Networking Basics

Raj Jain

Raj Jain is now at Washington University in Saint Louis
Jain@cse.wustl.edu
http://www.cse.wustl.edu/~jain/
Standards Organizations
ISO/OSI and TCP/IP Reference Model
Flow and Error Control
Ethernet, HDLC, PPP
Internet Protocol (IP), IPv6
TCP
Domain Name System
International Standards Organizations

- ISO: International Standards Organization
  Chartered by United Nations

- ITU: International Telecommunications Union
  - ITU-T: Consultative Committee on International Telephone and Telegraph (CCITT)
  - ITU-R: Consultative Committee on International Radio (CCIR)
  - Example Standards: G.724, X.25, Q.931
  - www.itu.ch

- IEC: International Electrotechnical Commission
National Standards Organizations

- ANSI: American National Standards Institute
  - www.ansi.org
  - Non-governmental, nonprofit, over 300 committees
  - ANSI T1.105-1995 SONET
    ANSI X3.131-1994 SCSI-2
  - Represents USA in ITU, IEC, and ISO
Professional Associations

- IEEE: Inst of Electrical and Electronic Engineers,
  - standards.ieee.org
  - IEEE ⇒ ISO (via ANSI)
  - Ethernet ⇒ IEEE 802.3 ⇒ ISO 8802-3:1998
- EIA: Electronic Industries Association, www.eia.org
  - Example: EIA-232 (RS-232)
- TIA: Telecommunications Industries Association,
  - www.tiaonline.org
- ATM Forum, www.atmforum.com
- Frame Relay Forum, www.frforum.com
Professional Communities

- **IETF:**
  - Internet Engineering Task Force, [www.i etf.org](http://www.i etf.org)
  - Originated by DARPA for TCP/IP protocol development
  - Now chartered by Internet Society
  - Request for Comments (RFC), E.g., [www.i etf.org/rfc/rfc0793.txt](http://www.i etf.org/rfc/rfc0793.txt) = TCP
    - [draft-bhani-mpls-te-eval-00.txt](http://ftp.i etf.org/internet-drafts/draft-bhani-mpls-te-eval-00.txt)
### ISO/OSI Reference Model

<table>
<thead>
<tr>
<th>Layer</th>
<th>Function</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>File transfer, Email, Remote Login</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ASCII Text, Sound</td>
<td></td>
</tr>
<tr>
<td>Presentation</td>
<td>Establish/manage connection</td>
<td></td>
</tr>
<tr>
<td></td>
<td>End-to-end communication: TCP</td>
<td></td>
</tr>
<tr>
<td>Session</td>
<td>Routing, Addressing: IP</td>
<td></td>
</tr>
<tr>
<td>Transport</td>
<td>Two party communication: Ethernet</td>
<td></td>
</tr>
<tr>
<td>Network</td>
<td>How to transmit signal: Coding</td>
<td></td>
</tr>
<tr>
<td>Datalink</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Raj Jain
**TCP/IP Reference Model**

- TCP = Transport Control Protocol
- IP = Internet Protocol (Routing)

<table>
<thead>
<tr>
<th>TCP/IP Ref Model</th>
<th>TCP/IP Protocols</th>
<th>OSI Ref Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>FTP, Telnet, HTTP</td>
<td>Application</td>
</tr>
<tr>
<td>Transport</td>
<td>TCP, UDP</td>
<td>Presentation</td>
</tr>
<tr>
<td>Internetwork</td>
<td>IP</td>
<td>Session</td>
</tr>
<tr>
<td>Host to Network</td>
<td>Ethernet, Packet</td>
<td>Transport</td>
</tr>
<tr>
<td></td>
<td>Radio</td>
<td>Network</td>
</tr>
<tr>
<td></td>
<td>Point-to-Point</td>
<td>Datalink</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Physical</td>
</tr>
</tbody>
</table>
Layered Packet Format

- Nth layer control info is passed as N-1th layer data.

Diagram:
- Ethernet Header
- IP Header
- TCP Header
- FTP Header
- FTP Data
- TCP Data
- IP Data
- Ethernet Data
- Ethernet Trailer

Raj Jain
Flow Control

- Flow Control = Sender does not flood the receiver, but maximizes throughput
- Sender throttled until receiver grants permission
- Methods: Stop and wait, Sliding window
Error Control

- Error Control = Deliver frames without error, in the proper order to network layer
- Error Detection: Cyclic Redundancy Check, Sequence Numbers, Ack/Nak, Time-out
- Error Recovery: Automatic Repeat Request (ARQ) Stop and Wait, Go back n Selective Reject

Raj Jain
Connection-Oriented vs Connectionless

- Connection-Oriented: Telephone System
  - Path setup before data is sent
  - Data need not have address. Circuit number is sufficient.

- Connectionless: Postal System.
  - Complete address on each packet
  - The address decides the next hop at each router
Multiple Access Protocols

(a) Multiple Access

(b) Carrier-Sense Multiple Access with Collision Detection
Multiple Access Protocols

- Aloha at University of Hawaii:
  Transmit whenever you like
  Worst case utilization = 1/(2e) = 18%

- CSMA: Carrier Sense Multiple Access
  Listen before you transmit

- CSMA/CD: CSMA with Collision Detection
  Listen while transmitting.
  Stop if you hear someone else.

- Ethernet uses CSMA/CD.
  Standardized by IEEE 802.3 committee.
Ethernet Standards

- 10BASE5: 10 Mb/s over coaxial cable (ThickWire)
- 10BROAD36: 10 Mb/s over broadband cable, 3600 m max segments
- 1BASE5: 1 Mb/s over 2 pairs of UTP
- 10BASE2: 10 Mb/s over thin RG58 coaxial cable (ThinWire), 185 m max segments
- 10BASE-T: 10 Mb/s over 2 pairs of UTP
- 10BASE-FL: 10 Mb/s fiber optic point-to-point link
- 10BASE-FB: 10 Mb/s fiber optic backbone (between repeaters). Also, known as synchronous Ethernet.
HDLC Family

- Synchronous Data Link Control (SDLC): IBM
- High-Level Data Link Control (HDLC): ISO
- Link Access Procedure-Balanced (LAPB): X.25
- Link Access Procedure for the D channel (LAPD): ISDN
- Link Access Procedure for modems (LAPM): V.42
- Link Access Procedure for half-duplex links (LAPX): Teletex
- Point-to-Point Protocol (PPP): Internet
- Logical Link Control (LLC): IEEE
- Advanced Data Comm Control Proc (ADCCP): ANSI
- V.120 and Frame relay also use HDLC
Primary station: Issue commands
Secondary Station: Issue responses
Combined Station: Both primary and secondary
Unbalanced Configuration: One or more secondary
Balanced Configuration: Two combined station
Normal Response Mode (NRM): Response from secondary
Asynchronous Balanced Mode (ABM): Combined Station
Asynchronous Response Mode (ARM): Secondary may respond before command
HDLC Framing: Bit Stuffing

- HDLC frames are delimited by flags: 01111110
- Stuff bits if pattern appears in data
- Remove stuffed bits at destination

Transmitter

0 11111 11111 11111 10010

Receiver

0 11111 11111 11111 10010
HDLC Frames

- Information Frames: User data
  - Piggybacked Acks: Next frame expected
  - Poll/Final = Command/Response

- Supervisory Frames: Flow and error control
  - Go back N and Selective Reject
  - Final ⇒ No more data to send

- Unnumbered Frames: Control
  - Mode setting commands and responses
  - Information transfer commands and responses
  - Recovery commands and responses
  - Miscellaneous commands and responses
**PPP: Introduction**

- Point-to-point Protocol
- Originally for User-network connection
- Now being used for router-router connection also
- PPP is used when you connect to an internet service provider (ISP) via modem
- PPP is a variation of HDLC
- Uses flags like HDLC
- Uses byte stuffing in stead of bit stuffing
PPP in HDLC-Like Framing

<table>
<thead>
<tr>
<th>Flag</th>
<th>Address</th>
<th>Control</th>
<th>Protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td>01111110</td>
<td>11111111</td>
<td>00000011</td>
<td></td>
</tr>
</tbody>
</table>

- **Flag** = 0111 1110 = 7E
- **Byte Stuffing:**
  - 7E ⇒ 7D 5E
  - 7D ⇒ 7D 5D
Internet Protocol (IP)

- Connectionless service. Variable size datagrams
- Best-effort delivery: Delay, out-of-order, corruption, and loss possible. Higher layers should handle these.
- Handles only data forwarding
  Uses routing tables prepared by other protocols, e.g., Open Shortest Path First (OSPF), Routing Information Protocol (RIP)
- Provides only “Send” and “Delivery” services
  Error and control messages generated by Internet Control Message Protocol (ICMP)
- IP address: 32-bit = 4 decimal #s, e.g., 164.107.61.210

Raj Jain
All hosts on a network have the same network prefix.
Subnetwork

- Network = Multiple subnets connected via routers
- Generally each subnet is one Ethernet
- All hosts on the subnet have the same address prefix
- Mask .AND. Address = Prefix
- Example: First 23 bits = subnet
  Address: 10010100 10101000 00010000 11110001
  Mask: 11111111 11111111 11111110 00000000
  .AND. 10010100 10101000 00010000 00000000

Subnet 1  R  Subnet 2  R  R  Subnet n
Forwarding an IP Datagram

- Delivers datagrams to destination network (subnet)
- Routers maintain a “routing table” of “next hops”
- Next Hop field does not appear in the datagram

Table at R2:

<table>
<thead>
<tr>
<th>Destination</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net 1</td>
<td>Forward to R1</td>
</tr>
<tr>
<td>Net 2</td>
<td>Deliver Direct</td>
</tr>
<tr>
<td>Net 3</td>
<td>Deliver Direct</td>
</tr>
<tr>
<td>Net 4</td>
<td>Forward to R3</td>
</tr>
</tbody>
</table>

Fig 16.2
IPv6: How Many Addresses?

- 10 Billion people by 2020
- Each person will be served by more than one computer
- Assuming 100 computers per person $\Rightarrow 10^{12}$ computers
- More addresses may be required since
  - Multiple interfaces per node
  - Multiple addresses per interface
- Some believe $2^6$ to $2^8$ addresses per host
- Safety margin $\Rightarrow 10^{15}$ addresses
- IPng Requirements $\Rightarrow 10^{12}$ end systems and $10^9$ networks. Desirable $10^{12}$ to $10^{15}$ networks
IPv6 Addresses

- 128-bit long. Fixed size
- $2^{128} = 3.4 \times 10^{38}$ addresses
  $\Rightarrow 665 \times 10^{21}$ addresses per sq. m of earth surface
- If assigned at the rate of $10^6/\mu s$, it would take 20 years
- Expected to support $8 \times 10^{17}$ to $2 \times 10^{33}$ addresses
  $8 \times 10^{17} \Rightarrow 1,564$ address per sq. m
- Allows multiple interfaces per host.
- Allows multiple addresses per interface
- Allows unicast, multicast, anycast
- Allows provider based, site-local, link-local
- 85% of the space is unassigned
Colon-Hex Notation

- **Dot-Decimal**: 127.23.45.88
- **Colon-Hex**:  
  FEDC:0000:0000:0000:3243:0000:0000:ABCD  
  - Can skip leading zeros of each word  
  - Can skip one sequence of zero words, e.g.,  
    FEDC::3243:0000:0000:ABCD  
    ::3243:0000:0000:ABCD  
  - Can leave the last 32 bits in dot-decimal, e.g.,  
    ::127.23.45.88  
  - Can specify a prefix by /length, e.g.,  
    2345:BA23:7::/40
IPv6 vs IPv4

- 1995 vs 1975
- IPv6 only twice the size of IPv4 header
- Only version number has the same position and meaning as in IPv4
- Added: Priority and flow label
- All fixed size fields.
- No optional fields. Replaced by extension headers.
- Allows “Plug and Play” as well as “Secure” address assignment
1000 Computers on the Dock

How are we going to install all these in one day?
TCP: Key Features

- Connection oriented
- Point-to-point communication: Two end-points
- Reliable transfer: Data is delivered in order
- Full duplex communication
- Stream interface: Continuous sequence of octets
- Reliable connection startup: Data on old connection does not confuse new connections
- Graceful connection shutdown: Data sent before closing a connection is not lost.
## TCP Header

### Table

<table>
<thead>
<tr>
<th>Source Port</th>
<th>Dest Port</th>
<th>Seq No</th>
<th>Ack No</th>
<th>Data Offset</th>
<th>Resvd</th>
<th>Control</th>
<th>Window</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>16</td>
<td>32</td>
<td>32</td>
<td>4</td>
<td>6</td>
<td>6</td>
<td>16</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Check-sum</th>
<th>Urgent</th>
<th>Options</th>
<th>Pad</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>16</td>
<td>x</td>
<td>y</td>
<td></td>
</tr>
</tbody>
</table>

Size in bits

- **Port (16 bits):** Identifies source user process
  - 20 = FTP, 23 = Telnet, 53 = DNS, 80 = HTTP, ...
- **Ack number (32 bits):** Next byte expected
- **Window = Number bytes allowed to send**
Domain Name System: Hierarchy

Example: cobra.netlab.ohio-state.edu
IETF’s RFCs and I-Ds are key sources for recent developments
HDLC uses 01111110 flag and requires bit-stuffing
Ethernet uses CSMA/CD
IP is a connectionless forwarding protocol with 32-bit addresses
IPv6 extends addresses to 128 bits
TCP is a connection-oriented reliable stream protocol
DNS allows name to address resolution
Networking Basics: Key References