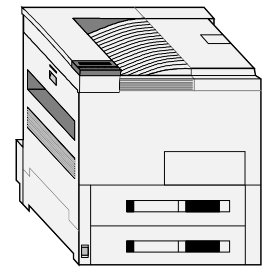
Computer Networking

Introduction

Chapter 1

Data Communication: Motivation

- Efficient way to share resources
  - Cost – less expensive
  - Accessibility – easier



- Efficient way to exchange information
  - Time – faster
  - Size – bigger
  - Correctness – more accurate

Data Communication: Definition

Delivery

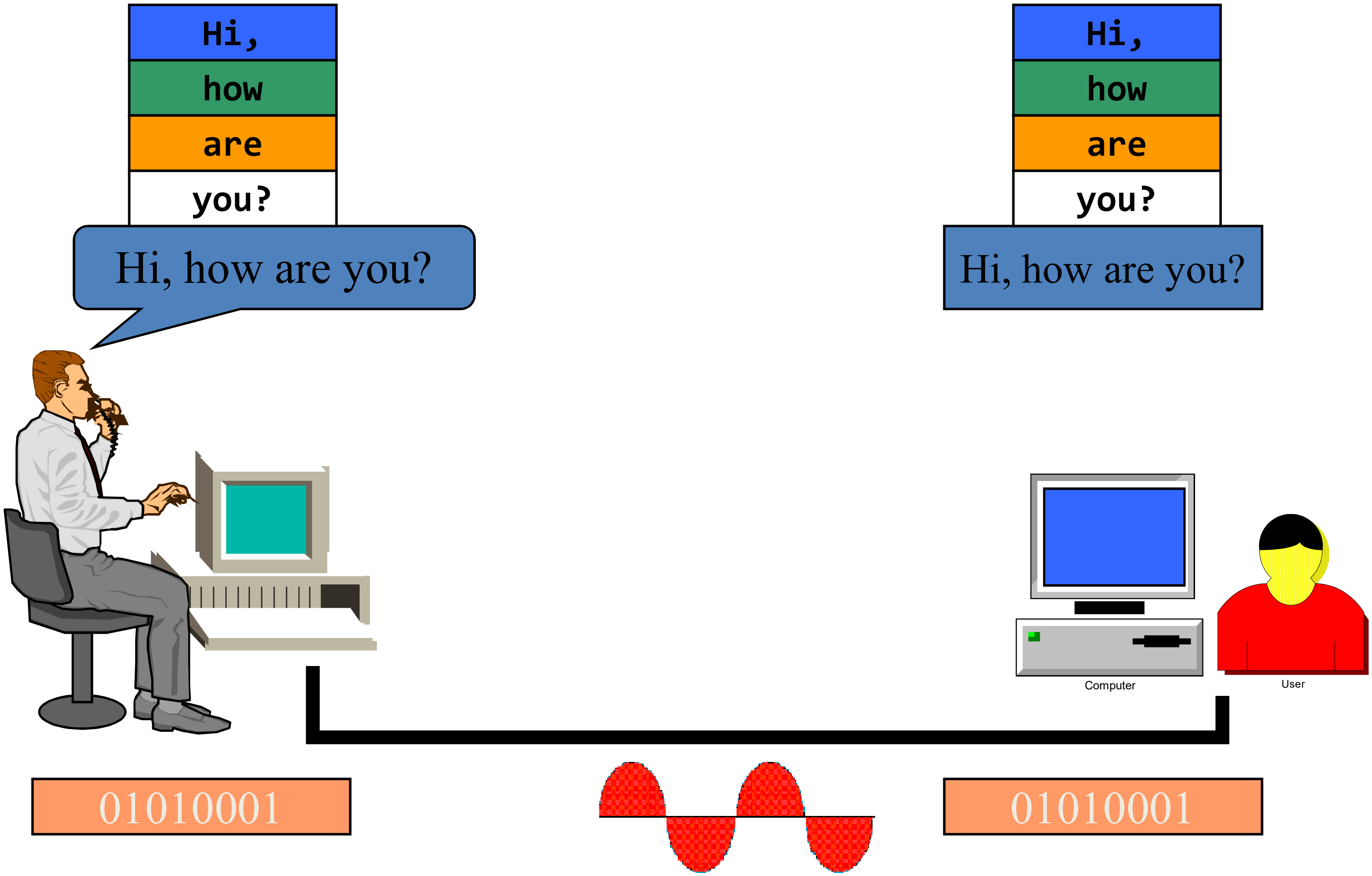
Accuracy

Transfer of data from one device to another via some form of transmission medium.

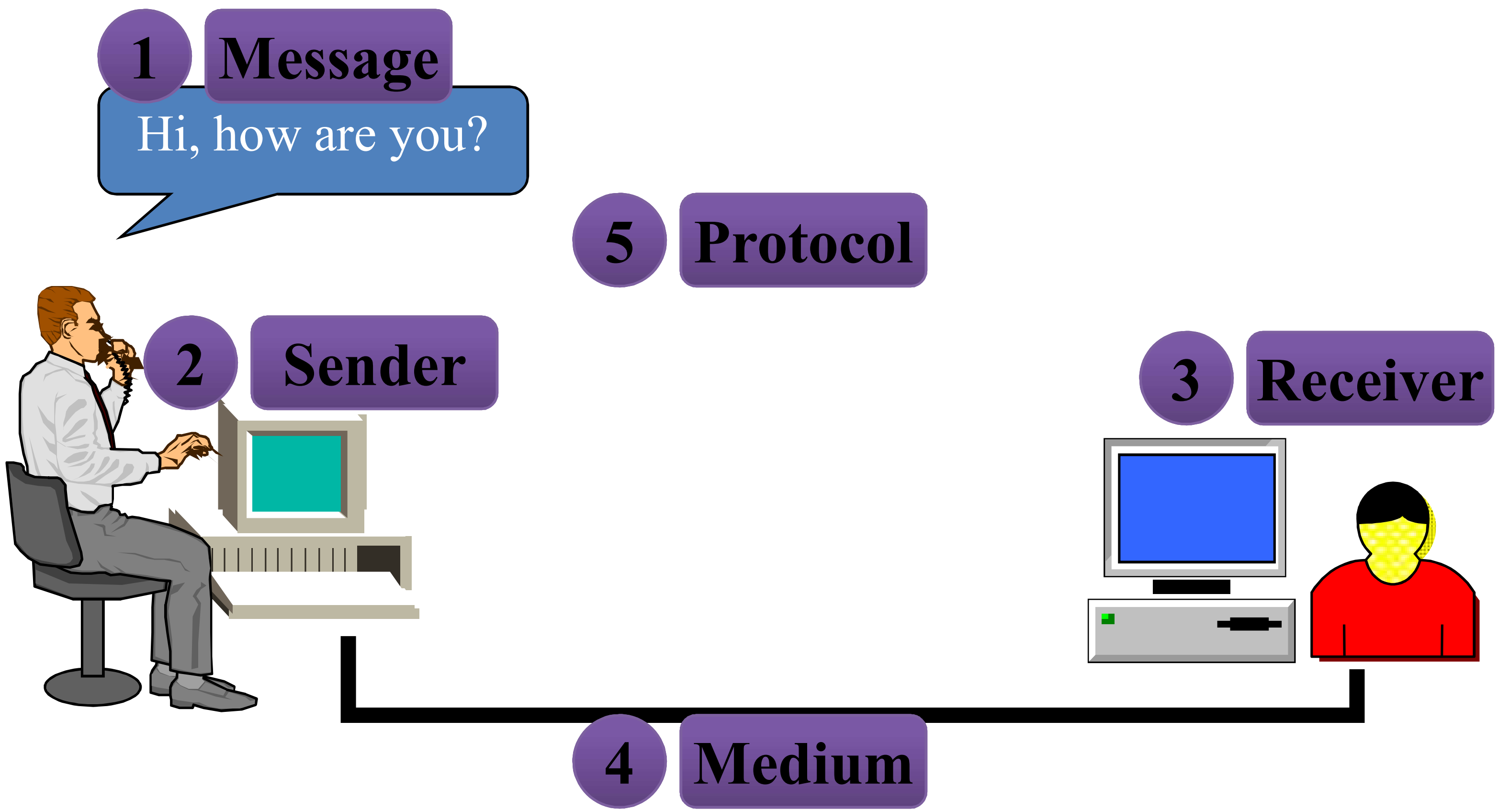
Timeliness

Jitter

Data Communication: Definition



Components in Communication

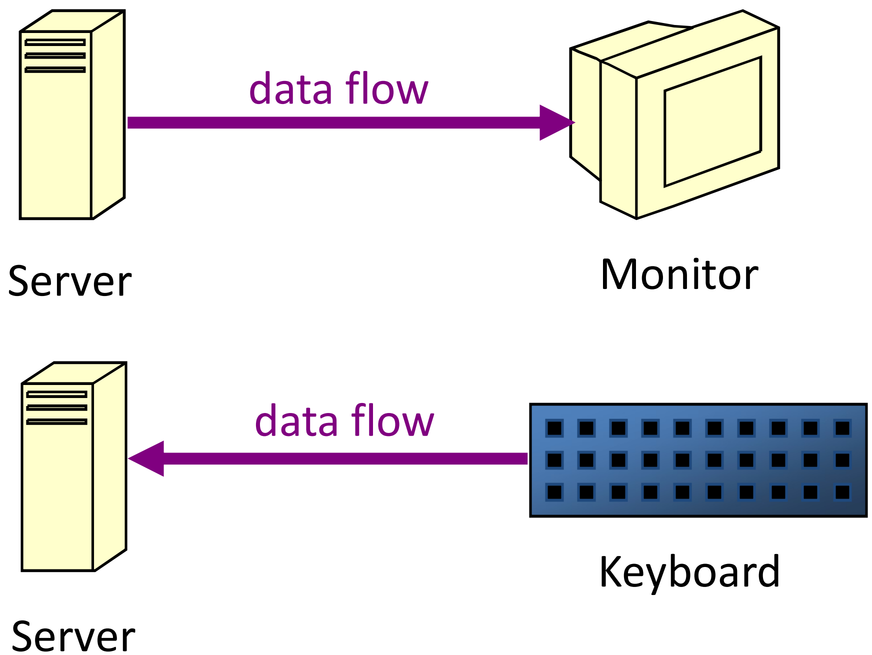


Data Representation

- Numbers
  - 8/16/32 bit integers
  - floating point
- Text
  - ASCII, Unicode
- Images
  - Bit patterns, Graphics formats JPG/GIF/etc
- Audio $\rightarrow$ Samples of continuous signal
- Video $\rightarrow$ Sequence of bitmap images

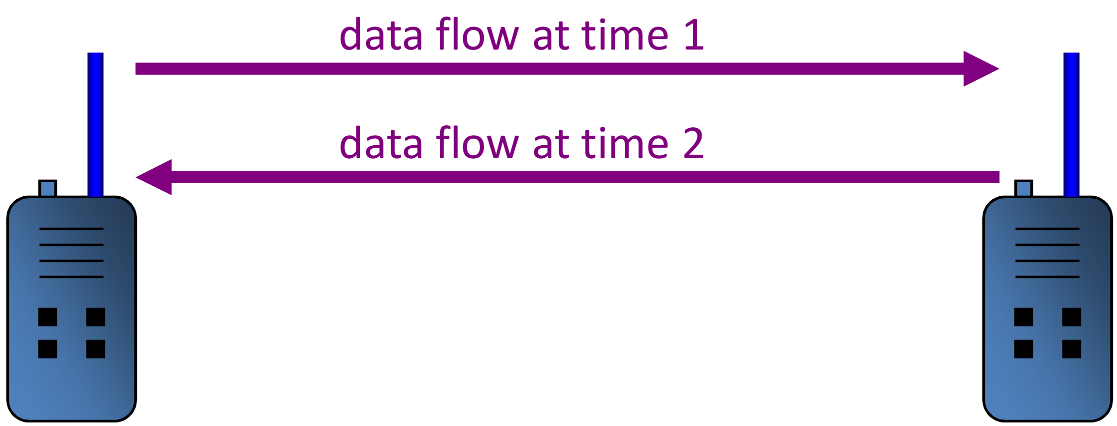
Direction of Data Flow

- **Simplex**: One direction only

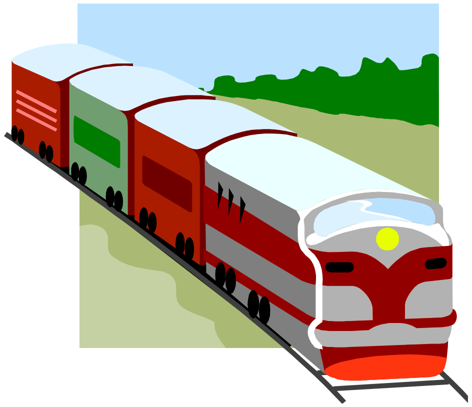


Direction of Data Flow

- **Half Duplex:** Both directions, one at a time



- E.g., walkie-talkies



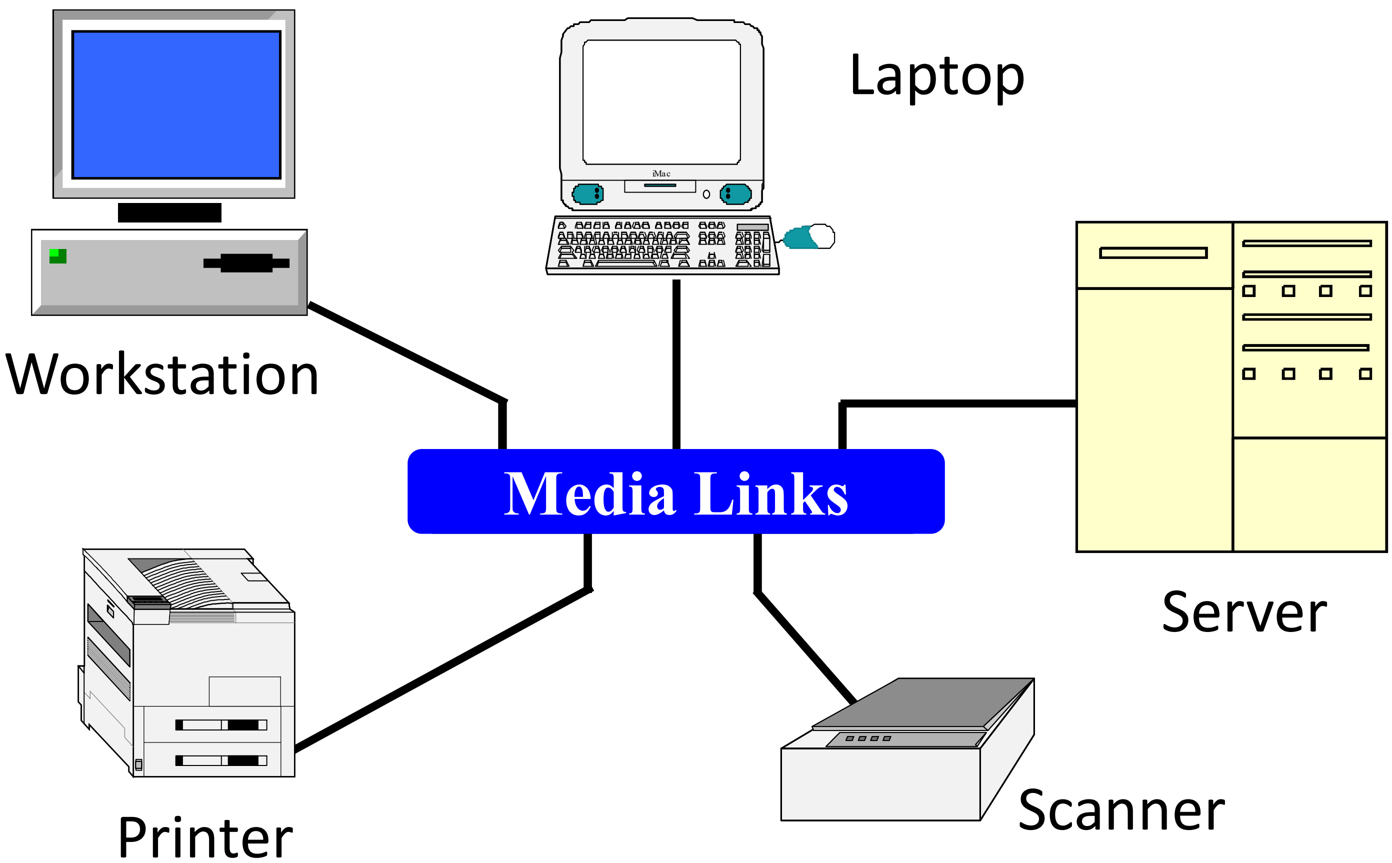
Direction of Data Flow

- **Full Duplex**: Both directions simultaneously

  - E.g. telephone
- The capacity of the channel is divided between the two directions.

Networks

- Network: *a set of devices connected by media links*



Networking Impacts in Our Daily Lives

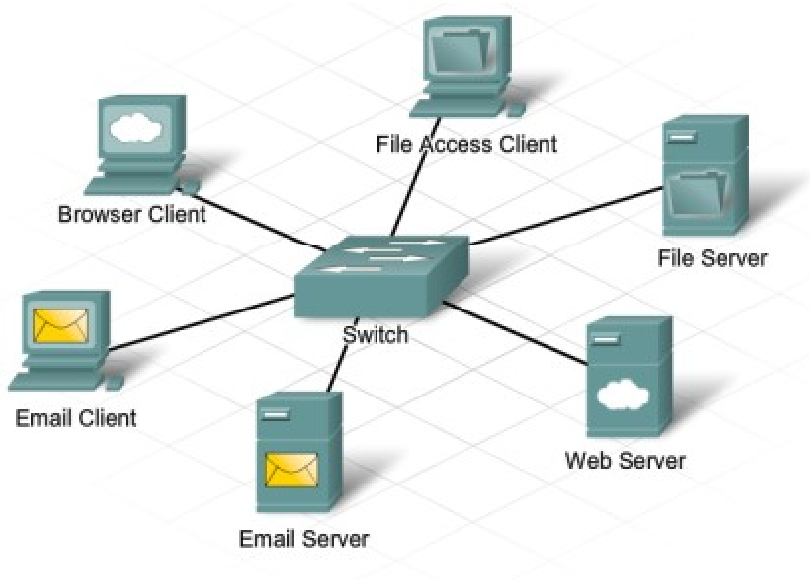
- Networks support the way we learn.
- Networks support the way we communicate.
- Networks support the way we work.
- Networks support the way we play.

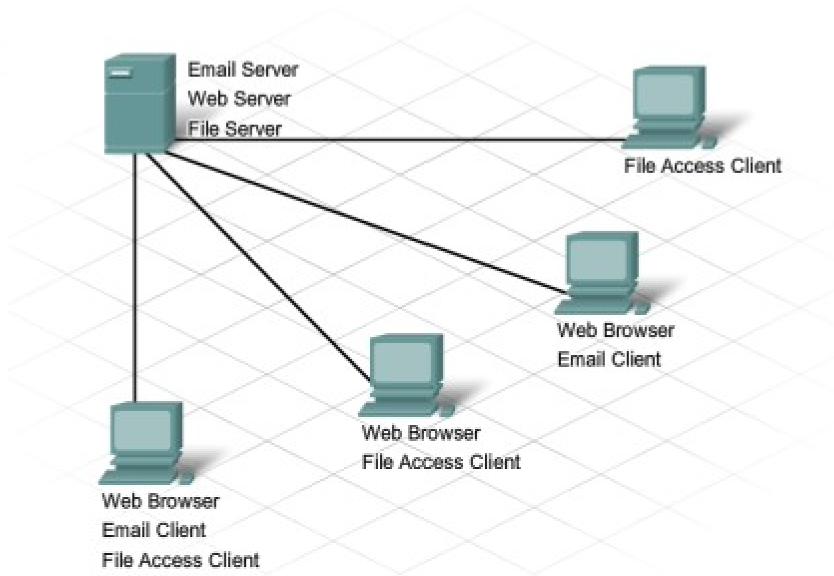
Network Criteria

- Performance
  - Throughput
  - Delay
- Reliability
  - Frequency of failure
  - Time to recover from a failure
  - Network’s robustness
- Security
  - Unauthorized access

Providing Resources in a Network

- Client-Server System

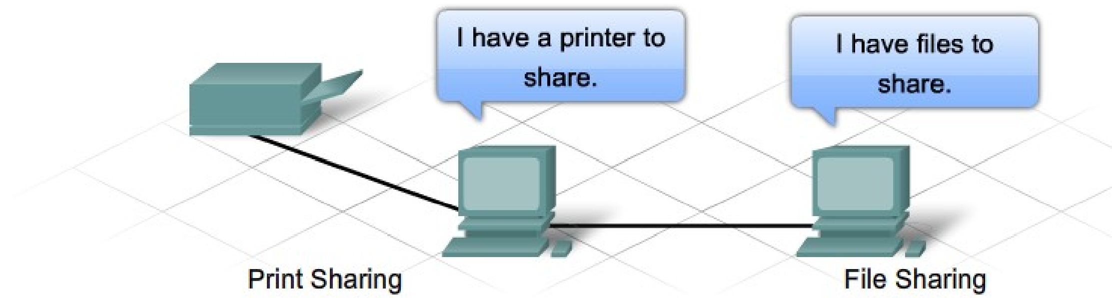




CCNA 1: 1.1.2.2 Clients and Servers

Providing Resources in a Network

- Peer-to-Peer System



The advantages of peer-to-peer networking:

- Easy to set up
- Less complexity
- Lower cost since network devices and dedicated servers may not be required
- Can be used for simple tasks such as transferring files and sharing printers

The disadvantages of peer-to-peer networking:

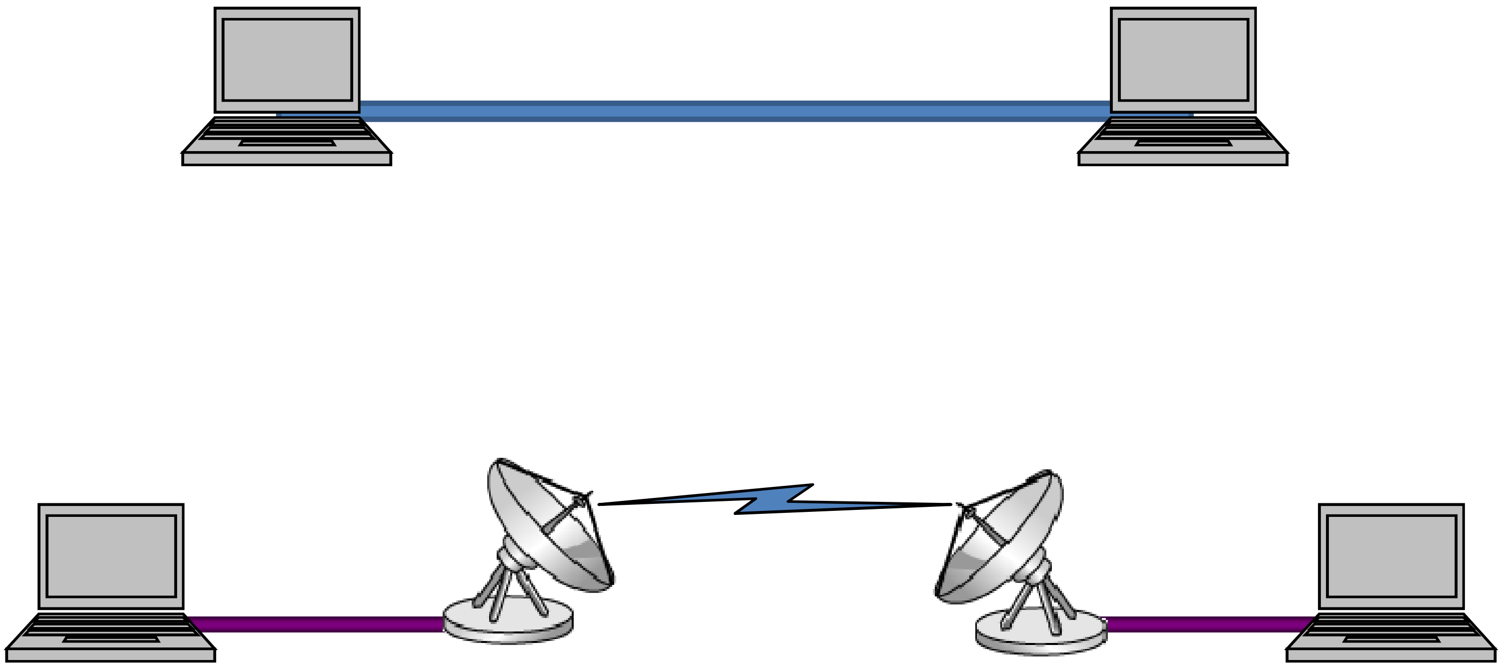
- No centralized administration
- Not as secure
- Not scalable
- All devices may act as both clients and servers which can slow their performance

CCNA 1: 1.1.2.4 Peer-to-Peer

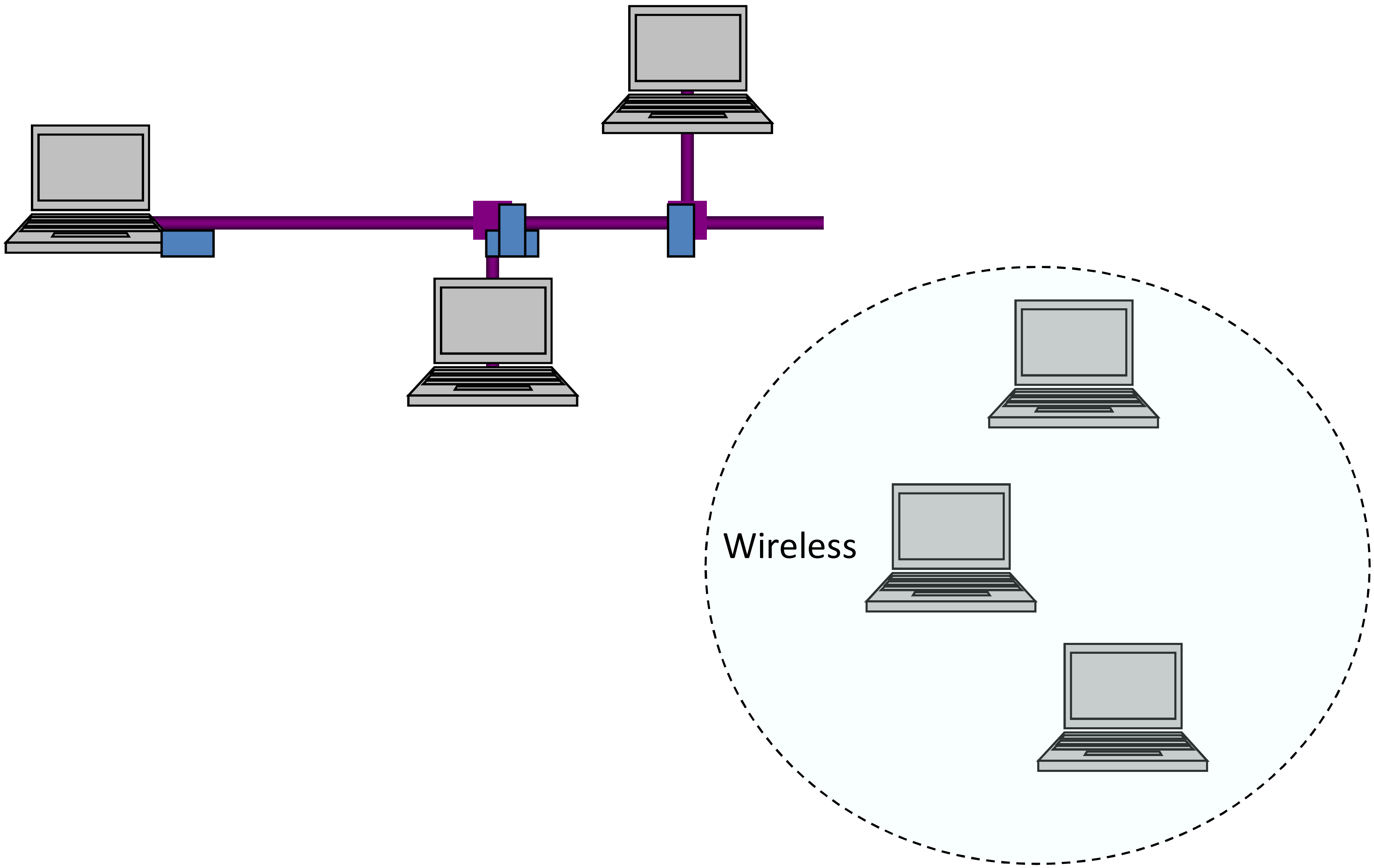
Types of Connections

- Point-to-point
  - A dedicated link between two devices
- Multipoint (multidrop)
  - Devices share a single link

Point-To-Point Connection



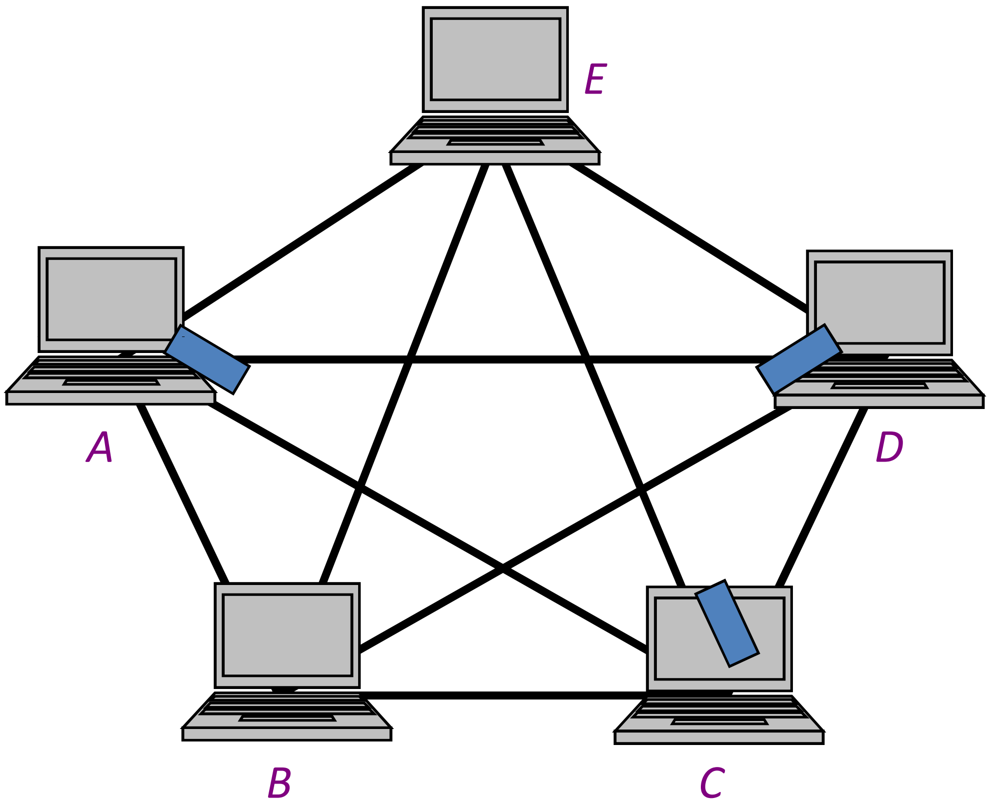
Multipoint Connection



Topology

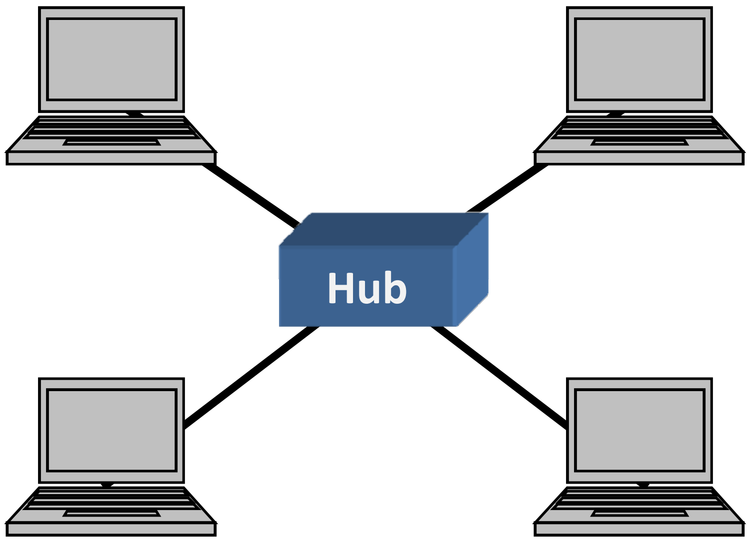
- Topology: physical arrangement of devices
  - Mesh
  - Star
  - Bus
  - Ring
  - Hybrid

Fully Connected Mesh Topology



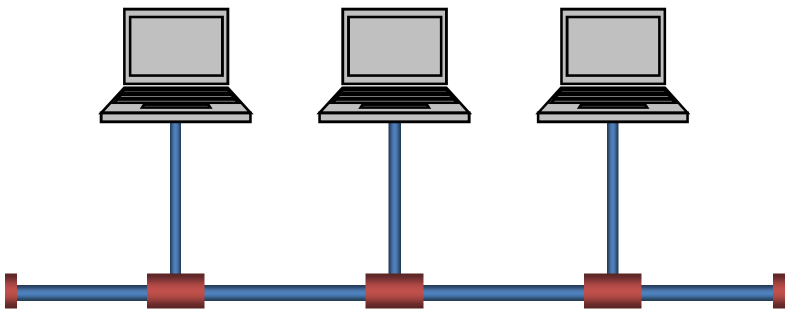
- **Pros:**
  - Dedicated links; n(n-1)/2 links
  - Robustness
  - Privacy
  - Easy to identify fault
- **Cons:**
  - A lot of cabling
  - I/O ports
  - Difficult to move

Star Topology



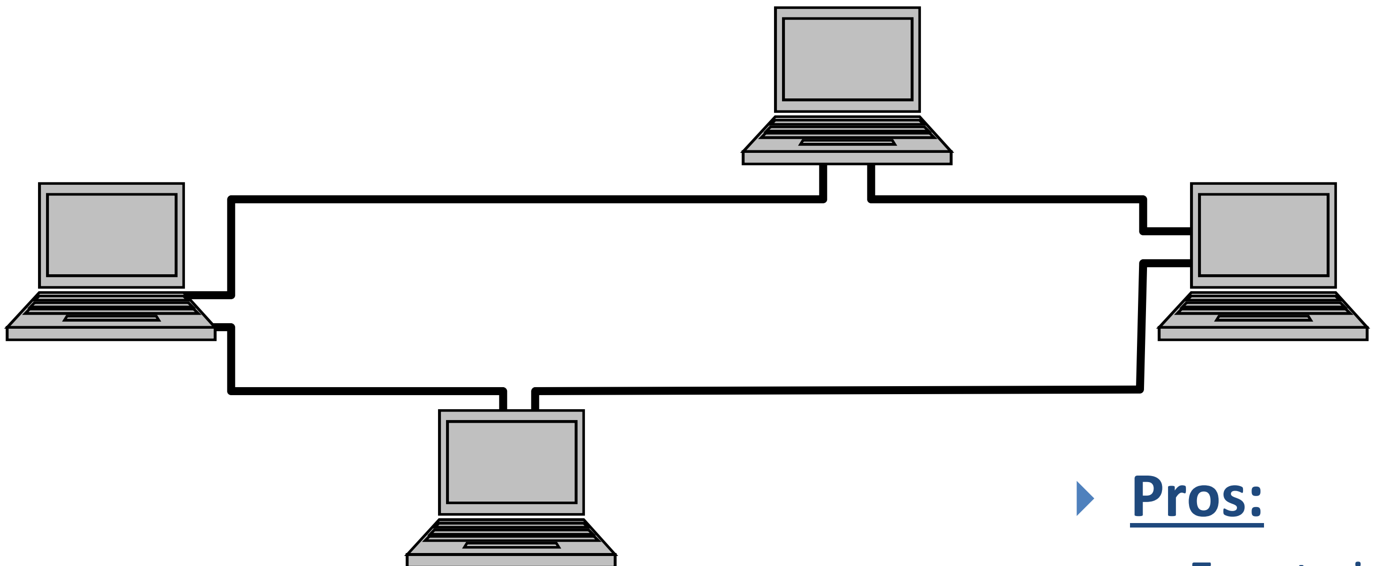
- **Pros:**
  - One I/O port per device
  - Little cabling
  - Easy to install
  - Robustness
  - Easy to identify fault
- **Cons:**
  - Single point of failure
  - More cabling still required

Bus Topology



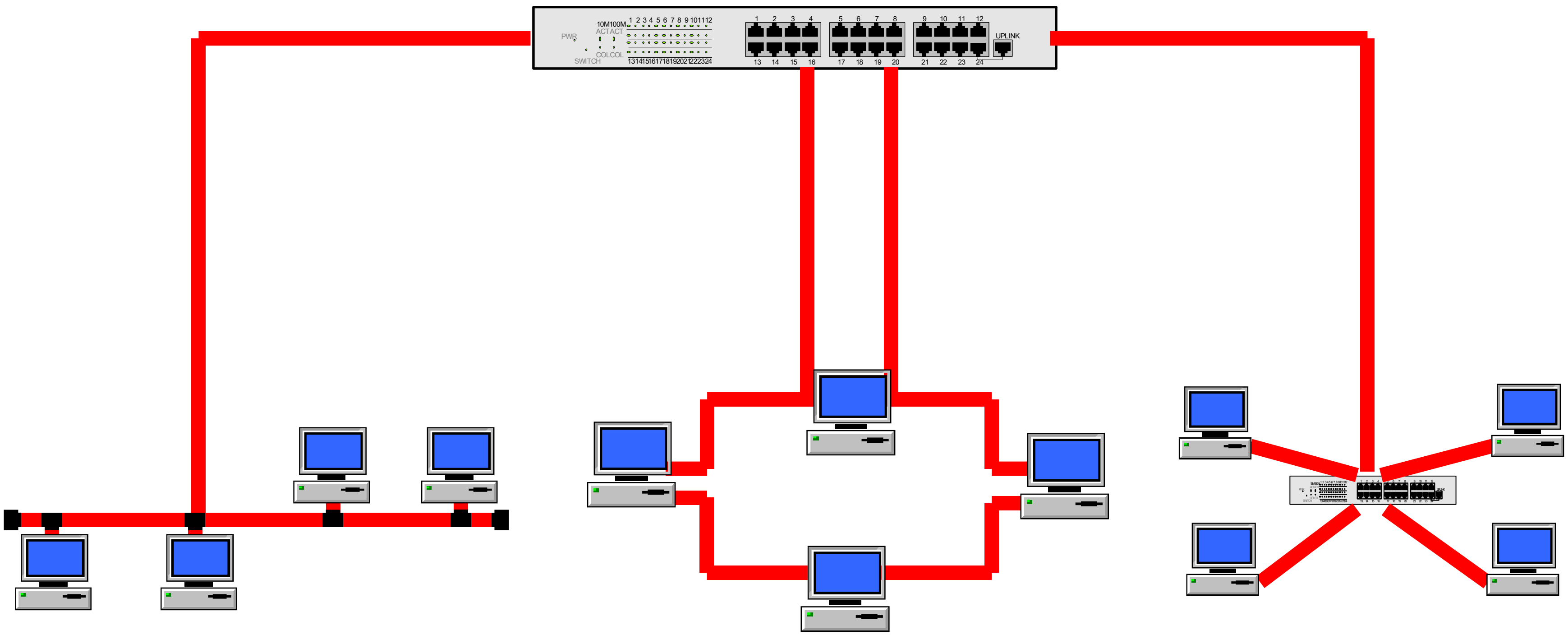
- **Pros:**
  - Little cabling
  - Easy to install
- **Cons:**
  - Difficult to modify
  - Difficult to isolate fault
  - Break in the bus cable stops all transmission

Ring Topology



- **Pros:**
  - Easy to install
  - Easy to identify fault
- **Cons:**
  - Delay in large ring
  - Break in the ring stops all transmission

Hybrid Topologies



Network Types

The two most common types of network infrastructures are:

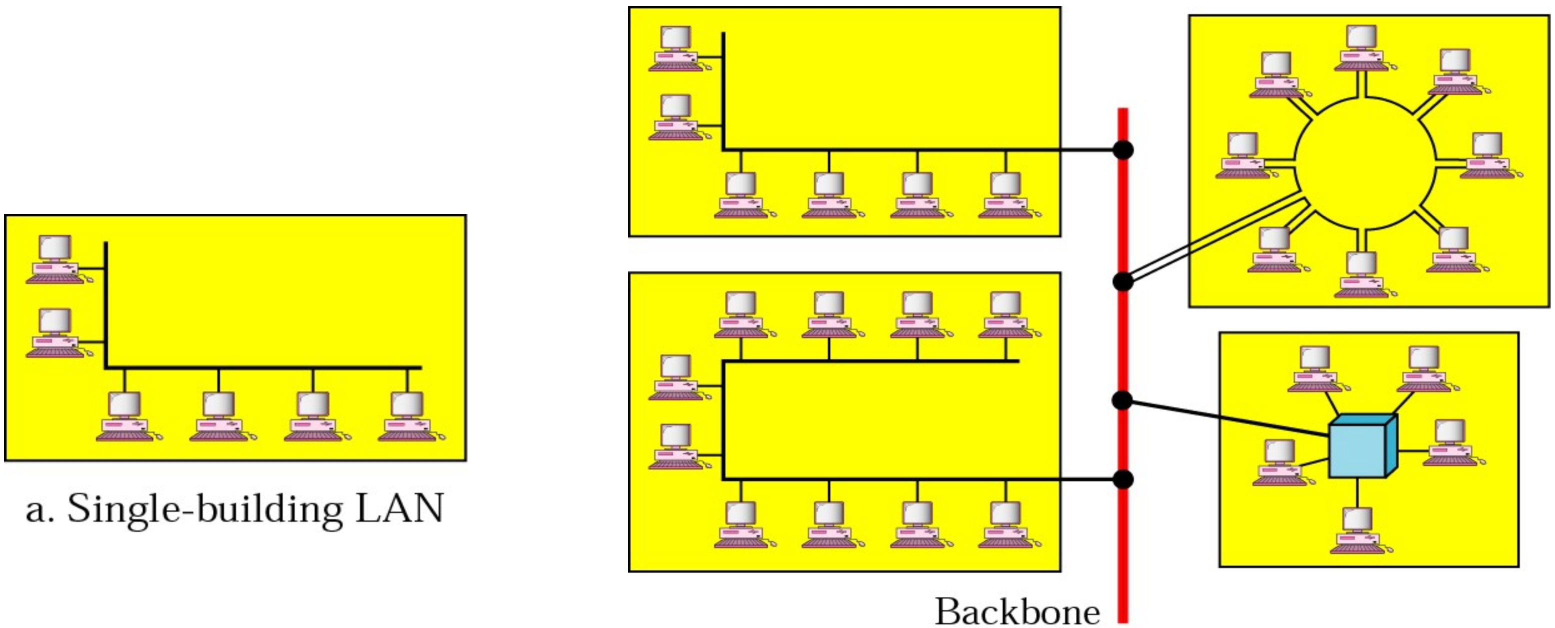
- Local Area Network (LAN)
- Wide Area Network (WAN)

Other types of networks include:

- Metropolitan Area Network (MAN)
- Wireless LAN (WLAN)
- Storage Area Network (SAN)

Local Area Networks

- Network in a single office, building, or campus

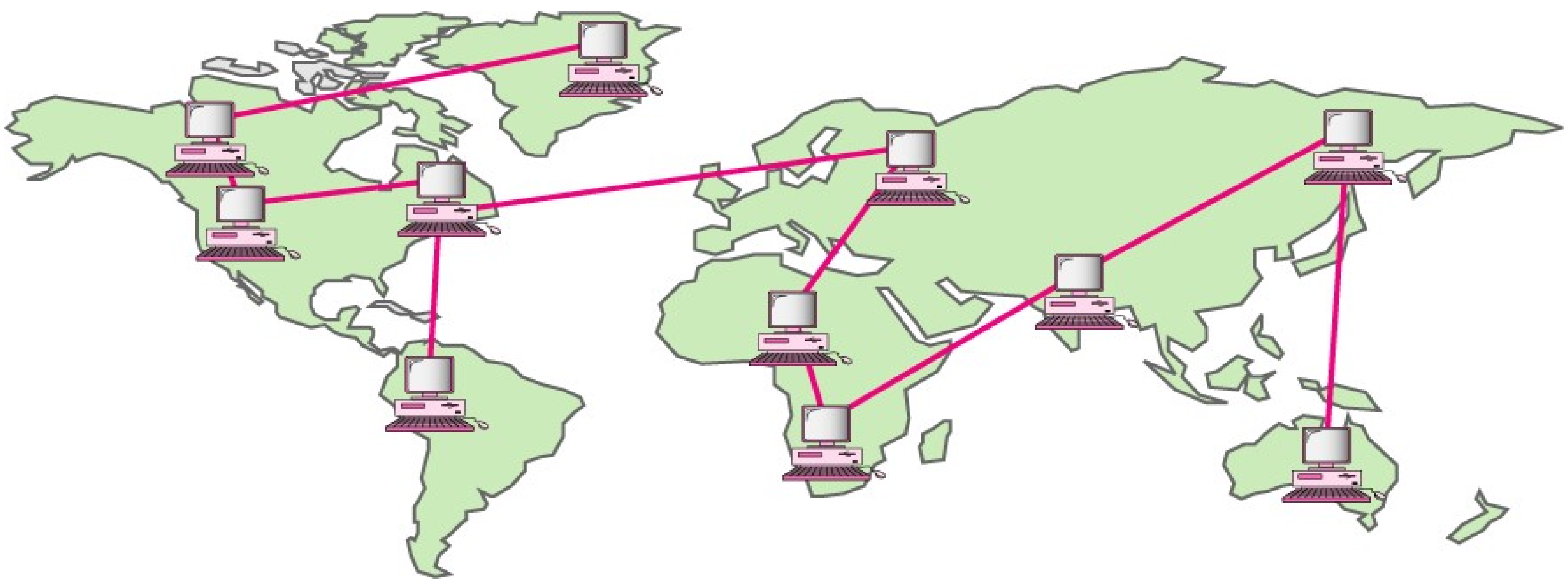


a. Single-building LAN

b. Multiple-building LAN

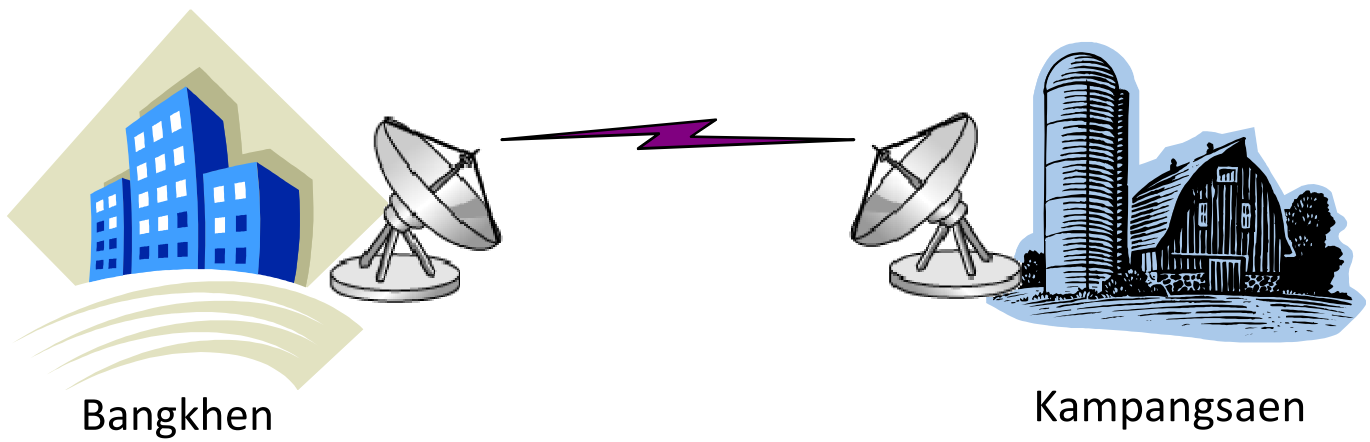
Wide Area Networks

- Network providing long-distance communication over a country, a continent, or the whole world



Metropolitan Area Networks

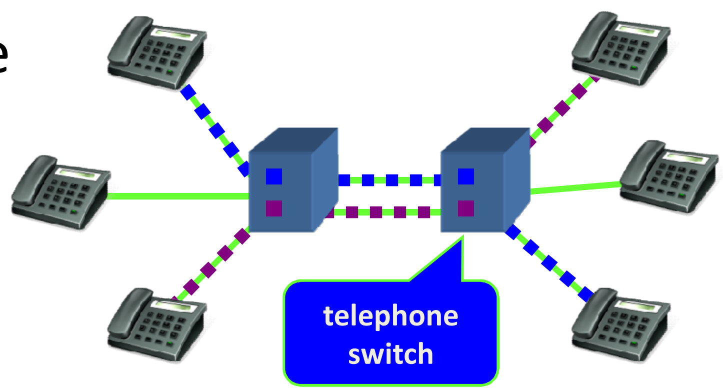
- Network extended over an entire city



Circuit Switching

End-to-end resources reserved for "call"

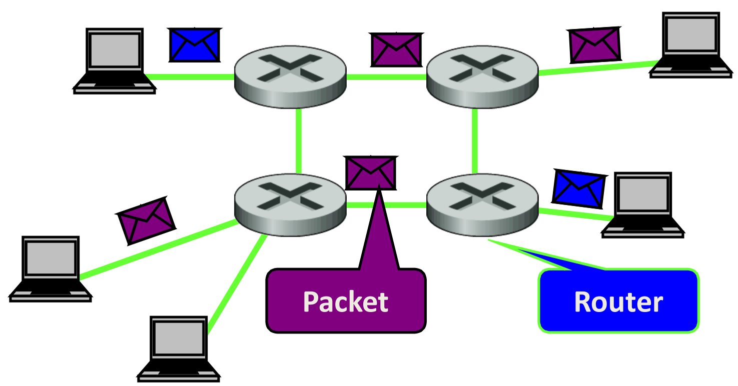
- Link bandwidth, switch capacity
- Dedicated resources: no sharing
- Circuit-like (guaranteed) performance
- Call setup required
- Re-establish call upon failure
- Telephone switches establish circuits for communication



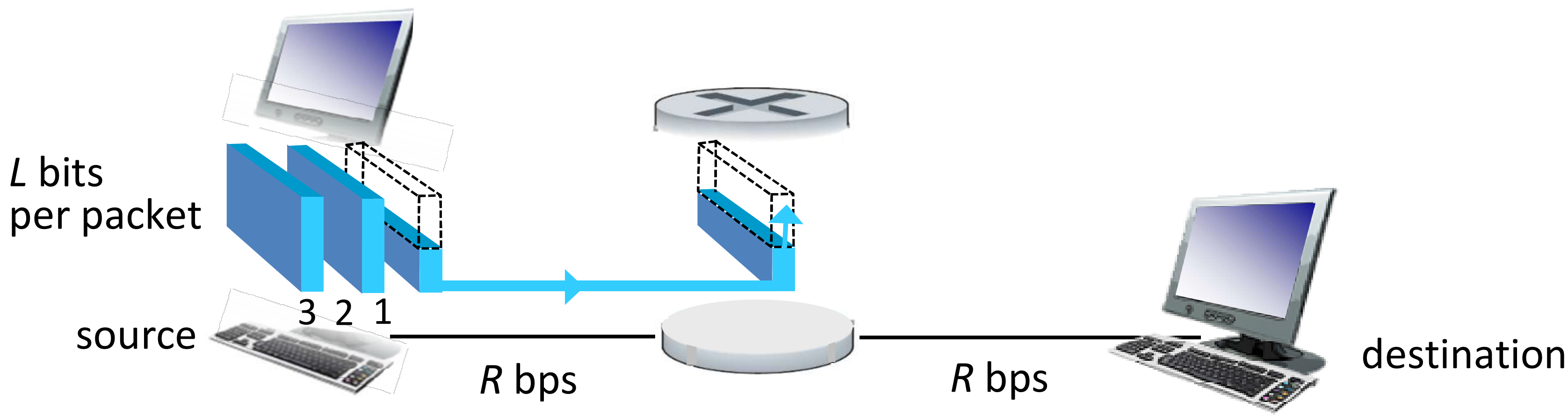
Packet Switching

Each end-to-end data stream (message) divided into *packets*

- Each packet stamped with source and destination addresses
- Routers know where to forward packets
- Each packet uses full link bandwidth
- Resources used *as needed*
- Congestion: packets queue, wait for link use
- Store and forward: packets move one hop at a time
  - Node receives complete packet before forwarding



Packet Switching: Store and Forward



- takes L/R seconds to transmit (push out) L-bit packet into link at R bps
- *store and forward:* entire packet must arrive at router before it can be transmitted on next link
- end-end delay = $2L/R$ (assuming zero propagation delay)

one-hop numerical example:

- L = 7.5 Mbits
- R = 1.5 Mbps
- one-hop transmission delay = 5 sec

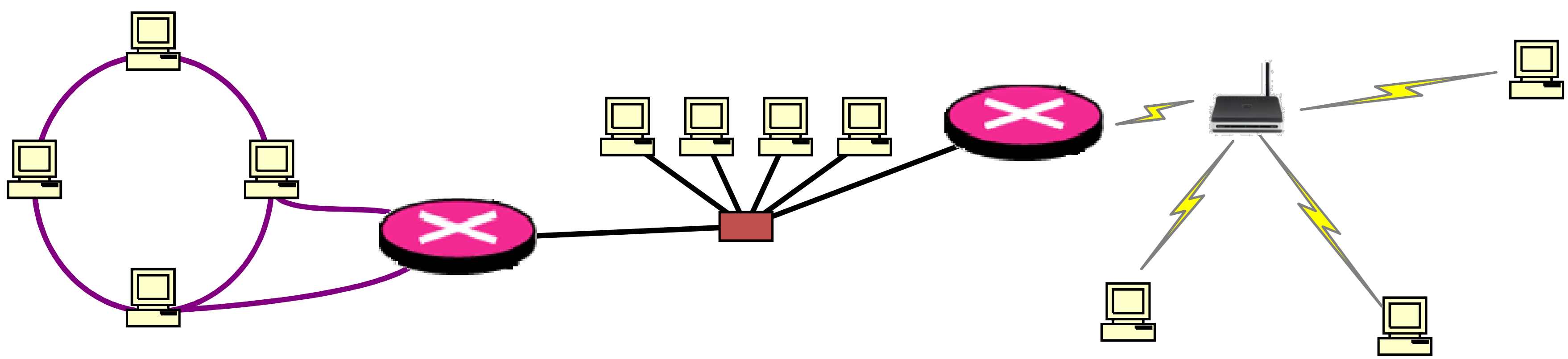
Circuit Switching vs Packet Switching

Is packet switching a “slam dunk winner?”

- great for bursty data
  - resource sharing (scalable!)
  - simpler, no call setup, more robust (re-routing)
- excessive congestion: packet delay and loss
  - Without admission control: protocols needed for reliable data transfer, congestion control

Internetworking

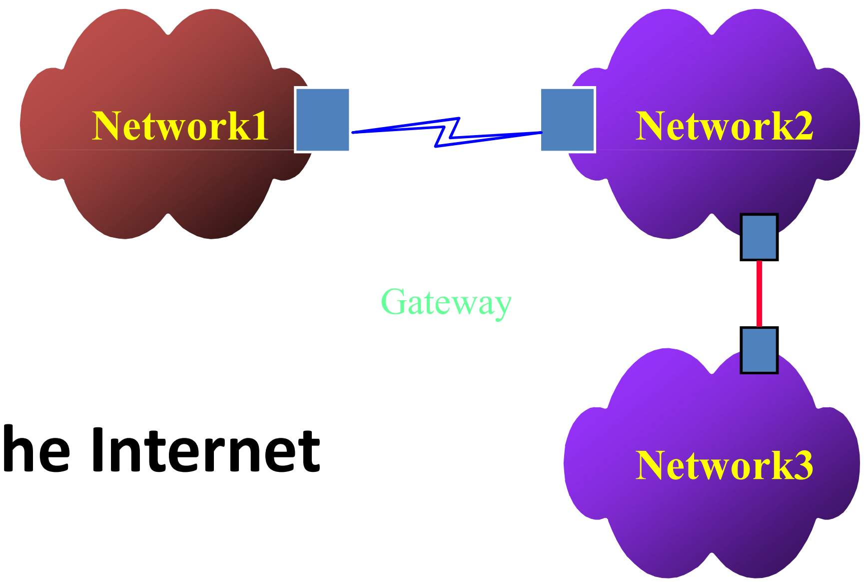
- How to allow devices from different standards to communicate
- **Gateways/routers** – devices capable of communicating in several standards



- These become "network of networks"

Internetworks

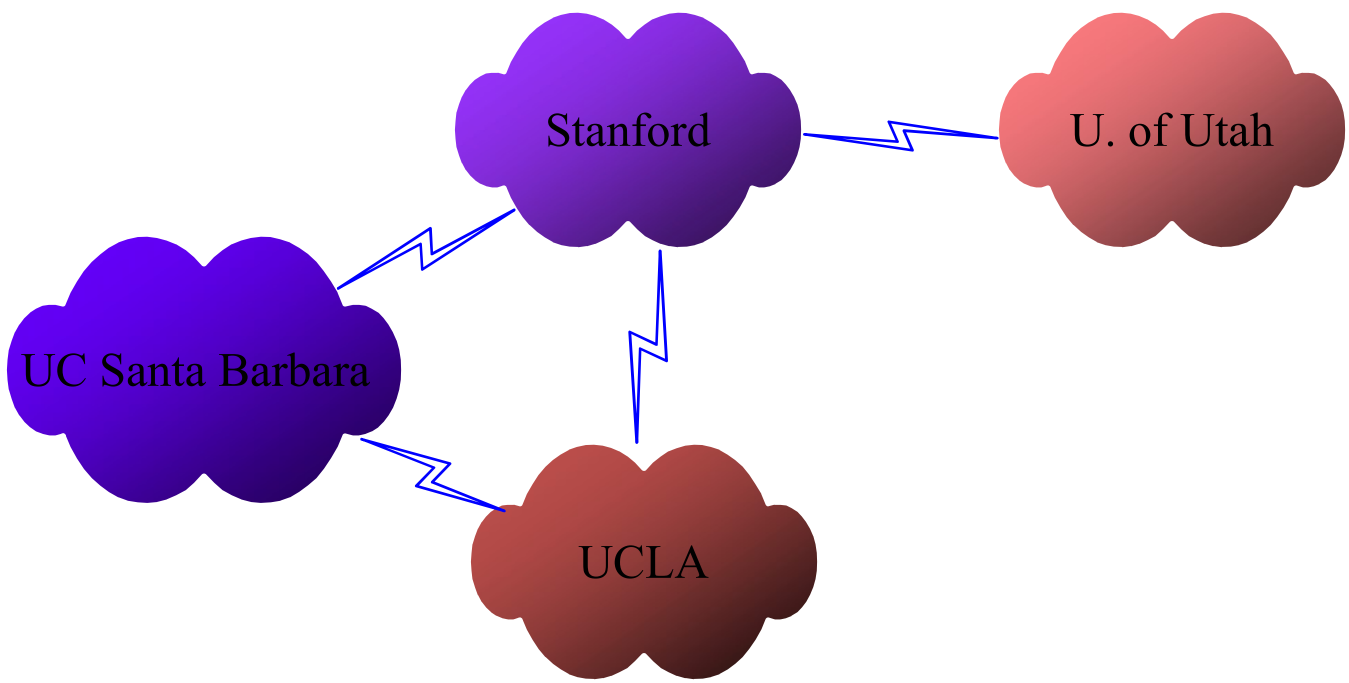
- Two or more networks connected become an *internetwork*, or *internet*



- Example: **The Internet**

The Internet

- The largest internetwork (network of networks) in the world
- The first packet switching network and predecessor to today's Internet was the Advanced Research Projects Agency Network (ARPANET), which came to life in 1969 by connecting mainframe computers at four locations.

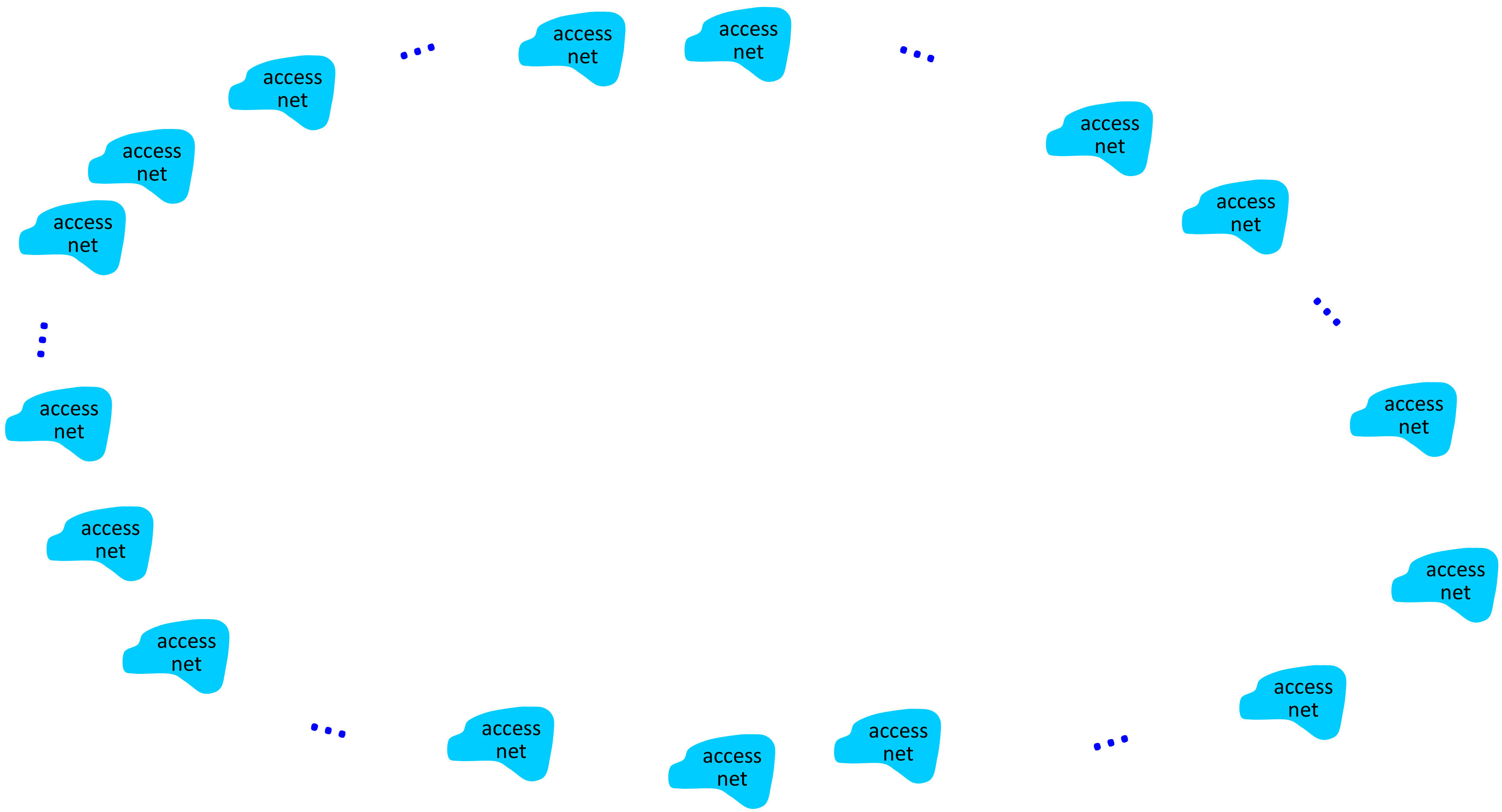


Creation of Internet, Development of TCP/IP

- ARPANET was funded by the U.S. Department of Defense for use by universities and research laboratories.
- In 1973, Robert Kahn and Vinton Cerf began work on TCP to develop the next generation of the ARPANET. TCP was designed to replace ARPANET's current Network Control Program (NCP).
- In 1978, TCP was divided into two protocols: TCP and IP. Later, other protocols were added to the TCP/IP suite of protocols including Telnet, FTP, DNS, and many others.

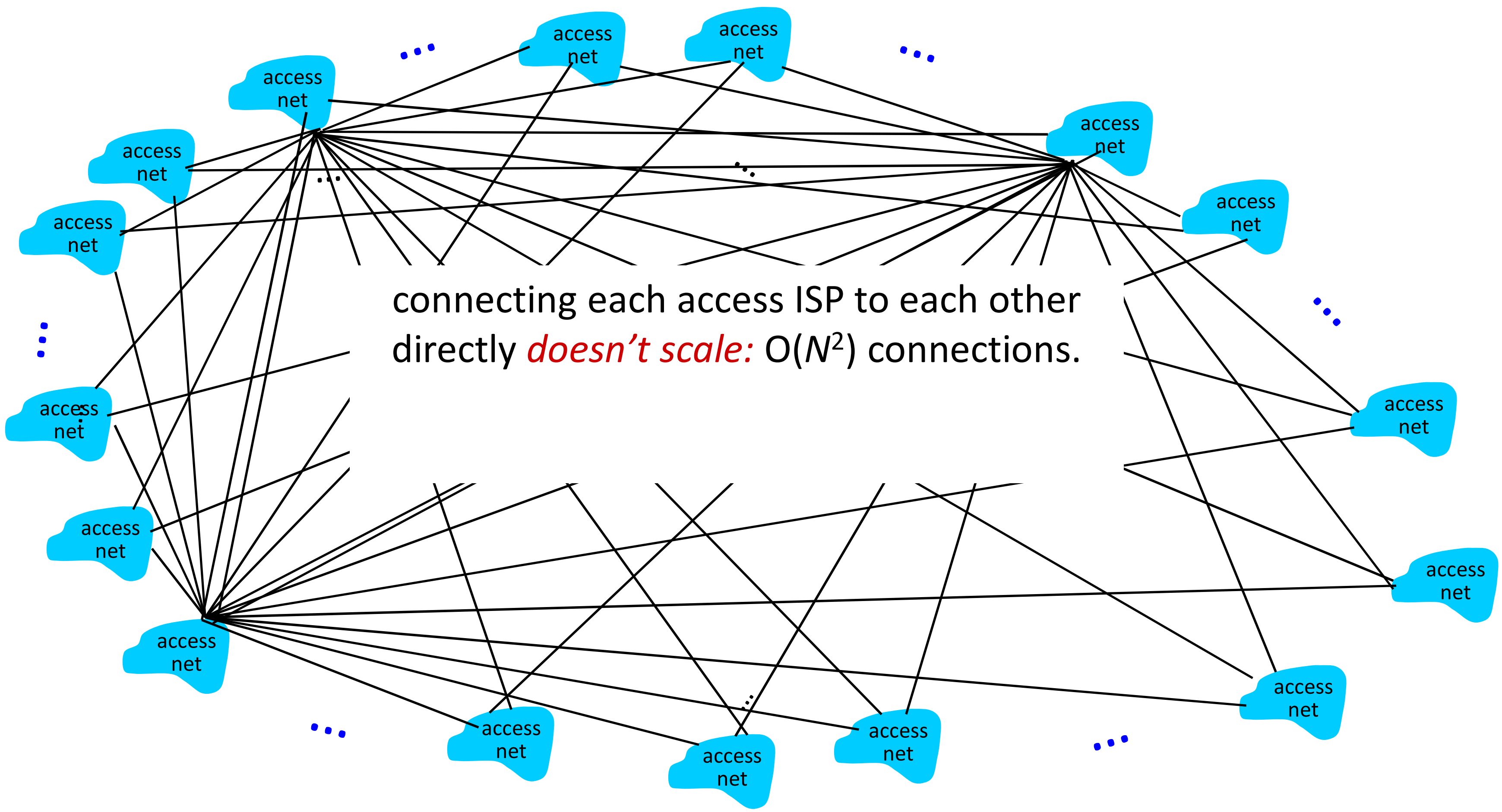
Internet structure: network of networks

Question: given *millions* of access ISPs, how to connect them together?



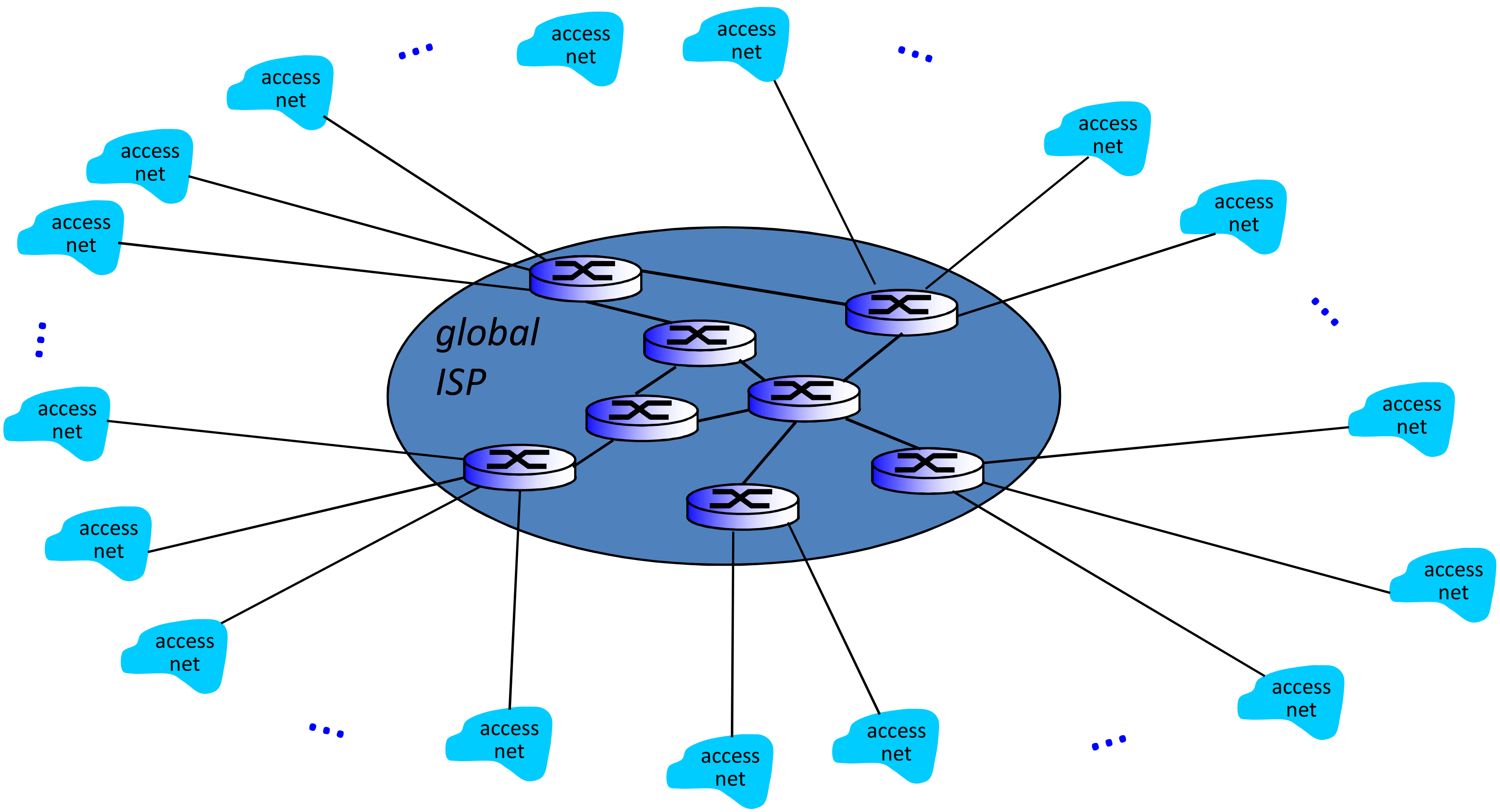
Internet structure: network of networks

Option: connect each access ISP to every other access ISP?



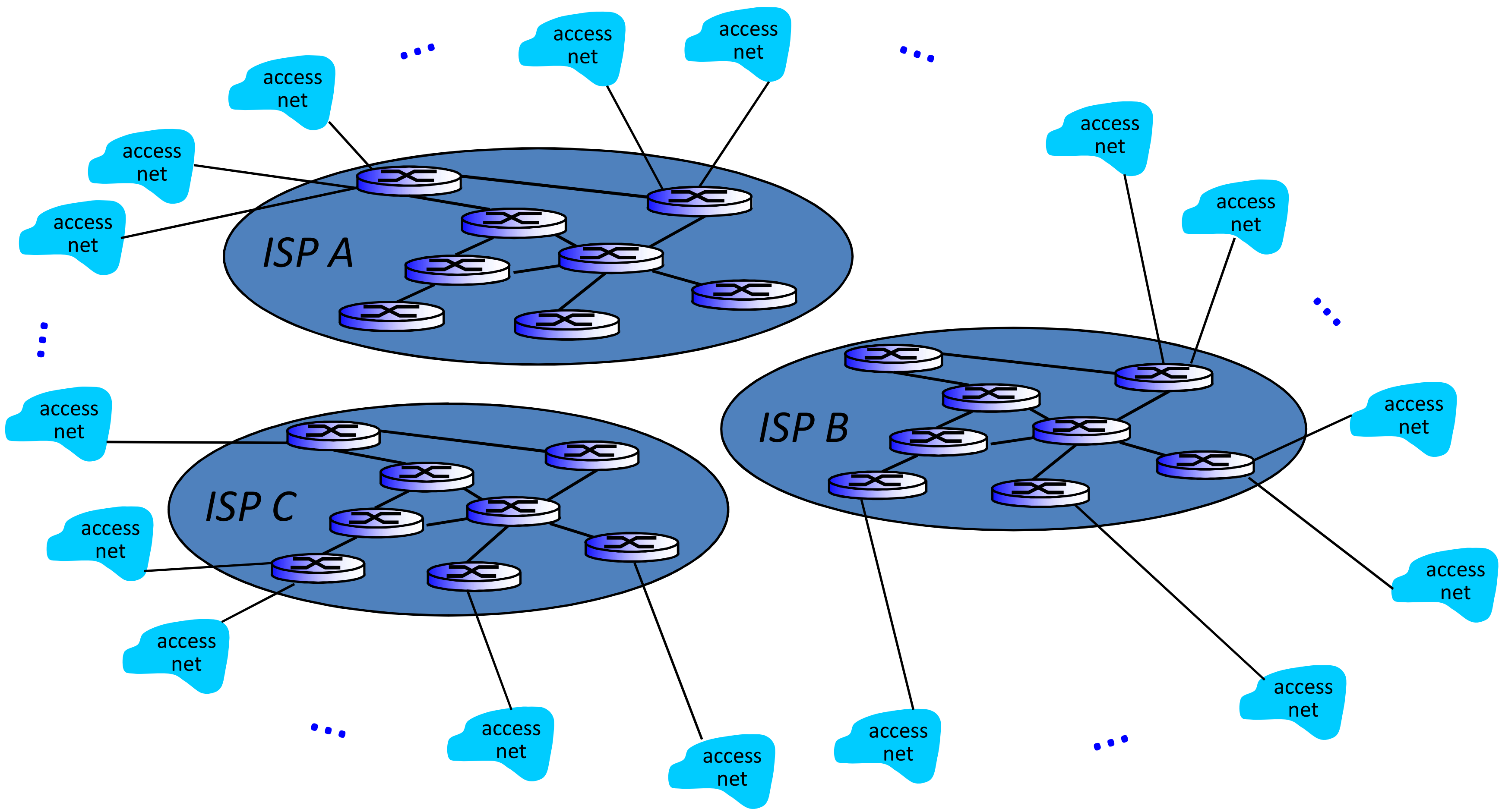
Internet structure: network of networks

Option: connect each access ISP to a global transit ISP? Customer and provider ISPs have economic agreement.



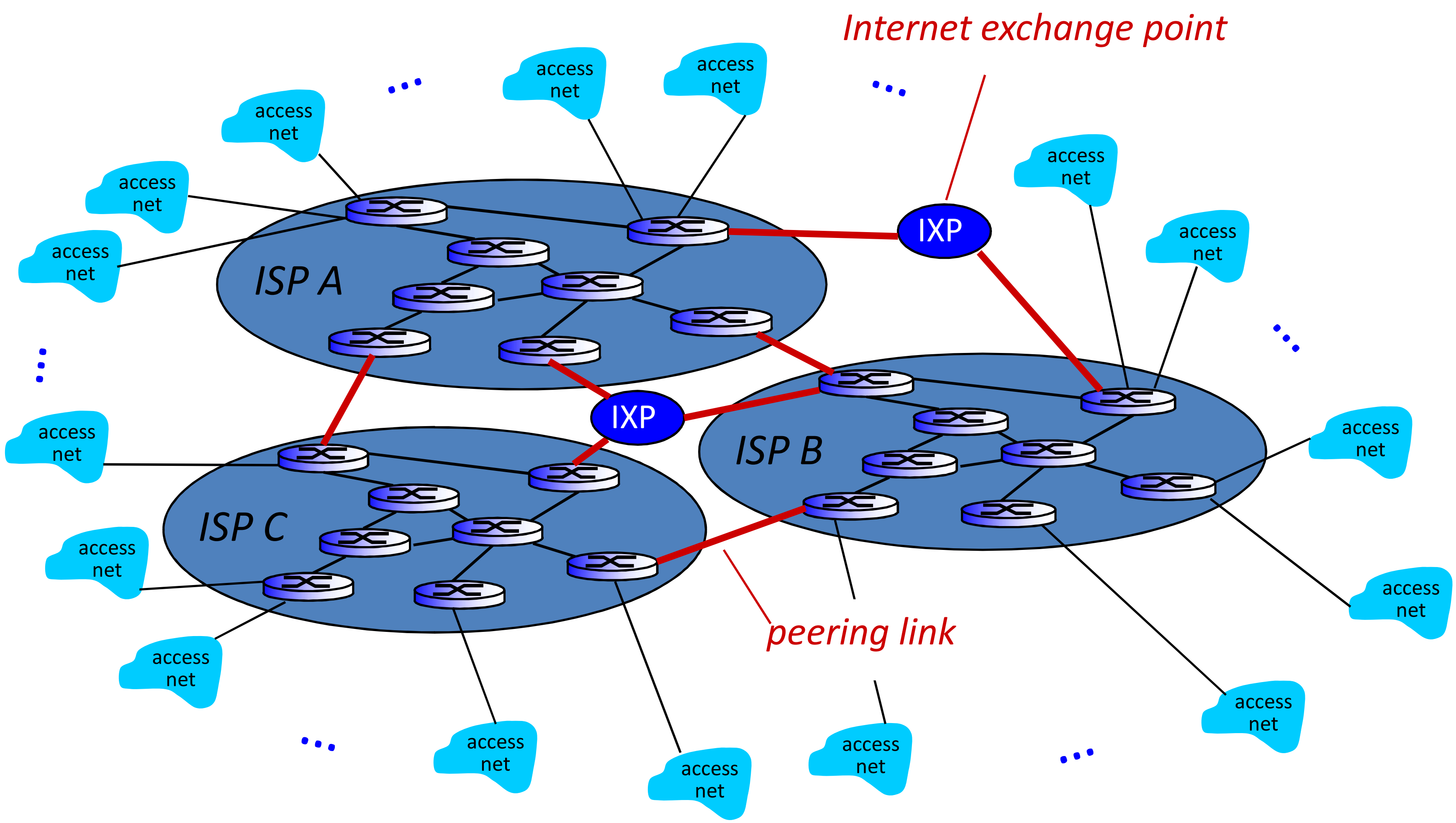
Internet structure: network of networks

But if one global ISP is viable business, there will be competitors ….



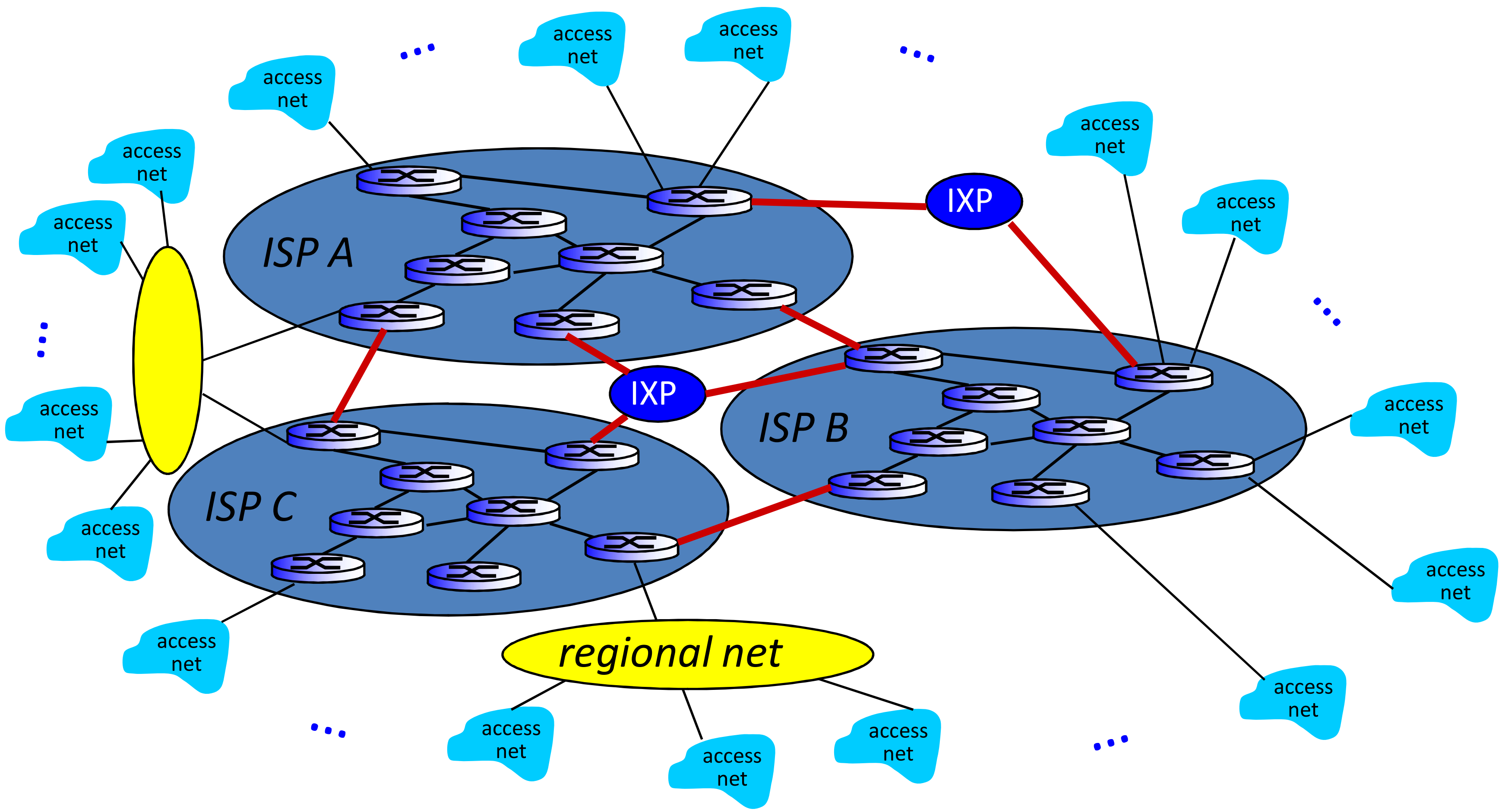
Internet structure: network of networks

But if one global ISP is viable business, there will be competitors …. which must be interconnected



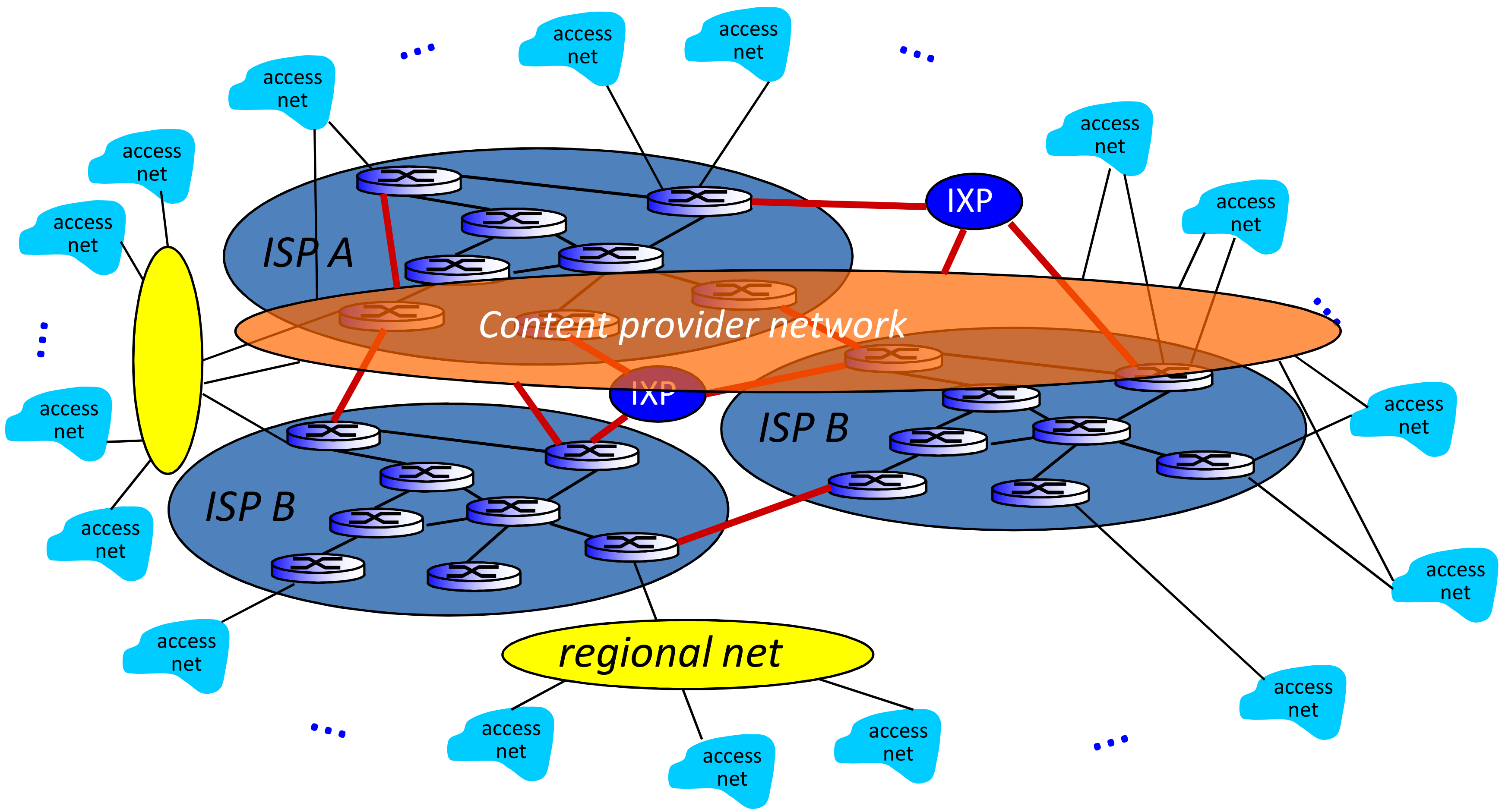
Internet structure: network of networks

… and regional networks may arise to connect access nets to ISPS

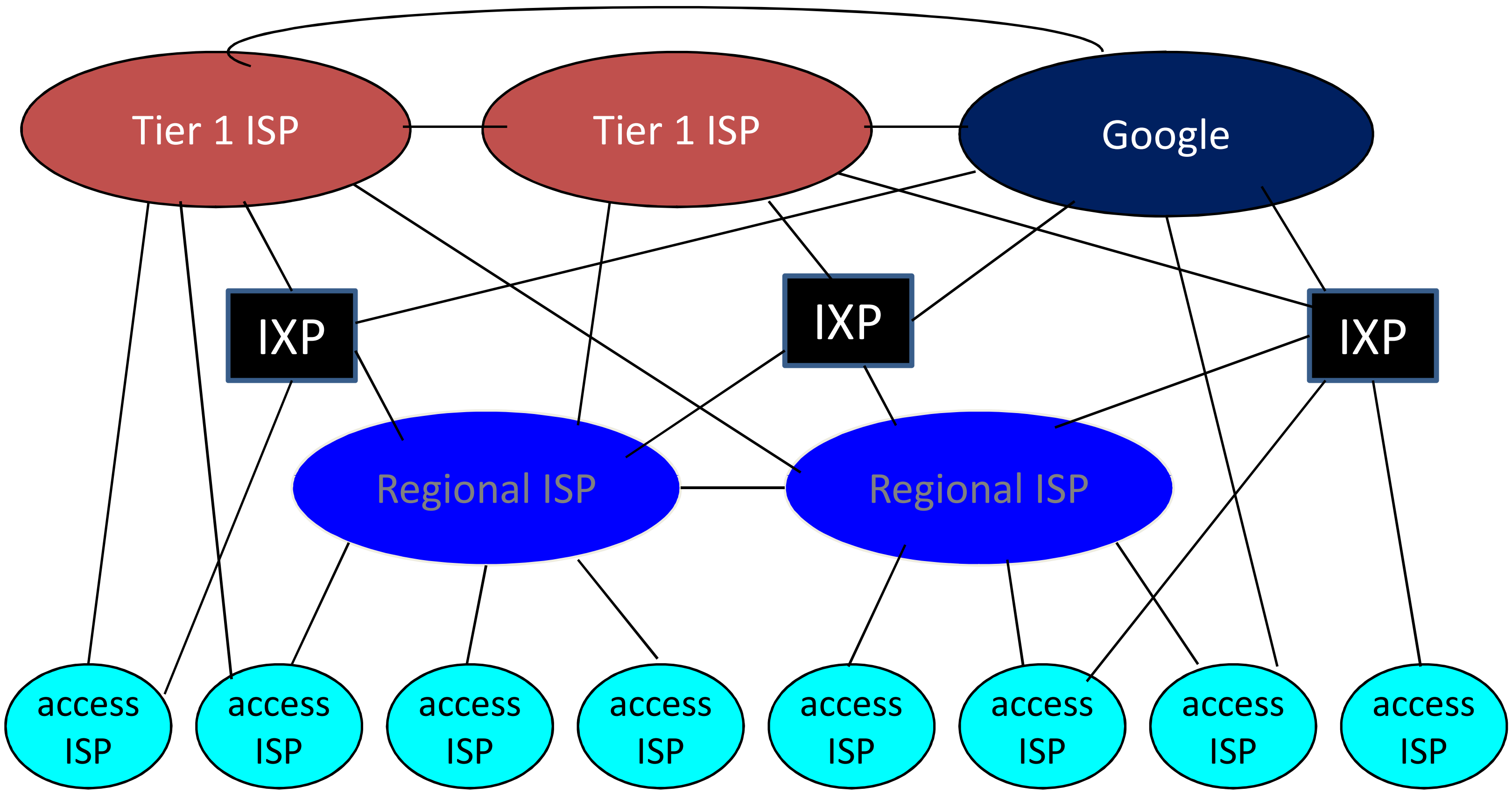


Internet structure: network of networks

… and content provider networks (e.g., Google, Microsoft, Akamai) may run their own network, to bring services, content close to end users



Internet structure: network of networks



- at center: small # of well-connected large networks
  - "tier-1" commercial ISPs (e.g., Level 3, Sprint, AT&T, NTT), national & international coverage
  - content provider network (e.g, Google): private network that connects it data centers to Internet, often bypassing tier-1, regional ISPs

“Real” Internet delays and routes

traceroute: rio.cl.cam.ac.uk to munnari.oz.au

(tracepath on pwf is similar)

Three delay measurements from rio.cl.cam.ac.uk to gatwick.net.cl.cam.ac.uk

trans-continent link

```
traceroute munnari.oz.au
traceroute to munnari.oz.au (202.29.151.3), 30 hops max, 60 byte packets
 1  gatwick.net.cl.cam.ac.uk (128.232.32.2)  0.416 ms  0.384 ms  0.427 ms
 2  cl-sby.route-nwest.net.cam.ac.uk (193.60.89.9)  0.393 ms  0.440 ms  0.494 ms
 3  route-nwest.route-mill.net.cam.ac.uk (192.84.5.137)  0.407 ms  0.448 ms  0.501 ms
 4  route-mill.route-enet.net.cam.ac.uk (192.84.5.94)  1.006 ms  1.091 ms  1.163 ms
 5  xe-11-3-0.camb-rbr1.eastern.ja.net (146.97.130.1)  0.300 ms  0.313 ms  0.350 ms
 6  ae24.lowdss-sbr1.ja.net (146.97.37.185)  2.679 ms  2.664 ms  2.712 ms
 7  ae28.londhx-sbr1.ja.net (146.97.33.17)  5.955 ms  5.953 ms  5.901 ms
 8  janet.mx1.lon.uk.geant.net (62.40.124.197)  6.059 ms  6.066 ms  6.052 ms
 9  ae0.mx1.par.fr.geant.net (62.40.98.77)  11.742 ms  11.779 ms  11.724 ms
10  ae1.mx1.mad.es.geant.net (62.40.98.64)  27.751 ms  27.734 ms  27.704 ms
11  mb-so-02-v4.bb.tein3.net (202.179.249.117)  138.296 ms  138.314 ms  138.282 ms
12  sg-so-04-v4.bb.tein3.net (202.179.249.53)  196.303 ms  196.293 ms  196.264 ms
13  th-pr-v4.bb.tein3.net (202.179.249.66)  225.153 ms  225.178 ms  225.196 ms
14  pyt-thairen-to-02-bdr-pyt.uni.net.th (202.29.12.10)  225.163 ms  223.343 ms  223.363 ms
15  202.28.227.126 (202.28.227.126)  241.038 ms  240.941 ms  240.834 ms
16  202.28.221.46 (202.28.221.46)  287.252 ms  287.306 ms  287.282 ms
17  * * *
18  * * *
19  * * *
20  coe-gw.psu.ac.th (202.29.149.70)  241.681 ms  241.715 ms  241.680 ms
21  munnari.OZ.AU (202.29.151.3)  241.610 ms  241.636 ms  241.537 ms
```

* means no response (probe lost, router not replying)