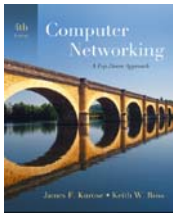
CSC 249
Computer Networks

Chapter 1, Introduction
Sections 1.1 to 1.4

Spring 2008
Room EGR 102, TR 3:00-4:50
Prof. Judith Cardell
Office EGR 105B



Computer Networking: A Top Down Approach, 4th edition. Jim Kurose, Keith Ross Addison-Wesley, July 2007.

Chapter 1: Introduction

Overview:

- What is the Internet?
- What is a protocol?

- The network edge: hosts, access net, physical media
- The network core: packet/circuit switching, Internet structure
- Performance: loss, delay, throughput
- **Protocol layers**, service models
- Security
- History

Course Overview

- Fundamental Question:
  - How is data transferred through the Internet?
  - How is our natural language communication transmitted over shared, binary-based media?
- Principles to develop
  - Reliable data transfer
  - Fast & error-free data transfer
  - Security and privacy safeguards
- Implementation
  - Network layer model
    - Application → Transport → Network → Link → Physical… layers

Course: Problems and Solutions

- List issues/problems to be overcome
  - Reliable communication over an unreliable network
  - Congestion and flow control
  - Interconnecting heterogeneous networks
  - Finding the best path through the networks
  - Sharing a multi-access channel
  - Identifying devices → addresses (physical v. IP)
  - Security, privacy & privacy rights
- Society's role
  - Court cases
  - Government intervention and surveillance
  - The Press and popular fiction

Chapter 1: roadmap

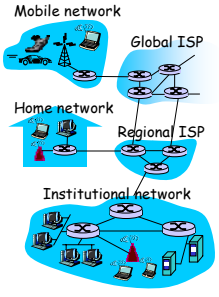
1.1 What *is* the Internet?
1.2 Network edge
- end systems, access networks, links

1.3 Network core
- circuit switching, packet switching, network structure

1.4 Delay, loss and throughput in packet-switched networks
1.5 Protocol layers, service models
1.6 Networks under attack: security
1.7 History

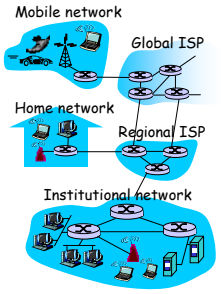
What is the Internet: "nuts and bolts" view

- millions of connected computing devices:
  hosts = end systems
  - running *network applications*
- *communication links*
  - fiber, copper, radio, satellite
- *routers:* forward packets (chunks of data)



What is the Internet: "nuts and bolts" view

- Protocols control the sending and receiving of messages
  - e.g., TCP, IP, HTTP, Skype, Ethernet
- Internet: "network of networks"
  - loosely hierarchical
  - public Internet versus private intranet



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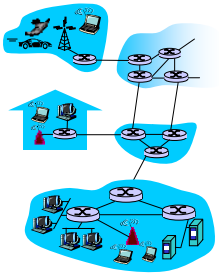
What is the Internet: A Service View

- Communication applications :
  - Web, VoIP, email, games, e-commerce, file sharing
- Communication services provided to applications:
  - reliable data delivery
  - "best effort" (unreliable) data delivery



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What is a protocol?

human protocols:

- "what's the time?"
- "I have a question"
- introductions

… specific messages sent

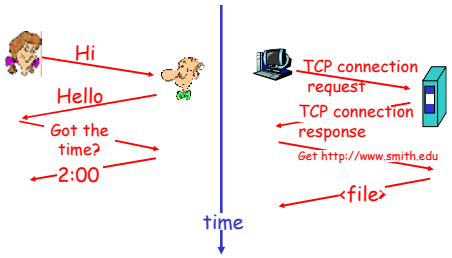
… specific actions taken when messages received, or other events

network protocols:

- machines rather than humans
- all communication activity in Internet governed by protocols

What is a protocol?

a human protocol and a computer network protocol:



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1.2 Network edge
  - end systems, access networks, links
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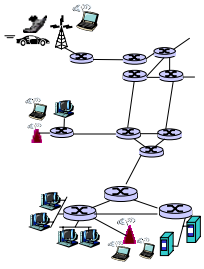
A closer look at network structure:

- network edge: applications and hosts
- access networks, physical media: wired, wireless communication links
- network core:
  - interconnected routers
  - network of networks



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The Network Edge

- End systems (hosts)
  - run application programs
  - e.g. Web, email
  - at "edge of network"
- Client/server model
  - client host requests and receives service from an always-on server
  - e.g. Web browser/server; email client/server
- Peer-to-peer model
  - minimal (or no) use of dedicated servers
  - e.g. Skype, BitTorrent

Network edge: reliable data transfer

Goal: data transfer between end systems

- *handshaking:* setup data transfer
  - Hello, hello back human protocol
  - *set up "state"* in two communicating hosts
- TCP - Transmission Control Protocol
  - Internet's reliable data transfer service
  - Congestion control
  - Flow control

Network edge: best effort (unreliable) data transfer

Goal: data transfer between end systems

- same as before!

- UDP - User Datagram Protocol:
  - unreliable data transfer
  - no flow control
  - no congestion control

App's using TCP:

- HTTP (Web), FTP (file transfer), Telnet (remote login), SMTP (email)

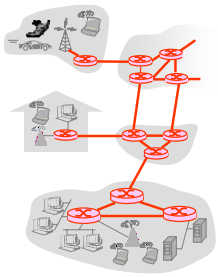
App's using UDP:

- streaming media, teleconferencing, DNS, Internet telephony

Chapter 1: roadmap

The Network Core

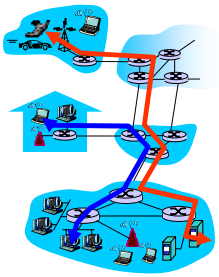
- mesh of interconnected routers
- *THE* Fundamental Question: how is data transferred through the Internet?
  - packet-switching: data sent thru net in discrete "chunks"
  - circuit switching: dedicated circuit per call: telephone net



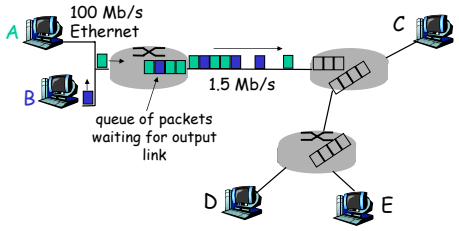
Network Core: Circuit Switching

End-end resources reserved for "call"

- link bandwidth, switch capacity
- dedicated resources: no sharing
- circuit-like (guaranteed) performance
- call setup required

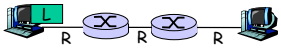


Packet Switching



Sequence of A & B packets does not have fixed pattern, bandwidth shared on demand

Packet Switching: store-and-forward



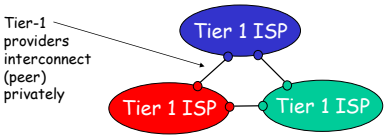
- takes L/R seconds to transmit (push out) packet of L bits on to link at R bps
- *Store and Forward:* entire packet must arrive at router before it can be transmitted on next link
- delay = 3L/R (assuming zero propagation delay)

Example:
- L = 7.5 Mbits
- R = 1.5 Mbps
- transmission delay = ? seconds

} more on delay shortly …

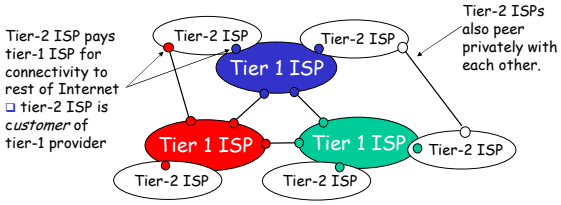
Internet structure: network of networks

- roughly hierarchical
- at center: "tier-1" ISPs (e.g., Verizon, Sprint, AT&T, Cable and Wireless), national/international coverage
  - treat each other as equals



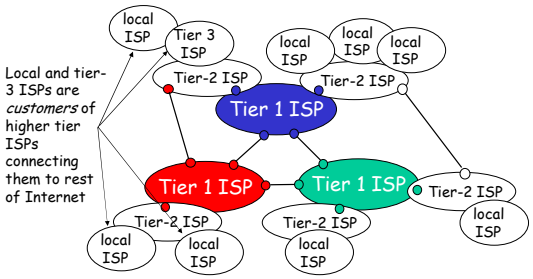
Internet structure: network of networks

- "Tier-2" ISPs: smaller (often regional) ISPs
  - Connect to one or more tier-1 ISPs, possibly other tier-2 ISPs



Internet structure: network of networks

- "Tier-3" ISPs and local ISPs
  - last hop ("access") network (closest to end systems)



Discussion Questions

- What is the distinguishing difference(s) between a tier-1 ISP and a tier-2 ISP?
  - Connections: to which other ISPs?
  - Technology: speed of routers and links

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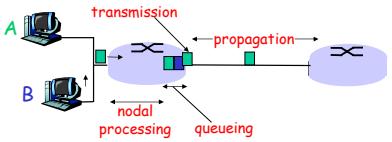
Four sources of packet delay

1. nodal processing
- Error checking
- Determine output link

2. queueing
- Time waiting at output link for transmission
- Depends on congestion level of router



Delay in packet-switched networks

3. Transmission delay
- R=link bandwidth (bps)
- L=packet length (bits)
- time to send bits into link = L/R

4. Propagation delay
- d = length of physical link
- s = propagation speed in medium (~2×10^8 m/sec)
- propagation delay = d/s

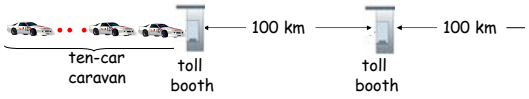
Note: s and R are *very* different quantities!

Nodal packet delay

$$d_{\text{nodal}} = d_{\text{proc}} + d_{\text{queue}} + d_{\text{trans}} + d_{\text{prop}}$$

- d_{proc} = processing delay
  - typically a few microsecs or less
- d_{queue} = queuing delay
  - depends on congestion
- d_{trans} = transmission delay
  - = L/R, significant for low-speed links
- d_{prop} = propagation delay
  - a few microsecs to hundreds of msecs

Caravan analogy

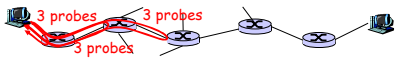


- car~bit; caravan ~ packet
- Toll booth takes 12 sec to service car (transmission time)
- Cars "propagate" at 100 km/hr
- Q: How long until the caravan is lined up before 2nd toll booth?

- Time to "transmit" entire caravan through toll booth onto highway = ?
- Time for last car to "propagate" from 1st to 2nd toll both: ?
- A:

"Real" Internet delays and routes

- What do "real" Internet delay & loss look like?
- Traceroute program: provides delay measurement from source to router along end-end Internet path towards destination. For all *i*:
  - sends three packets that will reach router *i* on path towards destination
  - router *i* will return packets to sender
  - sender times interval between transmission and reply.



"Real" Internet delays and routes

traceroute: gaia.cs.umass.edu to www.eurecom.fr

Three delay measurements from gaia.cs.umass.edu to cs-gw.cs.umass.edu

```
1  cs-gw (128.119.240.254)  1 ms  1 ms  2 ms
2  border1-rt-fa5-1-0.gw.umass.edu (128.119.3.145)  1 ms  1 ms  2 ms
3  cht-vbns.gw.umass.edu (128.119.3.130)  6 ms 5 ms 5 ms
4  jn1-at1-0-0-19.wor.vbns.net (204.147.132.129)  16 ms 11 ms 13 ms
5  jn1-so7-0-0-0.wae.vbns.net (204.147.136.136)  21 ms 18 ms 18 ms
6  abilene-vbns.abilene.ucaid.edu (198.32.11.9)  22 ms  18 ms  22 ms
7  nycm-wash.abilene.ucaid.edu (198.32.8.46)  22 ms  22 ms  22 ms
8  62.40.103.253 (62.40.103.253)  104 ms 109 ms 106 ms
9  de2-1.de1.de.geant.net (62.40.96.129)  109 ms 102 ms 104 ms
10  de.fr1.fr.geant.net (62.40.96.50)  113 ms 121 ms 114 ms
11  renater-gw.fr1.fr.geant.net (62.40.103.54)  112 ms  114 ms  112 ms
12  nio-n2.cssi.renater.fr (193.51.206.13)  111 ms  114 ms  116 ms
13  nice.cssi.renater.fr (195.220.98.102)  123 ms  125 ms  124 ms
14  r3t2-nice.cssi.renater.fr (195.220.98.110)  126 ms  126 ms  124 ms
15  eurecom-valbonne.r3t2.ft.net (193.48.50.54)  135 ms  128 ms  133 ms
16  194.214.211.25 (194.214.211.25)  126 ms  128 ms  126 ms
17  * * *
18  * * *
19  fantasia.eurecom.fr (193.55.113.142)  132 ms  128 ms  136 ms
```

trans-oceanic link

means no response (probe lost, router not replying)

"Real" Internet delays and routes

- Traceroute:
  - Play with traceroute
    - http://www.traceroute.org
  - Is part of homework, problem P16
    - Start early!
- PingPlotter freeware
  - http://www.pingplotter.com/freeware.html

Chapter 1: roadmap → for Thursday

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Today's Concepts Summary

- Question: How is data transferred through the Internet?
- Networking principles
- Network edge and network core
- Hardware vs. service model
- Protocols
- Reliability (TCP v. UDP)
- Packets and packet switching
  - Store and forward
- Delay in the Internet
  - Categories/origins of delay
  - Calculating delay

Course Administration

- Course webpage
  - www.science.smith.edu/~jcardell/Courses/CSC249
  - Course objectives
  - Grading
  - * Schedule *
- Current events discussions
  - Movies
  - News stories
  - The World is Flat, Thomas Friedman

Course Assignments

- Homework problems from text plus one programming assignment (Python)
  - Homework due on FRIDAYS, 4pm, EGR 105B
- Wireshark labs
- Participation
- Project
- Mid-term exam
- Final exam