Network Protocols and Architectures

Introduction
What’s the Internet: “nuts and bolts” view

- Millions of connected computing devices: *hosts, end-systems*
  - PC’s workstations, servers
  - PDA’s, phones, toasters
  running *network apps*

- *Communication links*
  - Fiber, copper, radio, satellite

- *Routers:* forward packets (chunks) of data through network
What’s the Internet: “nuts and bolts” view

- **Protocols**: control sending, receiving of messages
  - E.g., TCP, IP, HTTP, FTP, PPP

- **Internet**: “network of networks”
  - Loosely hierarchical
  - Public Internet versus private intranet

- Internet standards
  - RFC: Request for comments
  - IETF: Internet Engineering Task Force
What’s the Internet: A service view

- Communication infrastructure enables distributed applications:
  - WWW, email, games, e-commerce, database, voting,
  - More?

- Communication services provided:
  - Connectionless
  - Connection-oriented

- cyberspace [Gibson]:
  "a consensual hallucination experienced daily by billions of operators, in every nation, ...."
A closer look at network structure

- **Network edge:**
  - applications and hosts

- **Network core:**
  - Routers
  - Network of networks

- **Access networks, physical media:**
  Communication links
The network edge

- **End systems (hosts):**
  - Run application programs
  - E.g., WWW, e-mail
  - At “edge of network”

- **Client/server model**
  - Client host requests, receives services from server
  - E.g., WWW client (browser)/server; e-mail client/server

- **Peer-peer model:**
  - Host interaction symmetric
  - E.g., teleconferencing
Network edge: connection-oriented service

**Goal:** data transfer between end sys.

- **Handshaking:** setup (prepare for) data transfer ahead of time
  - Hello, hello back human protocol
  - *Set up “state”* in two communicating hosts

- **TCP – Transmission Control Protocol**
  - Internet’s connection-oriented service

**TCP service** [RFC 793]

- **Reliable, in-order byte-stream data transfer**
  - Loss: acknowledgements and retransmissions

- **Flow control:**
  - Sender won’t overwhelm receiver

- **Congestion control:**
  - Senders “slow down sending rate” when network congested
Network edge: connectionless service

Goal: Data transfer between end systems
   - Same as before!

- **UDP** – User Datagram Protocol [RFC 768]: Internet’s connectionless service
  - Unreliable data transfer
  - No flow control
  - No congestion control
The network core

- Mesh of interconnected routers
- **The fundamental question:** How is data transferred through net?
  - Circuit switching: Dedicated circuit per call: telephone net
  - Packet switching: Data sent through net in discrete “chunks”
Network core: Circuit switching

End-end resources reserved for “call”

- Link bandwidth, switch capacity
- Dedicated resources: no sharing
- Circuit-like (guaranteed) performance
- Call setup required
Network core: Packet switching

Each end-end data stream divided into *packets*

- Users’ A, B packets *share* network resources
- Each packet uses full link bandwidth
- Resources used *as needed*
Network core: Packet switching

Packet-switching versus circuit switching:
Human restaurant analogy
Network core: Packet switching

Resource contention:
- Aggregate resource demand can exceed amount available
- Congestion: packets queue, wait for link use
- Store and forward: packets move one hop at a time
  - Transmit over link
  - Wait turn at next link
Packet switching vs. circuit switching

Is packet switching a “slam dunk winner?”

- Great for bursty data
  - Resource sharing
  - No call setup
- Excessive congestion: packet delay and loss
  - Protocols needed for reliable data transfer, congestion control
- Q: How to provide circuit-like behavior?
  - Bandwidth guarantees needed for audio/video apps still an unsolved problem
Packet-switched networks: Routing

- **Goal:** Move packets among routers from source to destination
  - We’ll study several path selection algorithms

- **Datagram network:**
  - *Destination address* determines next hop
  - Routes may change during session
  - Analogy: driving, asking directions

- **Virtual circuit network:**
  - Each packet carries tag (virtual circuit ID), tag determines next hop
  - Fixed path determined at *call setup time*, remains fixed through call
  - Routers maintain per-call state
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 in our discussion of networks?
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 does not affect rest of system
- Layering considered harmful?
Internet protocol stack

- **Application**: supporting network applications
- **Transport**: host-host data transfer
- **Network**: uniform format of packets, routing of datagrams from source to destination
- **Link**: data transfer between neighboring network elements
- **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 application
- 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
Principles of the Internet

- Edge vs. core (end-systems vs. routers)
  - Dumb network
  - Intelligence at the end-systems
- Different communication paradigms
  - Connection oriented vs. connection less
  - Packet vs. circuit switching
- Layered System
- Network of collaborating networks