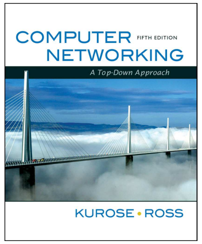
Chapter 1 Introduction



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Thanks and enjoy! JFK/KWR

Computer Networking: A Top Down Approach , 5th edition.
Jim Kurose, Keith Ross
Addison-Wesley, April 2009.

Chapter 1: Introduction

Our goal:
- get "feel" and terminology
- more depth, detail *later* in course
- approach:
  - use Internet as example

Overview:
- what's the Internet?
- what's a protocol?
- network edge; hosts, access net, physical media
- network core: packet/circuit switching, Internet structure
- performance: loss, delay, throughput
- security
- protocol layers, service models
- history

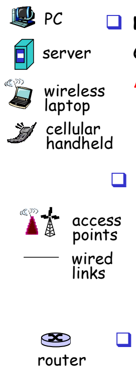
Chapter 1: roadmap

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

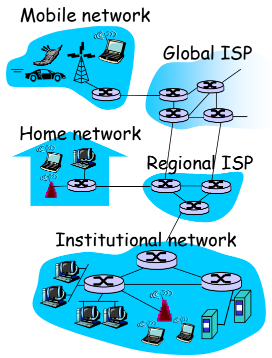
1.3 Network core
- circuit switching, packet switching, network structure

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's the Internet: "nuts and bolts" view



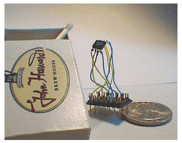
- millions of connected computing devices: *hosts = end systems*
  - running *network apps*
- *communication links*
  - fiber, copper, radio, satellite
  - transmission rate = *bandwidth*
- *routers:* forward packets (chunks of data)



“Cool” internet appliances

IP picture frame
http://www.ceiva.com/

Web-enabled toaster +
weather forecaster



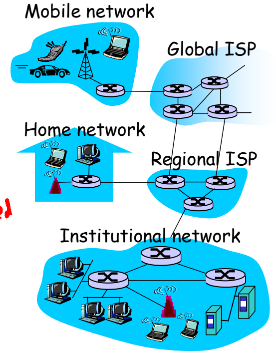
World’s smallest web server
http://www-ccs.cs.umass.edu/~shri/iPic.html

Internet phones

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

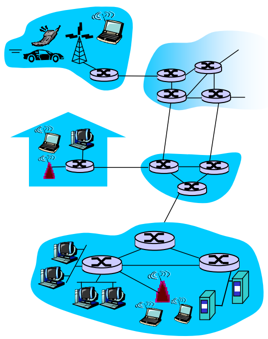
- *protocols* control sending, receiving of msgs
  - e.g., TCP, IP, HTTP, Skype, Ethernet
- *Internet:* “network of networks”
  - loosely hierarchical
  - public Internet versus private intranet
- Internet standards
  - RFC: Request for comments
  - IETF: Internet Engineering Task Force

numbered ~500



What’s the Internet: a service view

- communication *infrastructure* enables distributed applications:
  - Web, VoIP, email, games, e-commerce, file sharing
- communication services provided to apps:
  - reliable data delivery from source to destination
  - “best effort” (unreliable) data delivery



What’s a protocol?

human protocols:
- “what’s the time?”
- “I have a question”
- introductions

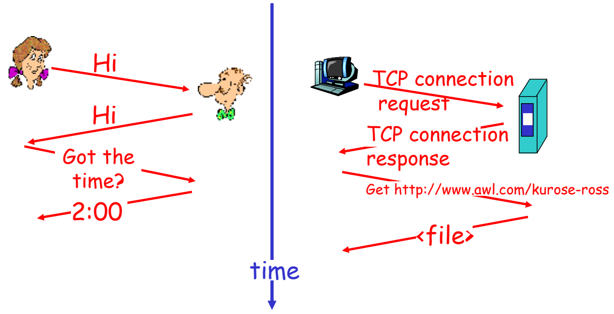
… specific msgs sent
… specific actions taken when msgs received, or other events

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

protocols define format, order of msgs sent and received among network entities, and actions taken on msg transmission, receipt

What's a protocol?

a human protocol and a computer network protocol:



Q: Other human protocols?

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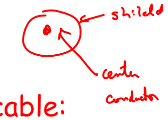
Physical Media

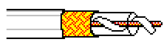
- Bit: propagates between transmitter/rcvr pairs
- physical link: what lies between transmitter & receiver
- guided media:
  - signals propagate in solid media: copper, fiber, coax
- unguided media:
  - signals propagate freely, e.g., radio

Twisted Pair (TP)
- two insulated copper wires
  - Category 3: traditional phone wires, 10 Mbps Ethernet
  - Category 5: 100Mbps Ethernet

Physical Media: coax, fiber



Coaxial cable:
- two concentric copper conductors
- bidirectional
- baseband:
  - single channel on cable
  - legacy Ethernet
- broadband:
  - multiple channels on cable
  - HFC



Fiber optic cable:
- glass fiber carrying light pulses, each pulse a bit
- high-speed operation:
  - high-speed point-to-point transmission (e.g., 10's-100's Gps)
- low error rate: repeaters spaced far apart ; immune to electromagnetic noise

Physical media: radio

- signal carried in electromagnetic spectrum
- no physical "wire"
- bidirectional
- propagation environment effects:
  - reflection
  - obstruction by objects
  - interference

Radio link types:

- terrestrial microwave
  - e.g. up to 45 Mbps channels
- LAN (e.g., Wifi)
  - 11Mbps, 54 Mbps
- wide-area (e.g., cellular)
  - 3G cellular: ~ 1 Mbps
- satellite
  - Kbps to 45Mbps channel (or multiple smaller channels)
  - 270 msec end-end delay
  - geosynchronous versus low altitude

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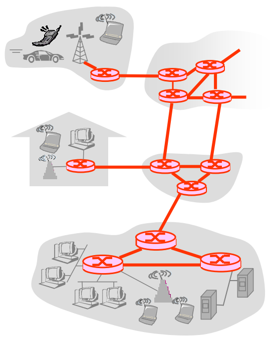
The Network Core

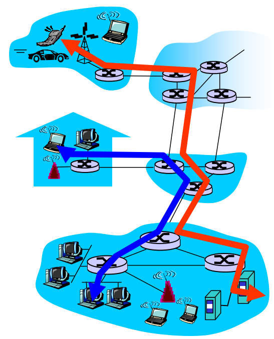
- mesh of interconnected routers
- *the* fundamental question: how is data transferred through net?
  - circuit switching: dedicated circuit per call: telephone net
  - packet-switching: data sent thru net in discrete "chunks"



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: Circuit Switching

network resources (e.g., bandwidth) divided into "pieces"

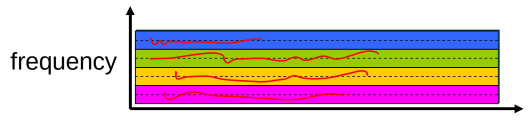
- pieces allocated to calls
- resource piece *idle* if not used by owning call *(no sharing)*

- dividing link bandwidth into "pieces"
  - frequency division
  - time division

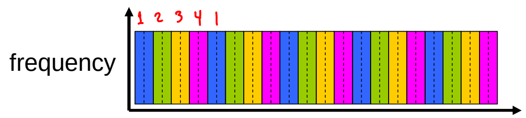
Circuit Switching: FDM and TDM

FDM frequency-division multiplexing

Example:
4 users



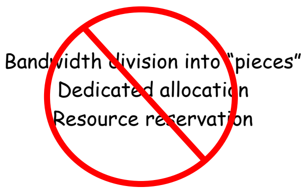
TDM time-division multiplexing



Network Core: Packet Switching

each end-end data stream divided into *packets*

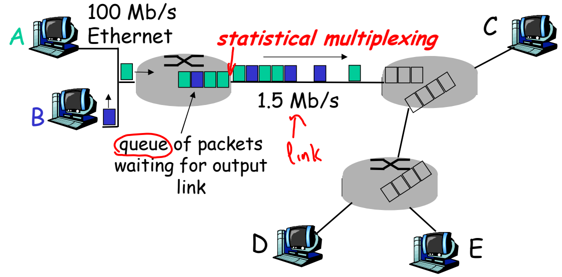
- user A, B packets *share* network resources
- each packet uses full link bandwidth
- resources used *as needed*



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
  - Node receives complete packet before forwarding

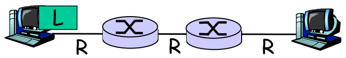
Packet Switching: Statistical Multiplexing



Sequence of A & B packets does not have fixed pattern, bandwidth shared on demand ➔ ***statistical multiplexing***.

TDM: each host gets same slot in revolving TDM frame.

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 = 15 sec

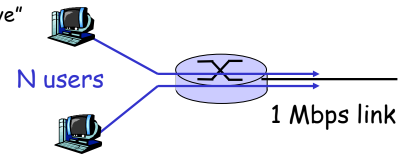
more on delay shortly …

Packet switching versus circuit switching

Packet switching allows more users to use network!

— In some circumstances.

- 1 Mb/s link
- each user:
  - 100 kb/s when "active"
  - active 10% of time
- *circuit-switching:*
  - 10 users
- *packet switching:*
  - with 35 users, probability > 10 active at same time is less than .0004



Q: how did we get value 0.0004?

Packet switching versus circuit switching

Is packet switching a "slam dunk winner?"

- great for bursty data
  - resource sharing
  - simpler, 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 (chapter 7)

Q: human analogies of reserved resources (circuit switching) versus on-demand allocation (packet-switching)?

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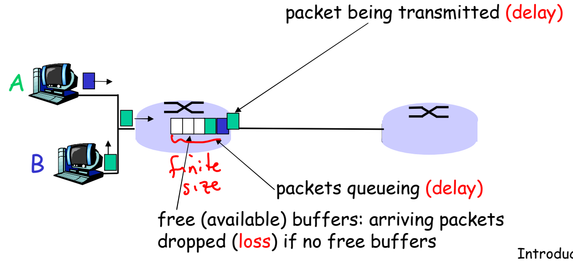
How do loss and delay occur?

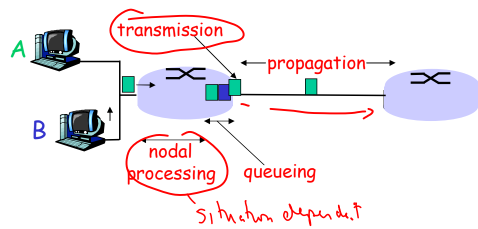
packets *queue* in router buffers

- packet arrival rate to link exceeds output link capacity
- packets queue, wait for turn



Four sources of packet delay

- 1. nodal processing:
  - check bit errors
  - determine output link
- 2. queueing
  - time waiting at output link for transmission
  - depends on congestion level of router



Delay in packet-switched networks

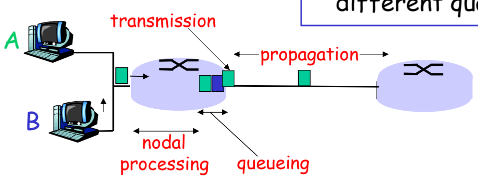
3. Transmission delay: bits/sec

- 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 (~2x10^8 m/sec)
- propagation delay = d/s

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



Magnitudes and Units: Very Important!

- Prefixes: nano (10^{-9}), micro (10^{-6}), milli (10^{-3}), | 1 | kilo (10^{3}), mega (10^{6}), giga (10^{9}), tera (10^{12}) – seconds, bits, bytes, meters
- For our purposes a byte (octet) is usually 8 bits – rounding off to 10 is a good approximation
- Don't confuse things with different units:
  - Packet length (L) – bits, bytes
  - Transmission Rate (R) – bits/sec, bytes/sec
  - Delay (d) – seconds
  - Propagation speed (s) – meters/sec
- Speed of light 2e8 m/sec, 2e5km/sec in wire or fiber; 3e8m/sec in free space

Example calculations

- How long does it take to send 1 Mbyte packet at a rate of 50kbits/sec (transmission delay)

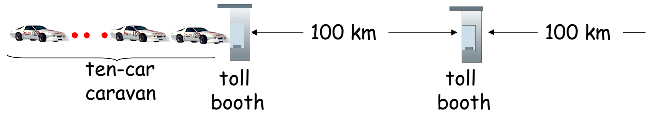
$\frac{8e6}{50e3} = \frac{8}{50} \times 10^3$ seconds $.16 \times 10^3 = 160$ sec

- What is the round trip delay for a bit sent from the earth to a synchronous orbit satellite at 40,000 km above the earth (propagation delay)

$\frac{40{,}000 \text{ Km}}{3 \times 10^5 \text{ Km/sec}} = .25$ sec

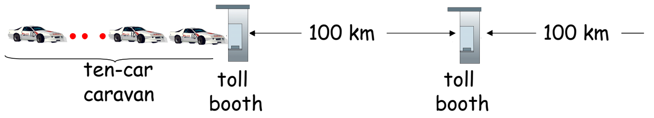
- In such calculations make sure you get the units right!

Putting it together: Caravan analogy



- cars "propagate" at 100 km/hr
- toll booth takes 12 sec to service car (transmission time)
- car~bit; caravan ~ packet
- Q: How long until caravan is lined up before 2nd toll booth?
- Time to "push" entire caravan through toll booth onto highway = 12*10 = 120 sec
- Time for last car to propagate from 1st to 2nd toll both: 100km/(100km/hr)= 1 hr
- A: 62 minutes

Caravan analogy (more)



- Cars now "propagate" at 1000 km/hr
- Toll booth now takes 1 min to service a car
- Q: Will cars arrive to 2nd booth before all cars serviced at 1st booth?
- Yes! After 7 min, 1st car at 2nd booth and 3 cars still at 1st booth.
- 1st bit of packet can arrive at 2nd router before packet is fully transmitted at 1st router!
  - See Ethernet applet at AWL Web site