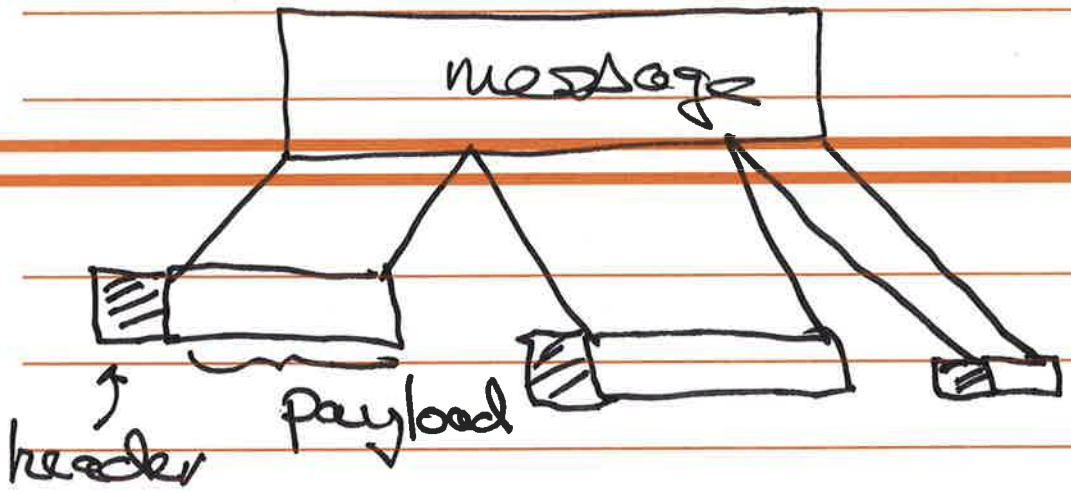
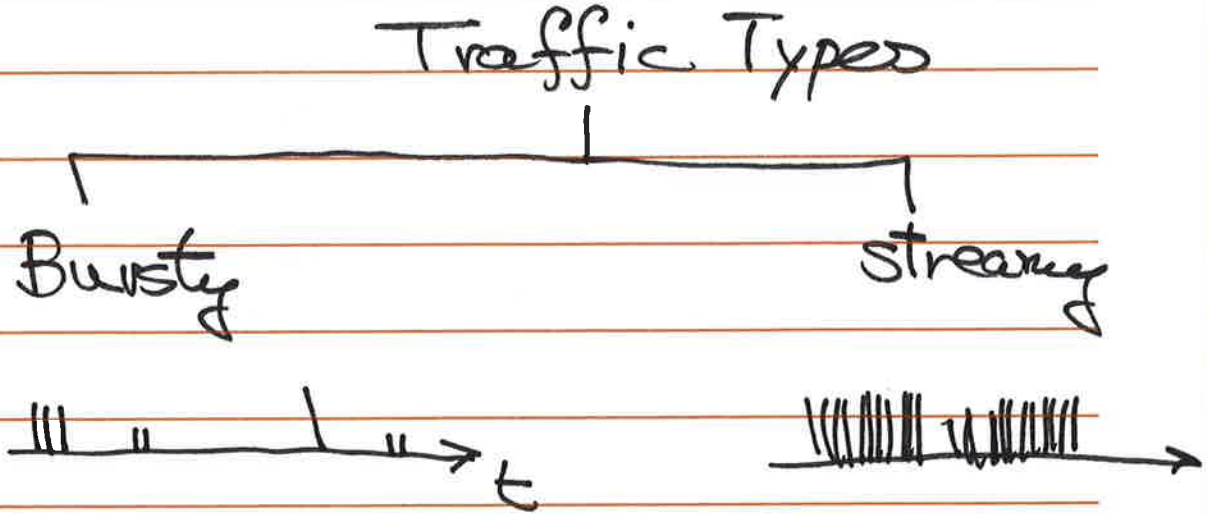
EE450, Fall 2015, Zahid

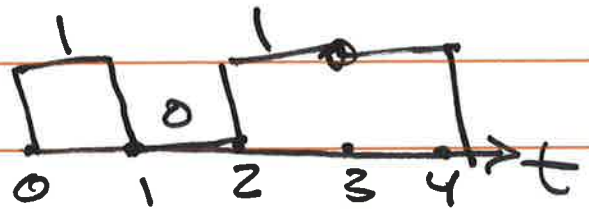
lecture #4

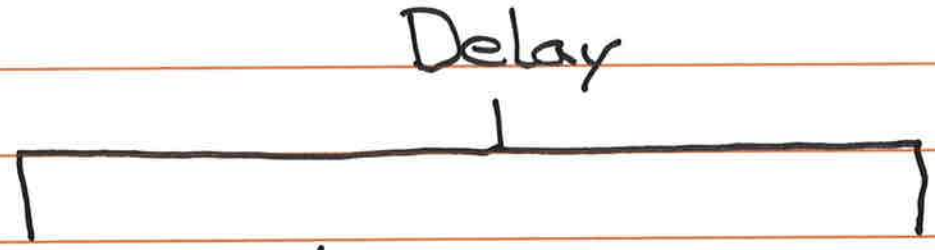
Thursday, Sept 3

IP is a connection less protocol unreliable (No guarantees for anything!)









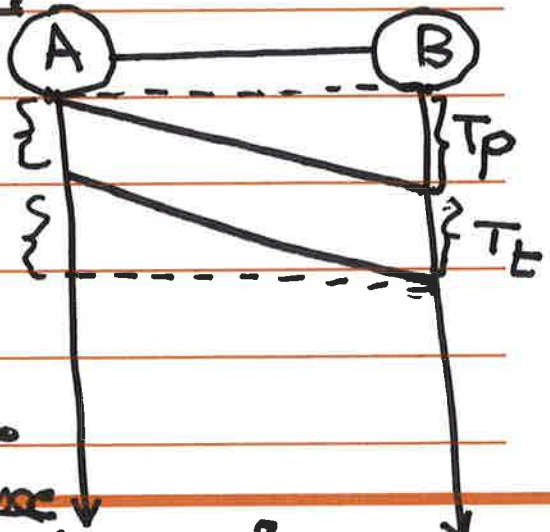
(EE503)

- Transmission T_t delay

- Propagation delay T_p

$$T_t = \frac{\text{Message length (bits)}}{\text{Data (bit) rate}}$$

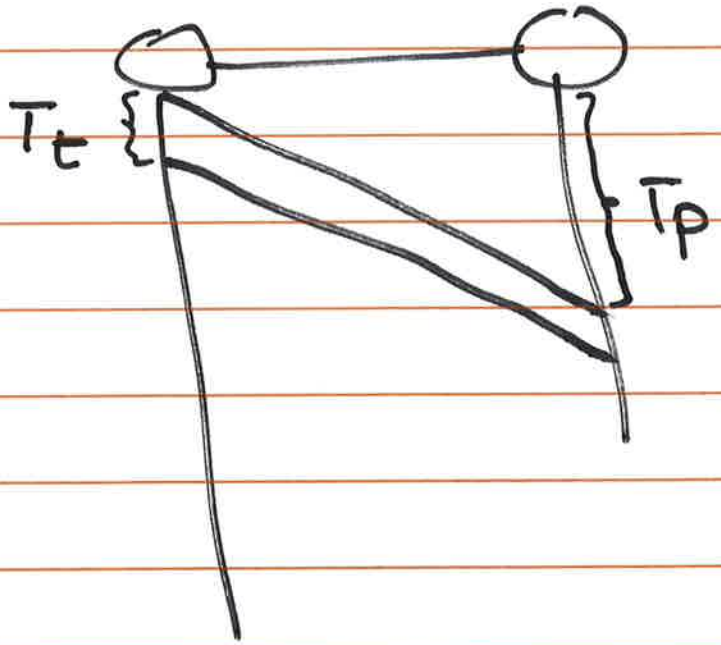
↑ in bps

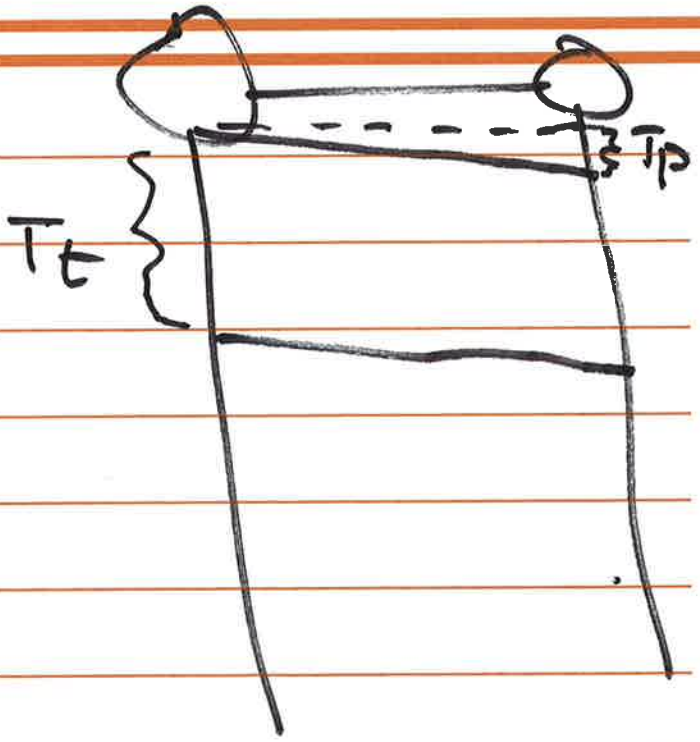


$$T_p = \frac{\text{Link length (m)}}{\text{velocity of propagation}}$$

↑ m/sec

usually speed of light $\approx 3 \times 10^8$ m/sec


T_t
T_p

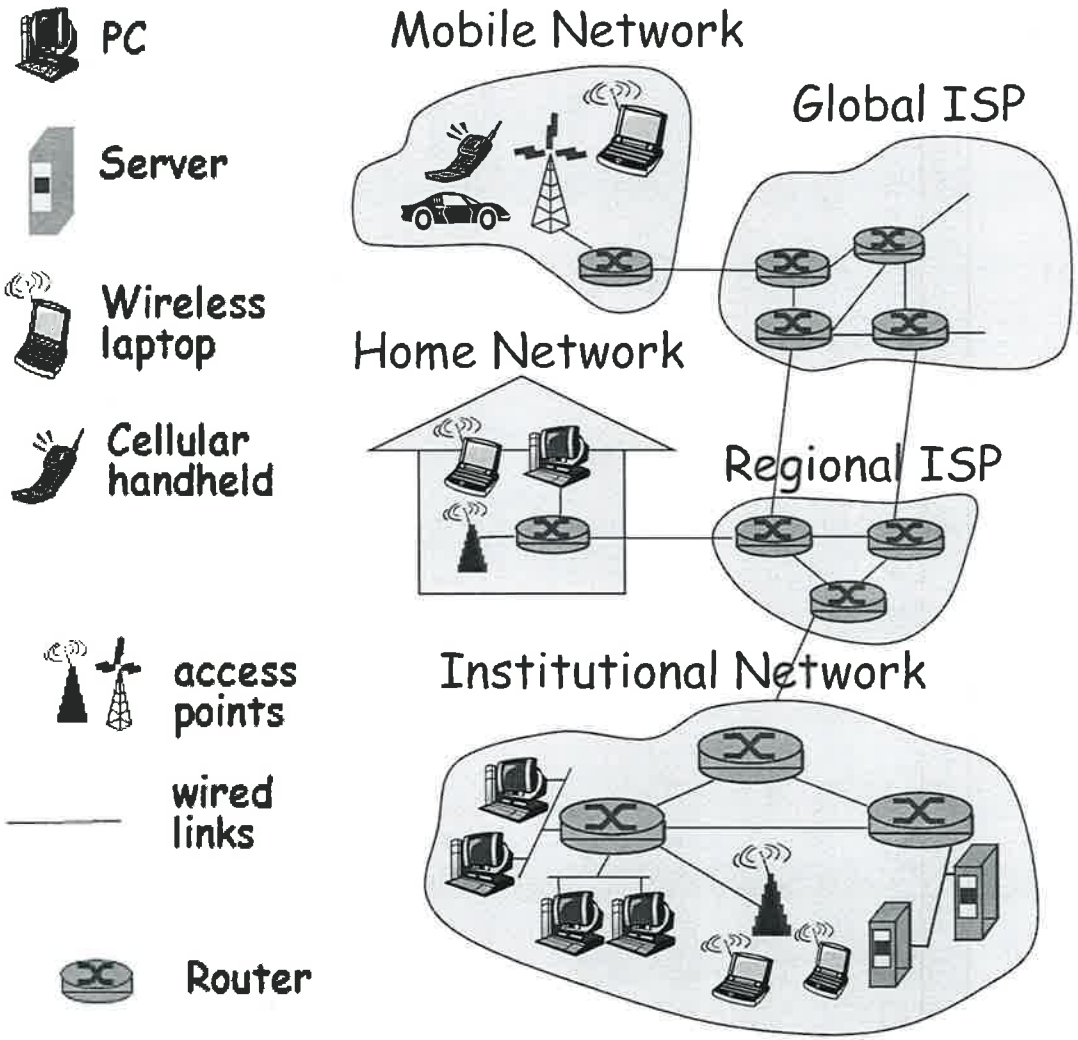

T_p
T_t

The Internet (Wikipedia)

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, such as electronic mail, online chat, file transfer, and the interlinked Web pages and other documents of the World Wide Web.

What is the Internet? Nuts and Bolts View

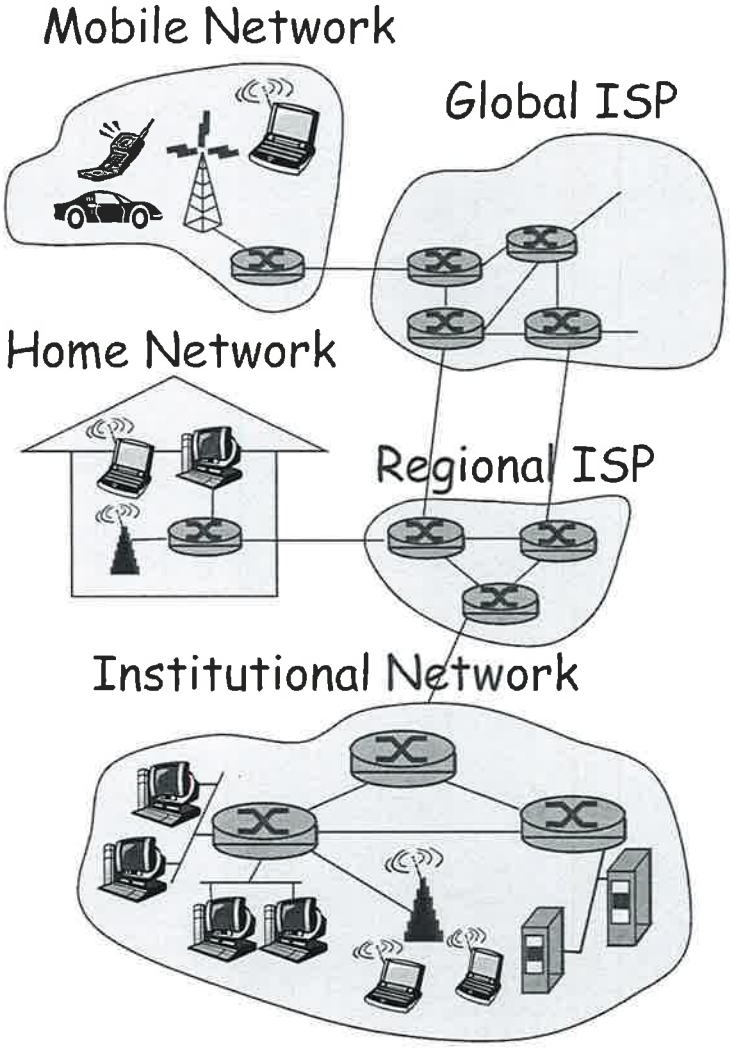
- Millions of connected computing devices
  - Hosts = end systems, run Network Applications
- Communication links
  - Fiber, Copper, Radio, Cable, Satellite, etc…
  - Provides Bandwidth
- Routers:
  - Forward Packets (chunks of data) from source to destination



What is the Internet? Nuts and Bolts View (Continued)

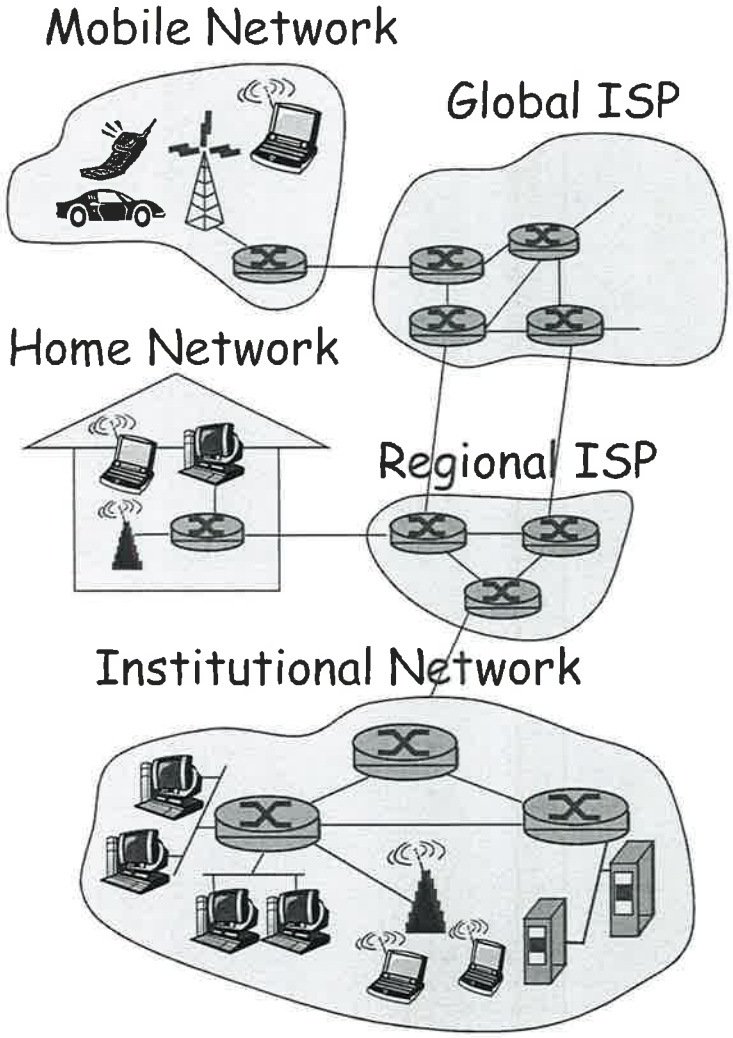
- Protocols control sending, receiving of msgs
  - TCP, IP, HTTP, Ethernet
- Internet:

  "Network of networks"
  - Loosely hierarchical
  - Public Internet v.s. Private Intranet
- Internet standards
  - RFC: Request for comments
  - IETF: Internet Engineering Task Force



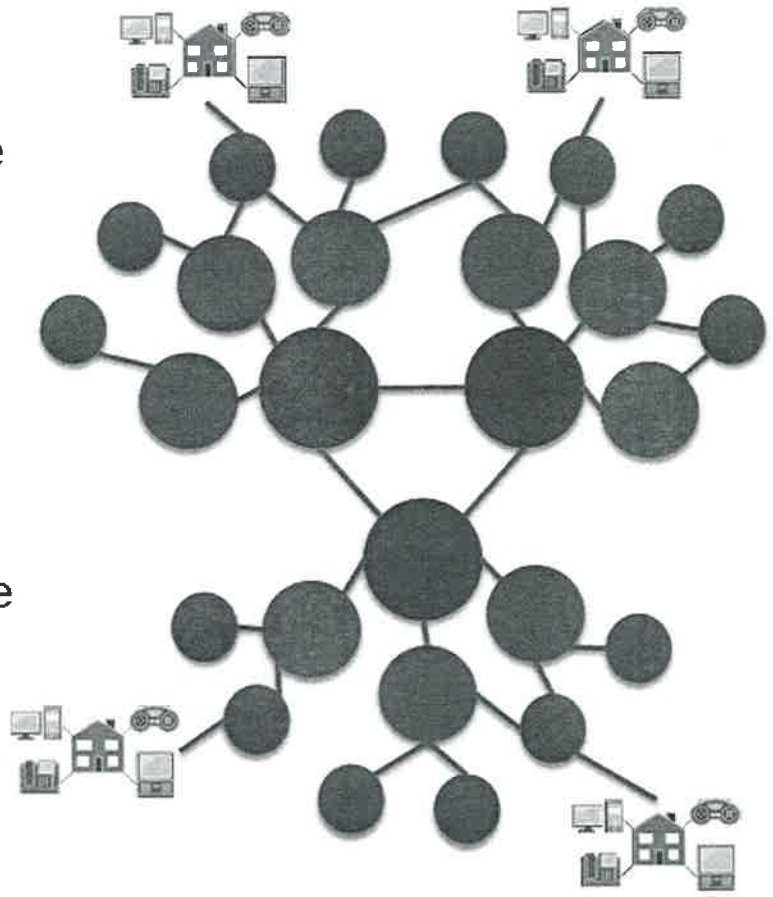
What is the Internet? A Service View

- Communication Infrastructure enables distributed applications:
  - Web, VoIP, email, games, e-commerce, file sharing
- Communication services provided to applications include
  - Reliable data delivery from source to destination
  - "Best effort" (unreliable) data delivery



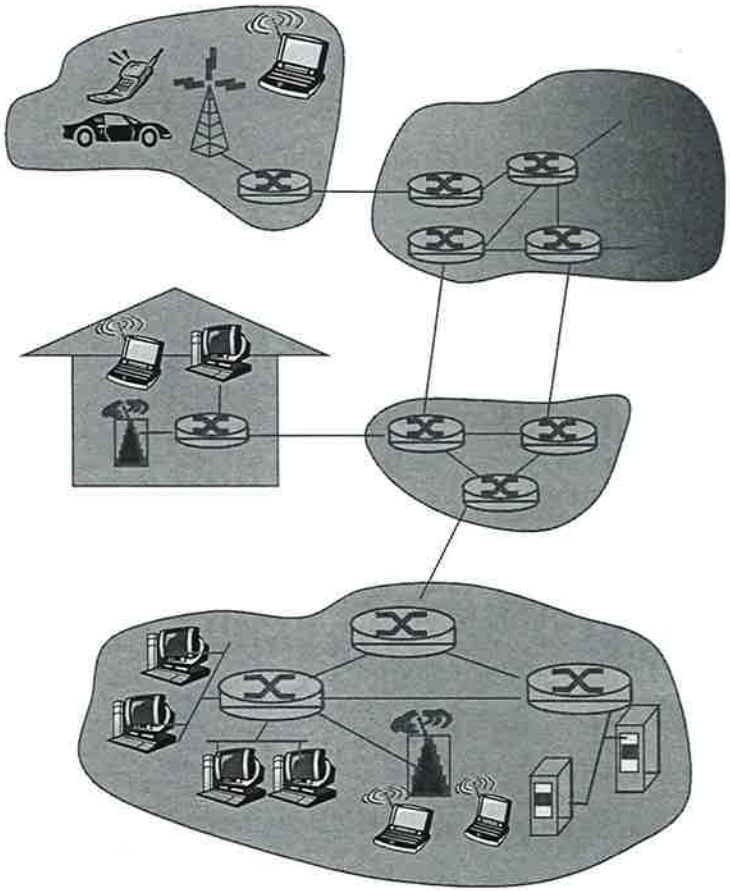
Networks Structure

- **Edge** – the boundary between the service-provider's premises and the customer's location. The concentration point where large numbers of customer connections will be terminated
- **Aggregation** – A concentration point where data from multiple Edge locations will be funneled
- **Core** - the heart of the network. The major switching locations that form the center of the network, where data from multiple Aggregation sites will be funnelled
  - This is typically where one sees the highest volume of data present in the network



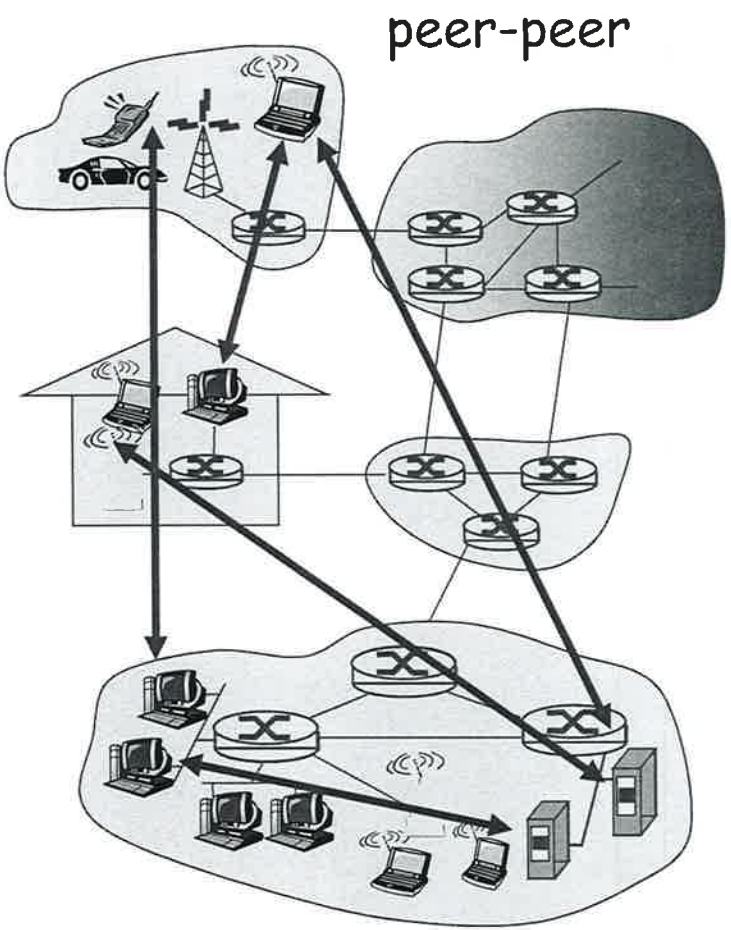
Network Structure

- Network edge:
  applications and hosts
- Access Networks,
  physical media: wired,
  wireless communication
  links
- Network core:
  - interconnected routers
  - Network of networks



Network Edge

- End systems (hosts):
  - run application programs
  - e.g. Web, email
  - at "edge of network"
- Client-Server model
  - client host requests, receives service from always-on server
  - e.g. Web browser/server; email client/server
- Peer-to-peer model:
  - Minimal (or no) use of dedicated servers
  - e.g. Kazaa, Gnutella, Skype, Napster,..



Network Edge Services (I) "Reliable Service"

Goal: data transfer between end systems

- handshaking: setup (prepare for) data transfer ahead of time
  - Hello, initial establishment
  - set up "state" in two communicating hosts
- TCP - Transmission Control Protocol
  - Internet's reliable data transfer service

TCP service

- 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 Services (II)
Best Effort "Unreliable" Service

Goal: data transfer between end systems
- same as before!

- UDP - User Datagram Protocol:
  - connectionless
  - unreliable data transfer
  - no flow control
  - no congestion control

App's using TCP:

- HTTP (Web), FTP (file transfer), Telnet (remote login), SMTP (email)

App's using UDP:

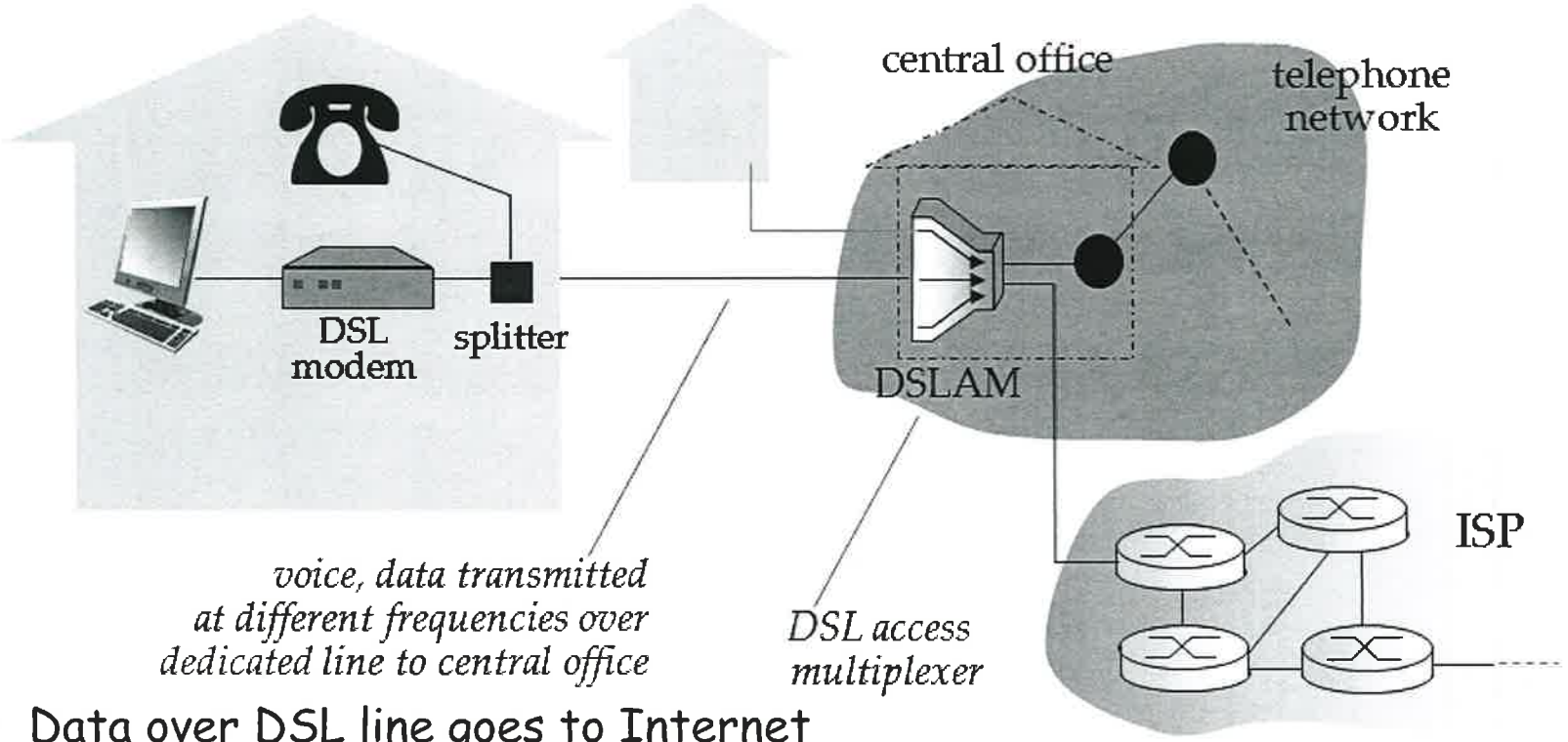
- streaming media, teleconferencing, DNS, Internet telephony

Access Networks

Q: How to connect end systems to edge router?

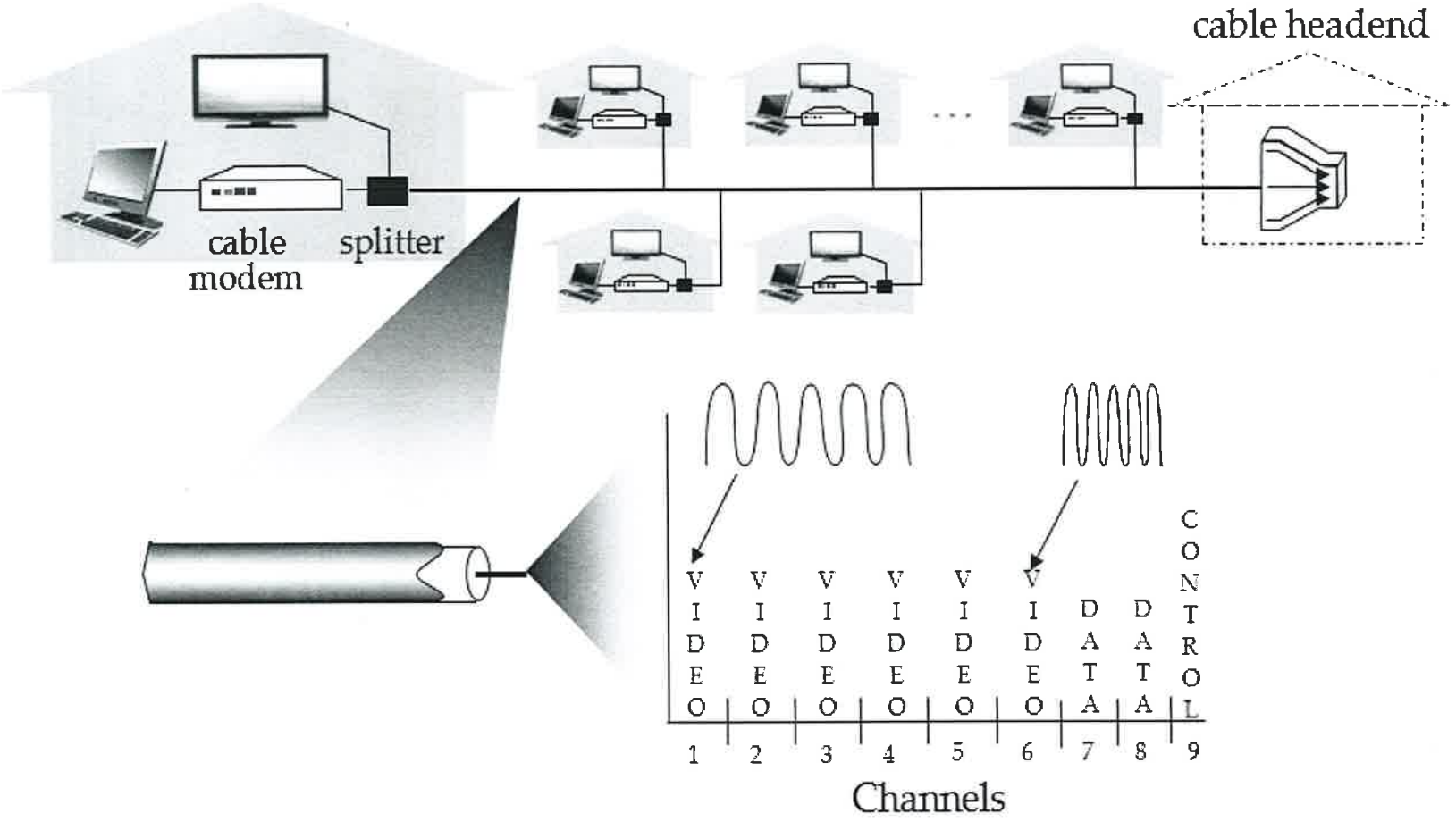
- Residential Access Networks
- Institutional access networks (school, company)
- Mobile access networks
  - Keep in mind:
  - bandwidth (bits per second) of access network?
  - shared or dedicated?

Internet Access: DSL

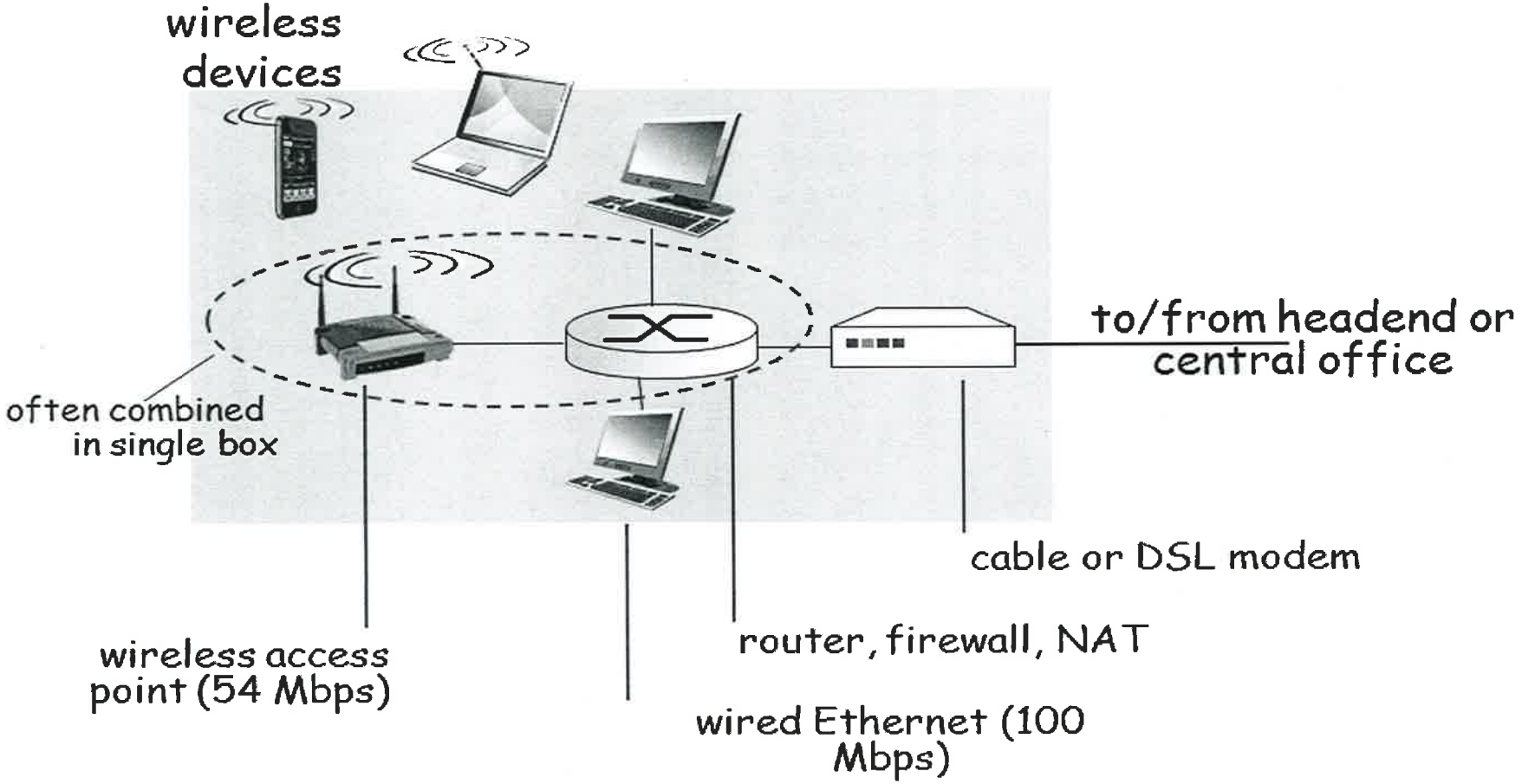


- Data over DSL line goes to Internet
- Voice over DSL line goes to telephone net
  - up to 1 Mbps upstream (today typically ~ 256 kbps)
  - up to 8 Mbps downstream (typically 1~2 Mbps)
  - dedicated physical line to telephone central office

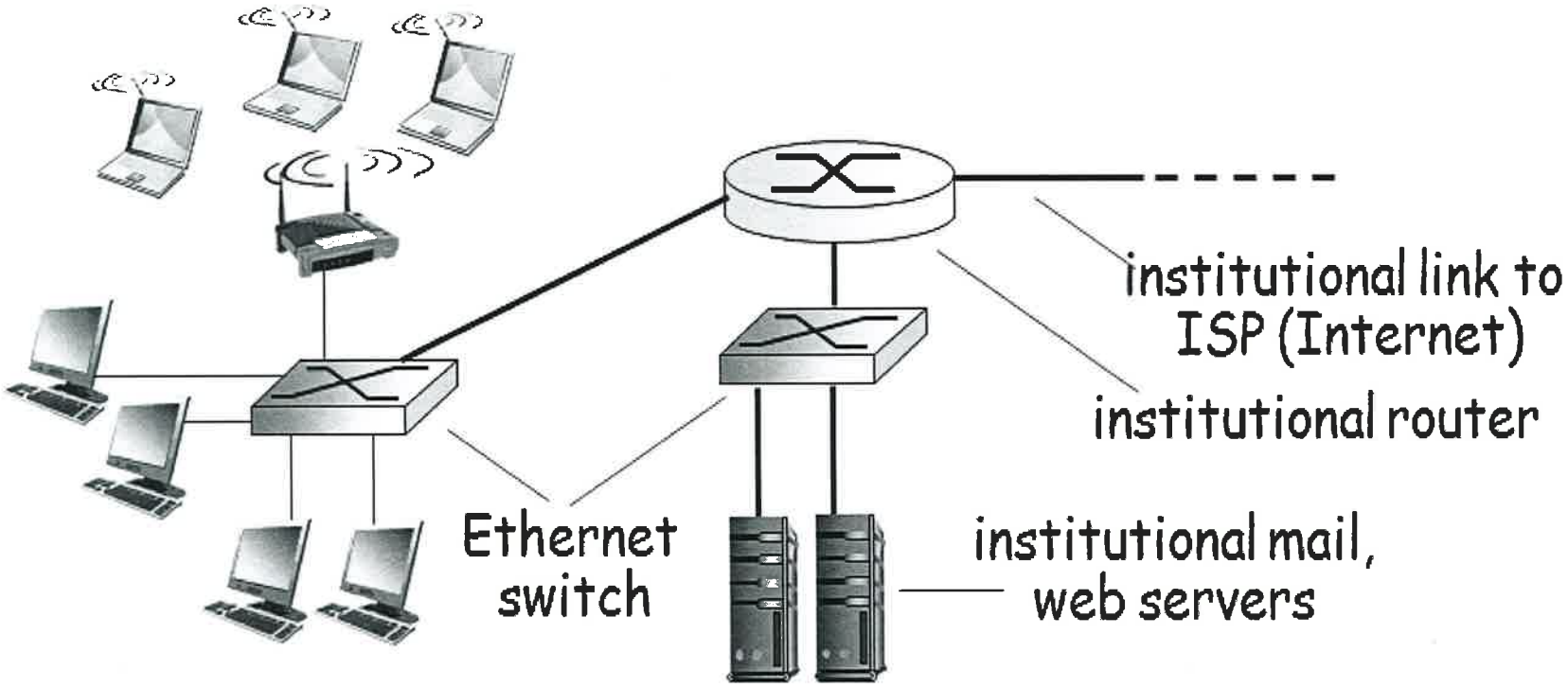
Internet Access: Residential Cable



Internet Access: Home Network



Internet Access: Enterprise Network



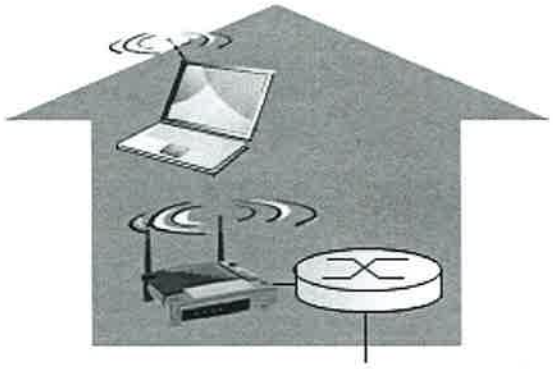
- typically used in companies, universities, etc
  - 10 Mbps, 100Mbps, 1Gbps, 10Gbps transmission rates
  - today, end systems typically connect into Ethernet switch

Internet Access: Wireless

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

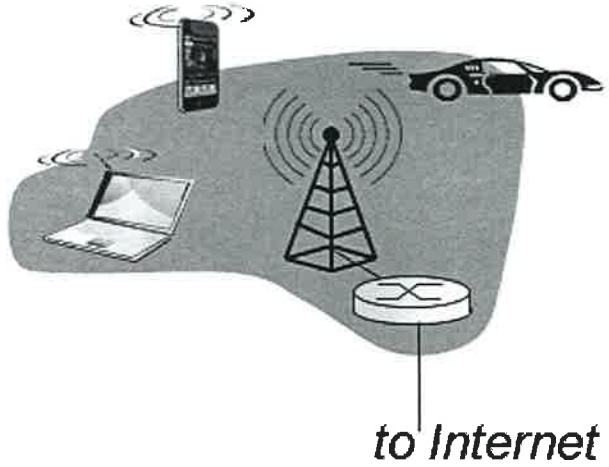
wireless LANs:

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



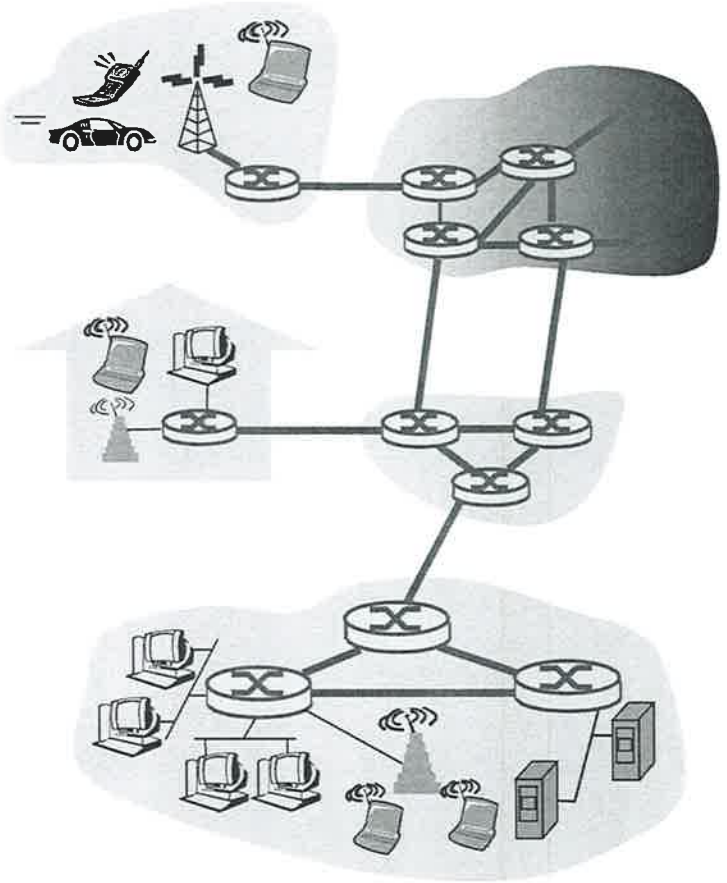
wide-area wireless access

- provided by cellular operators, 10's km
- between 1 and 10 Mbps
- 3G, 4G: LTE, WiMax, EVDO, HSDPA



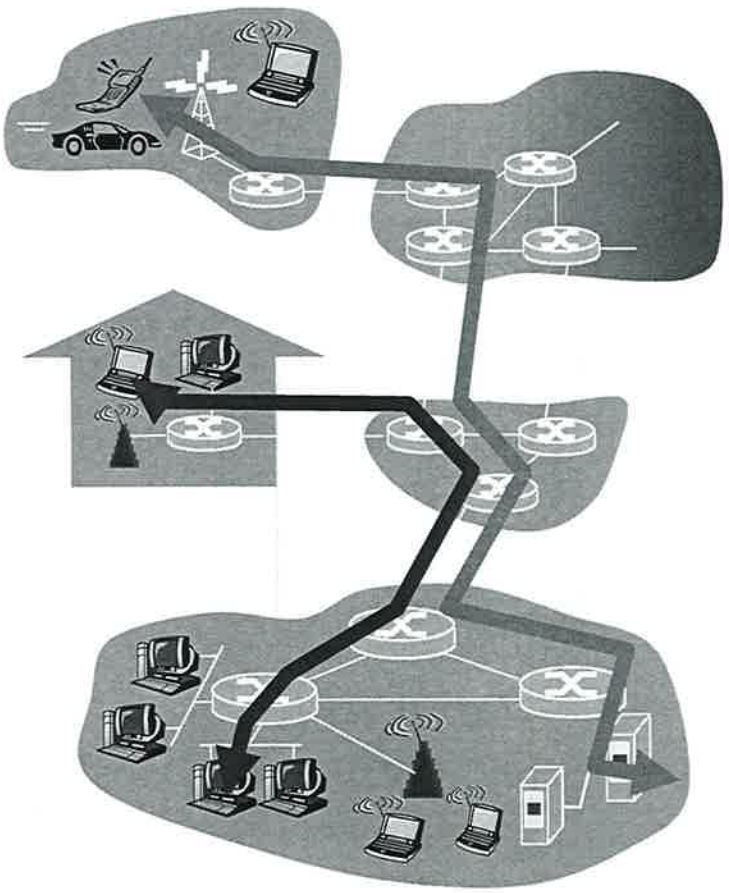
The Core Network

- Mesh of interconnected routers
- The fundamental question: how is data transferred through net?
  - Circuit Switching: dedicated circuit per call: telephone network (PSTN)
  - Packet Switching: data sent thru net in discrete "chunks": Internet



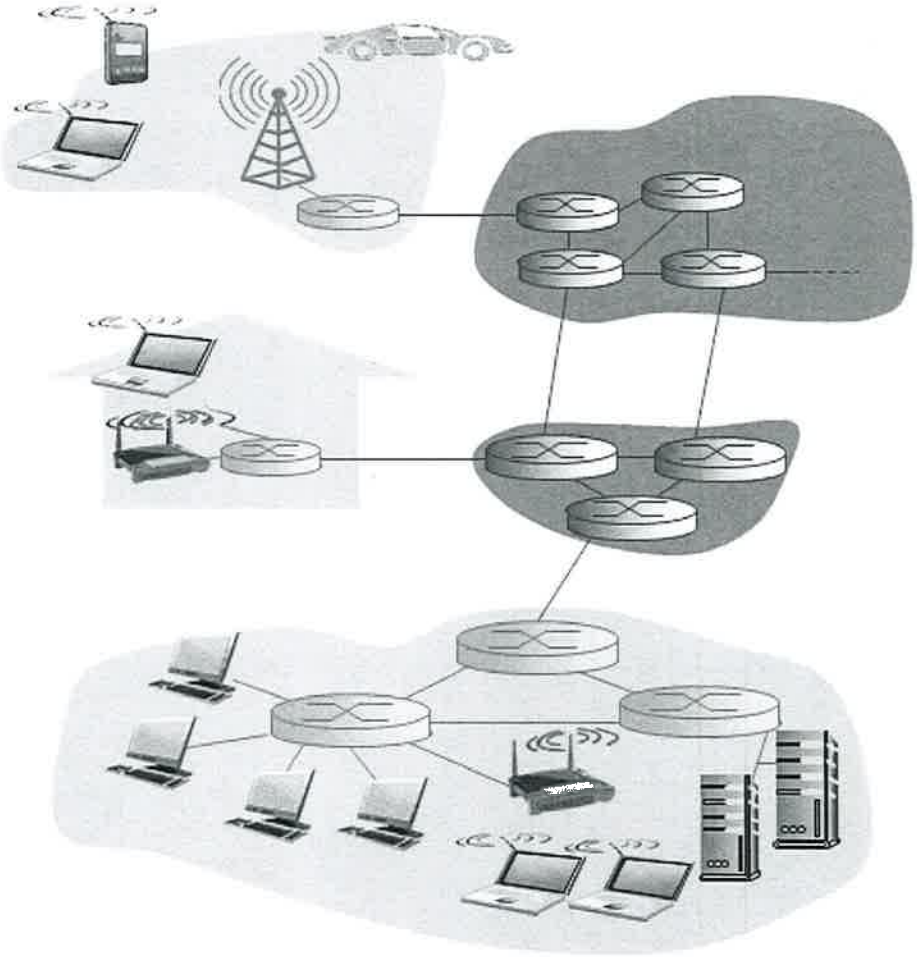
Network Core: Circuit Switching

- End-end resources reserved for duration of call
- link bandwidth, switch capacity
- dedicated resources: no sharing
- circuit-like (guaranteed) performance
- call setup required
- re-establish call upon failure
- Example: PSTN



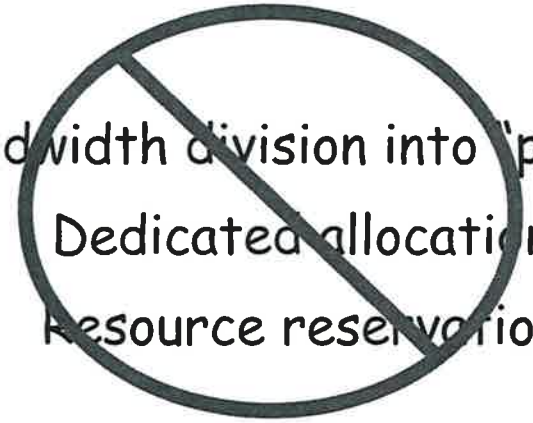
Network Core: Packet Switching

- 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



Packet Switching

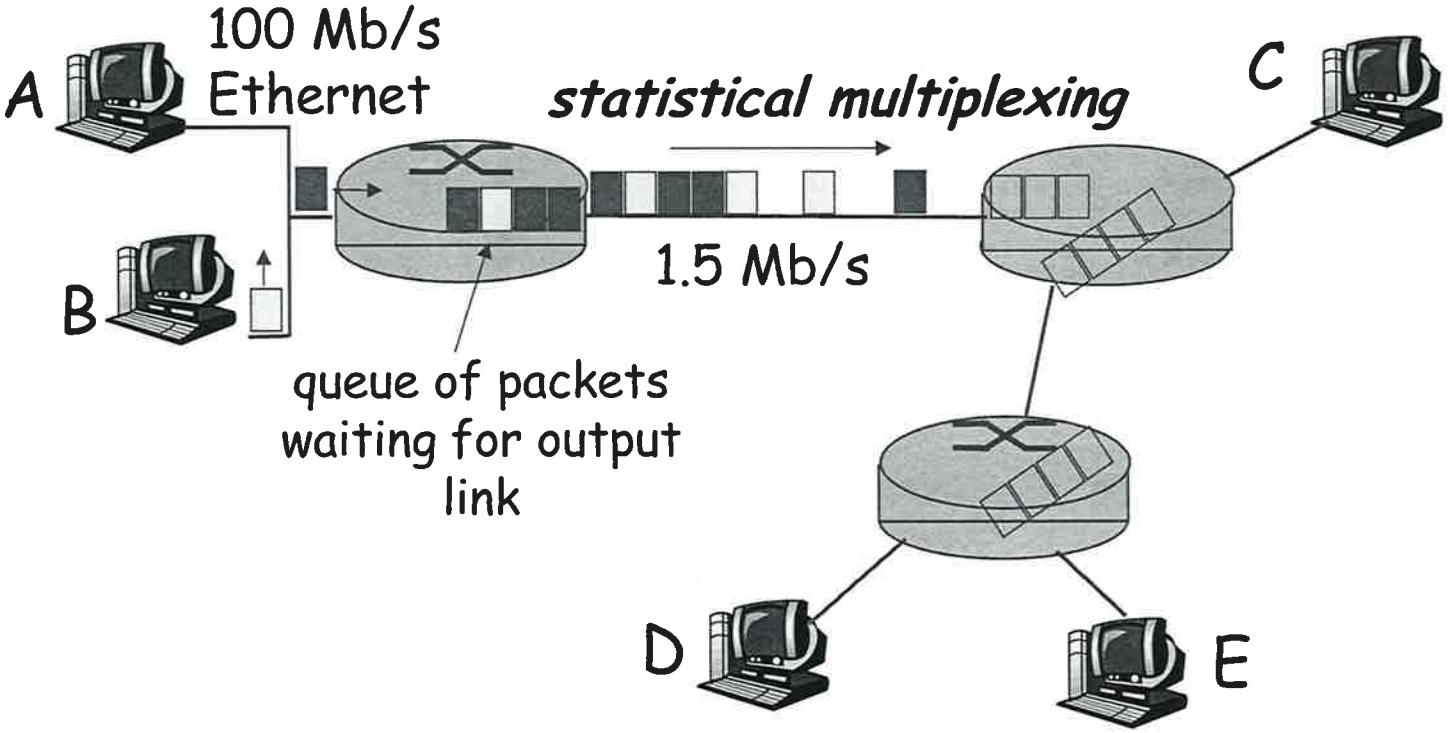
- each end-end data stream divided into packets
- user A, B packets share network resources
- Each packet uses full link bandwidth
- Resources used *as needed*



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 Node receives complete packet before forwarding

Packet Switching (Continued)

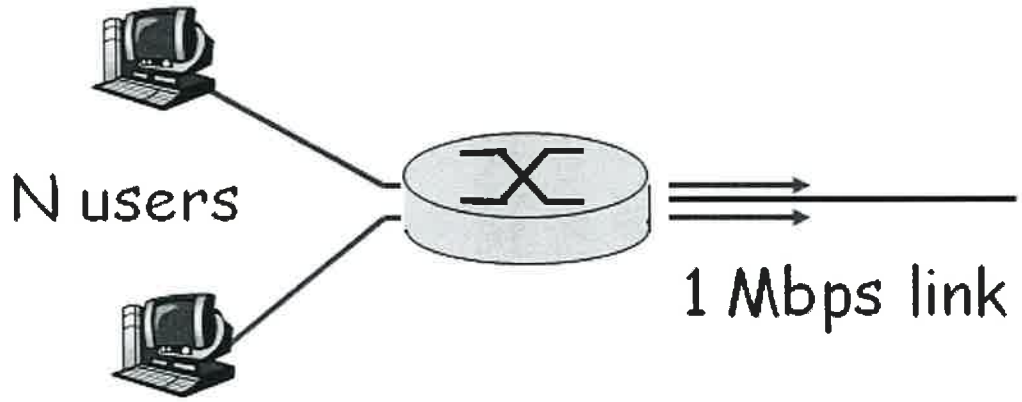


Packet vs. Circuit Switching

- PS 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
- Q: How to provide circuit-like behavior?
  - Bandwidth guarantees needed for audio/video apps
  - Possible solution: Virtual circuit

Packet vs. Circuit Switching (Cont.)

- 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



Q: how did we get value 0.0004?
Use binomial distribution ...

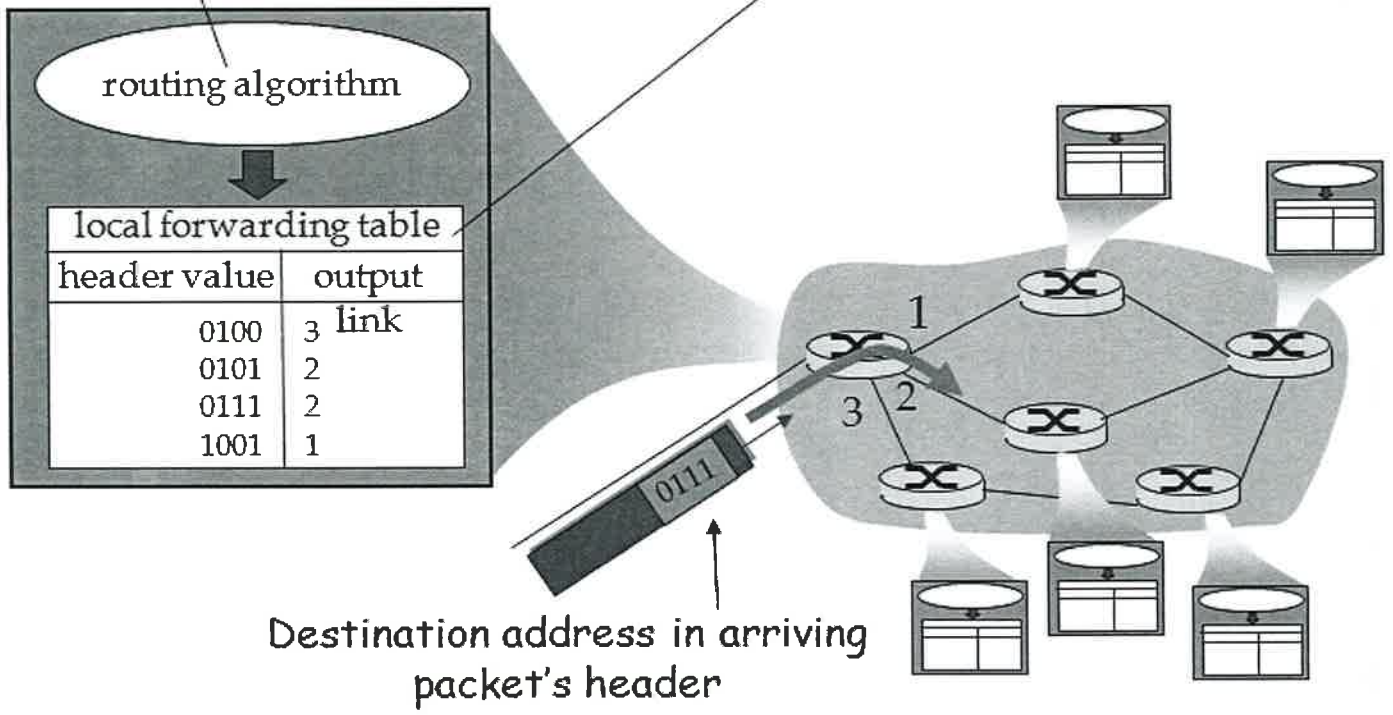
Packet switching allows more users to use network!

Functions of the Core Network

Routing: determines source-destination route taken by packets

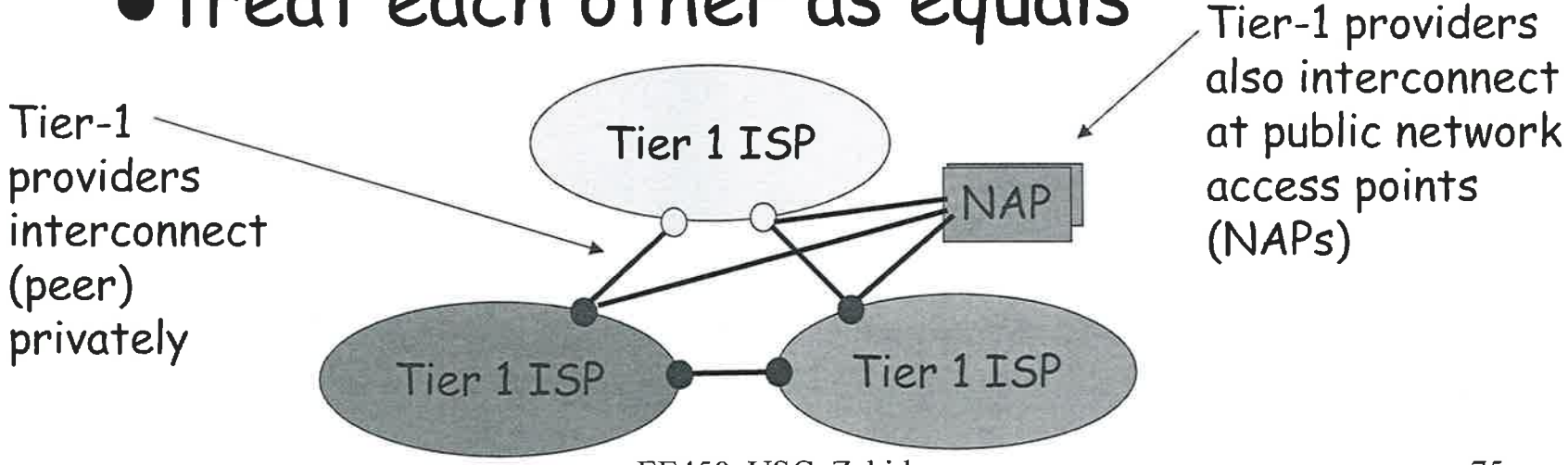
- Routing algorithms

Forwarding: Moving packets from router's input to appropriate router output

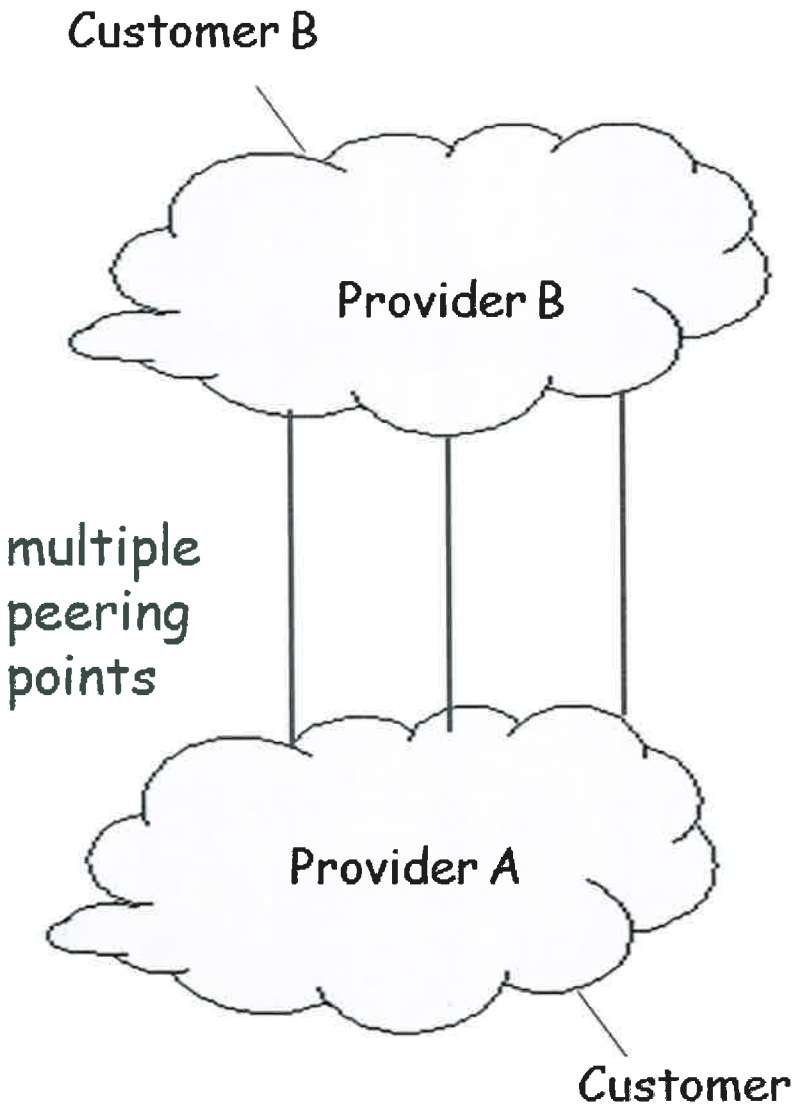


Internet Structure (Tier 1)

- Roughly hierarchical
- at center: "tier-1" ISPs (e.g., Verizon, Sprint, AT&T, Cable and Wireless), national/international coverage
  - treat each other as equals

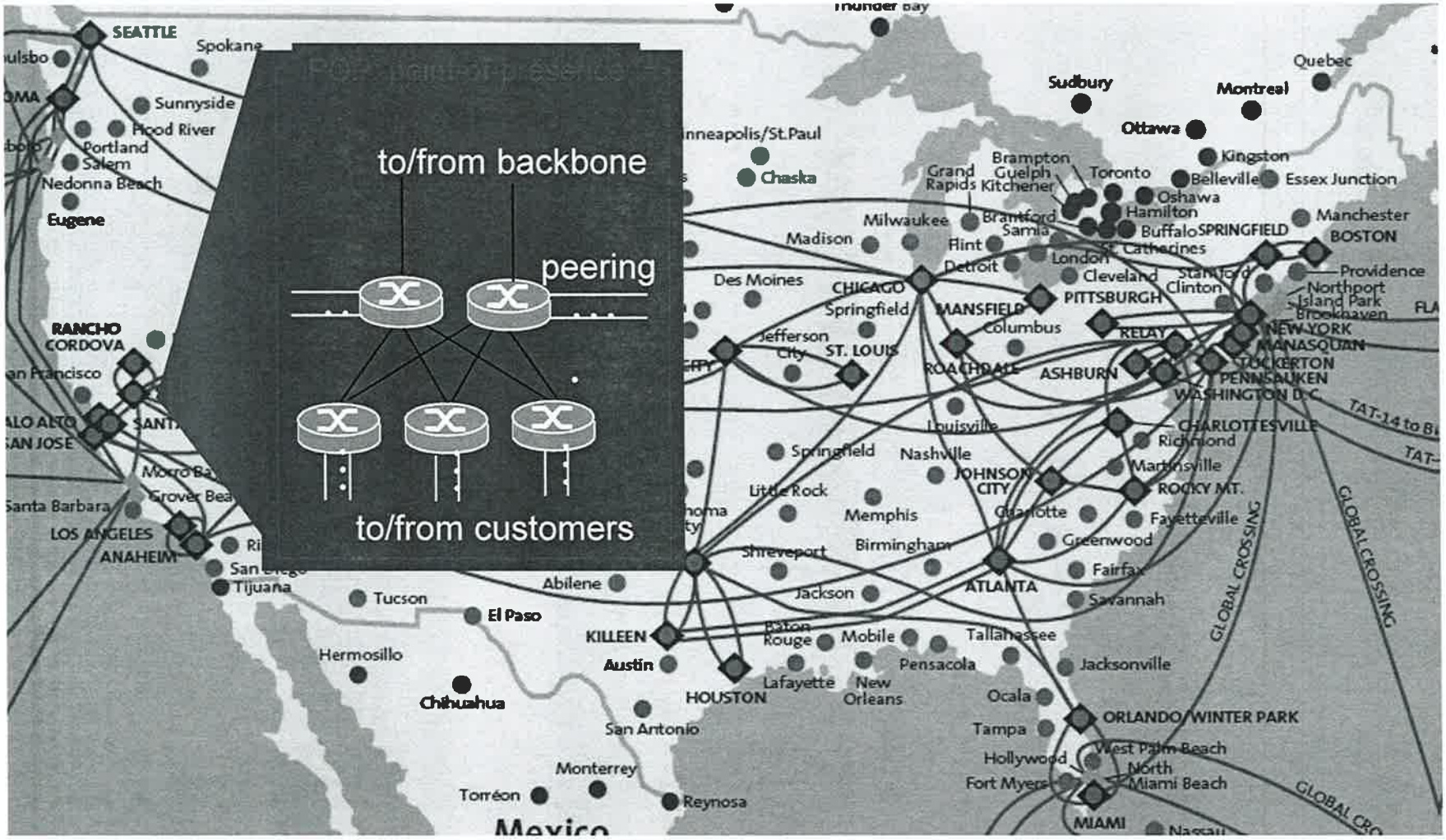


Peering



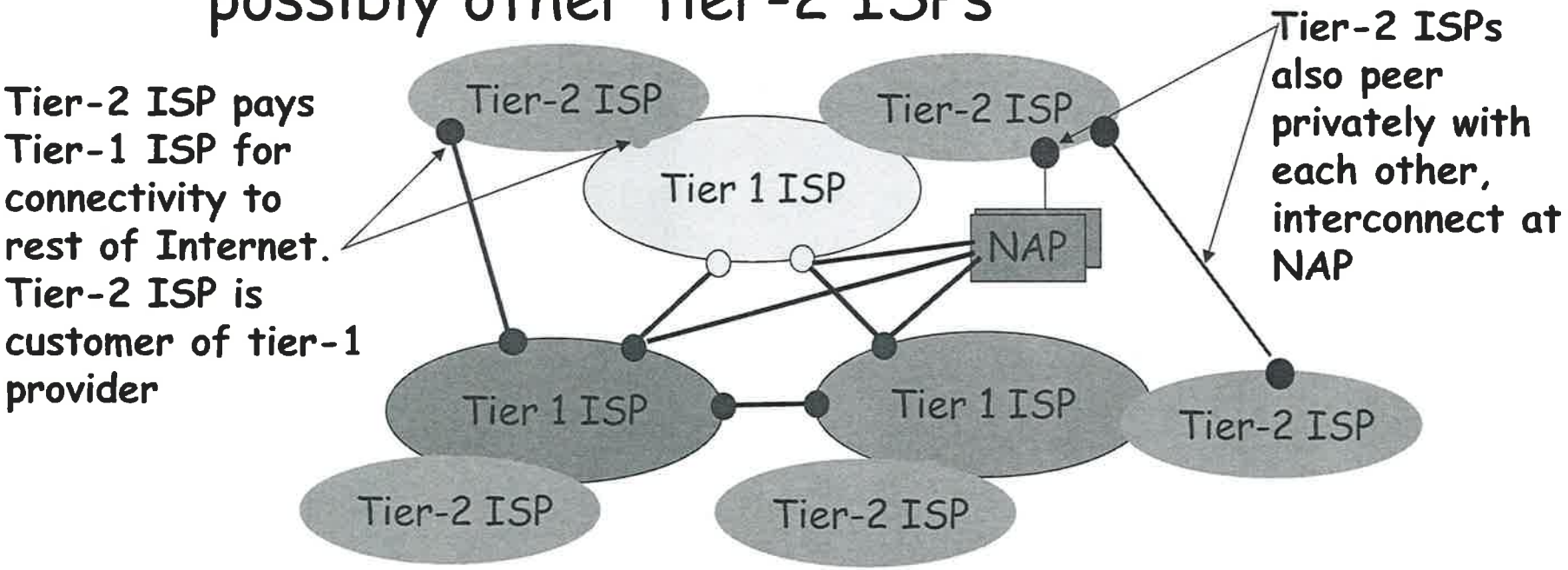
- Exchange traffic between customers
  - Settlement-free
- Diverse peering locations
  - Both coasts, and middle
- Comparable capacity at all peering points
  - Can handle even load

Tier 1 ISP: Sprint



Internet Structure (Tier 2)

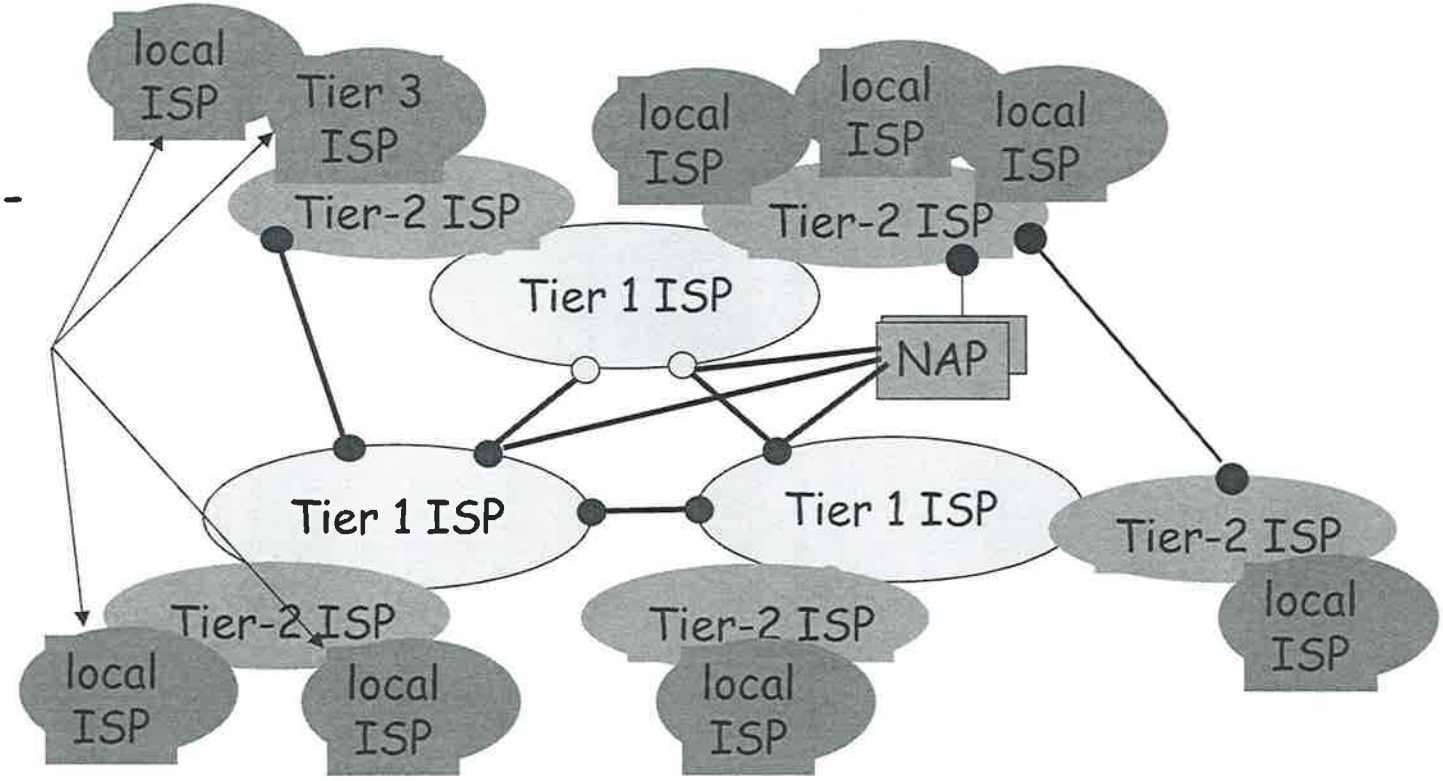
- "Tier-2" ISPs: smaller (often regional) ISPs
  - Connect to one or more tier-1 ISPs, possibly other tier-2 ISPs



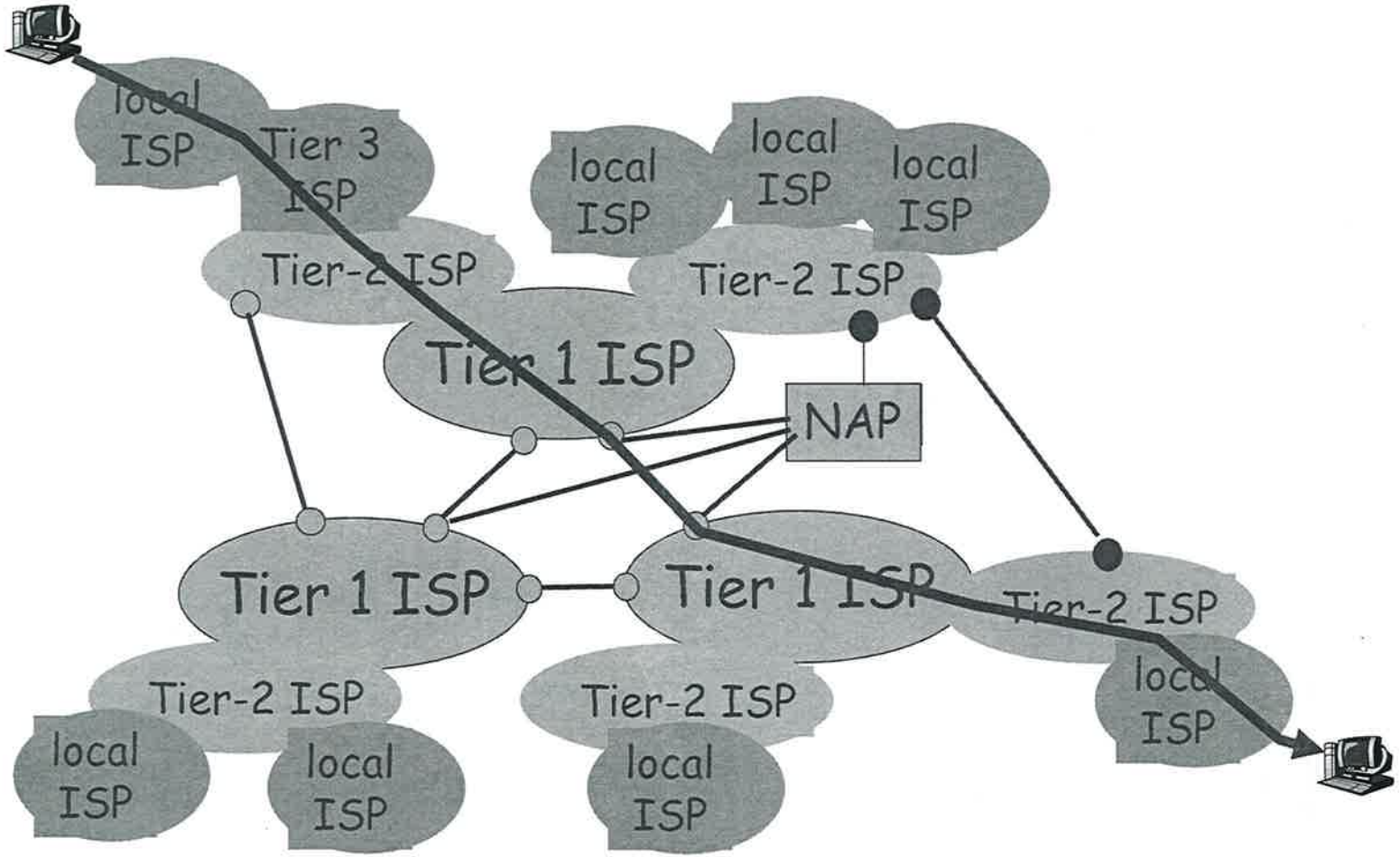
Internet Structure (Tier 3)

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

Local and tier-3 ISPs are customers of higher tier ISPs connecting them to rest of Internet

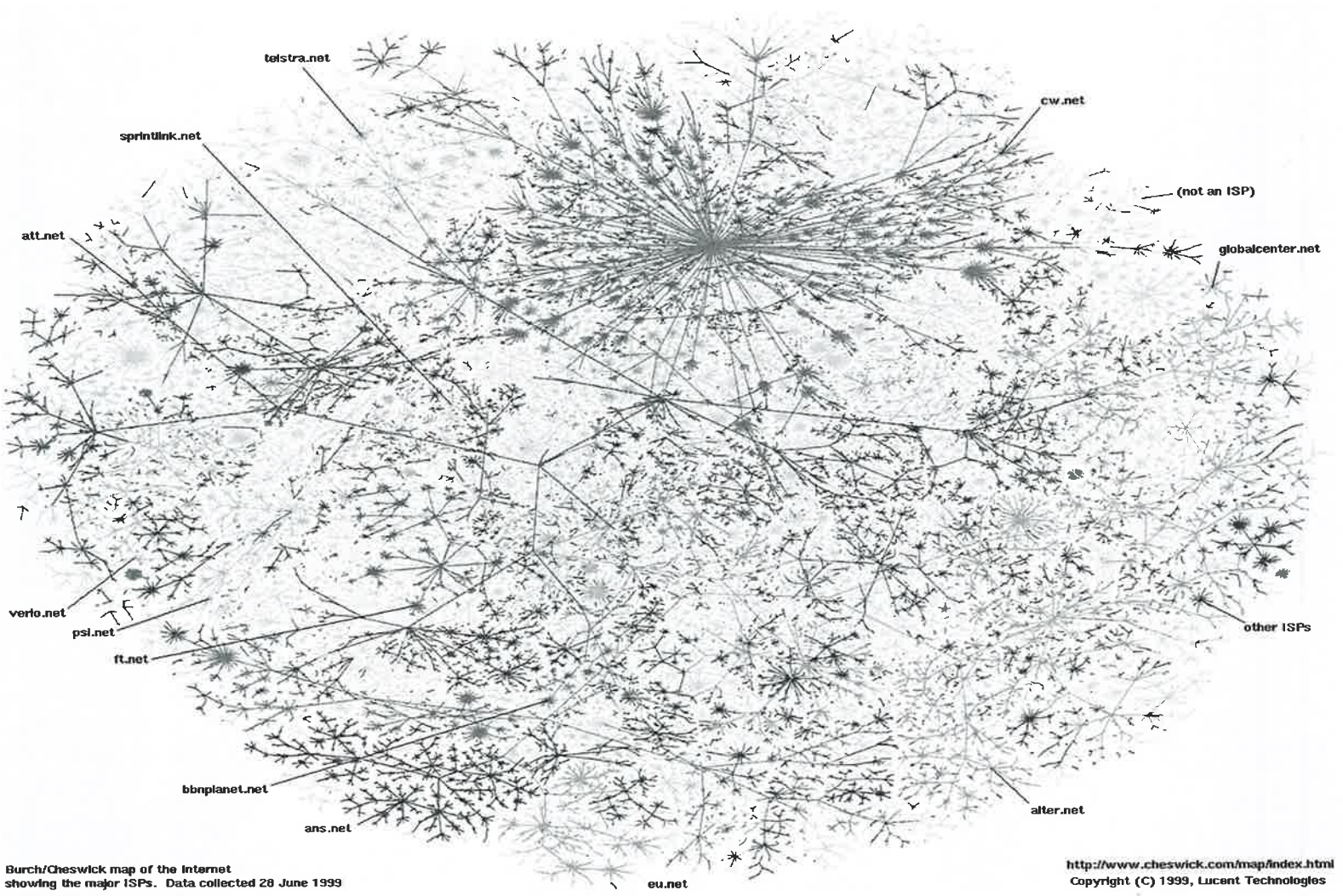


Internet Structure (Summary)

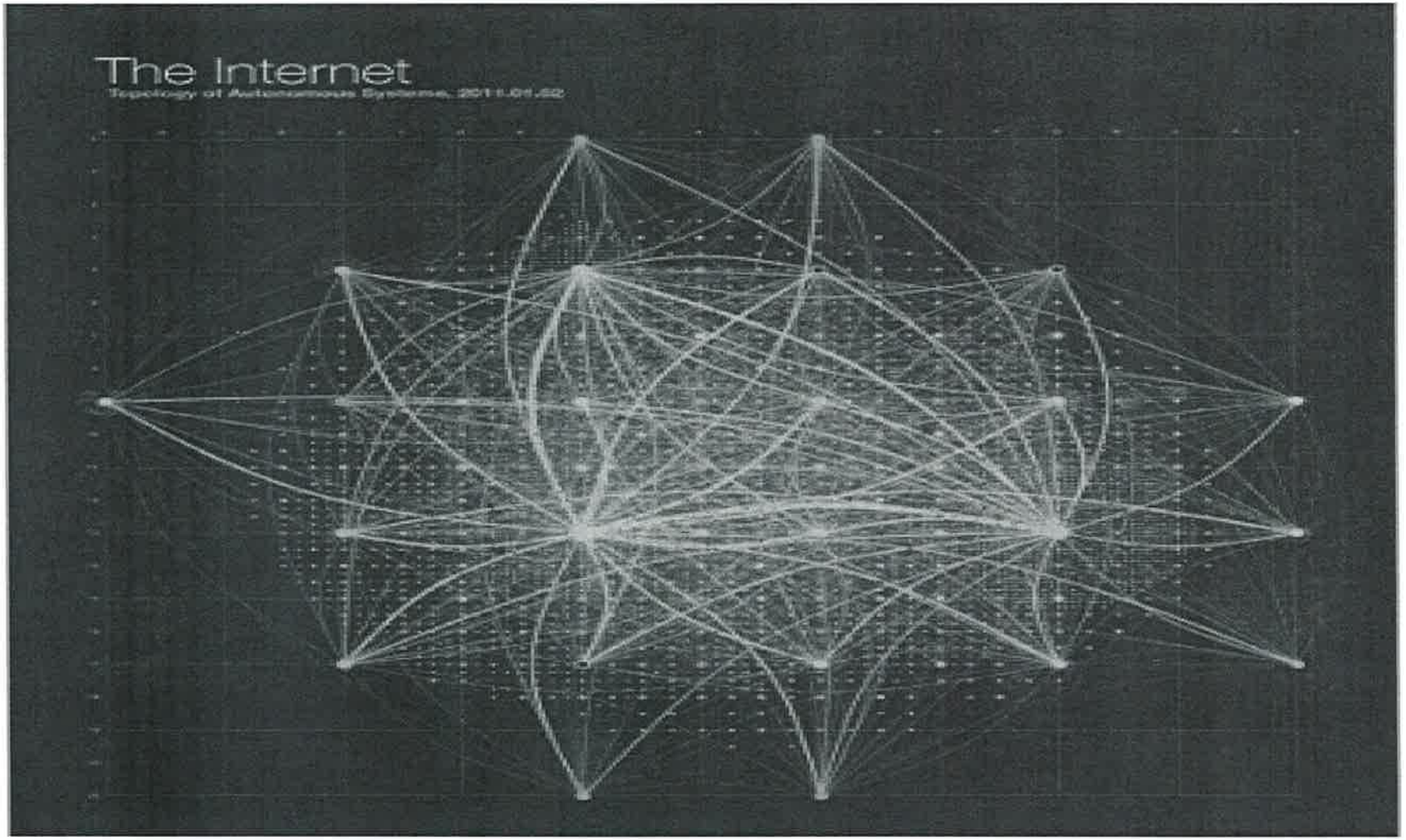


a Packet passes through many networks!

The Internet ?

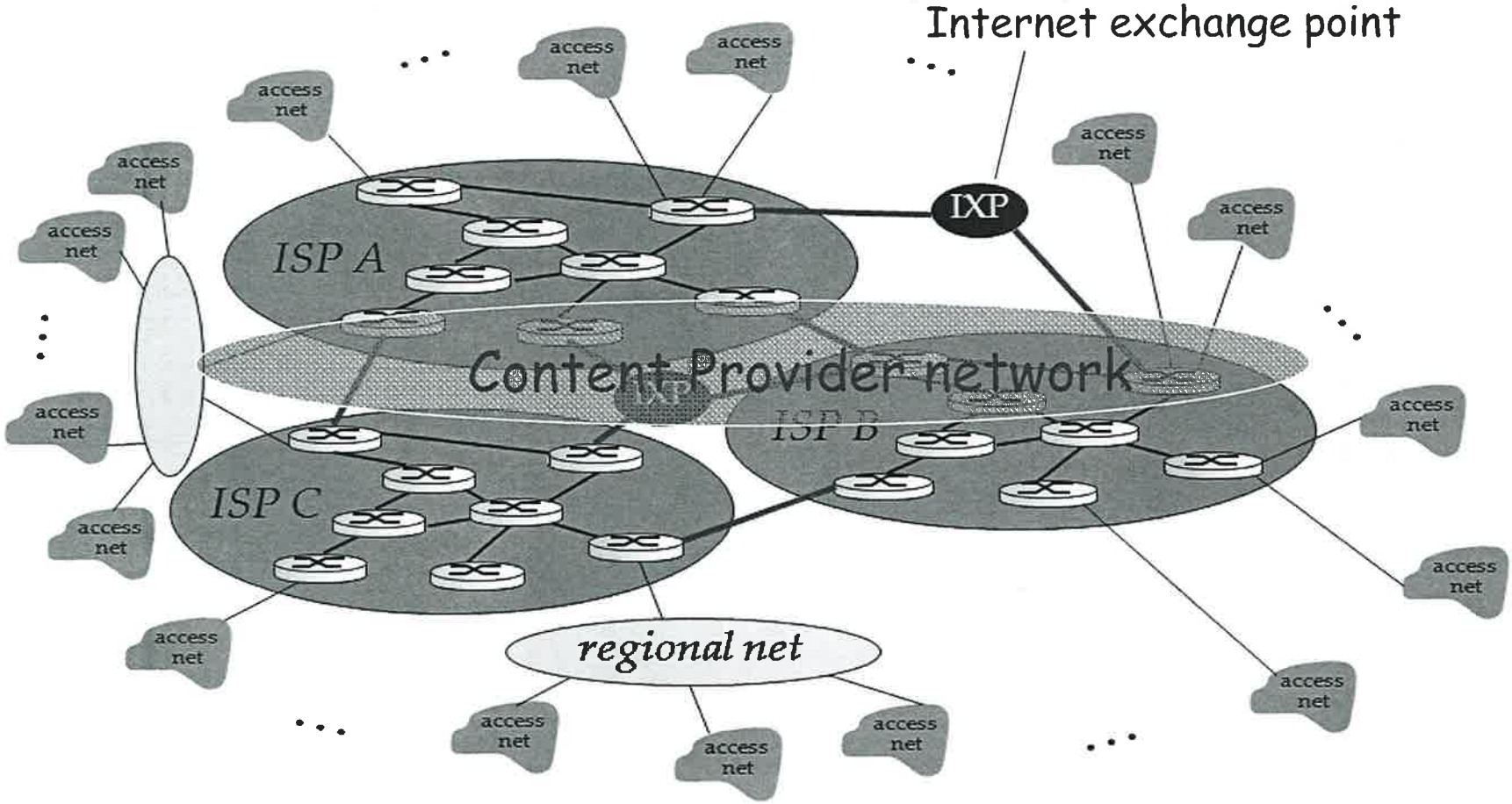


The Internet Map (More Recent)

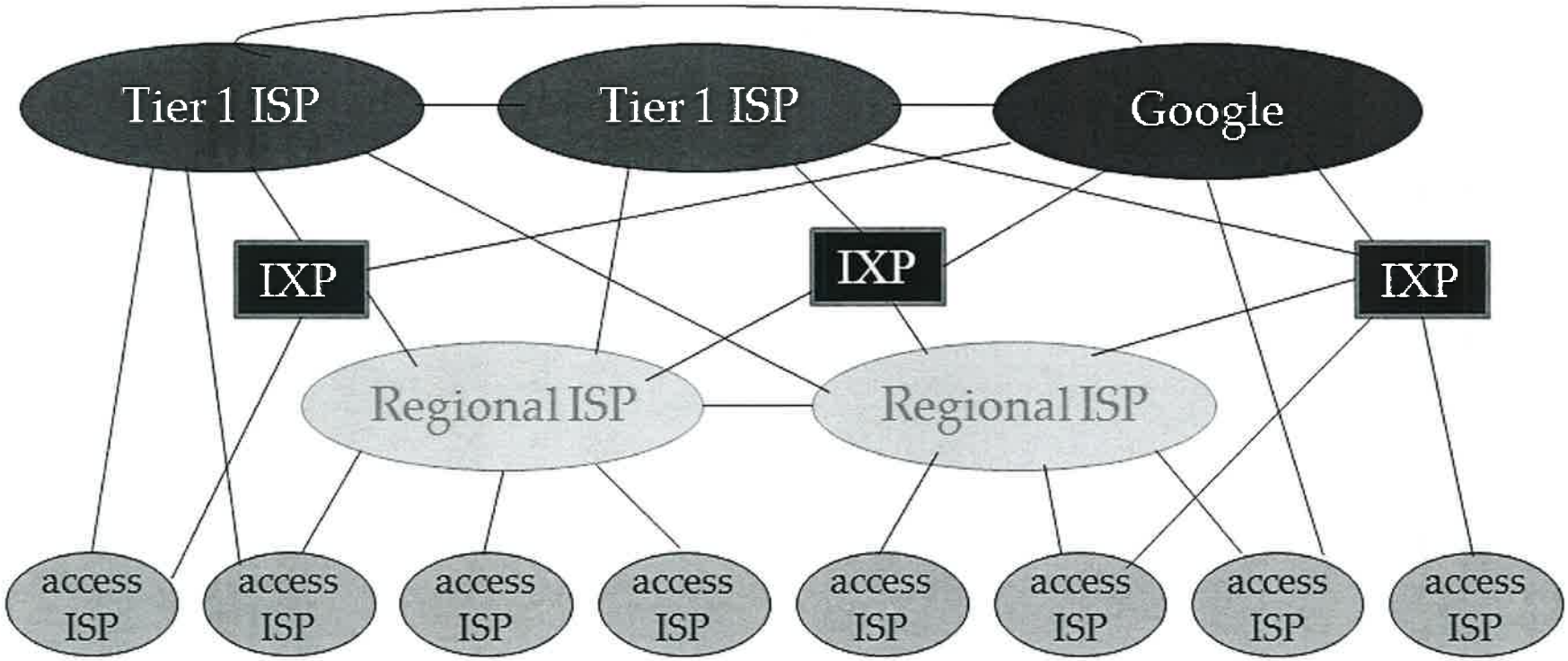


Content Provider Networks

Content Provider Networks (e.g., Google, Microsoft, etc..) run their own Networks, to bring services & content close to end users



Internet Structure: Summary



- 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