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ELE 437
Computer Network

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What Do You Learn?

1. Network Concepts and Architectures
2. Communication Protocols
   (e.g. TCP/IP)
3. Doing Useful Work on a Network

How?

- •Lectures,
- •Reading and programming
- •Project (20% of total grade),
- •Presentations (10% grade), and
- •Exams (40% for 2 Midtermexams + 30% for final).

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Main Focus of This Semester

1. TCP/IP Architecture
   - Internet
2. Ethernet LAN
3. Wireless Communication
   - ZigBee or Bluetooth
4. Application Protocols
5. Performance Evaluation

Lecture I: Introduction

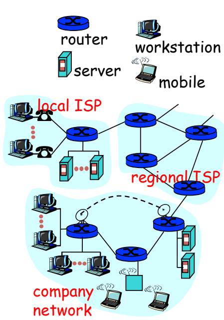
Goals:
- get context, overview, feel of networking
- more depth, detail *later* in course
- approach:
  - descriptive
  - use Internet as example

Overview:
- what is the Internet
- what is a protocol?
- network edge
- network core
- access net, physical media
- performance: loss, delay
- protocol layers, service models

What is the Internet: nuts and bolts view

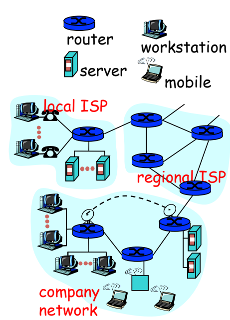
- millions of connected computing devices: *hosts, end-systems*
  - pc workstations, servers
  - PDA, phones, toasters

  running *network apps*
- *communication links*
  - fiber, copper, radio, satellite
- *routers:* forward packets (chunks) of data thru network



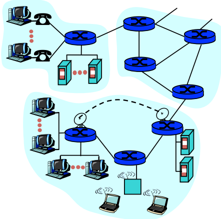
What is the Internet: nuts and bolts view

- *protocols*: control sending, receiving of msgs
  - 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



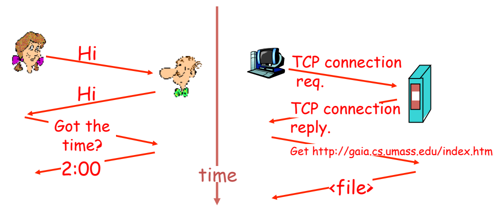
What is the Internet: a service view

- communication *infrastructure* enables distributed applications:
  - WWW, email, games, e-commerce, database., voting,
  - more?
- communication services provided:
  - connectionless
  - connection-oriented



What is a protocol?

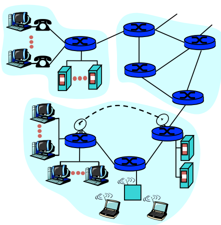
a human protocol and a computer network protocol:



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

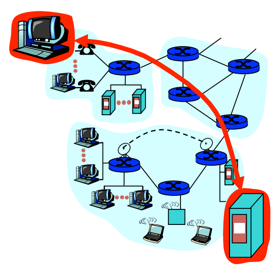
A closer look at network structure:

- 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, email
  - at edge of network
- client/server model
  - client host requests, receives service from server
  - e.g., WWW client (browser)/ server; email 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 will not 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 connectionless service
  - unreliable data transfer
  - no flow control
  - no congestion control

App using TCP:

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

App using UDP:

- streaming media, teleconferencing, Internet telephony

The Network Core

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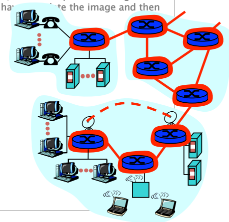
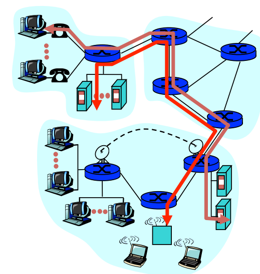
- mesh of interconnected routers
- *the* fundamental question: how is data transferred through net?
  - circuit switching: dedicated circuit per call: telephone net
  - packet-switching: data sent thru net in discrete chunks



Network Core: Circuit Switching

End-end resources reserved for call

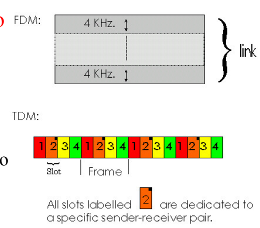
- link bandwidth, switch capacity
- dedicated resources: no sharing
- circuit-like (guaranteed) performance
- call setup required



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



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*,

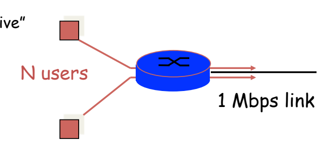
resource contention:

- aggregate resource demand can exceed amount available
- congestion: packets queue, wait for link use
- store and forward: packets move one hop at a time
  - transmit over link
  - wait turn at next link

Packet switching versus circuit switching

Packet switching allows more users to use network!

- 1 Mbit link
- each user:
  - 100 kbps when "active"
  - active 10% of time
- circuit-switching:
  - 10 users
- packet switching:
  - with 35 users, probability > 10 active less than .0004

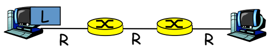


Packet switching versus circuit switching

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 6)

Packet-switching: store-and-forward



- Takes L/R seconds to transmit (push out) packet of L bits on to link or R bps
- Entire packet must arrive at router before it can be transmitted on next link: *store and forward*
- delay = 3L/R

Example:
- L = 7.5 Mbits
- R = 1.5 Mbps
- delay = 15 sec