



# **Broadband Internet**

## **Broadnets 2004**

Vint Cerf

MCI

October 28, 2004



# Creation of the Internet





## 35<sup>th</sup> Anniversary of ARPANET

- ◆ Sept 2, 1969, the first node of the ARPANET was installed at UCLA
- ◆ The success of this first wide-area packet switching network inspired the creation of the ground mobile Packet Radio Net and the Packet Satellite Net
- ◆ These became the core of the Internet



## 30<sup>th</sup> Anniversary of TCP/IP

- ◆ May 1974: “A Protocol for Packet Network Intercommunication,” Vint Cerf and Bob Kahn, IEEE Transactions on Communications
- ◆ A copy of this was auctioned for \$3,000 in 2002
- ◆ Another copy is in a NY antiquarian bookstore for \$7,500 in 2004




**IEEE TRANSACTIONS ON**  
**COMMUNICATIONS**



**MAY 1974**      VOLUME COM-22      NUMBER 5  
 A PUBLICATION OF THE IEEE COMMUNICATIONS SOCIETY

WILLIS TOWERS  
 WASHINGTON, D.C.

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# Internet - Global Statistics

22.5 Million Hosts  
(Bellcore June 1997)

50 Million Users  
(NUA Jul 1997)

250 Million Hosts  
(ISC Apr 2004)

797.9 Million Users  
(InternetWorldStats.com  
August 2004)

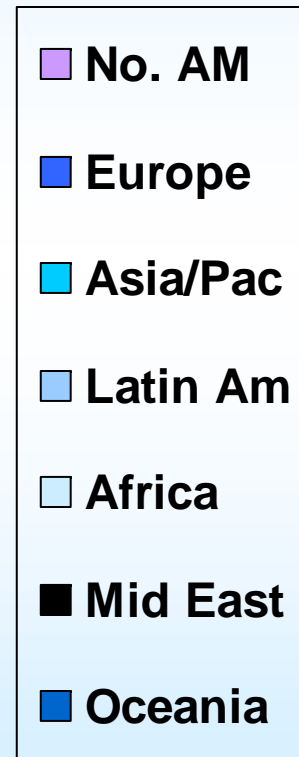
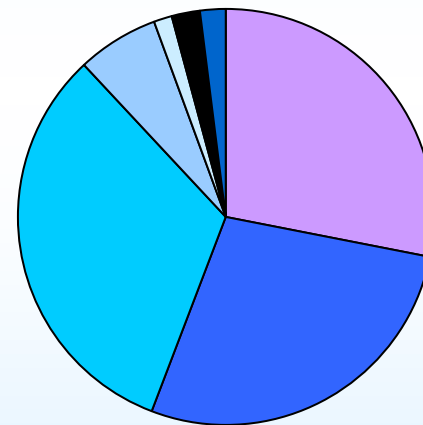
[Other estimates range  
from 850M-950M]

(approx. 2.3 Billion Telephone Terminations, 600 Million PCs [ITU]  
and 1.34B mobile phones; Washington Internet Daily, 10/6/04)



# Internet Penetration Aug. 2004

- ◆ Asia - 255.6 M
  - ◆ No. Amer. - 223.8 M
  - ◆ Europe - 222.2 M
  - ◆ Latin Am - 51.2 M
  - ◆ Africa - 12.3 M
  - ◆ Mid-east - 16.8 M
  - ◆ Oceania - 16.0 M
- 
- ◆ Total - 797.9 M

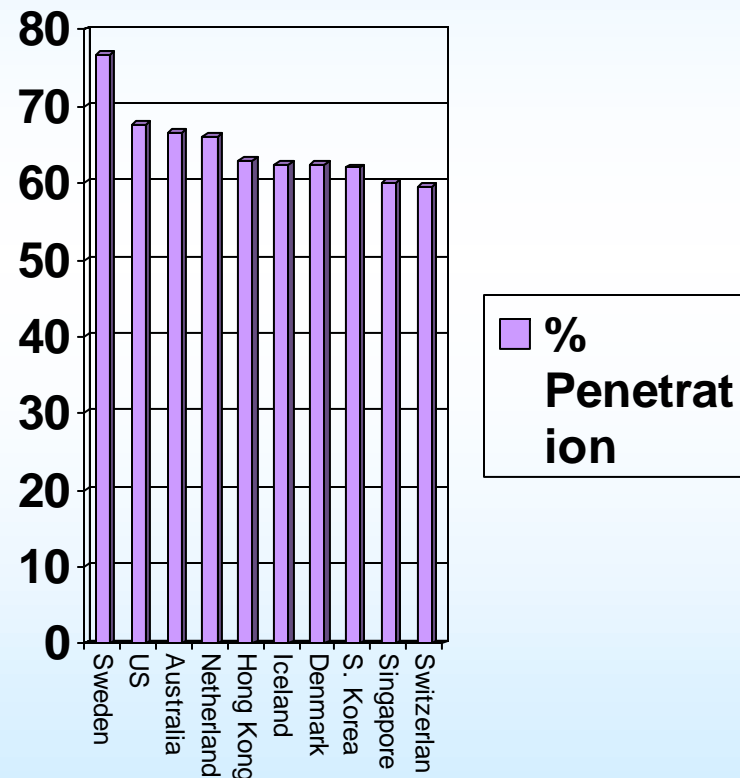


*(Source [www.internetstats.com](http://www.internetstats.com))*



## % Internet Use (May 2004)

- ◆ Sweden (76.8%)
- ◆ United States (67.6%)
- ◆ Australia (66.6%)
- ◆ Netherlands (66.0%)
- ◆ Hong Kong (63.0%)
- ◆ Iceland (62.5%)
- ◆ Denmark (62.5%)
- ◆ S. Korea (62.0%)
- ◆ Singapore (60.0%)
- ◆ Switzerland (59.6%)



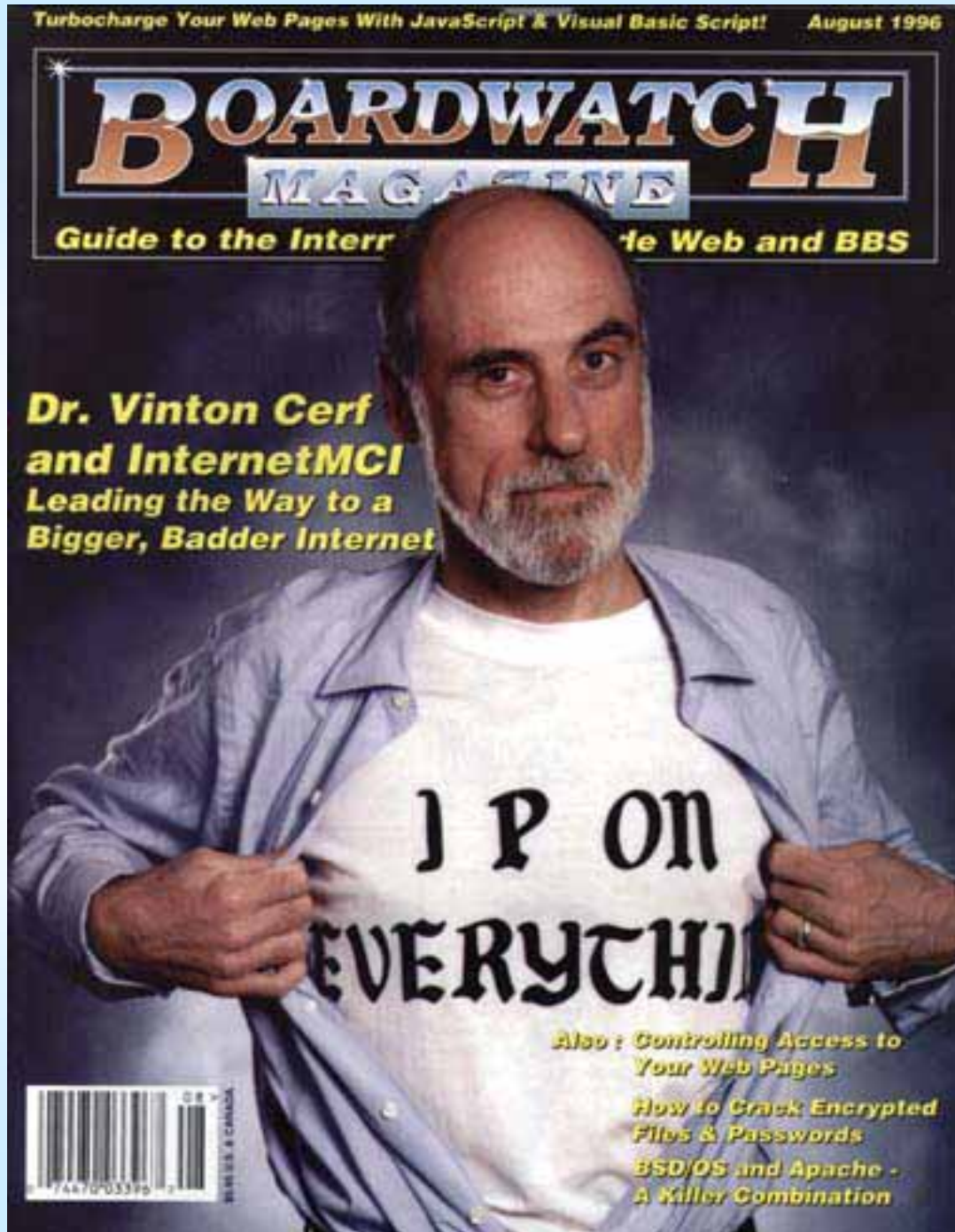
Total 66.7% (274.3 M)

ROW 7.8% (471.1 M)



# The Power of IP

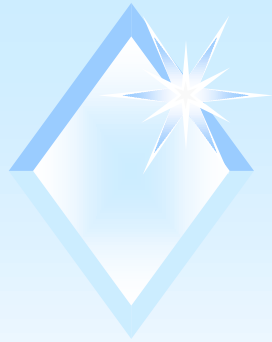
- ◆ Layering of Protocols
- ◆ IP decouples application from transmission/transport
  - ◆ IP does not care what transport is used (satellite, fiber, twisted pair, radio, ATM...)
  - ◆ IP does not care what application it is carrying (video, audio, web, email...)
- ◆ Embedding of all modalities under program control via IP
- ◆ Profound impact on regulatory models





# The Freedom of the Internet

- ◆ End/End principle drives opportunity and experimentation – no permissions needed
- ◆ Layering future-proofs the IP layer for all transport media
- ◆ Convergence of traditional services
- ◆ The WWW open to all inputs and information sharing (e.g. note effect on scientific research)



# Broadband Observations

- ◆ Core Data Rates
  - ◆ Ultra Long-Haul (1500+ km) w/o repeaters
  - ◆ 40 Gb/s per lambda, 160 lambdas/fiber
  - ◆ 6.4 Tb/s per fiber
- ◆ Edge “broadband”
  - ◆ Asymmetry (DSL, Cable Modem, Satellite)
  - ◆ FTTx (Curb, Home, Building) - symmetric
  - ◆ 1-10 Gb/s near-mid term



# Wireless Edge Capacity

- ◆ 802.11x (10-100 Mb/s)
- ◆ 802.15, 802.16 (10-100 Mb/s)
- ◆ EV-DO (500 – 1000 Kb/s?)
- ◆ UWB (up to 1 Gb/s?)
- ◆ Phased Arrays (Frequency Reuse)
- ◆ Optical (10 Mb/s-10 Gb/s)?



# Global Capacity Requirements

- ◆  $10^9$  end devices @  $10^8$  bps =  $10^{17}$  bps
- ◆ Edge fanout = 100
- ◆ Edge router capacity:
  - ◆  $10^2 \times 10^8 = 10^{10}$  bps = 10 Gb/s
- ◆ Assume each net has a factor of 100 aggregation above edge
- ◆  $10^5$  networks carrying  $10^{12}$  bps each



## Pushing the limits

- ◆  $10^{17}$  bps aggregate demand
- ◆  $6.4 \times 10^{12}$  bps per fiber
- ◆  $10/6.4 \times 10^{16} / 10^{12}$  fibers  $\sim O(2000)$   
backbone interconnect fibers



## Application Computations

- ◆ Compressed DTV: 1.5 GB/1 hour film
- ◆ MovieBeam (Disney): 10 movies/week
- ◆ Repeat TX 5 times
- ◆  $50 \times 1.5 \text{ GB} = 75 \text{ GB}$
- ◆  $75 \text{ GB} / (7 \times 24 \times 3600 \text{ sec}) = O(1 \text{ Mb/s})$
- ◆ But note: @ 1Gb/s = 12 sec!!



## More Applications

- ◆ Chip Design/Performance Data
  - ◆ 500 GB (4 Tb)
  - ◆ @1 Gb/s = 4000 sec
  - ◆ @10 Gb/s = 400 sec
- ◆ VOIP/Video over IP (VIP?)
  - ◆ 2.3 B devices = 1.2 B “conversations”
  - ◆ VOIP: 1.2 B X 10 Kb/s = only 12 Tb/s
  - ◆ VIP: 1.2 B X 1 Mb/s = 1200 Tb/s ( $1.2 \times 10^{15}$ )
    - ◆ Only 1% of  $10^{17}$  bps net capacity



# Sensor Networks

- ◆ Environmental sensors (HVAC, pollutants, meteorological, security, terroir...)
- ◆ Equipment instrumentation (automobiles, appliances, buildings, light bulbs/sockets, power plants...)
- ◆ Vital sign monitoring (pulse, EKG, EEG, oxygenation, blood factors, ...)
- ◆ On the order of billions of sensors
- ◆ 100 devices/person X 6 B X 1000 bps
  - ◆ =  $6 \times 10^{14}$  bps



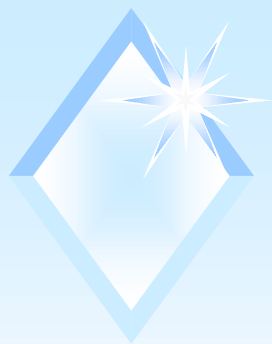
# Transaction Processing

- ◆ 6 B X 2 hrs video/day downloaded
  - ◆ 6 B X 9 GB/day =  $6 \times 10^9 \times 72 \times 10^9$  bits/day =  $432 \times 10^{18}$  bits
  - ◆ about 1.2 hours at  $10^{17}$  bps
- ◆ 6 B X 200 email/day X 30KB/msg
  - ◆ O ( $3 \times 10^{17}$  bits/day)



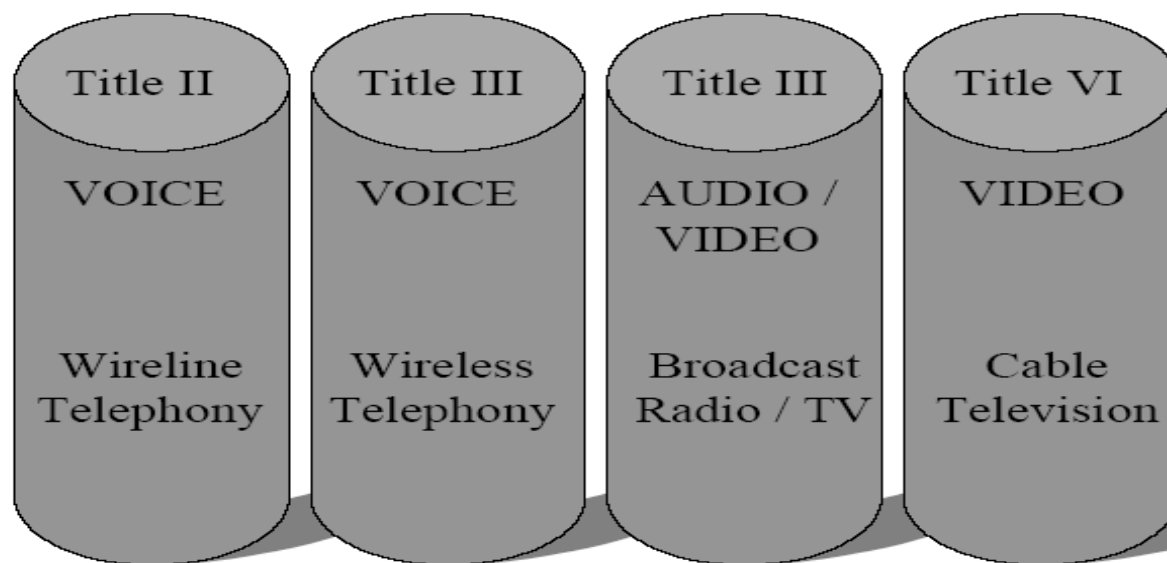
## Some Barriers to Broadband

- ◆ Router Architecture
- ◆ Policy
- ◆ Wireless Interference



# Vertical Regulation

## The Present “Silo Model” of Regulation





# MCI Proposed Model

Content/Transactions Layer

Applications Layer

Logical Network Layer

Physical Network Layer

Transport

Access



# Regulatory Layering

- ◆ Confine regulation to appropriate layer
- ◆ Minimize layer-crossing regulation
- ◆ Fit regulation to appropriate layer to avoid over-regulation or under-inclusion
- ◆ Defend against abuse of market power control of one layer to control higher ones
- ◆ Regulate only when market forces at a given layer fail to provide fair competition



## Applicability of Layers Analysis

- ◆ Jurisdiction
- ◆ Interconnection
- ◆ Inter-carrier compensation
- ◆ Universal Service
- ◆ Consumer welfare, safety, accessibility
- ◆ New Network investment
- ◆ Retail rate regulation



# Internet expansion





# Internet-enabled Appliances





# SIP Telephony

- ◆ Session Initiation Protocol Telephones
- ◆ Cisco Systems, Pingtel, etc.
- ◆ “email” addressing
- ◆ ENUM:



1.1.9.3.0.6.5.3.0.7.1.e164.arpa = sip:vinton.g.cerf@mci.com

*(any domain name)*

*NAPTR (naming authority pointer)*

*The power of SIP*



# Videoconferencing online

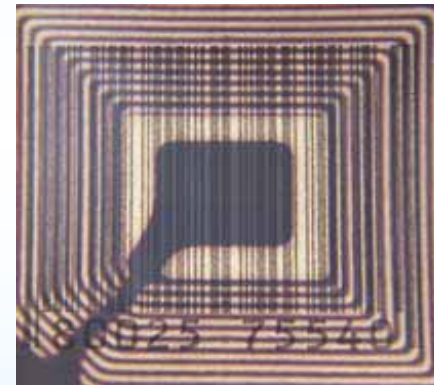
- ◆ Video-conferencing is a reality.
- ◆ High speed access is preferable but it can be made to work at dial up speeds (jerkily)
- ◆ Many suppliers





# RFID

- ◆ Toll-Road passive transponder
- ◆ Consumer product identifier (like UPC)
- ◆ Drug/Food shelf-life and identification
- ◆ Patient identification





# Internet-enabled Devices

- ◆ Programmable – Java, Python, etc.
- ◆ Examples:  
WebTV, Palm-Pilot, Mobiles, Video games, Picture Frames, Washing Machines, Surf Board!
- ◆ Refrigerator (and the bathroom scales)
- ◆ Automobiles (Japan, Germany)
- ◆ Internet-enabled wine corks (also note new quantum theory of wine: Schrödinger's wine bottle)
- ◆ Internet-enabled socks
- ◆ Universal Remote Control



## Side Effects of “Free”

- ◆ FIDONet (telephone store/forward email)
  - ◆ Replaced by wide area, managed services
  - ◆ Note similarity to “mesh” networks
- ◆ SPAM, SPIM, SPIT



# Convergence/Integration

- ◆ IP provides transport
  - ◆ Real-time and store/forward
  - ◆ Latter is just file transfer (any speed)
- ◆ Multimedia files – editable objects
  - ◆ Standards for interpretation, editing
  - ◆ Data type for program invocation
  - ◆ User interaction, immersion
  - ◆ Platform independence



# Smart Media Systems

- ◆ Cable, Satellite, Broadcast become file transfer facilities for all digital content
- ◆ Ancillary information makes these media data broadcasting carousels
- ◆ Computer screens, PDAs and TVs are display surfaces and interaction tools
- ◆ Challenge: getting this architecturally right (clean, structured)



## Conclusions

- ◆ Telecom (all modes) rapidly changing to be general digital transport service
- ◆ Digital media become data types subject to manipulation and control
- ◆ IP becomes platform control medium
- ◆ Interactive immersion
- ◆ User control of scheduling



Cerf's slides and other  
Internet information can be  
found at:

[www.mci.com/cerfsup](http://www.mci.com/cerfsup)

[www.isoc.org/internet](http://www.isoc.org/internet)

[livinginternet.com](http://livinginternet.com)

[www.ipnsig.org](http://www.ipnsig.org)

[www.dtnrg.org](http://www.dtnrg.org)