Lecture 5: Data Communications and Internet Technology

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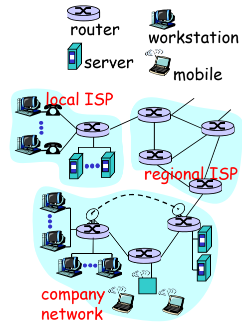
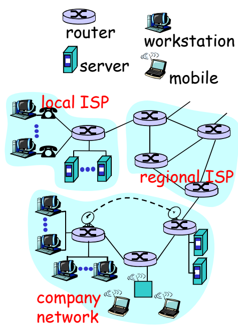
What's the Internet: "nuts and bolts" view

- 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)



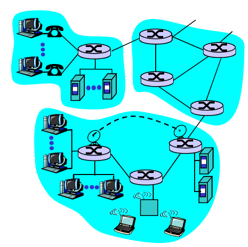
What's the Internet: "nuts and bolts" view

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



What's the Internet: a service view

- communication *infrastructure* enables distributed applications:
  - Web, email, games, e-commerce, file sharing
- communication services provided to apps:
  - Connectionless unreliable
  - connection-oriented reliable



What's a protocol?

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

… specific msgs sent

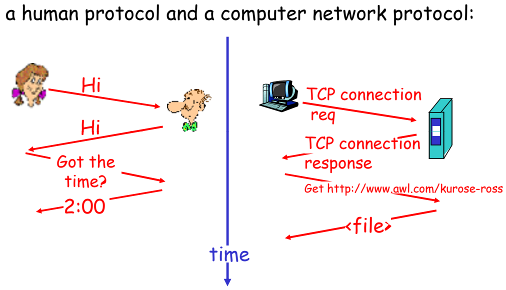
… specific actions taken when msgs received, or other events

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

What's a protocol?

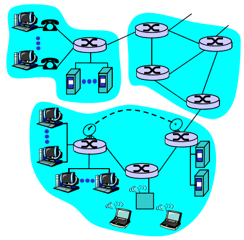
a human protocol and a computer network protocol:



Q: Other human protocols?

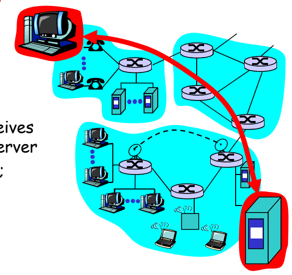
A closer look at network structure:

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



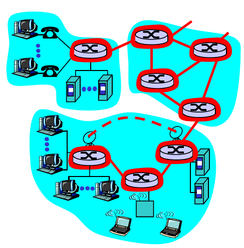
The network edge:

- 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



The Network Core

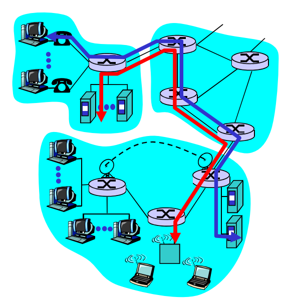
- mesh of interconnected routers
- *the* fundamental question: how is data transferred through net?
  - circuit switching: dedicated circuit per call: telephone net
  - packet-switching: data sent thru net in discrete "chunks"



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



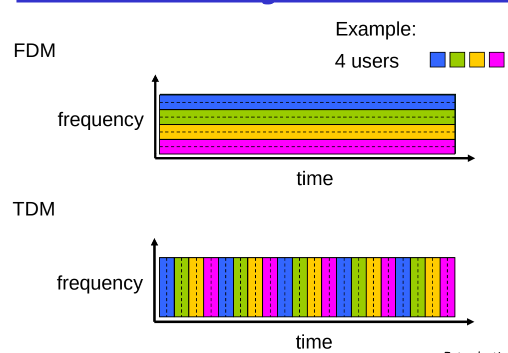
Network Core: Circuit Switching

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

Circuit Switching: FDM and TDM



Network Core: Packet Switching

each end-end data stream divided into *packets*

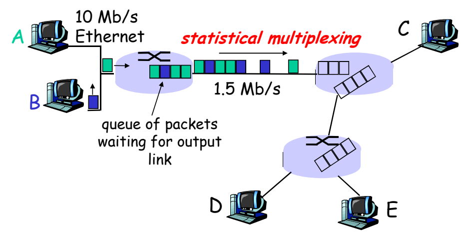
- user A, B packets *share* network resources
- each packet uses full link bandwidth
- resources used *as needed*

Bandwidth division into "pieces"
Dedicated allocation
Resource reservation

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: Statistical Multiplexing



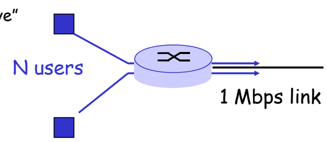
Sequence of A & B packets does not have fixed pattern ➔ ***statistical multiplexing***.

In TDM each host gets same slot in revolving TDM frame.

Packet switching versus circuit switching

Packet switching allows more users to use network!

- 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 less than .0004

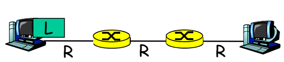


Packet switching versus circuit switching

Is packet switching a "slam dunk winner?"

- 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 (chapter 6)

Packet-switching: store-and-forward

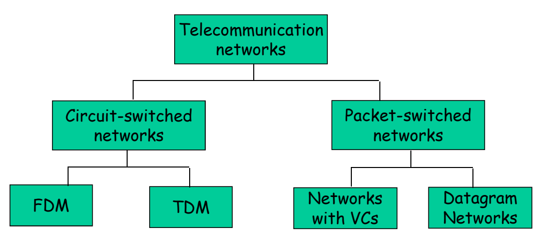


- Takes L/R seconds to transmit (push out) packet of L bits on to link or R bps
- Entire packet must arrive at router before it can be transmitted on next link: *store and forward*
- delay = 3L/R

Example:

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

Network Taxonomy



- Datagram network is *not* either connection-oriented or connectionless.
- Internet provides both connection-oriented (TCP) and connectionless services (UDP) to apps.

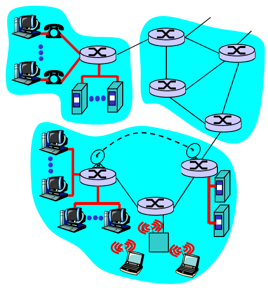
Access networks and physical media

Q: How to connect end systems to edge router?

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

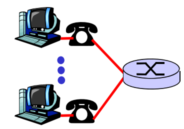
Keep in mind:

- bandwidth (bits per second) of access network?
- shared or dedicated?



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"



- ADSL: asymmetric digital subscriber line
  - up to 1 Mbps upstream (today typically < 256 kbps)
  - up to 8 Mbps downstream (today typically < 1 Mbps)
  - FDM: 50 kHz - 1 MHz for downstream
    4 kHz - 50 kHz for upstream
    0 kHz - 4 kHz for ordinary telephone

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

Residential access: cable modems

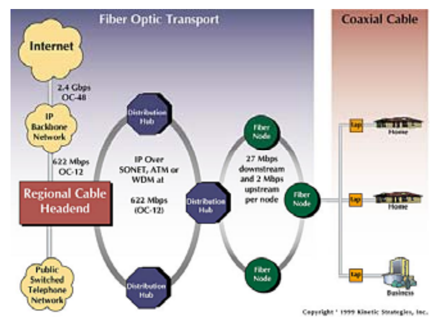
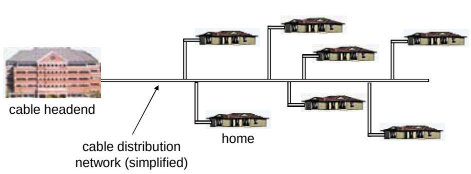


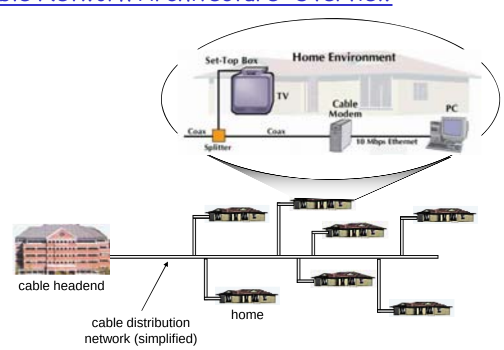
Diagram: http://www.cabledatacomnews.com/cmic/diagram.html

Cable Network Architecture: Overview

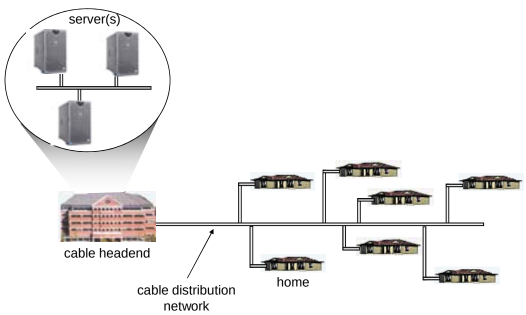
Typically 500 to 5,000 homes



Cable Network Architecture: Overview



Cable Network Architecture: Overview



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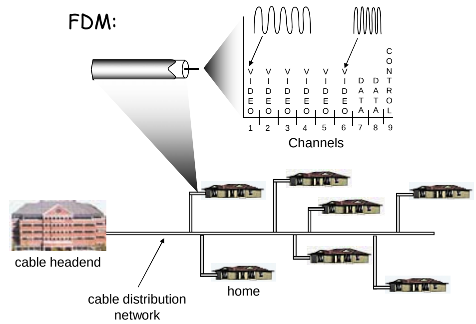
Cable Network Architecture: Overview



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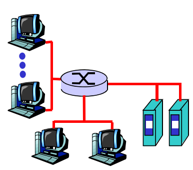
Company access: local area networks

- company/univ local area network (LAN) connects end system to edge router
- Ethernet:
  - shared or dedicated link connects end system and router
  - 10 Mbs, 100Mbps, Gigabit Ethernet
- LANs: chapter 5



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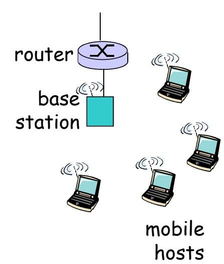
Wireless access networks

- shared *wireless* access network connects end system to router
  - via base station aka "access point"
- wireless LANs:
  - 802.11b (WiFi): 11 Mbps
- wider-area wireless access
  - provided by telco operator
  - 3G ~ 384 kbps
    - Will it happen??
  - WAP/GPRS in Europe



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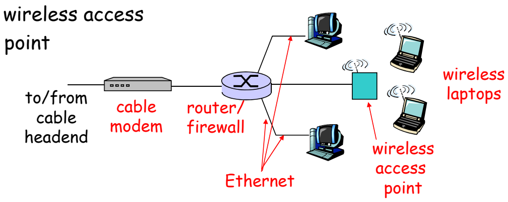
Home networks

Typical home network components:
- ADSL or cable modem
- router/firewall/NAT
- Ethernet
- wireless access point



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Physical Media

- Bit: propagates between transmitter/rcvr 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: coax, fiber

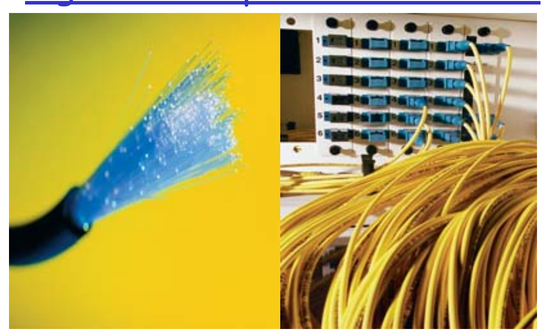
Coaxial cable:
- two concentric copper conductors
- bidirectional
- baseband:
  - single channel on cable
  - legacy Ethernet
- broadband:
  - multiple channel on cable
  - HFC

Fiber optic cable:
- glass fiber carrying light pulses, each pulse a bit
- high-speed operation:
  - high-speed point-to-point transmission (e.g., 5 Gps)
- low error rate: repeaters spaced far apart ; immune to electromagnetic noise

Figure 5-7 NIC Interface Card

Figure 5-8 Unshielded Twisted Pair (UTP) Cable

Figure 5-9 Optical Fiber Cable



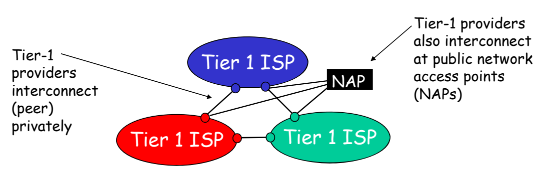
Physical media: radio

- 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
- wide-area (e.g., cellular)
  - e.g. 3G: hundreds of kbps
- satellite
  - up to 50Mbps channel (or multiple smaller channels)
  - 270 msec end-end delay
  - geosynchronous versus low altitude

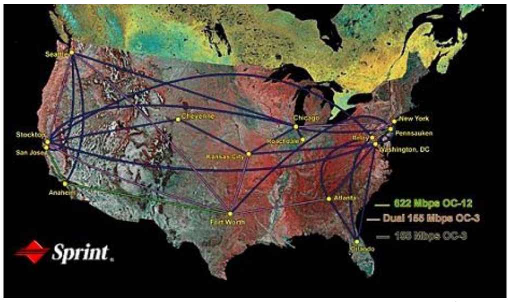
Internet structure: network of networks

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



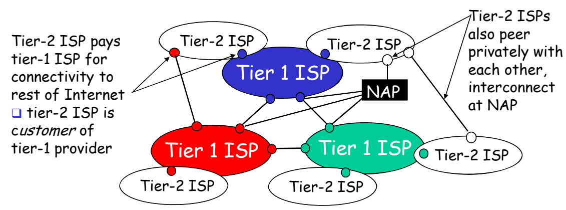
Tier-1 ISP: e.g., Sprint

Sprint US backbone network



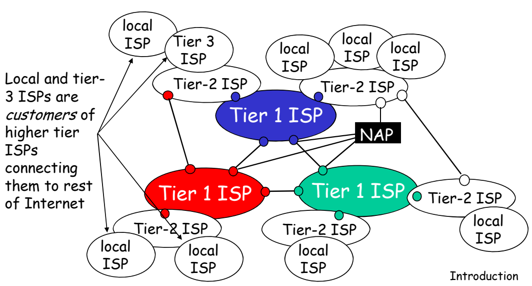
Internet structure: network of networks

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



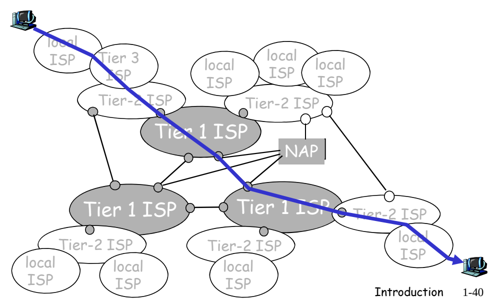
Internet structure: network of networks

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



Internet structure: network of networks

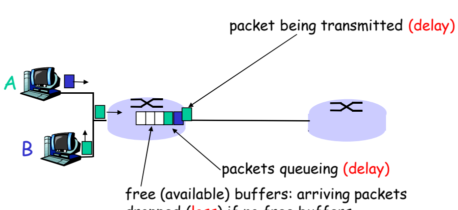
- a packet passes through many networks!



How do loss and delay occur?

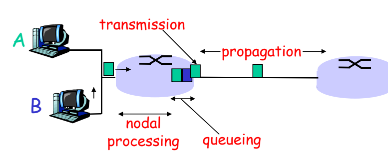
packets *queue* in router buffers

- packet arrival rate to link exceeds output link capacity
- packets queue, wait for turn



Four sources of packet delay

- 1. nodal processing:
  - check bit errors
  - determine output link
- 2. queueing
  - time waiting at output link for transmission
  - depends on congestion level of router

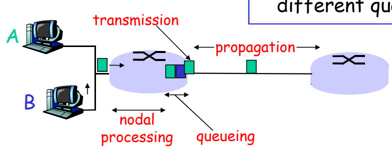


Delay in packet-switched networks

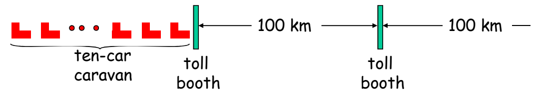
3. Transmission delay:
- R=link bandwidth (bps)
- L=packet length (bits)
- time to send bits into link = L/R

4. 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!



An Example: Caravan analogy



- Cars "propagate" at 100 km/hr
- Toll booth takes 12 sec to service a car (transmission time)
- car~bit; caravan ~ packet
- Q: How long until caravan is lined up before 2nd toll booth?
- Time to "push" entire caravan through toll booth onto highway = 12*10 = 120 sec
- Time for last car to propagate from 1st to 2nd toll both: 100km/(100km/hr)= 1 hr
- A: 62 minutes

Packet loss

- queue (aka buffer) preceding link in buffer has finite capacity
- when packet arrives to full queue, packet is dropped (aka lost)
- lost packet may be retransmitted by previous node, by source end system, or not retransmitted at all

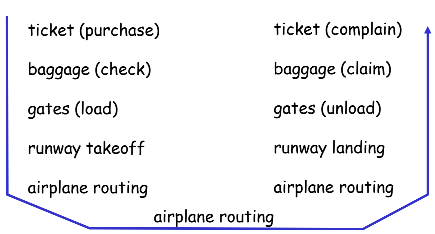
Protocol "Layers"

Networks are complex!
- many "pieces":
  - hosts
  - routers
  - links of various media
  - applications
  - protocols
  - hardware, software

Question:
Is there any hope of *organizing* structure of network?

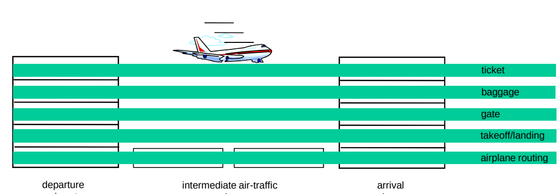
Or at least our discussion of networks?

Organization of air travel



- a series of steps

Layering of airline functionality



Layers: each layer implements a service
- via its own internal-layer actions
- relying on services provided by layer below

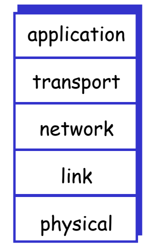
Why layering?

Dealing with complex systems:

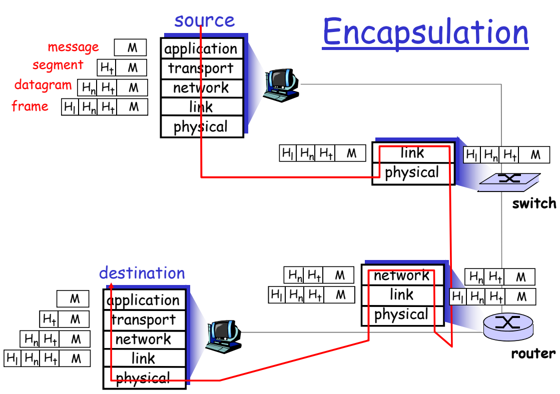
- explicit structure allows identification, relationship of complex system's pieces
  - layered reference model for discussion
- modularization eases maintenance, updating of system
  - change of implementation of layer's service transparent to rest of system
  - e.g., change in gate procedure doesn't affect rest of system
- layering considered harmful?

Internet protocol stack

- application: supporting network applications
  - FTP, SMTP, STTP
- transport: host-host data transfer
  - TCP, UDP
- network: routing of datagrams from source to destination
  - IP, routing protocols
- link: data transfer between neighboring network elements
  - PPP, Ethernet
- physical: bits "on the wire"

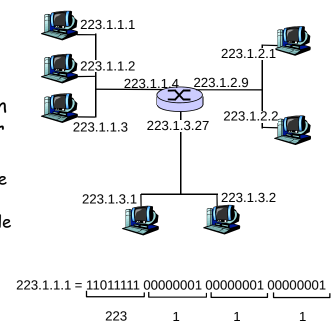


Encapsulation



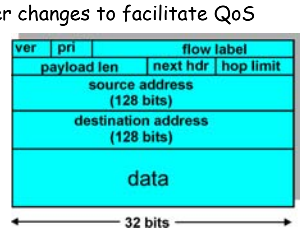
IP Addressing: introduction

- IP address: 32-bit identifier for host, router *interface*
- *interface:* connection between host/router and physical link
  - router's typically have multiple interfaces
  - host may have multiple interfaces
  - IP addresses associated with each interface



IPv6

- Initial motivation: 32-bit address space soon to be completely allocated.
- Additional motivation:
  - header format helps speed processing/forwarding
  - header changes to facilitate QoS



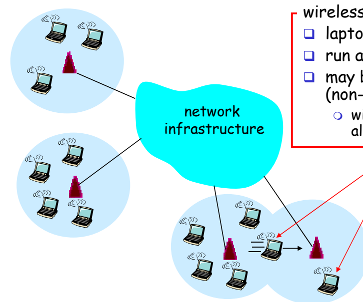
MAC Addresses and ARP

- 32-bit IP address:
  - *network-layer* address
  - used to get datagram to destination IP subnet
- MAC (or LAN or physical or Ethernet) address:
  - 48 bit MAC address (for most LANs) burned in the adapter ROM

LAN Address (more)

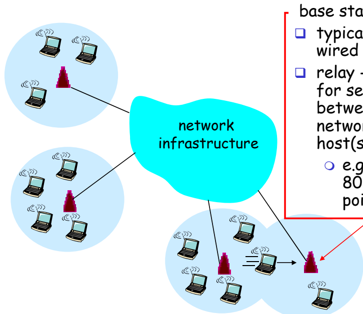
- MAC address allocation administered by IEEE
- manufacturer buys portion of MAC address space (to assure uniqueness)
- Analogy:
  - (a) MAC address: like Social Security Number
  - (b) IP address: like postal address
- MAC flat address ➜ portability
  - can move LAN card from one LAN to another
- IP hierarchical address NOT portable
  - depends on IP subnet to which node is attached

Elements of a wireless network



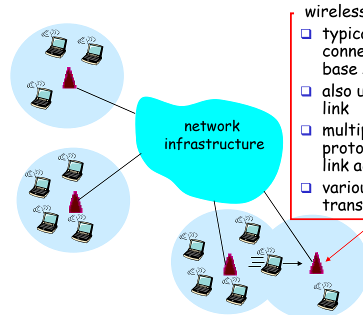
wireless hosts
- laptop, PDA, IP phone
- run applications
- may be stationary (non-mobile) or mobile
  - wireless does *not* always mean mobility

Elements of a wireless network



base station
- typically connected to wired network
- relay - responsible for sending packets between wired network and wireless host(s) in its "area"
  - e.g., cell towers 802.11 access points

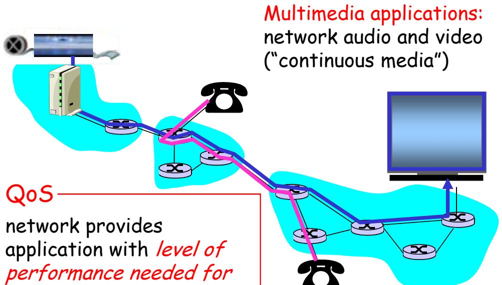
Elements of a wireless network



wireless link
- typically used to connect mobile(s) to base station
- also used as backbone link
- multiple access protocol coordinates link access
- various data rates, transmission distance

Multimedia, Quality of Service: What is it?

Multimedia applications: network audio and video ("continuous media")



QoS
network provides application with *level of performance needed for application to function.*

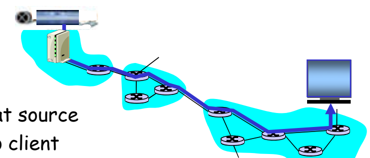
MM Networking Applications

Classes of MM applications:
1) Streaming stored audio and video
2) Streaming live audio and video
3) Real-time interactive audio and video

Jitter is the variability of packet delays within the same packet stream

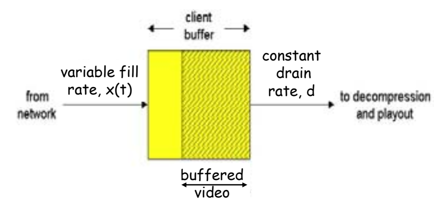
Fundamental characteristics:
- Typically **delay sensitive**
  - end-to-end delay
  - delay jitter
- But **loss tolerant**: infrequent losses cause minor glitches
- Antithesis of data, which are loss intolerant but delay tolerant.

Streaming Stored Multimedia



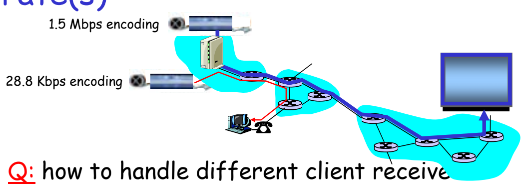
Streaming:
- media stored at source
- transmitted to client
- streaming: client playout begins *before* all data has arrived
  - timing constraint for still-to-be transmitted data: in time for playout

Streaming Multimedia: Client Buffering



- Client-side buffering, playout delay compensate for network-added delay, delay jitter

Streaming Multimedia: client rate(s)



Q: how to handle different client receive rate capabilities?
- 28.8 Kbps dialup
- 100Mbps Ethernet

A: server stores, transmits multiple copies of video, encoded at different rates

What is network security?

Confidentiality: only sender, intended receiver should "understand" message contents
- sender encrypts message
- receiver decrypts message

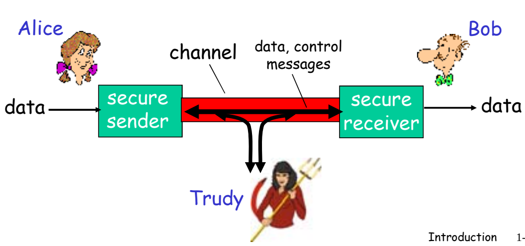
Authentication: sender, receiver want to confirm identity of each other

Message Integrity: sender, receiver want to ensure message not altered (in transit, or afterwards) without detection

Access and Availability: services must be accessible and available to users

Friends and enemies: Alice, Bob, Trudy

- well-known in network security world
- Bob, Alice (lovers!) want to communicate "securely"
- Trudy (intruder) may intercept, delete, add messages



There are bad guys (and girls) out there!

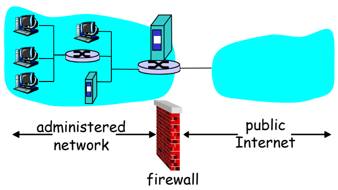
Q: What can a "bad guy" do?

A: a lot!
- *eavesdrop:* intercept messages
- actively *insert* messages into connection
- *impersonation:* can fake (spoof) source address in packet (or any field in packet)
- *hijacking:* "take over" ongoing connection by removing sender or receiver, inserting himself in place
- *denial of service*: prevent service from being used by others (e.g., by overloading resources)

more on this later ……

Firewalls

firewall
isolates organization's internal net from larger Internet, allowing some packets to pass, blocking others.



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Firewalls: Why

prevent denial of service attacks:
- SYN flooding: attacker establishes many bogus TCP connections, no resources left for "real" connections.

prevent illegal modification/access of internal data.
- e.g., attacker replaces CIA's homepage with something else

allow only authorized access to inside network (set of authenticated users/hosts)

two types of firewalls:
- application-level
- packet-filtering

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Virtual Private Network

- **Virtual private network (VPN)** is the fourth WAN alternative.
- A VPN uses the Internet or a private internet to create the appearance of private point-to-point connections.
- A VPN uses the public Internet to create the appearance of a private connection.
- A connection called a **tunnel**, is a virtual pathway over a public or shared network from the VPN client to the VPN server.

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Virtual Private Network (Continued)

- VPN communications are secure.
  - The VPN client software *encrypts*, or codes, the original messages so that its contents are hidden.
- Virtual private networks offer the benefit of point-to-point leased lines, and they enable remote access, both by employees and by any others who have been registered with the VPN server.

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Figure 5-18 Remote Access Using VPN: Actual Connections

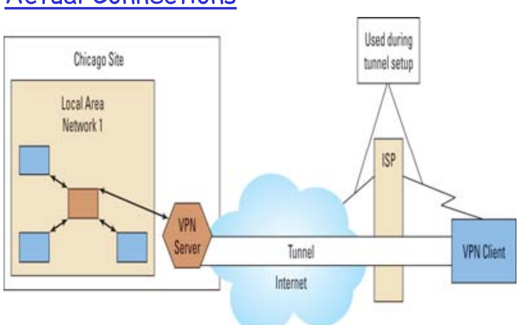

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Figure 5-19 Remote Access Using VPN: Apparent Connection

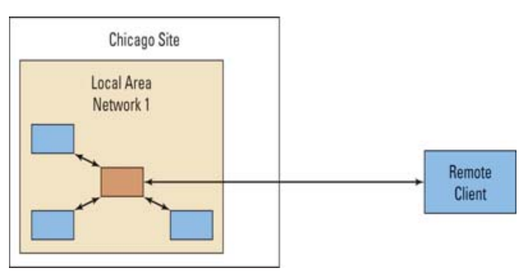

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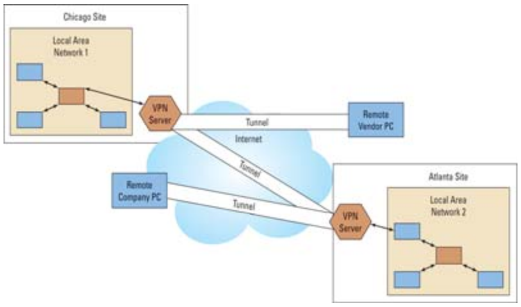
Figure 5-20 Wide Area Network Using VPN



Criteria for Comparing Network Alternatives

- Many different computer networking alternatives are available, each with different characteristics.
- There are three types of costs that need to be considered.
  - *Setup costs* include the costs of acquiring transmission lines and necessary equipment, such as switches, routers, and access devices.
  - *Operational costs* include lease fees for lines and equipment, charges of the ISP, the cost of ongoing training, etc.
  - *Maintenance costs* include those for periodic maintenance, problem diagnosis and repair, and mandatory upgrades.

Criteria for Comparing Network Alternatives (Continued)

- There are six considerations with regard to performance:
  - Speed
  - Latency
  - Availability
  - Loss rate
  - Transparency
  - Performance guarantees
- Other criteria to consider when comparing network alternatives include the growth potential (greater capacity) and the length of contract commitment.

Figure 5-21 Criteria for Comparing Networking Alternatives

Criteria Category	Criteria	Description
Cost	Initial setup	Transmission line Equipment Setup fees Setup labor Training costs
	Operational	Line lease fees Equipment lease fees ISP and other service fees Ongoing training
	Maintenance	Periodic maintenance costs Problem diagnosis and repair costs Mandatory upgrade costs
Performance	Speed	Line and equipment speed
	Latency	Delays during busy periods
	Availability	Frequency of service outage
	Loss rate	Frequency retransmission required
	Transparency	User involvement in operation
	Performance guarantees?	Vendors agree to cost penalties if levels of service not met
Other	Growth potential	How difficult to upgrade when service needs or capacity increase?
	Commitment periods	Length of leases and other agreements
	Management time	How much management activity is required?
	Financial risk	How much is at stake if system not effective?
	Technical risk	If using new technology, likelihood of failure

Domain Name System

- IP addresses are useful for computer-to-computer communication, but they are not well suited for human use.
- The purpose of the **domain name system (DNS)** is to convert user-friendly names into their IP addresses.
- Any registered, valid name is called a **domain name.**
- The process of changing a name into its IP address is called *resolving the domain name.*
- Every domain name must be unique, worldwide.
- To ensure duplicate domain names do not occur, an agency registers names and records the corresponding IP addresses in a global directory.

Domain Name Registration

- ICANN is a nonprofit organization that is responsible for administering the registration of domain names.
- ICANN does not register domain names itself; instead it licenses other organizations to register names.
- ICANN is also responsible for managing the *domain name resolution system.*
- The last letter in any domain name is referred to as the **top-level-domain (TLD).**
  - In the domain www.icann.org the top level domain is *.org*

Domain Name Resolution (Continued)

- A uniform resource locator (URL) is a document's address on the Web.
- URLs begin with a domain and then are followed by optional data that locates a document with that domain.
  - Thus, in the URL *www.prenhall.com/kroenke* , the domain name is www.prenhall.com , and */kroenke* is a directory within that domain.

Domain Name Resolution (Continued)

- **Domain name resolution** is the process of converting a domain name into a public IP address.
- The process starts from the TLD and works to the left across the URL.
- As of 2005, ICANN manages 13 special computers called **root servers that are distributed around the world.**
- Each root server maintains a list of IP addresses of servers that each resolve each type of TLD.

Domain Name Resolution (Continued)

- Domain name resolution proceeds quickly because there are thousands of computers called **domain name resolvers** that store the correspondence of domain names and IP addresses
  - These resolvers reside at ISPs, academic institutions, large companies, government organizations, etc.
  - For example, if a domain name solver is on your campus and whenever anyone on your campus needs to resolve a domain name, that resolver will store, or **cache**, the domain name and IP address on a local file.
    - When someone else on the campus needs to resolve the same domain name, the resolver can supply the IP address from the local file.

Figure 5-25 Top-Level Domains, 2005

TLD	Introduced	Purpose	Sponsor/Operator
.aero	2001	Air-transport industry	Societe Internationale de Telecommunications Aeronautiques SC (SITA)
.biz	2001	Businesses	
.com	1995	Unrestricted (but intended for commercial registrants)	VeriSign, Inc.
.coop	2001	Cooperatives	DotCooperation, LLC
.edu	1995	United States educational institutions	EDUCAUSE
.gov	1995	United States government	U.S. General Services Administration
.info	2001	Unrestricted use	Afilias, LLC
.int	1998	Organizations established by international treaties between governments	Internet Assigned Numbers Authority
.mil	1995	United States military	U.S. DoD Network Information Center
.museum	2001	Museums	Museum Domain Management Association (MuseDoma)
.name	2001	For registration by individuals	Global Name Registry, LTD
.net	1995	Unrestricted (but intended for network providers, etc.)	VeriSign, Inc.
.org	1995	Unrestricted (but intended for organizations that do not fit elsewhere)	Public Interest Registry; Global Registry Services
.pro	2002	Accountants, lawyers, physicians, and other professionals	RegistryPro, LTD

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
- late70's: proprietary architectures: DECnet, SNA, XNA
- late 70's: 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

1990, 2000's: commercialization, the Web, new apps

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

Late 1990's – 2000's:

- more killer apps: instant messaging, P2P file sharing
- network security to forefront
- est. 50 million host, 100 million+ users
- backbone links running at Gbps

Introduction: Summary

Covered a "ton" of material!

- Internet overview
- what's a protocol?
- network edge, core, access network
  - packet-switching versus circuit-switching
- Internet/ISP structure
- performance: loss, delay
- layering and service models
- history

You now have:

- context, overview, "feel" of networking
- more depth, detail *to follow!*

Problem-Solving Guide–Thinking Exponentially Is Not Possible, but…

- Nathan Myhrvold, the chief scientist at Microsoft Corporation during the 1990s, once said that humans are incapable of thinking exponentially.
  - Instead, when something changes exponentially, we think of the fastest linear change we can imagine and extrapolate from there.
  - His point was that no one could then imagine how much growth there would be in magnetic storage and what we would do with it.
  - We have all witnessed exponential growth in a number of areas: Internet connection, Web pages, and the amount of data accessible on the Internet.

Problem Solving Guide–Thinking Exponentially Is Not Possible, but… (Continued)

- Every business, every organization, needs to be thinking about ubiquitous and cheap connectivity that is growing exponentially.
  - What are the new opportunities?
  - What are the new threats?
  - How will our competition react?
  - How should we position ourselves?
  - How should we respond?
- Understand that technology does not drive people to do things they're never done before, no matter how much the technologists suggest it might.

Reflection Guide–Human Networks Matter More

- The Hungarian writer, Frigyes Karinthy, came up with the idea that everyone on earth is connected to everyone else by five or six people.
  - Today, in fact with the Internet, the number may be closer to three people than five or six.
- Suppose you want to meet your university's president.
  - The president has a secretary who acts as a gatekeeper.
  - If you walk up to that secretary and say, "I'd like a half hour with President Jones," you're likely to be palmed off to some other university administrator.
  - What else can you do?

Reflection Guide–Human Networks Matter More (Continued)

- The problem with the six-degree theory, is that even though those six people do exist, we don't know who they are.
  - Even worse, we often don't know who the person is with whom we want to connect.
- Most successful professionals consistently build personal human networks.
  - They keep building them because they know that somewhere there is someone whom they need to know or will need to know.
  - They meet people at professional and social situations, collect and pass out cards, and engage in pleasant conversation (all part of a social protocol) to expand their networks.