- IPv6 (IP Version 6) -

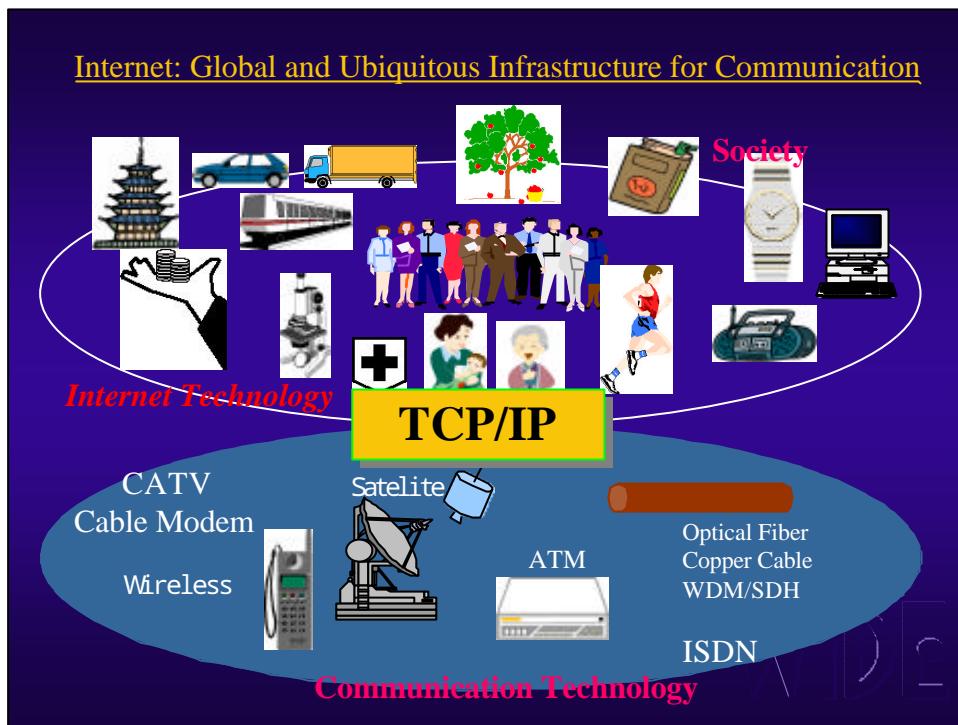1. Why We Need IP

2. How the Deployment Goes

jun@wide.ad.jp

1. Why We Need IP

Internet: Global and Ubiquitous Infrastructure for Communication

Society

Internet Technology

TCP/IP

CATV
Cable Modem

ATM

Optical Fiber
Copper Cable
WDM/SDH

ISDN

Communication Technology

Hobbes' Internet Timeline Copyright ©1998 Robert H Zakon
http://www.isoc.org/zakon/Internet/History/HIT.html

DATE	HOSTS		DATE	HOSTS
1969	4		10/85	1,961
04/71	23		02/86	2,308
06/74	62		11/86	5,089
03/77	111		12/87	28,174
08/81	213		07/88	33,000
05/82	235		10/88	56,000
08/83	562		07/89	130,000
10/84	1,024		10/89	159,000

■ New Survey
♦ Old Survey

Hosts

International Conn V7-1/93

- Internet
- BitNet but not Internet
- EMail Only (UUCP, FidoNet, or OSI)
- No Connectivity

Copyright © 1993
Larry Landweber
and the Internet Society
Version 7 - 1/93

INTERNATIONAL CONNECTIVITY
Version 16 - 6/15/97

- Internet
- Bitnet but not Internet
- EMail Only (UUCP, FidoNet)
- No Connectivity

This map may be obtained via anonymous ftp
from ftp.cs.wisc.edu, connectivity_table directory.

Copyright © 1997
Larry Landweber
and the Internet Society.
Unlimited permission to
copy or use is hereby granted
subject to inclusion of
this copyright notice.

(TCP/IP)

(1) "End-to-end principle"
   ==> "End-node has intelligent, network
       should be as simple as possible"
(2) Connectionless & Best Effort
   ==> Low Cost System
(3) "IP over everything"
   ==> "Connectivity is own reward"
(4) "Everything over IP"

Speed, Cost, Flexibility

Where the Internet Goes ?

Internet for Everything   Everything over IP
Internet for Everyone   Everyone with IP
Internet Everywhere/Anytime/Anyhow
            Everywhere and Anyhow to IP

(1) Scalability
(2) High speed large capacity
(3) Reliability/Robustness
(4) Easy Operation
(5) QoS/CoS

(6) Integrate layer 2 and 3
(7) Intranet/Extranet (=VPN)
(8) Mobile and Roaming
(9) Security
(10) New Services
        (e.g., Multicast)

Where the Internet Goes ?

Internet for Everything   Everything over IP
Internet for Everyone   Everyone with IP
Internet Everywhere/Anytime/Anyhow
         Everywhere and Anyhow to IP

" IP is for Everyone "

Quantitative Scalability
    until Massive Scalability
Qualitative Scalability
    Heterogeneity
    (e.g., Bandwidth, QoS/CoS, Media, etc.,)

Reasons   1-5

1: Keep End to End Internet Model

2: Network Administrator/Provider does not have special authority

3: ISP never manage nor control users, IPS only provide simple service.

4: Every site has independent from ISP

5: Expandable packet format

5

Reasons 5-10

6:Simple IP header

7: Multicast aware designing

8:Security aware designing

9:Mobility aware designing

10 Provision of an identification to handle flow

It IS fun involving from the
beginning !!! :-)

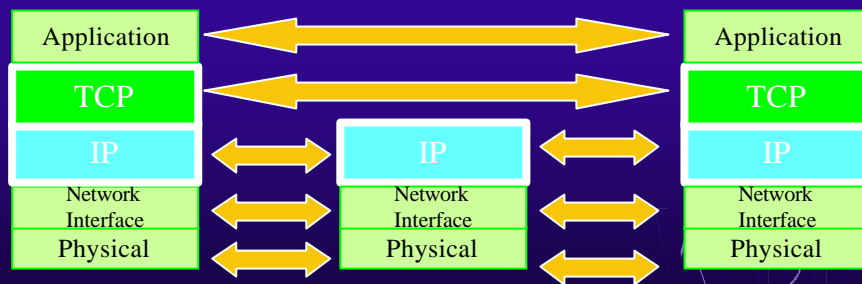## - News only just in a day (Nov.11,1999) -

◆

Source : 1999 11 10 http://www.asahi.com

◆ Sun Microsystems SONY

"This cooperation between Sun and Sony leverages the mutual strengths of two visionary companies," said Michael Vitelli, executive vice president of Sony Electronics' Broadcast and Professional Company. "Sun's proven expertise in building end-to-end digital network solutions, combined with Sony's vast knowledge of the broadcast video market, will help ensure the development of superior network solutions for the broadcast industry."

Source Sun Microsystems and Sony Deliver Flexibility at NAB '99

- IP (Internet Protocol)
  - IP
- TCP (Transmission Control Protocol)
  - End-to-End
- DNS
  - IP

					IP			
Application	← →							Application
TCP	← →							TCP
IP	← →	IP	← →					IP
Network Interface	← →	Network Interface	← →					Network Interface
Physical	← →	Physical	← →					Physical

- IP (Internet Protocol)
  - IP   : 32 bits 4×10^9 (40   )
    (60   )
-
  - 13 Digits   1
  - 10 Digits   10
            9 Digits   1   (   )
            2x8 Digits   2,000   …   …
  - 10 Digits   10   ….   …

                    >>

We Need Further Addresses
                x N (N=?)

Internet for Everyone

    -
    - B to B, B to C, C to C   toward End-to-End

- ◆   IPv6
- ◆   Mobile IP
- ◆   IPSec
- ◆   Diff-Serv, RSVP
- ◆   DWDM, IPv6
- ◆   IPv6
- ◆   PIM, MBGP
- ◆   MPLS

IPv6 (IP version 6)

                      (55   )

IPv4 (32 bits) =   43

                      (40,000 50,000)

1.
   - Challenge First, Rule Later

2.
  - End-to-End
  -

3.

&

(,   )

(,   )

(   )

Direct Feedback   *Direct Feedback*

&

( )

( )

Research Output

Direct Contribution

Direct Feedback
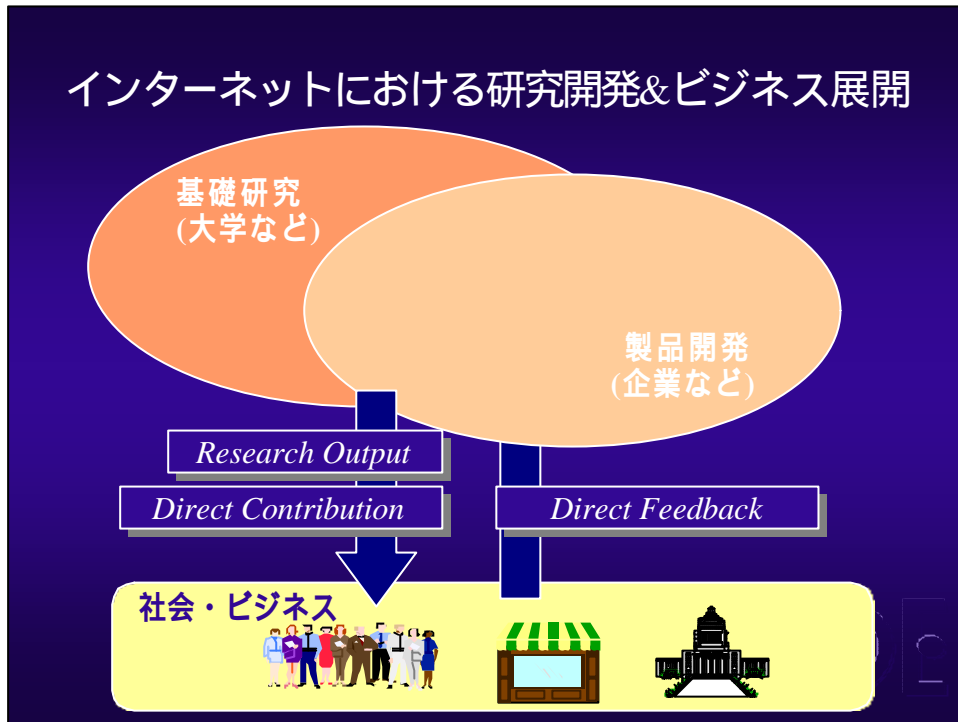
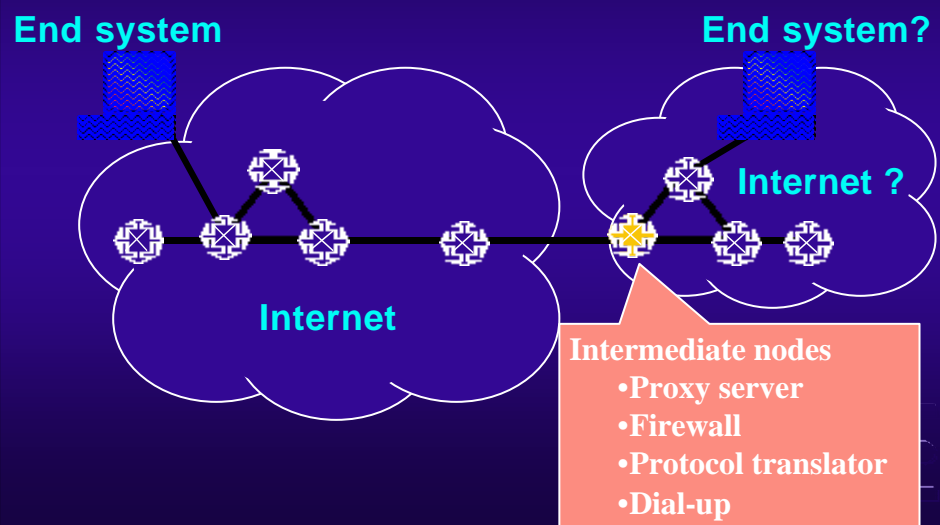
◆ End-to-End

◆ (development)
(Deployment)

➤ Applications

➤ Business model

➤ NOBODY KNOWS WHAT WILL HAPPEN!

◆ (Deployment)

➤ Running Code

Internet
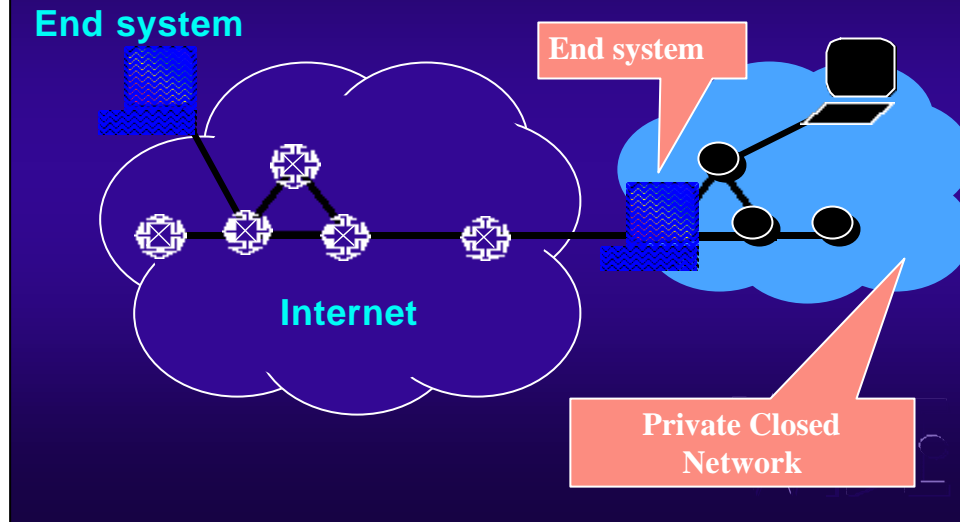## "end-to-end model"

End system

End system

Internet

Routers in the middle

What happen if ..

End system

End system?

Internet ?

Internet

Intermediate nodes
- Proxy server
- Firewall
- Protocol translator
- Dial-up
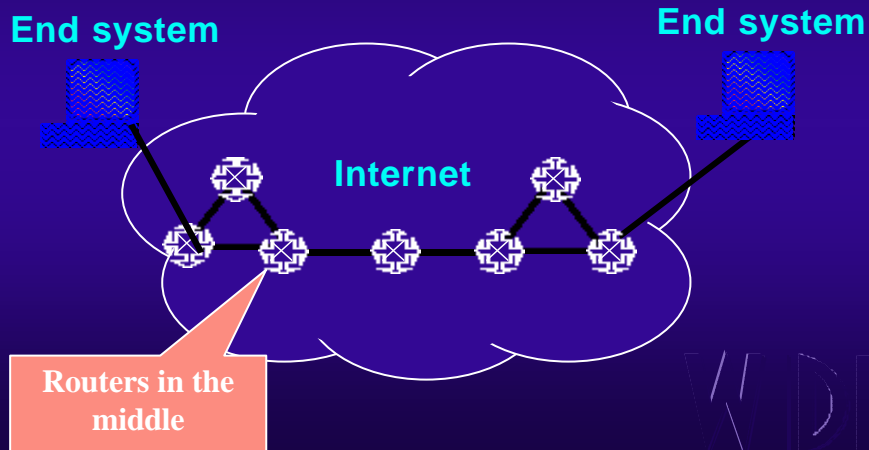
Enclosure by
the intermediate nodes

End system

End system

Internet

Private Closed Network

- ◆ NAT, Proxy   Ad Hoc
- ◆

    IP Version 6 (128 bits   )
- ◆ Intermediate Proxy
- ◆ Transparent firewall

- ◆ New Object Hooked to the Internet
  - ➢
  - ➢
  - ➢
- ◆ New Topological Regions Hooked to the Internet
  - ➢
  - ➢
  - ➢
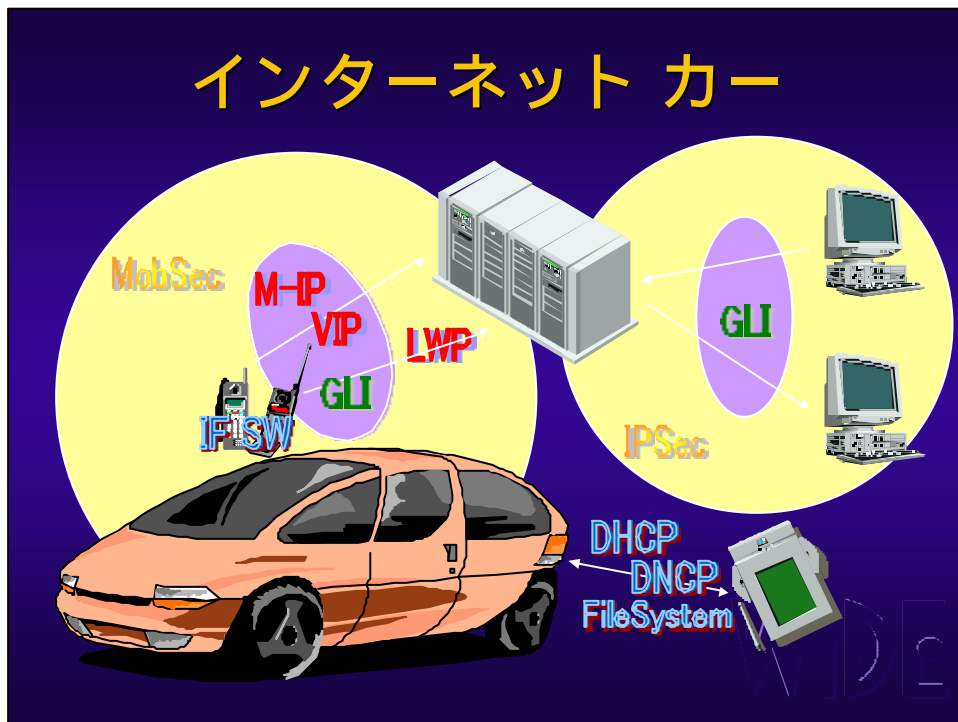
Number of automobiles
EuroMotor Reports "Databook"

	1990	2000	2010	
PanPacific	275,080	324,703	361,931	AU, CA, JP, NZ, US
Europe	205,086	267,829	330,610	
S. Americas	37,491	53,363	75,251	
Africa	13,267	18,178	24,309	
Asia	37,407	73,111	126,896	
Total	568,331	737,184	918,997	

- How many TV sets?
- How many Fridges?
- How many CD players?
- How many game players
- How many people?
- IP connected Control BOX?

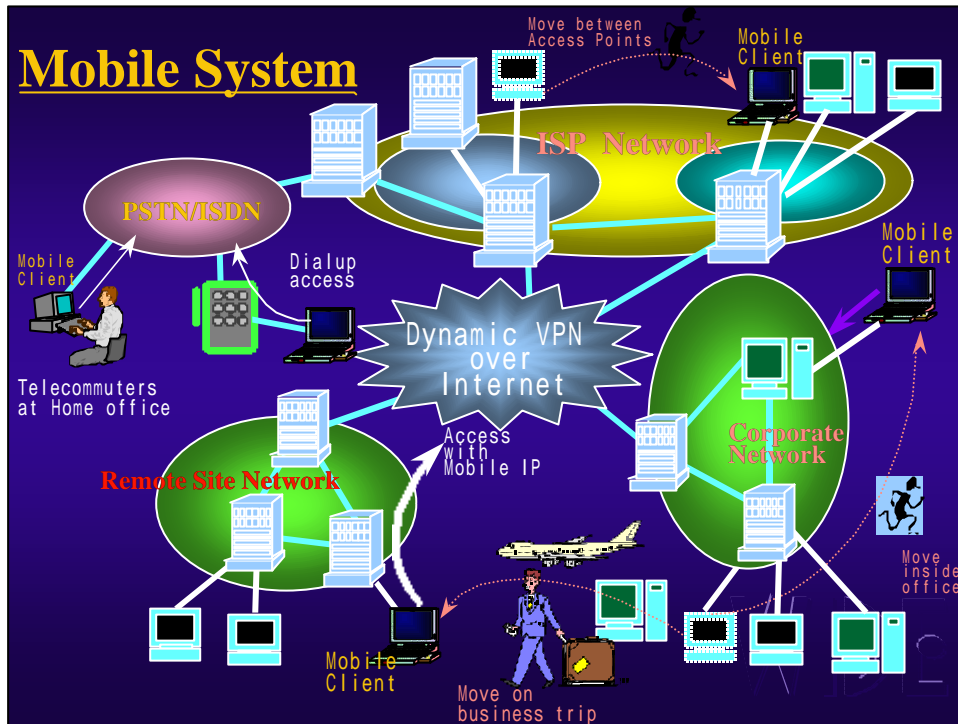Text information from Internet

Titles of Music

Everything on IP networks

	IP	Mainte nance	Synch	Guide	Knowle dge	Sales
TV	Ö	Ö	Ö	Ö	Ö	Ö
Refrigera tor	Ö	Ö	Ö	Ö	Ö	Ö
Microwav e Oven	Ö	Ö	Ö	Ö	Ö	Ö
Washing Machine	Ö	Ö	Ö	Ö	Ö	Ö

Internet 2000

◆ Everyone
  ➢ 6 billion people/Accessibility

◆ AAA
  ➢ Authentication, authorization and accounting

◆ Everything
  ➢ IPv6 will connect everything everywhere

◆ Everywhere
  ➢ Cell phone/PDA, satellite for the Internet

◆ New way of Communication
  ➢ VoIP, Reliable Multicast, MovieCast, AudioCast

2. How the Deployment Goes

2. How the Deployment Goes

[1] Standardization
[2] Development
    (i) End Host
    (ii) Routers
    (iii) Transition
    (iv) Interoperability Test
[3] Deployment
    (i) Address Allocation
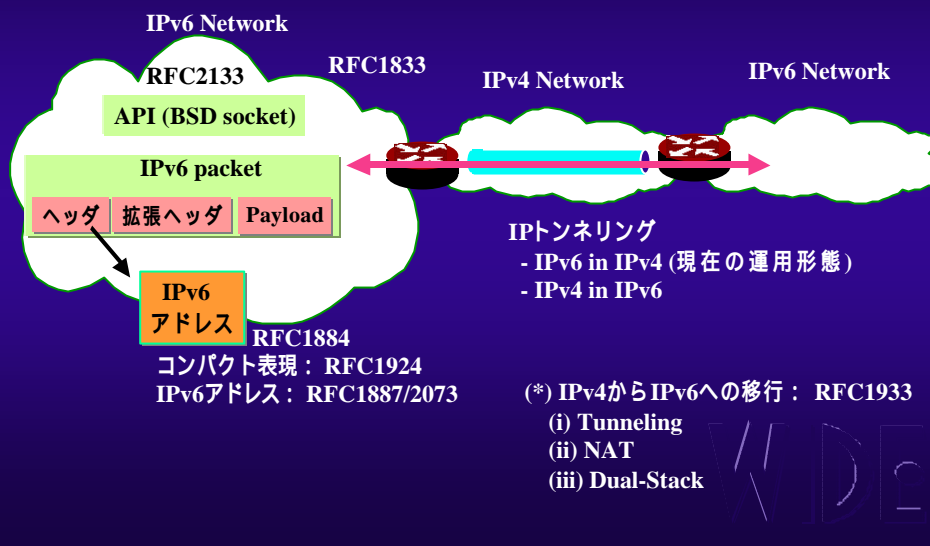   (ii) DNS Update
    (iii) Operating IPv6 Network

[1] Standardization

IETF(Internet Engineering Task Force)
- IPNG (IP Next Generation) WG
     5 Draft Standard RFC
   24 Proposed Standard RFC
     5 Informational RFC
     2 Experimental RFC
     1 BCP
- NGTRANS WG
     6 Proposed Standard RFC
     6 Informational RFC

[1] Standardization
- What has been Standardized -

IPv6 Network

RFC2133
RFC1833
IPv4 Network
IPv6 Network

API (BSD socket)

IPv6 packet

Payload

IPv6

RFC1884
RFC1924
RFC1887/2073

IPv6

IP
- IPv6 in IPv4 (   )
- IPv4 in IPv6

(*) IPv4   IPv6
(i) Tunneling
(ii) NAT
(iii) Dual-Stack

RFC1933

---

[2] Development
- End Stations -

- ◆ UNIX
  - ➢ BSDI, Lynux, FreeBSD, NetBSD
  - ➢ Solaris
- ◆ MacOS
  - ➢ MacOS IX (Client)
  - ➢ MacOS X (Server)
- ◆ MicroSoft
  - ➢ Windows2000
  - ➢ WindowsNT/95/98

[2] Development
- Router-

- ◆
  - ➢ KAME
- ◆ Commercial Router
  - ➢   Yes
  - ➢   Yes
  - ➢   ?
  - ➢   Yes ?

KAME Project

- ◆ A single effort
  - ➢ 8 core members from 7 Japanese companies
  - ➢ Fujitsu, Hitachi, IIJ, NEC, Toshiba, YDC, Yokogawa
- ◆ Two-years joint project
  - ➢ April 1998 - March 2000
  - ➢ The core members work for IPv6 three days a week
- ◆ KAME
  - ➢ A short word of KArigoME, where our office locates
  - ➢ Turtles

KAME Project Status

◆ The basic spec has been implemented

  ➢ IPv6, DNS, BGP4+, RIPng, translator, laptop computer support

    ➢ IPsec, IKE

    ➢ IPComp, IPv4 NAT, ECN, ATM, ALTQ

    ➢ Many applications

      ➢ SMTP, POP, HTTP, FTP, TELNET, SSH, X11,...

◆ Used in the worldwide 6bone

  ➢ More than 20 countries, 200 people

  ➢ Both as routers and hosts

◆ Reference code

  ➢ Merged: NetBSD

  ➢ Will be merged: BSD/OS, FreeBSD, OpenBSD

---

[2] Development
- Transition -

◆

  ➢ IPv6
         IPv4

  ➢ IPv4   IPv6

  ➢   IPv4   IPv6

IPv4 IPv6

◆ (Not Technical Issues)

➢ IPv4 IPv6

➢

➢ IPv6

➢ DNS

➢ IPv6

➢ Internet IPv6

IPv6 IPv4

◆ IPv6 (IPv6/IPv4 Dual-Stack)
IPv4

Routing   **<only IPv4>**   **<IPv4/IPv6>**   **<only IPv4>**

IPv4 Host | IPv4 | R | IPv6 | R | IPv4 | IPv4 Host

IPv4 Data ← IPv4 Data ← IPv4 Data

1. Native IPv4 Packet
2. IPv4
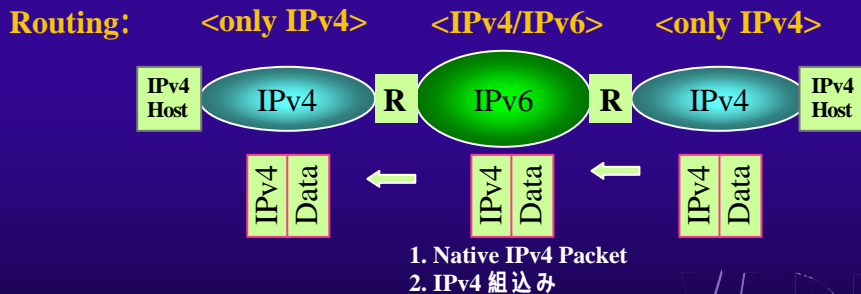
Hitachi v6 stack for Win98/95/NT

IPv4 application
(Telnet, Ftp, Mail, Web…..)

TCP/IPv4

NDIS mini port driver

| D N S | IPT | IPv4 |
| | | IPv6 |

Network Card Driver

Windows(R) 95/98/ NT4.0

IPv4

Network Card

IPv6

*IPT: IP Translator

:No need to change!!

---
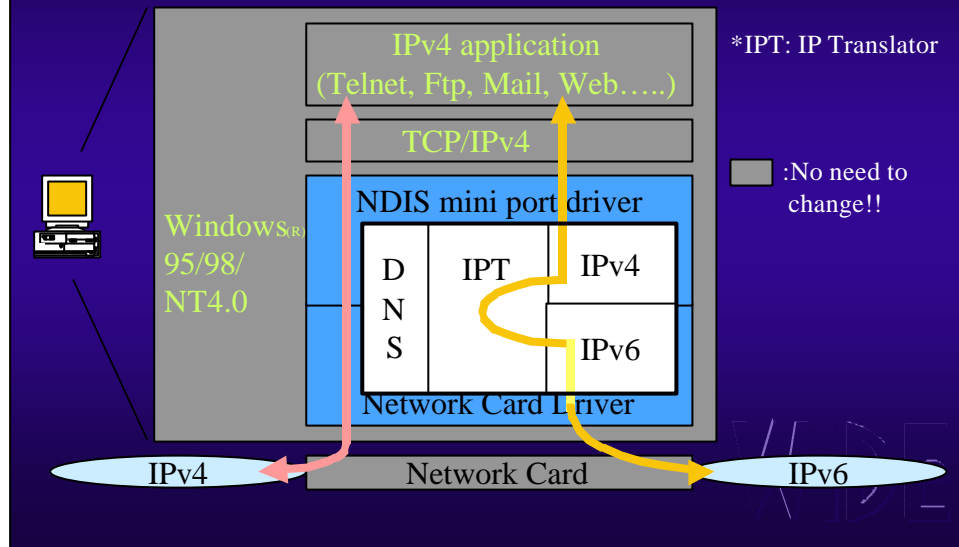
[2] Development
- Interoperability -

- ◆ UNH(University of New Hampsher)
  - ➢ Experimental Interoperability Test Event
- ◆ TAHI Project (http://www.tahi.org)
  - ➢ Production Quality Interoperability Software Suite
  - ➢ Making our tools freely available.

Test Event:
Where and When

- Tokyo, Japan
- 1999/09/26 - 10/1
- **15** Groups / **18** Implementations from Denmark, France, Japan, Korea, U.S.
- Interop. test (ad-hoc network based)
  - Configuring 4 network topologies
  - RIPng and/or BGP4+
  - 14 routers and 10 hosts

Test Event: Ad-hoc network topology
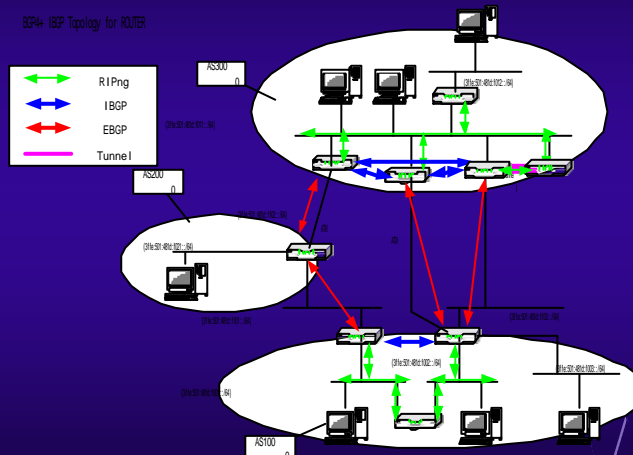
Test Event: The Test Room #1

Test Event: The Test Room #2

[3] Deployment
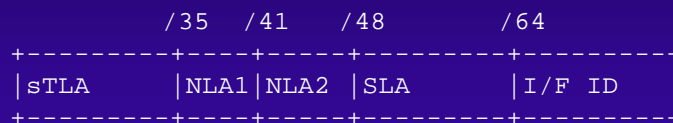## - Address Allocations -

◆ pTLA (pseudo TLA) 6bone
  ➢ 42

```
+-----+---+-----+-----+-------------------------+
|3ffe|   | NLA | SLA |  インターフェイス識別子   |
+-----+---+-----+-----+-------------------------+
        └──► pTLA
```

◆ sTLA (sub TLA)   (Production Quality)
  ➢ RIPE
  ➢ APNIC
  ➢ ARIN

```
         13  6 13
+-----+--+--+---+---+-------------------------+
|2001 |  |  |NLA|SLA|  インターフェイス識別子   |
+-----+--+--+---+---+-------------------------+
 sTLA─┘  └─予約
```

---

[3] Deployment
- Address Allocations -

◆ APNIC IPv6 Address Architecture

```
           /35   /41    /48          /64
+---------+----+-----+---------+---------+
|sTLA     |NLA1|NLA2 |SLA      |I/F ID   |
+---------+----+-----+---------+---------+
```

➢ NLA space is divied into NLA1 andNLA2.
  ➢ NLA1(/41) ; for ISPs that want to allocate IPv6 address to other organizations.
  ➢ NLA2(/48) ; for leaf sites (Companies, Academics, Research Institutes).
  e.g,
  2001:200:0:/48 (NLA1 = 0, NLA2 = 0)

IPv6 address allocation

- ◆ ICANN
    - ➢ Working with IANA, RIR not to slow down the process
- ◆ APNIC
    - ➢ 2001:200::/35 WIDE Project
    - ➢ 2001:208::/35 National University of Singapore
    - ➢ 2001:210::/35 CONNECT AT
    - ➢ 2001:218::/35 OCN (NTT)
- ◆ JPNIC
    - ➢ Started working with APNIC

6bone-JP Registry System

- Web based IPv6 registry system from 1997

- easy to update and view

- uses PGP public-key for authentication of maintainer

- can apply for IPv6 address via the Web

http://v6.sfc.wide.ad.jp/6bone/

[3] Deployment
- Address Allocations -

- ◆ APNIC (whois.apnic.net) s-TLA
  - ➢ APNIC-AP-SUBTLAS   2001:200::/23
  - ➢ CONNECT-AU-19990916   2001:210::/35
  - ➢ WIDE-JP-19990813   2001:200::/35
  - ➢ NUS-SG-19990827   2001:208::/35
  - ➢ NTT-JP-19990922   2001:218::/35
  - ➢ KIX-KR-19991006   2001:220::/35
  - ➢ JENS-JP-19991027   2001:228::/35

[3] Deployment
- Address Allocations -

AS2497 - AS2528 (JNIC-ASN)

- ◆ FUJITSU-LAB
- ◆ FUJITSU-LTD
- ◆ HITACHI-LTD
- ◆ IIJ: Internet Initiative Japan
- ◆ IMASY
- ◆ ITOJUN-ORG
- ◆ JAIST
- ◆ KEIO-UNIV-SFC
- ◆ KEK
- ◆ KYOTO-UNIV
- ◆ MGCS
- ◆ NAIST
- ◆ NEC-CORP
- ◆ NTT-SOFTWARE-LAB
- ◆ SOUM-CORP
- ◆ SUMITOMO-JP
- ◆ TDI
- ◆ TITECH
- ◆ TOSHIBA-CORP
- ◆ U-TOKYO
- ◆ WIDE-PROJECT

[3] Deployment
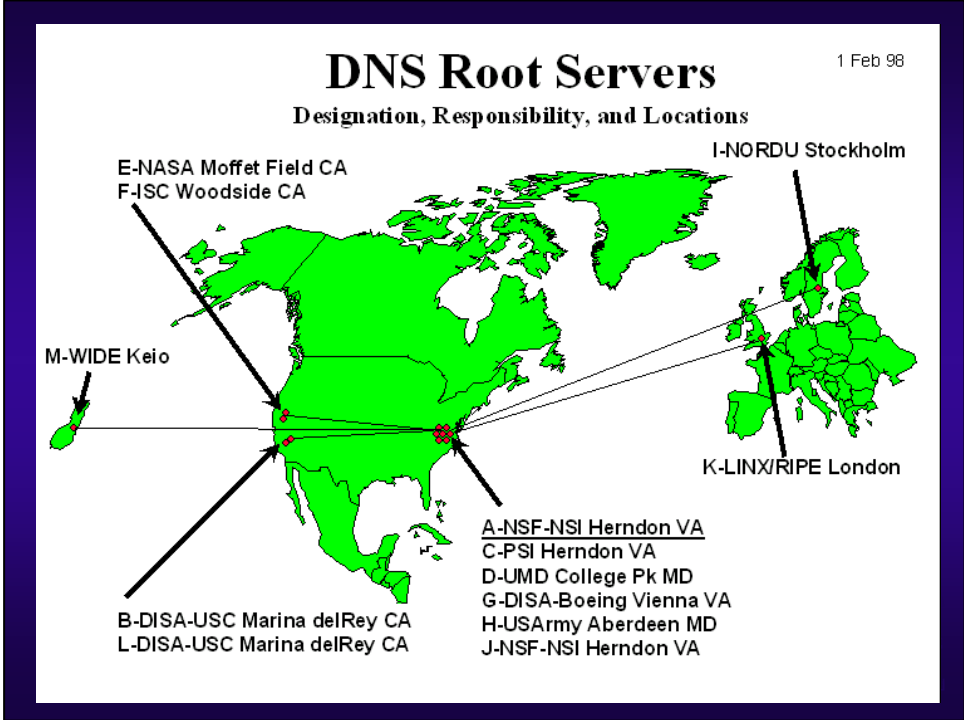## - Address Allocations -

- ◆ ARIN (whois.arin.net)
  - ➢ ESNET-V6   2001:0400::/35
  - ➢ ARIN-001   2001:0400::/23
  - ➢ VBNS-IPV6   2001:0408::/35
- ◆ RIPE (whois.ripe.net)
  - ➢ DE-SPACE-19990812   2001:0608::/35
  - ➢ EU-UUNET-19990810   2001:0600::/35
  - ➢ UK-BT-19990903   2001:0618::/35
  - ➢ CH-SWITCH-19990903   2001:0620::/35
  - ➢ AT-ACONET-19990920   2001:0628::/35
  - ➢ UK-JANET-19991019   2001:0630::/35
  - ➢ DE-DFN-19991102   2001:0638::/35
  - ➢ NL-SURFNET-19990819   2001:0610::/35

---

[3] Deployment
- DNS System Update -

- ◆
  - ➢ AAAA
    - ➢ $ORIGIN mew.org.
    - ➢ ftp AAAA 3ffe:501:8:1234:260:97ff:fe40:efab
- ◆
  - ➢ PTR
    - ➢ $ORIGIN 4.3.2.1.8.0.0.0.1.0.5.0.e.f.f.3.IP6.INT.
    - ➢ b.a.f.e.0.4.e.f.f.f.7.9.0.6.2.0 PTR ftp.mew.org.
- ◆   IPv4   IPv6

DNS Root Servers
Designation, Responsibility, and Locations
1 Feb 98

E-NASA Moffet Field CA
F-ISC Woodside CA

I-NORDU Stockholm

M-WIDE Keio

K-LINX/RIPE London

A-NSF-NSI Herndon VA
C-PSI Herndon VA
D-UMD College Pk MD
G-DISA-Boeing Vienna VA
H-USArmy Aberdeen MD
J-NSF-NSI Herndon VA

B-DISA-USC Marina delRey CA
L-DISA-USC Marina delRey CA

[3] Deployment
- 6Bone Network -

Operating IPv6 Network (1)

◆

- ➤ USA
  - ➤ Internet2　Abilene, vBNS, CAIRN
  - ➤ ESnet
  - ➤ IX　STARTAP 6TAP, etc
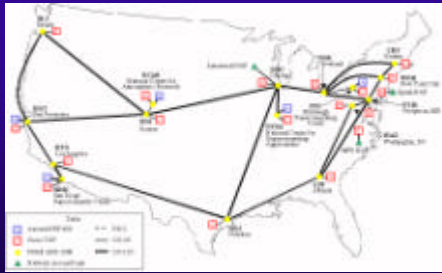
vBNS Backbone Topology

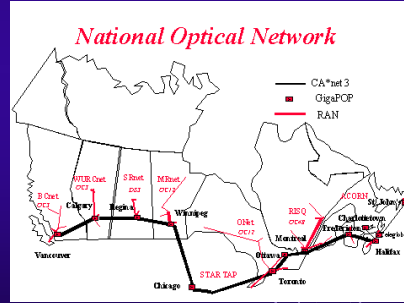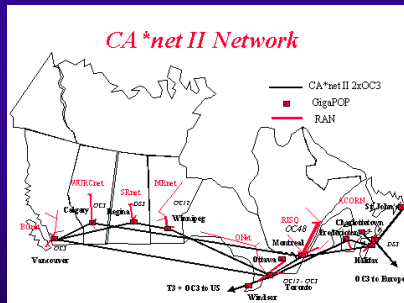# Operating IPv6 Network (2)

◆

- ➤ CANADA
  - ➤ CANARIE　CA*Net2, CA*net3

Operating IPv6 Network (3)

- ◆
  - ➢ DANTE (　　TEN-155)
  - ➢ NODUNET (　　　)
  - ➢ SURFNET (Netherland)
  - ➢ JANET (BK)
  - ➢ DFNET (Germany)

Operating IPv6 Network (4)

- ◆
  - ➢ APAN, AIII
  - ➢
    - ➢ 6Bone-JP, WIDE/JB
  - ➢
    - ➢ ETRI/KAIST
  - ➢
    - ➢ CERNET
  - ➢
    - ➢ SingAREN
  - ➢
    - ➢ TANET

Global relations of the 6bone-JP

2. How the Deployment Goes
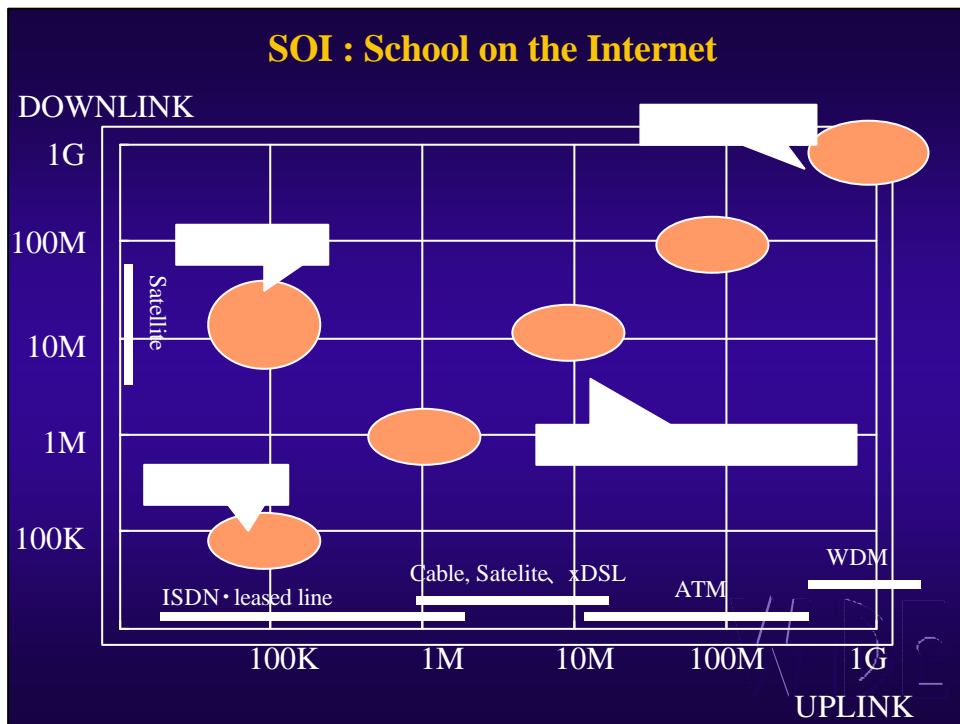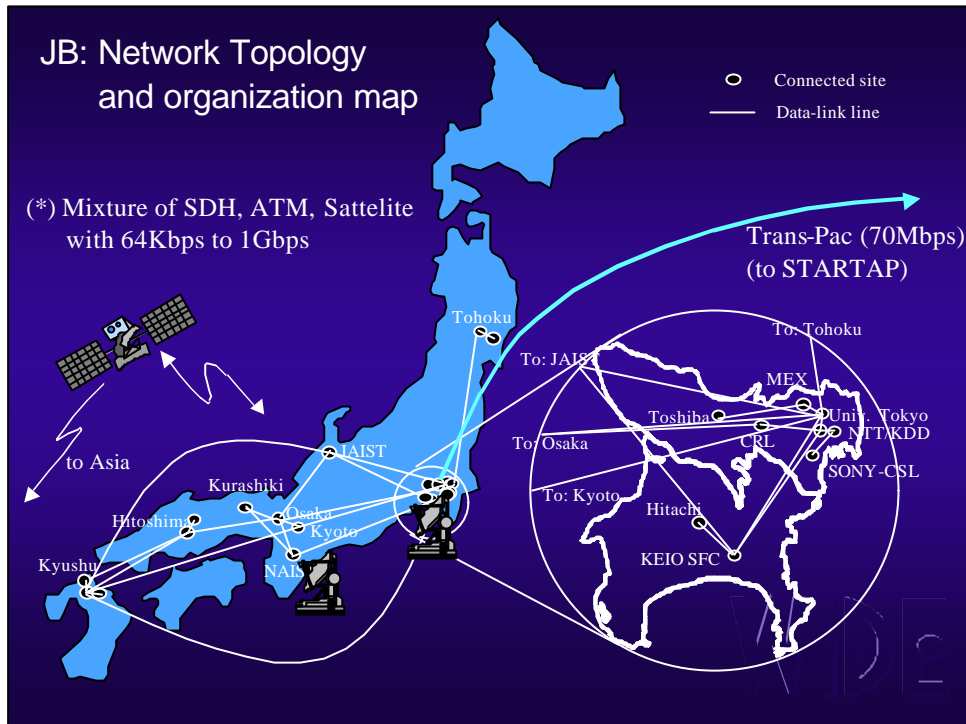
[1] Standardization
[2] Development
   (i) End Host
   (ii) Routers
   (iii) Transition
   (iv) Interoperability Test
[3] Deployment
   (i) Address Allocation
   (ii) DNS Update
   (iii) Operating IPv6 Network
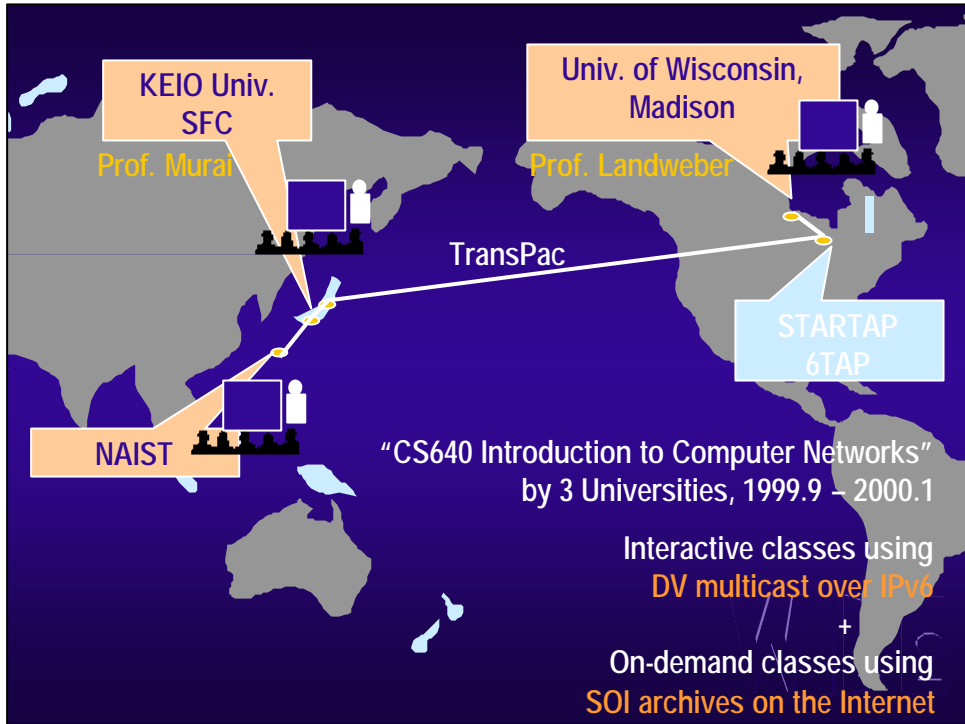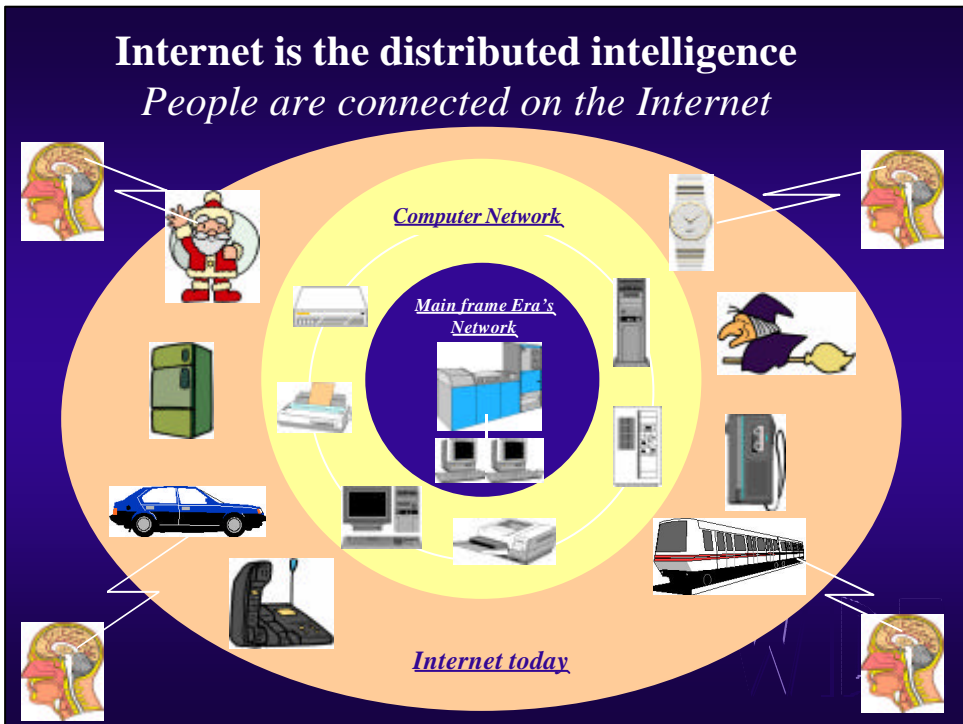
IPv6 on Production

- ◆ JB
  - ➢ WIDE backbone
    - ➢ IPv6, Diffserve, Multicast
    - ➢ # of IPv6 over IPv4 tunnel is being decreased
- ◆ Remote class
  - ➢ University of Wisconsin
    - ➢ Introduction to Computer Networks
    - ➢ Professor Lawrence Landweber
    - ➢ Digital Video via 6TAP
  - ➢ Credits
    - ➢ Keio University
    - ➢ Nara Institute of Science and Technology

JB: Network Topology and organization map

(*) Mixture of SDH, ATM, Sattelite with 64Kbps to 1Gbps

Trans-Pac (70Mbps) (to STARTAP)

SOI : School on the Internet

DOWNLINK

UPLINK

KEIO Univ. SFC
Prof. Murai

Univ. of Wisconsin, Madison
Prof. Landweber

NAIST

TransPac

STARTAP
6TAP

"CS640 Introduction to Computer Networks"
by 3 Universities, 1999.9 – 2000.1

Interactive classes using
DV multicast over IPv6
+
On-demand classes using
SOI archives on the Internet

Internet is the distributed intelligence
People are connected on the Internet

Computer Network

Main frame Era's
Network

Internet today

How Internet Works

Discussion & Agreement
Þ **Plan/Regulation**   Þ **Execution**

TOO SLOW

Challenges & Trials
Þ **Contribution to individuals and to the societies**
Þ **Evaluation**
Þ **Rules ?**
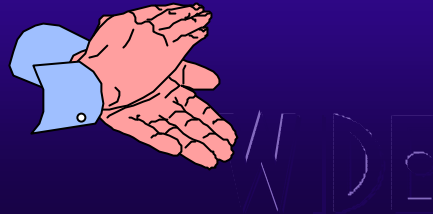
1.
   - Challenge First

2.
   - End-to-End

   -

3. Everything on the Internet

Where the Internet Goes ?

Internet for Everything   Everything over IP
Internet for Everyone   Everyone with IP
Internet Everywhere/Anytime/Anyhow
               Everywhere and Anyhow to IP

" *Internet is for Everyone* "