New Generation Network
Its Promises and Challenges

Hisashi Kobayashi

Princeton University, USA

NICT, Japan

Euroview 2012

July 23 & 24, 2012

Outline

I What is NwGN, and Why？

II What led the Internet to success？

III An End to the End-to-End Design

IV Network virtualization

V AKARI Architecture and JGN-X

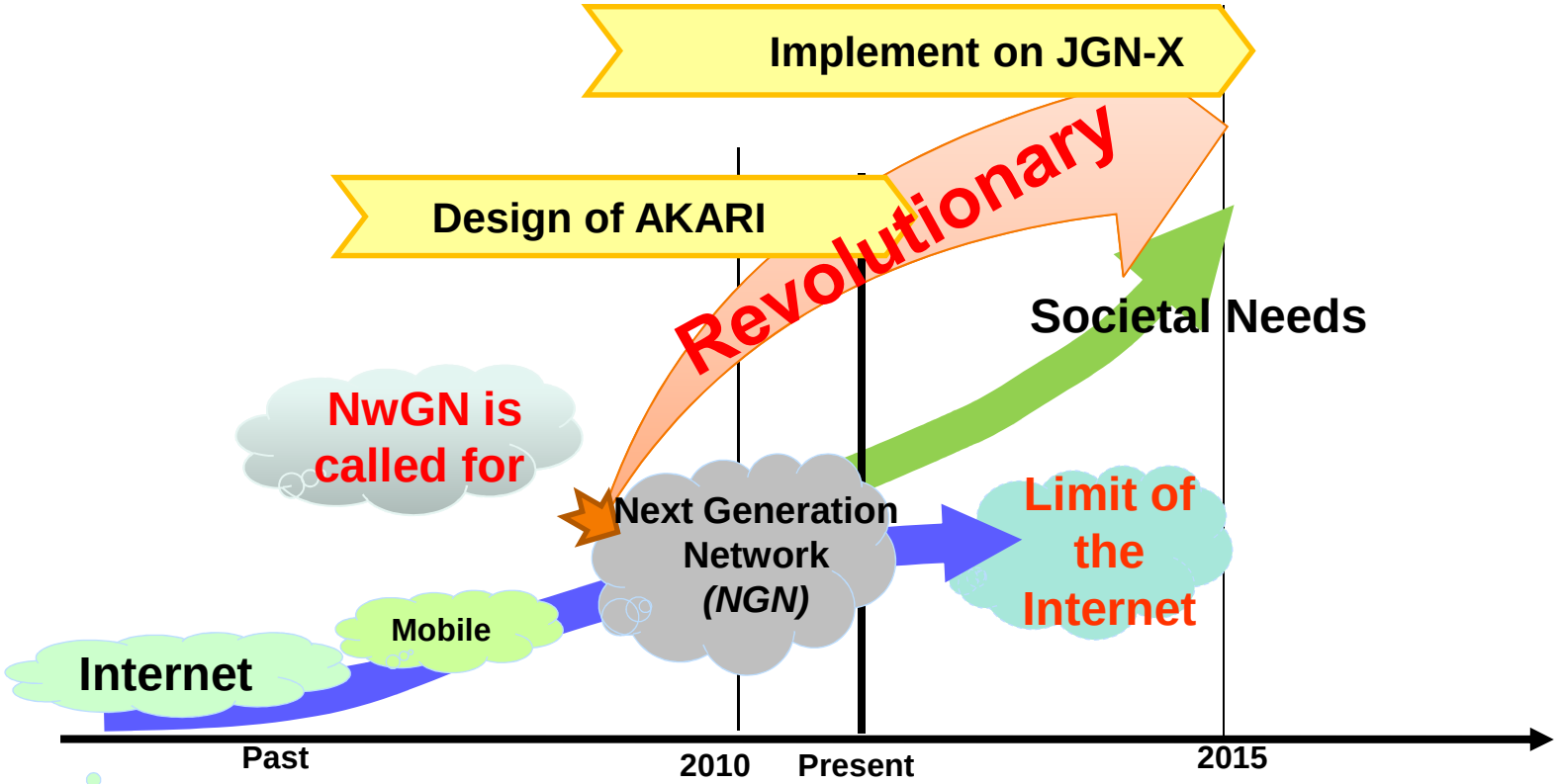
VI FIA and Testbeds, Ativities in the U.S.

VII What should be Japan’s strategies？

What is New Generation Network (NwGN)?

- A flagship of the networking research in Japan
- Design of a new network
  - A “clean slate” approach
- Implement and Verify on a testbed
- Experimentally operational by aound 2015.

Why NwGN？



Exploding Traffic

Security Issue

Mobilty

Diagam: AKARI Architectiure Design

Requirements for NwGN

1. **Scalability** (users, things, "**big data**")
2. **Heterogeneity** and **diversity** (in "**clouds**")
3. **Reliability** and **resilience** (against **natural disasters**)
4. **Security** (against **cyber attacks**)
5. **Mobility management**
6. **High performance**

Requirements for NwGN– cont'd

7. **Energy** and **Environment**

8. **Societal** needs

9. **Compatibility (**with today's Internet)

10. **Extensibility** (for the unforeseen and unexpected)

AKARI Architecture

- Cross-layer optimization
- ID/locator split architecture
- Virtualization
- Optical packet & circuit integration

ID and Locator in the Internet

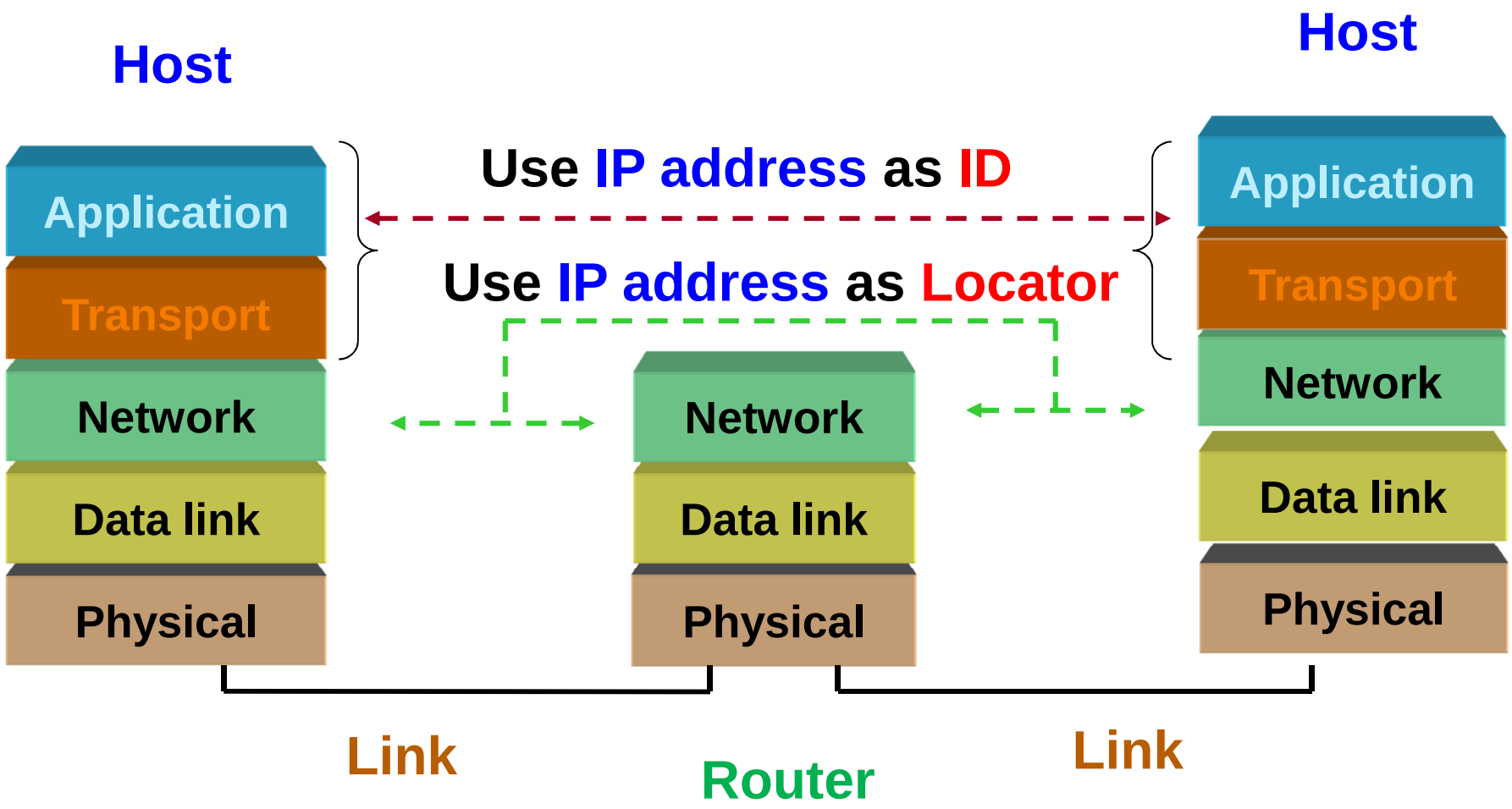


Diagram : Ved Kafle

ID/Locator Split Architecture

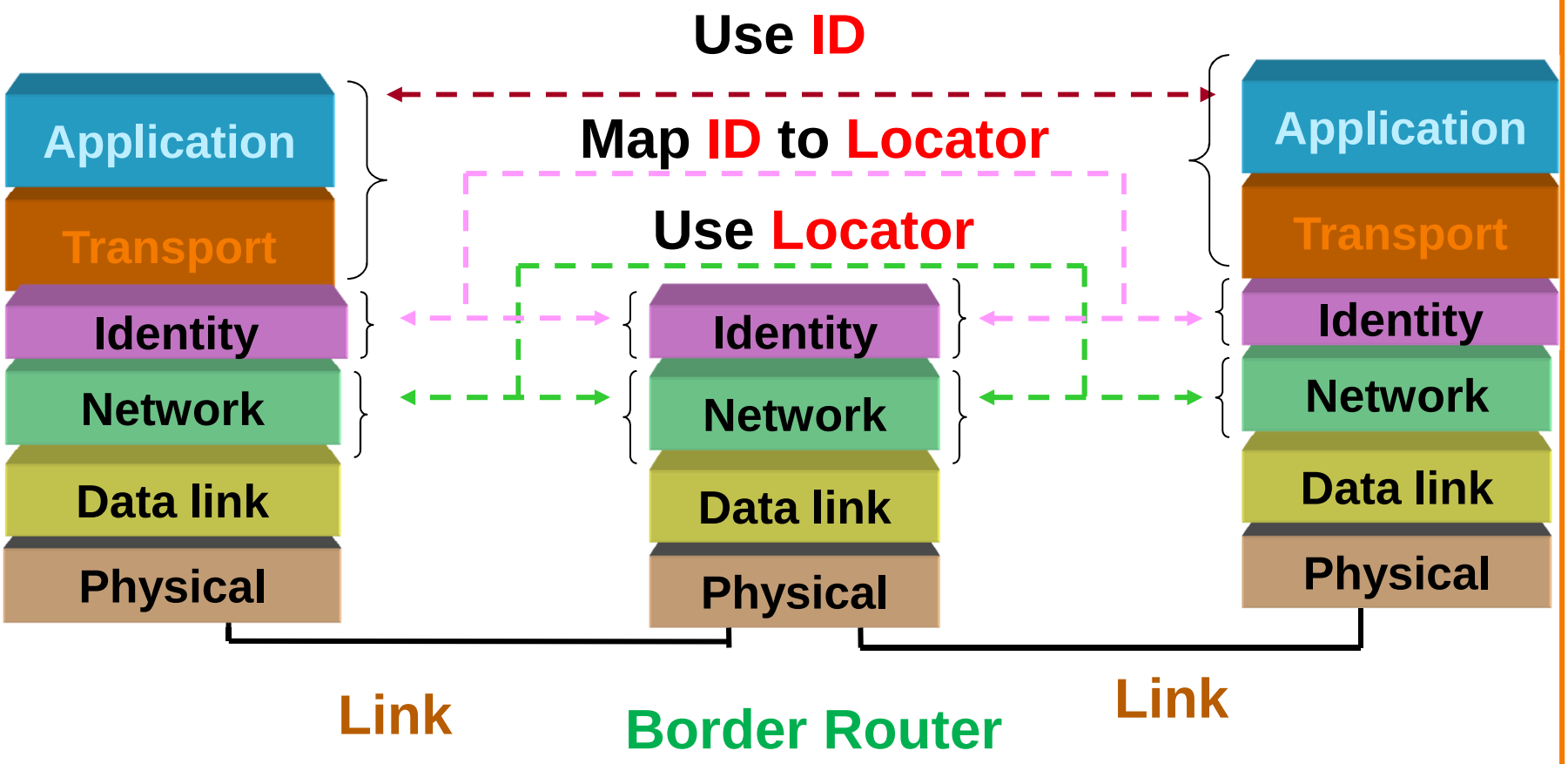


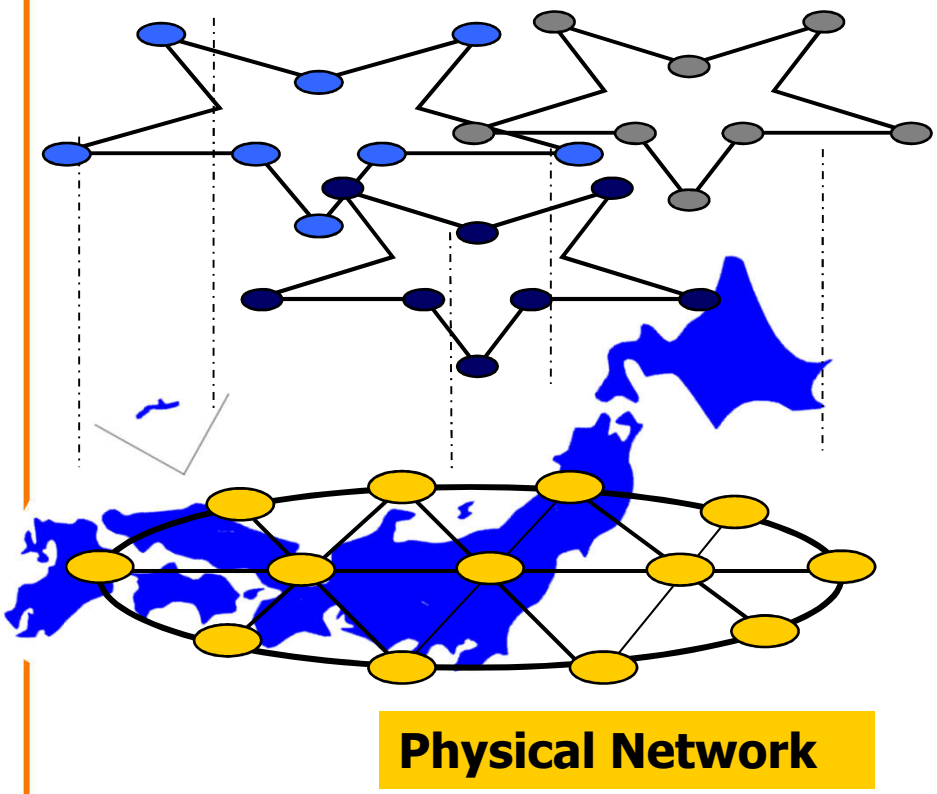
Diagram : Ved Kafle

Network Virtualization

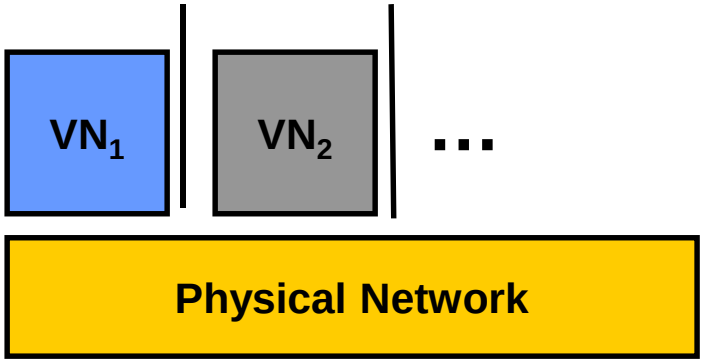
- Choose a subset of a collection of **physical resources** (routers, end users, links,etc.) and **functionalities** (routing, switching, transport) of one or multiple real networks and form a **logical network** .

- Provide a **testbed** for the future network architecture and its protocols.

Virtual Networks and Overlaid Networks



(a) Isolated Virtual Networks



(b) Overlaid Virtual Networks

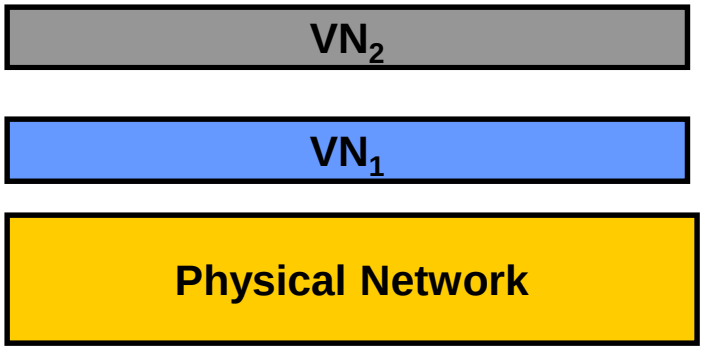


Diagram: Akihiro Nakao

Configuration of Virtual Node

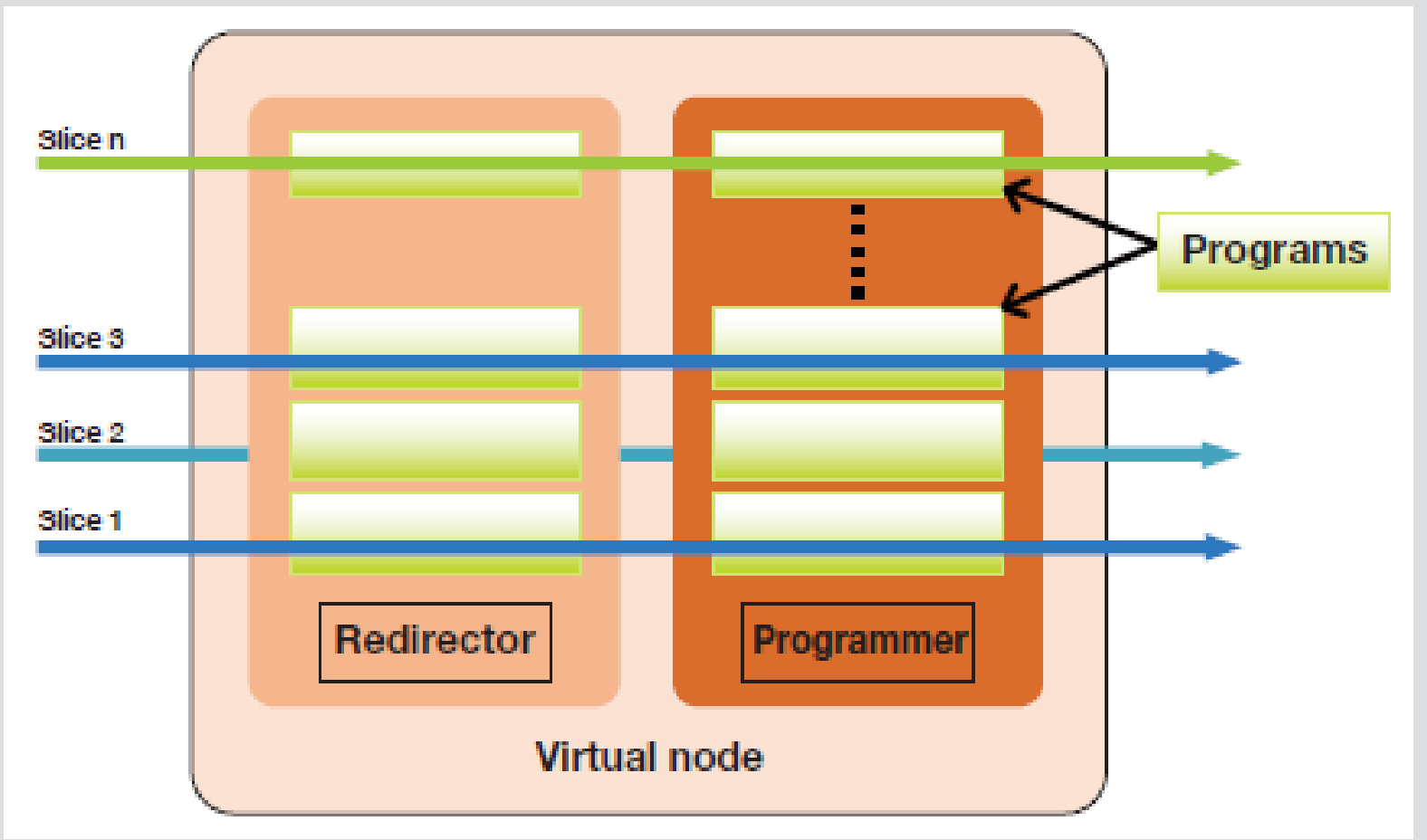


Figure 3 ●The configuration of virtual node (Router)

Diagram: NICT News No. 393

Virtual Node Project and Participating Companies

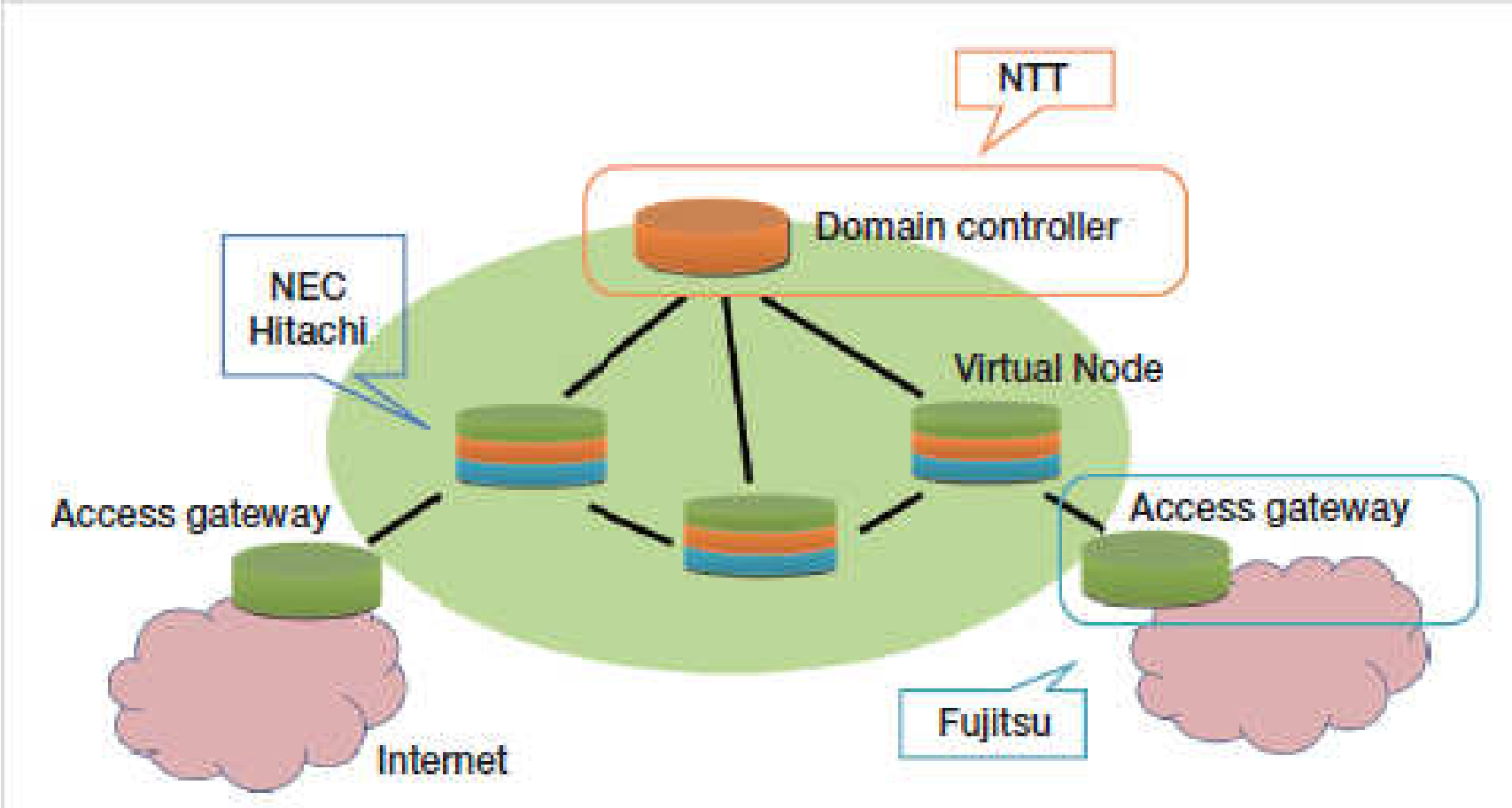


Figure 6 ●Assignments of each company in the Virtual Node Project

Diagram: NICT News No. 393

Optical Packet and Optical Path

Characteristics of Optical Technology

- Broadband
- Memory and operation circuits, not well developed

- Optical packet switching: translate the header into electric signal
- Optical path: Optical paths in WDM（wavelength division multiplexing）are equivalent to circuits in circuit switching
- AKARI Architecture integrates optical packets and optical paths

Integrated System of Optical Packets and Optical Paths

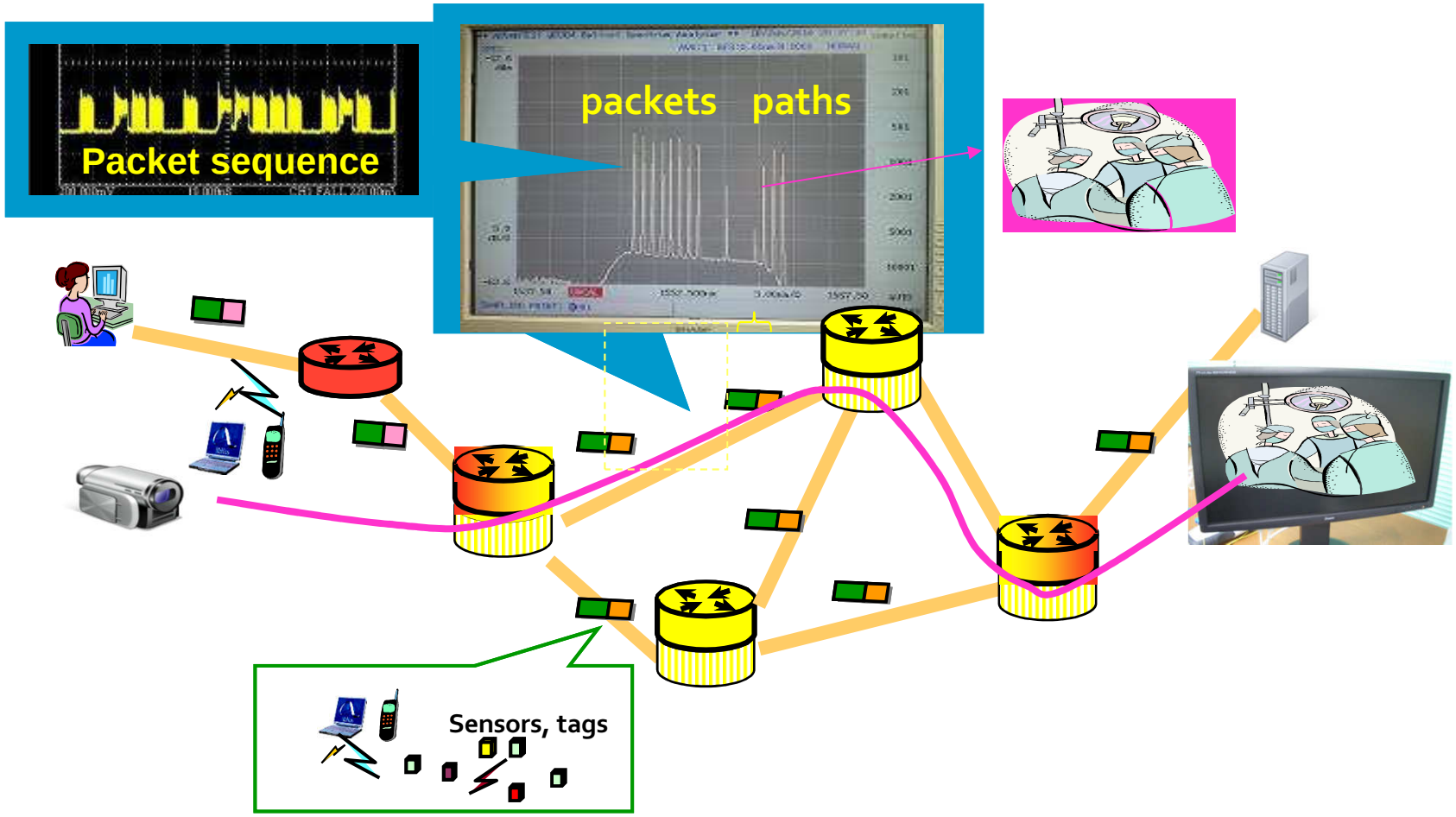


Diagram: Hiroaki Harai, NICT

JGN-X Network Overview

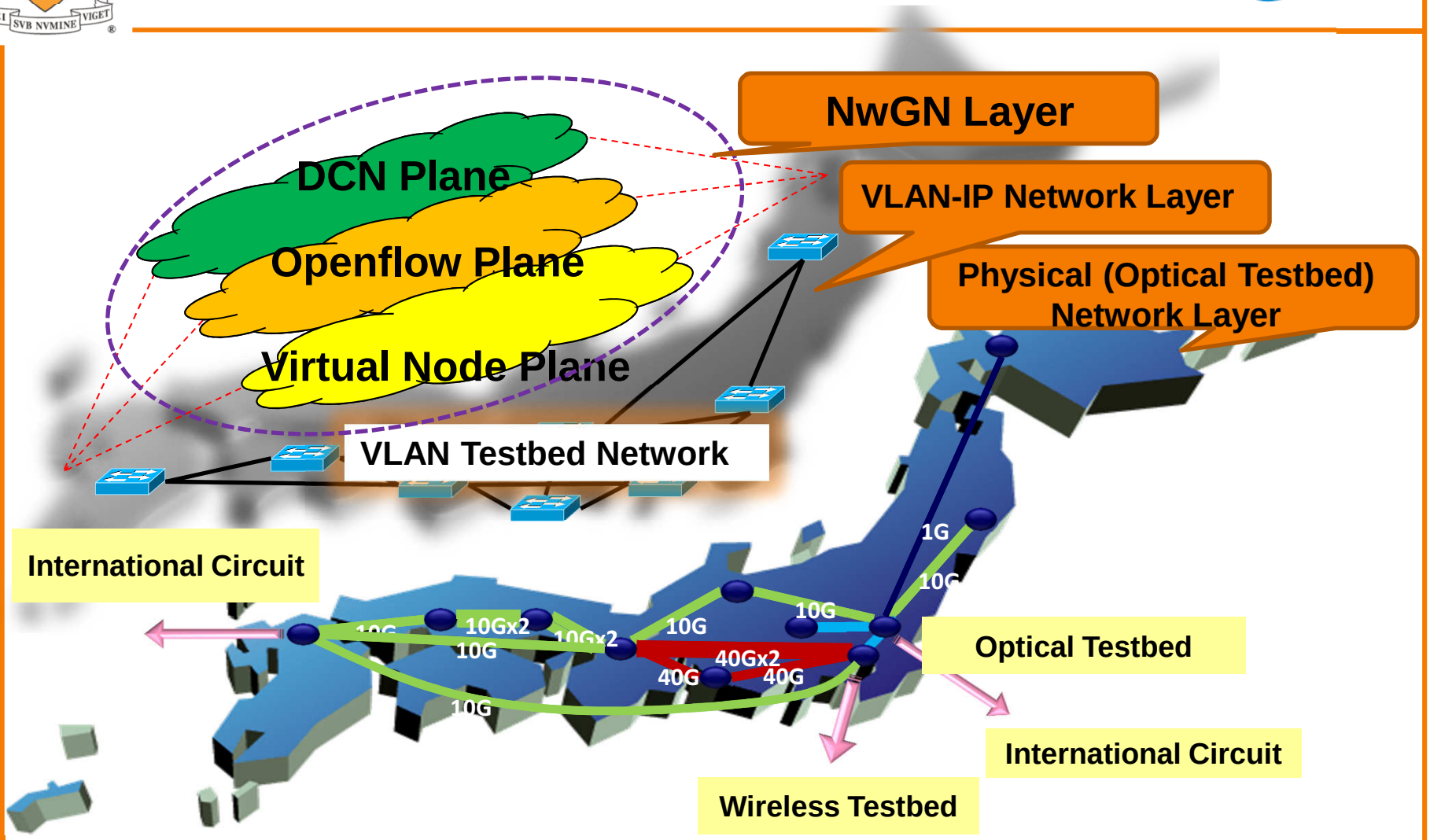


Diagram: Eiji Kawai, NICT

JGN-X International Circuits

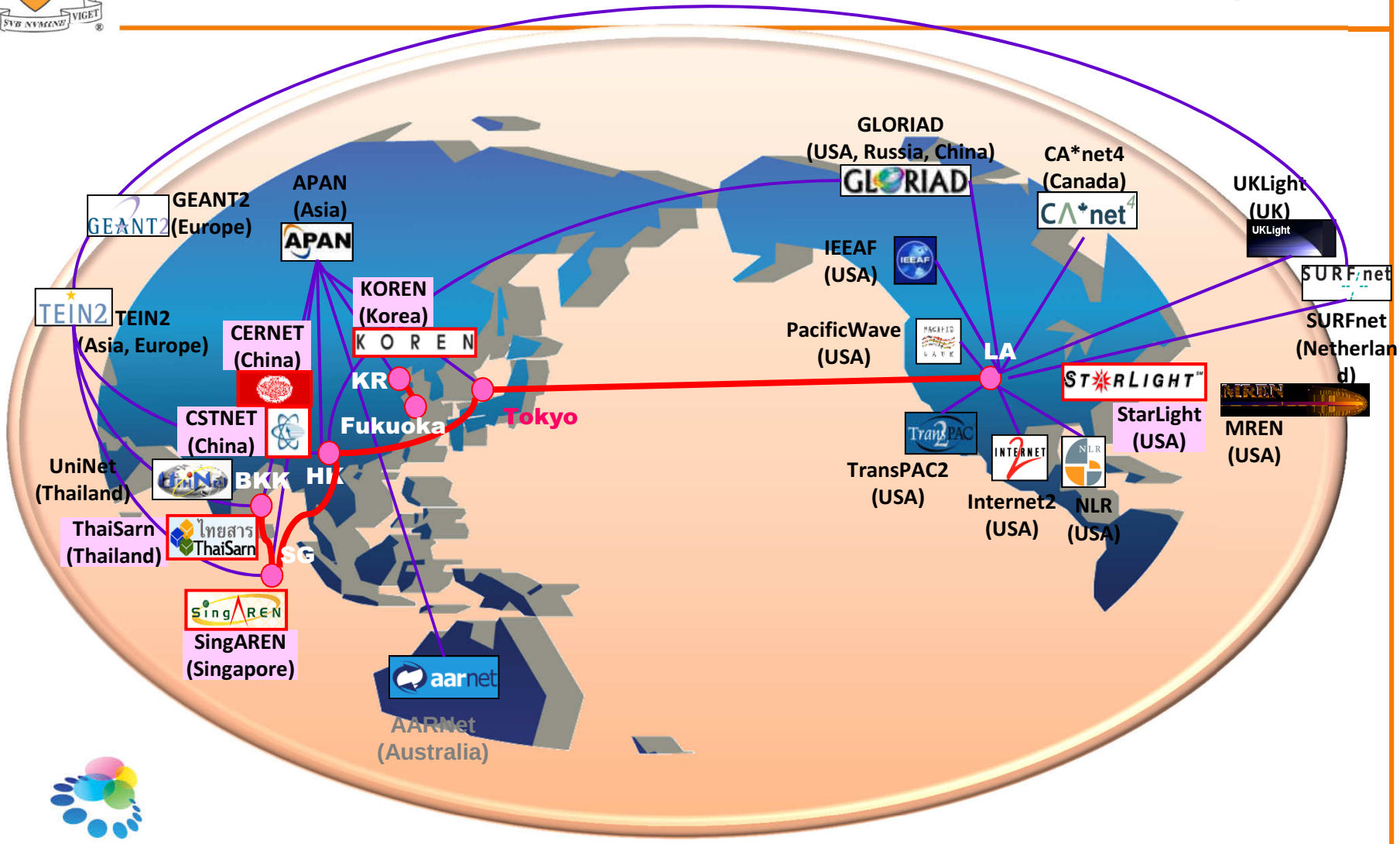


Diagram: Eiji Kawai, NICT

Research around JGN-X

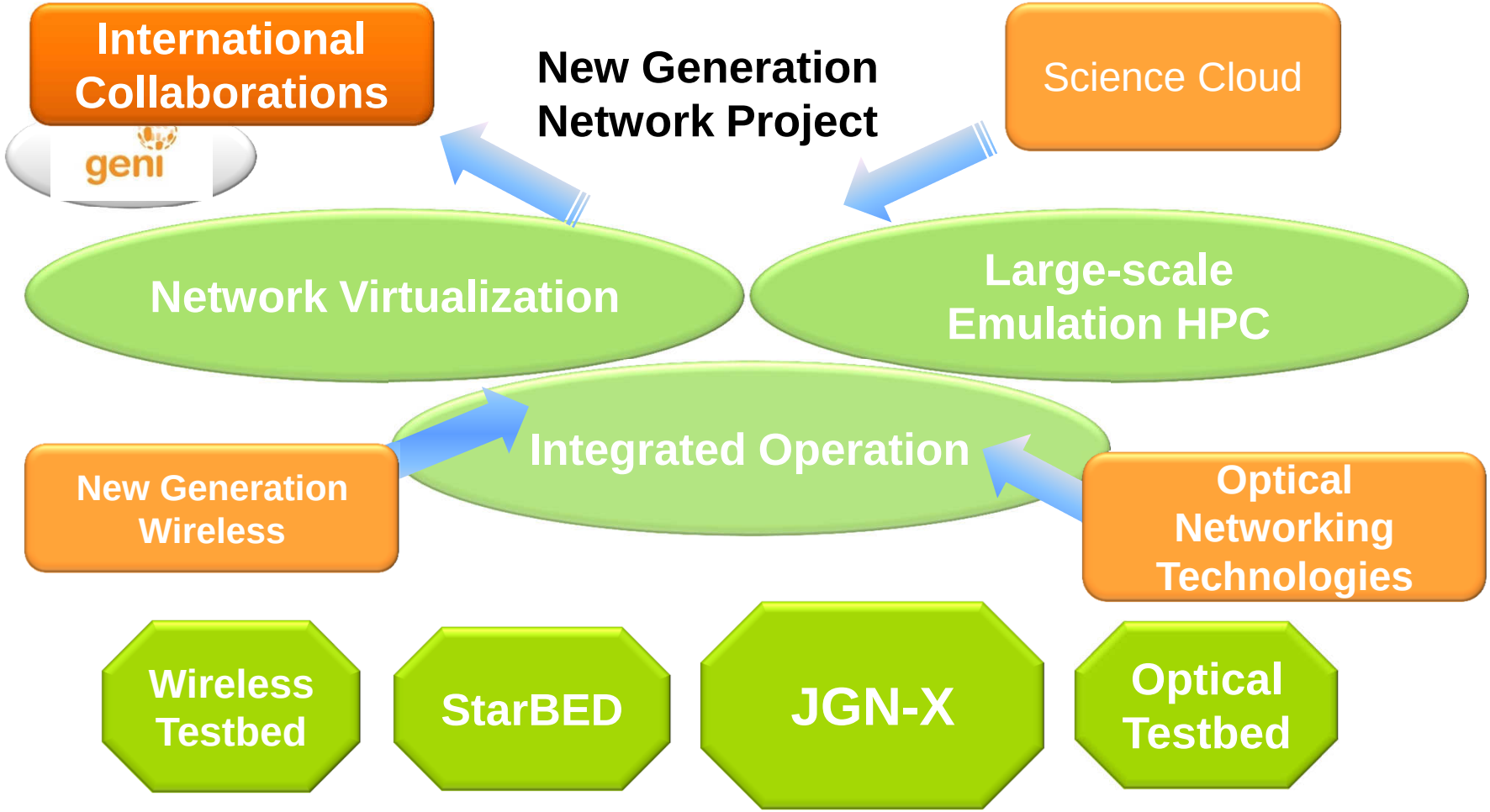


Diagram: Eiji Kawai, NICT

Challenges in the Future Internet Research

- Can we reach an agreement on the architecture?
  - How to deal with the NIH syndrome
  - Conflict of interest among different stakeholders
- Will backward compatibility be a decisive factor?
- Or should we aim at an "optimal" clean-slate architecture?
  - with a feasible migration path scenario?
  - or with a coexistence scenario (i.e., two virtual networks)

How to evaluate architectures?

- Comparison of different architectures is difficult
- Limited mathematical modeling techniques
- Lack of interest in quantitative arguments among the Internet community
  - its character, culture and history

TCP-IP Networks

- Provides only “best effort” services.
- So no need to characterize the network performance quantitatively
- Very few quantitative discussions in the Internet literature.
- The Internet community is not interested in “theoretical limits” of any sort.

Recall ATM/Broadband ISDN Efforts

- Telecommunication carriers' effort on B-ISDN in the 1980's and 1990s.

- Lost the race against the Internet in offering multi-media services

- A "Geankenexperiment":
  Suppose that the B-ISDN camp had won over the Internet.
  - No pervasive social networks yet?
  - No Lehman Shock or Flash Crash?
  - No cyber attacks that threaten us today?
  - No need for the future network architecture?

Over reliance on Testbed

- Prototyping or testbed
  - Useful for a proof-of-concept or protocol validation.
  - Will not lead to quantitative understanding or to a solution for optimal control.
- The Internet has been successfully running, because of its "overdimensioning."
  - Cost/performance of the network components have been improving geometrically.
  - No guarantee in the future.
  - Energy consumption of IT systems is a serious issue.

Modeling and Analysis Issues

- Little attention or effort paid to the performance aspect of a virtual network?
- Statistical sharing of limited physical resources by multiple logical networks (or slices).
- A network of “processor sharing” servers seems a reasonable mathematical abstraction of a virtual network, where a “processor” is a bottleneck resource (e.g., a router) at a node.

Processor Sharing (PS)

- Originally introduced as the limiting case of round-robin scheduling by L. Kleinrock

- Early work on PS was motivated by it's applicability to time-shared computers.

- Renewed interest in the PS scheduling
  - Modeling of statistical multiplexed traffic;
  - Modeling of Web servers;
  - Modeling of links congested with TCP traffic

Processor Sharing (PS) –cont'd

- "**Fair scheduling**" emulates PS.
- The stationary distribution of *the number of customers in a PS server* is ***insensitive*** (or ***robust***) to the distribution of service time (e.g., flow size).
- N. Dukkipati et al. [15] compare the performance of TCP/IP algorithms against the theoretical limit implied by a PS model.

Loss Network Model

- Loss network theory is a recent development, see Kelly [16], Kobayashi & Mark [13,14].
- Can characterize a network with resource constraints which supports multiple end-to-end circuits with different resource requirements.
- Can be viewed as a generalization of the classical Erlang or Engset loss models.
- Its insensitivity and robustness against the network traffic or load characteristics make this characterization very powerful.

Performance Analysis

- Blocking probability and call loss rate can be written in terms of the normalization constant *G* (the partition function).

- Product form solution and computational algorithms

- Asymptotic analysis becomes more accurate and simpler as the network parameters become greater.

Open Loss Network (OLN)

Number of links in the network: L=5

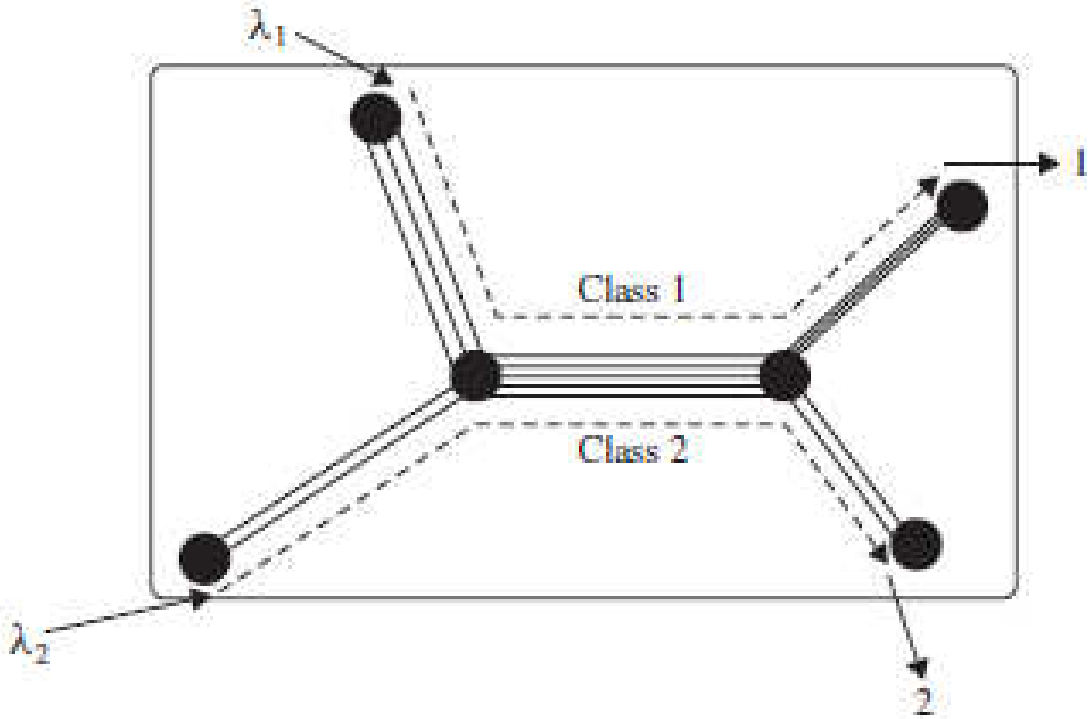


FIGURE 7.3-1: Open loss network (OLN).

Class of a call: r=(c, τ), c=routing chain, τ=call type

Generalized Erlang Loss Model

L=Number of the server types

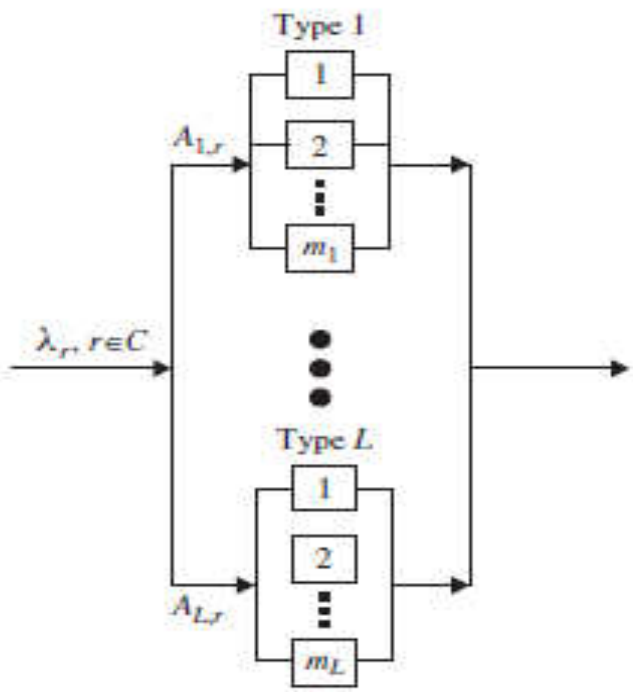


FIGURE 7.3-2: Generalized loss station (GLS) which is equivalent to the OLN.

$$\sum_{r \in \mathcal{R}} A_{\ell,r} n_r \leq m_\ell,$$

Mixed Loss Network (MLN)

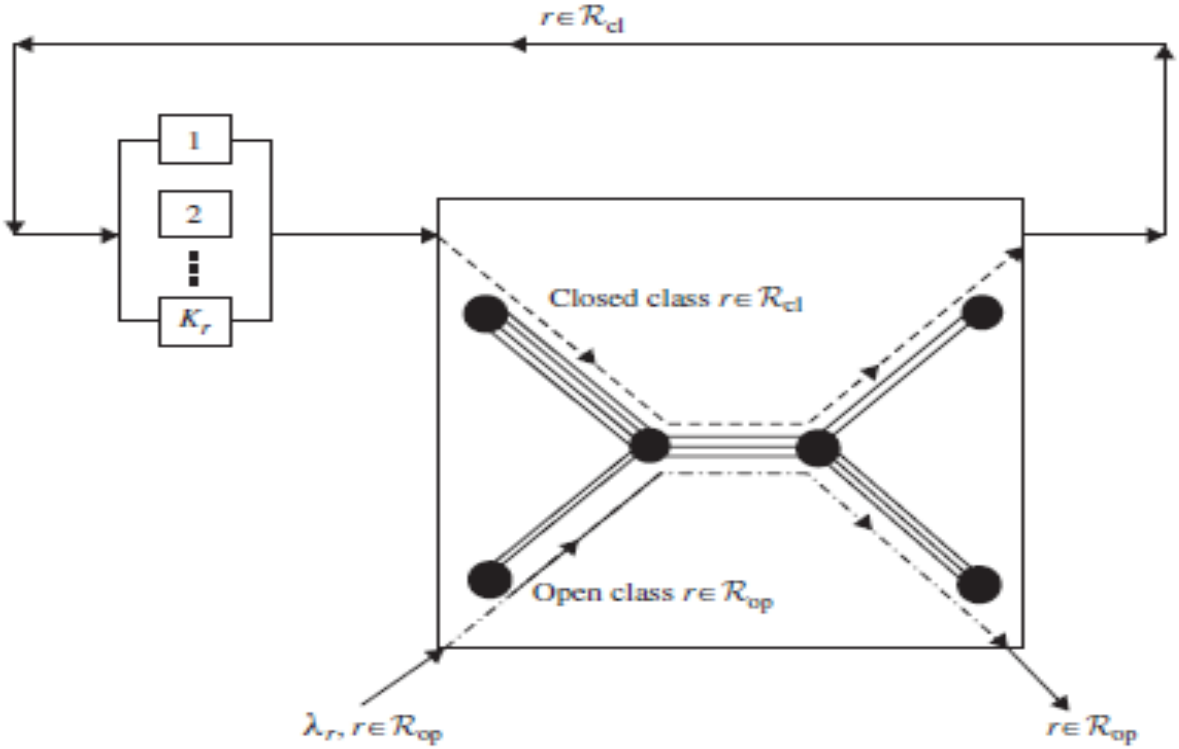


FIGURE 7.3-3: Mixed loss network.

Queuing and Loss Network (QLN)

Packet-switch routing and path circuits can coexist.

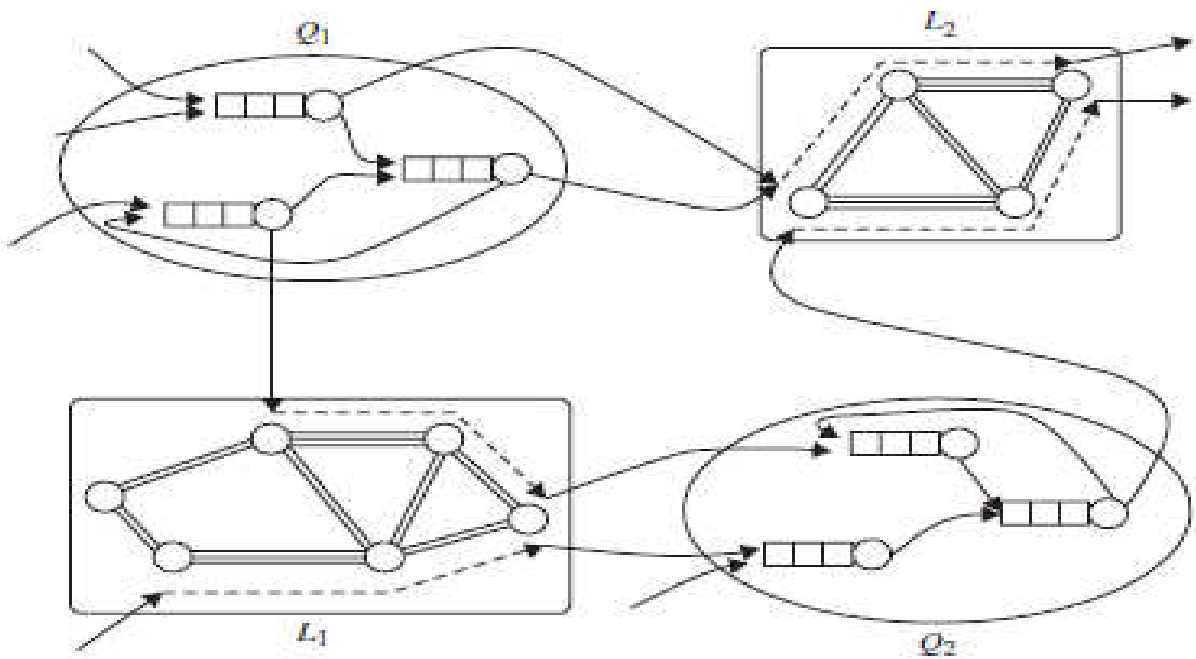


FIGURE 7.4-1: Queueing-loss network (QLN).

For further Information

For copies of my slides and text,

Send email to **Hisashi@Princeton.EDU**

or

See my blog **www.HisashiKobayashi.com** where the slides and text will be uploaded.

Thanks for your attention!!

References

[1] NICT, “New Generation Network Architecture AKARI: Its Concept and Design (ver2.0),” NICT, Kognei, Tokyo, Japan, September, 2009.

[2] T. Aoyama, “A New Generation Network: Beyond the Internet and NGN,” *IEEE Commun*. Mag., Vol. 47, No. 5, pp. 82-87, May 2008.

[3] N. Nishinaga, “NICT New-Generation Network Vision and Five Network Targets,” *IEICE Trans. Commun.*, Vol. E93-B, No. 3, pp. 446-449, March 2010.

[4] J. P. Torregoza, P. Thai, W. Hwang, Y. Han, F. Teraoka, M. Andre, and H. Harai, "COLA: COmmon Layer Architecture for Adaptive Power Control and Access Technology Assignment in New Generation Networks," *IEICE Transactions on Communications*, Vol. E94-6, No. 6, pp. 1526--1535, June2011.

[5] V. P. Kafle, H. Otsuki, and M. Inoue, "An ID/Locator Split Architecture for Future Networks," *IEEE Communications Magazine*, Vol. 48, No. 2, pp. 138--144, February 2010

References-cont'd

[6] ITU-T SG13, "Future Networks Including Mobile and NGN," http://itu.int/ITU-T/go/sg13

[7] A. Nakao, "Virtual Node Project: Virtualization Technology for Building New-Generation Networks," *NICT News*, June 2010, No. 393, June 2010, pp. 1-6. http://www.nict.go.jp/en/data/pdf/NICT_NEWS_1006_E.pdf

[8] A. Nakao, A. Takahara, N. Takahashi, A. Motoki, Y. Kanada and K, Matoba, "VNode: A Deeply Programmable Network Testbed Through Network Virtualization," submitted for publication. July 2012.

[9] H. Furukawa et al. , H. Harai, T. Miyazawa, S. Shinada, W. Kawasaki, and N. Wada, "Development of Optical Packet and Circuit Integrated Ring Network Testbed", *Optics Express*, Vol. 19, No. 26,pp. B242--B250, December 2011.

[10] H. Kobayashi, "An End to the End-to-End Arguments," *Euroview 2009*, Wurzburg, Germany, July 2009.

References-cont'd

[11] L. Kleinrock and R. R. Muntz, "Processor-sharing queueing models of mixed scheduling disciplines for time-sharing queuing systems," *J. ACM*. Vol. 72 (1972), pp. 464-472.

[12] H. Kobayashi and B. L. Mark, *System Modeling and Analysis: Foundations of System Performance Evaluation*. Pearson-Prentice Hall, 2009

[13] H. Kobayashi, B. L. Mark and W. L. Turin, *Probability, Random Processes and Statistical Analysis*, Cambridge University Press, 2012.

[14] N. Dukkipati, M. Kobayashi, R. Zhang-Shen and N. McKeown, "Processor Sharing Flows in the Internet," in H. de Meer and N. Bhatti (Eds.) *IWQoS 2005*, pp. 267-281, 2005.

[15] F. P. Kelly, "Loss Networks (invited paper)," *Ann. Appl. Probab*., Vol. 1, No. 3, pp. 319-378, 1991.