Structure of the Internet

David Conrad
drc@isc.org
Internet Software Consortium
Introduction

“The Internet” does not exist!
- You can’t buy it
  - No one owns it
- You can’t connect to it
  - Really.
- You can’t regulate it
  - You can regulate parts

However, you can become a part of it
- But what exactly is “it”?
- How is it structured?
Agenda

- Organizational Structure
  - How the Internet is put together
  - Internet History
  - Executive TCP/IP Summary

- Administrative Structure
  - Support, development, user, and operations groups
Structure of the Internet

- Today, the Internet is composed of over 61,000 autonomously run interconnected networks
  - The only guarantee is that all networks use the TCP/IP protocols
- Each machine on each network can offer useful services
  - Or not -- entirely dependent on the site
  - Each user of the network can use those services
- First bi-directional electronic communications medium that supports:
  - One to one (unicast, e.g. email) One to many (multi-cast, e.g., electronic news)
- Key point: Internet component networks are operated AUTONOMOUSLY
  - You don’t connect to the Internet, you become part of it
In the Beginning

- The Internet was a research network with lots of computer geeks jabbering at each other
  - Sometimes even getting interesting work done
- A very homogeneous community with essentially the same culture/language/values

Now, the Internet has commercialized

- People are trying to use the Internet for real work
  - And for the most part, succeeding
- Some of those people may be nice or not so nice
  - UCE, crackers, con-artists, pornographers, etc.
  - Good Samaritans, hackers, philanthropists, etc.
    - The Internet reflects society
Structure of the Internet (cont’d)

- From a million miles up, the Internet looks hierarchical
  - Big ISPs (backbones) provide services to smaller ISPs
  - Smaller ISPs provide services to yet smaller ISPs
  - Somebody eventually provides services to end users
However, as you get closer in, this nice hierarchy breaks down
- private deals, performance fixes, etc.

- Everybody provides services to the end users
- Service providers connect to multiple service providers
- End users connect to multiple service providers
Connectivity

- In order to exchange traffic, an organization must connect with another organization and agree to pass traffic back and forth
  - Many possible conditions and clauses
  - Two types of relationships between the 2 organizations
    - Customer/Provider
    - Peer to peer
- In a given geographical region, organizations tend to want to meet at the same place
  - Easier to make deals with a bunch of people at the same place, than deals at multiple places
    - Also saves on infrastructure costs
- Thus: the creation of a connection point
  - Known as *Internet Exchanges* (IXes)
    - NAPs, MAEs, etc.
Exchange Points

Who connects to exchange points?
- Almost always Internet Service Providers
  - The question is: who is a customer and who is a peer?
    - Customers pay, peers don’t
  - Non-ISPs can probably place equipment at an exchange point
    - But ISPs want customers who pay, not peers, so the ISPs probably won’t accept the customer’s traffic

Who runs exchange points?
- Usually a neutral body, unbiased to any organization connecting there.
  - Tending towards commercial organizations
These exchange points become Internet focal points

- Major exchanges exist in:
  - The US: MAE-East, MAE-West, the NAPs, etc.
  - Europe: The D-GIX points, LINX, etc.
  - Asia and Pacific Rim: HKIX, NZIX, JPIX, NSPIXP-2, etc.

- Generally, exchanges spontaneously generate where there is a high concentration of ISPs
- Provide a way to keep local traffic local
  - Sometimes ISPs may not want this

- Large ISPs may not want to connect
  - IXes encourage smaller ISPs to want to “peer” with large ISP
Current Structure of the Internet
History of the Internet

- **Stage 1**: DARPA Experiment, operation (1968-1973)
  - Kahn poses internet challenge 2Q 1973
  - Cerf-Kahn sketch gateway and TCP in 2Q 1973
  - Cerf-Kahn paper published May 1974
  - Cerf team full spec - Dec 1974

- **Stage 2**: Enterprise Internets, R&A scaling (1984-1990)
  - 1984-DNS created, DARPA divests Internet
  - Jan 1983-ARPANet adopts TCP/IP, CSNet created, first real Internet begins
  - 1986-NSFNet created
  - 1989-first public commercial Internets created
  - 1990-ARPANet ceases

- **Stage 3**: Universality (1990-2001)
  - 1992-Internet Society
  - 1995-NSFNet ceases, non-USA nets >50%

**Internet Hosts**

- 1968: 1
- 1973: 1
- 1979: 1
- 1984: 1
- 1990: 1
- 1995: 1
- 2001: 1

**Copyright** © 1995 A.M.Rutkowski & Internet Society
History of the Commercial Internet

- 1989 -- First commercial ISPs (UUNet and PSI) start taking customers
  - NSFNet disallowed commercial use
  - NSFNet operator soon forms commercial side-business (ANS CO+RE)
  - Many NSFNet regionals start commercial services

- European Internet hampered by TCP/IP vs. OSI wars
  - First commercial ISP (EUNet) around 1991

- AP Region Internet also OSIified
  - First AP region commercial ISP (IIJ) in Japan 1992
Commercial Internet Exchange

- NSFNet provided only AUP compliant transit
  - ANS CO+RE provided commercial transit
    - Wanted to charge other commercials per byte
- Existing commercial ISPs were unhappy
  - Created the CIX
    - Explicitly disallowed usage based charging
- ANS became CIX member
  - CIX filtered transit between ANS and its resellers
    - But filters only applied to ANS
      - Legal wrangling occurred
- CIX forced to apply filters to all non-CIX members
  - No one noticed despite much concern
The Internet Today

- A self organizing collection of autonomous components
  - If you think the Internet can be controlled, see Chaos and Complexity Theory
    - However, you can control parts
- Commercial traffic far outweighs non-commercial
  - Electronic commerce will accelerate this trend
  - Non-commercial networks heading off on their own
- Exponential growth in nearly all areas
  - Number of users
  - Amount of traffic
The Physical and Link Layers

- TCP/IP runs on almost anything
  - Ethernet, FDDI, Cable TV, telephone wires, radio waves, barbed wire, carrier pigeon, etc.

- It runs better on some things than others
  - It is best not to shred the data (read: ATM)
  - It is best not to do error checking under IP (read: X.25)
  - It is best not to asynchronously switch (read: Frame Relay)

- It’s all a question of overheads
  - low prices can make even “icky” things appealing
  - or when you don’t have a choice...
The Internet Protocol

- IP is an abstraction of the underlying hardware
  - Ethernet, serial, barbed wire all look the same from above
  - The problem of dealing with multiple hardware types hidden

- IP is unreliable
  - throw it to the hardware and hope

- IP handles fragmentation and re-assembly
  - But you don’t want to fragment...

- Want more? See RFC 791

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>0</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version</td>
<td>IP Header Length</td>
<td>Type of Service</td>
<td>Total Packet Length</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identification</td>
<td>0</td>
<td>D</td>
<td>F</td>
<td>M</td>
<td>Fragment Offset</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time To Live</td>
<td>Protocol</td>
<td>Header Checksum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Source Address</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Destination Address</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Options</td>
<td>Padding</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The User Datagram Protocol

- UDP provides an unreliable datagram facility to the user
  - No retransmission, duplicate detection or flow control
  - Optional corruption detection
  - Extends IP to allow multiplexing
- Want more? See RFC 768

- About as minimal as you can get
  - Gives the application protocol developer complete freedom
  - But developer usually has to re-implement TCP features
- Mostly used for DNS and network file system protocols (e.g., Sun’s NFS)

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 |
| Source Port | Destination Port |
| Length | Checksum |
| payload |
The Transmission Control Protocol

- TCP provides a reliable connection oriented stream of data
  - No framing or concept of blocks of data -- just a stream of bytes
  - Concept of “urgent” data
- Want more? See RFC 793

TCP handles:
- connection establishment, termination and reset
- Detection of data corruption and duplication
- Retransmissions and flow control
  - Uses “sliding window”

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>0</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source Port</td>
<td>Destination Port</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sequence Number</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acknowledgement</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Offset</td>
<td>Reserved</td>
<td>U</td>
<td>R</td>
<td>C</td>
<td>A</td>
<td>K</td>
<td>P</td>
<td>S</td>
<td>H</td>
<td>R</td>
<td>S</td>
</tr>
<tr>
<td>Window</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Checksum</td>
<td>Urgent Pointer</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Options</td>
<td>Padding</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TCP vs. UDP

- **TCP**
  - Gives you exactly what you started with
  - Makes efficient use of the network, but has overhead

- **UDP**
  - Might (or might not) give you what you started with
  - Minimal possible overhead
An Application Sampler

- **TCP Applications**
  - HTTP (WWW)
  - SMTP (Email)
  - NNTP (Electronic News)
  - Telnet (remote login)
  - FTP (remote file access)
  - Network File System
  - Whois
  - Rlogin/Rsh/Rdump, etc.

- **UDP Applications**
  - Domain Name System
  - Network File System
  - RADIUS (remote authentication)
  - Network Time Protocol
  - Trivial File Transfer Protocol
Administrative Support Groups

- Internet Hierarchy
- The IANA
- Numbers Support
  - Regional Registries
  - Local Registries
- Names Support
  - Top Level DNS Administrators
    - ISO 3166 TLD Administrators
    - Generic TLD Administrators
- Other support groups
  - Protocol development
Internet Hierarchy (Politically Correct History)

- Internet Society Membership
- Internet Society Board of Trustees
- Internet Architecture Board
- Internet Assigned Numbers Authority
- ccTLD Registrars
- InterNIC
- APNIC
- ARIN
- RIPE-NCC
- Internet Service Providers
- End Users
- End Users
- ...
- End Users
Internet Hierarchy
(Bottom Up View)
The Internet Assigned Numbers Authority

- The IANA was the parent of all regional registries and top level domain name administrators
  - In some context at least, the IANA could be said to “own” all administrative resources on the Internet
  - Handed out all globally unique numbers (IP addresses, protocol numbers, port numbers, object IDs, etc.)

- The IANA consisted of
  - Four (part-time) people
    - Located at USC ISI in Marina Del Rey, CA, USA
  - Had a yearly budget of roughly US $250,000
  - Delegated as much responsibility as possible
The ICANN phase

- US Government wants to ‘devolve’ the Internet’s administrative function to self-regulatory structures
- A bunch of DNS crazies step into the room
- ICANN attempts to ‘work out’ the DNS mess
- Address infrastructure management actually left to the RIRs
- US Government increasingly nervous about the whole deal
- Watch this space!
Regional Registry History

- First NIC at Stanford Research Institute (SRI-NIC)
  - Located in California (near Stanford University)
  - Funded by DOD DARPA
- SRI replaced by GSI in Washington DC area
  - Lowest bidder
    - Unpleasant transition
  - DOD DCA provided funding
- NSF issued InterNIC 5 year Cooperative Agreement
  - Cooperative agreement issued in 1992
  - AT&T, General Atomics, and Network Solutions, Inc. each awarded part of InterNIC
InterNIC History

- InterNIC consisted of 3 parts
  - Registration Services operated by NSI
  - Database and Directory Services operated by AT&T
  - Information services operated by General Atomics

- In 1995, NSF held a mid-term review
  - NSI commended, but told to stop relying on US Government for funding
  - AT&T told to do more
  - GA fired

- In 1997, InterNIC spins off Address allocator (ARIN)
  - NSI focuses on (now hugely profitable) domains
Address Registry Hierarchy

ICANN

APNIC
- Asia and Pacific Rim
  - ISPs
  - Confederations

ARIN
- Americas and S. Africa
  - National NICs
  - ISPs

RIPE-NCC
- Europe, FSU and N. Africa
  - Local Internet Registries
  - ISPs
Regional Address Registries

- Registries allocate numbers
  - Internet addresses
    - (plus in-addr.arpa domains)
  - Autonomous System Numbers

- Currently three regional registries exist
  - APNIC, InterNIC, RIPE-NCC
    - All but InterNIC are self-funded
  - The IANA may create others as needs arise
    - AfriNIC and ALyCNIC have been discussed recently
Regional Registries (cont’d)

- Regional Registries are **NOT** regulatory bodies
  - They do not “license” ISPs
    - This is a national governmental issue
  - They are not the authority for who can or cannot connect to the Internet
    - Anyone can who is permitted by law in their country
  - They cannot control any organization
    - So complaining to them is pretty pointless

- Regional registries also don’t make the rules
  - The Internet community does
    - Regional Registries simply implement policy, they don’t invent it
Regional Registry Funding

- The Internet community specified the creation of regional registries
  - But didn’t indicate how they would be funded
  - APNIC, ARIN and RIPE-NCC derive funding from their ‘membership’
APNIC

- Started as an APCCIRN/APEPG Pilot Project in Sept., 1993, received address space from IANA in April, 1994, Incorporated in April 1996
- Uses a tiered membership fee with self-determined tiers
  - US $10,000/$5,000/$2,500 for Large/Medium/Small
    - Has about 400 members
  - Also has a non-member fee structure
- Located in Brisbane, Australia
- More info: see http://www.apnic.net
ARIN

- Created out of InterNIC in 1997
- Costs recovered via membership and allocation fees
  - Membership fee: US $1000/year
  - Allocation fees depend on the amount of space allocated the previous year ($20,000, $10,000, $5,000, or $2,500 depending on last year’s allocations)
- Has a staff of about 20
- Based in Reston, Virginia US
- More info: see http://www.arin.net
RIPE-NCC

- Created in 1990 as the IP networking special interest group of RARE, a EU funded group working to deploy OSI networks in Europe
- Membership based organization using a self-determined tiered fee structure
  - Membership fees originally (about) US $10,000/$5,000/$2,500, but changed to US $5000/$3500/$3000
    - Has about 600 members
- Has a staff of about 30
- Based in Amsterdam, The Netherlands
- More info: see http://www.ripe.net
Local Internet Registries

- Regional Registries delegate authority to “Local Internet Registries” to allocate resources
  - Usually Internet Service providers
  - Sometime confederations of service providers (e.g., national NICs)

- Local Internet Registries sub-delegate to customers
  - Either end users or other ISPs

- Each Local Internet Registry may have its own rules, but all must follow the rules of their parent registry
Top Level Domains

? delegates all TLDs
Policies for delegation described in RFC 1591
InterNIC currently administers (and charges for) gTLDs and .ARPA
ISO 3166 TLDs delegated to organizations within the countries

The Root

ISO-3166 TLDs
    .AU .BE ...

"US" TLDs
    .GOV .MIL

.gTLDs
    .NET .COM .ORG .INT

International TLDs
    .ARPA
TLD Administrators

- Top Level Domain Administrators are assigned by?
  - See RFC 1591 for history
- Each TLD has its own rules and restrictions on what names can be delegated
Development Groups

- Internet Engineering Task Force (IETF)
  - Protocol development and standardization
  - Also dabbles in operational and user support issues
- Has evolved from a meeting of 15 people back in the late ‘70s to over 1000 people meeting three times a year.
- Meetings held outside the US every third meeting (theoretically)
  - Next meeting: Pittsburgh, US, August
- More info: http://www.ietf.org
IETF Hierarchy

Internet Architecture Board (IAB)
Nominated by an IETF working group
Approved by ISOC

Internet Research Task Force (IRTF)
Research Group

Internet Engineering Steering Group (IESG)
Composed of IETF Area Directors

Internet Research Task Force (IRTF)
Research Group

IETF Area

IETF Working Group

...
The Internet Society

- Around 1991, it was realized the IETF had no legal protection and as a standards making body, the IAB, IESG, and working group chairs could be sued by anyone unhappy with developing standards.

- In addition, there was no organized group which could promote the Internet, act as a clearinghouse for information, etc.

- In 1992, the Internet Society was formed.
Operations Groups

- North American Network Operations Group (NANOG)
  - Evolved out of an NSFNet technical working group composed of technical staff of NSFNet regional networks
  - Currently, open membership but targeted at the North American network operators
  - Partially funded by US NSF, coordinated by Merit (the organization that is running the US Routing Arbiter project)

- More information:
  - http://www.nanog.org
Operations Groups (cont’d)

- European Operators Forum (EOF)
  - Created out of the RIPE Community
  - Open membership, but focusing on the European Internet operators community
  - Currently unfunded, operating as a working group of RIPE

- More information:
  - contact ncc@ripe.net
Operations Groups (cont’d)

- Asia Pacific Operators Forum (APOPS)
  - Formed at an Asia Pacific Rim Internet Conference on Operational Technologies (APRICOT)
  - Hosted by APNIC
    - Only exists as an email list right now
      - To subscribe: apops-request@apnic.net
  - Open membership, targeted at the AP region
  - More info: send mail to hostmaster@apnic.net

- AFNOG – underway for Africa
The Internet is a collection of privately operated networks that use TCP/IP as a common protocol and agree to cooperate to exchange traffic. "Enlightened self-interest" allows the Internet to function. Various bodies around the world help coordinate Internet, but none are essential for its operation.
Where to get more information

- TCP/IP Internals
  - The RFCs (available from an archive near you)

- History of the Internet:
  - [www.isoc.org](http://www.isoc.org) web pages
Where to get more information

- **Internet Structure**
  - NANOG, EOF, APRICOT, AFNOG meetings (the Internet structure changes so rapidly, any documented form will be out of date almost immediately)

- **Internet Organizations**
  - RIPE-NCC (www.ripe.net), APNIC (www.apnic.net), ARIN (www.arin.net)
  - Internet Society (www.isoc.org)