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AIST

The Univ. of Tokyo

Energy Consumption Targets for Network Systems

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Part of this work is supported by
The New Energy and Industrial Technology Development Organization (NEDO).

Part of this presentation is after SAINT2008 Workshop PCFNS'08 and the Related Panel

UTYO

- Source
  - Workshop Title: Power Consumptions in Future Network Systems
  - Panel: Power Consumption Target of Network Systems in the 2030's
- Summary
  - Possible Technologies exist
  - Mobile Business has a lot of possible improvements
  - Carriers' or ISPs' Incentive?
    - Cost of energy over lifetime (5 years) is 1.5% of the average carrier-class router or switch CAPEX*

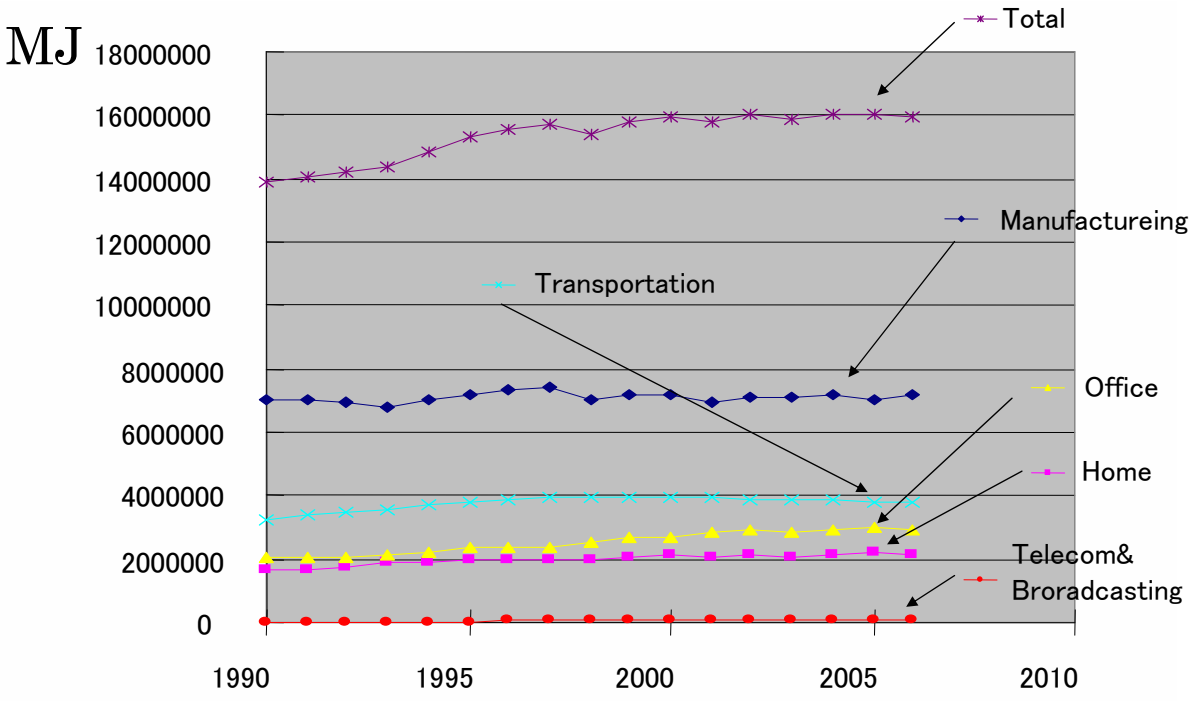
* Source Luc Ceuppens, SAINT 2008

T. Asami and S. Namiki, ECOC 2008, Tu.4.A.3, in Brussels, Belgium, Spet. 23, 2008

Outline

- Energy Consumption and Technologies Outlook and Our Target
- A Value Proposition for Optical Path Networks
- NEDO project on All Optical LAN using Dynamic Optical Path Switching
- Enabling Technologies
- Summary

Energy Consumption in Japan since 1990



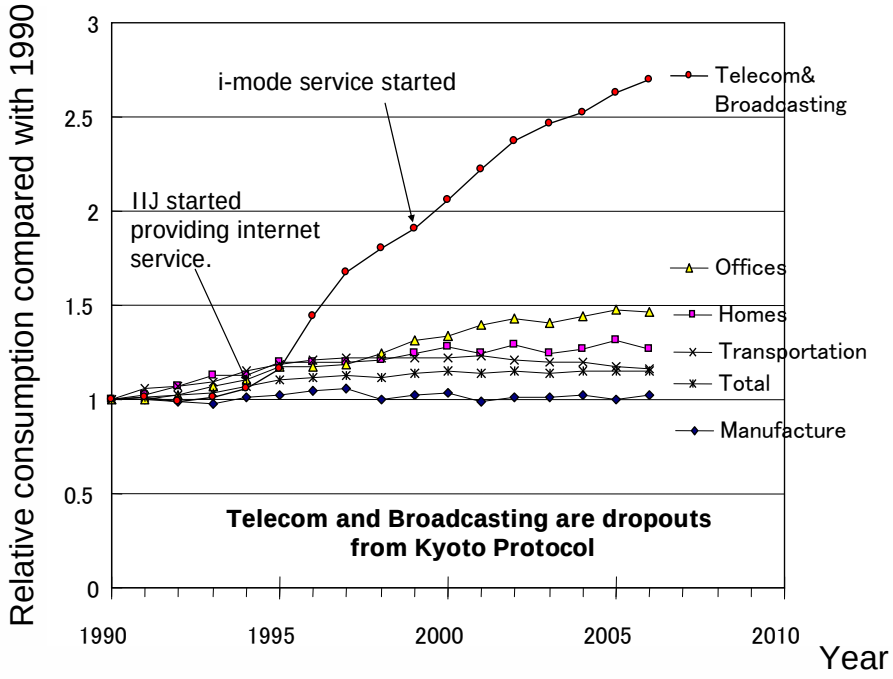
http://www.enecho.meti.go.jp/info/statistics/ jukyu/resource/xls/2006.xls

Energy Reduction

- Energy Reduction **BY** ICT
  - Optimum control of industrial equipment using ICT
    - WIDE Green IT Project, Power Grid, ….
- Energy Reduction **OF** ICT
  - Energy reduction of ICT Industry
    - Data center
    - Computers
    - Communication Network (Fixed, Mobile)
  - Energy reduction of Home Appliances
  - ….

T. Asami and S. Namiki, ECOC 2008, Tu.4.A.3, in Brussels, Belgium, Spet. 23, 2008

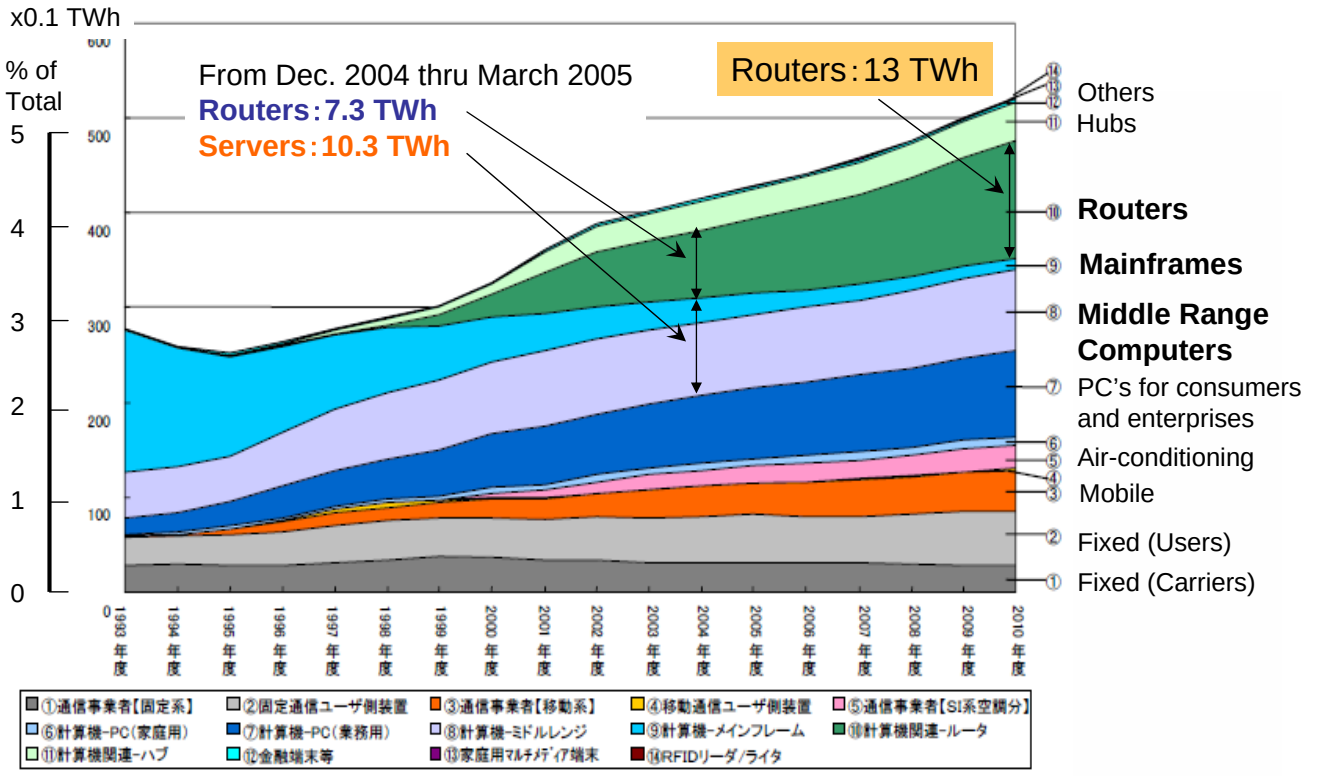
ICT Shares Power Consumptions at Home & Office



http://www.enecho.meti.go.jp/info/statistics/ jukyu/resource/xls/2006.xls

T. Asami and S. Namiki, ECOC 2008, Tu.4.A.3, in Brussels, Belgium, Spet. 23, 2008

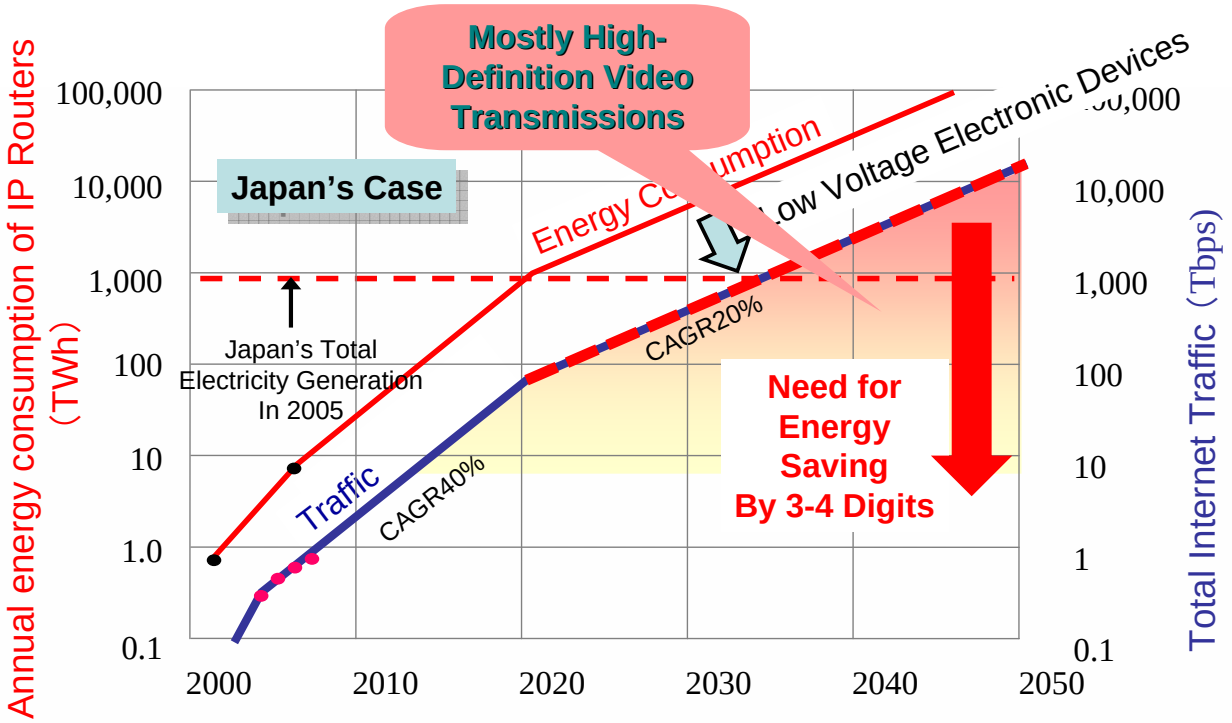
Forecast of the energy consumption for IT equipment



Source: Ministry of Internal Affairs and Communications (MIC)

T. Asami and S. Namiki, ECOC 2008, Tu.4.A.3, in Brussels, Belgium, Spet. 23, 2008

IP Bottleneck: Energy Consumption



- The current technologies can't scale to the increasing traffic in future.
- 3-4 digit energy saving is necessary, which means we need a new paradigm.

T. Asami and S. Namiki, ECOC 2008, Tu.4.A.3, in Brussels, Belgium, Spet. 23, 2008

‘Super Hi-Vision(SHV)’ by NHK

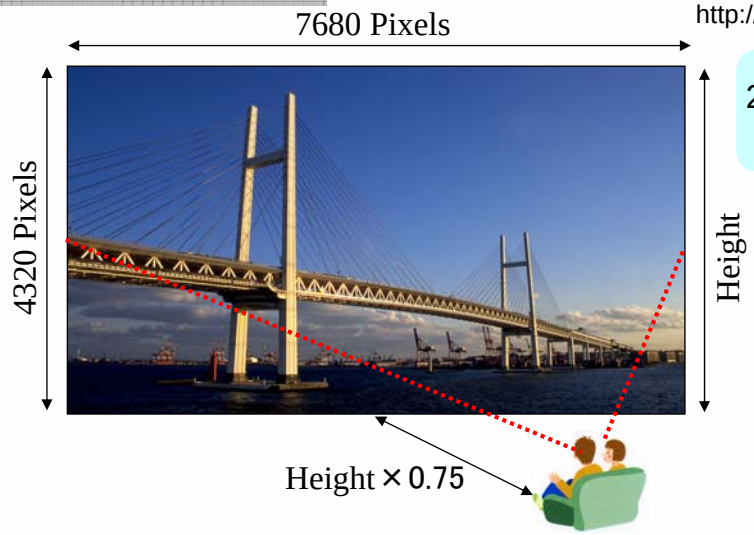
UTYO

~72Gb/s?

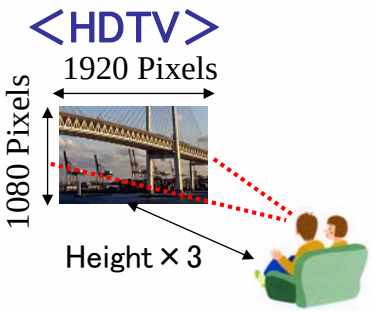
Service will begin in 2025.

Courtesy of NHK

http://www.nhk.or.jp/strl/publica/bt/en/to0025.pdf



20/20 vision can resolve 60 pixels within 1 degree of view angle



View Angle: 100° (Aspect Ratio 9:16)
View Distance: Height x 0.75

View Angle: 100° (Aspect Ratio 9:16)
View Distance: Height x 3

Data size of every video content will scale to the ‘Super Hi-Vision’

T. Asami and S. Namiki, ECOC 2008, Tu.4.A.3, in Brussels, Belgium, Spet. 23, 2008

Imaging the growing traffic

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Super high-def video based Remote Presence

P2P, IPTV, VOD
IP centric various services

Mobile Ubiquitous Sensors

Email
WWW

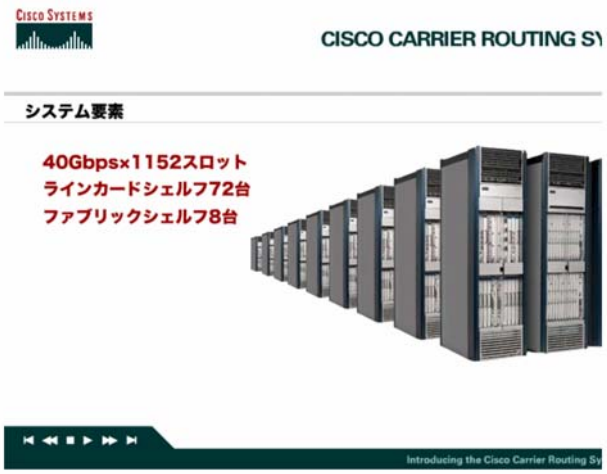
TODAY

TOMORROW

From Digital Packets to Fiber Links

T. Asami and S. Namiki, ECOC 2008, Tu.4.A.3, in Brussels, Belgium, Spet. 23, 2008

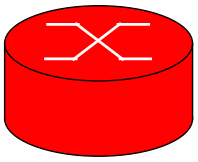
Cisco CRS-1 Router: Largest on earth



Can accommodate only 1000 SHV users!

Source: Cisco Homepage

Total Line Card Capacity: 92 Tbps on 80 Racks



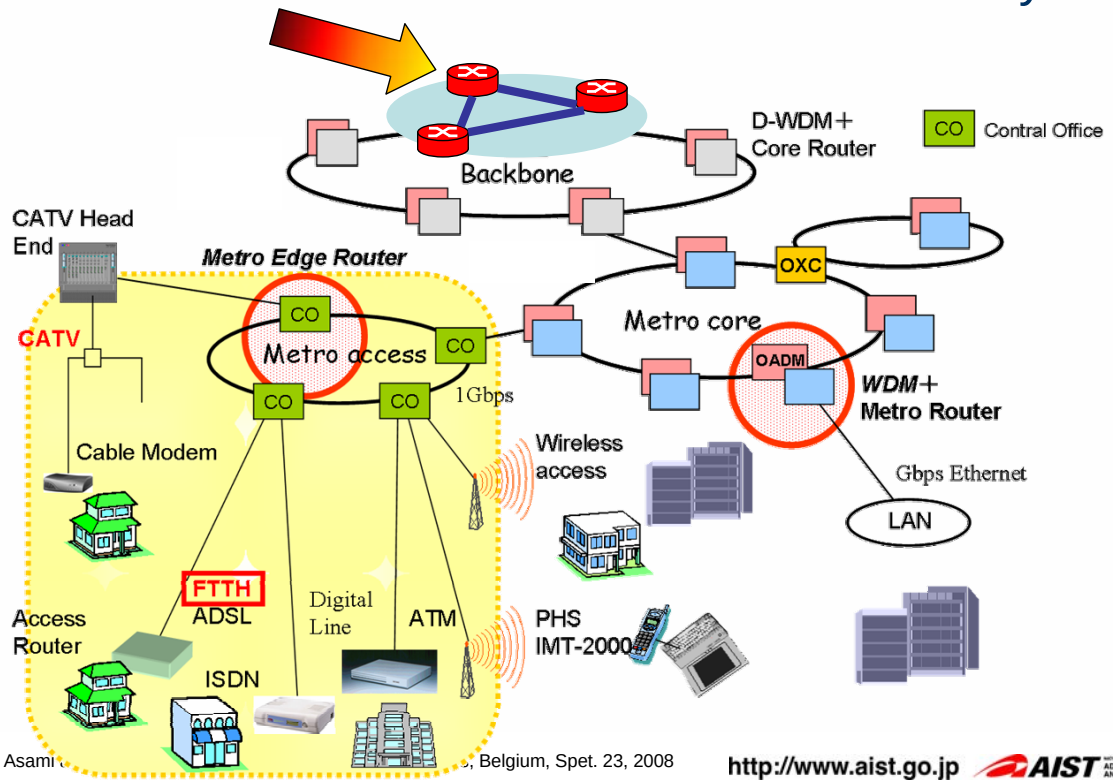
Total Required Power Supply ~ 1 MW

And Power for air-conditioning (~ 1MW)

T. Asami and S. Namiki, ECOC 2008, Tu.4.A.3, in Brussels, Belgium, Spet. 23, 2008

Network Topology: Today

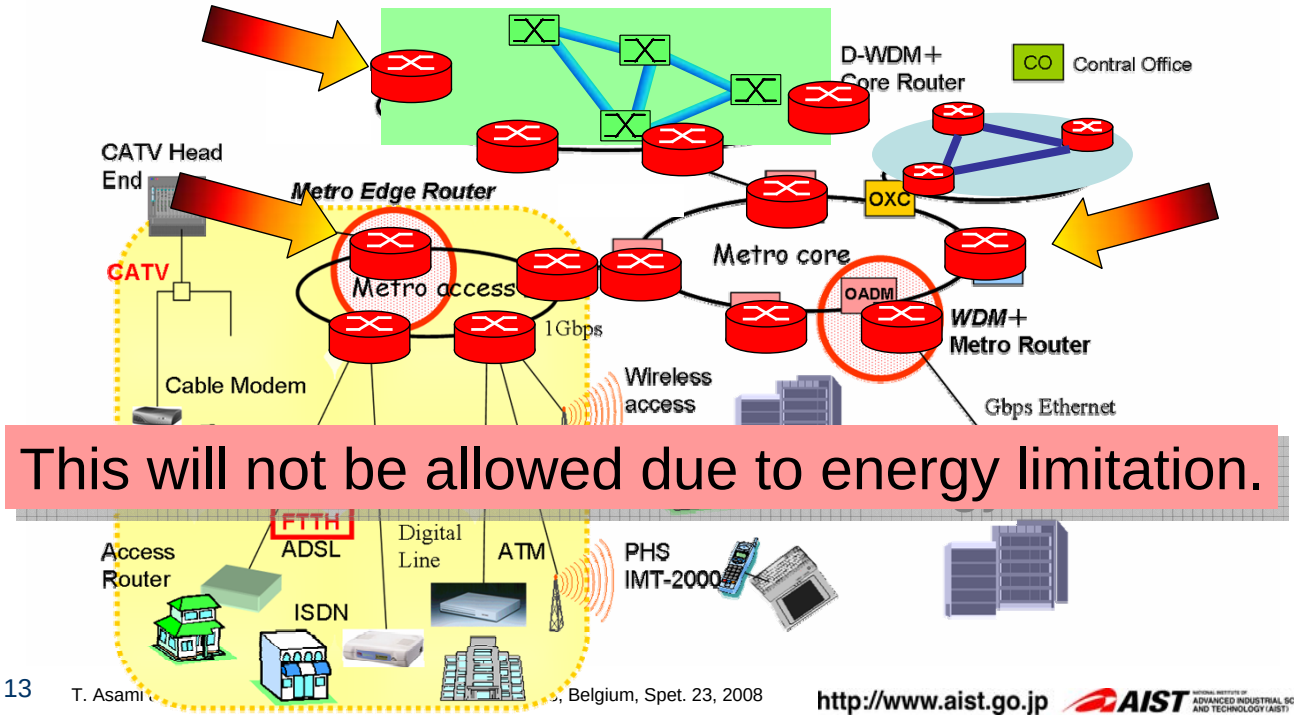
- CRS-1 Class Routers in Core Networks only



T. Asami , Belgium, Spet. 23, 2008

Network Topology: Tomorrow???

- Core networks will be based on OXC mesh.
- CRS-1 Class Edge-Routers Everywhere!!??



Network technologies: What's beyond?

Our Target!

Data(PC-PC) Video(person-person

Application aspects	Bandwidth Eaters	Email WWW	P2P YouTube	IPTV Video Conference	Immersive, Remote Presence
	Video Definition	SD 0.2 Gbps	HDTV 1.5 Gbps	4k 20 Gbps	8k(SHV) 72 Gbps
	Storage Media	CD 700MB	DVD 9 GB	Blu-ray 50 GB	Multi-layer Near field
	Year	1990's	2000's	2010's	2020's
Network aspects	Network Traffic	0.01	1	> 100	> 1,000
	Ethernet I/F to user	100BASE-T	1000BASE-T	10G-BASE-T	100G?
	Access Connectivity	Dial-up	ADSL/Cable	PON-FTTH	Dedicated connections
	Granularity per user	Voice 10 kbps	Twisted pair 1-10Mbps	Sub-wavelength to wavelegnth > 100Mbps	Wavelength to Fiber > 10Gbps
	Type of Network	Telephone	Internet	NGN/ROADM	Dynamic Optical Networks

Digital Packets Fiber Link

Two Measures for Energy Efficiency

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- PUE (Power Usage Effectiveness) Data Center

$$PUE = \frac{\text{Total Power Consumption}}{\text{Power Consumption of ICT}} > 1$$

- EER (Energy Efficiency Rate) IP Router
  - Bits processed by a unit energy (J)
    - Bits/J, Kbits/Wh, Gbps/kW,….

$$EER = \frac{T}{\sum_{i \in I} C(i)}$$

  - The faster, the more efficient

T. Asami and S. Namiki, ECOC 2008, Tu.4.A.3, in Brussels, Belgium, Spet. 23, 2008

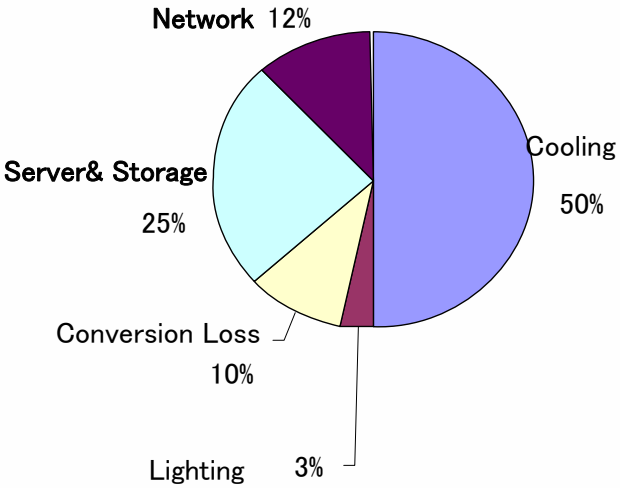
Data Centers: U.S. vs. Japan

UTYO

Total Consumption ∝ ICT Consumption

ICT=1/3 of Total

Energy Consumption in Data Center

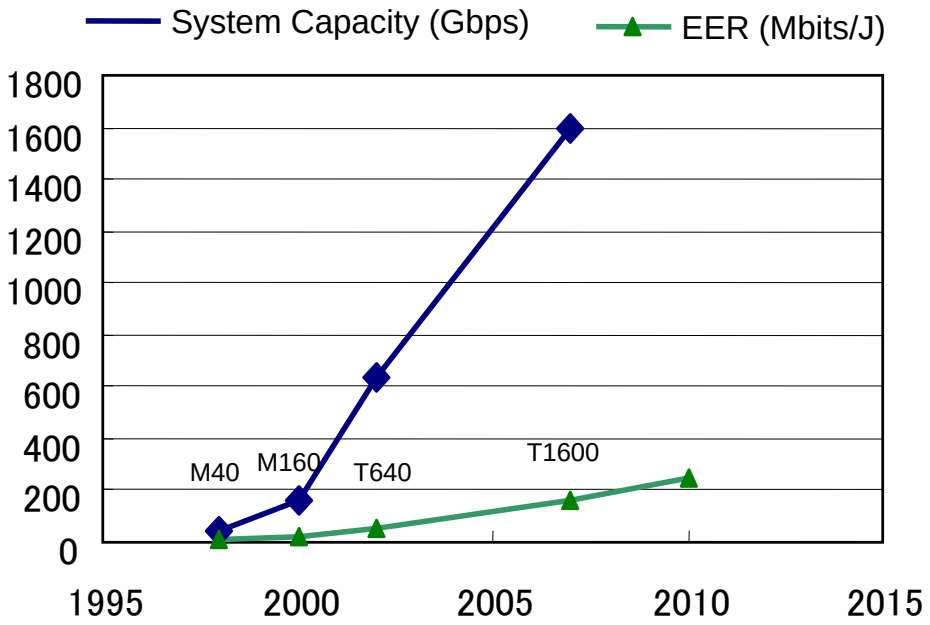


PUE=2.7 ⟷ **PUE of NTT 1.7 → 1.4**

Ref：APC(American Power Conversion)

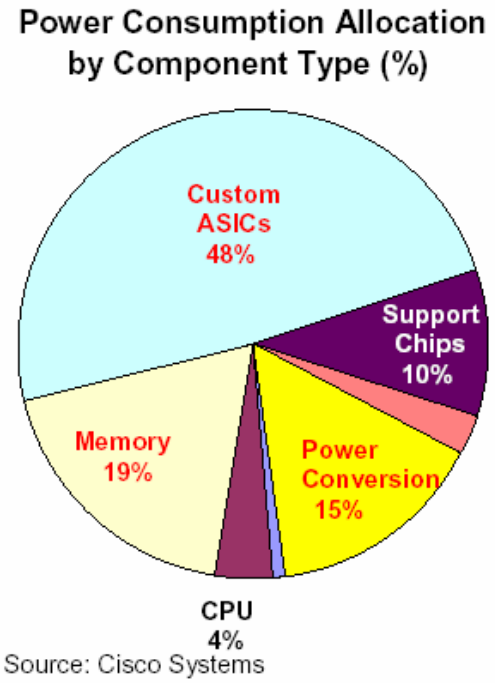
T. Asami and S. Namiki, ECOC 2008, Tu.4.A.3, in Brussels, Belgium, Spet. 23, 2008

Trend of Juniper Router Equipment EER



T. Asami and S. Namiki, ECOC 2008, Tu.4.A.3, in Brussels, Belgium, Spet. 23, 2008

Energy Consumption of Router Modules

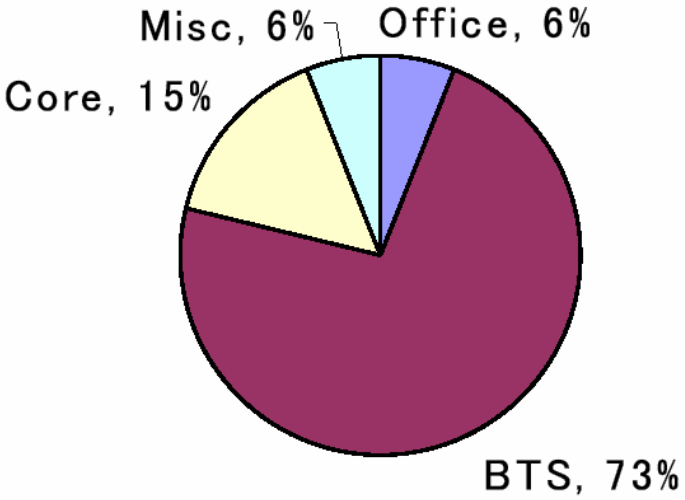


EER of CRS-1 ~ 50 Mbits/J

Luc Ceuppens, SAINT 2008

T. Asami and S. Namiki, ECOC 2008, Tu.4.A.3, in Brussels, Belgium, Spet. 23, 2008

Power Consumption by Mobile Business



China Mobile

7,890GWh,
357 M Subscribers
in 2007

#Base Stations: 305 x 1000

Minoru Etoh, SAINT 2008

T. Asami and S. Namiki, ECOC 2008, Tu.4.A.3, in Brussels, Belgium, Spet. 23, 2008

Power Consumption by Mobile Business

- China Mobile's Information in 2007
  - 7,890 GWh, 357 M Subscribers, 455min phone calls/month
- 7,890GWh /357 M users /365 days
  ≒ 60Wh/User/Day
- [455min/30(days)]*60(sec) *12Kbps(AMR)
  =10.92Mbits/User/Day (1.365MBytes/User/Day)
- Operating EER =10.92Mbits/60Wh
  = 182Kbits/Wh (22.8KBytes/Wh)
  = 50.6 bits/J

Equipment EER =163Mbits/J for Juniper Networks T1600

(Operating EER of Data center is not known)

Source http://www.chinamobileltd.com/images/pdf/2008/crr/

T. Asami and S. Namiki, ECOC 2008, Tu.4.A.3, in Brussels, Belgium, Spet. 23, 2008

Global Energy Efficient Communications

Goal = 1/10 of the current consumption per port

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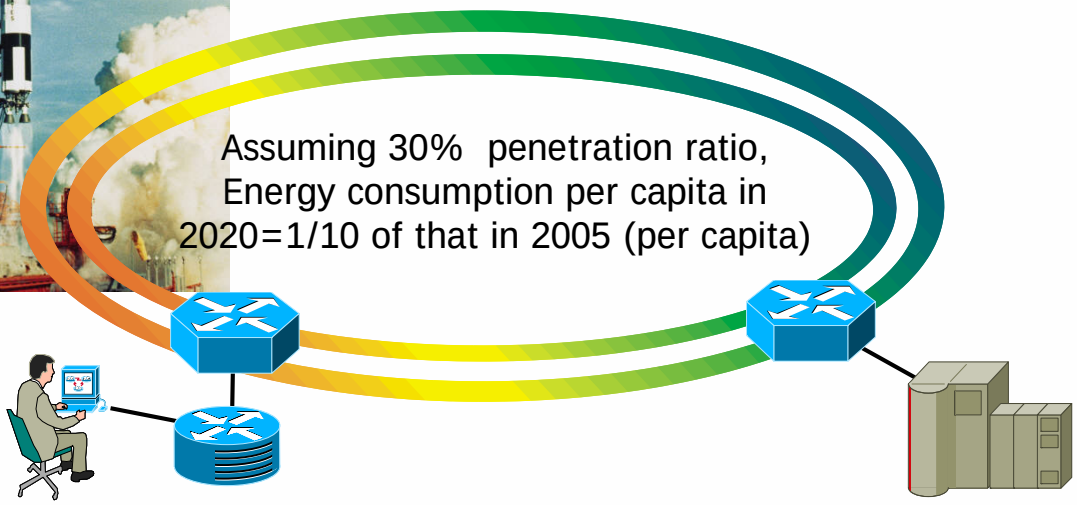
Why so much energy is required to transfer weightless information?

- The broadband subscribers in the world=215M in 2005(Penetration=3.35%：WHITE PAPER Information and Communications in Japan).
- World Population in 2020=7,500M.
- Energy consumption per capita =1/35



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Incentive in Industry

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- Cost of energy over lifetime (5 years) is 1.5% of the average carrier-class router or switch CAPEX*.
  - No economical reason for energy reduction
- Green IT is driven as a governmental policy.
- Ground-breaking technology has to be sought through ‘cross-layer’ approach.

* Source Luc Ceuppens, SAINT 2008

T. Asami and S. Namiki, ECOC 2008, Tu.4.A.3, in Brussels, Belgium, Spet. 23, 2008

http://www.aist.go.jp AIST

Possible Technologies

- Fixed Business
  - Optical Path Switching (Photonic Networks)
  - Optical Backplane (Optical Interconnects)
  - Power Efficient Electronic Circuits
    - CMOS, SFQ (Superconductive single Flux Quantum)
- Mobile Business
  - Optical Backhaul, Radio on Fiber
  - Efficient Transmissions (Smaller Cell Size using Photonic Networks)
  - Scheduling/Amplifier
- Common
  - Energy Harvesting from Wasted Energy

Summary of the panel discussion at SAINT 2008

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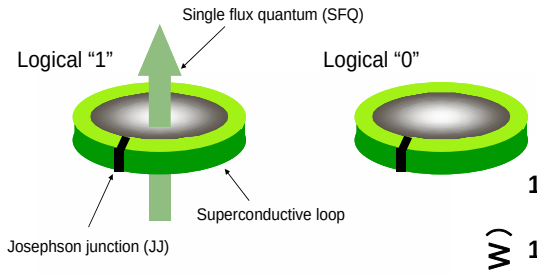
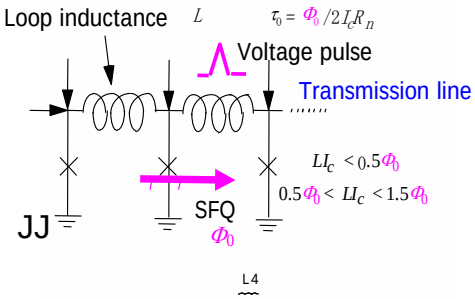
Super-conductor based SFQ device



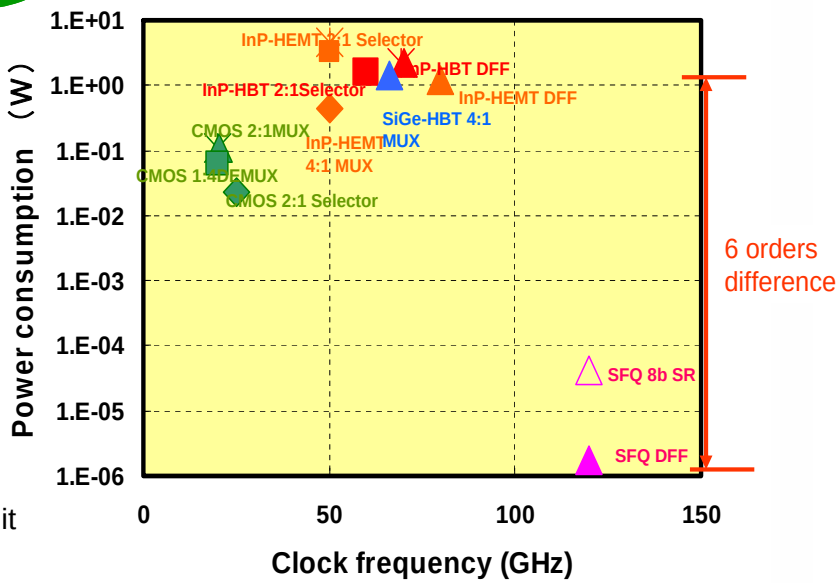
Superconductive SFQ device



Schematic diagram of an SFQ circuit

SFQ: Single Flux Quantum

Source: M. Hidaka in SAINT 2008

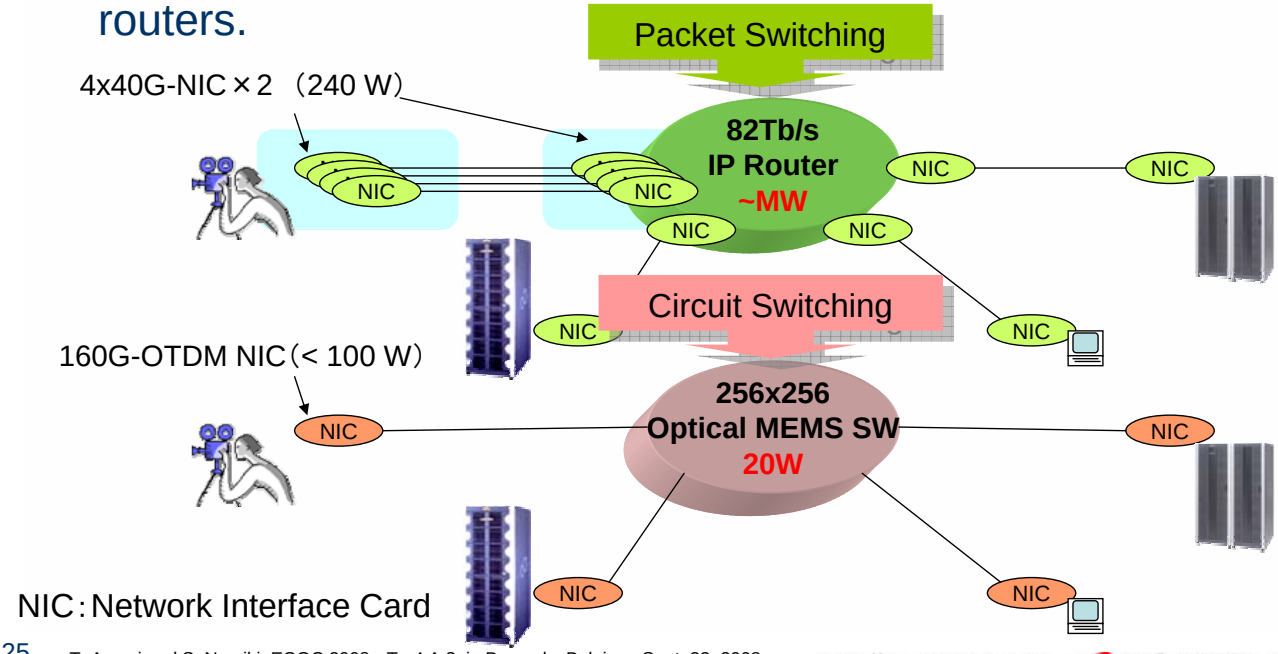


Power dissipation of SFQ and high-speed semiconductor gates
After H. Akaike et. al. Nagoya University & SRL

T. Asami and S. Namiki, ECOC 2008, Tu.4.A.3, in Brussels, Belgium, Spet. 23, 2008

A hypothesis: why can't we be simple?

- Circuit switching better suits real-time video services.
- At 82 Tb/s throughput, Optical circuit switch operates almost at four orders of magnitude lower electricity than IP routers.



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Fundamental Queueing Theory

- Packet Switching : M/G/1-PrSh

$$T_{PS} = \frac{E[S]/C_1}{1-\lambda_1 E[S]/C_1}$$

- Circuit (Path) Switching : M/G/1-FIFO

$$T_{OCS} = \frac{E[S]/C_2}{1-\lambda_2 E[S]/C_2}\left(1+\frac{\lambda_2 E[S]}{2C_2}\left(\frac{Var[S]}{E[S]^2}-1\right)\right)+G$$

S is the file size, *E*[*S*] is the mean file size, *C* is the transmission speed,
λ is the frequency of requests of file transfer,
Var[*S*] is the variance of the file size,
G is the guard time of the optical switch.

S. Shioda and S. Namiki, ICC2008, Beijing.
P. Molinero-Fernández and N. McKeown, J. Opt. Netw. ***2****, 83-96 (2003)*

T. Asami and S. Namiki, ECOC 2008, Tu.4.A.3, in Brussels, Belgium, Spet. 23, 2008

Data- versus Video-centric Network: Rough comparisons

UTYO

Service:	Data-based	High-Def Video-based
File Size:	From tiny to large	Huge
File Size Variance:	Large	Modest
Delay Fluctuation:	Tolerant	Intolerant
Call Blocking:	Intolerant	Can be tolerant
QoS/QoE:	Depends	Very important
Suitable Net-work Mode:	Connection-less Packet switching	Connection-oriented Circuit switching

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Post-NGN: Large Scale Dynamic Optical Path Network (DOPN)

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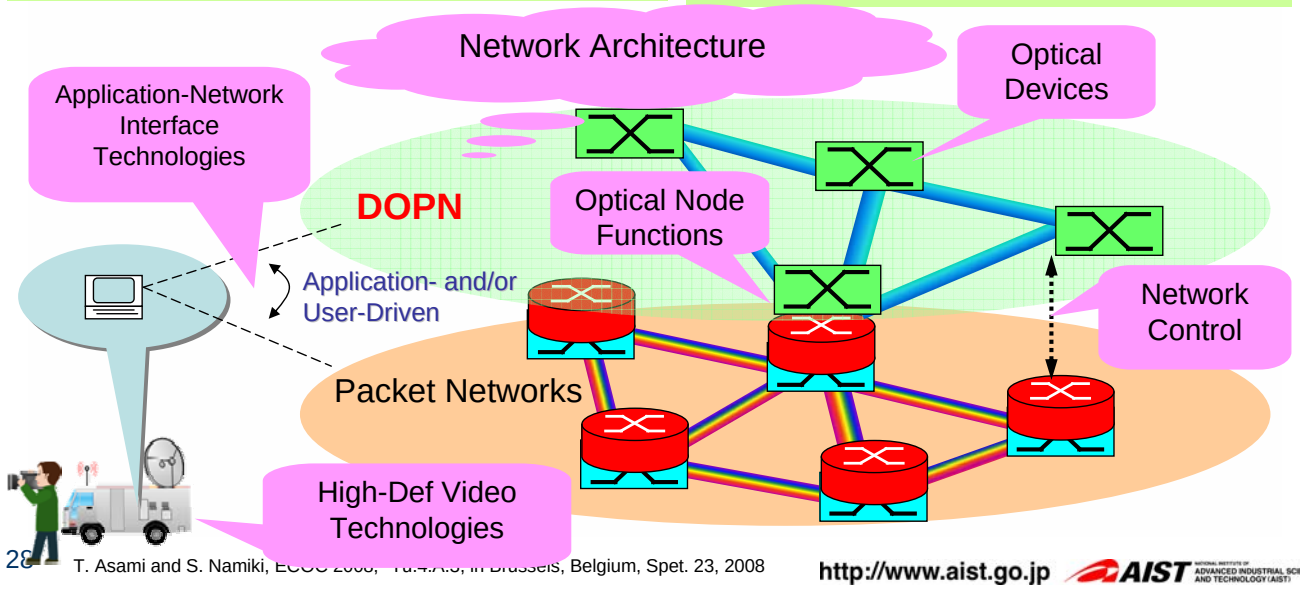
Application- and/or User-Driven Switching in Optical Layer

- Total Capacity: 1,000-10,000 Times Larger
- Energy Consumption: Decrease by 3 digits
- Main Services: High-Def Video Based
- User Connectivity: 10-100Gbps



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Network Topology: An Image

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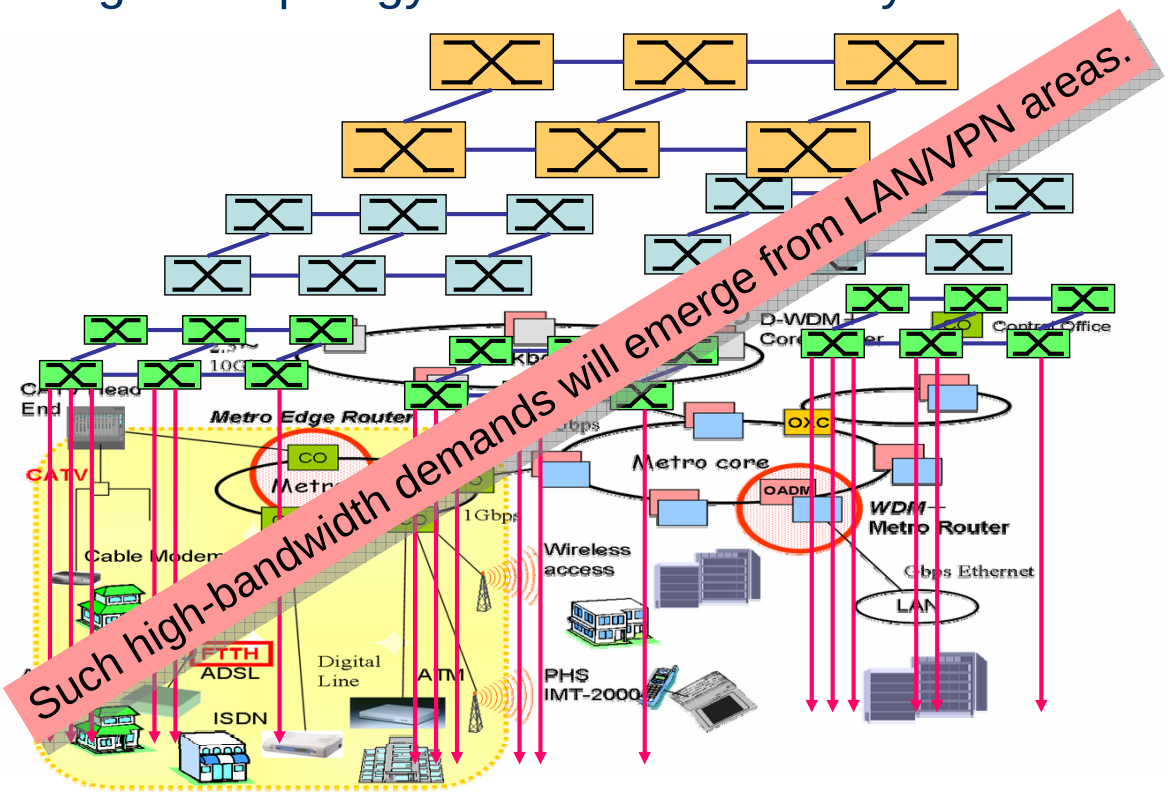
- Logical Topology of Fiber Mesh Everywhere



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NEDO Project on Ultra-fast OTDM-NIC

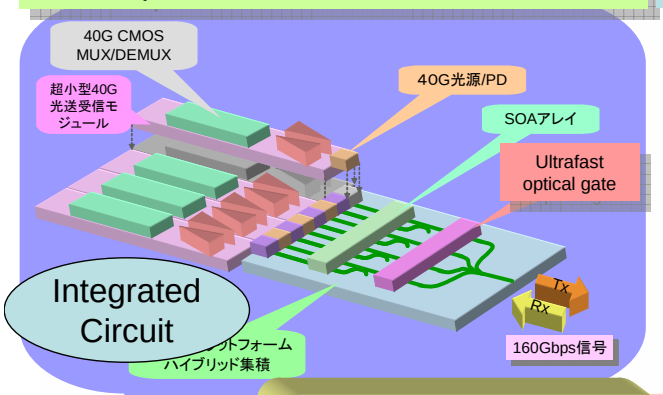
The New Energy and Industrial Technology Development Organization (NEDO)

UTYO

Development of Next-generation High-efficiency Network Device Technology

FY2007 – FY2011; FY2007 Project Budget: 1.16 billion yen

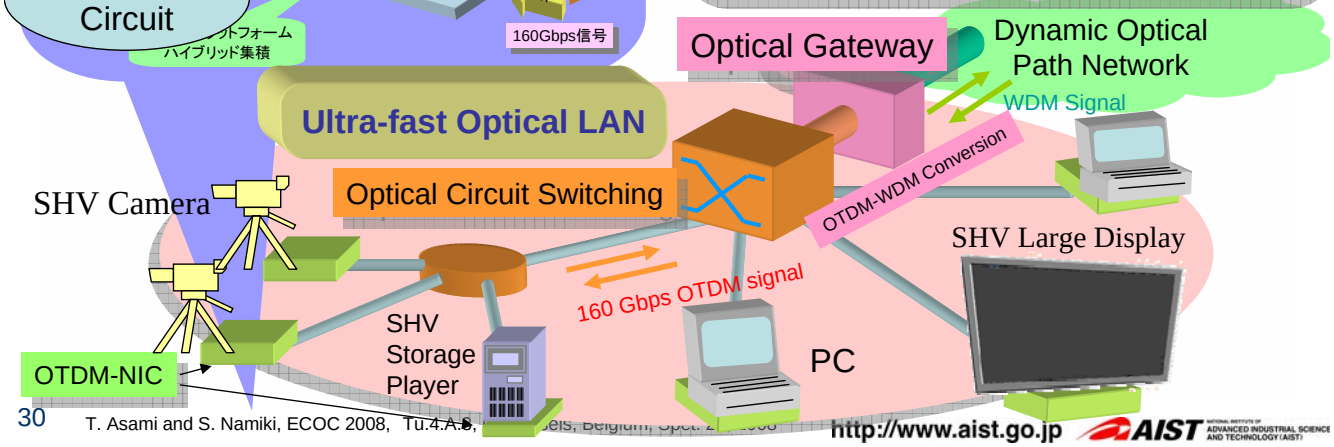
160 Gbps OTDM-Network Interface Card



Towards Telecom-Broadcast Convergence

Developing integrated opto-electronic devices technologies for the realization of energy efficient ultra-fast optical LAN for super high-def videos such as SHV

- Integrated 160 Gbps OTDM-NIC
- Integrated wavelength converters
- Demonstration of SHV contents delivery



T. Asami and S. Namiki, ECOC 2008, Tu.4.A.3,

The challenge still almost completely remains: How to build a global optical path network?

UTYO

- Potential technologies are there...
- But still need breakthroughs at practical levels.
  - Scalable optical switches and fiber deployment
  - Truly practical all-optical signal processing
  - New 'clean-slate' network architecture
- Need to overcome another Chicken-Egg dilemma
  - Top down and proactive, yet cross-layer approach from applications to optical layer is the key.
  - Need to concurrently identify migration paths and market drivers.

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Key Enabling Optical Technologies

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User- and/or Application-Driven Optical Path Switching

(1) Optical Path Processing
- Switches and fibers!!
  - Scalable Matrix or WSS
  - Low cost fiber deployment, like FTTH in Japan
- Optical TDM Switching
  - Burst Switching
  - Optical Delay Control

(2) Optical Path Conditioning
- Monitoring
  - Sophisticated fast optical performance monitors
- Optical regeneration
  - Optical dispersion compensators
  - Wavelength converters
  - O3R
  - All-optical format converters

(3) Optical Path Interface
- Integrated network interface cards (Tx/Rx)
  - Wavelength Division Multiplexing (WDM)
  - Optical Time Division Multiplexing (OTDM)
  - Multi-level optical coherent
  - Burst-mode Operation

Faster than Electronics
Seamless band
Colorless
Fast Response
Format-agnostic

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Summary

UTYO

- Identified the bottleneck of energy consumption in near future
- Proposed Dynamic Optical Path Network to be very energy-saving
- Introduced efforts on optical NIC development in NEDO project
- Listed enabling technologies and many challenges

- In conclusion, in the long run, the energy bottleneck will emerge from completely different levels to drastically modify the telecom industry.
- Governmental and/or academic, 'proactive' and global initiatives will be the key.
  - AIST recently launched a project called, "VICTORIES"; Vertically Integrated Center for Technologies of Optical Routing toward Ideal Energy Savings

Thank you!

UTYO

Contact:
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