A New Generation Network
- Beyond NGN -

May 12,   2008

Tomonori Aoyama

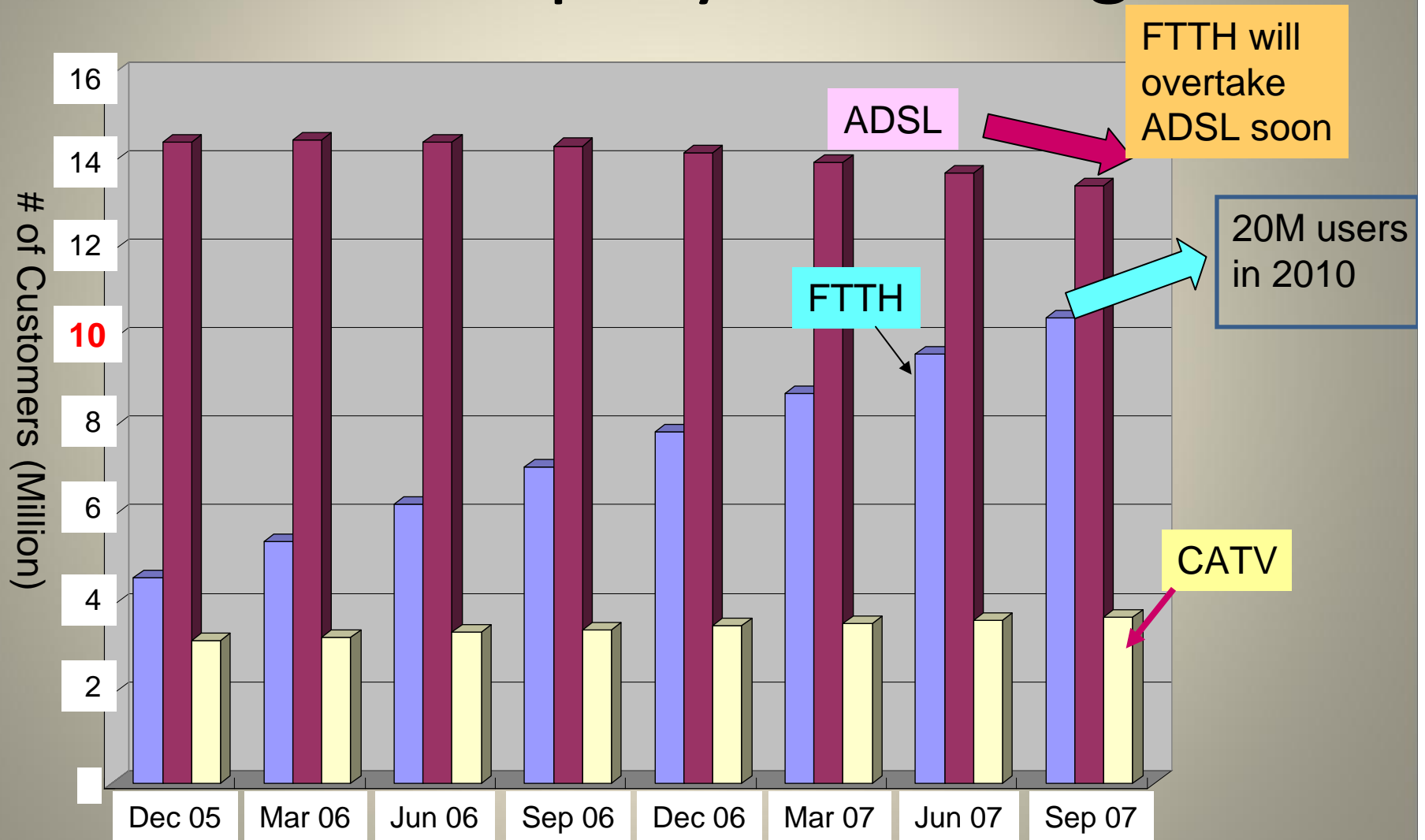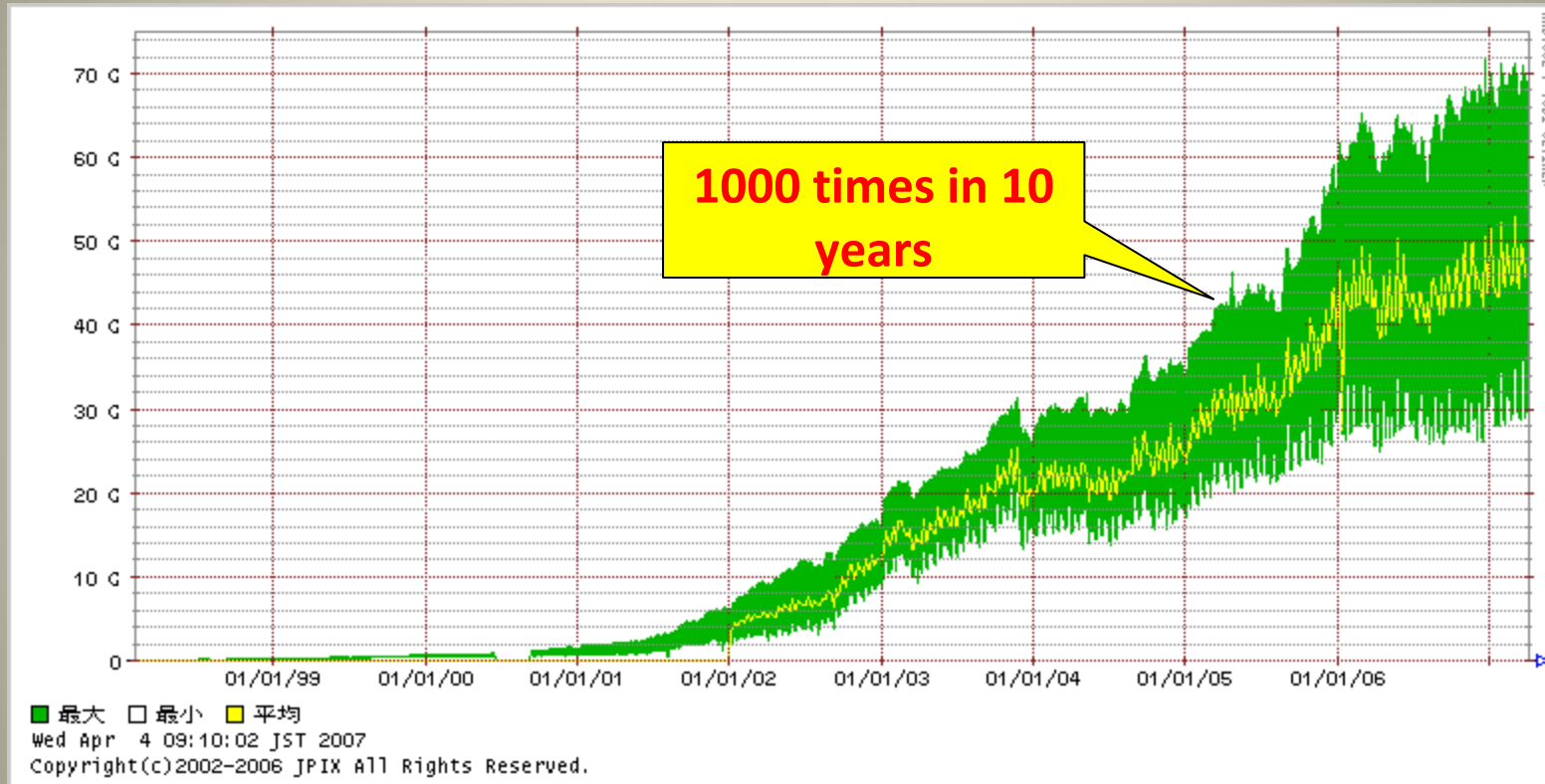**Keio University**
NICT

Contents

- Broadband Networks in Japan

- Next (NXGN) and New (NWGN)

- Current status of NWGN R&D in the world

- Key Technologies for NWGN

- Applications for NWGN

Broadband Users in Japan
FTTH is rapidly increasing

Rapid Expansion of Internet Traffic in Japan

http://www.jpix.ad.jp/jp/techncal/traffic.html

NGN services have been started in some countries.

ITU-T is now greatly contributing to standard the NGN specifications.

NGN Objectives

1. Replace legacy telephone networks with the state-of-the-art IP based networks

2. Integrate various services over IP networks

> **Triple-play Services: Voice, Data, Video**

> **Quadruple-play Services: + Cellarer Phone**

3. Solve the issues that the Internet is facing

> **Application-oriented QoS control**

> **Mobility support for FMC**

> **Weakness for Security**

4. Maintain the safety and reliability of telephone services
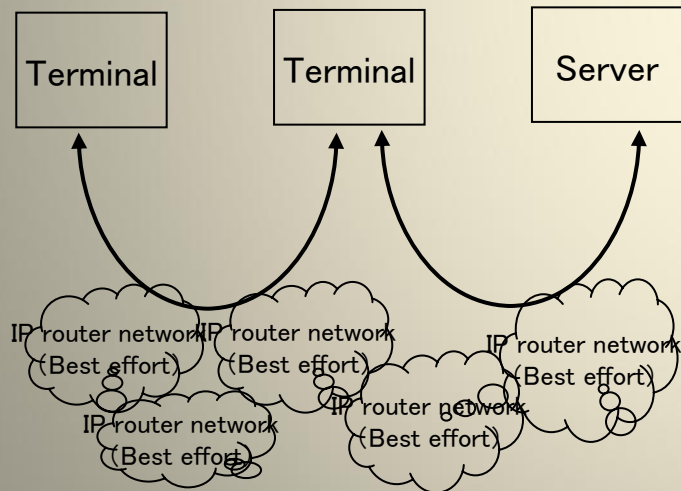
> **Meet the requirements for the social infrastructure**
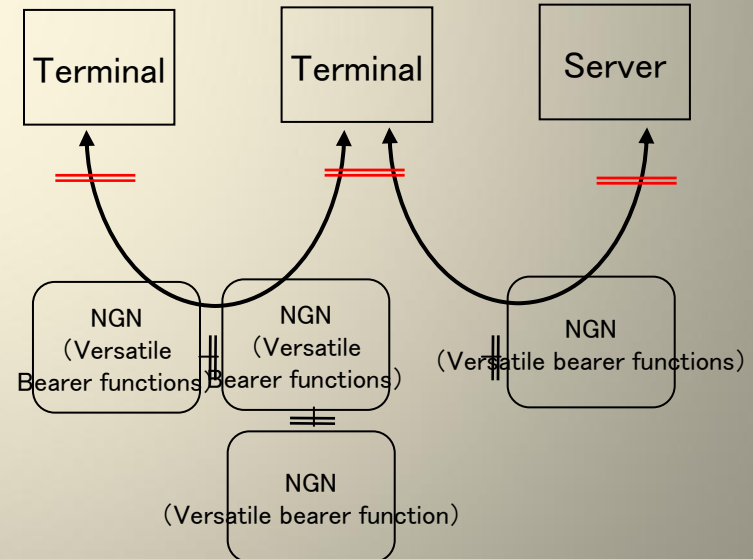
The Internet and NGN

【Internet】

- **No over all network planning**
- **TCP/IP Protocol is the only common rule**
- **Best effort based network and no clear responsibility and control rule exist among networks**
- **User can have freedom to install applications**

Terminal	Terminal	Server

IP router network (Best effort) IP router network (Best effort) IP router network (Best effort)

IP router network (Best effort) IP router network (Best effort)

Best effort bearer function to interconnect multiple router based network

【NGN】

- **I P based network with network control function and with clear responsibility for the control**
- **Qos control and security functions are installed**
- **Maintain the Internet connection function**

Terminal	Terminal	Server

NGN (Versatile Bearer functions)　　NGN (Versatile Bearer functions)　　NGN (Versatile bearer functions)

NGN (Versatile bearer function)

QoS controlled bearer function to interconnect multiple networks with clear responsibility

Aoyama

NXGN and NWGN

- **NXGN (NeXt Generation Network): NGN**

  Replacement of legacy telephone

  networks using IP-based networks to provide

  triple-play/quadruple-play services

  Industry is investing their resources to NXGN deployment.

- **NWGN（NeW Generation Network)**

  Clean-slate designed network architectures

  and main protocols different from IP-based

  networks which can be post-Internet/NGN

  NICT contributes to promote R&D on NWGN.

An image of network evolution

Legacy Telephone NW

Cellular Phone NW

The Internet

Started ⇒ NXGN(NGN)

Future ⇒ NWGN

2008   2020
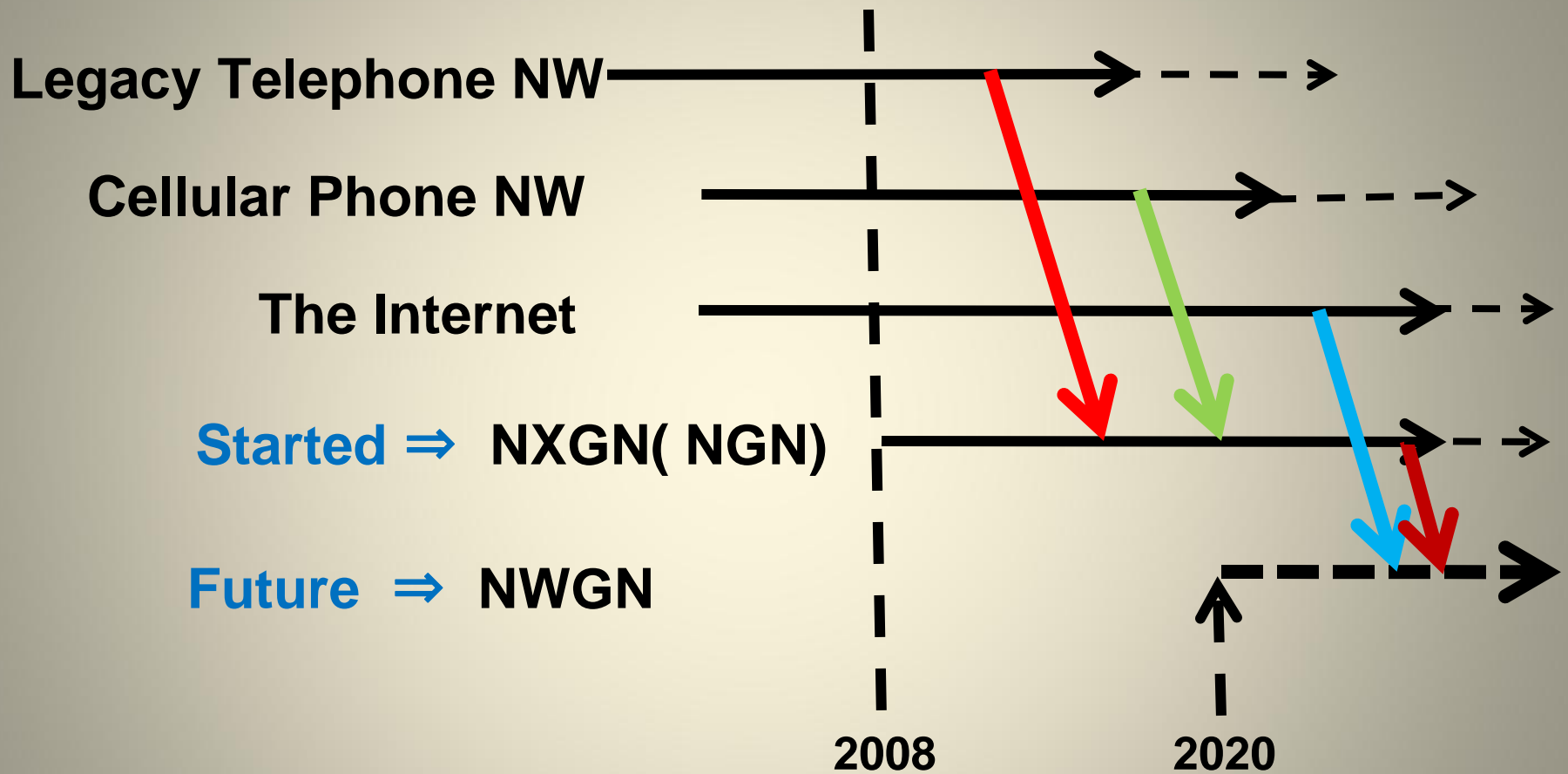
NXGN: Next Generation Network
NWGN: New Generation Network

Research on New Generation Networks has just started in the world !

The United States

FIND

- NSF's ambitious program to develop the future Internet architecture through a clean slate approach.
- make a small scale, but a large number of projects converge into a fewer number of full scale architectures, and to verify using GENI
- A total of 1,200 million dollars to 26 projects by 2006

GENI

- Aimed at developing a testbed organization to succeed Planet Lab's development. programmable
- Aimed at a large scale facility development's budget in NSF. International cooperation is also included as a target.
- Project Bureau (GPO) is BBN. Planning to offer prototype, 1,500 million dollars in December 2007 over a two year period.
- A scale of construction budget is 367 million dollars,

E.C.

FP7

- EC's Funding structure towards the total fields of science and technology
- Begin by selected 133's new projects in Call 1
- Call 2 is investigating

＜main individual programs＞
-Network of the Future
   (Call 1, D bureau) 2 billion Euros)
-FIRE
   (Call2, F bureau) 4,000 million Euros

GÉANT2

- EC's research network
- The E.C. Budget for GÉANT was 9,300 million Euros over 4 years since 2004.
- It is in the middle of preparations for upgrading and for greater capacity by transforming it into GEANT3 from 2008.

Japan

NWGN development projects

- NWGN AKARI architecture development project
（Official announcement of concept's specification in April 2007)
- R&D on evaluation and establishment in the structure of NWGN) (NICT commitment, up to 20 million Yen times 2 years、plural cases)
- R&D for dynamic network technology (NICT commitment, 4 years、plural cases)

NWGN research development promoting structure

- "The head quarter of NWGN research development strategy" in October, 2007, NICT.
- "NWGN promoting forum," established in November, 2007 Working in 4 WGs Ministry of International Affairs and Communications and NICT are a co-secretariat.

Testbed NW「JGN2」

- NICT's Testbed network for research development
- To provide "JGN2plus" from 2008 – 2010.

To realize NWGN, close collaboration among the E.C., U.S., and Japan is important.

Building up a framework to endorse collaboration of research organizations with each other.

NSF's Concept : Clean –slate Design for Future Network Architecture in 2020's

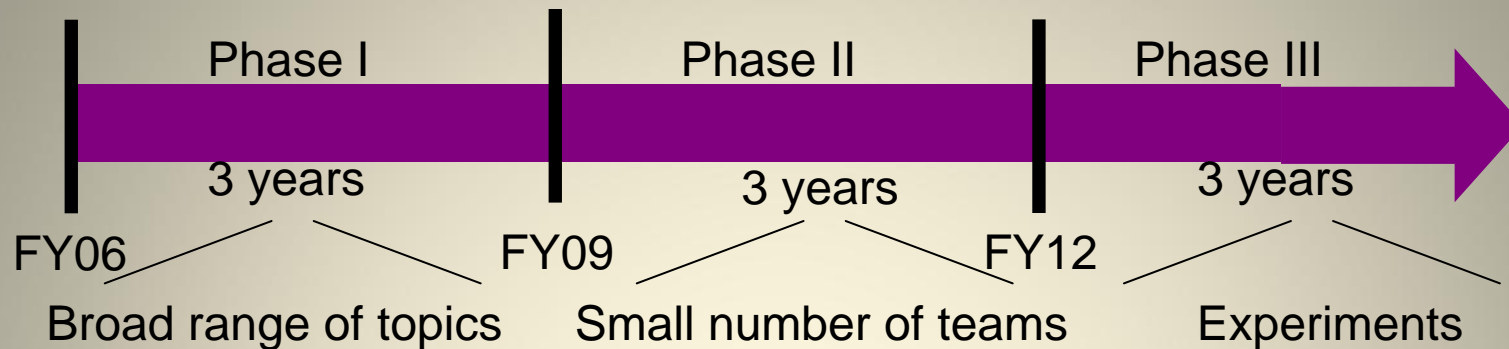### GENI : Global Environment Network Infrastructure

Large scale network test-bed
First Stage: $7.5M x 3years ($23M)

FIND : Future Internet Design

New ideas and technologies for clean-slate design
First Stage: 26 projects funded in 2006

GENI Schedule

FY05   FY07 FY08   FY11

Planning Group   **GPO (BBN)**

Design (3-4 years)

Plan (2 years)

led by
Larry Peterson
(Princeton)

Concept
Design
(0.75
year)

Preliminary
Design
(1.5-2.5 years)

Final
Design
(1 year)

Construction
(5 years)

Operations
(TBD years)

359M USD

CDR   PDR FDR

Prototyping (7.5M USD x 3 years)

Future Internet Design (FIND)

Phase I — 3 years — FY06 — Broad range of topics
Phase II — 3 years — FY09 — Small number of teams
Phase III — 3 years — FY12 — Experiments

- **Leader: David Clark (Senior Research Scientist @ MIT)**
- **NSF PD: Darleen Fisher and Allison Mankin**
- **Clean-Slate Approach with Competitive-Cooperation Model**
- **NSF Networking Technology and Systems (NeTS)**
- **FIND ~$15M, 38% of NeTS $40M**
- **26 projects are funded in FY06 (out of 98 proposals)**
- **11 projects in FY07**
- **Budget: $0.1M-$1M/project (1-3 years) (1 year seed investment)**
- **3 PI Meetings per year, non-PI with white paper**
- **http://www.nets-find.net/**

Last (4th) PI Meeting @ Washington DC
AKARI white paper by Hirabaru and Harai accepted
CN and KR were also invited.
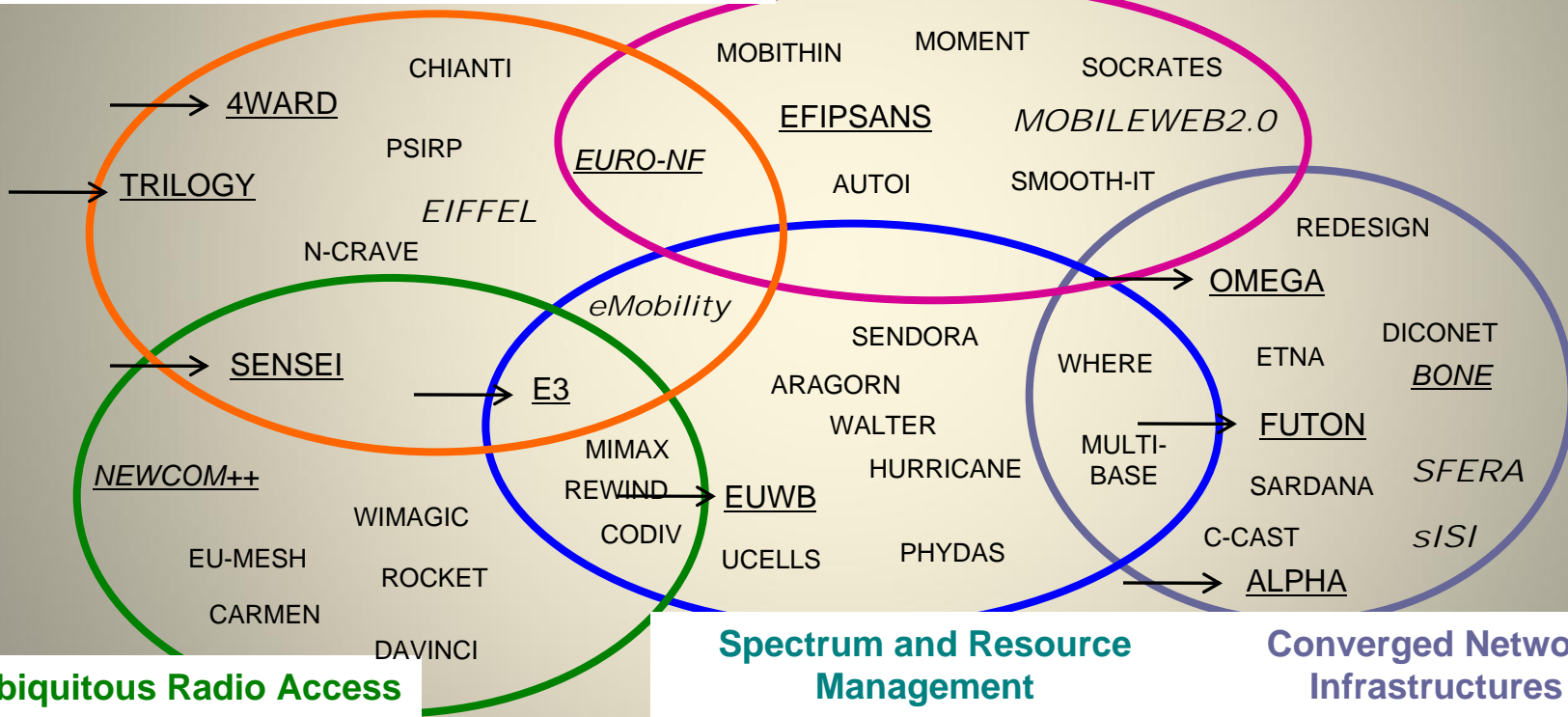
Clean-slate Designs for a Future Internet
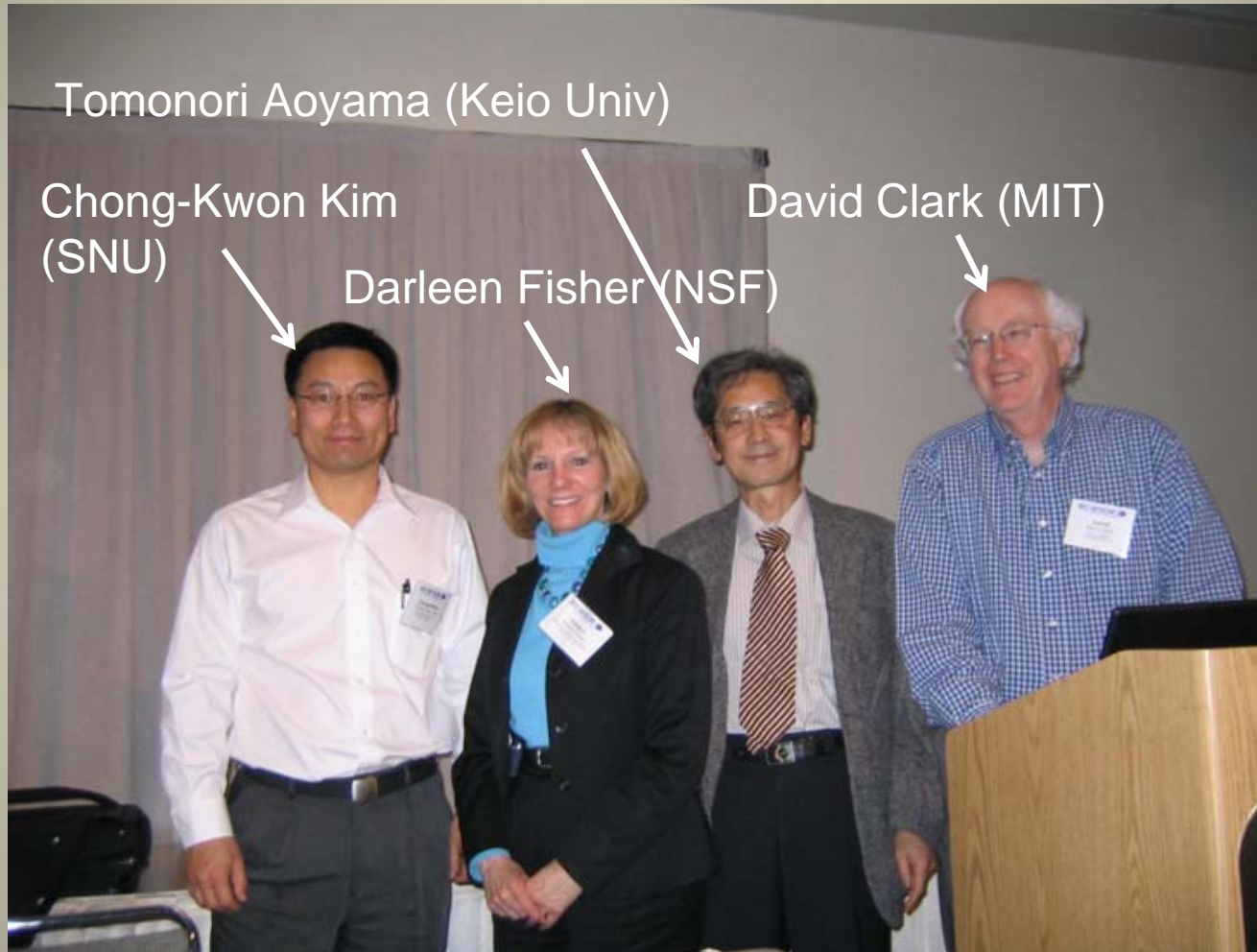
IEEE   INFOCOM2007@Anchorage Opening Panel

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EU FP7 The Network of the Future

ICT Challenge1 1.1 "The Network of the Future"⊦

Future Internet Architecture and Protocols

Future Internet Management and Operation

CHIANTI

MOBITHIN

MOMENT

SOCRATES

4WARD

EFIPSANS

MOBILEWEB2.0

PSIRP

EURO-NF

TRILOGY

AUTOI

SMOOTH-IT

EIFFEL

REDESIGN

N-CRAVE

eMobility

OMEGA

SENSEI

SENDORA

WHERE

ETNA

DICONET
BONE

E3

ARAGORN

WALTER

MULTI-
BASE

FUTON

NEWCOM++

MIMAX

HURRICANE

SARDANA

SFERA

WIMAGIC

REWIND

EUWB

sISI

EU-MESH

CODIV

C-CAST

ROCKET

UCELLS

PHYDAS

ALPHA

CARMEN

DAVINCI

Ubiquitous Radio Access

Spectrum and Resource Management

Converged Network Infrastructures

INTEGRATED PROJECT (IP)

NETWORK OF EXCELLENCE (NoE)

SPECIFIC TARGETED RESEARCH PROJECT (STREP)

Coordination and Support Action (CSA)

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2008 EU-Japan Cooperation Forum on ICT Research

Conclusions - Session on Future Internet (EU) / New Generation Networks (Japan)

EU and Japan are at the beginning of collaboration

- Public authorities can only stimulate collaboration
- Actual collaboration to be between respective researchers/industry

Next steps

- Possibility for cross participation in research programmes: Initiative has to come from the respective "home" players
- Deeper exchange between research communities on EU-Japan Symposium on New Generation Networks / Future Internet Research, planned for 9-10 June 2008 in Brussels

Collaboration needs beyond research

- Connecting networks and experiments
- Collaboration on standardisation to support ideas of mutual interest

Japanese Strategy for NWGN

All Japan Forum ⇒ **NWGN Promotion Forum**

NICT set the NWGN Strategic Headquarter

COE for NWGN Architecture Research ⇒**AKARI Project**

Network Testbed ⇒ **JGN2plus**

Funding for R&D on NWGN in Industry ,Academia & NICT
　　　\ 2.1 billion for NWGN
　　　 \ 3.6 billion for photonic network
　　　 \ 1.5 billion for ubiquitous network platform
Collaboration with EU, NSF & CK

R&D Promoting Structure and Collaboration between Industry, Academia, and Government

NICT (National Institute of Information and Communications Technology)

"Headquarters of NWGN Research Development Strategy"

（Chief of Headquarters：
President, Dr. Hideo Miyahara
Installation: October 1, 2007.

• Formulating mid- and long- term research development strategy to realize New Generation Network

• Promoting methods of research development related to New Generation Network in NICT and examination of implementation structure

• Examination for cooperation methods with other countries

◆ NICT operates new generation network architecture and implements research development of the component. Also, it examines the network architecture and its elemental technology by using test-bed network.

◆ The related research development project is implemented through private corporations, and broad research development is promoted.

Reflecting knowledge from other fields for their strategies

Active contribution for forum activities

・Outgoing strategies

・Participating in the Investigations

"NWGN Network Promoting Forum"

・The Organization Meeting, November 6, 2007.
Members：241

（President：Dr. Tadao Saito Professor Emeritus, The University of Tokyo）http://forum.nwgn.jp/

新世代ネットワーク推進フォーラム設立総会
平成19年11月6日

Activities

• Research Development Approach and Roadmap Investigation

• Investigations of social and economic aspects

• Promoting international cooperation through symposiums and workshops

In the initial round, not sticking with specific methods or logics, multiple ideas and methods are conducted in parallel. A technical "bud" that is coming from these ideas and methods can be taken care of. Also, from a clean state, a research development that designs a future network will be promoted.
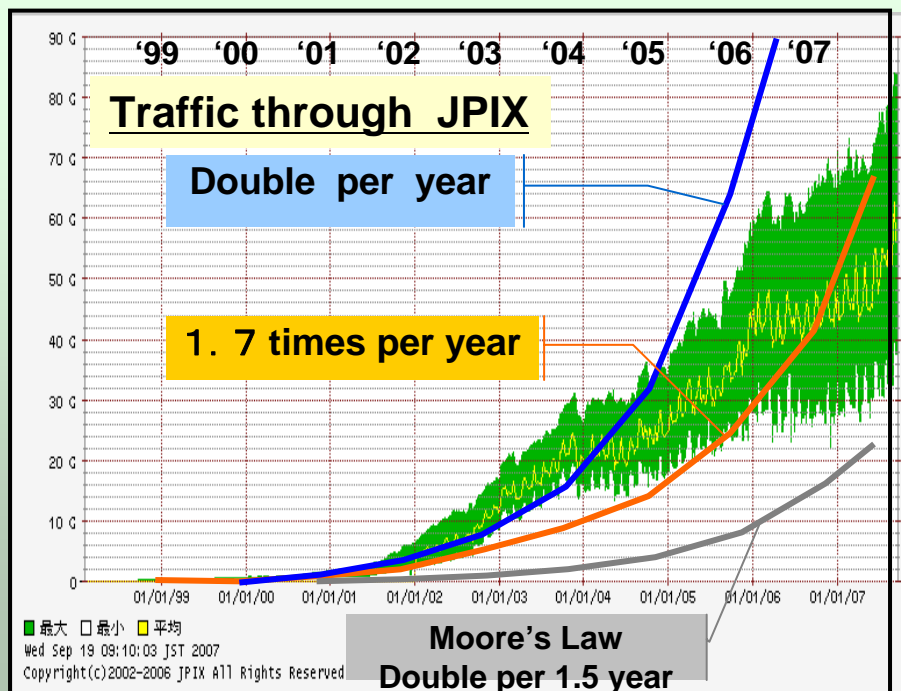
AKARI Project

- a small light in the dark pointing to the future -

- - Started in 2006

- - NWGN Architecture Design based on Clean-slate approach

- - NICT Researchers + University Professors

- - First Conceptual Paper opened
  http://nag.nict.go.jp/topics/20070430.html

- - AKARI Workshop

AKARI

Capacity Requirement

Traffic through JPIX

Double per year

1. 7 times per year

**Moore's Law
Double per 1.5 year**

Legend: 最大 最小 平均
Wed Sep 19 09:10:03 JST 2007
Copyright(c)2002-2006 JPIX All Rights Reserved

1.7 times per year ⇒
1000 times in 13 years

Switching and Transmission Capacity
In 2020

◇**Switching:** **T bps→P bps**
◇**Link for core:** **10 Gbps→10 Tbps**
◇**Access :** **10 Mbps→10 Gbps**

http://www.jpix.ad.jp/jp/techncal/traffic.html
http://www.soumu.go.jp/s-news/2007/070822_2.html

Power Consumption for Peta b/s Router

cisco CRS-1

○Throughput 1.2 Tbps
（／Shelf)
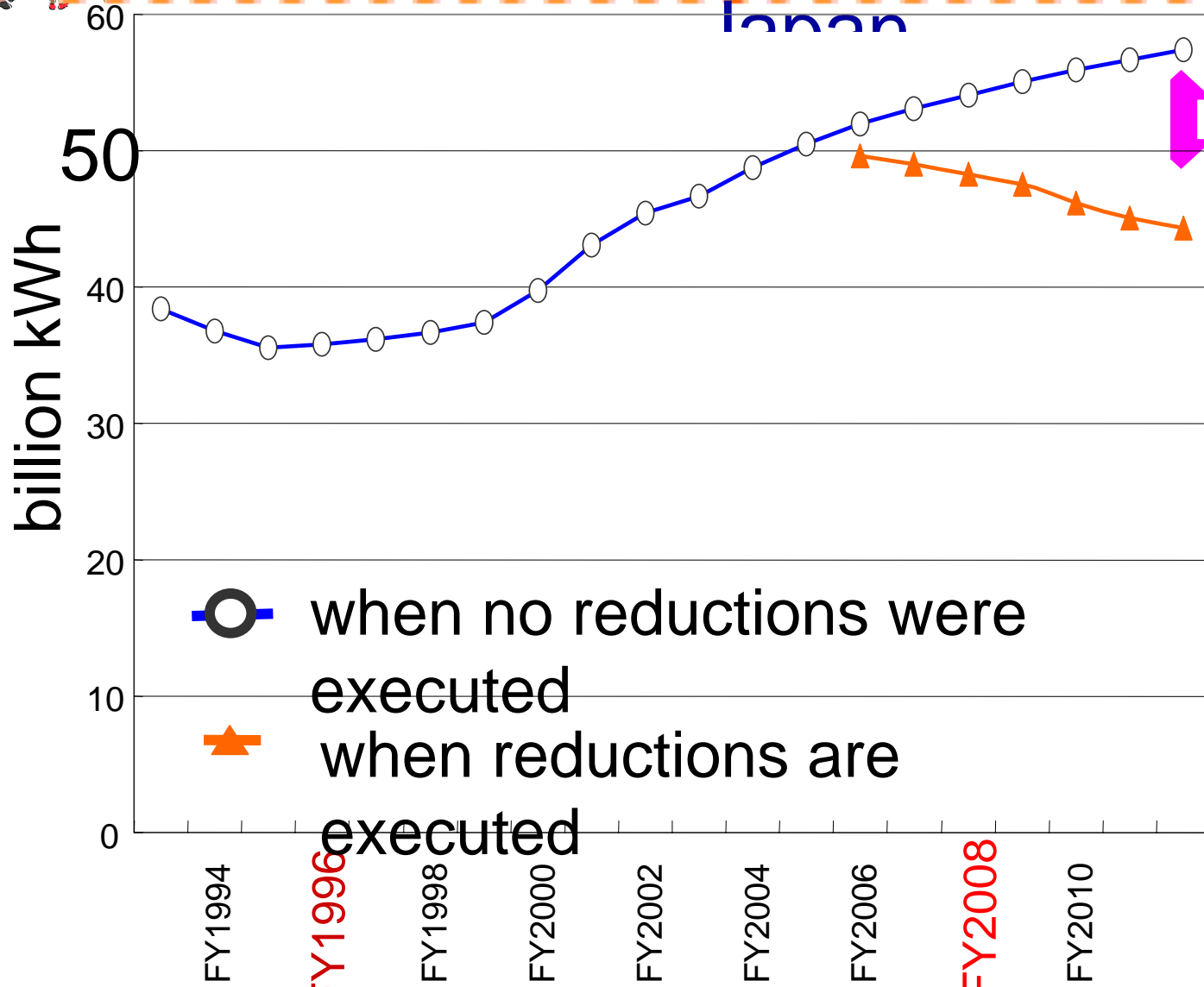→ 15.5 KW

x80

○Throughput 92 Tbps
→ 1,200 KW

x10

○ Peta b/s Throughput
Router → 10 MW

100 X Peta b/s throughput
routers need 1 Nuclear
Power Plant

Telecom Power Consumption in Japan

13 bkWh expected

20 mTN CO2 emission in total

○ — when no reductions were executed

▲ — when reductions are executed

billion kWh

FY1994 FY1996 FY1998 FY2000 FY2002 FY2004 FY2006 FY2008 FY2010 FY2012

Roles of ITU-T

1) how to reduce energy consumed by ICT equipment and services,

2) how to evaluate energy savings of various social activities by ICT power,

3) how to measure climate change,

4) how to encourage society to reduce energy by ICT power including CDM, Clean Development Mechanism, and

5) how to promote enlightenment of ICT power.

Telecommunication Technology Committee

Contents in the ubiquitous society
From tiny to huge
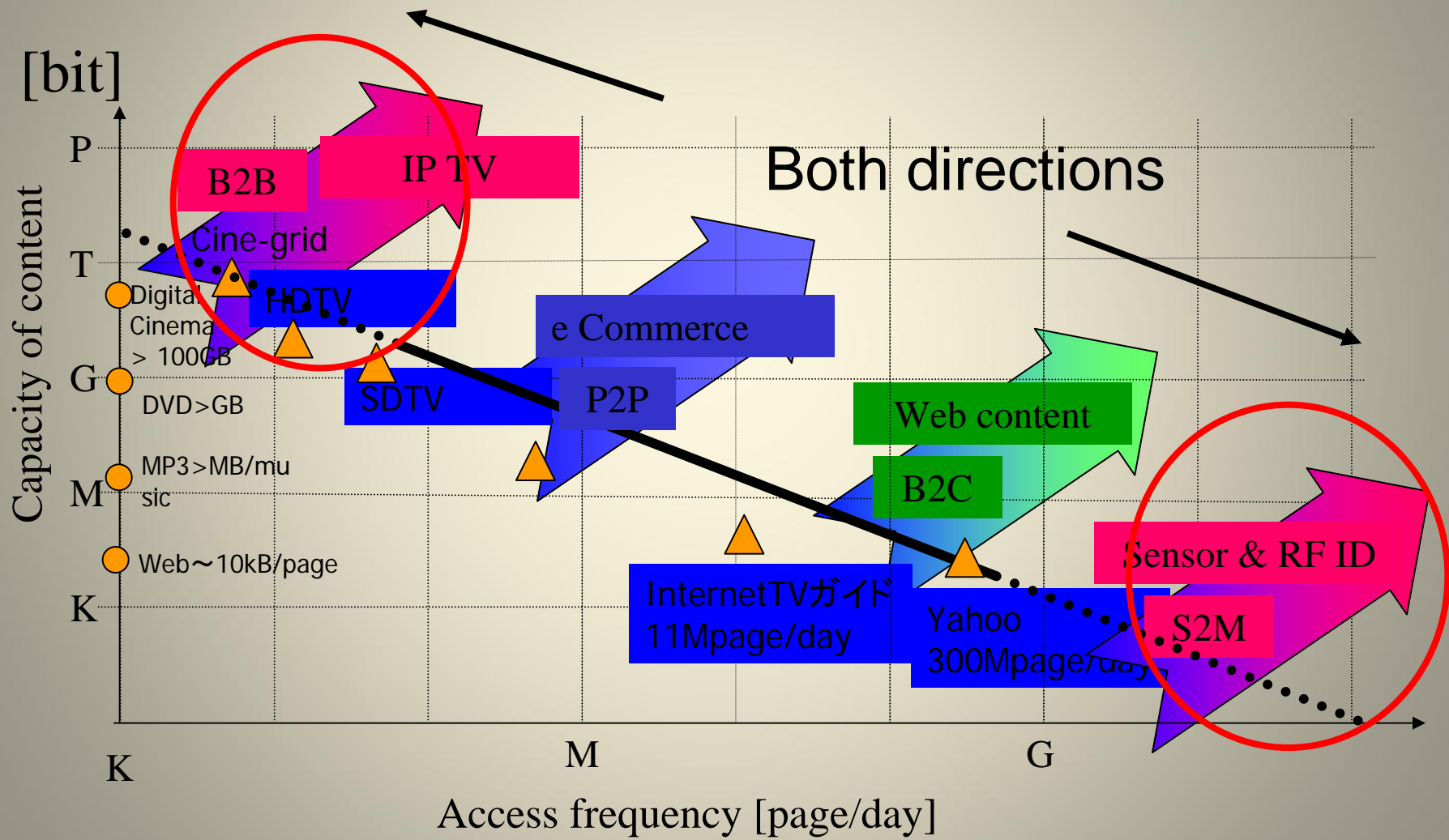
NWGN, Enables Overcoming the Limitations of IP Network

【Problems・Limitations】

◆Challenges of the Internet
Increased IP Packet Costs (TCP performance is "bad"), lacking security and service quality. Low availability as social infrastructure, so many scopes existing to optimize, like choice of routes, anonymity on the Internet, expansion of the network, limitation of upgrading, much too complicated, and occurrence of functional discordance.

◆Approach to Information Explosion
Appearing unstoppable are growing communication traffics, electric power consumption, and user participation type community.

◆Development of Ubiquitous Networking
It is necessary to transmit large and sometimes a small amount of information that is sent from ubiquitous terminals, increasing enormously because of widespread of ubiquitous network.

◆Appearance of Various Terminals
Diversification of Information electronics and home networks, 3D systems, and integration between real and virtual.
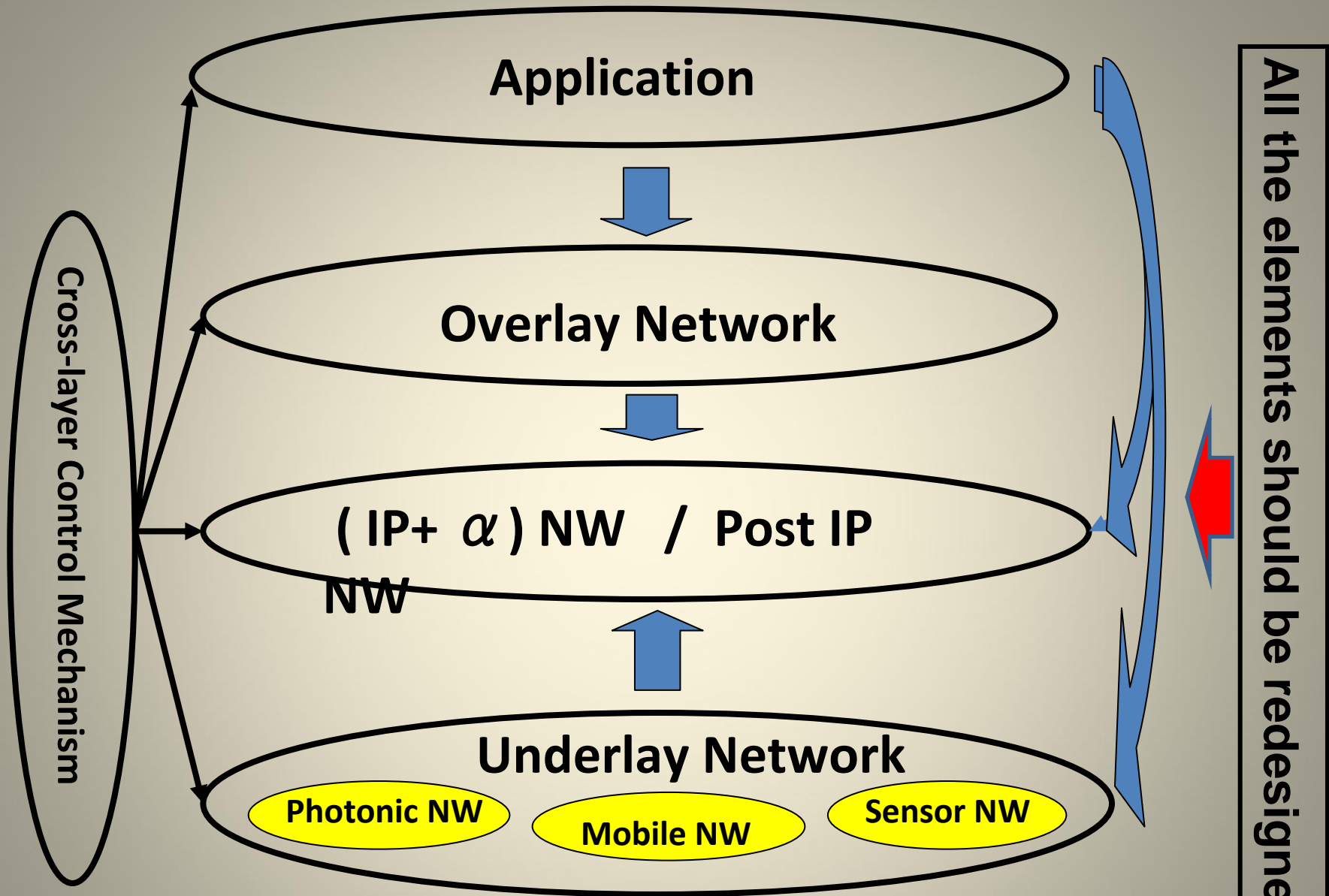
◆Concerns for Security and Reliability
Assuring network equipment's complex, quality, and security level.

Expectations for NWGN

(1) Network that users can use simply and easily
Users can use the network intuitively and it meets the user's situations and expectations by judging them adequately. In other words, respecting the idea of "Network follows users."
(virtualized network. new network architecture, and network control)

(2) Network that is flexible and good for the environment
Regardless of the size of the data, users do not need to choose a network based on the kinds and uses of contents because optimum distribution of network resources is automatically ensured. Through electric power saving of network equipment and efficient transmission, It tends to reduce the load on the global environment.
(Scalable network technology and virtualized network)

(3) Upgrading terminal usage environment
Various devices can be connected to the network. The system will be developed that will ensure a variety of terminals can be used easily and safely. Because of the development of highly realistic, sensational telecommunications technologies, new communication forms will be appearing. An environment will be developed in which users can quickly recreate their communication environment with any terminals. In different platforms, users also can work continuously in such an environment. (Terminal platform technology, virtualized technology, and new network architecture)

(4) Secure and reliable network as social infrastructures
Unstoppable network will become standard, by deploying a self-examination and auto-restoration against damages from incidents and disasters (Dependability Assuring technology)

Necessity of realizing the new generation network.

Application

Overlay Network

$(IP + \alpha)$ NW / Post IP NW

Underlay Network

Photonic NW   Mobile NW   Sensor NW

Cross-layer Control Mechanism

All the elements should be redesigned.

Study Items for NWGN Architecture

NWGN Architecture Study in AKARI Project

Connectionless Datagram Packet ➡

  Combination of Packet and Circuit Switched Networking

Identification & Location ➡ **Separate Structure**

Naming & Discovery ➡ **New Scheme should be needed**

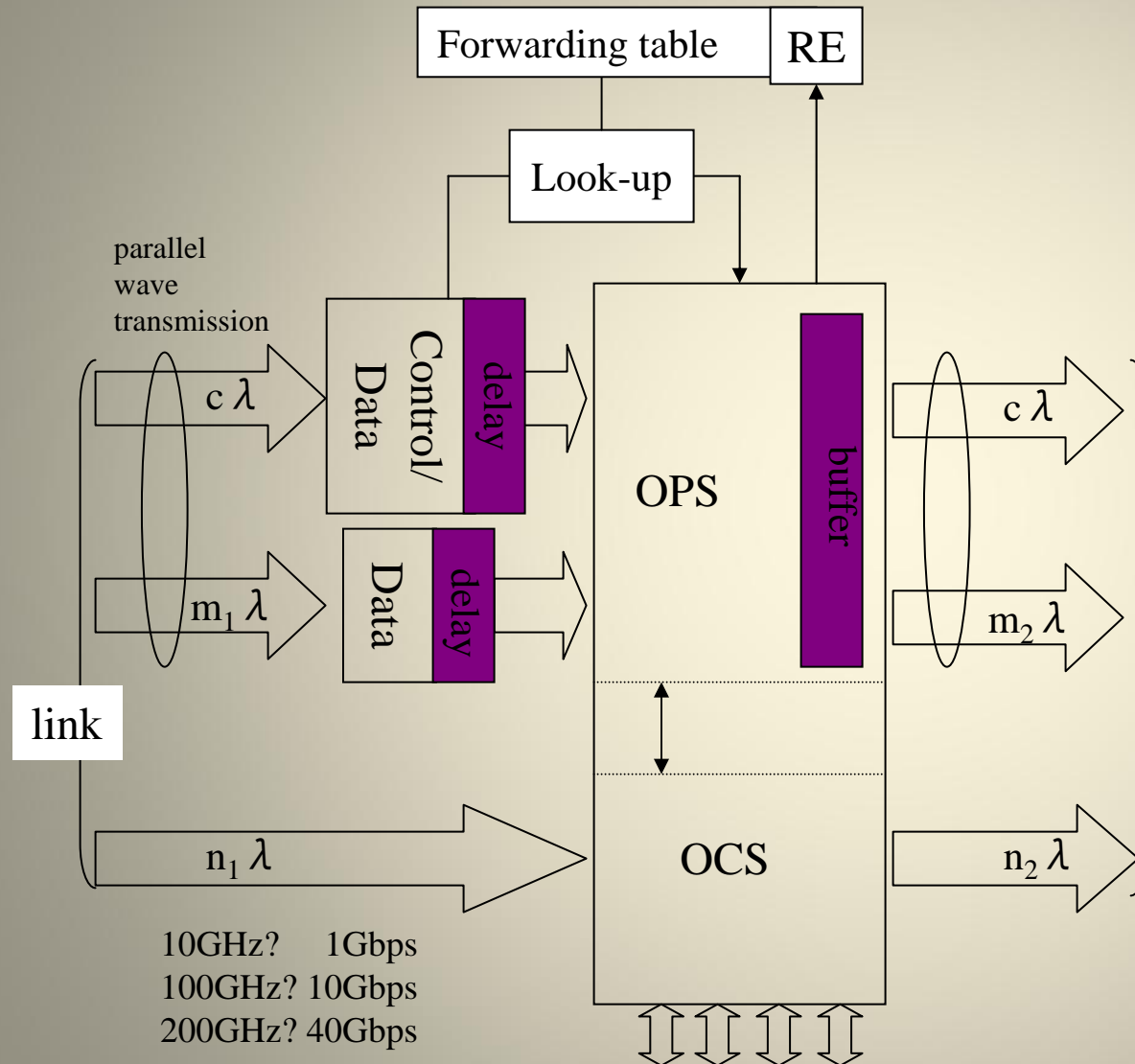**Layered Architecture** ➡ **Cross-layered Architecture**

Mobile Networking ➡ **PDMA (Packet Division Multiple Access)**

Overlay network ➡ **Overlay testbed over JGN2**

Autonomous/Self-organization mechanism

⬅ **Network Science**

Optical Packet & Path Combination Architecture

Forwarding table   RE

Look-up

parallel wave transmission

link

Control/Data   delay

Data   delay

OPS

buffer

OCS

$c\,\lambda$

$m_1\,\lambda$

$n_1\,\lambda$

$c\,\lambda$
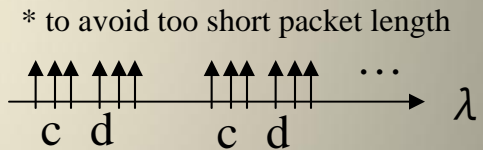
$m_2\,\lambda$

$n_2\,\lambda$

10GHz?   1Gbps
100GHz? 10Gbps
200GHz? 40Gbps

Assumptions:
Packet loss due to small buffer size
OCS for guaranteed services
(current buffer size by NICT = 31 p at 10Gbps)

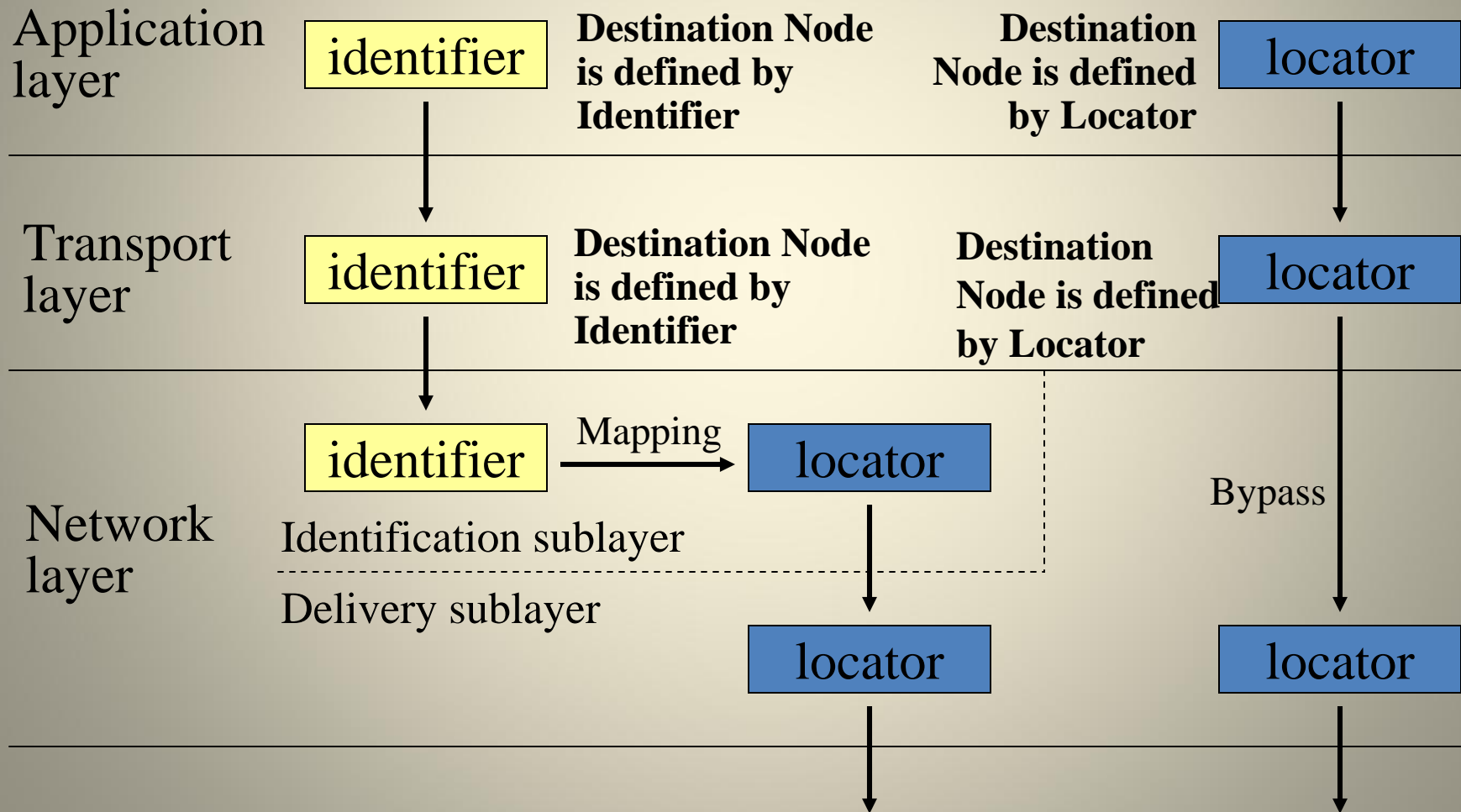Questions:
OPS: Label Swapping? at L2
OCS: GMPLS?

* to avoid too short packet length

c d   c d λ

Hirabaru & Harai
2006-10-19
Akari meeting

NiCT National Institute of Information and Communications Technology

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Separation of Identifier & Locator

【ID/Locator Separation】   【Conventional】

Application layer	identifier	**Destination Node is defined by Identifier**	**Destination Node is defined by Locator** locator

Transport layer	identifier	**Destination Node is defined by Identifier**	**Destination Node is defined by Locator** locator

Network layer

identifier → Mapping → locator

Identification sublayer

Delivery sublayer

locator

locator

Bypass

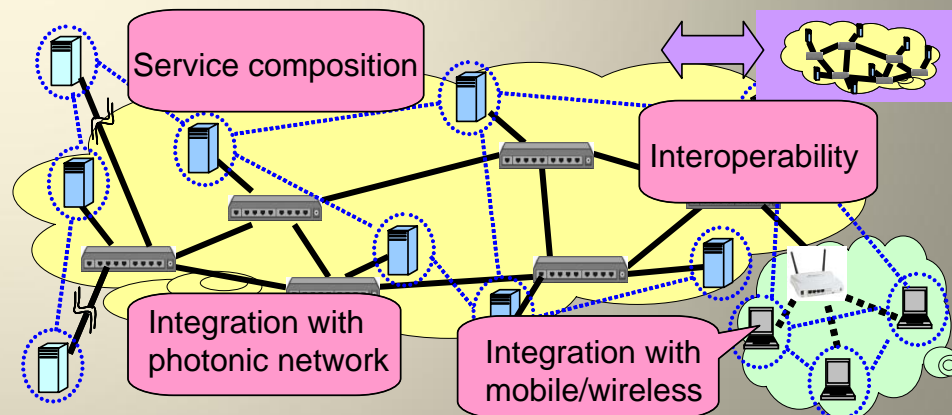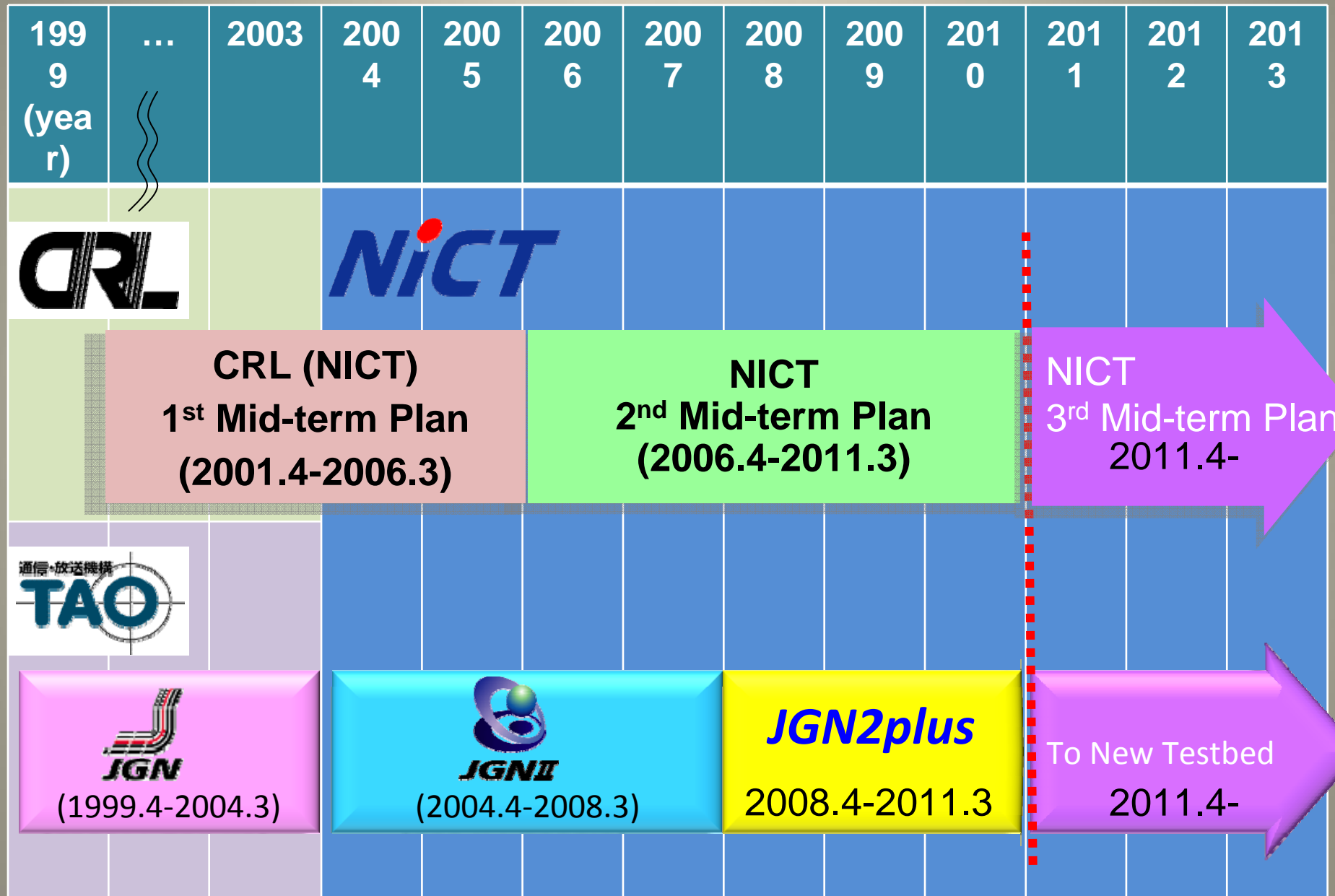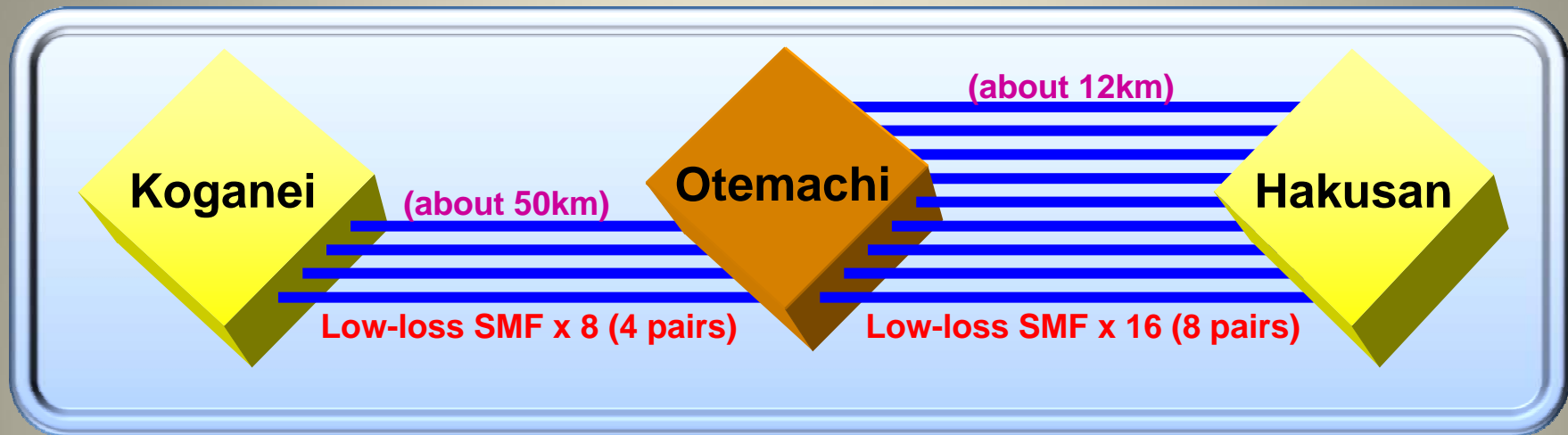locator

Virtualization of Network

- ## Role of overlay
  - **Testbed for distributed applications (general view)**
  - **Testbed for new architecture (general view)**
  - **"Infrastructure" enabling highly flexible service composition and on-demand setup of virtual networks in accordance with users' needs**

- ## Key technologies
  - **Control plane integrating underlay and overlay**
  - **Interoperability**

- ## NICT's activities
  - **Core Project**
    JGN2 plus Overlay Testbed
  - **PlanetLab Japan**

Service composition

Interoperability

Integration with photonic network

Integration with mobile/wireless

JGNⅡ

PLANETLAB Japan
An open platform for developing, deploying, and accessing planetary-scale services

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JGN Project Mile Stone

1999 (year)	...	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013

CRL (NICT) 1st Mid-term Plan (2001.4-2006.3)

NICT 2nd Mid-term Plan (2006.4-2011.3)

NICT 3rd Mid-term Plan 2011.4-

JGN (1999.4-2004.3)

JGNII (2004.4-2008.3)

JGN2plus 2008.4-2011.3

To New Testbed 2011.4-

JGN2plus Services
Optical Testbed Service

Koganei — (about 50km) — **Otemachi** — (about 12km) — **Hakusan**

Low-loss SMF x 8 (4 pairs)   Low-loss SMF x 16 (8 pairs)

- JGN2plus Optical Testbed Service
  - ➢ Koganei-Otemachi Section
    - about 50km
    - Single mode optical fiber (ITU-T G.652) x 8
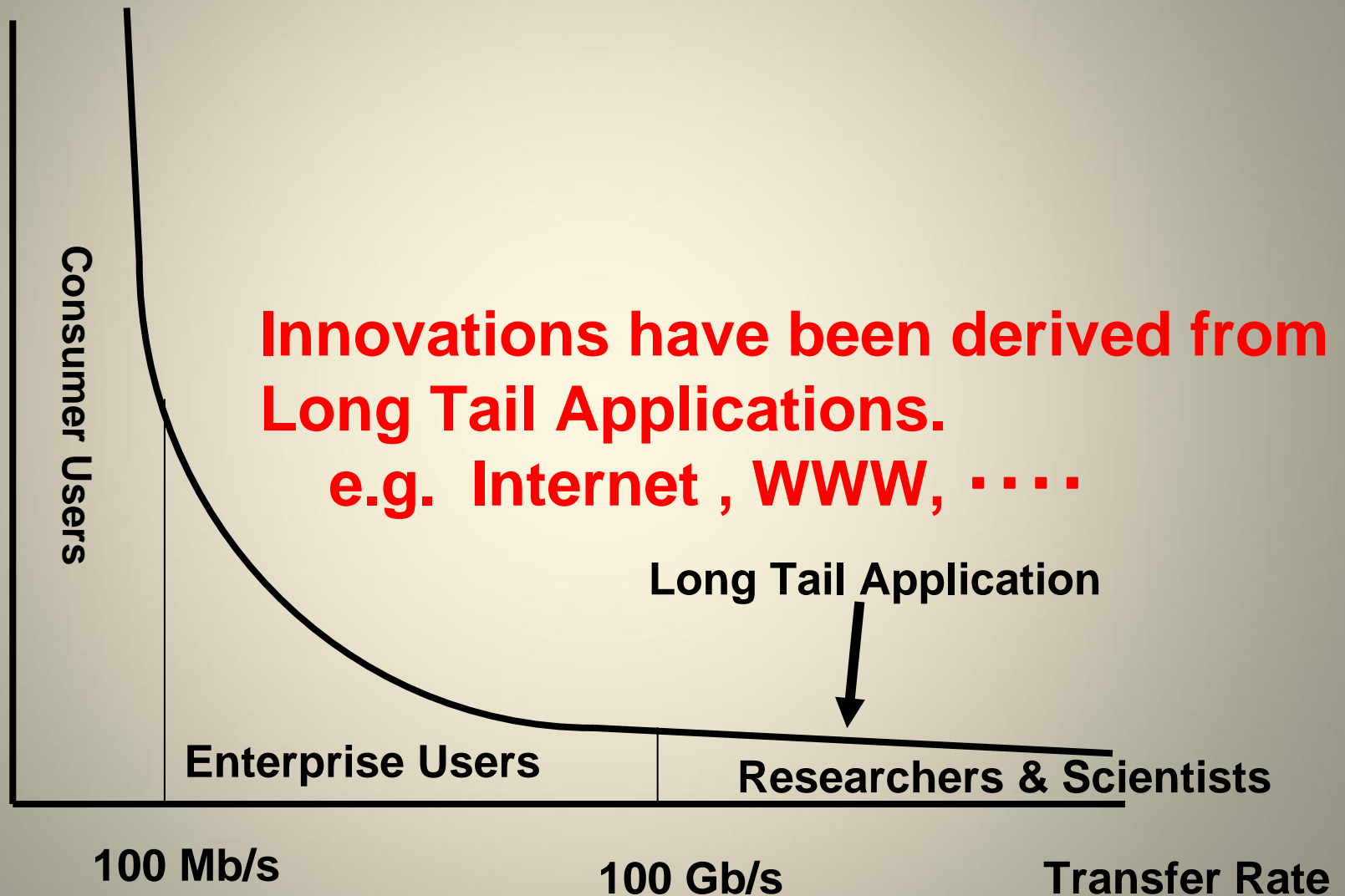   - Low-loss SMF (within 20dB loss at 1550nm band, without any transponders / amplifiers)
  - ➢ Otemachi-Hakusan Section
    - About 12km
    - Single mode optical fiber (ITU-T G.652) x 16
    - Low-loss SMF (within 10dB loss at 1550nm band, without any transponders / amplifiers)

"JGN2 plus" Activities for Innovation

GEANT2
(Europe)

APAN
(Asia)

KOREN
(Korea)

GLORIAD
(USA, Russia, China)

GLORIAD

CA*net4
(Canada)

SURFnet

SURFnet
(Netherlands)

TEIN2
(Asia, Europe)

APAN

KOREN

TWAREN
(Taiwan-China)

TWAREN

CA*net⁴

CERNET
(China)

CSTNET
(China)

KR

HK

APII Asia Pacific Information Infrastructure

HARNET
(Hong Kong)

HARNET

Chicago

UKLight

UKLight
(UK)

STARLIGHT

MREN
(USA)

LA

UniNet
(Thailand)

ThaiSarn
(Thailand)

BKK

StarLight (USA)

Tokyo

PACIFIC WAVE

TransPAC2

IEEAF

INTERNET2

NLR

SG

TransPAC2
(USA)

Pacific Wave
(USA)

IEEAF
(USA)

Internet2
(USA)

NLR
(USA)

SingAREN
(SingAREN)

JGNII

AARNet
(Australia)

Network Research and Operation

[Predicted Research Projects]

· **Network Operation Technology**
· **Traffic Measurement Technology**
· **New Generation Network Architecture**
· **Grid Network**
· **Overlay Network**
· **Advanced Internet**
· **Verification of Interconnection**
· **…………..**

Examples of Long Tail Applications for NWGN

- **Grid Computing** over optical networks

- Connection of tailed display for visualization of e-science

- Connection of entertainment contents with ultra

  high quality such as D-Cinema & ODS (Other Digital Stuff)

      (Cine Grid Community)

- Networking for huge amount of sensors to cover

  environment

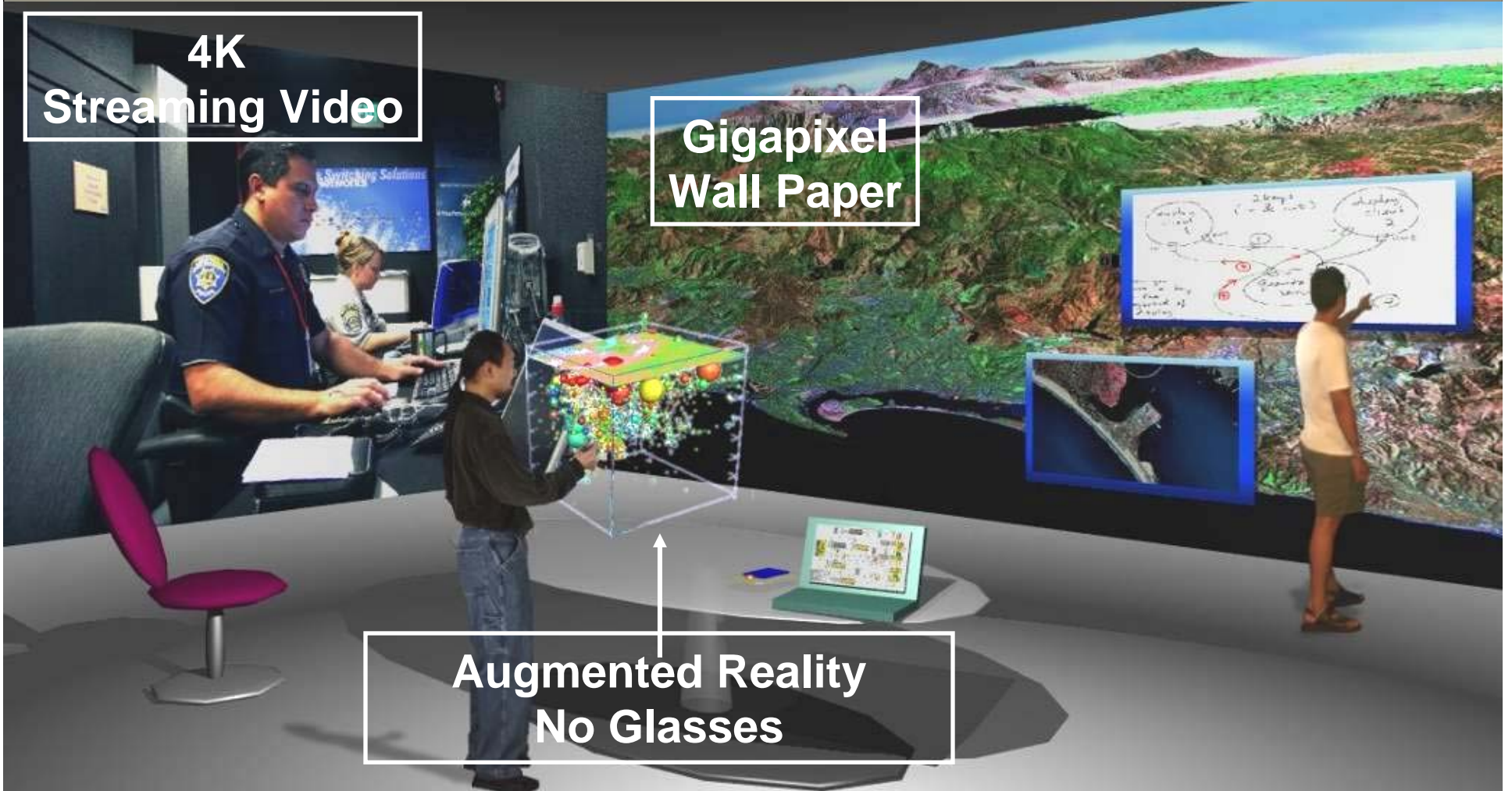- Web2.0, Web3.0, Impact of Google approach

A Vision for the Next Decade

4K
Streaming Video

Gigapixel
Wall Paper

Augmented Reality
No Glasses

1 GigaPixel x 3 Bytes/pixel x 8 bits/byte x 30 frames/sec ~ 1 Terabit/sec!

Source: Jason Leigh,
EVL

OptIPuter 100 MegaPixel Displays

55-Panel Display
  100 Megapixels

  30 x 10GE interfaces
    1/3 Tera bit/sec

Driven by 30 unit Cluster
  of 64 bit Dual
  Opterons

60 TB Disk

Linked to OptIPuter

Working with NASA ARC
  Hyperwall Team to
  Unify Software
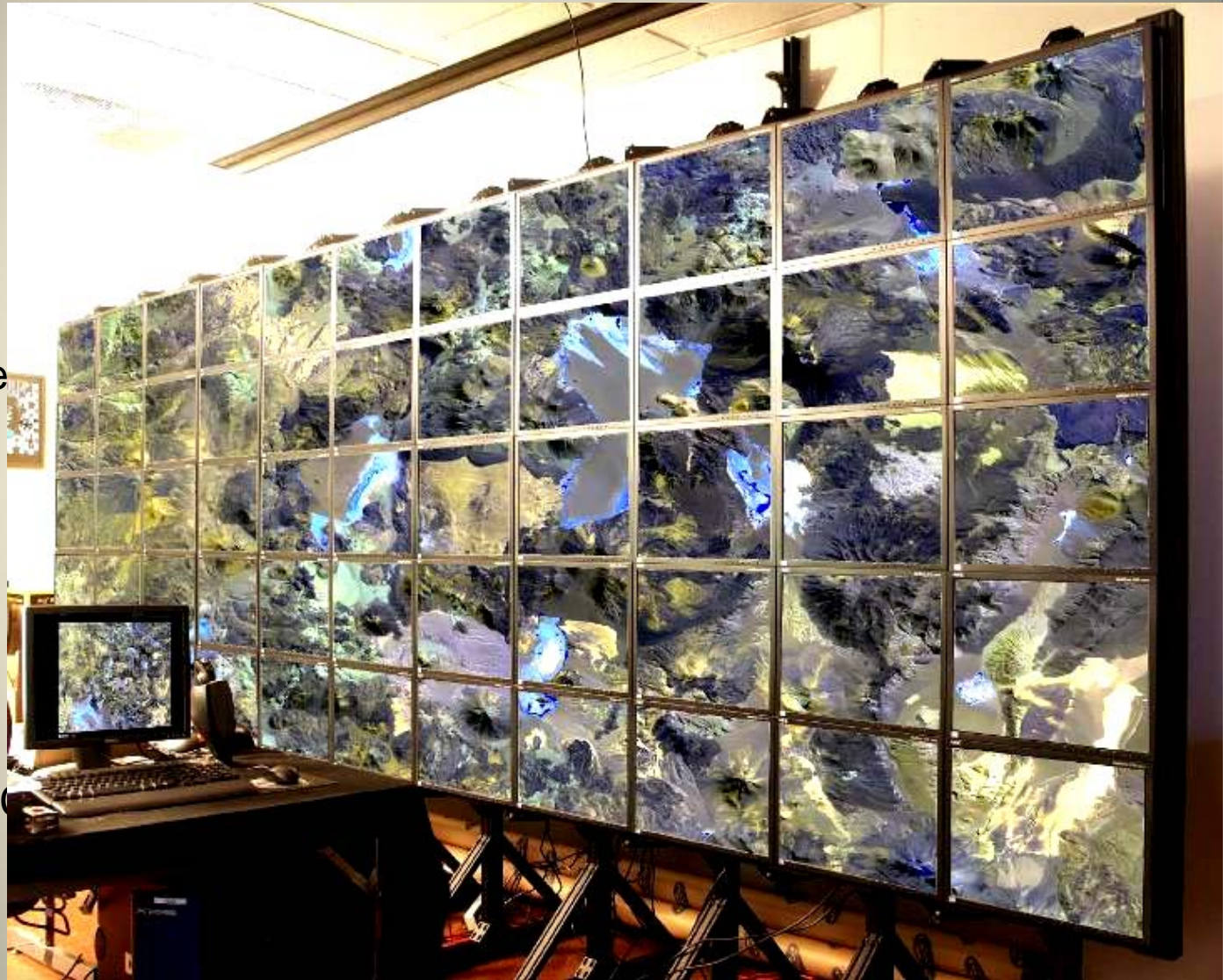
Source: Jason Leigh, Tom DeFanti, EVL@UIC

2K vs 4K

K : 1K=1024 Pixel
2K=2048
4K=4096

30 frames/s Interlace　　　　　　**24 frames/s Progressive**

【Digital TV】　　　　　　　　　　【Digital Cinema】

TV

=720×480

Digital HDTV

=1920×1080

=2048×1080
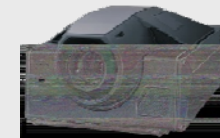
＝**4096×2160（4K）**

Digital Cinema standard was made by DCI and SMPTE is proceeding with the detailed specifications

Digital Screen

No. of Digital Screen

Rapid Expansion

5500

1000

849

500

335

T-Joy Open (Japan)

188

159

100

41

31

2000   2001   2002   2003   2004   2005   2007
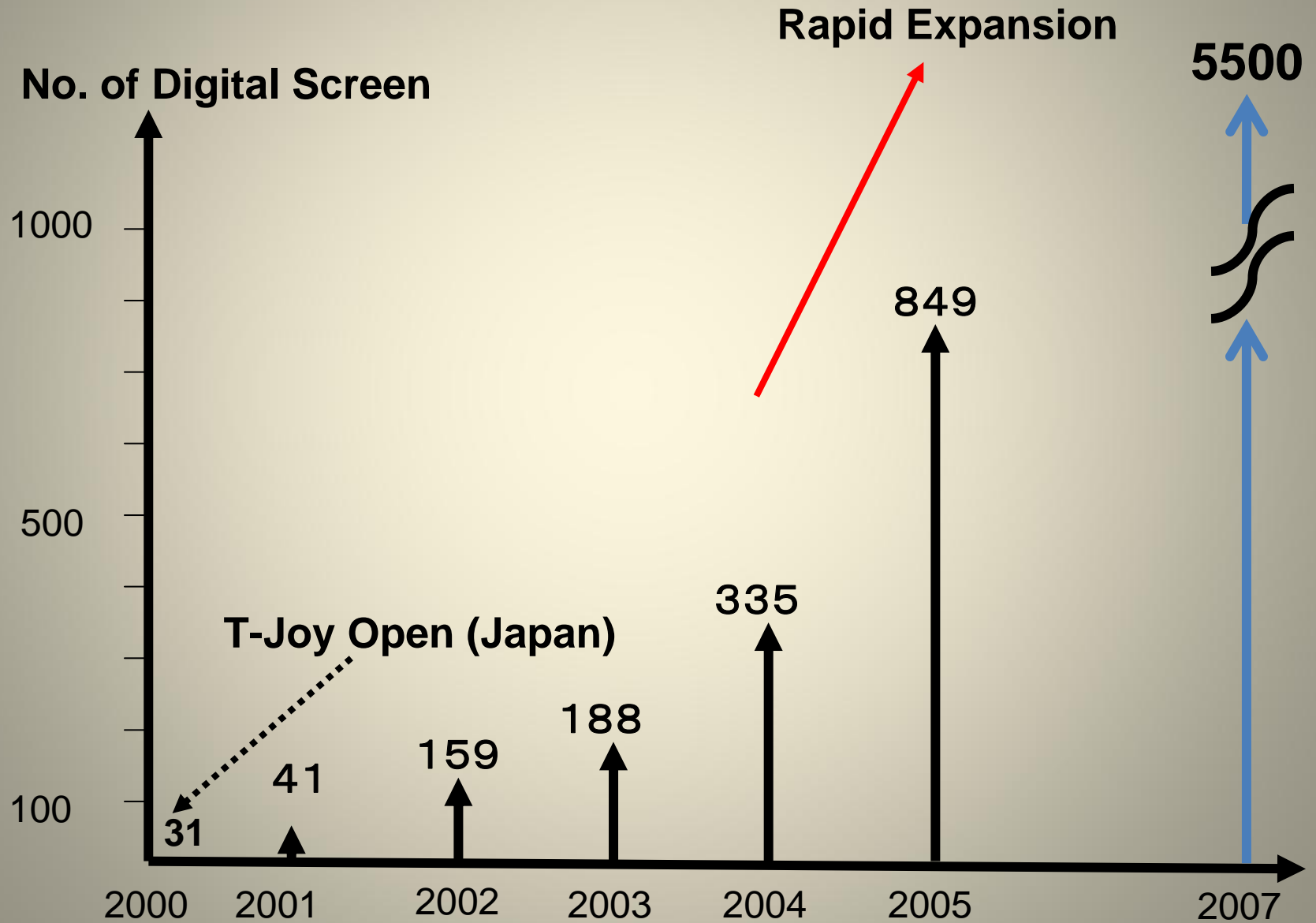
ODS : Other Digital Stuff
(On-Line Digital Source)
Public Viewing

Example
Opera: **NY Metropolitan Opera(HD)**
*Holland Festival (4K)
Musical: **Takarazuka Kageki (HD)**
Kabuki: **Cinema Kabuki (HD)**
Concert: ***Saito Kinen Concert (4K)**
Sports: **Toyota Cup Final (HD)**
* Trial

Keio—UCSD 15,000km 4K Live Streaming IP Transport Experiment

Like High-Def? Here Comes the Next Level

By JOHN MARKOFF
Published: September 26, 2005

The New York Times
ON THE WEB

Keio University
President Anzai

UCSD
Chancellor Fox

Used
1Gbps
Dedicated

NTT
Sony
SGI
Olympus
Mitsubishi
Yamaha
Toppan

*i*Grid 2005
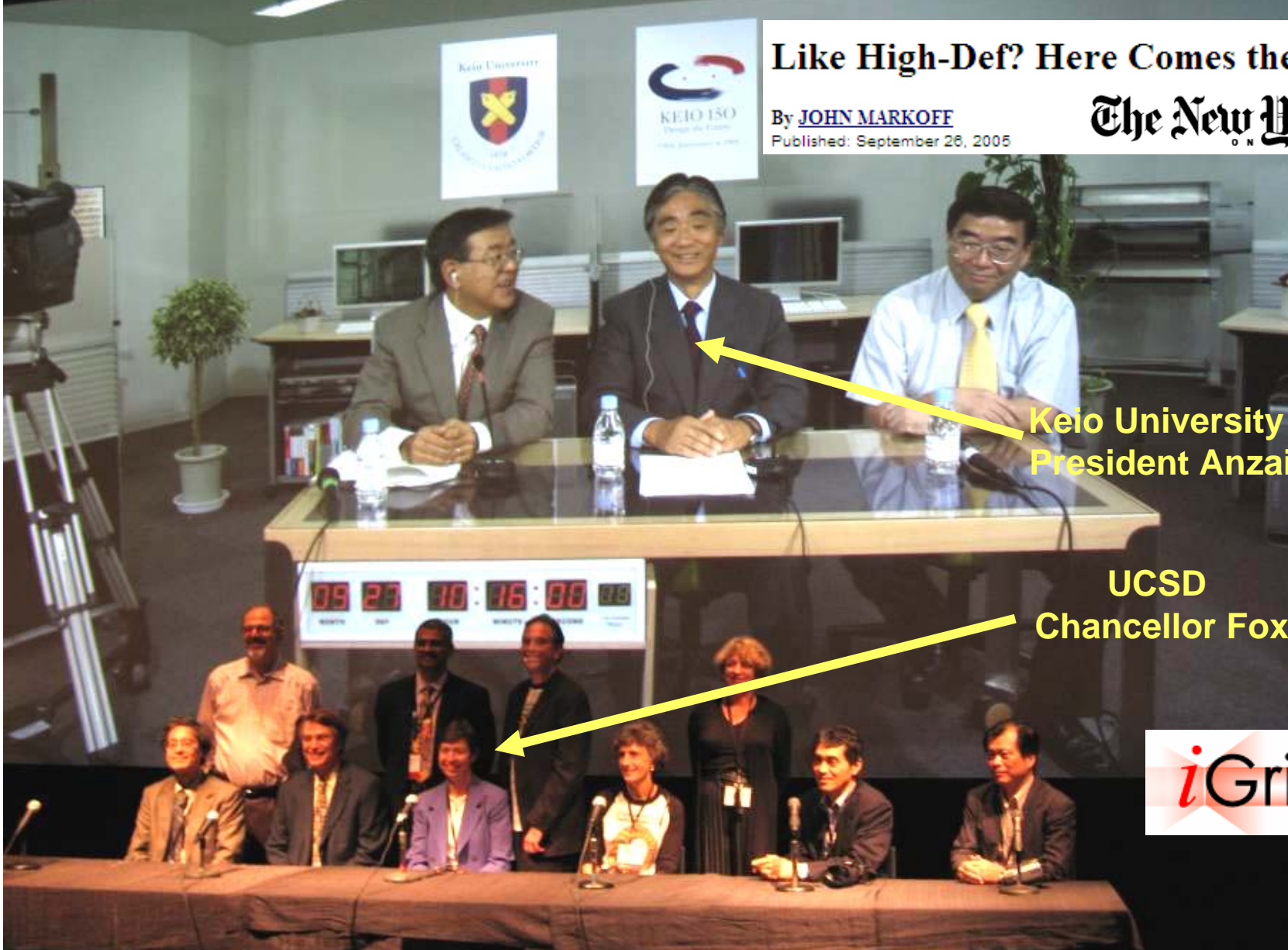
4K Live Streaming of Kyoto Prize Ceremony form Kyoto to Stockholm

Olympus 4K Digital Camera

4K Uncompressed Transmission System

NTT is developping 4k uncompressed streaming system, "4k Gateway " based on i-Visto technology (HD over IP)4x HD-SDI over IP (HD-SDI transparent)

- 4x UDP streams over IP
- Jumbo frame (9000B)
- streaming control from PC
- Frame sync over Ethernet

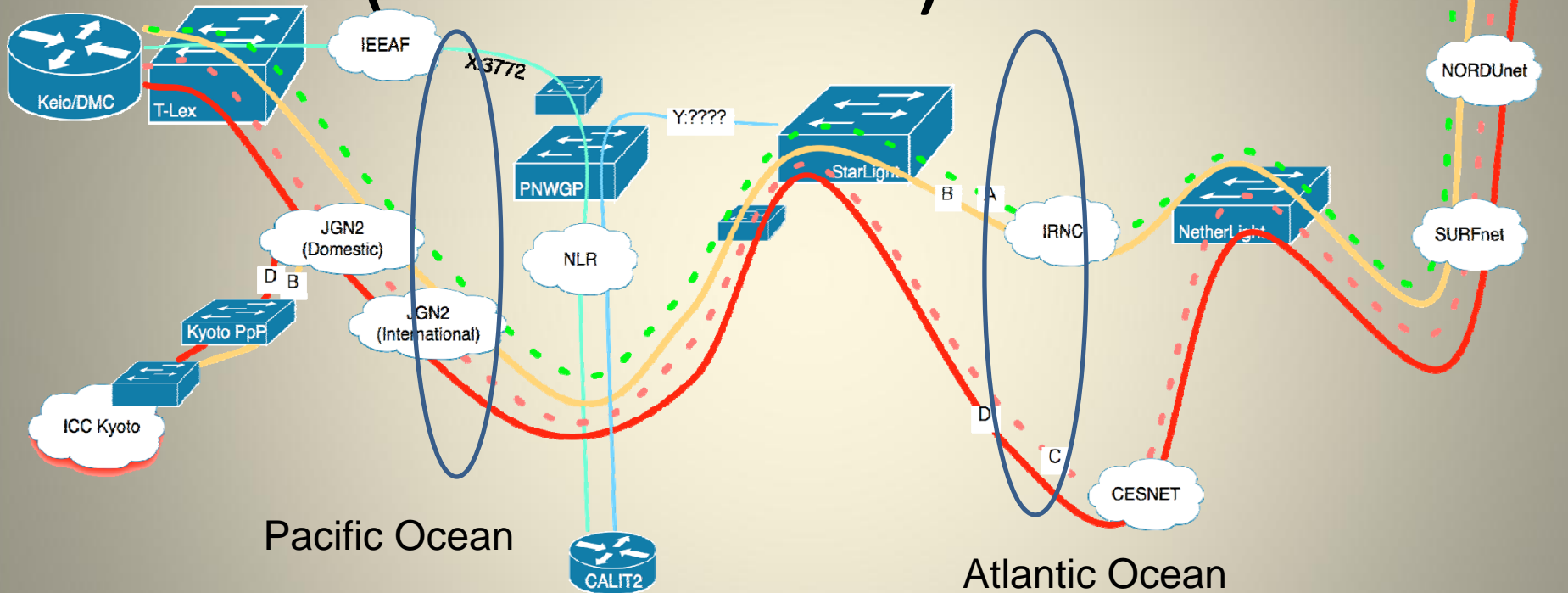Over 6Gbps
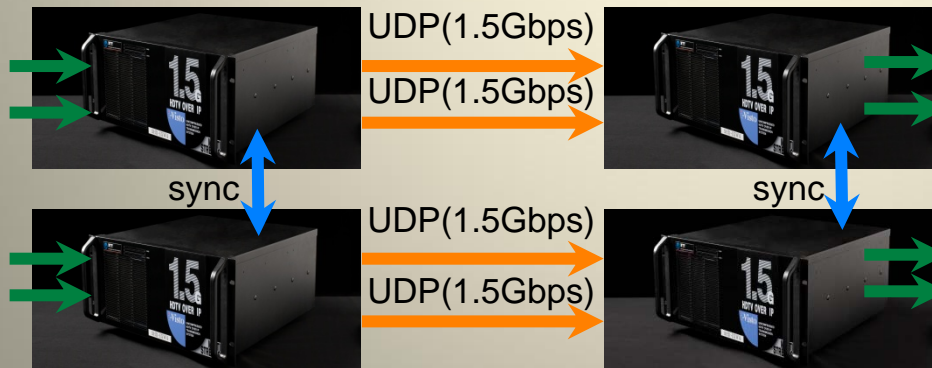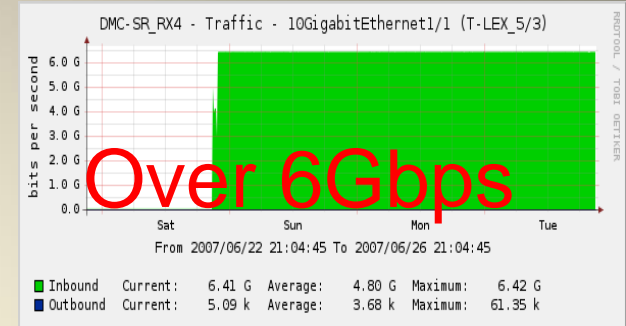
10Gbps Ethernet HDSDI in/out board(1)

Sync Control Ethernet HDSDI in/out board(2)

UDP(1.5Gbps)
UDP(1.5Gbps)
sync
UDP(1.5Gbps)
UDP(1.5Gbps)
sync

43
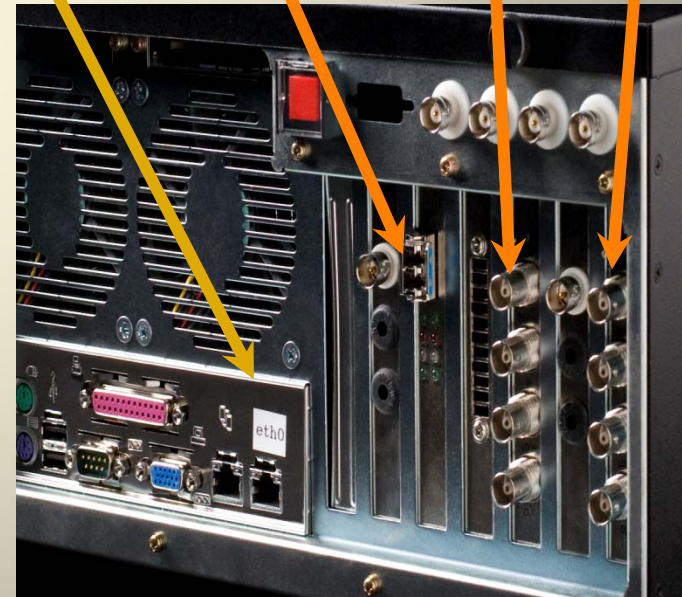
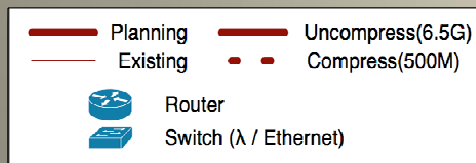# Network Plan for Kyoto Prize 4k Transmission

Network (International)

A: IRNC link (compress)
B: IRNC link (uncompress)
C: CESNET link (compress)
D: CESNET link (uncompress)

X&Y: Existing backup link of JGN2 to Chicago

Stockholm

NORDUnet

SURFnet

Keio/DMC

T-Lex

IEEAF

X:3772

PNWGP

Y:????

StarLight

IRNC

NetherLight

JGN2 (Domestic)

NLR

JGN2 (International)

D B

Kyoto PpP

ICC Kyoto

CALIT2

Pacific Ocean

D

C

CESNET

Atlantic Ocean

Schedule

Testing(from KEIO/DMC to Stockholm)
10/24 20:00(UTC+9) - 10/27 3:00 (UTC+9) = 10/24 13:00(UTC+2) - 10/26 20:00 (UTC+2)
Testing and Rehersal(from Kyoto to Stockholm)
11/8 12:00(UTC+9) - 11/9 20:00 (UTC+9) = 11/8 4:00(UTC+1) - 11/9 12:00 (UTC+1)

show 1st day (from Kyoto to Stockholm)
11/10 14:00(UTC+9) - 11/10 17:00 (UTC+9) = 11/10 6:00(UTC+1) - 11/10 9:00 (UTC+1)
show 2nd day (from Kyoto to Stockholm)
11/11 12:00(UTC+9) - 11/11 17:00 (UTC+9) = 11/11 4:00(UTC+1) - 11/11 9:00 (UTC+1)

Planning   Uncompress(6.5G)
Existing   Compress(500M)
Router
Switch (λ / Ethernet)

kaneko@dmc.keio.ac.jp, 2007/10/10

Requirement for Networking

2 hour 4K digital cinema contents
   Non-compressed   : **5TB**
   JPEG2000 Compressed   : **250GB**   (1/20 compressed ratio)

File Transfer
   10 hours over 1Gb/s link   Non-compressed
   30 minutes over 1Gb/s link   1/20 compressed

Real time streaming
   6Gb/s Non-compressed
   300Mb/s 1/20 compressed

Multicast function

QoS Requirements
   Packet Loss
   Latency
   Synchronization

Conclusion

- **NXGN is now being deployed, standardized, and the first services have just started in some countries.**

- **The Internet and NGN will coexist giving users their merits from now on.**

- **NWGN is in the research phase toward 2020.**

  We have to accelerate R&D on NWGN technologies to provide advanced and secure ICT infrastructure with low carbon toward the decade of 2020.

  International collaboration for R&D on NWGN/Future Internet is important, and world-wide network testbeds should be established.

Thank you !