Optical Communications as a Social Infrastructure and its Enabling Technologies

22 September 2008

Hideo Kuwahara
FUJITSU LABORATORIES LTD.

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1. Introduction
2. Optical communications as a social infrastructure
3. Energy issues and opt. comm.
4. Technologies supporting opt. comm.
5. Summary

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Traffic Explosion

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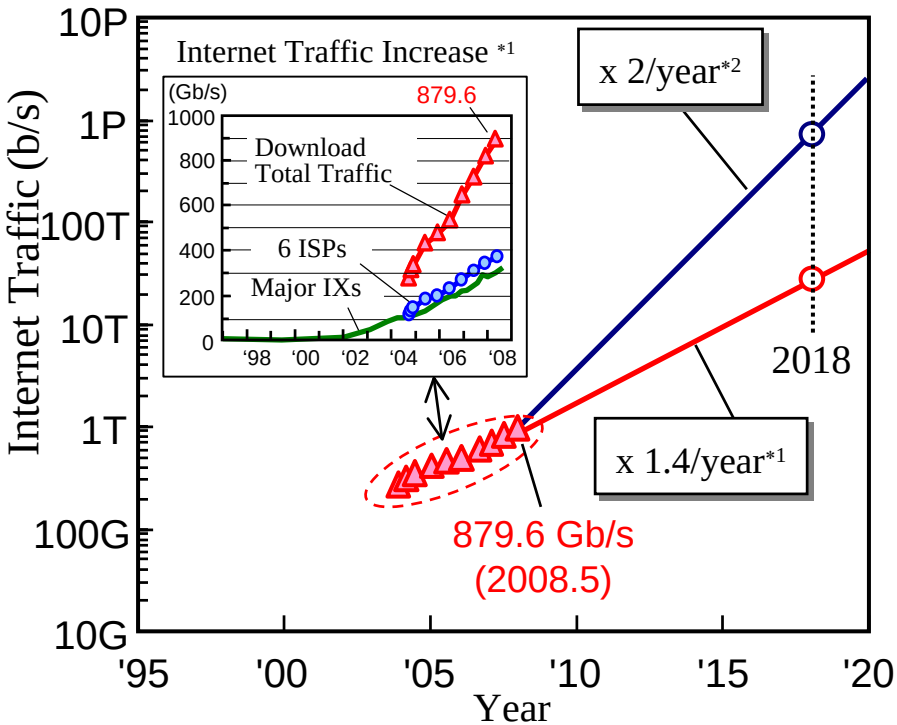
- Traffic Increase (in Japan)



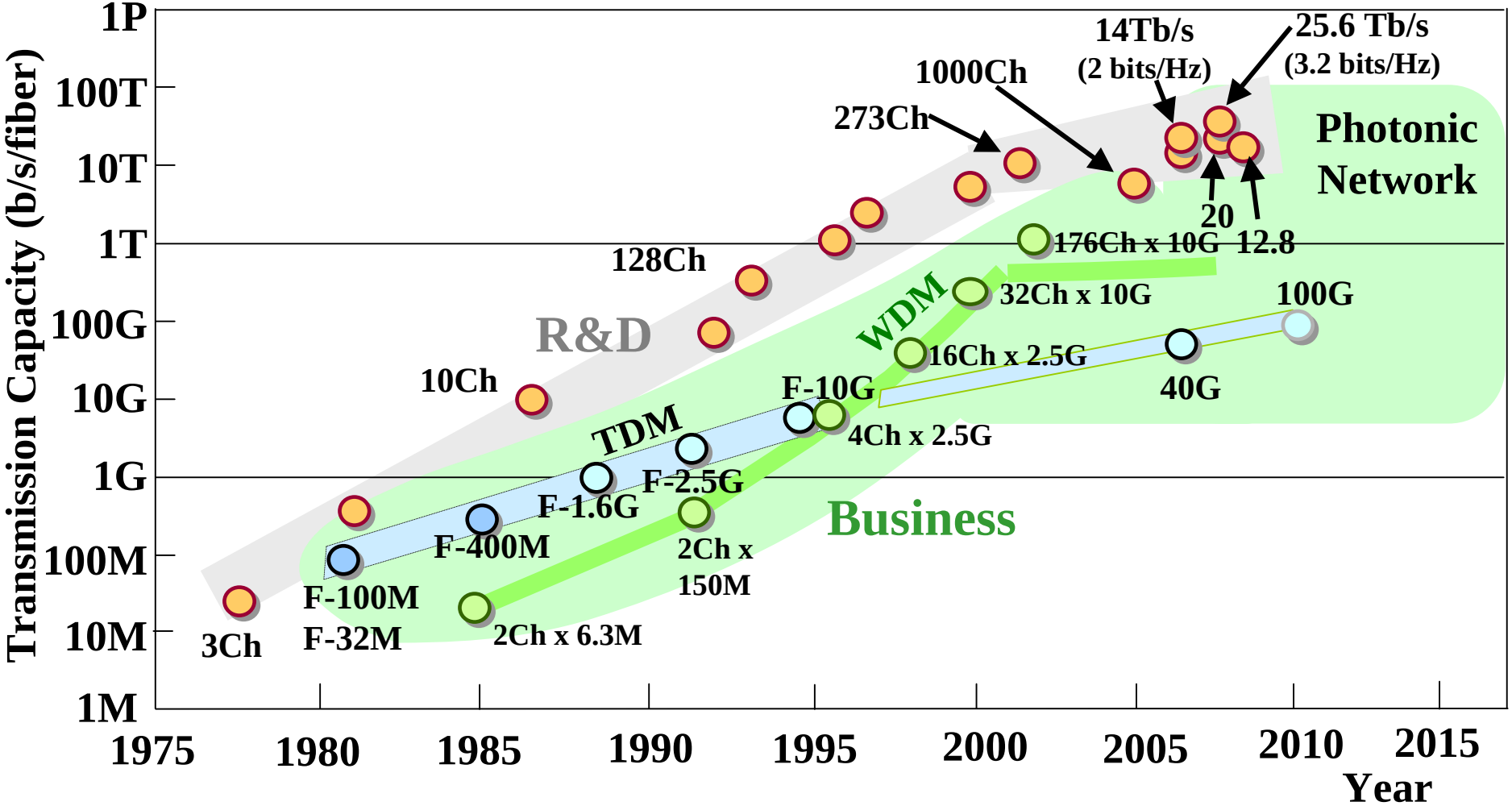
∗1 MIC, 2008.8.29
∗2 "New Gen Network Architecture" (AKARI), MIC(NICT)

- Estimated Network Size in 10 years (in Japan)

- **Traffic Capacity:**
  0.8 Tb/s → 30 - 800 Tb/s
- **Backbone:**
  10 Gb/s → 300 Gb/s - 10 Tb/s
- **Access:**
  10 Mb/s → 0.3 - 10 Gb/s
- **Power Consumption of Routers (Ratio to total E power plant):**
  0.6 % → 18 %

- This traffic explosion, enabled by the optical communication,
  - Supports our infrastructure and our social life.
  - Consumes, however, enormous amounts of energy, and contributes to global warming.
  - Must be supported by development of new technologies.

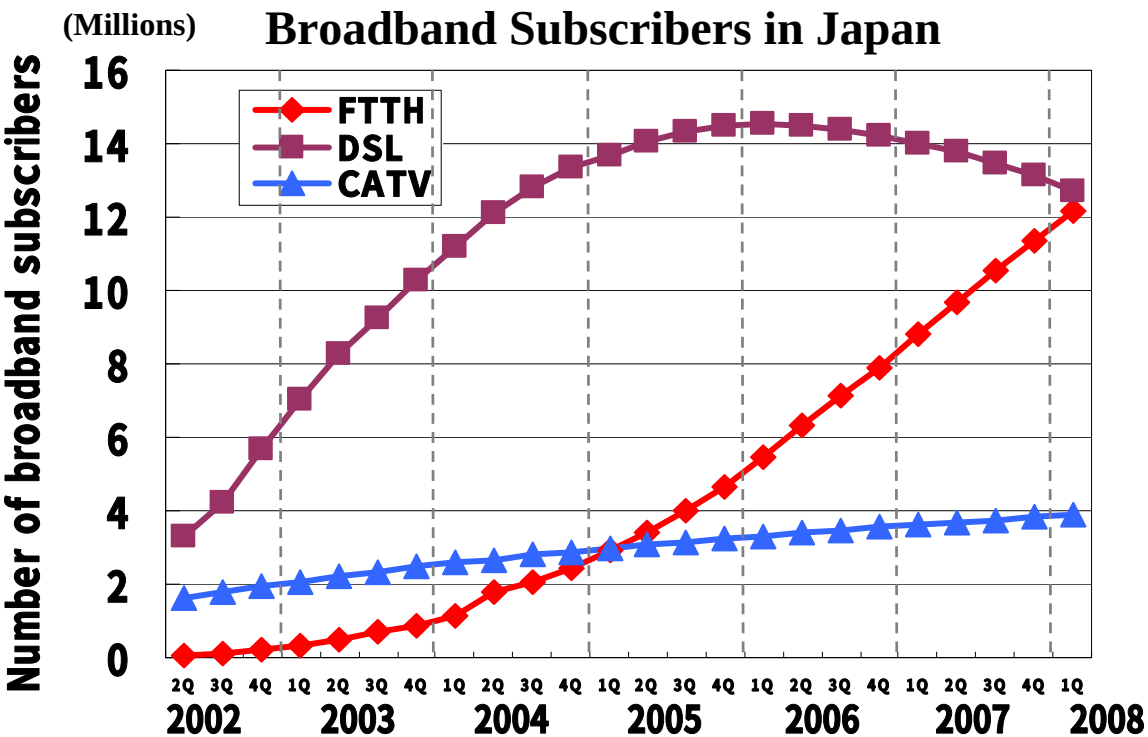
Challenge for Capacity

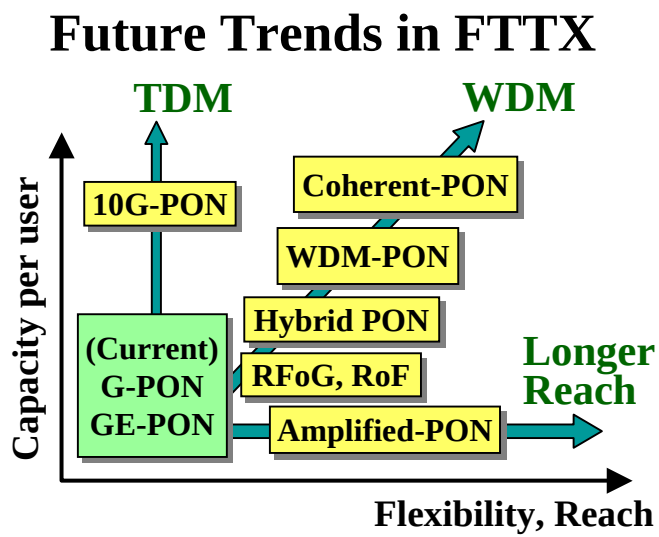


(Source: Revised data from MIC and Prof. Miki, Univ. of Electro-Comms.)

Broadband Access Penetration

- FTTH become the major broadband access means in Japan, exceeding DSL.
- FTTH is becoming FTEH (Fiber To Every Home!)
- Emerging applications: contents delivery services such as IPTV and VoD, and in the future, UDTV and 3D TV.

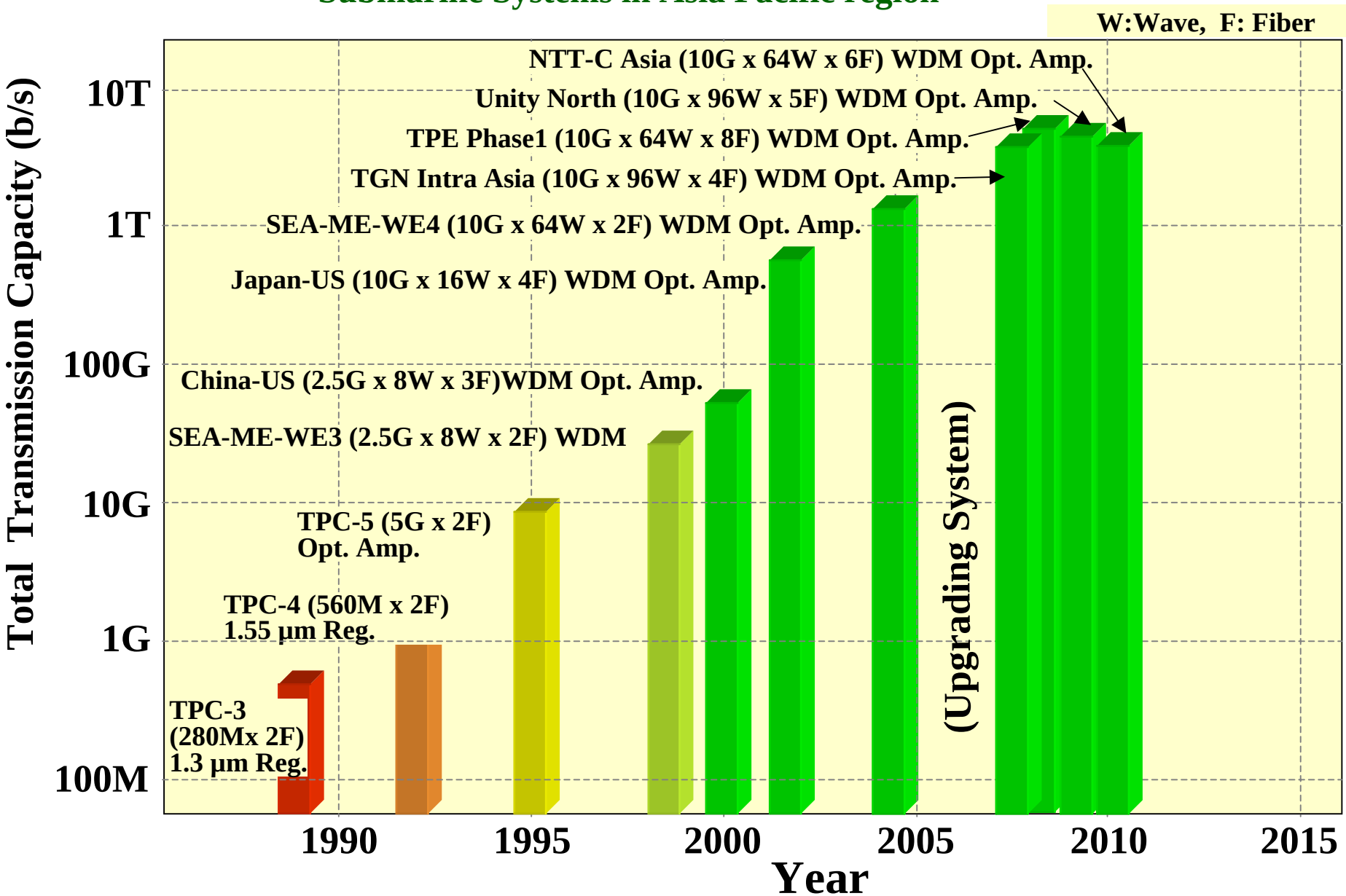




[Source: MIC (Ministry of Internal Affairs and Communications, Japan)
and http://www.johotsusintokei.soumu.go.jp/new/index.html]

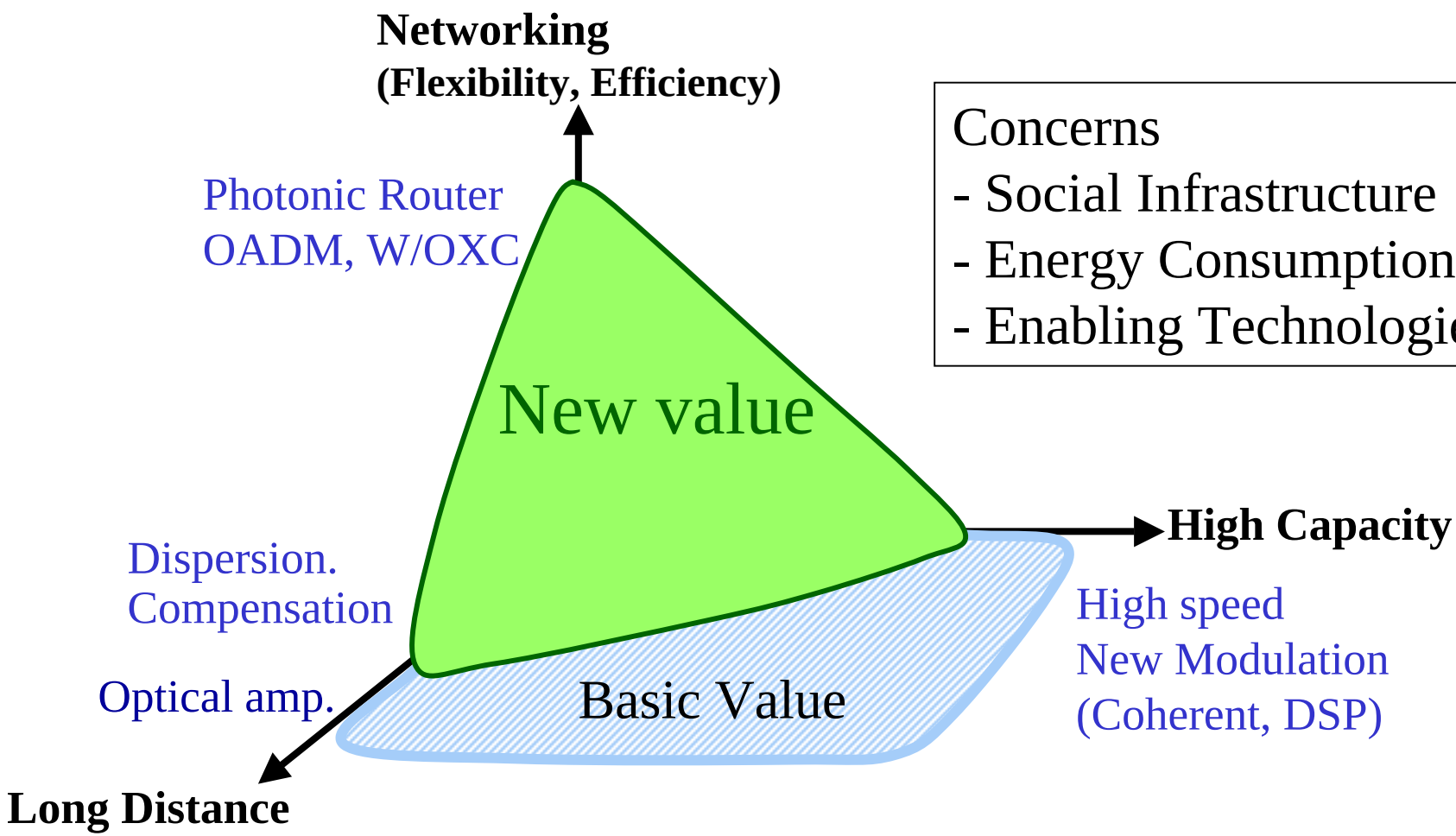
Rapid Increase of International Traffic

- Submarine Systems in Asia Pacific region -



Evolution from Optical Transport to Networking

- From "Distance and High-Capacity" to "Flexible and Efficient Networking" which generates new values -



Concerns
- Social Infrastructure
- Energy Consumption
- Enabling Technologies

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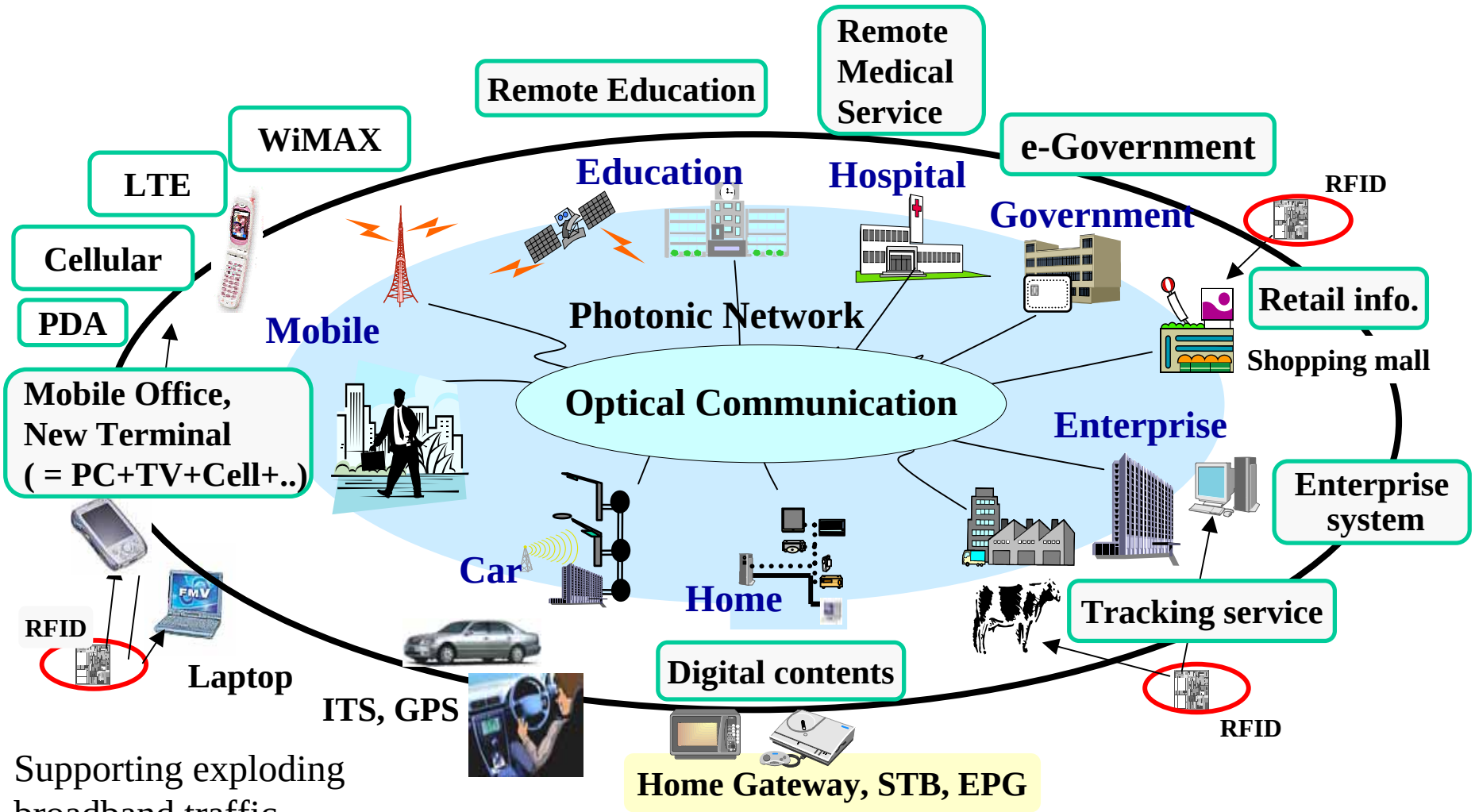
Optical Comm. is Supporting Social Infrastructure



Supporting exploding broadband traffic, including wireless backhaul

- Abundant network capacity is not cost free.
- Similar to precious natural resources like air and water

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Market Trends in NXTcomm2008

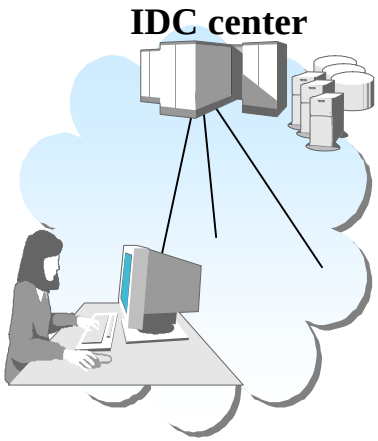
(held in Las Vegas, NV in June, 2008)

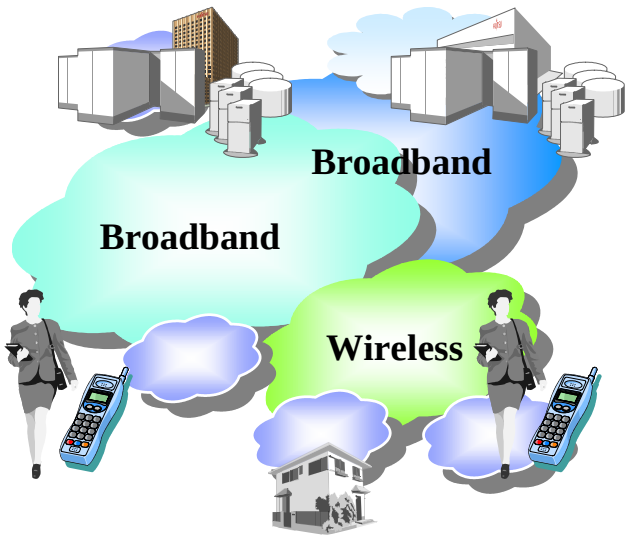
- Market is moving toward **IPTV**, **VoD** services.
  - Though the definition and likely business models are still under discussion, they are the killer applications for optical communication.
- **Home Networking** is another big theme.
- "With the penetration of broadband, the **HD video** can be seen at any time in your home. In the future everything will be **streaming**." (Telstra)
- TV is changing, and it is said that "**Current TV is like the PC in the 80s.**"
- **Convergence** is another big trend. (FMC, with broadcast...)
- **100Gb/s activity:** several alliance and group activities are seen, commercial deployment unclear.

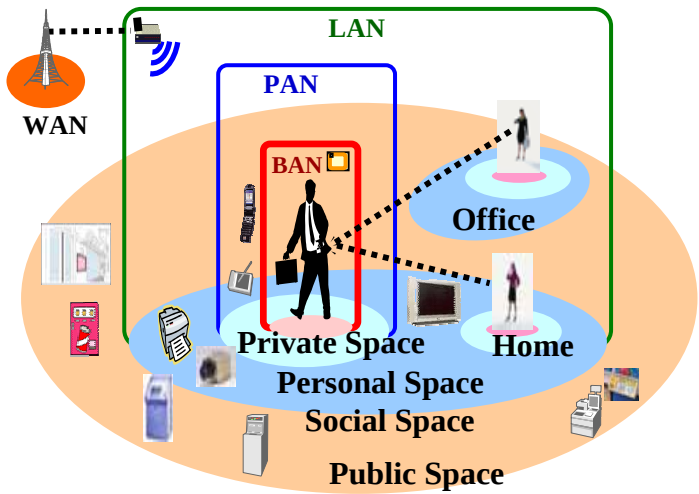
Paradigm Shift in ICT and the effects to Social Life

- From an social infrastructure to “user/human centric” one

From	Now	To
Computer centric	Network centric	User centric (Security & Privacy)
Expert can use	Everybody can use	Dependable (Resilient & Flexible)
Data Processing	Info. Retrieval/Collection	Knowledge creation (Service Provisioning/Creation)







→ New Values

New values are connected to solutions to our major social concerns

New Values

- **User Centric**
  - Adaptively provided services
  - User can access everything.
  - Comfortable services
- **Dependable**
  - Non-stop operation
  - High security/credibility
  - Sustainable development
- **Knowledge Creation**
  - Converting user centric knowledge

Social concerns

- Competitiveness : effective investment & operation
- Aging society
- Environment issues
- Securing food safely
- Realizing safer social life
- Comfortableness, Convenience
- “Digital Divide”
- Collecting knowledge and wisdom from the world

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Impact of Optical Comm. on Social life

- Increasing with the performance of opt communication.
- The traffic explosion includes services like personal video exchange. The business model of BB services is still under discussion.
- Monitoring and controlling signal condition will be necessary to ensure QoS of network and business model.

- Optical comm. is not only the **infrastructure,** but is also opening the door to **new paradigm**, and is creating **new industries**.
- There is no other alternative technology to process that amount of information traffic.
- We are responsible and must be **more aware** of the big impact of our technology on social life.

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Environment and Energy

- **December, 1997 at Kyoto, Japan (Kyoto Protocol)**
  Reducing greenhouse gas (GHG) emissions: - 5% against 1990 level by 2012.

- **June, 2007 G8 Summit at Heiligendamm, Germany**
  "Emissions to be halved by the middle of the century."

- **July 2008 G8 Summit at Toyako, Japan**
  Communiqué says, "We seek to share with all Parties .....
  .....the goal of achieving at least 50% reduction of global emissions by 2050, ...
  and will depend on the development and deployment of low-carbon technologies.

An Estimation of CO_2 Emissions Reduction by ICT in Japan

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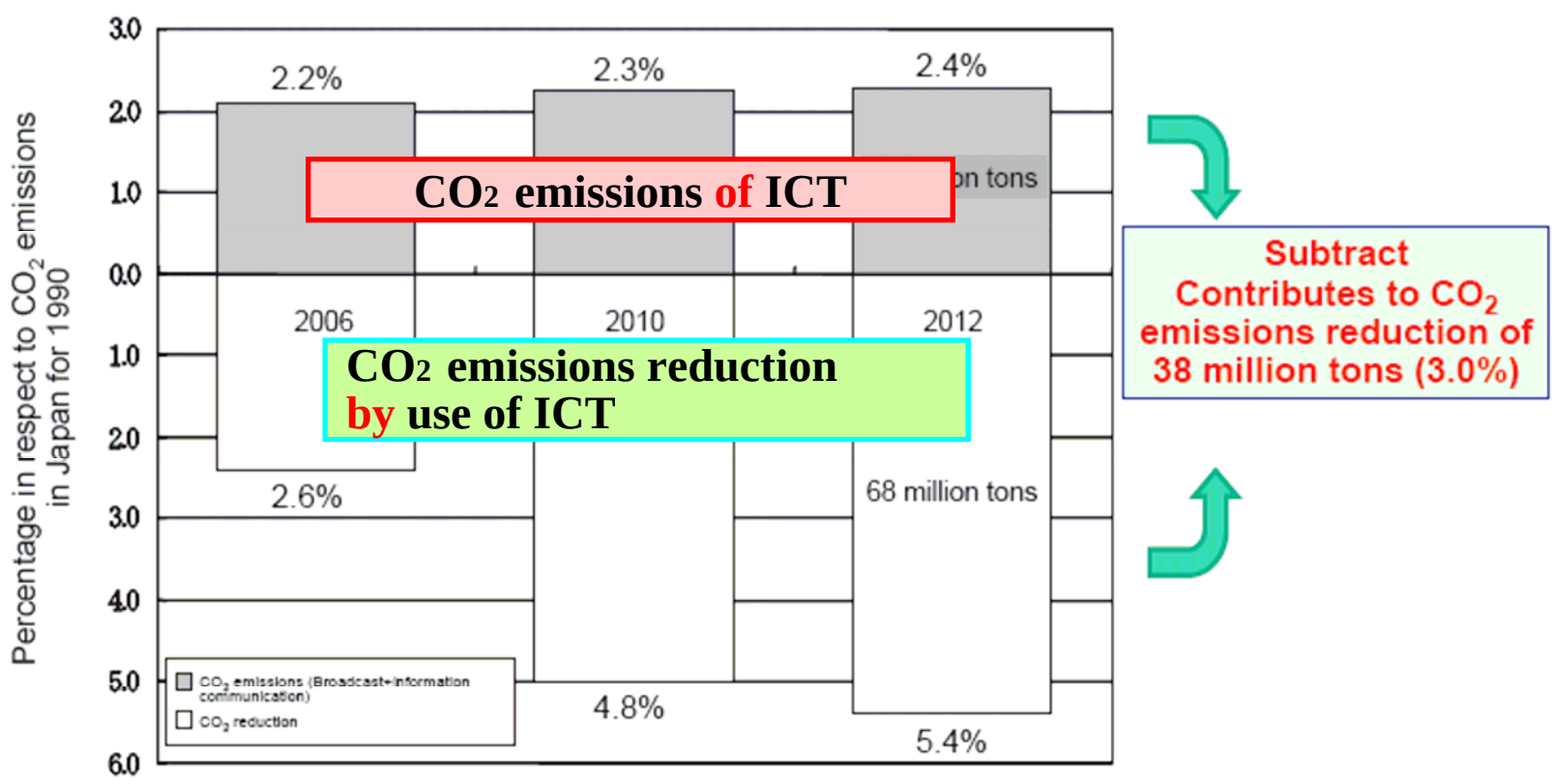
◆ Estimation Result



◆ Method of Estimation

CO_2 emissions reduction = **CO_2 emissions reduction by use of ICT** - **CO_2 emissions of ICT**

[Source: MIC, at ITU Symposium on ICTs and Climate Change, Kyoto, April 15-16,2008]

New Group in ITU to focus on the impact of ICT and climate change

Press Release

International Telecommunication Union

For immediate release

Telephone: +41 22 730 6039
Telefax: +41 22 730 5933
E-mail: pressinfo

ITU responds to industry call to accelerate work on cleaner and greener environment

New group to focus on the impact of ICT and climate change

Geneva, 11 July 2008 — Responding to an industry call, ITU has set up a new group to work on standards related to the impact of information and communication technologies (ICT) on climate change. The new group will focus in particular on the reduction of ICT emissions and how ICTs can assist in cutting emissions in other industry sectors such as energy, transportation and buildings.

Since the adoption of the Kyoto Protocol, in December 1997, the number of ICT users has tripled worldwide. It is estimated that the ICT sector produces between two to three per cent of global greenhouse gas emissions. But ICTs are also seen as a part of the solution to the climate change challenge.

ICTs could help cut global emissions by between 15 to 40 per cent, depending on the methodology used to make these estimates. Two recent ITU symposia on ICTs and climate change in Kyoto in April and in London in

(http://www.itu.int/newsroom/press_releases/2008/20.html)

Energy Efficiency of Telecom Equipment

An example in Alliance for Telecommunications Industry Solutions

(http://www.atis.org/0050/tee.asp)

- Actual discussion for lowering power consumption has already been started.

- Fujitsu is actively engaged with the group and driving the creation of the new standard.

Exploding Network Traffic and Power Issue

[Source: Report on Optical Technology Roadmap 2007FY-001-1 (written in Japanese) from OITDA (Optoelectronics Industry and Technology Development Association)]

- Traffic will increase up to 1000 times by 2030. (assuming AGR 40%)

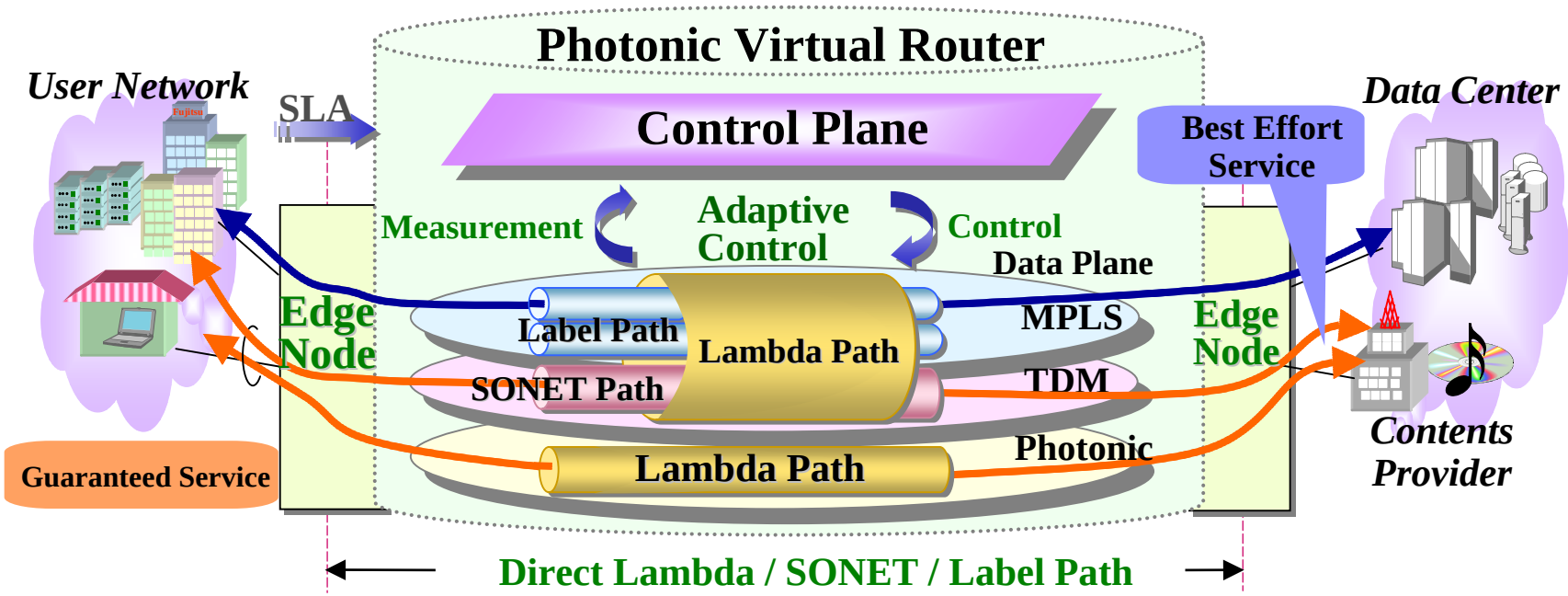
- Use of current technology would increase the power consumption by 1000 times. The challenge should be developing enabling technologies to carry 1000 times the traffic at the same power consumption, or reducing the power per bit by **1/1000**.

- Some strategies and approaches:

  - Decrease **1/10 by network control**
    (by monitoring, bypassing, tariff, suppressing spam mails, etc.)
  - Decrease **1/10 by semiconductor technologies**
    (by pursuing further the Moore's Law and More than Moore...)
  - Decrease **1/10 by optical technologies**
    (by reducing unnecessary opto/electronic conversion, use of optical cut-through and optical signal processing, etc.)

Photonic Virtual Router

(Our proposal in 2003, Soumiya et al., Photonic Switching 2003)



- Offering various transport plane pipes according to services (Introducing optical switching devices)
- Autonomous and automatic network control using control plane (Detouring, shutting down spam mails, etc.)

We are expecting less power by network and control technologies.

Efforts in Semiconductor Arena

- More Moore (Miniaturization)
  Baseline CMOS
  Post-CMOS, Beyond CMOS
- More than Moore (Diversification)
  Superconductive devices, etc
  SiP; System in Package
- ISSCC and VLSI Symposium are well-known conferences in this area.
- Previously the research was pursuing higher performance, so called Hot Chips. (Cooking Pan ➔ Nuclear Reactor ➔ Sun)
  Recently the discussion is focused how to reduce the power consumption.
- An International conference, called COOLChips, was held in Yokohama, Japan in April, 2008.
- Lower voltage, Multi-core, Power gating approaches, ...

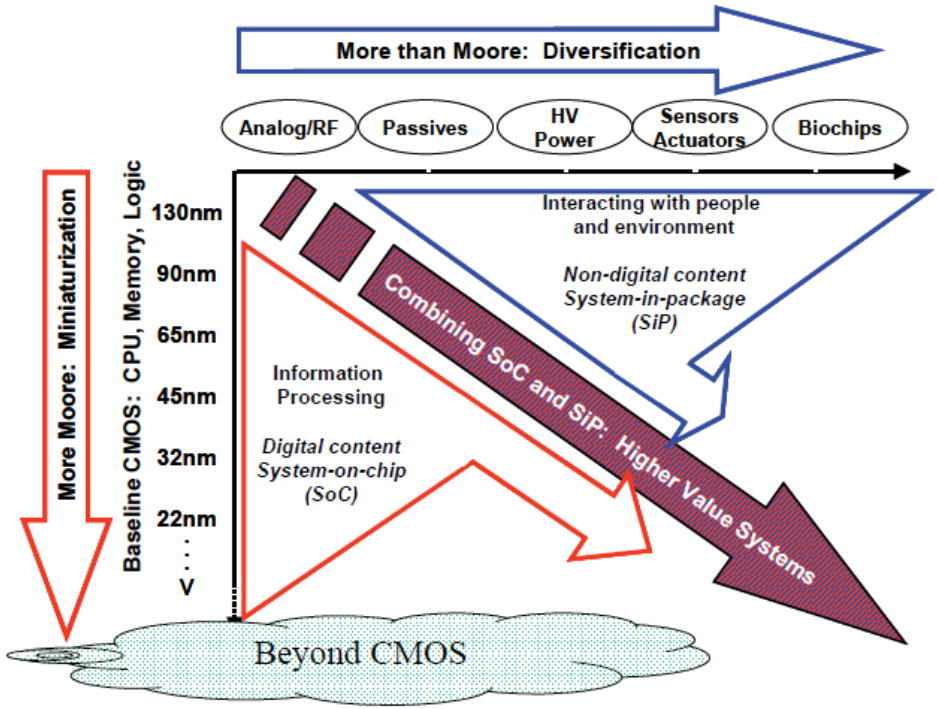


Figure 4 Moore's Law and More

ITRS: International Technology Roadmap for Semiconductors
(http://www.itrs.net/Links/2007ITRS/ExecSum2007.pdf)

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Efforts of Opt. Comm. Technology on Energy Savings

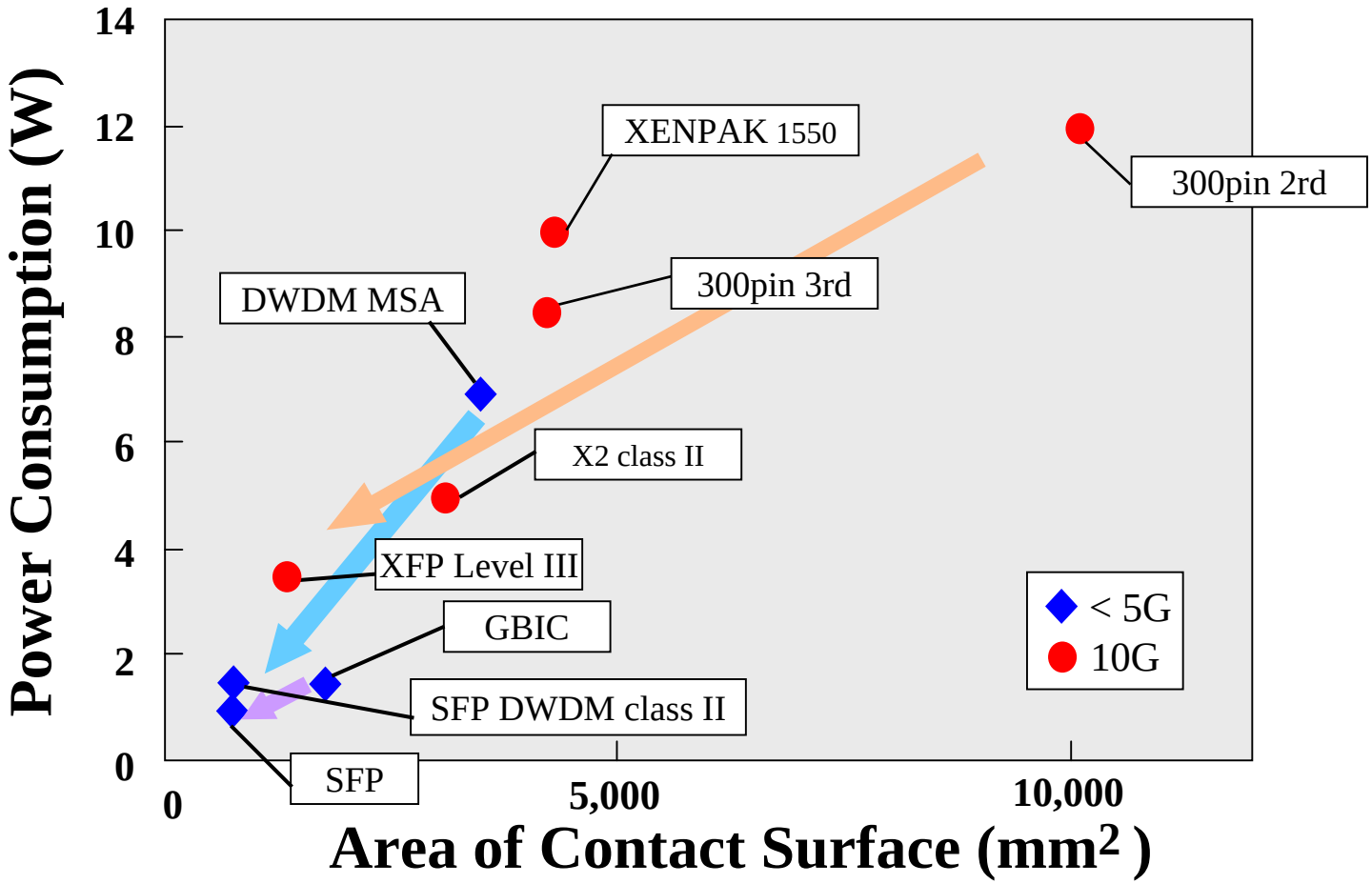
- Opt comm. has already reduced the power consumption required for transporting information.

- Compared with coaxial system, the power consumption of per bit and per distance is reduced to $10^{-4} \sim 10^{-5}$, using low loss fiber, EDFA repeater, etc.

	Coax	Optical Fiber
Repeater spacing;	1.5 - 2 km	80 - 100 km,
Bit rate;	100 - 400 Mb/s	10 Gb/s x WDM

- Possible to continue this efforts of reducing energy consumption by,
  - Convergence of optics and electronics,
  - Flexible routing and cut-through by ROADM, OXC/WXC
  - Optical processing, new materials, etc.

Reduction in Size and Power Consumption in MSA optical module



- Realizing the same function by smaller MSA module and lower power consumption

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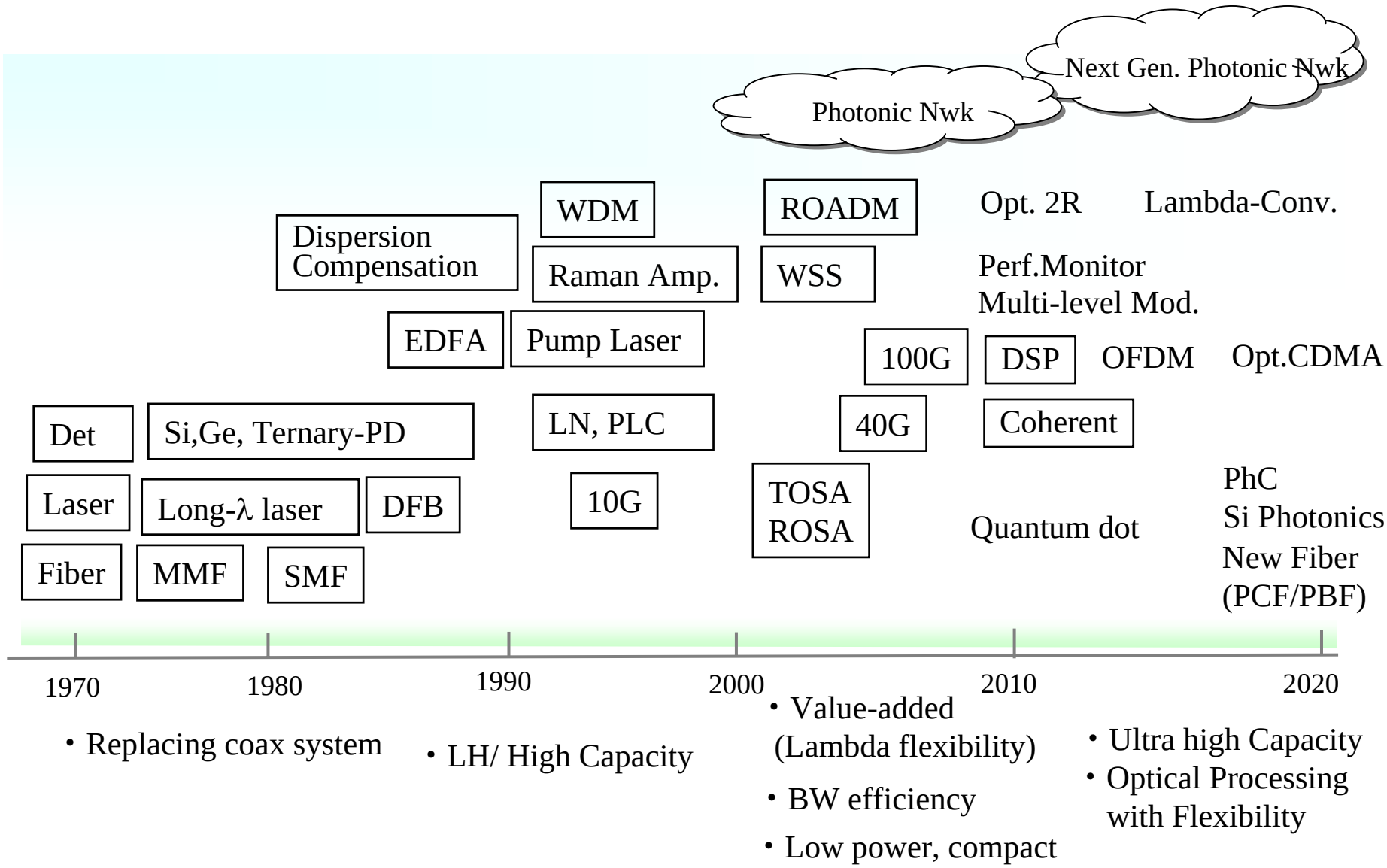
Key Technologies in Optical Communications

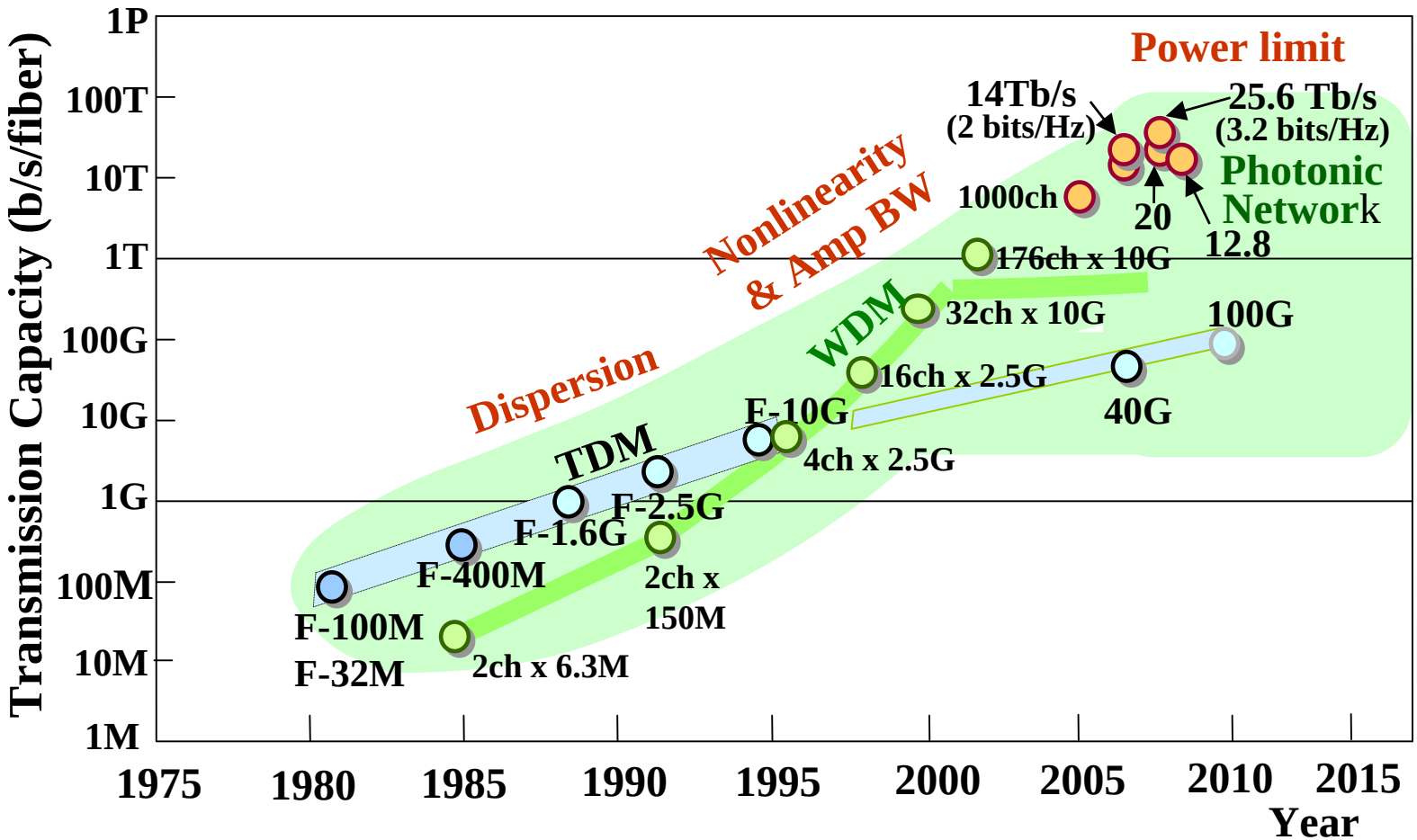


Challenge and Limiting Factors

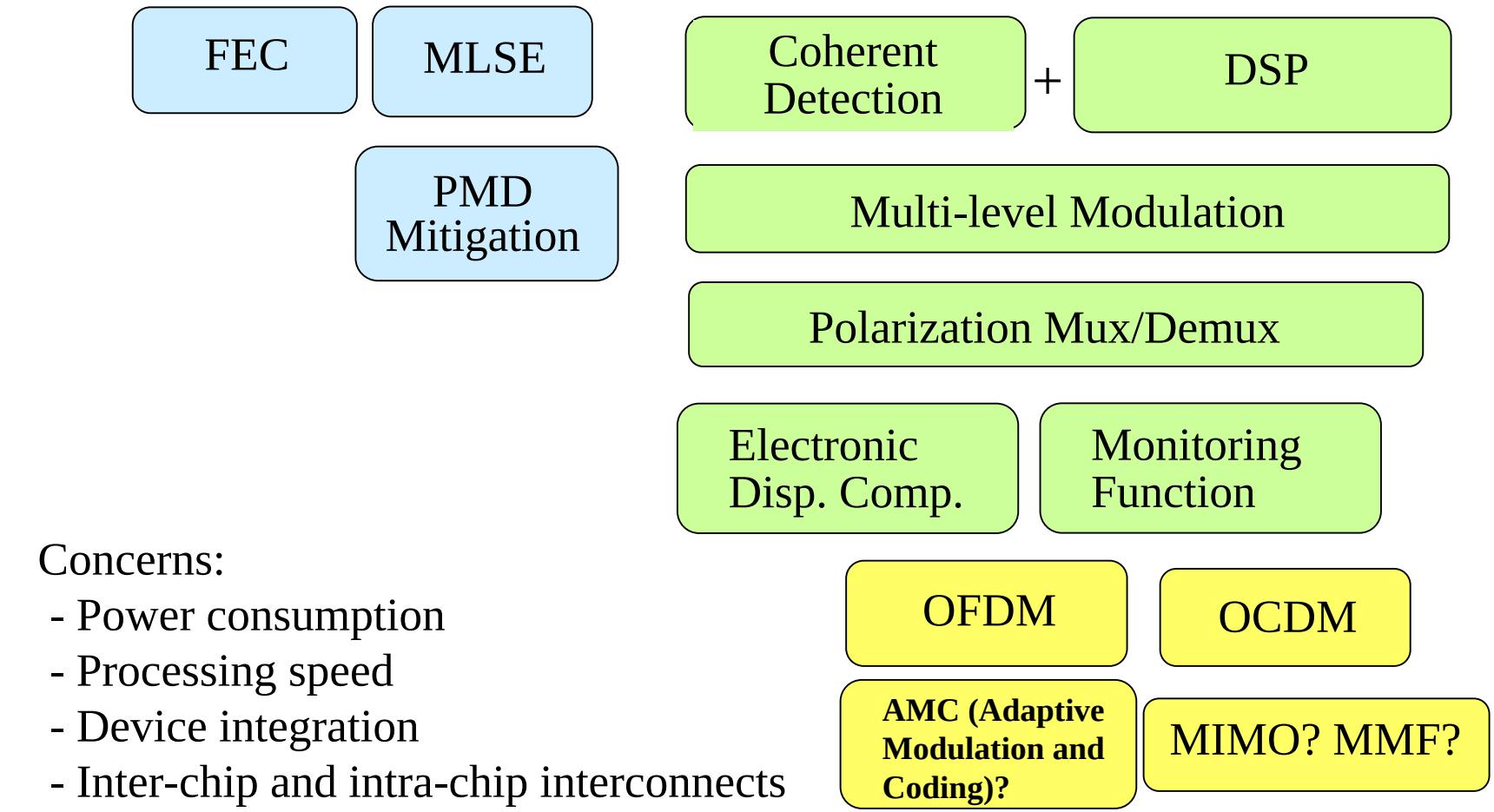
In TDM, dispersion was a big concern. In WDM, nonlinearity is the limiting factor, and amplifier bandwidth may be another one.
Now high optical power density in the fiber is becoming another limiting factor.
(e.g., 1mW x 1000 Lambda = 1 watt in a fiber core ! Dangerous!)

New fiber?
(Low NL fiber)
Large core?
Hollow core?

Multi-level modulation



Processing by Electronics in Optical Comm.



Concerns:
- Power consumption
- Processing speed
- Device integration
- Inter-chip and intra-chip interconnects

Digital Coherent Receiver Benefits

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Module level

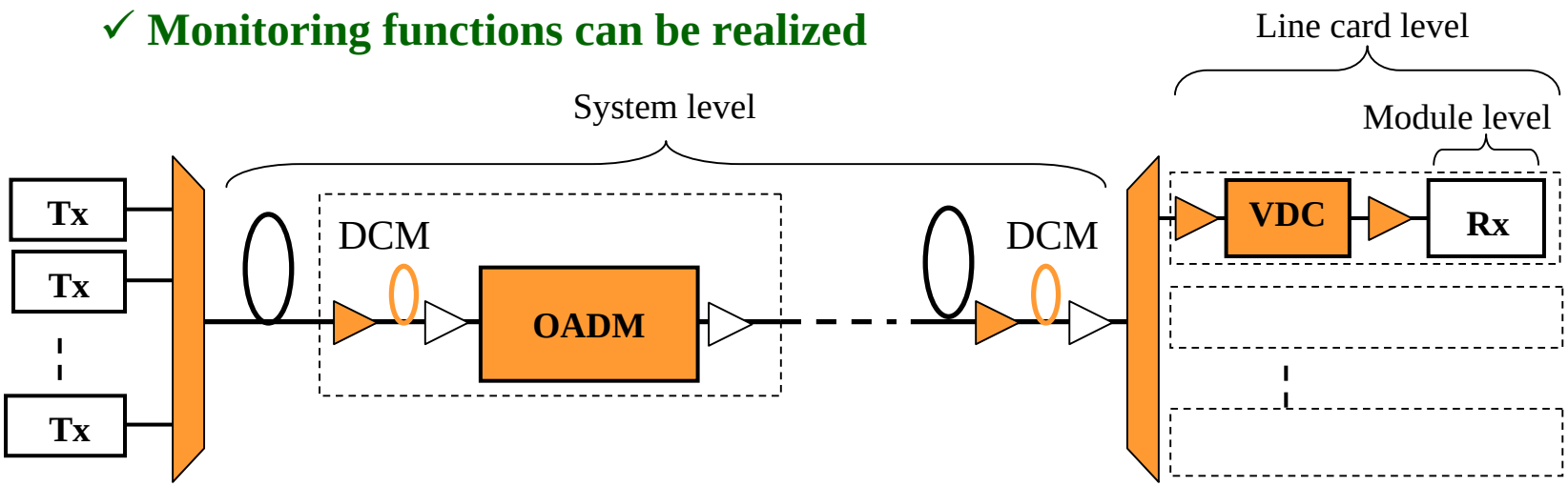
- ✓ Fewer analog parts, and more tolerance to device deviations
- ✓ Higher reliability

Line card level

- ✓ No need for optical variable dispersion compensator
- ✓ Potential to achieve high PMD tolerance

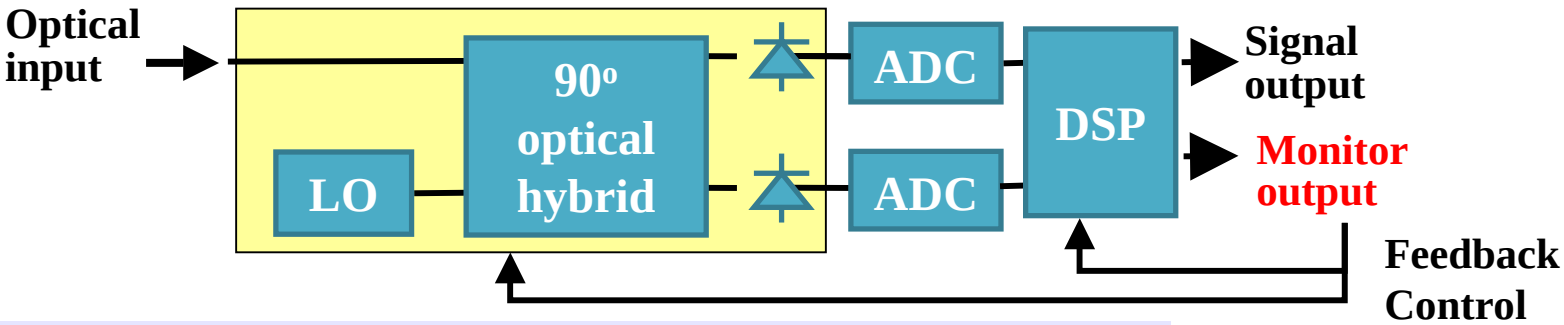
System level

- ✓ Reduce (Eliminate) dispersion compensating modules
- ✓ Enhanced OSNR tolerance
- ✓ Fast dispersion adaptation for quick path provisioning and protection
- ✓ Compensation of intra-channel nonlinear distortion
- ✓ **Monitoring functions can be realized**

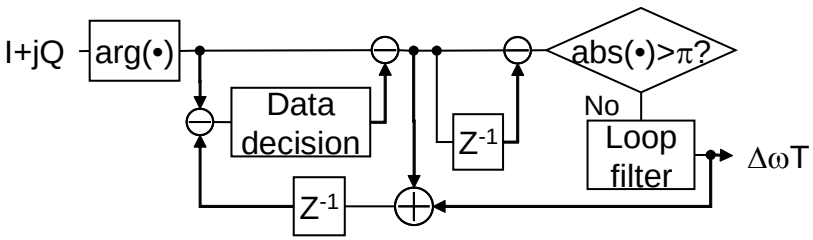


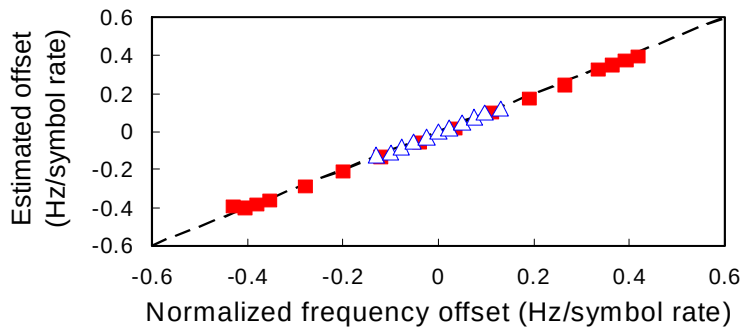
DCM: Dispersion Compensating Module, Tx: Transmitter, Rx: Receiver, OADM: Optical Add/Drop Multiplexer, VDC: Variable Dispersion Compensator

Optical monitoring and control in digital coherent receiver



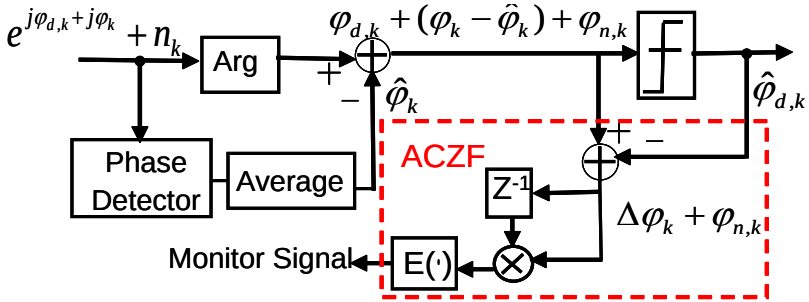
Ex.1) LO frequency offset (Nakashima et al., ECOC2008 Mo3.D.4)

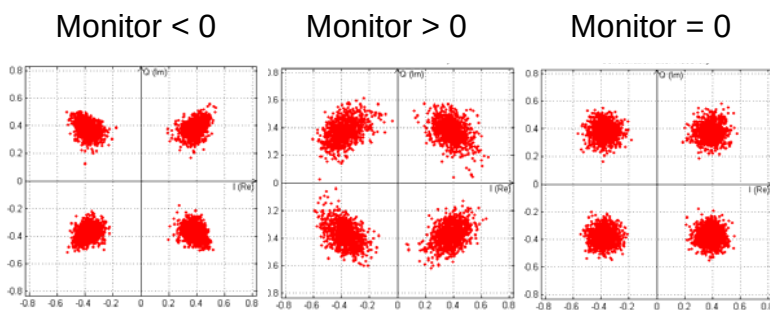




Wide range monitor sufficient for standard LDs

Ex.2) Optimal block size for carrier recovery (Li et al., LEOS Summer Topicals 2008)





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Electronics and Optics

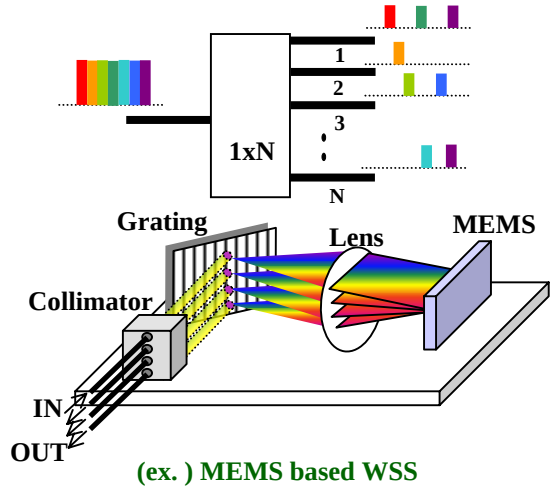
"... So the battle between optics and electronics is going to be fought on several fronts: speed, energy consumption and size. .....

... Electronics still wins when it comes to miniaturization, but optics excels in terms of speed and low energy consumption. ....."

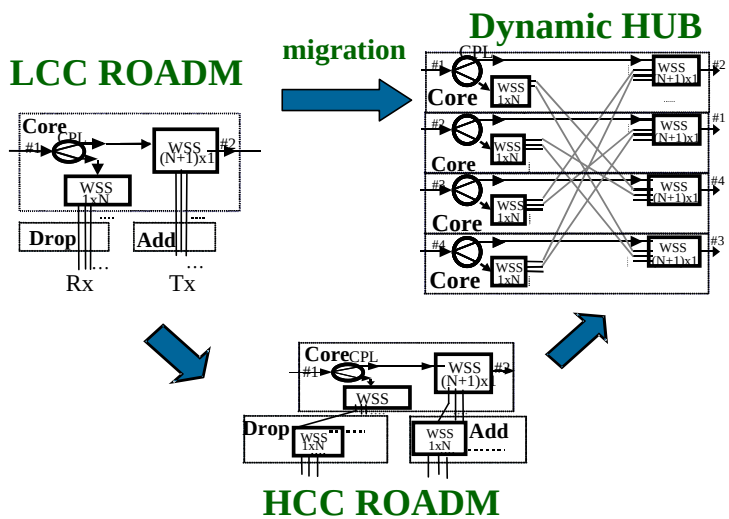
Source:
"THE THINKING PILL and other technology that will change our lives"
by R. van Santen, D.Khoe and B. Vermeer, (Nieuw Amsterdam Uitgevers)

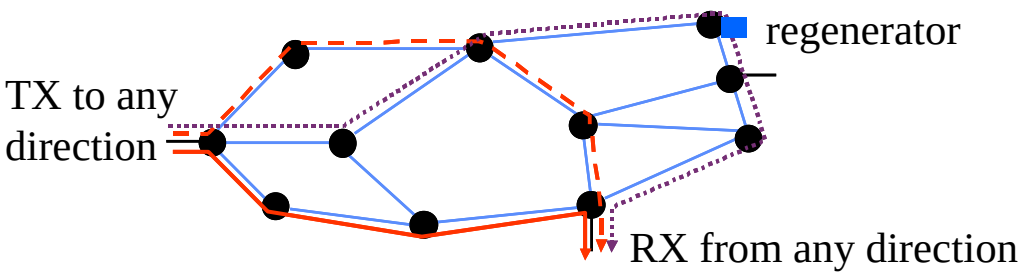
Development of ROADM

- **Reconfigurable, WSS based, scalable**
  - from LCC to HCC in ring to Hub in mesh.
- **Cascadability,** band narrowing
- **Dynamic multi-degree** architecture
  - **Colorless**; add/drop ports are independent of λ.
  - **Directionless**; transmit/receive from/to any add/drop access port to/from any direction
- **Drop and Continue** function (for video distribution)
- **Dense frequency spacing**;
  - From 100GHz, 50, 25, .. and waveband (grouping)
- **Convergence** with higher layers



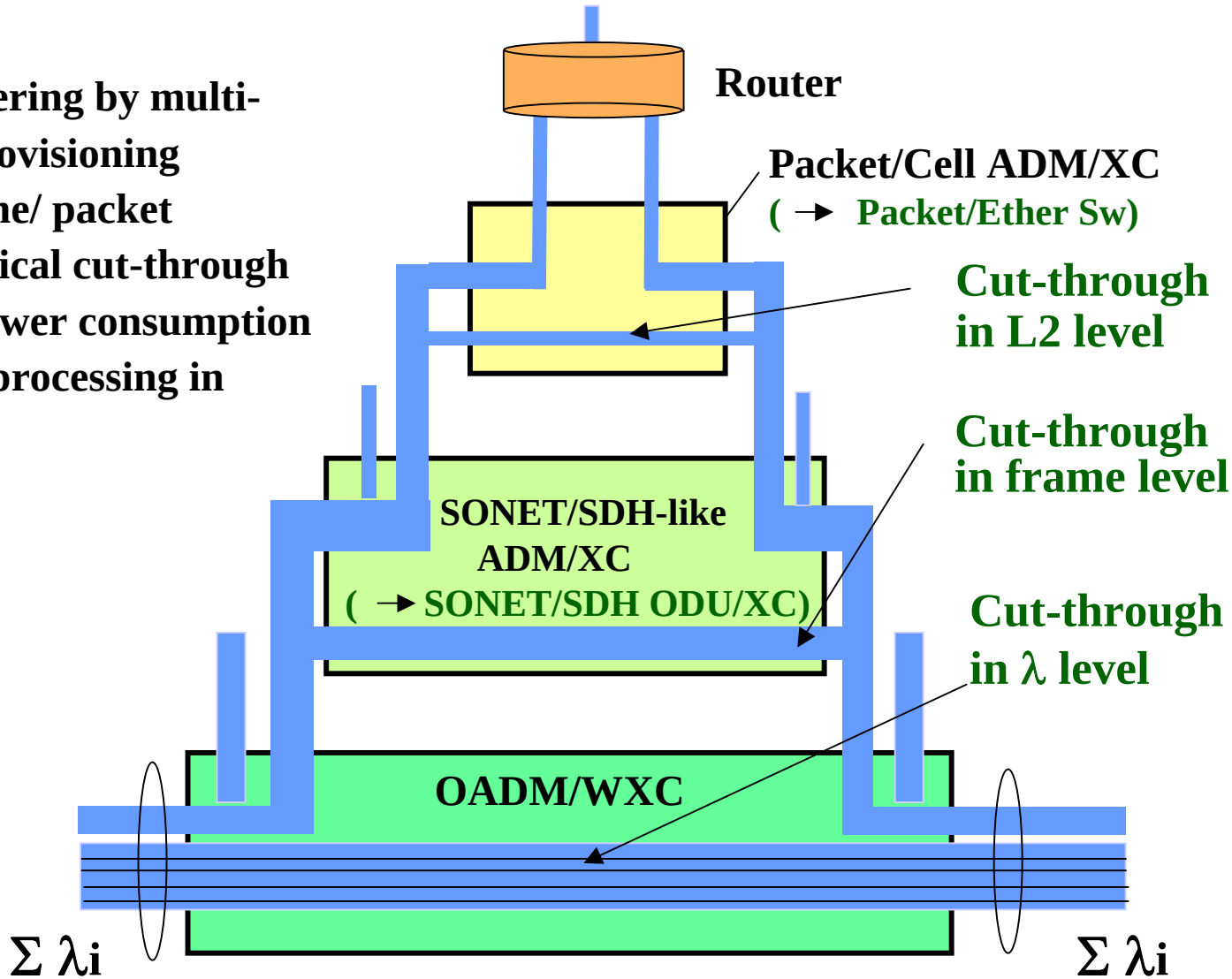
(ex.) MEMS based WSS





Packet/Optical Converged Node (Proposed in 2000)

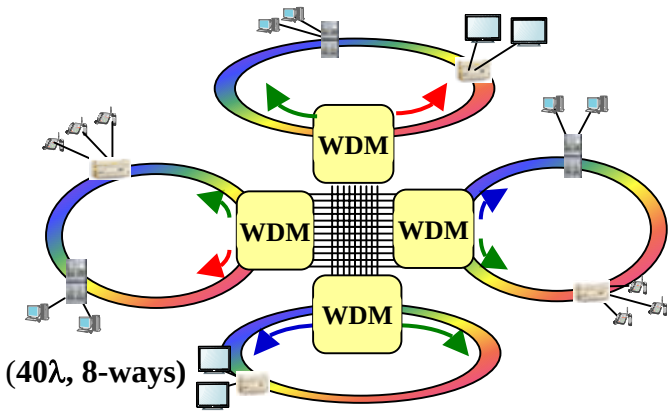
- High speed recovering by multi-path, and QoS provisioning
- Reduction of frame/ packet processing by optical cut-through
- Reducing total power consumption compared to the processing in each level



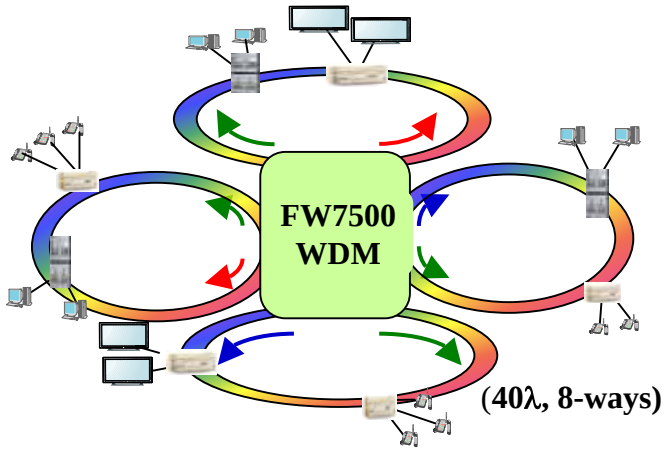
(T.Tsuda et al, AsiaTelecomm2000)

Photonic Convergence in ROADM

Conventional (Back to Back)



New Photonic Node (Optical Hubbing)

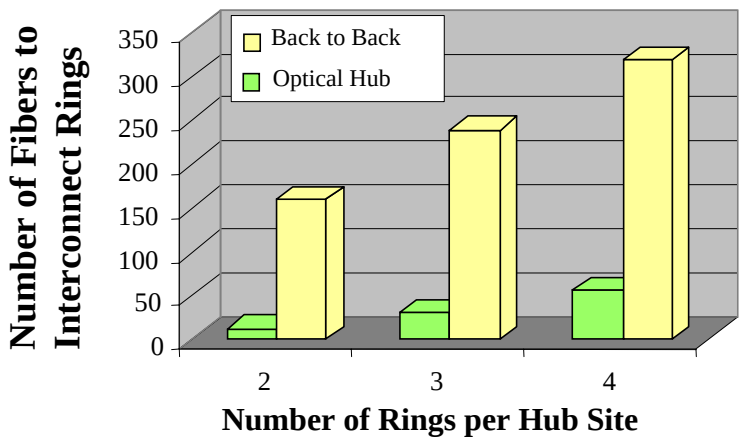


FLASHWAVE 7500

Benefits:

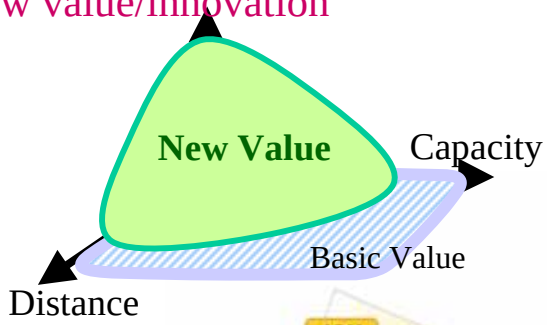
- Eliminates transponders
- Reduction in fibering (about 1/10)
- Flexible backbone, automatic reconfiguration
- Fibering is independent of
  - wavelength routing
  - wavelength assignment
  - wavelength quantity
- Allows multiple network deployment scenarios (to mesh, to routing in optical signal)
- Power reduction, Cost reduction,...

Optical Hubbing Simplifies Fibering



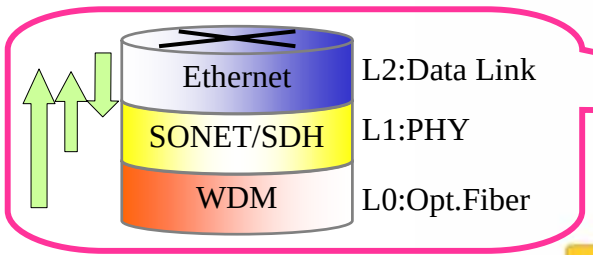
Multi-Layer Convergence

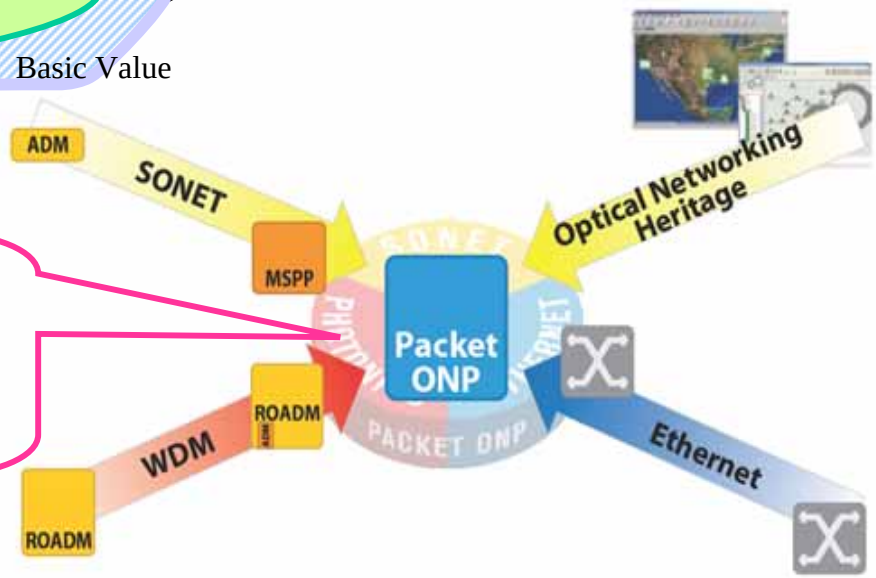
Efficient network creating new value/innovation



Providing scalable functions optimally matched to aggressive network variations.

Multi-Layer Convergence



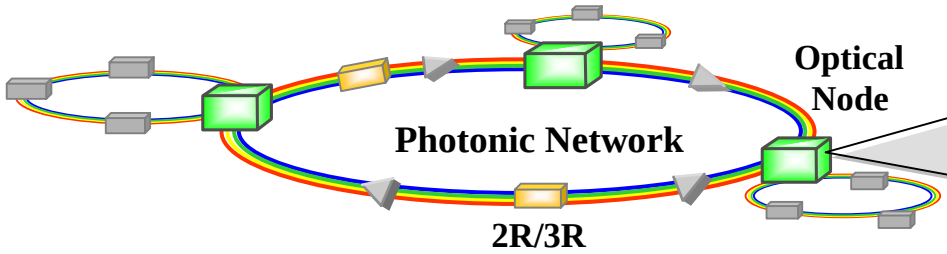


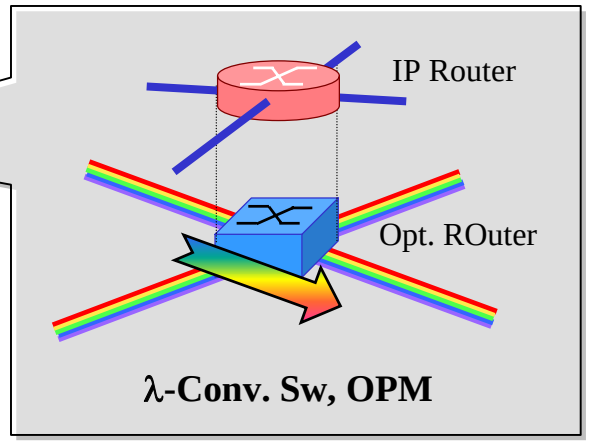
FLASHWAVE 9500
Packet Optical Networking Platform

Creating new value, enhancing effects of investment and reducing operation cost in telecom businesses, while promoting the sustainability of existing network services

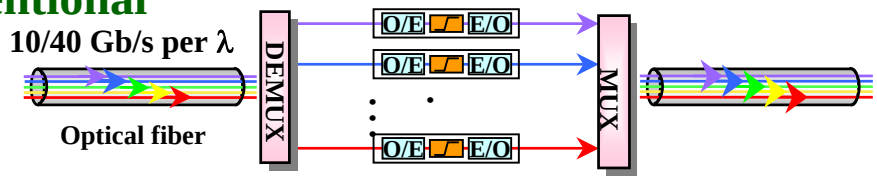
[Next Step]
- Rapid network reconfiguration by faster tunable optical devices and switches

Optical Signal Processing



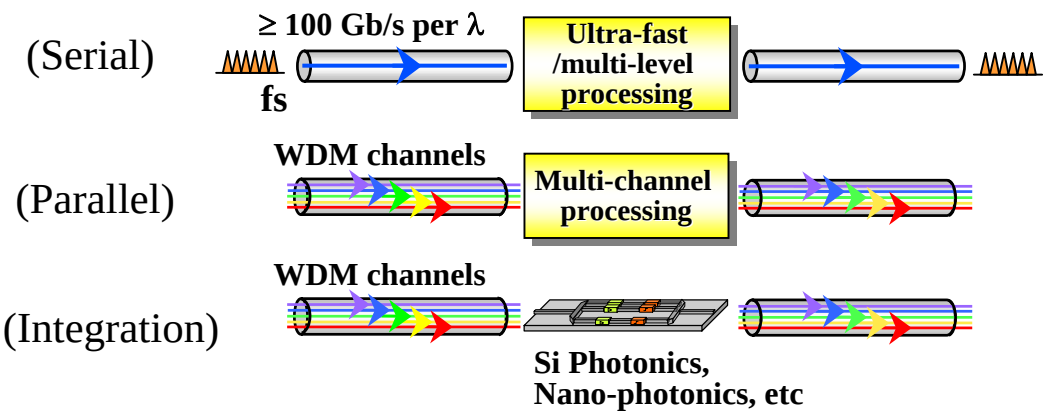


◆ Conventional

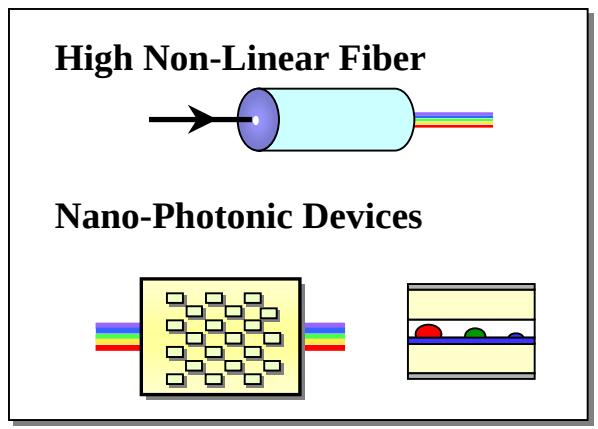


- Speed limitation by electronic processing
- Complex config. of equipment by λ-mux.demux
- Huge power consumption

◆ Optical Signal Processing



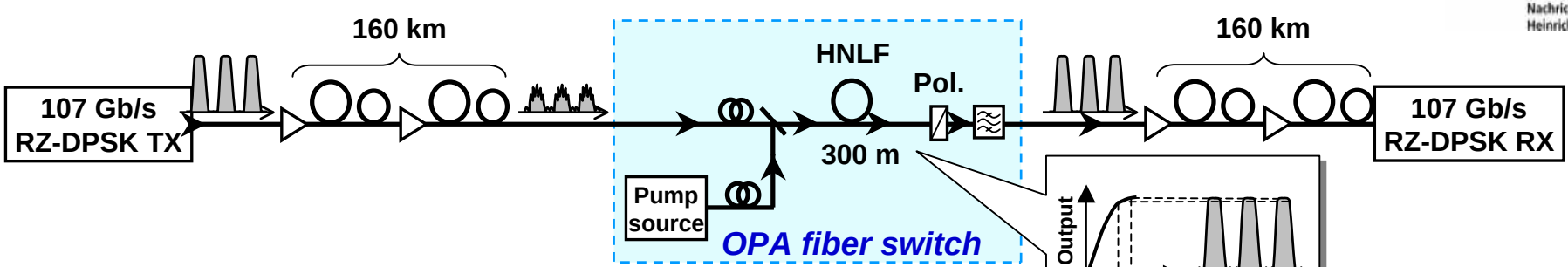
◆ Optical Element device



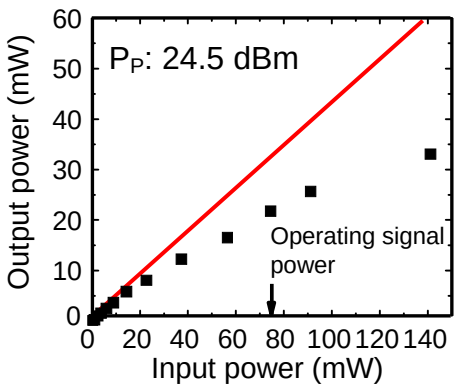
◆ Ultra fast, Low power, Bitrate independent, Optical header recognition, ...

Amplitude Noise Suppression by Parametric Amplifier

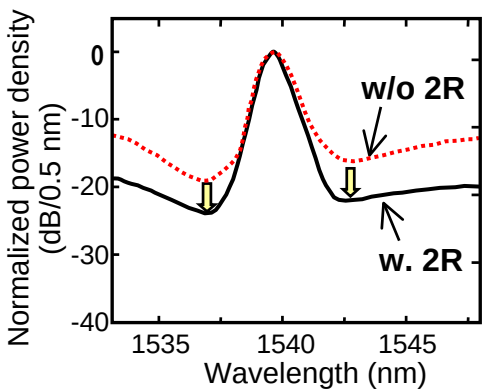
107 Gb/s RZ-DPSK Optical 2R Transmission (OFC2008, OWS5)



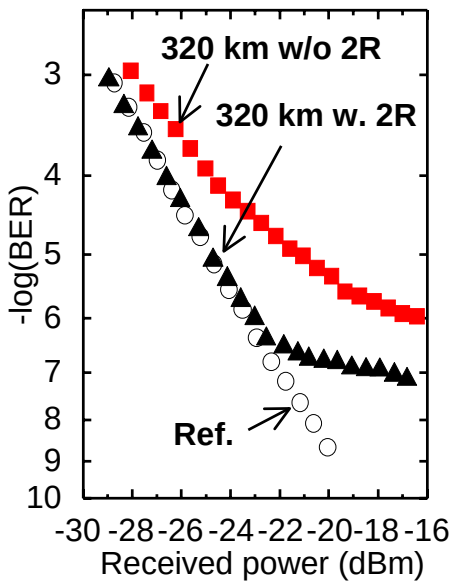
Limiter performance

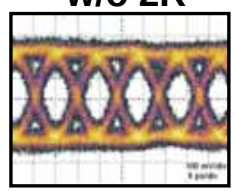


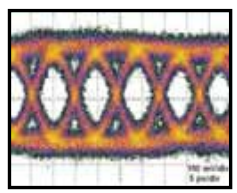
Optical spectrum



BER characteristics



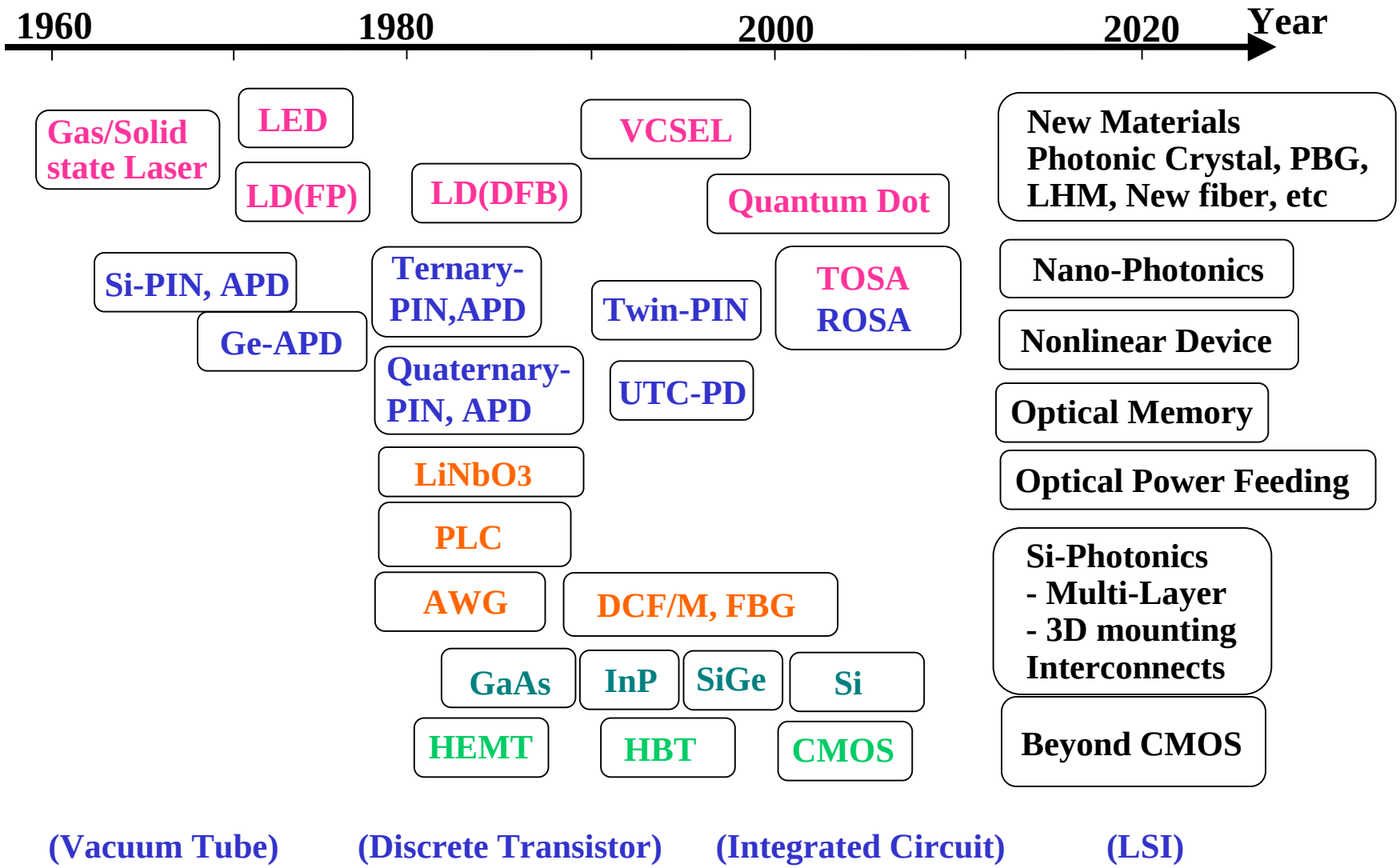




- Amplitude noise suppression by gain saturation of optical parametric amplification (OPA)
- About 5 dB improvement of OSNR

- With coherent; From dispersion limit to OSNR limit
- Noise reduction, Reach extension, Lower signal power

Innovation in Device/Component Technologies



Device/component development should be fully linked with system evaluation.

Newly launched Japanese Project, “VICTORIES”

“Vertically Integrated Center for Technologies of Optical Routing toward Ideal Energy Savings”

Network Architecture Study Group in collaboration w/ Nagoya Univ.

AIST

Network-Application Interface

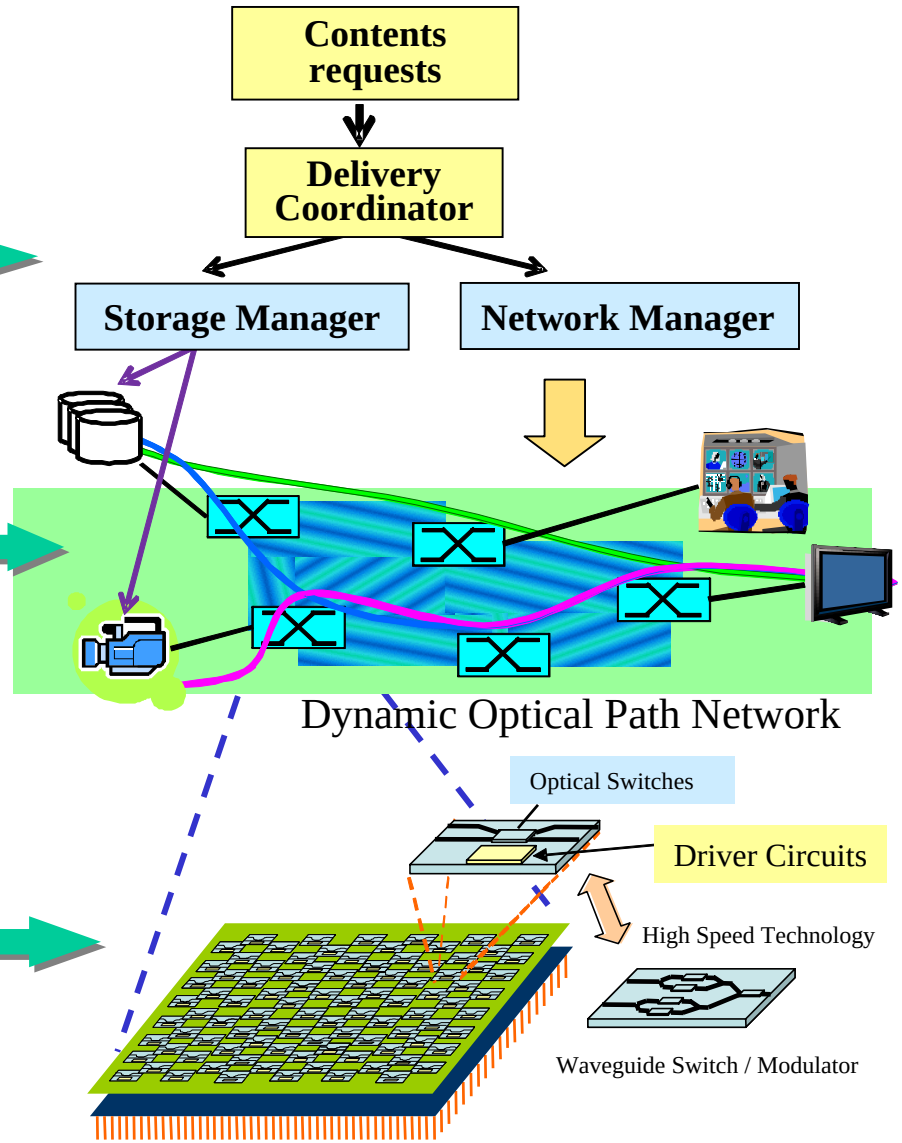
NTT

Optical Path Conditioning
- Optical TDC
- Adaptive Path Control

Furukawa Electric
Trimatiz

Silicon Photonics
- Large scale integrated optoelectronics
- Ultra-compact Optical Path Processor

Fujitsu Labs.



AIST; National Institute of Advanced Industrial Science and Technology

http://www.mext.go.jp/b_menu/houdou/20/05/08051604/001/001.htm

Roadmap of Photonic Networking Technology

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Flexibility in Wavelength

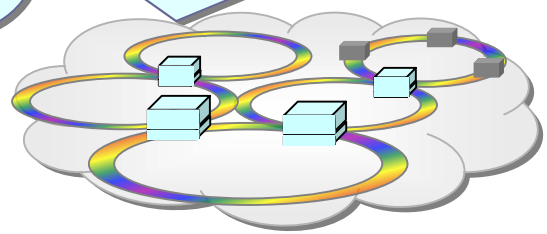
> 10 Tbit/s

1 - 10 Tbit/s

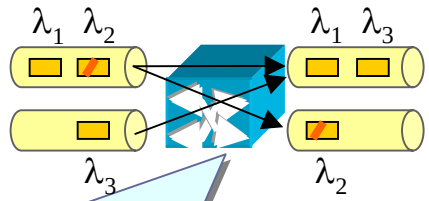
- GMPLS signaling and protection
- WSS (free space)
- Full band tunable LD/ transceiver module
- Variable disp. comp.
- PON (Gb/s)

◆ ROADM
◆ Ring

- Multi-Layer convergence
- WSS (integrated, compact)
- 40G/100G, Coherent
- Quantum dot LD/SOA
- Optical Noise Reduction
- Opt. Interconnection



◆ Hub, WXC
◆ Mesh



- Fast tunable LD/VCSEL
- Si-Photonics, PhC
- λ conversion
- NG PON (10G/WDM/Hybrid)
- Optical buffer/memory
- New band / Optical Amp
- Opt. power feeding
- Quantum Comm.

◆ Opt. Burst/Packet Routing

- Metro WDM
- FTTX (initial stage)

- FTTX (mass stage)
- IP based network construction

- Mass deployment of converged network (with wireless)

2000 2005 2010 2015 2020

(Broadband) (NGN, Safe and Secure) (Ubiquitous, Comfortable)

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Contents

1. Introduction

2. Optical communications as a social infrastructure

3. Energy issues and opt. comm.

4. Technologies supporting opt. comm.

5. Summary

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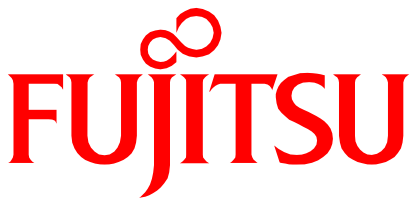
Summary

- Optical Communication technology is **supporting the infrastructure** of today's networked society. It eliminates the issue of time and distance, enables the world borderless economy, and is **generating new businesses**. Optical communication is further expected to play a more important role, while we must further discuss recent unexpected usages, network control and the **business models** of broadband connection for **healthier networked society** .
- **Energy consumption** is becoming a big concern. Though optical comm. has surely contributed to the suppression of global warming (1) by realizing efficient social activities, and (2) by improving energy efficiency of information transport, we must **continue to pursue further R&D** of optical communication for enhanced contribution.
- Following the brilliant technologies of fiber, laser, EDFA, ROADM, **we will continue to explore new technologies**, including coherent detection combined with electronic signal processing, optical processing, new materials such as Si-Photonics, PhC, and quantum dot, while aiming for scalable, flexible, energy efficient, intelligent, safe and secure networks.

Thank you !



THE POSSIBILITIES ARE INFINITE