Business Data Communications and Networking

11th Edition

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Chapter 6

Wired and Wireless Local Area Networks

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Chapter 6: Outline

6.1 - Introduction

6.2 - LAN Components

6.3 - Wired Ethernet

6.4 - Wireless Ethernet

6.5 - Best Practice LAN design

6.6 - Improving LAN Performance

6.7 - Implications for Management

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6.1 Introduction

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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**

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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 30 copies of the same program)**
    - **Assumes that only 10 users would simultaneously use the software**

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Sharing Software on a LAN

- **LAN Metering**
  - **Used to control the number of copies of software used on a LAN**
  - **Available for many software packages**
  - **Keeps track of the users**
  - **Prohibits using more copies of the package than the licensed number**
  - **Helps to minimize copyright violations**
    - **40% of software used in the world is illegal, $40B loss**

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Dedicated Servers vs. Peer-to-Peer

- **Dedicated server network**
  - **A server is permanently assigned a specific task**
  - **Most popular network type**
    - **90+% of all LANs**
- **Peer-to-peer network**
  - **No dedicated servers used**
  - **All computers act as both clients and servers**
  - **Cheaper than dedicated, but less capability**

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Dedicated Server Networks

- **Requires one or more dedicated computers**
  - **Permanently assigned a specific task**
  - **Enable users to share files, printers, etc.,**
  - **May form a powerful enterprise network replacing mainframes**
  - **May form a server farm (aka server cluster)**
  - **Runs a server Network Operating System (NOS)**
    - **Windows Server 2003/8, Linux (Red Hat, CentOS)**
  - **Also requires a special communication software to enable communications with client computers (FTP, SQL etc)**

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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 servers**
    - **Handle print requests**
    - **Could be a separate computer or a “Black Box” or “NetGear”**

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Peer-to-Peer Networks

- **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**

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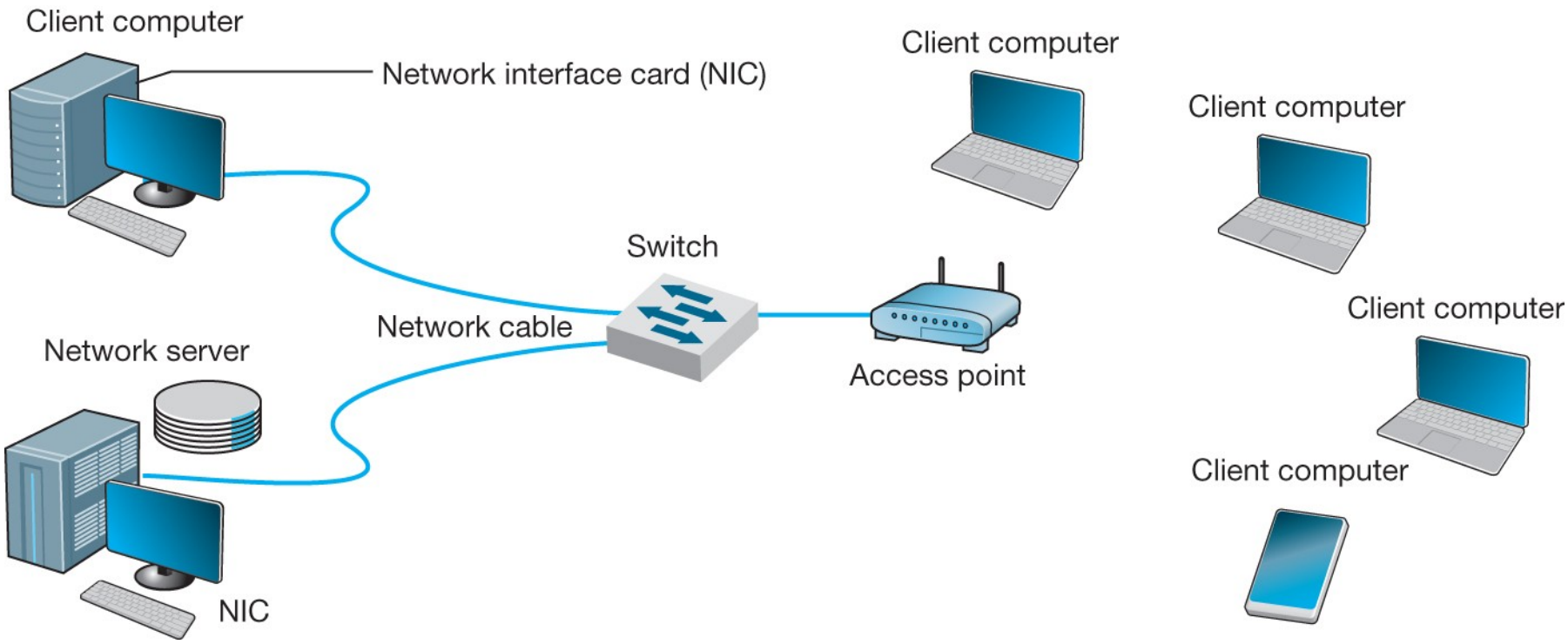
6.2 LAN Components



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Network Interface Cards (NICs)

- **Also called network cards and network adapters**
- **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**
- **Mostly built into motherboards today**
- **Can be plugged into the USB port**

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Network Circuits

- **Used to connect a computer physically to the network**
- **Types of cables**
  - **Untwisted wire pairs (UTP) – leading LAN cable type**
  - **Shielded twisted pair (STP)**
  - **Optical fiber – high capacity, just beginning in LANs**

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Hubs & Switches

Functions:

1)Act as junction boxes, linking cables from several computers on a network

1) **Usually sold with 4, 8, 16 or 24 ports**
2) **May allow connection of more than one kind of cabling, such as UTP and coax.**

2)Repeat (reconstruct and strengthen) incoming signals

- **Important since all signals become weaker with distance**
- **Extends the maximum LAN segment distance**

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Hubs & Switches



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

http://homestore.cisco.com/en-us/Switches/linksys-EZXS55W_stcVVproductId53934575VVcatId543809VVviewpro



b) Data center chassis switch with 512 10 Gbps ports

Source: newsroom.cisco.com/dlls/2008/prod_012808b.html

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Access Points

- **APs are used instead of hubs/switches in a wireless environment**
- **Act as a repeater**
  - **They must be able to hear all computers on a WLAN**

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Access Points



(a) AP for SOHO use



(b) A Power-Over-Ethernet AP for enterprise use

Source: Alan Dennis

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Access Points

- **Power over Ethernet (POE)**
  - **Used to supply power to some APs**
  - **No external power is needed**
  - **Power flows over unused Cat5 wires**

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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**
  - **Most often used on inside of an exterior wall**
    - **To reduce the security issue**
      - **A potential problem with WLANs**
  - **Antennas can be made from Pringles, etc. cans and are called "Cantennas" (www.cantenna.com)**

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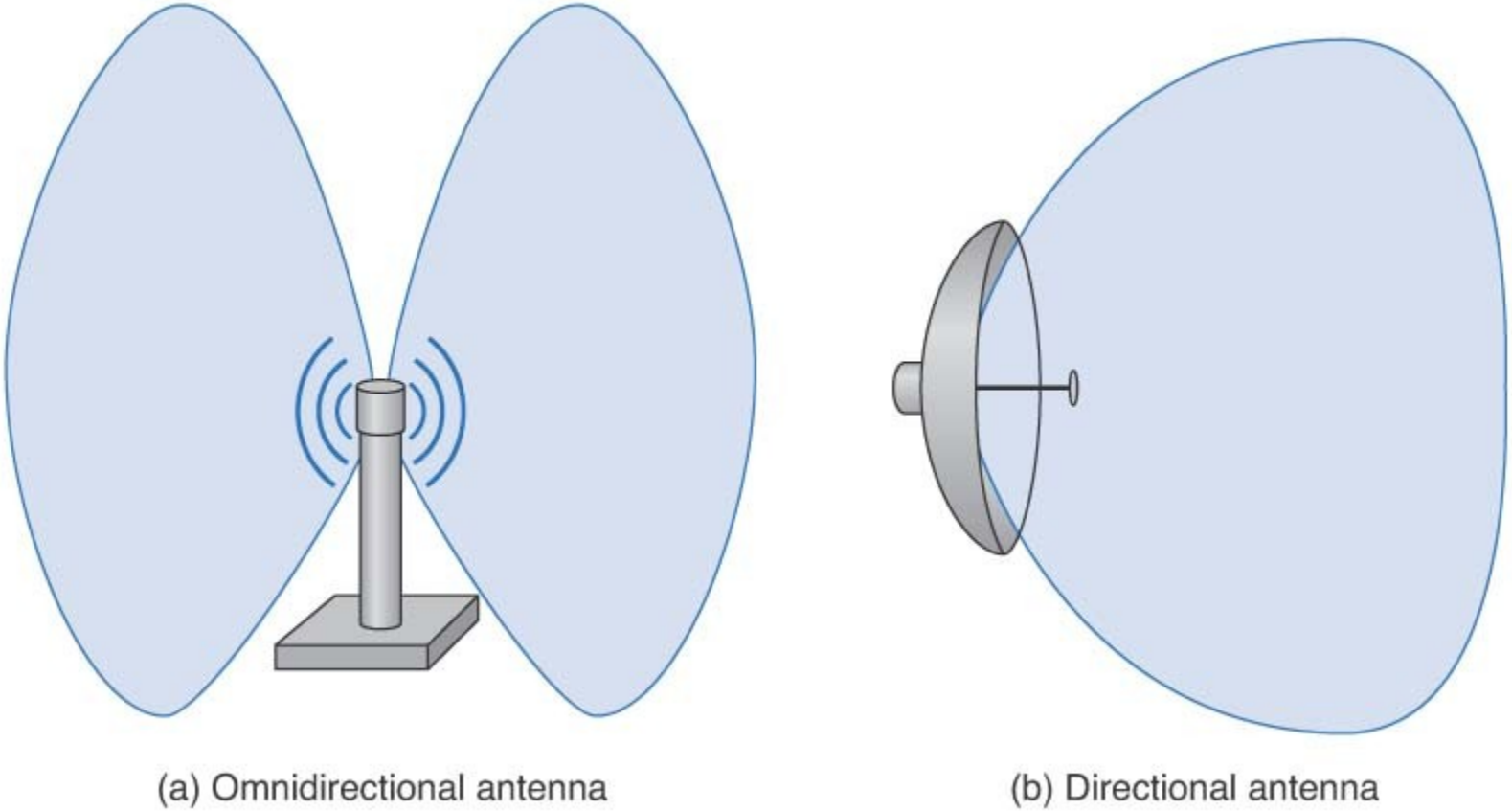
Types of Antennas



(a) Omnidirectional antenna

(b) Directional antenna

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Network Operating Systems

- **Software that controls the LAN**
- **Parts of NOS**
  - **Server version of NOS (runs on server)**
  - **Client version of NOS (runs on client computers)**
- **Directory Service**
    - **Provide information about resources on the LAN**
- **Network Profiles**
    - **Indicate the resources available in the network and authorized users**

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**
  - **Microsoft Windows Server 2003/8**
  - **Linux (Red Hat, Debian, etc)**

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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 such as Windows XP and Vista and up**
- **Allows client to view and access available network resources**

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NOS Directory Service

- **Provides information about resources on the LAN**
- **Example is Active Directory Service (ADS) by Microsoft**
  - **An AD domain controller authenticates and authorizes all users and computers in a Windows domain type network**
  - **Assigning and enforcing security policies for all computers and installing or updating software.**
    - **For example, when a user logs into a computer that is part of a Windows domain, Active Directory checks the submitted password and determines whether the user is a system administrator or normal user.**
  - **Active Directory makes use of Lightweight Directory Access Protocol (LDAP) versions 2 and 3, (Microsoft's version of Kerberos)**
    - **LDAP is an application protocol for accessing and maintaining distributed directory information services over an Internet Protocol (IP) network.**
    - **Directory services may provide any organized set of records, often with a hierarchical structure, such as a corporate email directory.**
    - **Similarly, a telephone directory is a list of subscribers with an address and a phone number.**
    - **LDAP is specified in a series of Internet Engineering Task Force (IETF)**

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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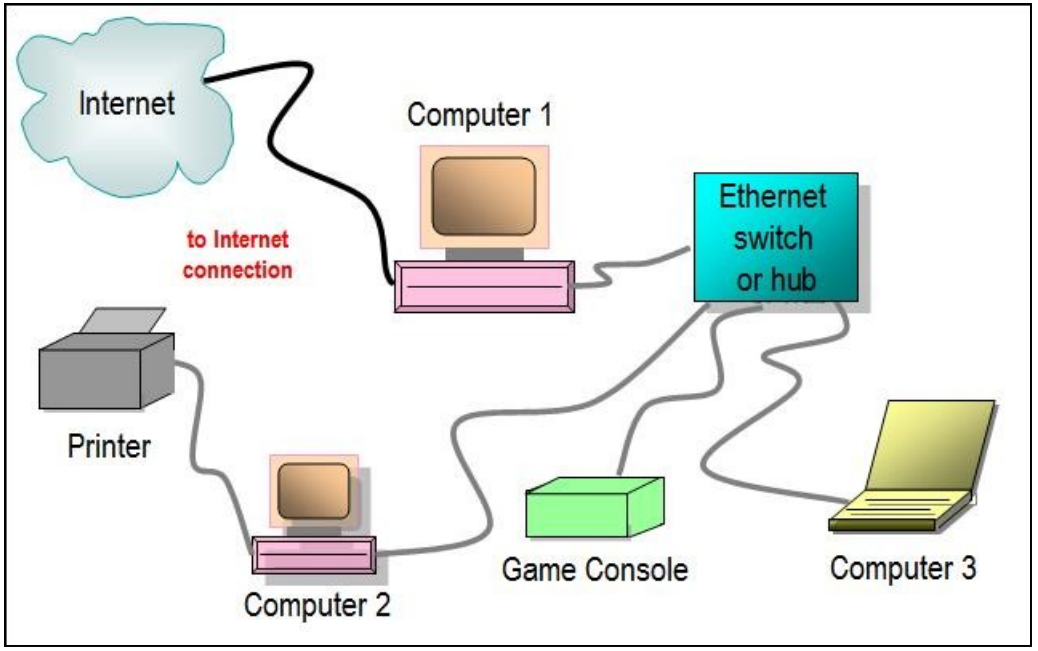
6.3 Wired Ethernet

- **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**

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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**

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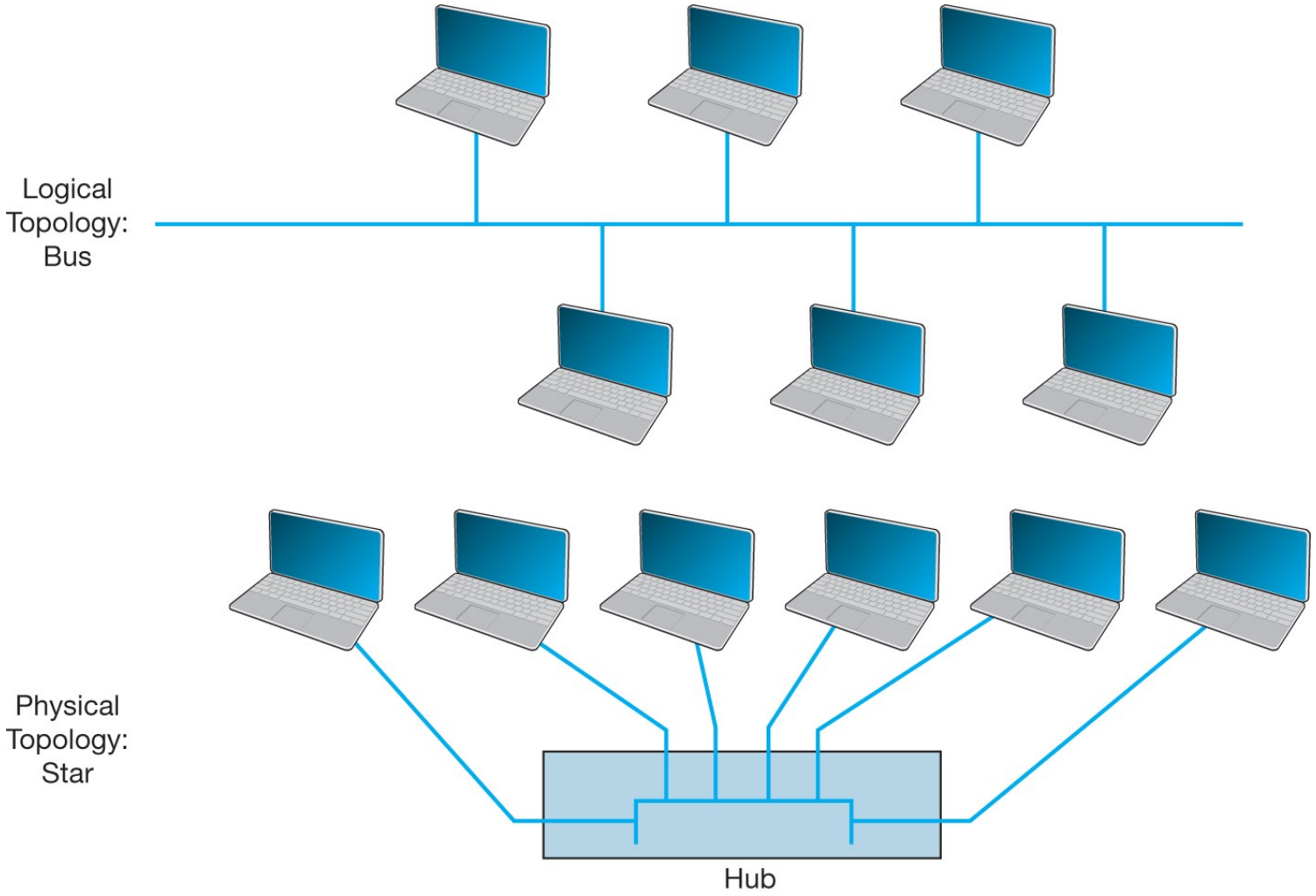
Shared Ethernet's Physical Topology



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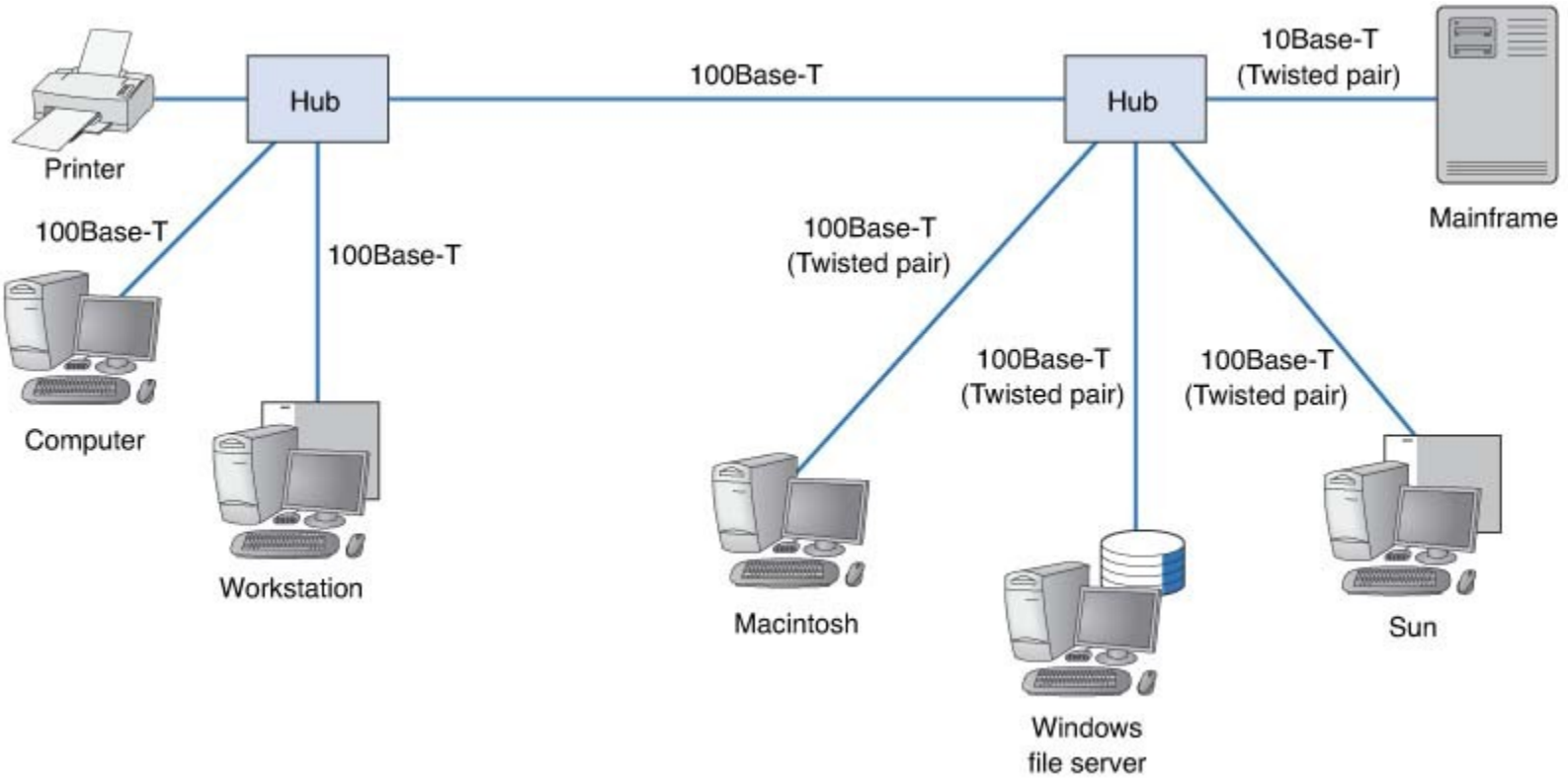
Multiple Hub Ethernet Design



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Switched Ethernet Topology

- **Uses workgroup switches**
  - **Designed to support a small set of computers (16 to 48 ports) 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**
- **Logical and physical topology of the network becomes a star topology via switch**
- **Switch reads destination address of the frame and only sends it to the corresponding port**
  - **While a hub broadcasts frames to all ports**

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	HUB	SWITCH
Technical Spec	Hubs classify as Layer 1 devices in the OSI	Network switches operate at layer two (Data Link Layer) of the OSI model.
Layer:	Physical layer(Layer 1 Device)	Data Link Layer (Layer 2 devices)
Transmission Type:	only Broadcast	At Initial Level Broadcast then Uni-cast & Multicast
Spanning-Tree:	No Spanning-Tree	Many Spanning-tree Possible
Table:	no MAC table in Hub, Hub can't learn MAC address	Store MAC address in lookup table and maintain at its own, Switch Learns MAC addr
Used in	LAN	LAN
Ports:	4 ports	Switch is multi port Bridge. 24/48 ports
Collision:	In Hub collision occur.	In Full Duplex Switch no Collision occur.
Transm. Mode:	Half duplex	Full duplex
***CollisionDomain:**	Hub has One collision domain.	in Switch, every port has its own collision domain.
Cost:	Cheaper than switches	3-4 times costlier than Hub
Device Type:	Passive Device (Without Software)	Active Device (With Software) & Networking device

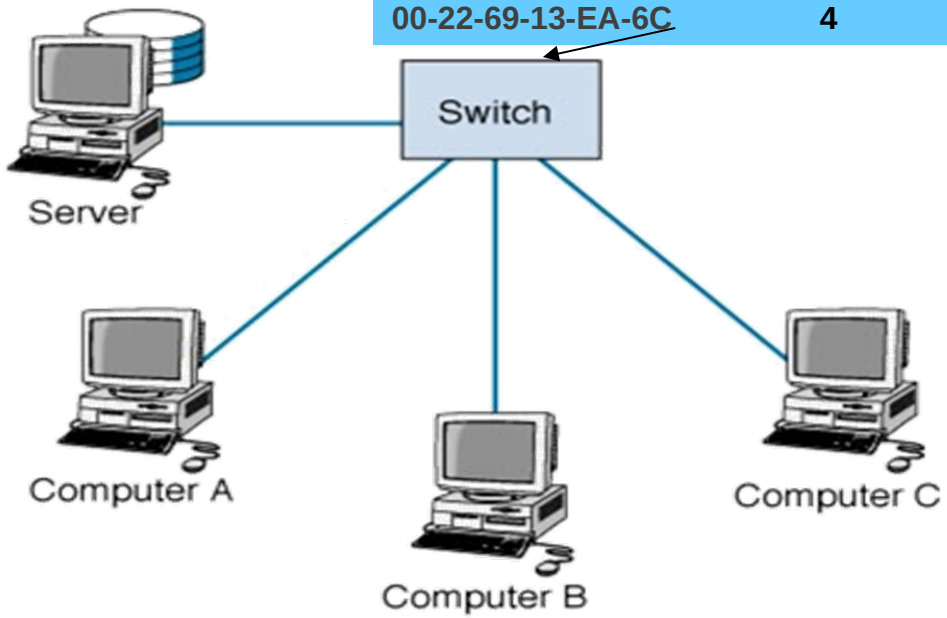
***A collision domain is a section of a network where data packets can collide with one another when being sent on a shared medium or through repeaters**

Forwarding Tables

- **Similar to routing tables**
- **Lists the Ethernet address of computers connected to each port**
- **When a frame is received, the switch reads its Layer 2 data link layer destination address and sends the frame out of the corresponding port in its forwarding table.**

Forwarding Table

MAC	Port
00-22-69-13-EA-3E	1
00-22-69-13-EA-3A	2
00-22-69-13-EA-01	3
00-22-69-13-EA-6C	4



Learning Switch Operation

- **Switch starts by working like a simple hub**
  - **With an empty forwarding table**
- **It gradually fills its forwarding table by learning about the nodes**

Forwarding Table	
MAC	**Port**
00-22-69-13-EA-3E	1
00-22-69-13-EA-3A	2
00-22-69-13-EA-01	3
00-22-69-13-EA-6C	4

  - **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**

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Modes of Switch Operations

1. **Cut through switching**
   - Reads destination address and starts transmitting without waiting for the entire message to be received
   - Low latency; but may waste capacity (errored messages)

2. **Store and forward switching**
   - Waits until the entire frame is received, perform error control, and then transmit it
   - Less wasted capacity; slower network

3. **Fragment free switching**
   - Reads the first 64 bytes (contains the header)
   - Performs error checking; if it is OK then begins transmitting
   - It is a compromise between previous two modes

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Media Access Control (MAC) with Shared Ethernet

- **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 destroy each other**
  - **Can be termed as “ordered chaos” since it is tolerated, rather than avoids, collisions completely**

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CSMA/CD

- **Carrier Sense (CS):**
  - **A computer listens to the bus to determine if another computer is transmitting before sending anything**
  - **Transmit when no other computer 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**
    - **To avoid a collision, both wait a random amount of time and then resend message**

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Media Access Control (MAC) with Switched Ethernet

- **Each circuit shared by a computer and the switch**
- **Still uses CSMA/CD media access control**
  - **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 one of the frame in memory until it finishes sending the other, then forwards the stored one**

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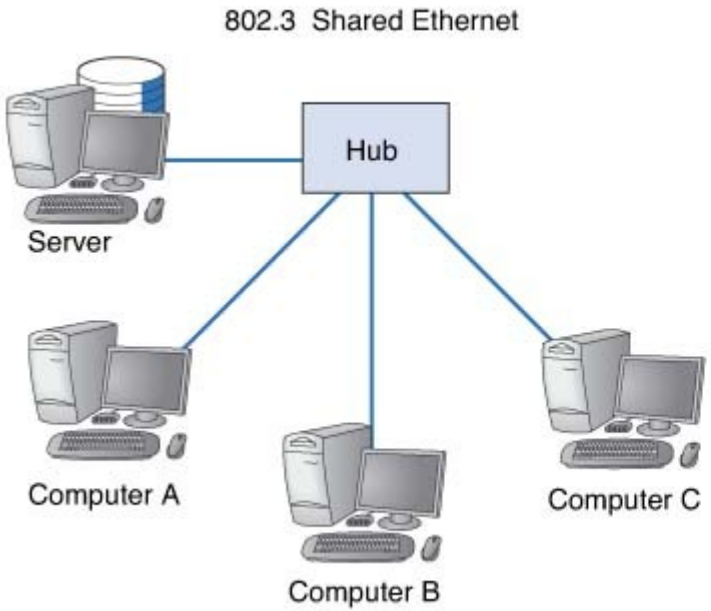
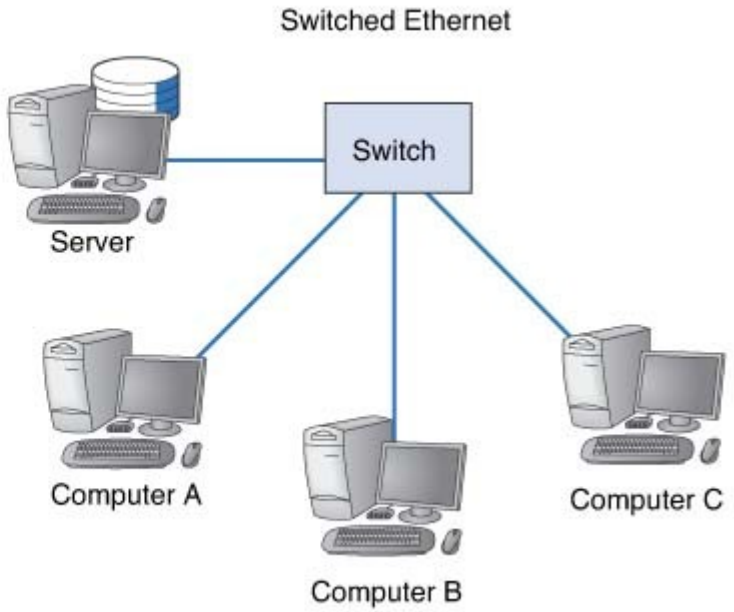
Performance Comparison





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

Runs at up to 95% capacity on 100Base-T**

*** 10BaseT is ordinary telephone twisted pair wire. 10BASE-T supports Ethernet's 10 Mbps transmission speed.**

**** 100BaseT is a networking standard that supports data transfer rates up to 100 Mbps**

Twisted Pair Ethernets

- **10Base-T**
  - **Uses Cat 3 (UTB for 10Mbit/s), and Cat 5 UTP, very inexpensive**
  - **Runs up to 100 meters**
  - **Rapidly losing ground to 100Base-T**
- **100Base-T**
  - **Uses Cat 5 UTP**
  - **Also called Fast Ethernet, replaced 10Base-T in sales volume**
  - **More common format today**
- **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**
- **1000Base-F**
  - **1 Gbps fiber**
- **10 GbE**
  - **10 Gbps Ethernet. Uses fiber and is typically full duplex**
- **40 GbE**
  - **40 Gbps Ethernet. Uses fiber and is typically full duplex.**

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Summary - Ethernet Media Types

Name	Maximum Data Rate
10Base-T	10 Mbp
100Base-T	100 Mbps
1000Base-T	1 Gbps
1000Base-F	1 Gbps
10 GbE	10 Gbps
40 GbE	40 Gbps

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6.4 Wireless Ethernet

- **Use radio frequencies to transmit signals through the air (instead of cables)**
  - **Wi-Fi grown in popularity**
    - **Eliminates cabling**
    - **Facilitates network access from a variety of locations**
    - **Facilitates for mobile workers (as in a hospital)**
    - **Used in 90 percent of companies**

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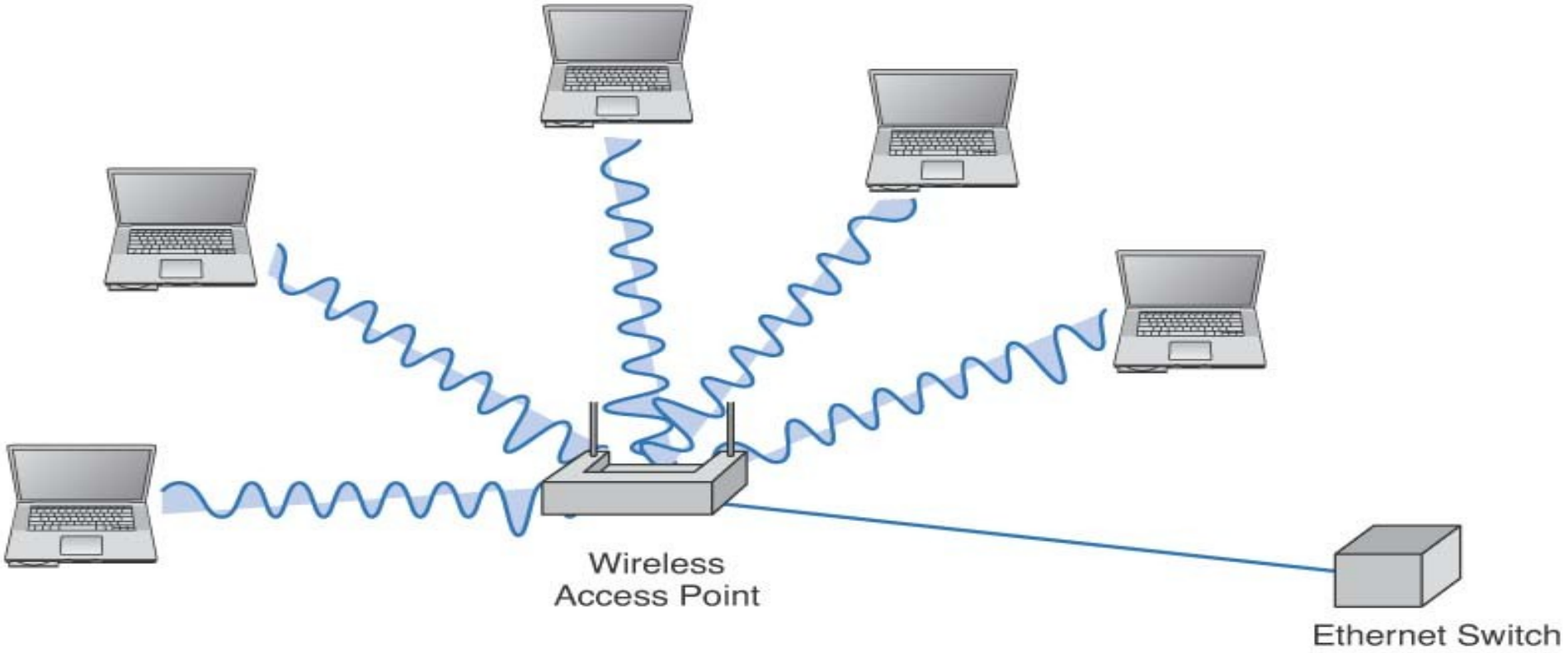
WLAN Topology

Same as Ethernet

- **Physical star**
- **Logical bus**



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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**

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Association with an AP

- **Scanning- searching for available Aps**
- **Two types**
  - **Active**
    - **NIC transmits probe frame on all active channels**
    - **AP responds with info to associate with it**
  - **Passive**
    - **NIC listens on all channel for beacon frame**
    - **NIC can use info in beacon frame to associate with AP**

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MAC Techniques

- **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”)**

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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 (Automatic Repeat reQuest)**
  - **ACK/NAK received to signal the transmission is over or not**

Point Coordination Function

- **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**
- **Solution**
  - **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**

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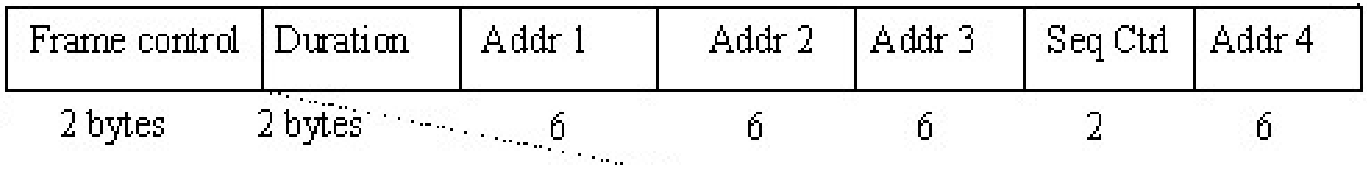
Wireless Ethernet Frame Layout



Two major differences between 802.3 and 802.11

- **.11 frame has 4 address fields**
- **.11 has new field for sequence control**
  - **Indicates how large frame is fragmented (chopping large data to smaller chunks)**
    - **Wired networks – segmentation at transport layer**
    - **Wireless- at data link layer**

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WLAN Characteristics

- **Two frequency ranges**
  - **2.4 GHz**
  - **5 GHz**
- **Distance range of 100-150 meters**
- **Channels are used to reduce interference**

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Types of Wireless Ethernet

	Max bandwidth	Max range	
802.11a	54 Mbps	50 meters	Legacy
802.11b	11 Mbps	150 meters	Legacy
802.11g	54 Mbps	150 meters	Legacy
802.11n	200 Mbps -or- 600 Mbps	150 meters	Latest version

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IEEE 802.11n

- **Backward compatible with a, b, and g**
- **Disadvantage: one laptop using a, b, or g slows down access by all other laptops (even when they are using n)**

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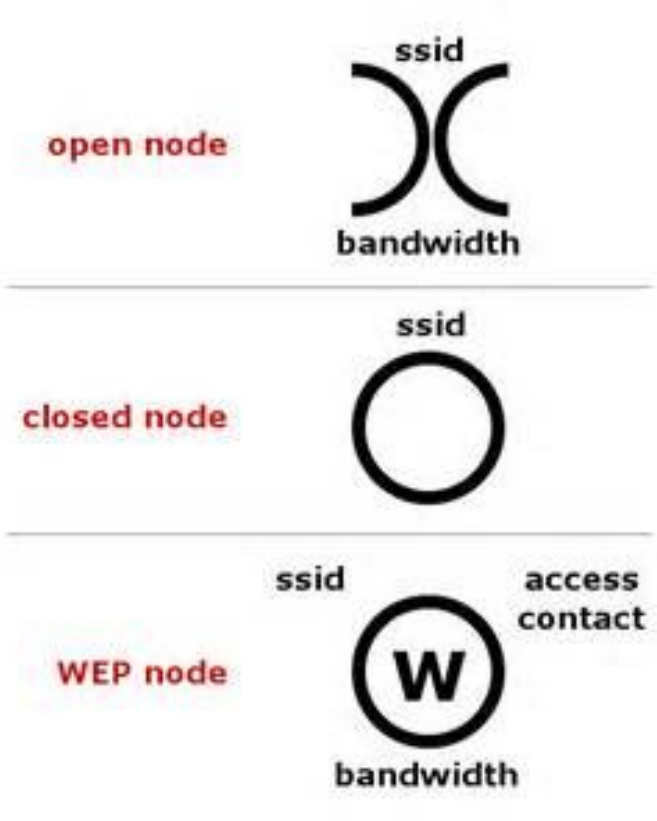
WLAN Security

- **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**



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)**
  - **One time WEP keys created dynamically after login**
  - **Requires a login (with password) to a server**

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Types of WLAN Security, cont'd

- **Wi-Fi Protected Access (WPA)**
  - **new standard**
  - **longer key, changed for every packet**
- **802.11i (WPA2)**
  - **EAP login used to get session key**
  - **uses AES encryption (see next slides)**

- **MAC address filtering**
  - **Allows computers to connect to AP only if their MAC address is entered in the "accepted" list**

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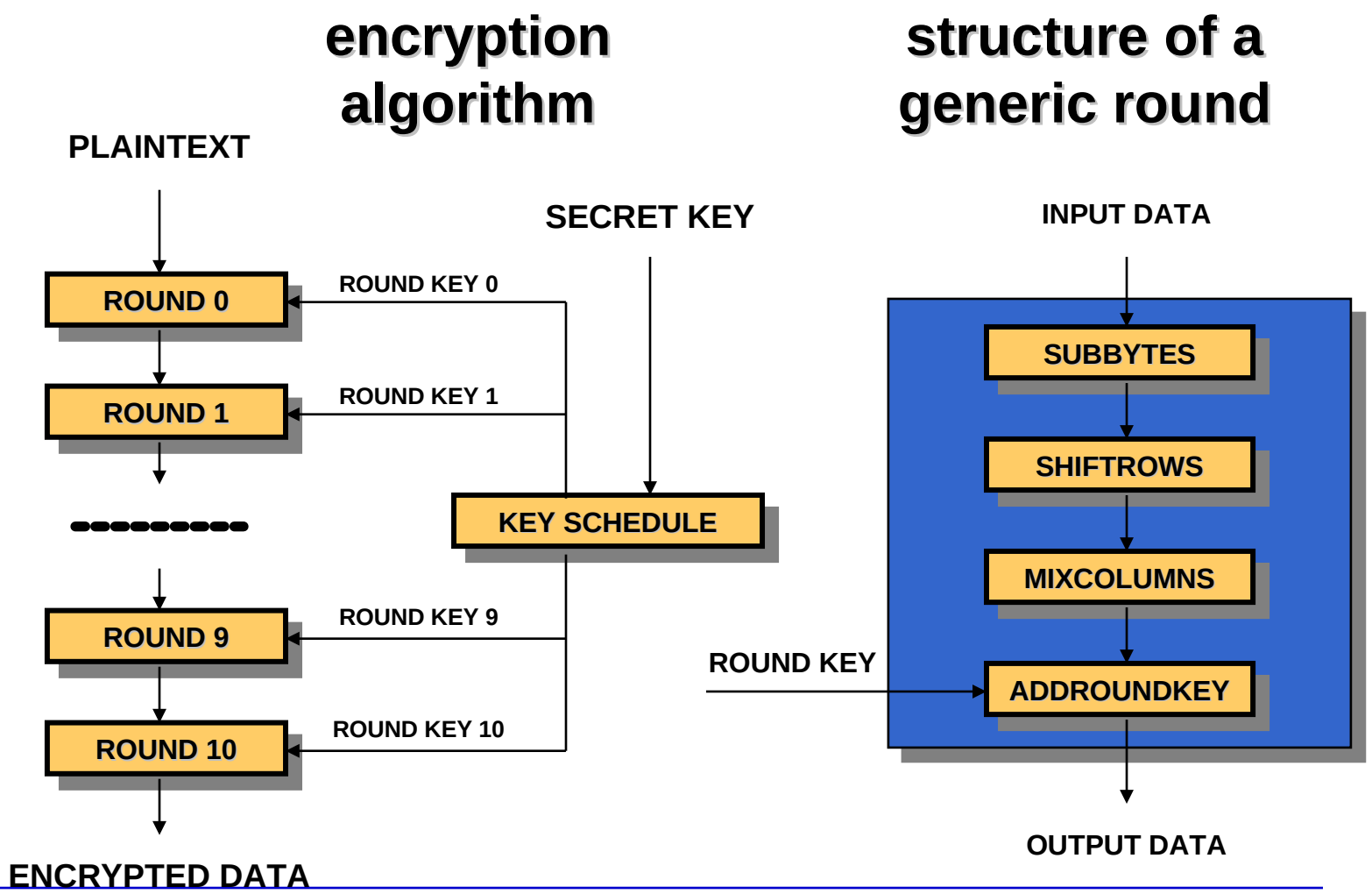
Advanced Encryption Standard
AES ENCRYPTION

- **Rijndael is the selected algorithm for AES**
- **It is a block cipher algorithm, operating on blocks of data.**
- **It needs a secret key, which is another block of data.**

AES ENCRYPTION

- **Performs encryption and the inverse operation, decryption (using the same secret key).**
- **It reads an entire block of data, processes it in rounds and then outputs the encrypted (or decrypted) data.**
- **Each round is a sequence of four inner transformations.**
- **The AES standard specifies 128-bit, 192-bit or 256-bit secret keys.**

AES Algorithm – Encryption



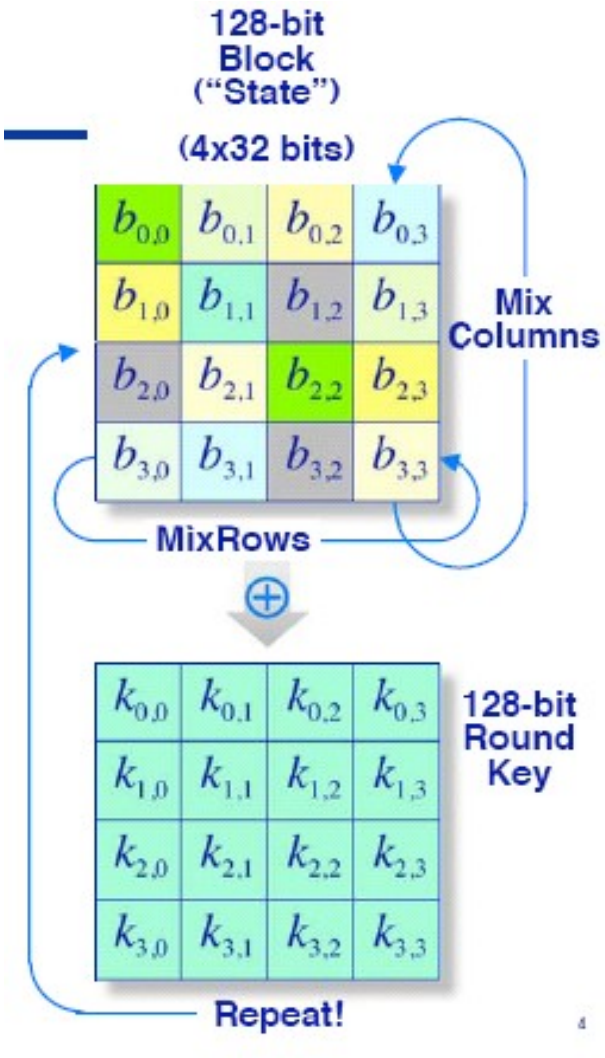
AES Algorithm – Encryption
A little closer look

1. **Perform a byte by byte substitution**
2. **Perform a row by row shift operation**
3. **Perform a column by column transformation**
4. **Perform a XOR with a round key**

No of rounds = 10 for 128 bits

12 for 192 bits

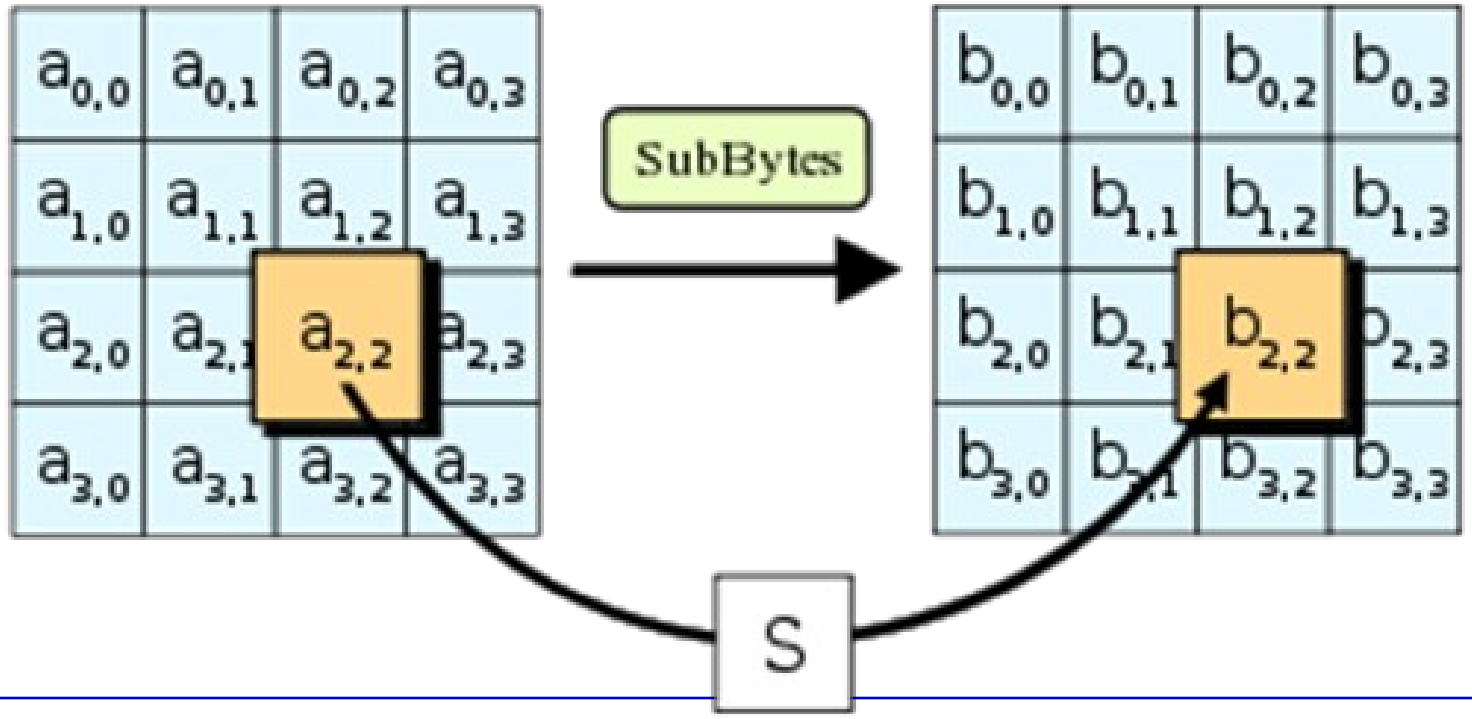
14 for 256 bits



AES

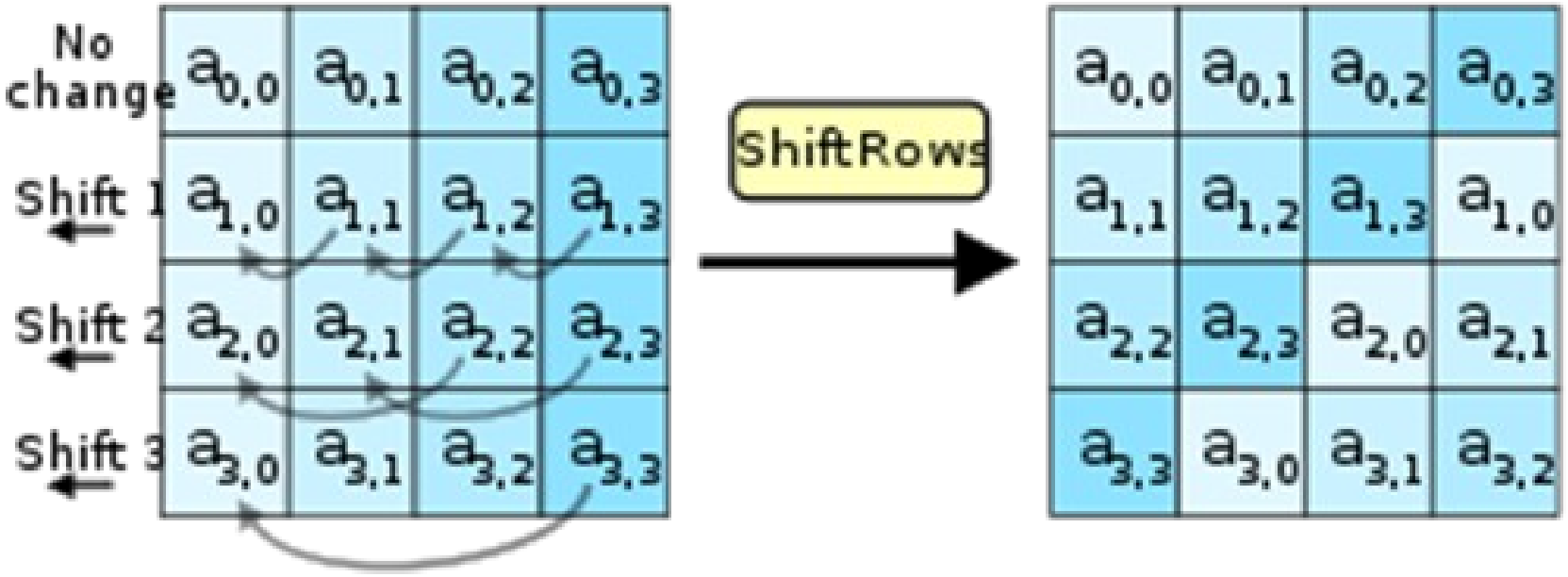
~~Advanced Encryption Standard~~

1. The SubByte Step



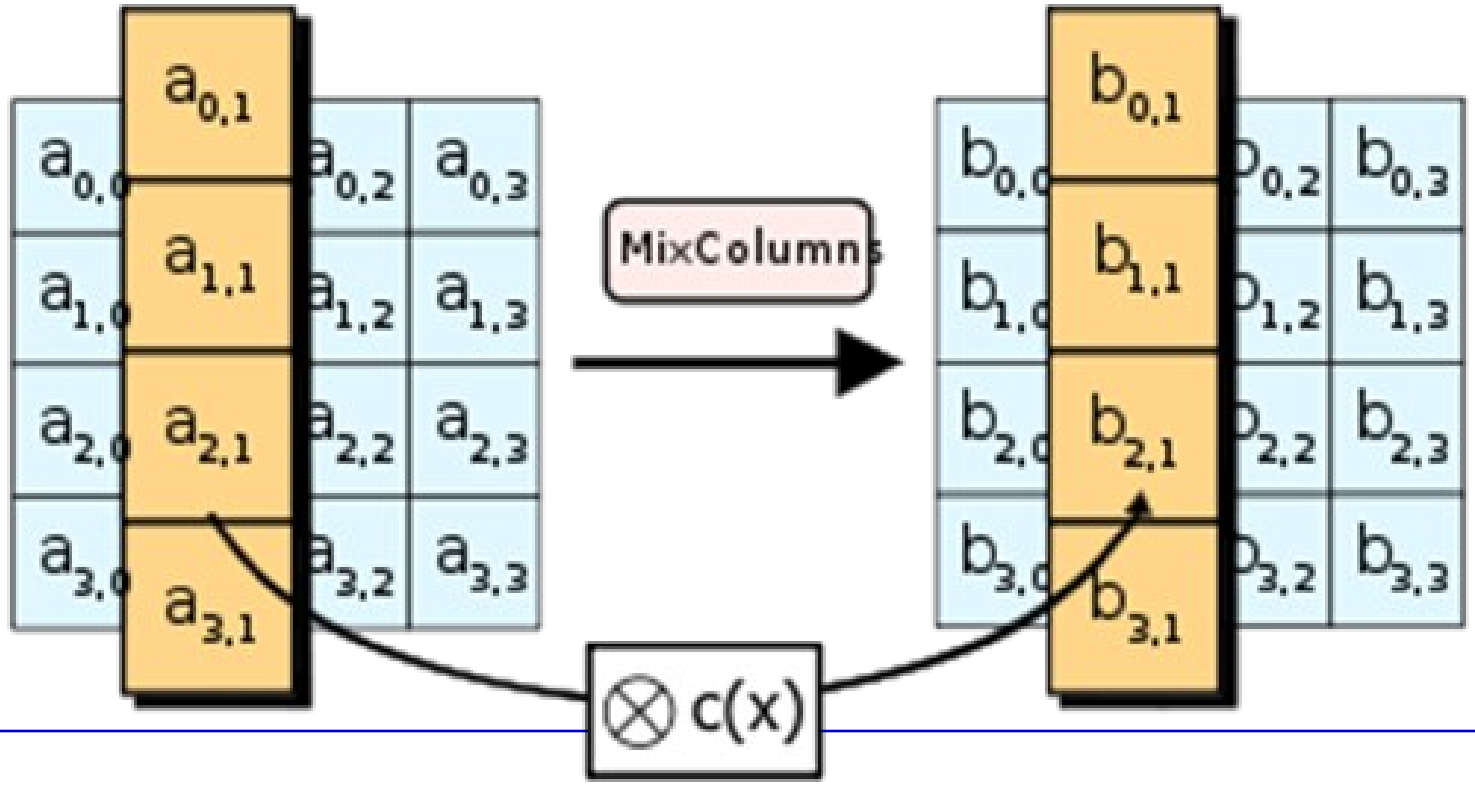
AES
Advanced Encryption Standard

2. The ShiftRow Step

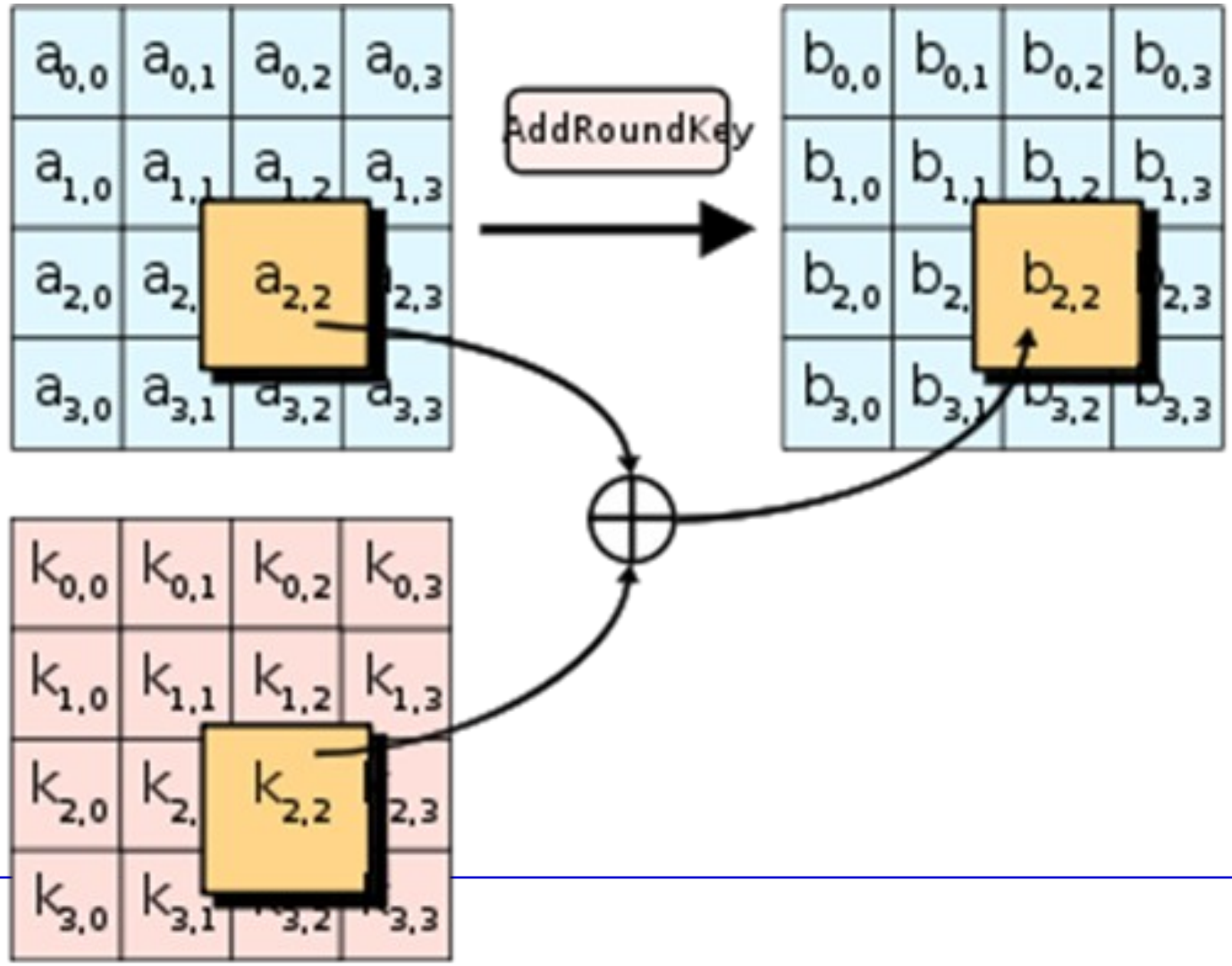


AES
Advanced Encryption Standard

3. The MixColumns Step



AES
The AddRoundKey step



Some facts about AES

- **AES keys (128bits)**

  340,000,000,000,000,000,000,000,000,000,000,000,000

  possible keys

- **Suitable for a wide variety of platforms - ranging from smart cards to servers**

AES ‘built-into’ products

- **Navastream Crypto Phones**
- **PGP Mobile for the TREO 650**
- **Nokia’s solutions for mobile VPN client – AES 256**



AES Cracking - 2006

- **Assumptions**
  - **3 GHz dedicated processor**
  - **1 clock cycle per key generation**
- **2^128 keys / 3E9 processes per second =**
  - **1.13E29 seconds**
  - **3.6E21 years, 3.6 Zy (Zetta years)**
  - **3.6 Sextillion years**

6.5 The Best Practice LAN Design

- **Recently costs have dropped while speeds have increased**
- **WI-FI cheaper b/c of no wires to install**
  - **$150-400 per wire in retrofitted building**
  - **$50-$100 per wire in new building**
- **Best practice today: Wired Ethernet for primary LAN and WI-FI as overlay**

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Best Practice Recommendations: Wired

- **Switched 100Base-T over Cat5e**
  - **Relatively low cost and fast**
- **Category 5e cables**
  - **Costs decreasing**
  - **Provides room for upgrades to 100Base-T or 1000Base-T**

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Best Practice Recommendations: Wireless

- **Pick newest one, cost permitting**
  - **802.11n (in 2011)**
- **Placement of APs should be considered**

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Physical WLAN Design

- **More challenging than designing a traditional LAN**
  - **Use a temporary AP and laptop to evaluate placement of APs**
  - **Locations are chosen to provide coverage as well as to minimize potential interference**
- **Begin design with a site survey, used 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**

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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**
- **Set each AP to transmit on a different channel (next slide)**

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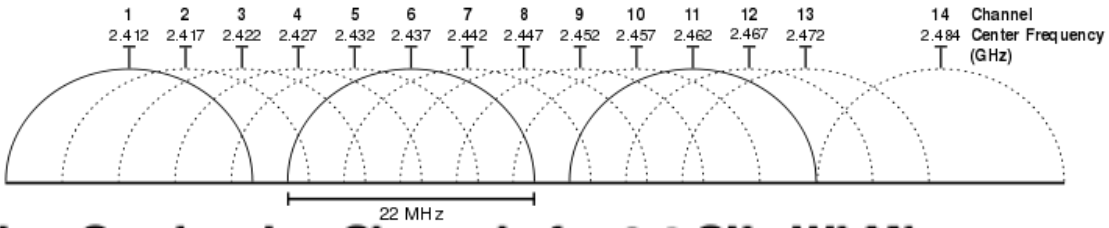
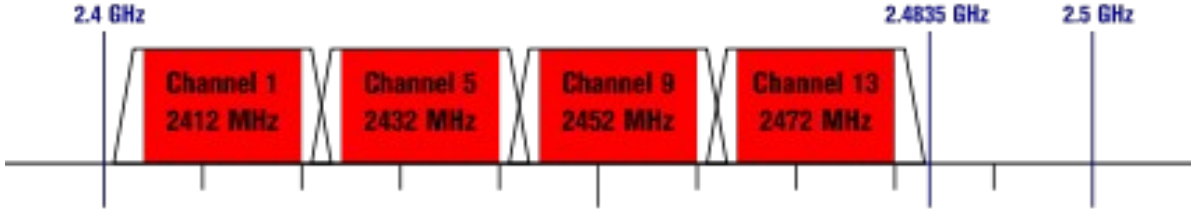


Non-Overlapping Channels for 2.4 GHz WLAN

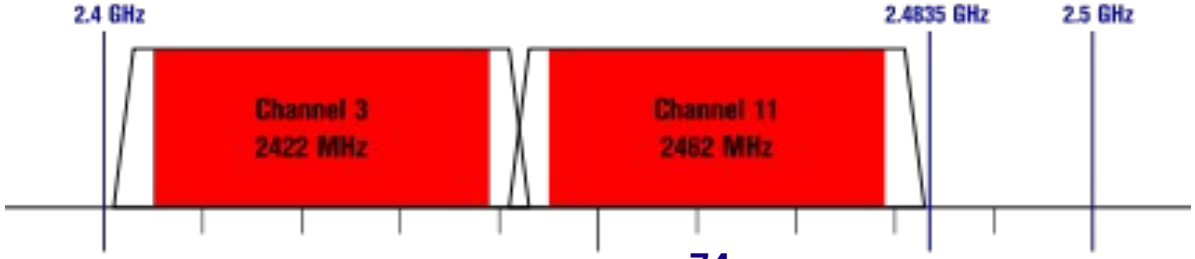
802.11b (DSSS) channel width 22 MHz

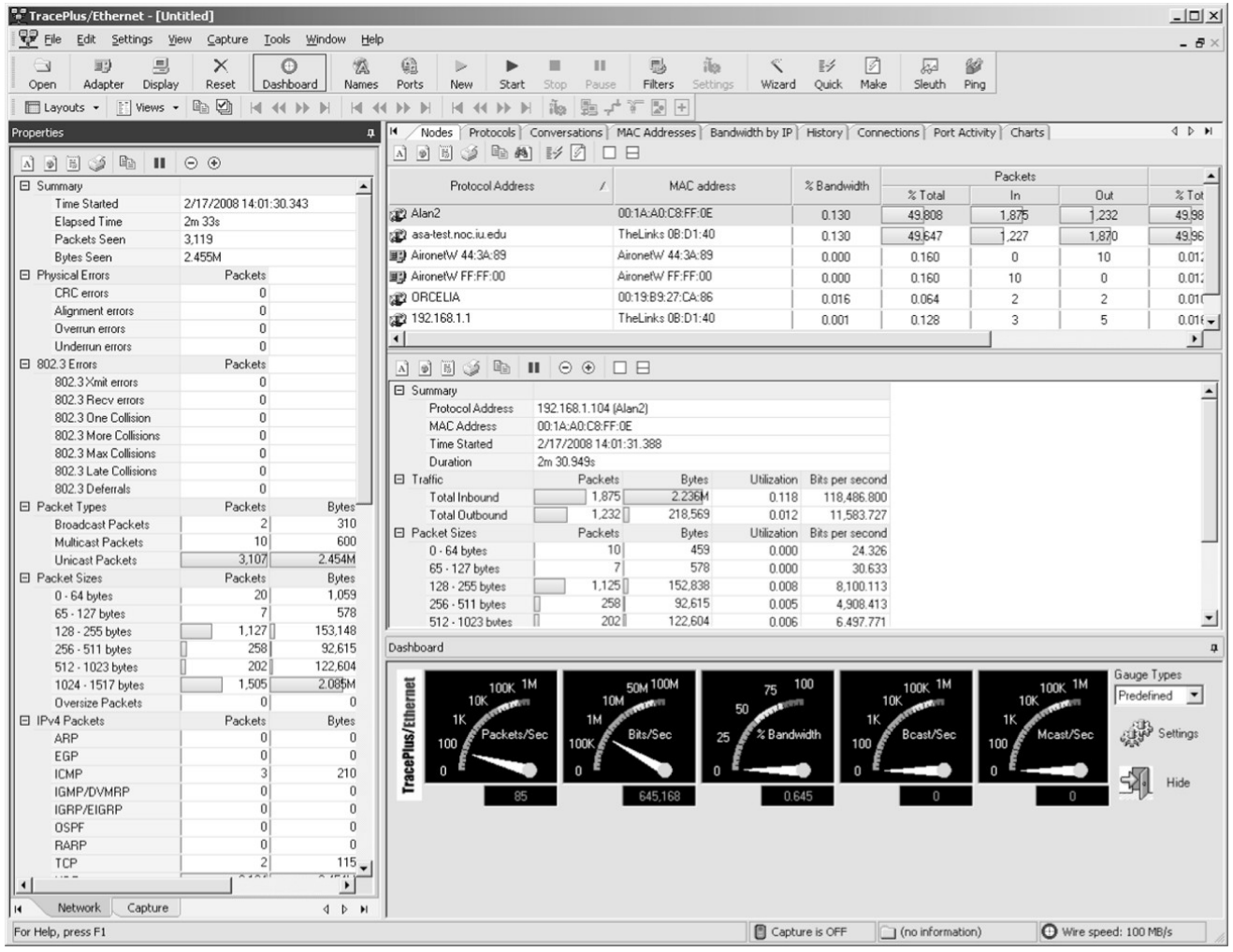


802.11g/n (OFDM) 20 MHz ch. width – 16.25 MHz used by sub-carriers



802.11n (OFDM) 40 MHz ch. width – 33.75 MHz used by sub-carriers





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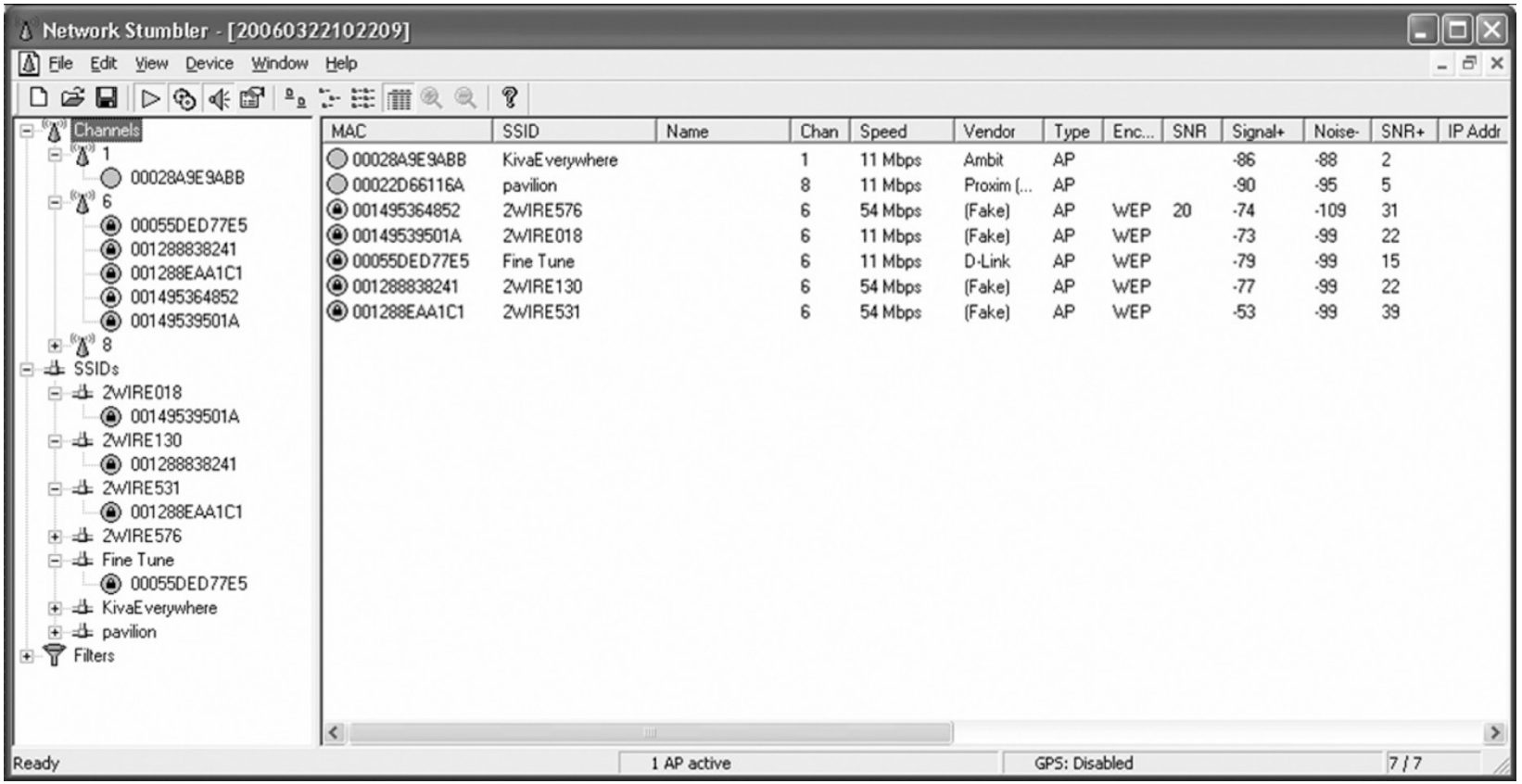

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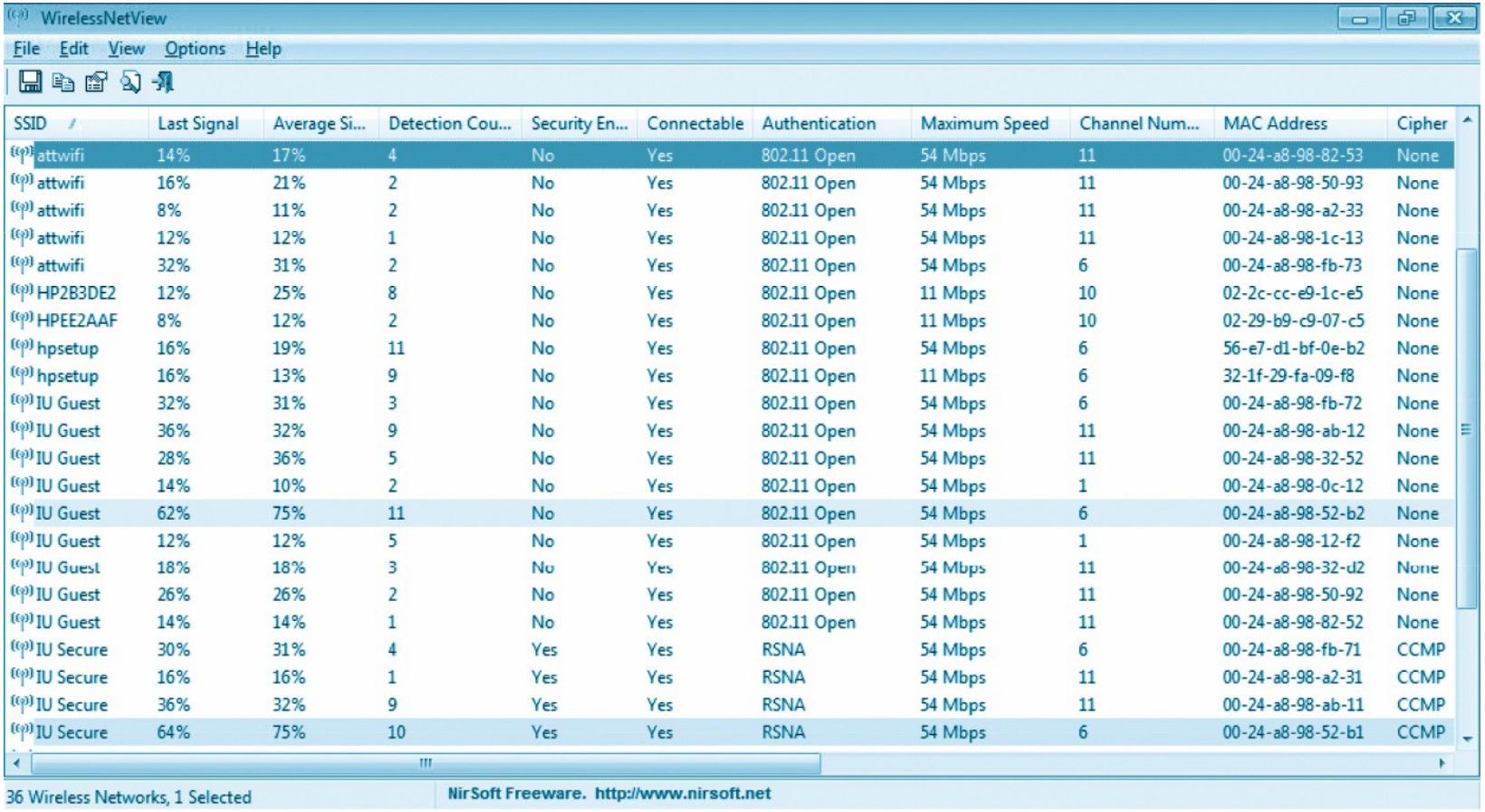

Source: Alan Dennis

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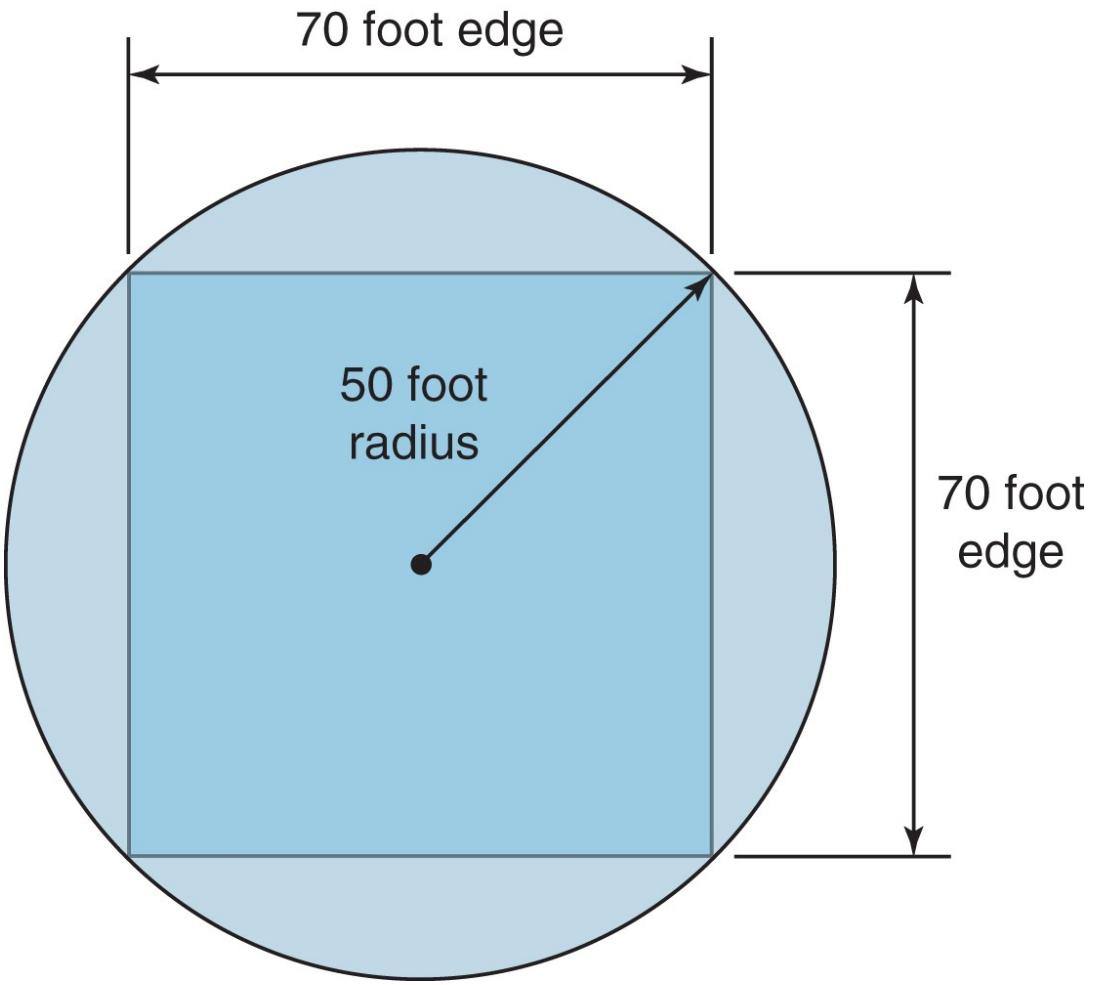

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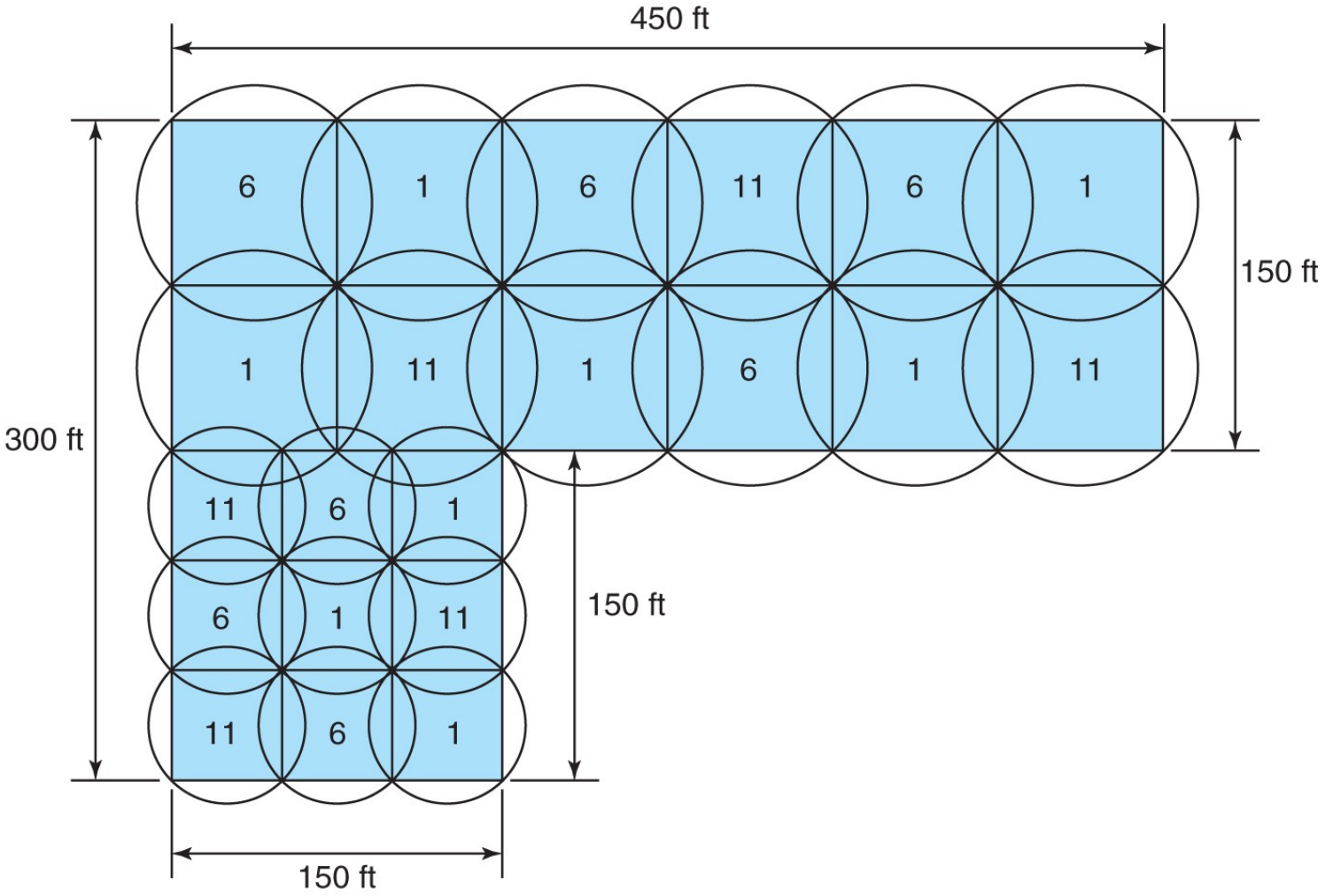

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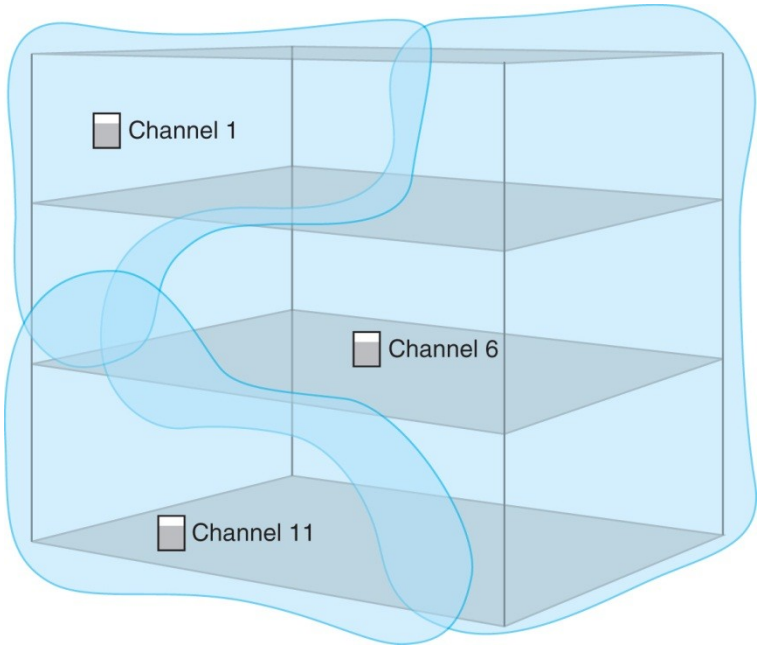
Multistory WLAN Design

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



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Designing for SOHO Environments

- **Small Office / Home Office**
- **Typically use AP, switch, and router**
  - **-or- cable modem and wireless router**
  - **-or- all could be in one device**

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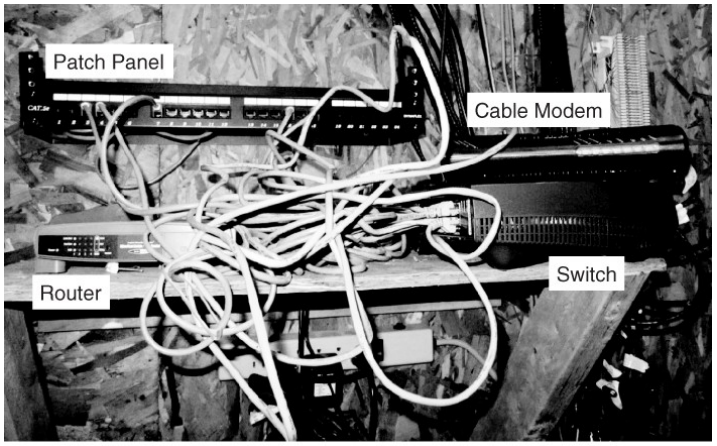
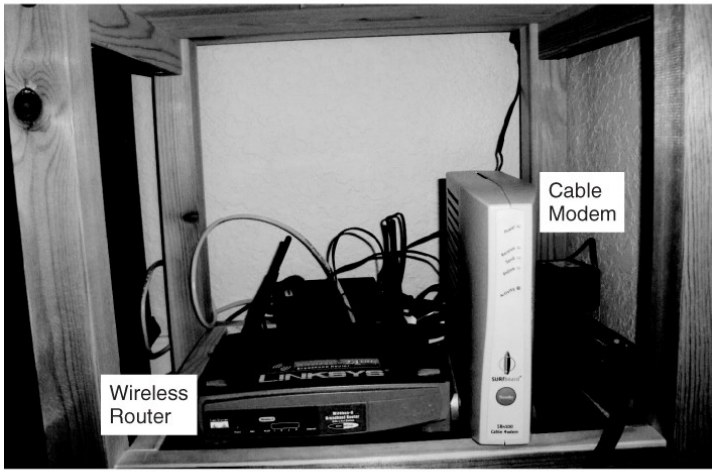
Designing for SOHO Environments



(a) Alan's home network



(b) Alexandra's home network

Source: Alan Dennis

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6.6 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 and LAN performance, identify and eliminate bottlenecks**
  - **Bottlenecks are points in the network where congestion is occurring**
  - **Congestion is when the network or device can't handle all of the demand it is experiencing**

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Identifying Network Bottlenecks

- **Potential places**
  - **Network server**
  - **Network circuit**
  - **Client's computer**

- **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**

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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**

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Improving Disk Drive Performance

- **Especially important, since disk reads are the slowest task the server needs to do**
- **Consider 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 so drive failure does not result in any loss of data**

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Improving Circuit Capacity

- **Upgrade to a faster protocol**
  - **Means upgrading the NICs and possible cables**
  - **Examples:**
    - **Upgrading the network from 100Base-T to 1000Base-T**
    - **Upgrading the segment to the server from 100Base-T to 1000Base-T**
- **Increase number of circuits**
  - **Network segmentation**
    - **Wired**
      - **Add NICs to server that connect to multiple switches**
    - **Wireless**
      - **Add more APs on different channels**

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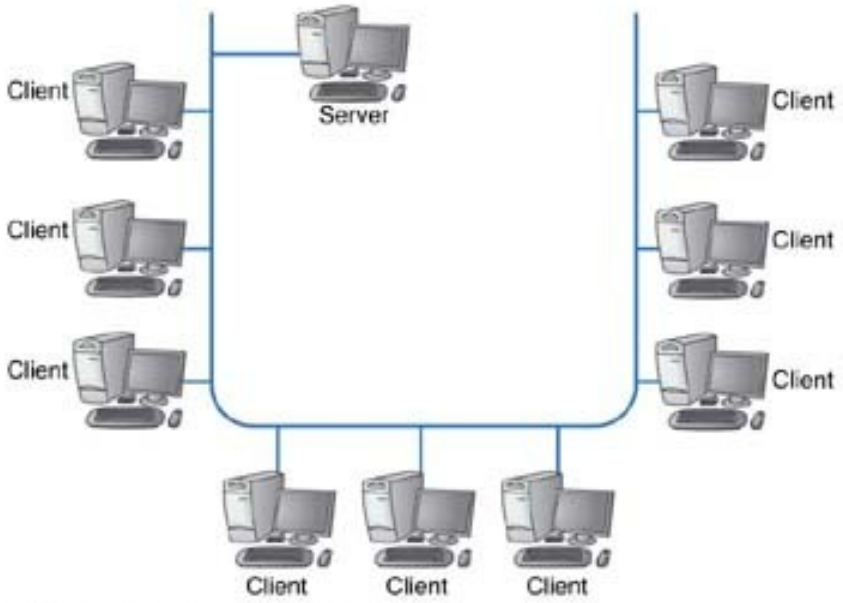
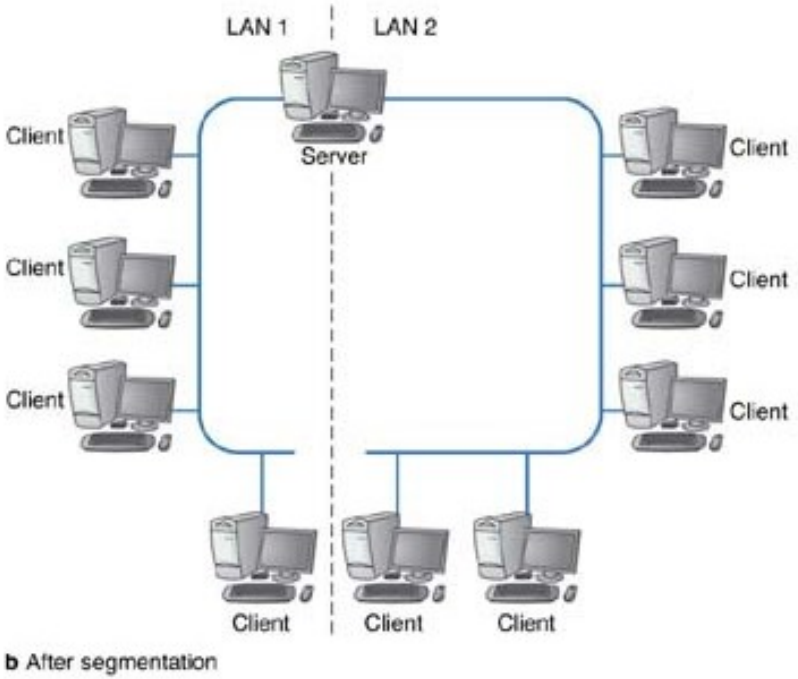
Network Segmentation



a Before network segmentation



b After segmentation

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Reducing Network Demand

- **Move files to client computers**
  - **Such as heavily used software packages**
- **Encourage balancing of wired and wireless network usage by users**
- **Move user demands to off peak times**
  - **Encourage users to not use the network as heavily during peak usage times such as early morning or after lunch**
  - **Delay some network intensive jobs to off-peak times, such as run heavy printing jobs at night**

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6.7 Implications for Management

- **Cost of LAN equipment dropping quickly**
  - **Commodity market**
    - **Flood of vendors into the market**
    - **Varying quality of products**
  - **Hard to justify the purchase of high quality LAN equipment with cheap alternatives**
- **Wired Ethernet now a legacy technology**
  - **Few new products developed for it so prices increasing**
  - **Move towards wireless**

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