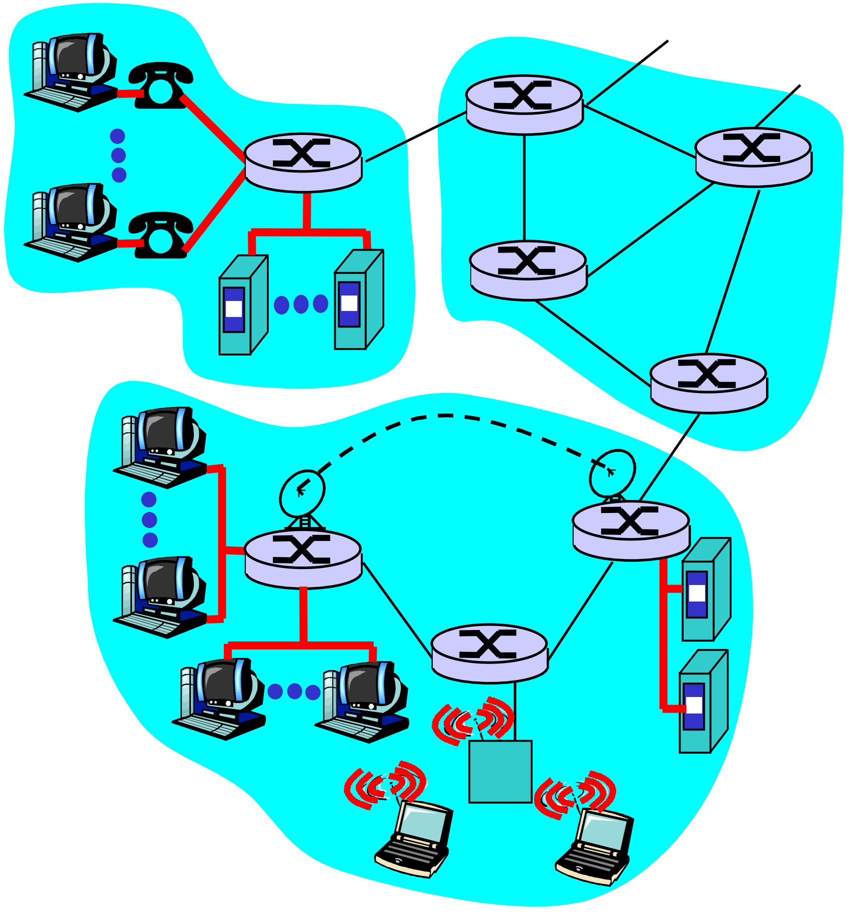
Access networks and physical media

Q: How to connect an end system to an edge router?

- Residential access nets
- Institutional access networks (school, company)
- Mobile access networks

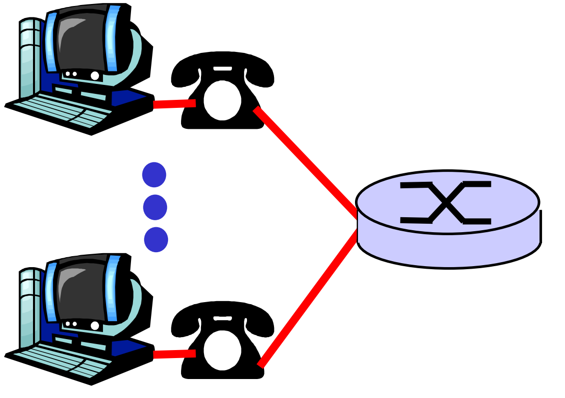
Keep in mind:

- Bandwidth (bits per second) of access network?
- Shared or dedicated?



Residential access: point to point access

- Dialup via modem
  - up to 56Kbps direct access to router (conceptually)
- ISDN: integrated services digital network: 128 Kbps all-digital connect to router
- ADSL: asymmetric digital subscriber line
  - up to 1 Mbps home-to-router
  - up to 8 Mbps router-to-home
  - ADSL deployment: happening



Residential access: cable modems (1)

- HFC: hybrid fibre coax
  - asymmetric: up to 10 Mbps upstream, 1 Mbps downstream
- Network of cable and fibre attaches homes to ISP router
  - shared access to router among homes
  - issues: congestion, dimensioning
- Deployment: available via cable companies, e.g. MediaOne

Residential access: cable modems (2)

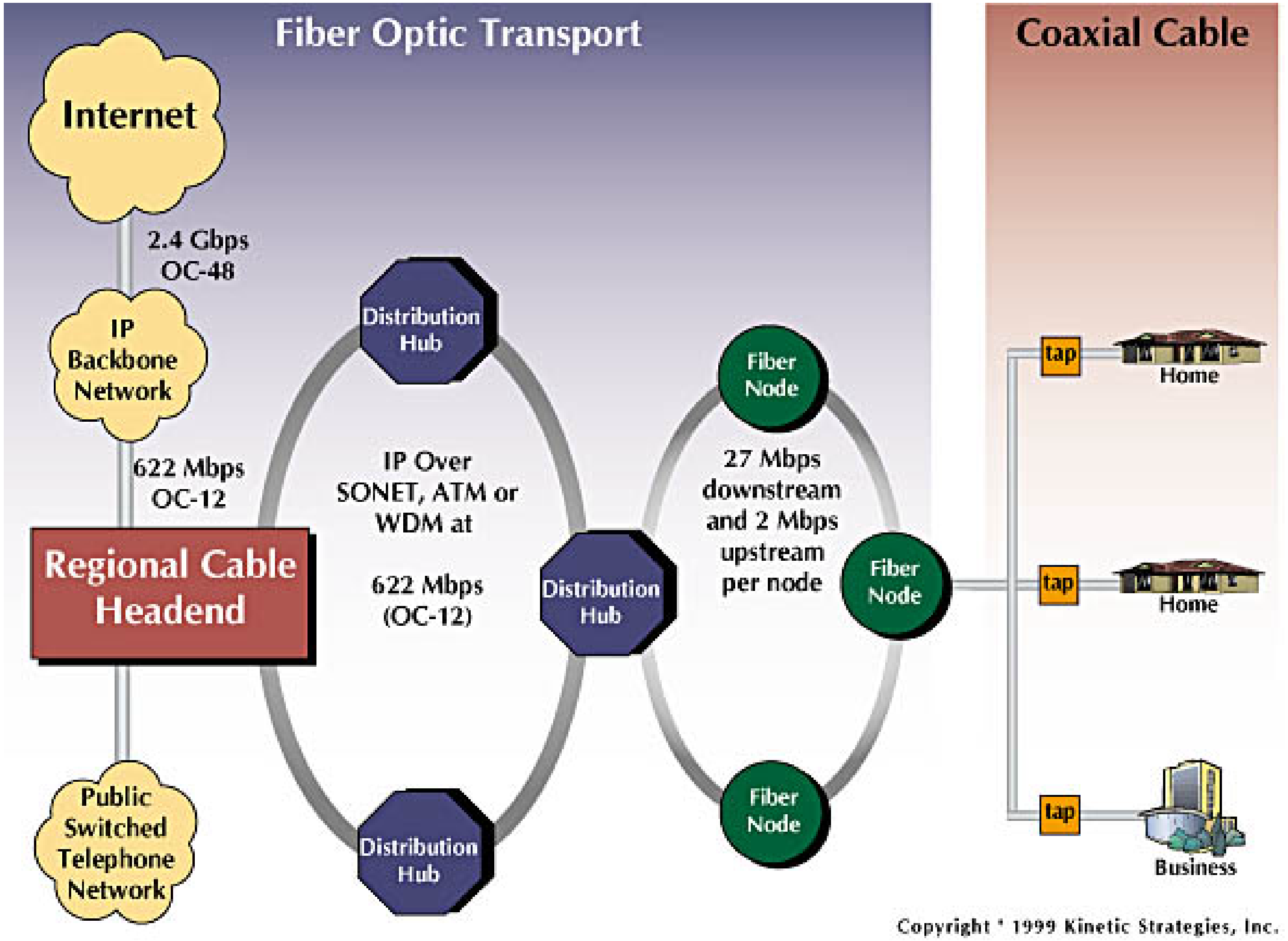
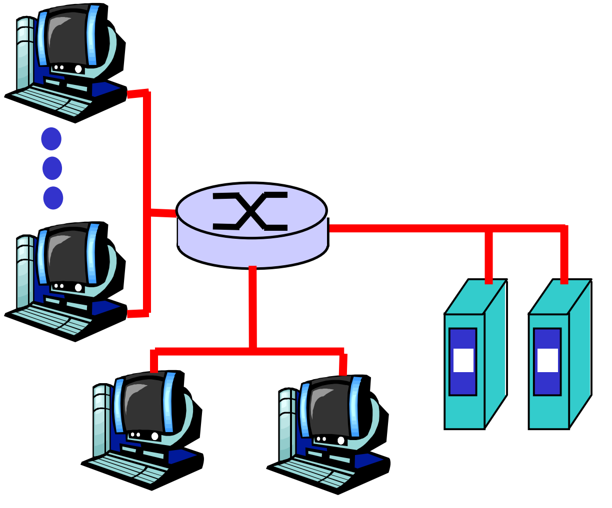


Diagram: http://www.cabledatacomnews.com/cmic/diagram.html

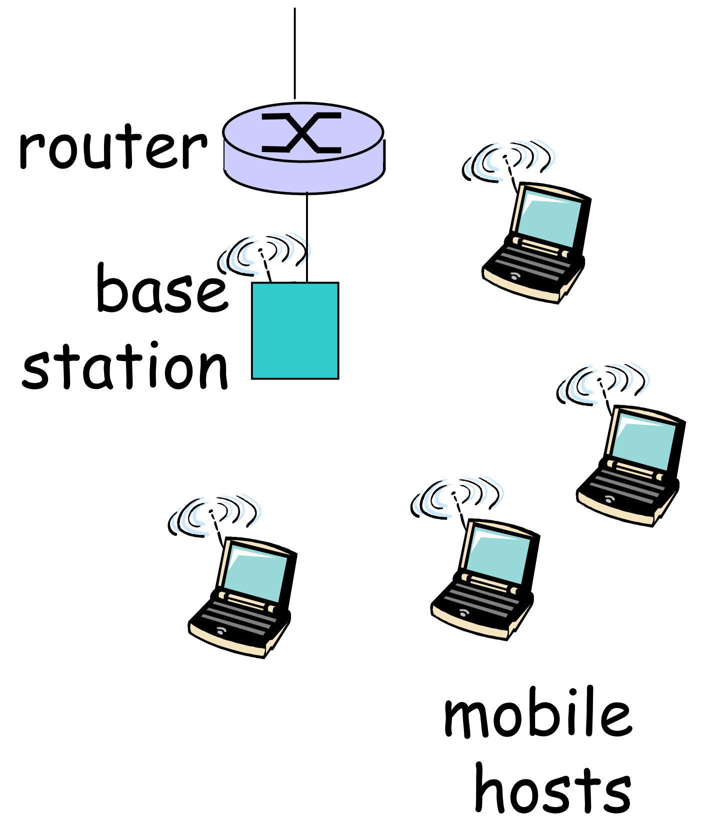
Institutional access: local area networks

- Company/univ local area network (LAN) connects end system to edge router
- Ethernet:
  - shared or dedicated cable connects end system and router
  - 10 Mbs, 100 Mbps, Gigabit Ethernet
- Deployment: institutions, home LANs happening now
- LANs: chapter 5



Wireless access networks

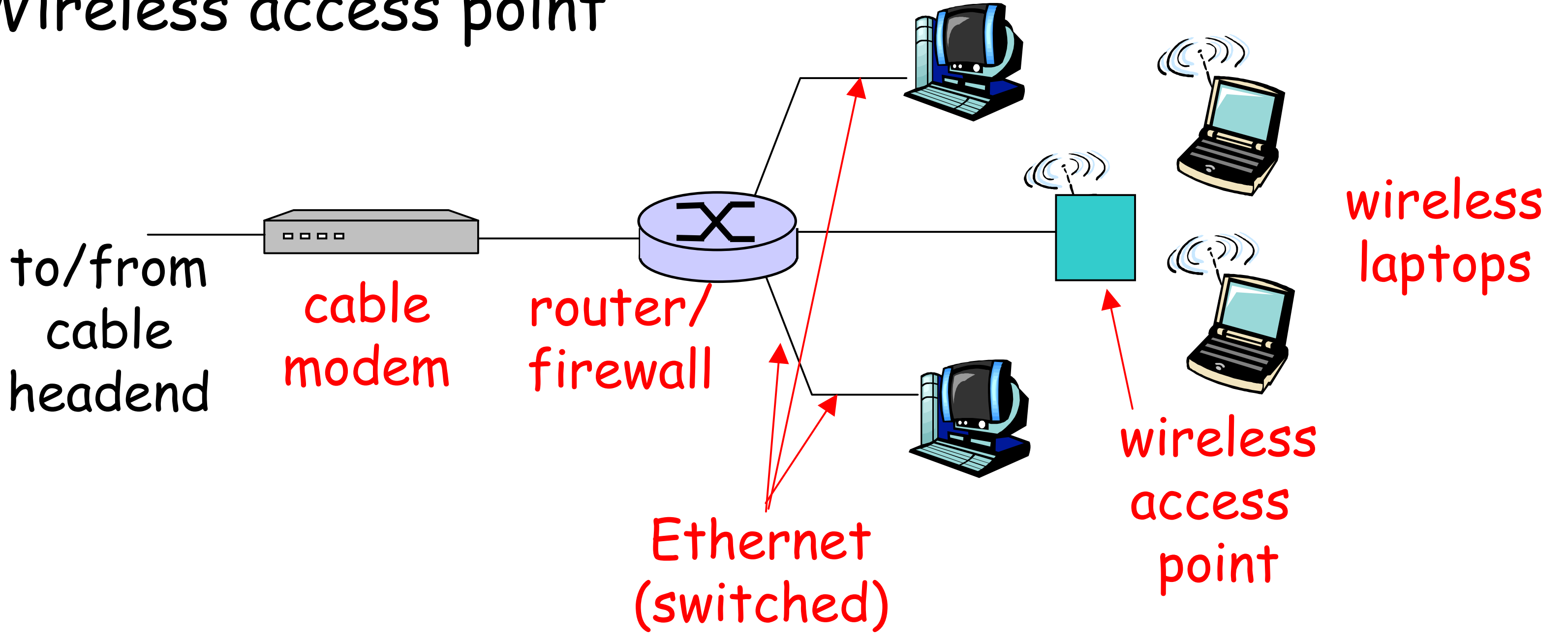
- Shared *wireless* access network connects end system to router
- Wireless LANs:
  - radio spectrum replaces wire
  - e.g., Lucent Wavelan 11 Mbps
- Wider-area wireless access
  - CDPD: wireless access to ISP router via cellular network



Home networks

Typical home network components:

- ADSL or cable modem
- Router/firewall
- Ethernet
- Wireless access point



Physical media

- Physical link: transmitted data bit propagates across link
- Guided media:
  - signals propagate in solid media: copper, fibre
- Unguided media:
  - signals propagate freely, e.g., radio

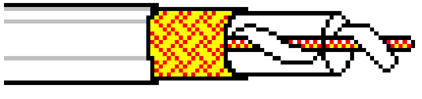
Twisted Pair (TP)

- Two insulated copper wires
  - Category 3: traditional phone wires, 10 Mbps Ethernet
  - Category 5 TP: 100 Mbps Ethernet

Physical media: coax, fibre

Coaxial cable:

- Wire (signal carrier) within a wire (shield)
  - baseband: single channel on cable
  - broadband: multiple channel on cable
- Bidirectional
- Common use in 10 Mbs Ethernet



Fibre optic cable:

- Glass fibre carrying light pulses
- High-speed operation:
  - 100 Mbps Ethernet
  - high-speed point-to-point transmission (e.g., 5 Gps)
- Low error rate

Physical media: radio

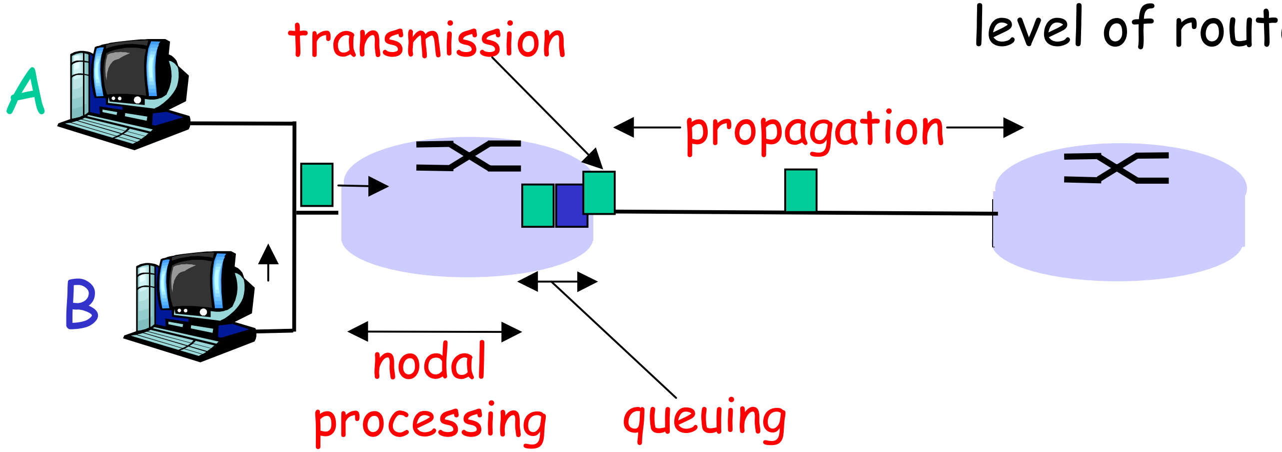
- Signal carried in electromagnetic spectrum
- No physical 'wire'
- Bidirectional
- Propagation Environment effects:
  - reflection
  - obstruction by objects
  - interference

Radio link types:

- Microwave
  - e.g. up to 45 Mbps channels
- LAN (e.g., WaveLAN)
  - 2 Mbps, 11 Mbps
- Wide-area (e.g. cellular)
  - e.g. CDPD, 10's Kbps
- Satellite
  - up to 50 Mbps channel (or multiple smaller channels)
  - 270 Msec end-end delay
  - geosynchronous versus LEOS

Delay in packet-switched networks (1)

- Packets experience delay on end-to-end path
- Four sources of delay at each hop
- Nodal processing:
  - check bit errors
  - determine output link
- Queuing
  - time waiting at output link for transmission
  - depends on congestion level of router



Delay in packet-switched networks (2)

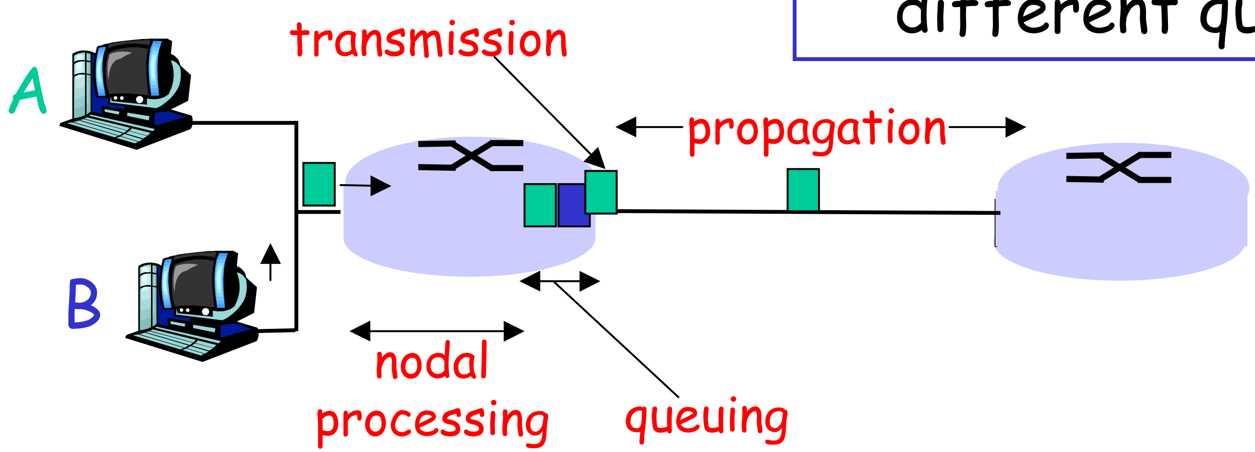
Transmission delay:

- R=link bandwidth (bps)
- L=packet length (bits)
- time to send bits into link = L/R

Propagation delay:

- d = length of physical link
- s = propagation speed in medium (~2×10^8 m/sec)
- propagation delay = d/s

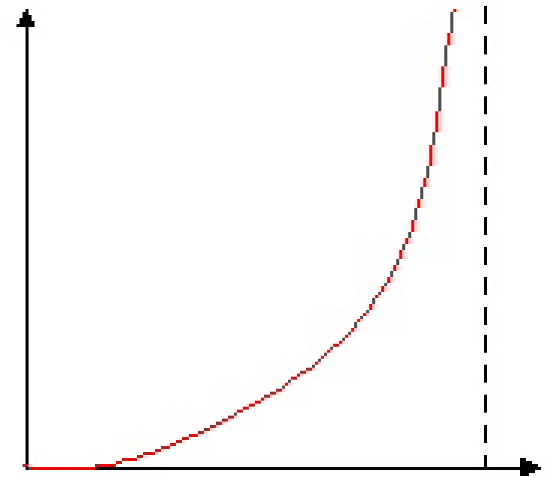
Note: s and R are *very* different quantities!



Queuing delay (revisited)

- R=link bandwidth (bps)
- L=packet length (bits)
- a=average packet arrival rate

traffic intensity = La/R



- La/R ~ 0: average queuing delay small
- La/R -> 1: delays become large
- La/R > 1: more 'work' arriving than can be serviced, average delay infinite!

'Real' Internet delays and routes

traceroute: routers, rt delays on source-dest path
also: pingplotter, various windows programs

1 cs-gw (128.119.240.254) 1 ms 1 ms 2 ms
2 border1-rt-fa5-1-0.gw.umass.edu (128.119.3.145) 1 ms 1 ms 2 ms
3 cht-vbns.gw.umass.edu (128.119.3.130) 6 ms 5 ms 5 ms
4 jn1-at1-0-0-19.wor.vbns.net (204.147.132.129) 16 ms 11 ms 13 ms
5 jn1-so7-0-0-0.wae.vbns.net (204.147.136.136) 21 ms 18 ms 18 ms
6 abilene-vbns.abilene.ucaid.edu (198.32.11.9) 22 ms 18 ms 22 ms
7 nycm-wash.abilene.ucaid.edu (198.32.8.46) 22 ms 22 ms 22 ms
8 62.40.103.253 (62.40.103.253) 104 ms 109 ms 106 ms
9 de2-1.de1.de.geant.net (62.40.96.129) 109 ms 102 ms 104 ms
10 de.fr1.fr.geant.net (62.40.96.50) 113 ms 121 ms 114 ms
11 renater-gw.fr1.fr.geant.net (62.40.103.54) 112 ms 114 ms 112 ms
12 nio-n2.cssi.renater.fr (193.51.206.13) 111 ms 114 ms 116 ms
13 nice.cssi.renater.fr (195.220.98.102) 123 ms 125 ms 124 ms
14 r3t2-nice.cssi.renater.fr (195.220.98.110) 126 ms 126 ms 124 ms
15 eurecom-valbonne.r3t2.ft.net (193.48.50.54) 135 ms 128 ms 133 ms
16 194.214.211.25 (194.214.211.25) 126 ms 128 ms 126 ms
17 * * *
18 * * *
19 fantasia.eurecom.fr (193.55.113.142) 132 ms 128 ms 136 ms

Protocol 'layers'

Networks are complex!

- Many 'pieces':
  - hosts
  - routers
  - links of various media
  - applications
  - protocols
  - hardware, software

Question:

Is there any hope of *organizing* the structure of a network?

Or at least our discussion of networks?

Internet history

1961-1972: Early packet-switching principles

- 1961: Kleinrock - queueing theory shows effectiveness of packet-switching
- 1964: Baran - packet-switching in military nets
- 1967: ARPAnet conceived by Advanced Research Projects Agency
- 1969: First ARPAnet node operational
- 1972:
  - ARPAnet demonstrated publicly
  - NCP (Network Control Protocol) first host-host protocol
  - First e-mail program
  - ARPAnet has 15 nodes

Internet history

1972-1980: Internetworking, new and proprietary nets

- 1970: ALOHAnet satellite network in Hawaii
- 1973: Metcalfe's PhD thesis proposes Ethernet
- 1974: Cerf and Kahn - architecture for interconnecting networks
- late70s: proprietary architectures: DECnet, SNA, XNA
- late 70s: switching fixed length packets (ATM precursor)
- 1979: ARPAnet has 200 nodes

Cerf and Kahn's internetworking principles:

- minimalism, autonomy - no internal changes required to interconnect networks
- best effort service model
- stateless routers
- decentralized control

define today's Internet architecture

Internet history

1980-1990: new protocols, a proliferation of networks

- 1983: deployment of TCP/IP
- 1982: smtp e-mail protocol defined
- 1983: DNS defined for name-to-IP-address translation
- 1985: ftp protocol defined
- 1988: TCP congestion control

- New national networks: Csnet, BITnet, NSFnet, Minitel
- 100,000 hosts connected to confederation of networks

Internet history

1990s: commercialization, the WWW

- Early 1990s: ARPAnet decommissioned
- 1991: NSF lifts restrictions on commercial use of NSFnet (decommissioned, 1995)
- early 1990s: WWW
  - hypertext [Bush 1945, Nelson 1960s]
  - HTML, http: Berners-Lee
  - 1994: Mosaic, later Netscape
  - late 1990s: commercialization of the WWW

Late 1990s:

- est. 50 million computers on Internet
- est. 100 million+ users
- backbone links running at 1 Gbps

Summary

Covered:

Internet overview

- What is a protocol?
- Network edge, core, access network
  - packet-switching versus circuit-switching
- Performance: loss, delay
- Layering and service models
- Backbones, NAPs, ISPs
- History

You now have:

- Context, overview, 'feel' of networking
- More depth, detail *later* in course