CSC465 – Computer Networks
Spring 2004

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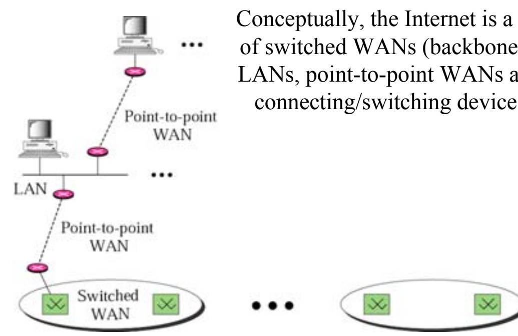
These slides are based on material by B. Forouzan for "TCP/IP Protocol Suite (2nd Edition)"

Chapter 3 ***Underlying Technologies***

CONTENTS

- **LANS**
- **POINT-TO-POINT WANS**
- **SWITCHED WANS**
- **CONNECTING DEVICES**

Internet Model



Conceptually, the Internet is a set of switched WANs (backbones), LANs, point-to-point WANs and connecting/switching devices

3.1

LOCAL AREA NETWORKS (LANS)

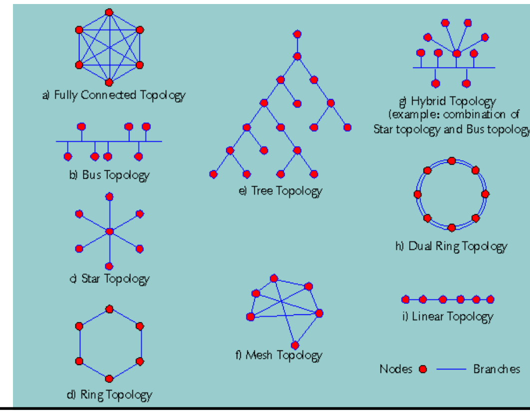
LAN

- Local Area Network
- Data communication system that allows independent devices to communicate directly over limited areas
- Ethernet (IEEE 802.3 standard)
  - Most widely used
  - Designed by Xerox in 1973
- Token Ring
- Wireless
- ATM

Ethernet LAN

- 10Mbps, 100Mbps and 1Gbps+ versions
- IEEE 802.3 defines ***carrier sense multiple access with collision detection (CSMA/CD)***
- Physical bus or star; but logically always bus
- Medium (channel) is shared by multiple stations (MA) but only one station at a time can transmit
- Intended destination adapter keeps the frame while the rest “drop” (disregard) it
- Contention for medium requires protocol

NETWORK TOPOLOGY



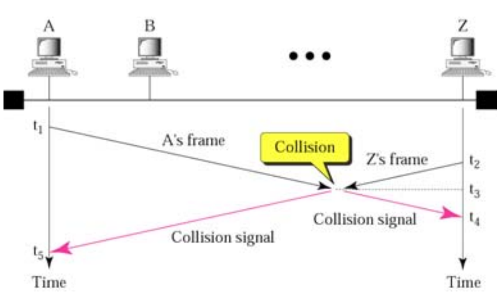
Ethernet LAN: CSMA/CD

1. The transmitting Ethernet adapter obtains a network-layer PDU from its parent node, prepares an Ethernet frame, and puts the frame in an adapter buffer if the channel is busy
2. If adapter sense that the channel is idle (no signal energy from the channel entering the adapter), it starts sending (CS)
3. Station must keep sensing while sending
4. If a *collision* occurs, all senders will sense it
5. Each sending station aborts & sends a jam signal (48 bits) to destroy the data on the channel
6. Each waits a random amount of time before resending (to avoid another collision)

Ethernet LAN: CSMA/CD

Each Ethernet adapter runs the CSMA/CD protocol without explicit coordination with the other adapters

CSMA/CD



Collision Response

- After aborting, i.e. transmitting the jam signal, the network adapter enters an exponential backoff phase
- When transmitting a frame, after experiencing the *n*th collision in a row for the frame, the adapter chooses a value for *K* at random from $\{0,1,2,\ldots,2^m-1\}$ where $m = min(n,10)$
- K must increase since it is unknown how many adapters were involved in the transmission
- Adapter then waits K * 512 bit times and then senses again to attempt to transmit

10-Mbps Ethernet Layers

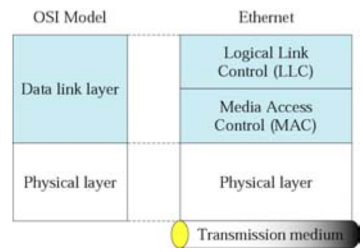
Ethernet Data Link Layer has two sublayers:

1. Logical Link Control (LLC)
   – Responsible for flow and error control in DLL
2. Media Access Control (MAC)
   – Responsible for CSMA/CD access method

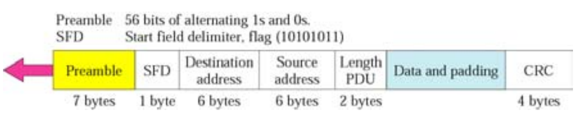
Ethernet Physical Layer:

- Transfers data into electrical signal
- Tightly coupled with MAC sublayer

10-Mbps Ethernet layers



Ethernet frame



PDU → Protocol Data Unit

SFD: last two bits warn that next bits are Dest. Addr.

Padding necessary to obtain minimum frame length

CRC → Cyclic Redundancy Check

Ethernet has no mechanism for acknowledging received frames (so it is termed an "unreliable medium")

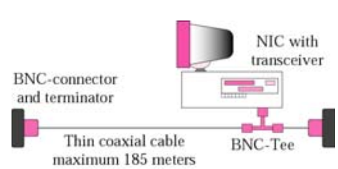
Ethernet Addressing Types

- Each station (workstation, printer) on an Ethernet network has its own NIC
- NIC provides 6-byte physical address
- Unicast address → LSB of 1st byte is 0
- Multicast Address → LSB of 1st byte is 1
- Broadcast Address → forty-eight 1s
- Source address is always unicast

Ethernet Implementation: 10BASE2

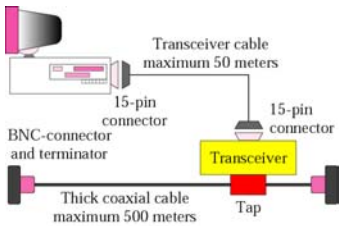
- Once popular, now legacy
- "10" stands for 10 Mbps
- "2" stands for 200 meters, which is the approximate maximum distance between stations, without using "repeaters" (185m)
- maximum nodes is 30 before signal attenuation
- Thin coaxial cable
- 10BASE5
  – Thick coaxial cable
  – 500 meters

10BASE2 Ethernet implementation



b. 10BASE2

Ethernet implementation

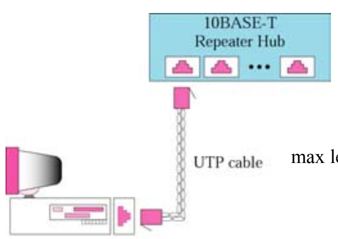


a. 10BASE5

Ethernet Implementation: 10BASET

- "10" stands for 10 Mbps
- "T" stands for "twisted pair"
- Star topology
- Each adapter on each node has a direct *point-to-point* connection to the *hub (center of star)*
- Hub is a repeater
  - Some have network management features
  - Can internally detach malfunctioning adapter

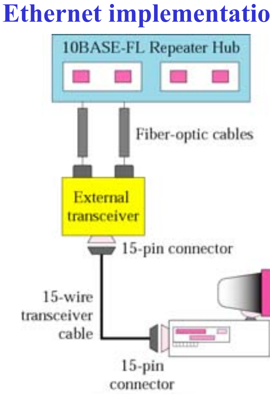
Ethernet implementation



max length: 100m

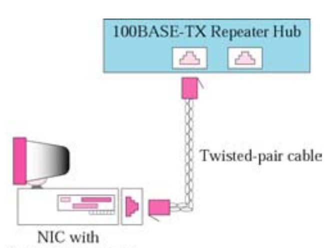
c. 10BASE-T

Ethernet implementation



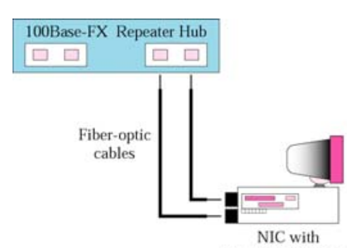
d. 10BASE-FL

Fast Ethernet implementation



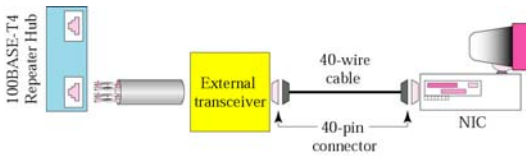
a. 100BASE-TX

Fast Ethernet implementation



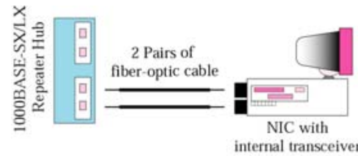
b. 100BASE-FX

Fast Ethernet implementation



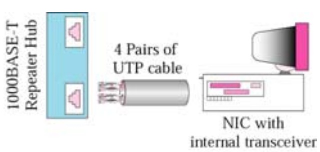
c. 100BASE-T4

Gigabit Ethernet implementation



a. 1000BASE-SX/LX

Gigabit Ethernet implementation



b. 1000BASE-T

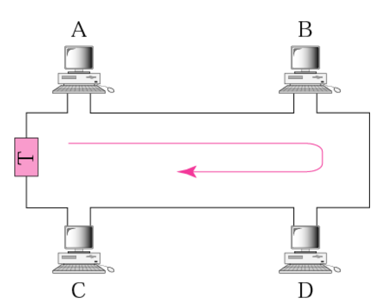
Token Ring LAN

- Defined in IEEE Project 802.5
- Originally created by IBM in 1970s
- Remains IBM's primary LAN technology
- Uses token passing access method
- IEEE 802.5 modeled after Token Ring and still shadows its development

Token Ring LAN Operation

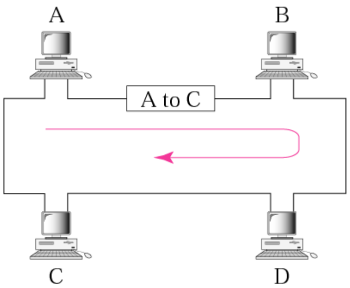
1. When network unoccupied, simple 3-byte token circulates until landing on host with data to send
2. Station keeps token and sends a data frame
3. Frame circulates; regenerated by each station
4. Each intermediate station examines the destination address, finds frame address to another, then relays it to their neighbor
5. Intended recipient recognizes its own address, copies the message, checks for errors and changes 4 bits in last byte of frame to indicate address recognized and frame copied
6. Packet continues until returning to sender

Token passing



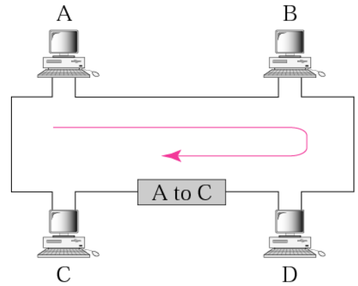
a. Station A captures the token

Token passing



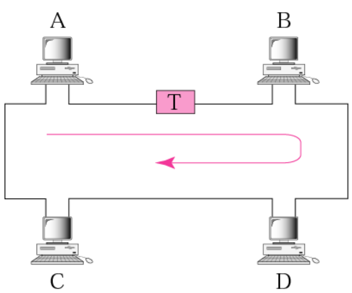
b. Station A sends data to station C

Token passing



c. Station C copies data and sends frame back to A

Token passing



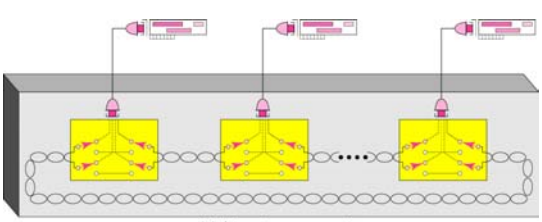
d. Station A releases the token

Data frame

SD Start delimiter (flag)
AC Access control (priority)
FC Frame control (frame type)
ED End delimiter (flag)
FS Frame status

SD	AC	FC	Destination address	Source address	Data	CRC	ED	FS
1 byte	1 byte	1 byte	6 bytes	6 bytes	Up to 4500 bytes	4 bytes	1 byte	1 byte

Multistation Access Unit (MAU)



Multistation access unit
MAU

Wireless LAN

- Wireless LANs are popular for mobile Internet access
- Nomadic Internet Access
  - employee returning from trip uploads data collected
  - moving around home, building cluster (campus)
- Ad Hoc Networking
  - peer-to-peer network – no centralized server
  - Ex: employees form network for duration of JFK meeting
  - Conference attendees
- Cross Building Interconnection
- Connect LANS between 2 buildings (really a *bridge*)
- Novel applications

Ad Hoc Networks

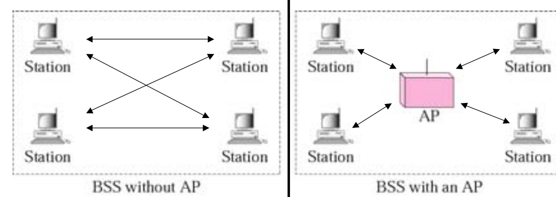
- IEEE 802.11 stations can dynamically form a group without *access point* (AP)
- Ad Hoc Network: no pre-existing infrastructure
- Applications: "laptop" meeting in conference room, car, airport; interconnection of "personal" devices (bluetooth); battlefield; pervasive computing (smart spaces)
- IETF MANET (Mobile Ad hoc Networks) working group

Basic Service Set (BSS)

Ad Hoc Mode

(Independent BSS)

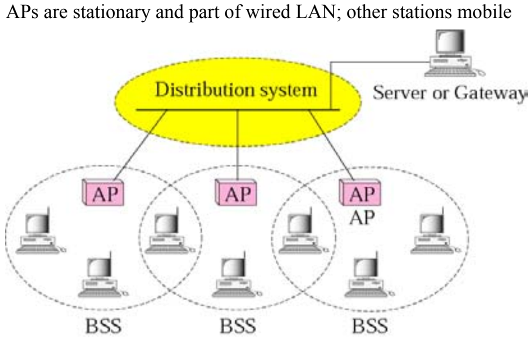
Infrastructure Mode



Extended Service Set (ESS)

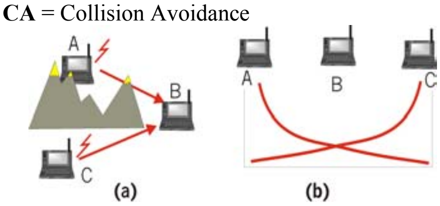
BSSs connected through distribution system (any IEEE LAN)

APs are stationary and part of wired LAN; other stations mobile



Hidden Terminal effect

- CSMA inefficient in presence of hidden terminals
- Hidden terminals: A and B cannot hear each other because of obstacles or signal attenuation; so, their packets collide at B
- Solution? **CSMA/CA**
- **CA** = Collision Avoidance



IEEE 802.11 Protocol Architecture

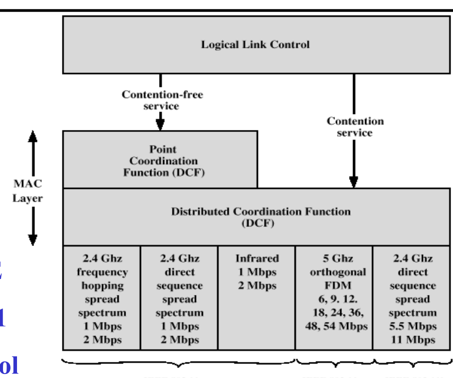


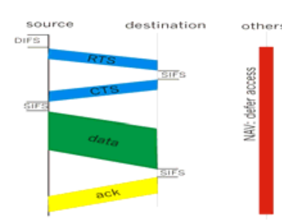
Figure 14.5 IEEE 802.11 Protocol Architecture

Collision Avoidance: RTS-CTS

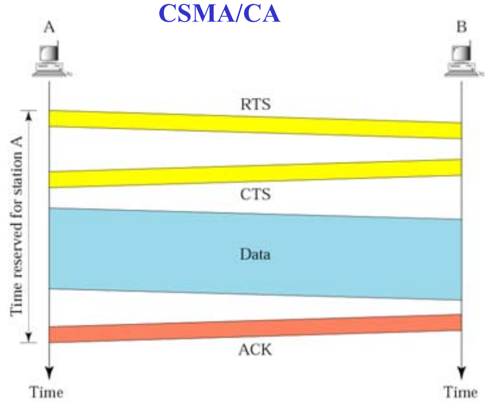
- Sender sends short RTS (request to send) request
- Receiver chooses 1 sender and sends it CTS (clear to send)
- **CTS** "freezes" stations within range of receiver (but possibly hidden from transmitter); this prevents collisions by hidden station during data

•**RTS** and **CTS** are very short: collisions during data phase are thus very unlikely (the end result is similar to Collision Detection)

•Note: IEEE 802.11 allows **CSMA, CSMA/CA** and "**polling**" from AP



CSMA/CA



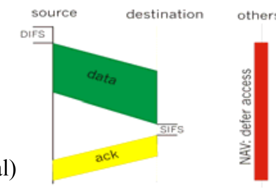
IEEE 802.11 MAC Protocol

CSMA Protocol:

- sense channel idle for **DISF** sec (Distributed Inter Frame Space)
    - transmit frame (no Collision Detection)
    - receiver returns ACK after **SIFS** (Short Inter Frame Space)

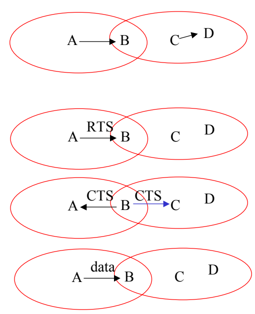
-if channel sensed busy then expo. backoff

NAV: Network Allocation Vector (min time of deferral)

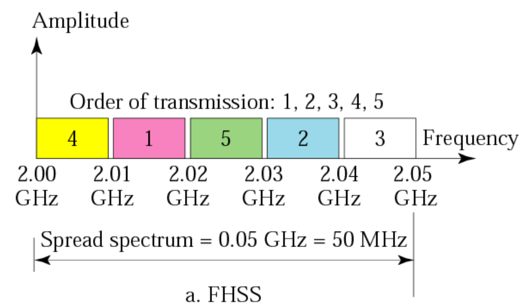


MAC Protocol

- hidden terminal problem:
- RTS-CTS exchange:
    - RTS = request to send
    - CTS = consent to send
    - problem: high overhead for short frames

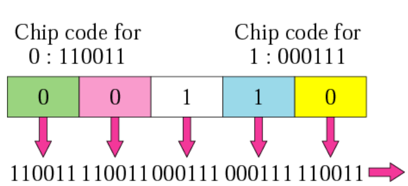


Spread spectrum techniques



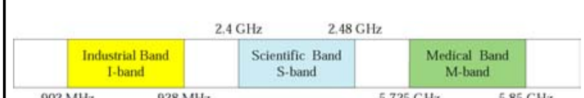
a. FHSS

Spread spectrum techniques



b. DSSS

ISM bands



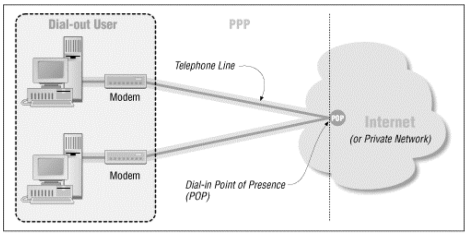
IEEE 802.11 standards defines MAC protocol; unlicensed frequency spectrum bands: 900MHz, 2.4GHz

915 MHz: lowest capacity; cordless phones, wireless mics and amateur radio

2.4 GHz: microwave oven; more leakage with age

5.8 GHz: less competition but higher cost

Point-to-Point WANS

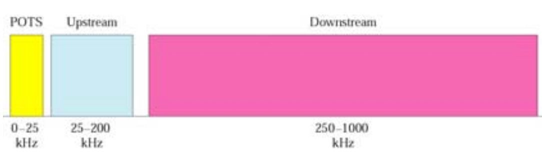


Point-to-Point Protocol (PPP)

Point-to-Point WANS: Physical

- V.90 (56K) Modems
  - Subscriber connected to switching station of phone company, which is connected to to ISP server
  - Asymmetric (56Kbps down, 33.6Kbps down)
- Digital Subscriber Line (DSL)
  - Phone companies have high-speed digital WANS between main facilities
  - Part (or all) of link to user is analog (1MHz)
  - DSL adds digital signal to POTS
  - Asymmetric

Band for ADSL



Point-to-Point WANS: Physical

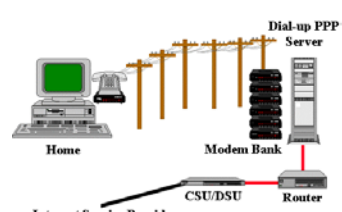
- Cable Modem
  - Cable TV uses 500MHz coaxial cable
  - TV station needs 6MHz so >75 channels can broadcast simultaneously -some can be used for data
- T Lines
  - Standard digital telephone carriers for multiplexed (digital) voice channels; now used for data
  - Connect organization to Internet or 2 WAN nodes
  - Part (or all) of link to user is analog (1MHz)

Point-to-Point WANS: Physical

- T Lines Specs
  - T-1: (24 voice chan* 8 bits) +1 sync = 193 bit frame
  - T-1: 8000 frames per second * 193 = ***1.544Mbps***
  - T-3: 672 voice channels equivalent to 28 T-1 lines
  - T-3: ***44.736Mbps***
- SONET ***S****ynchronous* ***O****ptical* ***Net****work*
  - Rates range from ***51Mbps*** to ***9953Mbps or more***

  - 1 Gigabit = 1024 Megabits

Point-to-Point WANS



Channel Service Unit /
Data Service Unit

Point-to-Point Protocol (PPP)

- Point to point, wired data link easier to manage than broadcast link: no Media Access Control
- Several Data Link Protocols: PPP, HDLC, SDLC, Alternating Bit protocol, etc
- PPP (Point to Point Protocol) is very popular: used in dial up connection between residential Host and ISP; on SONET/SDH connections, etc
- PPP is extremely simple (the simplest in the Data Link protocol family) and very streamlined

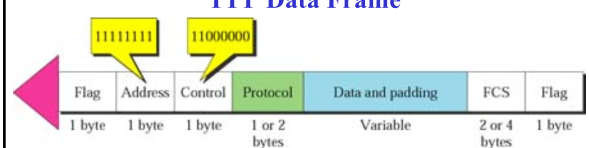
PPP Requirements

- Pkt framing: encapsulation of packets
- bit transparency: must carry any bit pattern in the data field
- error detection (no correction)
- multiple network layer protocols
- connection liveness
- Network Layer Address negotiation: Hosts/nodes across the link must learn/configure each other's network address

Not Provided by PPP

- error correction/recovery
- flow control
- sequencing
- multipoint links not directly supported

PPP Data Frame



- Flag: delimiter (framing)
- Address: does nothing (only one option)
- Control: does nothing; in the future possible multiple control fields (no sequence #)
- Protocol: upper layer to which frame must be delivered (eg, *PPP-Link Control Protocol*, IP, *PPP-Network Control Protocol*, etc)

Byte Stuffing

- For "data transparency", the data field must be allowed to include the pattern <01111110> ; i.e., this must not be interpreted as a flag
- to alert the receiver, the transmitter "stuffs" an extra < 01111110> byte after each < 01111110> data byte
- the receiver discards each 01111110 followed by another 01111110, and continues data reception

PPP Data Control Protocol

- PPP-LCP establishes/releases the PPP connection; negotiates options
- Starts in DEAD state
- Options: max frame length; authentication protocol
- Once PPP link established, Network control protocol) moves in (on top of PPP) to configure IP network addresses etc.