Lecture 3
Protocol Stacks and Layering

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What is a Communication Network?
(from end-system point of view)

- Network offers a service: move information
  - Bird, fire, messenger, truck, telegraph, telephone, Internet ...
  - Another example, transportation service: move objects
    - Horse, train, truck, airplane ...
- What distinguish different types of networks?
  - The services they provide
- What distinguish the services?
  - Rich of the services
  - Latency
  - Bandwidth
  - Loss rate
  - Number of end systems
  - Service interface
  - Other details
    - Reliability, unicast vs. multicast, real-time, message vs. byte ...
What is a Communication Network?
Infrastructure Centric View

- Electrons and photons as communication medium
- Links: fiber, copper, satellite, ...
- Switches: electronic/optic, crossbar/Banyan
- Protocols: TCP/IP, ATM, MPLS, SONET, Ethernet, X.25, FrameRelay, AppleTalk, IPX, SNA
- Functionalities: routing, error control, flow control, congestion control, Quality of Service (QoS)
- Applications: telephony, FTP, WEB, X windows, ...
How to Draw a Network

Node  Link  Node
Building block: The Links

- **Electrical questions**
  - Voltage, frequency, …
  - Wired or wireless?

- **Link-layer issues: How to send data?**
  - When to talk – can everyone talk at once?
  - What to say – low-level format?
  - Stay tuned for lecture 5

- Okay… what about more nodes?
What Is In a Network?

- **End system**
- **Switch (router)**
  - Access switch
  - Core switch
- **Access line**: linking switch and end systems
- **Trunk line**
  - Between switches
  - Multiple connections simultaneously
    - Multiplexing/demultiplexing
**What Does Switch Do?**

- **Multiplexing**: multiple demands X use a shared resource Y
  - multiple voice circuits on a shared trunk link
  - Multiple applications on top of a shared protocol stack

- **Switching**
  - Packet switching
  - Circuit switching

- **Tradeoffs?**
Packet vs. Circuit Switching

- **Packet-switching: Benefits**
  - Ability to exploit statistical multiplexing
  - More efficient bandwidth usage

- **Packet switching: Concerns**
  - Needs to buffer and deal with congestion:
  - More complex switches
  - Harder to provide good network services (e.g., delay and bandwidth guarantees)
Protocol and Service Interfaces

Application

End-to-end

Core Network
What is a Protocol

- An agreement between parties on how communication should take place.
- Protocols may have to define many aspects of the communication.
- **Syntax:** Data encoding, language, etc.
- **Semantics:** Error handling, termination, ordering of requests, etc.
- Protocols at hardware, software, all levels!
- Example: Buying airline ticket by typing.
- Syntax: English, ascii, lines delimited by “\n”

Example: Buying airline ticket by typing.

- Friendly greeting
- Muttered reply
- Destination?
- Pittsburgh
- Thank you
Interfaces

- Each protocol offers an interface to its users, and expects one from the layers on which it builds
  - Syntax and semantics strike again
    - Data formats
    - Interface characteristics, e.g. IP service model
- Protocols build upon each other
  - Add value
    - E.g., a reliable protocol running on top of IP
  - Reuse
    - E.g., OS provides TCP, so apps don’t have to rewrite
Internet Protocol Architecture

FTP program
TCP
IP
Ethernet Driver

FTP protocol
TCP protocol
IP protocol
Ethernet protocol
ATM protocol
ATM Driver
Internet Protocol Architecture

MPEG Server program

UDP

IP

Ethernet Driver

RTP protocol

UDP protocol

IP protocol

Ethernet protocol

MPEG Player program

UDP

IP

Ethernet Driver

ATM Driver

IP protocol

RTP protocol

Ethernet protocol

ATM protocol
Solution: Intermediate layer that provides a single abstraction for various network technologies

- O(1) work to add app/media
- variation on “add another level of indirection”
TCP/IP Protocol Suite

- The complete TCP/IP protocol suite contains many protocols.
- Not even the following graph is a complete list.
Application Layer

- **Service:** Handles details of application programs.
- **Functions:**
  - Application Layer: telnet, ftp, email, www, AFS
  - Transport Layer: TCP, UDP
  - Network Layer: IP, ICMP, OSPF, RIP, BGP
  - (Data) Link Layer: Ethernet, WiFi, PoS, T1
Transport Layer

- **Service**: Controls delivery of data between hosts.
- **Functions**: Connection Establishment, Termination, Error control, flow control.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Protocols/Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application Layer</td>
<td>telnet, ftp, email, www, AFS</td>
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</table>
Network Layers

- **Service**: Moves packets inside the network.
- **Functions**: Routing, addressing, switching, congestion control.

![Layer Diagram]

- Application Layer: telnet, ftp, email, www, AFS
- Transport Layer: TCP, UDP
- Network Layer: IP, ICMP, OSPF, RIP, BGP
- (Data) Link Layer: Ethernet, WiFi, PoS, T1
Data Link Layer

» **Service**: Transfer of frames over a link.
» **Functions**: Synchronization, error control, flow control
Encapsulation

- As data is moving down the protocol stack, each protocol is adding layer-specific control information.
A Finer Grain Layering Model

The Open Systems Interconnection (OSI) Model.
OSI Functions

- (1) Physical: transmission of a bit stream.
- (2) Data link: flow control, framing, error detection.
- (3) Network: switching and routing.
- (4) Transport: reliable end to end delivery.
- (5) Session: managing logical connections.
- (6) Presentation: data transformations.
- (7) Application: specific uses, e.g. mail, file transfer, telnet, network management.

Multiplexing takes place in multiple layers
Which Protocols Are Implemented Where?
Example: Sending a Web Page

Http hdr

Web page

TCP header

Application payload

...
A TCP/IP/802.3 Packet

Homework explores tradeoffs in header sizes, etc., with different applications
Limitations of the Layered Model

- Some layers are not always cleanly separated.
  - Inter-layer dependencies in implementations for performance reasons
  - Some dependencies in the standards (header checksums)
- Higher layers not always well defined.
  - Session, presentation, application layers
- Lower layers have “sublayers”.
  - Usually very well defined (e.g., SONET protocol)
- Interfaces are not always well standardized.
  - It would be hard to mix and match layers from independent implementations, e.g., windows network apps on unix (w/out compatability library)
  - Many cross-layer assumptions, e.g. buffer management
Standardization

- **Key to network interoperability.**
- **A priori standards.**
  - Standards are defined first by a standards committee
  - Risk of defining standards that are untested or unnecessary
  - Standard may be available before there is serious use of the technology
- **De facto standards.**
  - Standards is based on an existing systems
  - Gives the company that developed the base system a big advantage
  - Often results in competing “standards” before the official standard is established
Relevant Standardization Bodies

- **ITU-TS** - Telecommunications Sector of the International Telecommunications Union.
  - government representatives (PTTs/State Department)
  - responsible for international “recommendations”

- **T1** - telecom committee reporting to American National Standards Institute.
  - T1/ANSI formulate US positions
  - interpret/adapt ITU standards for US use, represents US in ISO

- **IEEE** - Institute of Electrical and Electronics Engineers.
  - responsible for many physical layer and datalink layer standards

- **ISO** - International Standards Organization.
  - covers a broad area
The Internet Engineering Task Force

- The Internet society.
  - Oversees the operations of the Internet

- Internet Engineering Task Force.
  - Decides what technology will be used in the Internet
  - Based on working groups that focus on specific issues
  - Encourages wide participation

- Request for Comments.
  - Document that provides information or defines standard
  - Requests feedback from the community
  - Can be "promoted" to standard under certain conditions
    - Consensus in the committee
    - Interoperating implementations
  - Project 1 will look at the Internet Relay Chat (IRC) RFC
Higher Level Standards

- Many session/application level operations are relevant to networks.
  - encoding: MPEG, encryption, ...
  - services: electronic mail, newsgroups, HTTP, ...
  - electronic commerce, ....

- Standards are as important as for “lower-level” networks: interoperability.
  - defined by some of the same bodies as the low-level standards, e.g. IETF