Growing Demands of Internet Traffic in Japan

Total 813 Gb/s, Growing 2.5 times per 3 years (@ Nov. 2007).

Total traffic amount will reach 1 Tbit/s (1000 Gbit/s) until 2009, 1 Peta bit/s will be realistic in 2030th.

Can current technologies accommodate effectively Peta bit/s traffic without traffic congestion?

http://www.soumu.go.jp/joho_tsusin/policyreports/chousa/jise_ip/
Driving Force, Current & Future in Japan

Core Optical NW : ~ 1Tera bit/s
Future NW (NWGN) : ~ Peta bit/s

Cell Phone Access
3G Mobile : < 10 Mbit/s
→ 100Mbit/s - 1 Gbit/s

Sensor NW
Home security, Children & Elders
→ Power saving control

Wireless Access
WiMAX : 70 Mbit/s
→ 100Mbit/s - 1 Gbit/s

Broadcast Contents
IP-TV, HD-TV, VOD
→ Digital Cinema : 7.64 Gbit/s
Super High Vision : 39.8 Gbit/s

Optical Access to Office/Home
FTTH : 100Mbit/s, >10 million, GE-PON
IP-Phone (Fix-Mobile convergence)
→ 10GE-PON, 100 GbE (Office, Labs)

Access Network

Bullet Train
ITS (DSRC)
Current Photonic NW Project Formation


Ultimate Photonic NW Tech
Ultrafast, highly efficient node & Link

All optical RAM
Photonic crystal integrated buffer for ultra low power consumption

High performance photonic node
100 Tbit/s class router architecture

Lambda Utility
Modulation Format (QPSK +)、FEC
Lambda path resource sharing in Hetero NW

Lambda Access
Terabit LAN, 100 GE parallel/serial format

Active access NW
Low cost, compact 10GbE

Realization of 10 Gb/s Per user access

Penetration

Establishment of network architecture for Petabit/s photonic network

Challenging
Fundamental
Basic
Research

Public NW

Long Haul Core (Nation wide)

Metro System (Intra province)

Core Node

Core Edge Node

Center station (NTT Office)

Access system

Houses, Buildings

Intra NW

100 GE

Intra building LAN

NICT own
Mission of NICT Photonic Network Group 2006-2010

(1) Ultrafast Optical Packet Switching
   Ultrafast optical signal processing
   Label recognition
   Switching
   Buffering

User data
Label
Optical signals

(2) Highly Efficient Transmission

Ultrafast Multi-level

WDM

Node
Link

http://www2.nict.go.jp/w/w112/index.html
Formation of Research Promotion of Photonic NWG

NIC T internal system

- Network Architecture G.
- Quantum-OptoElectronics G.
- Research Promotion Dep. JGN2 Field Optical test bed JGN2+(2008~)

Photonic NWG

Inter-Institute Collaboration

- Ultrafast Optical Packet Switching Osaka Univ., Japan Women’s Univ., Fujitsu Labs., Yokogawa Electric Tsing Hua University Rome Univ., CNIT, Heriot-Watt Univ….and more!

- Highly Efficient Transmission KDDI R&D, AIST, CNIT, Tokyo-Univ., Harvard Univ.

Forum activity

Outcome (Standardization, Technical translation)
Node Technology toward NWGN

**Current Optical Network**

- Opaque electrical network
- Many Opt. ↔ Elec. conversion

 Optical signal → Electrical → Optical signal

- Electrical processing << 100 Gb/s
- Huge power consumption
  > MW @ 100Tb/s

**Future Photonic Network**

- All optical at least in data plane

 Optical Signal → Node → Optical Signal

- Ultrafast optical processing
- Low power consumption
- Small footprint

NICT has been investigating Optical Packet Switch for Peta bit/s networks.
160 Gb/s Optical Packet Switch Prototype (2005)

Optical Packet

Routing
Making the route list for routing packet transmission

Label processing
Address search and output port decision

Switching
Physical transmission of packet

Buffering
Packet maintenance of definite period

Label processing/Scheduling/buffering

Scheduling
Control signal generation for packet collision evasion

Optical label
16 chip, 25 Gchip/s

160 Gb/s user data
61440 bits

Optical label

160 Gb/s Optical packet switch prototype

N. Wada, H. Furukawa, K. Fujinuma, T. Wada, T. Miyazaki, ECOC2005, Wednesday 1.4.1, 2005
Pros: Ultrafast (sub ns order) label processing free from electrical speed limit.
Cons: Multiple decoder devices for many output ports are required in label bank.
Multi-Port Optical En/Decoder

2nd Generation: 2006-

- Simultaneous 16-address encoding and decoding
- $2^N$ (16<N) address processing by port combination

Optical Label Encoding

Optical Label Decoding

We are developing 50x50 Optical En/Decoder.

Addressing Scalability will be enhanced Up to $2^{50} \sim 1$ Peta.

Path switching vs Packet switching

At first, we thought
“Optical packet switching seems to be suitable for data centric NW.”

However in terms of universal service accommodation,
Path-Packet convergence is suitable for New Generation Networks.
EX.)
Path switching is suitable for stream services (HD IP-TV etc.)
Packet switching is suitable for instant data transaction.
10GbE over 160Gbit/s OPS Field Trial

- Colored optical packet having payload capacity flexibility with fixed packet length.
- Burst mode EDFA
- Burst mode optical Tx/Rx
- 10GbE/OPS converter
- Multi-Port Optical En/Decoder

- Converting to ultrafast optical packet
- Label
- Payload

Colored Optical Packet

Burst mode EDFA

Transient characteristics of EDFA

160Gb/s OPS Backbone

10GbE/OPS converter

Multi-port Optical en/decoder

Optical packet Rx

Conventional Burst mode 100ns/div Burst mode 100ns/div

Technical transferring

Kyoto
Keihanna
Osaka
Nara

OFC2007 PDP4
Why Higher Spectral Efficiency $>> 1 \text{ bit/s/Hz}$?

Bandwidth MUX Amplifier

Higher SE

1. Current installed C-band EDFA is applicable for capacity upgrade.
2. Power consumption reduction ($\Delta WxN$) is possible in N-cascaded repeaters links.
Field Trial on JGN II Optical Test Bed 2004~2007 / Photonic NW Group

1.24 Tb/s OCDM (10Gb/s, 5WDM, 25 users)
OFC‘07 PDP14

(A) 160Gb/s Multi-level (2bit/Symbol)
200-km Field Trial in JGNII Link.
Before(left), After(right) Transmission
Loop back between Otemachi-Tsukuba
OFF1, OFC ’05

1.28 Tb/s (160Gb/s x 8) 200km Field Trial in JGNII
Collaborative with KDDIR&D We 2.2.1, ECOC ‘05

Koganei-Otemachi loopback 100km
Collaborative with Rome Univ. Osaka Univ.

Optical packet / lambda ROADM
40 Gb/s 16 Lambdas 173-km, Keihanna-Osaka
ECOC ’07, Tu 4.6.4
Collaborative with Fujitsu, Osaka Univ.
Summary

1. Efficient accommodation of endlessly increasing internet traffic is urgent technical issue to solve traffic jams for Peta-bit/s New Generation Network in Japan.

2. We have been investigating
   - Ultrafast optical packet switching node system
   - Highly efficient link transmission system
by collaboration with domestic and foreign research institutes, utilizing also optical test bed effectively.

Please visit  http://www2.nict.go.jp/w/w112/index.html
or just search in Google “NICT, Photonic”
I hope to see you again in Brussels, ECOC 2008 !!
Electrical vs. All optical (Photonic) node

Optical multiplexed signal TDM, WDM, etc

Electrical processing node

Optical processing node

Optical multiplexed signal TDM, WDM, etc

Nano Technology?
Possibility of high speed node with low power

Performance : bit/J
(Logarithmic scale)

10Gbit/J

1Gbit/J

100Mbit/J

10Mbit/J

10Gbps

100Gbps

1Tbps

Throughput/port (Logarithmic scale)

Electronic Routers

EPS Router #2
16x16 (40G-IF, 1.28Tbps)

EPS Router #1
32x32 (10G-IF, 640Gbps)

Electronic Processing
Speed Limitation

Next OPS node
(640G-IF)

OPS Prototype
2x2 (DWDM)

Prospect of OPS

( ▲ without optical buffering )

EPS: Electronic Packet Switch
OPS: Optical Packet Switch
Phase noise tolerant M-PSK, M-QAM homodyne
Non-Offline real time demodulation

200-kHz external cavity LD

30-Gb/s-8PSK constellation: Experiment

80-Gb/s-256QAM constellation: Numerical simulation

M.Nakamura, Y.Kamio, T.Miyazaki, 8.3.6, ECOC ‘07
Development for Optical Packet Receiver, Packet-BERT
Collaborated with Anritsu and NTT Electronics
Live demonstration
In ECOC ‘04 in Stockholm

Optical Packet Transmitter
Optical Switch
Optical Buffer
Optical Packet Switch Prototype
Scheduler
Opt. Label Processor

Transmission experiment
Switching experiment
Routing
Buffering

Packet PPG
Electrical Packet data

Packet ED
Clock

Data
Label

Optical Packet 3R Receiver

N.Wada et al., ECOC ’04, Post-Deadline Paper, Th4.5.4
IP/Optical packet (OP) Converter for 10GbE/Ultrafast network interface

10GbE / 80 Gbit/s optical packet transporting
1/8 packet length compression 8x10Gbit/s WDM
Optical label generation according to table

- Label processing latency: 100ps
- IP packet throughput: 7.2Gbit/s
- IP packet loss: 10^-6

3D-HDTV Video stream transport demonstrated.

Live demo in ECOC 06

H. Furukawa et al., OFC 2007, OWC5
A 31-FDL Buffer Based on Trees of 1x8 PLZT Optical Switches

- Use only 4 port of 1st stage switch with 15 FDL, but can expand it to 31 FDL
- "Routers with Very Small Buffers" Nick McKeown, IEEE INFOCOM'06

H. Furukawa, H. Harai, N. Wada, N. Takezawa, K. Nashimoto, T. Miyazaki, ECOC '07, Tu 4.6.5
Optical Test bed B
Terabit class transmission capability is expecting in Optical Test beds.

Koganei
Keihanna
Nara
16 km
Osaka
Kyoto
Keihanna
Nara
16 km
Osaka
Kyoto
Keihanna
Kyoto
Osaka
Nara
Otemachi
Akihabara
Kashiwa
Tsukuba

JGN 2 Optical Test bed
2004-2007
2006-2007

Town of Research Institutes
Potential huge capacity
users for science.

Ring Accelerator (Tsukuba)

“Maiko-san” Kyoto

Big Statue of Buda in Nara

KDDI Otemachi Bldg.
International gateway station to global submarine cable network

Potential huge capacity
users for science.