



新世代ネットワークの研究 に寄せる期待

小林 久志

プリンストン大学

シャーマン・フェアチャイルド名誉教授

NICT 特級研究員

NICT新ビジョン発表会

November 9, 2011



概要



- I 新世代ネットワークとは何か、そして何故か？
- II 何がインターネットを成功に導いたか？
- III エンド・ツー・エンド設計原理への終止符
- IV ネットワークの仮想化
- V AKARIアーキテクチュアとJGN-X
- VI FIAとテストベッド、米国諸外国での活動状況
- VII これからの戦略はどうあるべきか？
- VIII ステーブ ジョブズ氏から何を学ぶべきか？

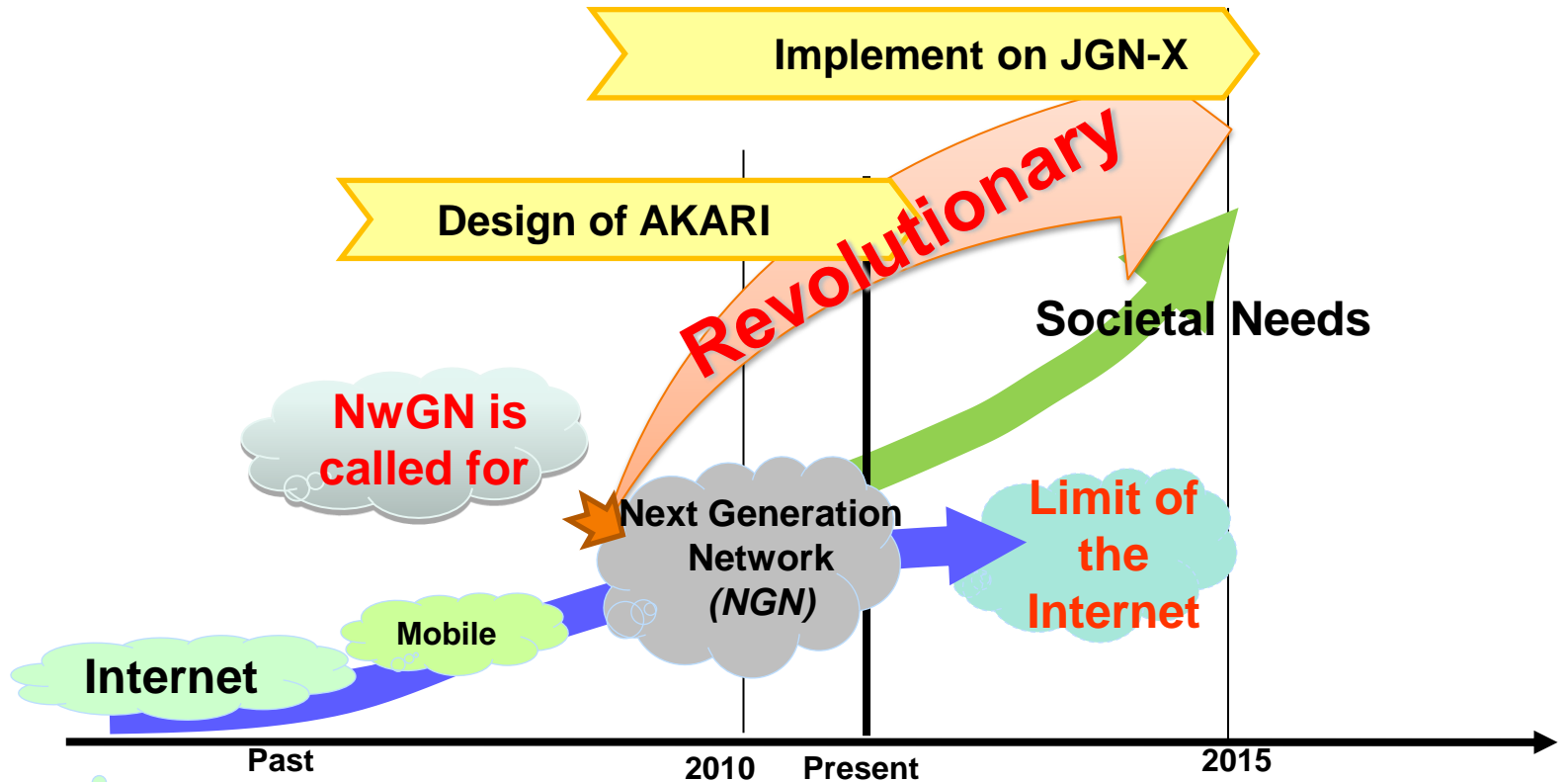


新世代ネットワークとは何か？

- 日本におけるネットワーク研究のフラッグシップ
- 新しいアーキテクチャを設計(Design)
 - A “clean slate” approach.
- 実験的なネットワーク(Testbed)上で、実装(Implement)し、検証(Verify)
- 2015年頃から稼働段階に入る。



何故NWGNか？



- Exploding Traffic
- Security Issue
- Mobility

Diagram: AKARI Architecture Design



NwGNの要求事項



1. **Scalability** (users, things, data, traffic)
2. **Heterogeneity and diversity**
3. **Reliability and resilience**
4. **Security and privacy**
5. **Mobility management**
6. **High performance**



NwGNの要求事項– cont'd



7. Energy and Environment

8. Societal needs

9. Compatibility (with today's Internet)

10. Extensibility (for the unforeseen and unexpected)



□ ネットワーク・アーキテクチャ

A logical and structural framework of the network

□ プロトコル

A set of rules that enable communications between two computers



- ❑ **TCP/IP Suite: V. Cerf and R. Kahn (1974)**
Implemented in ARPANET (1983)
 - **Internet Protocol (IP)**
Foundation protocol of the internet
Provides only connectionless service
 - **Transmission Control Protocol (TCP)**
For connection-oriented services

- ❑ **Other commonly used protocols**
 - **File Transfer Protocol (FTP)**
 - **Hypertext Transfer Protocol (HTTP)**



何がインターネットを成功に導いたか？



- 1969 ARPANET carried its first packet: UCLA and SRI
- 1974 **TCP/IP paper published: Vinton Cerf and Robert Kahn**
- 1983 **NCP (Network Control Program) protocol replaced by TCP/IP**
- 1985 NSFNet replaced ARPANET. 56 kbps
- 1988 NSFNet upgraded to 1.5 Mbps
- 1989 PSINet, 1st ISP (Internet Service Provider) founded
- 1991 **World Wide Web: Tim Berners-Lee**
- 1992 NSFNet upgraded to 45 Mbps
- 1995 New Internet architecture with commercial ISPs connected at NAPs (Network Access Points)
- 1995 IPv6 proposed
- 1995 Amazon.com online retailer
- 1995 eBay online auction and shopping
- 1996 Internet 2 Consortium founded
- 1998 Google Search
- 2001 Wikipedia, the free encyclopedia
- 2003 Skype Internet voice calls



何がインターネットを成功に導いたか？



- 2003** iTunes Store
- 2003** LinkedIn business networking
- 2003** Myspace social networking site
- 2004** Facebook social networking site
- 2005** YouTube video sharing
- 2005** Google Earth virtual globe
- 2006** Twitter micro-blogging
- 2006** Wiki Leaks
- 2007** Kindle, e-book reader
- 2007** Google Street View
- 2008** Amazon Elastic Compute Cloud (EC2)



Telephone Network Architecture *NICT*

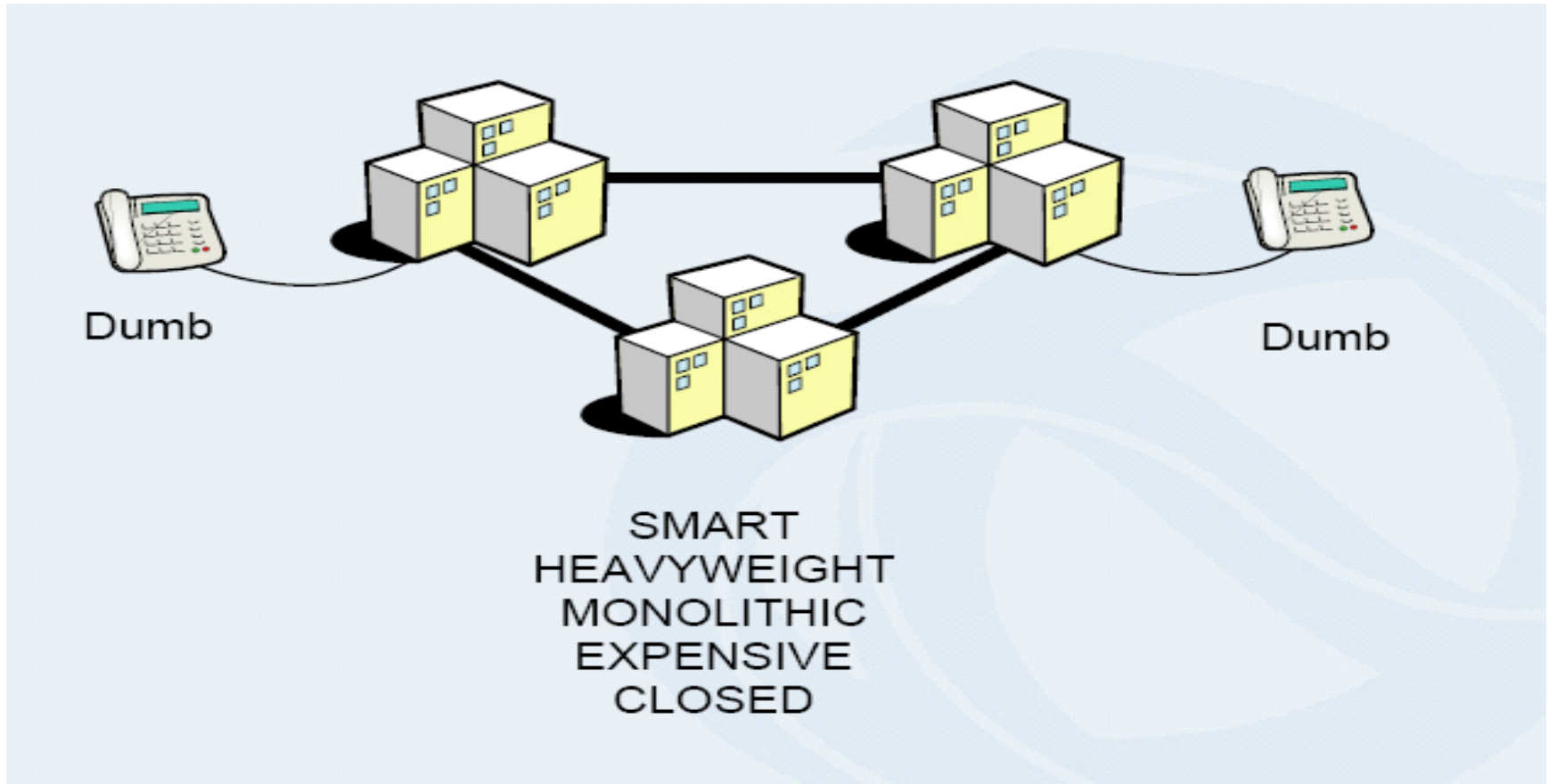


Diagram : Paul Wilson, Asia Pacific Network Information Center



TCP/IP based Internet

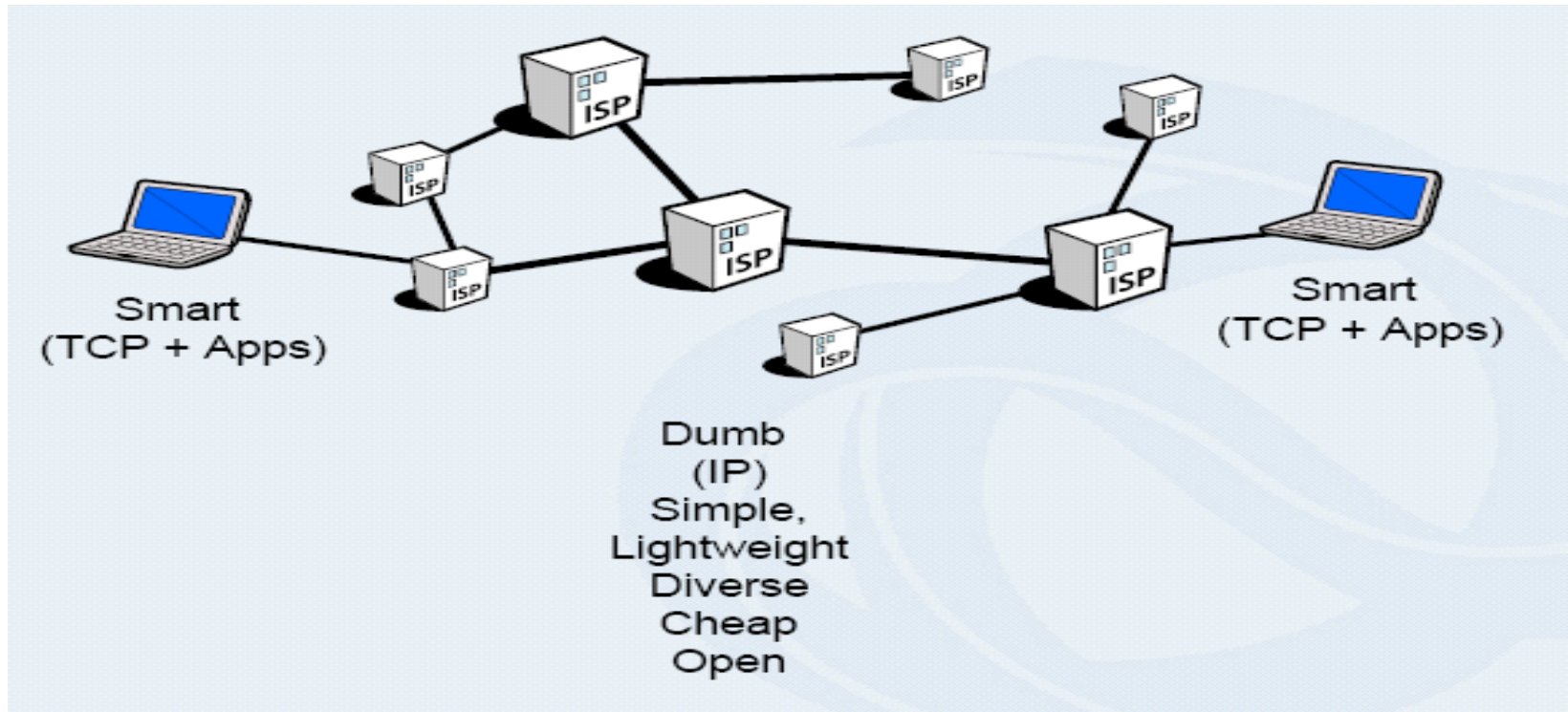
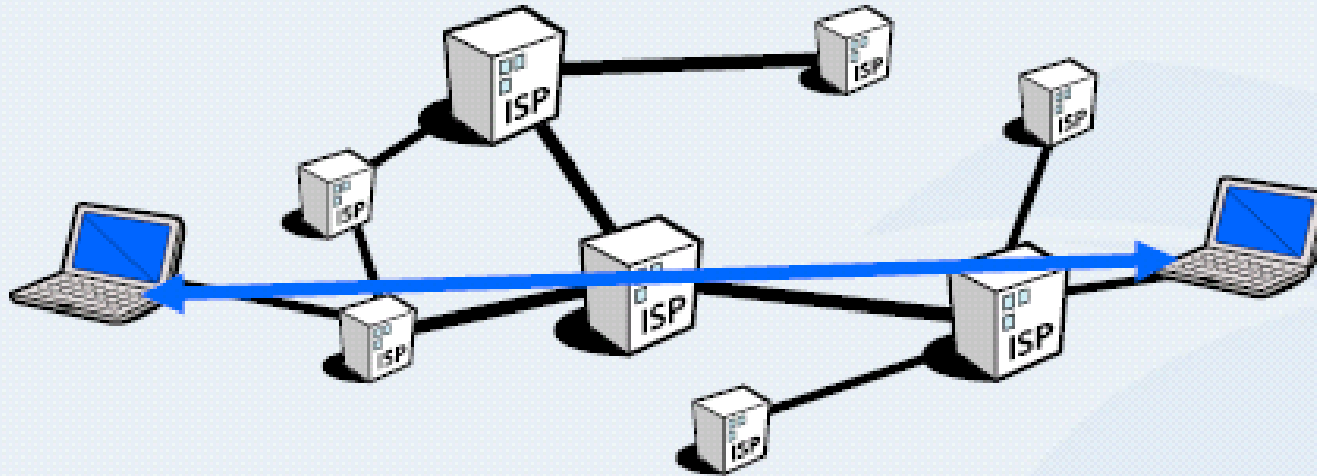


Diagram : Paul Wilson, Asia Pacific Network Information Center

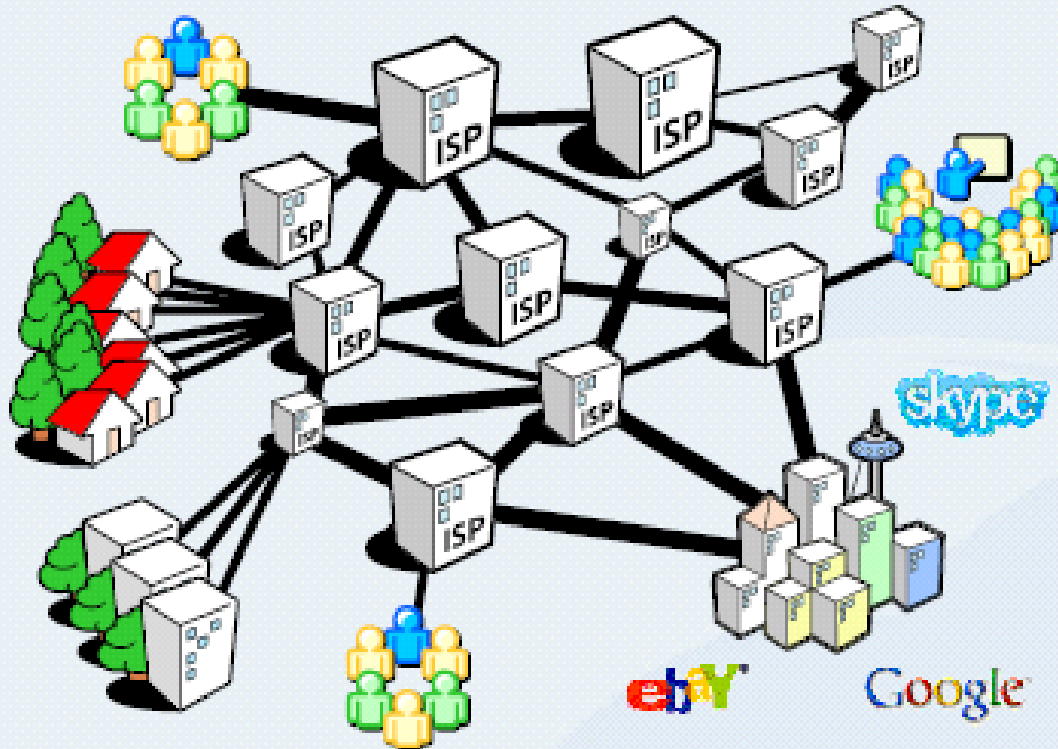


IPのデータグラム・サービス TCPの接続型サービス



- **IP** provides basic packet delivery service (called **datagram** or **connectionless** service)
- **TCP** provides a **connection-oriented** service.

E2E 設計原理の結果



- Every service is an end-to-end application.
- New applications can be deployed by anyone.



E2E設計原理の問題点



- ❑ Make the network **intrinsically inefficient**
 - **wastes network resources e.g., bandwidths.**

- ❑ Make the network **slow**
 - **unnecessary retransmissions when errors occur in e.g., radio links**

- ❑ Make the network **insecure**
 - **A dumb network cannot handle attacks.**



仮想化技術とは？



□ 仮想化の定義

- Logical representation of a given physical resource, when the resource is shared by multiple users.

□ 仮想化技術の例

- 仮想メモリ (e.g., Atlas machine, UK, 1960)
- 仮想マシン (e.g., IBM VM/370, 1972)



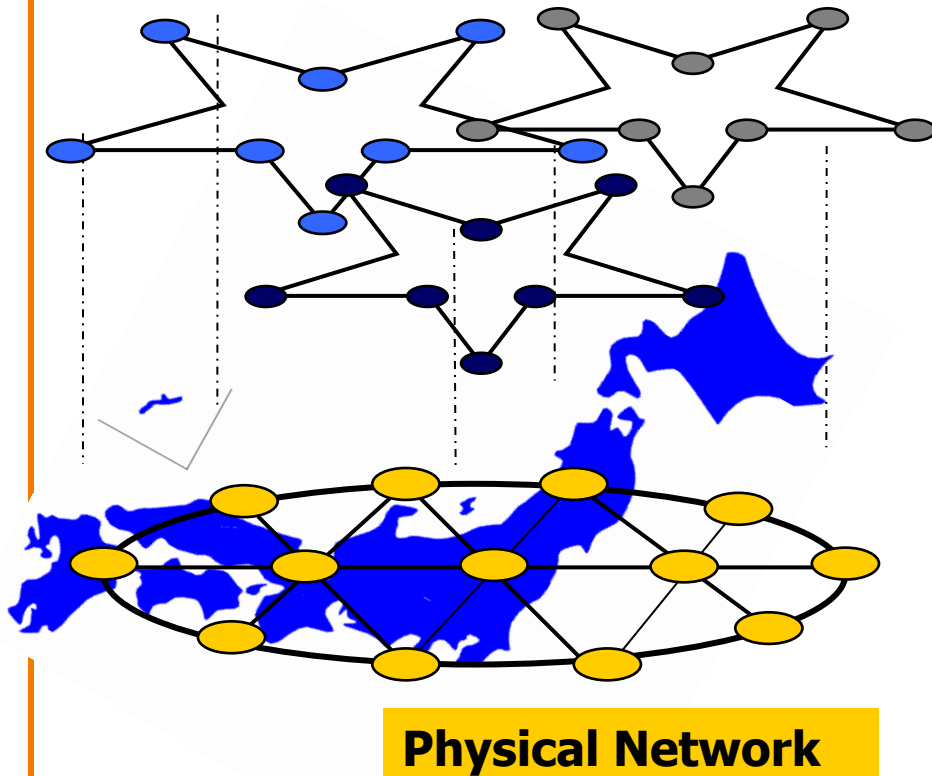
ネットワークの仮想化



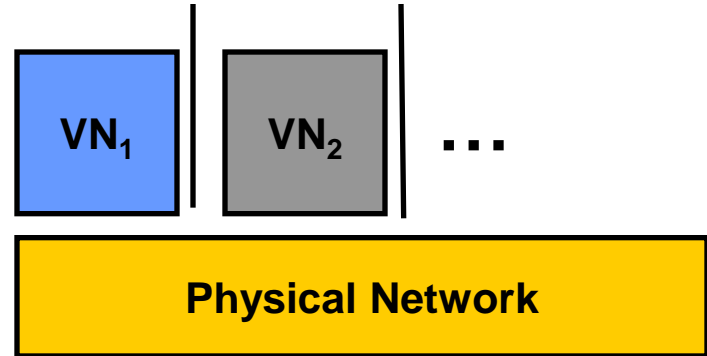
- ❑ Choose a subset of a collection of **physical resources** (routers, end users, links, etc.) and **functionalities** (routing, switching, transport) of one or multiple real networks and form a **logical network**.
- ❑ Provide a **testbed** for the future network architecture and its protocols.



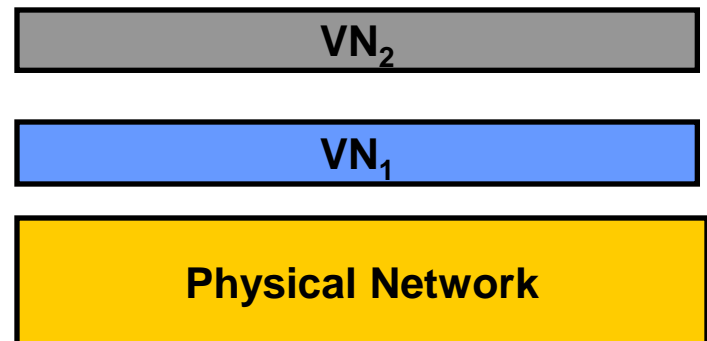
仮想ネットワークと オーバーレイ・ネットワーク



(a) Isolated Virtual Networks



(b) Overlaid Virtual Networks





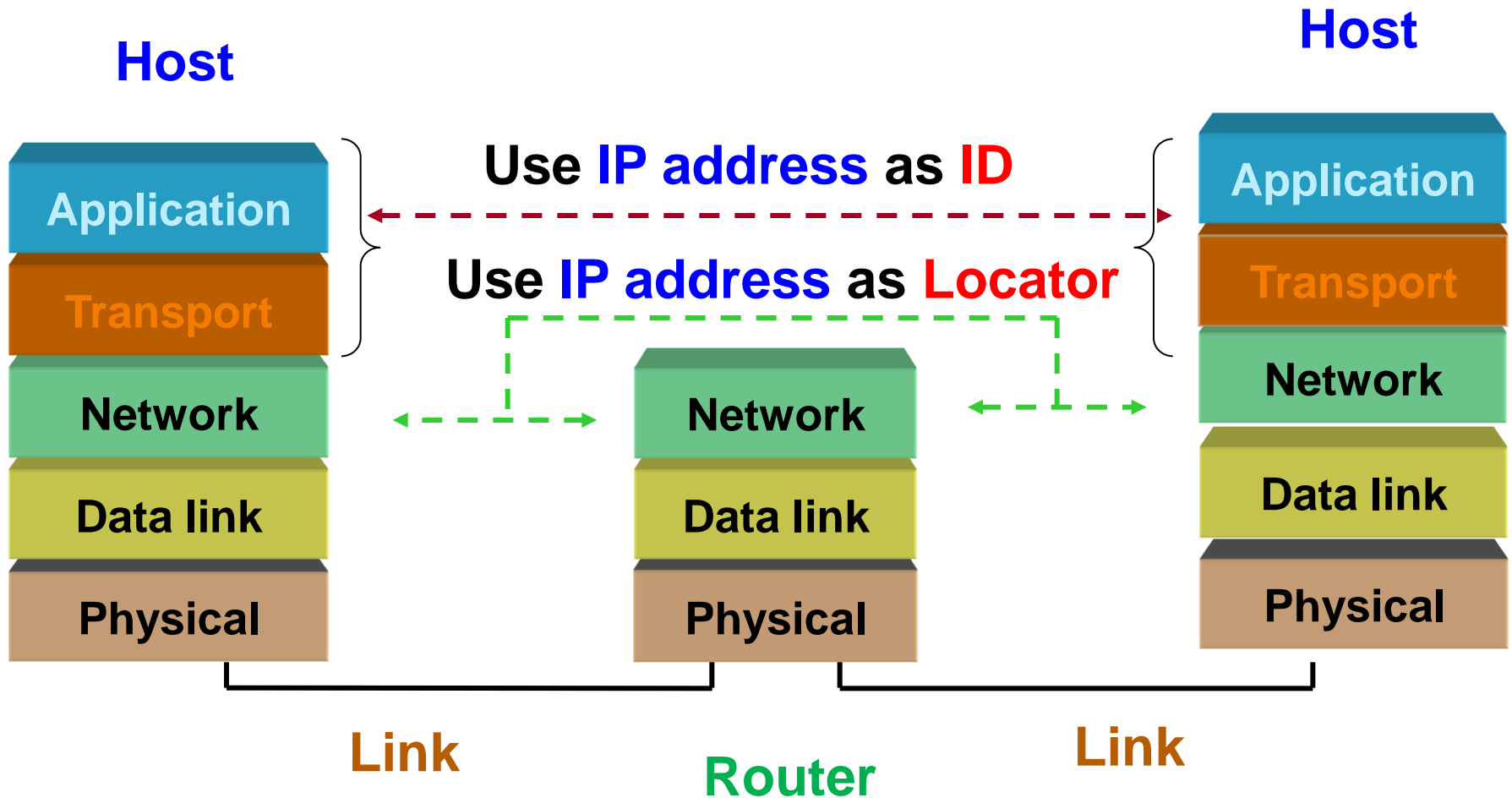
AKARIアーキテクチャ



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

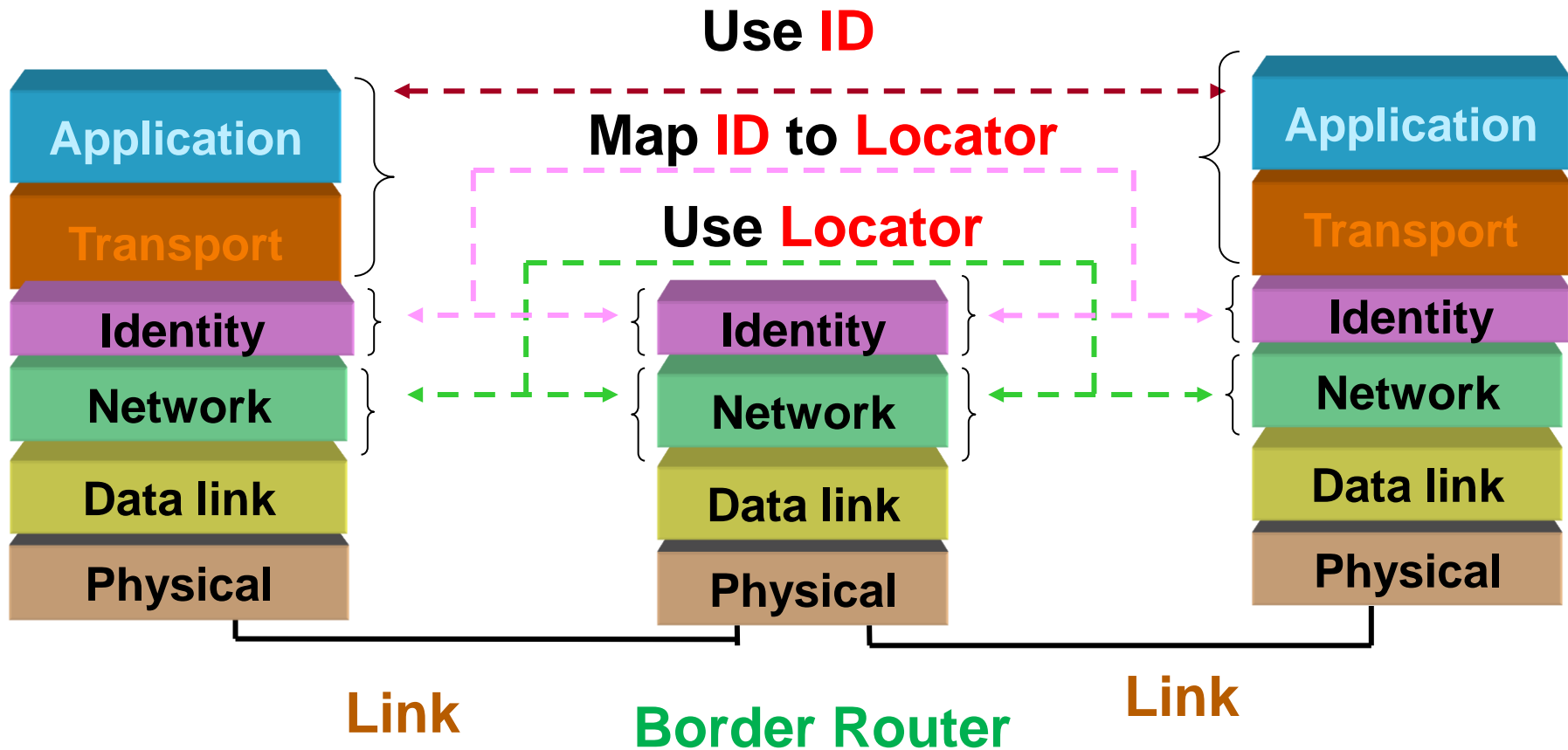


ID and Locator in the Internet





ID/Locator Split Architecture



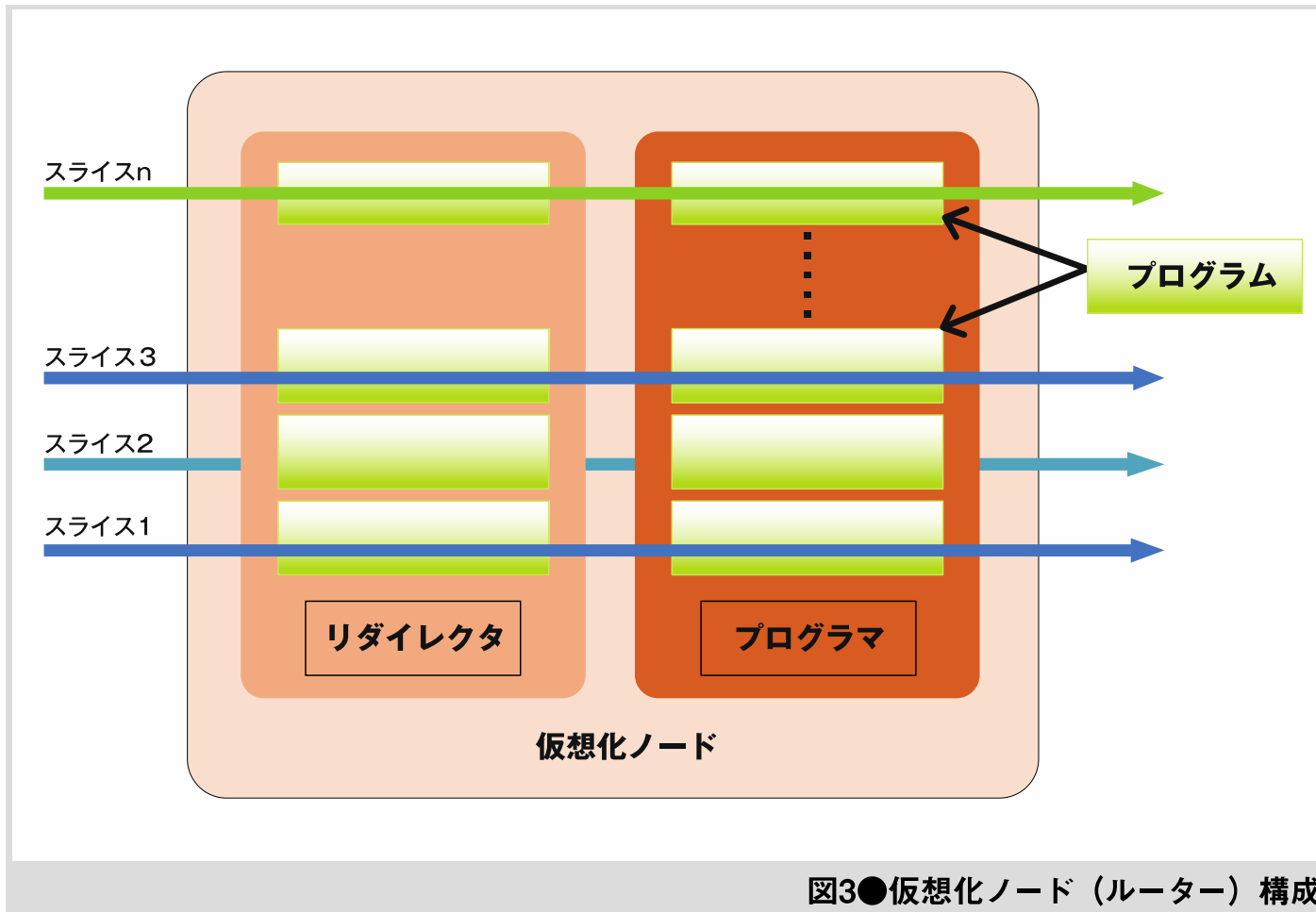


図3●仮想化ノード（ルーター）構成

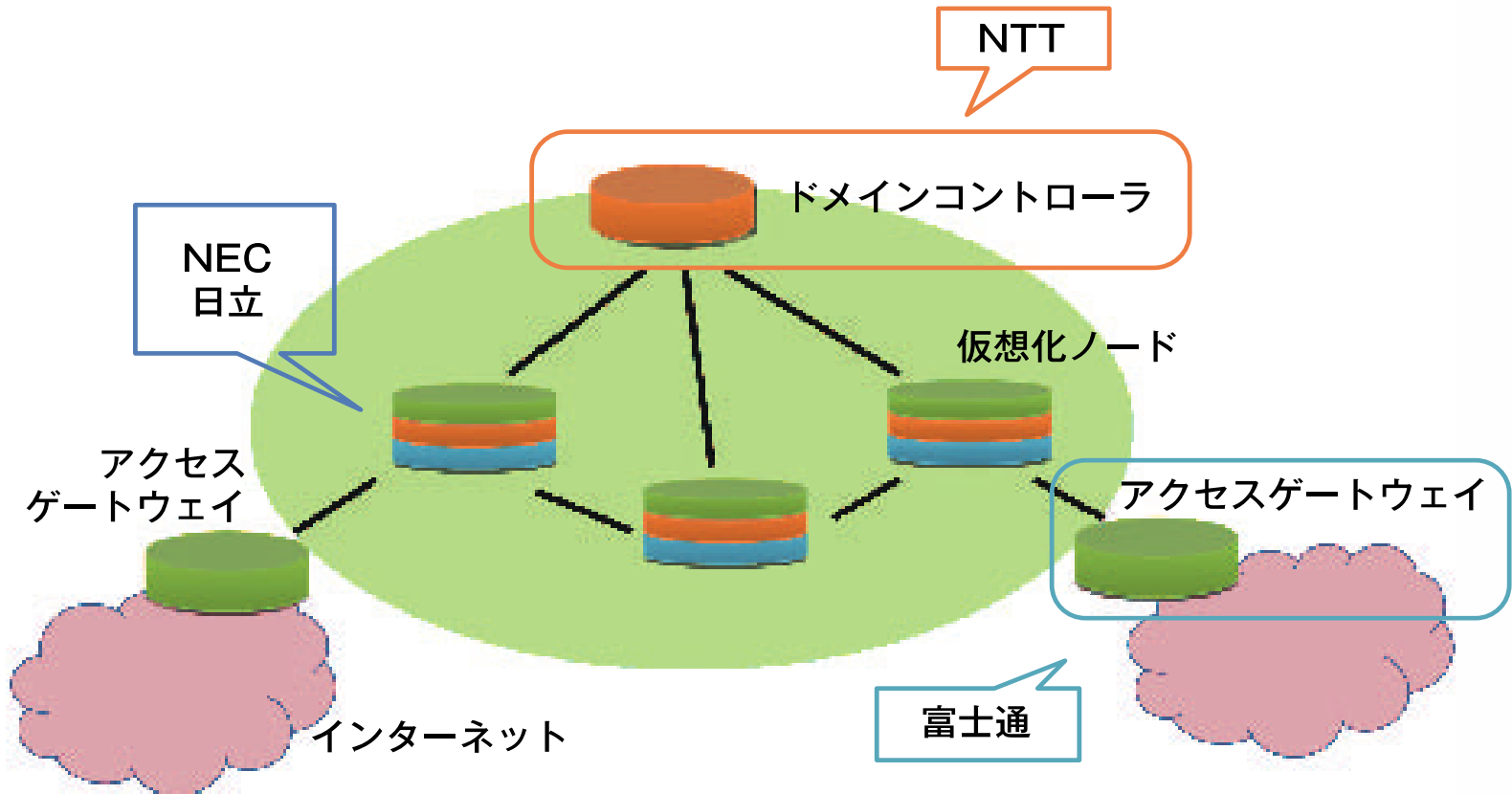


図6●仮想化ノード・プロジェクトでの各社の分担



光技術の特性：光パケット光パス



光技術の特性

- 広帯域
- メモリー、演算回路は未熟
 - 光パケット交換: ヘッダのみ電子信号へ変換する
 - 光パス: WDM（波長分割多重）の光パスは回線交換と等価
- AKARI アーキテクチャは光パケットと光パスの統合システムを打ち出す。

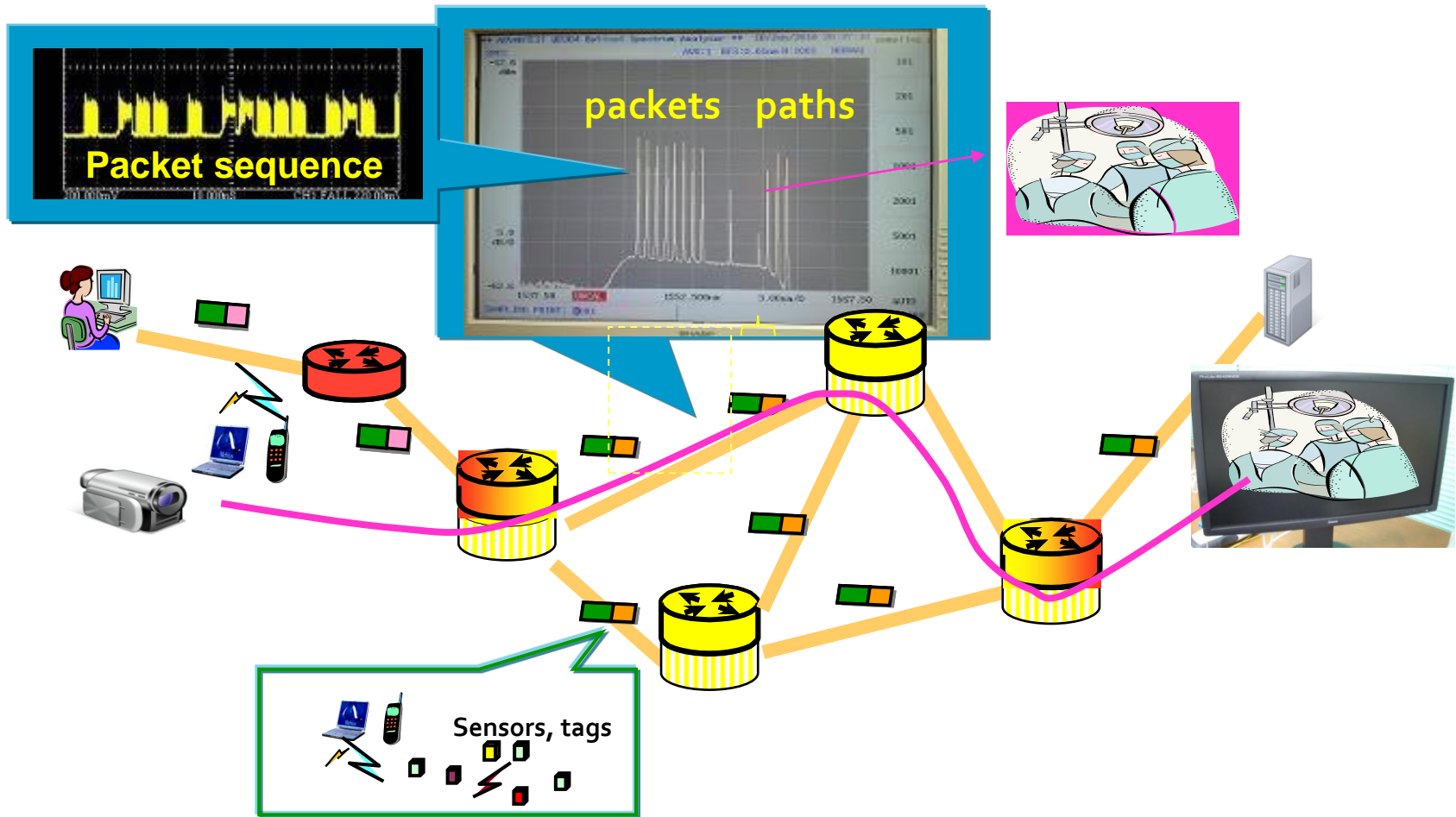


Diagram: Hiroaki Harai, NICT



JGN-X Network Overview

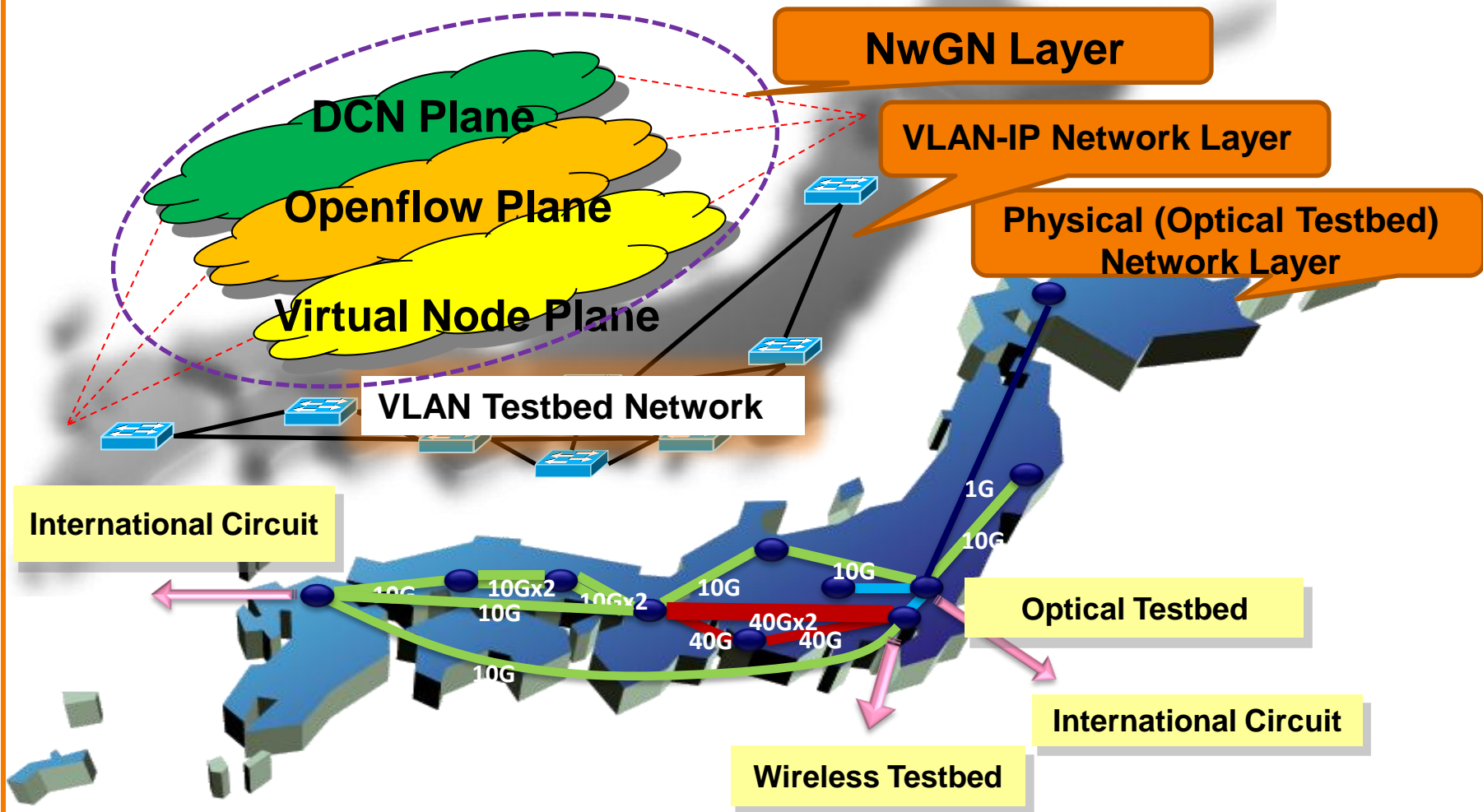


Diagram: Eiji Kawai, NICT



JGN-X International Circuits

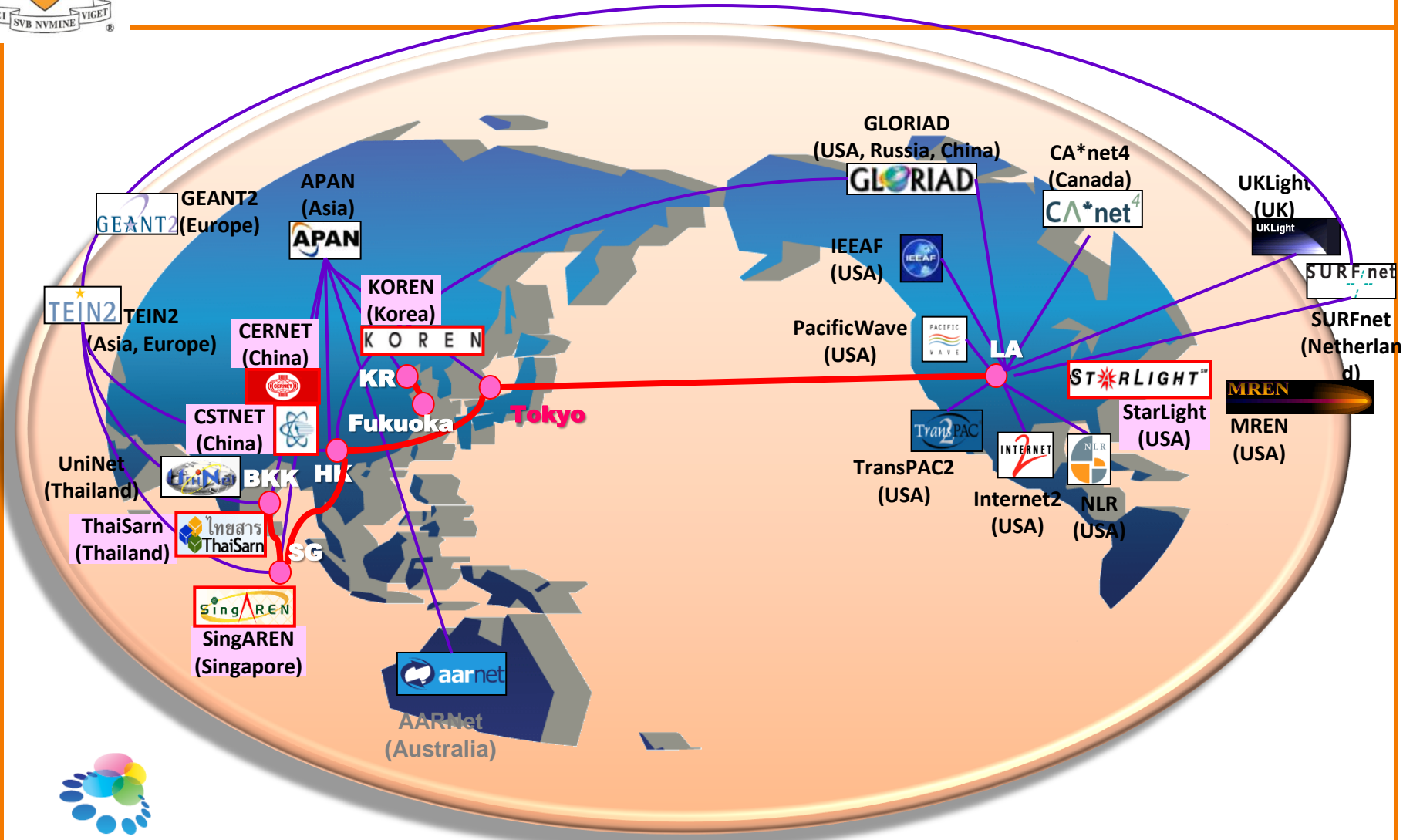


Diagram: Eiji Kawai, NICT



Research around JGN-X

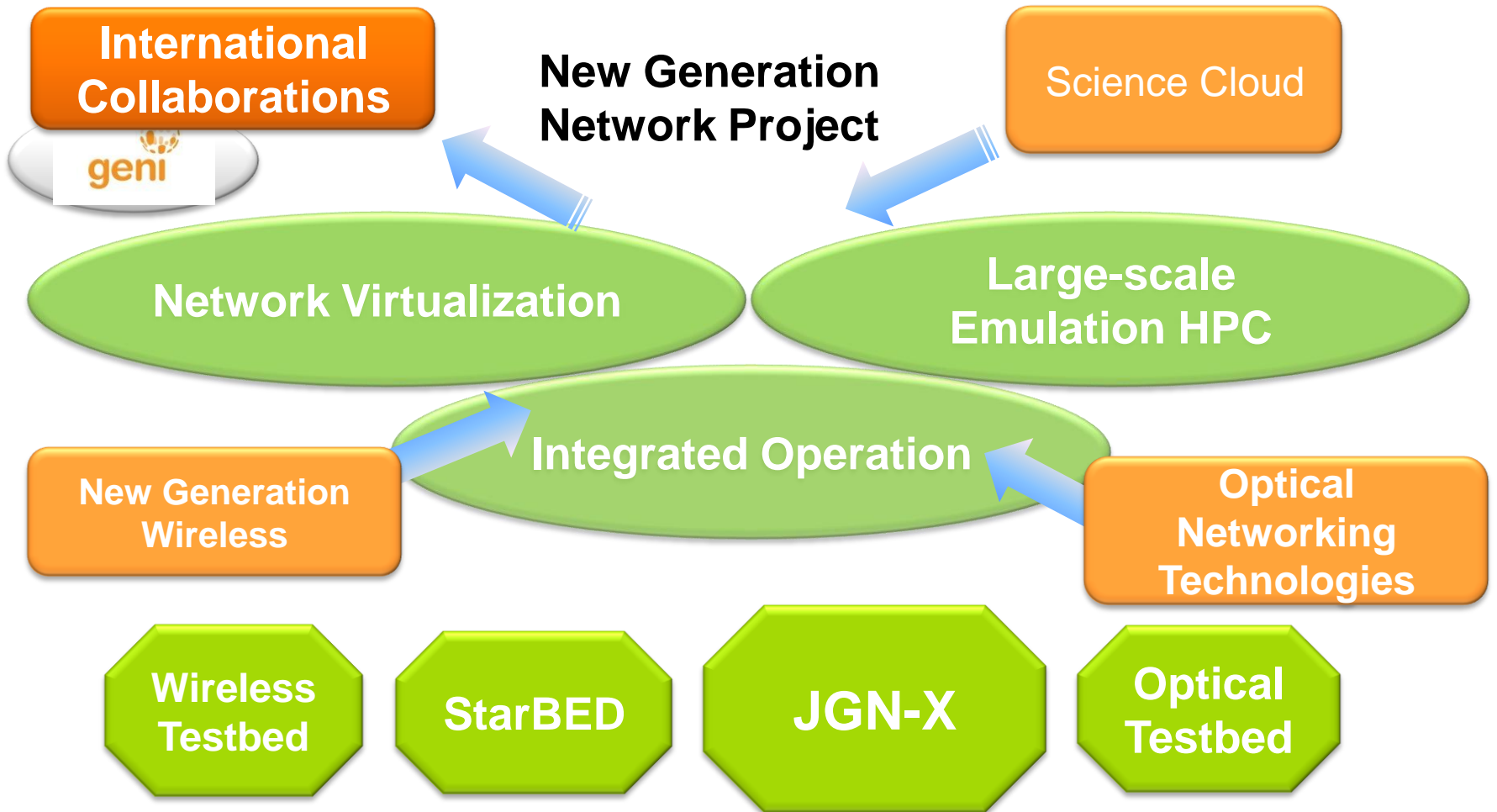


Diagram: Eiji Kawai, NICT



□ In U.S. the National Science Foundation (NSF) has launched

- FIND (Future Internet Network Design)
- **GENI (Global Environment for Network Innovations) cf JGN-X**
- **FIA (Future Internet Architecture), cf AKARI**
- NetSE (Network Science and Engineering)
- US Ignite Initiative



GENI Program



- ❑ PlanetLab (プリンストン大学)
- ❑ ProtoGENI (ユタ大学):
- ❑ ORCA (デューク大学と *RENCI-Renaissance Computing Institute*).
- ❑ ORBIT (ラトガース大学)



NSF Future Internet Architecture (FIA) Program



- ❑ **MobilityFirst** (Rutgers and 7 other univ.)
- ❑ **Named Data Networking** (NDN: UCLA and 10 others)
- ❑ **eXpressive Internet Architecture** (XIA: CMU and 2 others)
- ❑ **NEBULA** (U. of Penn and 11 others)



EU's Efforts on Future Internet



❑ In Europe

- Seventh Framework Programme (FP7)
- Future Internet Assembly (FIA) :
a European collaboration among FP7 projects on Future Internet research.
- FI-PPP (Future Internet Private-Public Partnership) Initiative was launched in May 2011, as a fourth PPI cf.
“Factory of the Future,” “Energy-efficient Buildings,”
“Green Cars”



G-Lab, etc.



- ❑ **German Lab (G-Lab): A nation-wide effort funded by BMBF (Bundesministerium für Bildung und Forschung: Federal Ministry of Education and Research)**

- ❑ **South Korea**
 - **Already claims the world's fastest Internet connections—fastest globally by far.**
 - **Plans to connect every home to the Internet at 1 Gigabits per sec by the end of 2012.**
 - **Has “Future Internet Program” in place.**

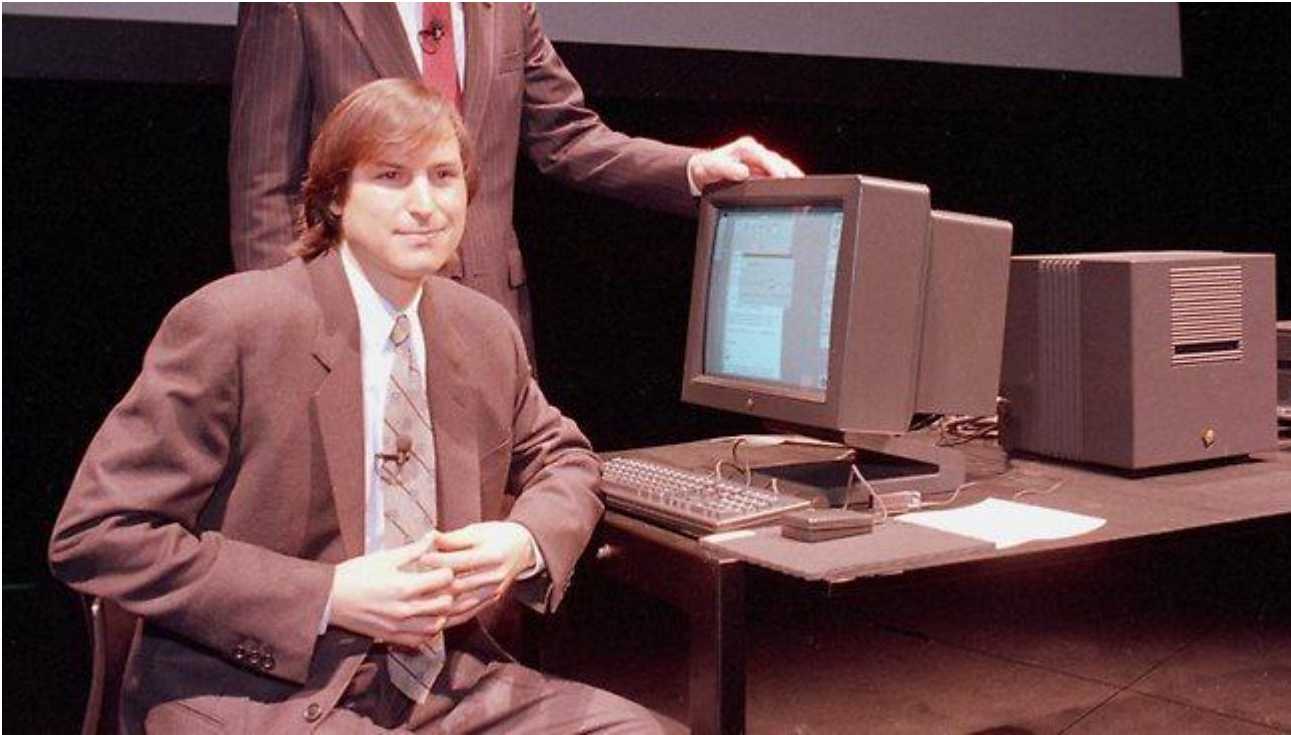


これからの戦略はどうあるべきか？

- ❑ Number of researchers and students in networking research
 - NSF's FIA supports 4 architecture projects
 - NSF's GENI supports 4 control plane projects
- ❑ Active role in the international standardization
- ❑ Stimulate and nurture next generation networking talents
 - Inject “new blood” continuously into our system
- ❑ Innovative applications are more important



スティーブ ジョブズ氏から 何を学ぶべきか？





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] H. Kobayashi, “Forword,” in D. Raychaudhuri and M. Gerla (editors), *Emerging Wireless Technologies and the Future Mobile Internet*, Cambridge University Press, 2011.
- [2] 新世代ネットワーク・アーキテクチャAKARI概念設計書改訂版 (ver2.0) 2009年9月
- [3] V. G. Cerf and R. E. Kahn, “A Protocol for Packet Network Intercommunication,” *IEEE Trans. on Comm.*, 22(5), pp. 637-648, May 1974.
- [4] J. H. Saltzer, D. P. Reed and D. D. Clark, “End-to-End Argument in System Design,” *ACM TOCS*, Vol. 2, No. 4, November 1984, pp. 278-288
- [5] H. Kobayashi, “An End to the End-to-End Arguments,” *Euroview 2009*, Wurzburg, Germany, July 2009



References-cont'd



[6] A. Nakao, "Virtual Node Project: Virtualization Technology for Building New-Generation Networks," *NICT News*, June 2010, No. 393, June 2010, pp. 1-6.

[7] J. Pan, S. Paul and R. Jain, "A Survey of the Research on Future Internet Architectures," *IEEE Communications Magazine*, July 2011, pp. 26-35.

[8] New York Times "Home Internet May Get Even Faster in South Korea," February 21, 2011.

http://www.nytimes.com/2011/02/22/technology/22iht-broadband22.html?_r=3

[9] Steve Jobs's Speech at Stanford University Commencement, 2005

<http://www.youtube.com/watch?v=D1R-jKKp3NA>

<http://sago.livedoor.biz/archives/50251034.html>