Network Protocols and Architectures

Introduction

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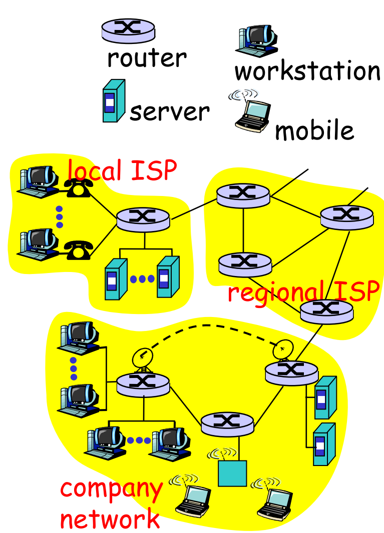
What's the Internet: "nuts and bolts" view

- 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



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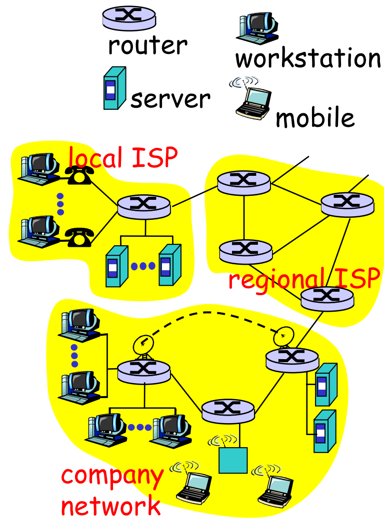
What's the Internet: "nuts and bolts" view

- *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



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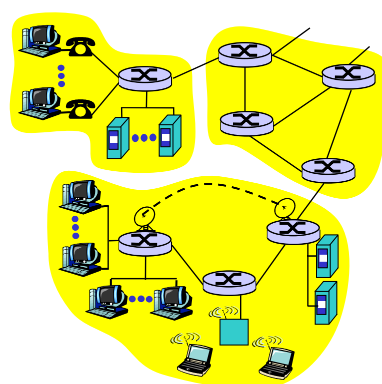
What's the Internet: A service view

- 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, ..."



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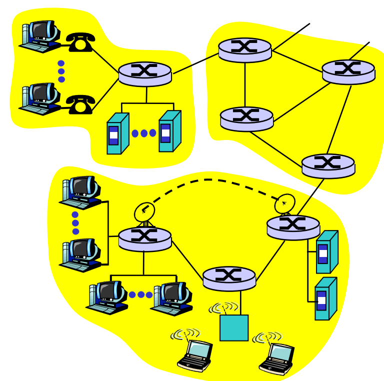
A closer look at network structure

- Network edge: applications and hosts
- Network core:
  - Routers
  - Network of networks
- Access networks, physical media: Communication links



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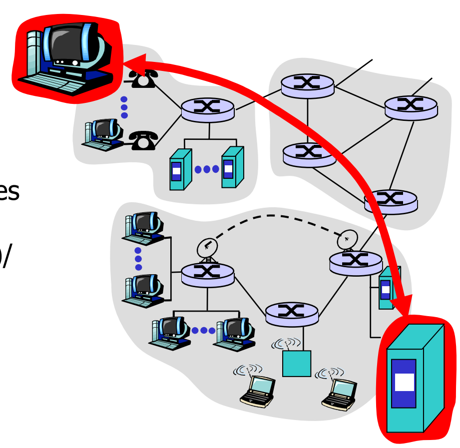
The network edge

- 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



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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

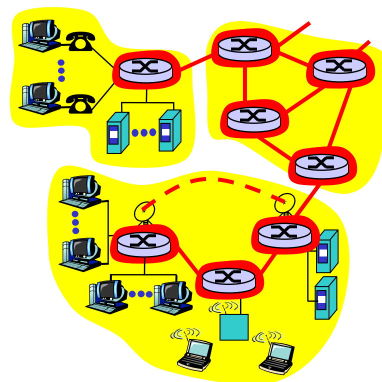
Goal: Data transfer between end systems

- 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"



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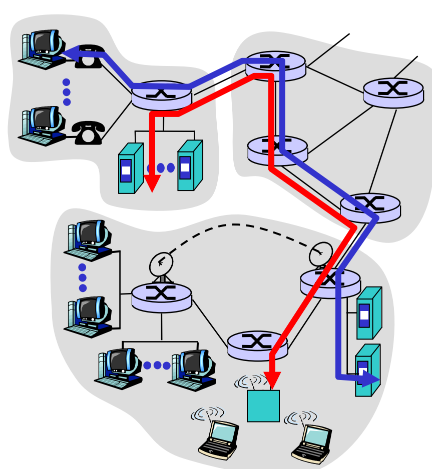
Network core: Circuit switching

End-end resources reserved for "call"

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



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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*

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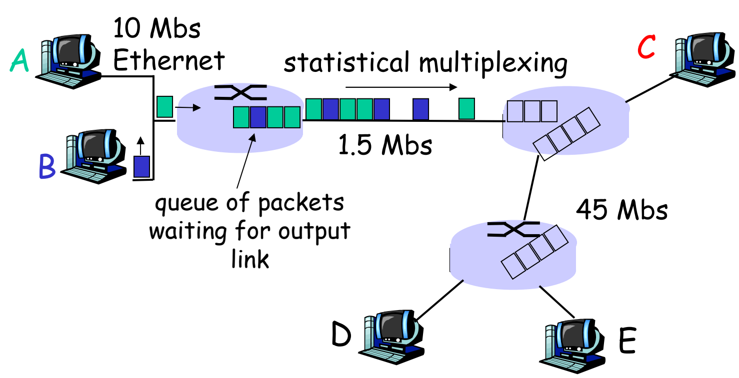
Network core: Packet switching



Packet-switching versus circuit switching:
Human restaurant analogy

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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

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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?

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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?

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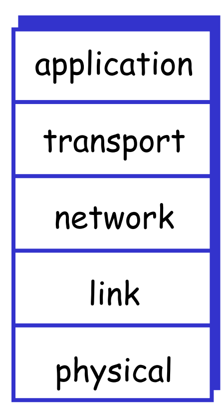
Internet protocol stack

- 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"



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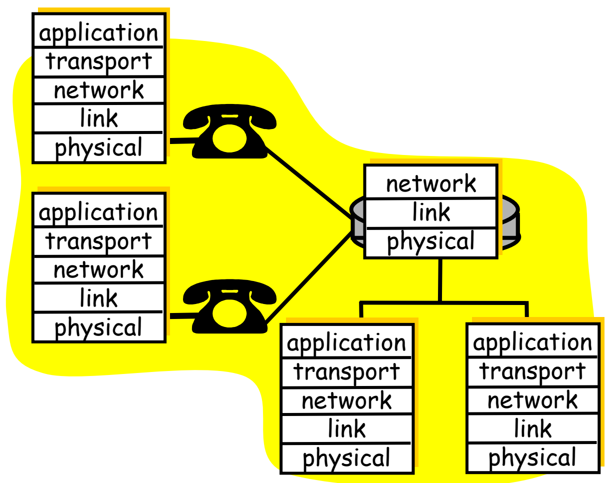
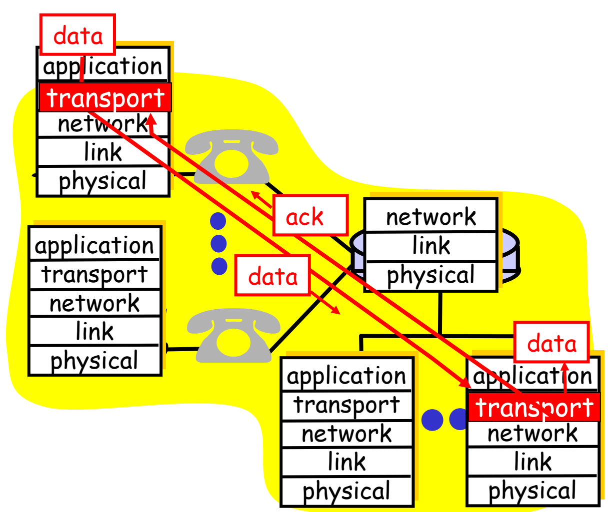
Layering: *Logical* communication

Each layer:
- Distributed
- "Entities" implement layer functions at each node
- Entities perform actions, exchange messages with peers

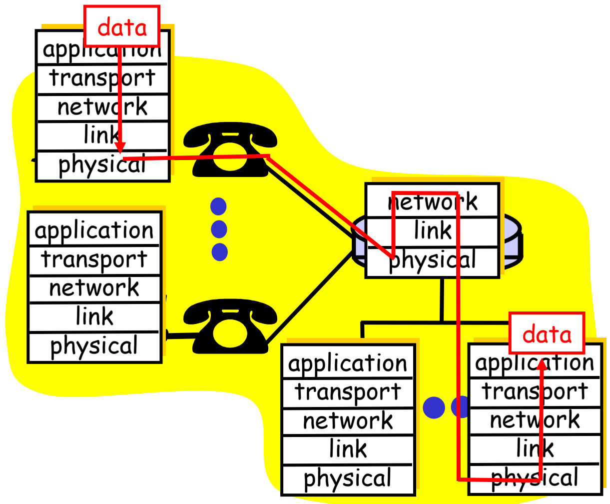


Layering: *Logical* communication

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



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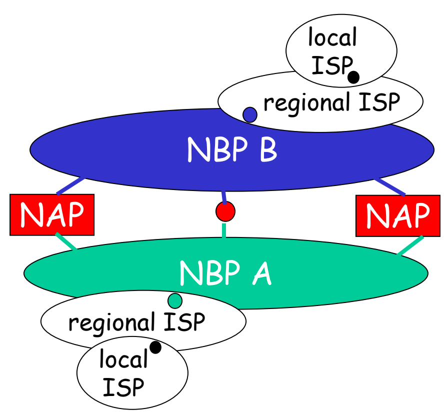
Internet structure: Network of networks

- 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



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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

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