Protocol “Layers”

Networks are complex!

- many "pieces":
  - hosts
  - routers
  - links of various media
  - applications
  - protocols
  - hardware, software

Question:
Is there any hope of organizing structure of network?

Or at least our discussion of networks?

Organization of air travel

- ticket (purchase)
- baggage (check)
- gates (load)
- runway takeoff
- airplane routing

- ticket (complain)
- baggage (claim)
- gates (unload)
- runway landing
- airplane routing

- a series of steps
Organization of air travel: a different view

<table>
<thead>
<tr>
<th>Layer</th>
<th>Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>ticket</td>
<td>ticket (purchase)</td>
</tr>
<tr>
<td>baggage</td>
<td>baggage (check)</td>
</tr>
<tr>
<td>gates</td>
<td>gates (load)</td>
</tr>
<tr>
<td>runway</td>
<td>runway takeoff</td>
</tr>
<tr>
<td>airplane routing</td>
<td>airplane routing</td>
</tr>
</tbody>
</table>

Layers: each layer implements a service
- via its own internal-layer actions
- relying on services provided by layer below

Layered air travel: services

- Counter-to-counter delivery of person+bags
- Baggage-claim-to-baggage-claim delivery
- People transfer: loading gate to arrival gate
- Runway-to-runway delivery of plane
- Airplane routing from source to destination
### Distributed implementation of layer functionality

<table>
<thead>
<tr>
<th>Departing airport</th>
<th>Arriving airport</th>
</tr>
</thead>
<tbody>
<tr>
<td>ticket (purchase)</td>
<td>ticket (complain)</td>
</tr>
<tr>
<td>baggage (check)</td>
<td>baggage (claim)</td>
</tr>
<tr>
<td>gates (load)</td>
<td>gates (unload)</td>
</tr>
<tr>
<td>runway takeoff</td>
<td>runway landing</td>
</tr>
<tr>
<td>airplane routing</td>
<td>airplane routing</td>
</tr>
</tbody>
</table>

### intermediate air traffic sites
- airplane routing
- airplane routing
- airplane routing

### Why layering?

**Dealing with complex systems:**
- explicit structure allows identification, relationship of complex system’s pieces
  - layered reference model for discussion
- modularization eases maintenance, updating of system
  - change of implementation of layer’s service transparent to rest of system
  - e.g., change in gate procedure doesn’t affect rest of system
- layering considered harmful?
Protocol layering and data

Each layer takes data from above
- adds header information to create new data unit
- passes new data unit to layer below

The OSI model

**OSI Layers**


---

**TCP/IP and OSI model**

Internet protocol stack

- **application**: supporting network applications
  - ftp, smtp, http
- **transport**: host-host data transfer
  - tcp, udp
- **network**: routing of datagrams from source to destination
  - ip, routing protocols
- **link**: data transfer between neighboring network elements
  - ppp, ethernet
- **physical**: bits “on the wire”

Layering: logical communication

Each layer:
- distributed
- “entities” implement layer functions at each node
- entities perform actions, exchange messages with peers
Layering: logical communication

E.g.: transport
- take data from app
- add addressing, reliability check info to form “datagram”
- send datagram to peer
- wait for peer to ack receipt
- analogy: post office

Layering: physical communication
Internet structure: network of networks

- roughly hierarchical
- national/international backbone providers (NBPs)
  - e.g. BBN/GTE, Sprint, AT&T, IBM, UUNet
  - interconnect (peer) with each other privately, or at public Network Access Point (NAPs)
- regional ISPs
  - connect into NBPs
- local ISP, company
  - connect into regional ISPs

National Backbone Provider

e.g. BBN/GTE US backbone network
Other Backbone - vBNS

vBNS Backbone Network Map

Other Backbone - vBNS (cont'd)

vBNS POS Backbone 2Q’00
Internet History

1961-1972: Early packet-switching principles

- **1961:** Kleinrock - queueing theory shows effectiveness of packet-switching
- **1964:** Baran - packet-switching in military nets
- **1967:** ARPAnet conceived by Advanced Research Projects Agency
- **1969:** first ARPAnet node operational
- **1972:**
  - ARPAnet demonstrated publicly
  - NCP (Network Control Protocol) first host-host protocol
  - first e-mail program
  - ARPAnet has 15 nodes
Internet History

1972-1980: Internetworking, new and proprietary nets

- 1970: ALOHAnet satellite network in Hawaii
- 1973: Metcalfe's PhD thesis proposes Ethernet
- 1974: Cerf and Kahn - architecture for interconnecting networks
- Late 70's: proprietary architectures: DECnet, SNA, XNA
- Late 70's: switching fixed length packets (ATM precursor)
- 1979: ARPAnet has 200 nodes

Cerf and Kahn's internetworking principles:
- minimalism, autonomy - no internal changes required to interconnect networks
- best effort service model
- stateless routers
- decentralized control define today's Internet architecture

1980-1990: new protocols, a proliferation of networks

- 1983: deployment of TCP/IP
- 1982: smtp e-mail protocol defined
- 1983: DNS defined for name-to-IP-address translation
- 1985: ftp protocol defined
- 1988: TCP congestion control
- New national networks: Csnet, BITnet, NSFnet, Minitel
- 100,000 hosts connected to confederation of networks
Internet History

1990's: commercialization, the WWW

- Early 1990's: ARPAnet decommissioned
- early 1990s: WWW
  - hypertext [Bush 1945, Nelson 1960's]
  - HTML, http: Berners-Lee
  - 1994: Mosaic, later Netscape
  - late 1990's: commercialization of the WWW

Late 1990's:
- est. 50 million computers on Internet
- est. 100 million+ users
- backbone links running at 1 Gbps

ATM: Asynchronous Transfer Mode nets

Internet:
- today's de facto standard for global data networking

1980's:
- telco's develop ATM: competing network standard for carrying high-speed voice/data
- standards bodies:
  - ATM Forum
  - ITU

ATM principles:
- small (48 byte payload, 5 byte header) fixed length cells (like packets)
  - fast switching
  - small size good for voice
- virtual-circuit network: switches maintain state for each "call"
- well-defined interface between "network" and "user" (think of telephone company)
### ATM layers

- **ATM Adaptation Layer (AAL):** Interface to upper layers
  - End-system
  - Segmentation/reassemblcy
- **ATM Layer:** Cell switching
- **Physical**

### Chapter 1: Summary

**Covered a “ton” of material!**
- Internet overview
- What’s a protocol?
- Network edge, core, access network
- Performance: loss, delay
- Layering and service models
- Backbones, NAPs, ISPs
- History
- ATM network

**You now hopefully have:**
- Context, overview, “feel” of networking
- More depth, detail later in course