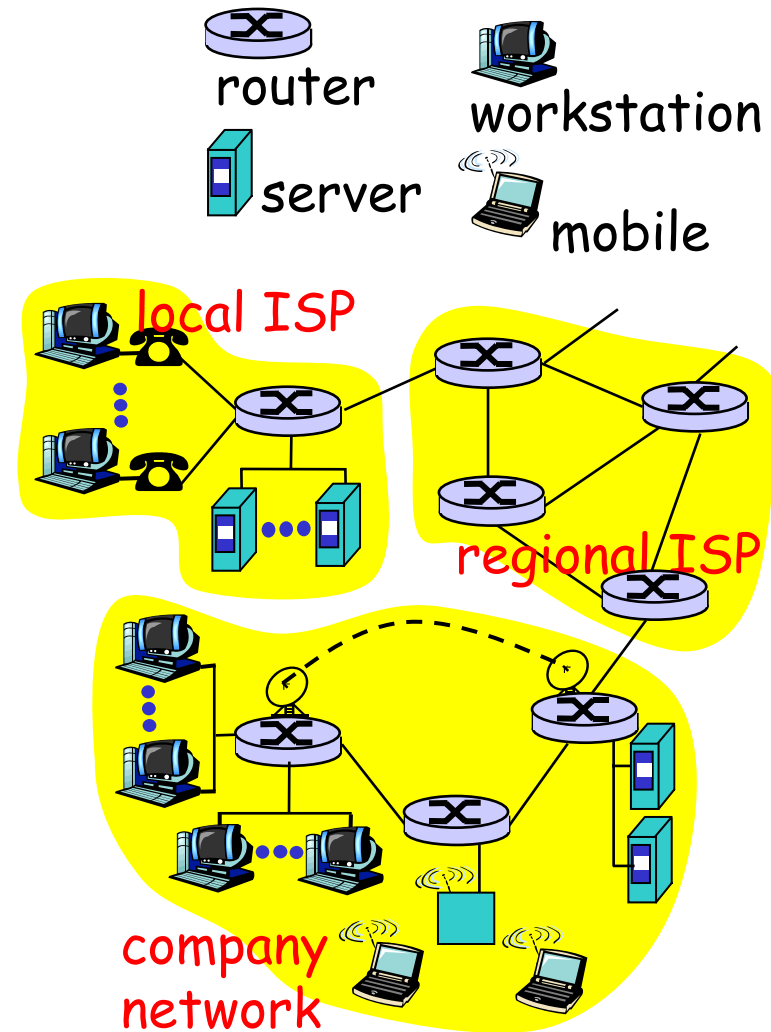


Internet Routing

Review of Networking Principles

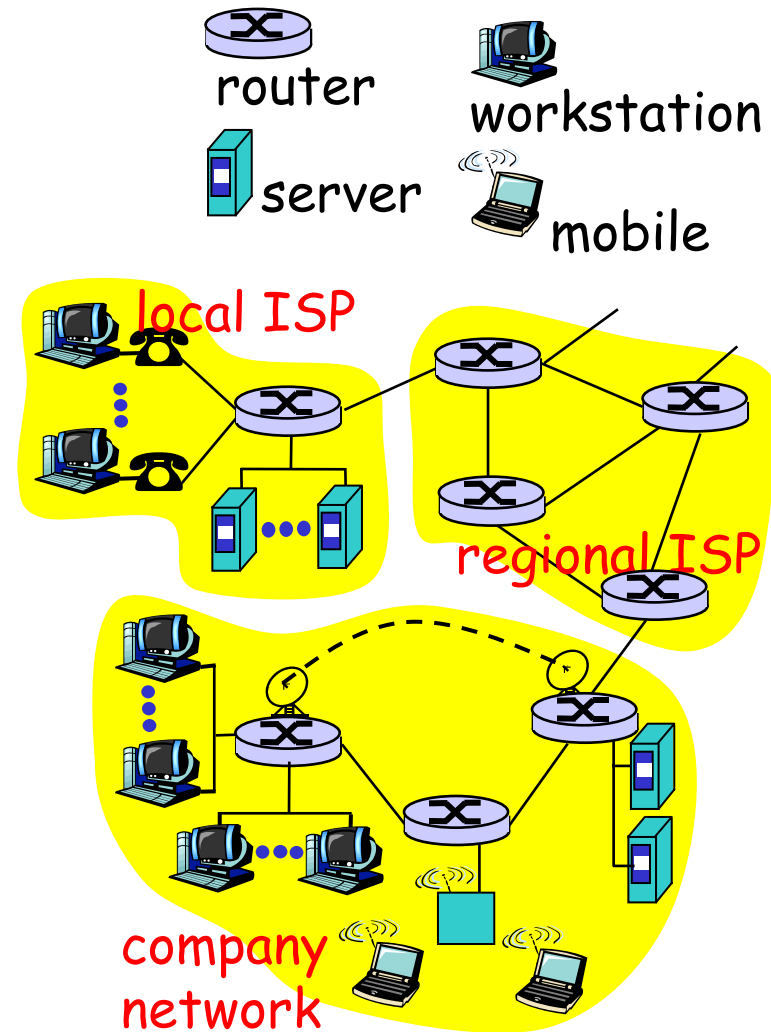
What's the Internet: "nuts and bolts" view

- ❑ 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



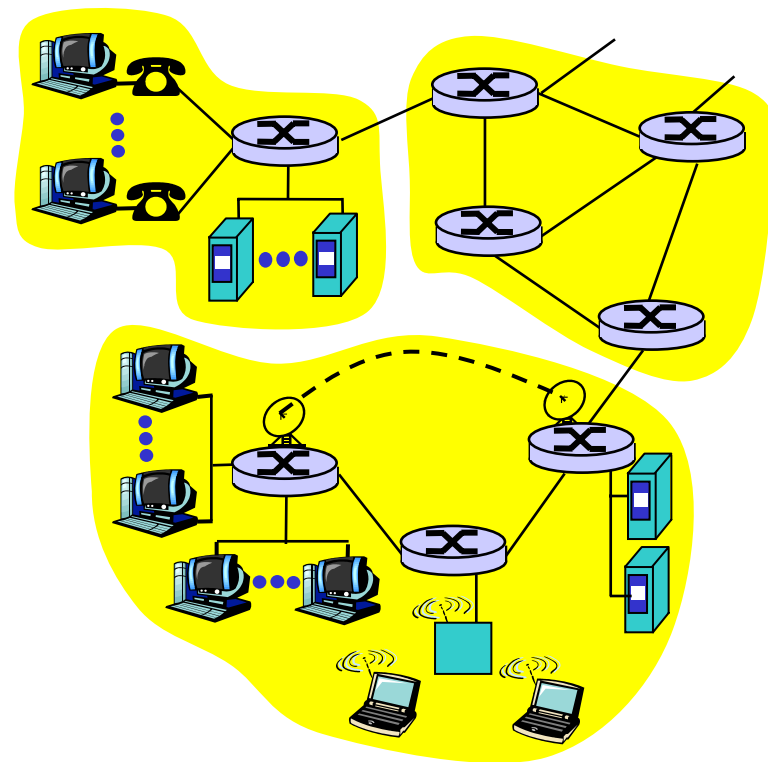
What's the Internet: "nuts and bolts" view

- *Protocols*: control sending, receiving of messages
 - E.g., TCP, IP, HTTP, FTP, PPP
- *Internet*: "network of networks"
 - Loosely hierarchical
 - Public Internet versus private intranet



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



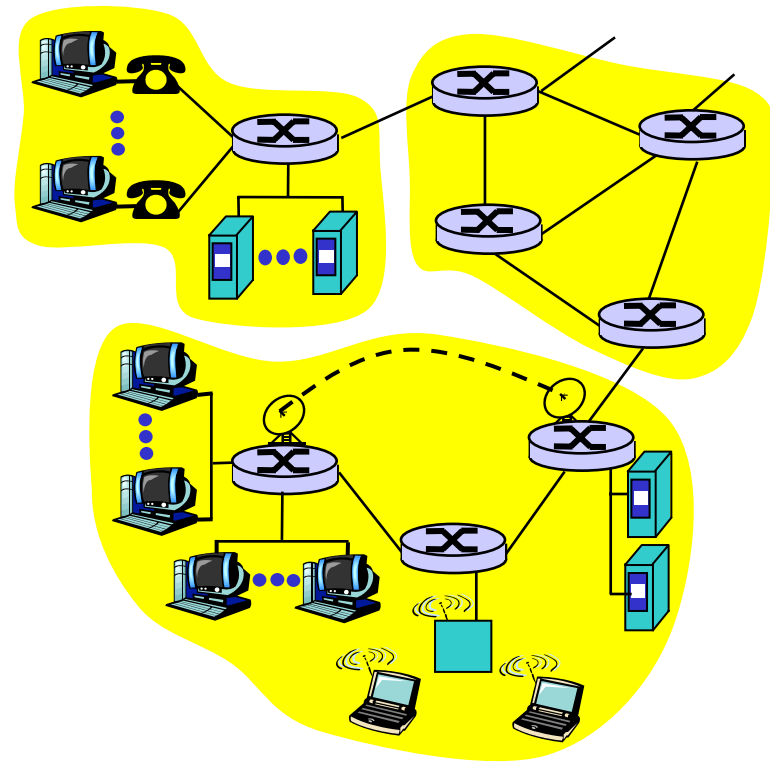
A closer look at network structure

□ Network edge:

- Applications
- Hosts

□ Network core:

- Routers
- Network of networks



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

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

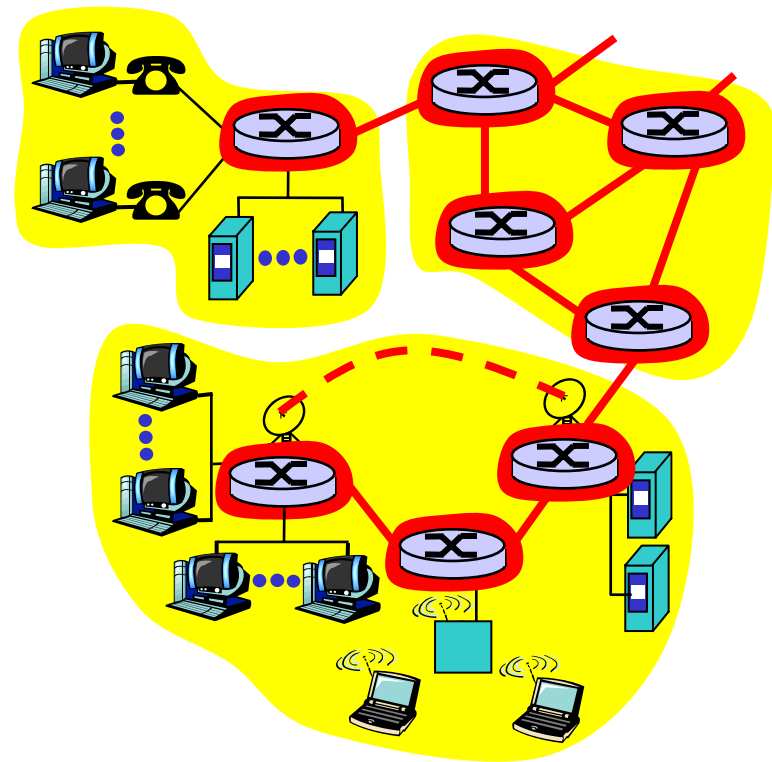
Goal: Data transfer between end systems

- 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”



Routing

□ Goal

Move pkts among routers from src to dst

□ **Datagram network**

- *Destination address* determines next hop
- Routes may change during session

□ **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

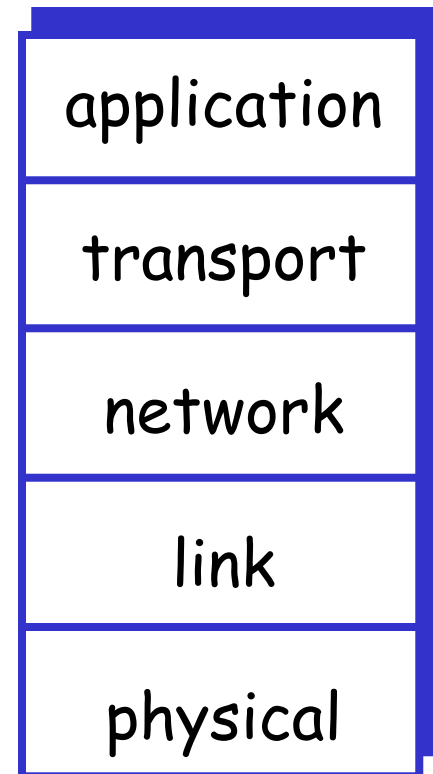
Question:

Is there any hope of
organizing structure of
network?

Or at least in our
discussion of networks?

Internet protocol stack

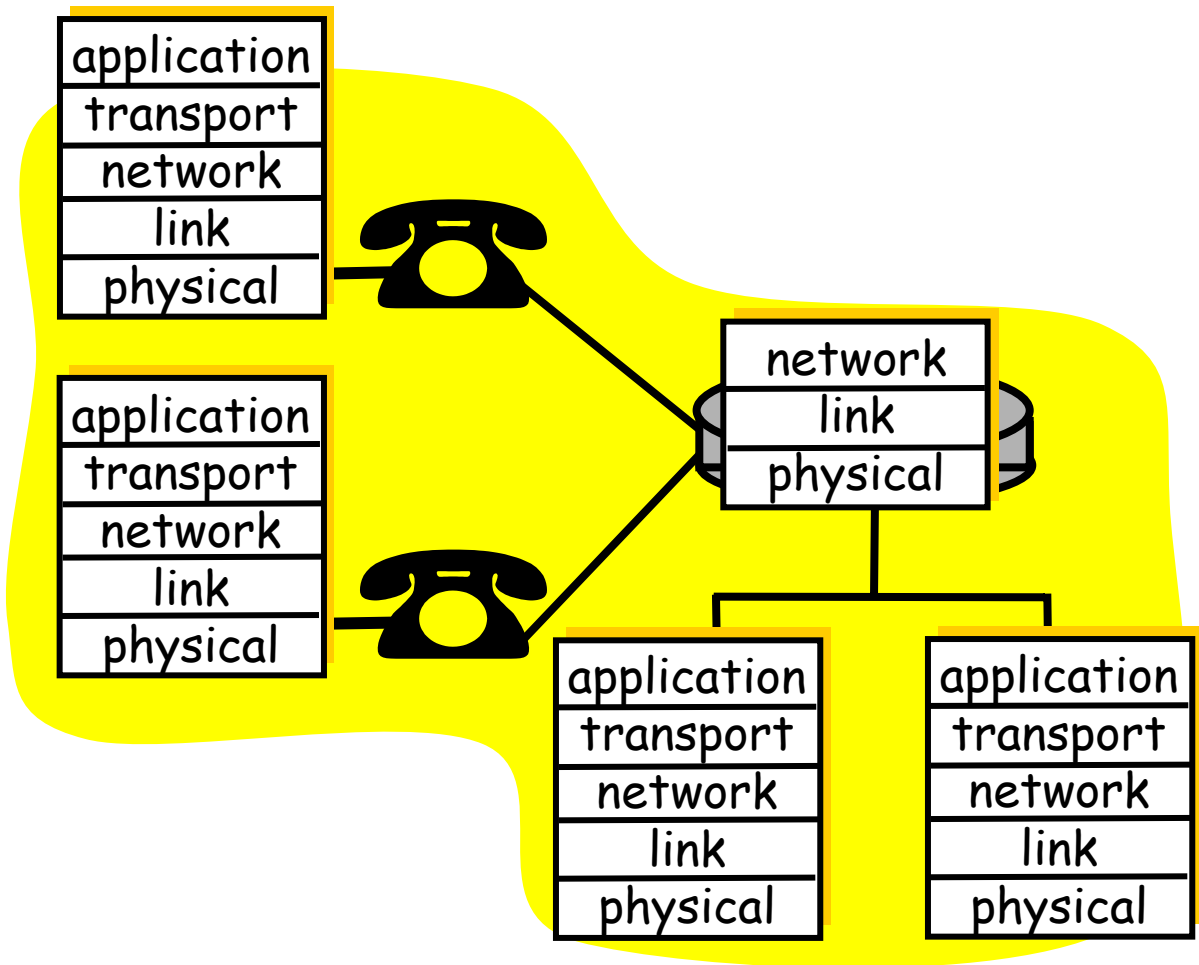
- ❑ **Application:** supporting network applications
- ❑ **Transport:** host-host data transfer
- ❑ **Network:** uniform format of packets, routing of datagrams from source to destination
- ❑ **Link:** data transfer between neighboring network elements
- ❑ **Physical:** bits “on the wire”



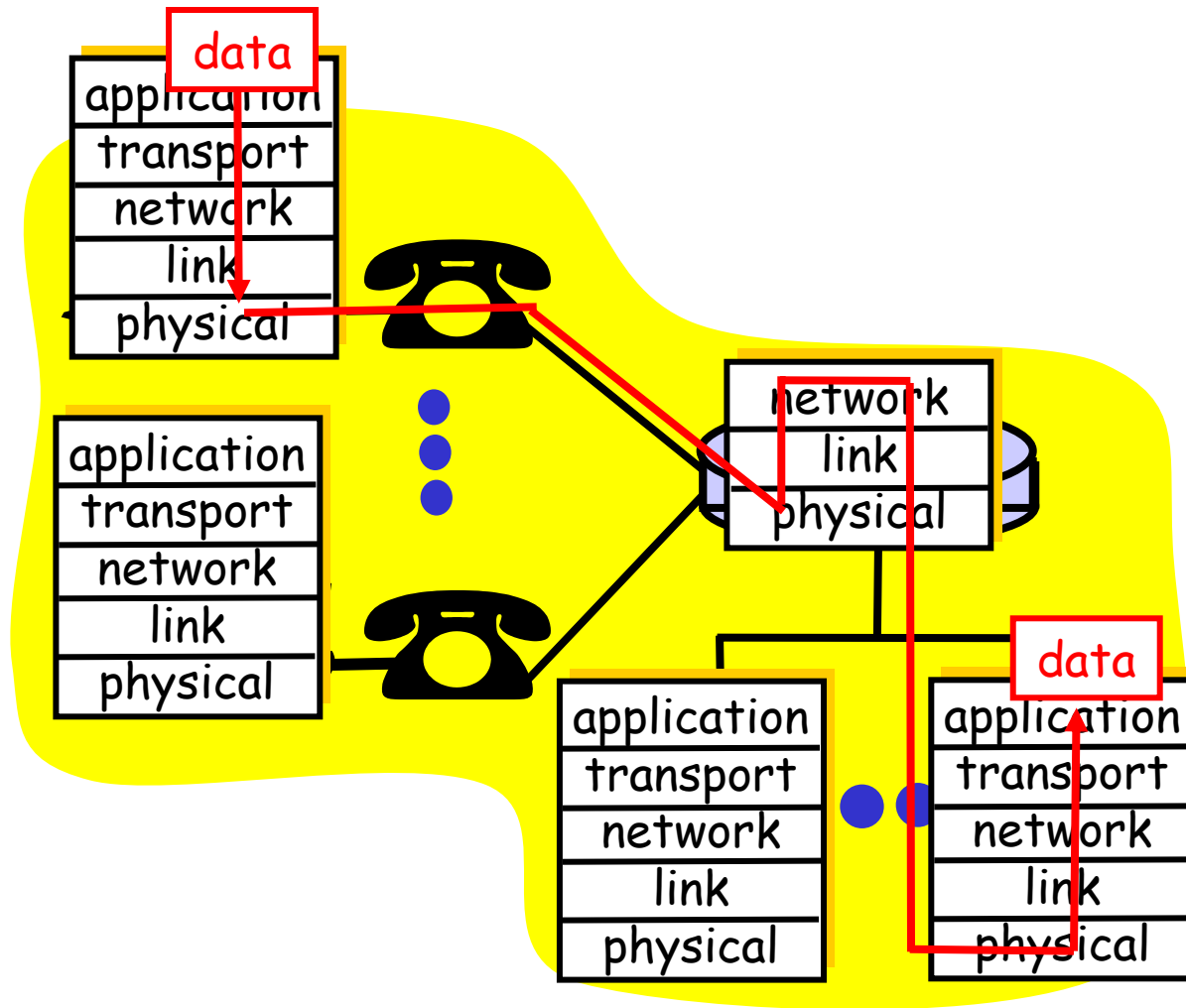
Layering: Logical communication

Each layer:

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

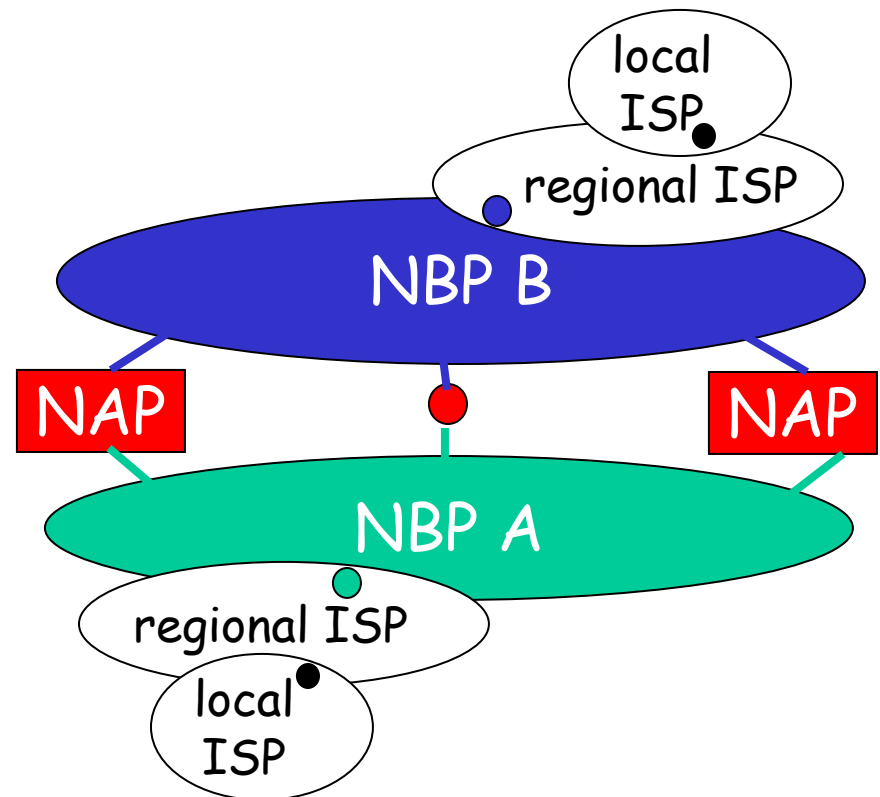


Layering: Physical communication



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



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