

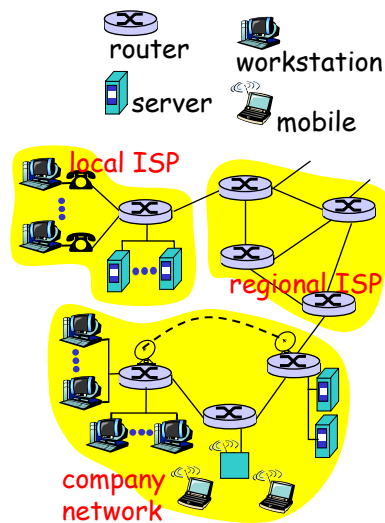
Network Protocols and Architectures

Introduction

1

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

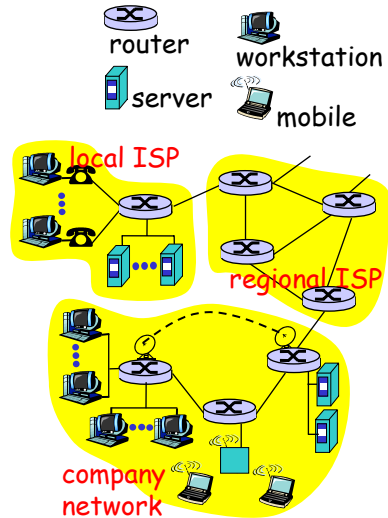
- Millions of connected computing devices: *hosts, end-systems*
 - PC's workstations, servers
 - PDA's, phones, toasters running *network apps*
- *Communication links*
 - Fiber, copper, radio, satellite
- *Routers*: forward packets (chunks) of data through network



2

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

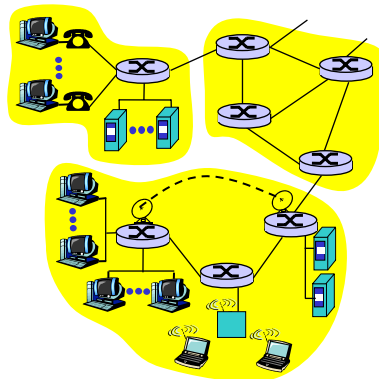
- **Protocols:** control sending, receiving of messages
 - E.g., TCP, IP, HTTP, FTP, PPP
- **Internet: "network of networks"**
 - Loosely hierarchical
 - Public Internet versus private intranet
- **Internet standards**
 - RFC: Request for comments
 - IETF: Internet Engineering Task Force



3

What's the Internet: A service view

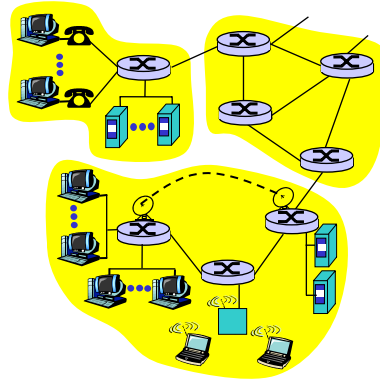
- **Communication infrastructure** enables distributed applications:
 - WWW, email, games, e-commerce, database, voting,
 - More?
- **Communication services provided:**
 - Connectionless
 - Connection-oriented
- **cyberspace [Gibson]:**
 - "a consensual hallucination experienced daily by billions of operators, in every nation,"



4

A closer look at network structure

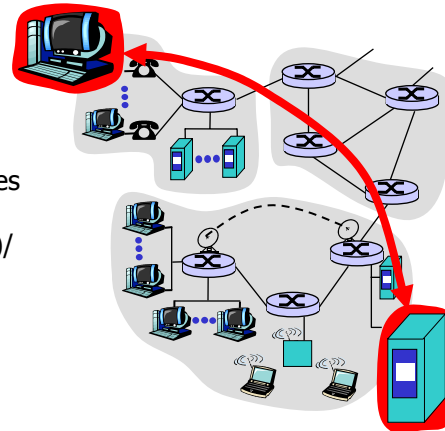
- **Network edge:**
applications and hosts
- **Network core:**
 - Routers
 - Network of networks
- **Access networks, physical media:**
Communication links



5

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



6

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

7

Network edge: connectionless service

Goal: Data transfer between end systems

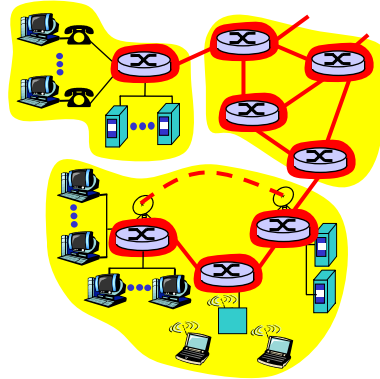
- Same as before!

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

8

The network core

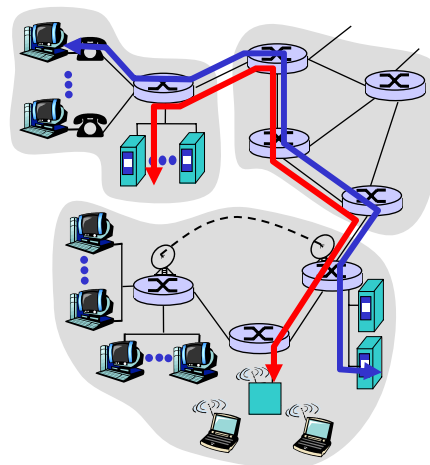
- Mesh of interconnected routers
- **The fundamental question:** How is data transferred through net?
 - **Circuit switching:** Dedicated circuit per call: telephone net
 - **Packet switching:** Data sent through net in discrete "chunks"



9

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



10

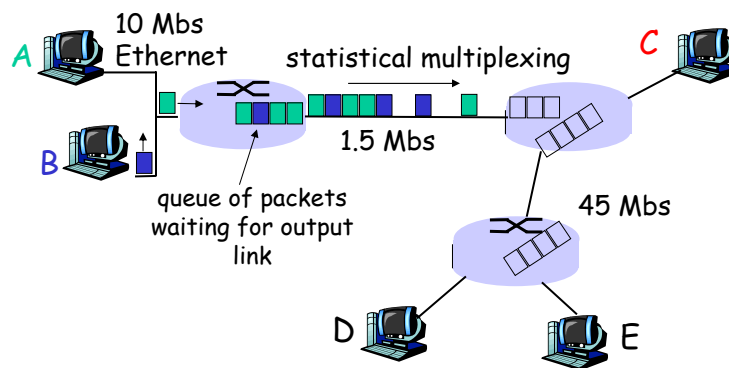
Network core: Packet switching

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*

11

Network core: Packet switching



Packet-switching versus circuit switching:
Human restaurant analogy

12

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

13

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

14

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

15

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?

16

Why layering?

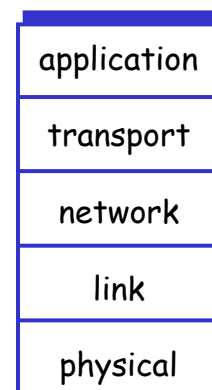
Dealing with complex systems:

- ❑ 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?

17

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"

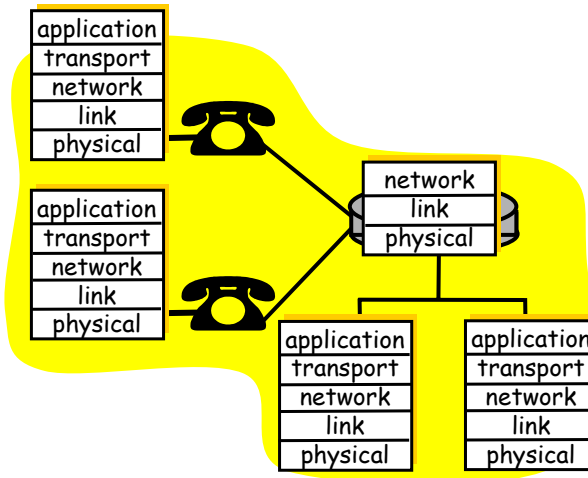


18

Layering: *Logical* communication

Each layer:

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

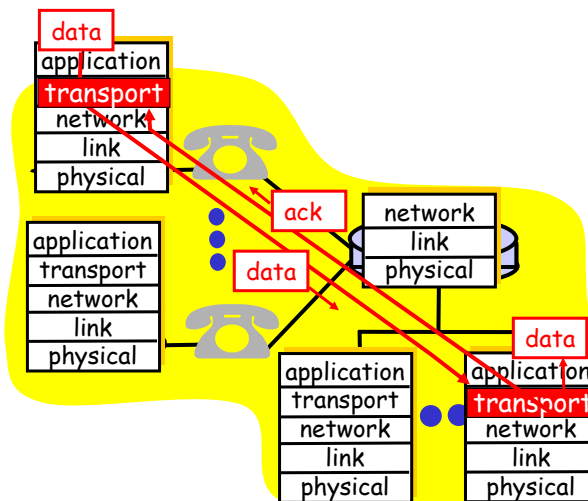


19

Layering: *Logical* communication

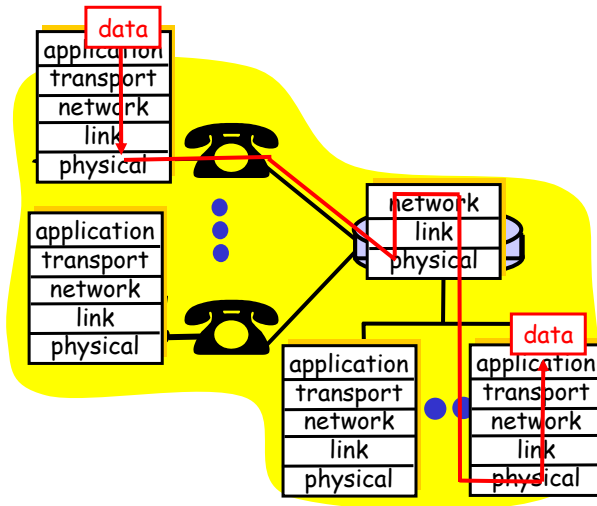
E.g., transport

- 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



20

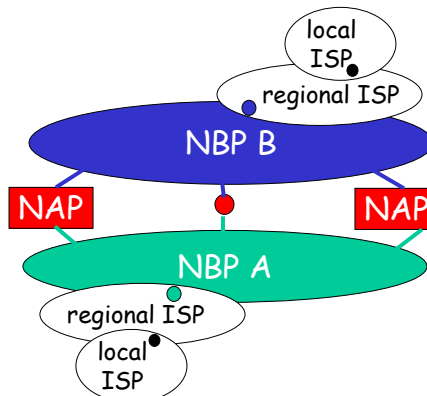
Layering: *Physical communication*



21

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



22

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