
University of Colorado Boulder

Fundamentals of Data Communications CSCI 5010

Networks Overview

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Review

- **Syllabus**

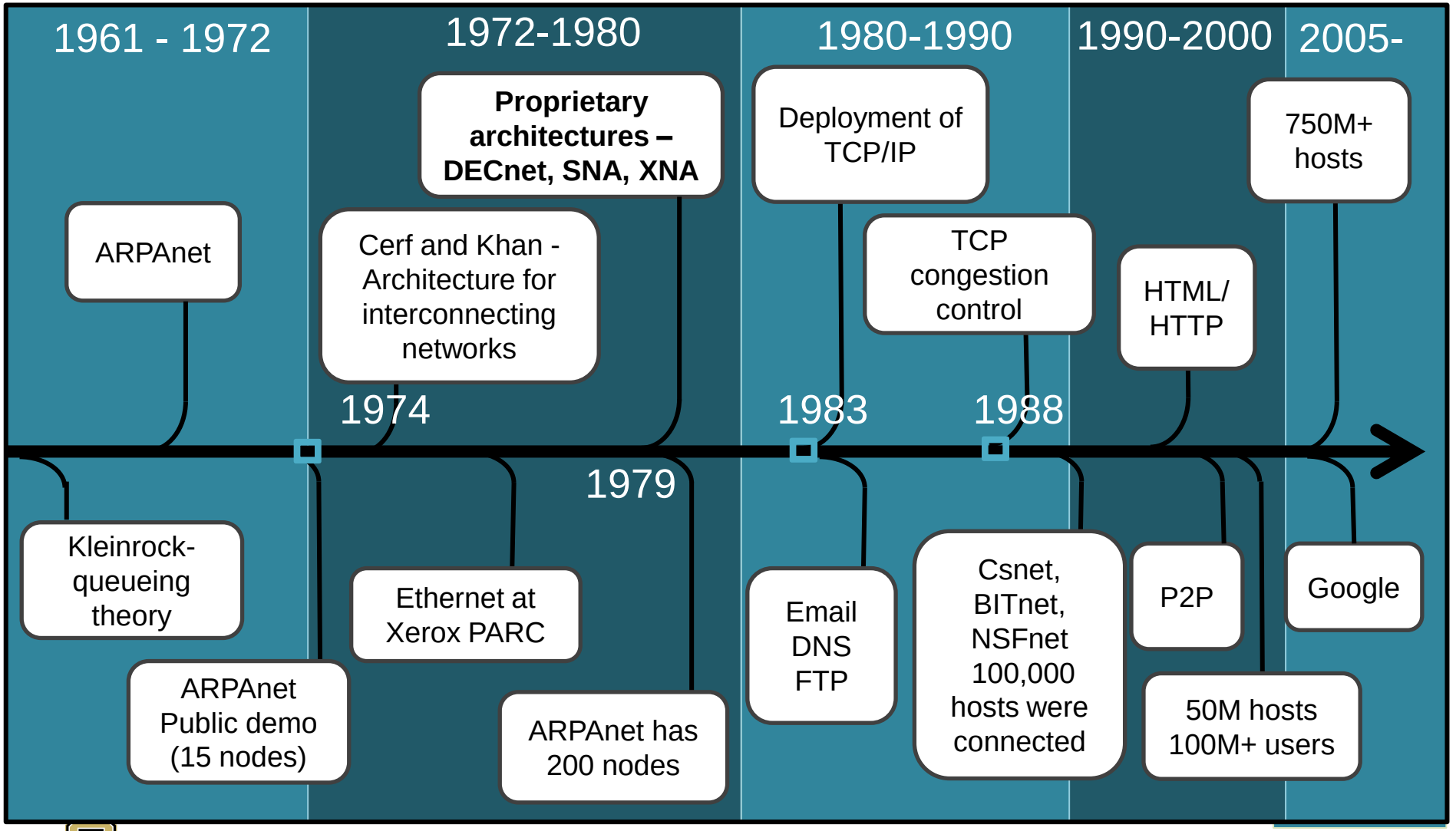
What *is* the Internet?

What is the Internet?

The Internet is the worldwide, publicly accessible network of interconnected computer networks that transmit data by packet switching using the standard Internet Protocol (IP).

It is a "network of networks" that consists of millions of smaller domestic, academic, business, and government networks, which together carry various information and services.

Internet History

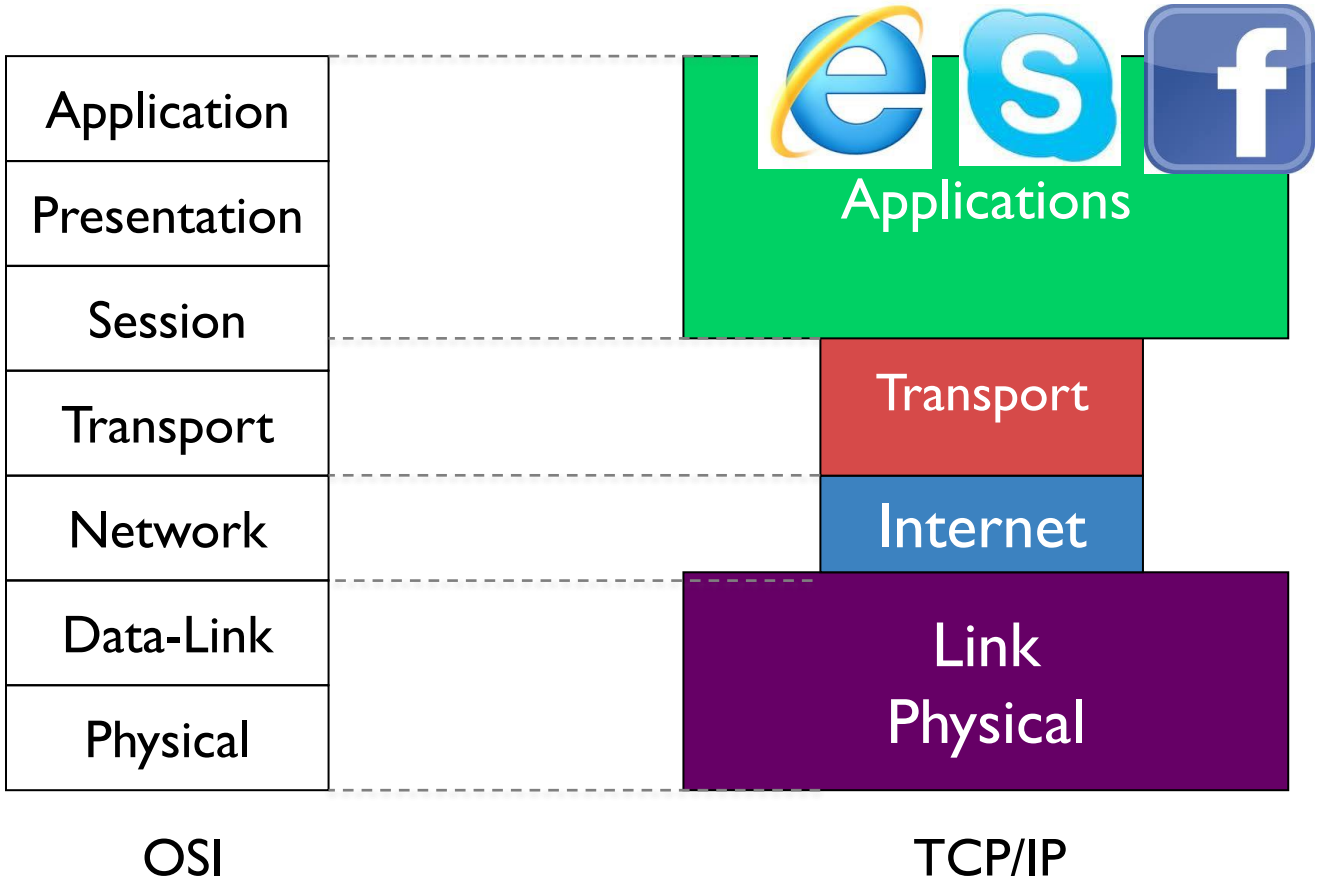


Key Concepts in Networking

- **Protocols**
  - Speaking the same language
  - Syntax and semantics
- **Layering**
  - Standing on the shoulders of giants
  - A key to managing complexity
- **Resource allocation**
  - Dividing scarce resources among competing parties
  - Memory, link bandwidth, wireless spectrum, paths
- **Naming**
  - What to call computers, services, protocols, …

The Layered Network Stack

- The OSI Model vs. TCP/IP Model

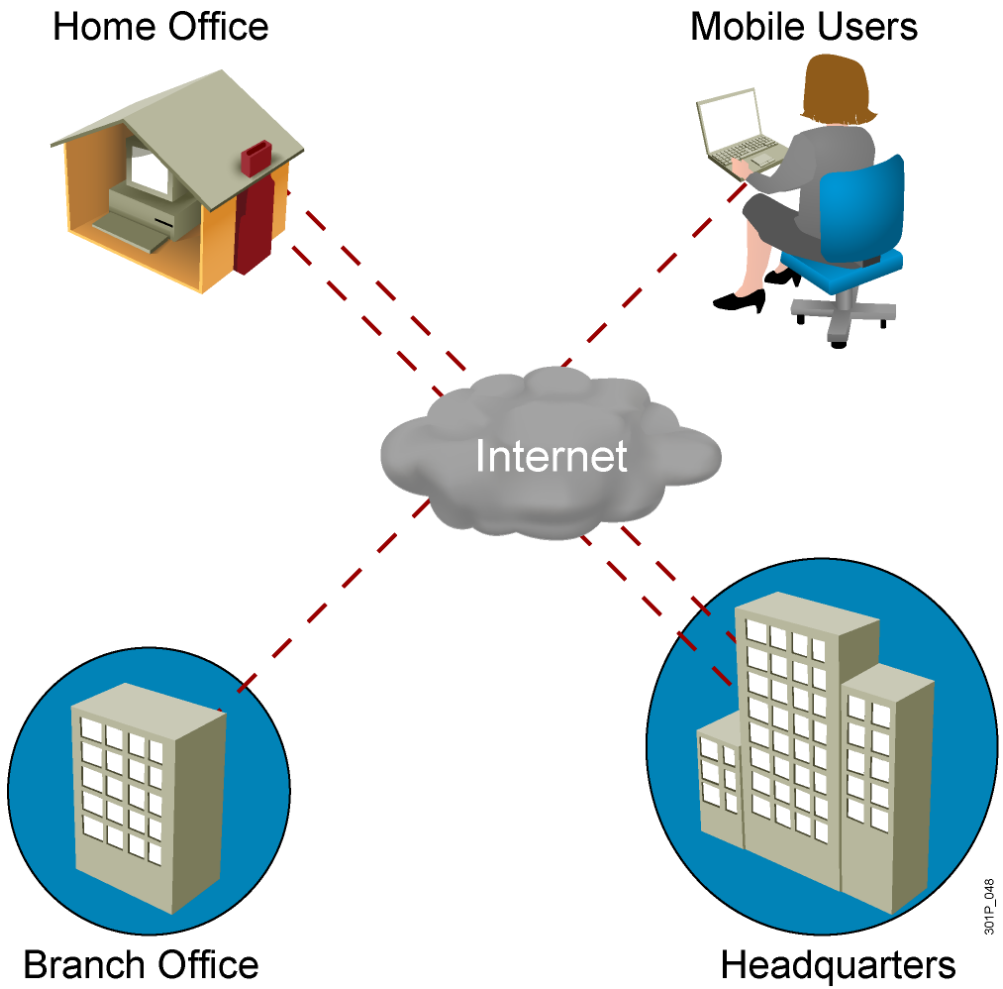


What is a network?

- **A network is a connected collection of devices that can communicate with each other.**
  - Why?

- **Networks carry data in many kinds of environments:**
  - Homes
  - Small businesses
  - Large enterprises

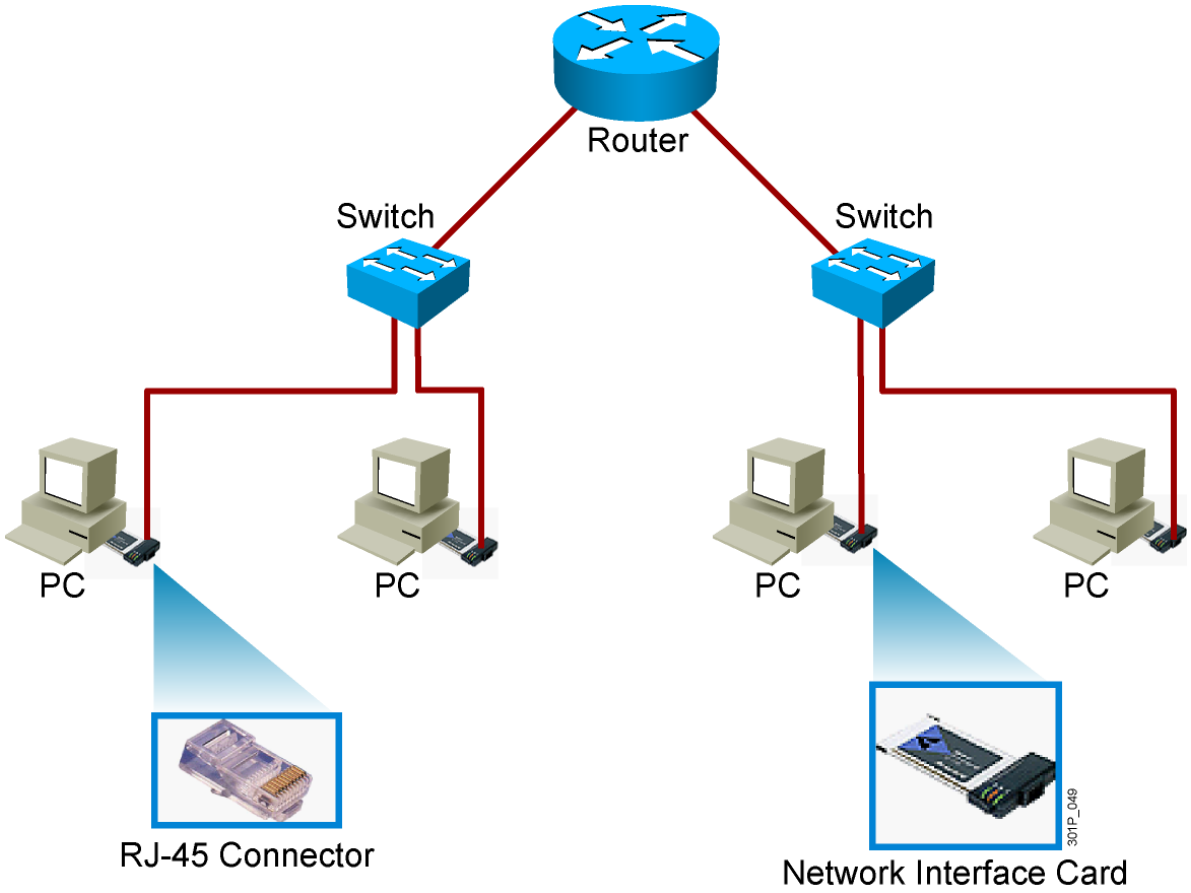
What is a network?



Common Physical Components of a Network

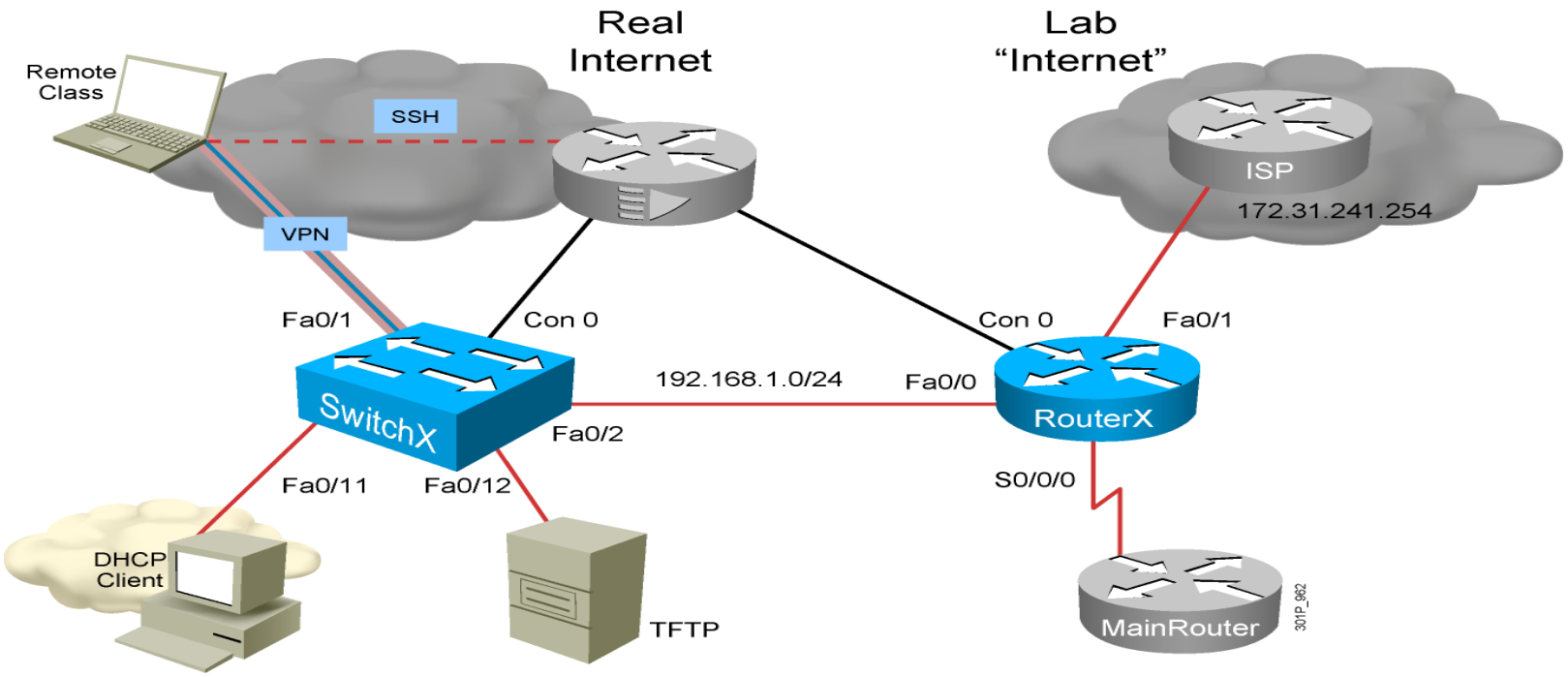
- **There are major categories of physical components in a computer network:**
  - Computers/servers
  - Interconnections
  - Network devices
    - ***Switches***
    - ***Routers***
    - ***Firewalls***
    - ***Phones***

Common Physical Components of a Network



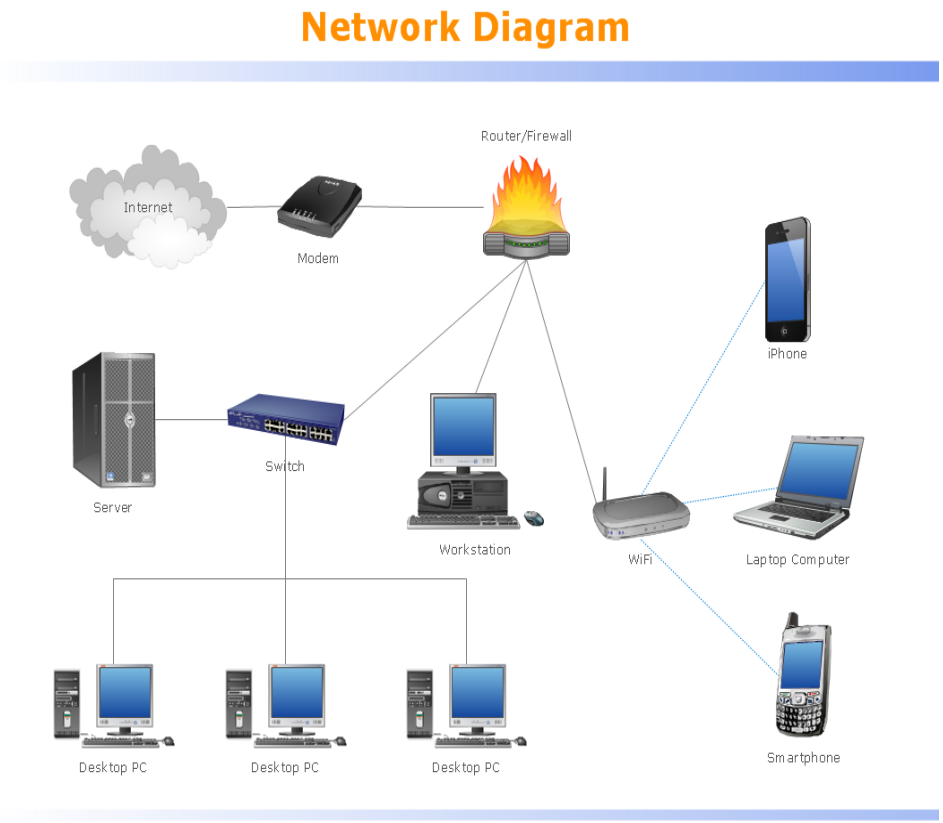
Interpreting a Network Diagram

– Networks are depicted graphically using a set of standard icons.



Resource-Sharing Functions and Benefits

- **Data and applications**
- **Resources**
- **Network storage**
- **Backup devices**
- **Why?**



Network User Applications (Business)

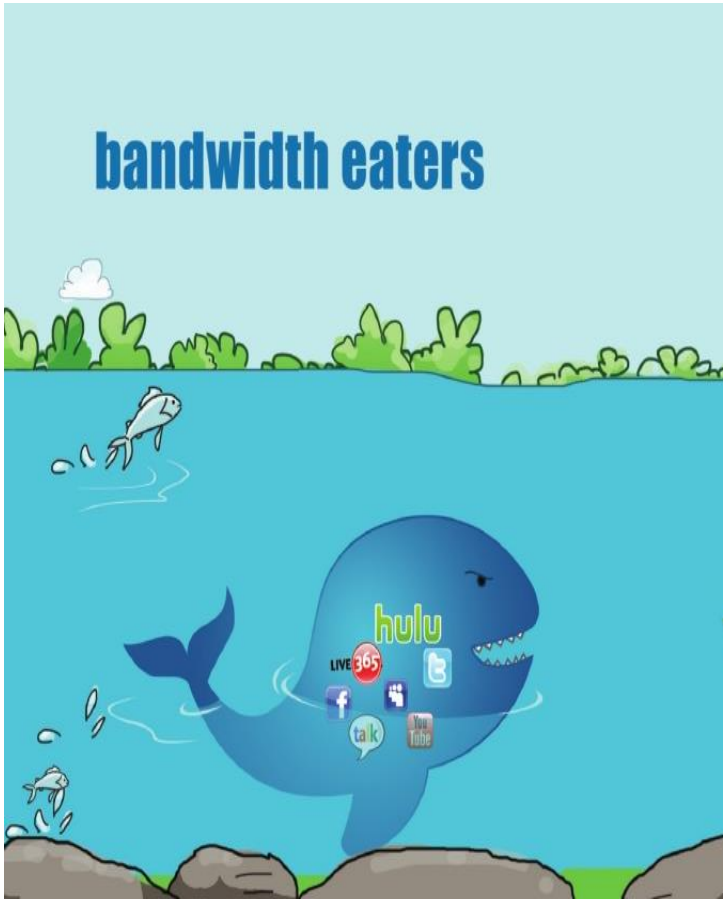
- **E-mail (Outlook, POP3, Gmail)**
- **Web browser (IE, Firefox, Chrome)**
- **Instant messaging (What's App, Facebook, Snap)**
- **Collaboration (Zoom, Whiteboard, GoToMeeting, WebEx)**
- **Databases (file servers)**
- **Applications**

Impact of User Applications on the Network

- **Interactive applications**
  - Inventory inquiries, database updates.
  - Human-to-machine interaction.
  - Because a human is waiting for a response, response time is important but not critical, unless the wait becomes excessive.

- **Real-time applications**
  - VoIP, video, gaming
  - Human-to-human interaction
  - End-to-end latency critical
    - ***Latency under load***

- **Internet applications**
  - Social media
  - Streaming: audio & video



Characteristics of a Network

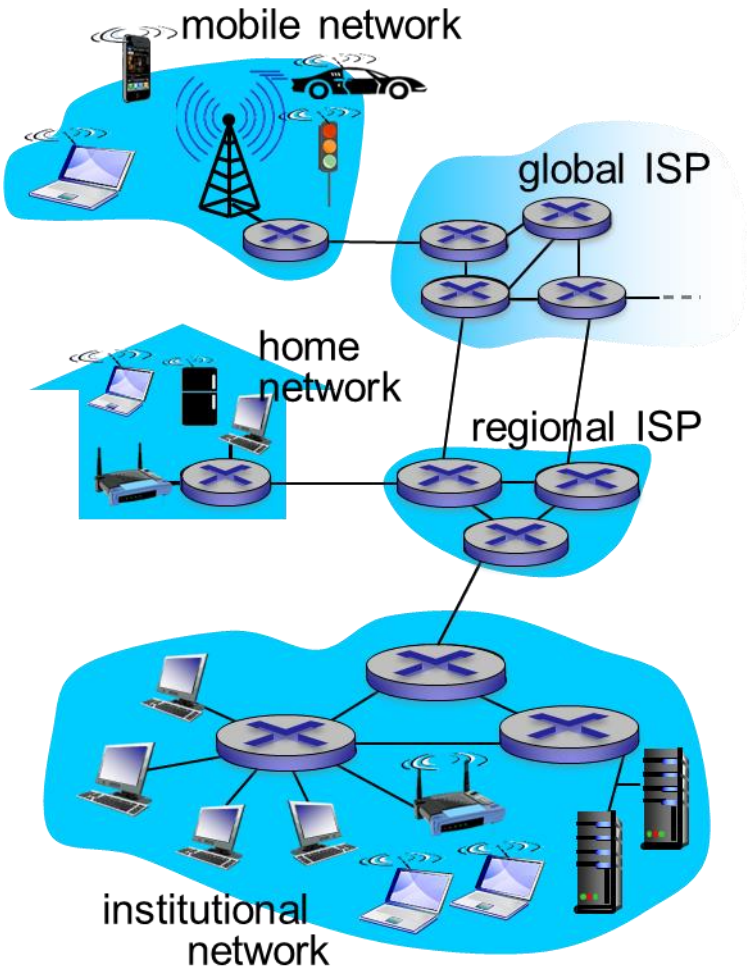
- **Speed**
- **Cost**
- **Security**
- **Availability**
- **Scalability**
- **Reliability**
- **Topology**

Connection to the Internet

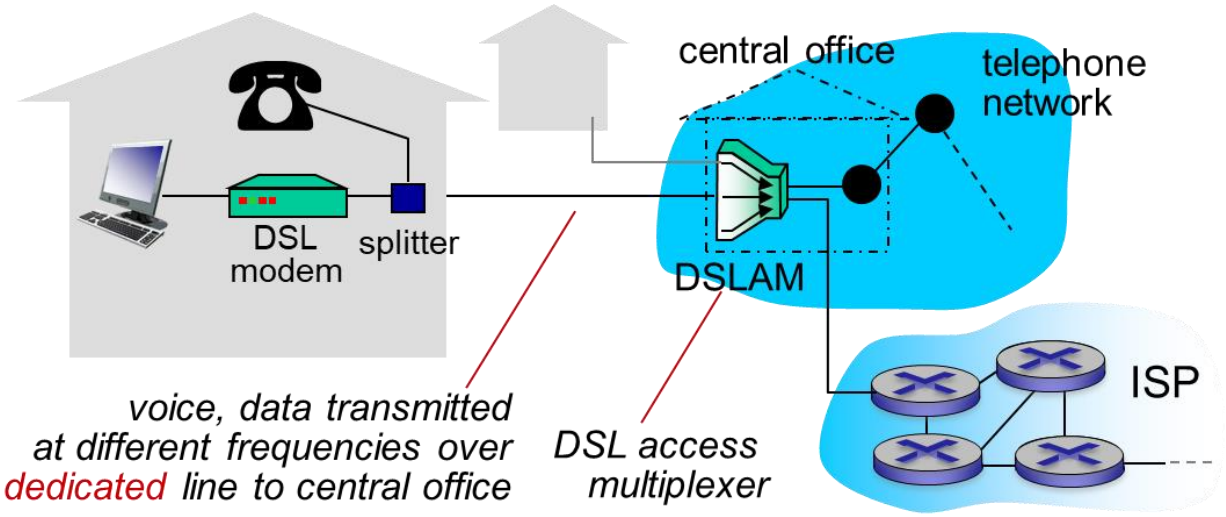
- **There are several common methods of connecting the small office to the Internet:**
  - DSL
    - ***Using the existing telephone lines***
  - Cable modem
    - ***Cable using the CATV infrastructure***
  - Fiber
    - ***Optical cables***
  - Wireless
    - ***Microwave, LTE, 802.11, 5G***

Network Structure

- **Network edge**
  - Hosts: clients and servers
  - Servers often in data centers
- **Access networks/physical media**
  - Wired, wireless
- **Network core**
  - Interconnected routers
  - Network of networks
- **How to connect networks?**
  - Bandwidth (bits per second)
    - ***Shared or dedicated***

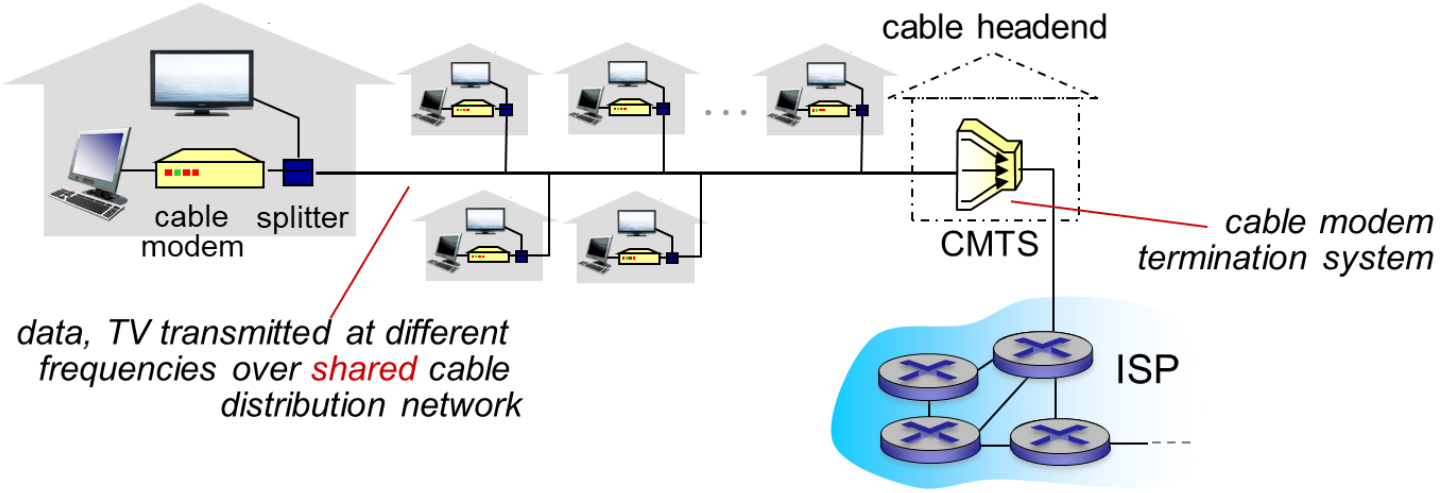


Access Network: Digital Subscriber Line (DSL)



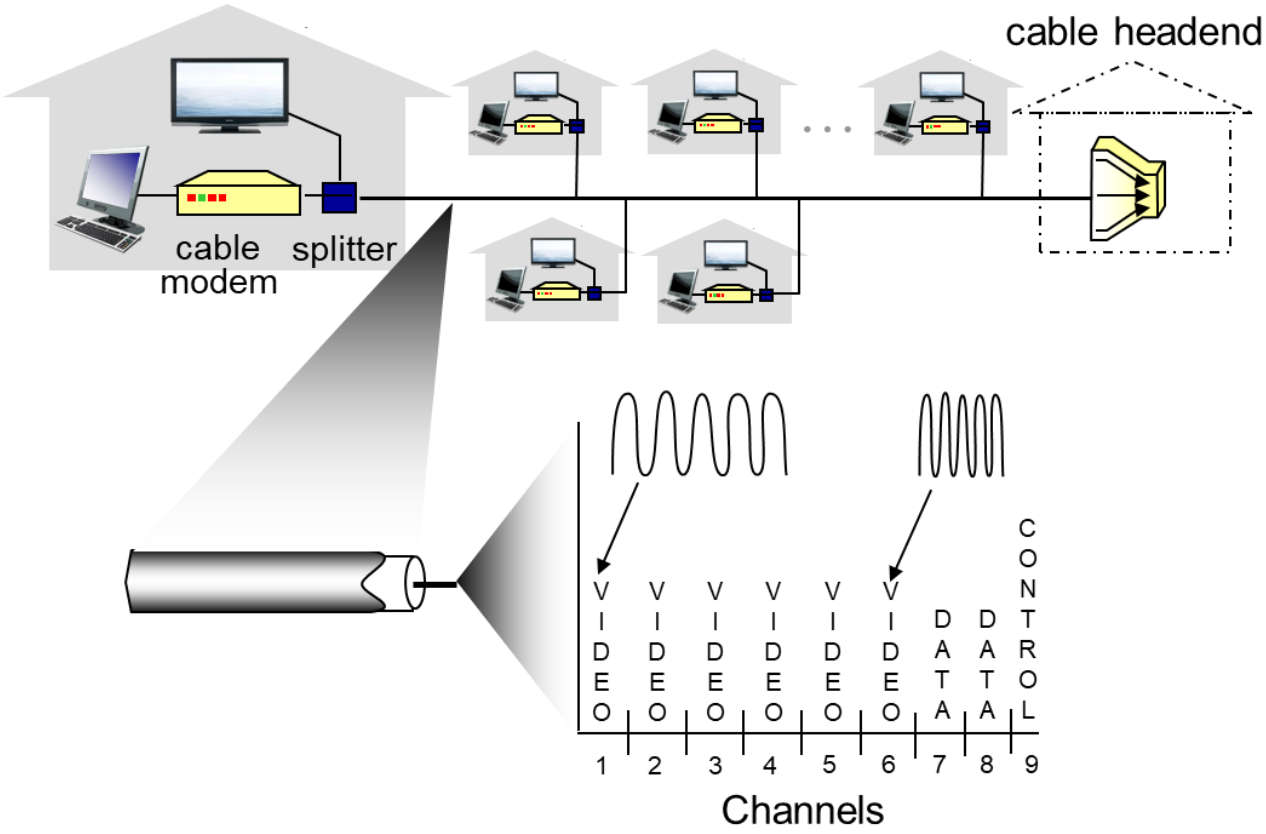
- **Use existing telephone line to central office DSLAM**
  - data over DSL phone line goes to Internet
  - voice over DSL phone line goes to telephone net
- **< 2.5 Mbps upstream transmission rate (typically < 1 Mbps)**
- **< 24 Mbps downstream transmission rate (typically < 10 Mbps)**

Access Network: Cable Network



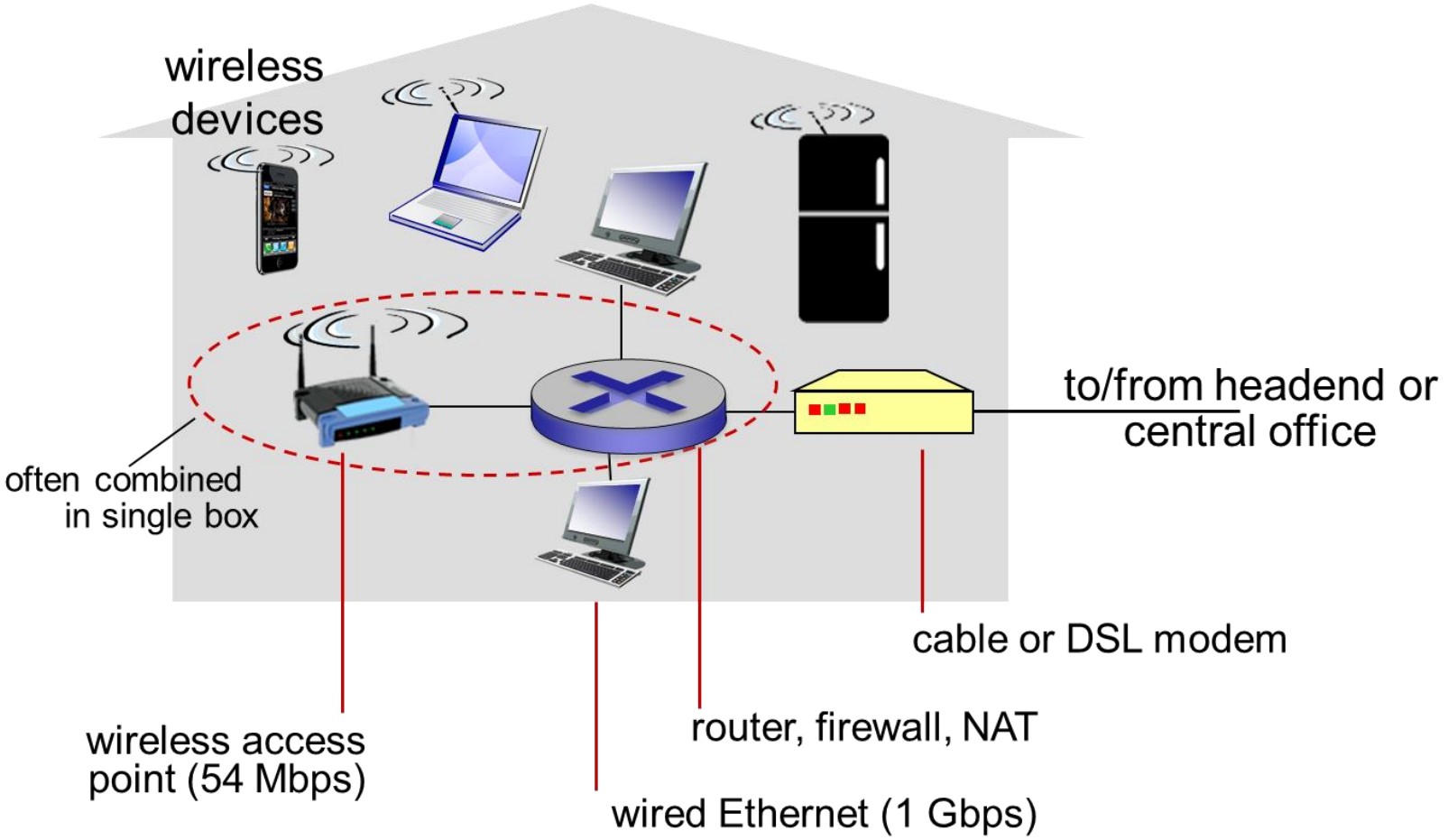
- HFC: hybrid fiber coax
  - asymmetric: up to 30Mbps downstream transmission rate, 2 Mbps upstream transmission rate
- network of cable, fiber attaches homes to ISP router
  - homes *share access network* to cable headend
  - unlike DSL, which has dedicated access to central office

Access Network: Cable Network

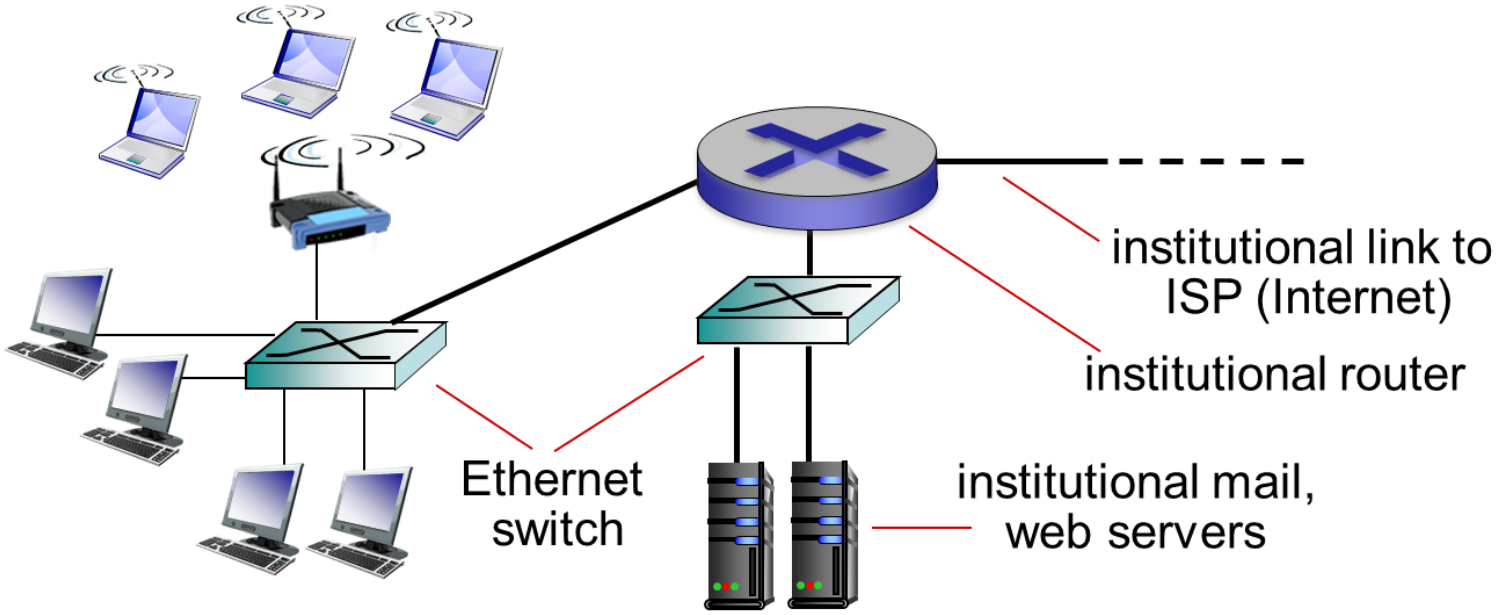


frequency division multiplexing: different channels transmitted
in different frequency bands

Access Network: Home Network



Access Network: Enterprise (Ethernet)



- typically used in companies, universities, etc.
- 10 Mbps, 100Mbps, 1Gbps, 10Gbps transmission rates
- today, end systems typically connect into Ethernet switch

Access Network: Wireless

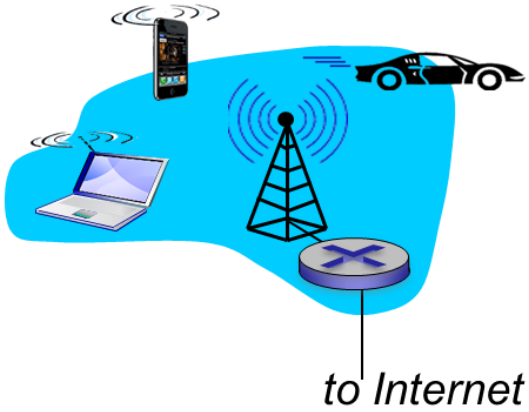
- shared *wireless* access network connects end system to router
  - via base station aka "access point"

wireless LANs:

- within building (100 ft.)
- 802.11b/g/n (WiFi): 11, 54, 450 Mbps transmission rate

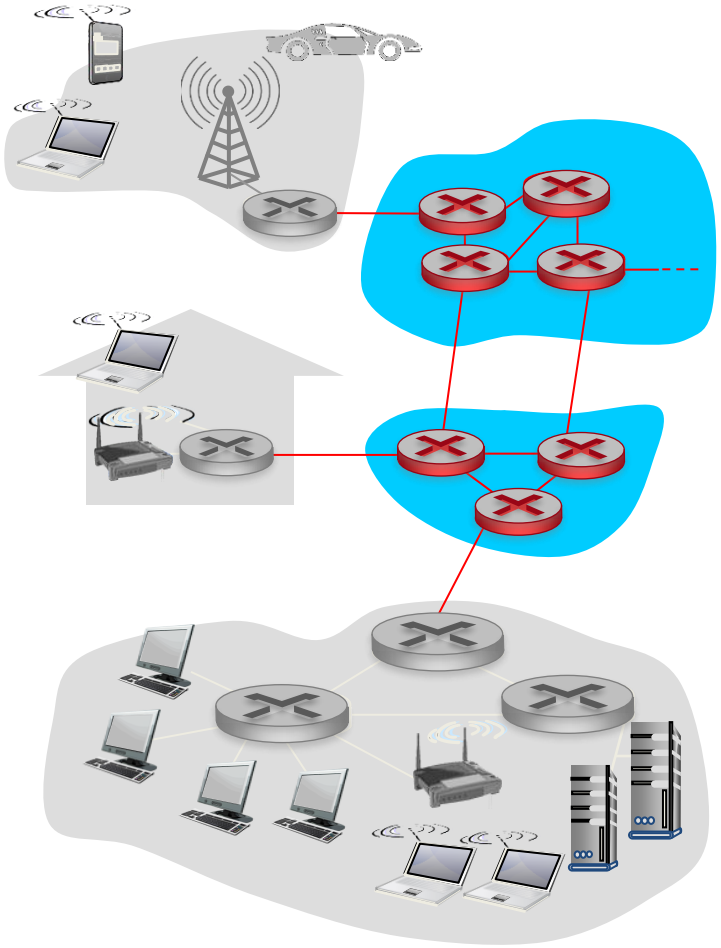
wide-area wireless access

- provided by telco (cellular) operator, 10's km
- between 1 and 10 Mbps
- 3G, 4G: LTE



The Network Core

- **Mesh of interconnected routers**
- **Packet-switching: hosts break application-layer messages into *packets***
  - forward packets from one router to the next, across links on path from source to destination
  - each packet transmitted at full link capacity

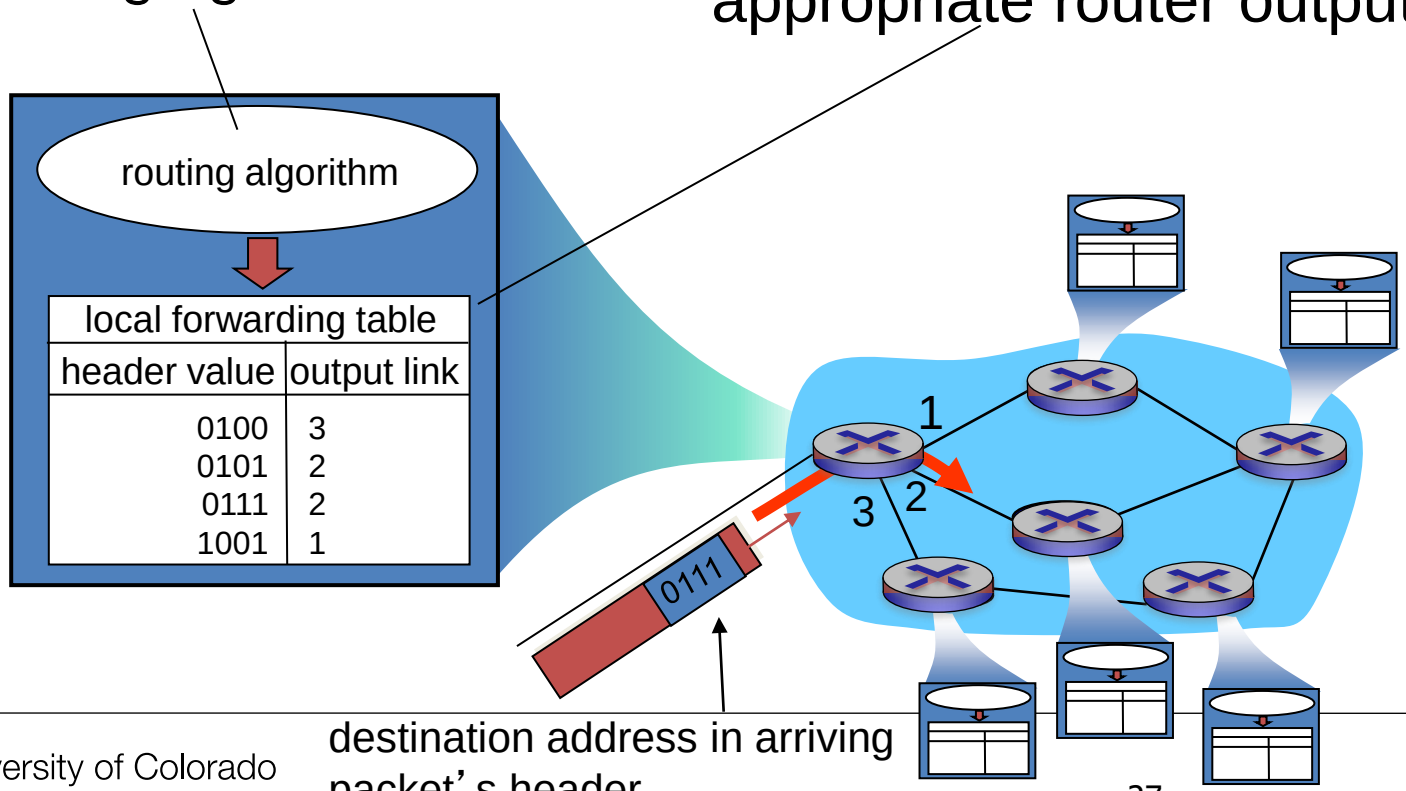


Two Key "Network-core" Functions

routing: determines source-destination route taken by packets

- *routing algorithms*

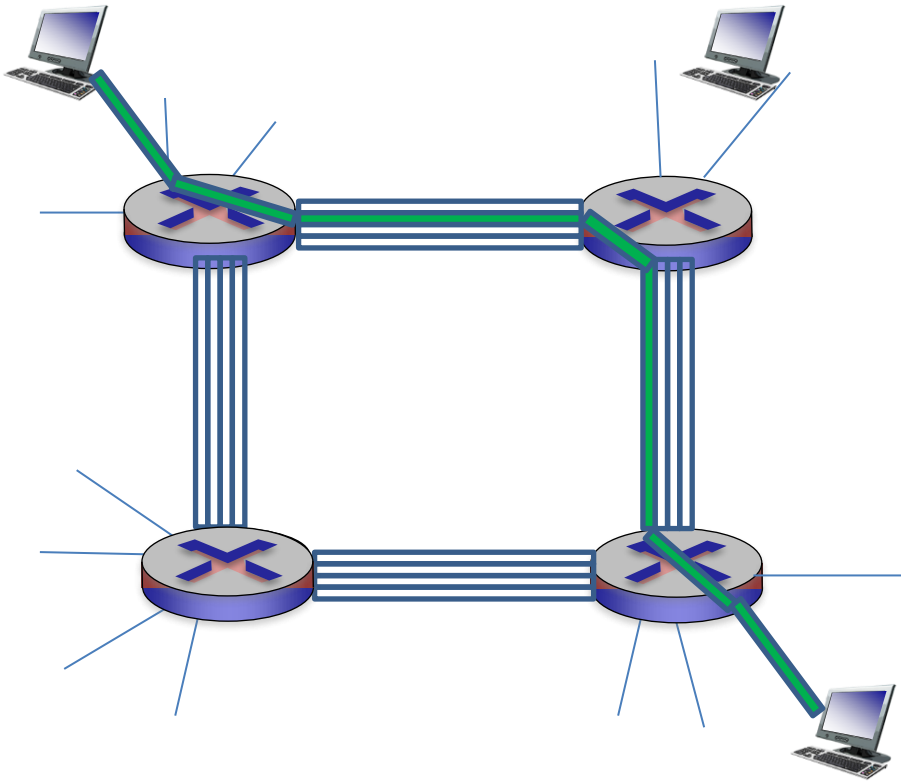
forwarding: move packets from router's input to appropriate router output



Alternative Core: Circuit Switching

End-end resources allocated to, reserved for "call" between source & dest:

- **In diagram, each link has four circuits.**
  - call gets 2nd circuit in top link and 1st circuit in right link.
- **Dedicated resources: no sharing**
  - circuit-like (guaranteed) performance
- **Circuit segment idle if not used by call *(no sharing)***
- **Commonly used in traditional <u>telephone</u> networks**

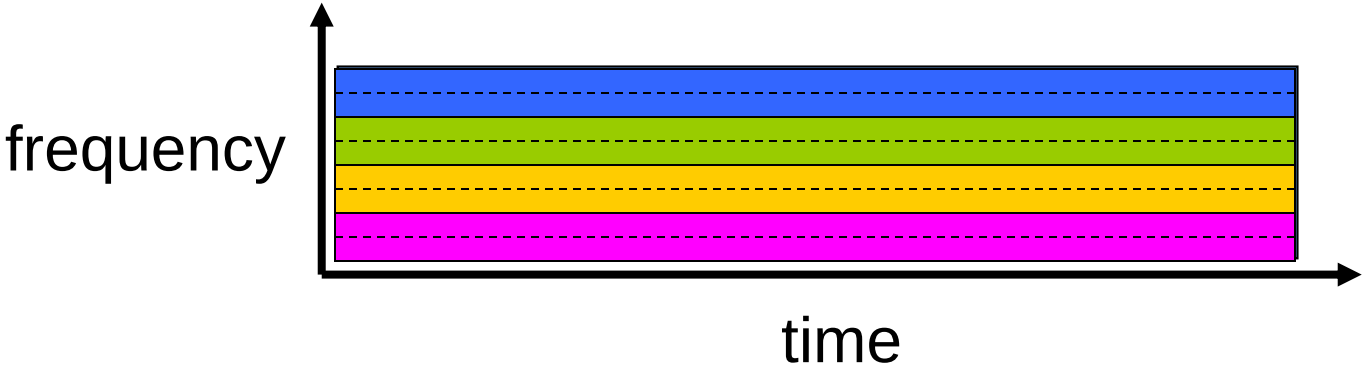


Circuit switching: FDM versus TDM

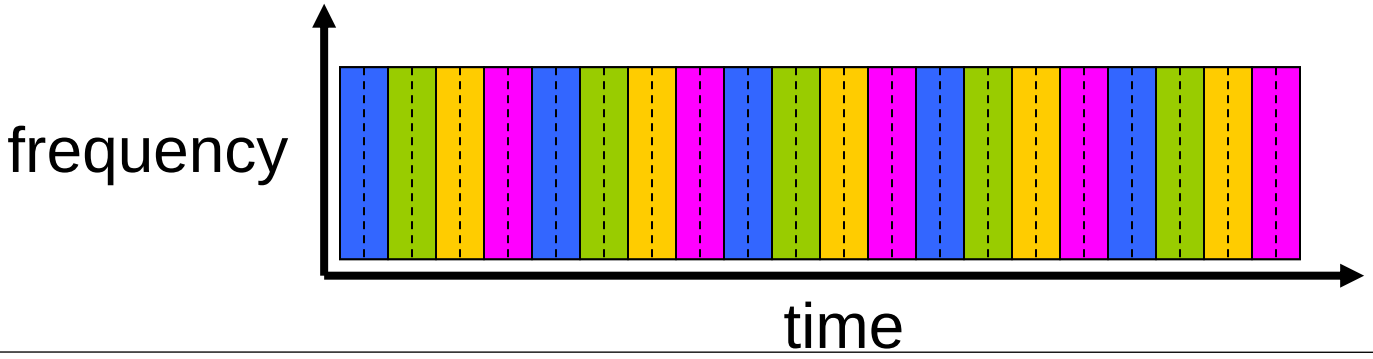
Example:

4 users

FDM



TDM



Packet Switching vs. Circuit Switching

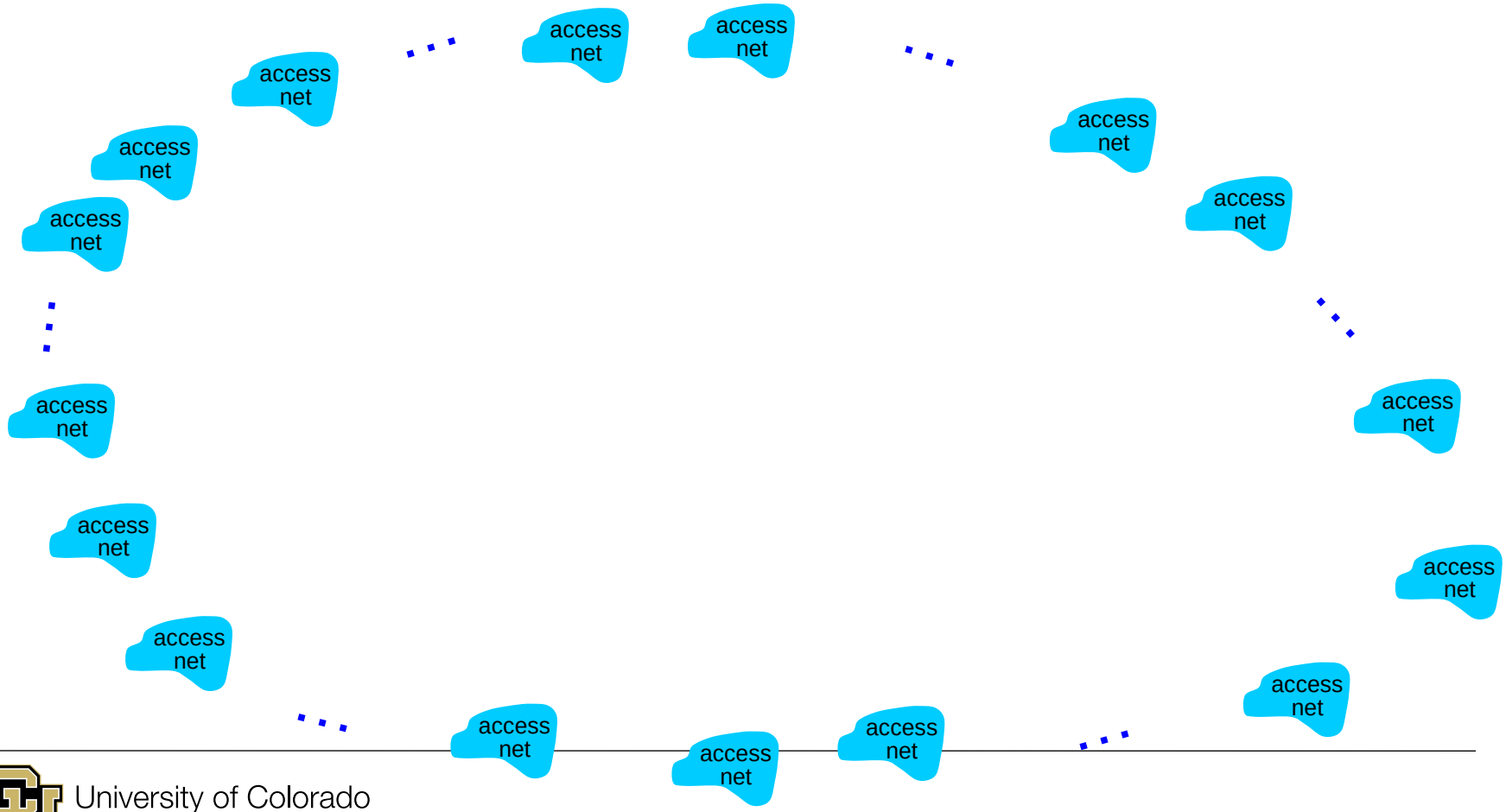
- **Packet switching allows more users to use the network**
  - Great for bursty data
    - ***Resource sharing***
    - ***Simpler, no call setup***
  - Excessive congestion possible
    - ***Packet delay and loss***
    - ***Protocols need reliable data transfer, congestion control***

Internet Structure: Network of Networks

- End systems connect to Internet via access ISPs (Internet Service Providers)
  - Residential, company, and university ISPs
- Access ISPs in turn must be interconnected
  - So that any two hosts can send packets to each other
- Resulting network of networks is very complex
  - Evolution was driven by economics and national policies

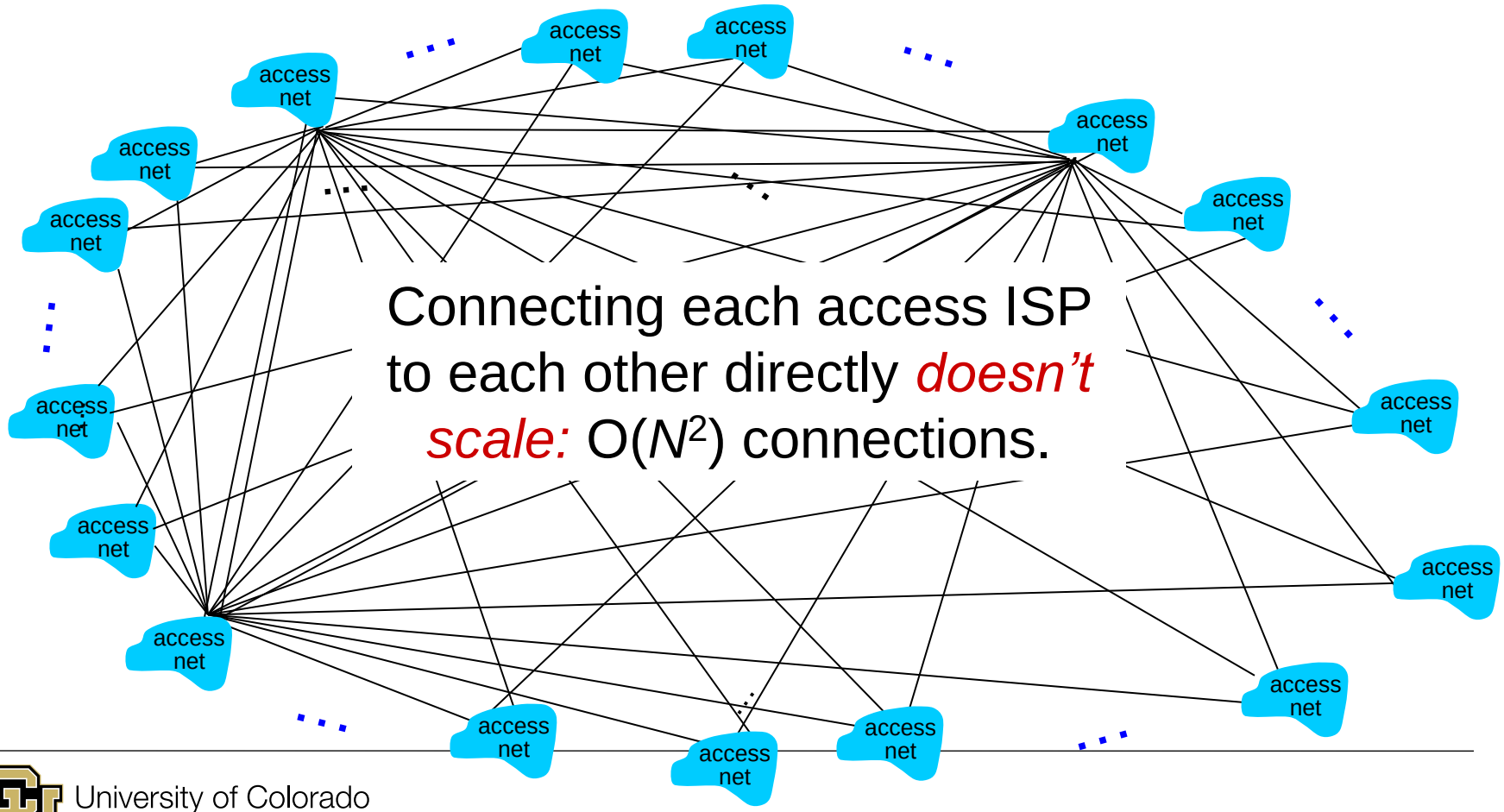
Internet Structure: network of networks

Question: given _millions_ of access ISPs, how should we connect them?



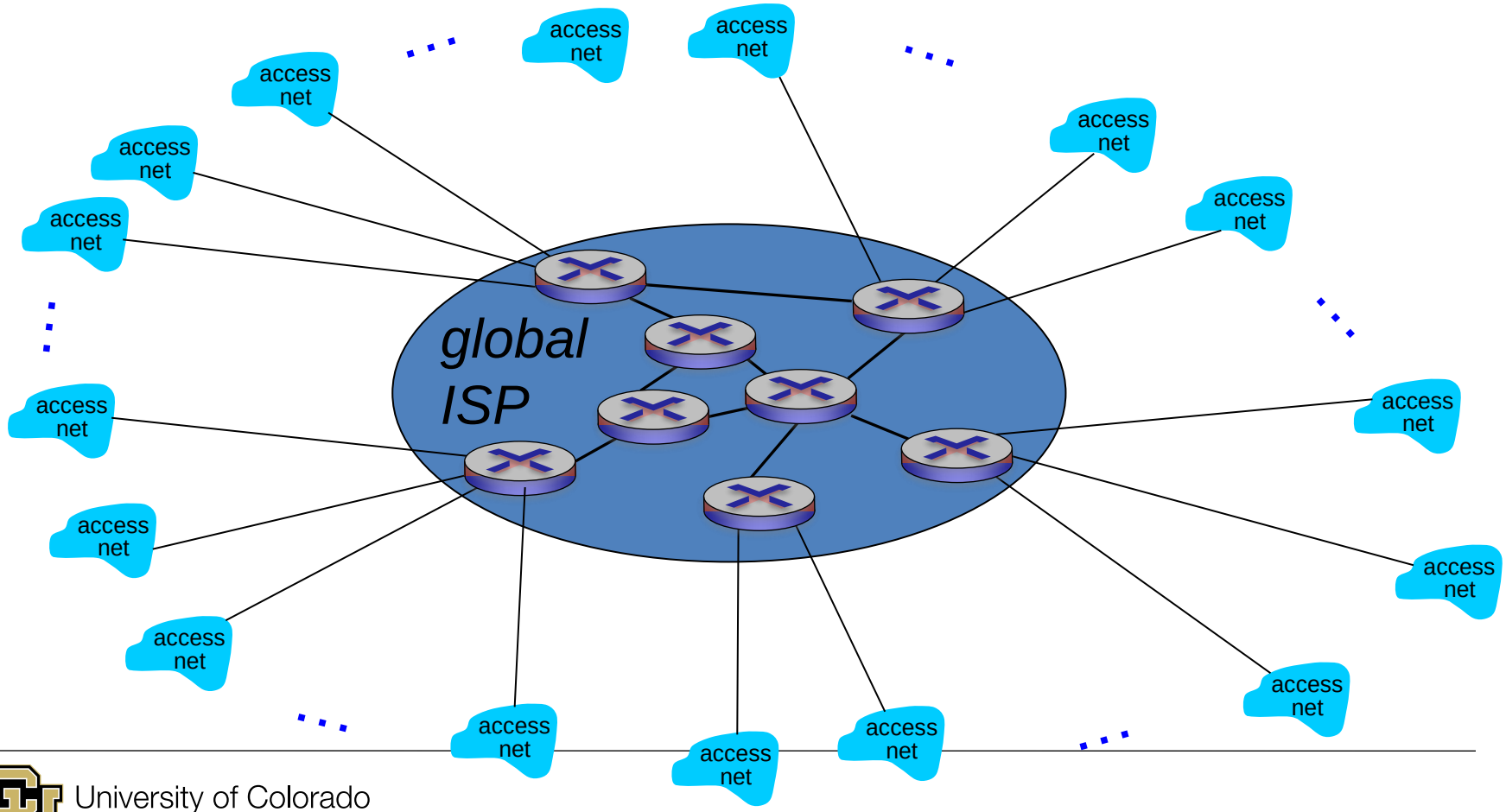
Internet structure: network of networks

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



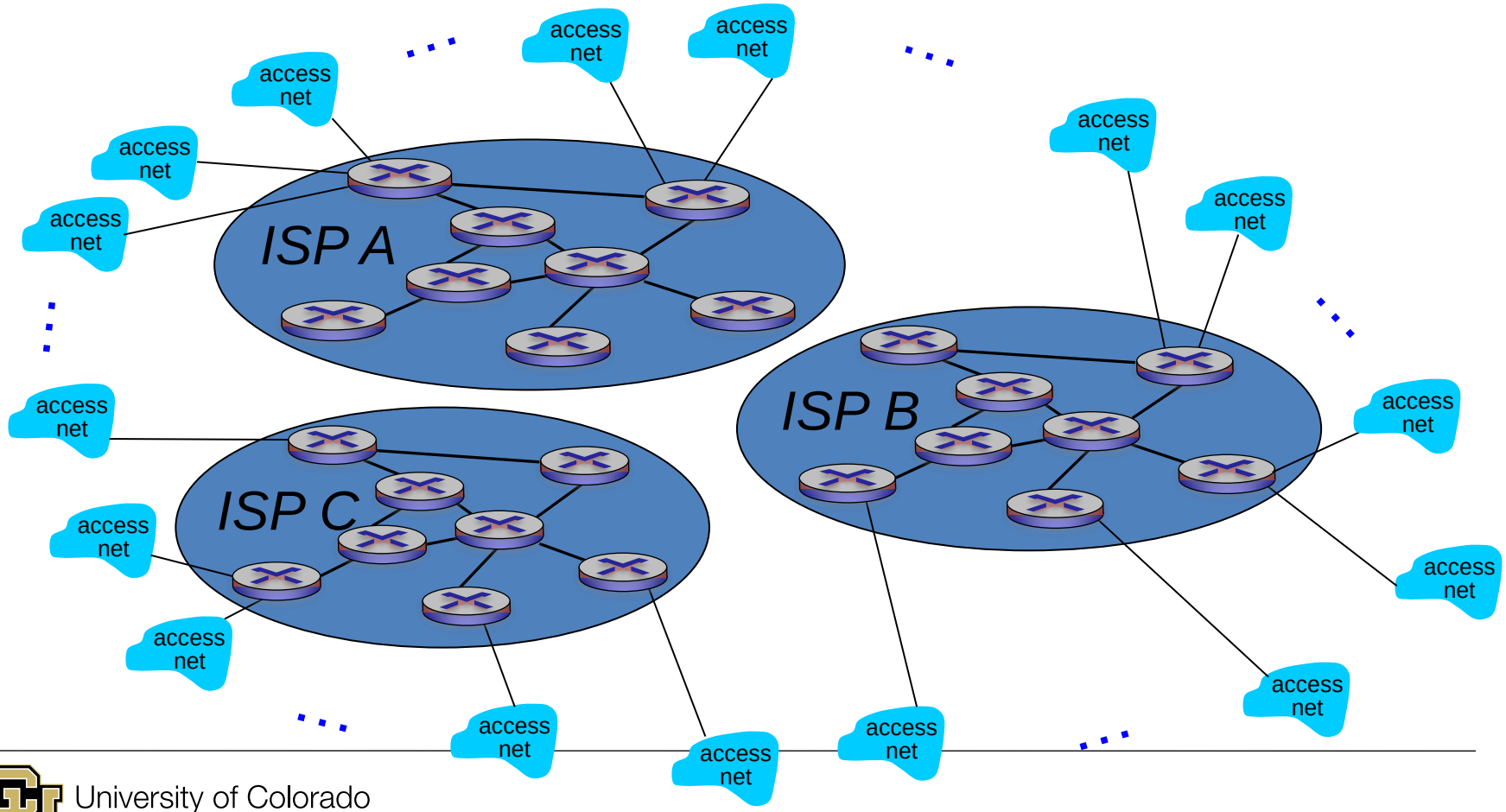
Internet structure: network of networks

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



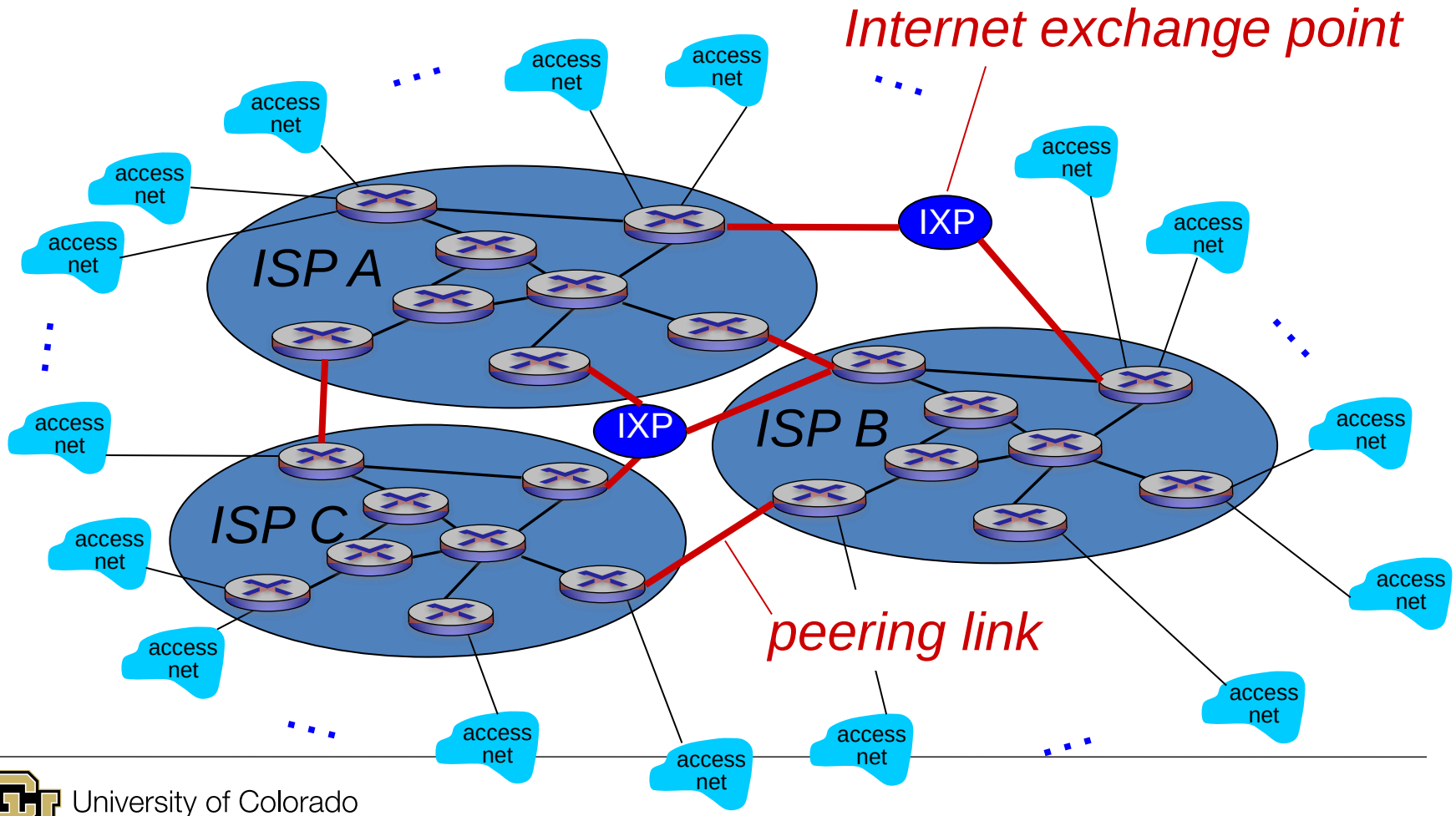
Internet structure: network of networks

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



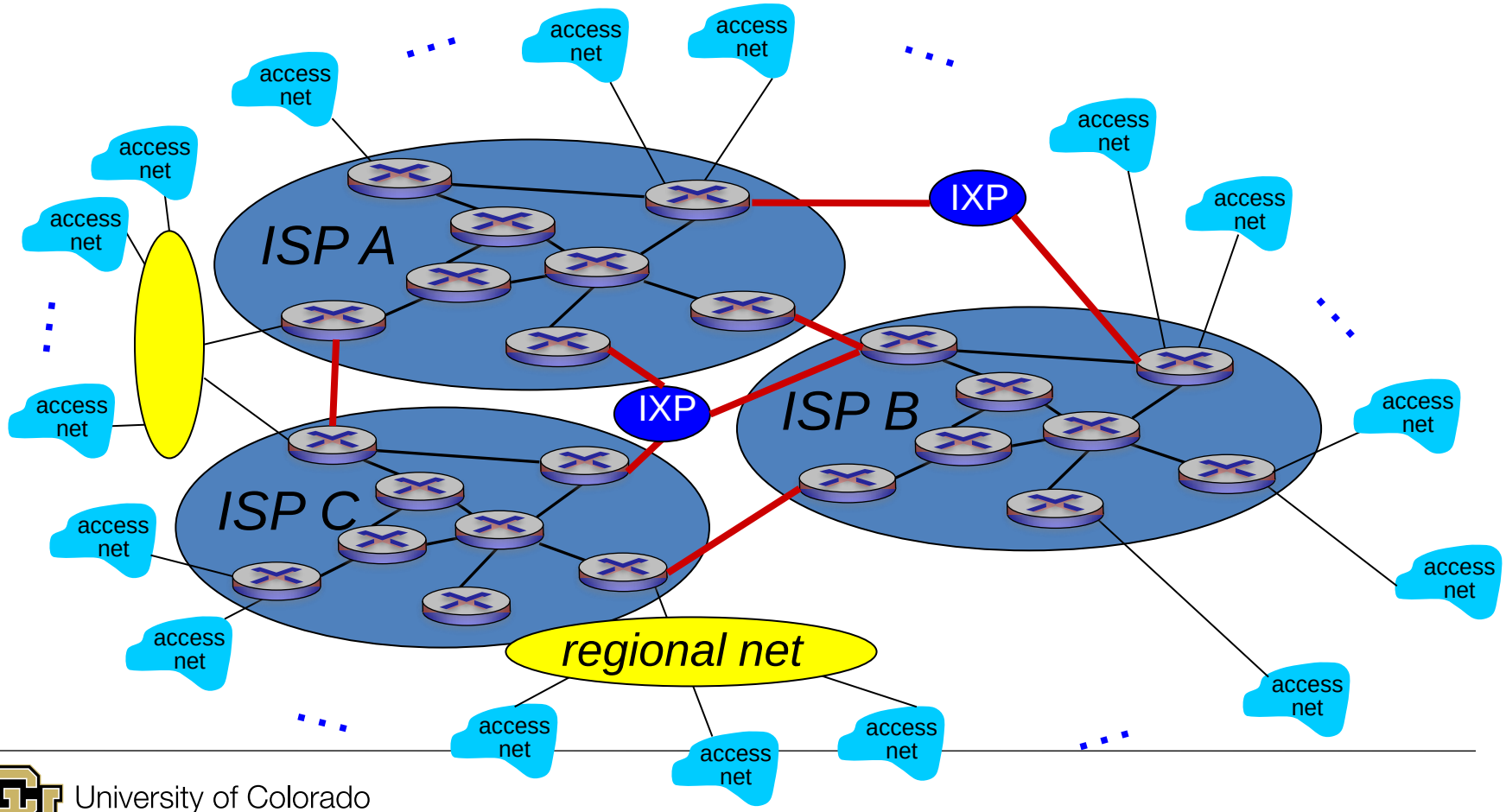
Internet structure: network of networks

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



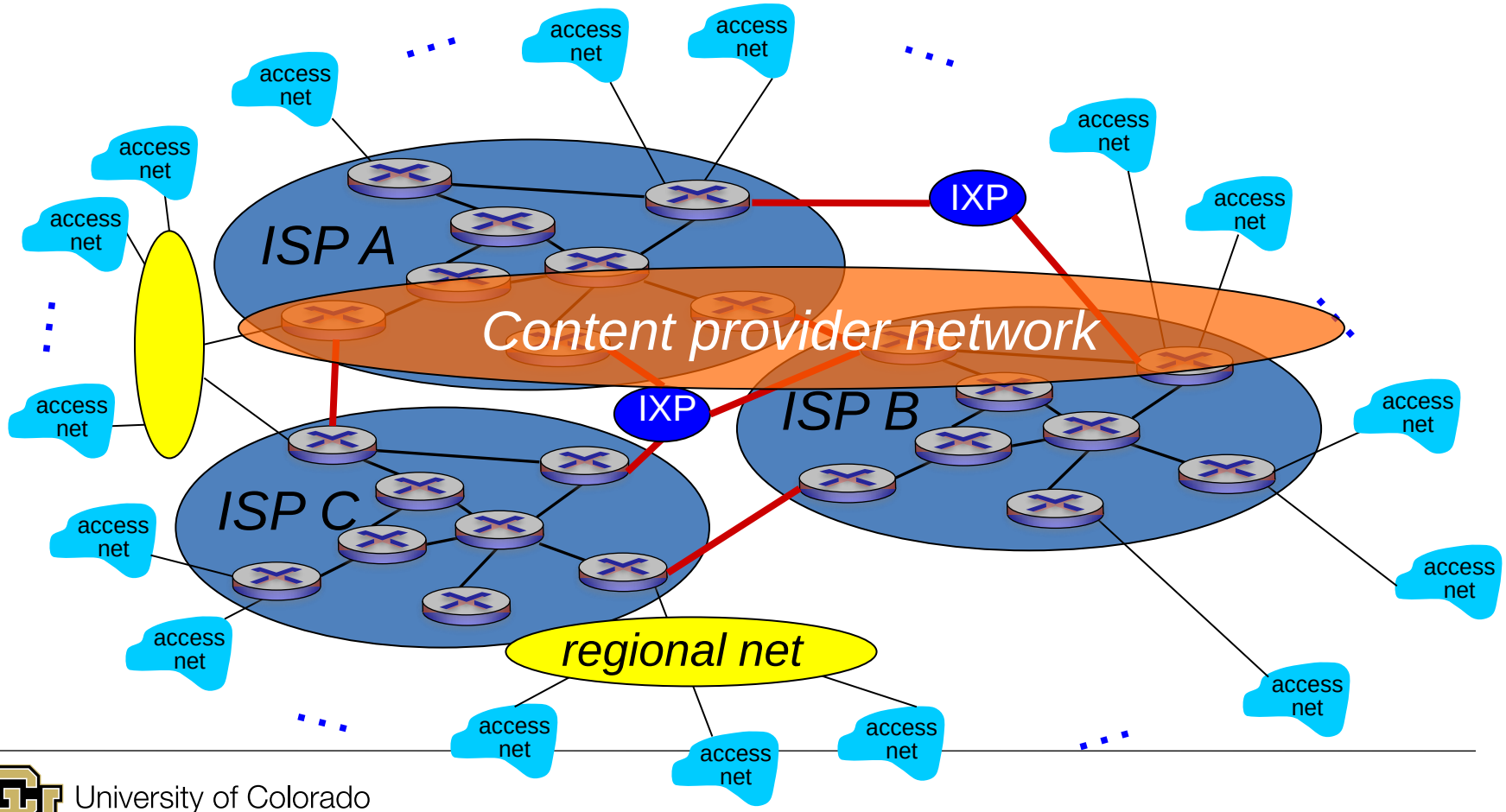
Internet structure: network of networks

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

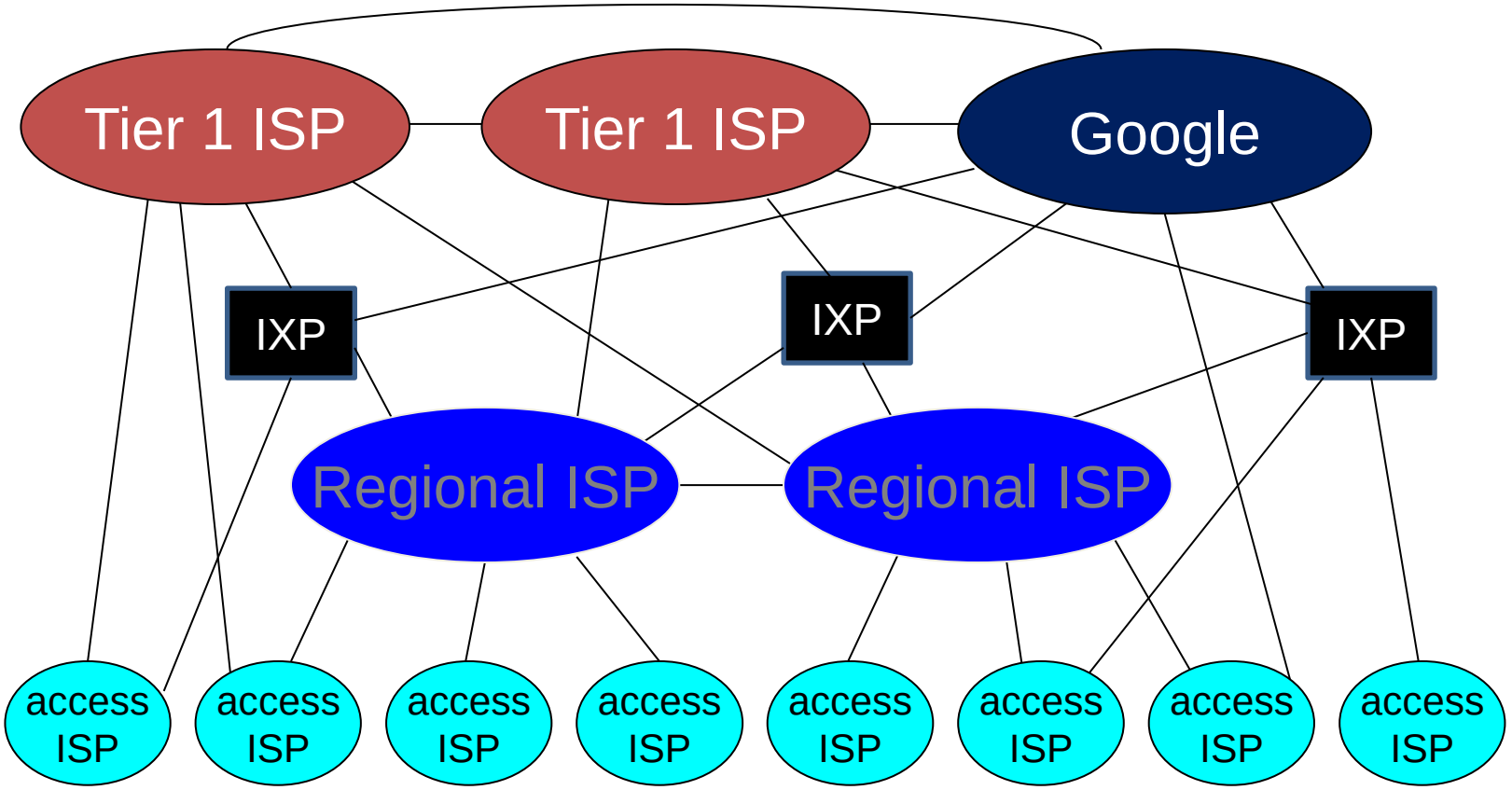


Internet structure: network of networks

… 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., CenturyLink, Comcast, 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

Questions?