Computer Networks

Network Edge and Network Core

Based on Computer Networking, 4th Edition by Kurose and Ross

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What's the Internet: "Nuts and Bolts" View

PC

server

wireless laptop

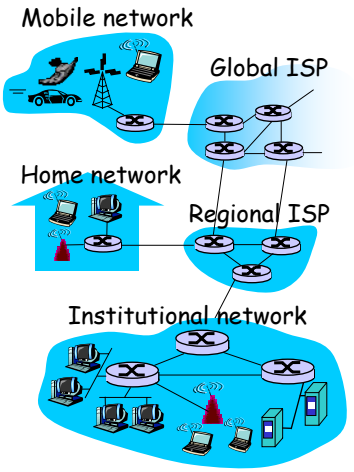
cellular handheld

access points

wired links

router

- millions of connected computing devices: *hosts = end systems*
- running *network apps*
- *communication links*
  - fiber, copper, radio, satellite
  - transmission rate = ***bandwidth***
- *routers:* forward packets (chunks of data)



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"Cool" Internet Appliances

IP picture frame
http://www.ceiva.com/

Web-enabled toaster + weather forecaster

Shaver with a LAN connectivity

Internet phones

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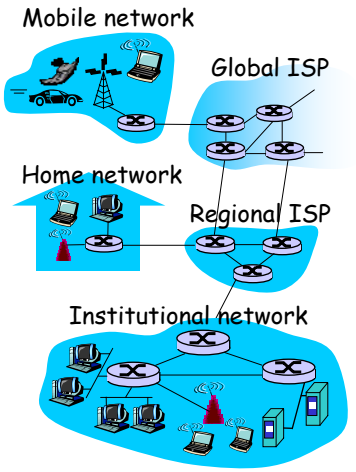
What's the Internet: "Nuts and Bolts" View

- *protocols* control sending, receiving of messages
  - e.g., TCP, IP, HTTP, FTP, PPP, Skype, Ethernet
- *Internet:* "network of networks"
  - loosely hierarchical
  - public Internet versus private intranet
- Internet standards
  - RFC: Request for comments
  - IETF: Internet Engineering Task Force



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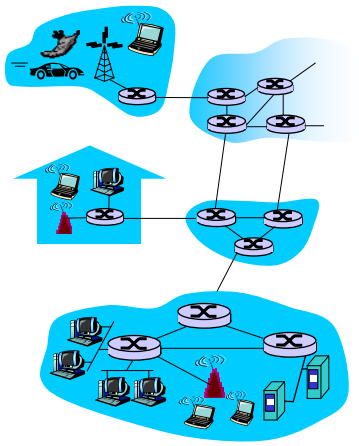
What's the Internet: a Service View

- communication *infrastructure* enables distributed applications:
  - Web, email, voice over IP, games, e-commerce, file sharing
- communication services provided to apps:
  - reliable data delivery from source to destination
  - "best effort" (unreliable) data delivery



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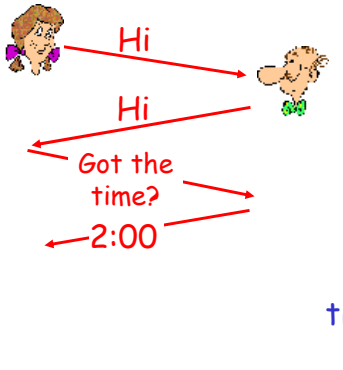
What's a Protocol?

human protocols:

- "what's the time?"
- "I have a question"
- introductions

... specific msgs sent

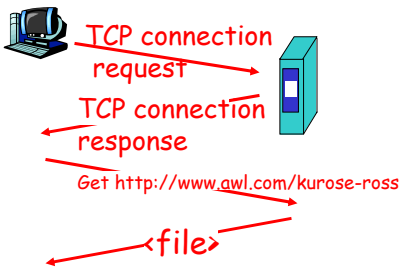
... specific actions taken when msgs received, or other events



network protocols:

- machines rather than humans
- all communication activity in Internet governed by protocols

protocols define format, order of msgs sent and received among network entities, and actions taken on msg transmission, receipt



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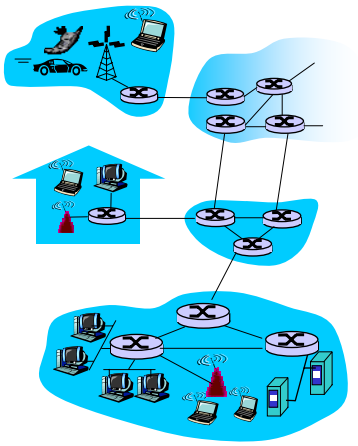
A closer Look at Network Structure

- network edge:
  - applications and hosts
- network core:
  - interconnected routers
  - network of networks
- access networks, physical media:
  - wired and wireless communication links



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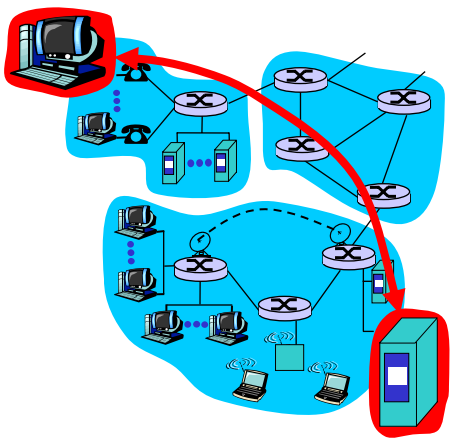
The Network Edge

- 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-peer model:
  - minimal (or no) use of dedicated servers
  - e.g. Gnutella, KaZaA, Skype, BitTorrent



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Network Edge: Reliable Data Transfer Service

Goal: data transfer between end systems

- *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

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Network Edge: Best Effort (Unreliable) Data Transfer Service

Goal: data transfer between end systems

- same as before!

- UDP - User Datagram Protocol [RFC 768]:
  - 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

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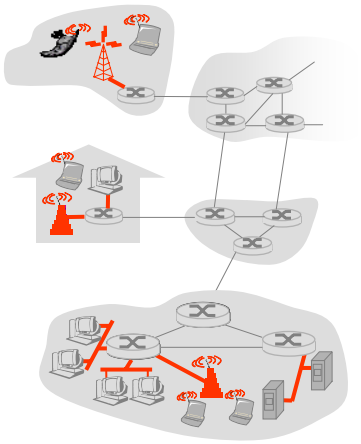
Access Networks and Physical Media

- How to connect end systems to edge router?
  - residential access nets
  - institutional access networks (school, company)
  - mobile access networks
- Keep in mind:
  - bandwidth (bits per second) of access network?
  - shared or dedicated?



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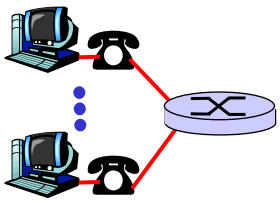
Residential Access: Point to Point Access

- Dialup via modem
  - up to 56Kbps direct access to router (often less)
  - Can't surf and phone at same time: can't be "always on"
- DSL: digital subscriber line
  - deployment: telephone company (typically)
  - up to 1 Mbps upstream (today typically < 256 kbps)
  - up to 8 Mbps downstream (today typically < 1 Mbps)
  - dedicated physical line to telephone central office



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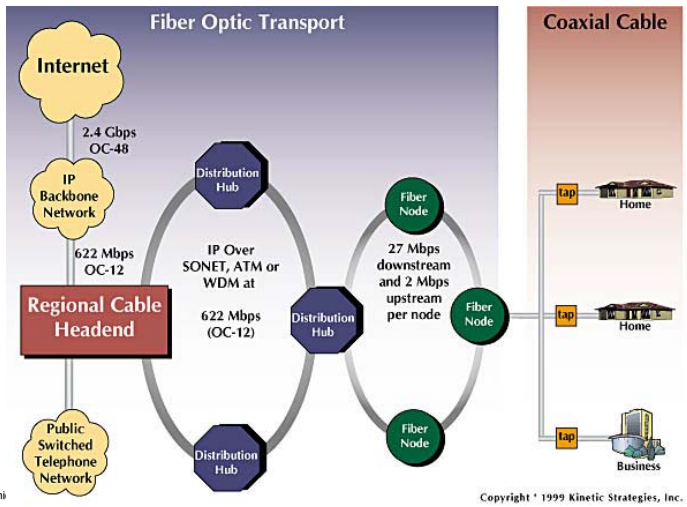
Residential Access: Cable Modems

- HFC: hybrid fiber coax
  - asymmetric: up to 30Mbps downstream, 2 Mbps upstream
- network of cable and fiber attaches homes to ISP router
  - homes share access to router
- deployment: available via cable TV companies



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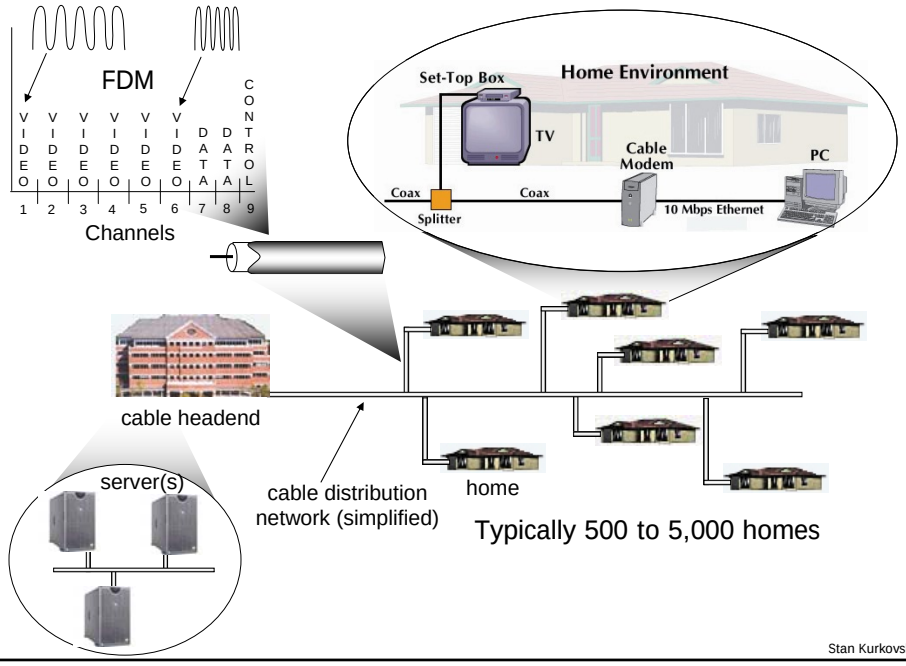
Cable Network Architecture: Overview



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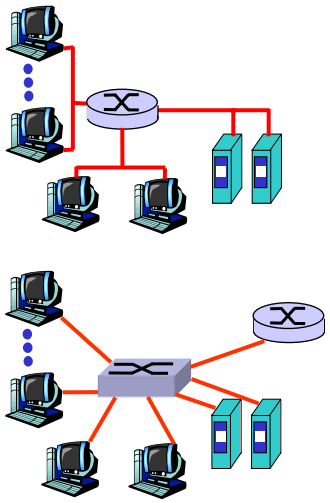
Company Access: Local Area Networks

- company/university local area network (LAN) connects end system to edge router
- Ethernet:
  - 10 Mbs, 100Mbps, 1Gbps, 10Gbps Ethernet
  - modern configuration: end systems connect into *Ethernet switch*
- LANs: chapter 5



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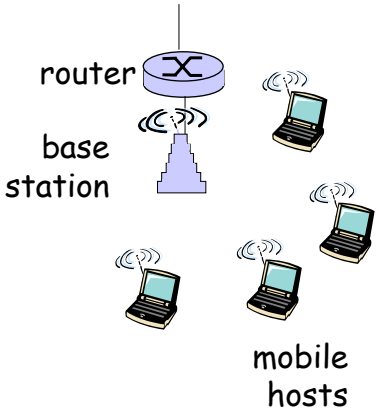
Wireless Access Networks

- shared *wireless* access network connects end system to router
  - via base station aka "access point"
- wireless LANs:
  - 802.11b/g (WiFi): 11 or 54 Mbps
- wider-area wireless access
  - provided by telco operator
  - ~1Mbps over cellular system (EVDO, HSDPA)
  - next up (?): WiMAX (10's Mbps) over wide area



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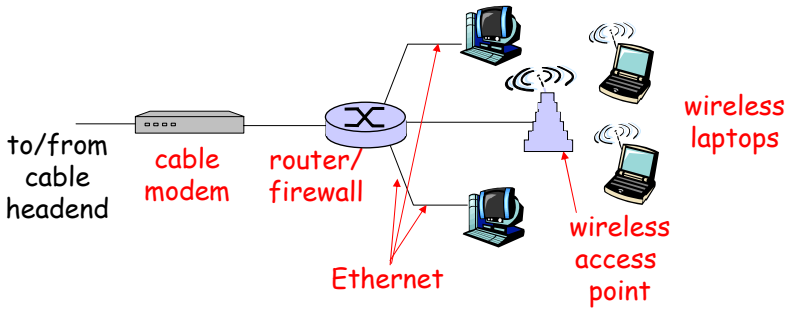
Home Networks

Typical home network components:

- DSL or cable modem
- router/firewall/NAT
- Ethernet
- wireless access point



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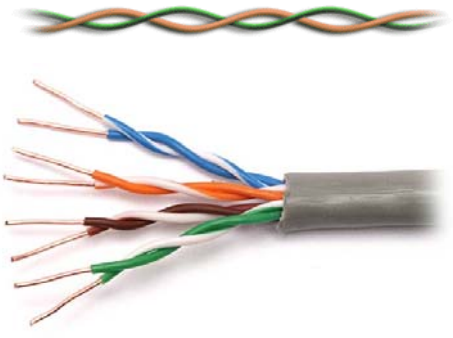
Physical Media

- Bit: propagates between transmitter/receiver pairs
- physical link: what lies between transmitter & receiver
- guided media:
  - signals propagate in solid media: copper, fiber, coax
- unguided media:
  - signals propagate freely, e.g., radio

- Twisted Pair (TP): two insulated copper wires
  - Category 3: traditional phone wires, 10 Mbps Ethernet
  - Category 5: 100Mbps Ethernet



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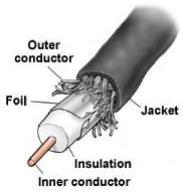
Physical Media

- Coaxial cable: two concentric copper conductors
- bidirectional
- baseband:
  - single channel on cable
  - legacy Ethernet
- broadband:
  - multiple channels on cable
  - HFC



- Fiber optic cable: glass fiber carrying light pulses, each pulse a bit
- high-speed operation:
  - high-speed point-to-point transmission (e.g., 10's-100's Gps)
- low error rate: repeaters spaced far apart;
- immune to electromagnetic noise

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Physical Media

- Radio: signal carried in electromagnetic spectrum
- no physical "wire"
- bidirectional
- propagation environment effects:
  - reflection
  - obstruction by objects
  - interference
- Radio link types:
  - terrestrial microwave
    - e.g. up to 45 Mbps channels
  - LAN (e.g., WiFi)
    - 2Mbps, 11Mbps, 54 Mbps
  - wide-area (e.g., cellular)
    - e.g. 3G: hundreds of kbps
  - satellite
    - Kbps to 45Mbps channel (or multiple smaller channels)
    - 270 msec end-end delay
    - geosynchronous versus low altitude

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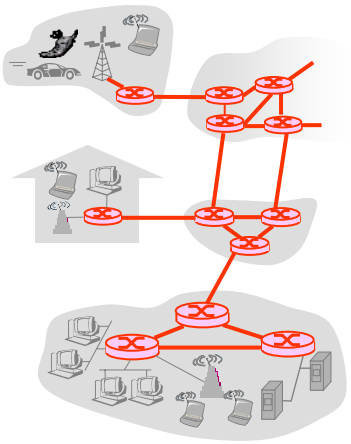
The Network Core

- 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 thru net in discrete "chunks"



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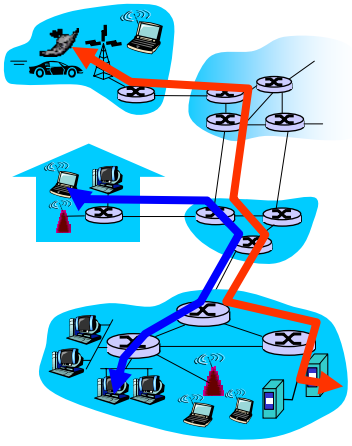
Network Core: Circuit Switching

End-end resources reserved for "call"

- link bandwidth, switch capacity
- dedicated resources: no sharing
- circuit-like (guaranteed) performance
- call setup required

- network resources (e.g., bandwidth) divided into "pieces"
  - pieces allocated to calls
  - resource piece *idle* if not used by owning call *(no sharing)*
- dividing link bandwidth into "pieces"
  - frequency division
  - time division



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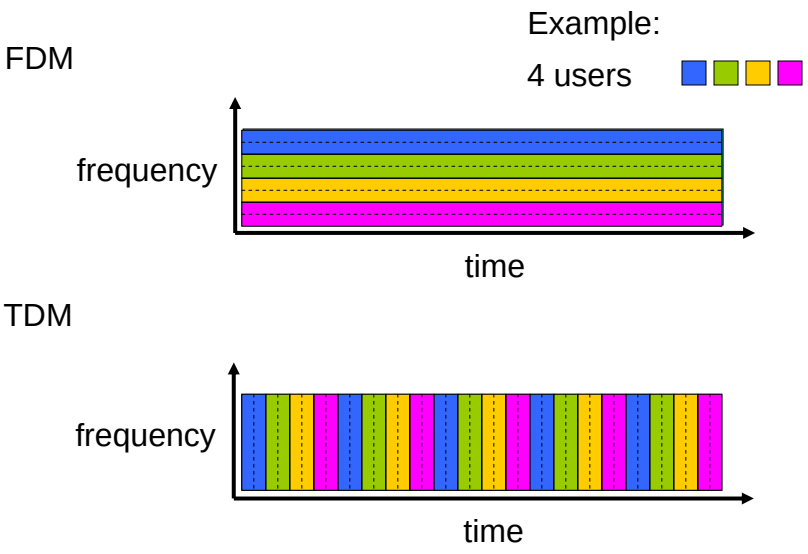
Circuit Switching: FDM and TDM



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Numerical Examples

- How long does it take to send a file of 640,000 bits from host A to host B over a circuit-switched network?

- All links are 1.536 Mbps
- Each link uses TDM with 24 slots/sec
- 500 msec to establish end-to-end circuit

- All links are 1.536 Mbps
- Each link uses FDM with 24 channels/frequencies
- 500 msec to establish end-to-end circuit

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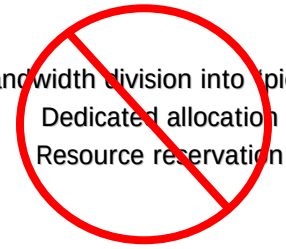
Network Core: Packet Switching

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

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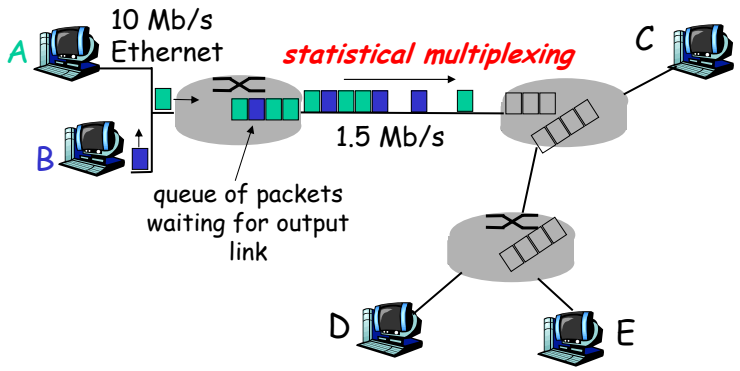
Packet Switching: Statistical Multiplexing



Sequence of A & B packets does not have fixed pattern, shared on demand

➔ ***statistical multiplexing***

TDM: each host gets same slot in revolving TDM frame

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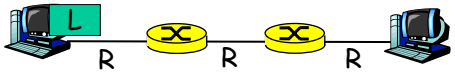
Packet Switching: Store-and-Forward



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

- Example:
  - L = 7.5 Mbits
  - R = 1.5 Mbps
  - Transmission delay = 15 sec

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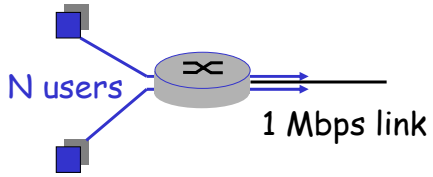
Packet Switching versus Circuit Switching

- Packet switching allows more users to use network!



- Great for bursty data
  - resource sharing
  - simpler, no call setup
- Excessive congestion: packet delay and loss
  - protocols needed for reliable data transfer, congestion control
- Q: How to provide circuit-like behavior?
  - bandwidth guarantees needed for audio/video apps
  - still an unsolved problem
- Q: What are human analogies?
  - reserved resources (circuit switching)
  - on-demand allocation (packet-switching)

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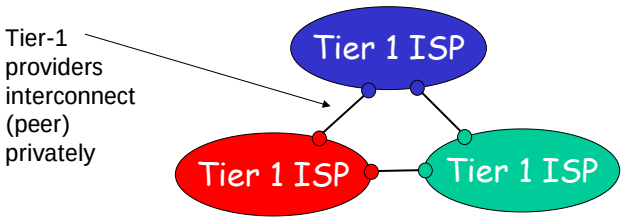
Internet Structure: Network of Networks

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



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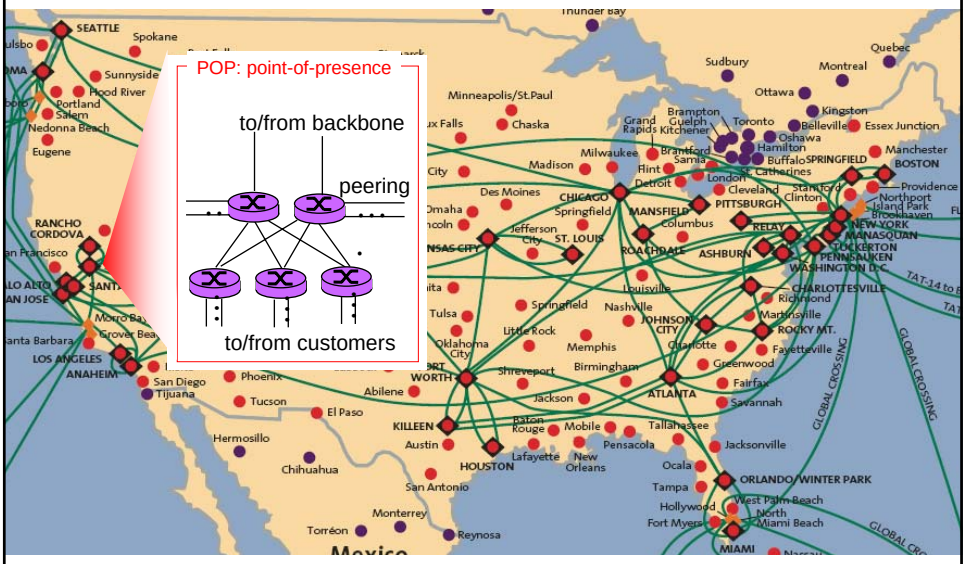
Tier-1 ISP: e.g., Sprint



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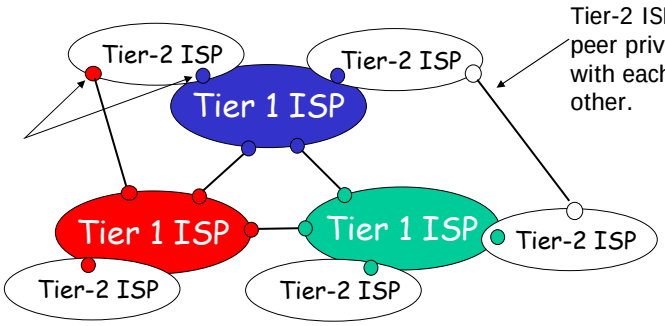
Internet Structure: Network of Networks

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

Tier-2 ISP pays tier-1 ISP for connectivity to rest of Internet Tier-2 ISP is c*ustomer* of tier-1 provider



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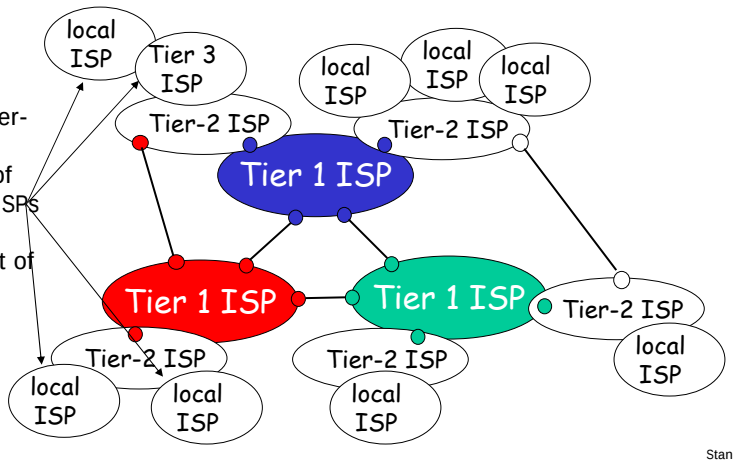
Internet Structure: Network of Networks

- "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



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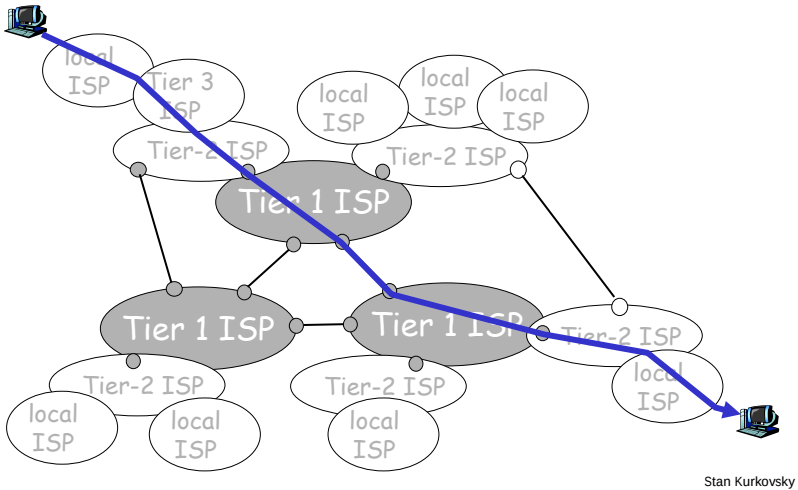
Internet Structure: Network of Networks

- a packet passes through many networks



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