

Internet Foundations

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Internet Foundations

- Internet standardization
- Internet architecture
- basic Internet protocols: IP, UDP, TCP, ...

See <http://www.cs.columbia.edu/~hgs/internet> for resources.

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Internet Standards

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Who makes the rules?

ITU.T (itu.int): telecom standards by 16 study groups:

- E. Overall network operation, telephone service (E.164)
- G. transmission systems and media, digital systems and networks (G.711)
- H. Audiovisual and multimedia systems (H.320, H.323)
- V. Data communication over the telephone network (V.24)
- X. Data networks and open system communications (X.25, X.400, X.500)

IETF and IESG (ietf.org): (Internet Engineering Task Force, ... Steering Group)
develop/bless protocols ("RFCs")
open admission, but not quite egalitarian

W3C: HTML, XML, SVG, SMIL, voiceXML, ...

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Internet Operational Bodies

ISOC: membership organization; legal “home” of IETF

IANA: (Internet Assigned Numbers Authority) assigns numbers, top-level domains

NANOG: North American Network Operators Group

ICANN: administers IANA, TLD registrars

RIPE, ARIN, APNIC: hands out blocks of addresses, regionally

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IETF: WG + IESG + IAB

Internet Architecture Board: IAB

- architectural oversight
- process appeals
- elected by ISOC through nominations committee

Internet Engineering Steering Group (IESG): approves standards, composed of area directors

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IETF Areas

- general (1): POISSON
- user services (2): handbooks, guides, standard policies
- applications (29 WGs): calendar, LDAP, NNTP, IMPP, URN, ...
- operations and management (22): SNMP, MIBs, routing issues, benchmarking
- security (19): IPsec, S/MIME, PGP, XML security, firewall
- transport (23): RTP, SIP, RTSP, RSVP admission, TCP, SCTP
- routing (14): multicast, mobile IP, IS-IS, BGP
- internet (15): IPv6, IP over x , interface MIBs, PPP, zeroconf
- sub-ip (7): MPLS, IP over optical

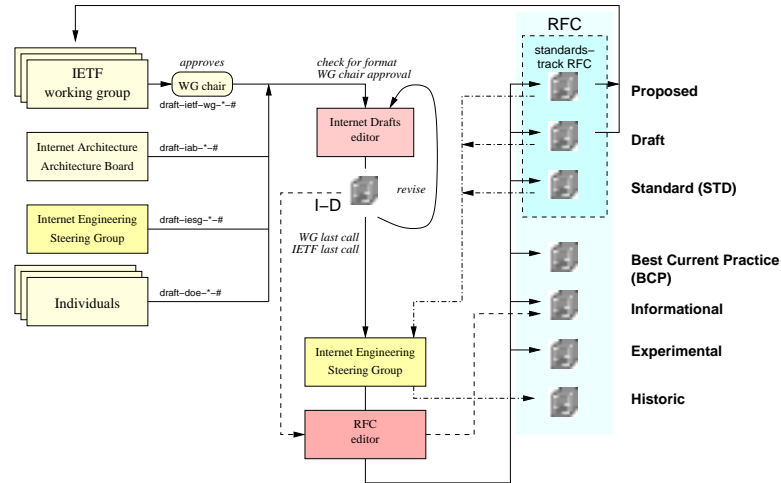
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IETF Working Groups

- headed by chair(s) designated by AD
- should be single, well-defined topic
- discussions on public mailing list
- small groups of authors do detail work
- meet at IETF (three times a year)
- possibly interim meetings
- done \Rightarrow dissolve, but sometimes linger

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IETF standards process



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Standardization process (RFC 2026)

1. new topic \Rightarrow BOF at IETF meeting
2. if response, create working group with charter
3. create Internet drafts = temporary (≤ 6 months) working drafts
4. status and discussion presentations at IETF meetings
5. working group last call
6. IETF last call
7. IESG "votes" (by consensus)
8. published as RFC: *proposed standard*
9. 2 implementations + ≥ 6 months \Rightarrow *draft standard*
10. operational experience + 4 months \Rightarrow *Internet standard (STD)*

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RFCs

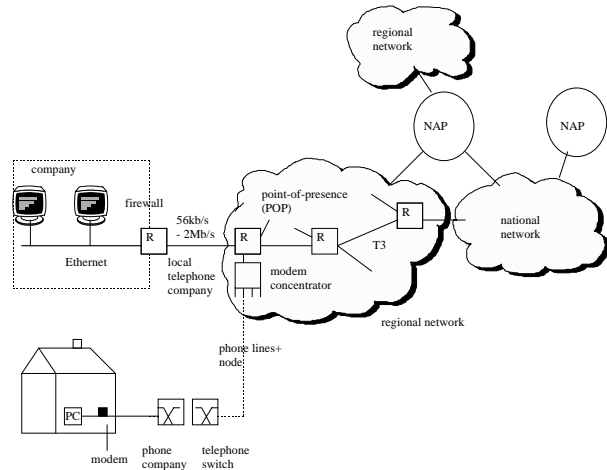
- ASCII + PostScript, no charge (see www.normos.org)
- published RFCs never change (no IP-1994)
- also:
 - experimental
 - informational (possibly "FYI")
 - historic(al)
- anybody can submit RFC, but editor can filter for content, conflict with existing work
- check the April 1 ones... (RFC 1149)

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Internet Access and Infrastructure

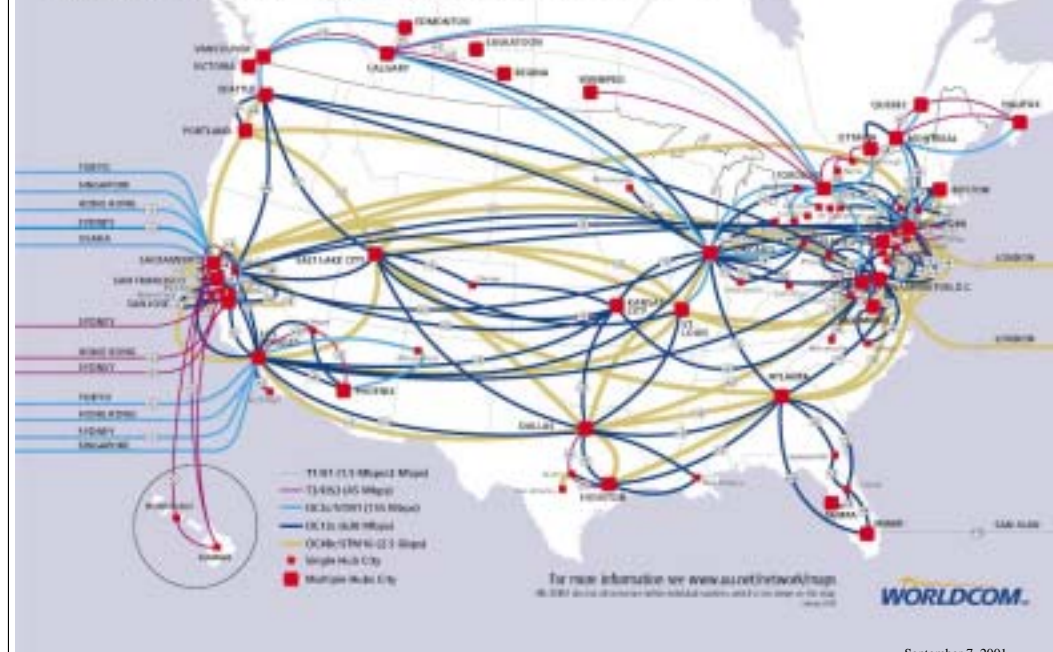
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Network Access and Interconnection



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WorldCom's North America UUNET Internet network



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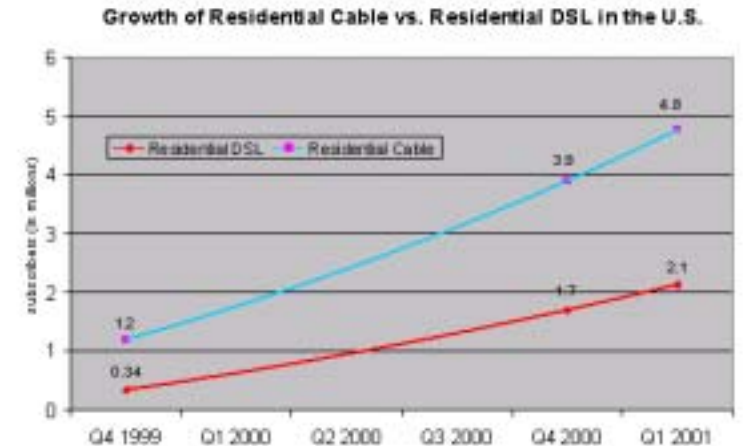
Large Consumer ISPs

- 201 million Internet users in the world, 112.4 million in U.S. and Canada (1 subscriber = 2.5 users!).
- many outsource network or modems (e.g., AOL to GTE, UUnet and Sprint)

company	subscribers (10 ⁶) Aug. 2001
AOL	25.5
Microsoft Network	6.5
EarthLink	4.9
NetZero	3.4
Prodigy	3.3
Juno Online	3.3
small ISPs (below 350k)	6.4
Total	70.7

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Residential Cable Modems and DSL

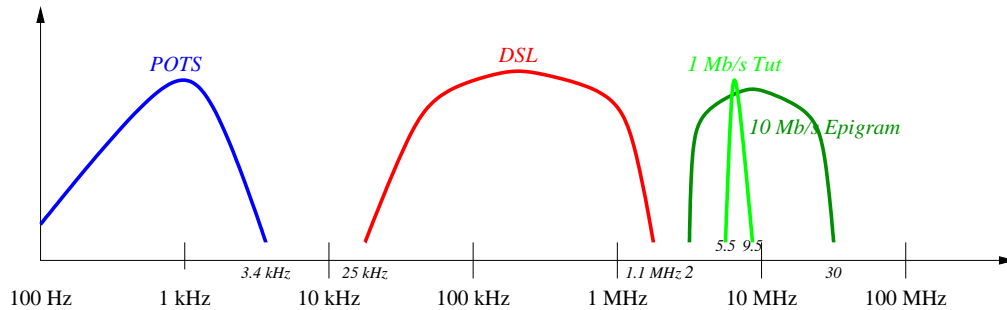


4.1m DSL total, including small businesses

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Home Networking

phone lines 1-10 Mb/s, operate at higher frequency than DSL
 power lines < 10 Mb/s
 wireless 1-11 Mb/s in 2.4 GHz band (3 ch, IEEE 802.11b, 300')
 < 50 Mb/s in 5 GHz band (8 ch, IEEE 802.11a, 200')



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Carriers

About 40 *tier-1 backbones*, use various *right-of-ways*; some just IP (“ISPs”), others also ATM or FR (carriers)

Carrier	right-of-way	fibermiles
UUnet (Worldcom)		
Sprint		
GlobalCrossing	mostly cross-oceanic	20,000 (U.S.)
AT&T Worldnet		
Level3	railroad?	11,000 (goal: 20,000)
PSINet (Chapter 11)	leased	
Qwest	railroad	104,000
Williams	pipelines	25,000
Enron	pipelines, HV	
Exodus (hosting)		
Verio (NTT)		

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Internet Access

method	media	downstream	upstream
modem	POTS	≤ 53 kb/s	33.6 kb/s
Intercast	VBI	150 kb/s	modem
ISDN	POTS	128 kb/s	128 kb/s
DSL	POTS	160 kb/s	160 kb/s
ADSL	POTS	0.6...9 Mb/s	16...640 kb/s
cable modem	CATV	10 Mb/s	1 Mb/s
T1	copper	1.5 Mb/s	1.5 Mb/s
T3	fiber, copper	45 Mb/s	45 Mb/s

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Network utilization

Averaged over one week:

local phone line	4%
U.S. long distance switched voice	33%
Internet backbones	10-15%
private line networks	3-5%
LANs	1%

- peak personal-use hours: 5-11 pm
- “world wide wait”: web servers? DNS? NAPs? access?
- average speed: 40 kb/s

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ISP Service

- average connect time: 310.3 min/month home, 417.4 min/month work \Rightarrow \$3.85 hour
- 66 MB average transfer/month \Rightarrow 33 c/MB
- 10:1 modem concentration ratio, also 4:1 (business) or 10:1 (consumer) DSL oversubscription ratio
- T1: 500 GB/month each direction \Rightarrow 0.3c/MB (\$1200-1500/month)
- but ISP T1 utilization \approx 40-45%
- ISP costs: \$2.50/month for phone line, \$2/month for equipment depreciation, \$0.20/month for network
- fiber: \$30,000-\$50,000/mile

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ADSL Limits

name	Mb/s	distance (ft)	km	
DS1 (T1)	1.544	18,000	4.5	<80%
E1	2.048	16,000	4.1	
DS2	6.312	12,000	3.0	
E2	8.448	9,000	2.3	
1/4 STS-1	12.960	4,500	1.1	
1/2 STS-1	25.920	3,000	0.8	
STS-1	51.840	1,000	0.3	
OC-3	155.000	100	0.03	

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ADSL Pricing Example

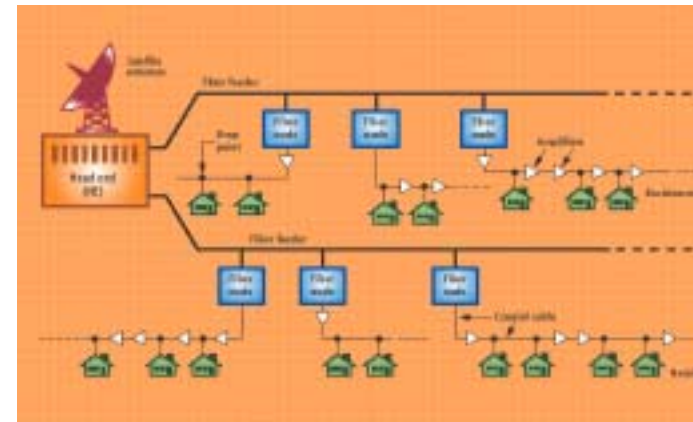
Verizon (for NJ), August 2001:

downstream	upstream	rate
640 kb/s	90 kbs/s	\$ 49.95
1.5 Mb/s	128 kb/s	\$ 59.95
384 kb/s	384 kb/s	\$ 69.95
1.5 Mb/s	384 kb/s	\$ 79.95

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Cable plant architecture

HFC = hybrid fiber-coax architecture



A. Dutta-Roy, "Cable - it's not just for TV", *IEEE Spectrum*, May 1999; © 1999 IEEE

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Cable plant architecture

- coax cable: < 1 GHz bandwidth, typically 500 MHz
- 35 (80) TV channels in typical older (newer) CATV systems = 200 (500) MHz
- 500–2000 homes for single headend or fiber node
- head-end to residence < 80 km
- fiber node to residence < 350 m
- US: 67% of households have, 95 mio. residence “passed”

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Cable modems

- always-on, but maybe temporary IP addresses
- hybrid fiber coax
- CMTS (cable modem termination system) = “headend”
- Ethernet interface to user’s PC
- but: conversion to bidirectional amplifiers, power
- DHCP + network address translation (NAT) or PPP-over-Ethernet
- conversion cost: \$200–\$800/household

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Cable modem standards

- Data-Over-Cable Service Interface Specification (DOCSIS) 1.1
- IEEE 802.14: ATM MAC
- Multimedia Cable Network System Partners (MCNS): contention
- Davic (Europe)

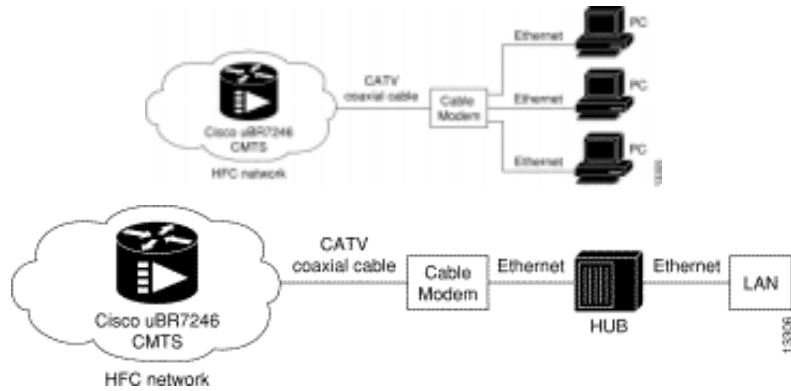
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Cable modem network modes



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Cable modem: downstream

- one or more 6 MHz channels in 54–550 MHz range
- typical bit consumption (no A/V): 40 kb/s, 4 kb/s upstream
- 30-50% active \Rightarrow 420 customers per channel
- 64 QAM (6 bits/symbol) $\Rightarrow \leq 30$ Mb/s
- newer equipment: 256 QAM $\Rightarrow 40$ Mb/s

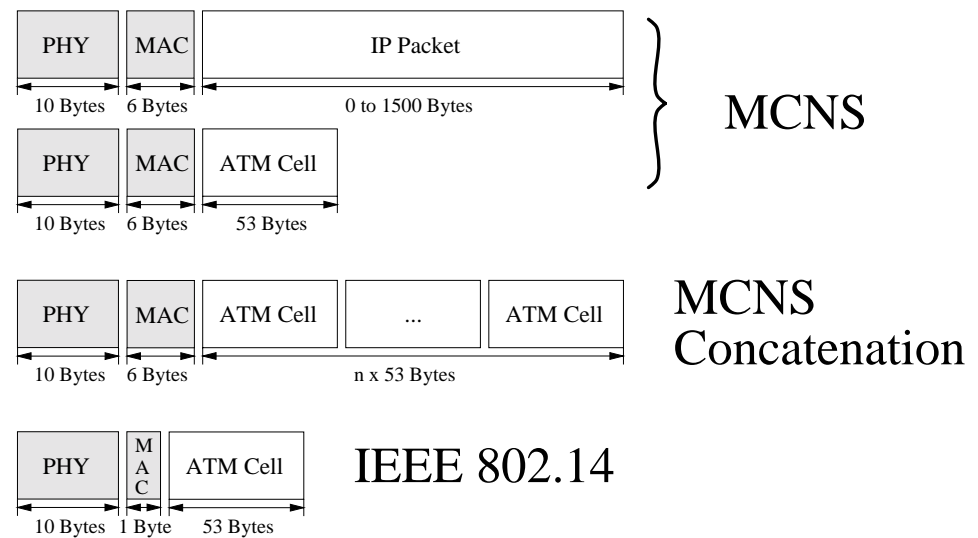
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Cable modem: upstream

- 5–42 MHz (usually band < 3 MHz, typically 200 kHz)
- noise aggregation \Rightarrow QPSK with 2 bits/symbol (5 Mb/s)
- actual throughput: 768 kb/s
- can't use Ethernet-style CDMA.
- TDMA variation: headend asks for potential senders
- headend returns *grant*: 2^k 6.25 μ s mini slots
- send 6-byte request to transmit \Rightarrow delay variation!
- encryption: 40/56 bit DES

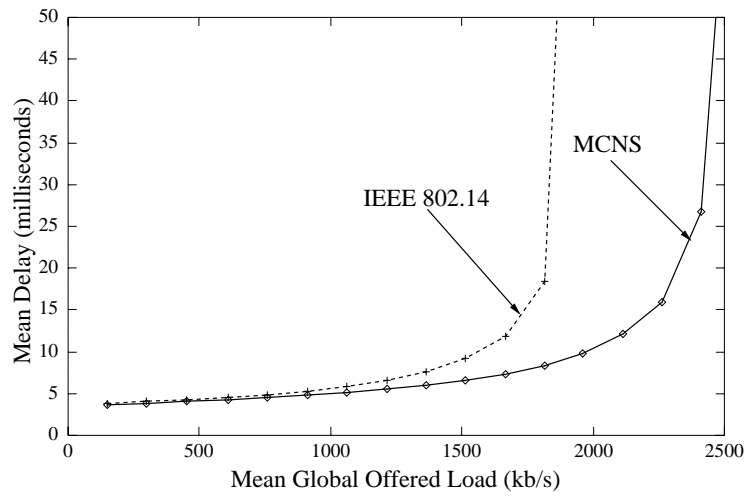
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Cable modems: IEEE 802.14 vs. MCNS



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Cable modems: access delay



N. Gollmie, F. Mouveaux, D. Su, "A comparison of MAC protocols for hybrid fiber/coax networks: IEEE 802.14 vs. MCNS", ICC, June 99.

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