Recent Advances in Photonic Networking Technologies

2005. 2. 24.

Nagoya University
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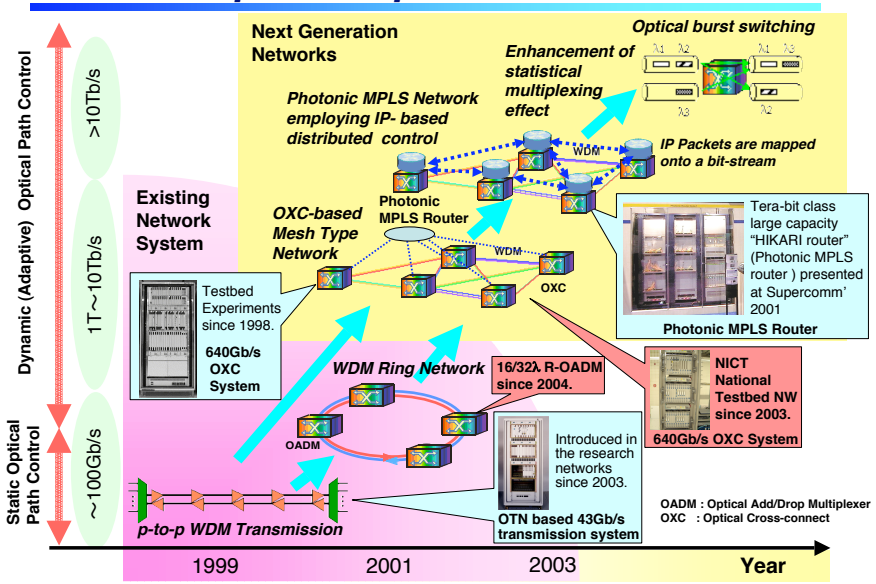
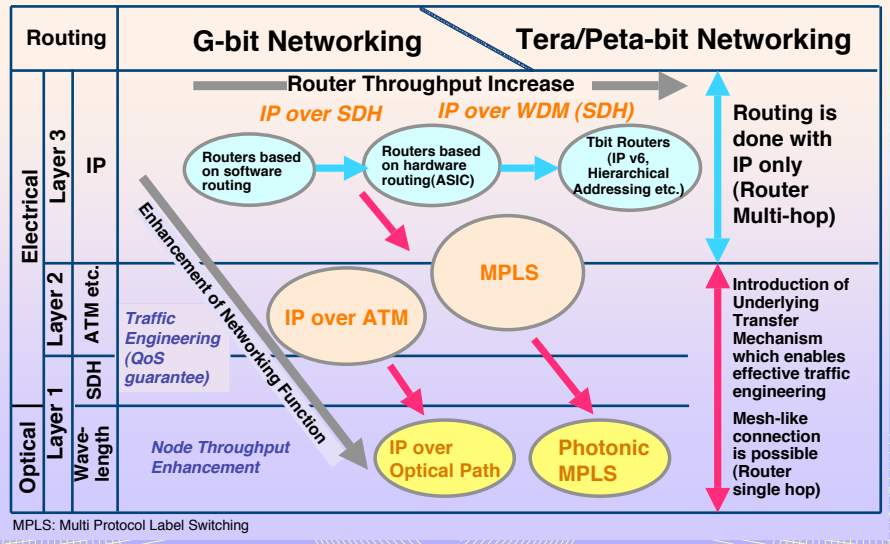
Development of Photonic Network



Evolution of IP transport mechanism

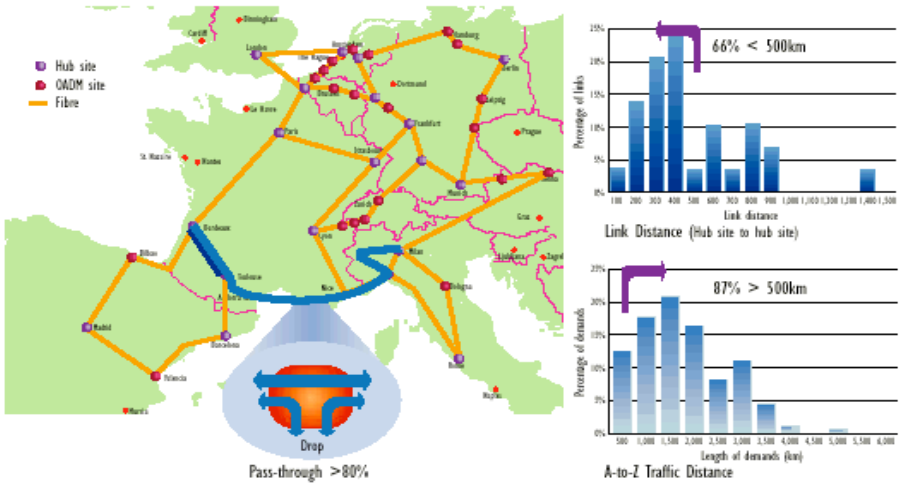


MPLS: Multi Protocol Label Switching

Comparison Between Ring and Mesh Networks

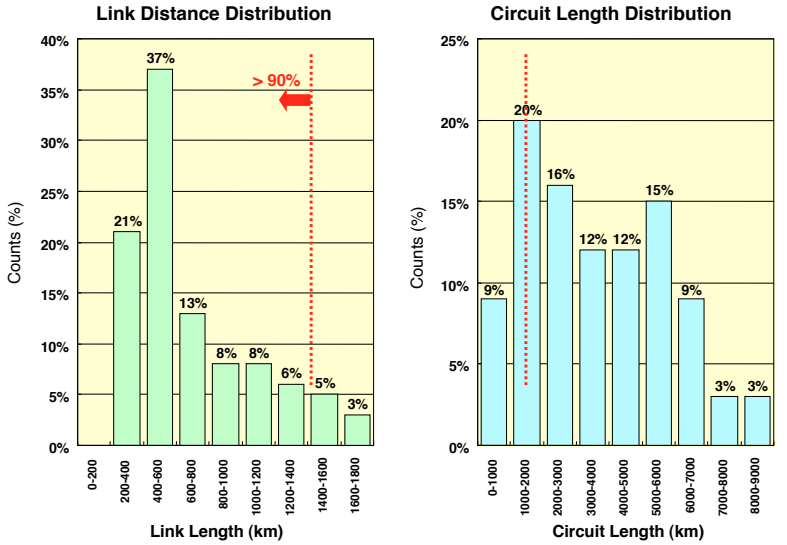
	2/4 Fiber Ring Architecture	*Mesh Architecture*
Adaptability to dynamic traffic patterns (cannot plan 10 years anymore; IP traffic is unpredictable.)	Total throughput must be pre-planned and installed.	Minimum planning. Add capacity as needed (Pay as you grow solution). Hot-spot bandwidth upgrade.
Adaptability to distance-insensitive traffic pattern (internet traffic).	Low	High
Bandwidth Scalability	Limited (two fiber to four fiber up-grade and multiple ring interconnection).	Controlled and managed growth is possible.
Network Scalability	Limited (multiple ring arrangement).	Controlled and managed growth is possible.
Network Resource Utilization	Lower	High
Restoration Speed	- 50 ms	< 1 s
Network Management	Simple	More complicated

Link Distance and Circuit Length Distribution in Europe



From A. Solheim, Business Briefing, World Markets Research Center, pp. 50-54.

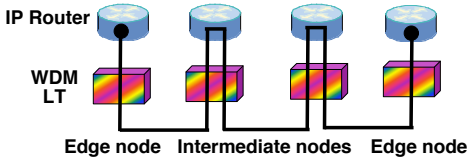
Link Distance and Circuit Length Distribution in North America (40 node Model)



From J-K Rhee et al., Proc. SPIE, ITCom 2002, vol. 4872, pp. 121-132.

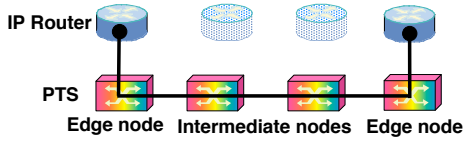
End-to-End Node Cost Reduction

• IP over WDM

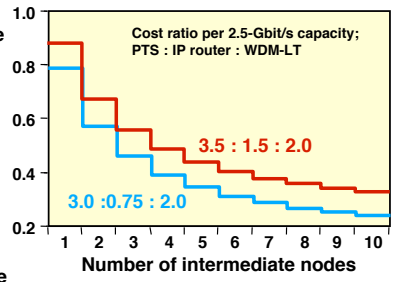


- 2.5 Gbit/s IP router I/F (OC-48c or STM-16)
- 20 Gbit/s transmission (2.5 Gbit/s ∞ 8 λ)

• IP over Photonic



End-to-End node cost ratio
"IP over photonic" to "IP over WDM"



Photonic Network with Intelligence

★ **Plug-&-Play**
- Self-Recognition of Topology, Resource and Neighbors
- Operation Cost Reduction

★ **One Click Prompt Service Provisioning**
- Operation Cost Reduction
- Enhanced Service Quality

★ **Simple Transmission Layer (Core Network with Optical Nodes Employing Wavelength Routing), and Separation of Transport and Service Operation**
- Operation Cost Reduction
- Node Cost Reduction

★ **Mesh-like Network based on Distributed Control**
- Network Flexibility Enhancement
- Efficient Network Resource Utilization

Node Systems Controlled with GMPLS

PSC: Packet-Switch Capable; MPLS Router

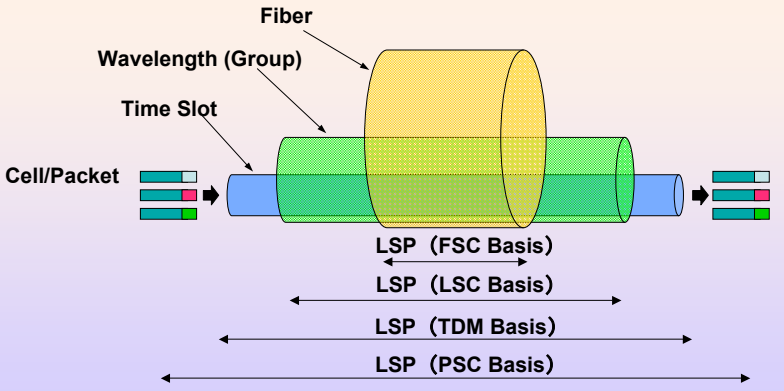
L2SC: Layer2-Switch Capable; GbE-SW, ATM-SW FR-SW, MAPOS-SW

TDM: Time-Division Multiplex Capable; SDH(VC)-XC

LSC: Lambda-Switch Capable; OXC(PXC)

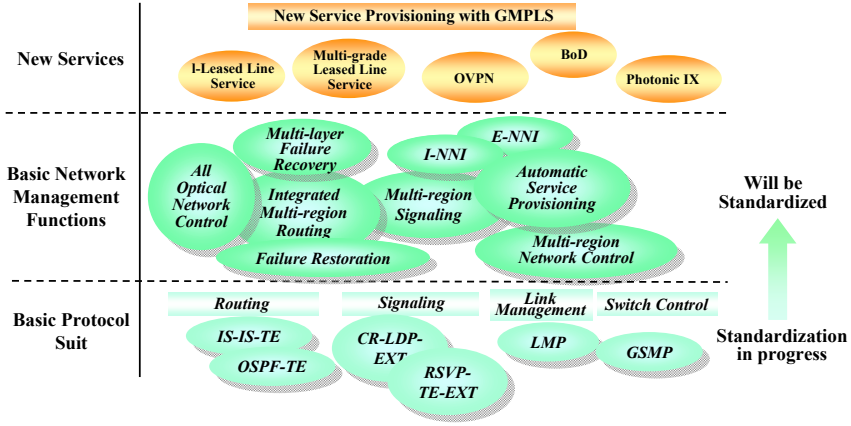
FSC: Fiber-Switch Capable

LSP Hierarchy

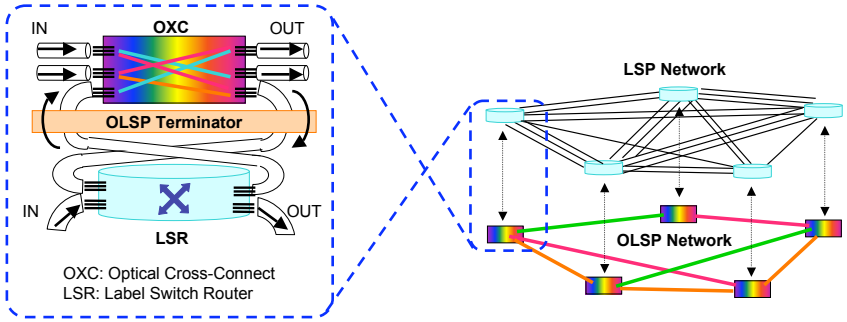


FSC: Fiber Switch Capable, LSC: Lambda Switch Capable,
TDM: Time Division Multiplex Capable, PSC: Packet Switch Capable
Each Node Is Treated As an MPLS Label-switching Router (LSR).

Progress in GMPLS Protocol Development



Photonic IP Network



Optical level routing (optical path): via OXC
Electrical level routing (packet): via LSR

Network Design Procedure -Step-1-

Input:

Physical network topology

LSP traffic demand

Parameter:

OLSP set-up criteria (policy)

Node/link cost etc.

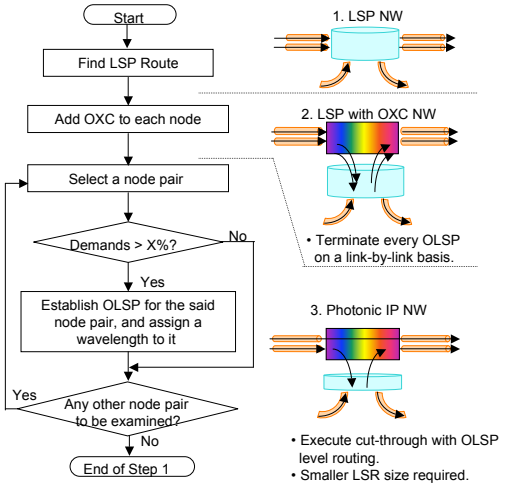
Output:

Total network cost

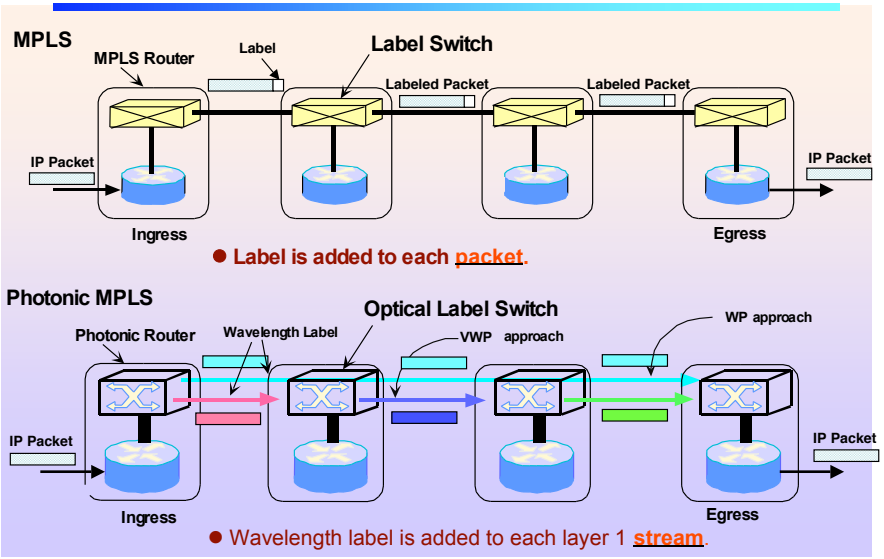
LSP routes

OLSP routes

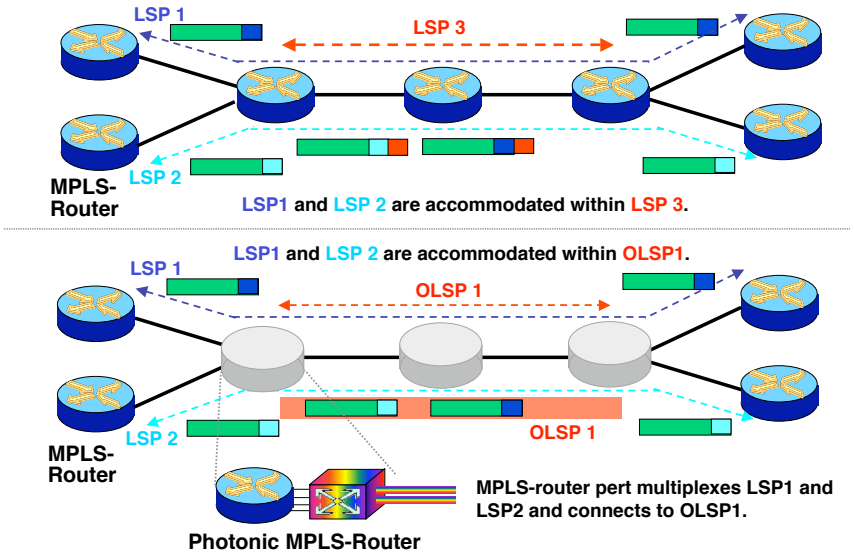
OLSP wavelengths



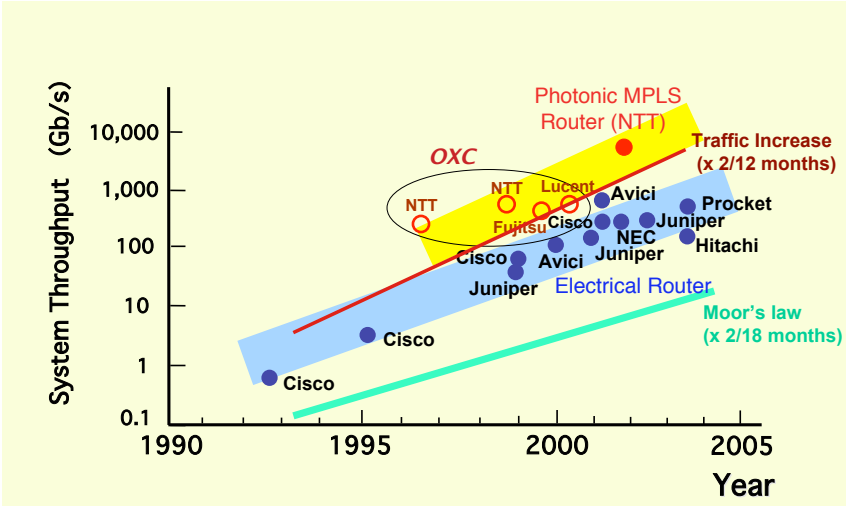
MPLS and Photonic MPLS



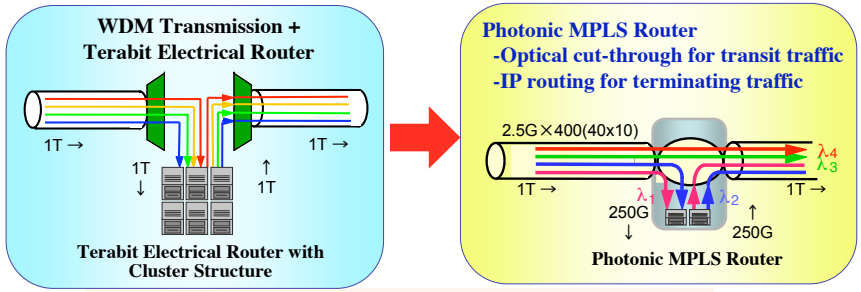
MPLS and Photonic MPLS

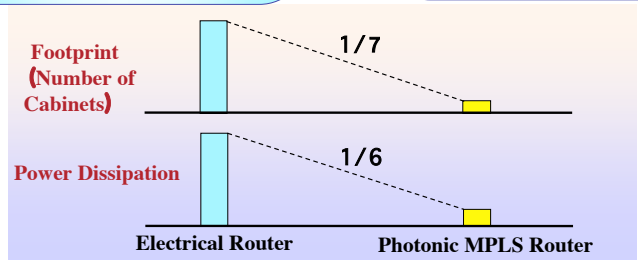


Progress of Router Throughput



Benefit of Photonic Network

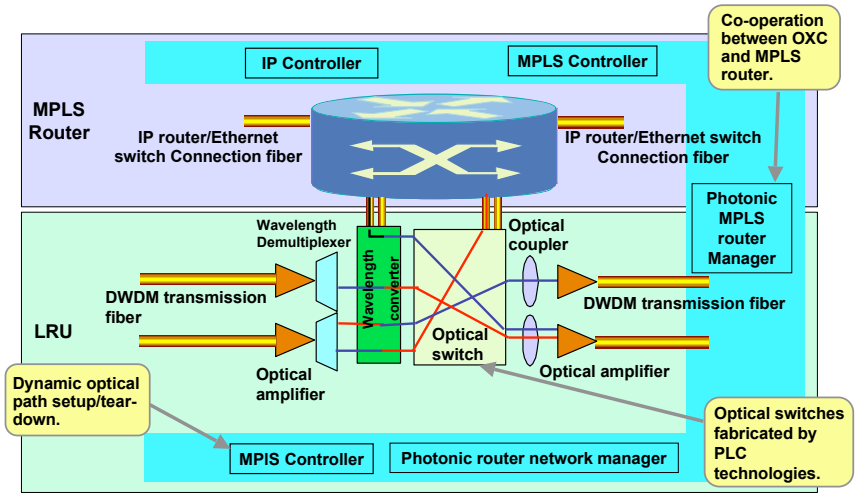




Comparison of Electrical MPLS and Photonic MPLS

	Electrical MPLS	Photonic MPLS
Path	Label Switched Path (Label is attached to each packet)	Optical Path (Label is attached to data stream)
Path State	Soft	Hard
# of Paths/Link	Can be very large (2^{20}=1,048,576)	Limited (< 1,000)
Path Bandwidth	Any	Usually fixed and large (Gb/s)
Label Swapping	Yes	Yes (with wavelength conversion) No (without wavelength conversion)
Label Merge	Yes	Difficult
Label Stack	Yes	Difficult
Hit-less Route Change	Yes (Make-before-break)	No (possible only at electrical level)

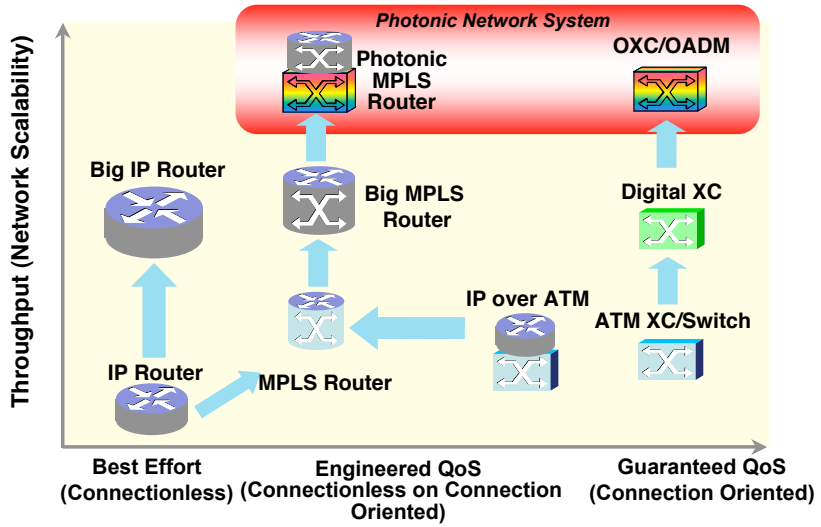
Configuration of Photonic MPLS Router



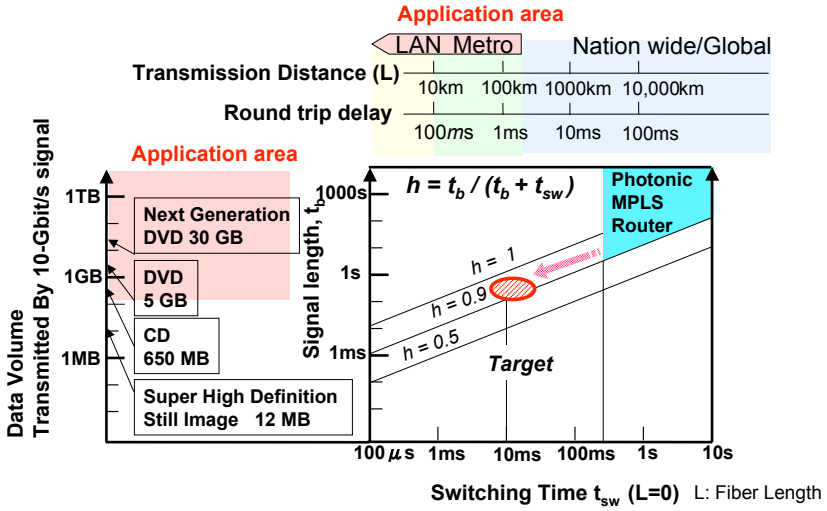
Outlook and Specifications of Photonic MPLS Router

Item	*Specifications*
Throughput	More than 5Gpps (Obtained with wavelength routing and MPLS router)
System throughput	Maximum 2.56 Tbit/s
UNI	POS, ATM, GEther, etc.
Optical switch architecture	Delivery and coupling type
Optical switch	Planar Lightwave Circuit (PLC) thermo-optical switch
Wavelength band	1550 nm band (C-band)
Optical channel speed	2.5 Gbit/s (up gradable to 10 Gbit/s)
Number of wavelengths	32 per fiber
Number of fiber ports	8 input /output pairs (fiber port can be added one by one)
Total switch scale	256 x 256 channels
Scalability	The number of available optical channels is expandable up to 256, with 8 wavelengths' modularity (each switch module accommodates 8 wavelengths.)
MPLS router scalability	Maximum number of available POS interface is 128. Consists of one to twenty MPLS routers.

Network node system and QoS.



Switching time design target & application area

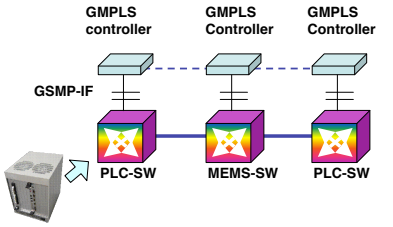


A. Sahara et al, ECOC 2004, Th2.6.6 , Sep. 2004

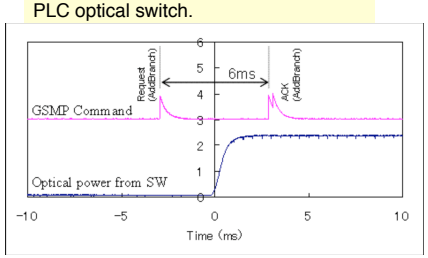
Fast switching technology using GSMP

GSMP(General Switch Management Protocol)
•Protocol for node control in photonic networks.
•PLC switch achieves fast switching of less than 6 ms.

The benefit of GSMP
A network constructed by various switches can be controlled.

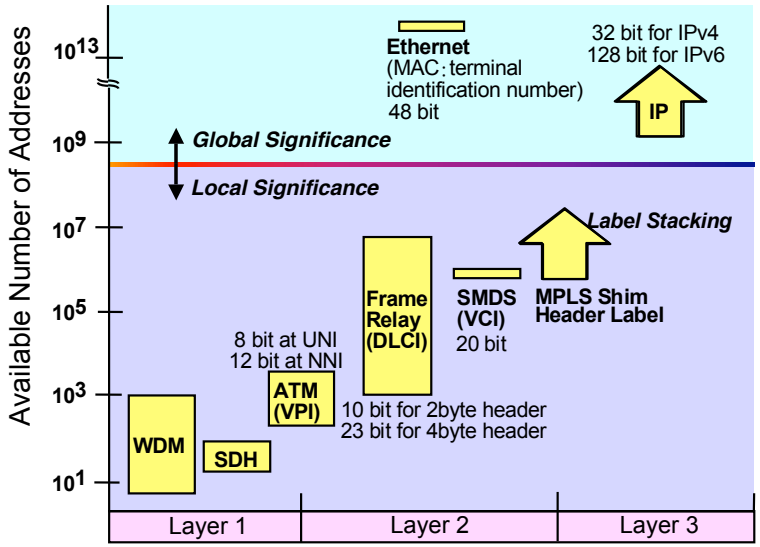


Response of optical switch controller with GSMP
SW setup time (< 6ms) is achieved in PLC optical switch.

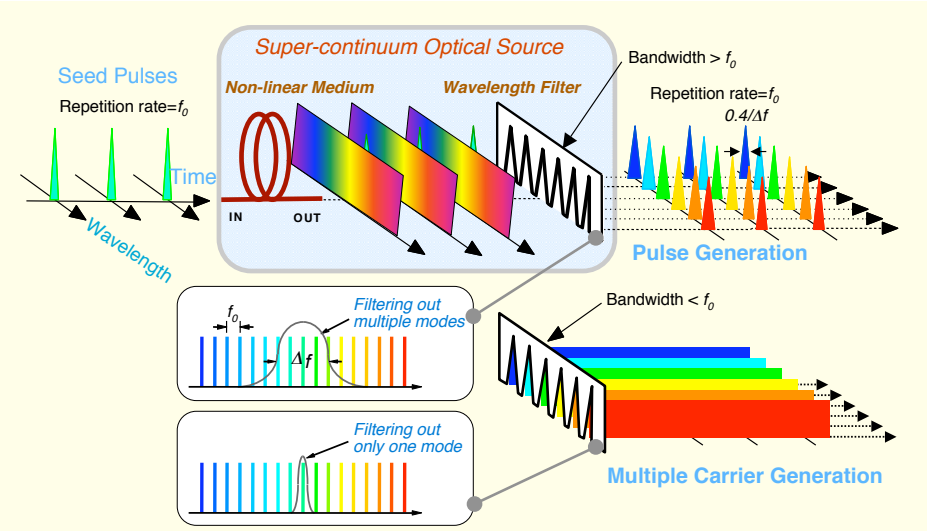


A. Sahara et al, ECOC 2004, Th2.6.6 , Sep. 2004

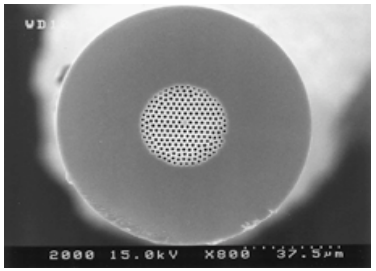
Addressing Space

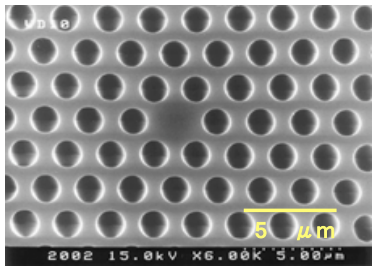


Multi-wavelength Pulse and CW Light Generation with SC Optical Source

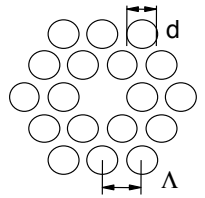


Photonic Crystal Structure Fiber





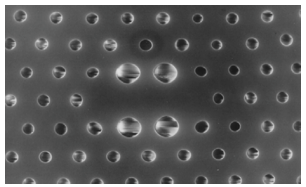
Optical Loss=3.2dB/km@1.55μm
Zero Dispersion Wavelength=0.81μm



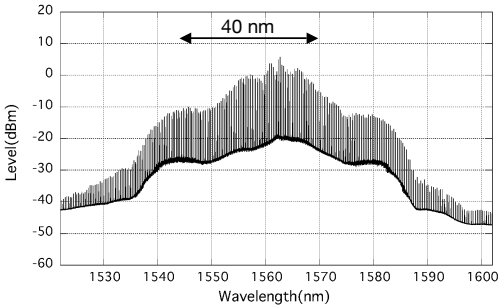
d = 1.5 μm
Λ = 2.3 μm

Kubota et al (NTT), CLEO 01 PD, CPD3

Supercontinuum optical carrier generation with PCF

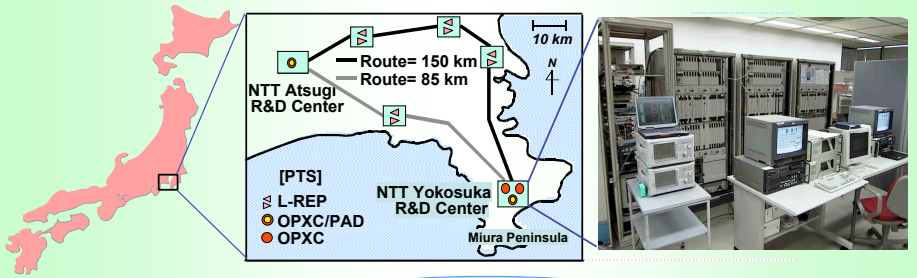


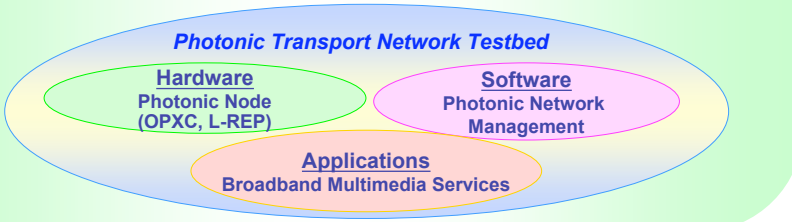
Micrograph of PM-PCF



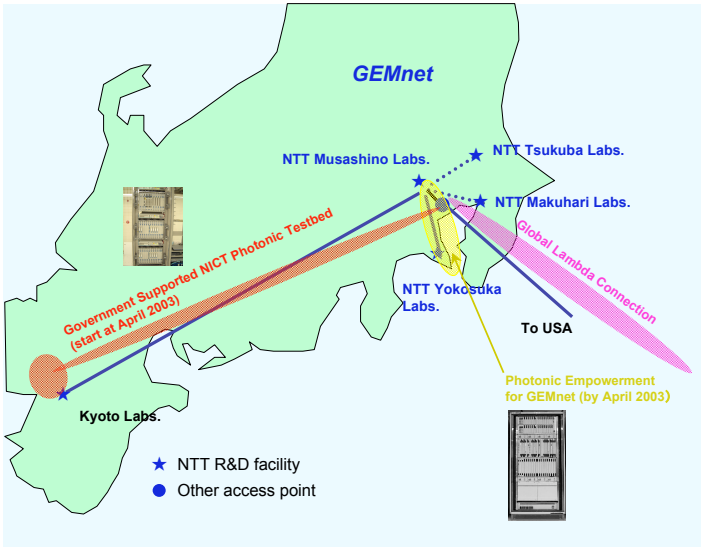
SC spectra generated with PM-PCF

Photonic Transport Network Testbed (1999-2002)





Photonic Testbed Experiments in Japan



光トランスポートシステム（武蔵野・横須賀接続に適用）