Internet: Technology, Protocols and Services

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Credits

- A.M. Rutkowski, Internet Society
- Jim Kurose, University of Massachusetts

Introduction

- Course Objectives, Prerequisites, Overview
- Readings
- A Brief History of the Internet
- How big is the Internet?
- Who runs the Internet?
- The Internet View of the World
- Subnetwork technology
- Internet technology and Standards

Course Objectives

- understand Internet technology, terminology, issues, constraints
- evaluate alternatives, strengths, weaknesses
- ability to design Internet applications

not: how to *use* services (email, WWW, …)

Prerequisites

- introductory course in networking
- know Ethernet, packet vs. circuit switching, OSI layers, …(but we'll refresh your memory)
- a bit of C (some programming examples)
- no performance evaluation or statistics needed
- …but a bit of English for slides

Course Overview

- overview of history, standardization, design principles
- network components and addressing
- network, transport: IP, UDP, TCP
- mapping addresses: ARP and DNS
- programming the Internet: socket services
- routing: RIP, OSPF, BGP, …
- IP multicast and MBONE
- IPv4 → IPv6 (IPng)
- traditional data services: ftp, telnet, nntp, smtp (and MIME)
- global clock synchronization: NTP

- World-Wide Web
- real-time services: RTP, RSVP
- network management with SNMP
- Internet as the global information infrastructure?
- site visit: networks and services at GMD

`http://www.fokus.gmd.de/step/hgs/internet/`

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References

[1] D. E. Comer, *Internetworking with TCP/IP*, vol. 1. Englewood Cliffs, New Jersey: Prentice Hall, 3rd ed., 1995.

[2] D. C. Lynch and M. T. Rose, *Internet system handbook*. Reading, Massachusetts: Addison-Wesley, 1993.

[3] A. S. Tanenbaum, *Computer Networks; Second Edition*. Prentice-Hall, 2nd ed., 1988.

[4] D. E. Comer and D. L. Stevens, *Internetworking with TCP/IP*, vol. 2. Englewood Cliffs, New Jersey: Prentice Hall, 1991.

[5] C. Partridge, *Gigabit networking*. Reading, Massachusetts: Addison-Wesley, 1993.

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Introduction

What is the Internet?

internet, intranet: connection of different LANs within an organization

- private
- may use leased lines
- usually small, but possibly hundreds of routers
- may be connected to the Internet (or not), often by *firewall*

(the) Internet : "collection of networks and routers that spans 61 countries and uses the TCP/IP protocols to form a single, cooperative virtual network". (Comer)

Internet Actors

Started by U.S. research/military organizations:

(D)ARPA: (Defense) Advanced Research Projects Agency ➠ funds technology with military usefulness

DoD: U.S. Department of Defense ➠ early adaptor of Internet technology for production use

NSF: National Science Foundation ➠ funds university research

A Short History of the Internet: 1960's

1830: telegraph

1876: circuit-switching (telephone)

early 1960's: concept of packet switching (Paul Baran)

1965: MIT's Lincoln Laboratory commissions Thomas Marill to study computer networking

1968: ARPAnet contract awarded to Bolt Beranek and Newman (BBN)

1969: ARPAnet has 4 nodes (UCLA, SRI, UCSB, U. Utah), connected by IMPs (interface message processors); connected by 50 kb/s lines

A Short History of the Internet: 1970's

- multiple access networks: ALOHA, Ethernet (10 Mb/s)
- companies: DECnet (1975), IBM System Network Architecture (1974)

1971: 15 nodes and 23 hosts: UCLA, SRI, UCSB, U of Utah, BBN, MIT, RAND, SDC, Harvard, Lincoln Lab, Stanford, UIU(C), CWRU, CMU, NASA/Ames

1972: First public demonstration at ICCC

1973: TCP/IP design

1973: first satellite link from California to Hawaii

1973: First international connections to the ARPANET: England and Norway

1979: ARPAnet $\approx$ 100 nodes

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A Short History of the Internet: 1980's

- proliferation of local area networks: Ethernet and token rings
- late 1980's: fiber optic networks; fiber distributed data interface (FDDI) at 100 Mb/s

1980's: DARPA funded Berkeley Unix, with TCP/IP

1981: Minitel deployed in France

1980-81: BITNET (IBM protocols) and CSNET (NSF-funded $\rightarrow$ 200 sites)

Jan. 1, 1983: flag day: NCP $\rightarrow$ TCP

early 1980's: split ARPANET (research), MILNET (military)

1984: Domain Name Service replaces hosts.txt file

1986: NSFNET created (56 kb/s backbone)

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Nov. 1, 1988: Internet worm

1989: Internet passes 100,000 nodes

1989: first proposal for World-Wide Web

1989: NSFNET backbone upgraded to T1 (1.544Mbps)

A Short History of the Internet: 1990's

- high-speed networks: Asynchronous Transfer Mode (ATM) at 150 Mb/s and higher
- focus on new applications
- wireless local area networks
- commercialization
- National Information Infrastructure (NII) (Al Gore, U.S. VP)

1990: Original ARPANET disbanded

Fall 1991: CSNET discontinued

1991: Gopher released by University of Minnesota

1992: NSFNET backbone upgraded to T3 (44.736Mbps)

March 1992: First MBONE audio multicast

November 1992: First MBONE video multicast

February 1993: NCSA Mosaic

June 1993: 1,776,000 hosts

April 30, 1995: NSFNET backbone disbanded

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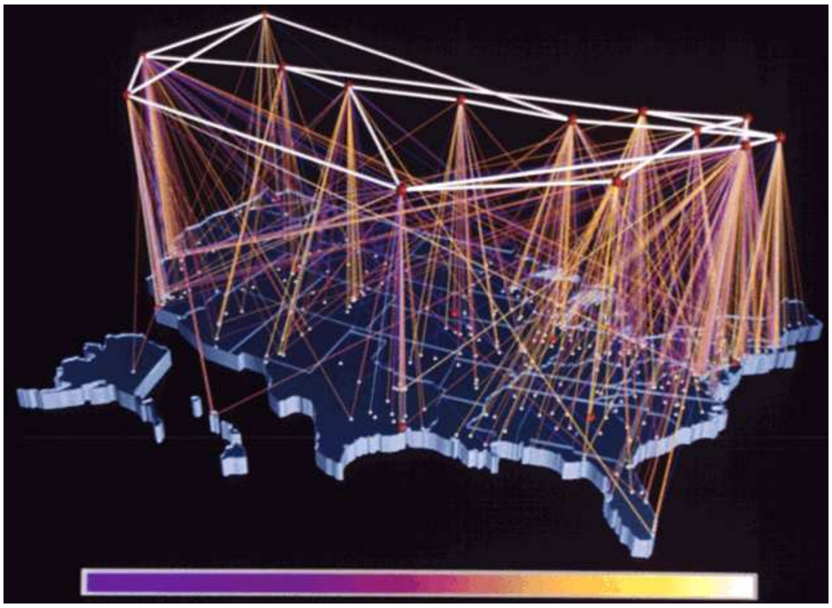
The T1 NSFNET Byte Volume



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How Big is the Internet?

Many measures:

- networks (routed entities)
- domains, host names (but: several names per host!)
- directly (continuously) attached hosts (“ping’able”)
- IP-connected hosts (SLIP, PPP)
- firewalled hosts
- e-mail reachable

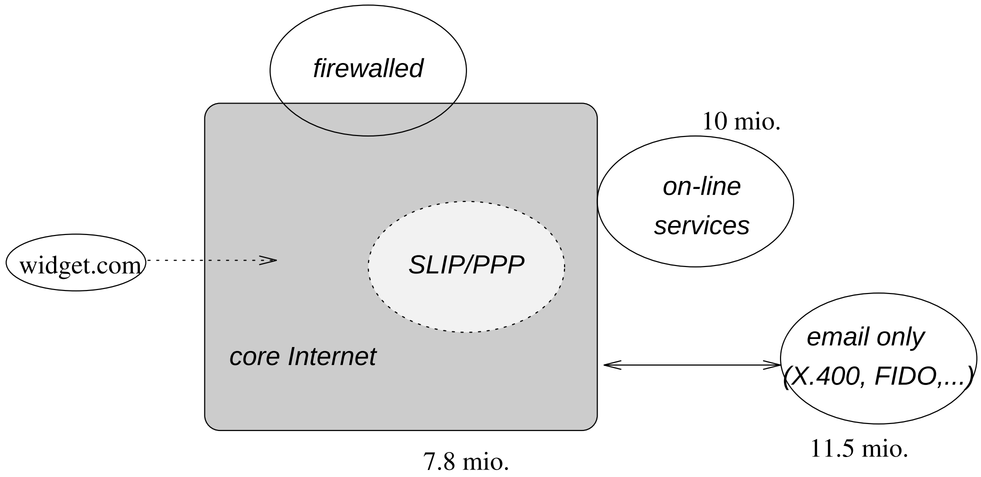
“Consumer” Internet

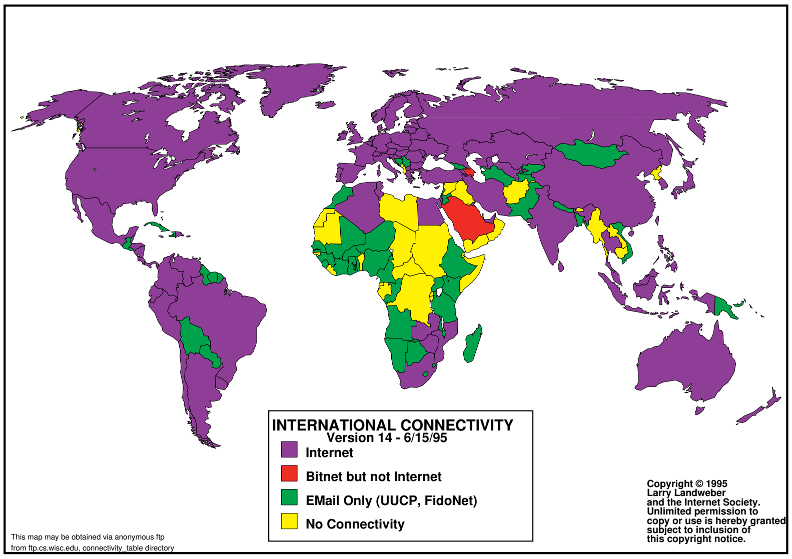
Internet access through on-line services:

- America Online (AOL; 5 mio subscribers)
- Compuserve (3.6 mio subscribers, 100,000 in Germany)
- Prodigy (2 mio “members”)
- T-Online/Datex-J (750,000 in Germany)
- lots of small ones

or count *people* with access to services

Internet User Populations





Who's on the Internet?

July 1994

Domain Name	Code	Internet Hosts	GNP Total (M$)	GNP/Host
Iceland	is	3,268	5,456	1.67
Australia	au	127,514	290,522	2.28
Norway	no	38,759	98,079	2.53
Finland	fi	49,598	129,823	2.62
U.S. Total	var	2,044,716	5,694,900	2.79
New Zealand	nz	14,830	46,200	3.12
Sweden	se	53,294	202,498	3.80
Netherlands	nl	59,729	249,600	4.18
Canada	ca	127,516	542,774	4.26
Czech Republic	cz	5,639	25,600	4.54
Switzerland	ch	47,401	238,050	5.02
U.K.	uk	155,706	923,959	5.93
South Africa	za	15,595	96,000	6.16
World Median	ww	3,225,177	19,935,936	6.18
Israel	il	8,464	56,400	6.66
Denmark	dk	12,107	91,100	7.52
Hong Kong	hk	9,141	71,303	7.80
Austria	at	20,130	164,100	8.15
Chile	cl	3,703	30,500	8.24
Germany	de	149,193	1,495,679	10.03
Slovak Republic	sk	868	9,300	10.71

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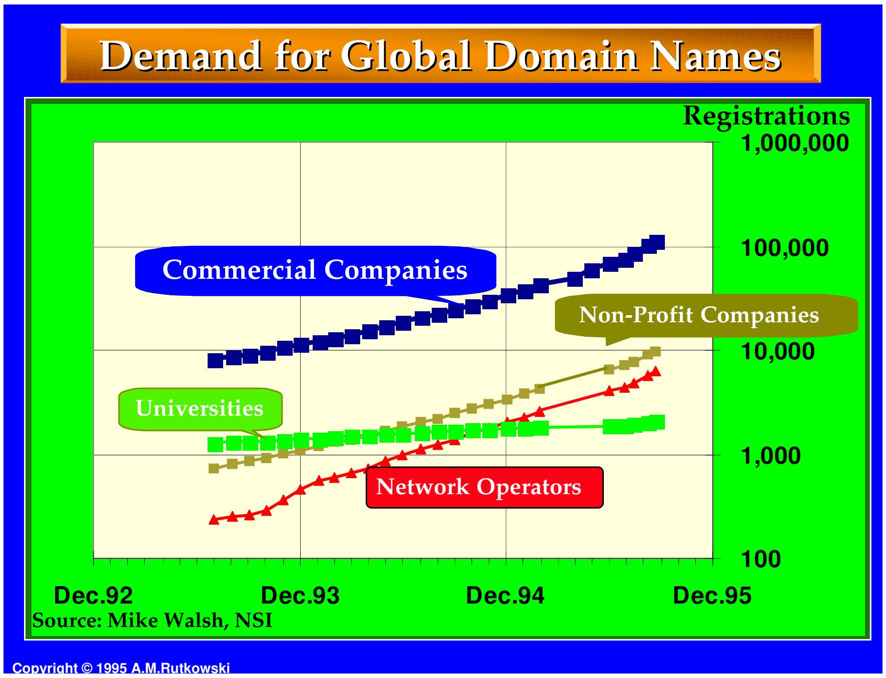

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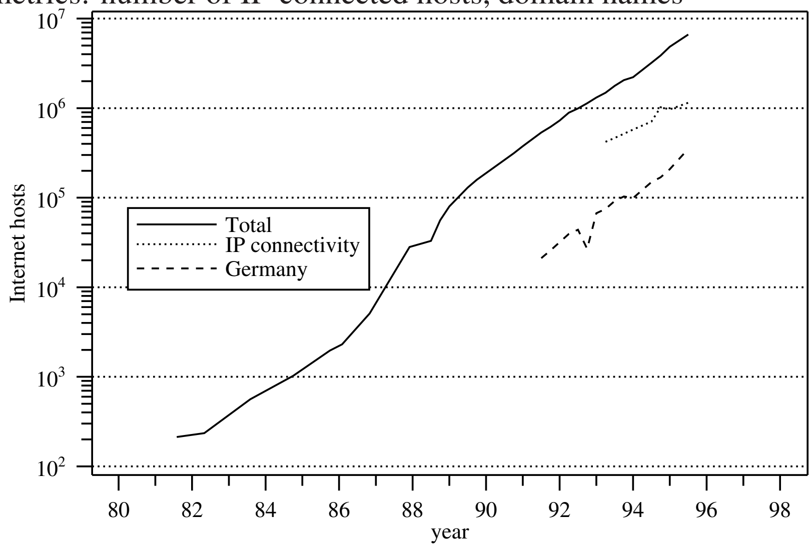
Internet Growth

Two metrics: number of IP-connected hosts, domain names



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Most popular on-line services

1. E-Mail
2. Downloads
3. Internet access
4. News on Topics (includes sports scores)
5. Info and Reference
6. Chat

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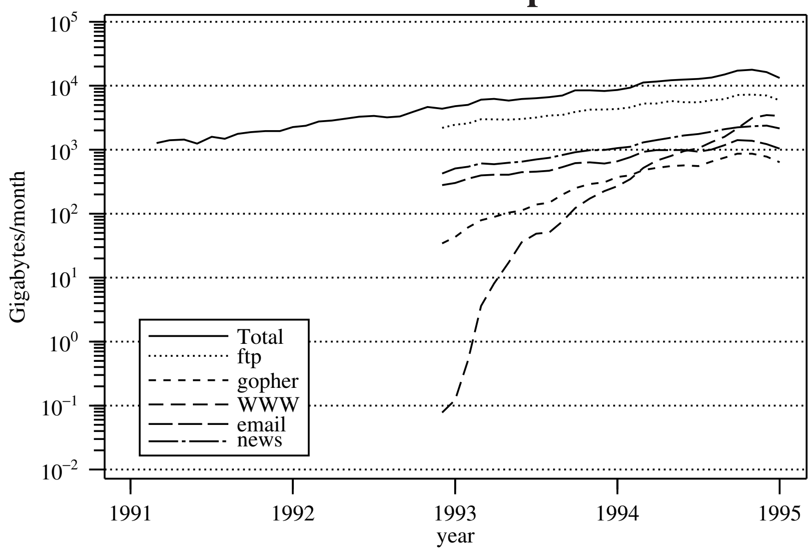
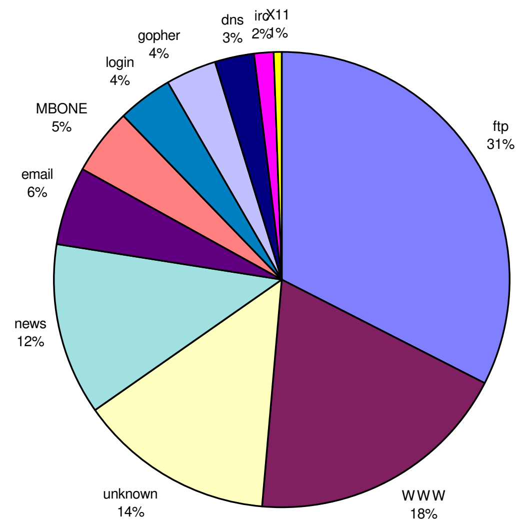
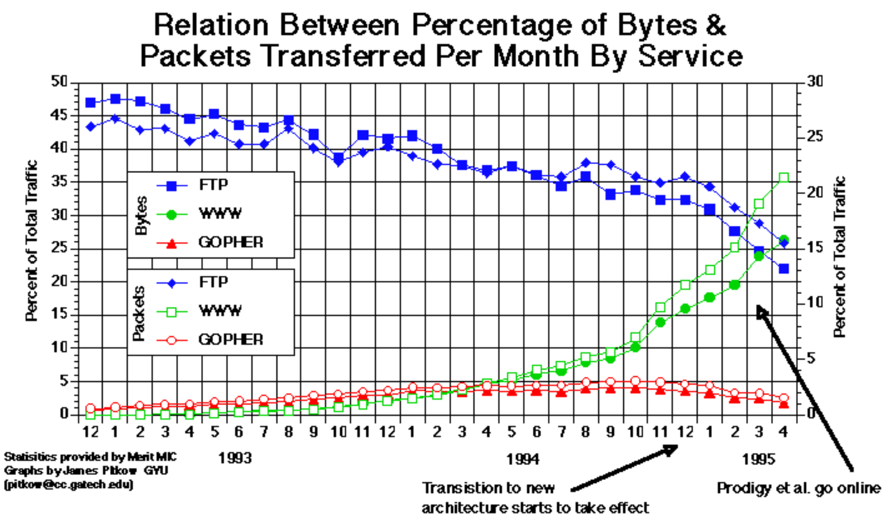
Internet Traffic Report

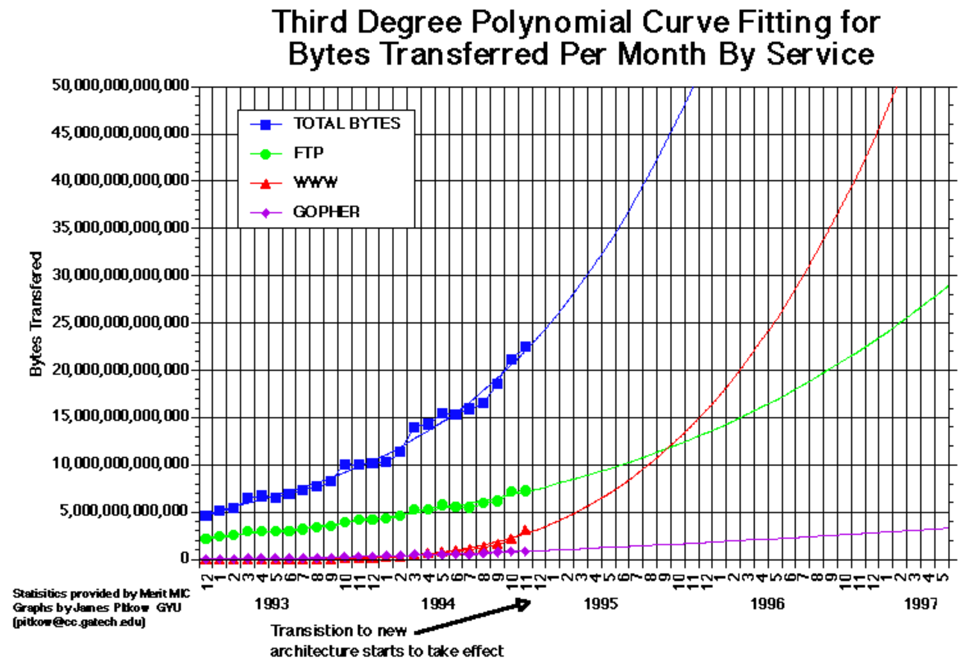


Internet Services

January 1995 NSFnet




Relation Between Percentage of Bytes & Packets Transferred Per Month By Service
Percent of Total Traffic
Bytes
FTP
WWW
GOPHER
Packets
FTP
WWW
GOPHER
Percent of Total Traffic
1993
1994
1995
Statisitics provided by Merit MIC
Graphs by James Pitkow GVU
(pitkow@cc.gatech.edu)
Transistion to new architecture starts to take effect
Prodigy et al. go online


Third Degree Polynomial Curve Fitting for Bytes Transferred Per Month By Service
Bytes Transfered
TOTAL BYTES
FTP
WWW
GOPHER
1993
1994
1995
1996
1997
Statisitics provided by Merit MIC
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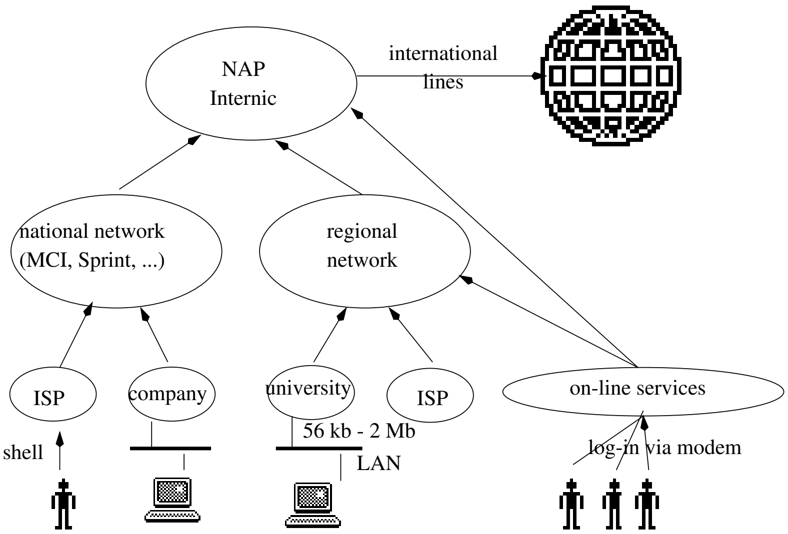
Transistion to new architecture starts to take effect

Who runs the Internet?

- “nobody”
- standards: Internet Engineering Task Force (later…)
- names: Internic (US), RIPE (Europe), …
- numbers: IANA (Internet Assigned Numbers Authority)
- operational coordination: IEPG (Internet Engineering Planning Group)
- network: ISPs (Internet Service Providers), NAPs (Network Access Points), DFN, …
- fibres: telephone companies (mostly)
- content: thousands of companies, universities, individuals, …

Who pays for the Internet?



How is the Internet paid for?

Generally: distance-insensitive

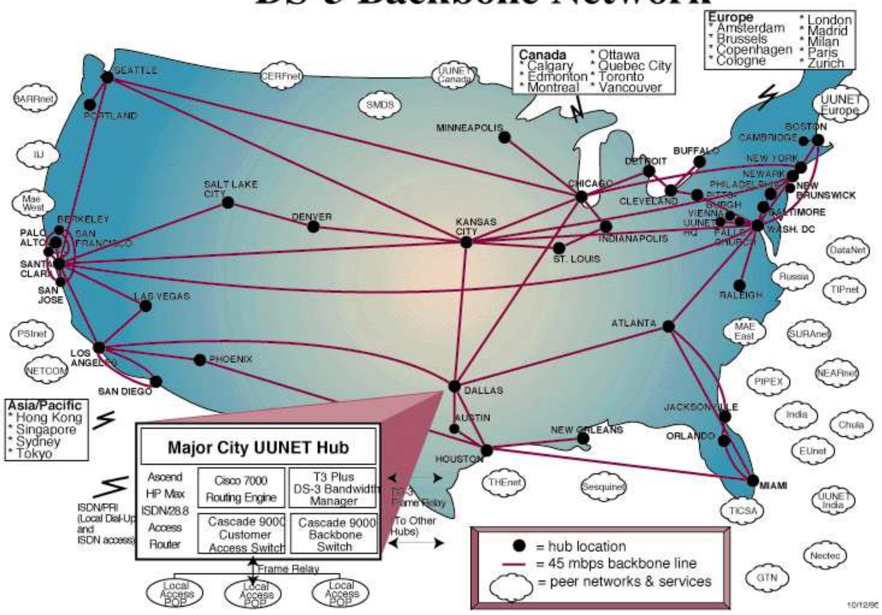
dial-up: per minute (peak/off-peak) or flat monthly

direct connection: flat rate or volume bands; rarely extra for international bytes; no time zones

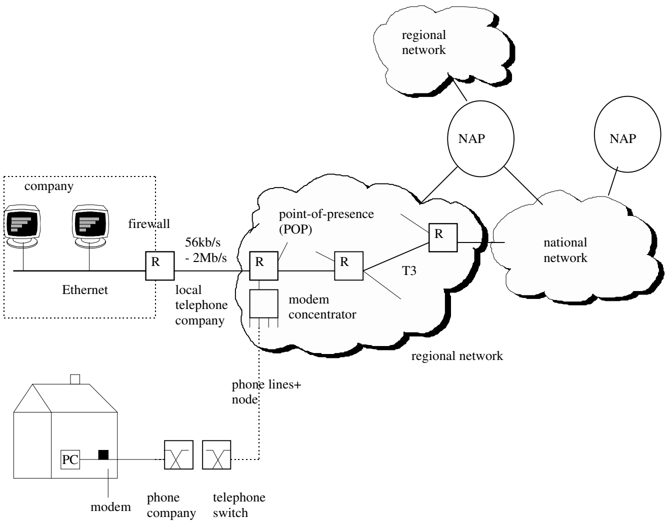
↔ German telephone: 4 time zones, 4 distance zones, plus international tariffs

➠ may change with reserved bandwidth!

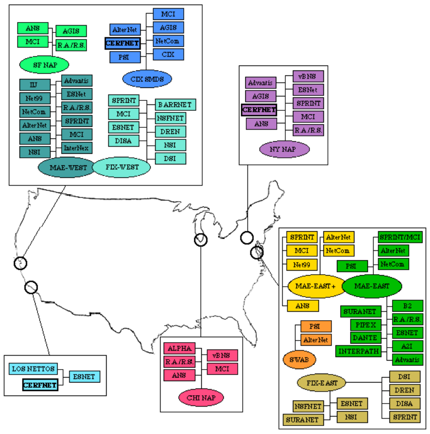
DS-3 Backbone Network



Network Access and Interconnection

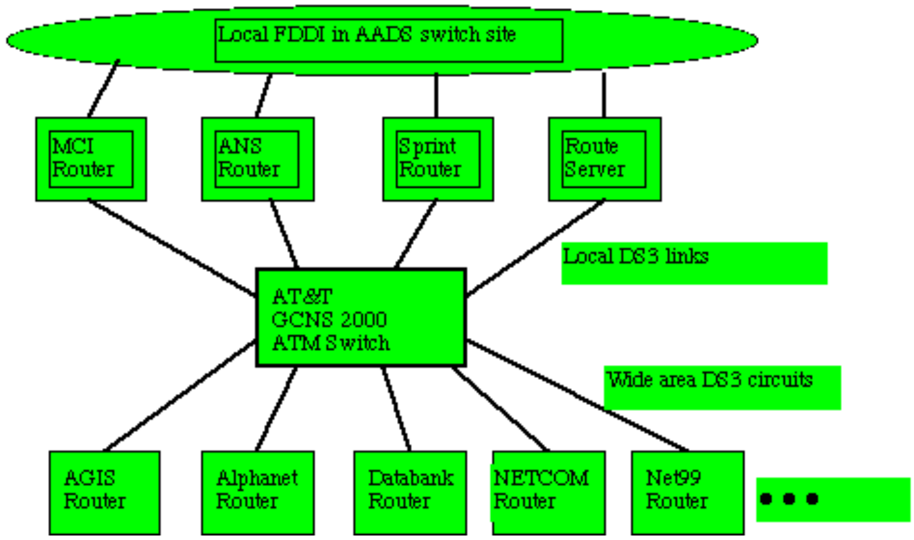


Network Interconnection



Brought to you by CERFNET

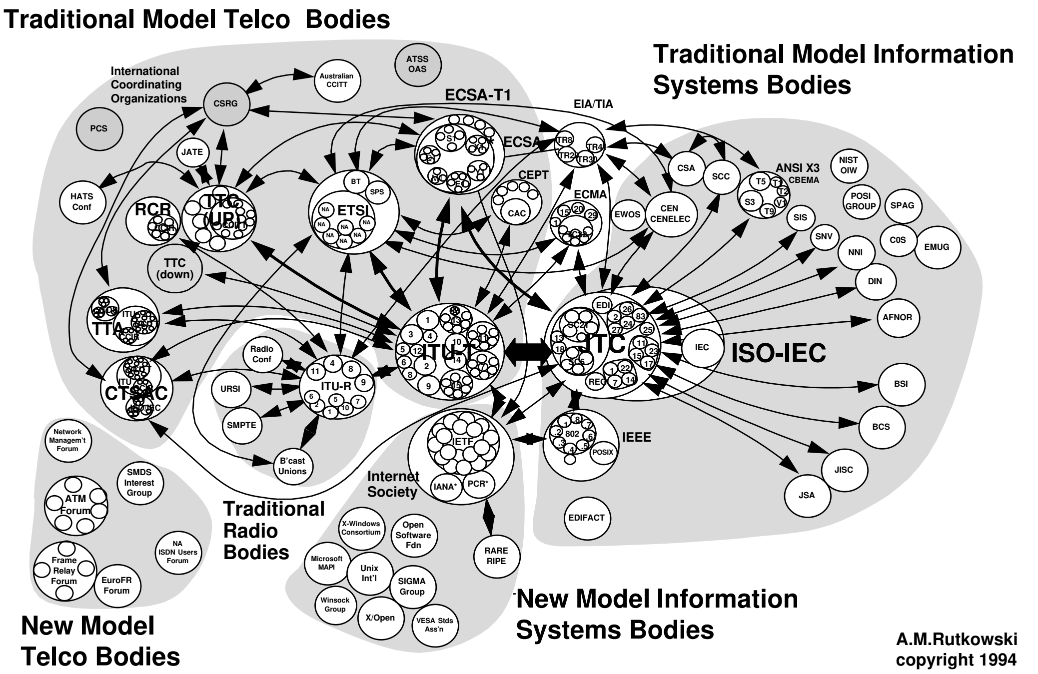
Chicago NAP

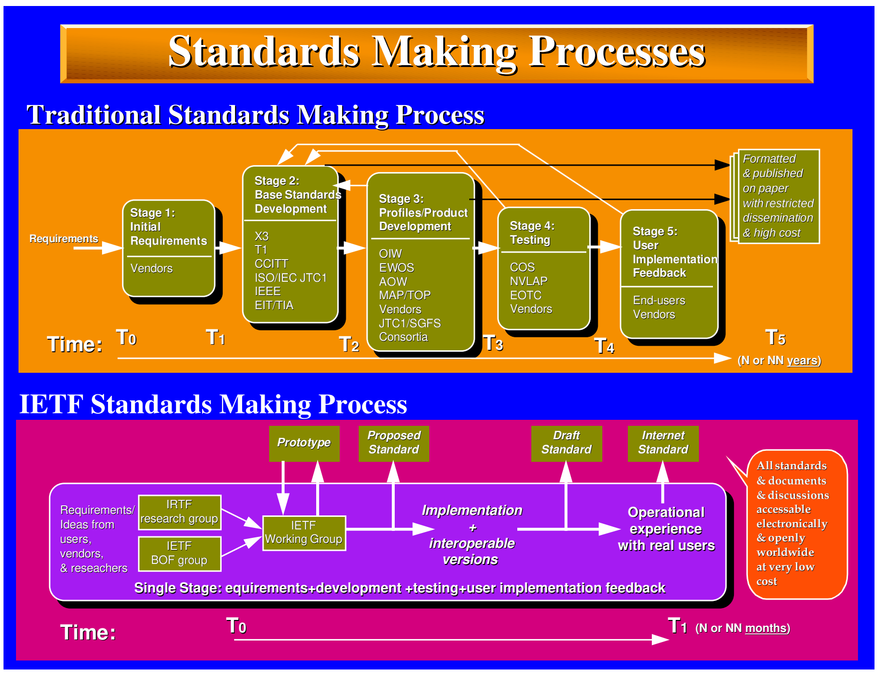


Internet in Germany

	USA	Germany
highest access speed	45 Mb/s	2 Mb/s
high-speed access	$12,000/a (1.5 Mb/s)	$253,000/a (2 Mb/s)
ATM 155 Mb/s fixed	$7899/month	$26700/month
ATM traffic	free	$1834/hour
local (ISDN) calls	free	$0.80/h
data networks	leased lines	X.25
Internet use	upper-income males	CS students
service offerings	White House, FTD	universities, Spiegel
student use	sociology freshmen	CS PhDs
on-line users	O(5 mio.)	100,000 (700,000 Btx)
president on line	yes	no
Post Office on line	yes	Btx?
computer use (households)	36%	40%
equipped with modems	53%	

The Standards-Making Universe





IETF, IESG, IAB, ISOC

Internet Architecture Board: IAB

- architectural oversight
- elected by ISOC

Internet Engineering Steering Group (IESG): approves standards

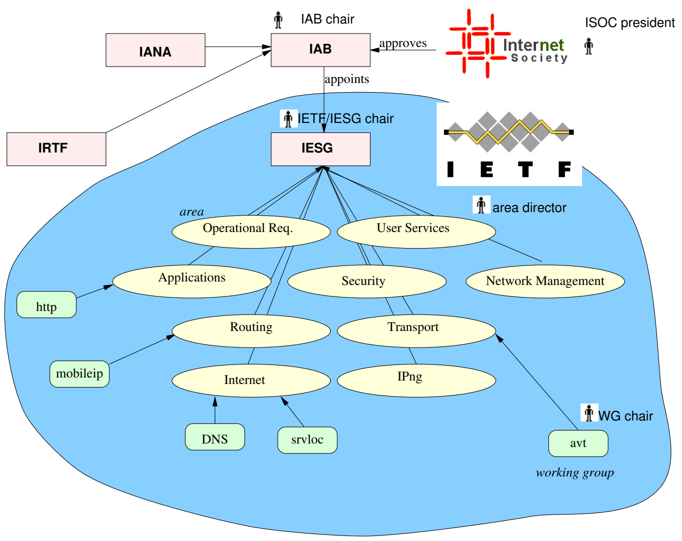
Internet Society: ISOC

- conferences
- “hosts” IANA

Internet Assigned Number Authority: IANA

- keeps track of numbers
- delegates Internet address assignment

IETF, IESG, IAB, ISOC



IETF

- small focused efforts preferred to larger comprehensive ones
- published goals and milestones
- no formal voting
- disputes resolved by discussion and demonstration (mostly…)
- “Rough consensus (and running code!)”
- mailing list and face-to-face meetings
- open, no-fee membership ($\leftrightarrow$ ATM Forum)
- standardization only after several implementations
- specifications available without charge by ftp ($\leftrightarrow$ ITU, IEEE)

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Internet Standards $\subset$ RFCs

- “Request for Comments”, since 1969
- most RFCs are not standards!
- Internet drafts: working documents, but often used for prototypes
- edited, but not refereed
- numbered sequentially (around 1900 now)
- check the April 1 ones…(RFC 1149)
- `ftp://ftp.fokus.gmd.de/pub/rfc/` or `ftp://ds.internic.net/rfc`

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