SC/CSE 3213 Winter 2014

L1: Introduction to Communication Networks

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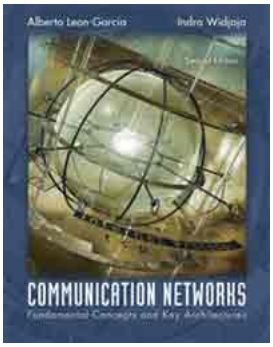
Outline

- Course texts, mark breakdown, topics
- Telegraph
  - A connectionless message-switching network
- Telephone
  - A connection-oriented circuit-switching network
- ARPANET
  - A connectionless datagram network
- Internet
  - A connectionless/connection-oriented datagram network
  - best-effort service
- Local Area Networks
  - Ethernet: connectionless protocol, medium access control

Textbook & Topics

- Textbook: Communication Networks
- Ch. 1 – 8
  1. Network Introduction (1.1-1.2)
  2. Models, Layers and Applications (2.1-2.5)
  3. Digital Information & Transmission (3.1-3.9)
  4. Data Link Protocols (5.1-5.5)
  5. Multiple Access & LANs (6.1,6.2,6.6,6.7)
  6. Packet Switching (7.1-7.5)
  7. TCP/IP Architecture (8.1-8.6)



Mark Breakdown

Component	Percentage
Assignments	10
Quizzes (3)	15
Midterm (Wed. Feb. 26)	25
Final	50

Overview

- Basic Internet operations and applications
  - structure, addressing, routing, DNS, HTTP, etc.
- Basic network principles
  - sharing, metrics, scalability
- Physical layer (communications THEORY!!!!)
  - signals, modulation, error detection, error correction, wires
- Data Link layer
  - Flow control, framing
- Medium Access Control
  - Dynamic medium control, ALOHA, Ethernet
- Network Layer
  - routing & IP
- Transport Layer
  - TCP

Telegraph

- 1850's text message service
- Tap on machine that sends voltage pulses

- A basic circuit…

Digital Communications (1850s style)

- Conceptually convert text into sequence of dots and dashes

	Morse Code		Morse Code		Morse Code		Morse Code
A	· —	J	· — — —	S	· · ·	2	· · — — —
B	— · · ·	K	— · —	T	—	3	· · · — —
C	— · — ·	L	· — · ·	U	· · —	4	· · · · —
D	— · ·	M	— —	V	· · · —	5	· · · · ·
E	·	N	— ·	W	· — —	6	— · · · ·
F	· · — ·	O	— — —	X	— · · —	7	— — · · ·
G	— — ·	P	· — — ·	Y	— · — —	8	— — — · ·
H	· · · ·	Q	— — · —	Z	— — · ·	9	— — — — ·
I	· ·	R	· — ·	1	· — — — —	0	— — — — —

Physical Signal Characteristics

- Ideal signal as a function of time

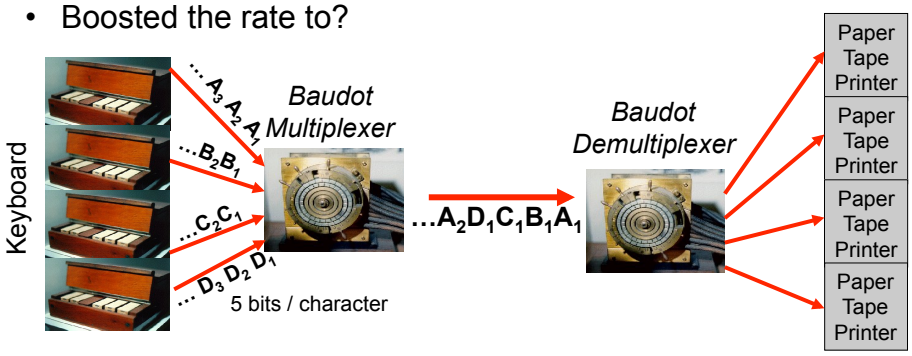
- What does it actually look like?
  - Intersymbol interfrence (ISI)

A Little Telegraph Quantification

- What was the data rate of this technology? (In bps)
  - Operators could send 30 words-per-minute (wpm)
    - Think of the dots/dashes as 1s/0s…
    - Or approximate the bits per character for constant length code

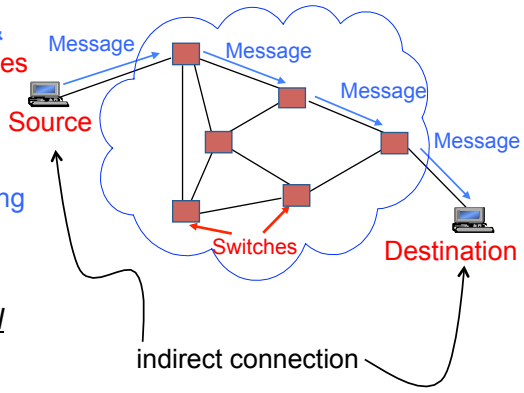
Multiplexing

- Baudot multiplexer let 5 operators use a line at the same time
- Boosted the rate to?



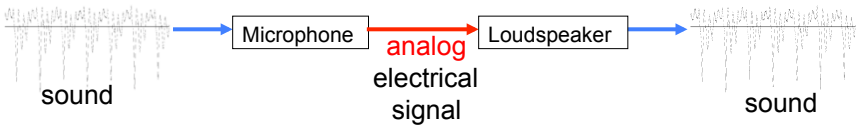
Message Switching

- "Vast" *network of stations* arose
  - Operator examines source & destination address and routes the message to next most reasonable switch
  - store-and-forward : examine message in full before sending to next node (as opposed to cut-through)
- Transmission by *occasional connections* referred to as message-switching



The Telephone

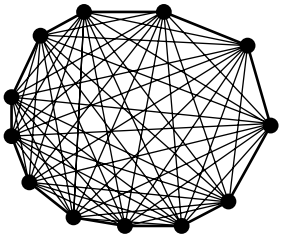
- ~ 30 years after telegraph (1876 Bell's patent)
- Direct conversion of sound pressure to an electrical analog

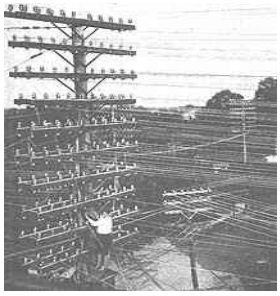


- No need for digital translation, a direct end-user service
  - Plug and play
- Rough data rate? Shannon's Theorem

The Telephone "Network"

- Originally sold in pair
  - What's the problem with this?

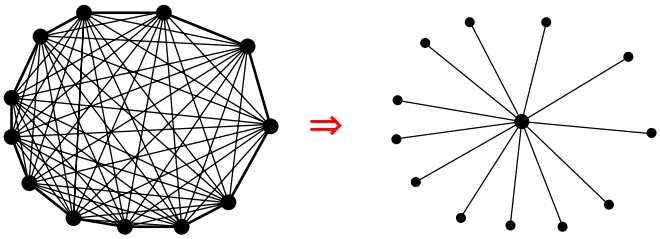




- *N* users requires *????* connections
- 1000 users ⇒ 499,500 connections

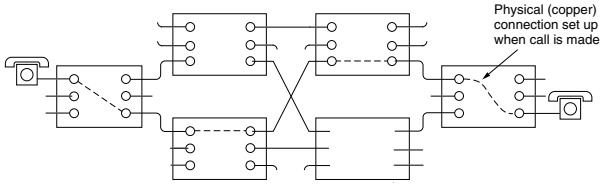
The Telephone Network

- The birth of the switching office (and *Bell Telephone Company*, 1877)…a wiring hub

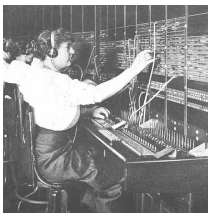


- Run a wire between the customer and the telephone company switching office
- Now only need *N* connections to central office (CO) (aka end office or local central office)

The Switch



Human Switch

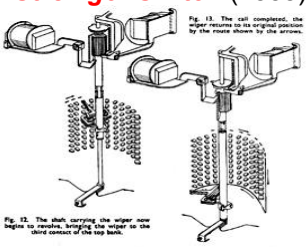


verbal instructions

Circuit Switching
(contrast with
message switching)

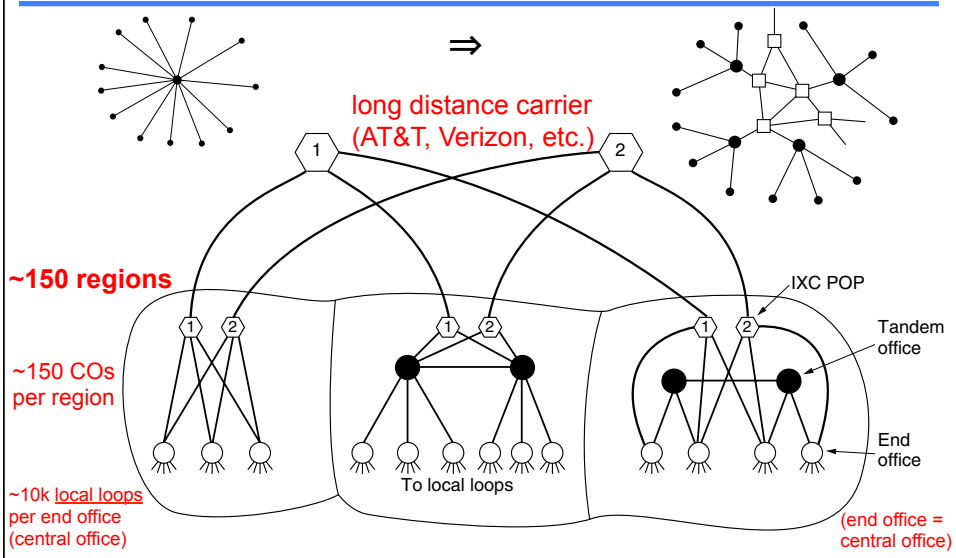
now all digital

Strowger Switch (1888)



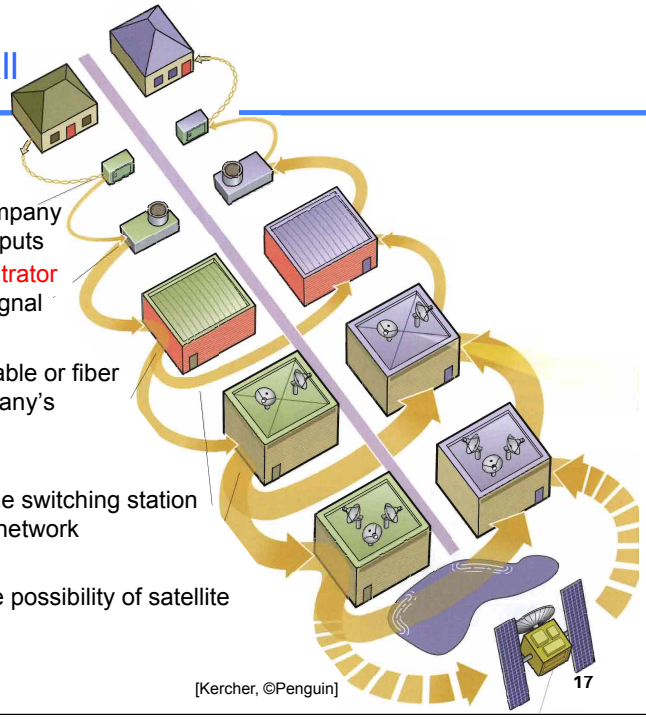
number dialed

Telephone Network Hierarchy



Path of a Call

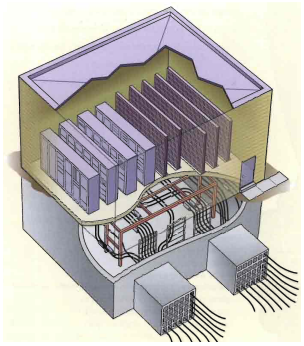
- Phone signal out on copper pair
- To local phone company box with 100s of inputs
- To a digital concentrator that digitizes the signal
- Then via coaxial cable or fiber to the phone company's switching station
- Then perhaps to the switching station of a long distance network
- And so on, with the possibility of satellite transmission



[Kercher, ©Penguin]

Switching Station

- New York has 80 for 8,000,000
  - About 100,000 lines served by a station



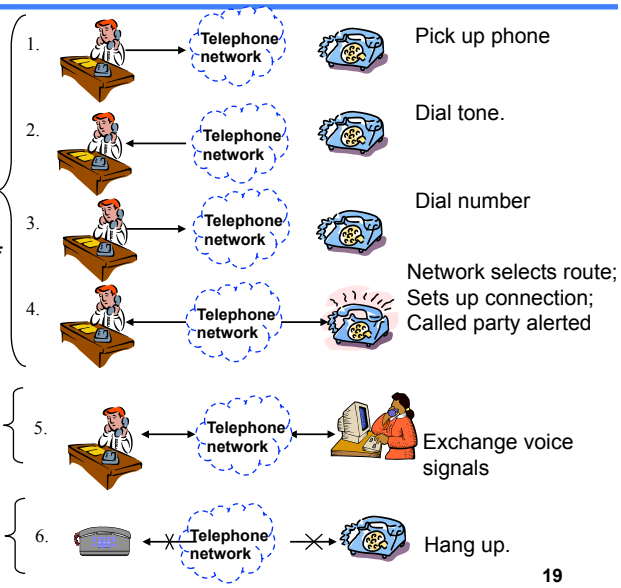
[Kercher, ©Penguin]

Three Phases of a Connection

1. Connection set up

connection oriented: *a network that establishes a connection before transmitting information*

circuit switching: *formation of dedicated path between source and destination*



2. Information transfer

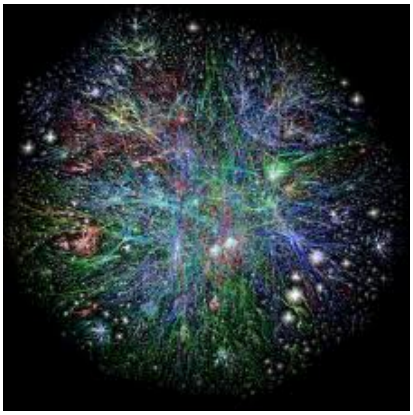
3. Connection release

Digitization of the Telephone Network

- Pulse Code Modulation
  - 64 kbps uncompressed voice signal (8-bit sample every 125 μs)
- Time Division Multiplexing (TDM)
  - Put multiple signals on the trunk
  - T1 carrier method sends a signal from one of 24 messages every 125 us
  - (24*8+1)/125 us = 1.544 Mbps
- Digital Switching (no analog conversion)
  - No need to go back to analog at switch
- Optical Transmission
  - 10^{12} bps!!!

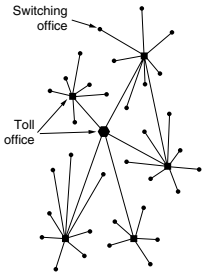
Internet

- An internetwork
- Multi-tiered, decentralized organization
- A network of computers
  - Powerful processing at network edge
  - Move communication complexity towards the edge
  - Develop sophisticated protocols

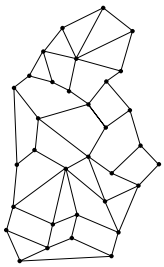


Telephone vs. Internet

Public Switched Telephone Network (PSTN)



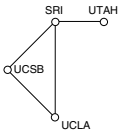
Distributed Switching System



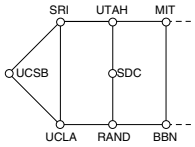
- U.S. military dependent on PSTN in 50's
- Easy to cripple by taking out switching centers
- RAND Corp. (Paul Baran) proposes a distributed network
- AT&T rejected the idea when asked to build prototype

ARPANET

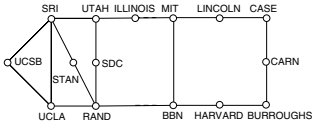
- RAND idea implemented in late 60's as network of computers between research centers



Dec. '69

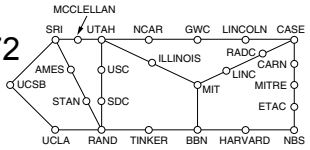


July '70

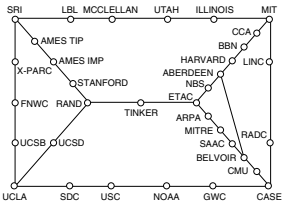


Mar. '71

Apr. '72



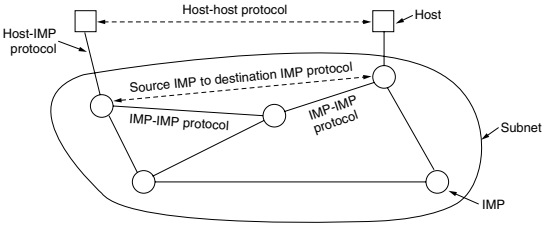
Sept. '72

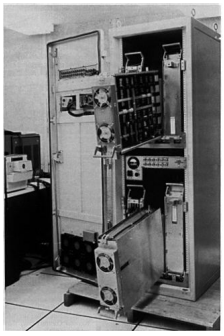


- Retired in '90 at >100 hosts
  - California - Norway

ARPANET: Basic Structure

- Nodes consisted of minicomputers connected to hosts
  - Interface Message Processors (IMPs)
- Linked by 56-kbps lines leased from telephone company





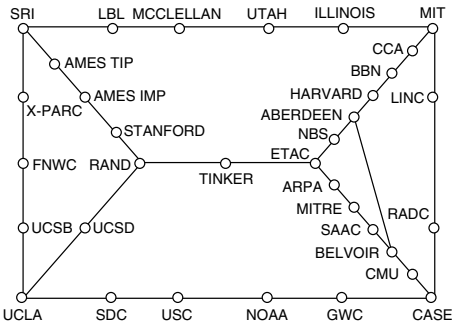
- Protocols developed for communication
  - agreement/rules on how communications are to proceed
  - IMP-IMP, S/IMP-D/IMP, Host-IMP, Host-Host

Key ARPANET Characteristics

- Datagram service (just like telegraph)
  - connectionless (contrast with connection-oriented)
  - unreliable (unacknowledged)
- Packet switched
  - messages up to 8063 bits could be sent
  - BUT…IMPs broke it up into 1008 bit (*max*) packets
- Automated routing
  - no connection setup prior to packet transmission
  - distributed routing algorithm to update routing tables
- Error control
- Congestion control
- Flow control

ARPANET Applications

- ARPANET introduced many new applications
  - Email
  - remote login
  - file transfer…

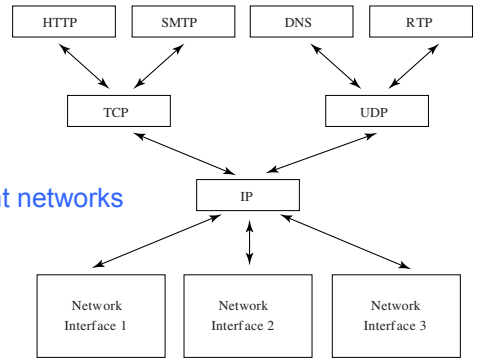


Internetworking

- ARPANET was a great WAN demonstration
  - A robust network
  - Capable of supporting a variety of applications
- But…
  - Its protocol structure did not support the merging of various networks well
  - Not an internet
  - E.g. ARPANET + packet radio + satellite performed poorly
- A reorganized design was proposed…

TCP/IP

- New set of rules proposed to enable internetworking
- Kahn & Cerf argued for common rule layer
  - Hide differences between different networks instead of translation
- The layer was eventually separated into 2 protocols
  - IP (Internet Protocol)
    - A means of getting messages moving over multiple links: **connectionless**
  - TCP (Transmission Control Protocol)
    - A means of strengthening delivery guarantees between end-points: **connection-oriented**



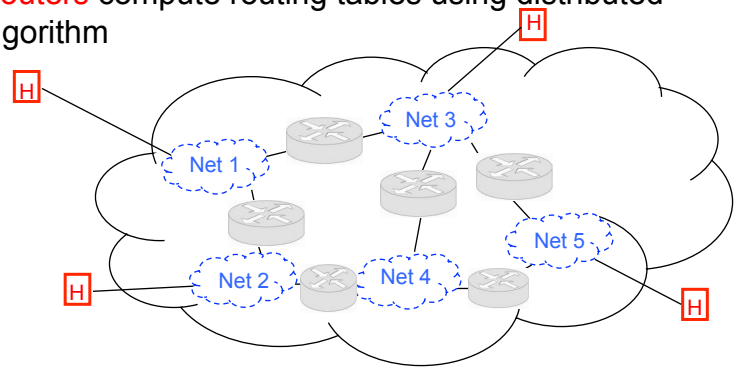
Layers & Structural Ideas

- With universally understood communication rules hosts in different types of network can talk to each other

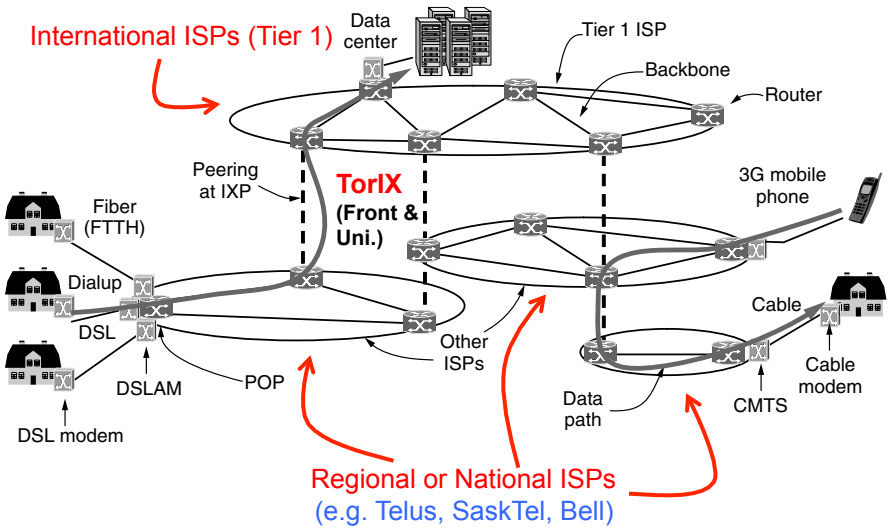
- Routers talk IP, hosts talk TCP & IP
  - Encapsulation

IP Addressing and Routing

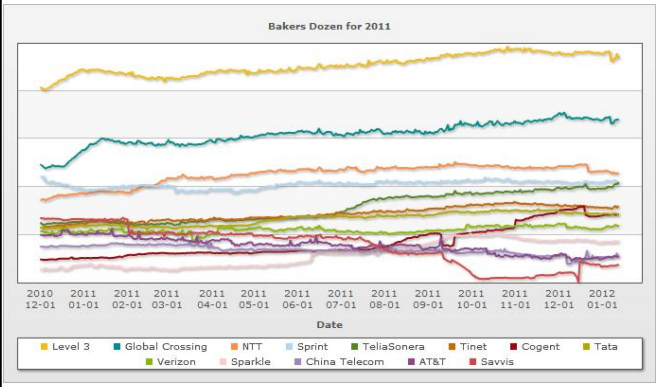
- Location based addressing
- Hierarchical address: Net ID + Host ID
- IP packets routed according to Net ID
- Routers compute routing tables using distributed algorithm



Internet Today



Tier-1 ISPs

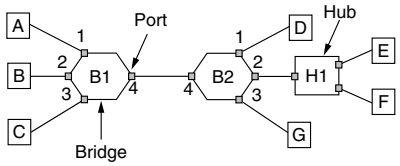


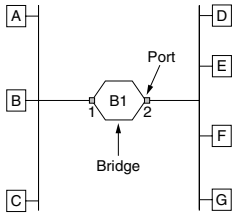
1. Level 3
2. Global Crossing
3. NTT
4. Sprint
5. TeliaSonera
6. Tinet
7. Tata
8. Cogent
9. Verizon
10. AT&T

- Google, Facebook, etc. also setting up private pathways to move data between centers

Local Area Networks

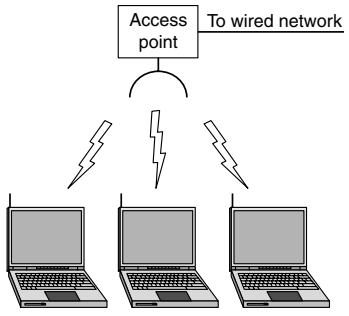
- A major component of the internet are concentrated networks of computers
  - university, business
- These simpler networks interface to the internet via routers but what happens inside?
- Basic components
  - hubs
  - bridges/switches

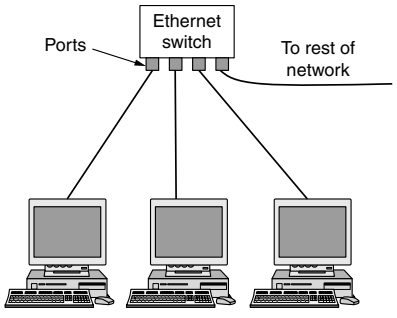




Popular LANs

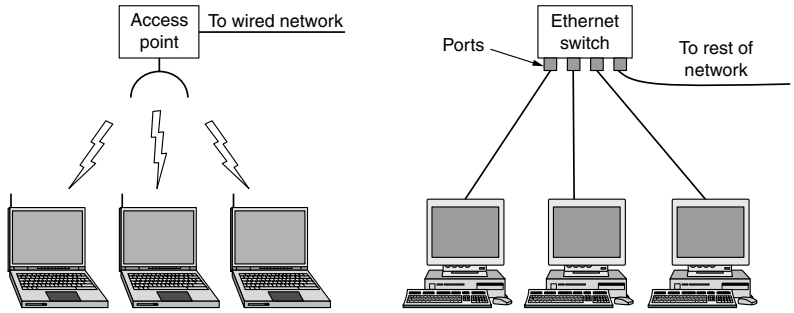
- IEEE 802.11 (WiFi) & IEEE 802.3 (Ethernet)
  - Best-effort connectionless service





Medium Access Control (MAC)

- A common challenge: communicating with multiple nodes over a shared medium
- Medium Access Controls for sharing were developed
- Example: Polling protocol on a multidrop line



LAN Addressing

- How do LANs identify themselves?
  - If they share a medium some means of identification is necessary
- Globally unique address
  - MAC address, MAC-48, physical address
  - consists of 48-bits
  - burned inside network interface card (NIC)
- How does this work with IP?
  - The layering concept

Summary of Some Network Terms

- connectionless
  - Send to source before you know that source is accepting
- connection-oriented
  - Send to source only after you hear that it is willing to accept
- packet-switching
  - Non-dedicated link to source made on fly for each chunk of message
- circuit-switching
  - Dedicated link created to source for duration of message
- best-effort service
  - not guaranteed
- datagram service
  - unacknowledged connectionless service