PIL Photonic Internet Lab.

TBWG-20-02

「フォトニックネットワークの未来と技術」

2014.12.8

慶應義塾大学　理工学部

山中　直明

KEIO UNIVERSITY 1858 CALAMVS GLADIO FORTIOR

Yamanaka Lab.

概要

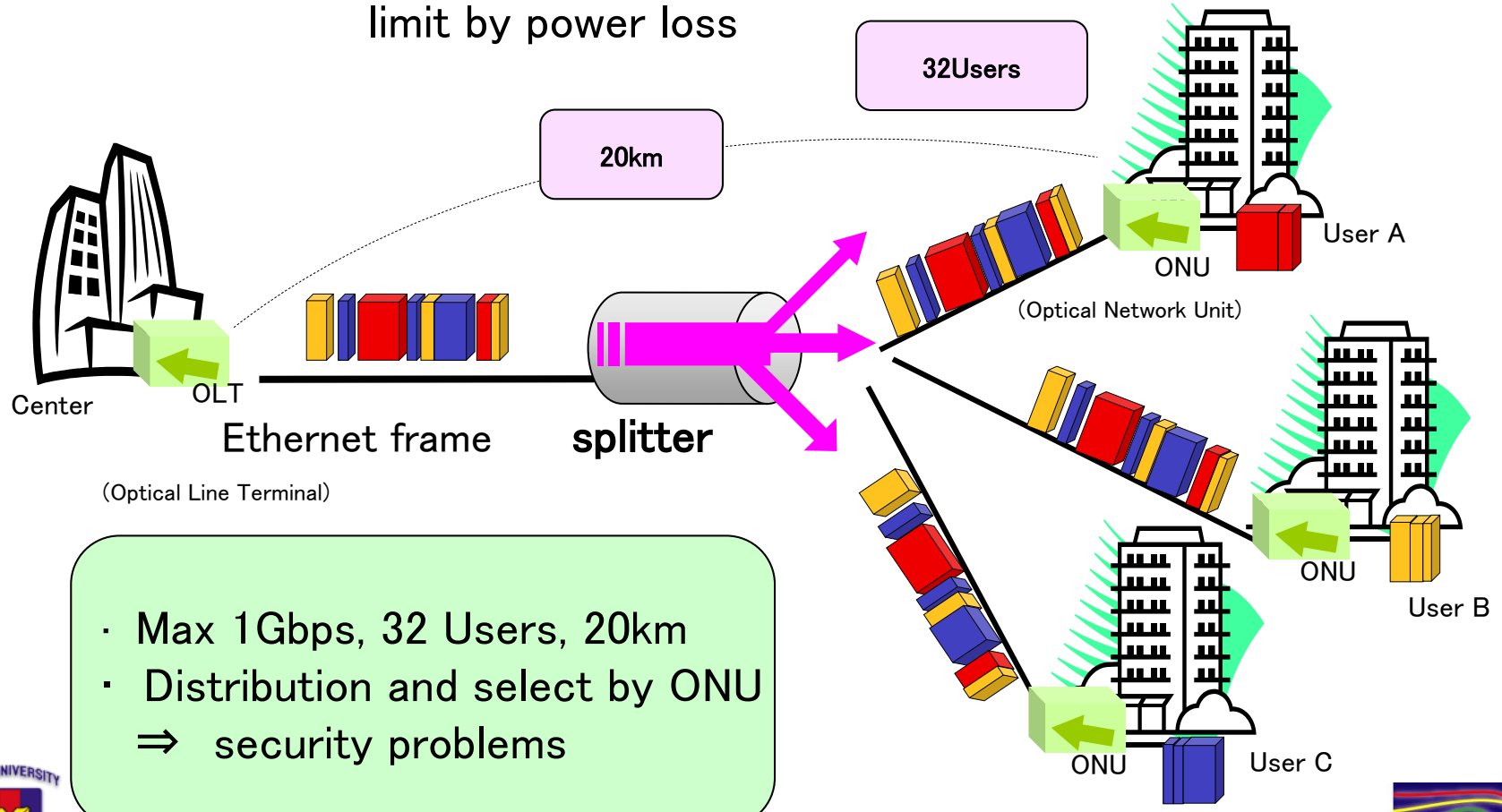
帯域や距離を意識しないネットワーク、さらに、ダイナミックに、そして高付加価値を

1. Data Center Centric アプローチ
2. Distributed Linked NW アプローチ
3. これからの光ネットワーク

PON : Passive Optical Network)

Today's PON system

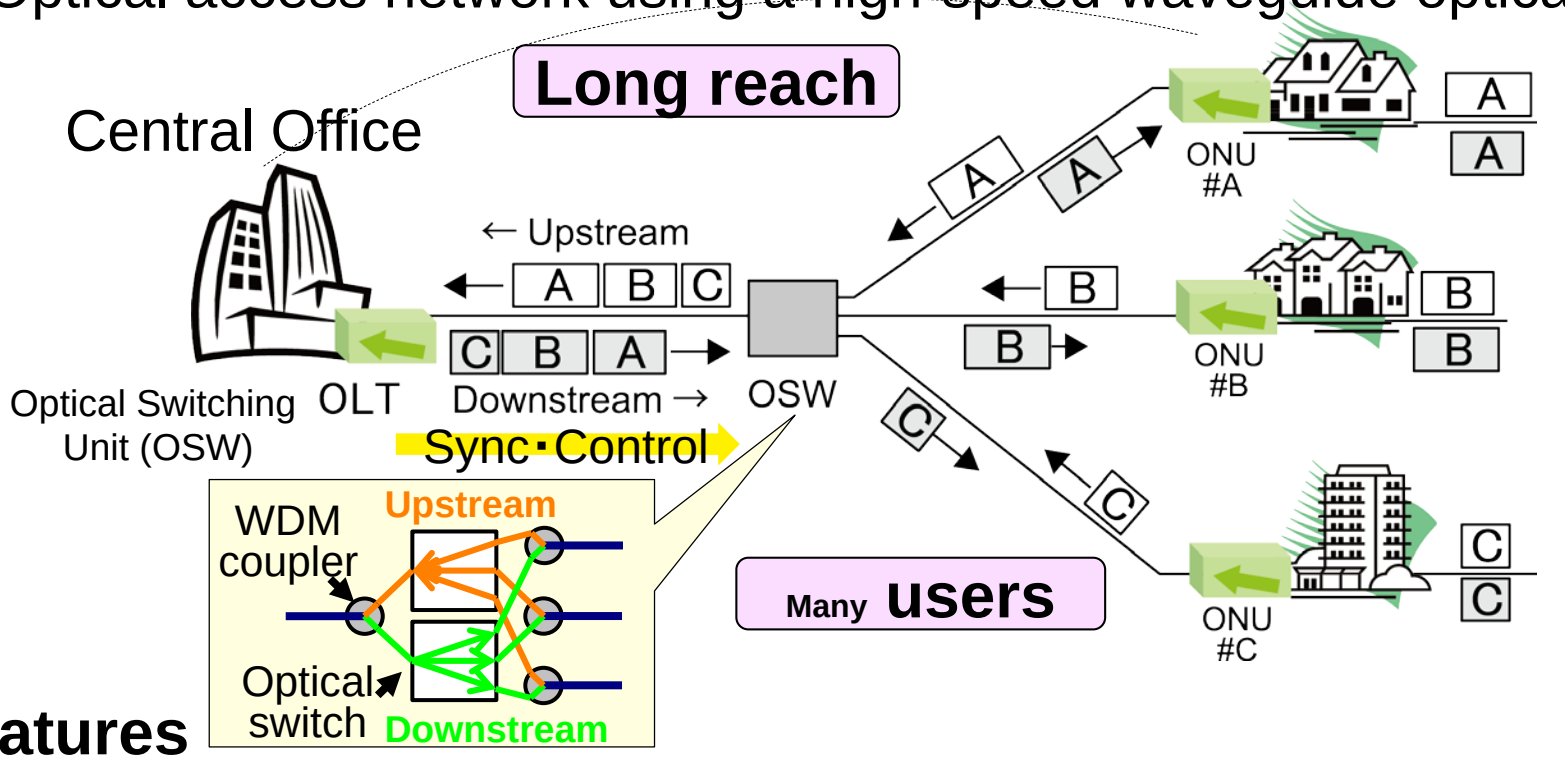
limit by power loss



- Max 1Gbps, 32 Users, 20km
- Distribution and select by ONU
  ⇒ security problems

Active Optical access Network (ActiON)

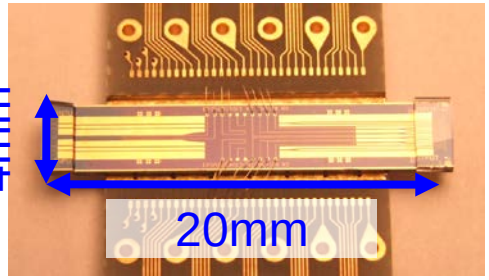
- Optical access network using a high-speed waveguide optical switch



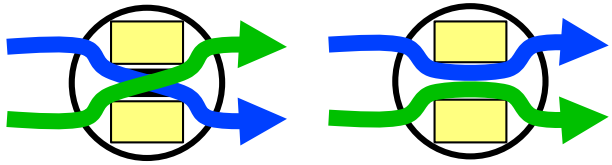
Features

- Low insertion loss of optical switch → Large-scale system
  - **quadruplicate the number of users (more than 128 ONUs)**
  - **double the maximum transmission distance (more than 40 km)**
- Establishment of **secure connection** between OLT and each ONU
- Provision of **fast fiber and OLT protection/restoration** by switching.

Key device: PLZT optical switch



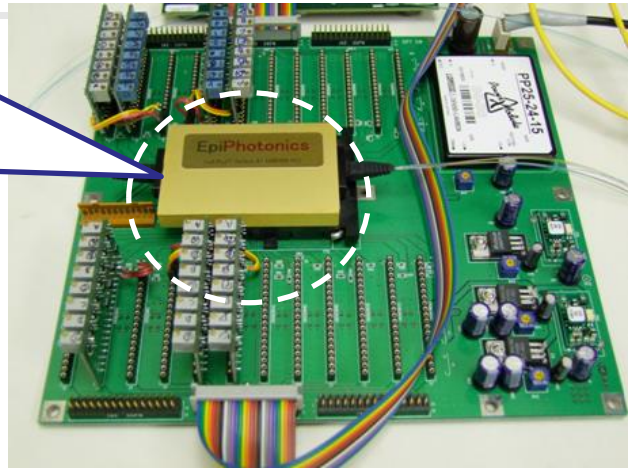
PLZT Optical Switch chip



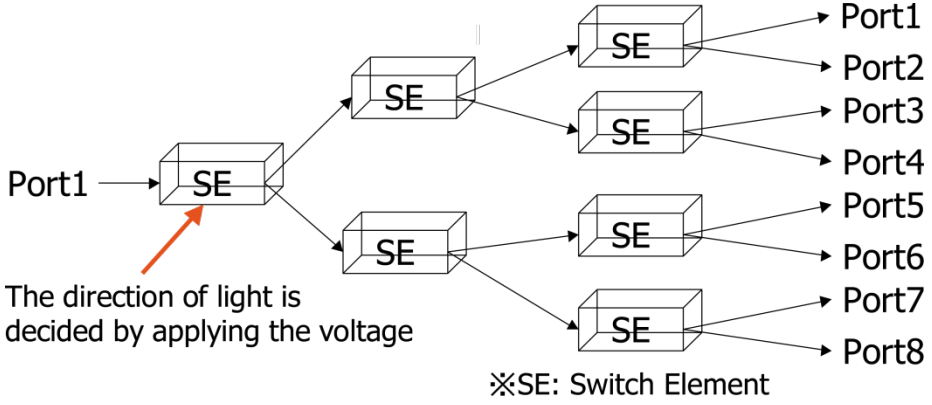
(a) Cross-mode (b) Bar-mode

※Switched by changing voltage

States of switch element



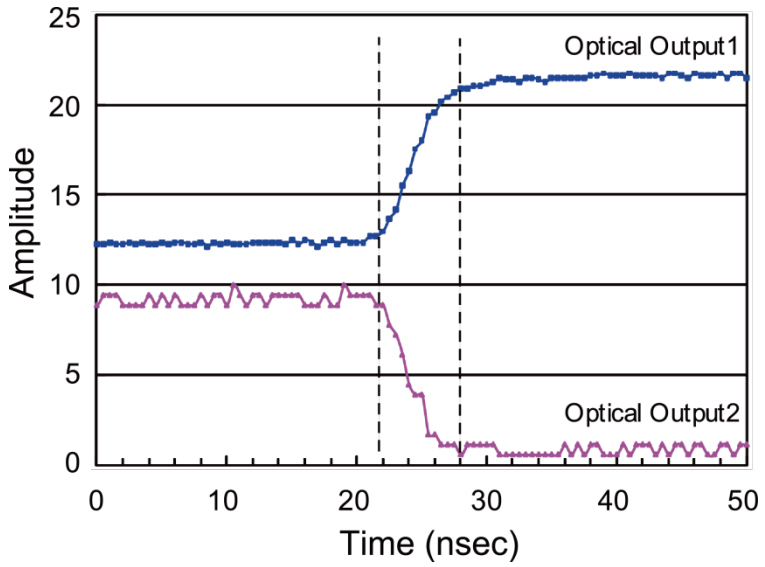
※PLZT((Pb,La)(Zr,Ti)O3)



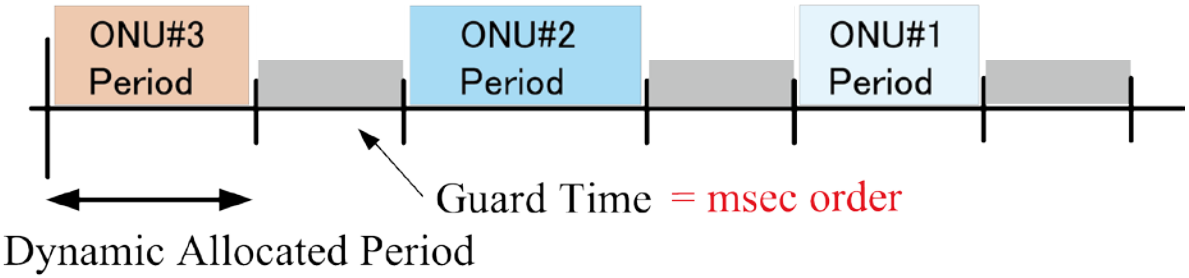
【Insertion loss】

1x8 SW: 5dB

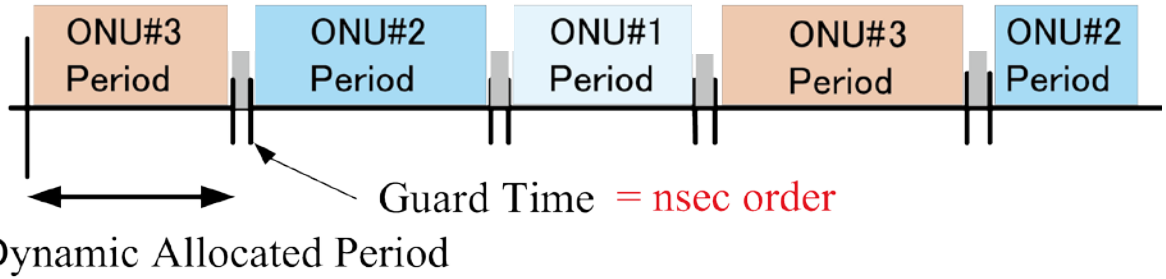
1x16 SW: 6dB



Effect of high speed switching



(a) MEMS Switch



(b) PLZT Switch

Advantage: High Speed Switching

MEMS switch (msec order) >> PLZT (less than 10nsec)

High bandwidth efficiency

PLZT switch

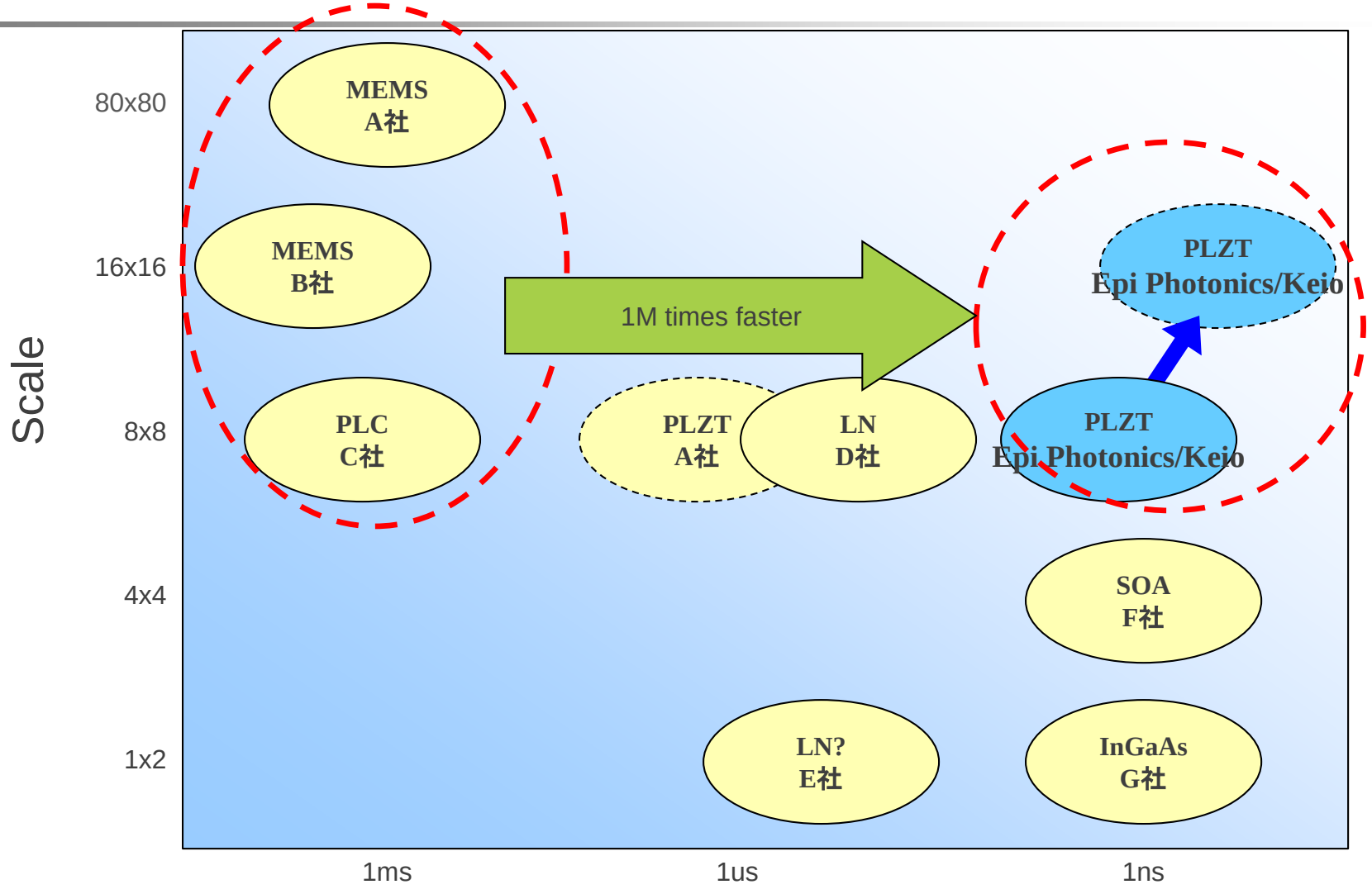
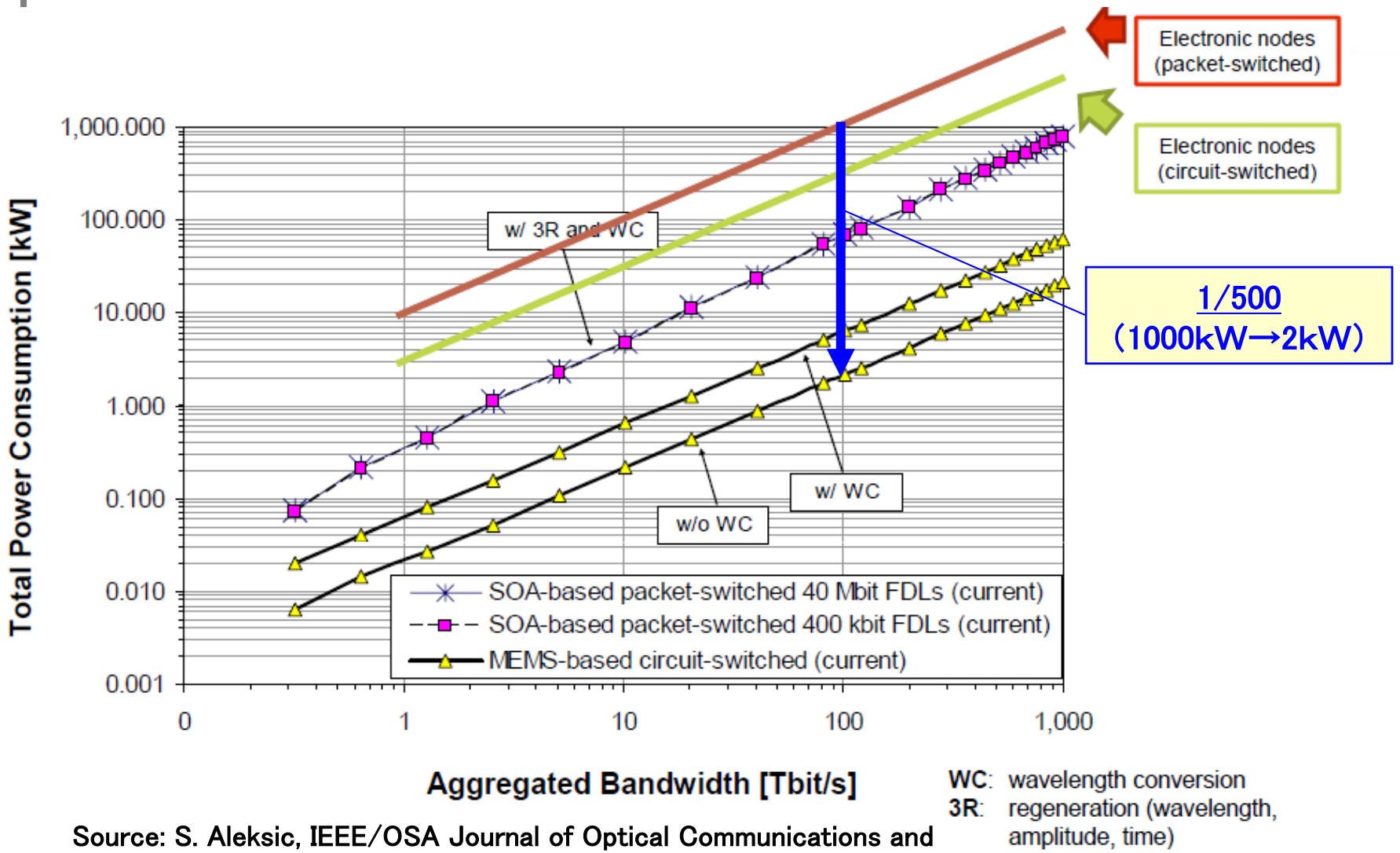

80x80
16x16
8x8
4x4
1x2
Scale
MEMS
A社
MEMS
B社
PLC
C社
1M times faster
PLZT
A社
LN
D社
PLZT
Epi Photonics/Keio
PLZT
Epi Photonics/Keio
SOA
F社
LN?
E社
InGaAs
G社
1ms
1us
1ns
Speed

Photo of PLZT switch

Future optical network architecture #1

Optical aggregation network

Power consumption : Optical vs Electrical

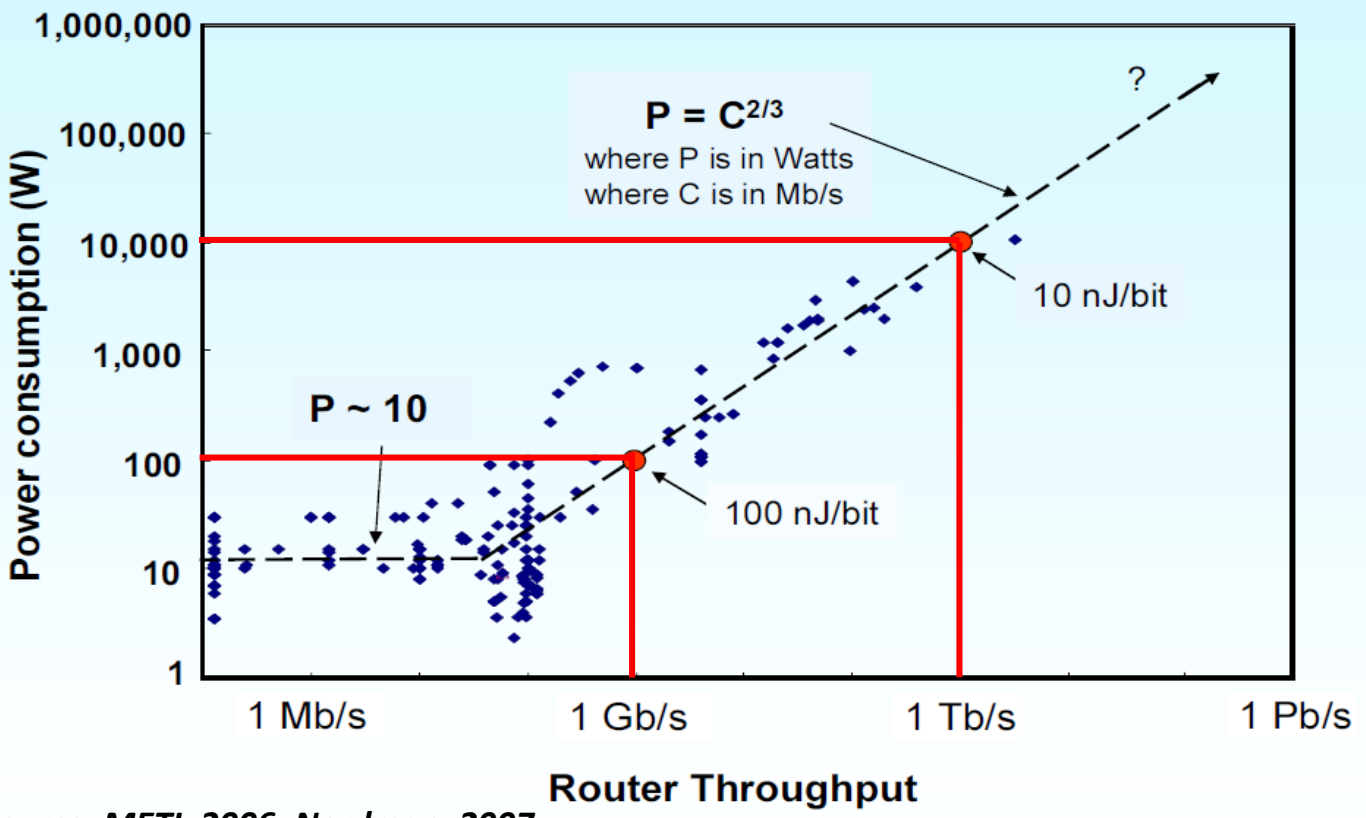


WC: wavelength conversion
3R: regeneration (wavelength, amplitude, time)

Source: S. Aleksic, IEEE/OSA Journal of Optical Communications and Networking, Vol. 1, No. 3, pp. 245–258, 2009.

Ref : Didier Colle, "Energy-Efficiency in Telecommunications Networks: Link-by-Link versus End-to-End Grooming'', 2-5, ONDM 2010, Feb. 2010.

Power consumption in Routers

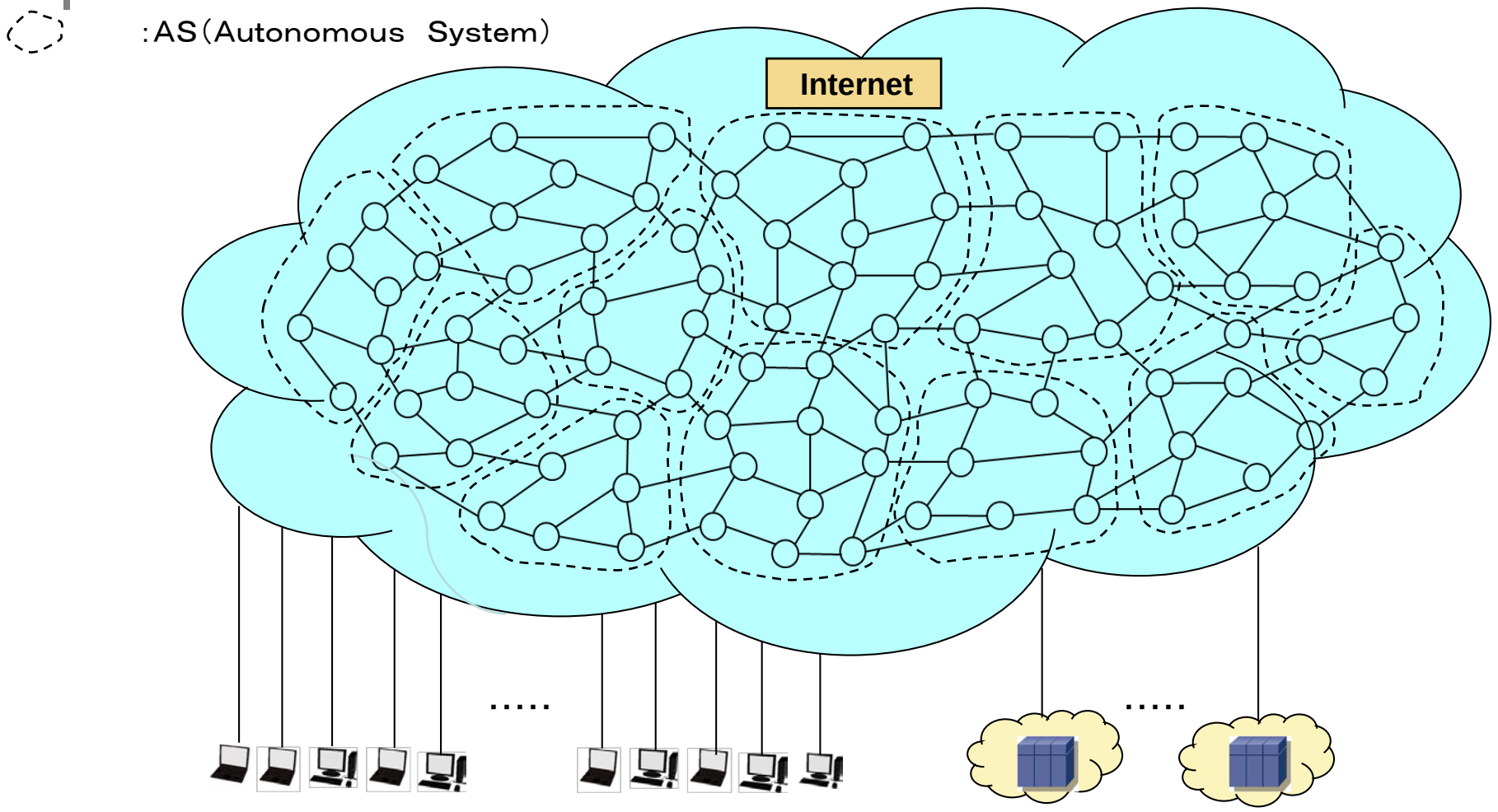


Source: METI, 2006, Nordman, 2007

$$\frac{\text{1Gb/s router} \times \text{1000unit(1Tb/s)}}{\text{100kW}} > \frac{\text{1Tb/s router} \times \text{1unit}}{\text{10kw}}$$

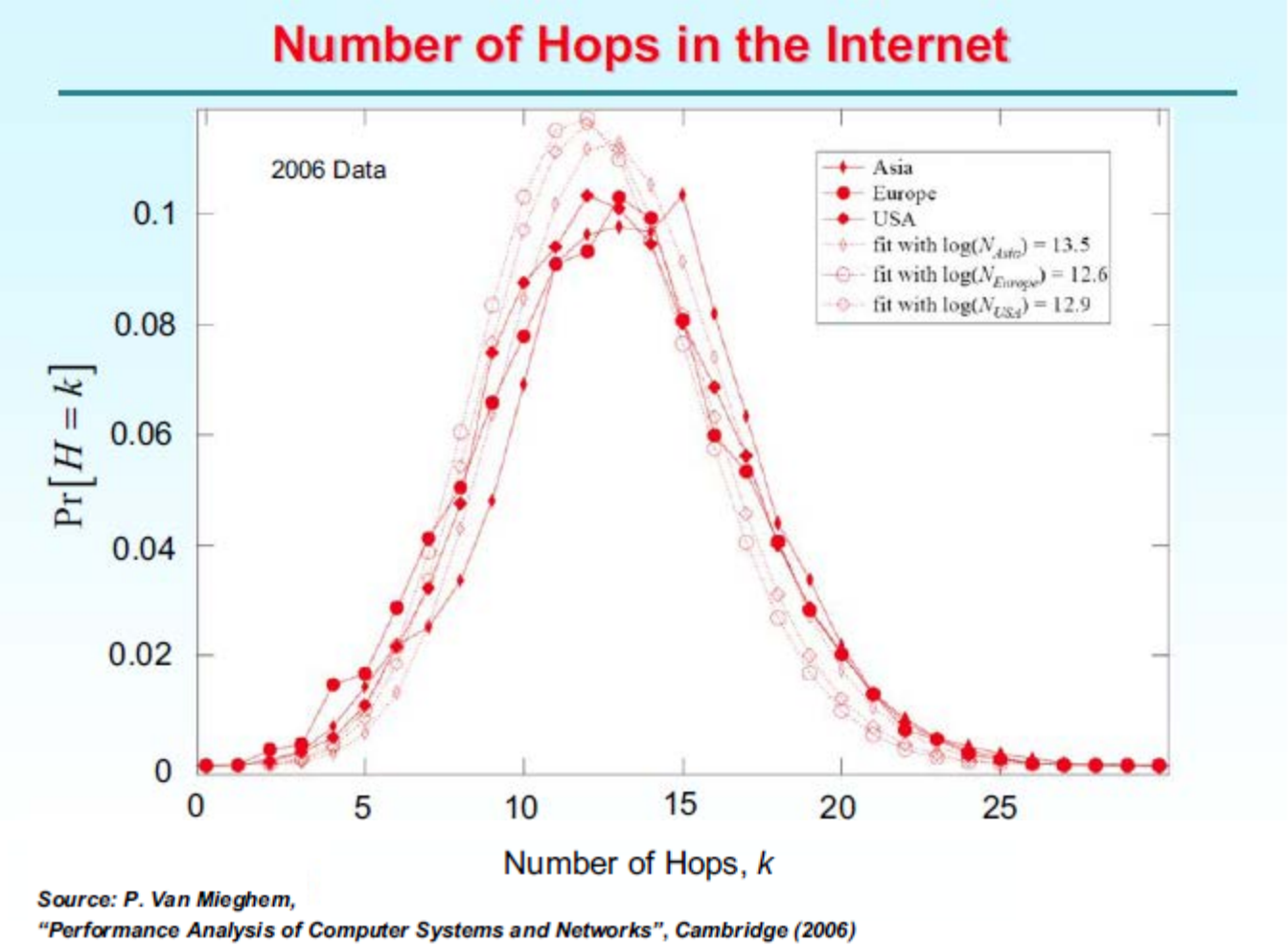
Ref : Rodney S. Tucker, "Optical Packet-Switched WDM Networks : a Cost and Energy Perspective", OMG1, OFC/NFOFC 2008, March 2008.

Basic Internet structure



Number of hops in Internet

Ave. 12hops



Source: P. Van Mieghem,
"Performance Analysis of Computer Systems and Networks", Cambridge (2006)

Proposed Optical Network Architecture for centralized data #1

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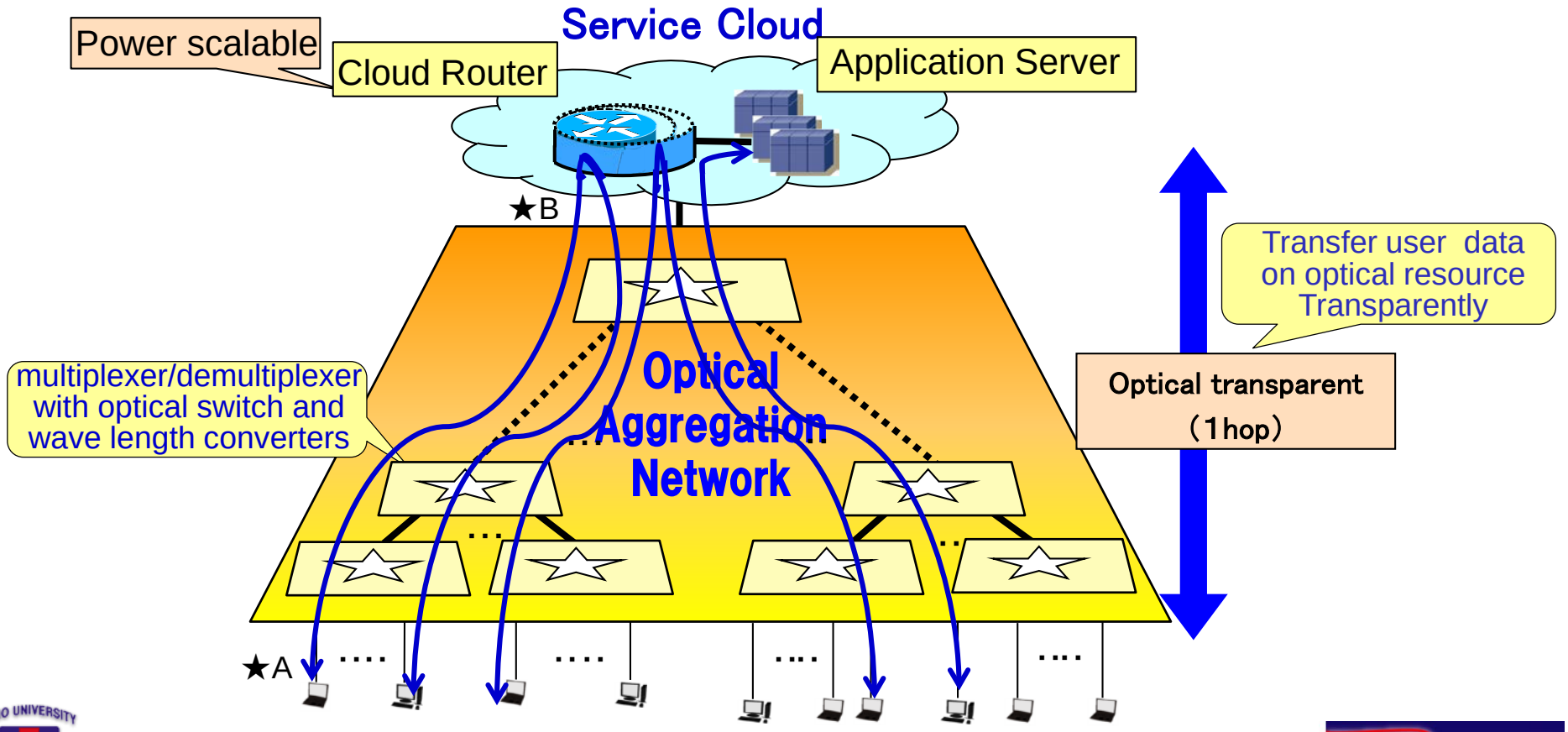
- Cloud Router is one large power scalable router with the amount of traffic proportionally .
- Optical Aggregation Network consists of multiplexers/de-multiplexers with optical switches and wavelength multiplexers/de-multiplexers.
- Optical Aggregation Network transfers consumer data on optical resources (optical slot / λ)transparently.



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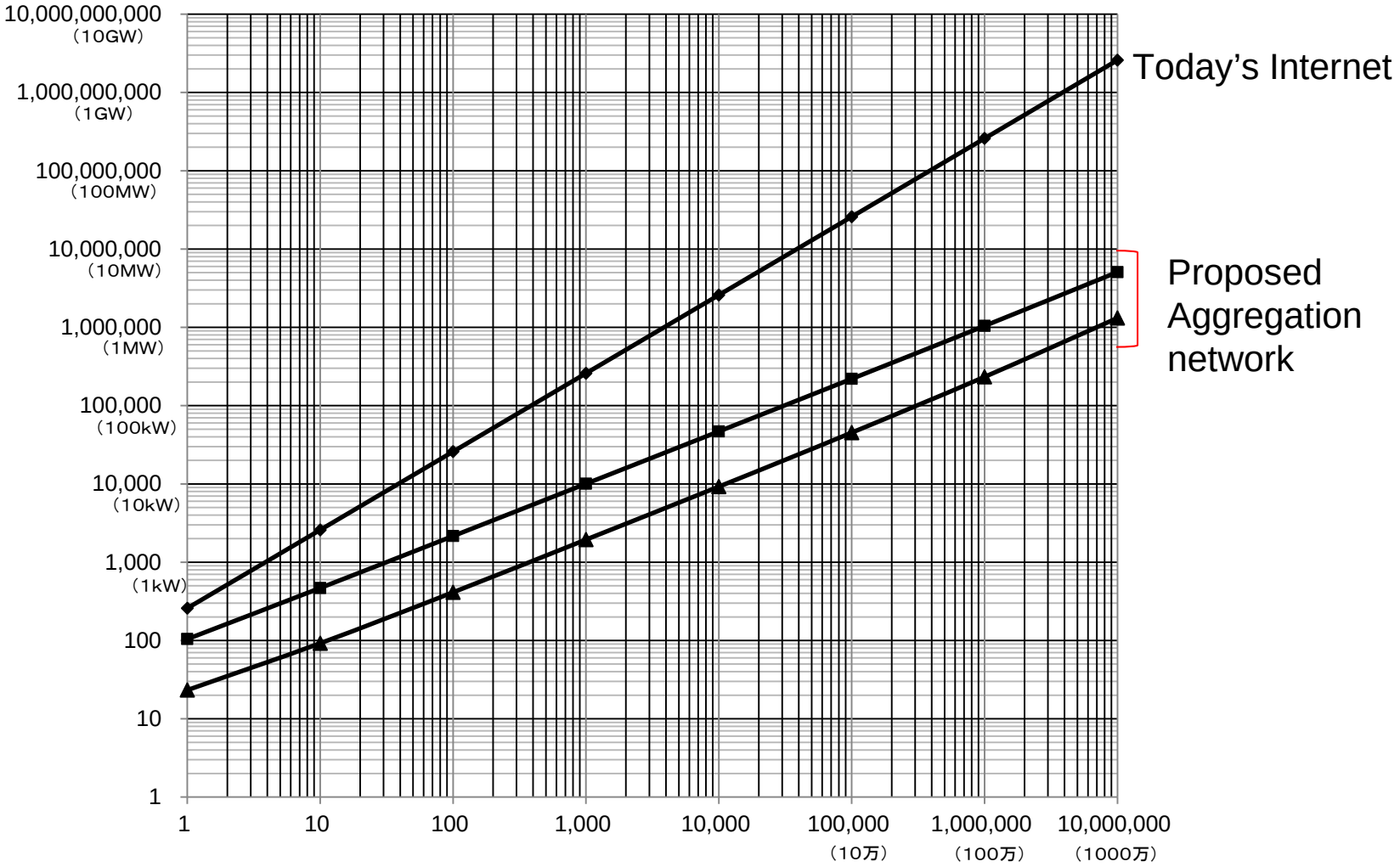
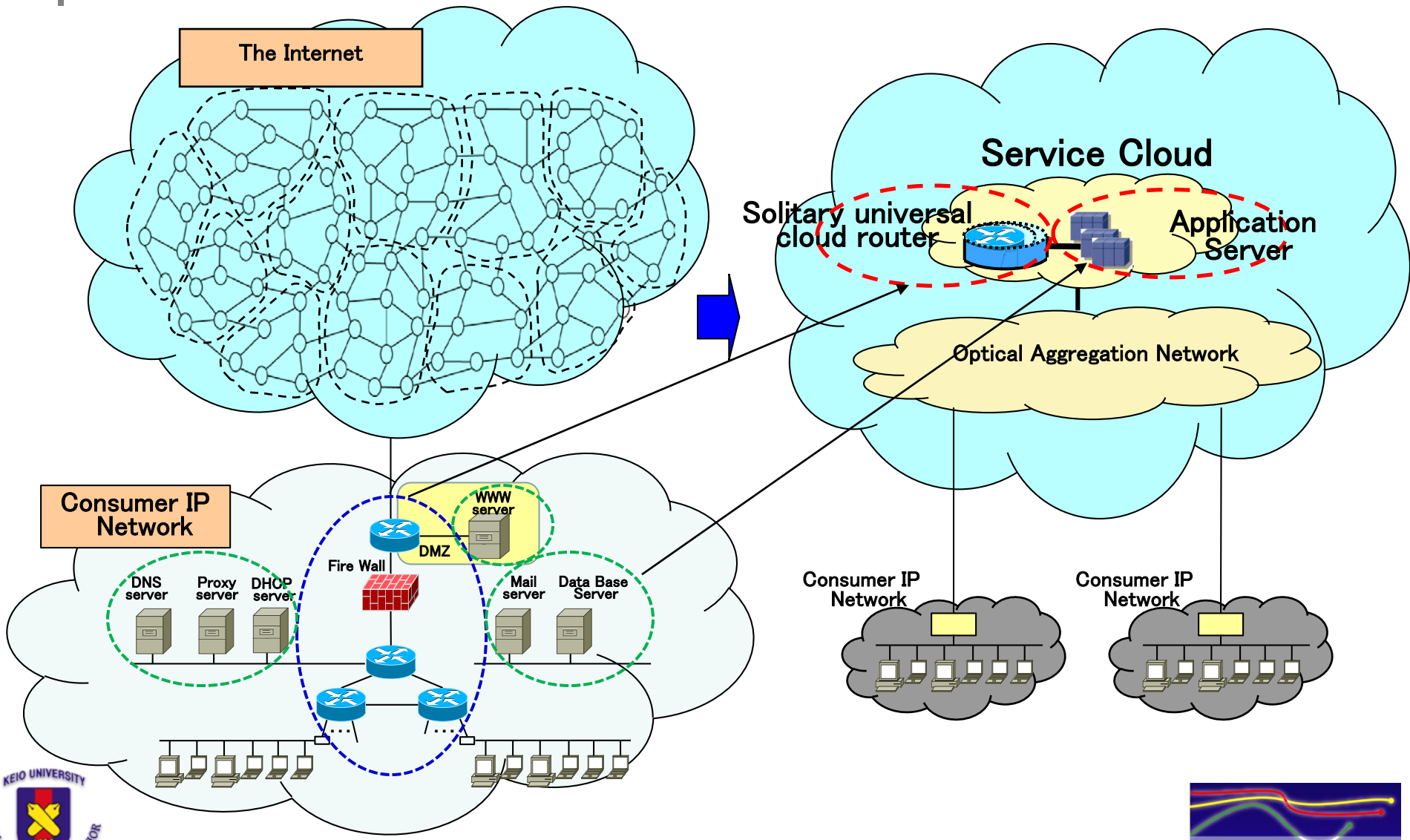
Optical aggregation NW is green technology



User's firewall will become SaaS service

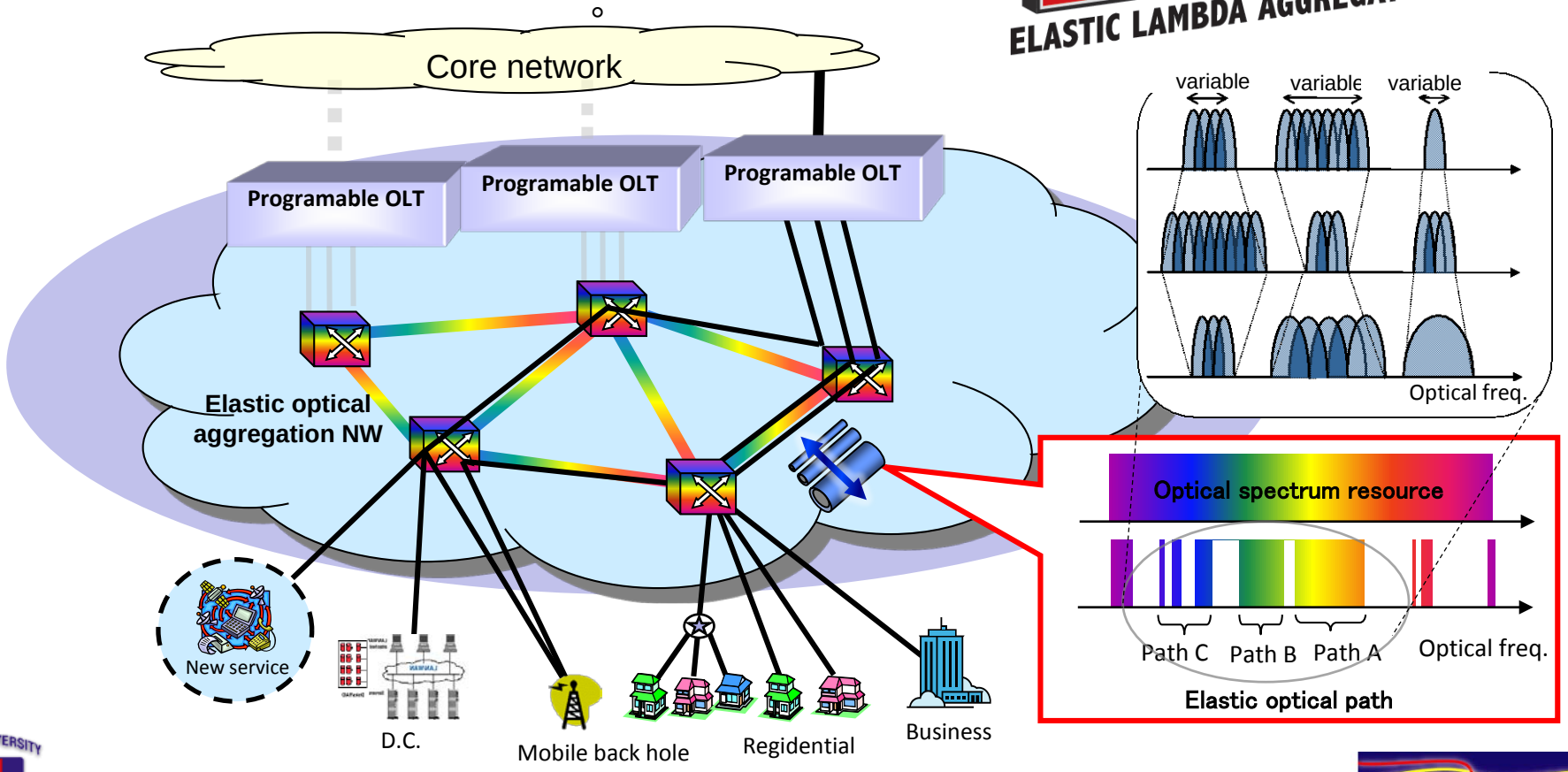


Elastic Lambda aggregation (National project)

Elastic optical access/ aggregation network
Programmable OLT

Energy efficient
High-reliability

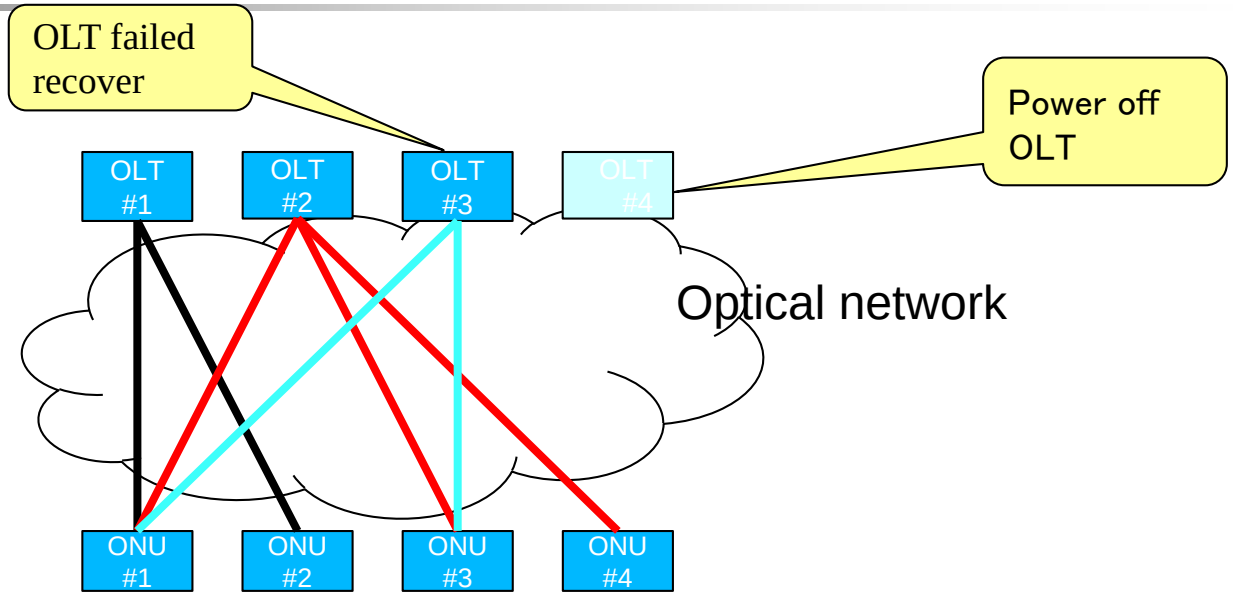
ELASTIC LAMBDA AGGREGATION NETWORK

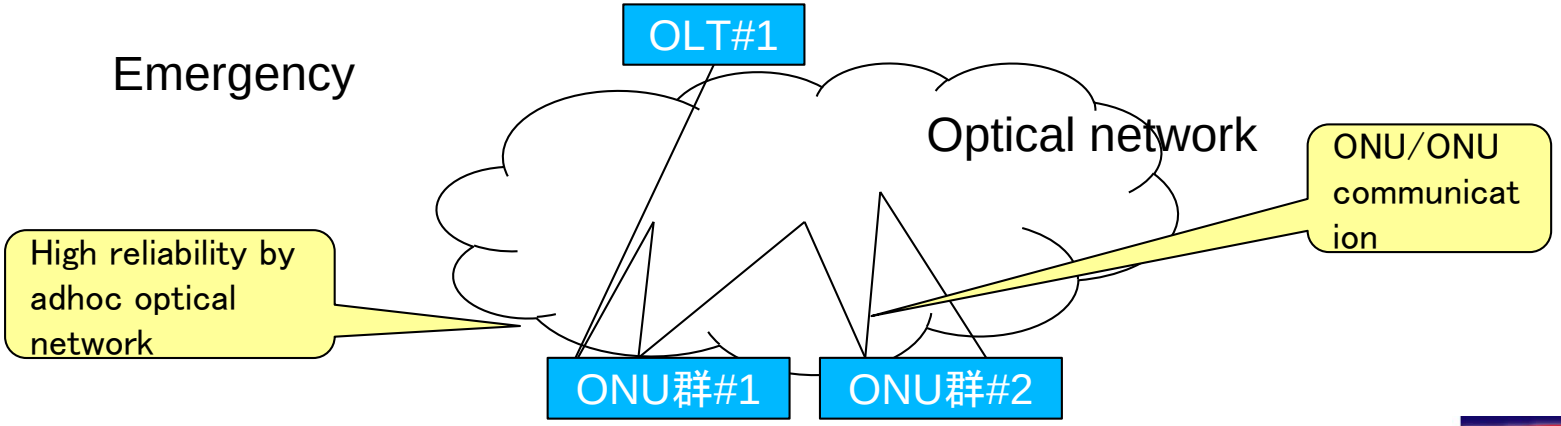


KEIO UNIVERSITY

Yamanaka Lab.

What can we do by new architecture?





概要

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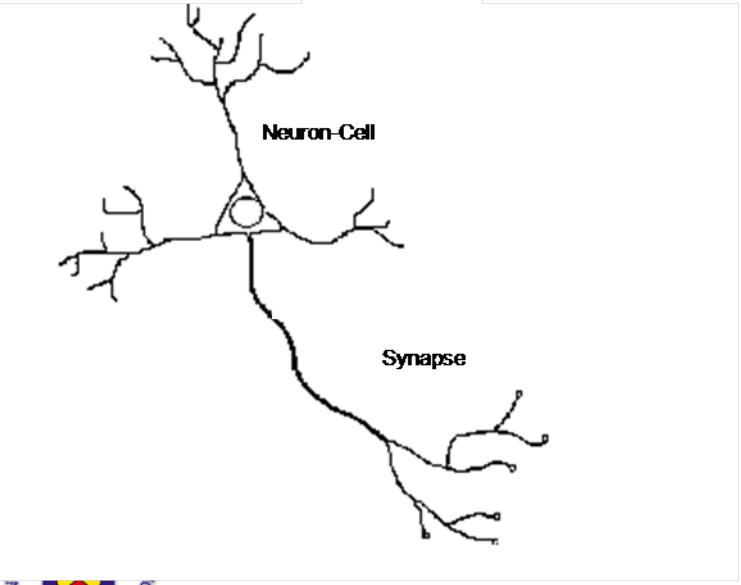
3. これからの光ネットワーク

Future optical network architecture #2

Optical wire creates mash-up service



Ubiquitous Grid(uGrid) Networking Environment

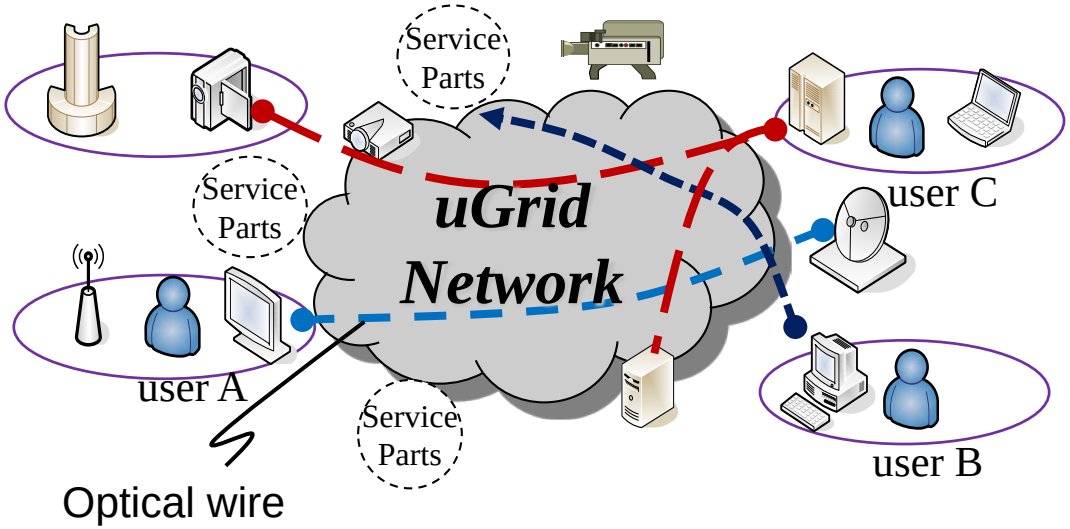
- An concept of uGrid is that “Everything” will be connected to network.

Not only CPU, memory, storage

contents, display, camera

software, program

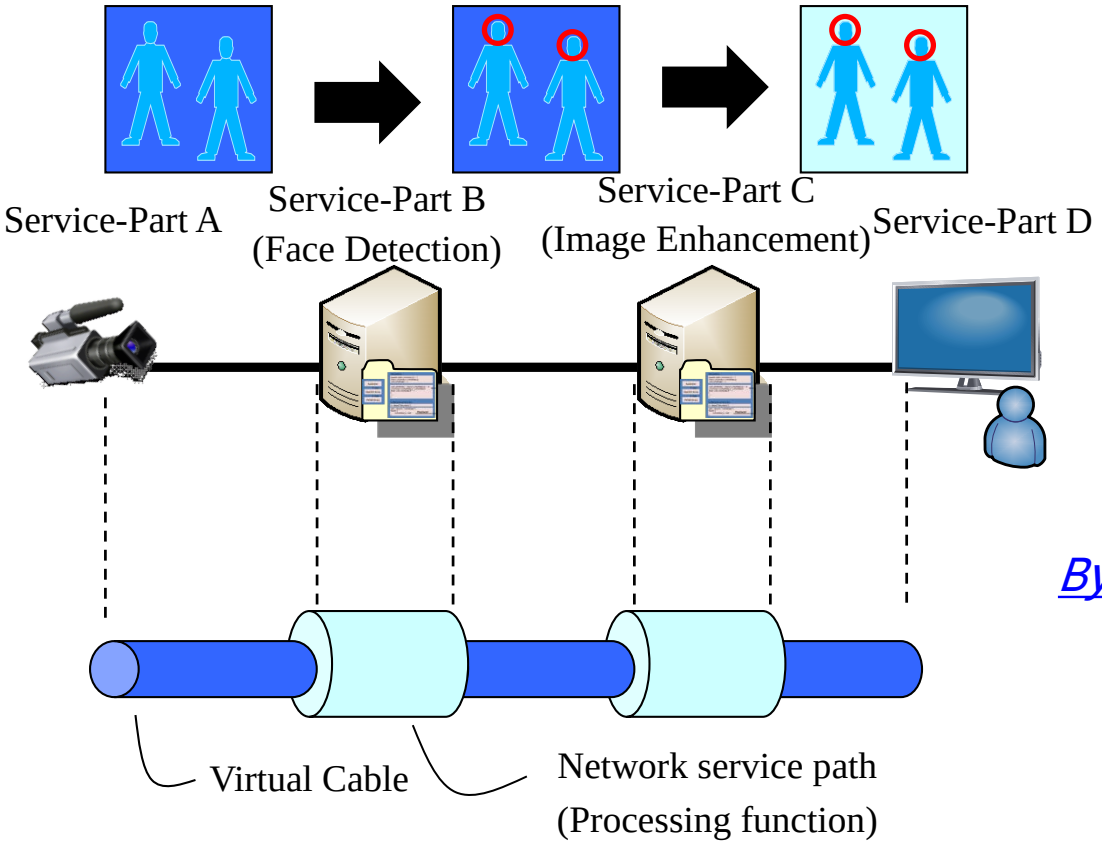
are defined as **Service-Parts**



User selects the desired Service-Parts and receives the service by combining each Service-Part.

Network Service path in Service-Signaling

- To realize Service-Signaling, GMPLS and extended RSVP-TE protocol are used.



Conventional IP network

IP, transparent path

By extended signaling protocol

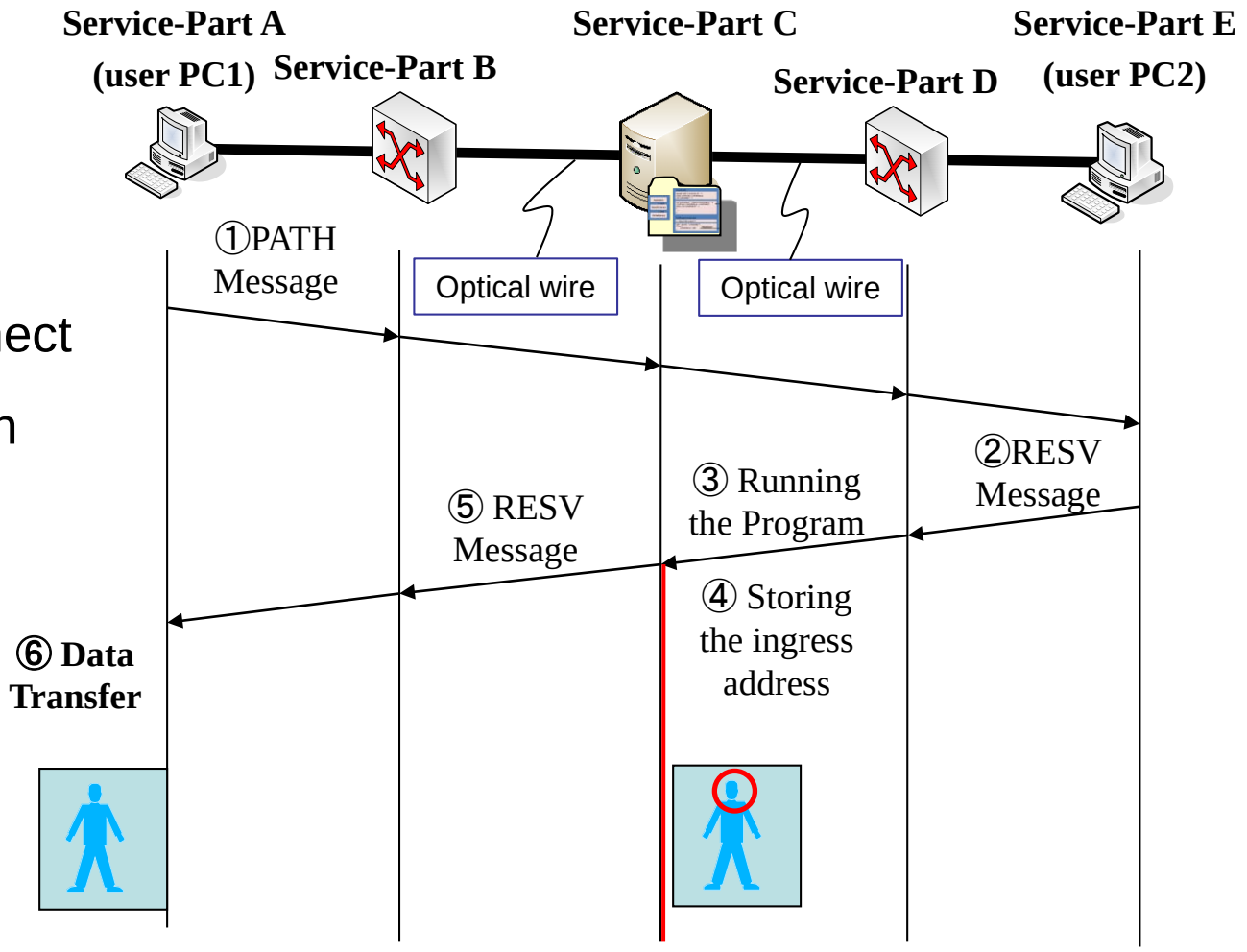
In-network processing

=Data conversion

Experimental Implementation

Switched optical wire

- Huge bandwidth
- Dynamic interconnect
- Distributed function
- Mush-up service

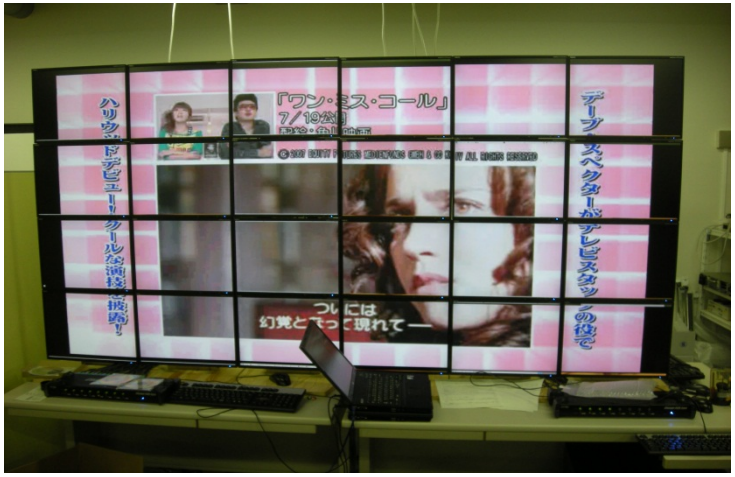


Flow of the experimental actions.

Implementation

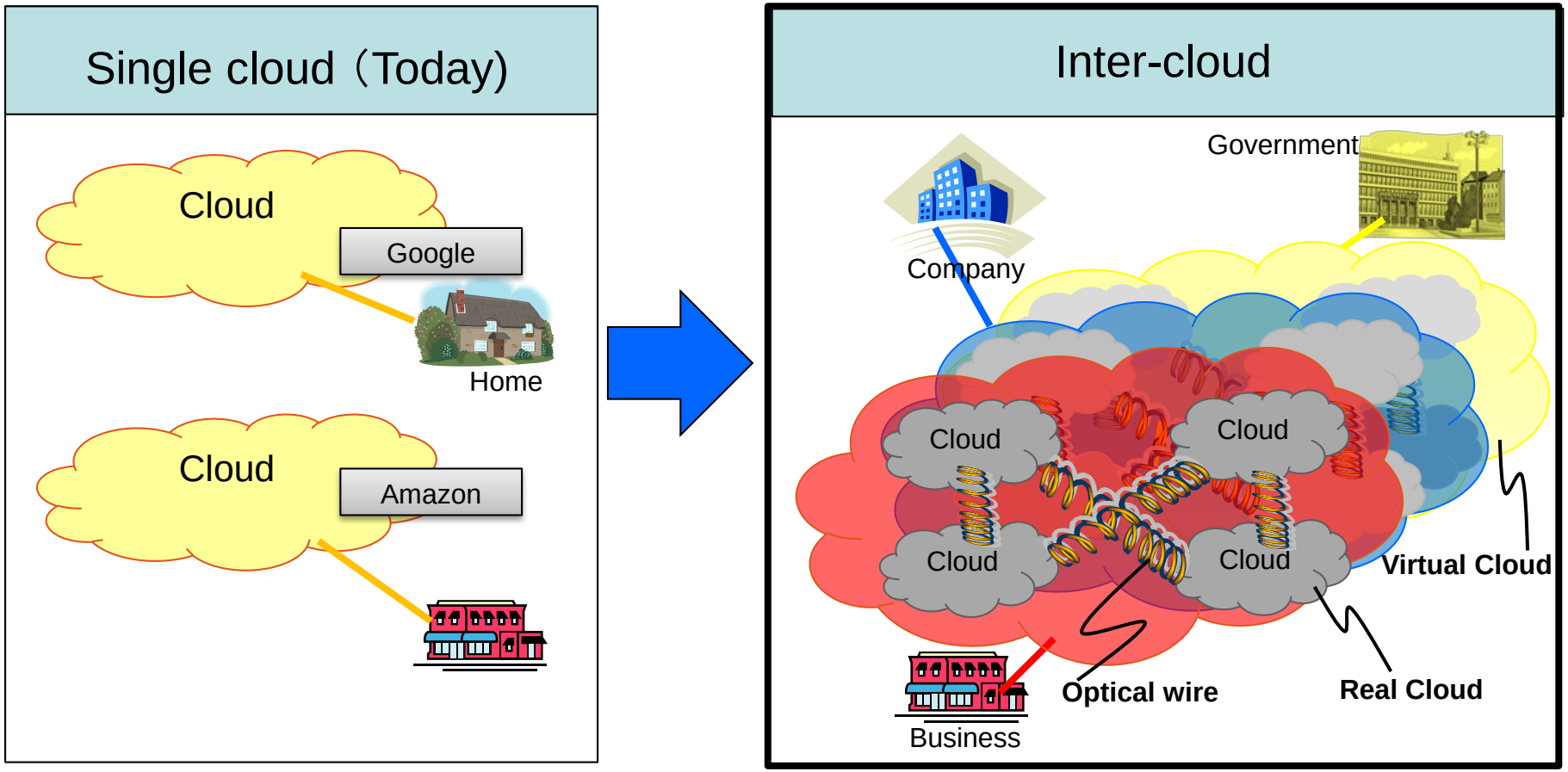
Prototype of Scale Free display system

- 24 tiled display
- 19inch (1280 × 1024) × 24
- resolution : 7680 × 4096



prototype of scale free display system

Inter-cloud network



Virtual Cloud realizing by inter-cloud technique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SUPER PLATINUM
CISCO
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BT
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telenor
clearwire
TELECOM

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3. これからの光ネットワーク

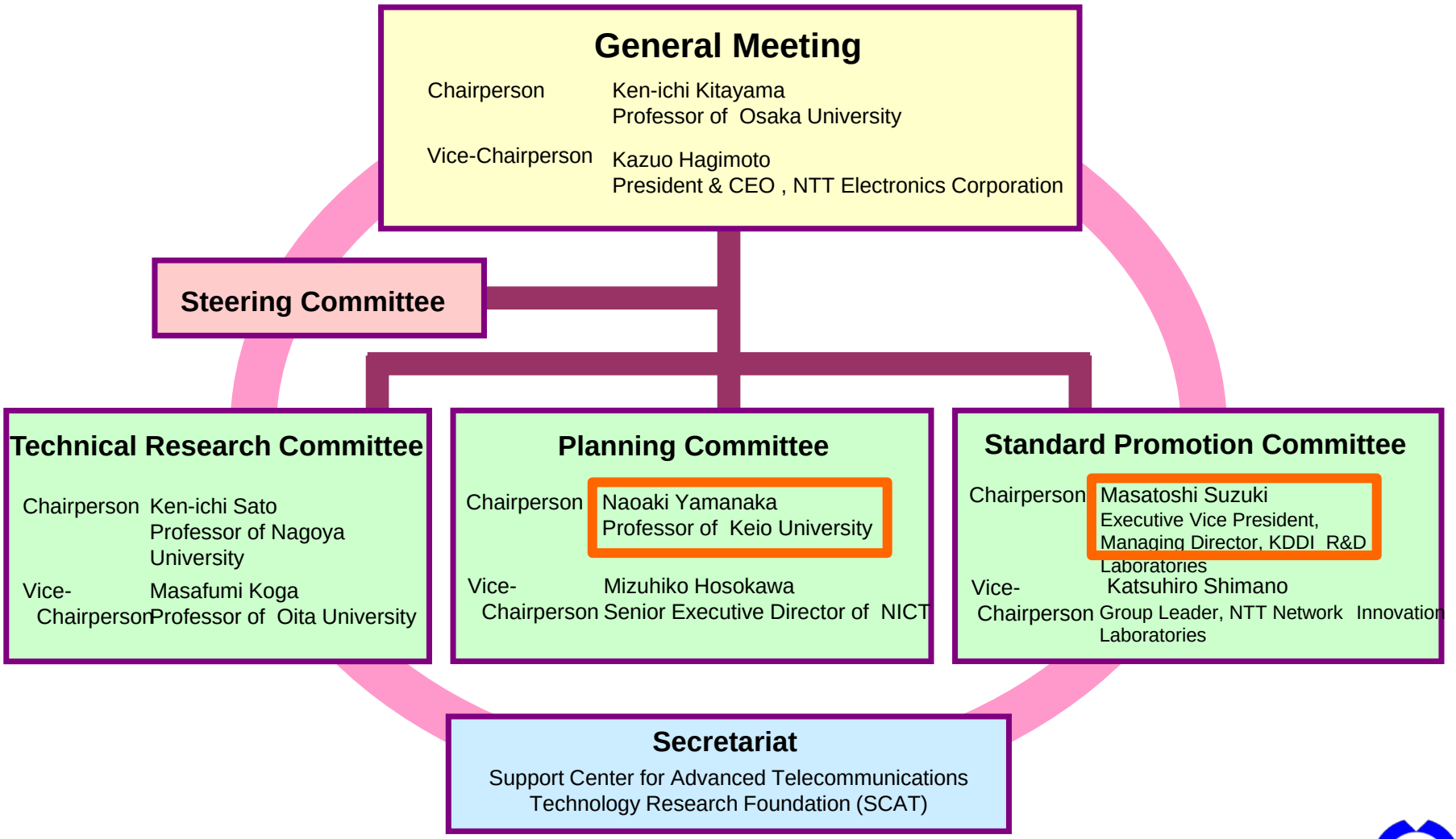
PHOTONIC INTERNET FORUM

Introduction to *Photonic Internet Forum*

Ken-ichi Kitayama

Chairperson of the *Photonic Internet Forum*
Osaka University, Japan
kitayama@comm.eng.osaka-u.ac.jp

Organization chart



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Photonic Network Vision 2020—Toward Smart Photonic Cloud

Ken-ichi Kitayama, *Fellow, IEEE*, Atsushi Hiramatsu, *Member, IEEE*, Masaki Fukui, Takehiro Tsuritani, Naoaki Yamanaka, *Fellow, IEEE*, Satoru Okamoto, *Senior Member, IEEE*, Masahiko Jinno, *Senior Member, IEEE*, and Masafumi Koga, *Member, IEEE*

(Invited Tutorial)

***Abstract*—A vision of the photonic network in 2020 is presented, which envisages a "smart photonic cloud." A smart photonic cloud is defined as a universal network platform without any physical or logical constraint that provides flexible connectivity for machine-to-machine communication such as networked high-performance computing or intra- and inter-data center networks. The key requirements for the network in the Big Data era include an ultralarge capacity with low power consumption, low latency, as well as flexibility on demand to the changes in the configuration and bandwidth of the optical path. To cope with the growing demand for network virtualization, novel photonic layer virtualization will be proposed, which differs from the conventional approach in terms of the number of slices and the dynamic range of the bandwidth of each slice. First, the objectives and the guiding principle of the vision will be addressed. Next, three "Ss" will be presented that represent the key enabling technologies, namely scale-free photonics, smart photonic networking, and a synthetic transport platform. A key engine with which to realize the above three enabling technologies is the photonic network processor (P-NP), which can define versatile functionality of switches and transmission systems by software. The P-NP takes advantage of the rapid progress made on digital signal processing for coherent optical transmission systems, and it consists of pools of optical frontends, digital signal processors, L1/L2 switches, which are either electrically or optically interconnected based on silicon photonic technology. Finally, a multifunctional optical cross-connect and a bit-rate-flexible optical transponder are presented as examples of P-NP applications.**

***Index Terms*—Digital signal processing (DSP), network virtualization, optical fiber communications, photonic network, photonic network processor.**

I. Introduction

THE photonic network will play a crucial role in the coming Big Data era. Commerce, medical care, education, entertainment, and social life will rely more heavily on cloud computing in the near future. Data are generated from various sources such as sensor networks, scientific meteorological simulations, genomics, computational physics, financial transactions, social network services, and the Internet logs of search engines. The network traffic for storing, updating and accessing to all those generated data sets in the data centers (DCs) is exponentially increasing. According to the Cisco white paper

K. Kitayama, et al., *IEEE/OSA J. Lightwave Technol.*, Vol.32, No.16, pp.2760-2770, 2014.

R&D Toward “Smart photonic cloud”

R&D toward 2015
- 400G~1Tbps/core
- Nyquist-WDM
- SDM: Multicore/multi-mode
- Flex-grid/elastic NW

2020+
Smart photonic cloud
Converged service platform for fixed & 5G mobile in “Big Data” era

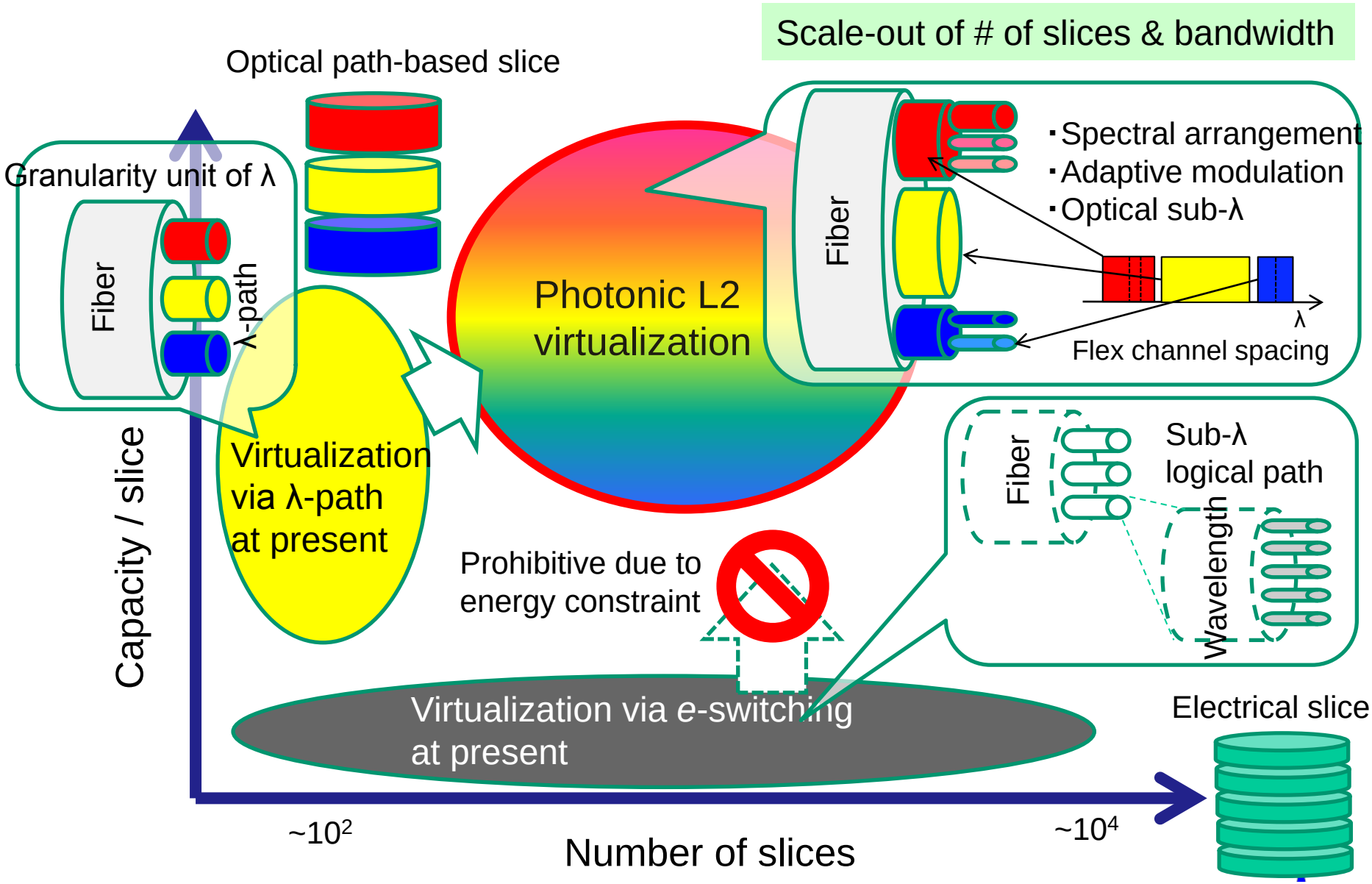
Full exploitation of photonic layer
ential

More capacity & flexibility

Opaquet photonic network
- Limited capacity on fixed grid
- Static NW configuration
- Poor energy efficiency&latecny

R&D toward 2020
- Scale-free photonics
- Smart photonic networking
- Synthetic transport platform

Photonic Layer 2 virtualization



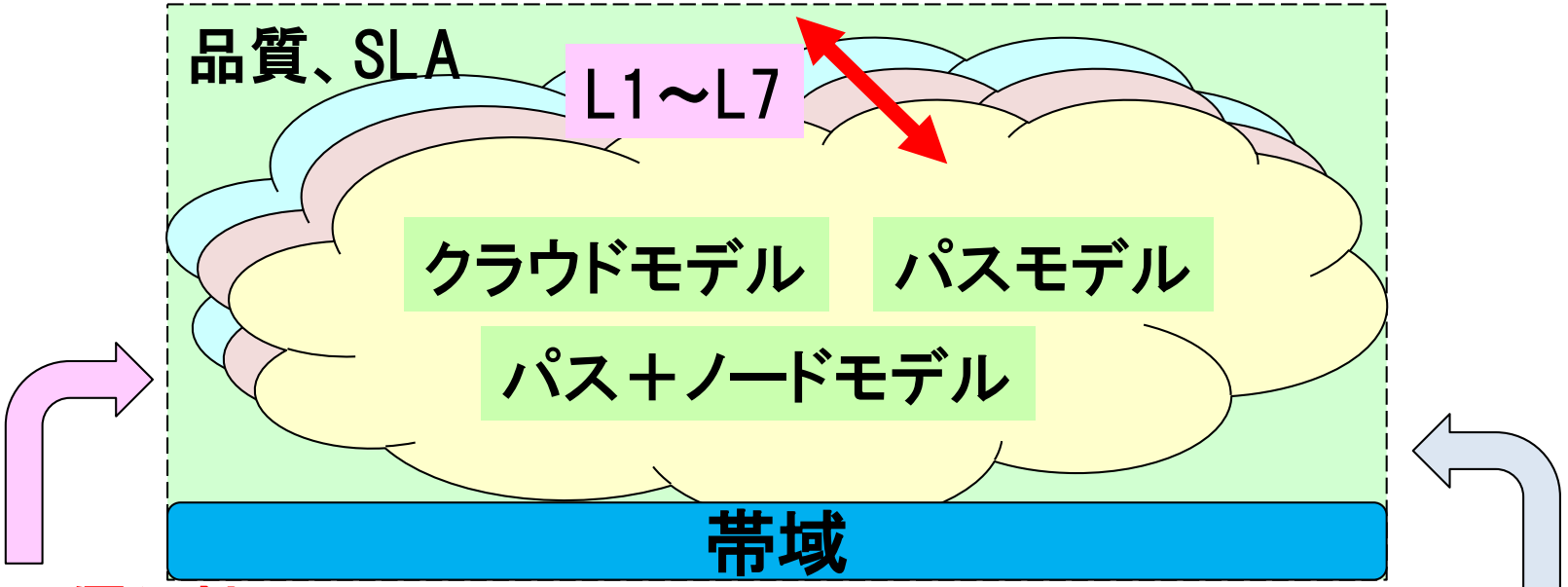
スマートフォトニックNWと光L2

2014.11.18

慶應義塾大学

マルチプロトコル(マルチレイヤ)SDNサービス

ユースケース毎に異なるNWモデル、提供レイヤ、帯域、品質等に柔軟かつ低コストに対応



光の優位性

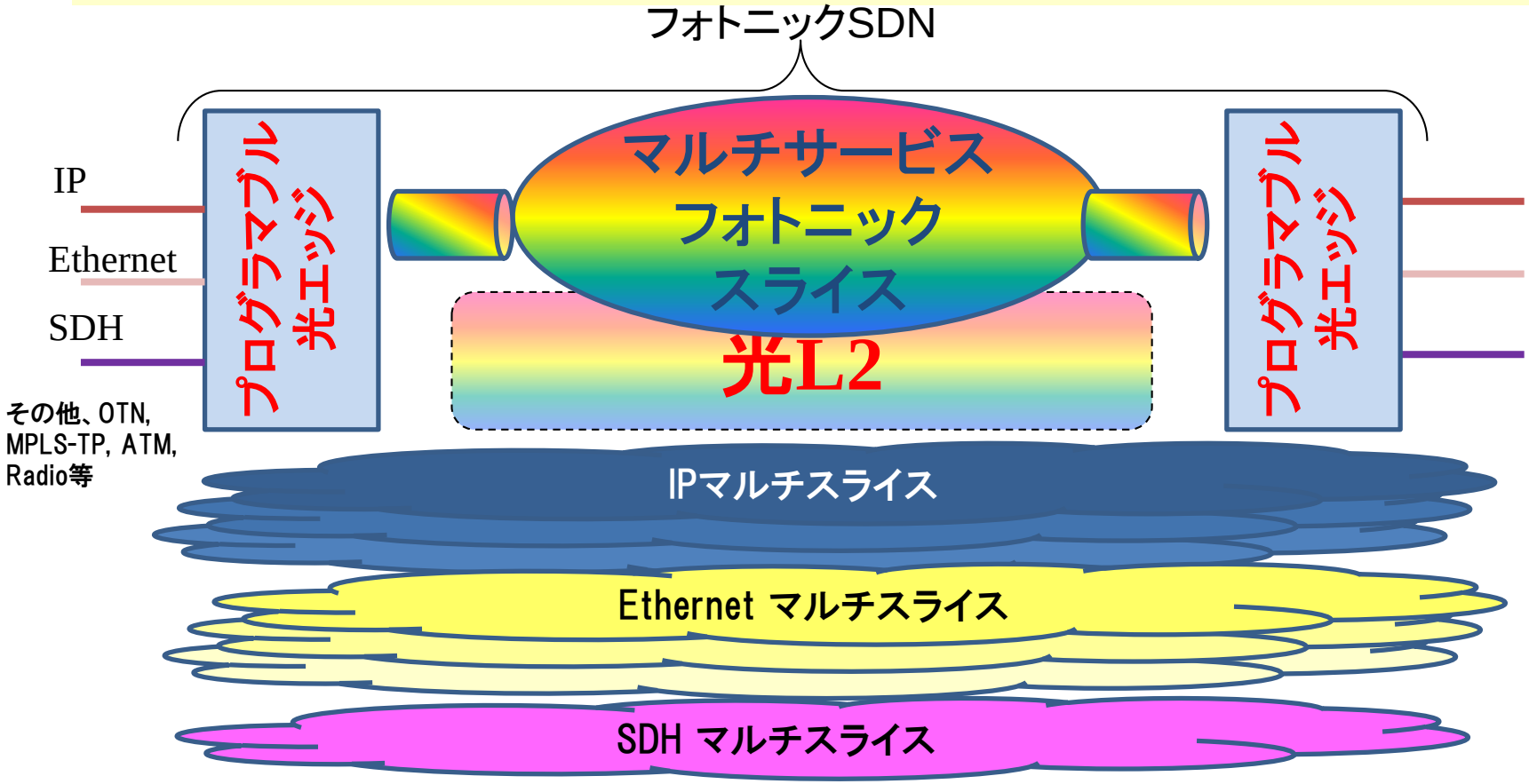
- 経済的な大容量パス(これは当たり前)
- 低遅延、低ジッタ(遅延時間の規定(保証)が可能)
- 完全な帯域保障が可能(他のトラフィック等に、原理的に全く影響されない)
- エラスティック技術によりパス容量が自由に選択可能
- トランスペアレント(プロトコルフリー)

仮想化(SDN)の優位性

- 一般的に仮想化NWやSDNで主張されている優位性があてはまる

スマートフォトニックNWアーキテクチャの提案

- プログラマブル光エッジでL1～L7(いいすぎ?)の全サービスを提供
- マルチサービスフォトニックスライスでは、サービス毎に帯域エラスティックなハードスライス(回線/パススイッチ)やソフトスライス(光L2スイッチ)を提供

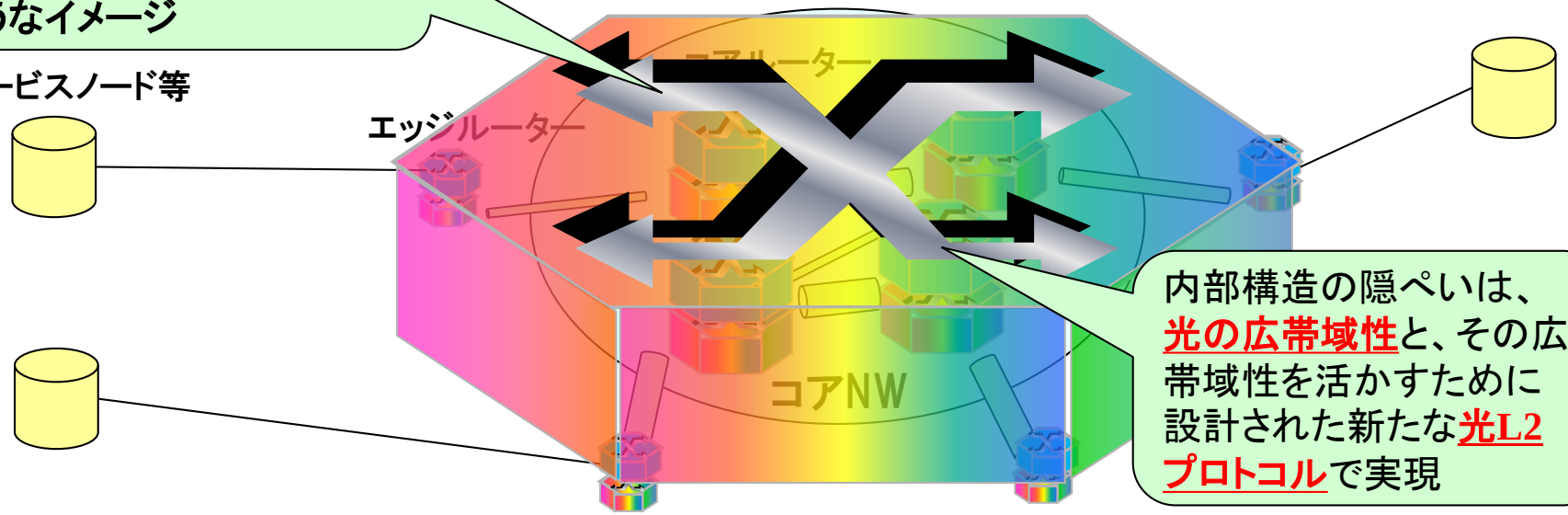


光L2のコンセプト

- 光のL1伝送技術(λ／サーキット)と、光のL3転送技術(光パケット)の間を埋める新たなトランスポート技術
- LAN向けのL2技術ではなく、光技術を最大限活用する伝達網指向に特化した新たなL2技術
  - サービスからは伝達網がL2網として見える

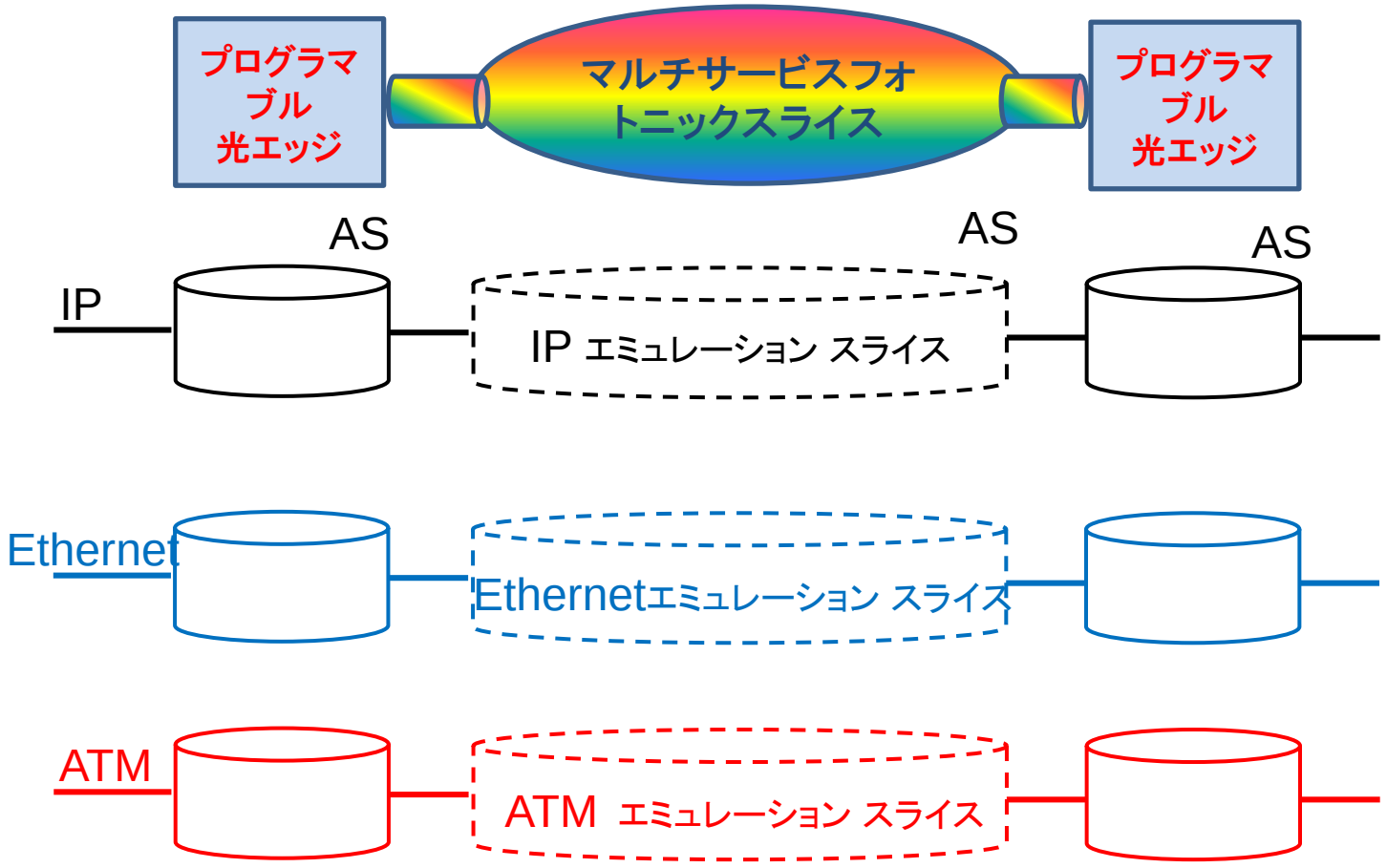
コアNW部分がスイッチファブリック、エッジの部分がインターフェースパッケージのようなイメージ

コアNW ≡ 光L2NW ≈ L3ルータレスNW



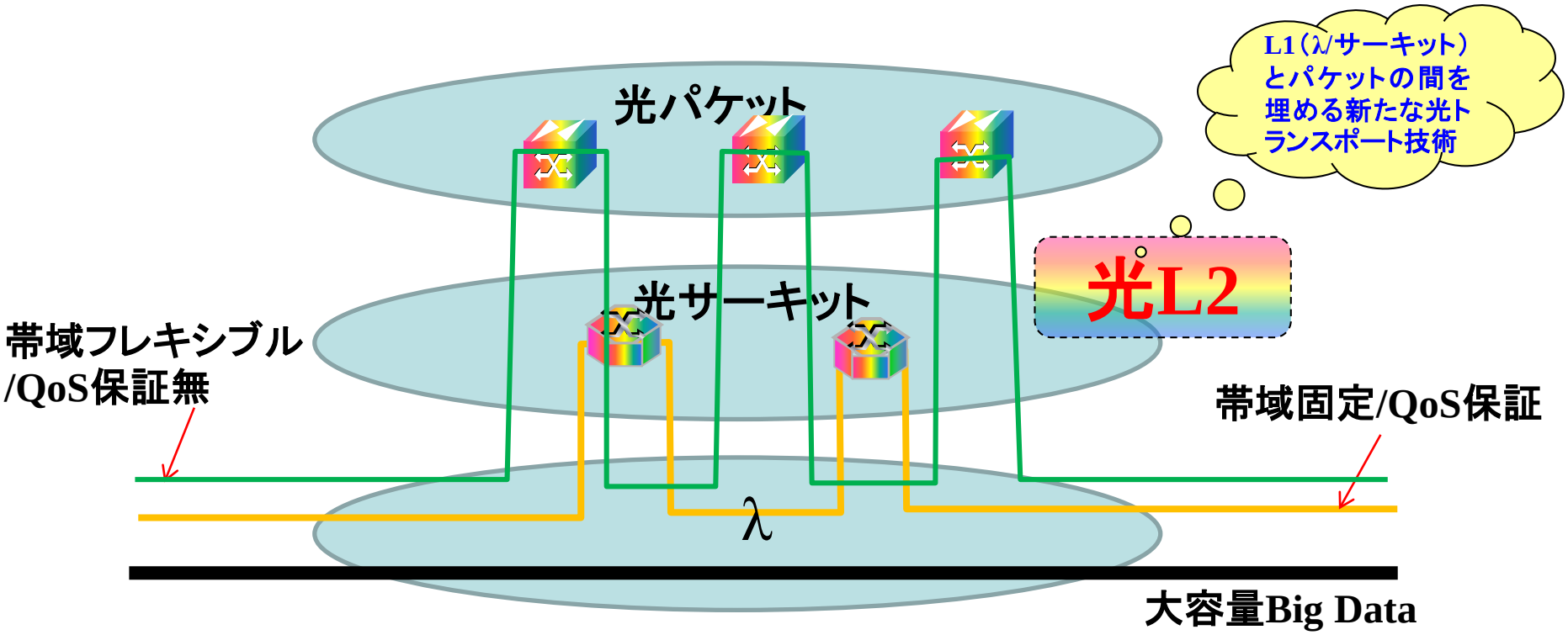
内部構造の隠ぺいは、光の広帯域性と、その広帯域性を活かすために設計された新たな光L2プロトコルで実現

スマートフォトニックNW上での
マルチトランスポートエミュレーションスライス



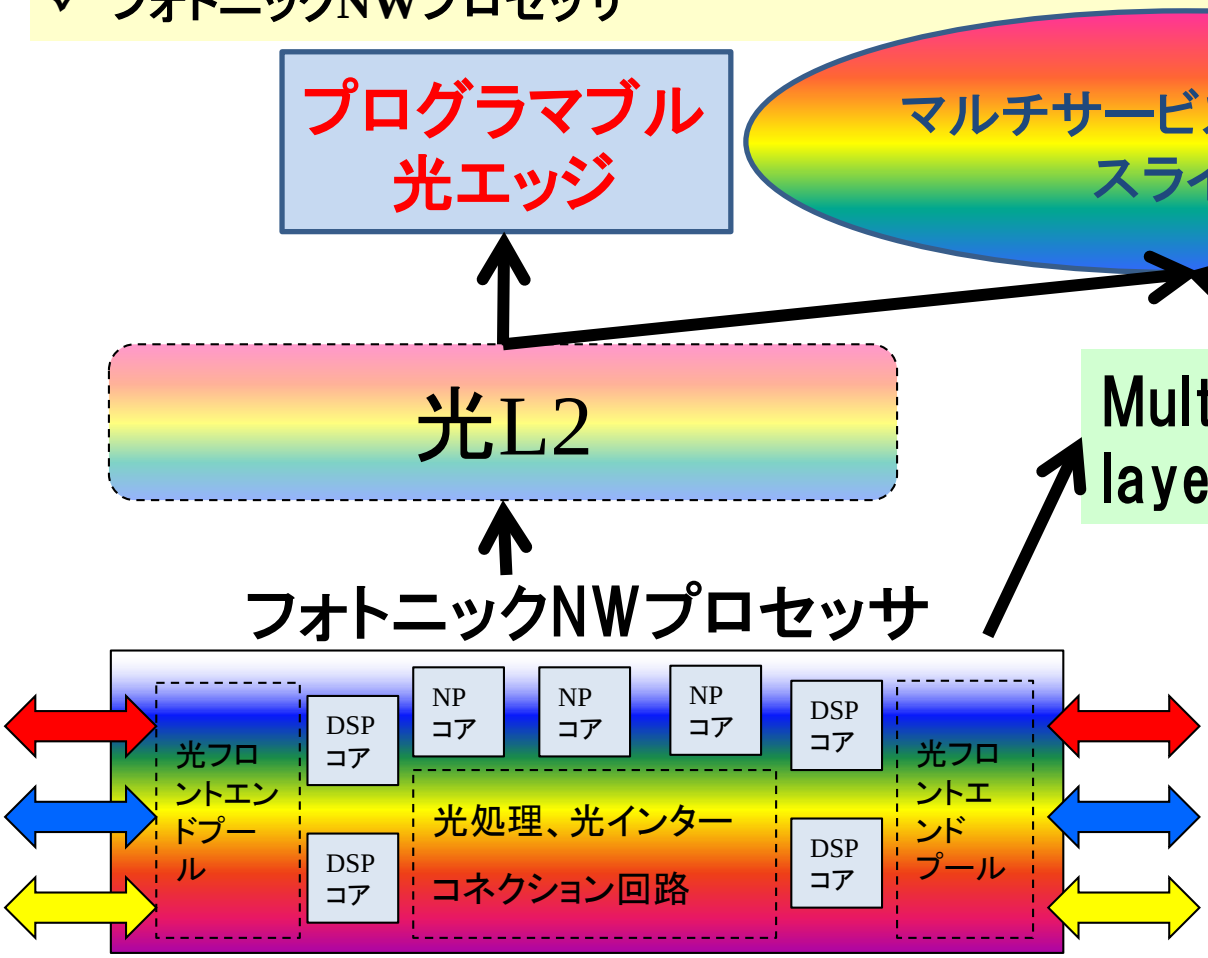
マルチサービスフォトニックスライスの構成例

サービスグラニュアリティに対応して光パケット/光サーキット/波長直結を使い分ける



スマートフォトニックNWを実現するための技術

- ✓ プログラマブル光エッジ
- ✓ マルチサービスフォトニックスライスアーキテクチャ
- ✓ 光L2（アーキテクチャ、プロトコル、実現方式）
- ✓ フォトニックNWプロセッサ

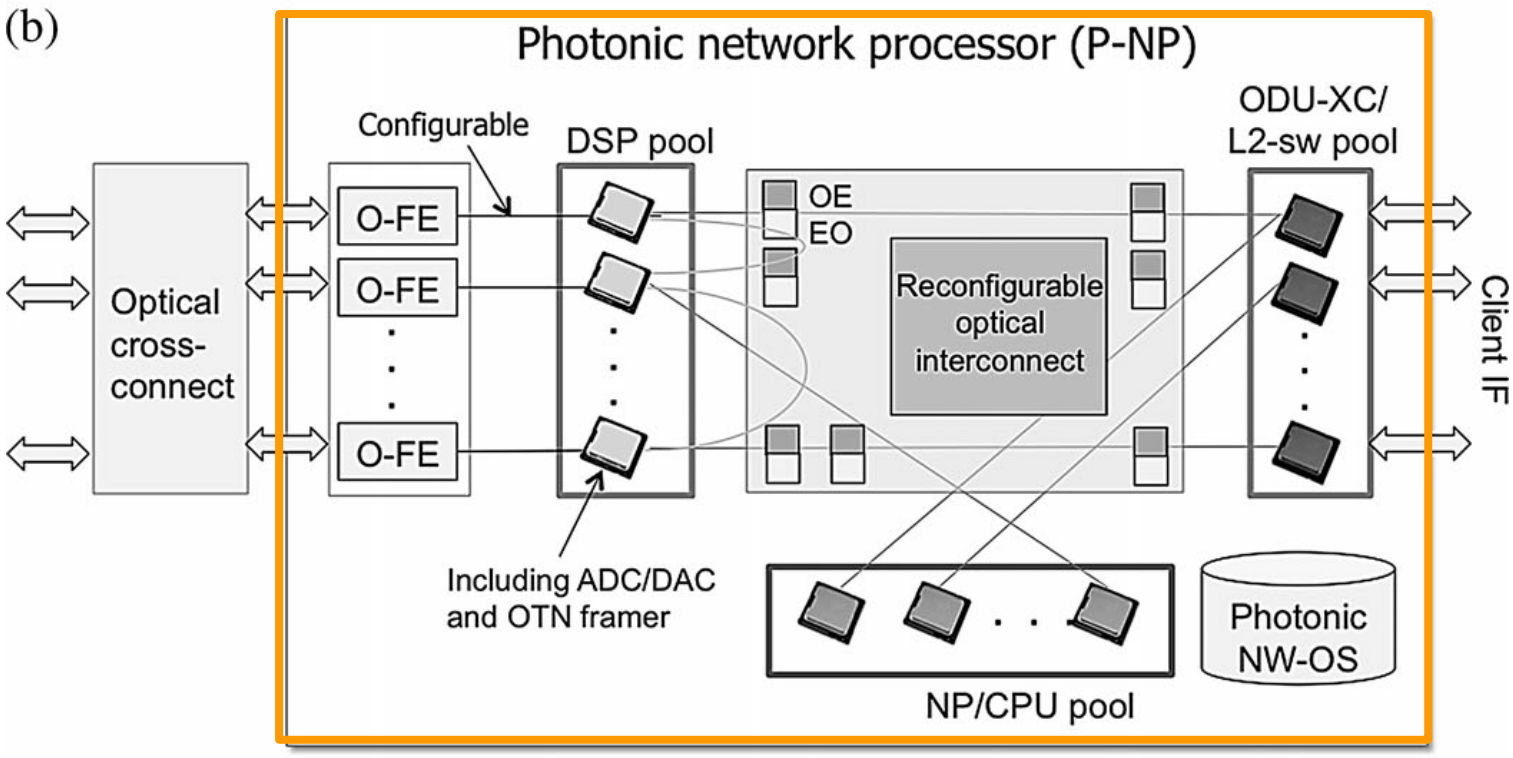


Multi-granularity, Multi-layer フォトニックNW技術

マルチフロートラポン
バーチャライズド光エッジ 等

Photonic Network Processor (P-NP)

- リコンフィギュラブルな光インターコネクトで、DSP、NP/CPU、ODU-XC/L2-sw といったリソースを接続
  - リンクトリソーシス (Linked Resources)による、各種機能の実現



K. Kitayama, et al. “Photonic Network Vision 2020 - Toward Smart Photonic Cloud,” IEEE JLT) Vol. 32, No. 16, pp. 2760-2770, Aug. 2014.

むすび

1. 光技術の将来の可能性について述べた。
   ネットワークは、データセンタセントリック、もしくは完全分散リンクドサービスを指向する。
2. 光技術をより高度に利用するため、現在のリンクから、ネットワークへ、L1からL2へ進化させたいキーとなるシリコンフォトニクスの光ネットワークプロセッサの研究が急がれる。