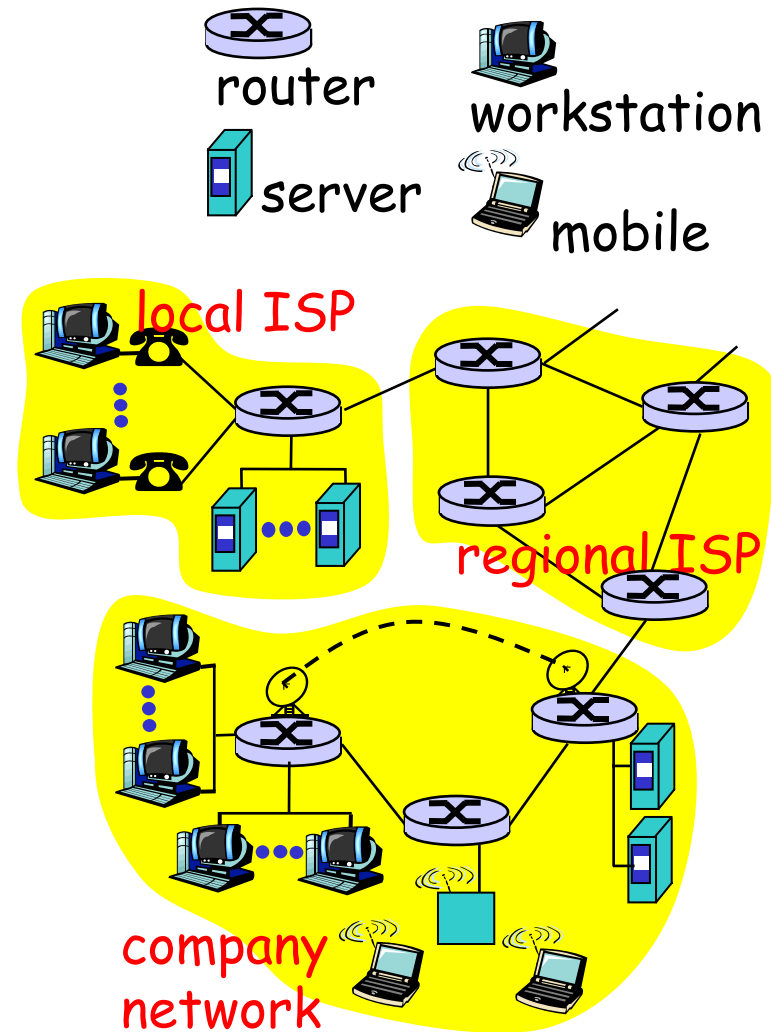


# Network Protocols and Architectures

## Introduction

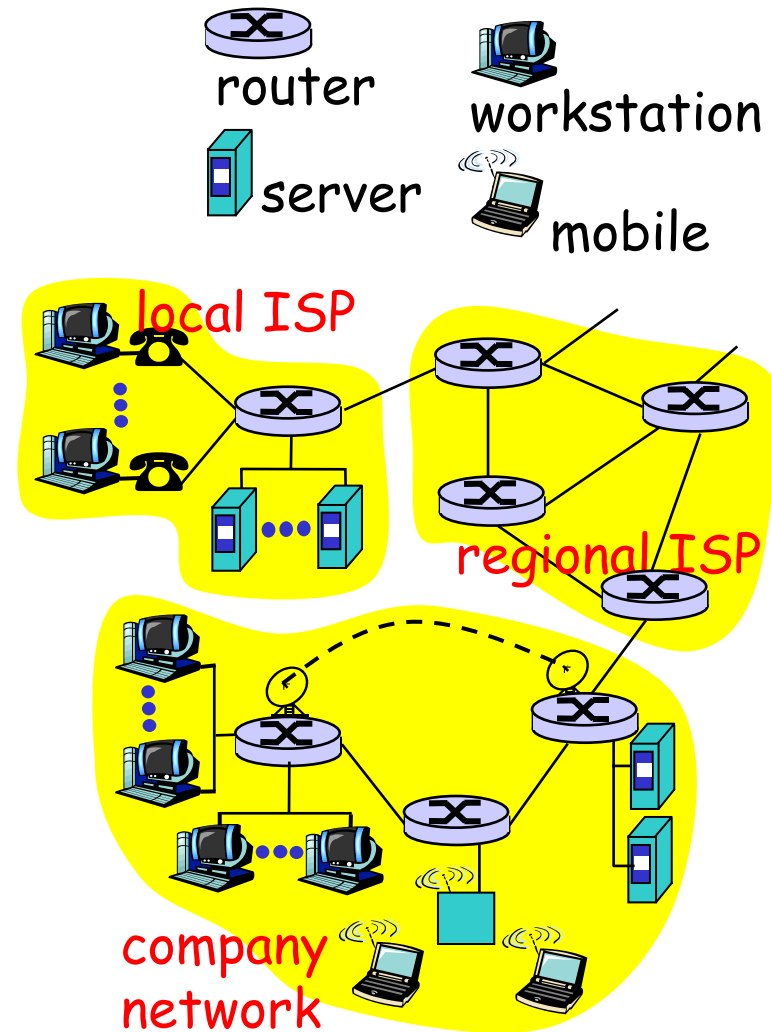
# What's the Internet: "nuts and bolts" view

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



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

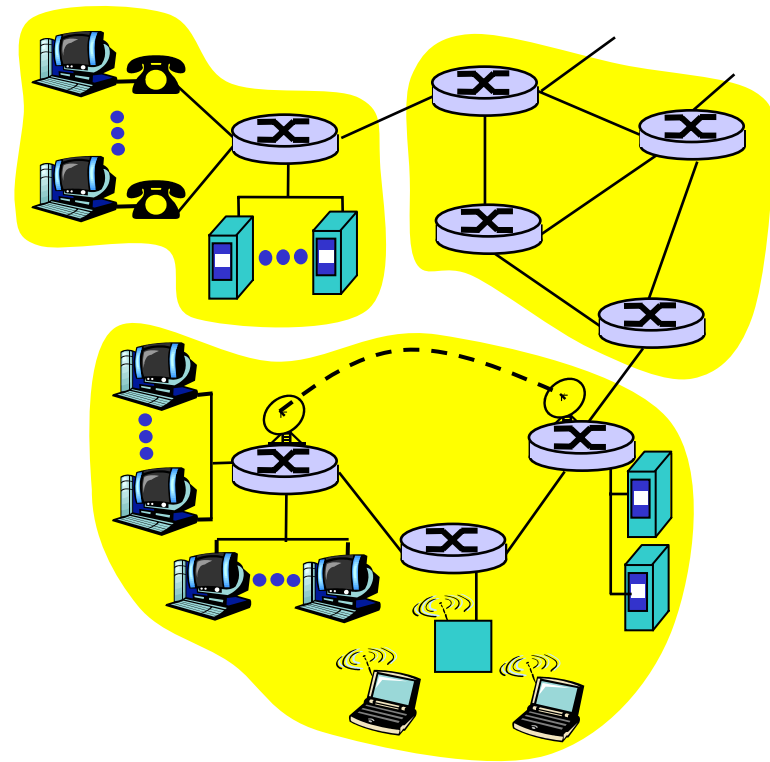
- ❑ **Protocols:** control sending, receiving of messages
  - E.g., TCP, IP, HTTP, FTP, PPP
- ❑ **Internet: "network of networks"**
  - Loosely hierarchical
  - Public Internet versus private intranet
- ❑ **Internet standards**
  - RFC: Request for comments
  - IETF: Internet Engineering Task Force



# What's the Internet: A service view

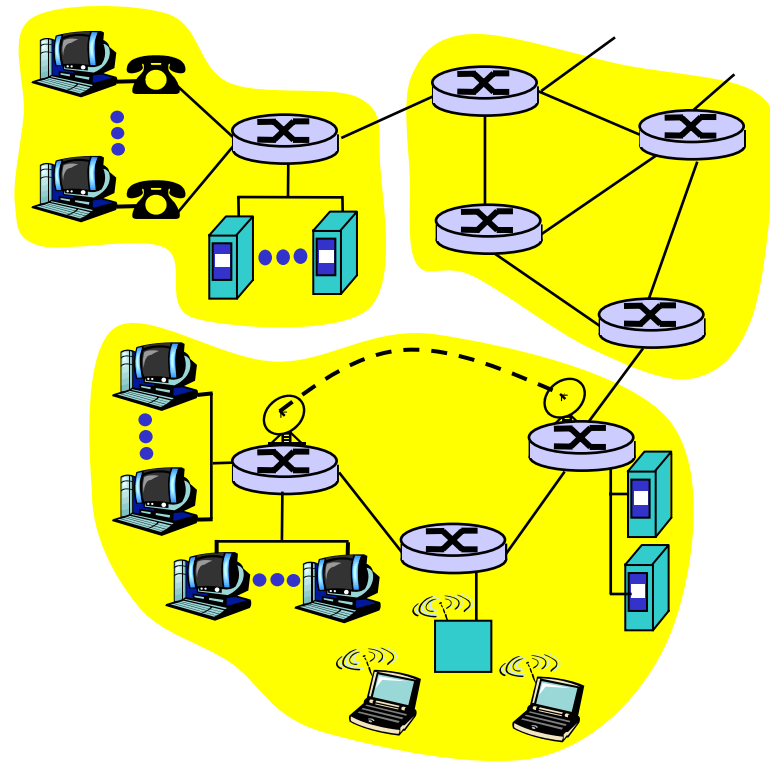
- **Communication infrastructure** enables distributed applications:
  - WWW, email, games, e-commerce, database, voting,
  - More?
- **Communication services provided:**
  - Connectionless
  - Connection-oriented
- **cyberspace [Gibson]:**

“a consensual hallucination experienced daily by billions of operators, in every nation, ....”



# 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):

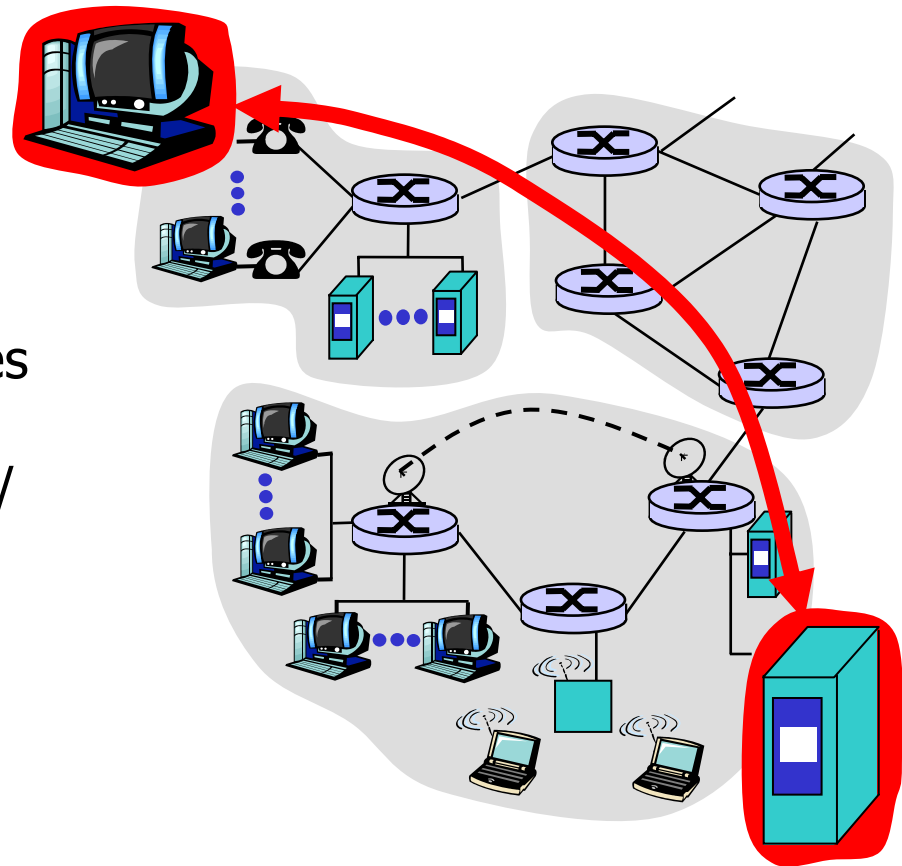
- Run application programs
- E.g., WWW, e-mail
- At "edge of network"

## □ 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



# 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

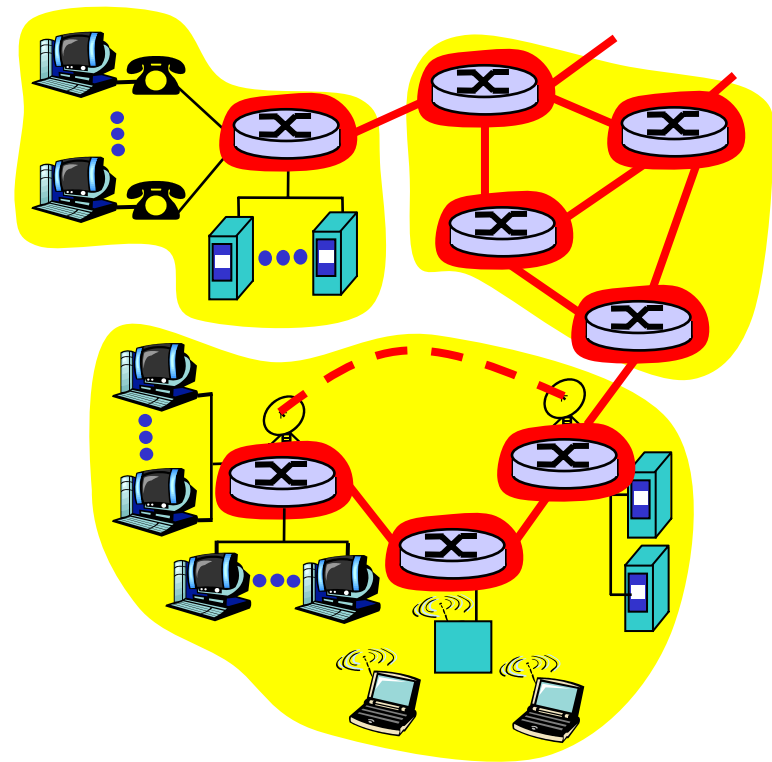
**Goal:** Data transfer between end systems

- 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

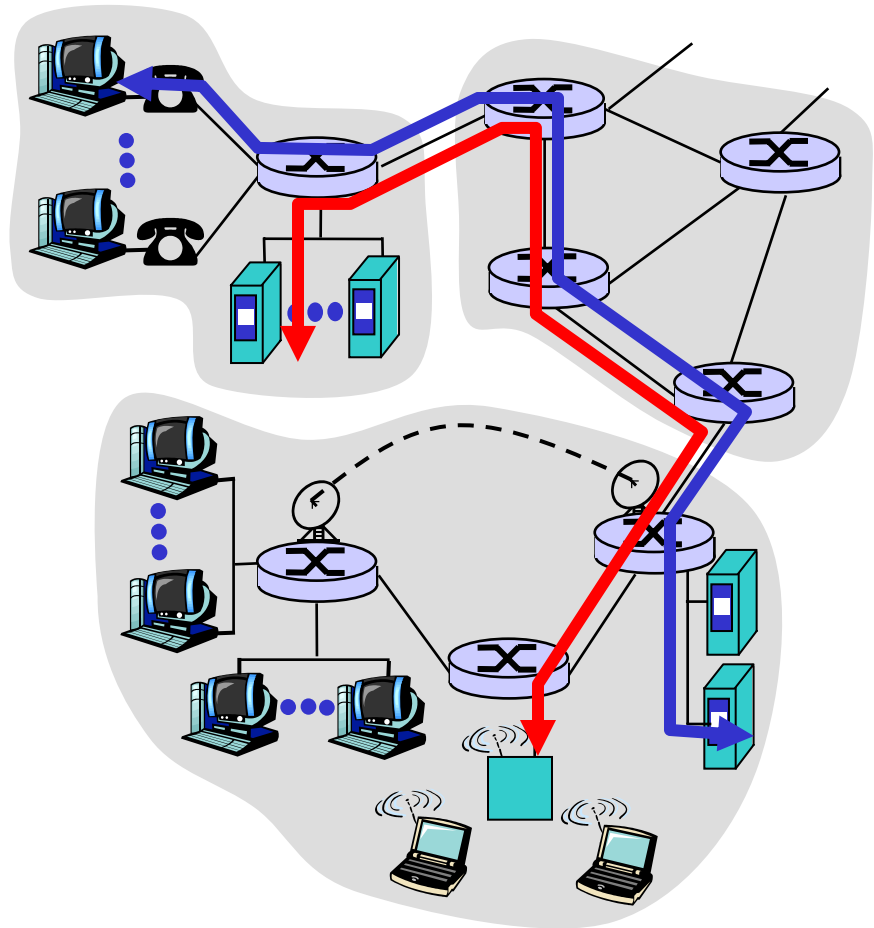
- Mesh of interconnected routers
- ***The fundamental question:***  
How is data transferred through net?
  - **Circuit switching:**  
Dedicated circuit per call: telephone net
  - **Packet switching:** Data sent through net in discrete “chunks”



# 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

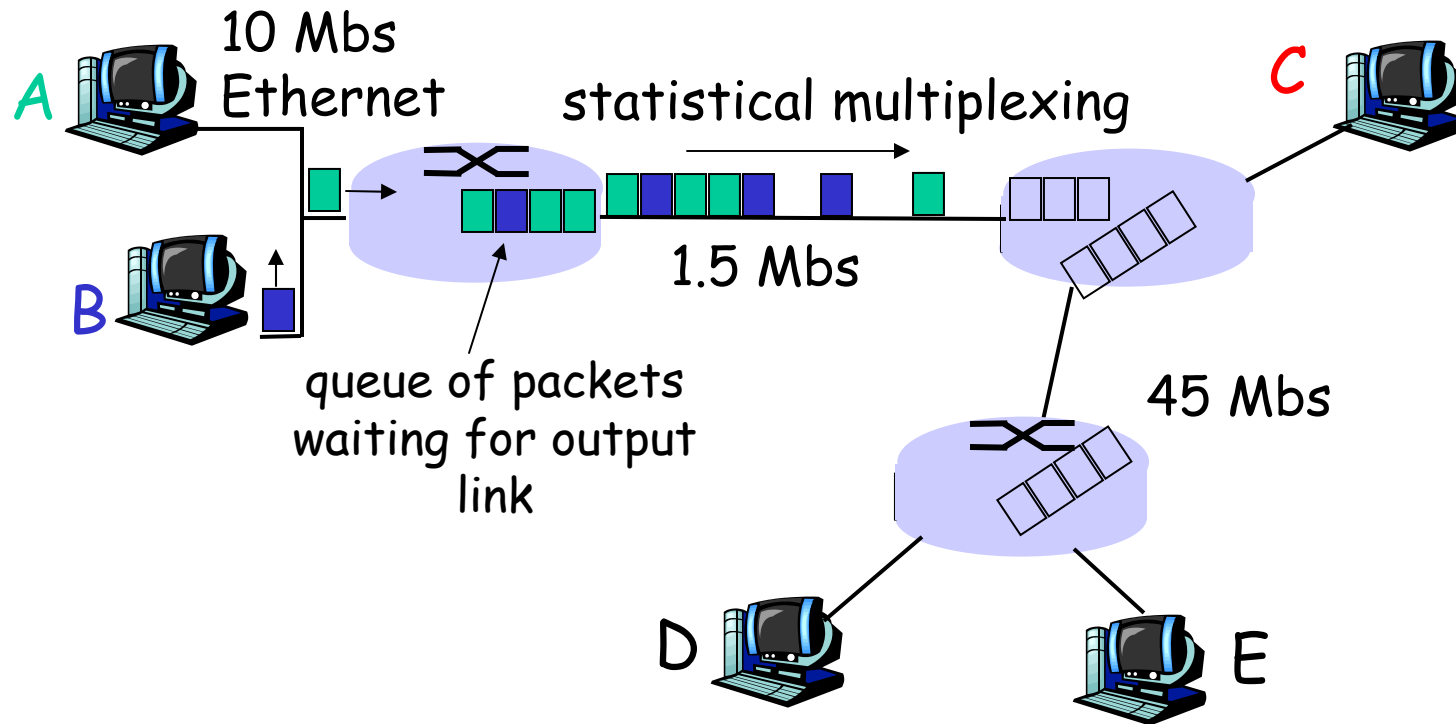


# Network core: Packet switching

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*

# Network core: Packet switching



Packet-switching versus circuit switching:  
Human restaurant analogy

# 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

# 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?



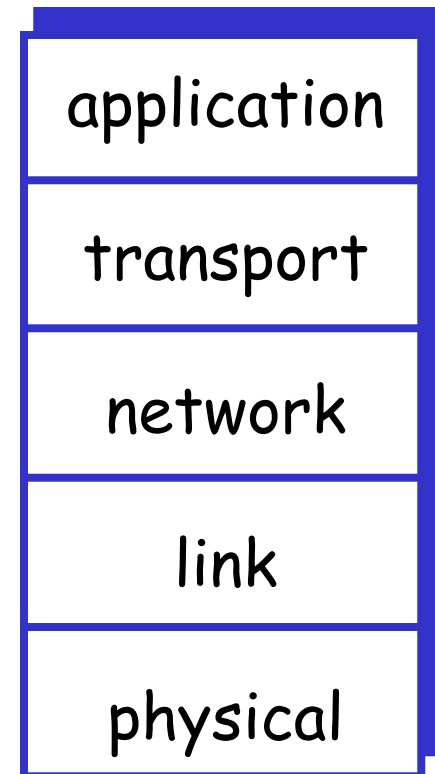
# Why layering?

## 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?

# Internet protocol stack

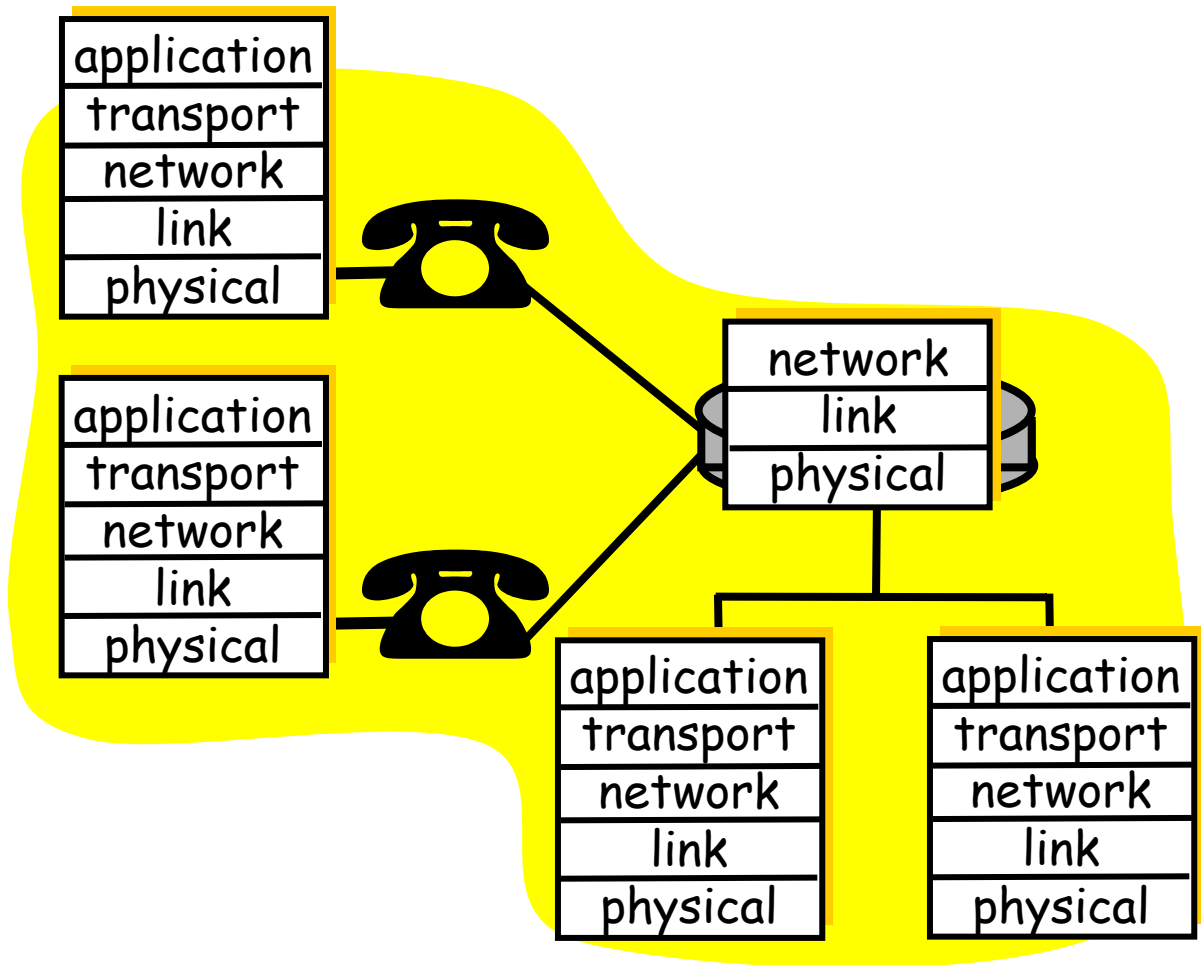
- ❑ **Application:** supporting network applications
- ❑ **Transport:** host-host data transfer
- ❑ **Network:** uniform format of packets, routing of datagrams from source to destination
- ❑ **Link:** data transfer between neighboring network elements
- ❑ **Physical:** bits “on the wire”



# Layering: *Logical* communication

Each layer:

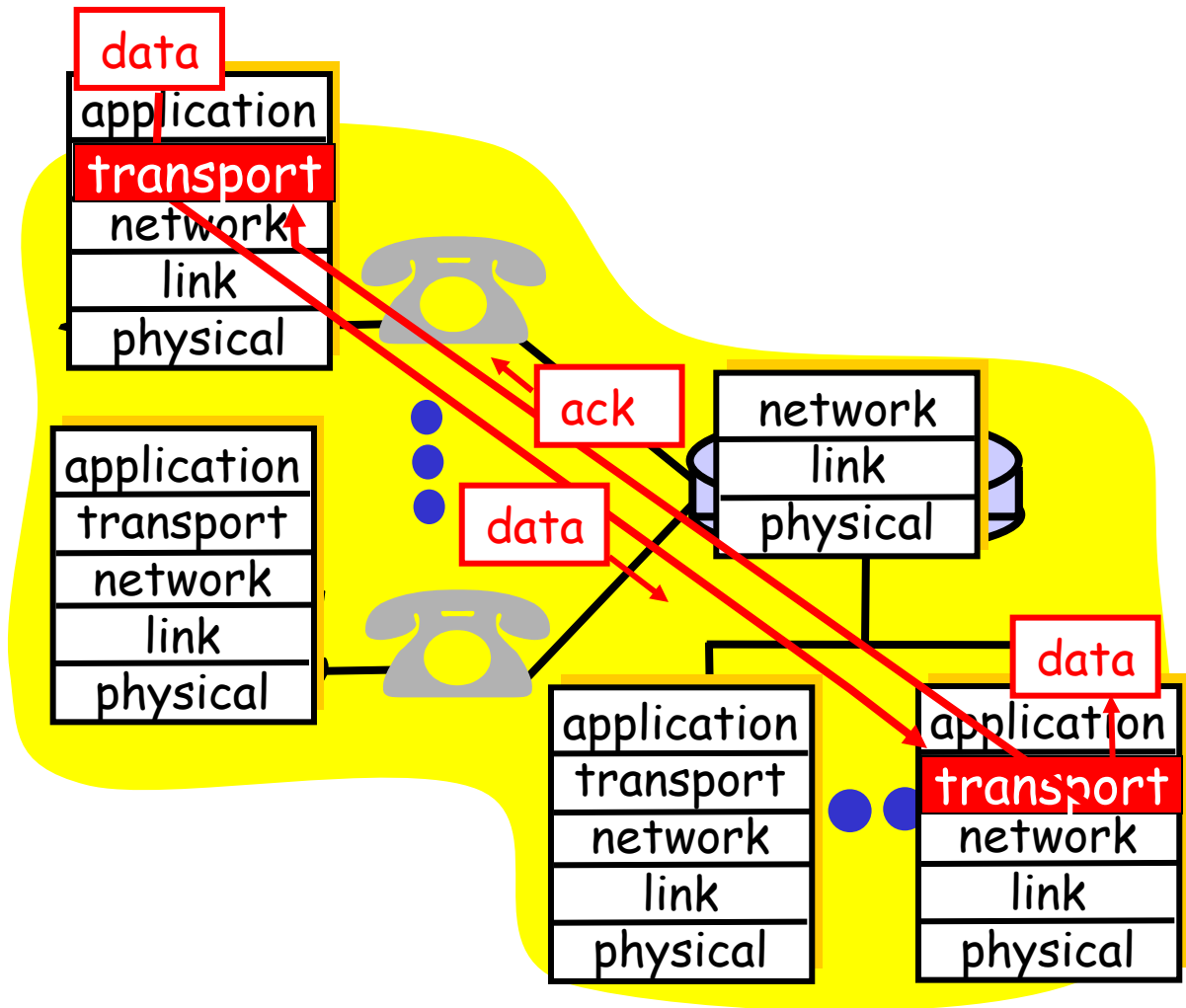
- ❑ Distributed
- ❑ "Entities" implement layer functions at each node
- ❑ Entities perform actions, exchange messages with peers



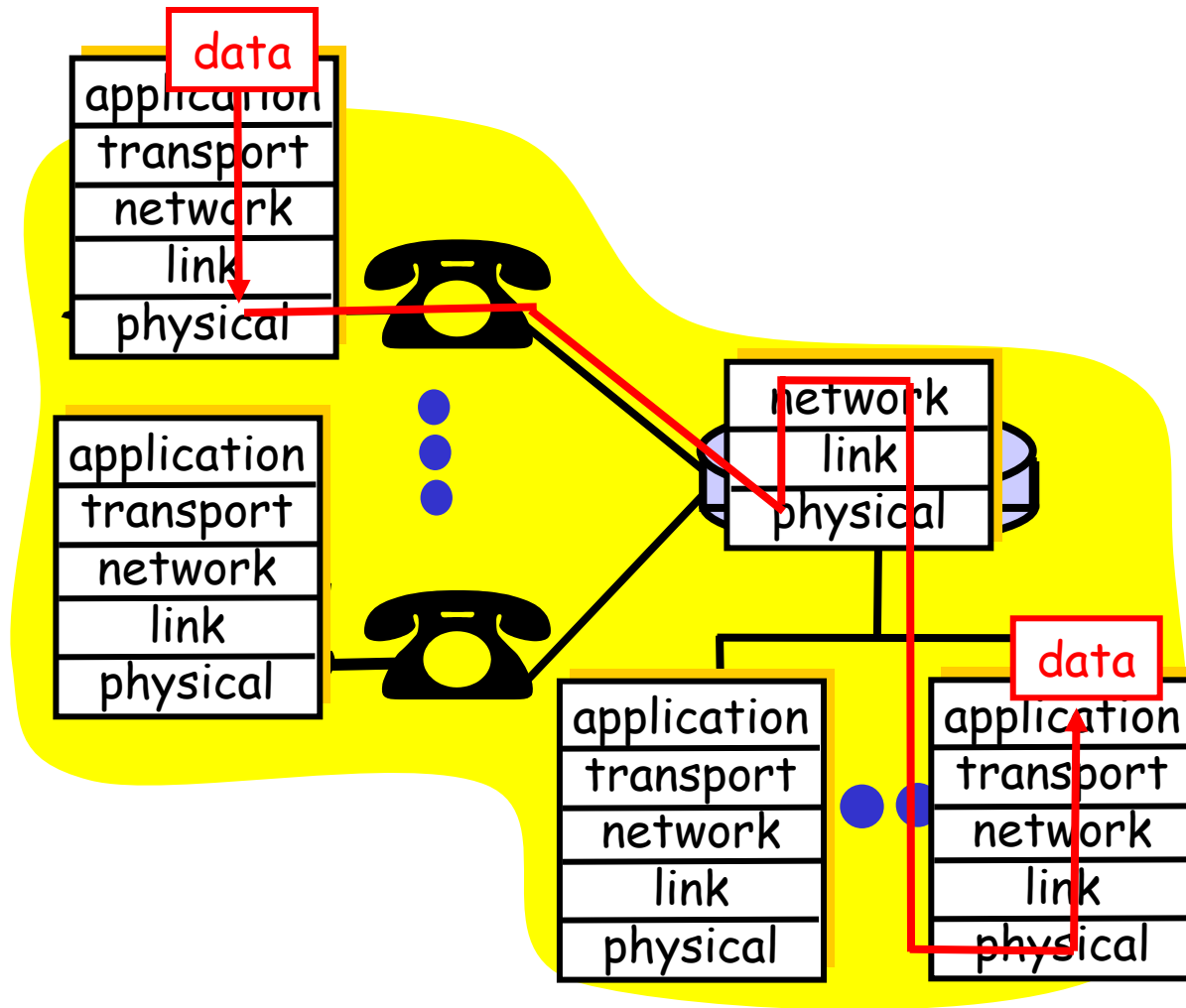
# Layering: *Logical* communication

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

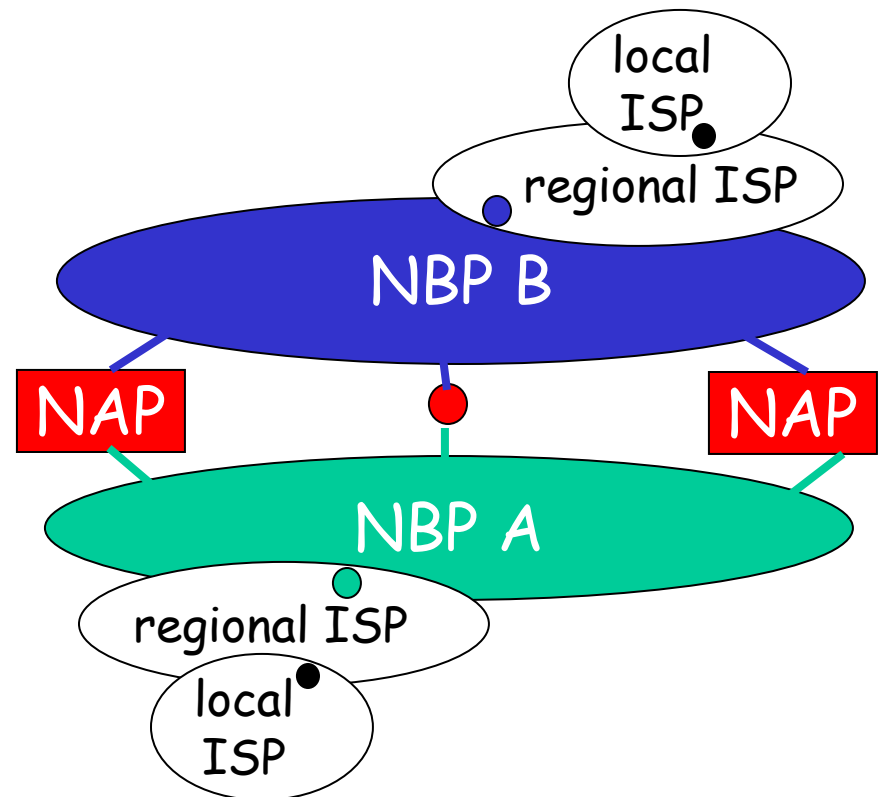


# Layering: *Physical* communication



# 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



# 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