Internet Foundations
Internet Foundations

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

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 WG): calendar, LDAP, NNTP, IMPP, URN, …
- operations and management (22): SNMP, MIBs, routing issues, benchmarking
- 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

- IETF working group
- Internet Architecture Board
- Internet Engineering Steering Group
- Individuals

RFC editor

WG chair

Internet Drafts editor

check for format
WG chair approval

I-D

revise

WG last call
IETF last call

RFC

standards-track RFC

Proposed

Draft

Standard (STD)

Best Current Practice (BCP)

Informational

Experimental

Historic

September 7, 2001
Standardization process (RFC 2026)

1. new topic ➔ 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 ➔ 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

- Local telephone company
- Regional network
- National network
- Point-of-presence (POP)
- Modem concentrator
- T3
- Ethernet firewall
- PC
- Modem
- Phone company
- Telephone switch
- Phone lines
- 56kb/s - 2Mb/s
- Dormitory
- Internet

September 7, 2001
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)

<table>
<thead>
<tr>
<th>company</th>
<th>subscribers ($10^6$) Aug. 2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>AOL</td>
<td>25.5</td>
</tr>
<tr>
<td>Microsoft Network</td>
<td>6.5</td>
</tr>
<tr>
<td>EarthLink</td>
<td>4.9</td>
</tr>
<tr>
<td>NetZero</td>
<td>3.4</td>
</tr>
<tr>
<td>Prodigy</td>
<td>3.3</td>
</tr>
<tr>
<td>Juno Online</td>
<td>3.3</td>
</tr>
<tr>
<td>small ISPs (below 350k)</td>
<td>6.4</td>
</tr>
<tr>
<td>Total</td>
<td>70.7</td>
</tr>
</tbody>
</table>
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)

<table>
<thead>
<tr>
<th>Carrier</th>
<th>right-of-way</th>
<th>fibermiles</th>
</tr>
</thead>
<tbody>
<tr>
<td>UUnet (Worldcom)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sprint</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GlobalCrossing</td>
<td>mostly cross-oceanic</td>
<td>20,000 (U.S.)</td>
</tr>
<tr>
<td>AT&amp;T Worldnet</td>
<td>railroad?</td>
<td>11,000 (goal: 20,000)</td>
</tr>
<tr>
<td>Level3</td>
<td>leased</td>
<td></td>
</tr>
<tr>
<td>PSINet (Chapter 11)</td>
<td>railroad</td>
<td>104,000</td>
</tr>
<tr>
<td>Qwest</td>
<td>pipelines</td>
<td>25,000</td>
</tr>
<tr>
<td>Williams</td>
<td>pipelines, HV</td>
<td></td>
</tr>
<tr>
<td>Enron</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exodus (hosting)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verio (NTT)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Internet Access

<table>
<thead>
<tr>
<th>method</th>
<th>media</th>
<th>downstream</th>
<th>upstream</th>
</tr>
</thead>
<tbody>
<tr>
<td>modem</td>
<td>POTS</td>
<td>≤ 53 kb/s</td>
<td>33.6 kb/s</td>
</tr>
<tr>
<td>Intercast</td>
<td>VBI</td>
<td>150 kb/s</td>
<td>modem</td>
</tr>
<tr>
<td>ISDN</td>
<td>POTS</td>
<td>128 kb/s</td>
<td>128 kb/s</td>
</tr>
<tr>
<td>DSL</td>
<td>POTS</td>
<td>160 kb/s</td>
<td>160 kb/s</td>
</tr>
<tr>
<td>ADSL</td>
<td>POTS</td>
<td>0.6…9 Mb/s</td>
<td>16…640 kb/s</td>
</tr>
<tr>
<td>cable modem</td>
<td>CATV</td>
<td>10 Mb/s</td>
<td>1 Mb/s</td>
</tr>
<tr>
<td>T1</td>
<td>copper</td>
<td>1.5 Mb/s</td>
<td>1.5 Mb/s</td>
</tr>
<tr>
<td>T3</td>
<td>fiber, copper</td>
<td>45 Mb/s</td>
<td>45 Mb/s</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>name</th>
<th>Mb/s</th>
<th>distance (ft)</th>
<th>km</th>
<th>&lt;80%</th>
</tr>
</thead>
<tbody>
<tr>
<td>DS1 (T1)</td>
<td>1.544</td>
<td>18,000</td>
<td>4.5</td>
<td>&lt;80%</td>
</tr>
<tr>
<td>E1</td>
<td>2.048</td>
<td>16,000</td>
<td>4.1</td>
<td></td>
</tr>
<tr>
<td>DS2</td>
<td>6.312</td>
<td>12,000</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>E2</td>
<td>8.448</td>
<td>9,000</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td>1/4 STS-1</td>
<td>12.960</td>
<td>4,500</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>1/2 STS-1</td>
<td>25.920</td>
<td>3,000</td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>STS-1</td>
<td>51.840</td>
<td>1,000</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>OC-3</td>
<td>155.000</td>
<td>100</td>
<td>0.03</td>
<td></td>
</tr>
</tbody>
</table>
## ADSL Pricing Example

Verizon (for NJ), August 2001:

<table>
<thead>
<tr>
<th>downstream</th>
<th>upstream</th>
<th>rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>640 kb/s</td>
<td>90 kbs/s</td>
<td>$49.95</td>
</tr>
<tr>
<td>1.5 Mb/s</td>
<td>128 kb/s</td>
<td>$59.95</td>
</tr>
<tr>
<td>384 kb/s</td>
<td>384 kb/s</td>
<td>$69.95</td>
</tr>
<tr>
<td>1.5 Mb/s</td>
<td>384 kb/s</td>
<td>$79.95</td>
</tr>
</tbody>
</table>
Cable plant architecture

HFC = hybrid fiber-coax architecture

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
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)
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) ➔ ≤ 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 $\mu$s mini slots
  - send 6-byte request to transmit ➔ delay variation!
- encryption: 40/56 bit DES
Cable modems: IEEE 802.14 vs. MCNS

MCNS

Concatenation

IEEE 802.14
Cable modems: access delay