Computer Networks 2012/2013

Introduction part 1 (01)

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Thanks to *A. Leon-Garcia & I. Widjaja, & I. Radovanovic & A. S. Tanenbaum*

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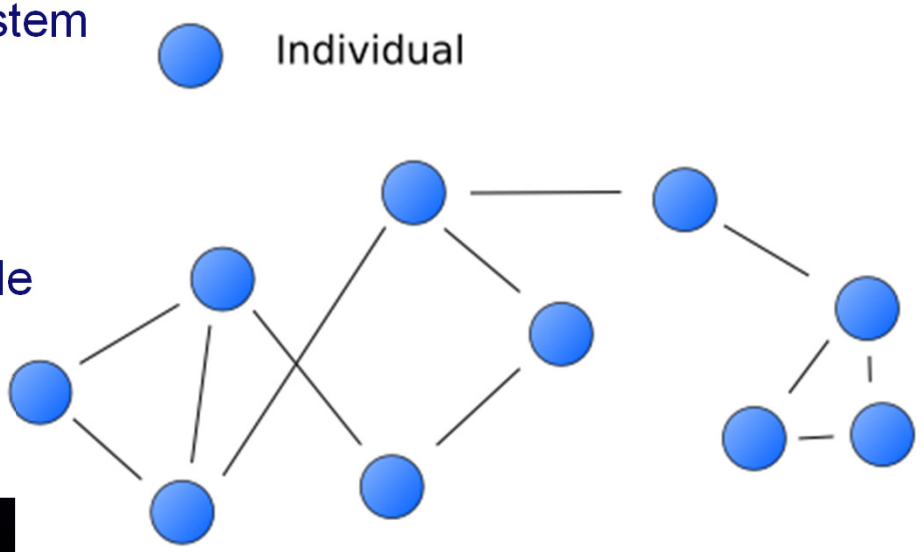
Where innovation starts

Outline

- What is the Internet?
- Why / How do networks evolve?
- Network Structure
  - Network edge: Hosts (servers & clients)
  - Access networks
  - Network core
- Performance: loss, delay, throughput
- Protocol layers, service models

What is a network?

- An interconnected configuration of system components
  - designed to communicate and share
- A connected system of things or people
  - e.g. a network of gossip or spies



What is a computer network?

Physically:

An “infrastructure” interconnecting “end-devices”

- End-devices
  - PC’s, workstations, PDA’s, TV’s, cell phones…
  - Network Interface Cards (NIC) and OS are included
- Infrastructure
  - Communication links (e.g. fiber cable, radio)
  - Packet switches (e.g. routers, link layer switches)

Logically:

A facility providing information exchange between applications that are **not** sharing memory

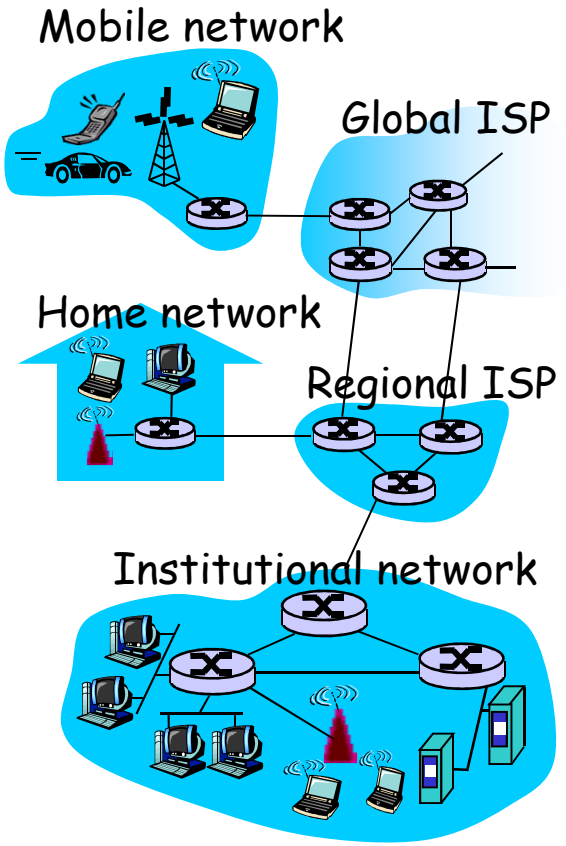
What is *the* Internet?

Physically:

- A public network of computer networks
  - millions of end-devices, networks…

Logically:

- A network infrastructure that provides services to distributed applications
  - e.g. e-mail, world-wide web (www), instant messaging, online games, VoIP, TV etc.
- A means for data/message delivery from a source device to a destination device
  - uses certain protocols to achieve this



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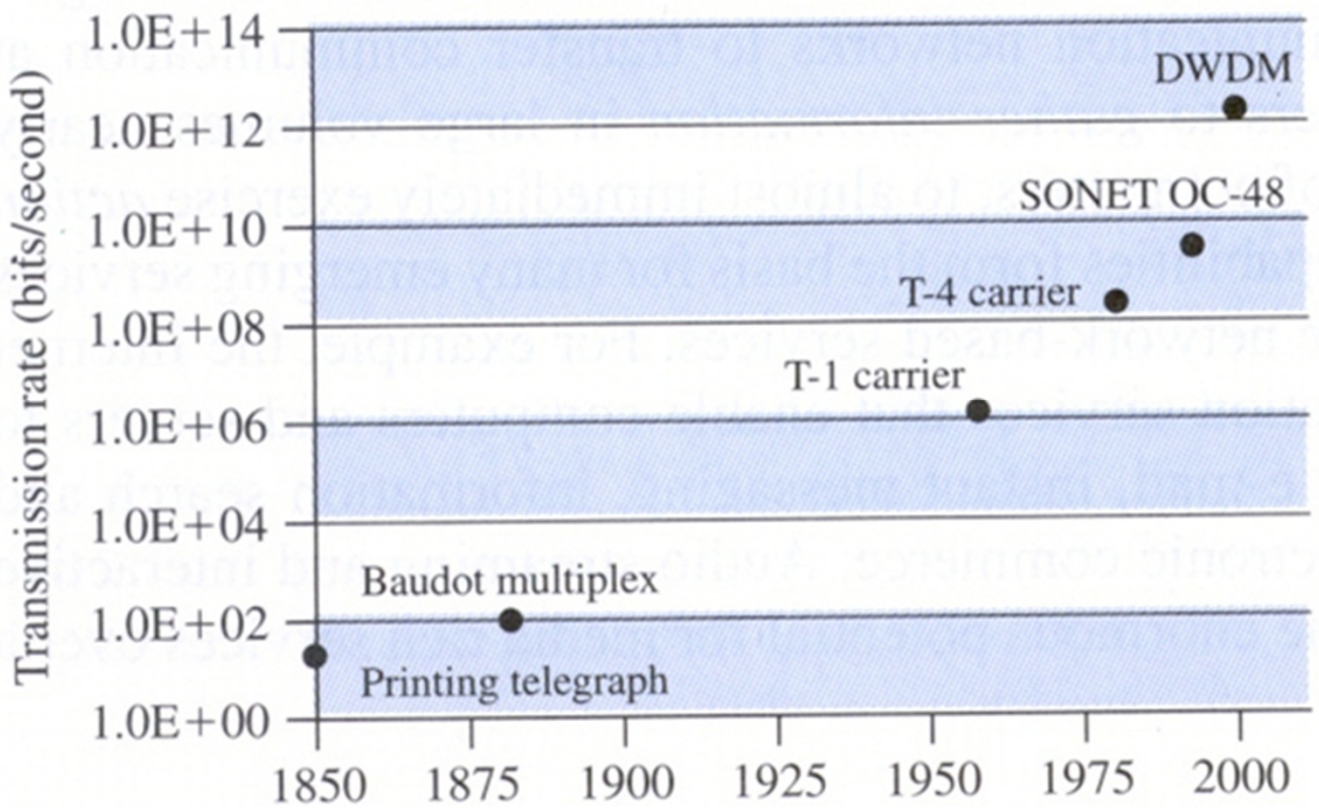
Network development: The push

There are several reasons for computer networks to evolve and to be widespread.

- Technology push
- Industry push
- Economy (huge economy…)
- Social push

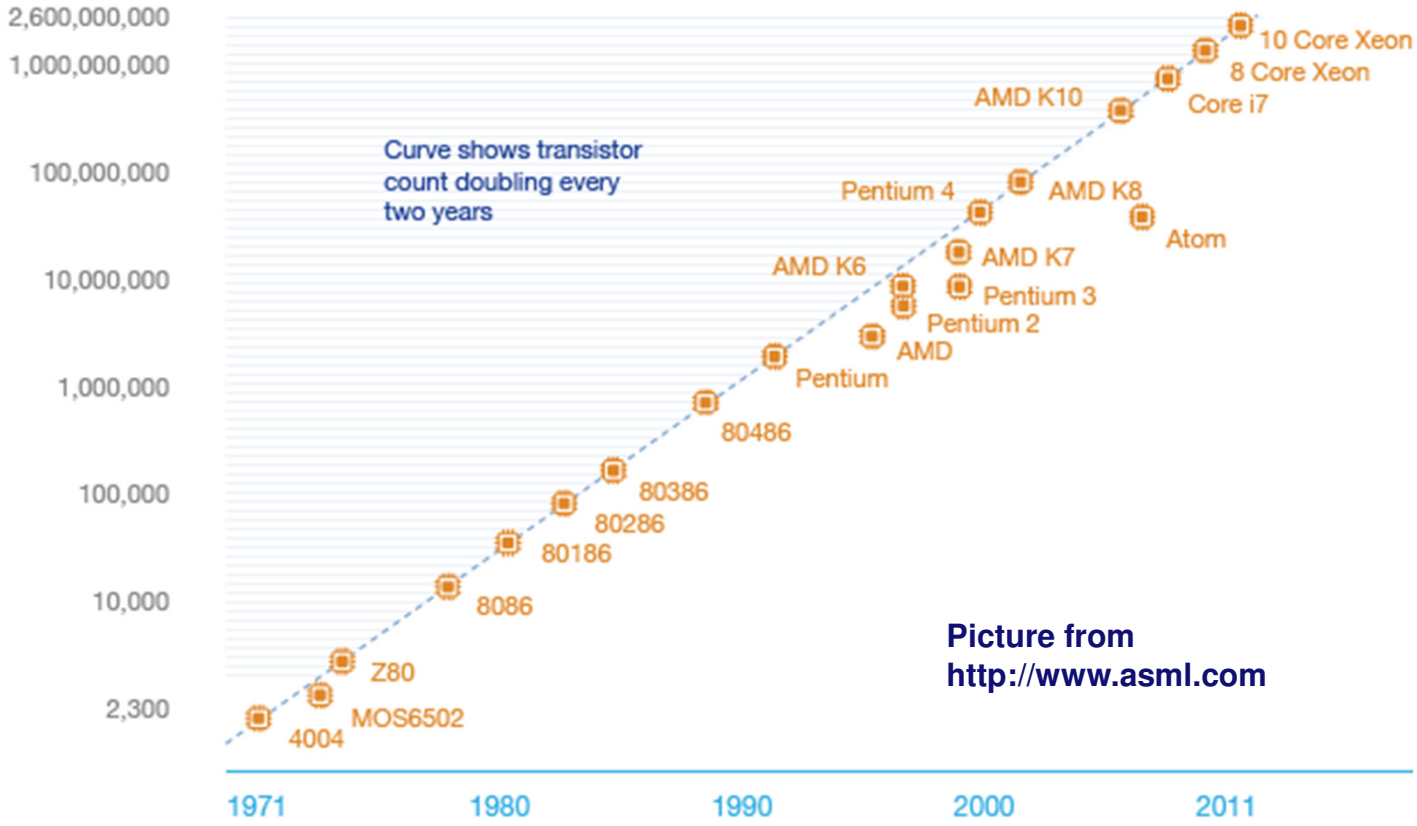
Technology advance: Communication networks

Data rate growth over years

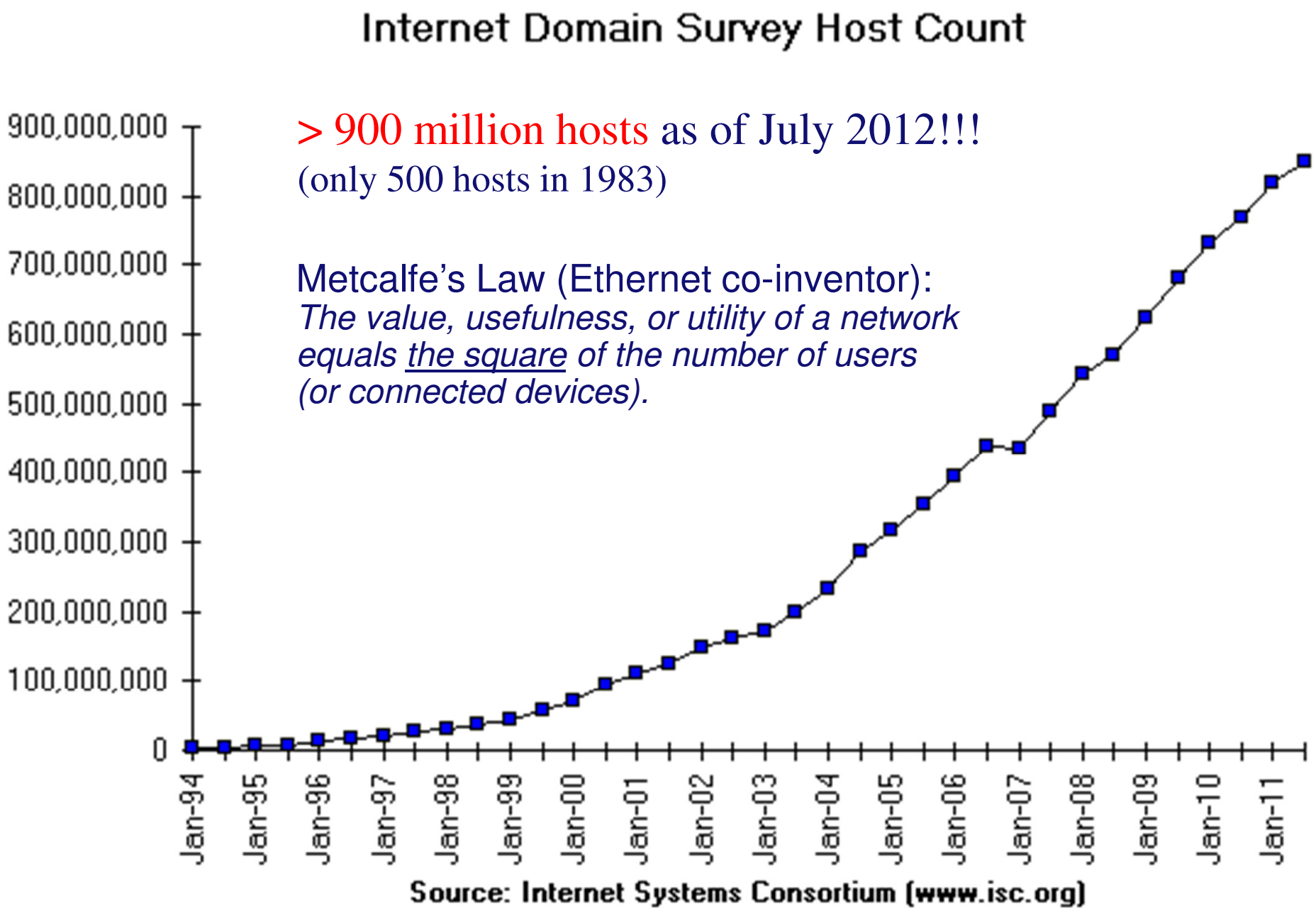


Better processors

Moore's Law: Number of transistors integrated into a processor doubles every 2 years.



Industry



> 900 million hosts as of July 2012!!!
(only 500 hosts in 1983)

Metcalfe's Law (Ethernet co-inventor):
The value, usefulness, or utility of a network equals the square of the number of users (or connected devices).

Economy

- **E-commerce:** e-banking, ticket reservation, shopping etc.
- **Dutch e-commerce:** "*Nearly 70% of the Dutch population shops online and 10% of all purchases in the Netherlands are now made online, with iDEAL being the favourite payment method.*"

  (from E-commerce Europe Report: Online Payments 2012).

Social aspects

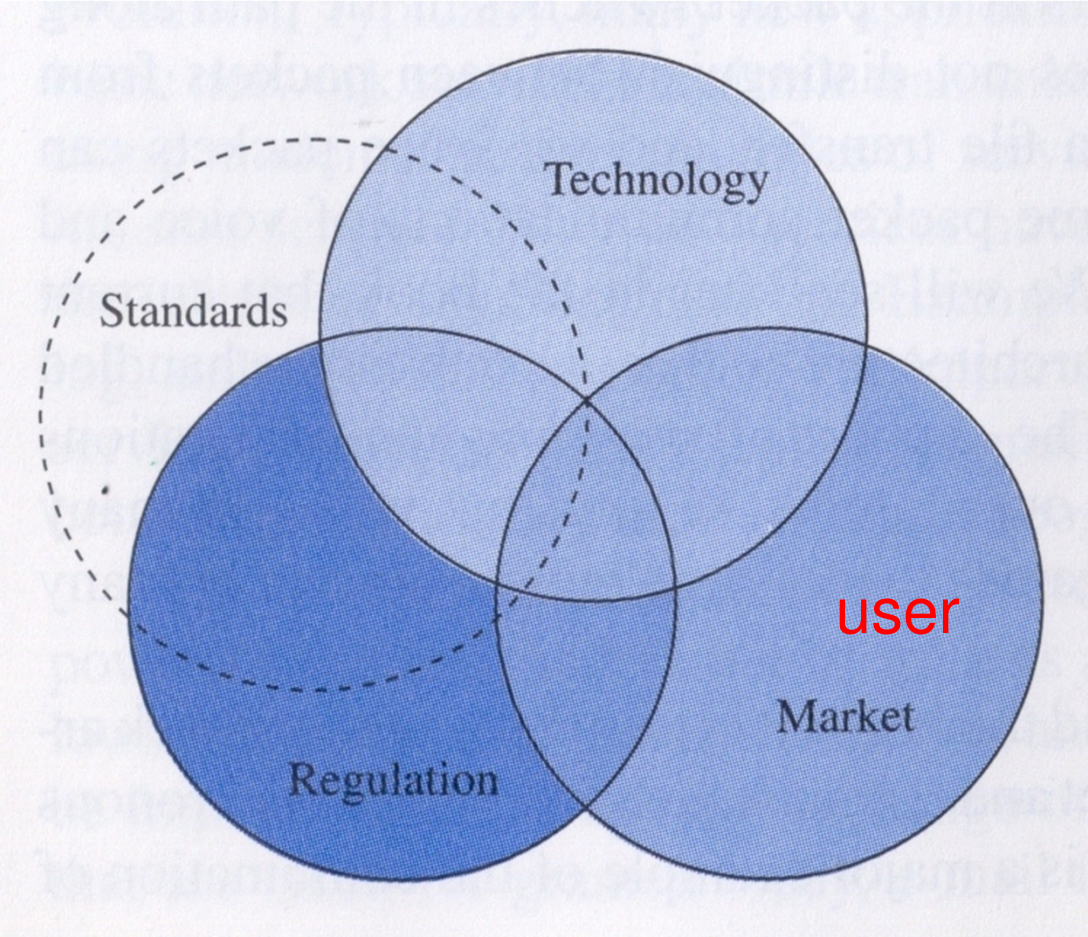
- Social networks
- Entertainment
- Better/cheaper communication (IM etc.)
- E-learning
- Working from home
- Second life
- …

The Evolution: How?

- **So the motivation is clear from many perspectives.**

- **But, the question remains:**
  - How do communication networks evolve?
  - What are the key factors?

Key factors in communication network evolution



Role of technology and market

- **Technology**
  - should not only be available but also be cost-effective
- **Market**
  - Trends and hypes
  - Trying to push technology has consequences!
    Look at WAP, MMS etc.

Role of standards

- Equipment interoperability between different vendors
  - Network value depends on the size of community it can reach (Metcalfe's Law!)
- more suppliers → competition → lower price → bigger community
- Standardization bodies:
  - International Telecommunication Union (ITU)
  - Internet Engineering Task Force (IETF)
  - Institute of Electrical and Electronics Engineers (IEEE)

Role of regulations

- Governmental regulation for industry protection
  - e.g. copyright issues
- Censorship
  - e.g. some governments
- Open market competition
  - No monopoly
- Local regulations (e.g. institution/company regulations)
  - e.g. some organizations block access to social network sites, using BitTorrent, excessive download/upload etc.

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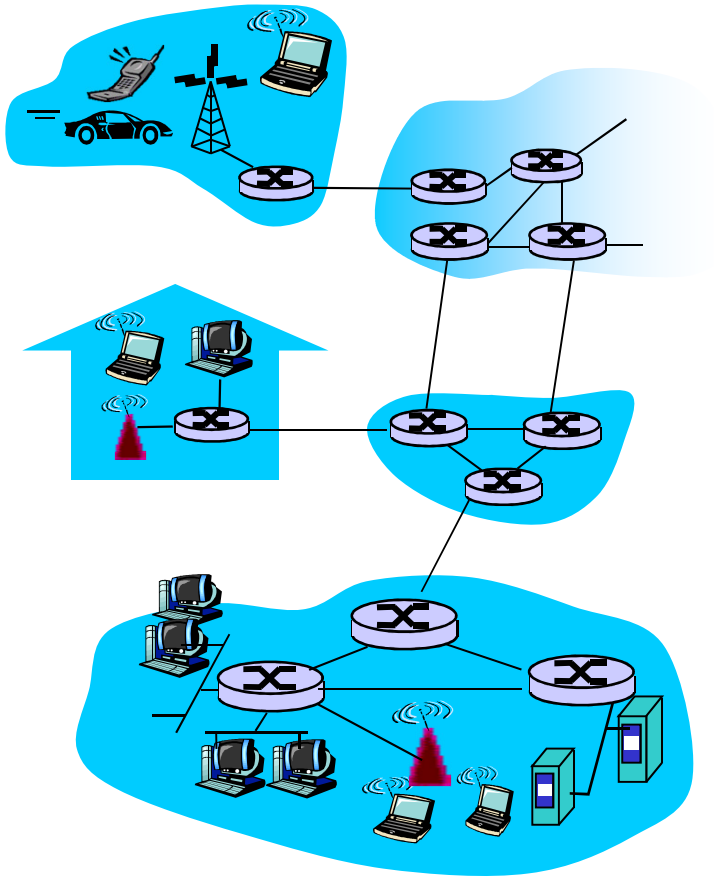
Network structure

- **network edge:**
  - *hosts* and *applications* that run on them
- **access networks, physical media:**
  - wired, wireless communication links
- **network core:**
  - interconnected routers



Network edge

End systems (hosts):

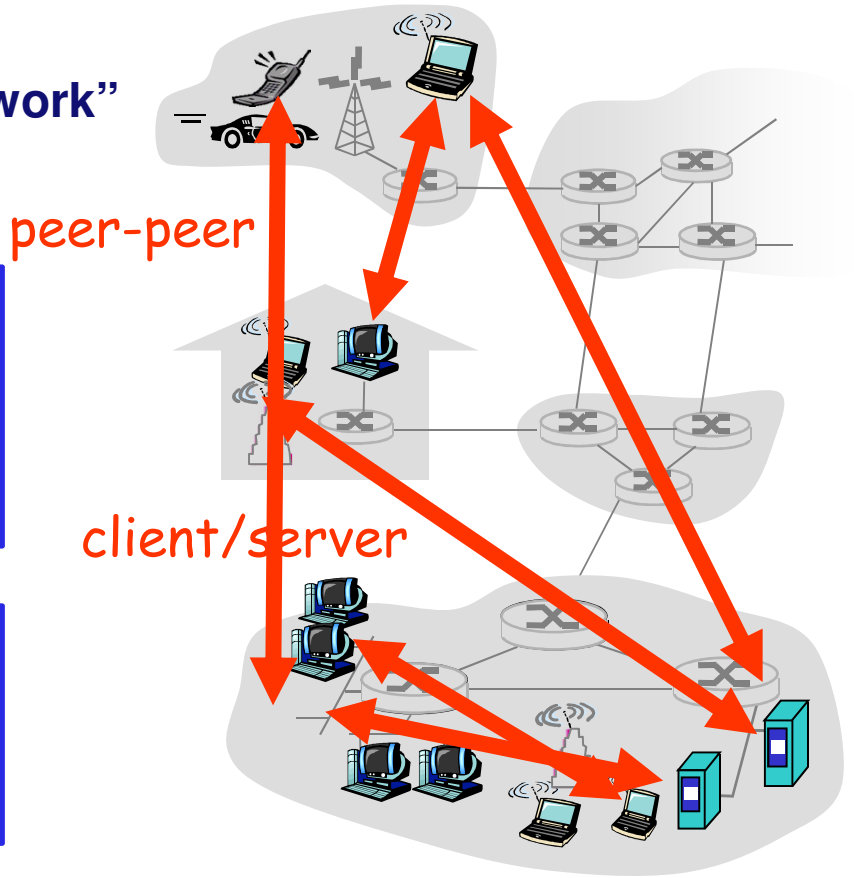
- **run applications at "edge of network"**
- **e.g. Web, email**

client/server model

client host requests, receives service from always-on server, e.g. Web browser/server; e-mail client/server

peer-to-peer model:

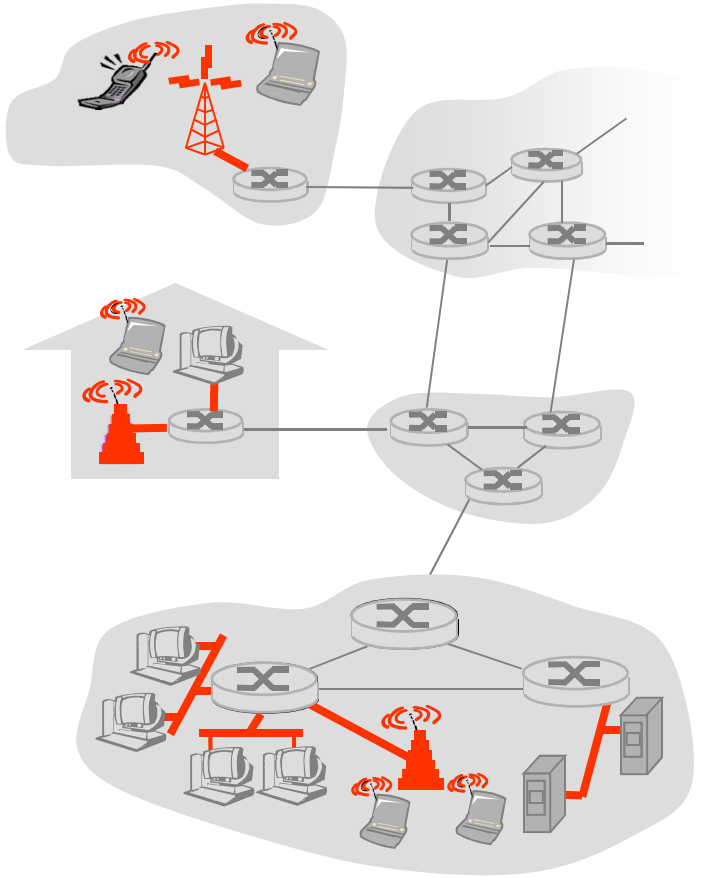
minimal (or no) use of dedicated servers, e.g. Skype, BitTorrent



Access networks

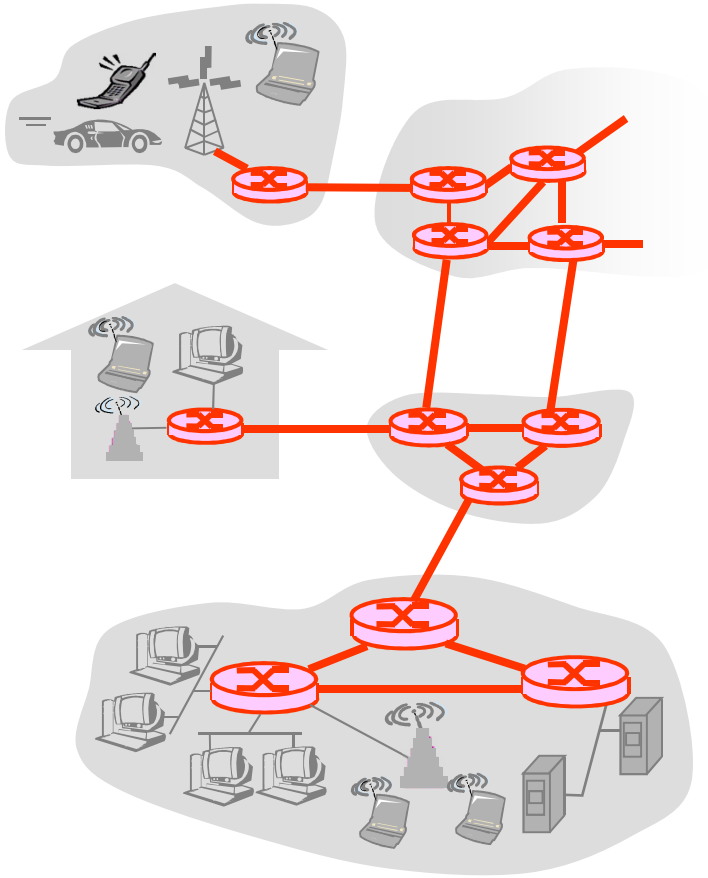
An access network connects end devices to a router

- residential access networks
- institutional access networks (school, company)
- mobile access networks



Network core

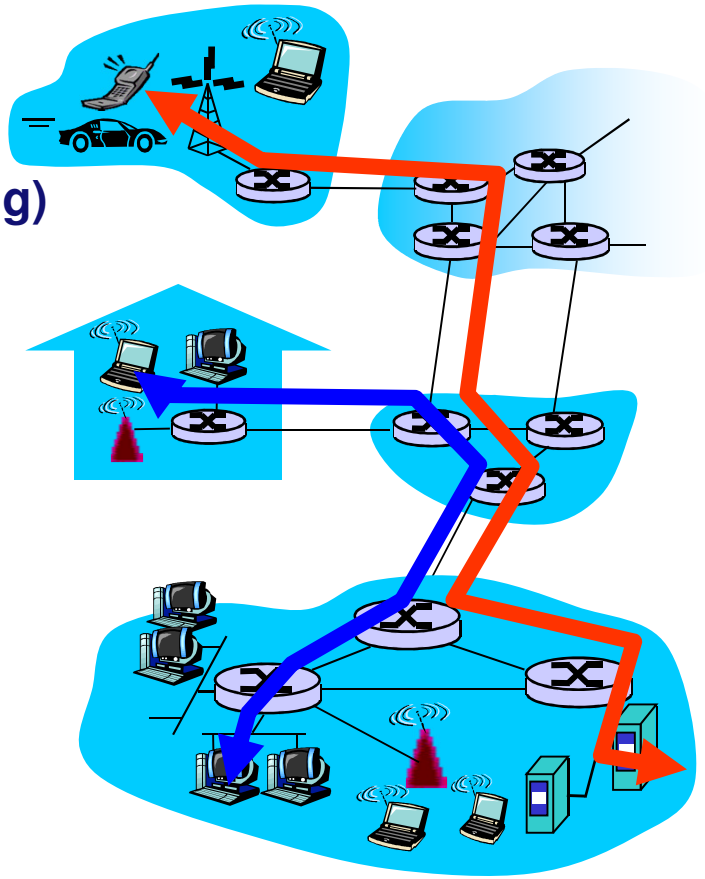
- Interconnected routers
- Fundamental question: How is data transferred from edge to edge?
  - circuit switching
  - packet-switching



Circuit switching

Provides:

- **dedicated circuit per call/session**
- **resources dedicated for the call (no sharing)**
  - e.g. link bandwidth, switch capacity
  - circuit-like (guaranteed) performance
- **call setup needed**
- **resources not used by call are *idle***



How to create such circuits?

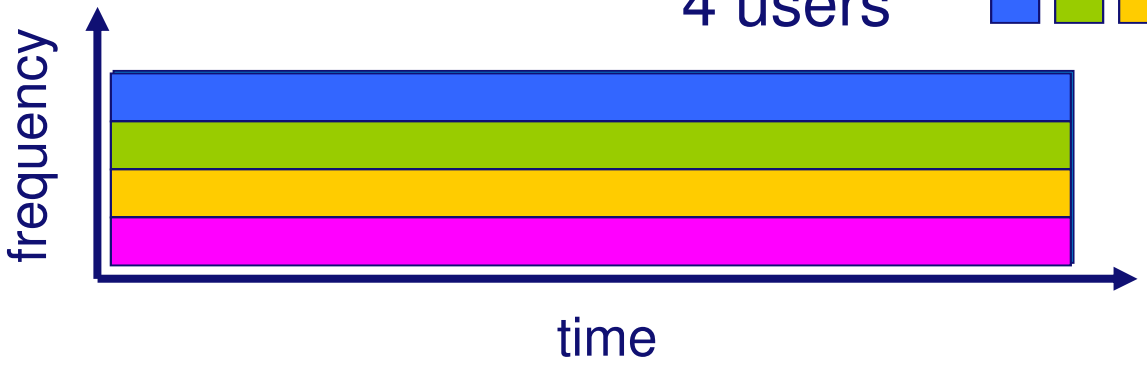
- **Network logically divided into pieces**

Circuit switching: FDM and TDM

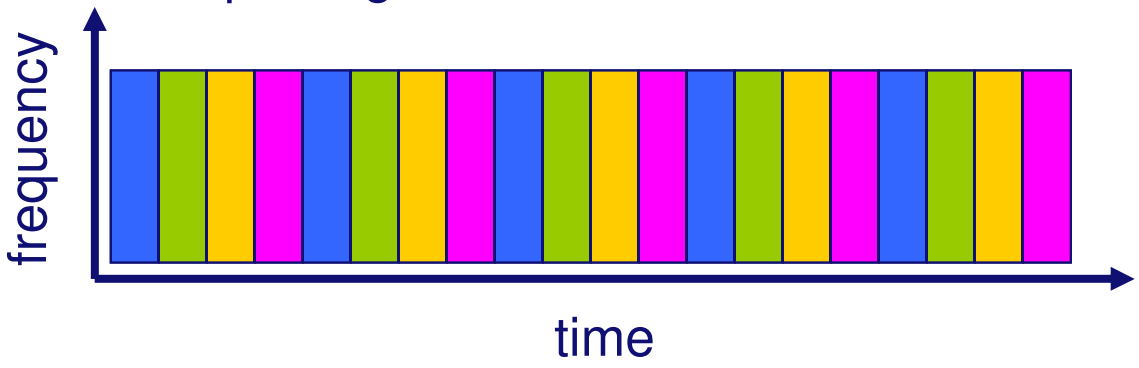
FDM: Frequency Division Multiplexing

Example:

4 users



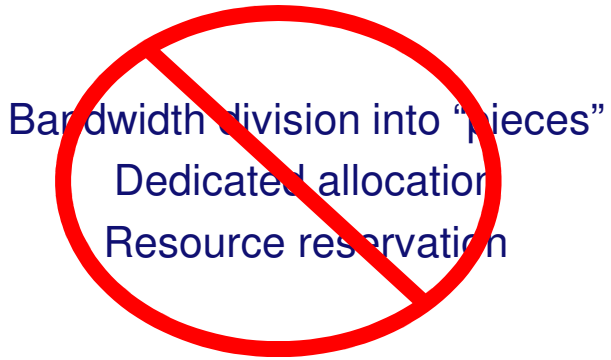
TDM: Time Division Multiplexing



Packet switching

Each end-to-end data stream divided into *packets*

- packets *share* network resources
- each packet uses full link bandwidth
- prevents idle time
- resources used *as needed* (no reservations)

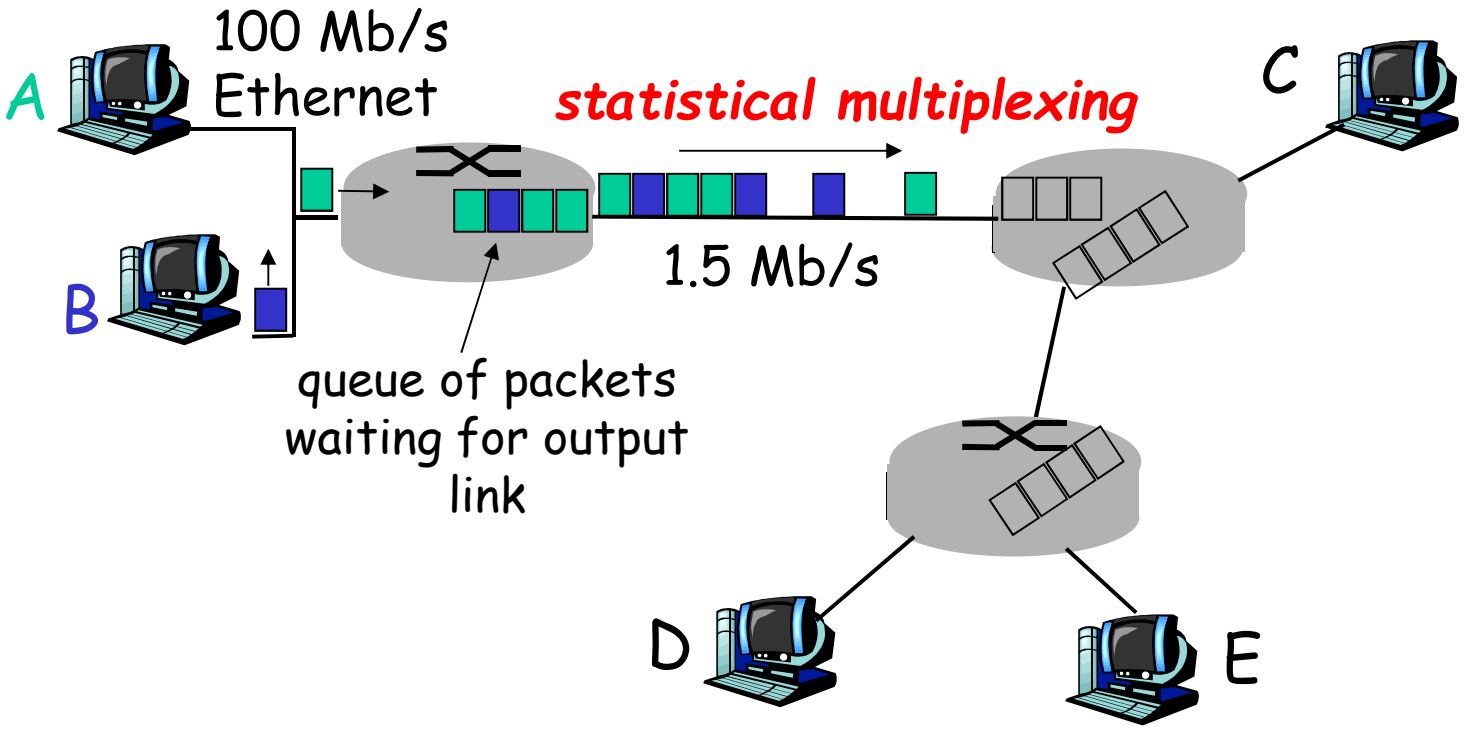


Resource contention:

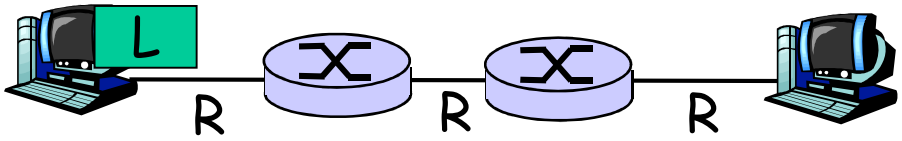
- bandwidth demand can exceed amount available (congestion): too many packets
- store and forward: packets move one hop at a time
  - Node receives complete packet before forwarding

Packet switching: Statistical multiplexing

Sequence of A & B packets does not have fixed pattern, bandwidth shared on demand ➔ *statistical multiplexing*.



Packet switching: Store-and-forward



- takes L/R seconds to transmit (push out) packet of L bits on to link at R bps
- *store and forward:* entire packet must arrive at router before it can be transmitted on next link
- delay = 3L/R (assuming zero propagation delay)

Example:

- L = 7.5 Mbits
- R = 1.5 Mbps
- transmission delay = 15 sec

more on delay shortly …

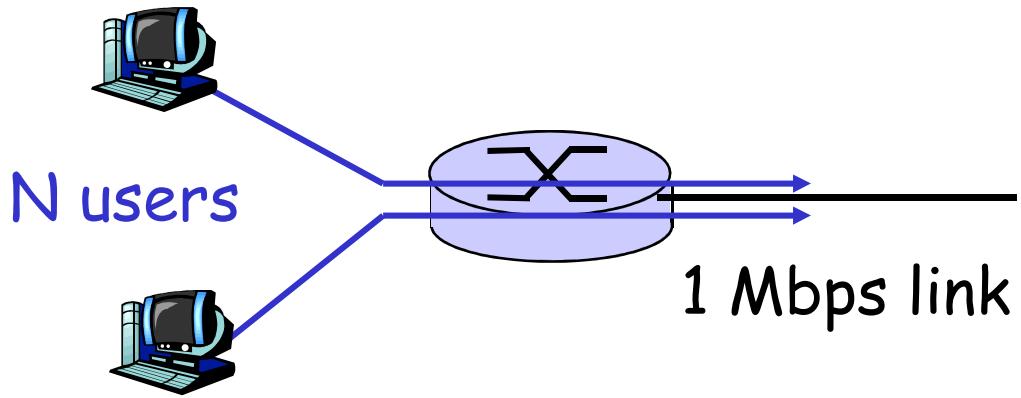
Packet switching vs. circuit switching

Packet switching allows more users to use the network!

Example:

- 1 Mb/s link
- Each user:
  - 100 kb/s when “active”
  - active 10% of time

HOW MANY users can be supported?

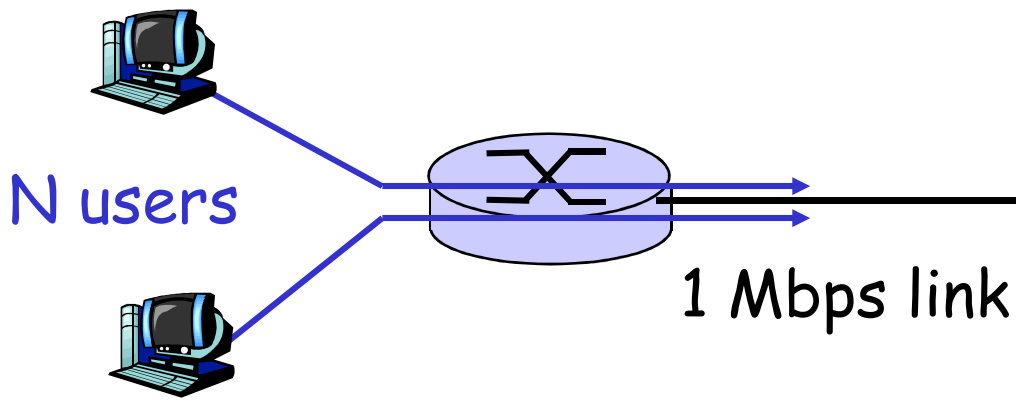


Packet switching vs. circuit switching

Packet switching allows more users to use the network!

Example:

- 1 Mb/s link
- Each user:
  - 100 kb/s when "active"
  - active 10% of time
  - *circuit-switching:* 10 users
  - *packet switching:* with 35 users, probability > 10 active at same time is less than .0004



Exercise: How did we get value 0.0004?

Packet switching vs. circuit switching

Is packet switching a "winner?"

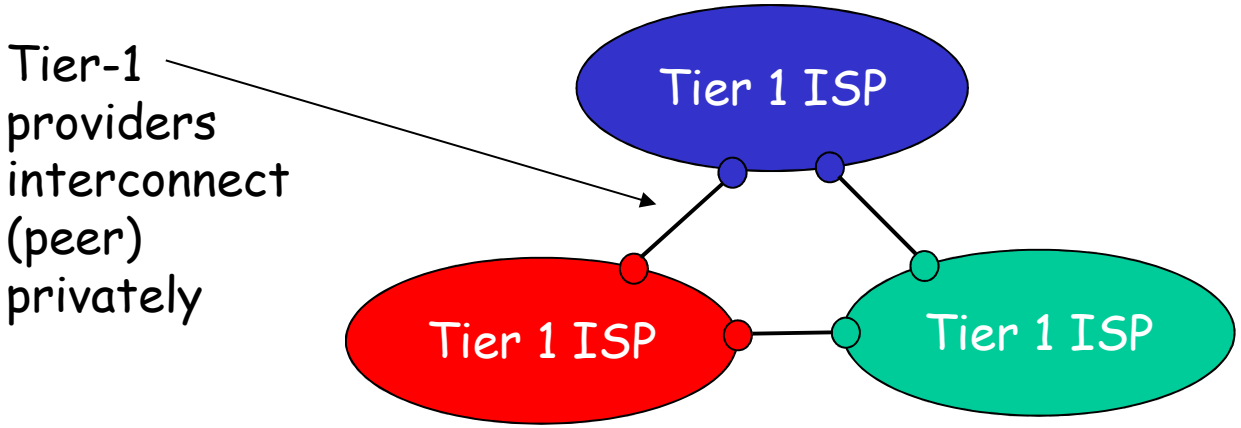
- **great for bursty data**
  - **efficiency in resource sharing**
  - **no call setup required**

- **congestion: causes packet delay and loss**
  - **protocols needed for reliable data transfer, congestion control**

- **Q: How to provide resource guarantees (circuit-like behavior)?**
  - **bandwidth guarantees needed for audio/video apps**
  - **still an unsolved problem (more later)**

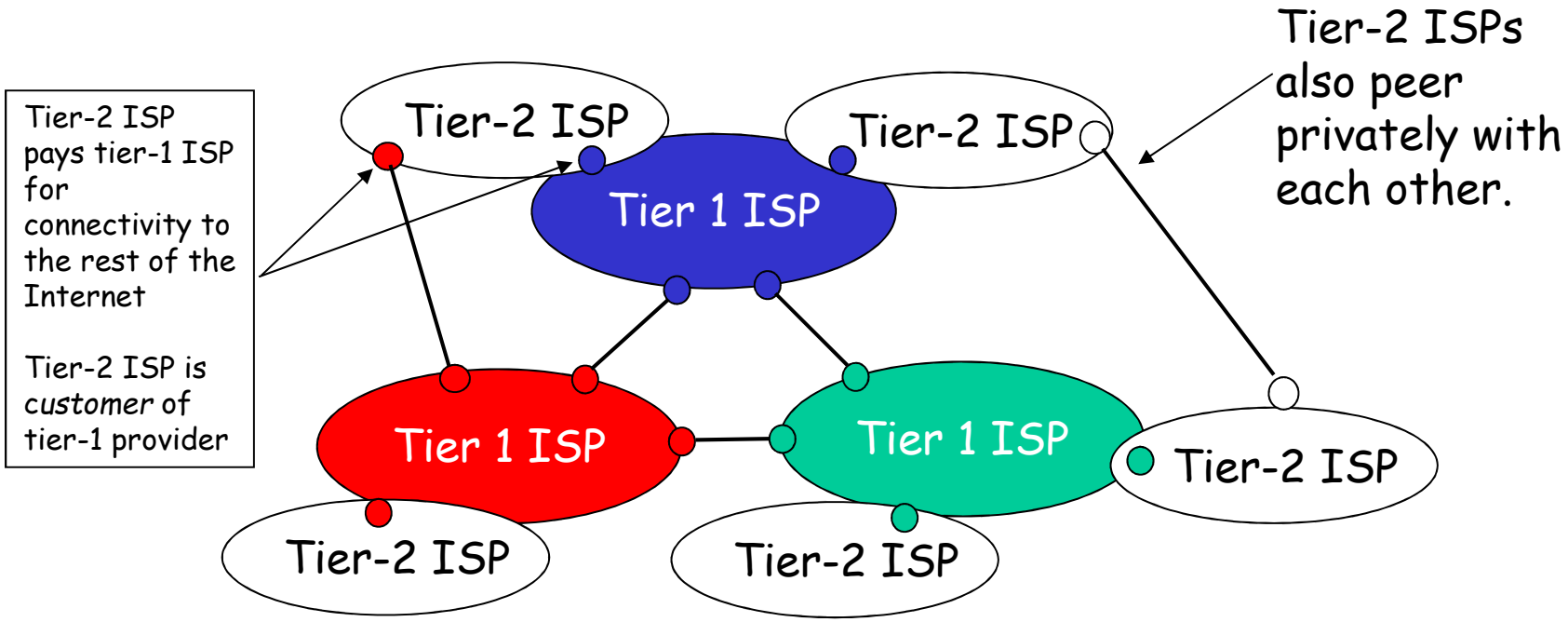
Internet structure: Network of networks

- roughly hierarchical
- at center: “tier-1” ISPs (e.g., Verizon, Sprint, AT&T), national/international coverage
  - treat each other as equals



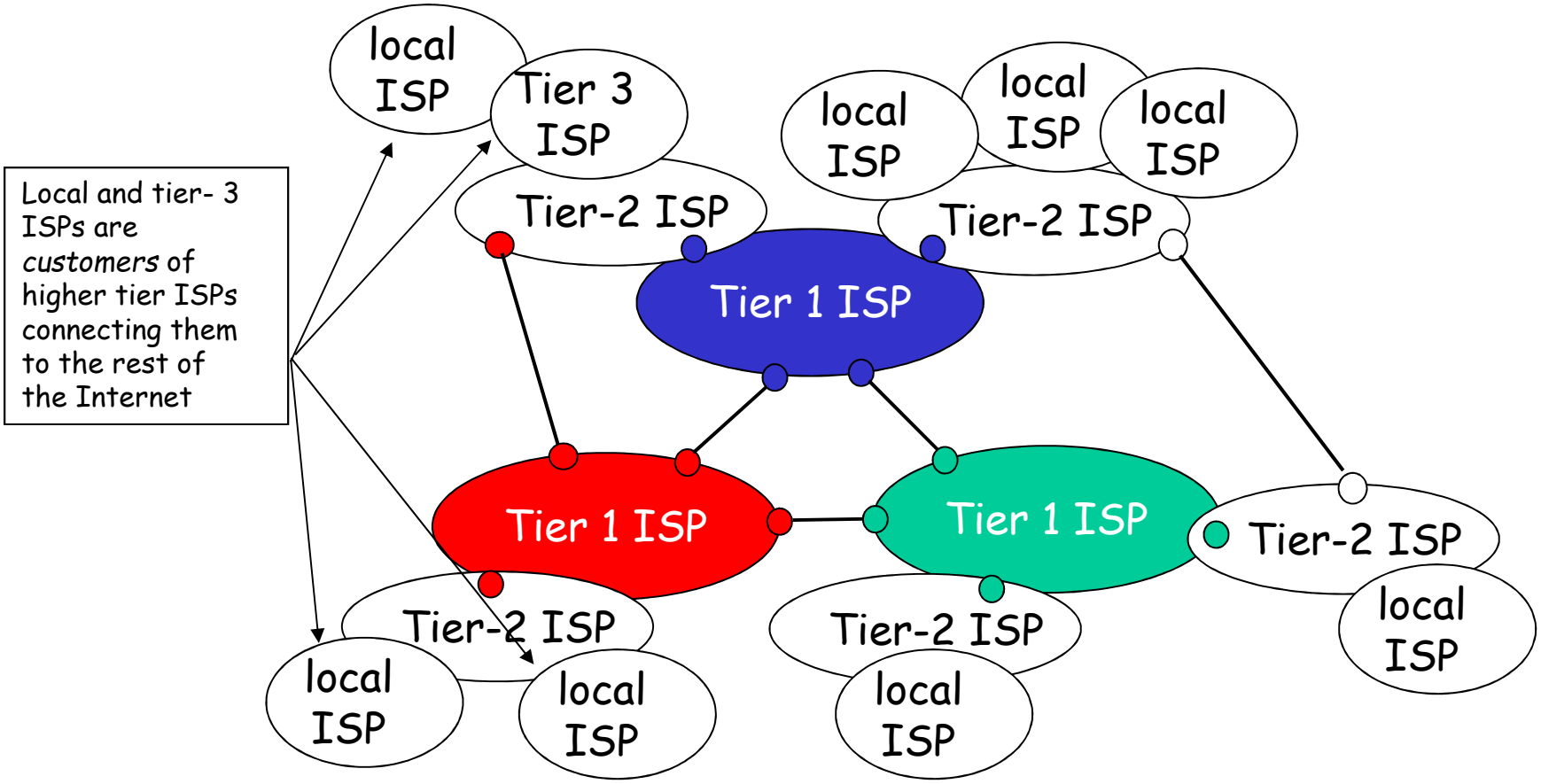
Internet structure: Network of networks

- "Tier-2" ISPs: smaller (often regional) ISPs
  - Connect to one or more tier-1 ISPs, possibly other tier-2 ISPs



Internet structure: Network of networks

- "Tier-3" ISPs and local ISPs
  - last hop ("access") network (closest to end systems)



Internet structure: Network of networks

A packet passes through many networks!