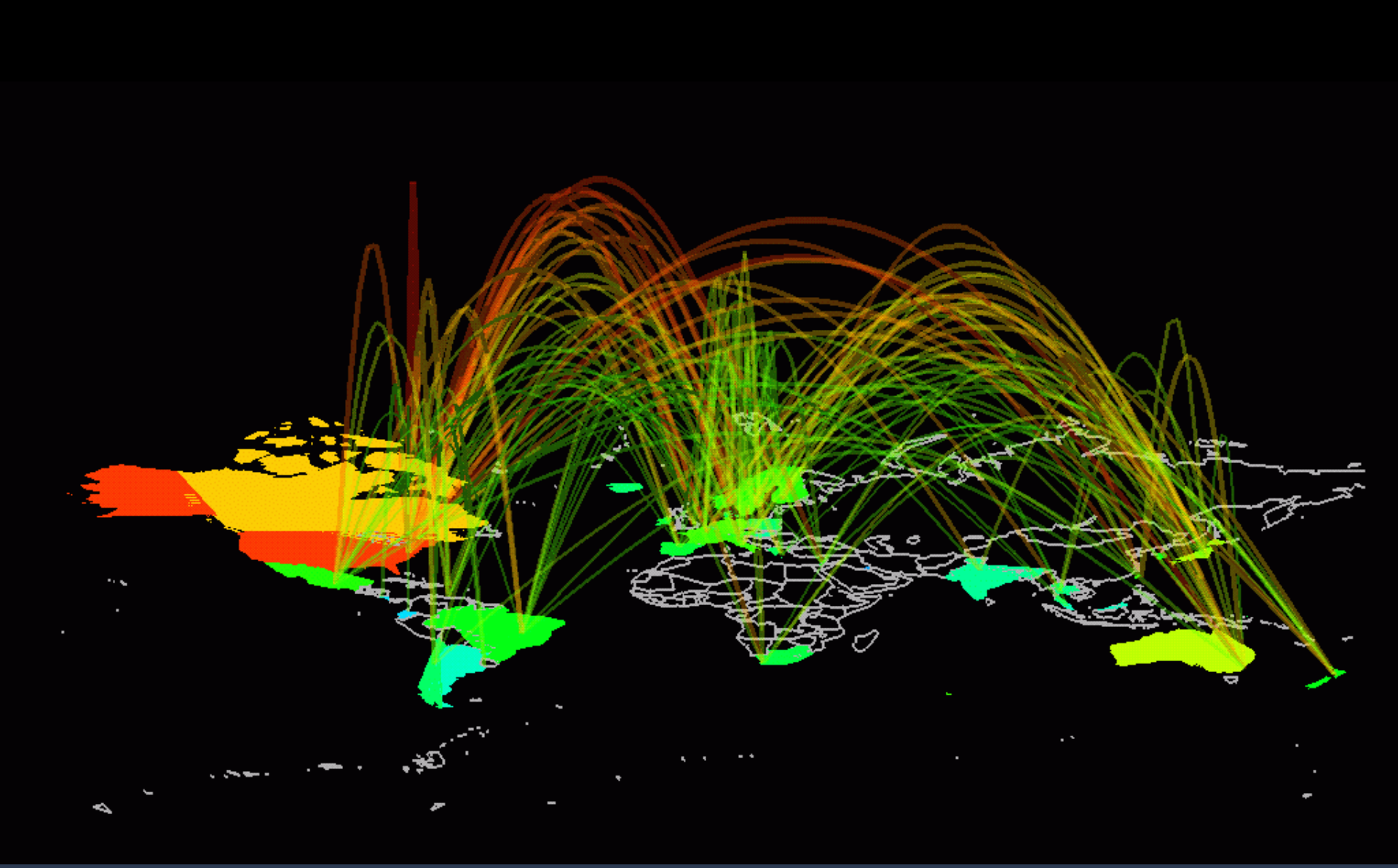
TODAY…


Alcatel·Lucent
Optical fibre submarine networks
SubOptic 2007
Installation vessels


EUROPE 10,318 Gbps
UNITED STATES & CANADA 4,979 Gbps
ASIA-PACIFIC 2,174 Gbps
LATIN AMERICA & CARIBBEAN 1,707 Gbps
AFRICA 71 Gbps
GLOBAL INTERNET MAP
TeleGeography
cisco
BY COLOR
BY SIZE
> 500 Gbps
250 Gbps
100 Gbps
50 Gbps
25 Gbps
10 Gbps
5 Gbps
2.5 Gbps
< 2.5 Gbps







Introduction

- How does one manage the tangle webs of cables and systems?

Network

- A system to manage the flow of data: initiate, terminate, switch, connect, route, allocation.. Service and maintenance
- Historically:
  - From telegraph (text), telephone (voice)
  - To today: data, IP traffic (internet)
  - Triple play, quad play, entertainment, new applications…

A recent history of US telecommunication

- 1970's: Long-haul carriers (IXCs), AT&T, MCI, GTE,…
  - Technologies: microwave link, electronic switches

- Early 1980's: IXCs (AT&T, MCI, GTE, LDDS, …), Cables vs. TV network
  - Technologies : optical fiber trunking, coax cables network, high-speed electronics

- Late 1980's – early 1990's: The war of all against all: IXCs (AT&T, MCI, GTE, WorldCom, …), RBOCs (Baby Bells), Wireless (cellular phones), Cables, DSS, TV network, Contents vs. Carriers,…
  - Technologies : more optical fiber trunking, coax, microwave bands, higher-speed electronics, digital signal processors, networking gears

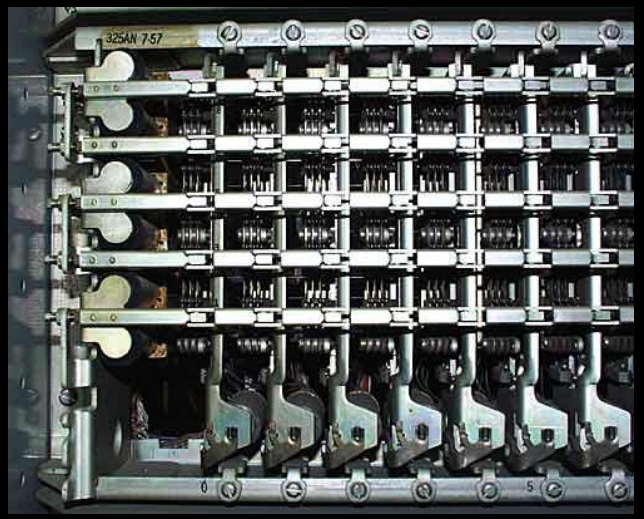
- Late 1990's: The war of all against all: IXCs, ILECs, CLECs, Wireless, Cables, DSS, TV network, ISP (new comer)
  - Technologies: optical fiber trunking, coax, modems, super ASICs, advanced electronics and optical networking gears.

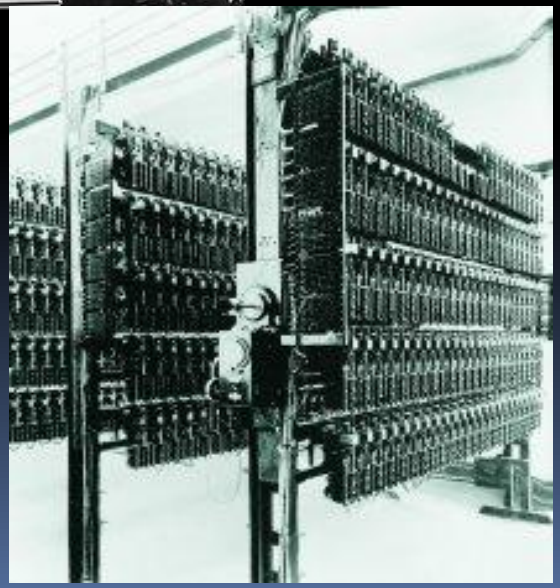
- Early 21st century: back to regional telephone service providers vs. cables
  - Technologies: Broadband, PON for the last (first) mile.

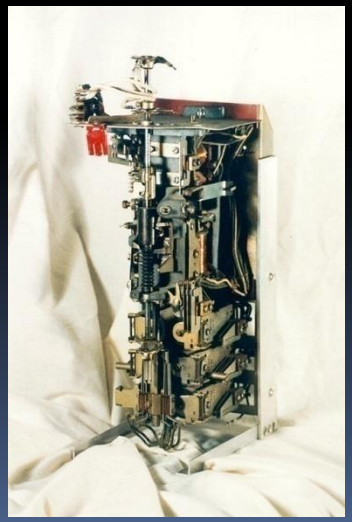
Key points in historical review

- Every generation of technology offers new capability, service, changing the supply/ demand landscape
- Network evolved in step with both technology AND business model
  - Applications of the Internet, global commerce…
  - Every generation has new (its own) “killer applications”
  - Example of latest/future: FTTH (access network): can it be for entertainment, health care?

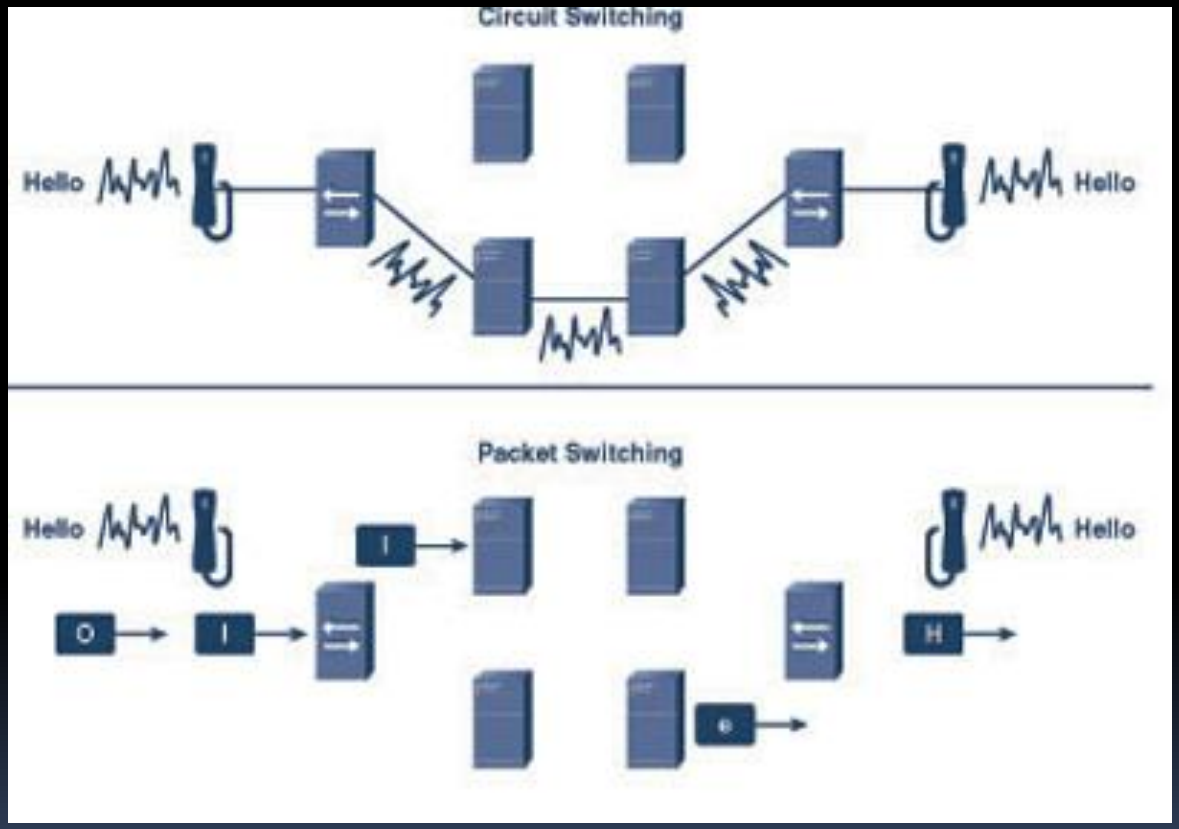
Physical







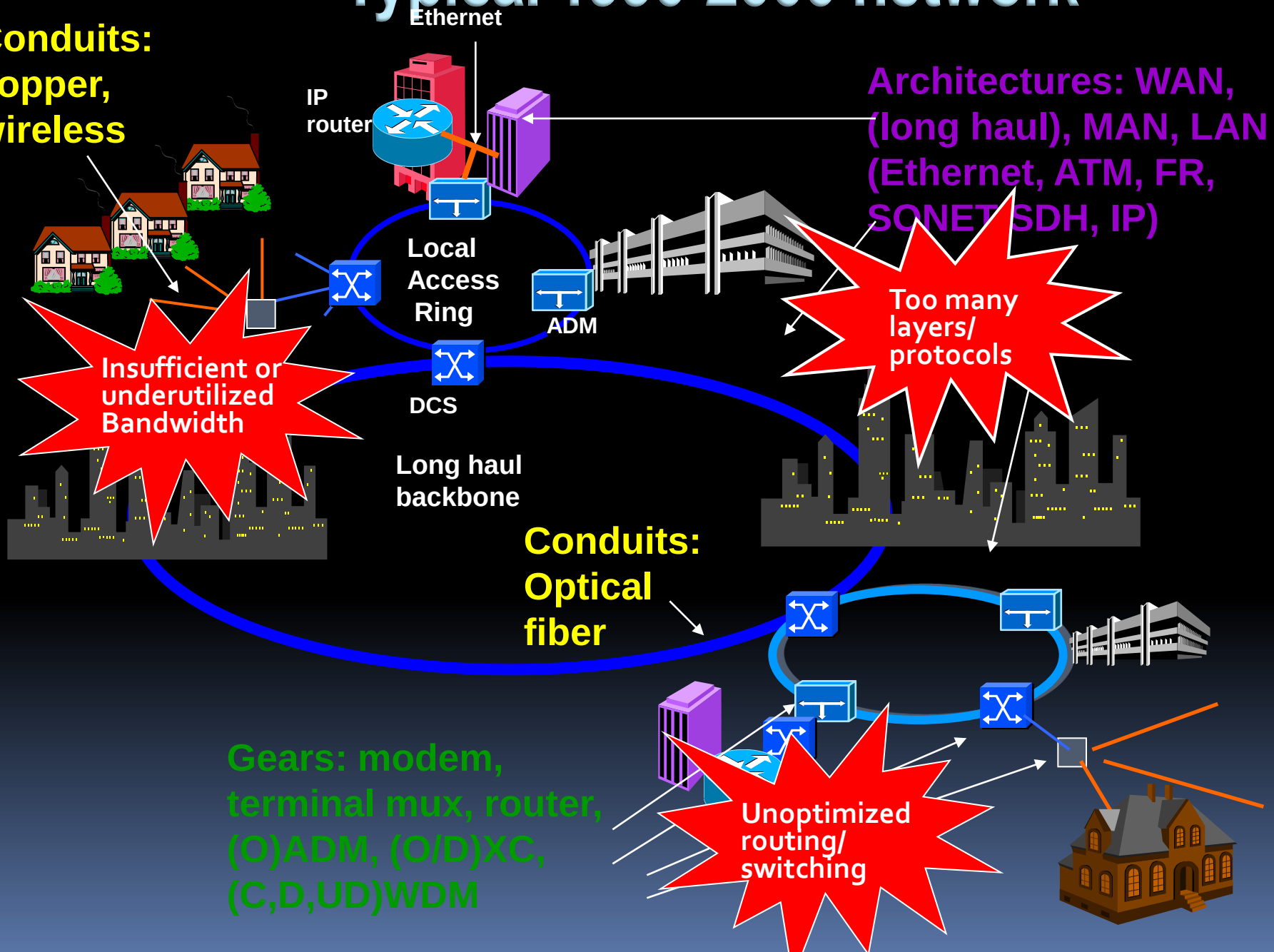
Logical



TDM voice

Voice over IP

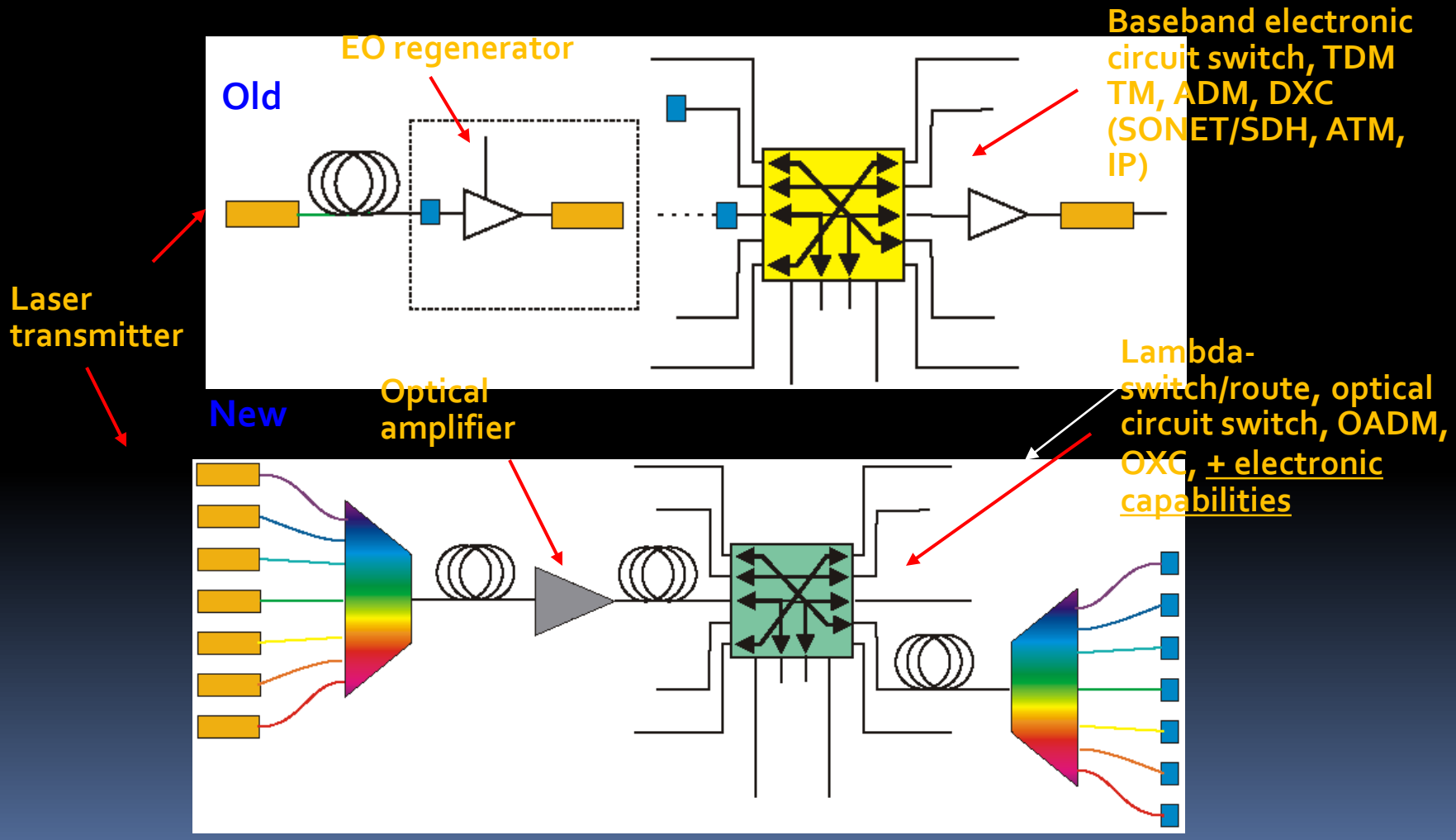
Typical 1990-2000 network



Technology issues late 1990's

- Network architecture:
  - Long haul (including global): Wide area network (WAN)
  - Metropolitan area network (MAN)
  - Local area network (LAN)
- LAN, MAN, WAN independently evolved: Ethernet, FDDI, SONET/SDH, ATM, IP (Internet): heavy overhead layers; complex OAM&P (operations, administration, maintenance & provisioning) to get compatibility
- Network equipment: unoptimized, electronic speed limit
- Conduit: Old copper network vs. optical fiber; capacity x reach
- Network usage: Voice traffic vs. data traffic; circuit switch vs. packet switch; use phone line to hook up to the Internet (data on voice circuit) and use Internet to make phone call (voice over IP)

Remember this:? Old vs. new optical network?

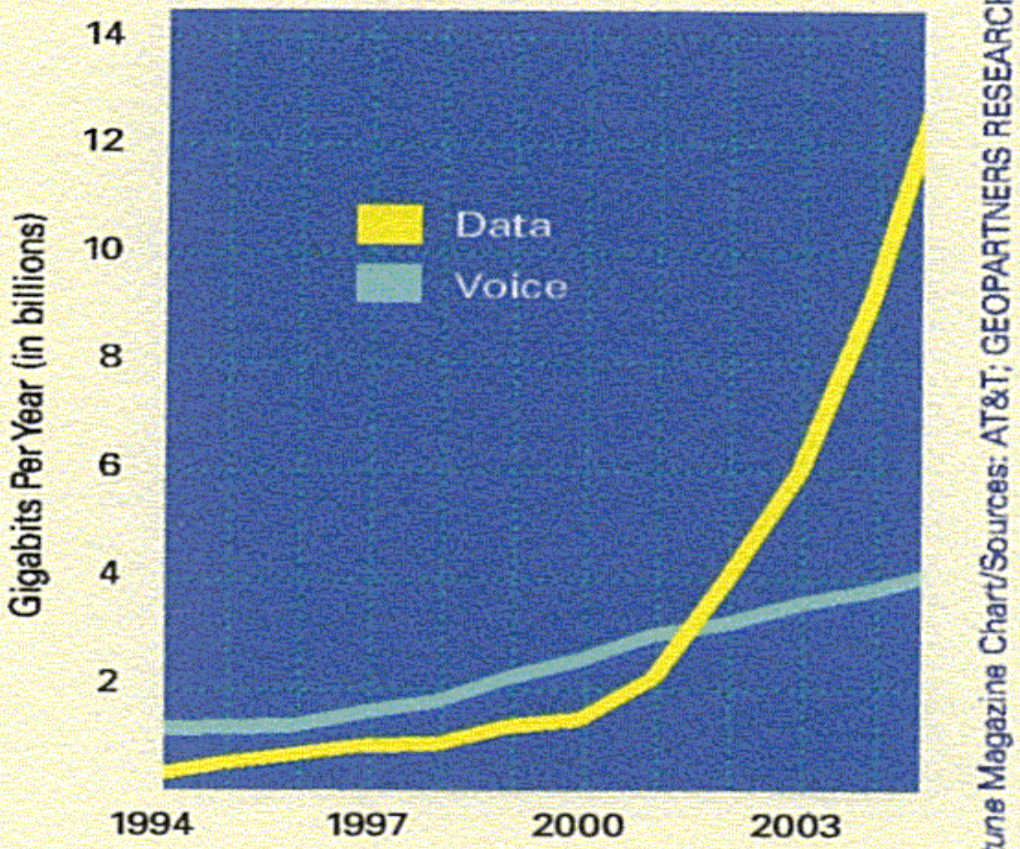


Optical Network

- Early optical communication: point-to-point fiber trunking: big pipe, but no new network architecture
- WDM optical network: new network architecture
- Business models also drive merging architecture:
  - End-to-end efficiency and quality of service
  - New growth, e. g. FTTH

Optical network continue to evolve and drive the future

PROJECTED NEED FOR BANDWIDTH

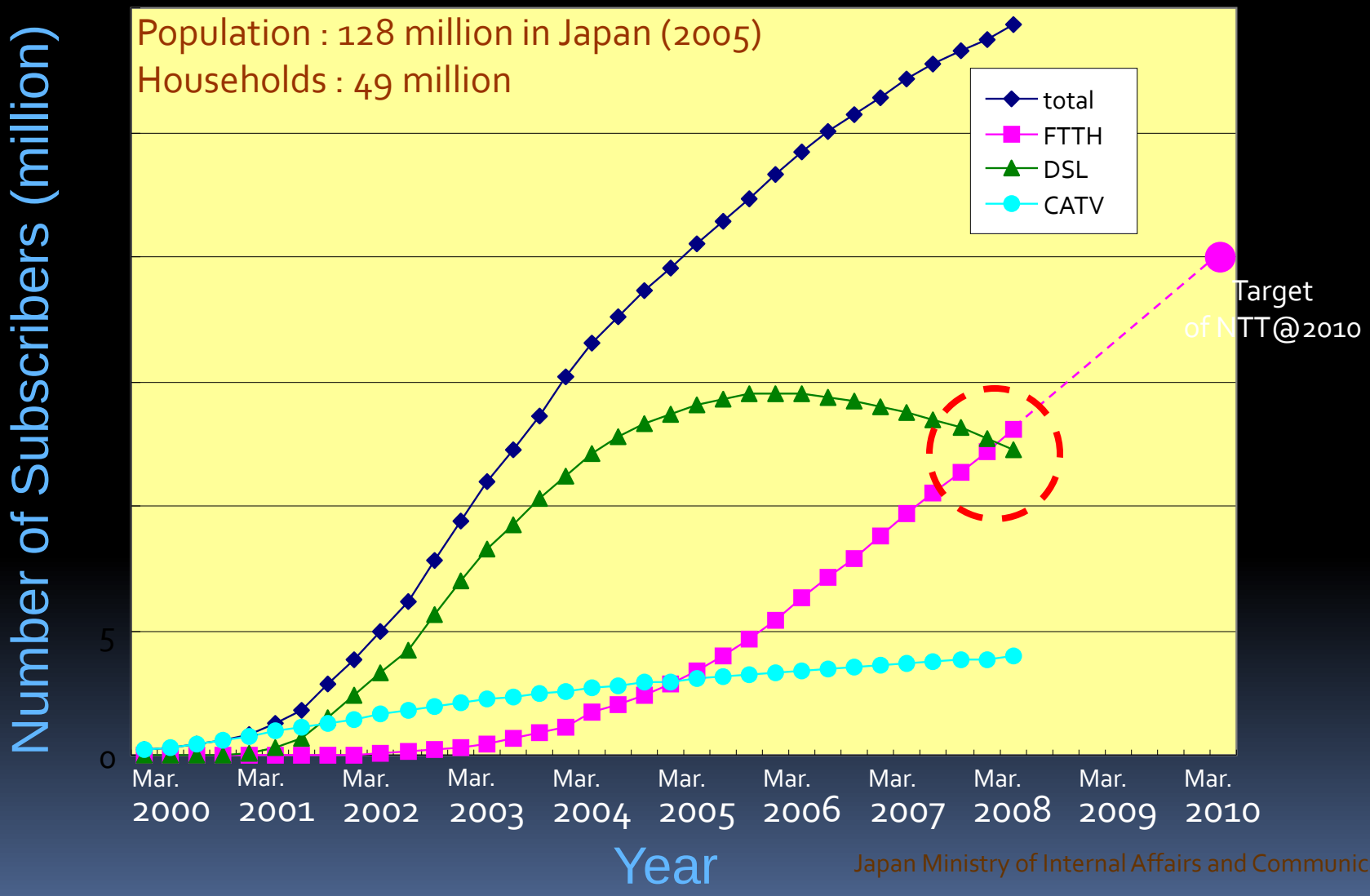


Fortune Magazine Chart/Sources: AT&T; GEOPARTNERS RESEARCH

By 2003, data services are projected to outpace voice significantly on U.S. long distance networks.

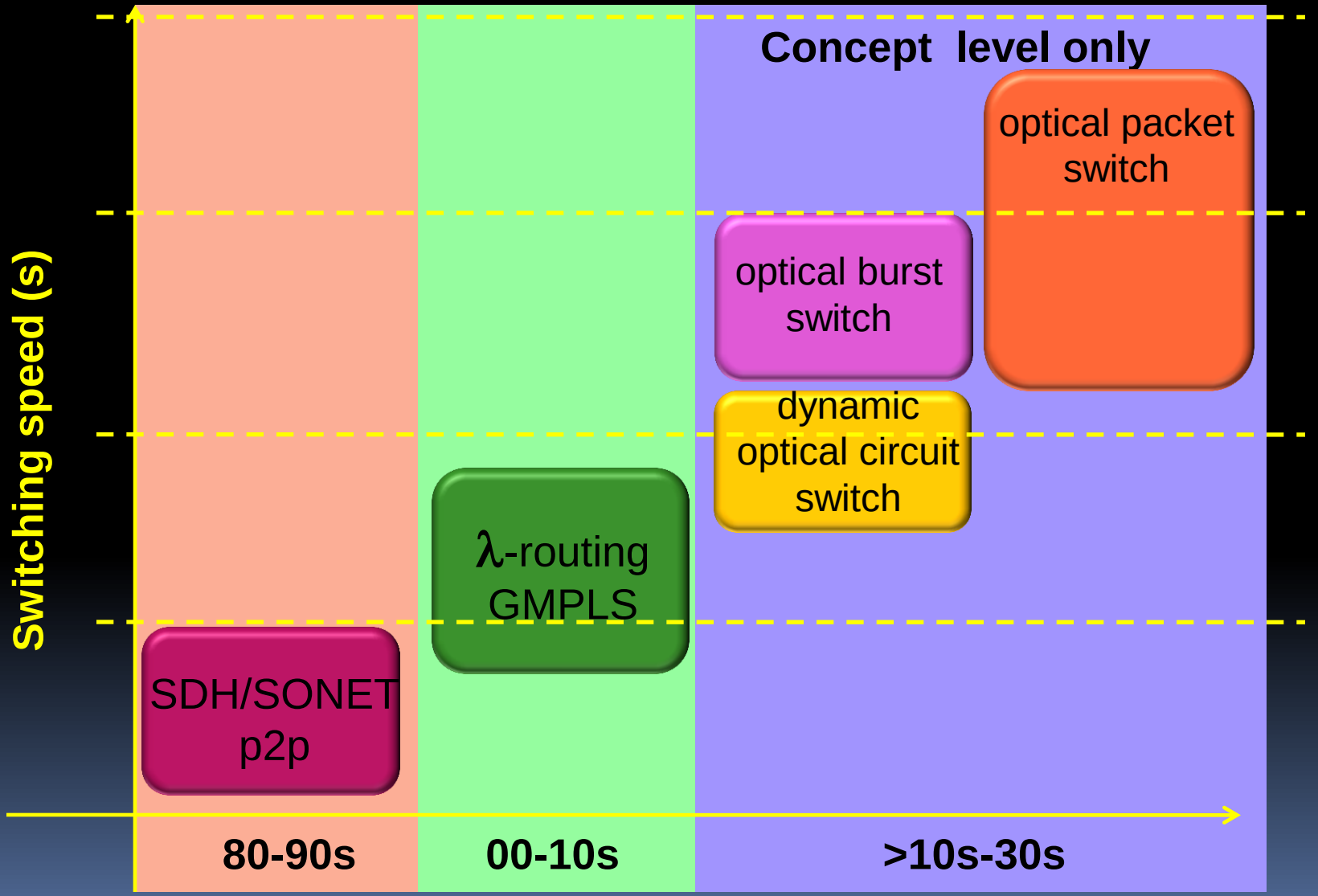
This does not include private networks!

Broadband Services in Japan



Japan Ministry of Internal Affairs and Communications

Network evolution (switching speed)



Roadmap of FUJITSU Photonics Technology

Flexibility in wavelength

> 10Tbit/s

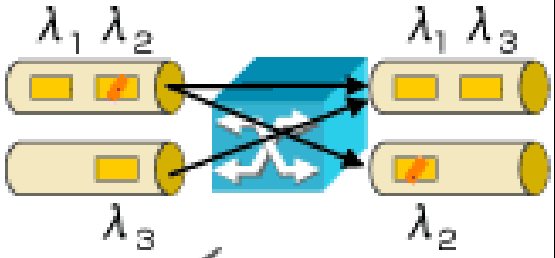
1 - 10Tbit/s

- GMPLS signaling & protection
- Wavelength selective switch
- Fullband tunable LD/ transceiver module
- Variable dispersion compensation
- PON(~ Gb/s)

・Optical ADM
・Ring

- Multi-layer convergence of network equipment
- 40G, Coherent technology
- Quantum-dot-based LD/SOA
- Optical wiring/ interconnection

・Optical crossconnect(OXC)
・Mesh



- Optical packet routing
- Fast tunable LD
- All-optical 2R/3R, Wavelength conversion
- Next-generation PON (10G/WDM)
- Quantum opt. comm.

・Optical packet switch
・Optical processing of routing

・Expansion of metro WDM
・Spread of FTTX

・Widespread of FTTX
・Construction of IP-based network infrastructure

・Ubiquitous communication with optical and wireless convergence

~2006 | 2007~2010 | 2011~

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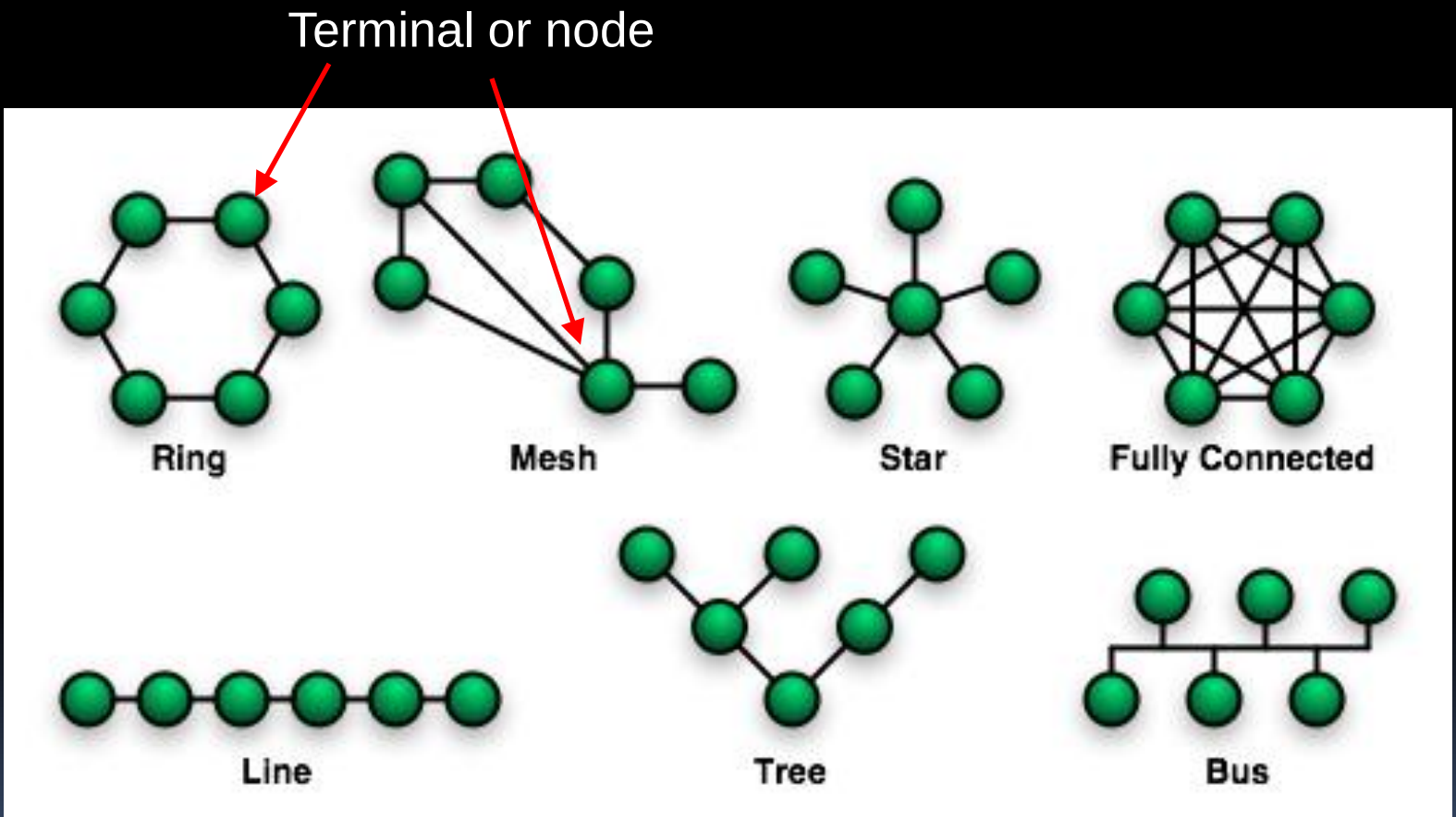
BASIC NETWORK CONCEPTS

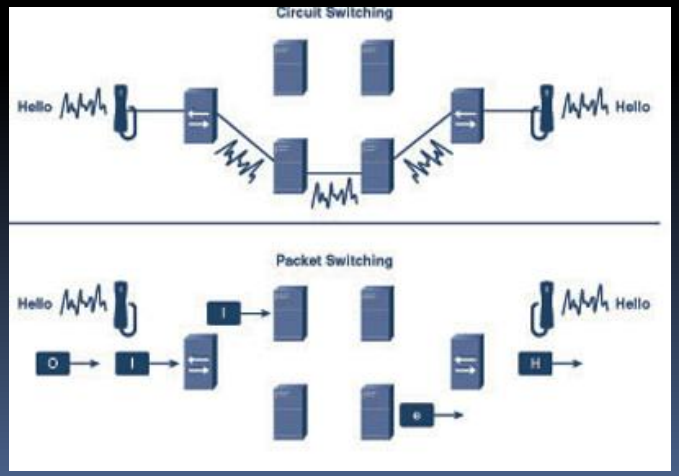
Basic network concepts: topology



Network concepts: connection and switch

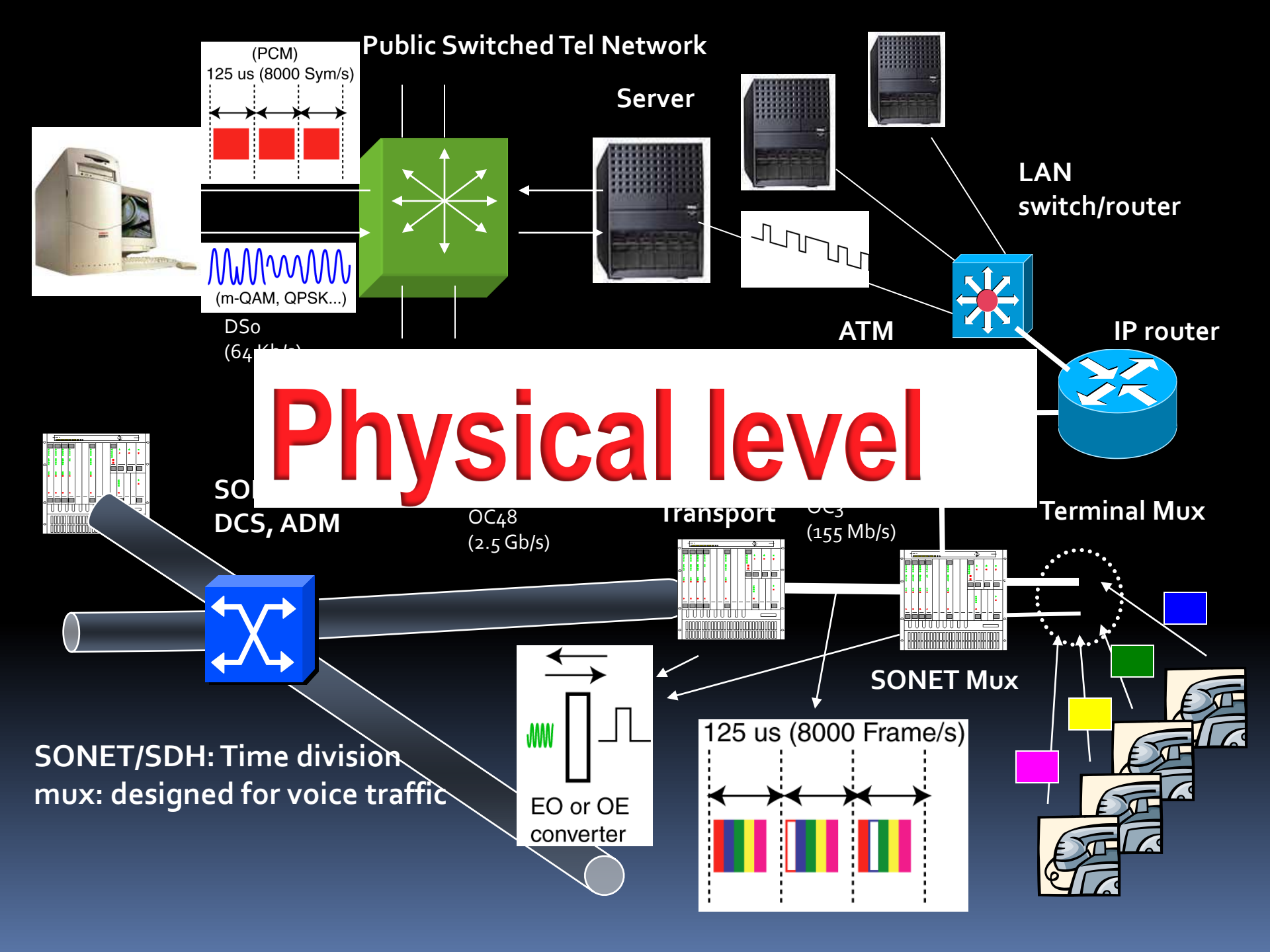
Connection vs. connectionless:

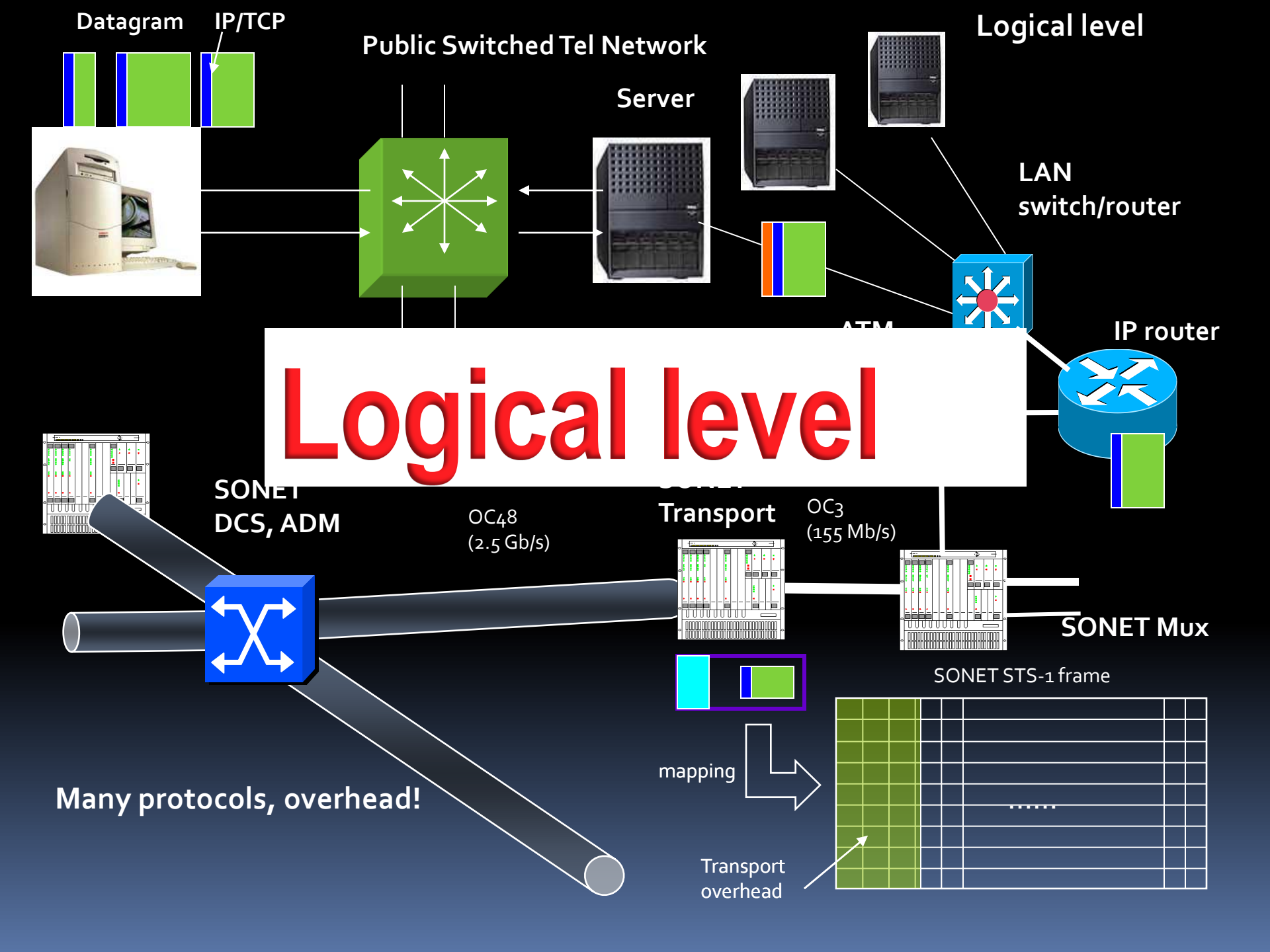
- Connection-oriented: ensure a connection path is established (handshake) before transmitting data: bi-directional communication: example X.25 (POTS: plain old telephone service)
- Connectionless: just launch the data packet; example: IP

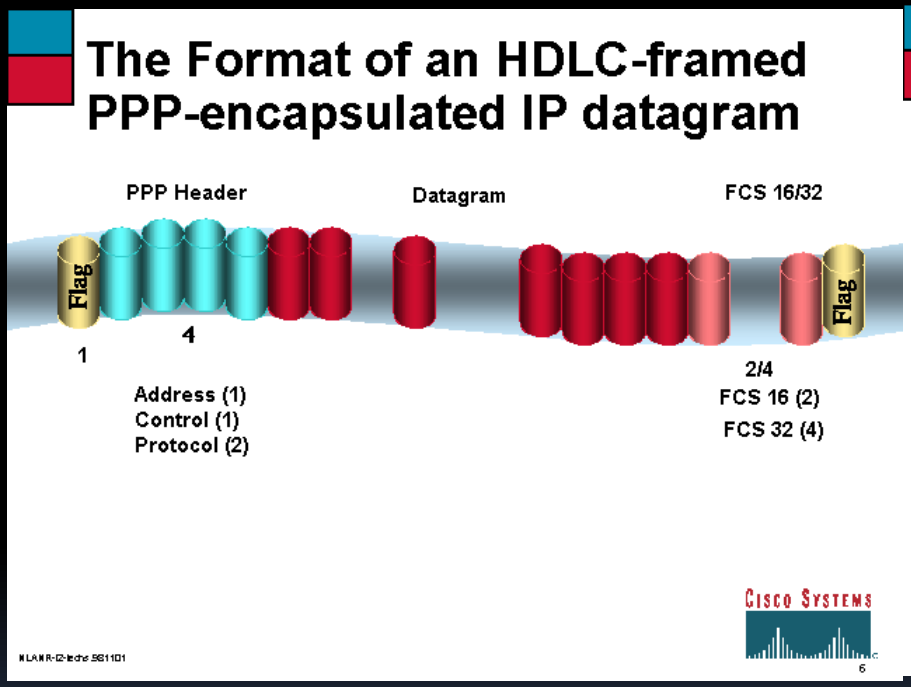


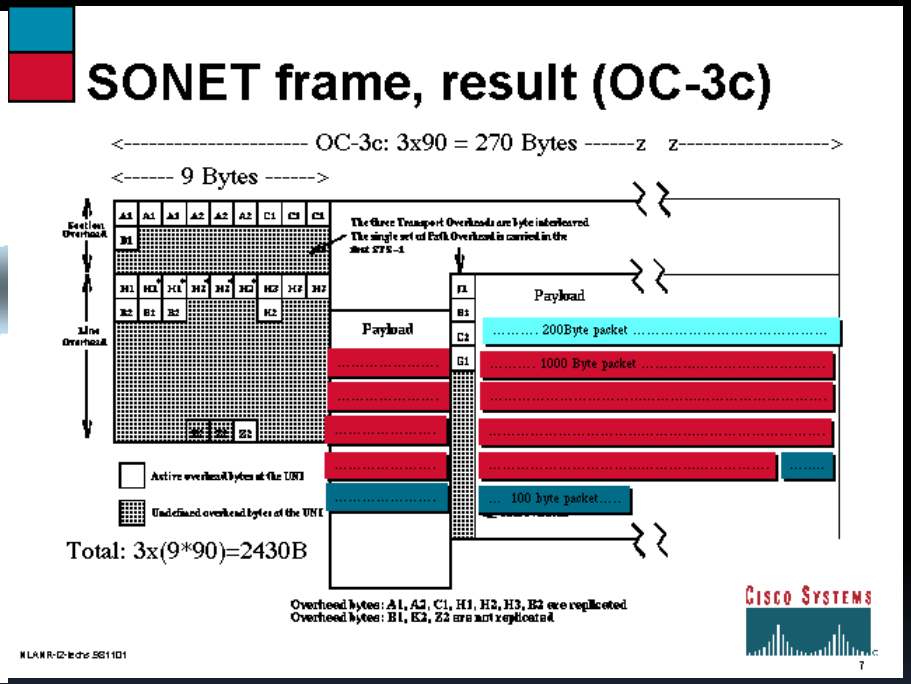
Switch:

- Circuit switch
- Packet switch – cell switch


(PCM)
125 us (8000 Sym/s)
Public Switched Tel Network
Server
LAN
switch/router
(m-QAM, QPSK...)
DS0
ATM
IP router
Physical level
DCS, ADM
OC48
(2.5 Gb/s)
Transport
(155 Mb/s)
Terminal Mux
SONET Mux
EO or OE
converter
125 us (8000 Frame/s)
SONET/SDH: Time division
mux: designed for voice traffic


Datagram
IP/TCP
Public Switched Tel Network
Server
Logical level
LAN
switch/router
IP router
Logical level
SONET
DCS, ADM
OC48
(2.5 Gb/s)
Transport
OC3
(155 Mb/s)
SONET Mux
SONET STS-1 frame
mapping
Transport
overhead
Many protocols, overhead!

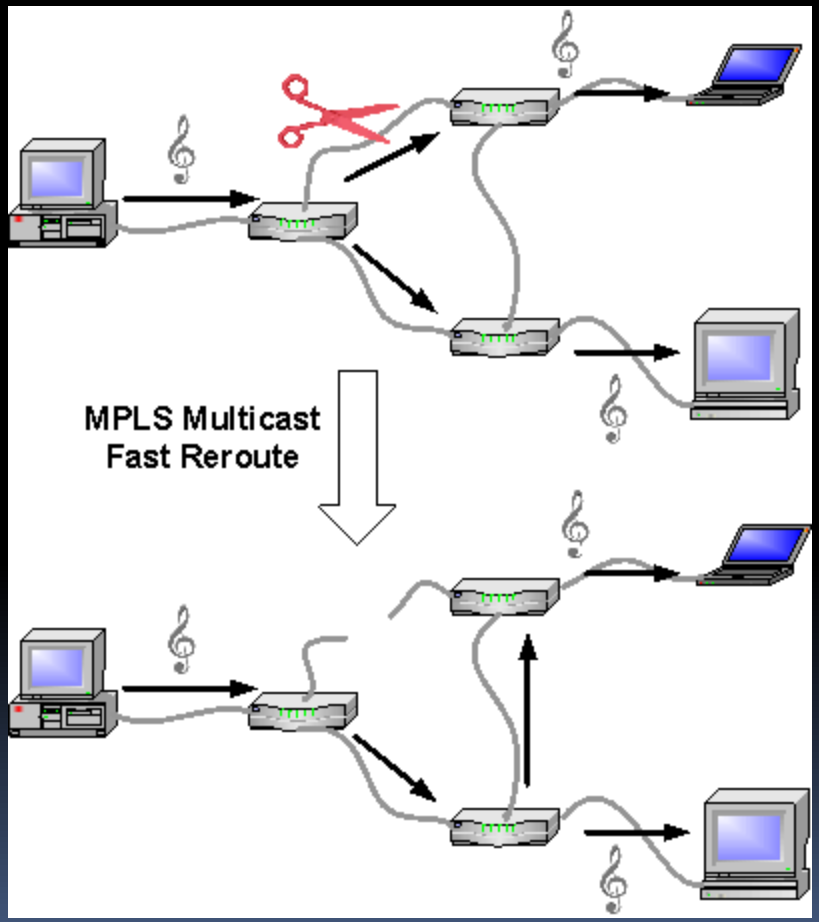




Source: Cisco System

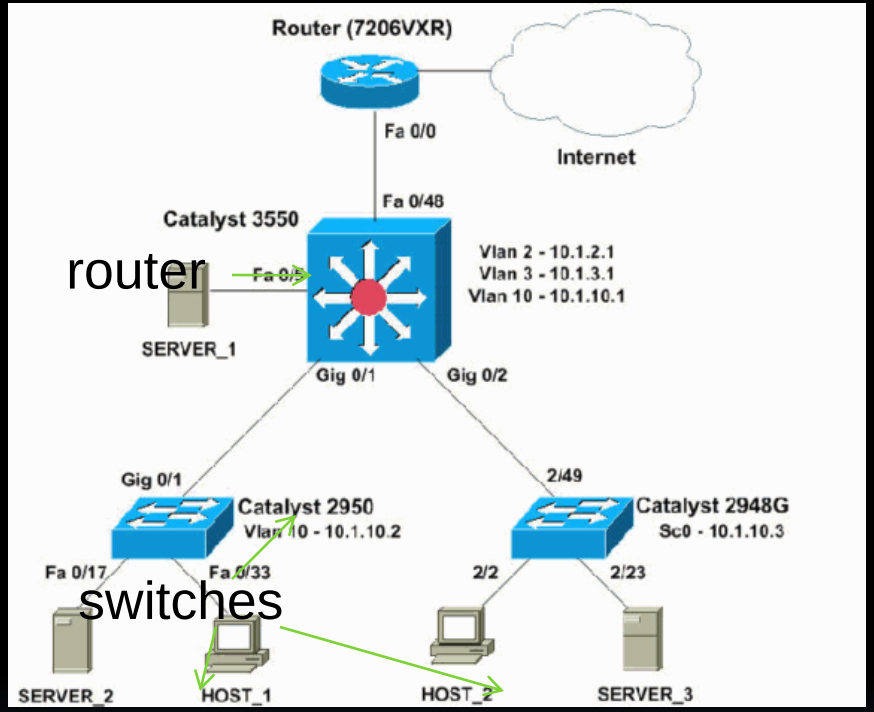
Network concepts: physical circuit vs. virtual circuit

- Physical circuit: a connection path established with physical transport
- Virtual circuit: a connection established only at the logical level: that the packet is known to be switched (doesn't matter which actual paths) and delivered to destination



Network concepts: routing

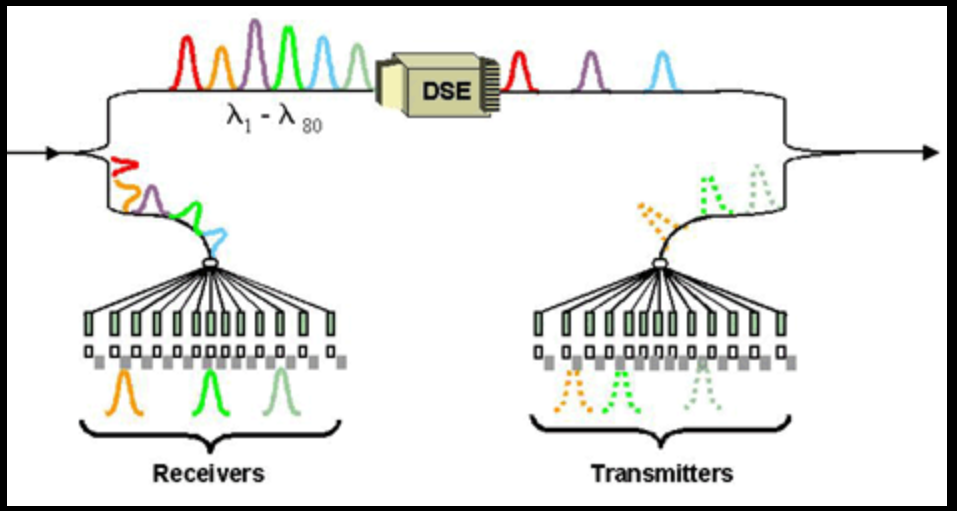
- Routing: A node determines how to send the packet:
  - Neighbor and topology discovery
  - Path selection
  - Routing protocols and algorithms
  - Forwarding table



- Other key concepts on network characteristics
  - Granularity: how fine is the level of management in a network
  - Modularity: how a network can add a unit or remove a unit (plug in or unplug)
  - Scalability: whether the architecture can be scaled up and still functioning the same way

Specific to Optical Network: λ-based functions

- WDM:
  - Trunking: transport many wavelength channels
  - Broadcast and select (“primitive”)
  - λ-routing



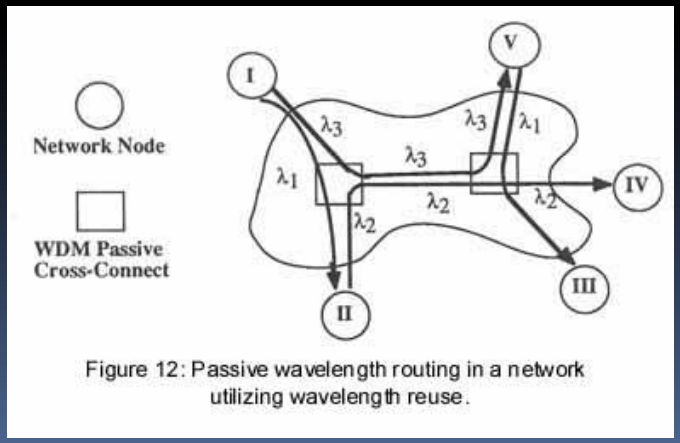
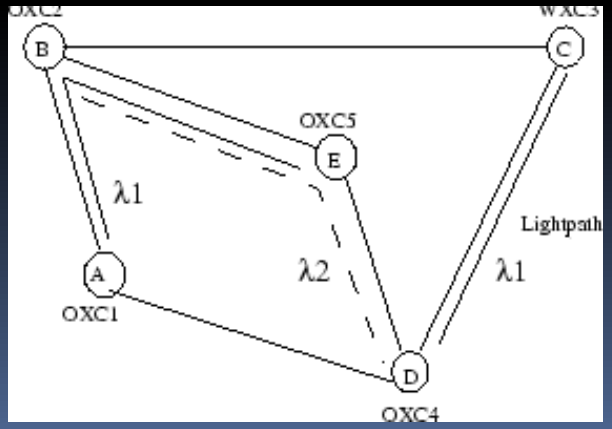
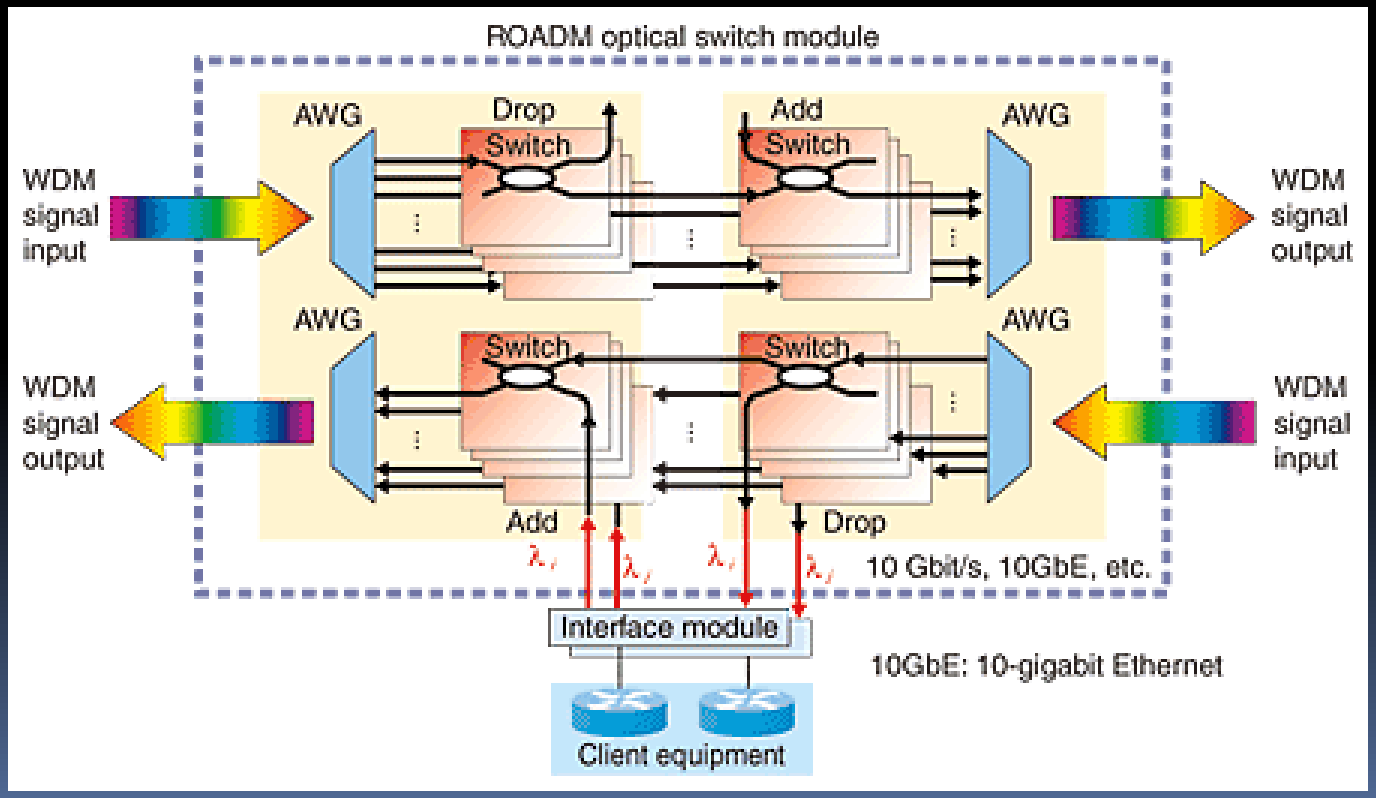


Figure 12: Passive wavelength routing in a network utilizing wavelength reuse.

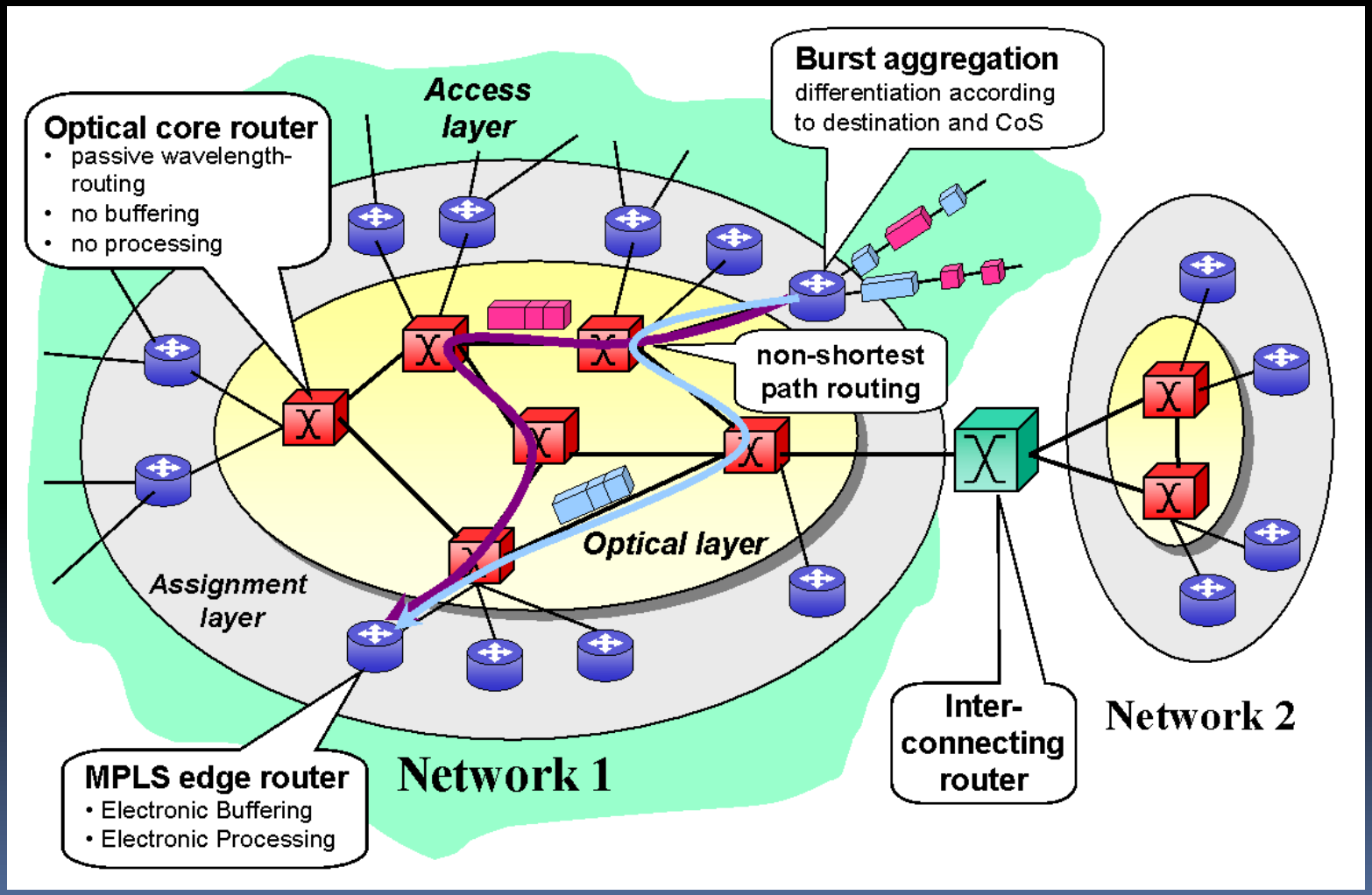


Specific to Optical Network: λ-based functions (continued)

- Optical switching, A/D routing, and cross-connect



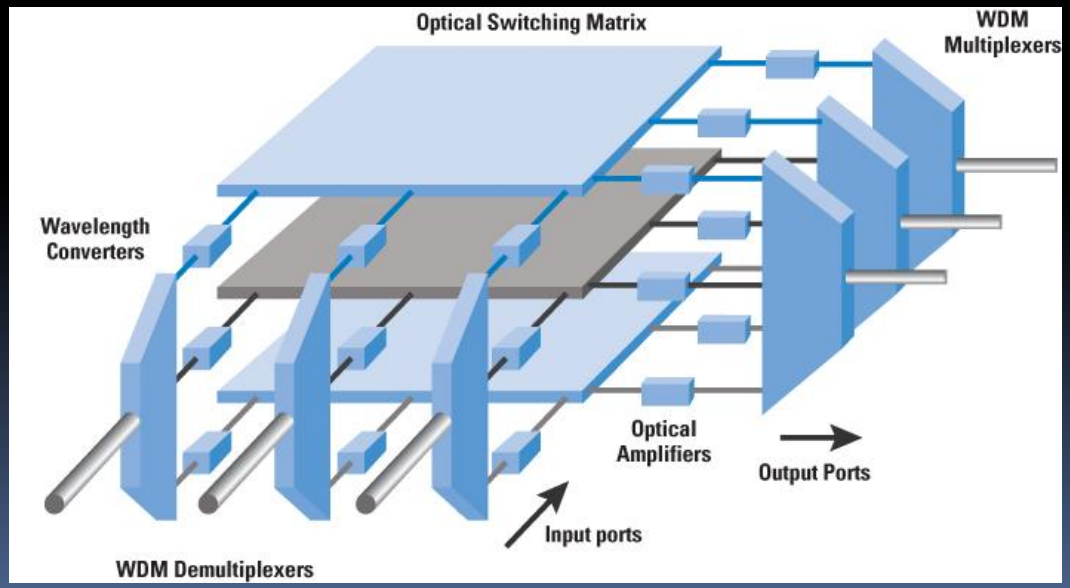
Advanced λ-routing concept



Specific to Optical Network: λ-based functions (continued)

Optical cross-connect: different levels and granularity:

- Physical optical paths (all wavelengths)
- A set of selected wavelengths: wavebands or finer (logical)
- Opaque: if EOE conversion is used. Transparent if all optical, and no blocking of any channels



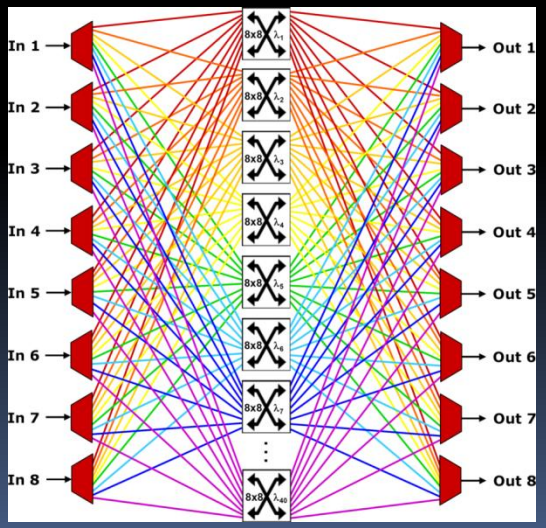
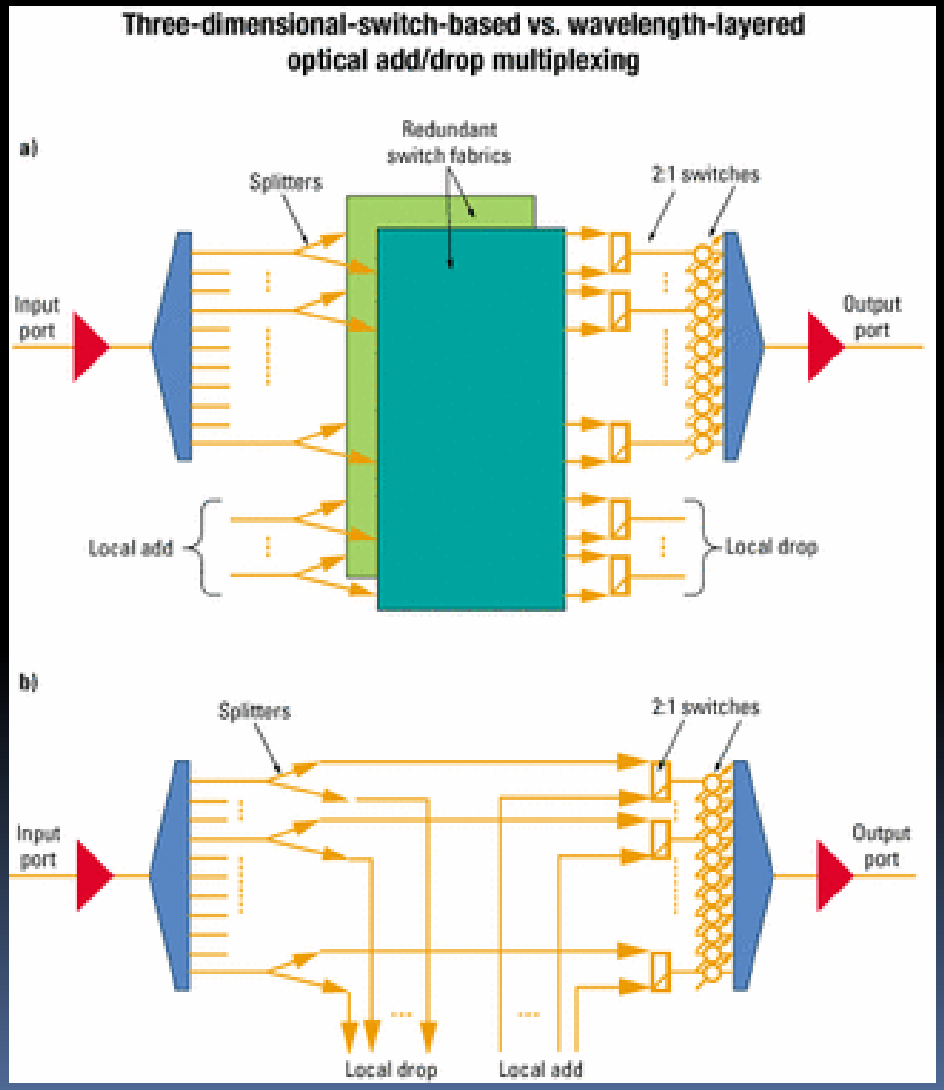
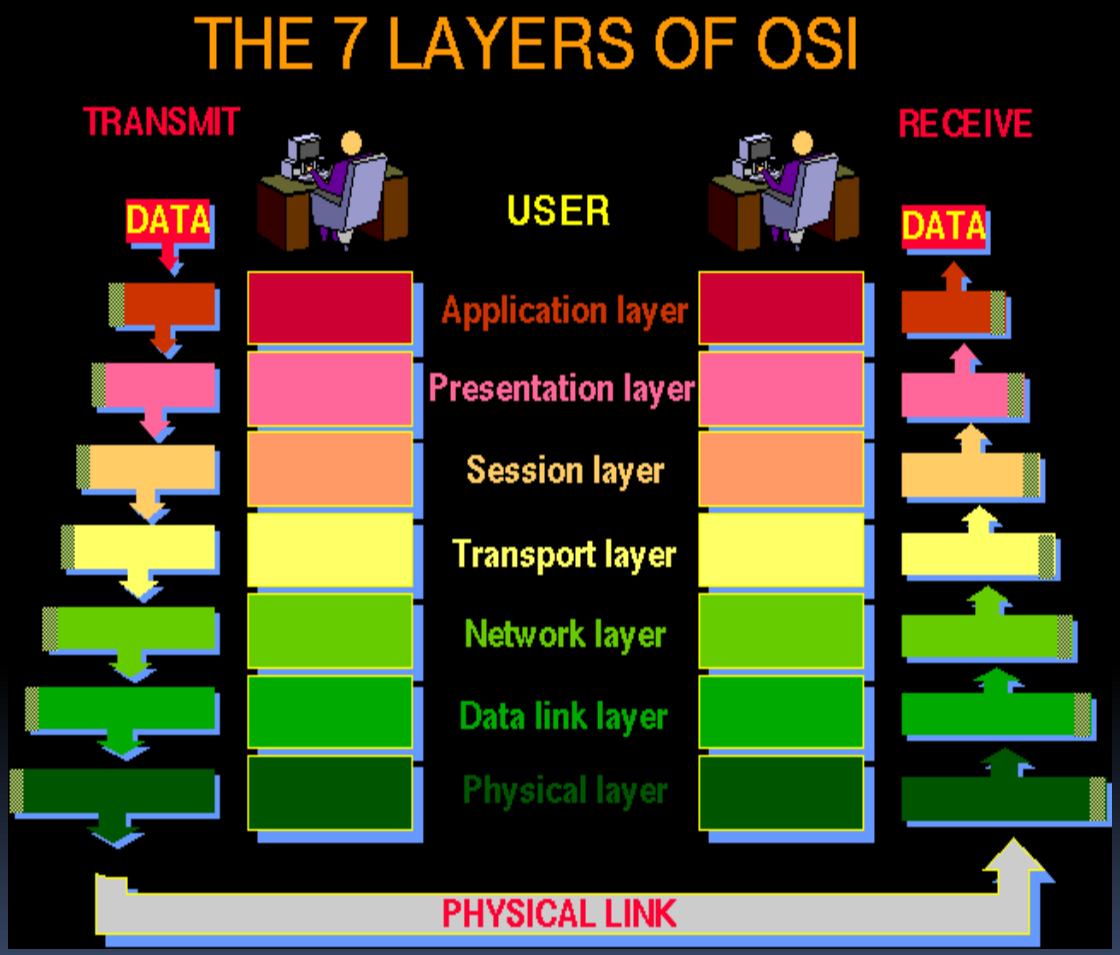
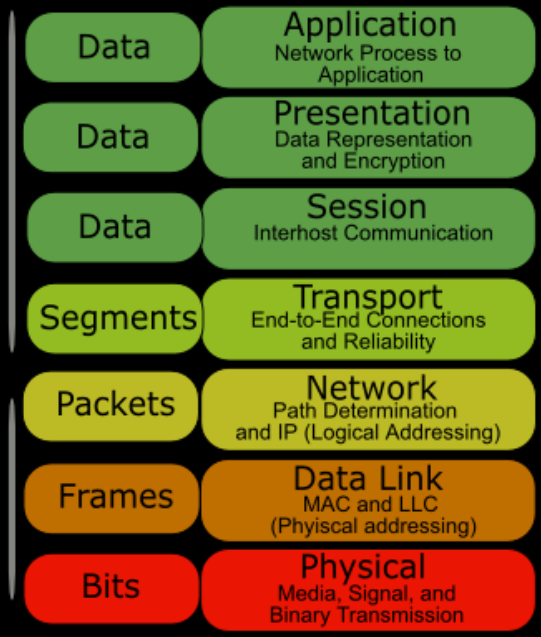


Illustration of an optical node concept



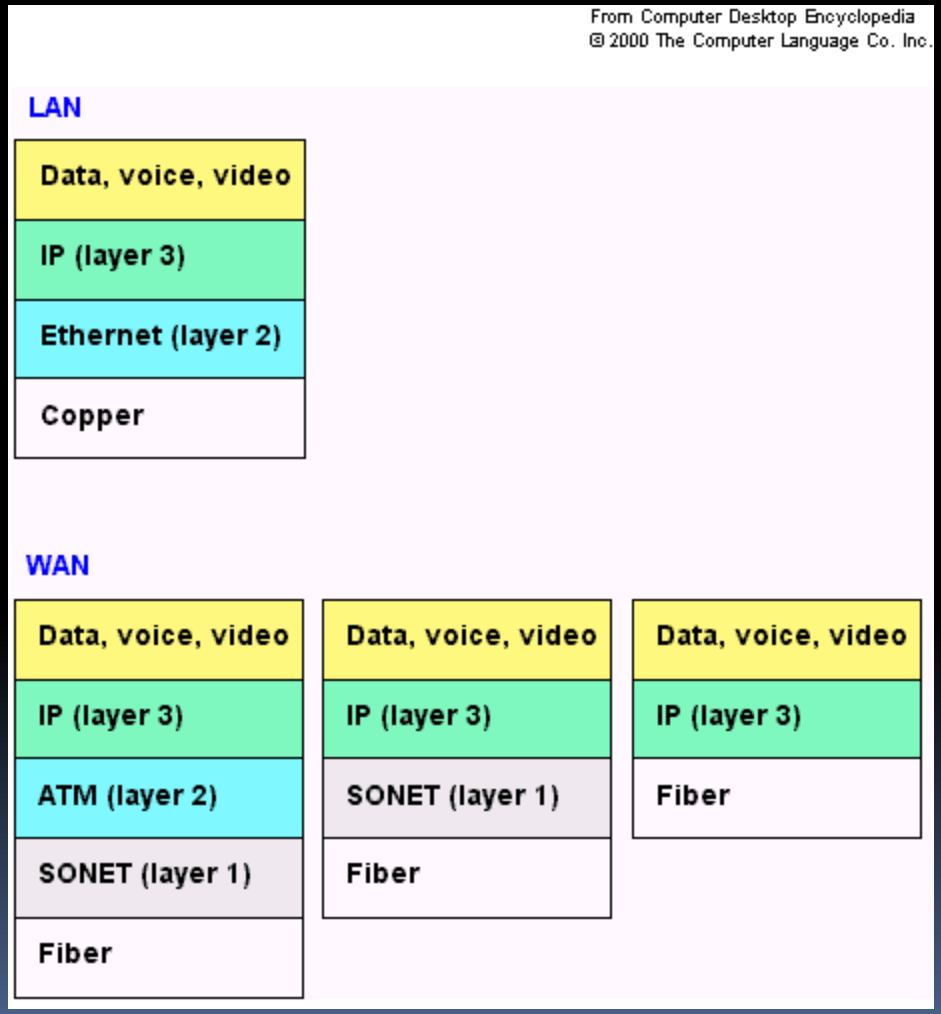
The 7-layer OSI Network Concept





Open System Interconnection: a framework for managing protocols in different network layers. Control is passed from one layer to the next.

Example of layers



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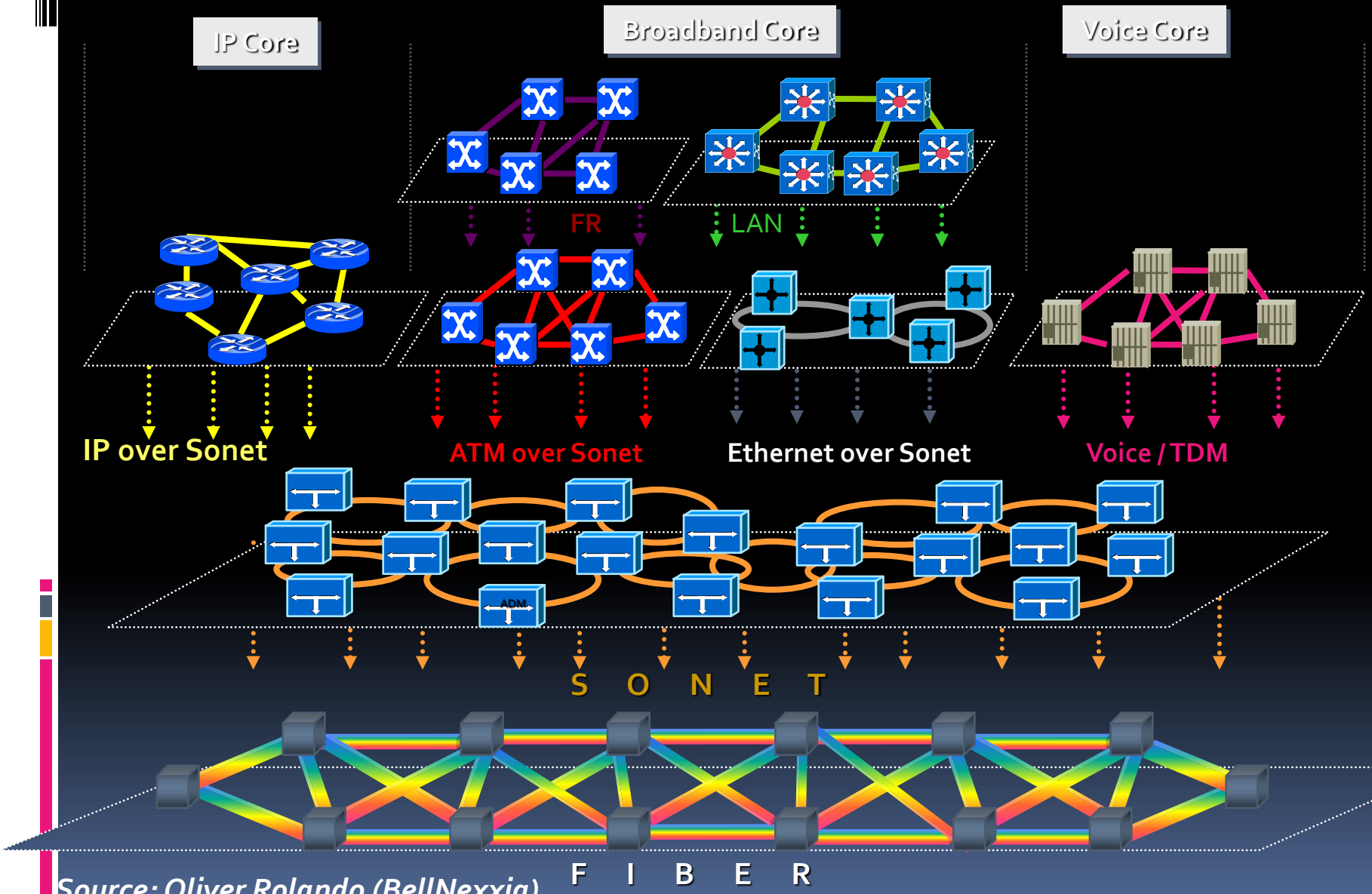
TODAY OPTICAL NETWORK

Today Network Protocols

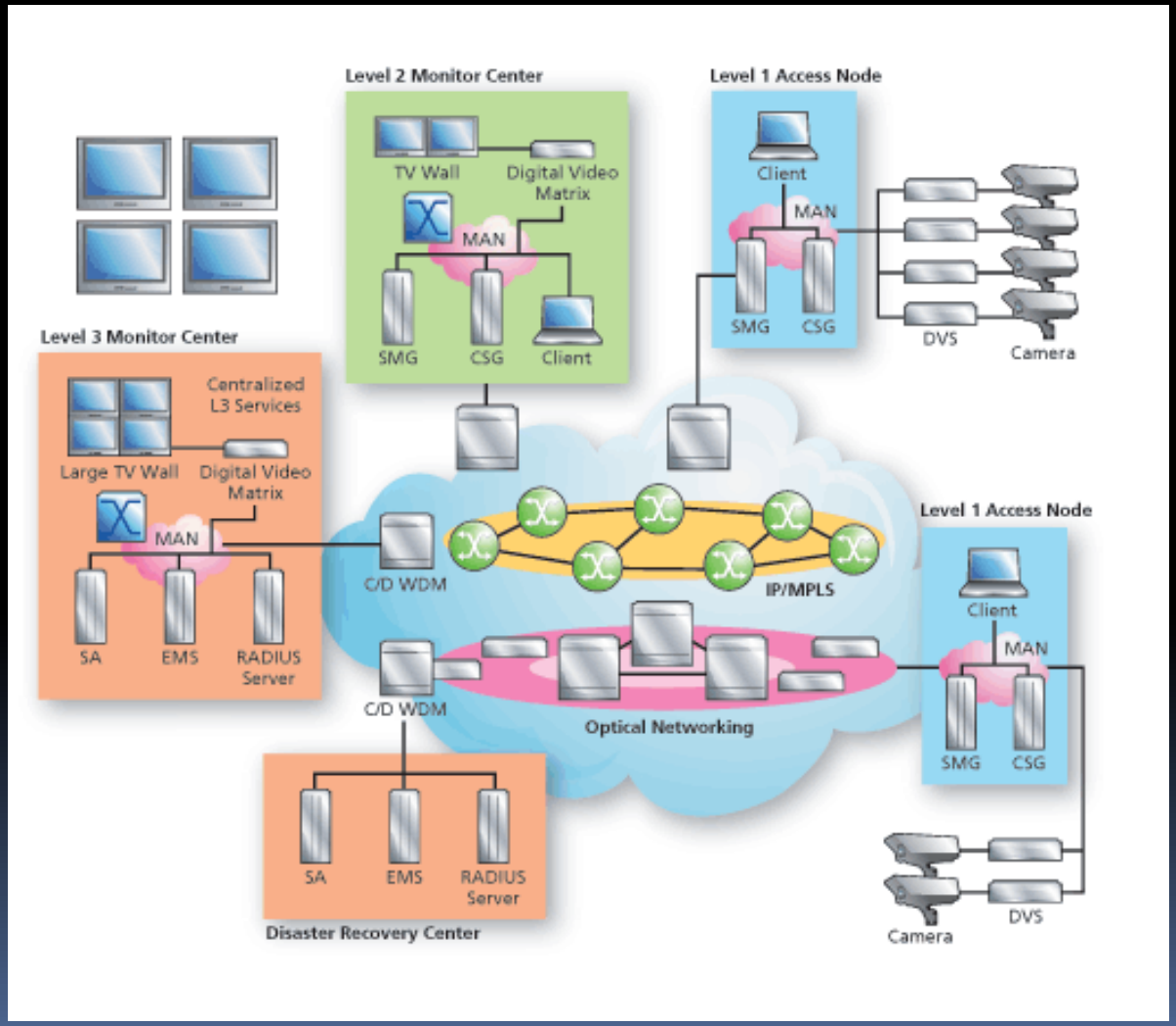


Source: Oliver Rolando (BellNexxia)

Technology issues late 1990's

- Network architecture:
  - Long haul (including global): Wide area network (WAN)
  - Metropolitan area network (MAN)
  - Local area network (LAN)
- LAN, MAN, WAN independently evolved: Ethernet, FDDI, SONET/SDH, ATM, IP (Internet): heavy overhead layers; complex OAM&P (operations, administration, maintenance & provisioning) to get compatibility
- Network equipment: unoptimized, electronic speed limit
- Conduit: Old copper network vs. optical fiber; capacity x reach
- Network usage: Voice traffic vs. data traffic; circuit switch vs. packet switch; use phone line to hook up to the Internet (data on voice circuit) and use Internet to make phone call (voice over IP)

Significant progress has been made in the last decade



OXC: core

ROADM: metro

Optical Network 1990-2000's

- Synchronous Optical Network: (SONET/ SDH) standard adopted ~1988
  - Requires synchronization of the network (all on the same clock): accurate, absolute timing (stratum clock) – time-based switching
- Asynchronous Transfer Mode (ATM): fixed length packet switching- above SONET
- Optical Transport Network (OTN): seek to combine SONET/SDH with DWDM advantages
- Internet Protocol/DWDM (IP and IP/DWDM): IP over ATM/SONET

Synchronous Optical Network (SONET)

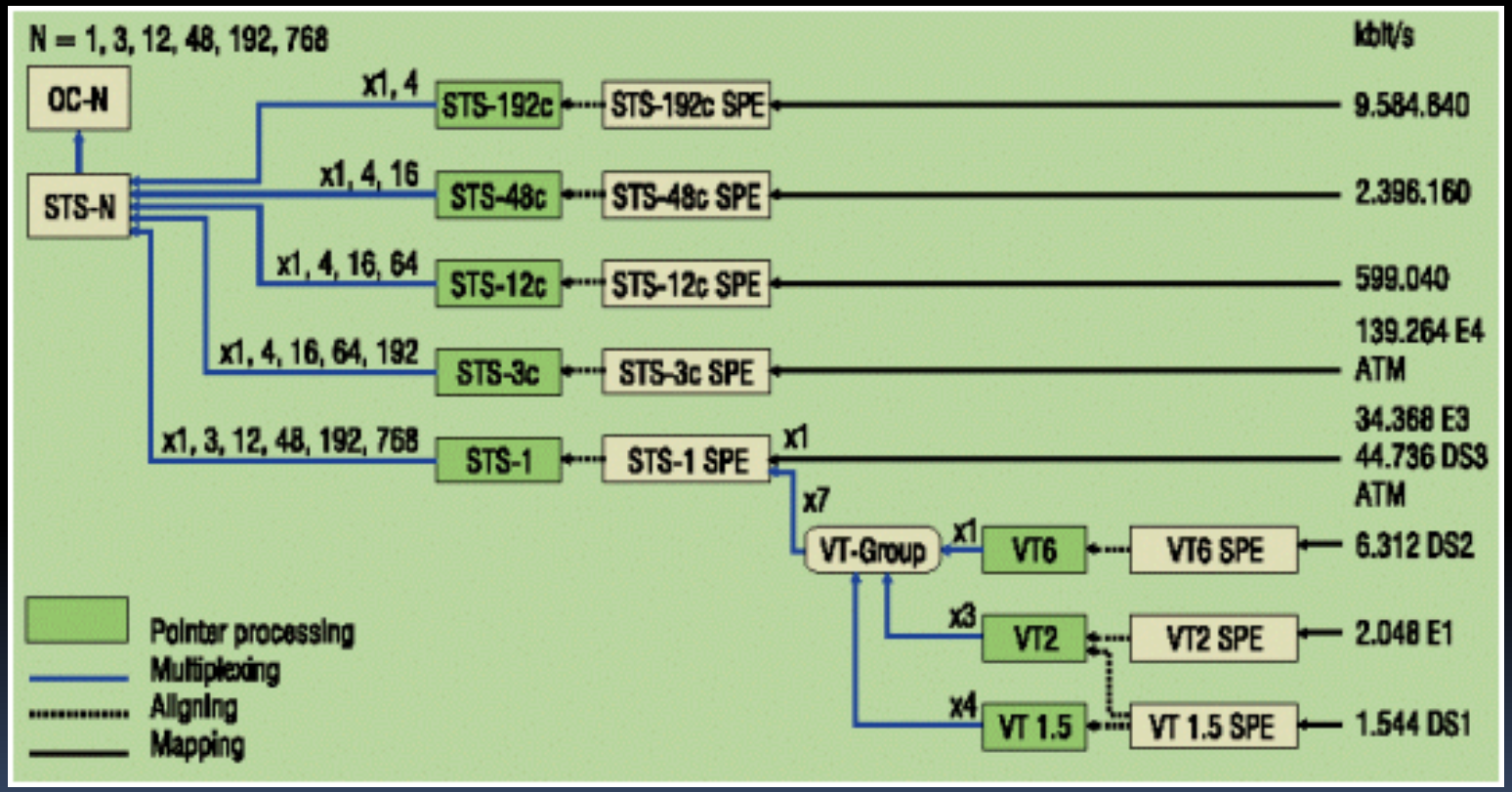
- A standard (from telecom companies) for the 1990's network (before DWDM)
- Important features:
  - Speeds: OC-n
  - Synchronization
  - Frame structure STS
  - Layers (architecture)
  - Overhead
  - SONET rings

SONET/SDH Speed

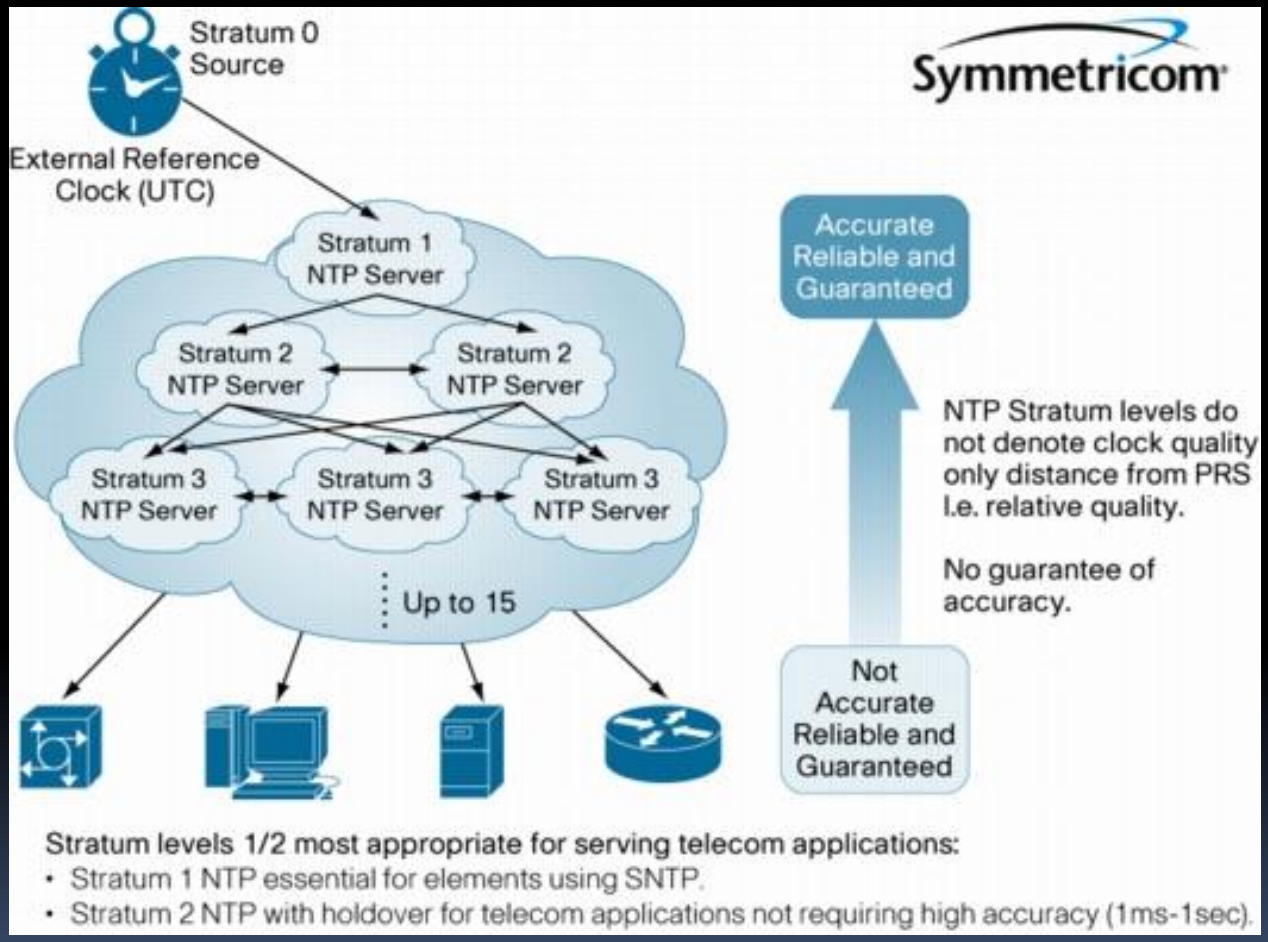
Optical Level	Electrical Level	Rate (Mbit/s) Line	Payload Rate (Mbit/s)	Overhead Rate (Mbit/s)	SDH Equivalent
OC-1	STS-1	51.840	50.112	1.728	STM-0
OC-3	STS-3	155.520	150.336	5.184	STM-1
OC-12	STS-12	622.080	601.344	20.736	STM-4
OC-48	STS-48	2488.320	2405.376	82.944	STM-16
OC-192	STS-192	9953.280	9621.504	331.776	STM-64
OC-768	STS-768	39813.120	38486.016	1327.104	STM-256

Note: current research speed is >= 100 Gb/s

Line rate hierarchy

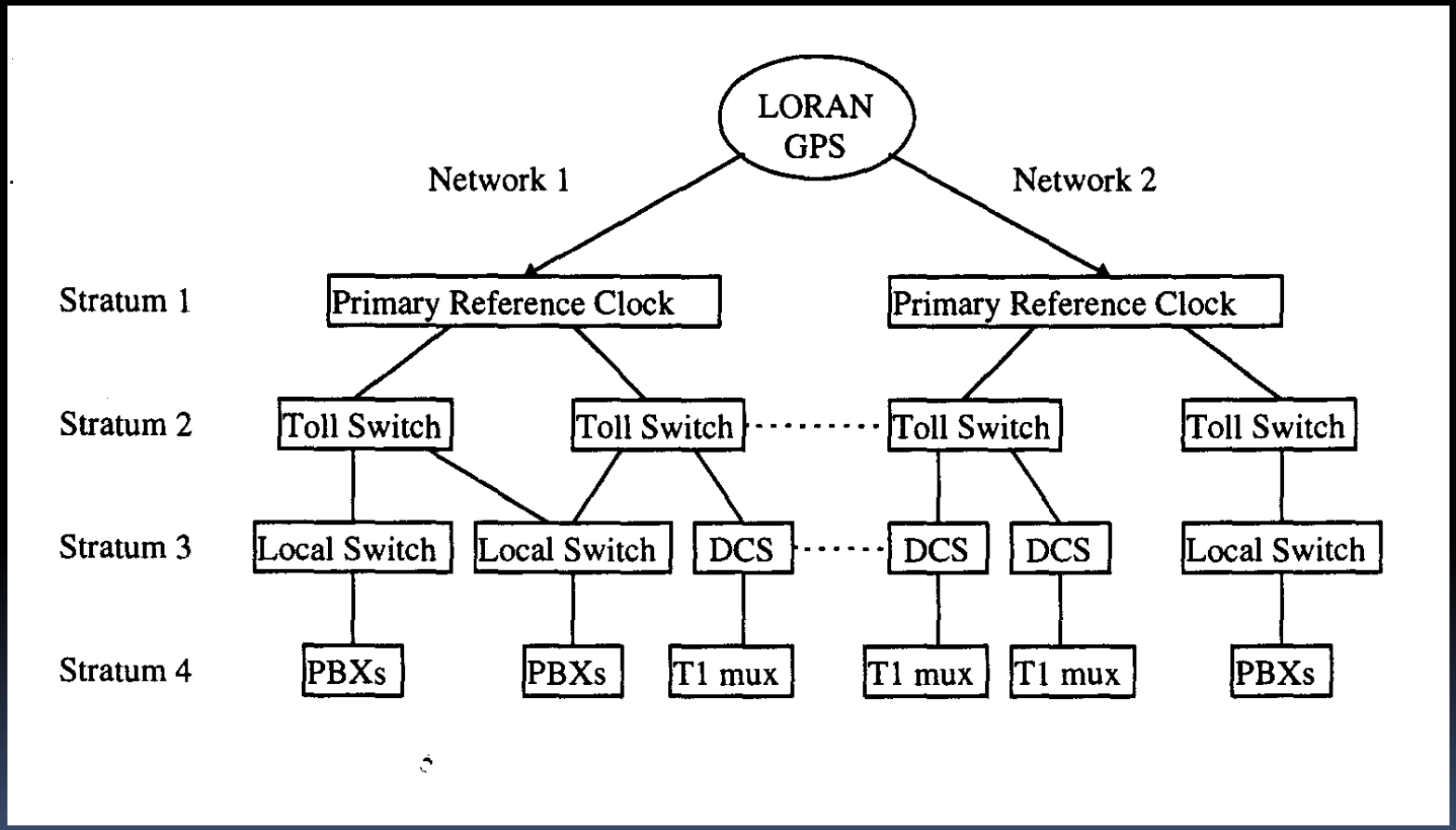


Synchronization of SONET networks

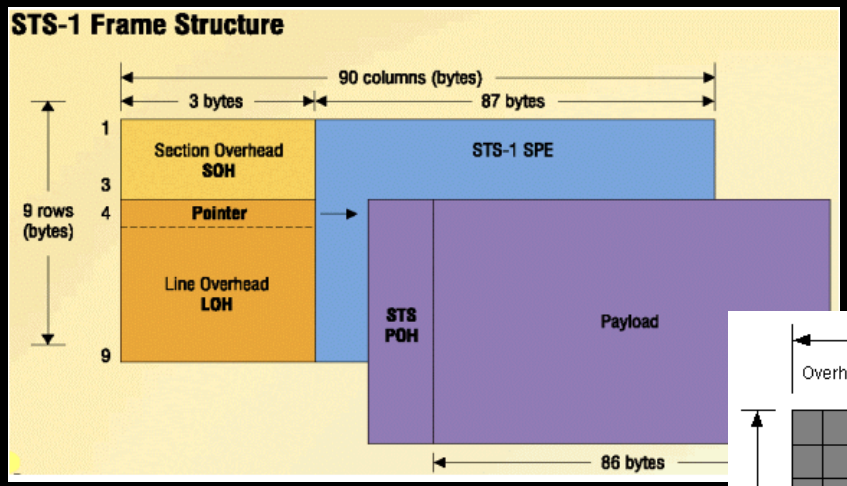


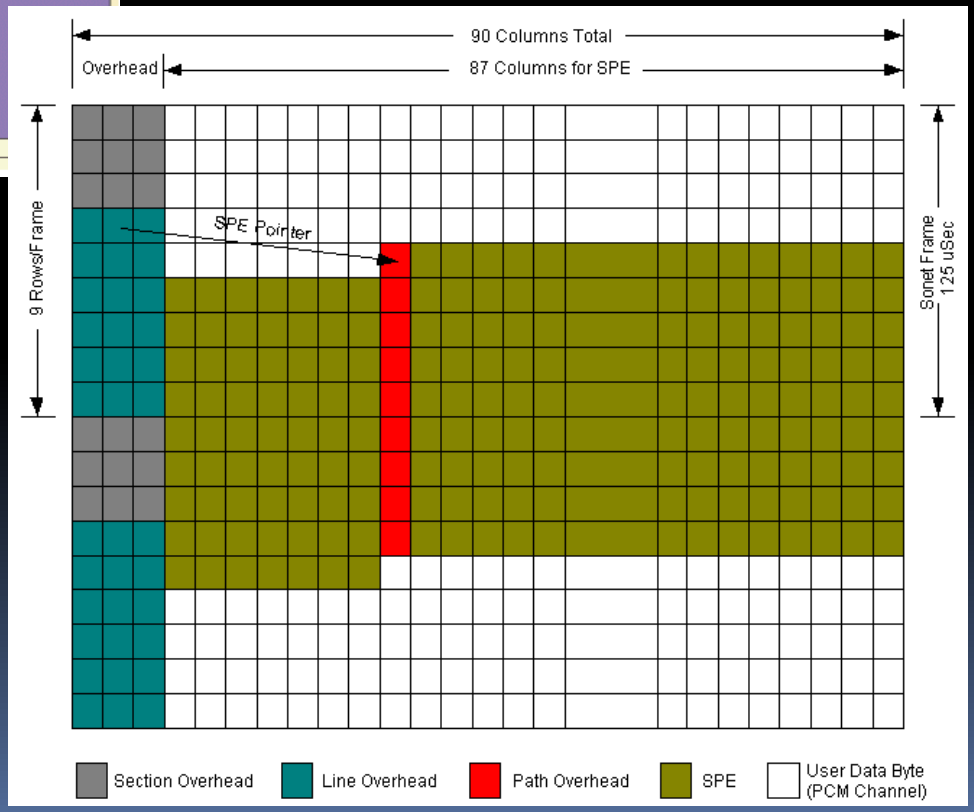
Need atomic clock to keep the network synchronized

Synchronization of SONET networks (cont)

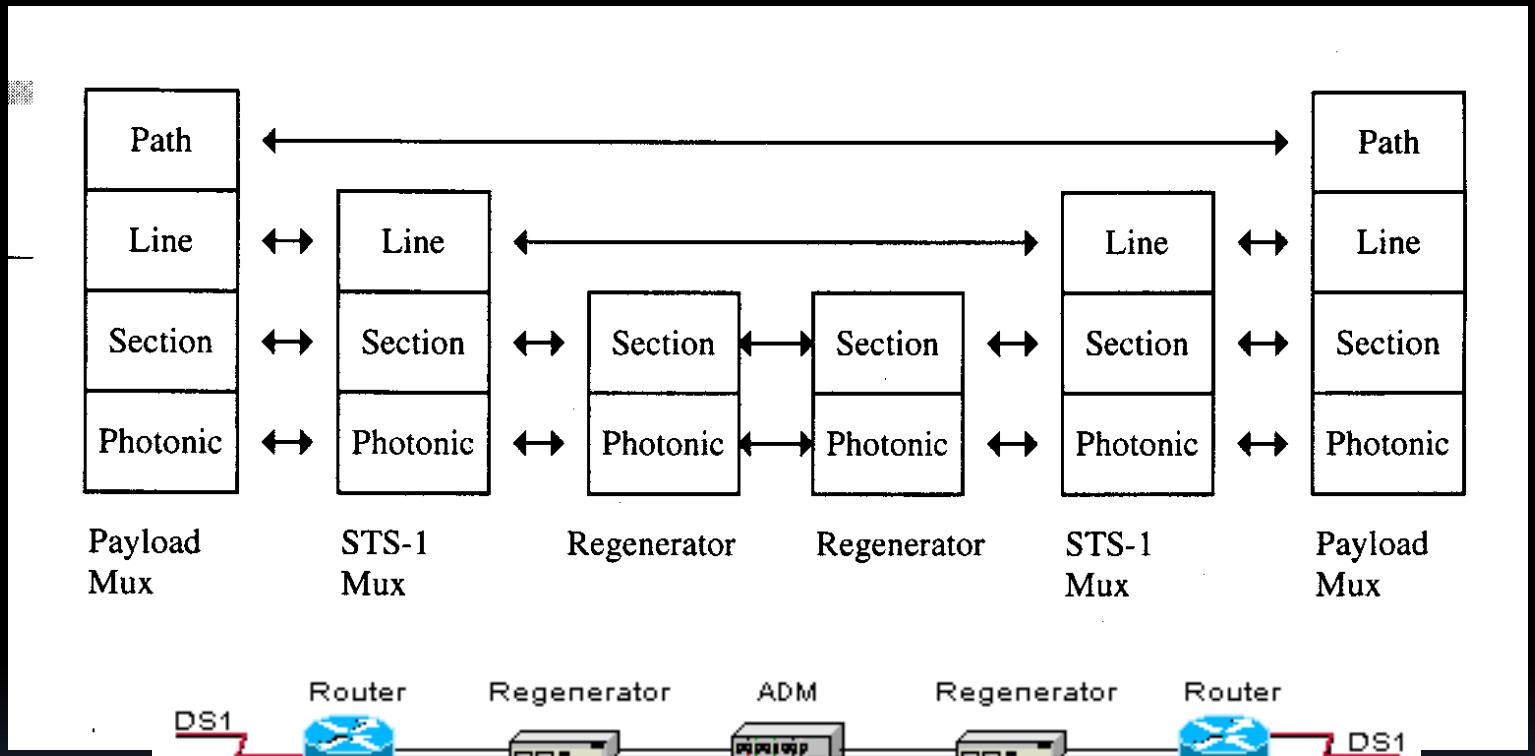


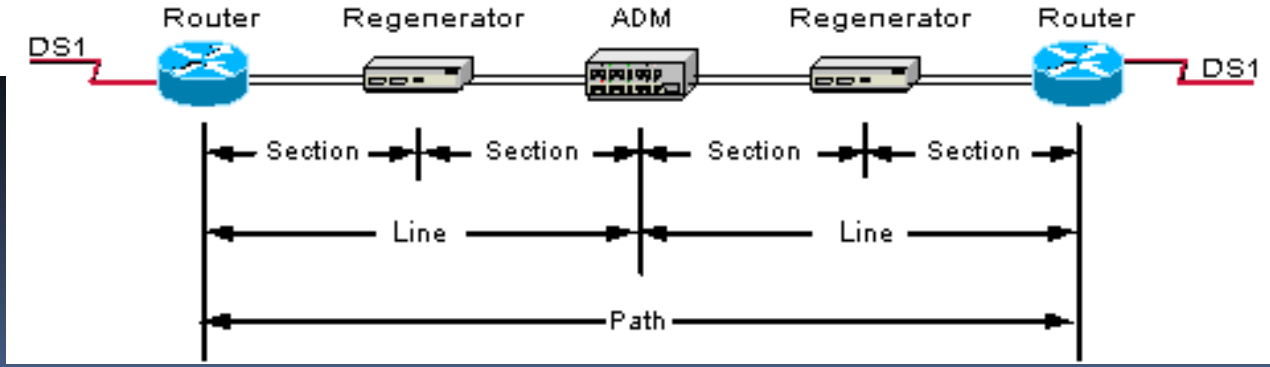
SONET STS-1 frame structure



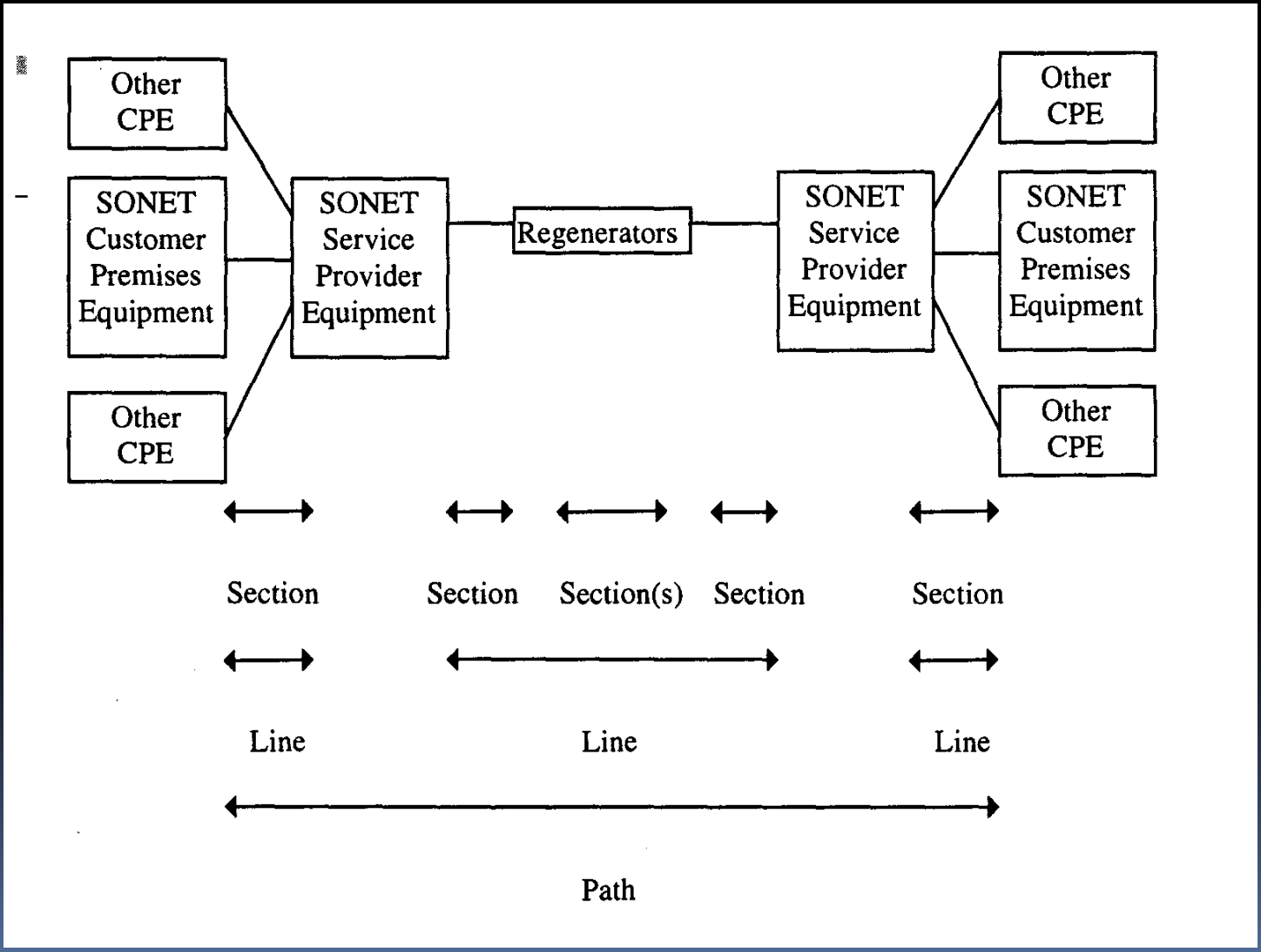


SONET architecture layers (hierarchy)





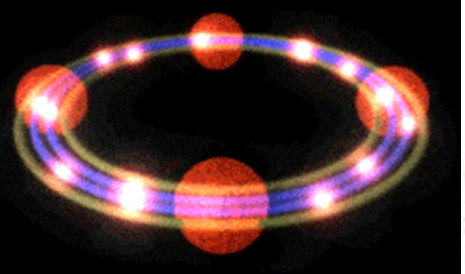
SONET overhead

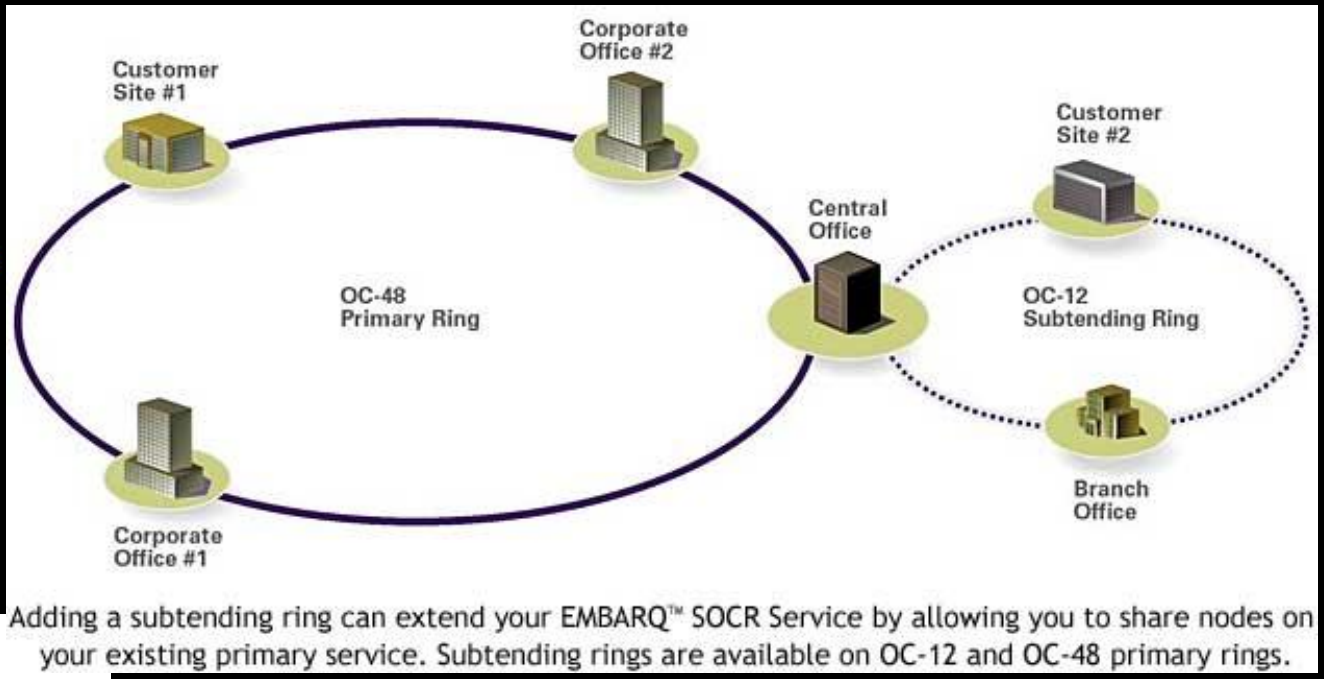


SONET overhead

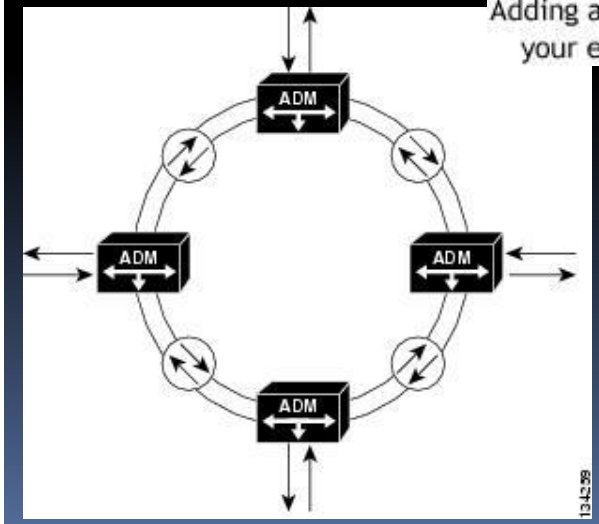
				Path Overhead
Section Overhead	A1 Framing	A2 Framing	A3 Framing	J1 Trace
	B1 BIP-8	E1 Orderwire	E1 User	B3 BIP-8
	D1 Data Com	D2 Data Com	D3 Data Com	C2 Signal Label
Line Overhead	H1 Pointer	H2 Pointer	H3 Pointer Action	G1 Path Status
	B2 BIP-8	K1	K2	F2 User Channel
	D4 Data Com	D5 Data Com	D5 Data Com	H4 Indicator
	D7 Data Com	D8 Data Com	D9 Data Com	Z3 Growth
	D10 Data Com	D11 Data Com	D12 Data Com	Z4 Growth
	S1/Z1 Sync Status/Growth	M0 or M1/Z2 REI-L Growth	E2 Orderwire	Z5 Tandem Connection

SONET deployment: rings





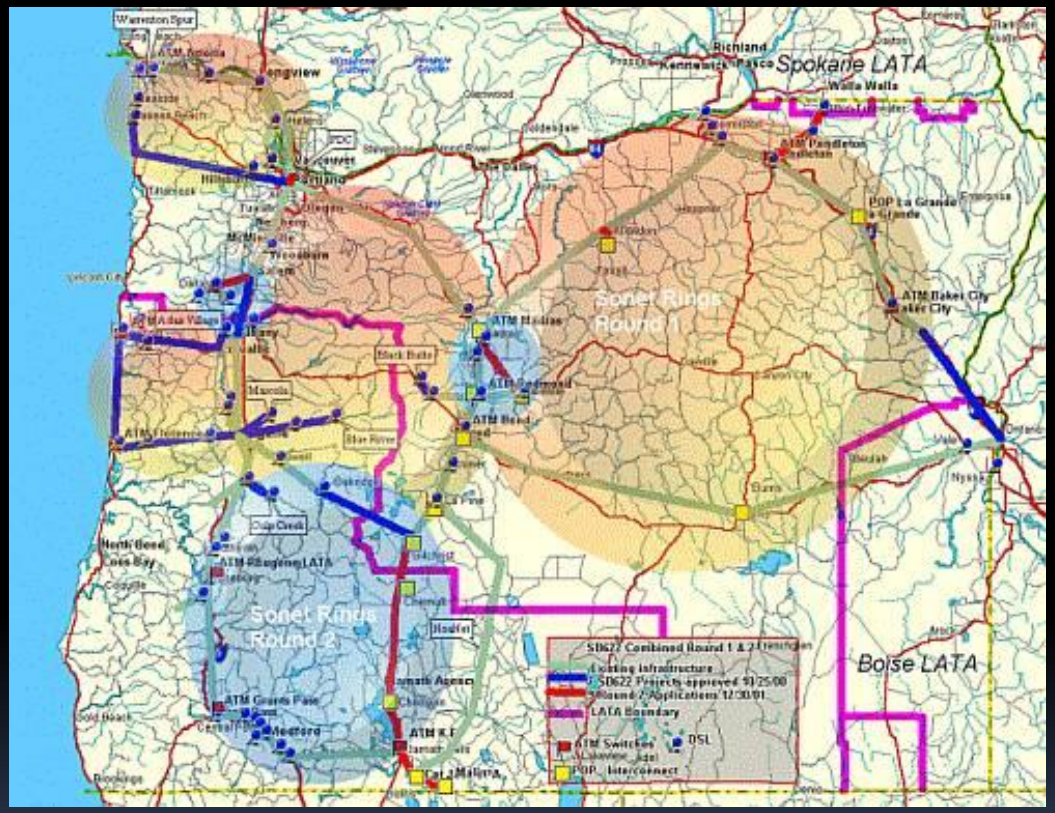
Adding a subtending ring can extend your EMBARQ™ SOCR Service by allowing you to share nodes on your existing primary service. Subtending rings are available on OC-12 and OC-48 primary rings.



Bidirectional Path Switched Ring (BPSR)
Rapid restoration
50-ms self-healing network

SONET deployment: rings

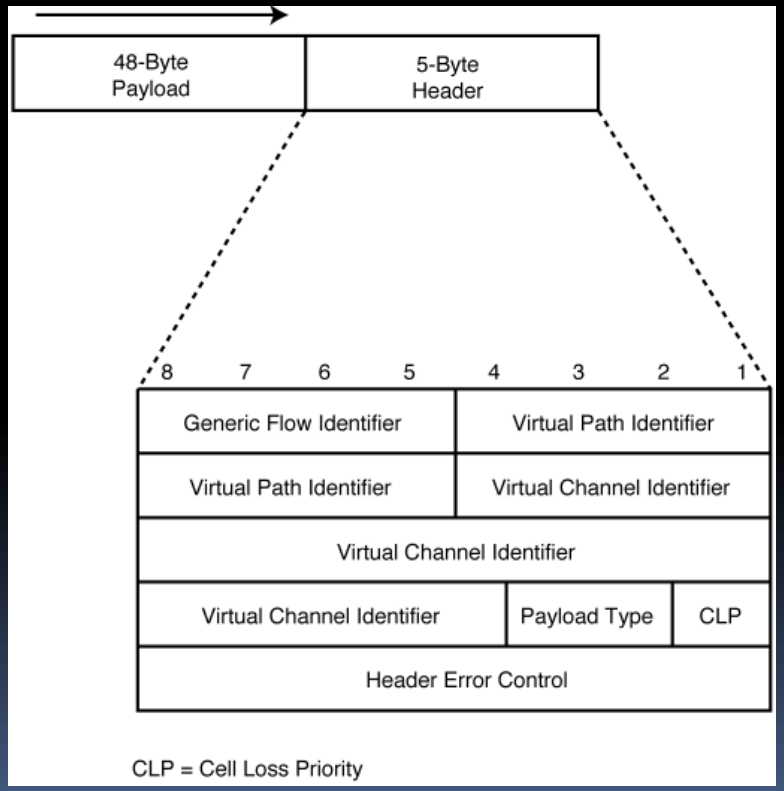
Oregon Fiber for Google



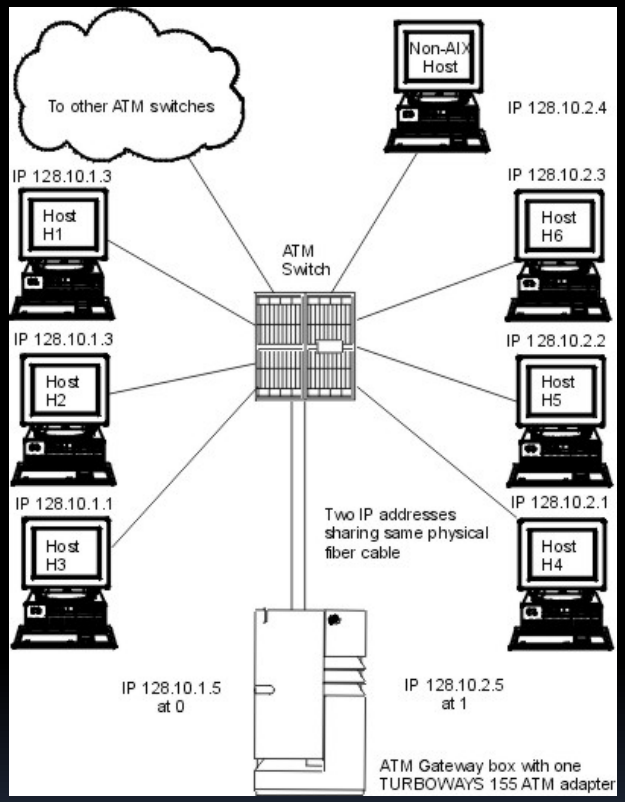
A state-wide fiber network, using seven SONET rings, provides redundancy throughout Oregon

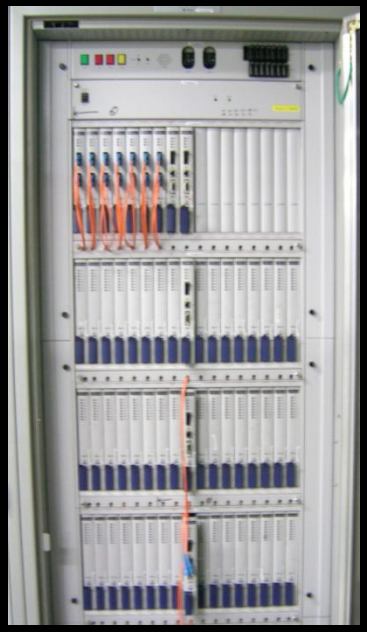
Asynchronous Transfer Mode

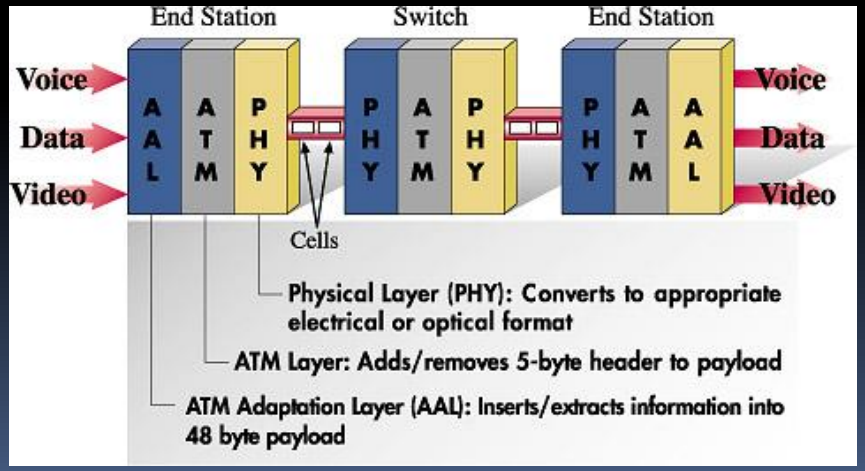
- A protocol for switching (independently of any data layer)
- Fixed length 53-byte packet. Switched according to packet length, not by any clock: hence asynchronous
- Routing: VCI header



ATM switch applications







ATM over SONET

- ATM is for efficient switching – SONET is for efficient transport

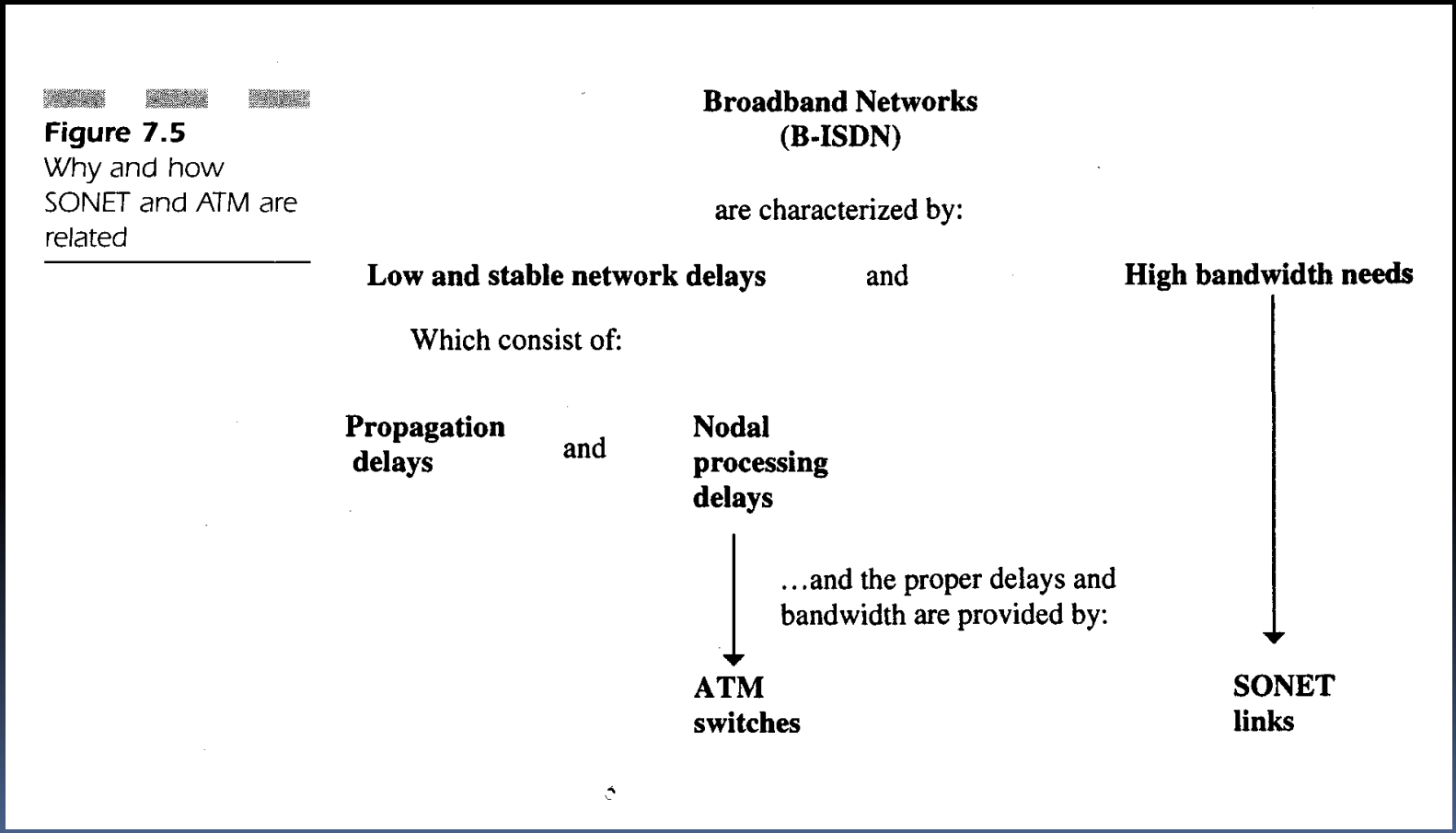
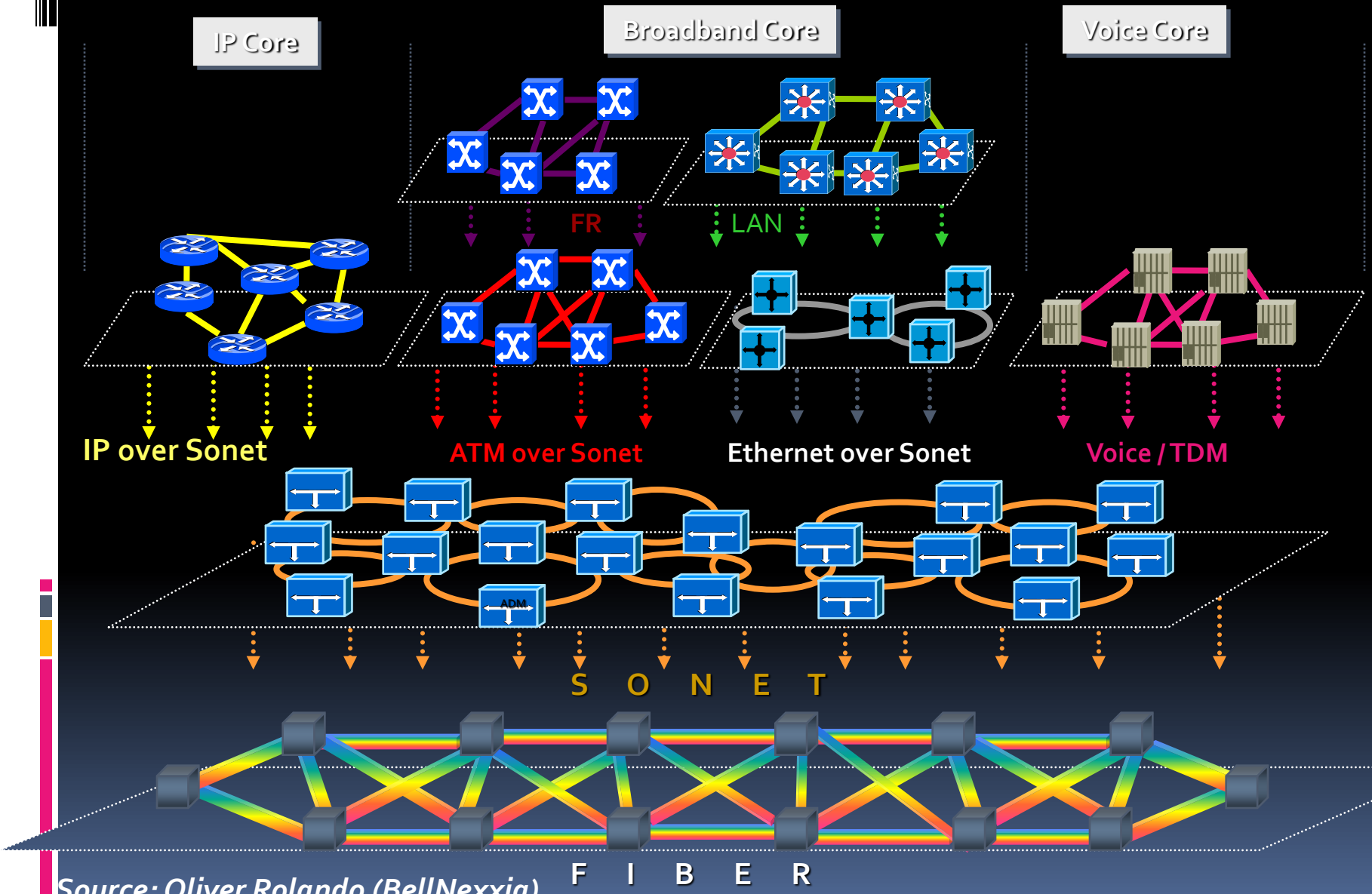


Figure 7.5 Why and how SONET and ATM are related

Today Network Protocols



Source: Oliver Rolando (BellNexxia)

Optical Transport Network

- SONET was developed prior to (D)WDM
- OTN: improve efficient use of (D)WDM + SONET
- Not a standard
- Support existing standards and protocols

ITU-T The leader on OTN standards

ARCHITECTURE

G.872 (11/2001), Architecture of optical transport networks

Network requirements and architectural framework of the optical transport network family of Recommendations.

FRAMING AND INTERFACES

G.709/Y.1331 (03/03), Interface for the Optical Transport Network (OTN) Framing structure ('digital wrapper'), overhead bytes, multiplexing and payload mappings for all payload types.

G.959.1 (03/06), Optical transport network physical layer interfaces

EQUIPMENT FUNCTIONS

G.798 (12/06), Characteristics of optical transport network (OTN) hierarchy equipment functional blocks

G.8251 (11/01), The control of jitter and wander within the optical transport network (OTN)

NETWORK MANAGEMENT

G.874 (03/08), Management aspects of the optical transport network element

G.874.1 (01/02), Optical transport network (OTN): Protocol-neutral management information model for the network element view

RELATED RECOMMENDATIONS

G sppl.43 (02/08), Transport of IEEE 10G Base-R in Optical Transport Networks (OTN)

G.65x, Series on optical fibre cables and test methods

G.664 (03/06), Optical safety procedures and requirements for optical transport systems

G.693 (05/06), Optical interfaces for intra-office systems

G.806 (03/06), Characteristics of transport equipment – Description methodology and generic functionality

G.870/Y.1352 (06/04), Terms and definitions for Optical Transport Networks (OTN)

G.873.1 (03/06), Optical Transport Network (OTN): Linear protection

G.7041/Y.1303 (08/05), Generic framing procedure (GFP)

G.7042/Y.1305 (03/06), Link capacity adjustment scheme (LCAS) for virtual concatenated signals

G.7710/Y.1701 (07/07), Common equipment management function requirements

G.8080/Y.1304 (06/06), Architecture for the automatically switched optical network (ASON)

G.8201 (09/03), Error performance parameters and objectives for multi-operator international paths within the Optical Transport Network (OTN)

NOTE: G.65x - hyperlink is to the ITU-T G-Series Recommendations page, and not to a specific G-Series Recommendation.

OTN means

- Transport for all digital payloads, with superior performance and support for the next generation of dynamic services with operational efficiencies not expected from current optical wavelength division multiplexing (WDM) transport solutions
- Support for a wide range of narrowband and broadband services like
  - SDH/SONET
  - IP-based services
  - Ethernet services
  - ATM services
  - Frame relay services
  - Audio/video services

Given the global scope of fibre optic transport networks based on WDM, the OTN market potential is bright.

For more information on other ITU-T activities:
workshops: www.itu.int/ITU-T/worksem/
e-flash and news: www.itu.int/ITU-T/news/
membership: www.itu/ITU-T/membership/
technology watch: www.itu/int/ITU-T/techwatch

05.2008 tsbpromo@itu.int

OTN

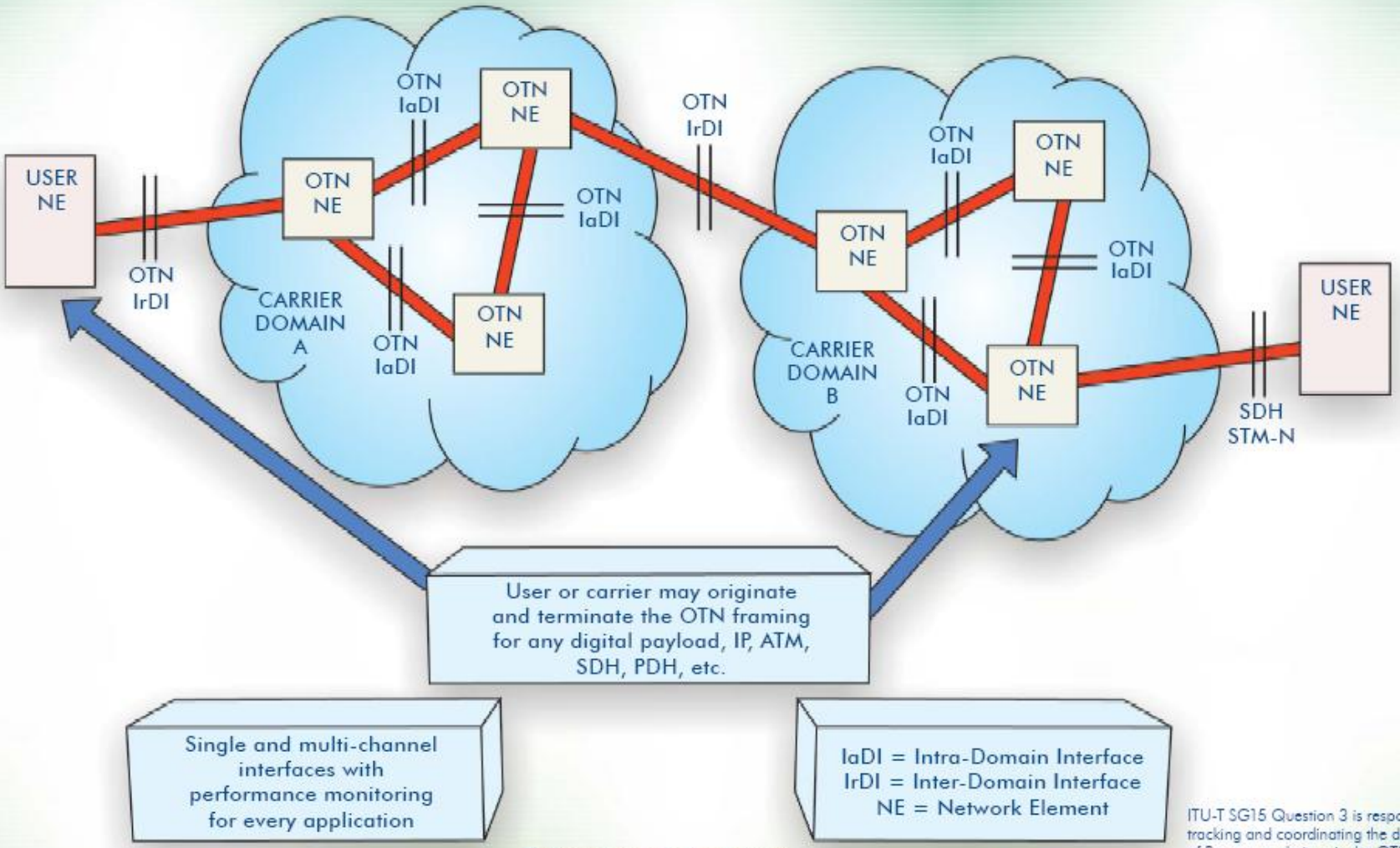
OPTICAL TRANSPORT NETWORK

Your new fibre optic transport solution

ITU-T

International Telecommunication Union

Global Optical Transport Network to Support Today's and Future Services

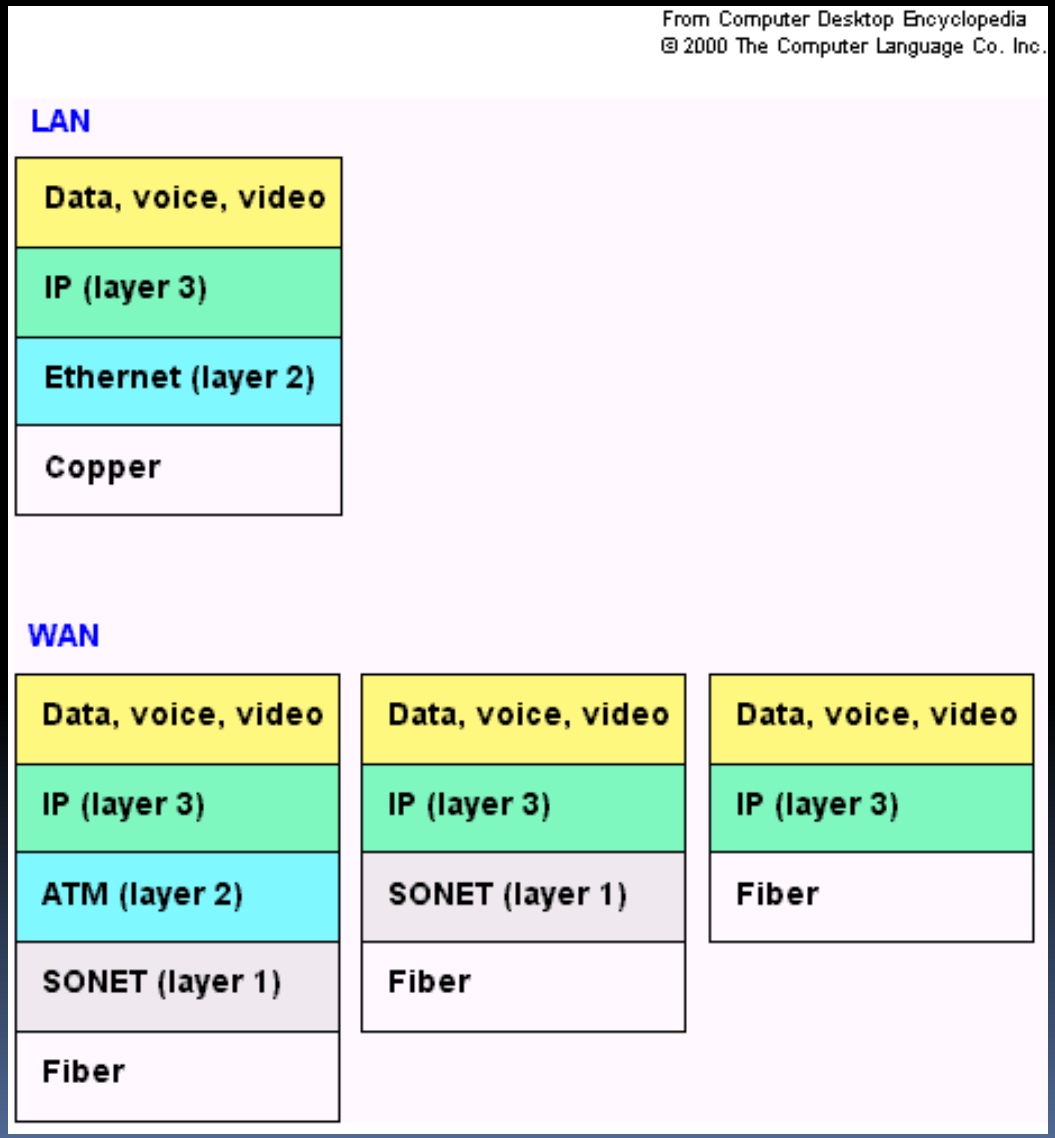


(The figure above represents one of many possible implementation scenarios)

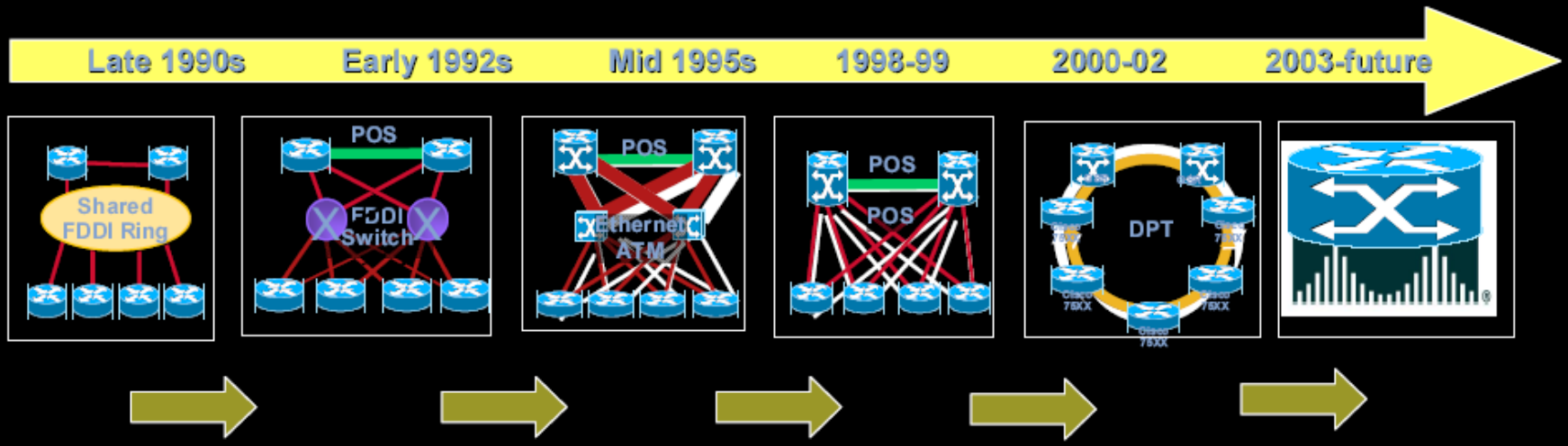
ITU-T SG15 Question 3 is responsible for tracking and coordinating the development of Recommendations in the OTN area.

For more detailed information, the "Optical Transport Networks and Technologies Standardization Work Plan" has been developed.
See www.itu.int/ITU-T/studygroups/com15/otn

IP over DWDM

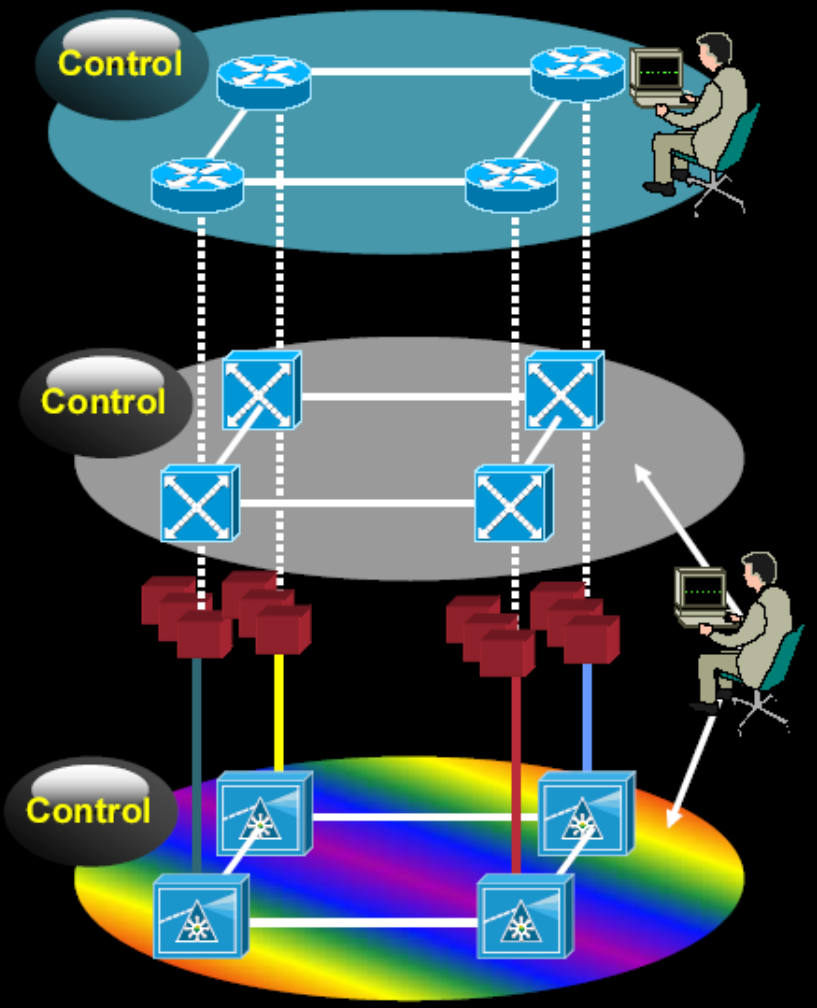

From Computer Desktop Encyclopedia
© 2000 The Computer Language Co. Inc.
LAN
Data, voice, video
IP (layer 3)
Ethernet (layer 2)
Copper
WAN
Data, voice, video
IP (layer 3)
ATM (layer 2)
SONET (layer 1)
Fiber
Data, voice, video
IP (layer 3)
SONET (layer 1)
Fiber
Data, voice, video
IP (layer 3)
Fiber

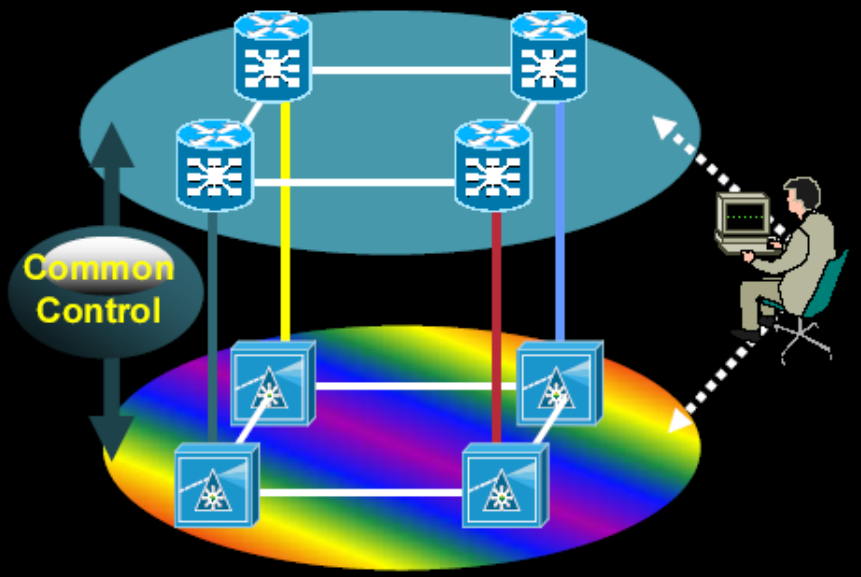
IP PoP Evolution



- Historically, scaling a POP is always a challenge
- Many interconnect technologies have evolved over time but all need to occupy a "revenue generation slot"
- POP consolidation leads to converged core, peering, and edge functions
- High Availability is one of the keys to PoP consolidation

IPoDWDM Simplifies and Scales the Network





Scaling IP traffic over WDM (vs EXC), with OAMP (G709, Protection)

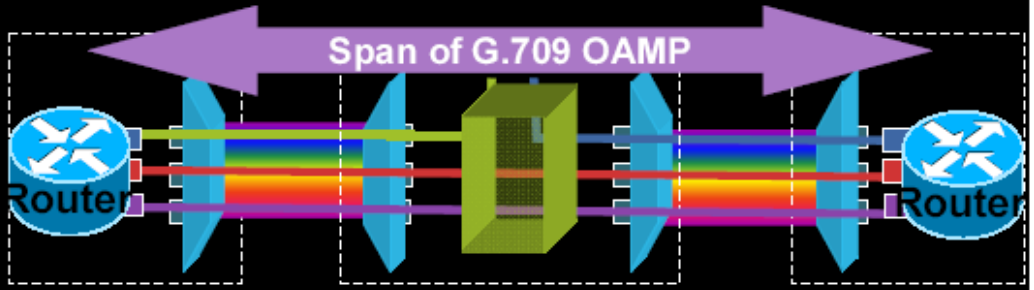
Network element integration vision (management, control plane)

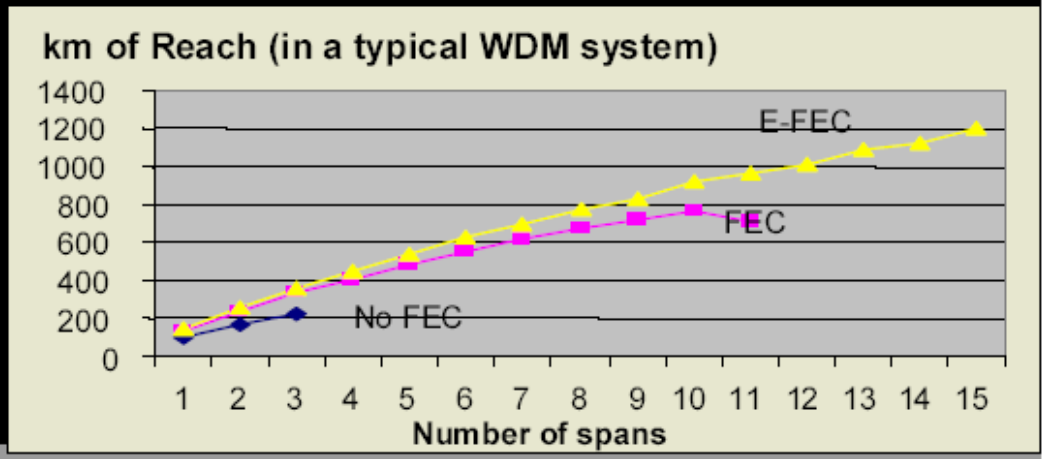
IPoWDM end-to-end OAM&P: G.709 innovation

- **10GE LANPHY payload over G.709 payload (over-clocked)**
- **OAM&P based** on **G.709 Standard** (**SDH-like, better)**
- **FEC enabled transmission** G.709 Standard modes, and Enhanced-FEC >1500 km

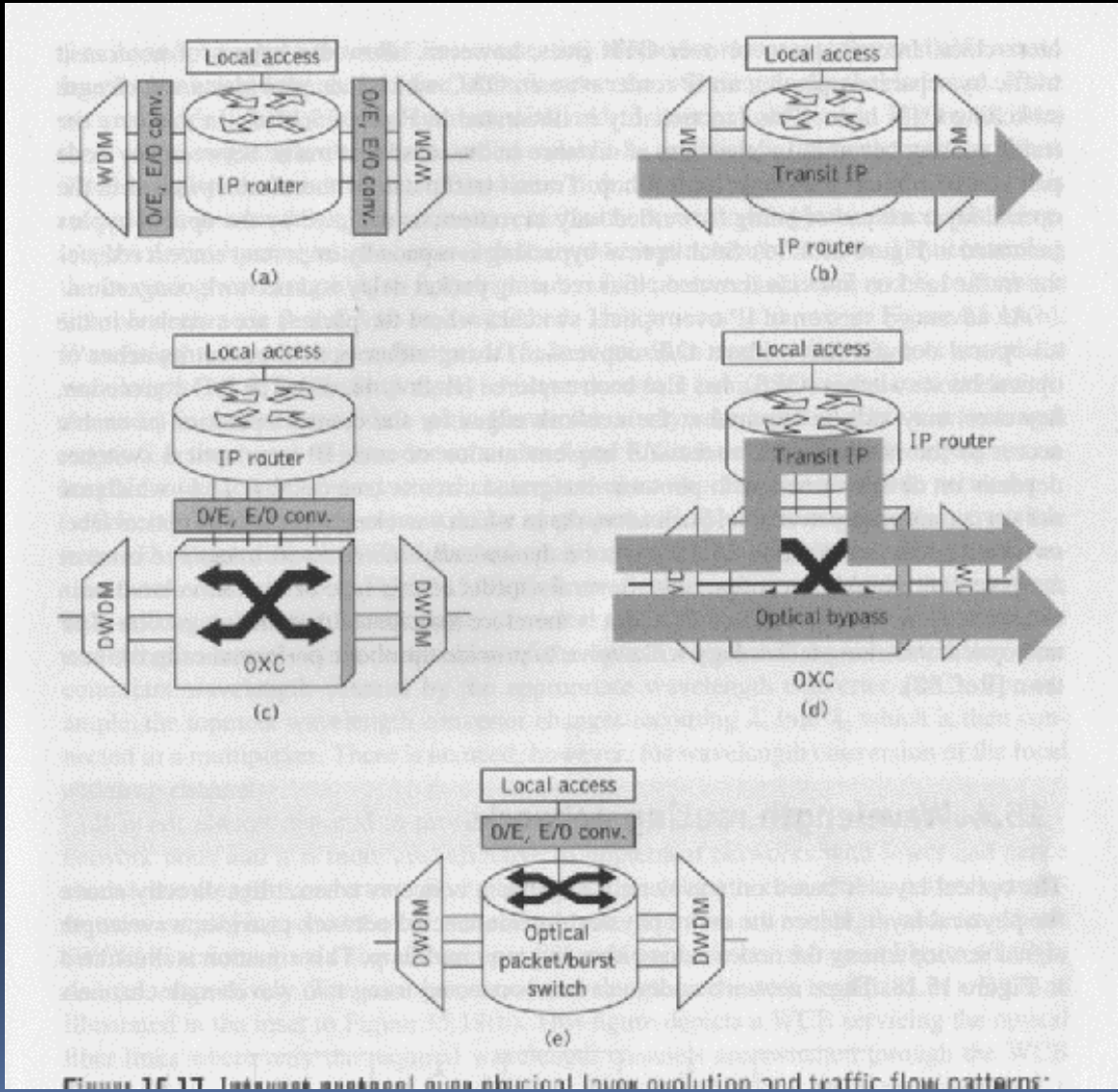
ITU standard references:

- ***G.709***
- *Overclocking: G.sup43, sub-clause 7.1*
- *Enhanced FEC: G.975.1 Appendix I.7*



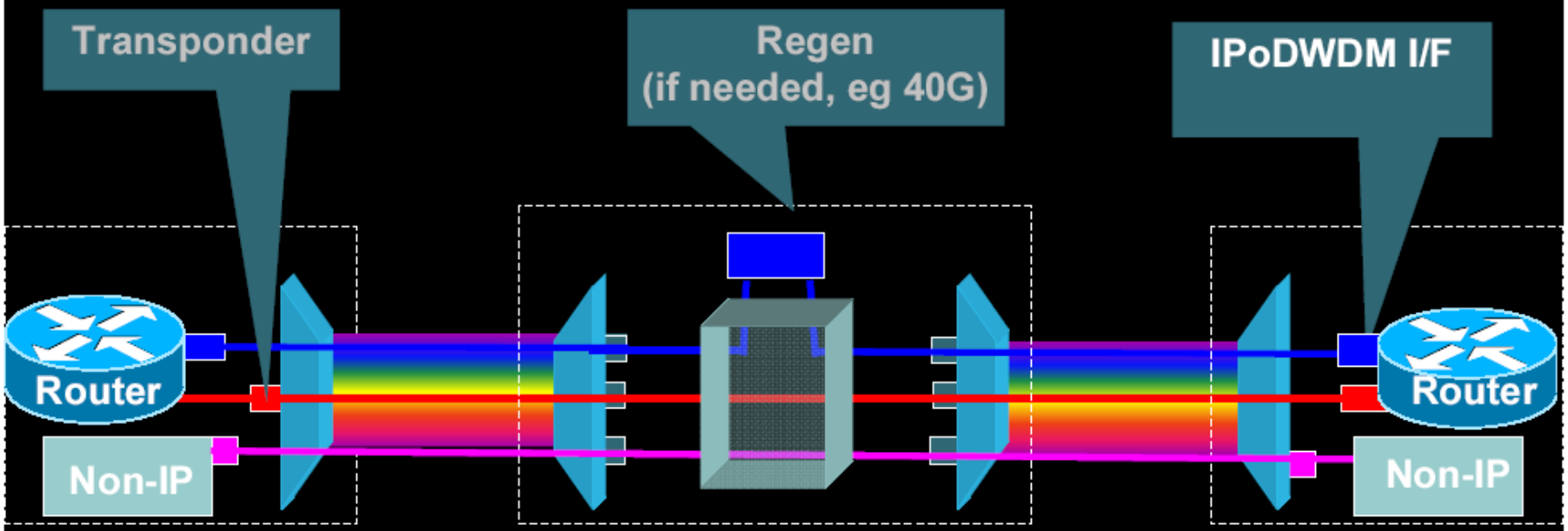


IP over DWDM


Local access
WDM
O/E, E/O conv.
IP router
O/E, E/O conv.
WDM
(a)
Local access
Transit IP
IP router
(b)
Local access
IP router
O/E, E/O conv.
DWDM
OXC
DWDM
(c)
Local access
IP router
Transit IP
Optical bypass
OXC
(d)
Local access
O/E, E/O conv.
DWDM
Optical packet/burst switch
DWDM
(e)

IPoDWDM Scalable Deployment

One Channel at a Time

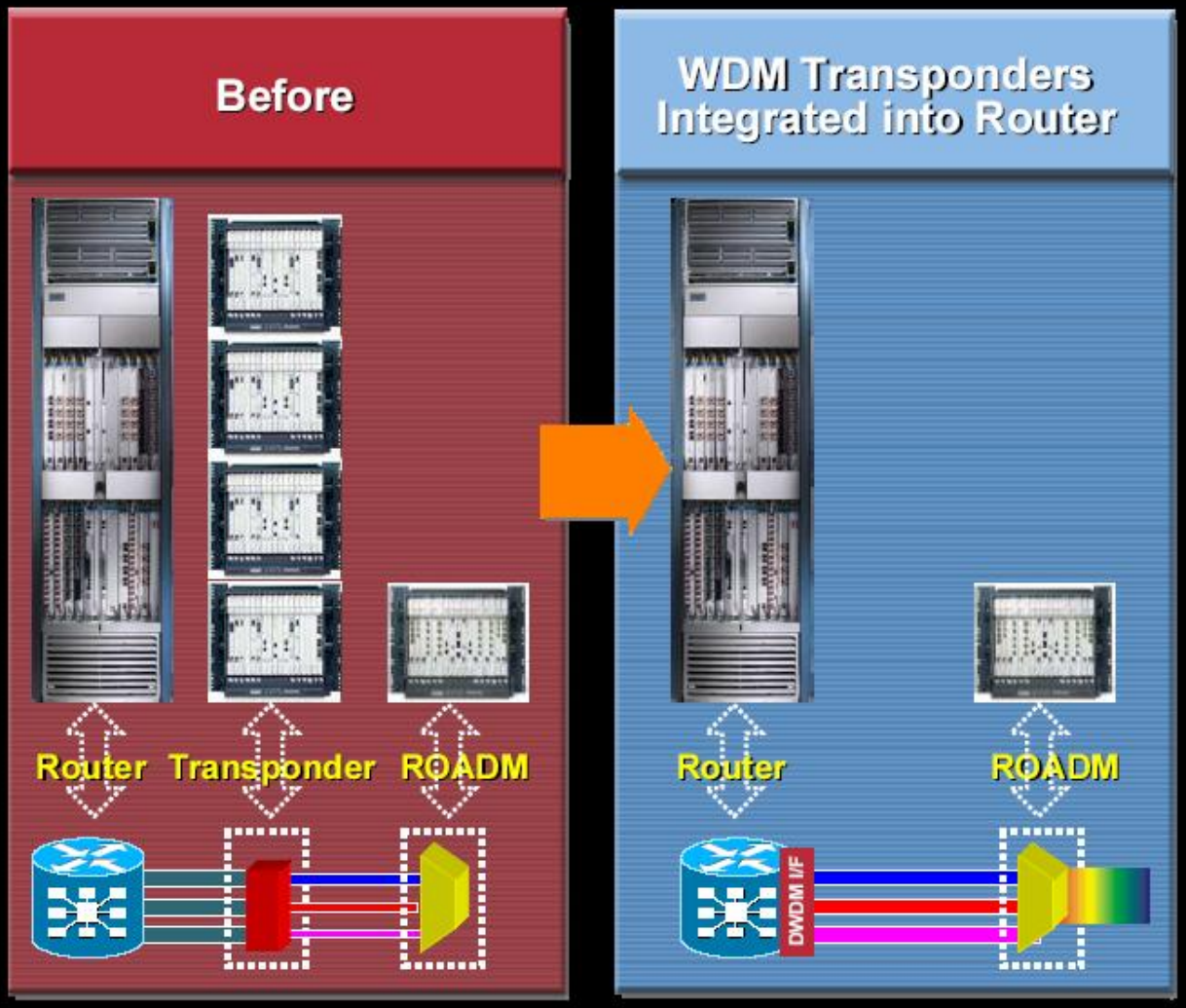


IPoWDM can be deployed one channel at a time,

leveraging Open WDM layer, with proven interop over existing (NELAS) infrastructure as “alien-wavelength”…

Containing cost (OpEx) for the high growth IP traffic…

IPoDWDM Element Integration Benefits



- **Lower CapEx**

  Elimination of OEOs
- **Lower OpEx**

  Space, power, management
- **Enhanced resiliency**

  Fewer active components
- **Investment protection**

  40G and beyond, interoperability over *existing* 10G systems

ADVANCED OPTICAL NETWORK

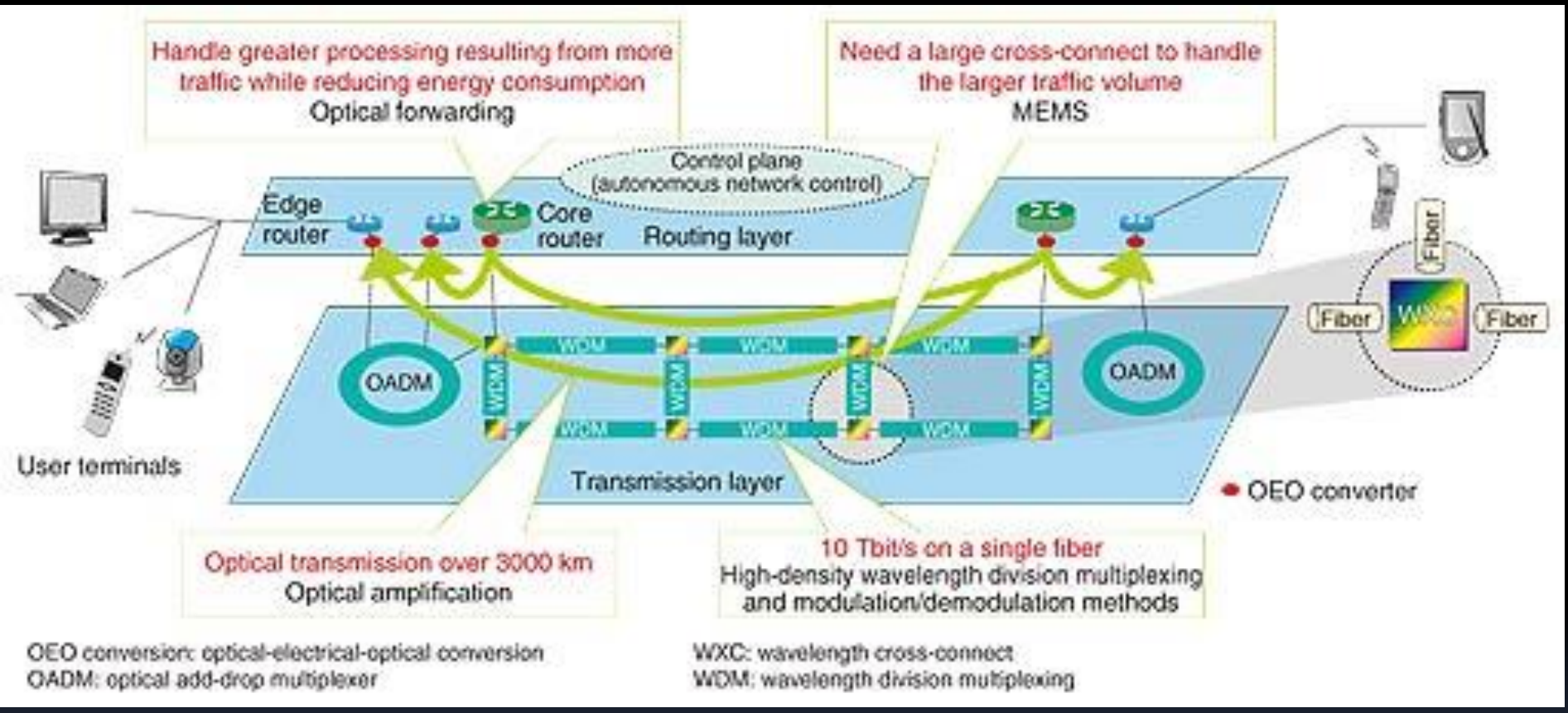
Advanced Concepts of Optical Networks

Core

- Wavelength routing networks
- Optical switching networks
- Multiprotocol Label Switching (MPLS) and generalized MPLS (GMPLS)
- Optical Burst Switching Networks

Edge

- Access: PON, APON, BPON, GE-PON, GPON in FTTx
- LAN: Optical Ethernet



OEO conversion: optical-electrical-optical conversion
OADM: optical add-drop multiplexer

WXC: wavelength cross-connect
WDM: wavelength division multiplexing

Optical transport network evolution - the market drivers & technology challenges

Richard Dorward
Ericsson Broadband Networks

ERICSSON
TAKING YOU FORWARD

Telecom market is redefining itself

Beyond voice – a fragmented market

The power of users

60 billion online searches conducted worldwide in August 2007

45% of US and European workers are away from their desk more than 20% of their time

Over **8.6 million** articles and over 5.7 million registered contributors on Wikipedia globally

World of Warcraft, the subscription-based online game, has more than **10 million** players

Global digital music sales reached **$3 billion** in 2007, half of the revenues came from mobile

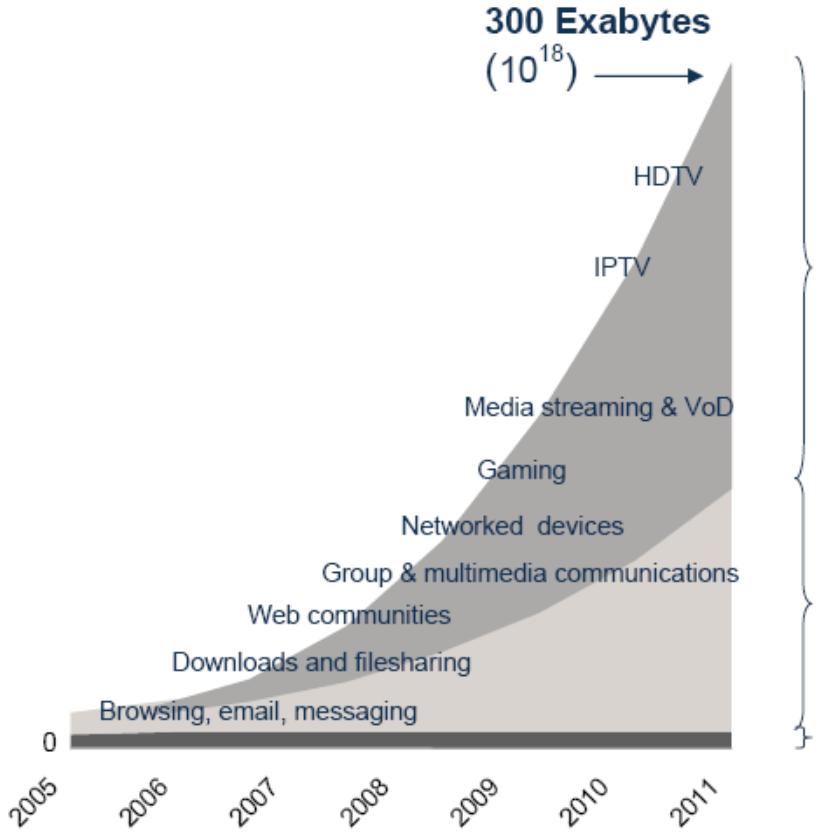
Over **3 billion** songs, 50 million TV episodes and 2 million Disney movies have been purchased and downloaded from iTunes

Full Service Broadband

30 minutes of TV viewing equivalent to 30 days of Internet surfing

The changing shape of networks

What the future might look like



Video

High bandwidth services with strict demand on QoS

- Broadcast
- VoD
- Downloads
- Peering video

High Speed Internet

Fixed and mobile multimedia broadband

- Information retrieval
- Gaming
- Social networking

Voice

Commodity

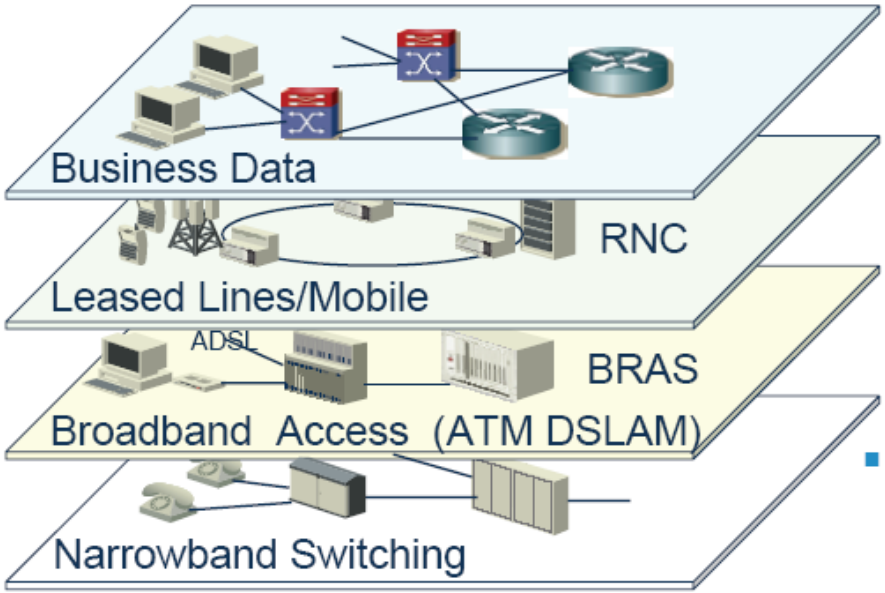
- Triple/quad play bundling

IPTV forecast growth by 2011= 160 million Tbytes pa

[based on >50m subscribers; ~5Mbit/s per user; 4hours/day]

Transport technology transformation

Separate technology layers converge

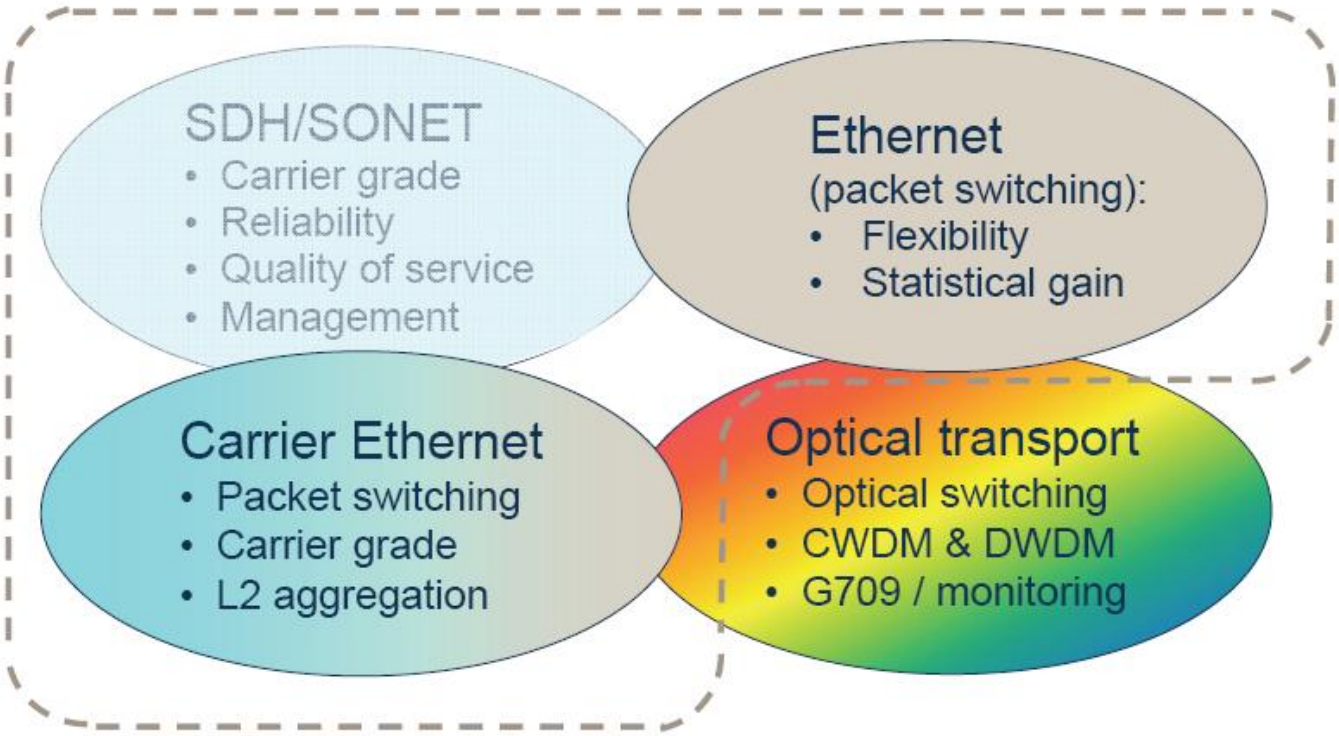


- SDH/SONET becomes ring fenced:
  - VC-12/VT1.5 granularity too fine
  - Transport technology shifts to Ethernet
- Ethernet becomes universal
  - Ethernet replicates carrier class performance of SDH
  - Emerging MPLS-TP & PBB-TE standards

- G.709 based OTN forms part of WDM layer
  - Wrapper includes FEC/EFEC for performance
  - Wrapper offers SDH-like Section OAM
- Economics for WDM moves it closer to the edge
  - Demand for flexibility introduces ROADM, WSS & high channel capacity

The emergence of the POTP

Offers scalability & technology configurability (SDH/Packet/WDM)



MSPP – Multi Service Provisioning Platform

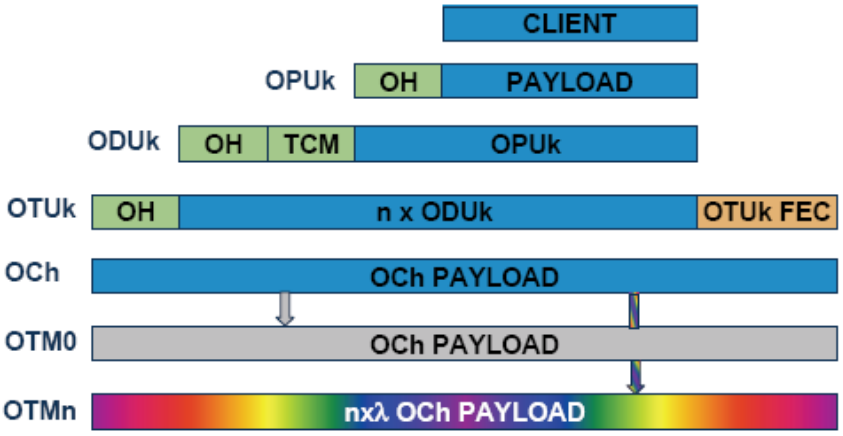
- SDH/SONET core with integrated packet capability

POT(P) – Packet Optical Transport (Platform)

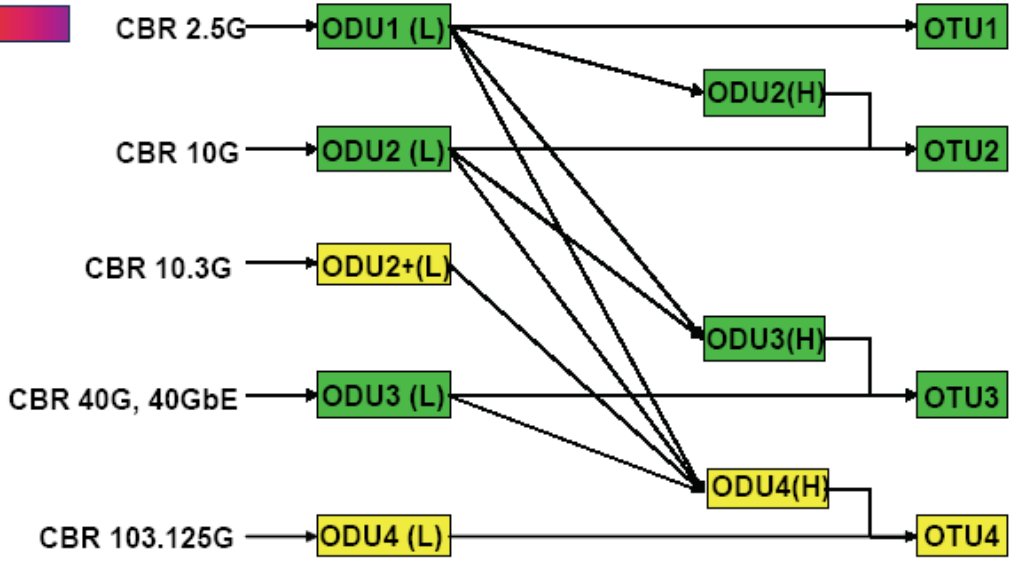
- Predominantly packet with integrated WDM and G.709 OTN
- Maintains residual but full SDH/SONET functionality

High capacity carrier class transport

Optical Transport Hierarchy (OTH) replaces SDH/SONET layer

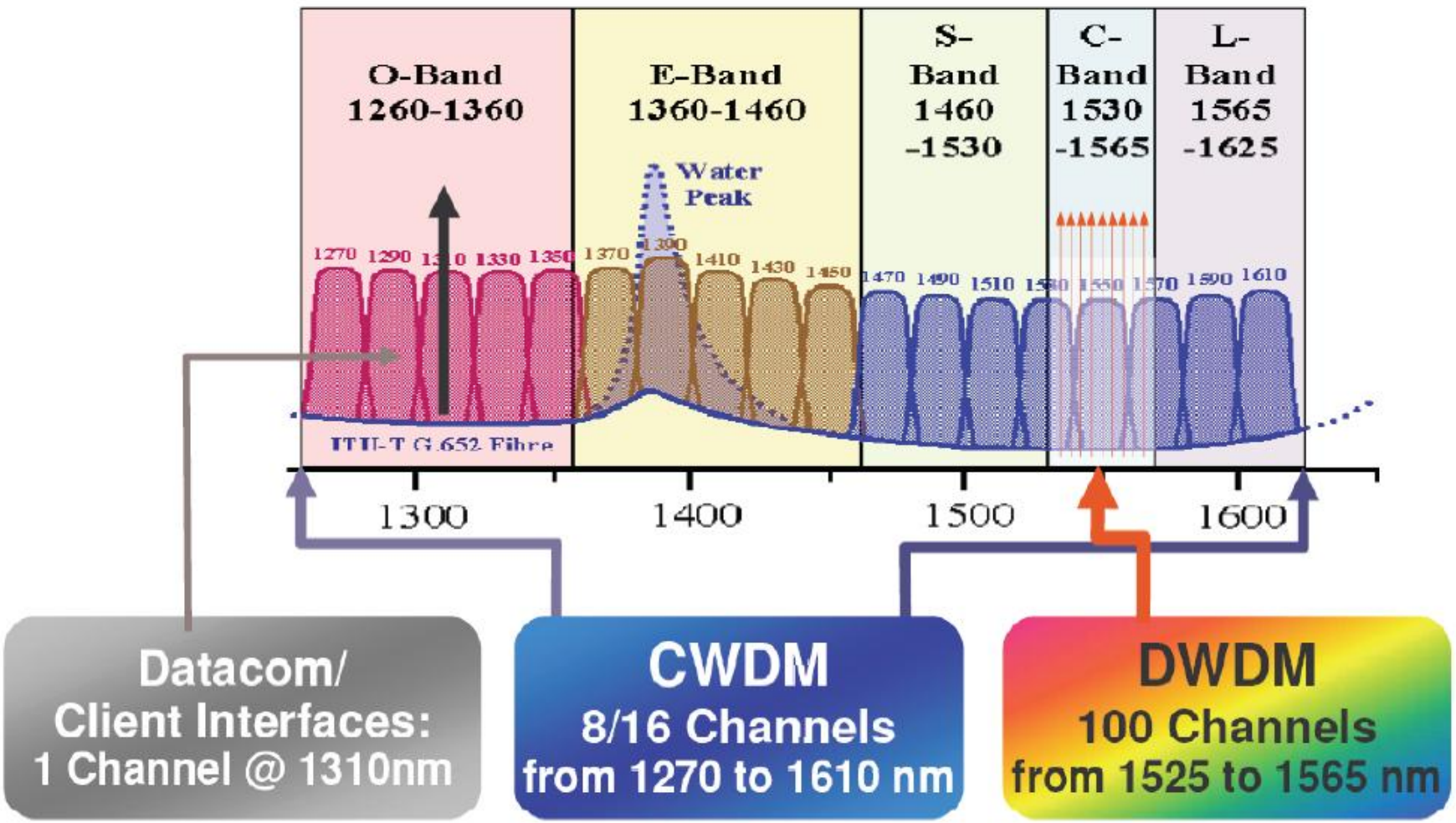


- The OTH provides all the components required for a managed optical layer



- Provisionally agreed future G.709 hierarchy *(ITU-T SG15 Q11 Meeting, 2-6 June 2008)*

Fibre utilisation and capacity



Source: Pirelli

Roadmap of FUJITSU Photonics Technology

Flexibility in wavelength

> 10Tbit/s

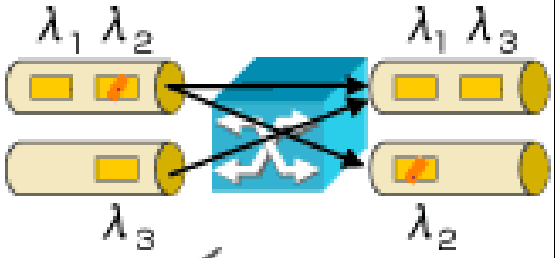
1 - 10Tbit/s

- GMPLS signaling & protection
- Wavelength selective switch
- Fullband tunable LD/ transceiver module
- Variable dispersion compensation
- PON(~ Gb/s)

・Optical ADM
・Ring

- Multi-layer convergence of network equipment
- 40G, Coherent technology
- Quantum-dot-based LD/SOA
- Optical wiring/ interconnection

・Optical crossconnect(OXC)
・Mesh



- Optical packet routing
- Fast tunable LD
- All-optical 2R/3R, Wavelength conversion
- Next-generation PON (10G/WDM)
- Quantum opt. comm.

・Optical packet switch
・Optical processing of routing

・Expansion of metro WDM
・Spread of FTTX

・Widespread of FTTX
・Construction of IP-based network infrastructure

・Ubiquitous communication with optical and wireless convergence

~2006 | 2007~2010 | 2011~

Outline

- Introduction
- Telecom/datacom network concept
- Optical network concepts and architecture
  - Overview
  - Layers and protocol
  - (D)WDM network and wavelength routing
  - Optical switching
- Optical network deployment
  - Global
  - Fiber to the premise (home, business,…)
- Summary

TO BE CONTINUED IN PART 2