Information Technology Engineering

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1401

Module C.3

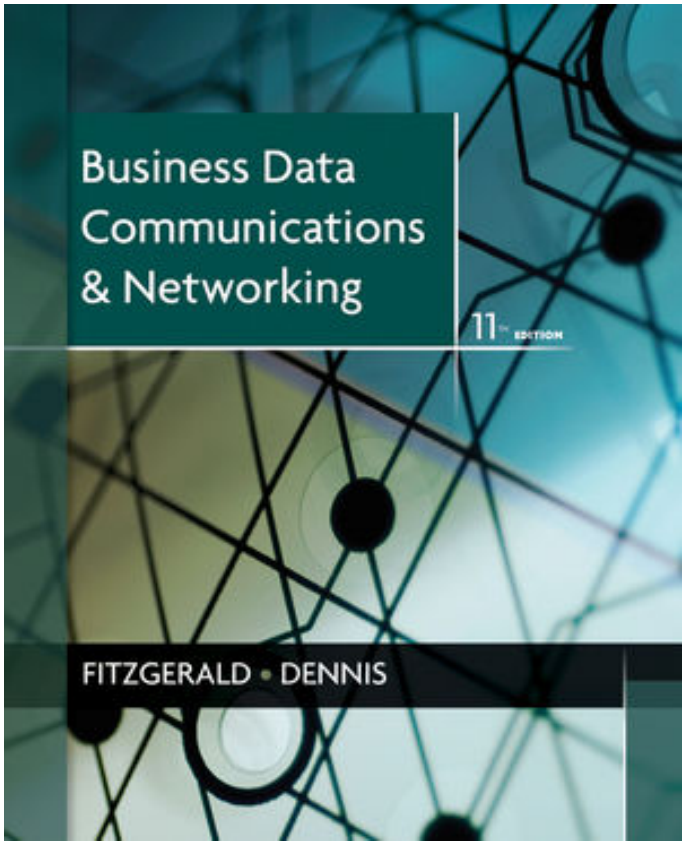
Backbone Networks

Reference:

Wired and Wireless LAN, Backbone Networks (Chapter 6 and 7)

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



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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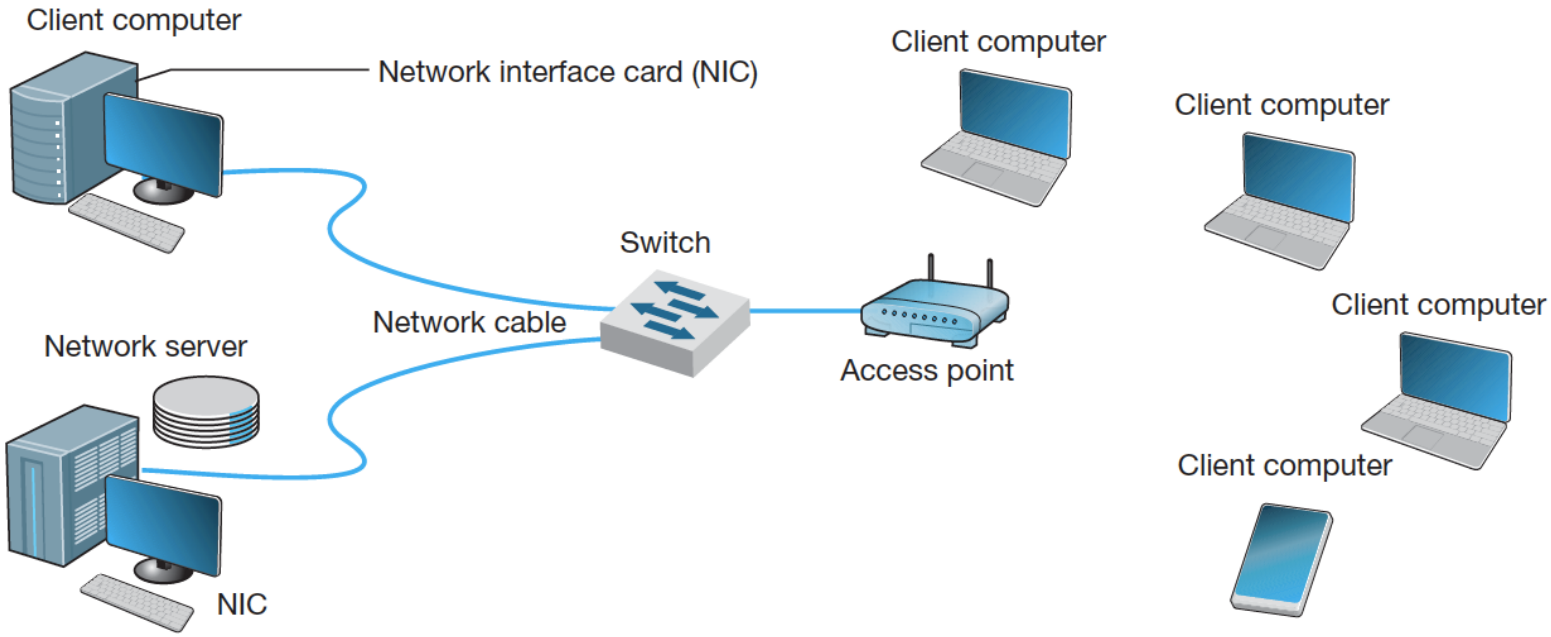
Basic LAN Components

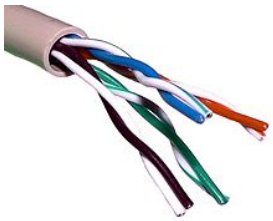


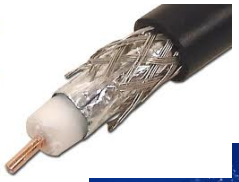
Network Interface Cards (NICs)

- **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

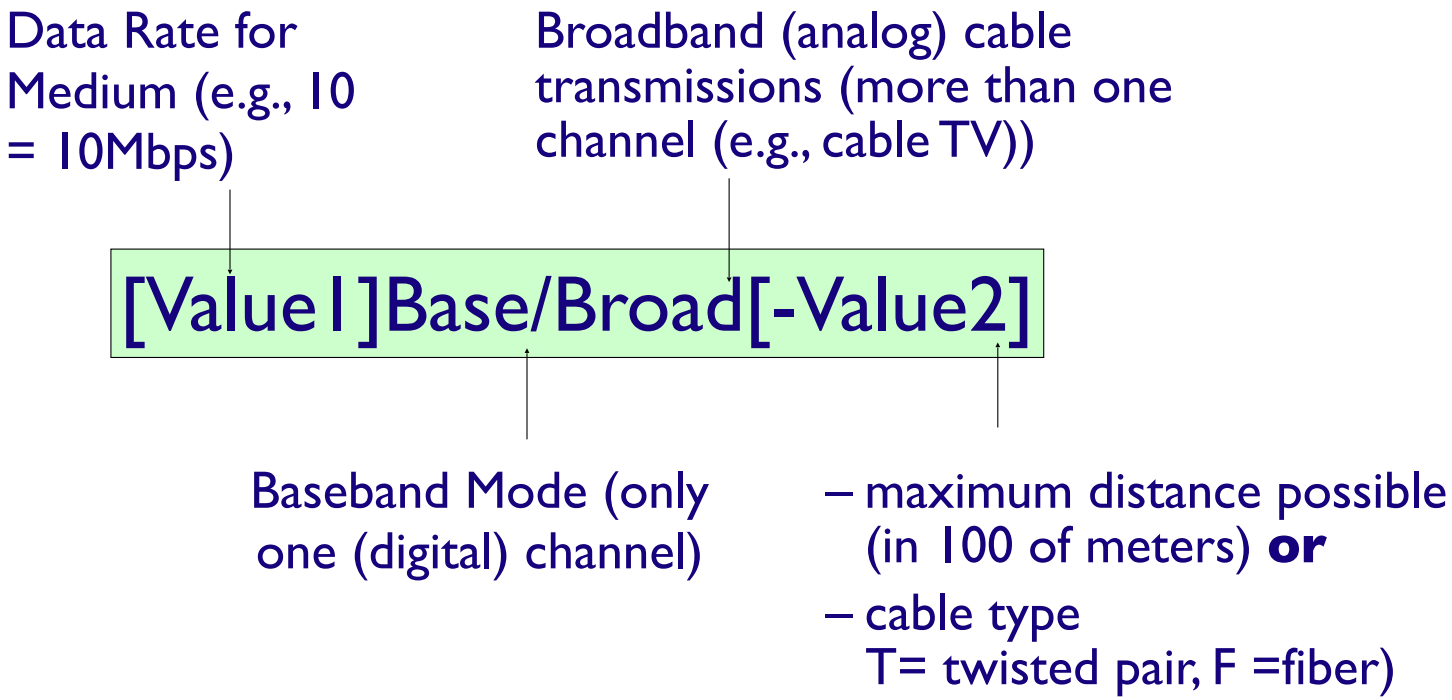
- Used to connect a computer physically to the network
- **Types of cables**
  - Unshielded twisted pairs (UTP) – leading LAN cable type
  - Shielded twisted pair (STP)
  - Coaxial cable – heavy, not flexible
  - Optical fiber – high capacity





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

Ethernet Physical Media Format



Coaxial Cable Ethernets

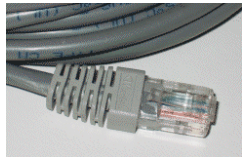
- **10Base-5**

  - 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

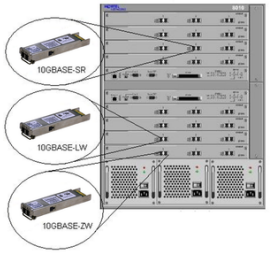
Twisted Pair Ethernets



- **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

TECHNICAL FOCUS

6.1 Commonly Used Network Cable Standards

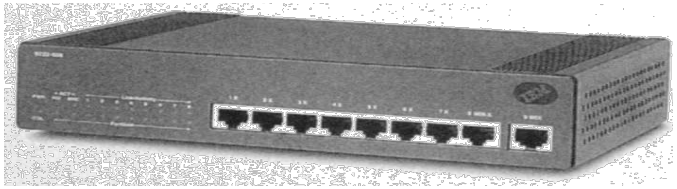
Name	Type	Maximum Data Rate	Often Used By	Cost[1] ($/foot)
Category 1[2]	UTP	1 Mbps	Modem	.04
Category 2	UTP	4 Mbps	Token Ring-4[3]	.35
Category 3	UTP	10 Mbps	10Base-T Ethernet	.06
Category 4	STP	16 Mbps	Token Ring-16[3]	.60
Category 5	UTP	100 Mbps	100Base-T Ethernet	.07
Category 5	STP	100 Mbps	100Base-T Ethernet	.18
Category 5e[4]	UTP	1 Gbps	1000Base-T Ethernet	.10
Category 6a	UTP	10 Gbps	10GBase-T	.15
Category 7a	STP	40 Gbps	10GBase-T	.25
62.5/50	Fiber	1,000	1000Base-T Ethernet	.25

Notes

1. These costs are approximate costs for cable only (no connectors). They often change but will give you a sense of the relative differences in costs among the different options.
2. Category 1 is standard voice-grade twisted-pair wires but it can also be used to support low-speed analog data transmission.
3. Token ring is an old local area network technology seldom used today.
4. Category 5e is an improved version of category 5 that has better insulation and a center plastic pipe inside the cable to keep the individual wires in place and reduce noise from cross-talk, so that it is better suited to 1000Base-T.

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

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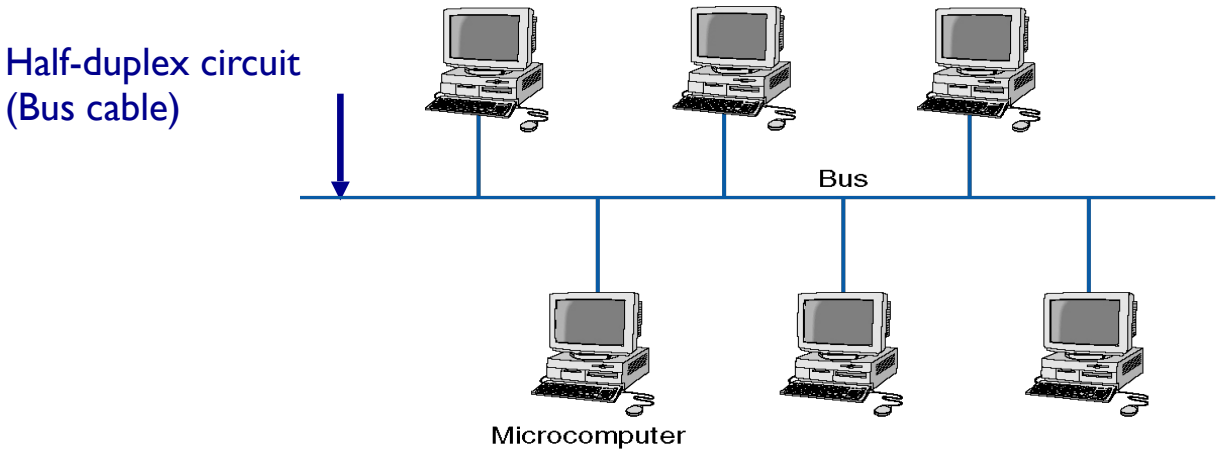
Ethernet (IEEE 802.3)

- 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
- **Physical Topology**
  - How the network is physically installed

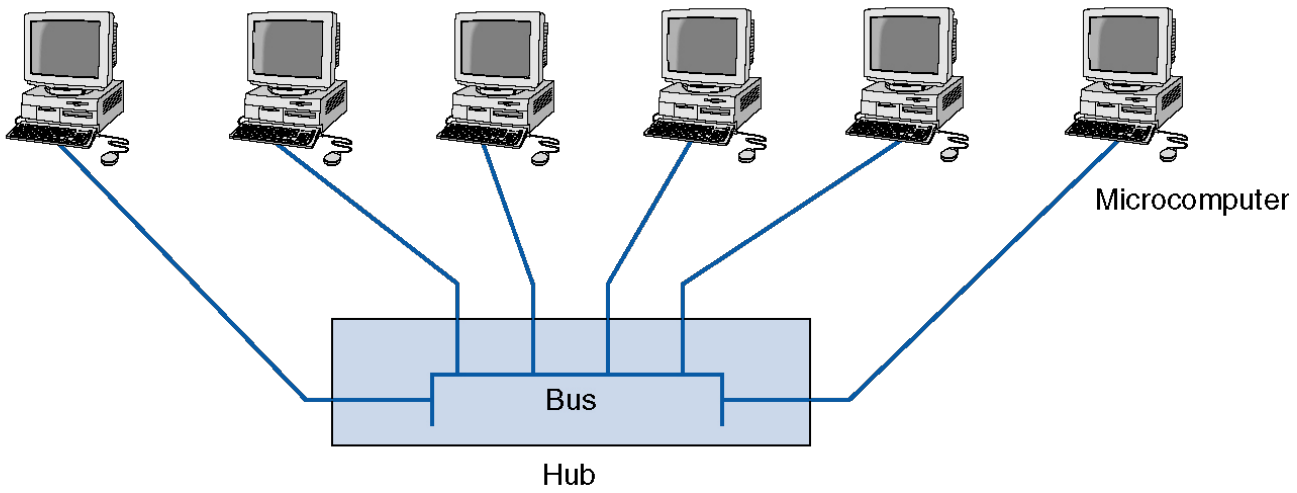
Shared Ethernet's Logical Topology



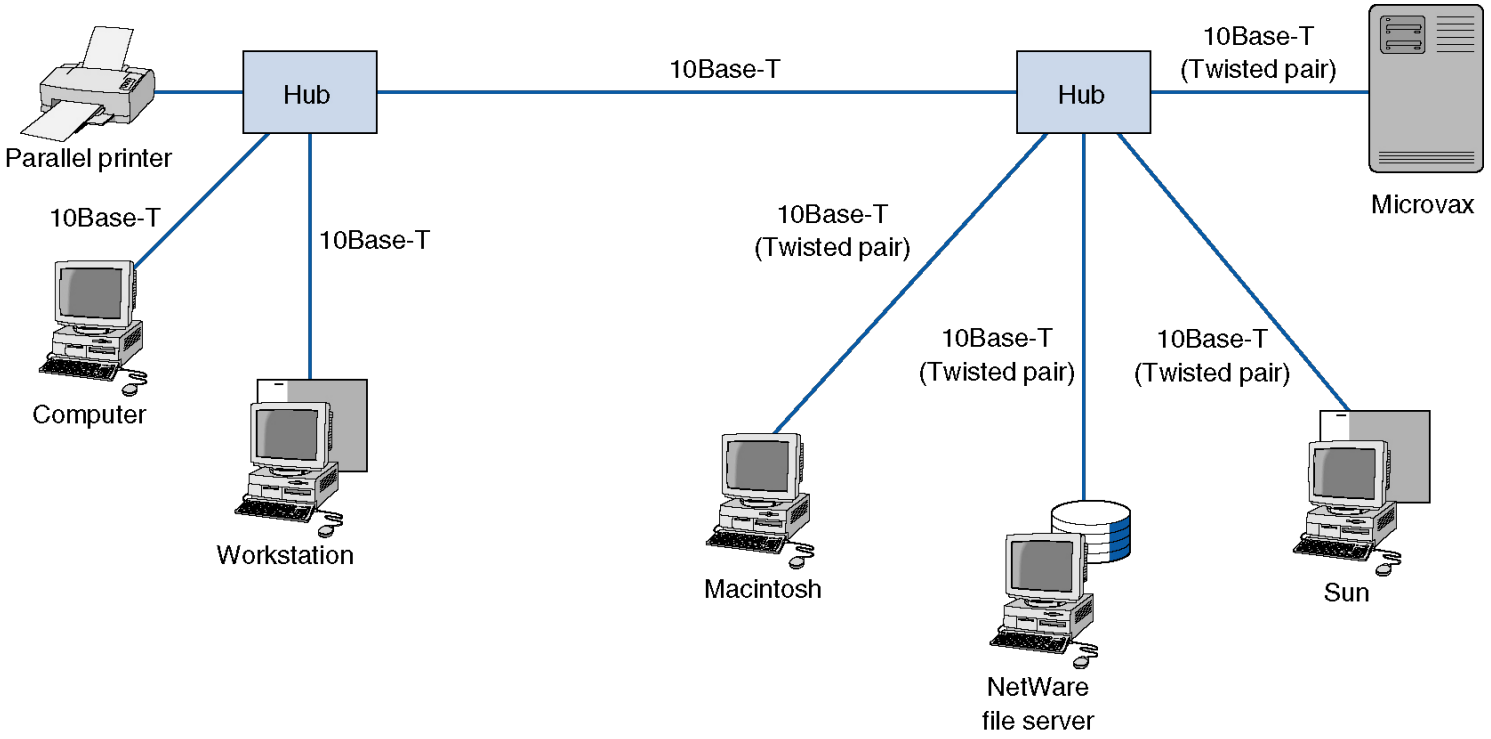
- Viewed logically as a bus topology
- All messages from any computer flow onto the central cable (bus)
  - A computer receive messages from all other computers, whether the message is intended for it or not
  - When a frame is received by a computer, the first task is to read the frame's destination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

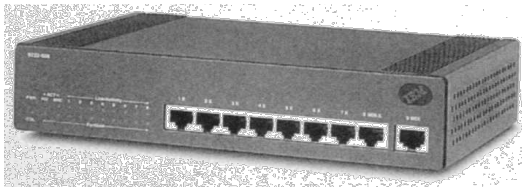
Media Access Control (MAC)

- 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

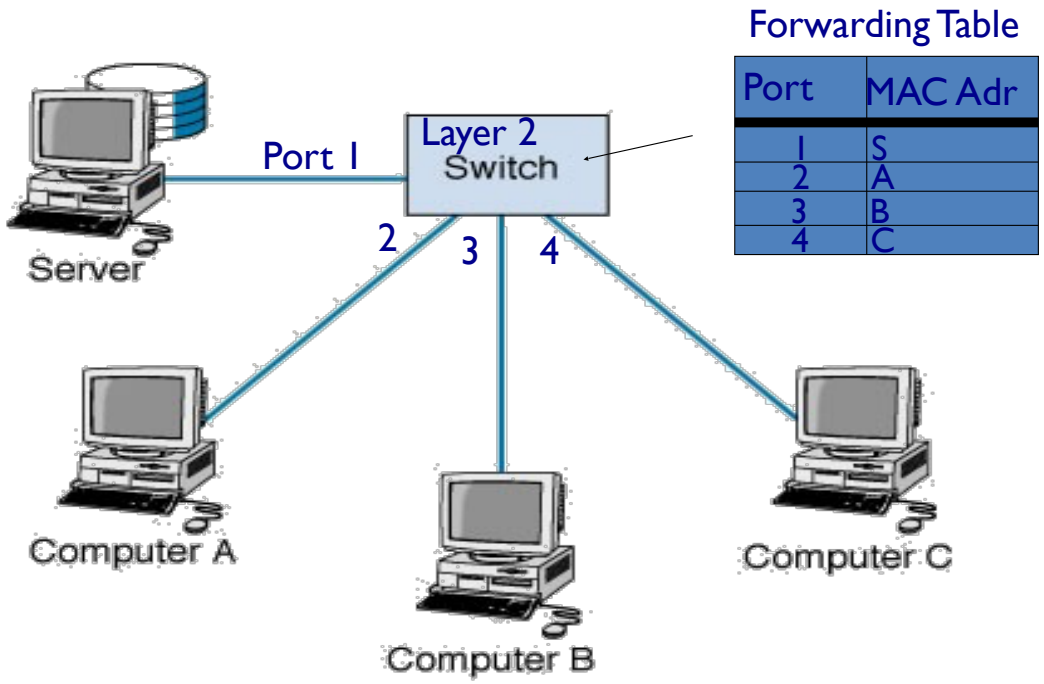
- **Carrier Sense (CS):**
  - Listen to the bus to see if another computer is transmitting
    - Before sending anything
  - Transmit when no one is transmitting
- **Multiple Access (MA):**
  - All computers have access to the network medium
- **Collision Detect (CD):**
  - Declared when any signal other 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



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

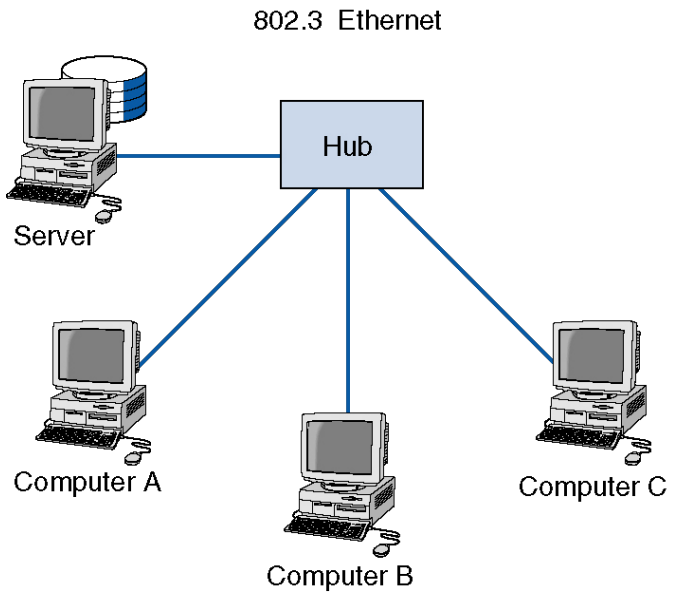
Modes of Switch Operations

- **Cut through switching**
  - Read destination address and start transmitting
    - Without waiting for the entire message is received
  - Low latency; but may waste capacity (error 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

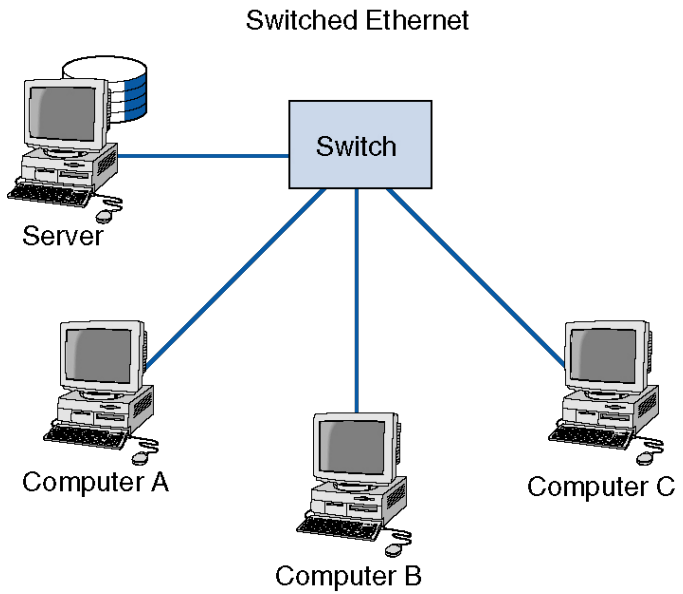
MAC in Switched Ethernet

- 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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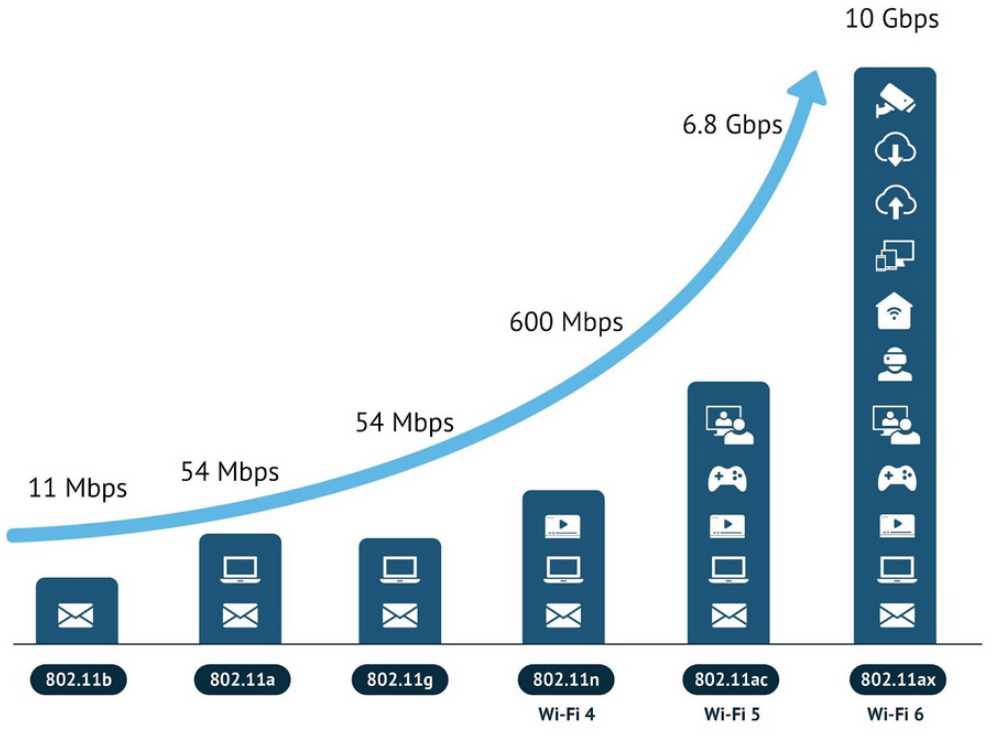
Wireless LANs (WLANs)

- Use radio or infrared frequencies to transmit signals through the air (instead of cables)
- Basic Categories
  - Use of Radio frequencies (FOCUS of this chapter)
    - 802.11 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



Wi-Fi Generations

Generation	IEEE Standard	Maximum Linkrate (Mbit/s)	Adopted	Radio Frequency (GHz)
Wi-Fi 7	802.11be	1376 to 46120	(2024)	2.4/5/6
Wi-Fi 6E	802.11ax	574 to 9608[3]	2020	2.4/5/6
Wi-Fi 6			2019	2.4/5
Wi-Fi 5	802.11ac	433 to 6933	2014	5[4]
Wi-Fi 4	802.11n	72 to 600	2008	2.4/5
(Wi-Fi 3)*	802.11g	6 to 54	2003	2.4
(Wi-Fi 2)*	802.11a	6 to 54	1999	5
(Wi-Fi 1)*	802.11b	1 to 11	1999	2.4
(Wi-Fi 0)*	802.11	1 to 2	1997	2.4

*: (Wi-Fi 0, 1, 2, 3, are unbranded common usage.[5][6])

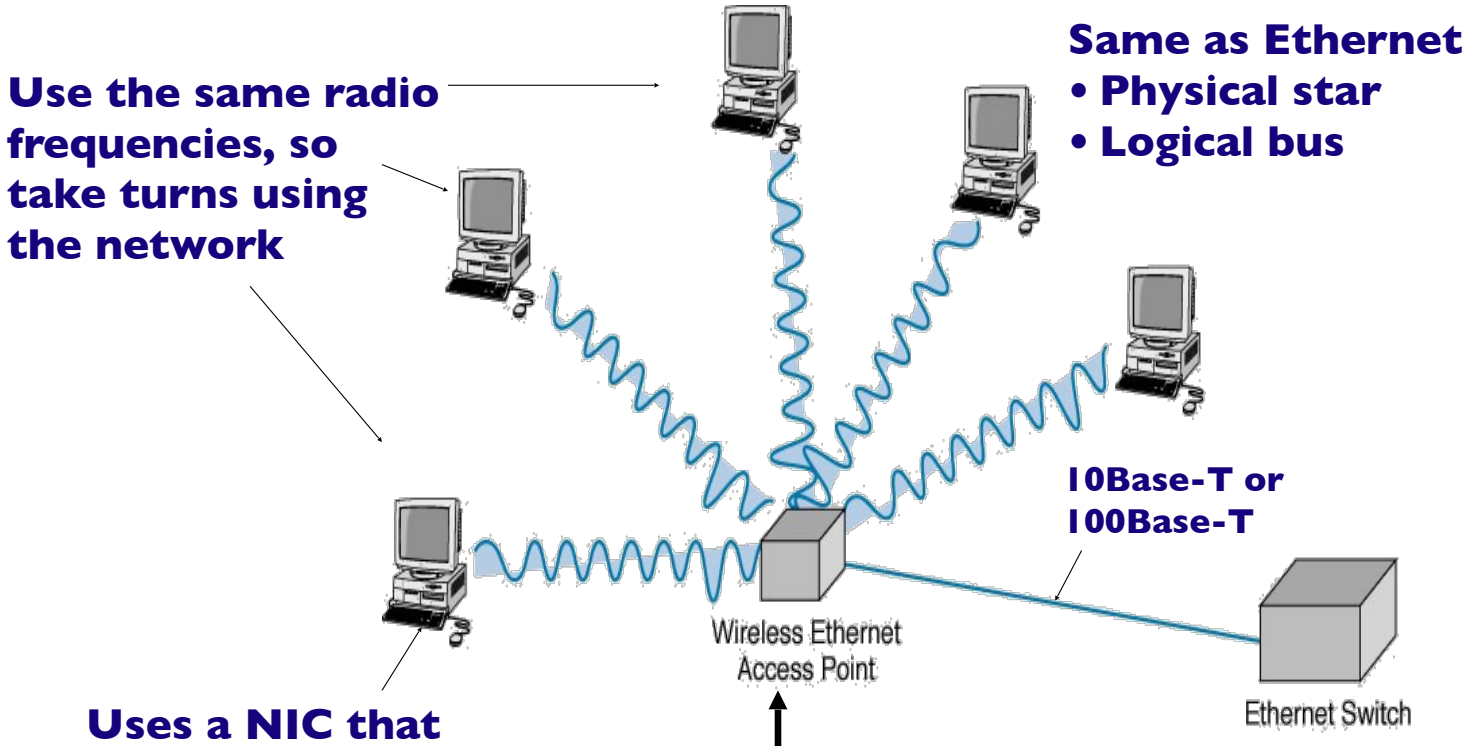
IEEE 802.11b

- 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



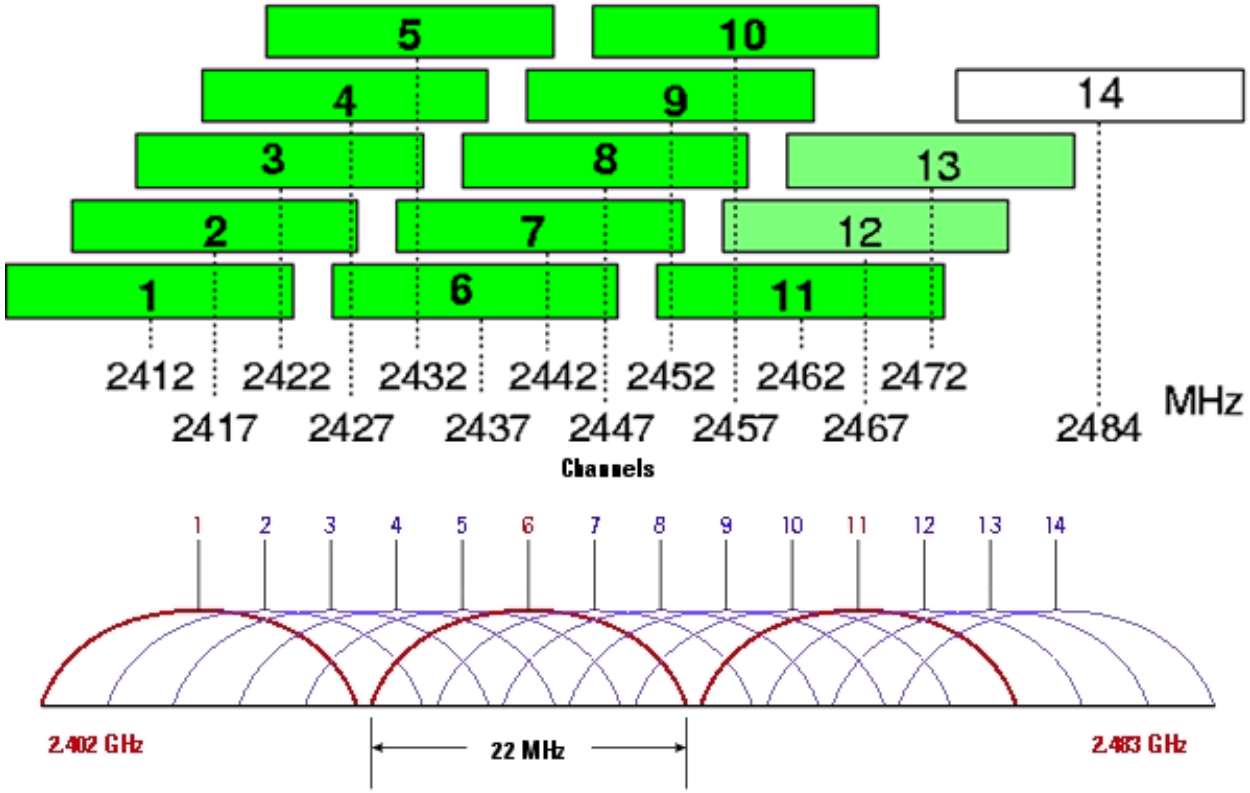
Components of WLANs

- **Network Interface Cards**
  - First was available for laptops as PCMCIA cards
  - Available for desktops as standard cards
  - Laptops/Smart Phones come with WLAN cards built in now
  - 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)

802.11b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7
8
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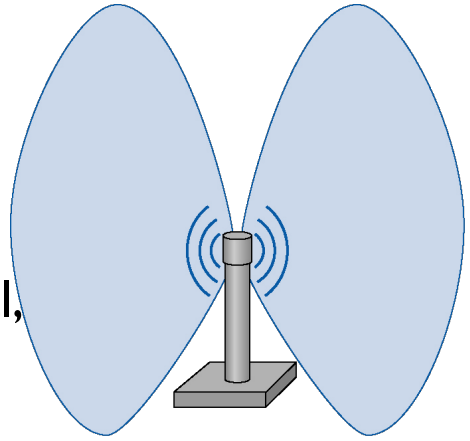
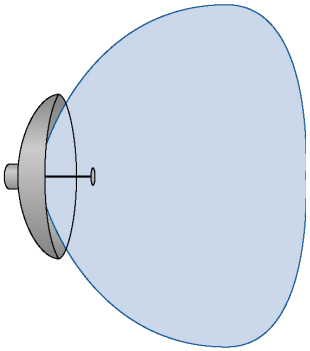
10
11
12
13
14
2.402 GHz
22 MHz
2.483 GHz

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