بسم الله الرحمن الرحيم

Information Technology Engineering

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1393

Wired and Wireless LAN, Backbone Networks

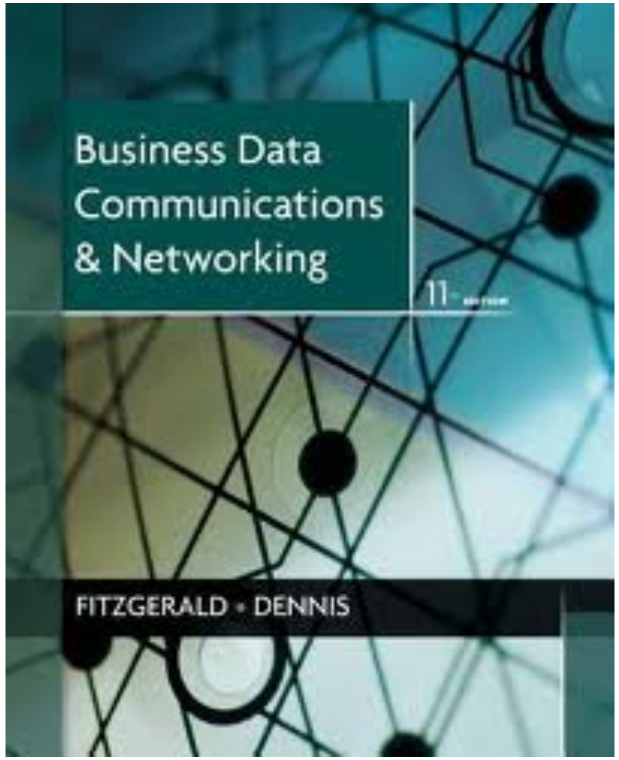
NETWORK TECHNOLOGIES

Some slides derived from those prepared for the book
"Business Data Communications and Networking,"
J. Fitzgerald and A. Dennis, John Wiley & Sons
By Prof. M. Ulema

Textbook (2)

Business Data Communications & Networking,
11th edition.
Jerry Fitzgerald and Alan Dennis
JOHN WILEY & SONS, INC. 2012

Chapter 7 (6, 8, and 9)



Chapter 6 (Business Data Communications and Networking, Fitzgerald)

WIRED AND WIRELESS LANS

Outline

6.1 Introduction

6.2 LAN Components

6.3 Wired Ethernet

6.4 Wireless Ethernet

6.5 The Best Practice LAN Design

6.6. Improving LAN Performance

Why Use a LAN

- **Information sharing**
  - Having users access the same files, exchange information via email, or use Internet
    - Ex: single purchase order database accessed by all users on the LAN
  - Results in improved decision making
- **Resource sharing**
  - Having hardware devices shared by all users
    - Printers, Internet connections
  - Having software packages shared by all users on a LAN
  - Results in reduced cost

Sharing Software on a LAN

- **Purchase software on a per seat basis**
  - Install software on a server for all to use
  - No need to have a copy on every computer on the LAN
  - Reduces cost
  - Simplifies maintenance and upgrades
  - Example
    - LAN: a 30 client network
    - Purchase only a 10-seat license for a software program (instead of purchasing 20 copies of the same program)
    - Assumes that only 10 users would simultaneously use the software

LAN Metering

- Used to control the number of copies of a software used on a LAN
- Typically comes with many software packages used on LANs
- Keeps track of the users
- Prohibits using more copies of the package than the licensed number
- Helps to minimize Copyright violations
  - 40% of SW used in the world is illegal, $40B Loss

Network Types

- **Dedicated server network**
  - – A server (computer) permanently assigned a specific task
  - – Most popular network type
    - 90% of all LANs
- **Peer-to-peer network**
  - – No dedicated servers used

Dedicated Server Networks

- **Requires one or more dedicated computers (servers)**
  - Permanently assigned a specific task (Web server, e-mail server, file server or print server)
  - Enable users to share files, printers, etc.,
  - May form a powerful enterprise network replacing mainframes
  - May form a server farm (many servers part of a network)
  - Runs a server network operating system (NOS)
    - Windows, LINUX
  - Also requires a special communication software to enable communications with client computers

Types of Dedicated Servers

- **Common Types:**
  - Web servers, e-mail servers, database servers
- **Others**
  - **File servers**
    - Allows many users to share the same files on a common disk drive
    - Typically with restricted access
  - **Print serves**
    - Handle print requests
    - Could be a separate computer or a "black box"
  - **Remote Access Servers**
    - Enable users to dial in and out of the LAN by phone (via modems)

Peer-to-Peer Networks

- Requires **no** dedicated server
  - Any computer can act as both a client or a server
- More appropriate for small networks
- **Advantage:**
  - Lower cost
    - No dedicated server, generally the most expensive network component
- **Disadvantage:**
  - Generally slower than dedicated server networks
    - Each computer may be in use as a client and a server at the same time
  - Difficult to manage

A Day in the Life: LAN Administrator

Most days start the same way. The LAN administrator arrives early in the morning before most people who use the LAN. The first hour is spent checking for problems. All the network hardware and servers in the server room receive routine diagnostics. All the logs for the previous day are examined to find problems. If problems are found (e.g., a crashed hard disk) the next few hours are spent fixing them. Next, the daily backups are done. This usually takes only a few minutes, but sometimes a problem occurs and it takes an hour.

The next step is to see if there are any other activities that need to be performed to maintain the network. This involves checking email for security alerts (e.g., Windows updates, antivirus updates). If critical updates are needed, they are done immediately. There are usually emails from several users that need to be contacted, either problems with the LAN, or requests for new hardware or software to be installed. These new activities are prioritized into the work queue.

And then the real work begins. Work activities include tasks such as planning for the next roll out of software upgrades. This involves investigating the new software offerings, identifying what hardware platforms are required to run them, and determining which users should receive the upgrades. It also means planning for and installing new servers or network hardware such as firewalls.

Of course, some days can be more exciting than others. When a new virus hits, everyone is involved in cleaning up the compromised computers and installing security patches on the other computers. Sometimes virus attacks can be fun when you see that your security settings work and beat the virus.

With thanks to Steve Bushert

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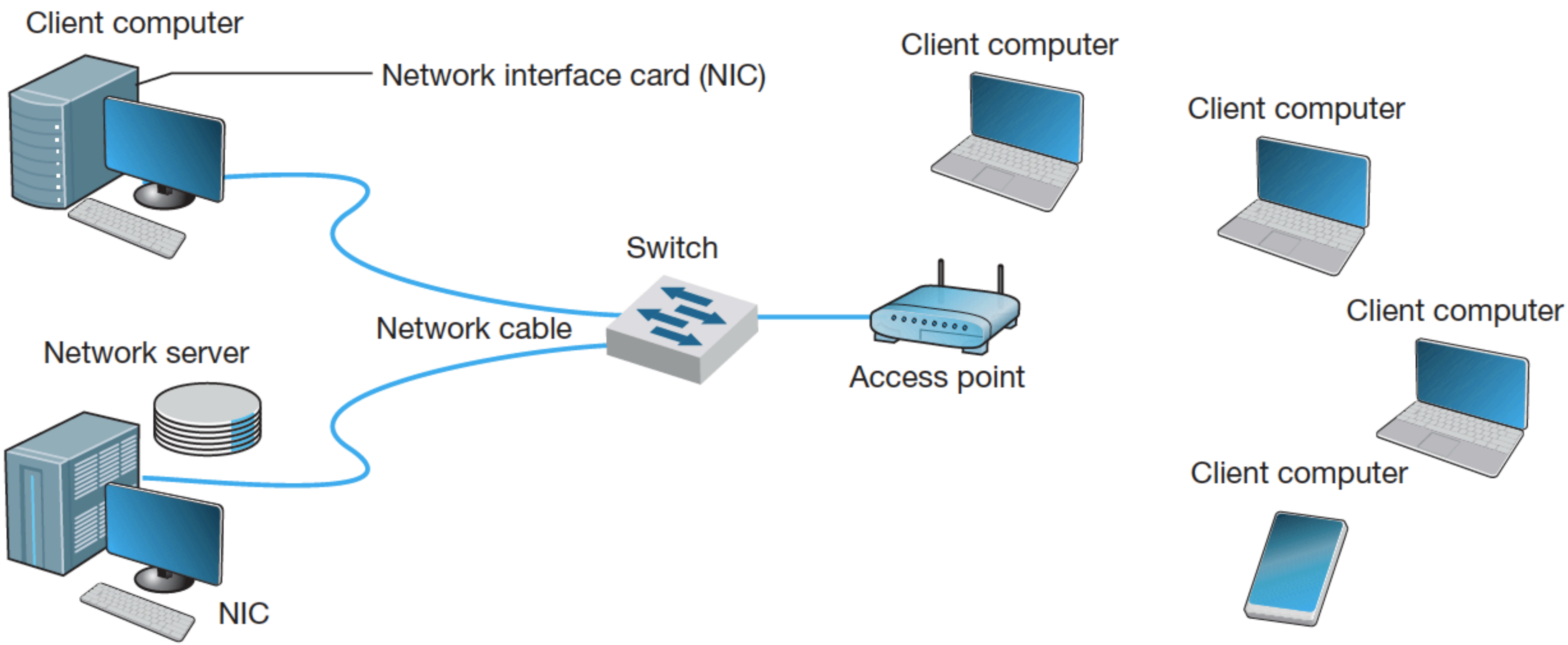
Basic LAN Components

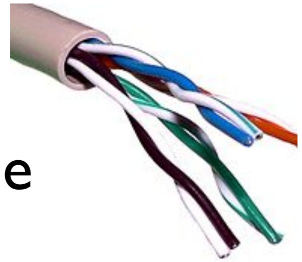


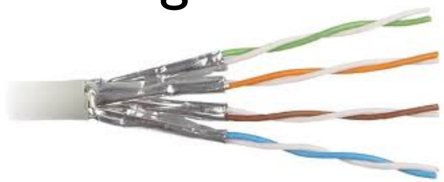
Network Interface Cards (NICs)

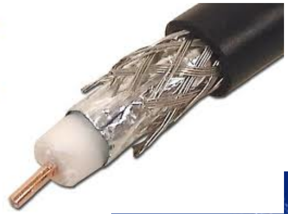
- **Contains physical and data link layer protocols**
  - Includes a unique data link layer address (called a MAC address), placed in them by their manufacturer
  - Includes a socket allowing computers to be connected to the network
  - Organizes data into frames and then sends them out on the network
- Also called network cards and network adapters

Network Cables

- Used to connect a computer physically to the network
- **Types of cables**
  - Unshielded twisted pairs (UTP) – leading LAN cable type
  - Shielded twisted pair (STP)
  - Coaxial cable – heavy, not flexible
  - Optical fiber – high capacity, just beginning in LANs







- May include multiple different types cables
  - Requires a special connector.
  - Example: BALUN (Balanced-Unbalanced) connects UTP and Coaxial Cable

Ethernet Physical Media Format

Data Rate for Medium (e.g., 10 = 10Mbps)

Broadband (analog) cable transmissions (more than one channel (e.g., cable TV))

[Value1]Base/Broad[-Value2]

Baseband Mode (only one (digital) channel)

– maximum distance possible (in 100 of meters) or

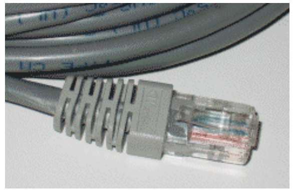
– cable type
  T= twisted pair,
  F =fiber)

Coaxial Cable Ethernets

- **10Base-5**
  - Thick Ethernet, uses thick coax
  - Original Ethernet specification
  - Capable of running 500 meters between hubs
  - Now uncommon

- **10Base-2**
  - Thin Ethernet, uses thin coax
  - Capable of running 200 meters between hubs
  - Became popular in the early 1990s as a cheaper alternative to 10Base-5
  - Now uncommon

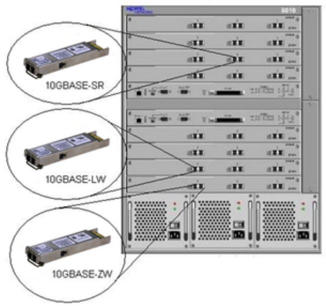
Twisted Pair Ethernets



- **10Base-T**
  - Uses Cat 3 and Cat 5 UTP, very inexpensive
  - Runs up to 100 meters
  - Common but rapidly losing ground to 100Base-T
- **100Base-T**
  - Uses Cat 5 UTP
  - Also called Fast Ethernet, replaced 10Base-T in sales volume
- **Combined 10/100 Ethernet**
  - Some segments run 10Base-T and some run 100Base-T

Fiber Optic based Ethernets

- **1000Base-T (1 GbE)**
  - Gigabit Ethernet.
  - Maximum cable length is only 100 m for UTP cat5
  - Fiber Optic based (1000Base-LX) runs up to 440 meters
- **10 GbE**
  - 10 Gbps Ethernet. Uses fiber and is typically full duplex
- **40 GbE**
  - 40 Gbps Ethernet. Uses fiber and is typically full duplex.



Summary - Ethernet Media Types

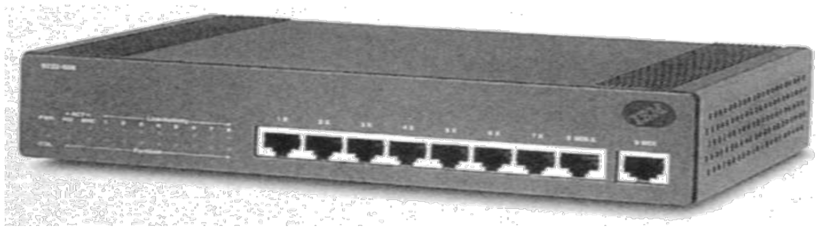
Name	Maximum Data Rate	Cables
10Base-5	10 Mbps	Coaxial
10Base-2	10 Mbps	Coaxial
10Base-T	10 Mbps	UTP cat 3, UTP cat 5
100Base-T	100 Mbps	UTP cat 5, fiber
1000Base-T	1 Gbps	UTP cat 5, UTP cat 5e, UTP cat 6, fiber
10 GbE	10 Gbps	UTP cat 5e, UTP cat 6, UTP cat 7, fiber
40 GbE	40 Gbps	fiber

Commonly Used Network Cables: With Price

Name	Type	Max Data Rate (Mbps)	Often Used By	Cost ($/foot)
Category 1	UTP	1	Modem	.04
Category 2	UTP	4	Token Ring-4	.35
Category 3	UTP	10	10Base-T	.06
Category 4	STP	16	Token Ring-16	.60
Category 5	UTP	100	100Base-T	.07
Category 5	STP	100	100Base-T	.18
Category 5e	UTP	1000	1000Base-T	.12
Category 6a	UTP	10000	10GBase-T	.18
Category 7a	STP	40000	10GBase-T	.30
RG-58	Coaxial	10	10Base-2	.20
RG-8	Coaxial	10	10Base-5	.90
X3T9.5	Fiber	100	FDDI	.35

Hubs

- Act as junction boxes, linking cables from several computers on a network
- Usually sold with 4, 8, 16 or 24 ports
- May allow connection of more than one kind of cabling, such as UTP and coax.
- **Repeat** (reconstruct and strengthen) incoming signals
  - Important since all signals become weaker with distance
  - Extends the maximum LAN segment distance



Switches

- **Uses switches (instead of hubs)**
  - Designed to support a small set of computers (16 to 24) in one LAN
  - Looks similar to a hub, but very different inside
  - Designed to support a group of point-to-point circuits
    - No sharing of circuits
- **Switch reads destination address of the frame and only sends it to the corresponding port**
  - While a hub broadcasts frames to all ports

LAN Switches

Small-Office, Home-Office (SOHO) switch with five 10/100/1000 ports

Data center chassis switch with 512 10 Gbps ports

Components of WLANs: Access Points and NICs

AP for SOHO use

A Power-Over-Ethernet AP for enterprise use

Network Interface Cards

Planning for LAN Installations

- Critically important with today's LAN explosions
- Cheapest point to install the cable:
  - During the construction of the building
  - Very expensive to add cable to existing building (Labor, construction material, etc.)
- Built-in LAN cable plan
  - Similar to power and phone lines
  - Wiring closet on each floor with LAN hubs
    - Cables from each room connected to hubs in the closet
  - Install 20-50% more cable than need (future planning)
    - If needed, simply add more hubs/switches

Network Operating Systems

- Software that controls the LAN
- Parts of NOS
  1. **Server version of NOS**
     - Runs on the network servers
  2. **Client version of NOS**
     - Runs on the client computers
  3. **Directory Service**
     - Provide information about resources on the LAN
  4. **Network Profiles**
     - Indicate the resources available in the network and authorized users

1. NOS Server Software

- **Enables servers to operate**
  - Handles all network functions
    - Performs data link, network, and application layer functions
  - Acts as the application software by executing and responding to the requests sent to them by clients
- **Replaces the normal OS on the server**
  - Optimized to provide better performance and faster response time (for its limited number of operations)
- **Examples**
  - MS Windows
  - Novell NetWare

2. NOS Client Software

- Provides data link and network layer functions
- Interacts with application software and computer's own operating system
- Included in most OS packages

3. Directory Service

- Provide information about resources on the LAN
- Active Directory Service (ADS) by Microsoft
  - Works like a DNS service
    - ADS servers (aka, domain servers) act as DNS servers as well
  - Resources organized into a tree
    - Each branch contains a domain (a group of resources)
      - A domain has a server (domain controller)
        - » Responsible for resolving address information (textual name of resource → network address)
        - » Responsible for managing authorization
    - A tree can be linked to other trees creating “forest”
  - Uses Lightweight Directory Service Protocol (LDAP) to interact with client computers

4. Network Profiles

- **Network Profiles**
  - Kept by servers
  - Specify resources available for use by other computers
    - Include data files, printers, etc.
  - Configured when the LAN is established, and updated
- **User profiles**
  - One profile for each user, used for security reasons
  - Describe what each user on a LAN has access to
  - Includes access codes assigned to devices and users
    - Only the user with a correct code can use a specific device

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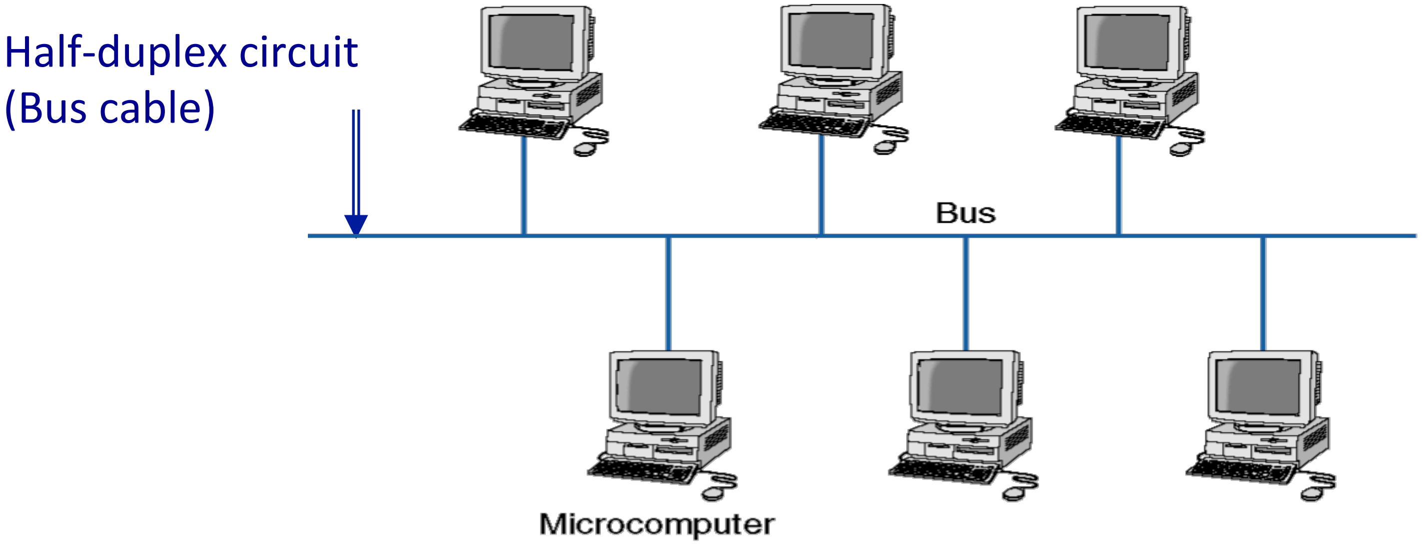
Ethernet (IEEE 802.3)

- Used by almost all LANs today
- Originally developed by a consortium of Digital Equipment Corp., Intel and Xerox
- Standardized as IEEE 802.3
- Types of Ethernet
  - Shared Ethernet
    - Uses hubs
  - Switched Ethernet
    - Uses switches

Topology

- Basic geometric layout of the network
  - The way computers on the network interconnected
- Logical Topology
  - How the network works conceptually
  - Like a logical data flow diagram (DFD) or
  - Like a logical entity relation diagram (ERD)
- Physical Topology
  - How the network is physically installed
  - Like physical DFD or physical ERD

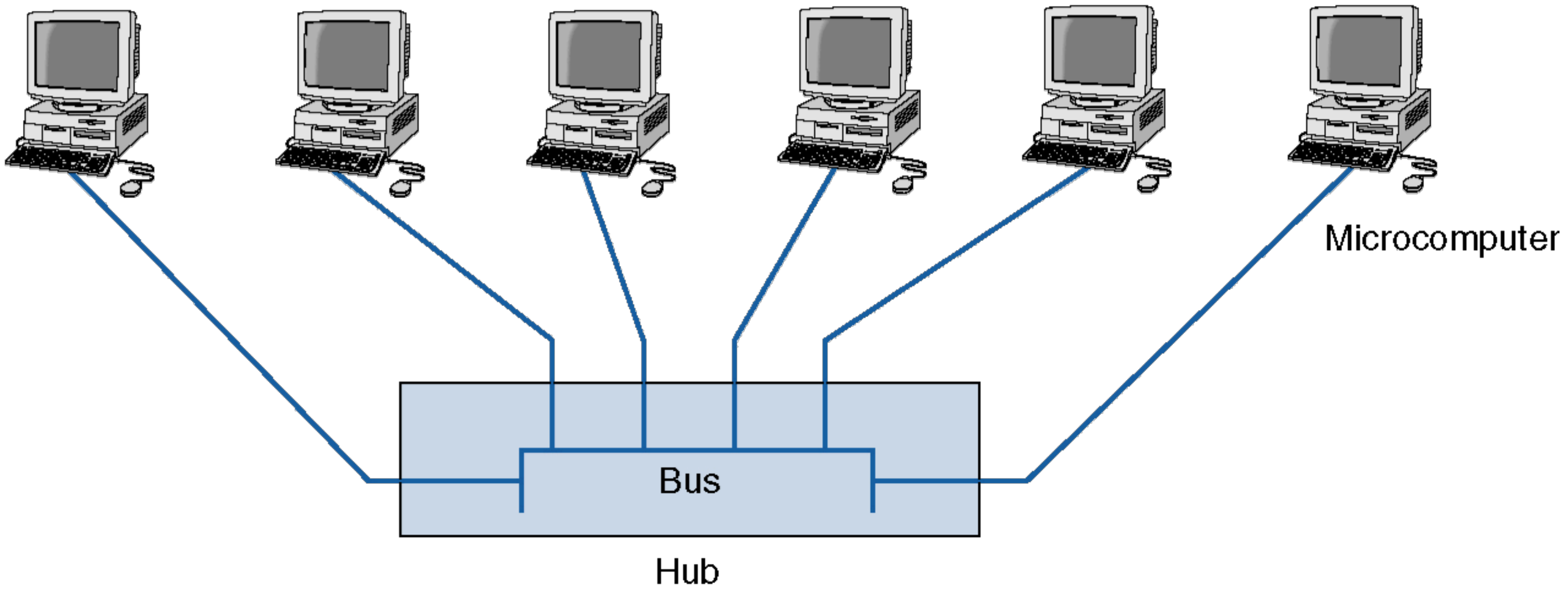
Shared Ethernet's Logical Topology



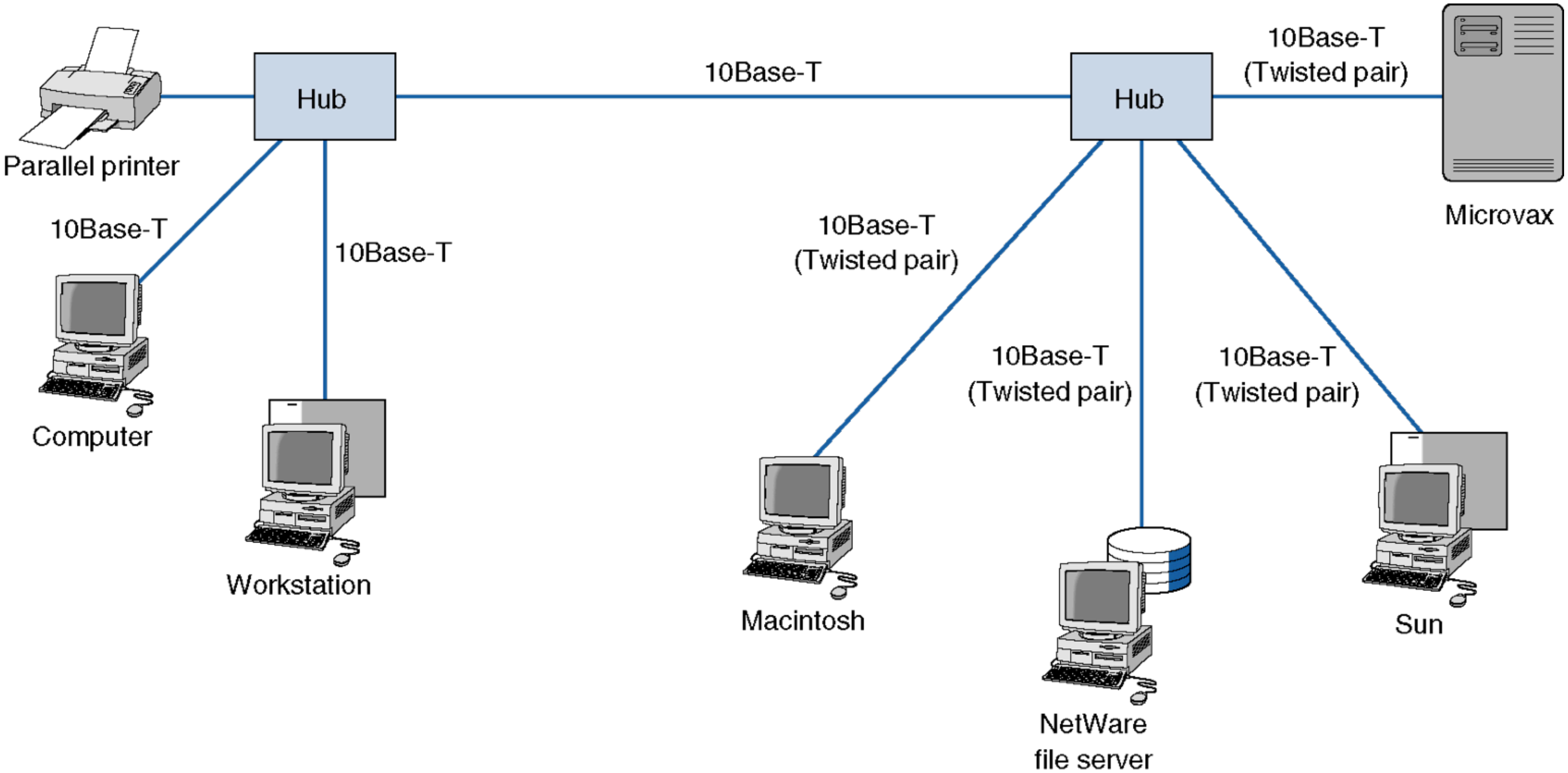
- Viewed logically as a bus topology
- All messages from any computer flow onto the central cable (bus)
  - A computer receive messages from all other computers, whether the message is intended for it or not
  - When a frame is received by a computer, the first task is to read the frame's destination address to see if the message is meant for it or not

Shared Ethernet's Physical Topology

- Appears to be a physical star topology
  - – Computers linked into the central hub



Multiple Hub Ethernet Design



Also common to link is to use multiple hubs to form more complex physical topologies.

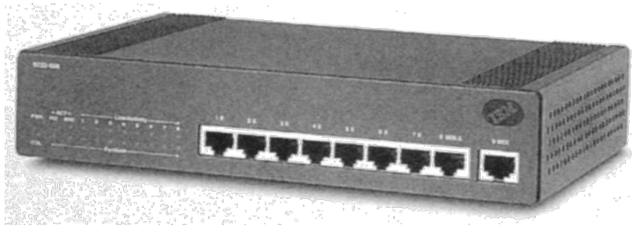
Media Access Control (MAC)

- Uses a contention-based protocol called CSMA/CD (Carrier Sense Multiple Access / Collision Detect)
  - Frames can be sent by two computers on the same network at the same time
    - They will collide and become garbled
  - Can be termed as “ordered chaos”
    - Tolerates, rather than avoids, collisions

CSMA/CD

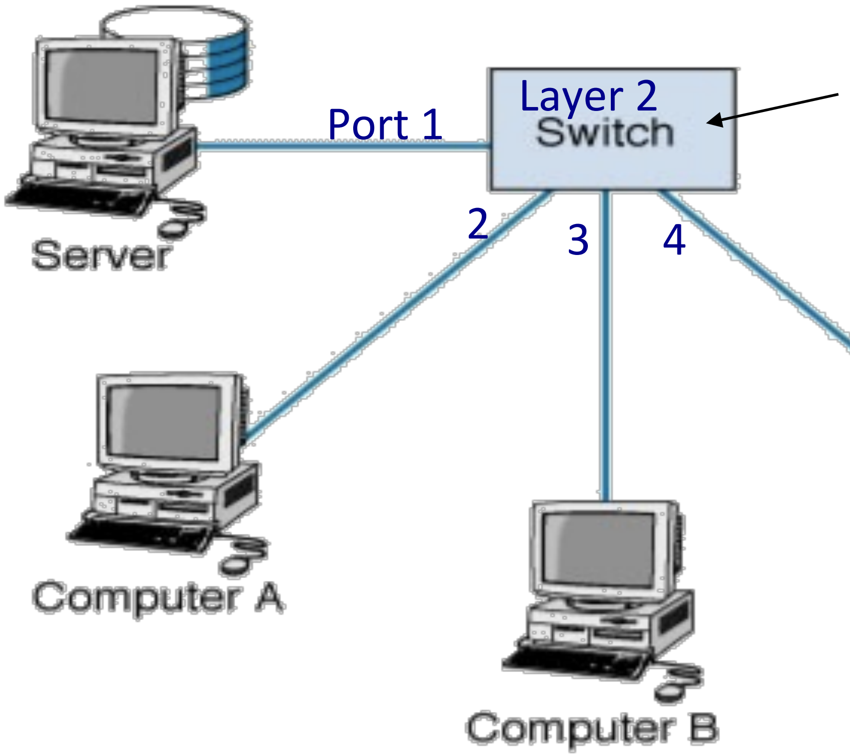
- **Carrier Sense (CS):**
  - Listen to the bus to see if another computer is transmitting
    - Before sending anything
  - Transmit when no one is transmitting
- **Multiple Access (MA):**
  - All computers have access to the network medium
- **Collision Detect (CD):**
  - Declared when any signal other than its own detected
  - If a collision is detected
    - Wait a random amount of time and then resend it
      - Must be random to avoid another collision

Switched Ethernet Topology



- **Uses switches (instead of hubs)**
  - Designed to support a small set of computers (16 to 24) in one LAN
  - Looks similar to a hub, but very different inside
  - Designed to support a group of point-to-point circuits
    - No sharing of circuits
- **Both Logical and physical topology of the network becomes a star topology**
- **Switch reads destination address of the frame and only sends it to the corresponding port**
  - While a hub broadcasts frames to all ports

Basic Switch Operation



Forwarding Table

Port	MAC Adr
1	S
2	A
3	B
4	C

Used to make forwarding decisions

When a frame is received, the switch reads its [data link layer] destination address and sends the frame out the corresponding port in its forwarding table.

Learning Switch Operation

- Switch starts by working like a hub
  - With an empty forwarding table
- It gradually fills its forwarding table by learning about the nodes
  - Reads the source MAC address of the incoming frame and records it to the corresponding port number
  - Reads the destination MAC address. If not in the Table then it broadcasts the frame to all ports
  - Waits for the destination computers to respond, and repeats the first step

Forwarding Table

Port	MAC Adr

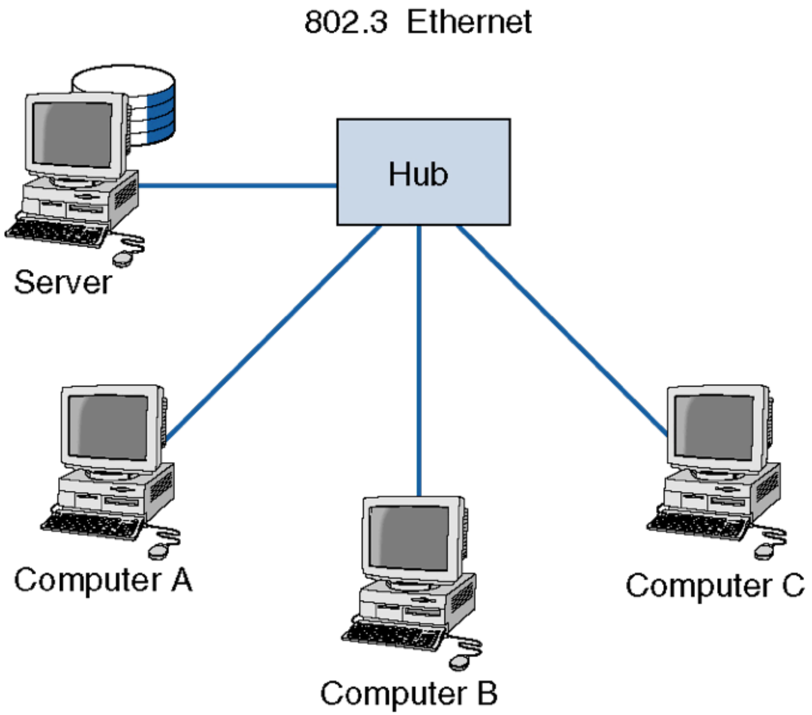
Modes of Switch Operations

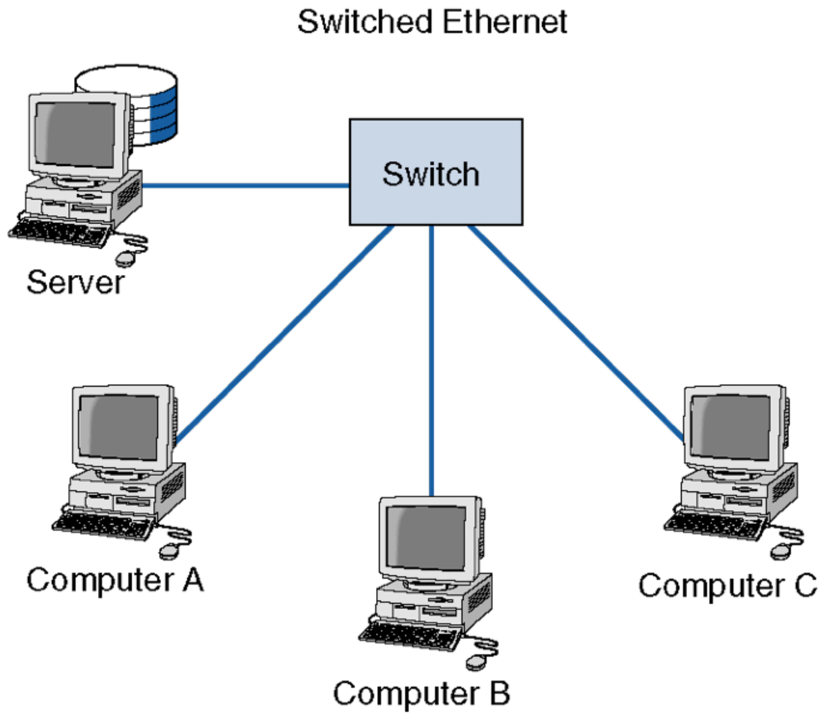
- **Cut through switching**
  - Read destination address and start transmitting
    - Without waiting for the entire message is received
  - Low latency; but may waste capacity (errorred messages)
  - Only on the same speed incoming and outgoing circuits
- **Store and forward switching**
  - Wait until the whole message is received, perform error control, and then transmit it
  - Less wasted capacity; slower network
  - Circuit speeds may be different
- **Fragment free switching**
  - Read the first 64 byte segment (contains the header)
  - Perform error check, if it is okay then start transmitting
  - Compromise between previous two modes

MAC in Switched Ethernet

- Each circuit shared by a computer and the switch
- Still CSMA/CD media access control used
  - Each device (computer or switch) listens before transmitting
- Multiple messages can be sent at the same time.
  - Computer A can send a message to computer B at the same time that computer C sends one to computer D
  - Two computers send frames to the same destination at the same time
    - Switch stores the second frame in memory until it finishes sending the first, then forwards the second

Performance Comparison





Capable of using about only 50% of capacity (10BaseT) before collisions become a problem

Runs at up to 90% capacity on 100Base-T

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Wireless LANs (WLANs)

- Use radio or infrared frequencies to transmit signals through the air (instead of cables)
- Basic Categories
  - Use of Radio frequencies (FOCUS of this chapter)
    - 802.1x family of standards (aka, Wi-Fi)
  - Use of Infrared frequencies (Optical transmission)
- Wi-Fi grown in popularity
  - Eliminates cabling
  - Facilitates network access from a variety of locations
    - Airports, cafes, restaurants, etc.,
  - Facilitates for mobile workers (as in a hospital)

Principal WLANs Technologies

- IEEE 802.11b
  - Standardization started after .11a, but finished before
- IEEE 802.11a
  - First attempt to standardization of WLANs; more complicated than .11b
- IEEE 802.11g
- IEEE 802.11n
- Bluetooth
  - Also an IEEE standard 802.15

IEEE 802.11b

- Reuses many Ethernet components
- Designed to connect easily to Ethernet
  - a.k.a., wireless Ethernet
- Also called Wi-Fi
  - Marketing ploy; sounds like Hi-Fi
- Versions of .11b
  - **Direct Sequence Spread Spectrum (DSSS)**
    - Focus of this chapter (more popular)
  - **Frequency Hopping Spread Spectrum (FHSS)**

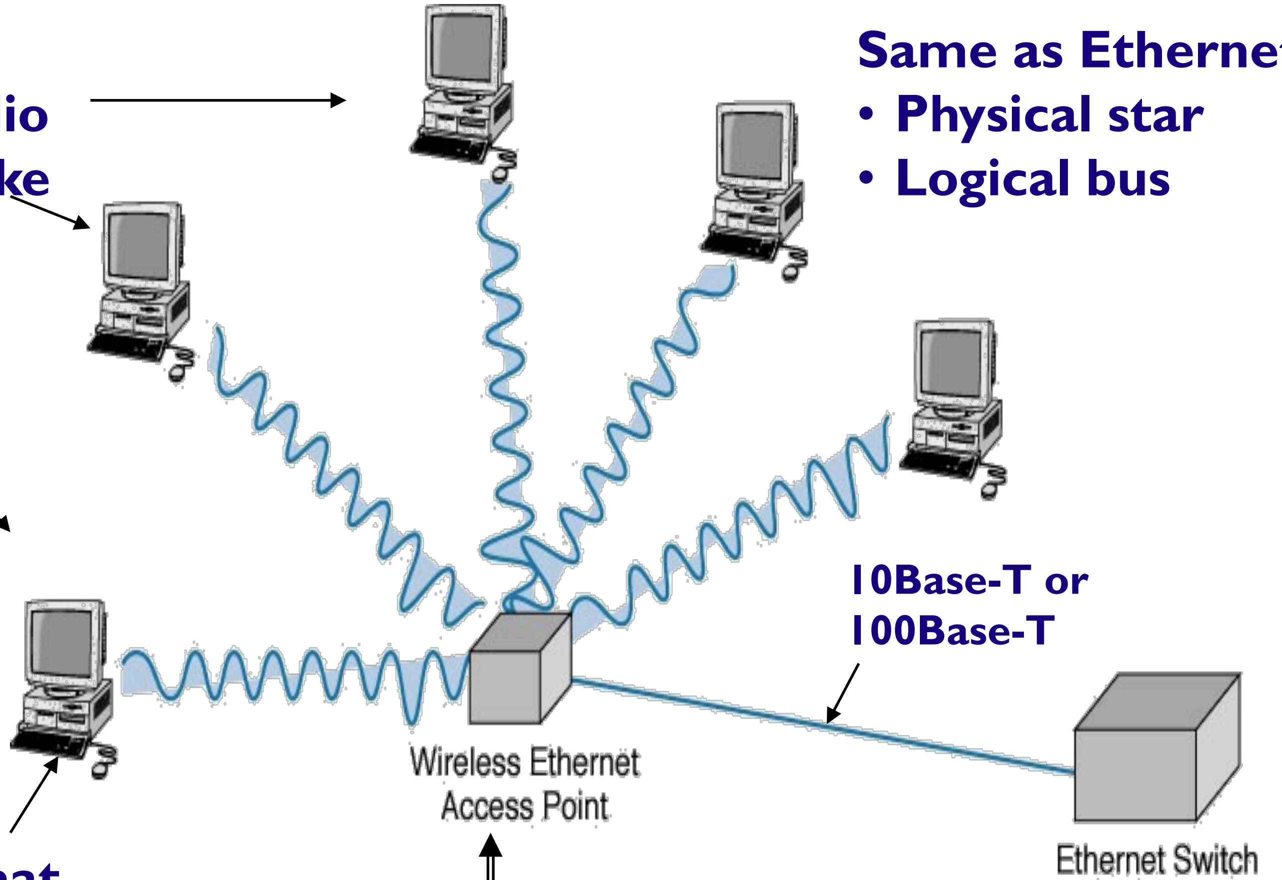
Versions of IEEE 802.11b

- **Direct Sequence Spread Spectrum (DSSS)**
  - Uses the entire frequency band to transmit information
  - Capable of data rates of up to 11 Mbps
  - Fallback rates: 5.5, 2 and 1 Mbps. (Used when interference or congestion occurs)
  - Dominates market place, because faster
- **Frequency Hopping Spread Spectrum (FHSS)**
  - Divides the frequency band into a series of channels
    - Then changes its frequency channel about every half a second, based on a pseudorandom sequence
    - More secure,
  - Only capable of data rates of 1 or 2 Mbps

WLAN Topology

Use the same radio frequencies, so take turns using the network

Same as Ethernet
- Physical star
- Logical bus



Uses a NIC that transmits radio signals to the AP

A wireless Access Point (AP) connected into an Ethernet Switch

Components of WLANs

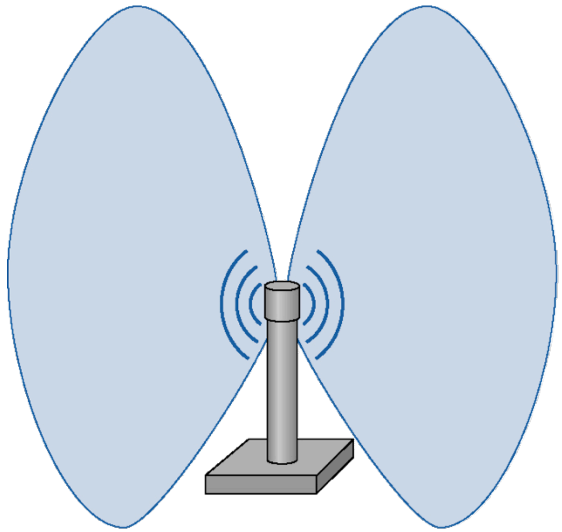
- **Network Interface Cards**
  - Available for laptops as PCMCIA cards
  - Available for desktops as standard cards
  - Many laptops come with WLAN cards built in
  - About 100-500 feet max transmission range
- **Access Points (APs)**
  - Used instead of hubs; act as a repeater
    - Must hear all computers in WLAN

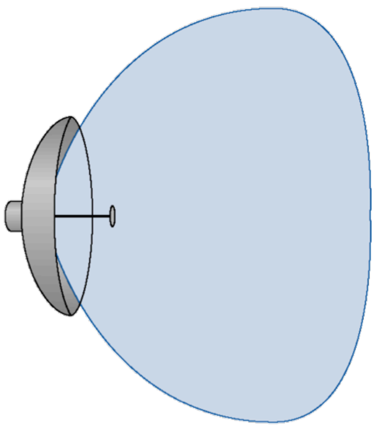
More on the APs and NICs

- **3 separate channels available for 802.11b**
  - All devices using an AP must use the same channel
    - WLAN functions as a shared media LAN
  - Reduces the interference
  - Users can roam from AP to AP
    - Initially NIC selects a channel (thus an AP)
      - Based on "strength of signal" from an AP
    - During roaming, if NIC sees another AP with a stronger signal, attaches itself to this AP
- Usually a set of APs installed to provide geographical coverage and meet traffic needs
  - NICs selects a less busy channel if its current channel becomes busy (too many users)

Antennas used in WLANs

- **Omni directional antennas**
  - Transmit in all directions simultaneously
  - Used on most WLANs
  - Dipole antenna (rubber duck)
  - Transmits in all direction (vertical, horizontal, up, down)





- **Directional antennas**
  - Project signal only in one direction
    - Focused area; stronger signal; farther ranges

WLAN Media Access Control

- **Uses CSMA/CA**
  - CA → collision avoidance
  - A station waits until another station is finished transmitting plus an additional random period of time before sending anything
- **May use two MAC techniques simultaneously**
  - **Distributed Coordination Function (DCF)**
    - Also called "Physical Carrier Sense Method"
  - **Point Coordination Function (PCF)**
    - Also called "Virtual Carrier Sense Method"
    - Optional: (can be set as "always", "never", or "just for certain frame sizes"

Distributed Coordination Function

- **Relies on the ability of computers to physically listen before they transmit**
  - When a node wants to send a message:
    - First listens to make sure that the transmitting node has finished, then
    - Waits a period of time longer
- **Each frame is sent using stop-and-wait ARQ**
  - By waiting, the listening node can detect that the sending node has finished and
  - Can then begin sending its transmission
  - ACK sent a short time after a frame is received

Point Coordination Function (PCF)

- **Solves Hidden Node problem**
  - Two computers can not detect each other's signals
    - A computer is near the transmission limits of the AP at one end and another computer is near the transmission limits at the other end of the AP's range
  - Physical carrier sense method will not work
- **Hidden Node Solution in DCF**
  - First send a Request To Send (RTS) signal to the AP
    - Request to reserve the circuit and duration
  - AP responds with a Clear To Send (CTS) signal,
    - Also indicates duration that the channel is reserved
  - Computer wishing to send begins transmitting

Message Delineation

Preamble	PLCP Header	Payload Header	LLC Protocol Data Unit	Payload Trailer

Preamble:

Sync Bytes	Start of Frame
7 or 16 bytes	2 bytes

PLCP Header:

Signal Rate	Service	Length	Header Error Check
1 byte	1 byte	2 bytes	2 bytes

Payload Header:

Frame Control	Duration ID	Destination Address	Source Address	Address 3	Sequence Control	Address 4
2 bytes	2 bytes	6 bytes	6 bytes	6 bytes	2 bytes	6 bytes

LLC PDU:

DSAP	SSAP	Control	Data
1 byte	1 byte	1–2 bytes	43–1497 bytes

Payload Trailer:

Frame Check Sequence
4 bytes

Preamble of 802.11b Packets

- Used to mark the start of the packet
- Always transmitted at 1 Mbps
- Sub fields of Preamble
  - Long preamble version
    - 16 sync bytes of alternating 1's and 0's
    - 1 byte of start of frame delimiter (10101101)
  - Short preamble version
    - 7 sync bytes
    - 1 byte of start of frame

Physical Layer Convergence Protocol (PLCP)

- Used to indicate data rates and packet length
- Transmitted at 1 Mbps (long preamble) or at 2 Mbps (short preamble)
- Fields of PLCP
  - Signal rate (1 byte)
    - Which of the four speeds to be used
  - Service field (1 byte)
    - Reserved for future use
  - Length field (2 bytes)
    - Length of the payload in bytes
  - Header error check field (2 bytes)
    - CRC-16 (if any error found, packet is discarded)

Fields of Payload Header

- **Frame control (2 bytes)**
  - Indicates version of the 802.11b protocol
  - Contains any ACK and RTS/CTS signals
- **Destination address (6 bytes)**
  - AP-NIC: Address of NIC; NIC-AP-NIC: Address of AP
- **Address 3 (6 bytes)**
  - NIC-AP-NIC: Address of the NIC
- **Source address (6 bytes)**
  - AP-NIC: Address of AP; NIC-AP-NIC: Address of NIC
- **Sequence control (2 bytes)**
  - Contains packet number for error control
- **Address 4 (6 bytes)**

Other Fields

- Logical Link Control Protocol Data Unit (LLC PDU)
  - Same as in 802.3 Ethernet
- Physical trailer
  - 4-byte CRC-32 used in Ethernet

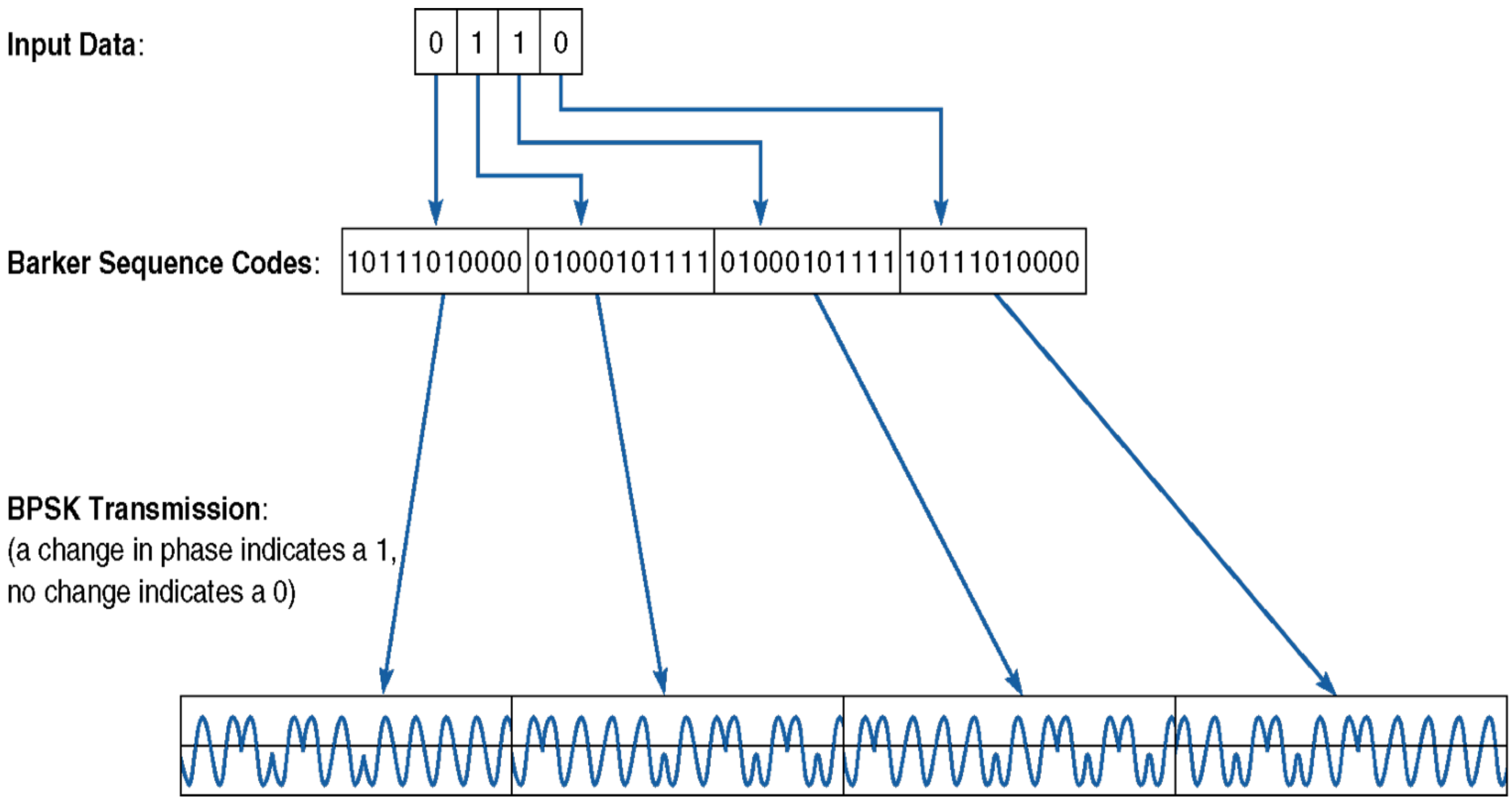
Data Transmission in PL

- Via radio waves
  - Analog medium
  - Digital computer data transmitted using analog transmission (Translations done by NIC and AP)
- Frequency and bandwidth (range of frequencies)
  - 2.4000 – 2.4835 GHz → 83.5 MHz bandwidth in USA
- Transmission
  - 83.5 MHz divided into 3 channels → 22 MHz each (with 3 MHz guard bands between channels)
  - Data capacity of the circuit:
    - Number of bits sent on each symbol x symbol rate
    - Max symbol rate: depends on bandwidth and SNR
      - 22 MHz → 22 million symbols/second (perfect conditions)

Bit Transmission in DSSS

- **Each bit converted into a special code**
  - 8-bit or 11-bit code (designed to reduce interference)
  - Called spreading a bit into many bits across spectrum
- **1-Mbps DSS**
  - Uses an 11-bit Barker sequence code
    - Transmitted using binary phase shift keying (BPSK) (1 bit per symbol)
    - 11 Mbps signaling rate → 1 Mbps data rate
- **2-Mbps DSS**
  - Uses the same 11-bit code
    - Transmits using Quadrature phase shift keying (QPSK) (2 bits per symbol)

1 Mbps DSSS with Barker code

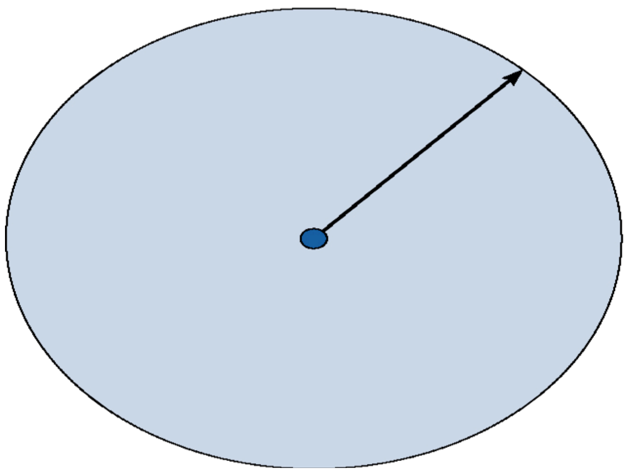


IEEE 802.11a

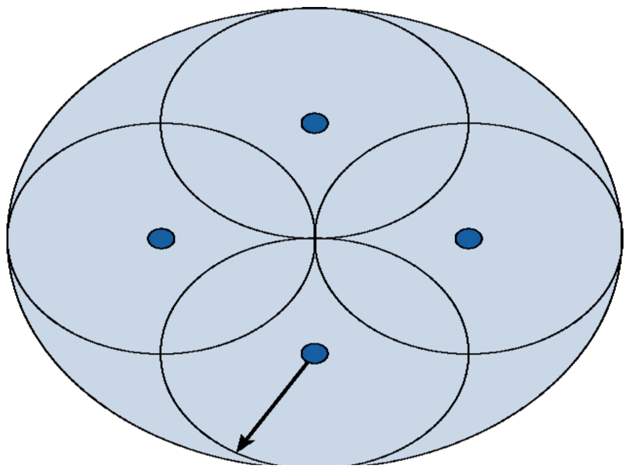
- Operates in a 5 GHz frequency range
- Total bandwidth is 300 MHz
  - Faster data rates possible: Up to 54 Mbps
    - 6, 9, 12, 18, 24, 36, 48, and 54 Mbps
- Uses the same topology as .11b
- Reduced range because of higher speed
  - 50 meters (150 feet)
  - Highest speed achievable within 15 meter

IEEE 802.11a Coverage

- Provides 4-12 channels (depending on configuration)
  - Important for coverage; takes more .11a AP to cover the same area (small range)
  - Make it possible to locate many APs in the same area to increase capacity



Range from 802.11b AP
100 meters = 5.5 -11 Mbps



Range from 802.11a AP
50 meters = 6 -12 Mbps

802.11a Media Access Control

- Same as .11b
- Similar packet format
  - – Preamble and PLCP Header: transmitted at 6 Mbps
  - – PLCP parity bit field: used for error checking of header
  - – PLCP tail field: used as a pad to “byte” align the packet
  - – Payload service field: to sync circuitry in NIC and AP

802.11a Packet Layout

Preamble	PLCP Header	Payload Header	LLC Protocol Data Unit	Payload Trailer

Preamble:

Sync Bytes	Start of Frame
8 bytes	2 bytes

PLCP Header:

Rate	Reserved	Length	Parity	Tail
4 bits	1 bit	12 bits	1 bit	6 bits

Payload Header:

Service	Frame Control	Duration ID	Destination Address	Source Address	Address 3	Sequence Control	Address 4
2 bytes	2 bytes	2 bytes	6 bytes	6 bytes	6 bytes	2 bytes	6 bytes

LLC PDU:

DSAP	SSAP	Control	Data
1 byte	1 byte	1-2 bytes	43-1497 bytes

Payload Trailer:

Frame Check Sequence	Tail
4 bytes	6 bits

802.11a Data Transmission

- Similar to 802.11b; spreads its transmission over a wider spectrum
- Each of 12 channel's bandwidth = 20 MHz
  - Broken into 52 separate channels: 312.5 KHz each, plus guard bands
    - 48 channels for data (sent across all channels in parallel using Orthogonal Frequency Division Multiplexing (OFDM)
    - 4 channels for control

OFDM Versions

- **6-Mbps version of .11a**
  - Groups data into sets of 24 data bits
  - Converts each group into an OFDM symbol of 48 bits
    - Pattern chosen enables some error correction
  - Transmit each symbol in one of 48 sub channels using BPSK sent at 250 KHz
    - 24 data bits x 250 KHz → 6 Mbps
- **9-Mbps version**
  - Groups data into sets of 36 bits
  - Transmits each symbol using BPSK
    - 36 data bits x 250 KHz → 9 Mbps

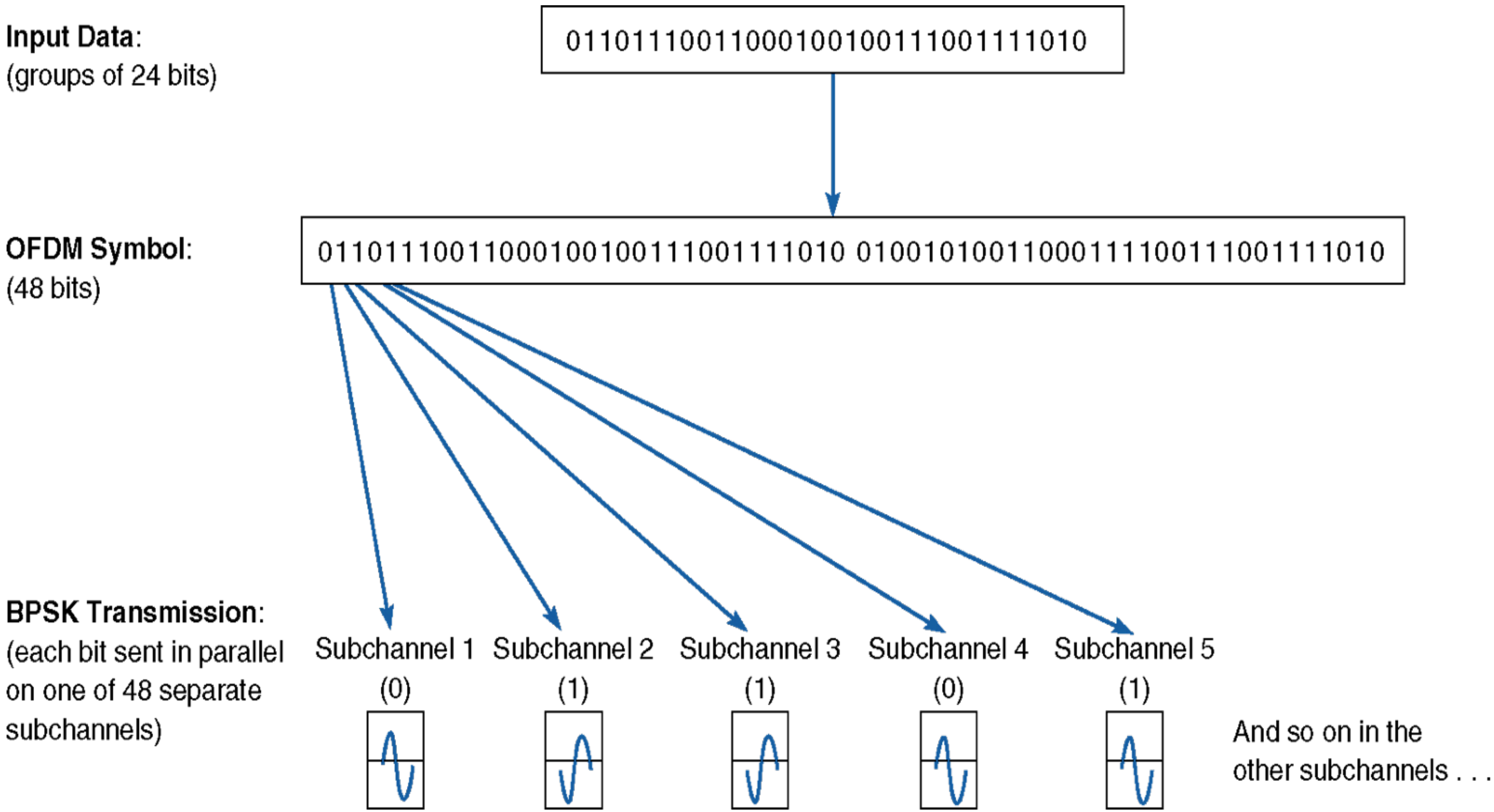
OFDM Versions (Cont.)

- **12-Mbps version**
  - Groups data into sets of 48 bits
  - Transmit OFDM symbol using QPSK (2 bits per symbol)
- **18-Mbps version**
  - Groups data into sets of 72 bits; uses QPSK
- **24-Mbps version**
  - Groups data into sets of 96 bits
  - Transmit OFDM symbol using 16-QAM (4 bits per symbol)

OFDM Versions (Cont.)

- **36-Mbps version**
  - Groups data into sets of 128 bits; uses 16-QAM
  - Transmit OFDM symbol using QPSK (4 bits per symbol)
- **48-Mbps version**
  - Groups data into sets of 192 bits
  - Transmit OFDM symbol using 64-QAM (6 bits per symbol)
- **54-Mbps version**
  - Groups data into sets of 216 bits; uses 64-QAM

802.11a: Use of OFDM and BPSK



IEEE 802.11g

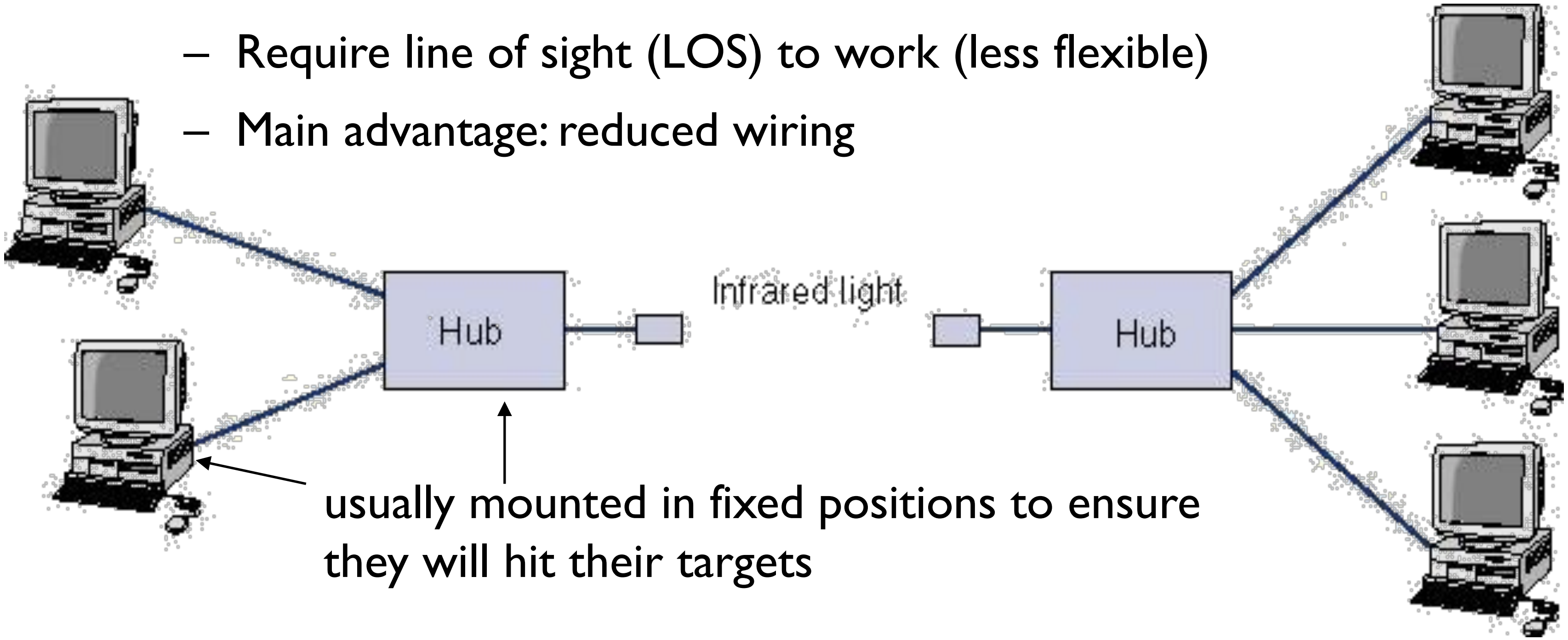
- Designed to combine advantages of 802.11a and 802.11b
  - Offers higher data rates (up to 54 Mbps) in 2.4 GHz band (as in .11b) with longer ranges
  - Backward compatible with 802.11b
    - .11b devices can interoperate with .11g APs
    - **Price to pay:** when an .11g AP detects an .11b device, it prohibits .11g devices from operating at higher speeds
- Uses the same topology as .11b
  - Provides 3-6 channels (depending on configuration)
  - 54 Mbps rate obtained within 50 meter range

802.11g Media Access Control

- Almost the same media and error control protocols as .11b
  - Similar packet layout, except
    - Preambles and headers transmitted at slower speeds (up to a maximum of 11 Mbps)
    - Payload transmitted at higher speeds (up to a max of 54 Mbps)
- Data Transmission in the Physical Layer
  - Same techniques in .11a and .11b
    - Uses PSK, QPSK, and CCK to provide .11b rates
    - Uses BPSK, QPSK, and QAM to provide .11a rates

Infrared Wireless LAN

- Require line of sight (LOS) to work (less flexible)
- Main advantage: reduced wiring



- New version: diffuse infrared,
  - Operates without a direct LOS by bouncing the infrared signal off of walls
  - Only able to operate within a single room and at distances of only about 50-75 feet

Effective Data Rates in WLANs

- Maximum speed in bits the hardware layers can provide
  - Depends on Nominal data rate, Error rate, Efficiency of data link layer protocol, and Efficiency of MAC protocol
- Error plays a greater role in WLANs
  - Significant impact of interference on performance
    - Causes frequent retransmissions, thus lower data rates

Data Link Protocol Efficiency

- **Factors involved:**
  - Typical WLAN overhead:
    - *51-bytes* (with a short preamble)
  - Packet size:
    - Data packets: assume a *1500-byte* for full length
    - Control packets: ACK packets
  - Transmission rates:
    - Overhead bits transmission speeds
    - Payload transmission speeds
- Assuming a mix of short and full length packets
  - 85% average efficiency for 802.11b
  - 75% average efficiency for 802.11a and 802.11g

Effective Rate Estimates

Technology	Effective Data Rate per User		
	Low Traffic	Moderate Traffic	High Traffic
802.11b under perfect conditions (11 Mbps)	4.8 Mbps	1.9 Mbps	960 Kbps
802.11b under normal conditions (5.5 Mbps)	2.4 Mbps	1 Mbps	480 Kbps
802.11a under perfect conditions (54 Mbps)	17.2 Mbps	6.9 Mbps	3.4 Mbps
802.11a under normal conditions (12 Mbps)	3.8 Mbps	1.5 Mbps	760 Kbps
802.11a under perfect conditions with four APs (54 Mbps)	34.4 Mbps	27.5 Mbps	13.7 Mbps
802.11g under perfect conditions (54 Mbps)	17.2 Mbps	6.9 Mbps	3.4 Mbps
802.11g under normal conditions (36 Mbps)	11.4 Mbps	4.5 Mbps	2.3 Mbps

Assumptions:
1. Most packets are 1,500 bytes or larger.
2. No transmission errors occur.
3. Low traffic means 2 active users, moderate traffic means 5 active users, high traffic means 10 active users.

Costs

- **802.11b**
  - Decreasing cost of NICs and AP s
- **802.11a and g**
  - Newer technologies, higher costs
- **Comparison with wired Ethernets**
  - (cost of .11b AP) = (cost of 10/100Base-T switch)
  - (cost of .11b NIC) = $20 + (cost of 10/100Base-T NIC)
  - No cost for cabling and its deployment in WLAN
    - Wired Ethernet cable deployment cost: $50 - $400
      - Cheapest to install during construction of building
  - For new buildings
    - Wired LANs are less expensive
  - Do not forget the need for mobility !!

Best Practice Recommendations

- **Adopt 802.11g**
  - Will replace 802.11b and .11a
  - Prices of .11g NICs and APs coming down
- **Wireless vs. Wired**
  - 802.11g ~ 10Base-T
    - Similar data rates for low traffic environment
    - When mobility important → 802.11g
- **Using WLAN as overlay network (over wired LAN)**
  - WLANs installed In addition to wired LANs
  - To provide mobility for laptops, etc.,
  - To provide access in hallways, lunch rooms, etc.,

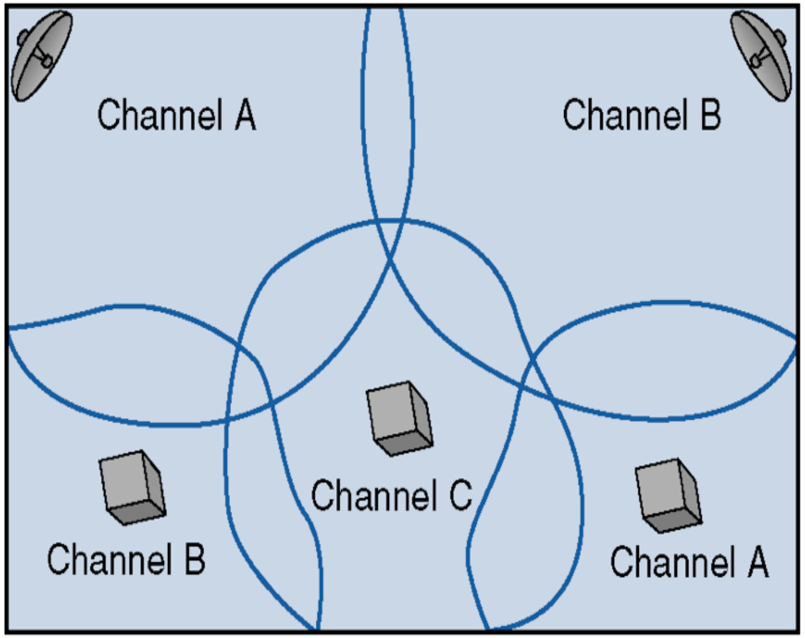
Physical WLAN Design

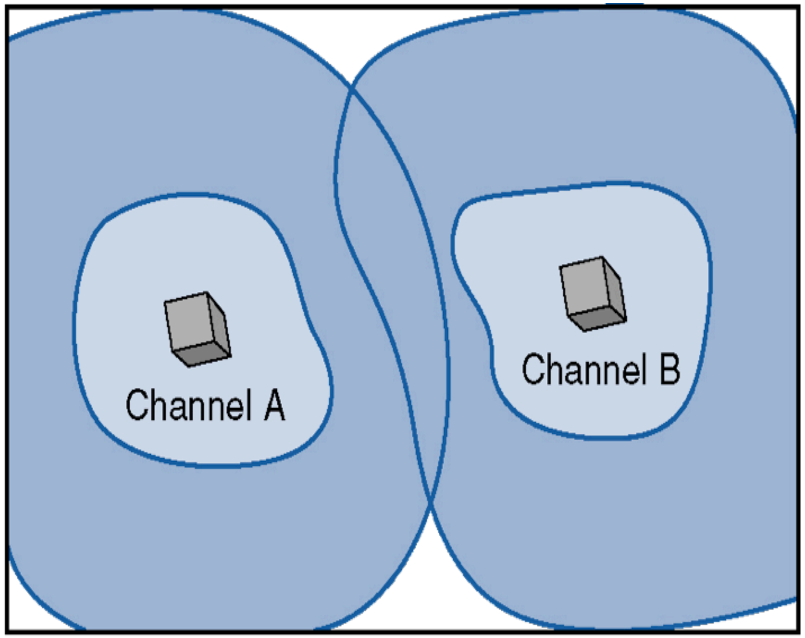
- **More challenging than designing a traditional LAN**
  - Placement of APs: Locations chosen to:
    - Provide coverage
    - Minimize potential interference
- **Begins with a site survey to determine**
  - Feasibility of desired coverage
    - Measuring the signal strength from temporary APs
  - Potential sources of interference
    - Most common source: Number and type of walls
  - Locations of wired LAN and power sources
  - Estimate of number of APs required

Physical WLAN Design

- **Begin locating APs**
  - Place an AP in one corner
  - Move around measuring the signal strength
  - Place another AP to the farthest point of coverage
    - AP may be moved around to find best possible spot
    - Also depends on environment and type of antenna
  - Repeat these steps several times until the corners are covered
  - Then begin the empty coverage areas in the middle
- Allow about 15% overlap in coverage between APs
  - To provide smooth and transparent roaming
- Set each AP to transmit on a different channel

WLAN Designs for the Same Area





More expensive
- **3 omni and**
- **2 directional antennas**

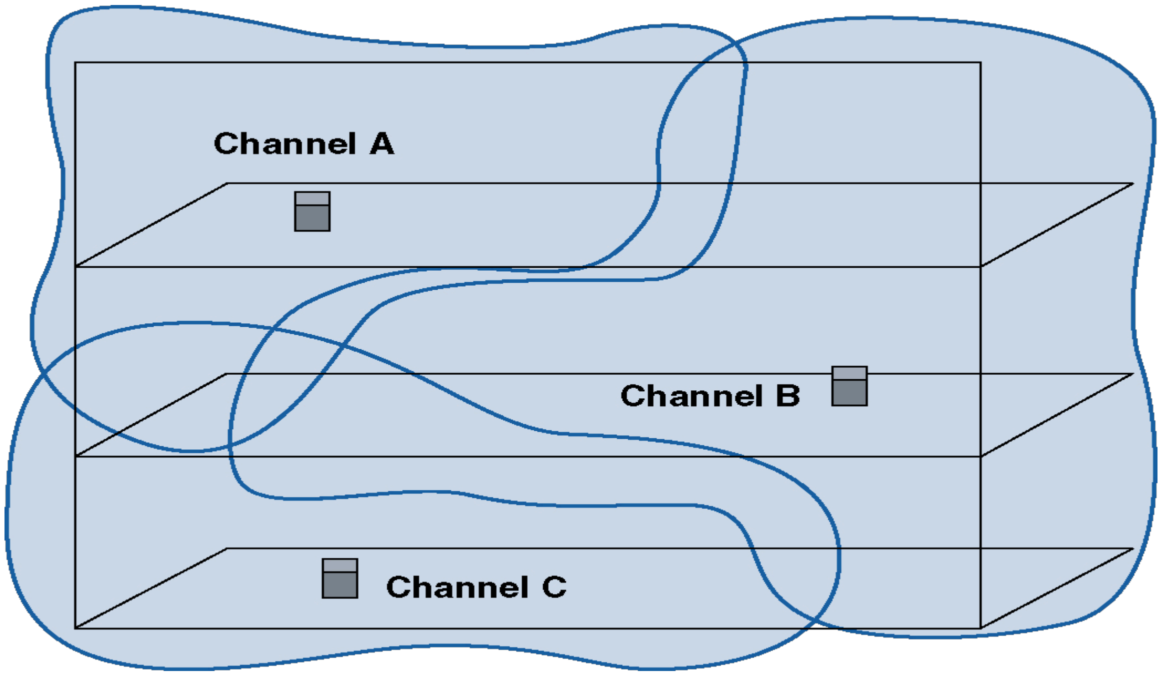
Evenly distributed

Less expensive
- **2 omnidirectional antennas**

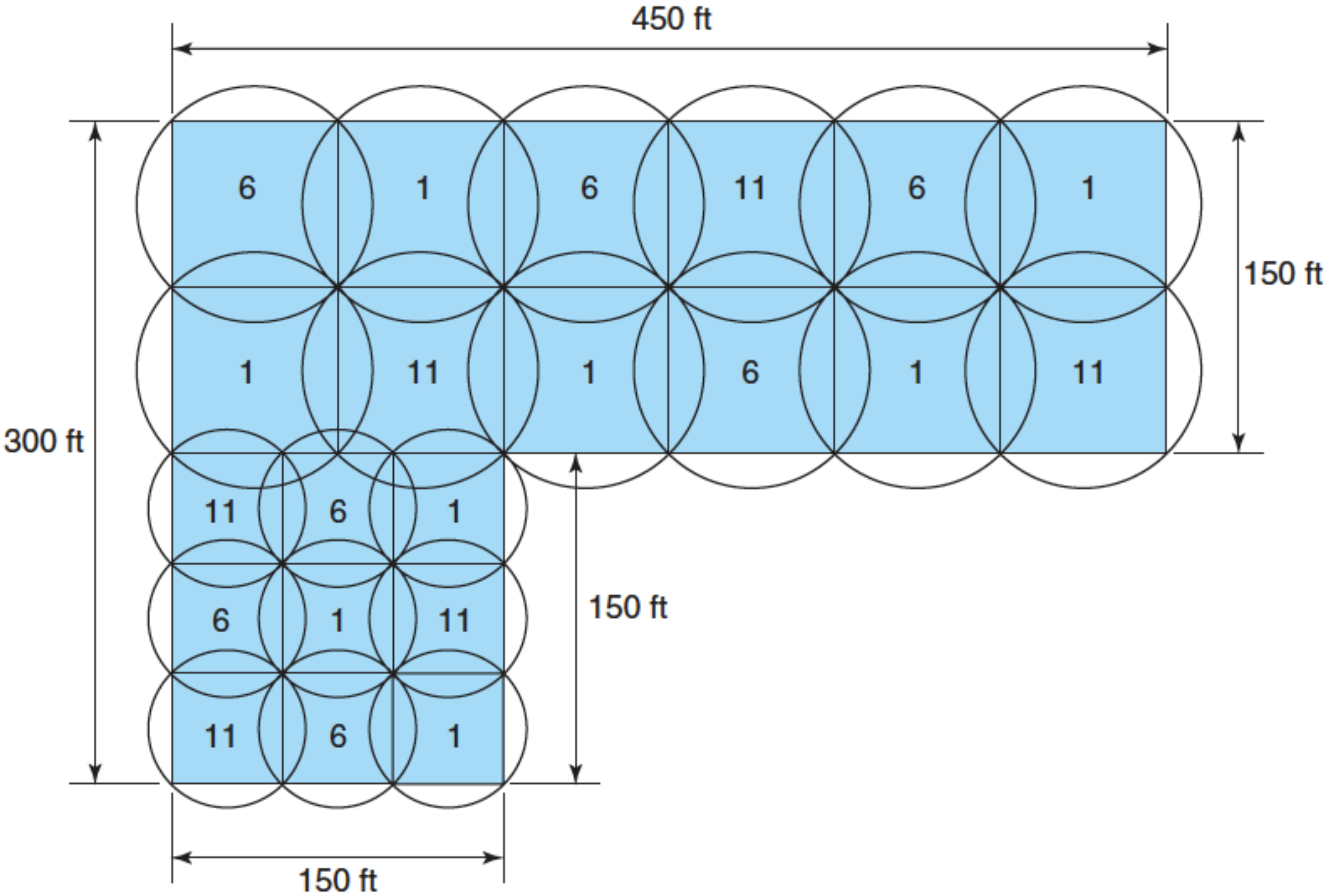
Not evenly distributed
(High speed: Areas closer to AP
Lower speed: Areas farther to AP
A few dead spots too)

Multistory WLAN Design

- **Must include**
  - Usual horizontal mapping, and
  - Vertical mapping to minimize interference from APs on different floors

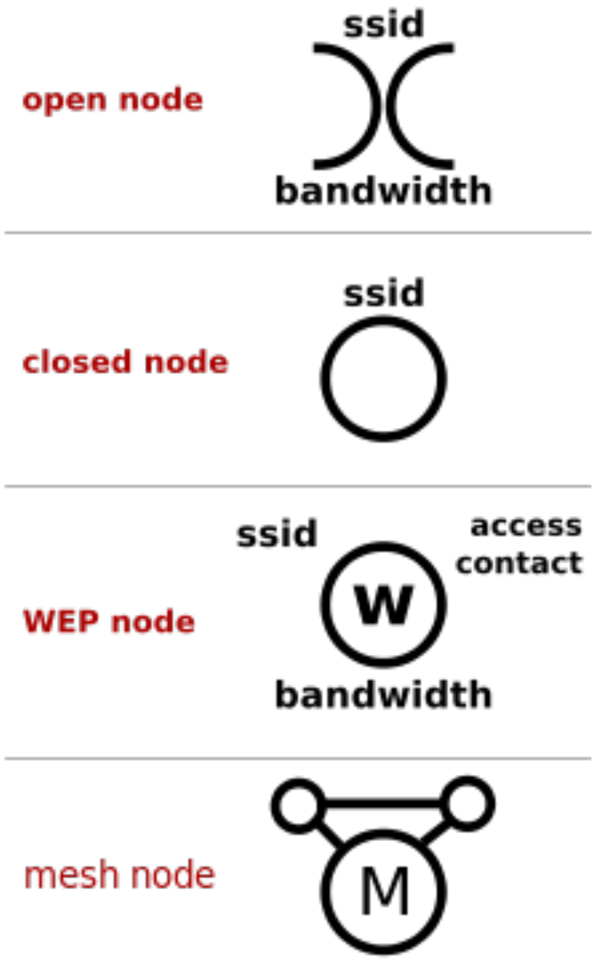


A WiFi Design: 802.11b

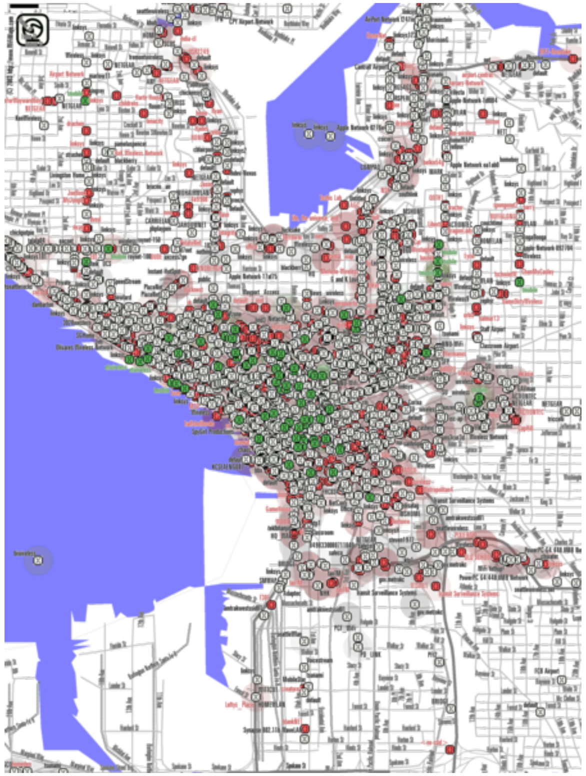


WLAN Security

- Especially important for wireless network
  - Anyone within the range can use the WLAN
- Finding a WLAN
  - Move around with WLAN equipped device and try to pick up the signal
  - Use special purpose software tools to learn about WLAN you discovered
    - *Wardriving* – this type reconnaissance
    - *Warchalking* – writing symbols on walls to indicate presence of an unsecure WLAN


open node
ssid
bandwidth
closed node
ssid
WEP node
ssid
access
contact
W
bandwidth
mesh node
M


FREE INTERNET
seattle
Wi Fi
hotspot
Connect Now...



Types of WLAN Security

- Service Set Identifier (SSID)
  - Required by all clients to include this in every packet
  - Included as plain text → Easy to break
- Wired Equivalent Privacy (WEP)
  - Requires that user enter a key manually (to NIC and AP)
  - Communications encrypted using this key
  - Short key (40-128 bits) → Easy to break by "brute force"
- Extensible Authentication Protocol (EAP)
  - WEP keys created dynamically after correct login
    - Requires a login (with password) to a server
  - After logout, WEP keys discarded by the server
- Wi-Fi Protected Access (WPA) – new standard
  - A longer key, changed for every packet

Outline

6.1 Introduction

6.2 LAN Components

6.3 Wired Ethernet

6.4 Wireless Ethernet

6.5 The Best Practice LAN Design

6.6. Improving LAN Performance

Factors in LAN Design

- Effective Data Rates
  - Data Link Protocol Efficiency
  - MAC Protocol Efficiency
- Costs

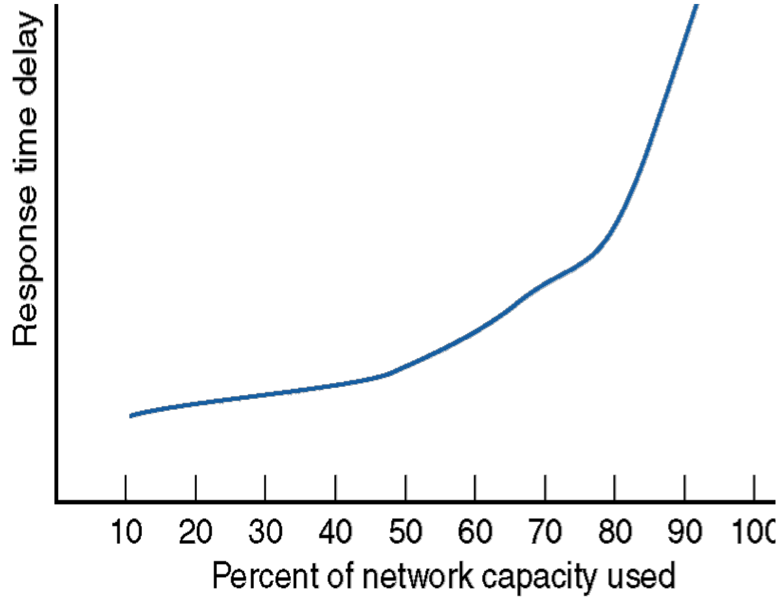
Effective Data Rates

- Maximum speed in bits the hardware layers can provide
- Depends on
  - Nominal data rate (provided by Physical layer)
    - 10Base-T → 10 Mbps
  - Error rate (determines retransmissions)
  - Efficiency of data link layer protocol
    - Percentage of transmission that contains user data
      - Depends on the number of overhead bits
  - Efficiency of MAC protocol
    - How well the MAC protocol can use the nominal data rate

Data Link Protocol Efficiency

- Depends on a typical packet size
  - 33-byte overhead in a 1500-byte packet
    - → 97.7% efficiency (assuming no retransmission)
  - 33-byte overhead in a 9000 byte (jumbo) packet
    - → 99.6% efficiency
  - 33-byte overhead in a 150 byte (small) packet
    - → 82% efficiency
- Average efficiency on a LAN
  - Depends on the traffic patterns; Typically
    - A number of small HTTP or SMT packets
    - Followed by a large number of larger packets
  - 97% presents a reasonable estimate for LAN traffic

MAC Protocol Efficiency



- CSMA/CD works well in low traffic LANs
- Response time vs. utilization: a good indicator
  - Works well when it is under 50% capacity
- Examples:
  - 10Base-T: 50% capacity x 97% efficiency x 10 Mbps rate
    - → 4.85 Mbps (shared by all computers on the LAN)
  - 100Base-T: 80% capacity x 97% efficiency x 100 Mbps
    - → 78 Mbps (total effective rate)

Effective Rate for a Computer

- Depends on number of computers using the LAN simultaneously
  - A typical LAN has 20 users; but not all of them use the LAN at the same time
- Examples:
  - 2 simultaneous users on a 10Base-T
    - 4.85 Mbps / 2 → 2.425 Mbps / per computer
  - 10 simultaneous users on a 10Base-T
    - 4.85 Mbps / 10 → 485 Kbps / per computer
  - 10 simultaneous users on a 100Base-T
    - 78 Mbps / 10 → 7.8 Mbps / per computer

Effective Rates for Switched Ethernets

- Dramatic improvements (No sharing)
- 95% capacity efficiency
- Examples:
  - 10Base-T: 95% capacity x 97% efficiency x 10 Mbps rate
    - → 9.2 Mbps
  - 100Base-T: 95% capacity x 97% efficiency x 100 Mbps
    - → 92 Mbps
  - 1 GbE: implemented in full duplex (1 Gbps each direction)
    - → 1.8 Gbps
- Per computer efficiency
  - Same as above
  - Not affected by the traffic (since each has own circuit)

Effective Rate Estimates

Technology	Effective Data Rate per User		
	Low Traffic	Moderate Traffic	High Traffic
Shared 10Base-T	2.5 Mbps	1 Mbps	500 Kbps
Shared 100Base-T	37.5 Mbps	15 Mbps	7.5 Mbps
Switched 10Base-T	9 Mbps	9 Mbps	9 Mbps
Switched 100Base-T	90 Mbps	90 Mbps	90 Mbps
Full Duplex 1 GbE	1.8 Gbps	1.8 Gbps	1.8 Gbps
Full Duplex 10 GbE	18 Gbps	18 Gbps	18 Gbps

Assumptions:

1. Most packets are 1,500 bytes or larger
2. No transmission errors occur
3. Low traffic means 2 active users, moderate traffic means 5 active users, high traffic means 10 active users

Costs

- Very cheap
  - Shared 10Base-T (old technology)
- Relatively inexpensive
  - Shared 100Base-T (old technology)
  - Switched Ethernet
- Very expensive
  - 1 GbE
  - 10 GbE

Best Practice Recommendations

- Switched 10Base-T
  - Less susceptible to response time delays
  - More robust as traffic increases
  - Provides the best cost-performance tradeoff
  - Costs almost the same as Shared 10Base-T
- Category 5 or 5e cables
  - Costs almost the same as cat3
  - Provides room for upgrades to 100Base-T or 100Base-T
- Fiber
  - LAN with very high traffic needs
  - Used with switched 100Base-T or 1 GbE
  - Currently expensive

Best Practice Recommendations

Most networks	Switched 10Base-T Ethernet over Category 5e cables
Very small networks (e.g., home networks)	Traditional shared 10Base-T Ethernet over Category 5 or Category 5e cables
Networks with high demands (e.g., multimedia networks)	Switched 100Base-T Ethernet over Category 5 cables or full duplex 1 GbE over fiber

Outline

6.1 Introduction

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6.3 Wired Ethernet

6.4 Wireless Ethernet

6.5 The Best Practice LAN Design

6.6. Improving LAN Performance

Improving LAN Performance

- **Throughput:**
  - Used often as a measure of LAN performance
  - Total amount of user data transmitted in a given period of time
- To improve throughput (thus LAN performance)
  - Identify and eliminate bottlenecks
- **Bottlenecks**
  - Points in the network where congestion is occurring
- **Congestion**
  - Network or device can’t handle all of the demand it is experiencing

Identifying Network Bottlenecks

- **Potential Places**
  - Network server
  - Network circuit (especially LAN-BN connection)
  - Client's computer (highly unlikely, unless too old)
- **How to find it**
  - Check the server utilization (during poor performance)
    - If high (>60%),
      - Then the server is the bottleneck
    - If low (<40%),
      - Then the network circuit is the bottleneck
    - If between (40% - 60%)
      - Both the server and circuits are the bottlenecks

Improving Server Performance

- **Software improvements**
  - Choose a faster NOS
  - Fine tune network and NOS parameters such as
    - Amount of memory used for disk cache
    - Number of simultaneously open files
    - Amount of buffer space
- **Hardware improvements**
  - Add a second server
  - Upgrade the server's CPU
  - Increase its memory space
  - Add more hard disks
  - Add a second NIC to the server

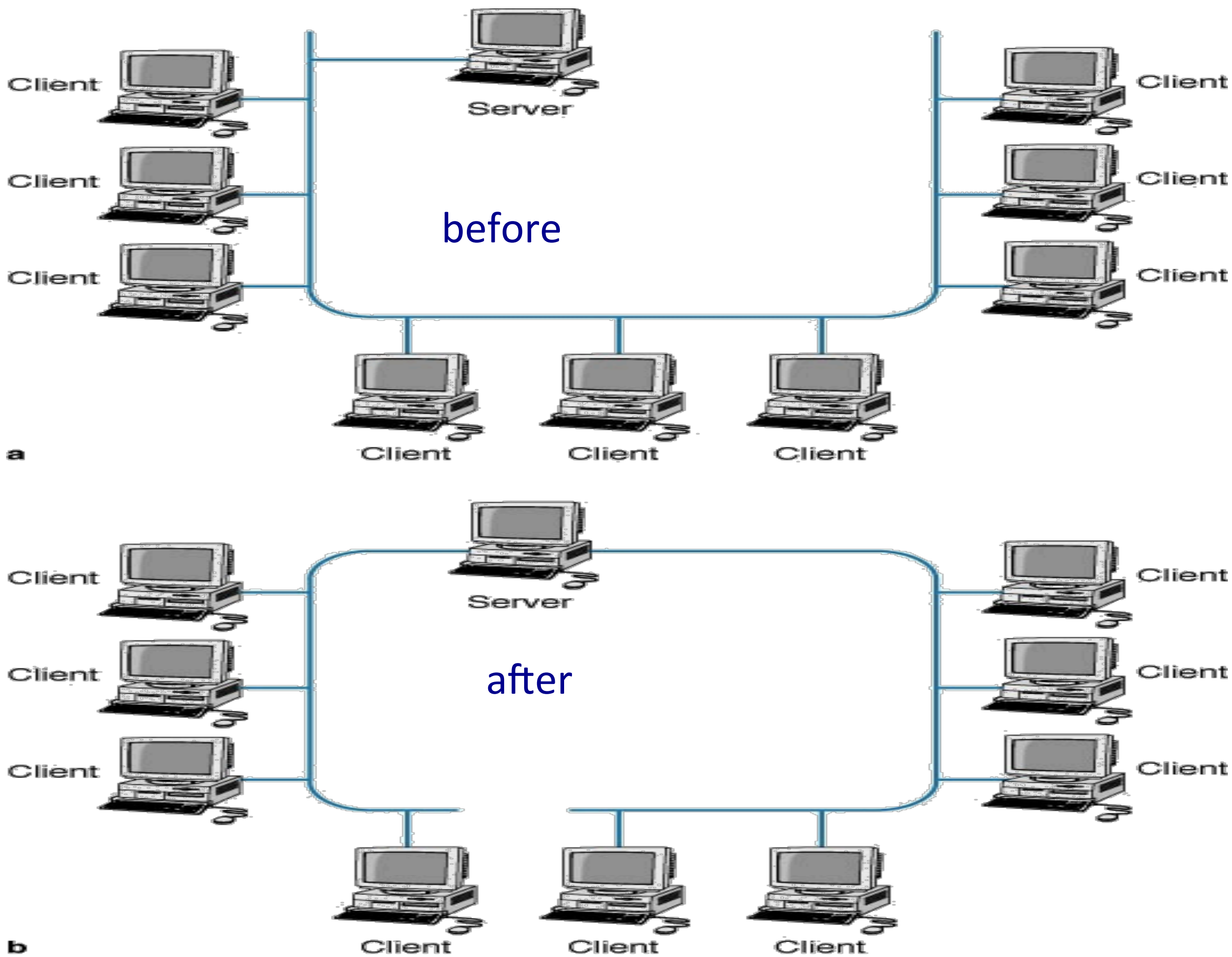
Improving Disk Drive Performance

- Especially important, since disk reads are the slowest task the server needs to do
- Redundant Array of Inexpensive Disks (RAID)
  - Replacing one large drive with many small ones
  - Can be used to both improve performance and increase reliability
    - Building redundancy into the hard drives
      - A hard drive failure does not result in any loss of data

Improving Circuit Capacity

- **Upgrade to a faster protocol**
  - Means upgrading the NICs and possible cables
  - Examples:
    - Upgrading the network from 10Base-T to 100Base-T
    - Upgrading the segment to the server from 10Base-T to 100Base-T
- **Increase number of segments to server**
  - Adding additional NIC cards to the servers
    - Increasing the number of ways to access to server
    - Ideal number of NICs/server = 3
      - More NICs may affect server's processing capacity

Network Segmentation



Reducing Network Demand

- Move files to client computers
  - Such as heavily used software packages
- Install disk caching software on client machines
  - Reduces the need to access files stored on the server
- Move user demands to off peak times
  - Tell network users about peak usage times
    - Typically: Early morning and after lunch
  - Encourage users to not use the network as heavily during these times
  - Delay some network intensive jobs to off-peak times
    - Run heavy printing jobs at night

Improving LAN Performance - Summary

- Increase Server Performance
  - Software: Fine-tune the NOS settings
  - Hardware:
    - Add more servers and spread the network applications across the servers to balance the load
    - Upgrade to a faster computer
    - Increase the server's memory
    - Increase the number and speed of the server's hard disk(s)
    - Upgrade to a faster NIC
- Increase Circuit Capacity
  - Upgrade to a faster circuit
  - Segment the network
- Reduce Network Demand
  - Move files from the server to the client computers
  - Increase the use of disk caching on client computers
  - Change user behavior

Implications for Management

- Cost of LAN equipment dropping quickly
  - Commodity market
    - Flood of vendors into the market
    - Varying quality of products
  - Difficult to justify the purchase of high quality LAN equipment
- Became more common everywhere
  - Look for applications to take advantage of this
- More network enabled devices to deal with
  - Networked printers, scanners, vending machines, etc.,

Improving WLAN Performance

- Similar to improving wired LANs
  – Improving device performance
  – Improving wireless circuit capacity
  – Reducing network demand

Improving WLAN Performance

- Similar to improving wired LANs
  - Improving device performance
    - If 802.11g widely deployed, replace 802.11b cards with .11g cards (may be the cause for slow performance
    - By high-quality cards and APs
  - Improving wireless circuit capacity
    - Upgrade to 802.11g
    - Reexamine placement of APs
    - Check sources of interference (other wireless devices operating in the same frequencies))
    - Use different type of antennas
  - Reducing network demand

Improving WLAN Device Performance

- If 802.11g widely deployed, replace 802.11b cards with .11g cards
  - May be the cause for slow performance
- By high-quality cards and APs
  - Better design
  - Stronger signals,
  - Longer ranges

Improving Wireless Circuit Capacity

- Upgrade to 802.11g
- Re-place APs
  - Fewest walls between AP and devices
  - Ceiling or high mounted to minimize obstacles
  - On halls, not in closets
- Remove sources of interference
  - Other wireless devices operating in the same frequencies
    - Bluetooth devices, cordless phones, etc.
- Use different type of antennas
  - Directional antennas in smaller range to get stronger signals (faster throughput)

Reducing WLAN Demand

- Never place a serve in a WLAN
  - Doubles the traffic between clients and server
    - Since all communications go through the AP
  - Locate the server in the wired part of the network (ideally with a switched LAN)
- Place wired LAN jacks in commonly used locations
  - If WLAN becomes a problem, users can switch to wired LAN easily

Implications for Management

- WLANs becoming common place
  - Access to internal data, any time, any place
    - Better protection of corporate networks
  - Public access through WLAN hotspots
    - Competition with cell phone technologies
      - New cell phone technologies (faster, longer ranges)
  - Drastic price drops of WLAN devices
    - Widespread Internet access via multiplicity of devices (PDAs, etc,)
  - Development of new Internet applications
    - New companies created; some old ones out of business
  - Drastic increase in the amount of data flowing around