Interconnection Technologies

Introduction to Internetworking
Fundamental technology review

- What internetworking is
- Binary digits
- Addressing
- Error and flow control
- Routing
- Protocols and standards
Motivation for internetworking

- Facilitating communications
- Information access
- Resource sharing
Internetworking versus Data Communications

• Datacomm: usually two nodes, mostly electrical engineering issues
• Internetworking: with more than two nodes, there are a lot more issues to deal with
Internet working challenges

• Compatibility
• Cost efficiency
• Error handling
• Management
Internetworking scope

- Local area networks (LANs)
  - Generally confined to one administrative boundary (e.g. building/campus)
  - No ongoing network service costs
- Wide area networks (WANs)
  - Generally involves third party carrier for connectivity (e.g. Internet service provider)
  - Ongoing communication costs
Binary digits (bits)

- The primary base–2 numbering system used throughout internetworking
- The base determines how many digits a numbering system uses
  - Decimal is base–10
- Computers and networks often encode data using bits
- The binary digits are 0 and 1
Using bits

Multiplying or dividing by 8 as appropriate.

It’s easy to convert between bytes and bits, just multiply or divide by 8 as appropriate.

Computer systems typically use bytes.

We often say octet to mean exactly 8 bits.

E.g., 10 Mbps Ethernet, 155 Mbps ATM.

Referred to in bits per second (b/s). Internet working speeds are almost always

*Using bits
## Counting in binary

<table>
<thead>
<tr>
<th>Binary number</th>
<th>Decimal number</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 00000000</td>
<td>• 0</td>
</tr>
<tr>
<td>• 00000001</td>
<td>• 1</td>
</tr>
<tr>
<td>• 00000010</td>
<td>• 2</td>
</tr>
<tr>
<td>• 00000011</td>
<td>• 3</td>
</tr>
<tr>
<td>• 00000100</td>
<td>• 4</td>
</tr>
<tr>
<td>• 00000101</td>
<td>• 5</td>
</tr>
<tr>
<td>• ...</td>
<td>• ...</td>
</tr>
<tr>
<td>• 11111111</td>
<td>• 255</td>
</tr>
</tbody>
</table>
Binary to decimal conversion

128  64  32  16  8  4  2  1
0  1  1  0  0  1  1  0

0 + 64 + 32 + 0 + 0 + 4 + 0 + 0 = 102
Addressing

- Help determine what/where something is
- Postal address is an example of an address
- www.ibm.com is an example of an address
- May be permanent or dynamic
- Addresses are often in decimal/hex/binary
  - 140.192.1.6
  - FF.FF.FF.FF
  - 10001100.11000000.00000001.00000110
Error control

- Error detection
  - Ability to recognize that an error occurred
  - Might not be able to fix it, but know not to use the corrupted data
- Error correction
  - Ability to correct errors when they occur
  - Implies reliability
- What does it cost to implement error control?
Error control strategies

- Integrity check
  - Parity bit
  - Checksum/CRC
- Notification
  - ACK/NAK
  - May generate a retransmission
- Redundant encoding/transmission
Flow control

• Match sending rate to capable receiving rate
• How do you know what the right rate is?
  • Implicit feedback from delay or loss
  • Explicit signals from the network/receiver
• Loosely related to congestion control
  • Internetwork based scheme to handle existing traffic overload
Routing

• How to get from one place to another
• Follow predetermined route?
• Ask directions along the way?
• How to route around failures?
• Who determines the route to take?
Protocols

- Agreed upon rules, syntax or formats
- TCP/IP is a suite of protocols
- Although TCP is a protocol
  ...and IP by itself is also a protocol
- We often talk about network protocol models
- ISO OSI Reference Model is an example
ISO OSI Reference Model

7: Application layer
6: Presentation layer
5: Session layer
4: Transport layer
3: Network layer
2: Data link layer
1: Physical layer
TCP/IP model

5: Application layer
4: Transport layer
3: Network layer
2: Data link layer
1: Physical layer
Protocol layers

- Many network protocols violate *strict* layering
- And that is perfectly OK in the real world
- It just helps to talk about protocols using the protocol models
- Most of the things we’ll be dealing with reside in layers 2, 3 and 4.
- We use the these protocol model terms a lot
Standards

- Agreed upon protocols used by a constituency of users and systems
- Standards bodies
- Open, proprietary, de facto and de jure
- Success may depend on a number of factors
  - Simplicity
  - Political maneuvering
  - Cost
Packets, Frames, Datagrams Oh My

• Block of data transmitted through a network
• Sometimes these are used interchangeably
  • Frames = Layer 2 (e.g. Ethernet frames)
  • Packets = Layer 3 (e.g. IP packets)
  • Datagrams = IP layer 3 packets
  • Segments = TCP layer 4 messages
  • Cells = Fixed length frames/packets
    • Common in ATM conversations
Headers, data and trailers

- Headers/trailers are control fields in packets
- They are used to describe the packet/data
- Data is the upper layer packet or just data
- Trailers are generally only used in layer 2 protocols and primarily for error control
Encapsulation

- Putting one layered protocol into the data portion of another layered protocol
- Generally a higher layer protocol goes into a lower layer protocol’s data field
Layer 1 and layer 2 review

- Physical layer
  - Transmission media
  - Signal Repeaters
  - LAN Hubs
- Data link layer
  - Ethernet
- IEEE 802 organization
Transmission media
Media connectors
Signal Repeaters

- Clean and regenerate the signal
- Amplify/boost the signal
- Act as a distance extender
- Laws of physics apply
- Repeaters may amplify *noise* too
LAN Hubs

• Essentially just a multi-port repeater
• Acts as a concentration point for end stations
• Distributes signal to many end stations
• Requires one active signal throughout the hub for error-free transmission
• May provide some management information
• Simple, cheap device
• Often referred to as shared hubs
Ethernet

- Standardized by IEEE 802.3 working group
- Shared Ethernet uses CSMA/CD
- Simple frame format
- Many popular generations
  - 10BASE–T
  - 100BASE–T
  - 1000BASE–X
- Most popular data link technology by far
IEEE 802 organization

- 802.1 – bridging/architecture
- 802.3 – CSMA/CD (Ethernet)
- 802.11 – WLAN (wireless LAN)
- 802.15 – WPAN (wireless personal LAN)
- 802.16 – BWA (broadband wireless access)
- 802.17 – Resilient packet ring
- Others disbanded or in hibernation
Internet Architecture Overview

- Internet history
- Internet technology bodies
- RFC standards process
- Network overview
Internet history – 1960’s

- Space race and threat of nuclear war
- 1st papers on packet switched networks
- BBN build IMPs for early Internet
- First 4 nodes of ARPANET go online
  - Stanford, UCSB, UCLA, U of Utah
- Network working group forms
  - Prelude to the IETF
Internet history – 1970’s

- Ethernet invented
- Early TCP/IP details designed
- V. Cerf and B. Kahn begin making history
- TCP and IP are separated
- Basic applications created and tested
- Email, file transfer, even voice
Internet history – 1980’s

- Domain name system (DNS)
- Berkeley UNIX (BSD) with IP installed
- IETF/IAB formed
- NFSNET takes over the backbone
- The infamous Internet worm hits
- High-speed backbone of the day is 1.5 Mb/s
- First IP multicast experiments
Internet history – 1990’s

- HTTP and world wide web developed
- ISOC forms
- OSI protocols quickly starts going away
- IPv6 design and development begin
- Internet becomes commercialized
- Windows 95 with IP installed
- High-speed backbones become 2.5 Gb/s
Internet history – 2000’s

- Y2K bug let down
- DDoS attacks
- MP3 file sharing (Napster) takes off
- The rise and fall of many startup .com’s
- TDC 365 at DePaul launched
Internet technology bodies

- Internet Society
- Internet Architecture Board
- Internet Engineering Task Force
- Internet Engineering Steering Group
- Internet Research Task Force
- Internet Assigned Numbers Authority
- Internet Corporation for Assigned Names and Numbers
IETF areas

- User Services
- Sub-IP
- Operations and Management
- Internet
- General
- Transport
- Security
- Applications
- Routing
IETF working groups

- Specific technical work is done in groups
- Working groups fall into a topic area
- Groups led by working group chairs
- Much of the work is done via mailing lists
- Participation is open to any interested individual
Publications

- Request for comment (RFC)
  - Publicly available Internet specifications
  - There are currently over 3000 in the series
- Internet–drafts
  - Draft versions of RFCs for public review
  - Each draft version expires in 6 months
  - IESG decides if it becomes an RFC
  - Many internet–drafts never become RFCs
Internet standard track

- Proposed standard
  - Entry level for an RFC
  - Of high interest
  - Major design choices are resolved
  - Implementation and operational experience is not required, but is desirable
  - Further experience and validation is needed
Internet standard track

• Draft standard
  • There exists 2 independent implementations
  • Interoperability has been shown
  • Sufficient successful operational experience has been obtained
  • Known to be quite stable
Internet standard track

• Internet standard
  • Highest level of the standards track
  • Significant successful implementation experience has been obtained
  • High degree of technical maturity
  • Significant benefit to Internet community
  • There are only a few dozen full Internet standard RFCs today
Other RFCs

• Non–standards track
  • Experimental
  • Informational
  • Historic
• Best current practice
Network overview

• There really is no well defined structure
• Organizations generally connect to some Internet service provider
• There can be many providers, large and small to choose from
• Those providers often connect to larger backbone (tier 1) providers
• Providers often meet at public exchange points (IXP, NAP)
Internet map
Who runs the Internet?

- No one and everyone
- Governments? – probably not in most places
- IETF? – not really, they just define standards
- ISPs? – some pieces, but less than you think
- Users? – kinda, but there’s lots of them
- Microsoft? – don’t think so
Final thoughts

• We skipped a lot of background stuff
• We will come back to binary, better learn it
• Subscribe to the class mailing list
  • Send email to: majordomo@forums.depaul.edu
  • In the body of the message put:
    • subscribe 2001spr365 <youremailaddress>
• One down ten more to go!