TCP/IP Protocol Suite

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"For each of these three terminals, I had three different sets of user commands. So if I was talking online with someone at S.D.C. and I wanted to talk to someone I knew at Berkeley or M.I.T. about this, I had to get up from the S.D.C. terminal, go over and log into the other terminal and get in touch with them.

I said, oh, man, it's obvious what to do: If you have these three terminals, there ought to be one terminal that goes anywhere you want to go where you have interactive computing. That idea is the ARPANET."

– New York Times Interview: December 20, 1999
Overview

• Terminology
• History
• Technical Details:
  – TCP
  – IP
  – Related Protocols
• Physical Media
• Social Implications
• Economic Impact
Terminology

• **Protocol**
  – A set of rules outlining the format to be used for communication between systems

• **Domain Name System (DNS)**
  – Converts an Internet domain into an IP address

• **Router**
  – A computer or software package used in packet switched networks to look at the source and destination addresses, and decide where to send the packets

• **Uniform Resource Indicators**
  – Uniform Resource Location (URL)
    • How to find the resource: HTTP, FTP, Telnet
  – Uniform Resource Names (URN)
    • What the resource is: Not as common as URL
History: Pre-TCP/IP

• Networks existed and information could be transferred within
• Because of differences in network implementation communication between networks different for each application
• Need for unification in protocols connecting networks
History: TCP/IP Development

• 1968: Plans develop for using Interface Message Processors (IMPs)
• Dec. 5, 1969: 4 IMPs connected to form ARPANET (UCLA, Stanford, UCSB, Utah)
• Early 70’s: DARPA begins work on new networking methods.
• 1972: ARPANET expands to 15 nodes and is showcased at the International Conference on Computer Communications
History: TCP/IP Development

• 1973: Robert Kahn and Vinton Cerf begin development of new protocol
  – Implement common internetwork protocol
  – Shifts burden of reliability from network to host
  – Facilitate adding more networks with different structures
• 1973: 1st out of country connection made to Norway (later converted to TCP/IP in 1982)
• 1974: Kahn and Cerf refer to creating a network of networks as internetting
• 1977: First demonstration of TCP/IP
History: Expansion of TCP/IP

• January 1, 1983: TCP/IP becomes the only approved protocol on ARPANET
• 1984: TCP/IP becomes military standard
• 1986: ARPANET merges with NSFNET to form beginnings of the Internet
  – The Internet refers to the collection of networks using TCP/IP
Growth

Example Network Topology

- Small company
  - Ethernet A
    - Bridge
  - Ethernet B
- IP Router
- Gateway
- Service provider's ATM backbone
- Gateway
- Gateway
- Wireless Router
- Another provider's Frame Relay Backbone
- Wireless Clients
Network Layers

Borrowed from Lecture by Prof. Dina Katabi, MIT
Layers of Encapsulation in a Modern Network Architecture

Example of Transmission through the Network Layers
Application Layer

- **HTTP**
  - Provides an interface for transmitting web pages and other files
- **DNS**
  - Maps [www.google.com](http://www.google.com) to an IP (i.e. 94.94.94.94)
- **DHCP**
  - Automatically obtains an IP for a host
- **IMAP, POP, SMTP**
  - Email interfaces
- **FTP**
  - File Transfer Protocol
- **AIM, MSN Messenger**
- **BitTorrent, Gnutella**
Transmission Control Protocol (TCP)

• Features
  – Connection establishment/close
  – Differentiates between various applications using the network connection
  – Error checking of data
  – Guaranteed packet delivery (eventually)
  – Breaks data into pieces at transmitter and reassembles at receiver
  – Only handled by the sender and receiver
Example TCP Session

Client

Listen for Requests

Open Connection

Connection Accepted/Denied

Request Data

Send Data

Check Data for Errors

Close Connection

Server

If Error
TCP Data

TCP header:

- **Source Port**
- **Destination Port**
- **Sequence Number**
- **Acknowledgment Number**
- **Data Offset**
- **Control Bits**
- **Window**
- **Checksum**
- **Urgent Pointer**
- **Options and padding**
- **Data**


- Port Number indicates the source/destination process on a host
  - Source port is arbitrary
  - Destination port is based on service
    - I.e Port 25=Email, Port 80=http
TCP Error Correction

- Packets can be lost by:
  - Collision
  - Physical Media Failure
  - Time to Live (TTL) reaches 0
- TCP expects an acknowledgement packet for every packet sent out
- Guaranteed Packet Delivery algorithms were designed to handle data congestion.
- Response to congestion is two-fold:
  - Breaking data into smaller pieces
  - Waiting a long time to retransmit data
- Wireless networks, which have fading, are not optimally dealt with
## TCP/UDP Comparison

### Features of UDP
- Connectionless
- Does NOT guarantee delivery
- Smaller packet sizes
- Faster (less overhead)

### TCP
- Data integrity is most important
  - HTTP
  - FTP
  - Telnet
  - SMTP, POP, IMAP
  - WINS, NFS (file transfer)

### UDP
- Data throughput is most important
  - VoIP
  - Videoconferencing
  - Pings
  - DNS
  - Time services
Internet Protocol (IP)

• Provides addressing of sender and receiver on the internet
• Protocol defines how to route messages through a network
  – Packetized
  – Not continuous
  – Delivery not guaranteed
• Dealt with at every router on the way from sender to receiver
IP Data

- Addresses of the form: 128.128.101.101 (i.e. 4 8-bit Numbers)
IP Routing
IP Routing
Link Layer

- Ethernet
- Wi-Fi
- PPP

Long Haul Systems: ATM, 100G Ethernet
## Physical Media

<table>
<thead>
<tr>
<th>Media</th>
<th>Bit Rate</th>
<th>Dist. (m)</th>
<th>Cost (per station)</th>
<th>Misc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Twisted Pair</td>
<td>16-155Mbps</td>
<td>100</td>
<td>$125</td>
<td>Used in telephone network predating Internet, so wires already in place</td>
</tr>
<tr>
<td>UTP</td>
<td>4-100Mbps</td>
<td>100</td>
<td>$90</td>
<td></td>
</tr>
<tr>
<td>Coax</td>
<td>10Mbps</td>
<td>500</td>
<td>$50</td>
<td>Cable TV</td>
</tr>
<tr>
<td>Fiber</td>
<td>100Mbps-2Gbps</td>
<td>2000</td>
<td>$250</td>
<td>Preferred for long distance</td>
</tr>
<tr>
<td>Radio</td>
<td>56Kbps-54Mbps</td>
<td>10 - 50000</td>
<td>$50-$15000</td>
<td>No physical wire</td>
</tr>
<tr>
<td>Satellite</td>
<td>100Mbps</td>
<td>36,000 km (satellite to earth)</td>
<td>239.6 ms delay</td>
<td></td>
</tr>
</tbody>
</table>

http://www.comptechdoc.org/
Network Overview

- Headend
- Fiber node
- Fiber cable
- Coaxial cable
- Hundreds of homes
Economic

- Late 1980’s many Internet Service Providers appear (ISPs)
  - PSINet, UUNET, Netcom, Portal
- Low cost goods available on the Internet because of reduced overhead costs
- Website advertising
Social

• Communication
  – E-mail
  – Instant Messaging
  – Telephone/Video Conferencing

• Information Access
  – Google
  – Wikipedia
The End
TCP/IP Protocols

- FTP - File Transport Protocol at the application layer.
- Telnet - Remote session at the application layer.
- SMTP - Simple Mail Transport Protocol at the application layer.
- DHCP - Dynamic host configuration protocol is used to assign IP addresses dynamically to network cards. It works at the application layer.
- TCP - Transport Control protocol is a connection oriented reliable protocol working at the transport layer.
- UDP - User Datagram Protocol is a connection less unreliable protocol working at the transport layer.
- ICMP - Internet Control Message Protocol is used to perform network error reporting and status. It works at the transport layer.
- IGMP - Internet Group Management Protocol is used to manage multicast groups and it works at the transport layer.
- IP - Internet Protocol is used for software addressing of computers and works at the network layer.
- ARP - Address Resolution Protocol is used to resolve the hardware address of a card to package the ethernet data. It works at the network layer.
- RARP - Reverse Address Resolution Protocol used for disk less computers to determine their IP address using the network. It works at the network layer.
Trace of Route to www.state.sd.us

- traceroute to www.state.sd.us (164.154.226.12), 64 hops max, 40 byte packets
- 1  b-wireless-gw (128.32.38.1)
- 2  g3-8.inr-202-reccev.berkeley.edu (128.32.255.169)
- 3  gige4-0-0.inr-666-doecev.berkeley.edu (128.32.0.249)
- 4  inet-lox-isp--ucb.cenic.net (137.164.24.141)
- 5  f5.ba01.b003070-1.sfo01.atlas.cogentco.com (38.112.6.225)
- 6  g1-5-102.core01.sfo01.atlas.cogentco.com (38.112.38.253)
- 7  p15-0.core02.sfo01.atlas.cogentco.com (66.28.4.70)
- 8  p10-0.core01.sjc03.atlas.cogentco.com (66.28.4.133)
- 9  pos4-3.br5.sac1.alter.net (204.255.174.209)
-10  0.so-2-1-0.xl1.sac1.alter.net (152.63.52.226)
-11  152.63.65.81 (152.63.65.81)
-12  pos6-0.gw2.msp3.alter.net (152.63.66.57)
-13  sdncomm-gw.customer.alter.net (65.206.183.214)
-14  66-231-27-158.sdn-pierre-ddn.sdnet.net (66.231.27.158) 131.426 m
-15  ddn-pierre-to-internet.core.rt.k12.sd.us (206.176.106.209)
-16  ddn-state-network-to-pierre.core.rt.k12.sd.us (206.176.70.106)