Internet Foundations

Internet Foundations

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

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

Internet Standards

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, . . .

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

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

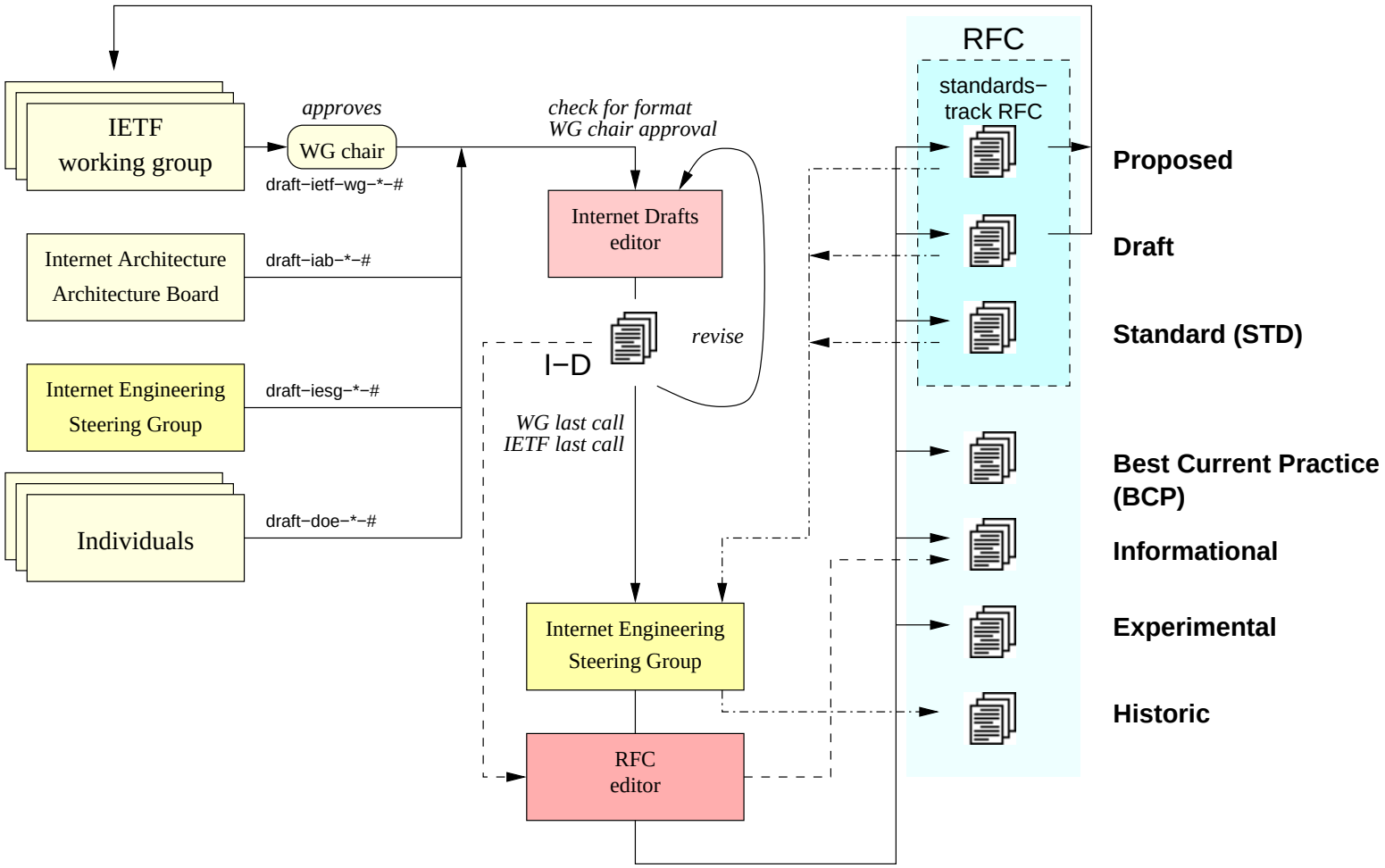
IETF Areas

- 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

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 ➠ dissolve, but sometimes linger

IETF standards process



Standardization process (RFC 2026)

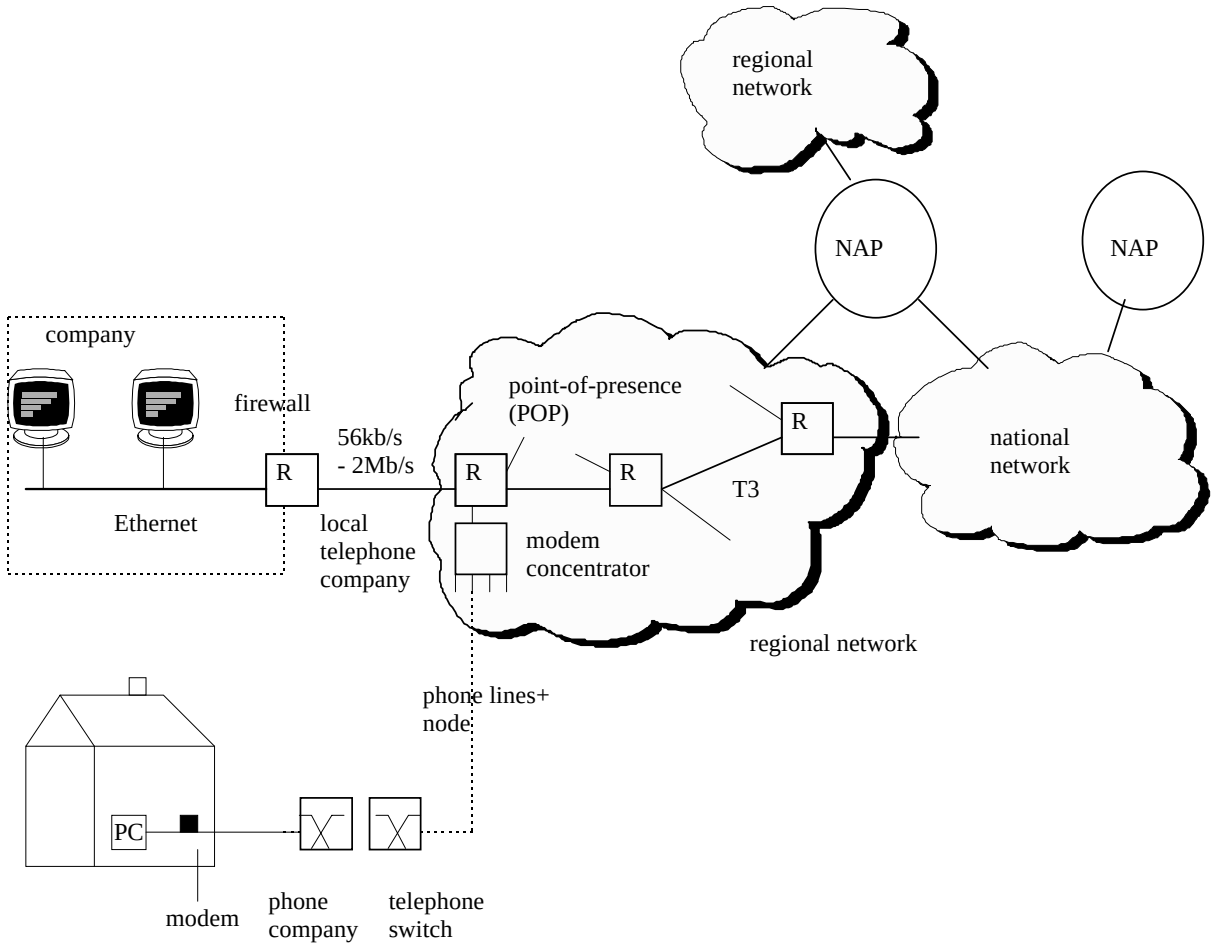
1. new topic ➠ BOF at IETF meeting
2. if response, create working group with charter
3. create Internet drafts = temporary ($\leq$ 6 months) working drafts
4. status and discussion presentations at IETF meetings
5. working group last call
6. IETF last call
7. IESG “votes” (by consensus)
8. published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

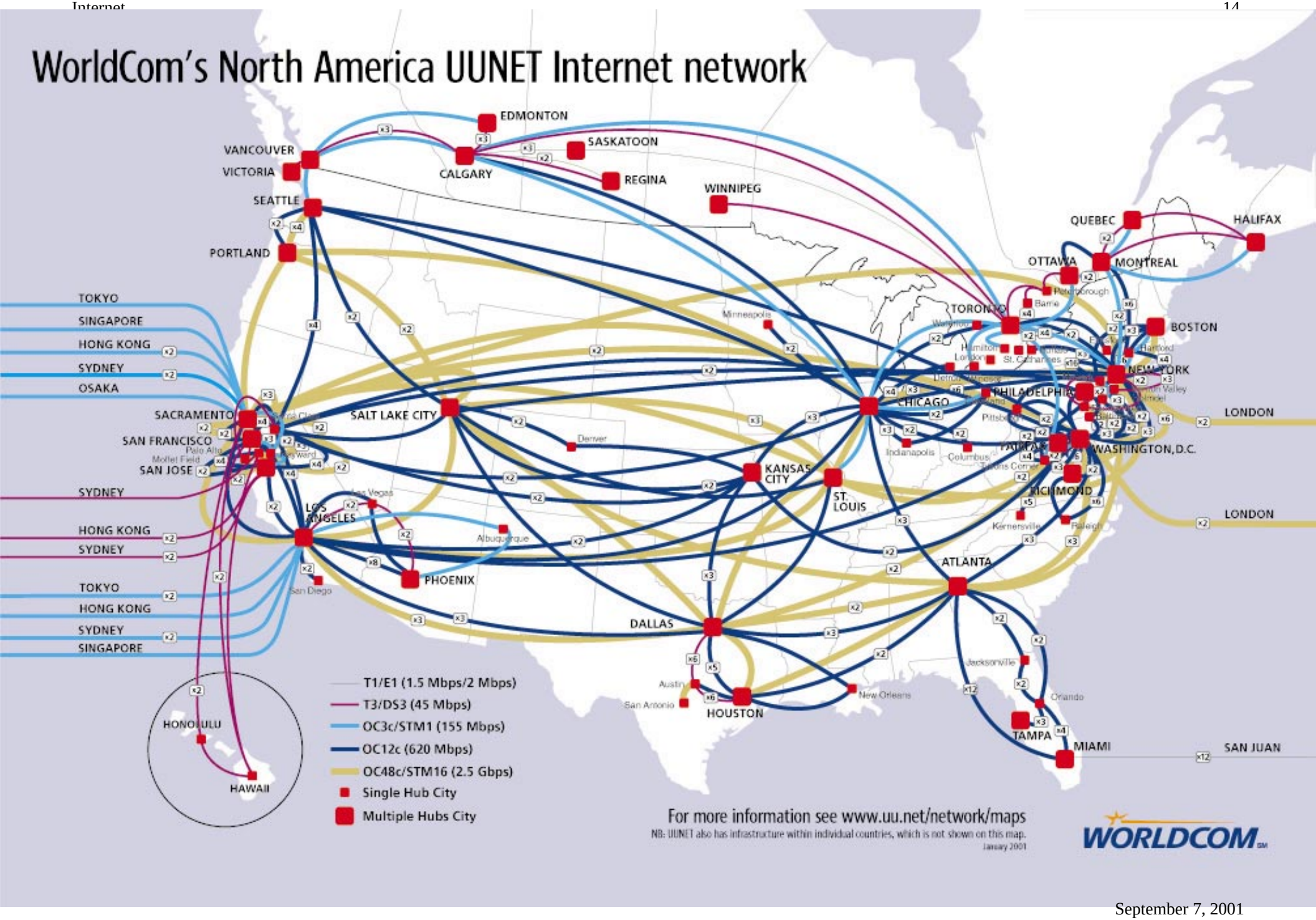
RFCs

- 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)

Internet Access and Infrastructure

Network Access and Interconnection



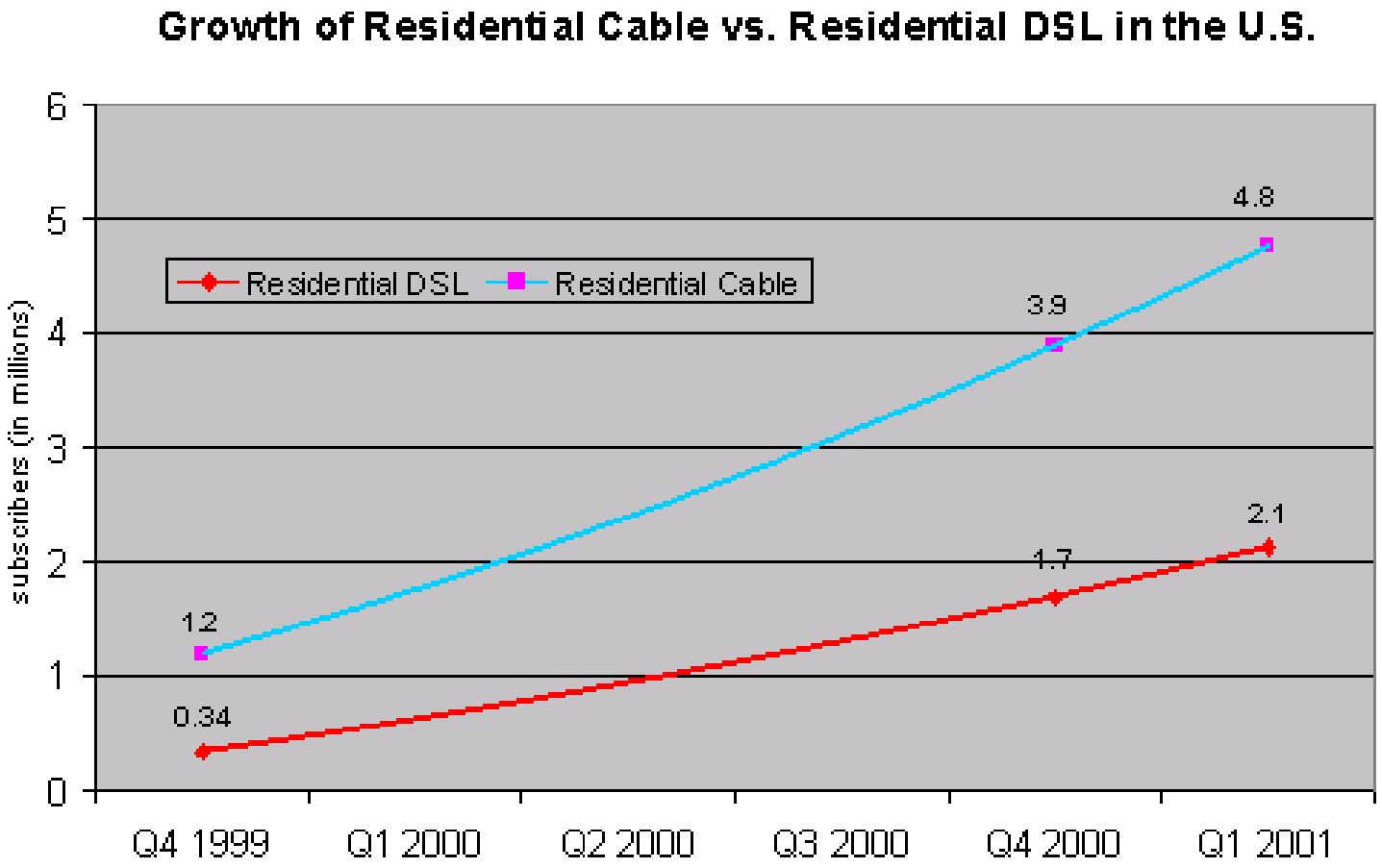

WorldCom's North America UUNET Internet network
EDMONTON
VANCOUVER
VICTORIA
CALGARY
SASKATOON
REGINA
WINNIPEG
SEATTLE
PORTLAND
QUEBEC
HALIFAX
OTTAWA
MONTREAL
TORONTO
BOSTON
NEW YORK
PHILADELPHIA
CHICAGO
WASHINGTON, D.C.
SALT LAKE CITY
SACRAMENTO
SAN FRANCISCO
SAN JOSE
KANSAS CITY
ST. LOUIS
ATLANTA
LOS ANGELES
PHOENIX
DALLAS
HOUSTON
TAMPA
MIAMI
HONOLULU
HAWAII
TOKYO
SINGAPORE
HONG KONG
SYDNEY
OSAKA
LONDON
SAN JUAN
T1/E1 (1.5 Mbps/2 Mbps)
T3/DS3 (45 Mbps)
OC3c/STM1 (155 Mbps)
OC12c (620 Mbps)
OC48c/STM16 (2.5 Gbps)
Single Hub City
Multiple Hubs City
For more information see www.uu.net/network/maps
NB: UUNET also has infrastructure within individual countries, which is not shown on this map.
January 2001
WORLDCOM

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

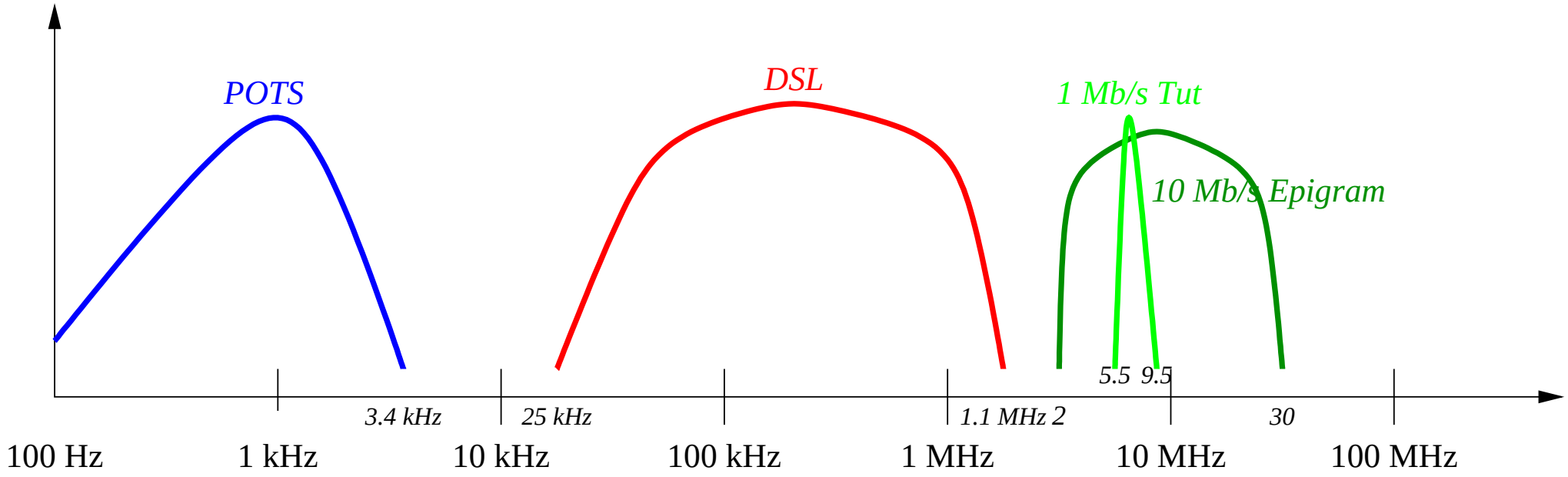
Residential Cable Modems and DSL



4.1m DSL total, including small businesses

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')



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)		

Internet Access

method	media	downstream	upstream
modem	POTS	$\leq$ 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

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

ISP Service

- average connect time: 310.3 min/month home, 417.4 min/month work ➠ $3.85 hour
- 66 MB average transfer/month ➠ 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 ➠ 0.3c/MB ($1200-1500/month)
- but ISP T1 utilization ≈ 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

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	

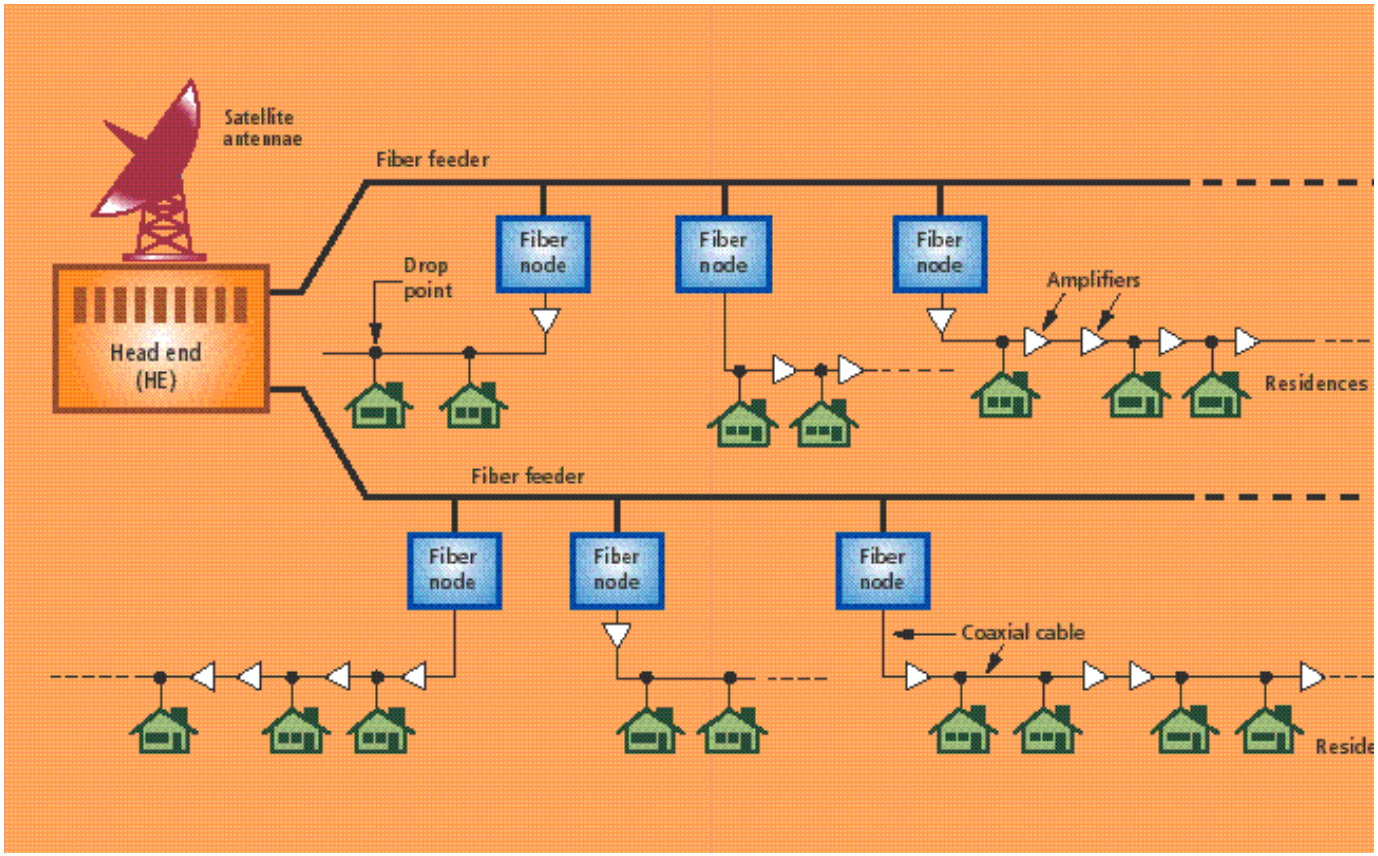
ADSL Pricing Example

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

Cable plant architecture

HFC = hybrid fiber-coax architecture



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

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”

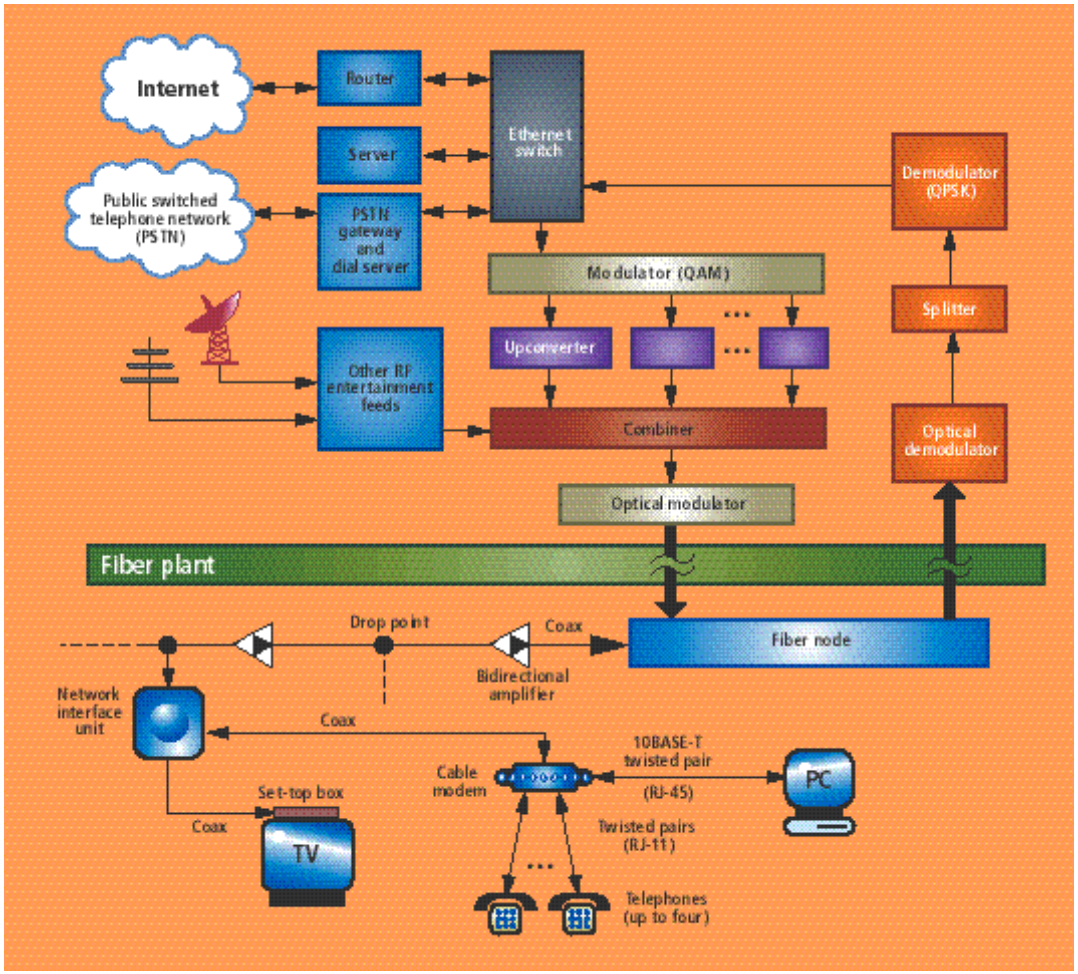
Cable modems

- 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

Cablem 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)

Cable plant architecture



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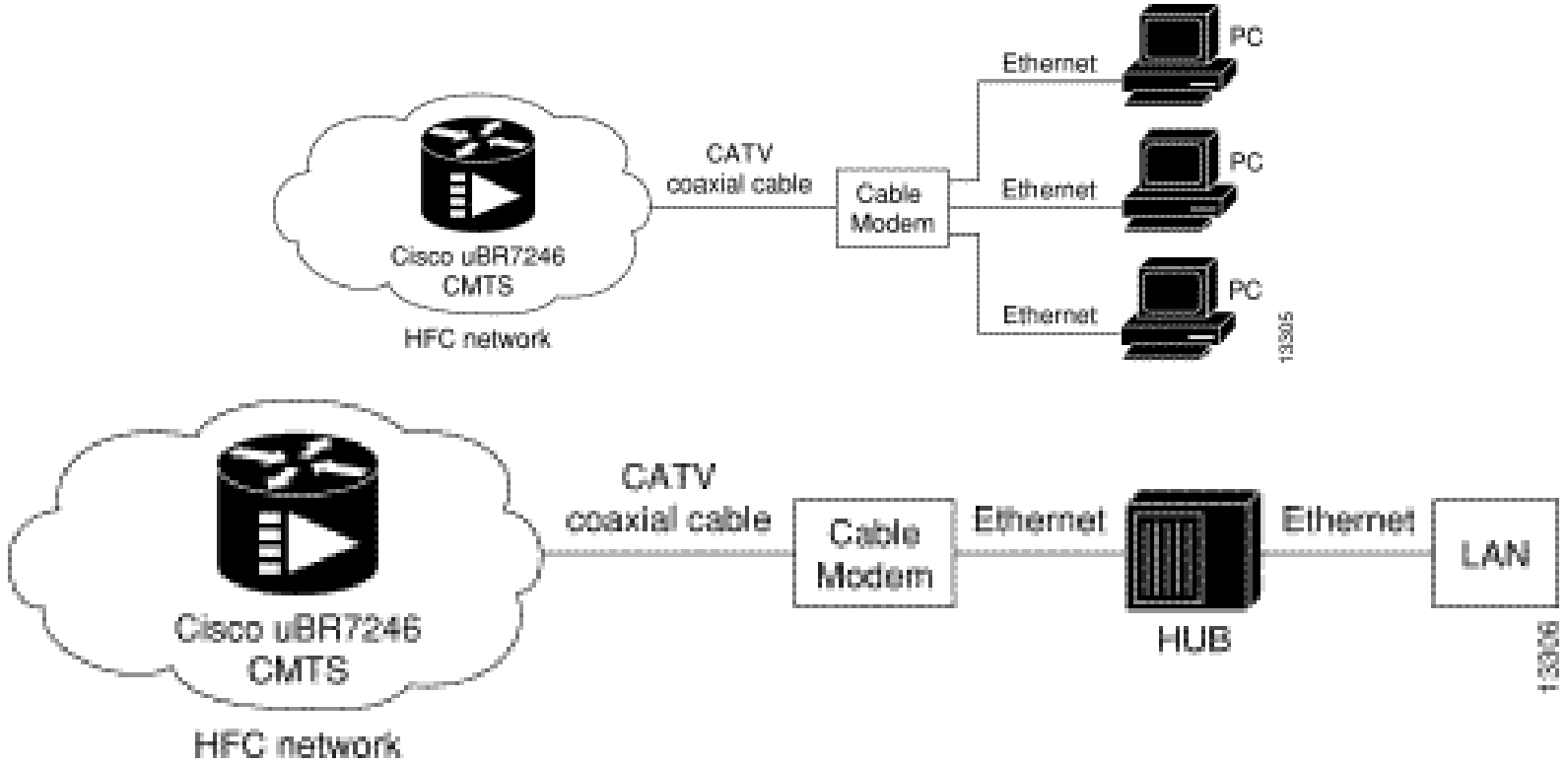
Cable modem network modes



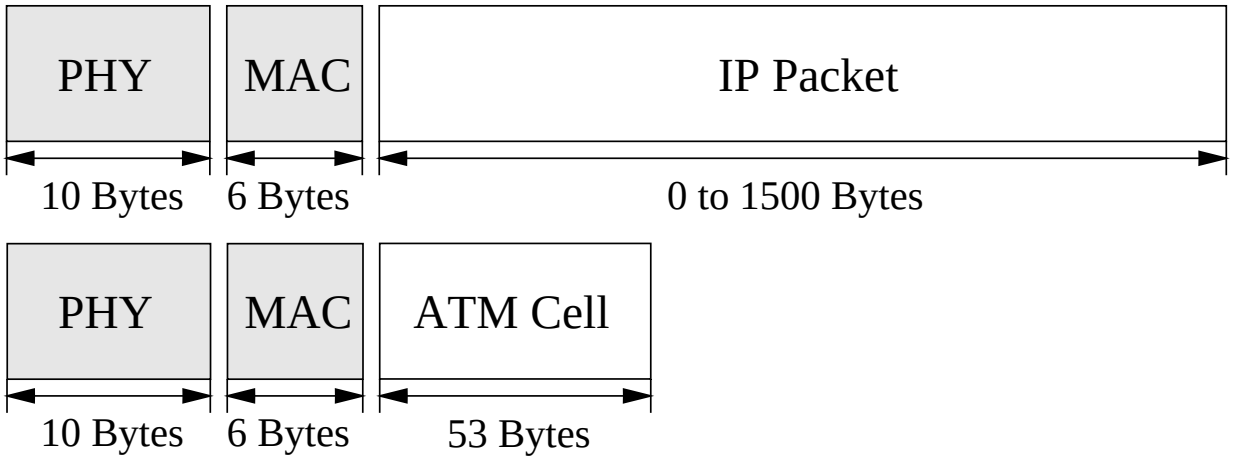
Cable modem: downstream

- 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 ➠ 420 customers per channel
- 64 QAM (6 bits/symbol) ➠ $\leq$ 30 Mb/s
- newer equipment: 256 QAM ➠ 40 Mb/s

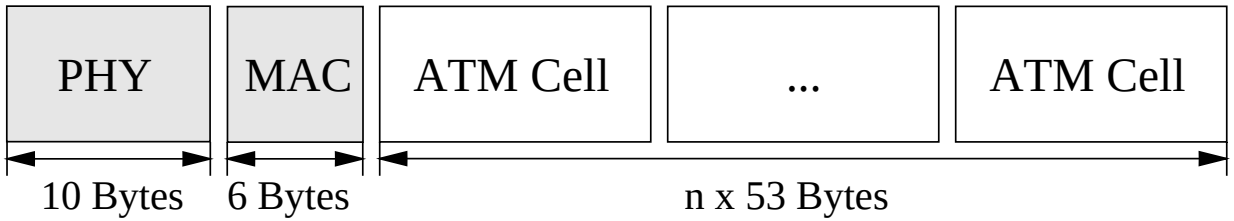
Cable modem: upstream

- 5–42 MHz (usually band $<$ 3 MHz, typically 200 kHz)
- noise aggregation ➠ 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 μs mini slots
- send 6-byte request to transmit ➠ delay variation!
- encryption: 40/56 bit DES

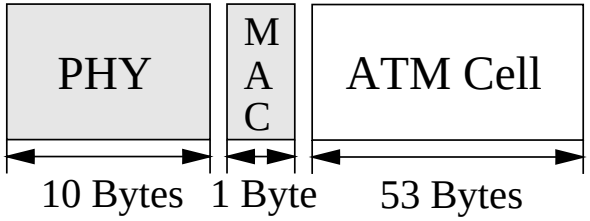
Cable modems: IEEE 802.14 vs. MCNS



MCNS

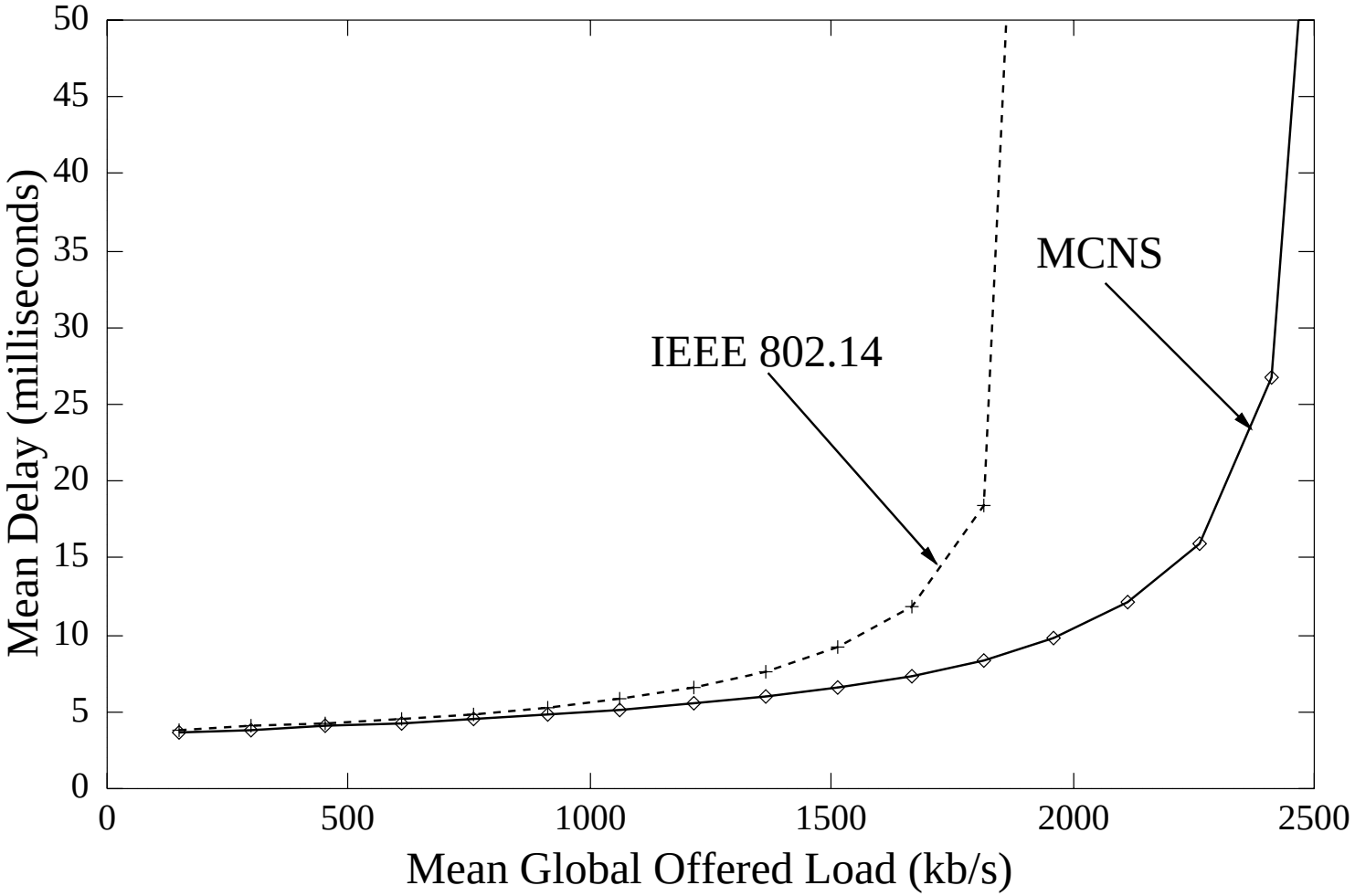


MCNS Concatenation



IEEE 802.14

Cable modems: access delay



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