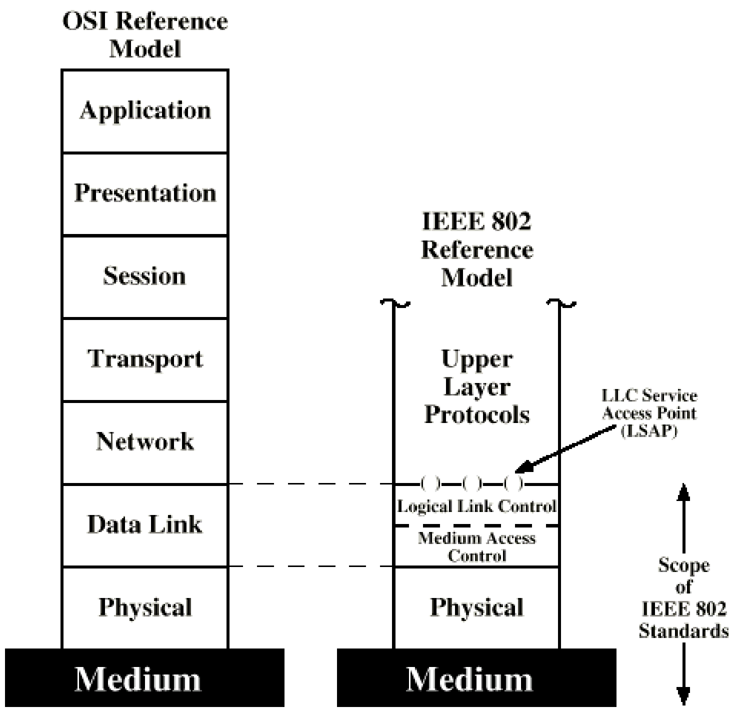
Chapter 4

LAN Technology

LAN Technology

Protocol architecture
Topologies
Media access control
Logical Link Control

Protocol Architecture



Protocol Architecture (2)

IEEE 802 reference model

- physical layer:
  - encoding/decoding of signals;
  - preamble generation/removal (for synchronization);
  - bit transmission/reception;
- in addition:
  - a specification of the transmission medium and topology;
- LLC layer:
  - *on transmission: assemble data into a frame, with address and error detection fields;*
  - *on reception: disassembles frame, perform error recognition and error detection;*
  - *govern access to the LAN transmission medium;*
  - provide an interface to higher layers and perform flow and error control;
- *MAC layer*

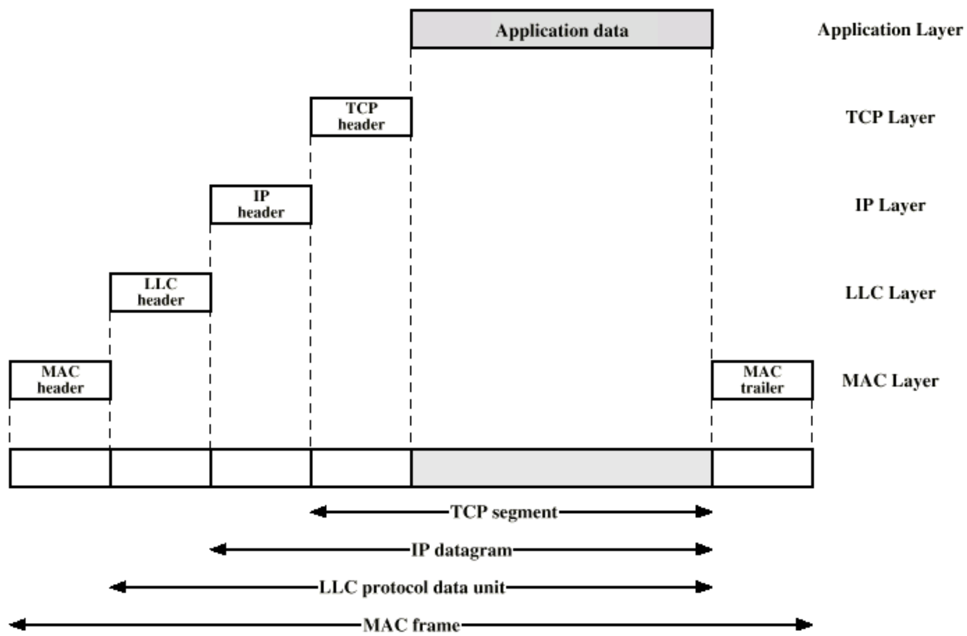
Separation:
- the logic required to manage access to a shared medium not found in traditional layer 2
- for the same LLC several MAC options may be provided

Protocol Architecture (3)

Relations between the levels of the architecture:

LLC layer: User data appends control information as a header → **LLC PDU** (protocol data unit)

MAC layer appends control info at the front and back of the packet → **MAC frame**

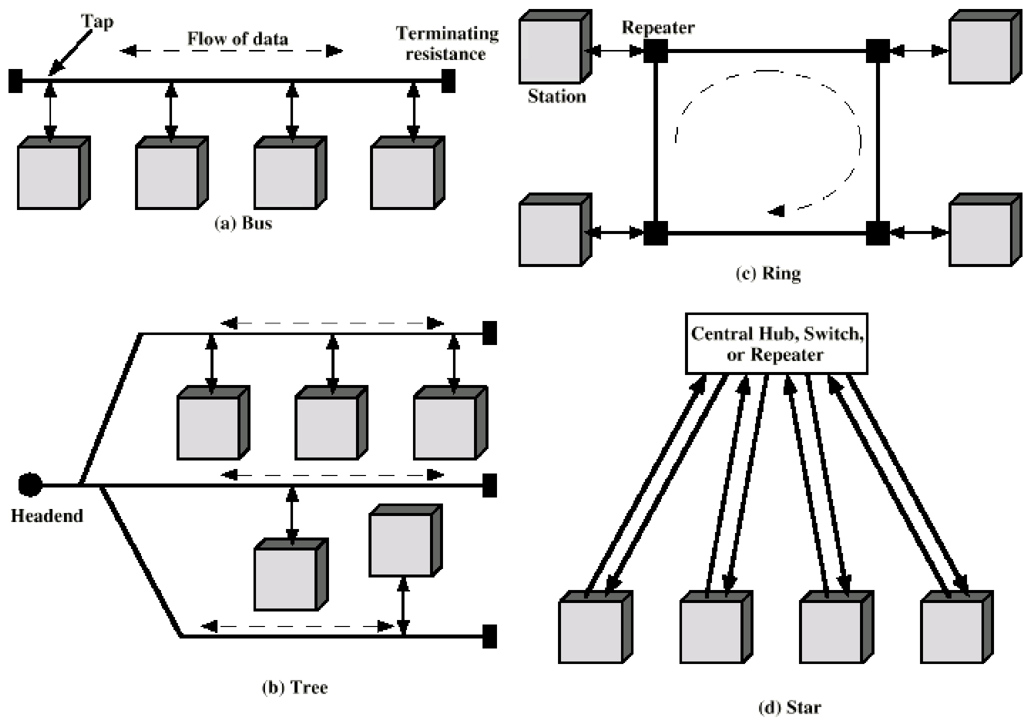


Topologies

- Tree
- Bus
    - Special case of tree

      One trunk, no branches
- Ring
- Star

Topologies (2)



Topologies (3)

Bus and Tree topologies

- multipoint medium
- HARDWARE INTERFACING- TAP
- full- duplex operation between the station and the TAP

Tree topology

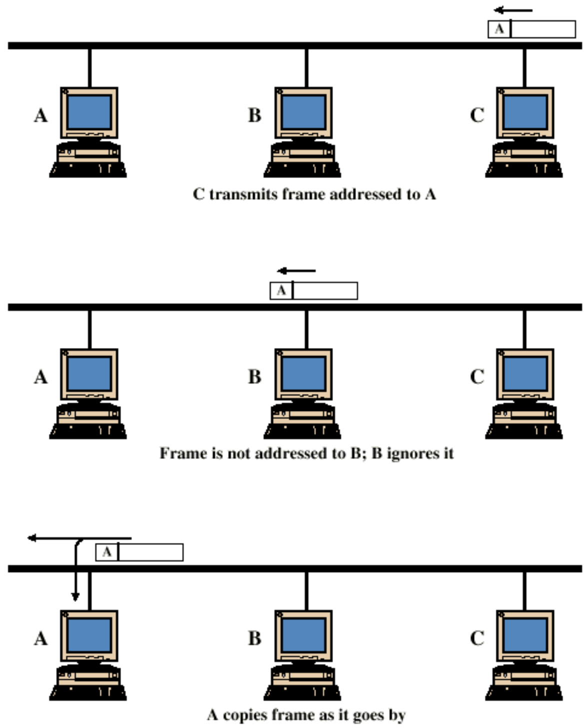
- generalization of the bus topology
- transmission medium- branching cable with no closed loops
- the tree layout begins at a point known as HEADEND

2 problems:

1) - indicating from whom the transmission is intended
2) - a mechanism is needed to regulate transmission

1) - the frame structure solves the first problem;
- it also provides the basic tool for solving the second problem

Topologies (4)



Topologies (4)

Ring topology

- the network consists of a set of repeaters joined by point-to-point links in a closed loop;

- repeater: receives data on one link and transmits them bit by bit on the other link with no buffering at the repeater;

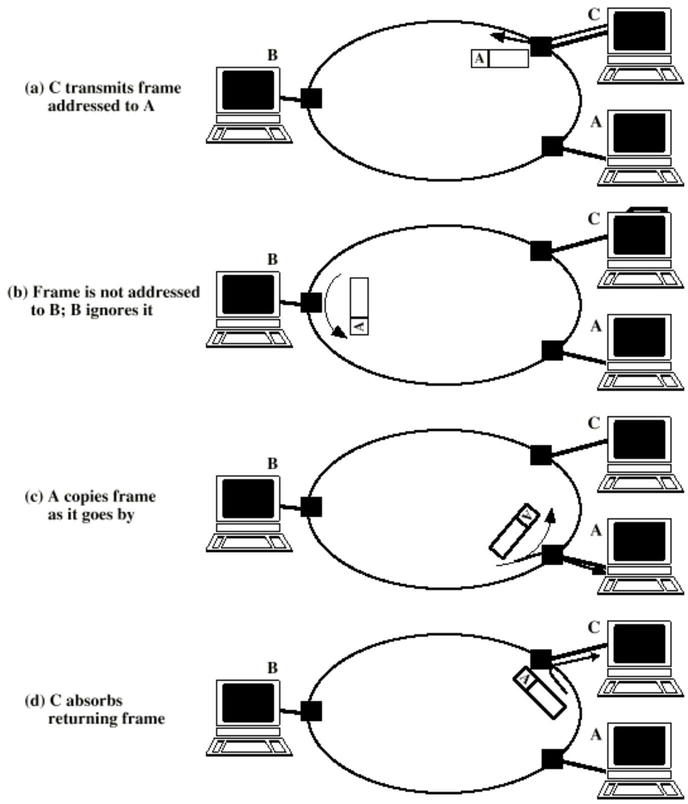
- links are unidirectional: clockwise or counterclockwise;

- each station attaches to the network at a repeater and transmit the data through the repeater;

- data are transmitted in frames

- because multiple stations share the ring medium access control is needed to determine at what time each station may insert frames

Topologies (5)



Topologies (6)

Star topology

- each station directly connected to a common central node - star coupler via 2 point-to-point links: one for trans and one for reception;

- the central node :

1) operates in a broadcast fashion:

- a transmission of a frame from one station to the node is retransmitted on all the outgoing links;

2) acts as a frame switching device:

- an incomming frame is buffered in the node and then retransmitted on an outgoing link to the destination;

Medium Access Control

Function: controls access to the transmission medium to provide an orderly an efficient use of that capacity – MAC protocol

The key parameters are *where?* and *how?*

Where - refers to whether control is exercised in a centralized or distributed fashion

How? – is constrained by the topology and is a trade-off among competing factors including: cost, performance and complexity;

Access control techniques:

- synchronous – not optimal in LANs and MANs – the needs of the stations are unpredictable;
- asynchronous – provide response to immediate demand;
  - 3 categories
    - round robin
    - reservation
    - contention

Medium Access Control (2)

Round Robin

- each station in turn is given the opportunity to transmit;
- The station may decline to transmit or may transmit subject to a specified upper band;
- when it is finished the station relinquishes its turns and the right to transmit passes to the next station in logical sequence

Control of sequence:

- centralized (e.g. Polling)
- distributed

RR efficient when many stations have to transmit over an extended period of time.

When only a few stations have data to transmit over an extended period of time techniques depending on whether the data traffic has a stream or bursty characteristic may be preferable

Medium Access Control (3)

Reservation – for stream traffic

- time on the medium is divided into slots
- a station reserves future slots for an extended or even an idefinite period
- reservation: - centalized
  - descentralized

Contention – for bursty traffic appropriate

- all stations contend for a time in a way that can be rather rough and tumble;
- these techniques are distributed by nature;

RR and Contention techniques are the most common.

Medium Access Control (4)

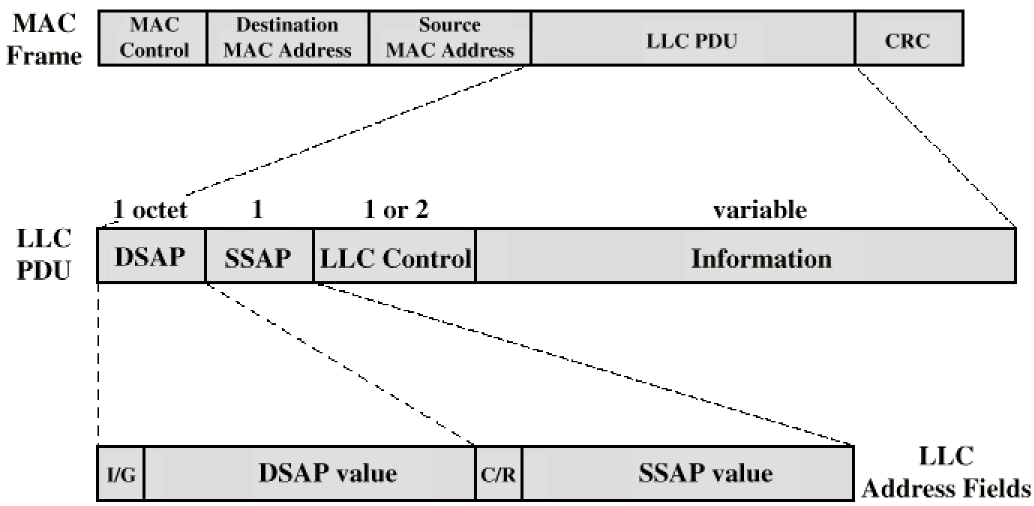
Standardized medium access control techniques

	Bus topology	Ring topology	Switched topology
Round robin	Token Bus (IEEE 802.4) Polling (IEEE 802.11)	Token Ring (IEEE 802.5; FDDI)	Request/priority(IEEE 802.12)
Reservation	DQDB (IEEE 802.6)		
Contention	CSMA/CD (IEEE 802.3) CSMA (IEEE 802.11)		CSMA/CD (IEEE 802.3)

Medium Access Control (5)

MAC Frame Format

PDU is referred to as a MAC frame



I/G = Individual/Group
C/R = Command/Response

Medium Access Control (6)

- MAC control
- Destination MAC address
- Source MAC address
- LLC
- CRC

Data link protocol entity responsible:

1) detecting error with CRC
2) recovering from those error by retransmitting

MAC+LLC:

1)MAC: detecting error and discarding any frames that are in error
2) LLC: keeps track of which frames have been successfully received and retransmit the unsuccessfully frames

LLC in LAN Technologies

LLC is concerned with the transmission of a link-level protocol between 2 stations:

- multi- access, shared medium
- relieved of some of the link access by the MAC layer

Addressing:

- DSAP(7 bits: I/G- individual or group address)
- SSAP(7 bits: C/R-command or response)

The source and destination LLC user(referred as SAP's – Service Access Points):

- a higher layer protocol or
- a network management function

LLC services

- Unacknowledged connectionless service
- Connection - mode service
- Acknowledged connectionless service

LLC in LAN Technologies (2)

LLC protocol - HDLC protocol

- Asynchronous balanced mode: ***Type 2 of operation***
- Connection-less service by using the unnumbered information PDU: ***Type 1 of operation***
- Acknowledged connectionless service by using 2 new unnumbered PDU's: ***Type 3 of operation***
- Multiplexing by the use of LLC service access points (LSAPs)

Type 1 of operation

- UI of PDU to transfer data
- 2 PDUs used to support management functions associated with all 3 types of operation:
  - LLC issues a command XID or TEST: C/R bit = 0
  - receiving LLC issues a corresponding XID or TEST in response
  - XID used to specify
    - types of operation supported
    - window size
  - TEST used to conduct a loop-back test of the transmission path between the 2 entities

LLC in LAN Technologies (3)

LLC protocol - HDLC protocol

Type 2 of operation

- a data link connection is establish between 2 SAPS (service access points) before UI of PDU to transfer data
- connection establishment : type 2 protocol:
  - LLC entity issues a SABME PDU to request a logical connection
  - connection accepted: LLC user designed by DSAP returns an unnumbered ack (UA) PDU
  - the connection is henceforth identified by the pair of user SAPs.
  - if the destination LLC user rejects the connection request: returns disconnected mode (DM) PDU
- data are exchanged using PDUs
- either LLC entity can terminate a logical connection by issuing a disconnect (DISC) PDU

LLC in LAN Technologies (4)

LLC protocol - HDLC protocol

Type 3 of operation

- each transmitted PDU is acknowledged:
  - a new unnumbered PDU is defined: Acknowledge Connectionless (AC) PDU
- user data are sent in AC command PDUs an must be ack using an AC response PDU.
- to guard against the lost PDUs, a 1-bit sequence number is used: the sender alternates 0 and 1…
- only one PDU in each direction may be outstanding at any time

BUS/TREE LANs

Multipoint configuration: requirements

- medium access technique
- signal balancing:
  - adjustments imposed by:
    - the receiver's requirements;
    - S/N ratio;
    - transmitter circuitry overloading;
  - solution: dividing the medium into smaller segments within which pairwise balancing is possible using repeaters;

Baseband coaxial cable medium

2 transmission techniques:

- baseband
- broadband

BUS/TREE LANs (2)

Baseband LANs and MANs

- digital signaling: Manchester or Differential Manchester encoding
- entire frequency spectrum of cable used
- single channel on cable
- bidirectional transmissions
- bus topology required by digital signaling
- few kilometer range
- Ethernet-10Mbps, basis for IEEE 820.3 standard
  - uses a 50 ohm cable: less intense reflections, better immunity against low frequency electromagnetic noise

Engineering trade-off involves:

- data rate
- cable length
- number of taps
- the electrical characteristics of cable
- the transmit/receive components

BUS/TREE LANs (3)

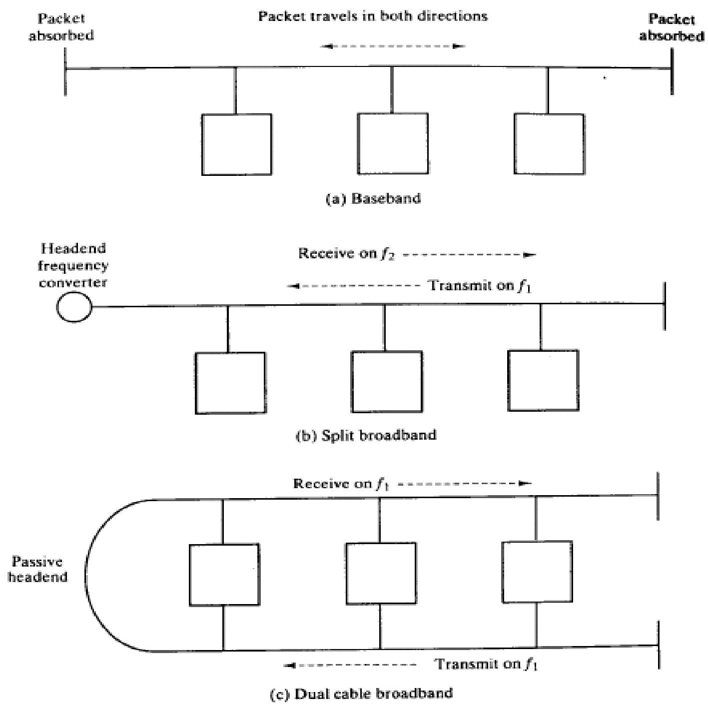


FIGURE 12.8 Baseband and broadband transmission techniques.

BUS/TREE LANs (4)

10BASE5

- Ethernet and 802.3 originally used 0.4 inch diameter cable at 10Mbps
- Max cable length 500m
- Distance between taps a multiple of 2.5m
- Ensures that reflections from taps do not add in phase
- Max 100 taps
- 10Base5

BUS/TREE LANs (5)

10BASE2

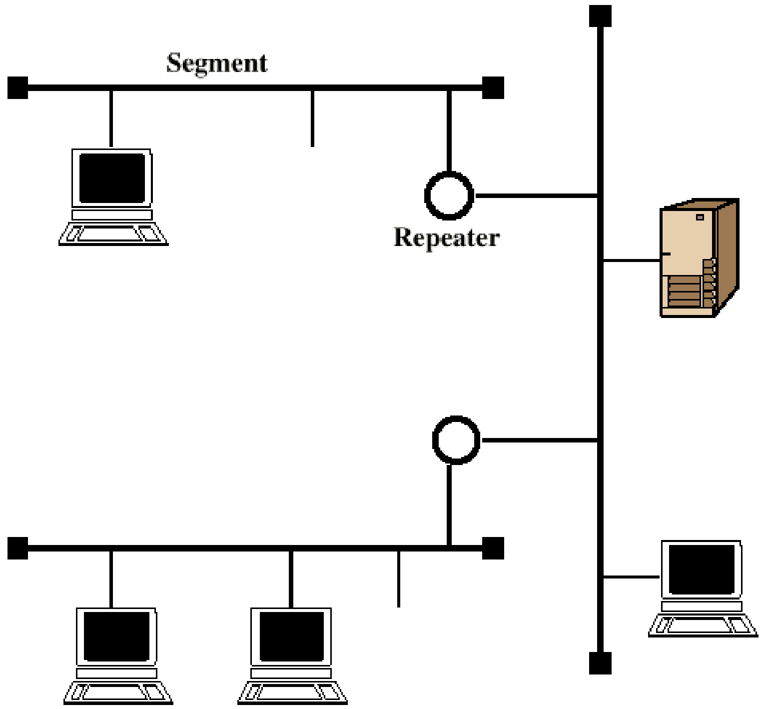
- Cheapernet
- 0.25 inch cable
- More flexible
- Easier to bring to workstation
- Cheaper electronics
- Greater attenuation
- Lower noise resistance
- Fewer taps (30)
- Shorter distance (185m)

BUS/TREE LANs (6)

Repeaters – extend the length of the network, work different than the repeaters of the ring

- Transmits in both directions
- Joins two segments of cable
- No buffering
- No logical isolation of segments
- If two stations on different segments send at the same time, packets will collide
- To avoid multipath interference only one path of segments and repeaters between any two stations

BUS/TREE LANs (7)



BUS/TREE LANs (8)

Broadband LANs and MANs

- analog signaling
- FDM possible: separate channels can support data traffic, video and radio signals
- inherently a unidirectional medium
- bus and tree topologies are possible because broadband components allow splitting and joining operations
- much greater distances – tens of kilometers – are possible

BUS/TREE LANs (9)

Baseband	Broadband
Digital signaling	Analog signaling (Requires RF modem)
Entire bandwidth consumed by signal – no FDM	FDM- possible- multiple channels for data, video, audio
Bidirectional	Unidirectional
Bus topology	Bus or tree topology
Distance: up to a few kilometers	Distance: up to tens kilometers

BUS/TREE LANs (10)

Dual and split configurations

- stations on a broadband LAN attach to the cable by means of a tap;
- broadband –inherently unidirectional → taps that are used allow signals inserted into the medium to propagate in only one direction;

How to achieve connectivity?

- 2 data path are needed
- the paths are joined at a point on the network known as the ***headend***
  - bus topology: - ***simply one end of the bus***
  - tree topology: - ***root of the branching tree:***
    - all stations transmit on one path toward the headend (inbound);
    - the headend propagates the signal along a second path: outbound. All stations receive on the outbound;

2 different configurations used to implement inbound and outbound paths:

- Split broadband
- Dual cable broadband

BUS/TREE LANs (11)

Dual cable broadband

- inbound and outbound paths are separate cables
- headend simply a passive connector
- stations send and receive on the same frequency

Split broadband

- inbound and outbound paths are different frequency bands on the same cable;
- bidirectional amplifiers:
    - pass lower frequencies inbound
    - pass higher frequencies outbound
    - guardband between the inbound and outbound frequency bands
- headend contains a device for converting inbound frequencies to outbound frequencies

BUS/TREE LANs (12)

Frequency conversion device

- analog: frequency translator; converts a bloskof frequency from one range to another;
- digital: remodulator; recovers the digital data from the inbound analog signal and then retransmits the data on the outbound frequency;

BUS/TREE LANs (13)

Frequency allocation of the 2 paths for split systems:

Format	Inbound Frequency Band	Outbound Frequency Band	Maximum two-way Bandwidth
Subsplit	5 to 30MHz	54 to 400MHz	25MHz
Midsplit	5 to 116MHz	168 to 400MHz	111MHz
Highsplit	5 to 174MHz	232 to 400MHz	168MHz
Dual Cable	40 to 400MHz	40 to 400MHz	360MHz

BUS/TREE LANs (14)

Carrierband or single-channel broadband

- Analog signaling on a LAN;
- The entire spectrum of the cable devoted to single transmission path;
- FDM not possible;
- Characteristics:
    - Bidirectional transmission using a bus topology;
        - no amplifiers, no need for headend;
        - most of signal energy concentrated at low frequencies
    - Electronics are simple and relatively inexpensive;
    - Some form of FSK (Frequency shift keying) used;
- Comparable performance at a comparable price to baseband;

RING LANs

RING LANs

- Each repeater connects to two others via unidirectional transmission links
- Single closed path
- Data transferred bit by bit from one repeater to the next
- Repeater regenerates and retransmits each bit
- Repeater performs ***data insertion, data reception, data removal***
- Repeater acts as attachment point
- Packet removed by transmitter after one trip round ring

RING LANs(2)

data insertion

- a variety of strategies: MAC protocols

data removal

- by the addressed repeater
- the transmitting repeater after one trip around the loop
  - permits automatic ACK
  - permits multicast addressing

data reception

RING LANs (3)

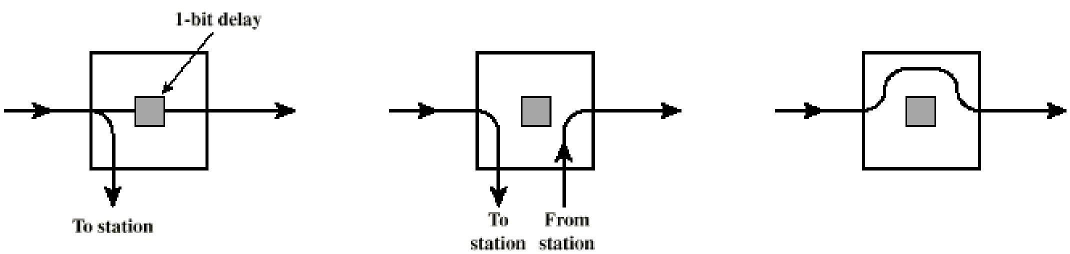
Repeaters have:

-two main purposes:

- contribute to the proper functioning of the ring
- provide an access point for attached stations to send an receive data

- two states:

- the listen state
- the transmit state



(a) Listen state (b) Transmit state (c) Bypass state

RING LANs (4)

Listen state functions

- Scan passing bit stream for patterns
  - Address of attached station
  - Token permission to transmit
- Copy incoming bit and send to attached station
  - Whilst forwarding each bit
- Modify bit as it passes
  - e.g. to indicate a packet has been copied (ACK)

RING LANs (5)

Transmit state:

- Station has data
- Repeater has permission
- May receive incoming bits
  - If ring bit length shorter than packet
    - Pass back to station for checking (ACK)
  - May be more than one packet on ring
    - Buffer for retransmission later

RING LANs (6)

Bypass state

- Signals propagate past repeater with no delay (other than propagation delay)
- Partial solution to reliability problem (see later)
- Improved performance

RING LANs (7)

Timing Jitter

- Clocking included with signal
  - e.g. differential Manchester encoding
  - Clock recovered by repeaters
    - To know when to sample signal and recover bits
    - Use clocking for retransmission
  - Clock recovery deviates from mid-bit transmission randomly
    - Noise
    - Imperfections in circuitry
- Retransmission without distortion but with timing error
- Cumulative effect is that bit length varies
- Limits number of repeaters on ring

RING LANs (8)

Solving Timing Jitter Limitations

- Repeater uses phase locked loop
  - Minimize deviation from one bit to the next
- Use buffer at one or more repeaters
  - Hold a certain number of bits
  - Expand and contract to keep bit length of ring constant
- Significant increase in maximum ring size

RING LANs (8)

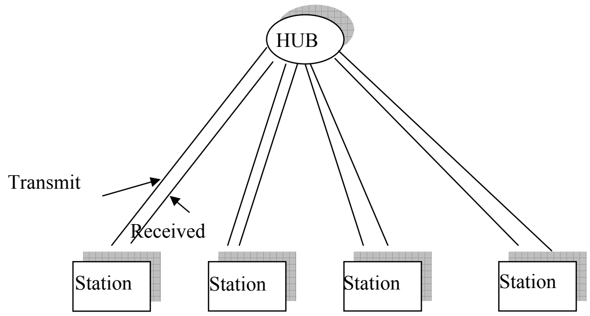
Potential Ring Problems

- Break in any link disables network
- Repeater failure disables network
- Installation of new repeater to attach new station requires identification of two topologically adjacent repeaters
- Timing jitter
- Method of removing circulating packets required
  - With backup in case of errors
- Mostly solved with star-ring architecture

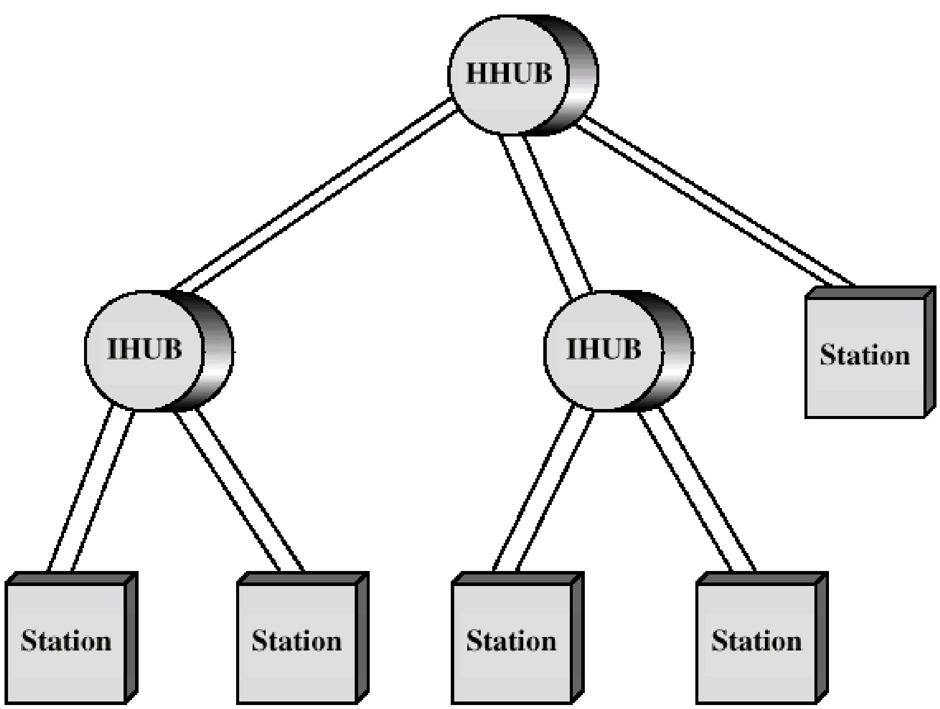
STAR LANs

- Use unshielded twisted pair wire (telephone)
  - Minimal installation cost
    - May already be an installed base
    - All locations in building covered by existing installation
- Attach to a central active hub
- Two links
  - Transmit and receive
- Hub repeats incoming signal on all outgoing lines
- Link lengths limited to about 100m
  - Fiber optic - up to 500m
- Logical bus - with collisions

STAR LANs (2)



STAR LANs (2)



Hubs and Switches

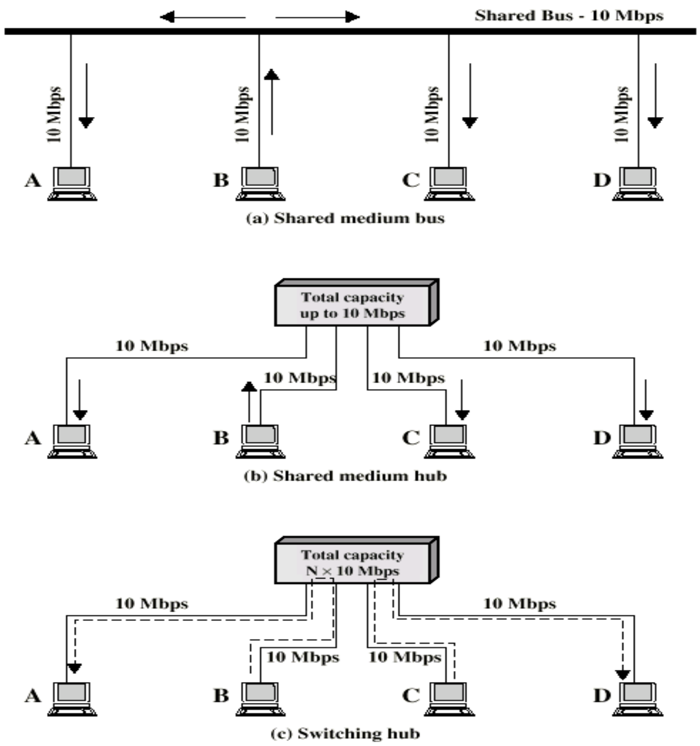
- Shared medium hub
  - Central hub
  - Hub retransmits incoming signal to all outgoing lines
  - Only one station can transmit at a time
  - With a 10Mbps LAN, total capacity is 10Mbps
- Switched LAN hub
  - Hub acts as switch
  - Incoming frame switches to appropriate outgoing line
  - Unused lines can also be used to switch other traffic
  - With two pairs of lines in use, overall capacity is now 20Mbps

Switched Hubs

- No change to software or hardware of devices
- Each device has dedicated capacity
- Scales well

- Store and forward switch
  - Accept input, buffer it briefly, then output
- Cut through switch
  - Take advantage of the destination address being at the start of the frame
  - Begin repeating incoming frame onto output line as soon as address recognized
  - May propagate some bad frames

Hubs and Switches



Wireless LANs

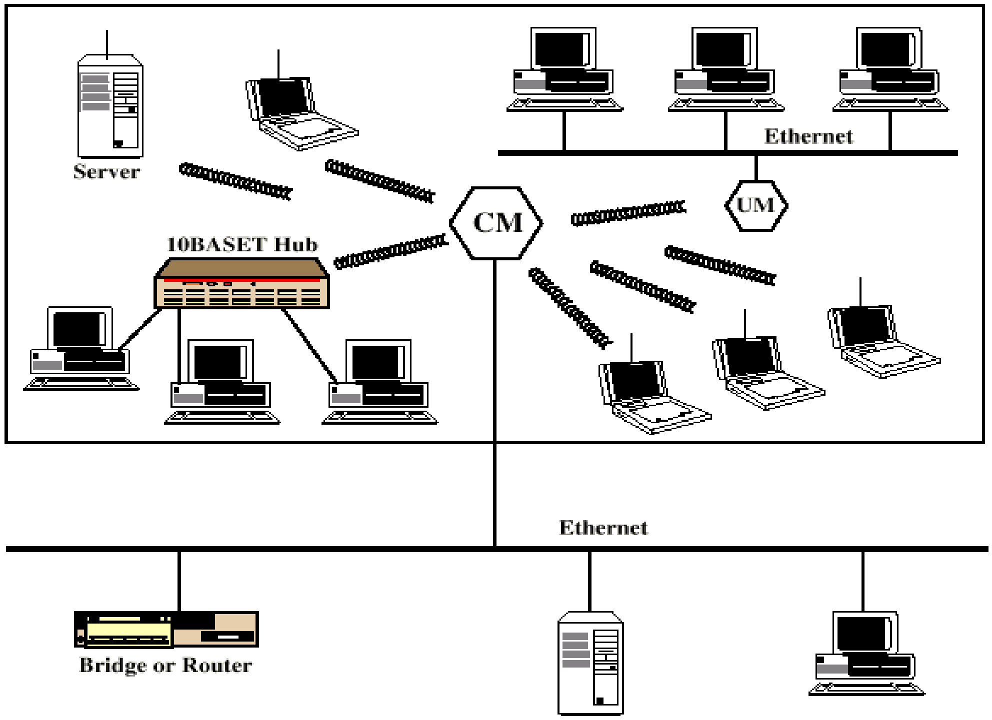
- Mobility
- Flexibility
- Hard to wire areas
- Reduced cost of wireless systems
- Improved performance of wireless systems

Wireless LAN Applications

- LAN Extension
- Cross building interconnection
- Nomadic access
- Ad hoc networks

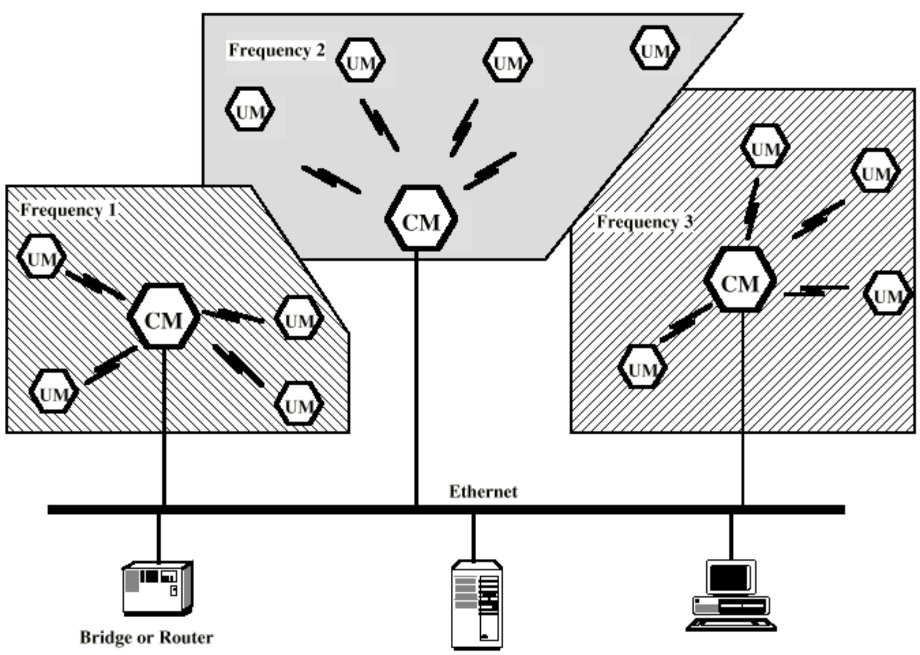
Wireless LANs

Single Cell Wireless LAN



Wireless LANs

- Multi Cell Wireless LAN



Wireless LANs

Cross Building Interconnection

- Point to point wireless link between buildings
- Typically connecting bridges or routers
- Used where cable connection not possible
  - e.g. across a street

Nomadic Access

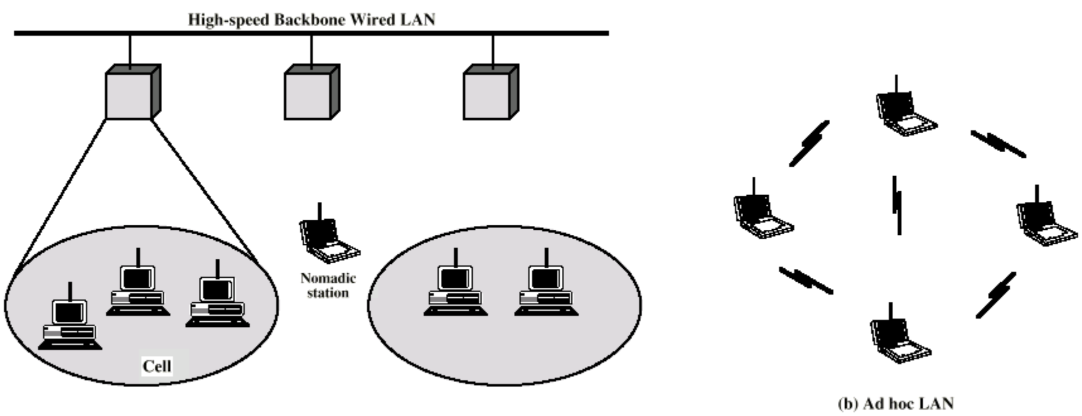
- Mobile data terminal
  - e.g. laptop
- Transfer of data from laptop to server
- Campus or cluster of buildings

Ad Hoc Networking

- Peer to peer
- Temporary
- e.g. conference

Wireless LANs

Wireless LAN Configurations



(a) Infrastructure Wireless LAN

(b) Ad hoc LAN

Wireless LANs

Differences between an Ad Hoc wireless LAN and a wireless LaN that supports LAN extension and nomadic access requirements

- Wireless LAN – forms a stationary environment consisting of one or more cells with a CM for each cell.
- Nomadic stations can move from one cell to another
- There is no infrastructure for an ad hoc network
- Rather a peer collection of stations within range of each other may temporary configure themselves into a ***temporary network***

Wireless LANs

Wireless LAN Requirements

- Throughput
- Number of nodes
- Connection to backbone
- Service area
- Battery power consumption
- Transmission robustness and security
- Collocated network operation
- License free operation
- Handoff/roaming
- Dynamic configuration

LAN Systems

Ethernet and Fast Ethernet

- Medium access technique
- Topology

Bus/tree and star topologies- ***carrier-sense multiple access with collision detection (CSMA/CD)***

- baseband version – Xerox
- broadband version – Mitre

Basis for IEEE 802.3 standard

LAN Systems

IEEE 802.3 Medium Access Protocol

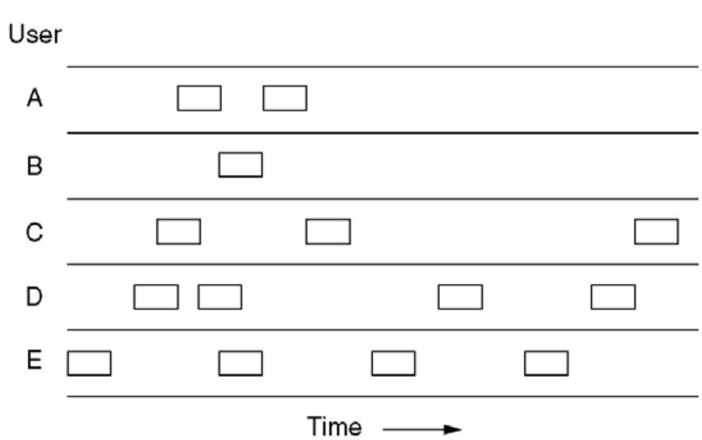
CSMA/CD - random access or contention techniques

random access – stations transmissions are randomly

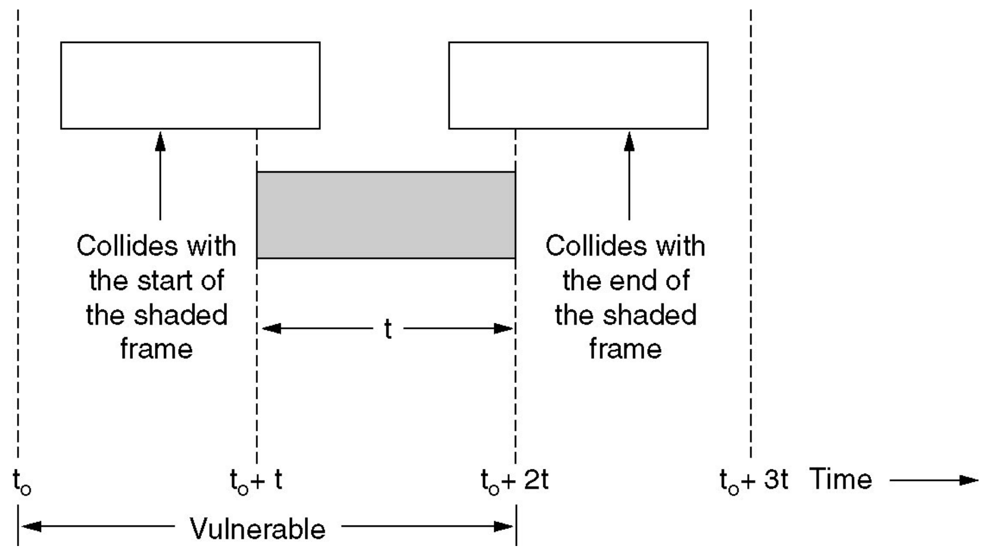
contention techniques – stations contend for time on medium

ALOHA

In pure ALOHA, frames are transmitted at completely arbitrary times

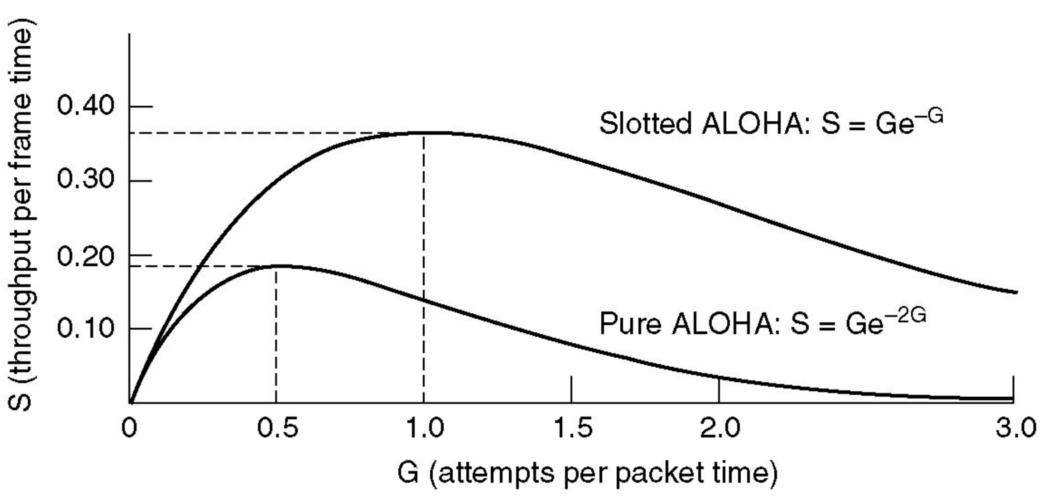


LAN Systems Pure ALOHA



Vulnerable period for the shaded frame.

LAN Systems Pure ALOHA (2)



Throughput versus offered traffic for ALOHA systems.

LAN Systems Pure ALOHA

- Both ALOHA and slotted ALOHA exhibit poor utilization;
- The propagation delay between stations is usually very small compared to frame transmission time;
- A short delay time provides the stations with better feedback about the state of the network;

The solution CSMA/CD

- First listen (carrier sense)
  - Medium in use – wait
  - Medium idle – transmission
    - 2 stations attempt to transmit at about the same time: collision

LAN Systems CSMA/CD

CSMA – algorithm needed to specify what a station should do if the medium is busy:

IEEE 802.3: ***1 - persistent – technique***:

1) medium idle → transmit

2) medium busy → continue to listen until the channel is sensed idle; then transmit immediately

Rules for CSMA/CD

1) medium idle → transmit

2) medium busy → continue to listen until the channel is sensed idle; then transmit immediately

3) If collision is detected during transmission transmit jamming signal and then cease the transmission

4) After transmitting the jamming signal wait a random amount of time and transmit again

LAN Systems CSMA/CD (2)

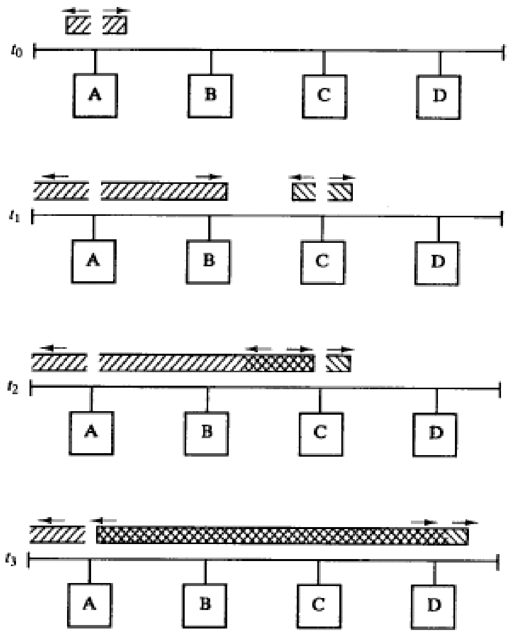


FIGURE 13.1 CSMA/CD operation.

LAN Systems CSMA/CD (3)

With CSMA/CD the amount of wasted capacity is reduced to the time it takes to detect a collision

How long it takes?

- Baseband bus: ***the time is no greater than twice the end-to-end propagation time***

- Broadband bus: The worst case occurs for 2 stations as close together as possible and as far as possible from the headend. The maximum time to detect a collision is 4 times the propagation delay from an end of the cable to the headend

Important rule: The frames should be long enough to allow collision detection prior to the end of transmission.

LAN Systems CSMA/CD (4)

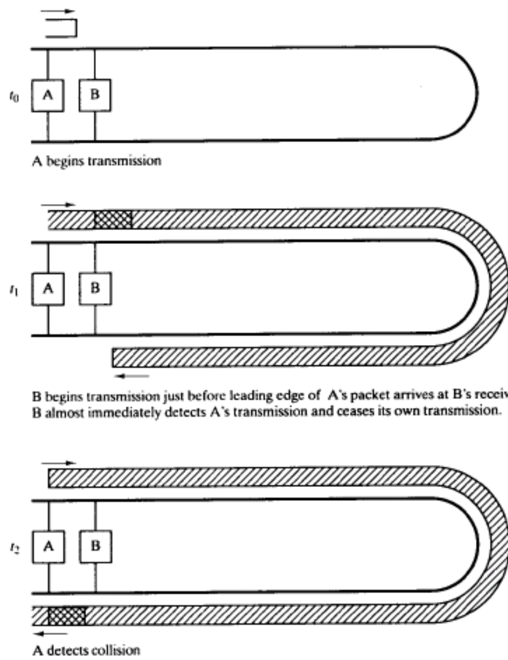


FIGURE 13.2 Broadband collision detection timing.

LAN Systems CSMA/CD (5)

Implementation of CSMA/CD is substantially the same for baseband and broadband.

Differencies:

1) the mean of performing carrier sense:

- for baseband systems: by detecting a voltage pulse train
- for broadband systems: by detecting the RF carrier

2) collision detection:

- for baseband systems: a collision should produce substantially higher voltage swings – CD treshold – restricts the maximum length of coaxial cable (500m for 10BASE5 and 200m for 10BASE2)
- for baseband systems: to compare bit –by- bit transmitted and received data.

MAC Frame for 802.3 protocol

	Preamble	SFD	DA	SA	Length	LLC data	Pad	FCS
octets	7	1	2 or 6	2 or 6	2	≥0	≥0	4

- Preamble
- SFD: Start Frame Delimiter
- DA: Destination Address
- SA: Source Address
- Length: length of the LLC data field
- LLC data: data unit supplied by LLC
- Pad: octets added to ensure that the frame is long enough for propre CD operation
- Frame check sequence (FCS)

IEEE 802.3 10 Mbps Ethernet

Notation:

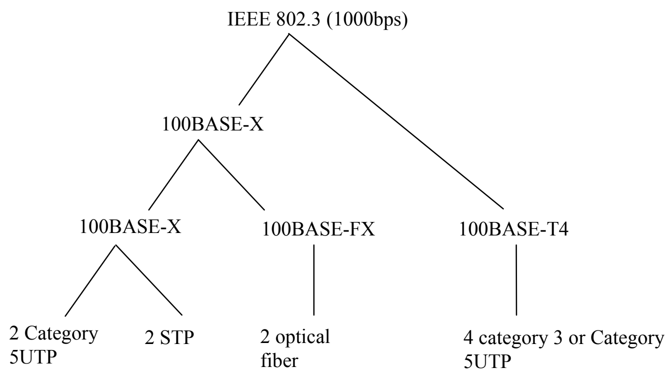
<data rate in Mbps><signaling method><maximum segment length in hundreds of meters>

	10BASE5	10BASE2	10BASE-T	10BROAD-36	10BASE-FP
Transmission medium	Coaxial cable (50Ω)	Coaxial cable (50)	Unshilded twisted pairs	Coaxial cable (75Ω)	850nm optical fiber pair
Signaling technique	Baseband(Manchester)	Baseband(Manchester)	Baseband(Manchester)	Broadband(DPSK)	Manchester ON/OFF
Topology	Bus	Bus	Star	Bus/Tree	Star
Maximum segment length(m)	500	185	100	1800	500
Nodes per segment	100	30	-	-	33
Cable dm	10mm	5mm	0,4-0,6mm	10-25mm	62,5-125µm

IEEE 802.3 100 Mbps Fast Ethernet

100base-T

The blanket designation for these standards

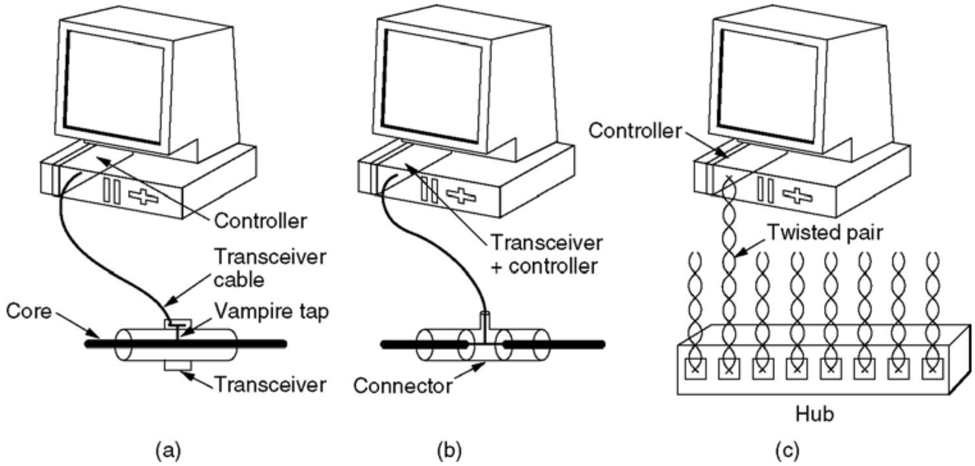


Ethernet Cabling

Name	Cable	Max. seg.	Nodes/seg.	Advantages
10Base5	Thick coax	500 m	100	Original cable; now obsolete
10Base2	Thin coax	185 m	30	No hub needed
10Base-T	Twisted pair	100 m	1024	Cheapest system
10Base-F	Fiber optics	2000 m	1024	Best between buildings

The most common kinds of Ethernet cabling.

Ethernet Cabling (2)



Three kinds of Ethernet cabling.
(a) 10Base5, (b) 10Base2, (c) 10Base-T.

Token Ring and FDDI

Two standards LANs that use token ring

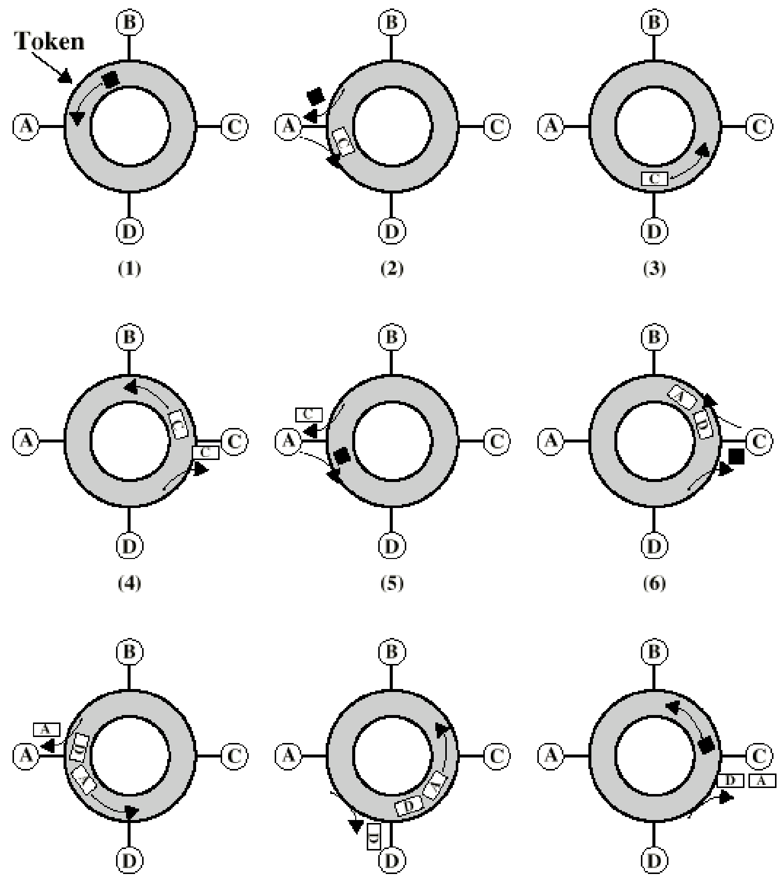
- IEEE 802.5
- FDDI (Fiber distributed data interface)

IEEE 802.5 – MAC

Token – small frame that circulates when stations are idle.

Principle:

- station wishing to transmit waits until it detects a token passing
- station seizes the token and begins to transmit data
- station will insert a new token on the ring:
  - the frame transmission was completed
  - the leading edge of the transmitted frame has returned to the station



Token Ring(2)

Advantages of Token Ring

- Fair access
- Scheme can be used to regulate access to provide for priority and for guaranteed bandwidth services

Disadvantages

- requirement for token maintenance
- duplication of the token can disrupt ring operation
- one station monitors the token presence on the ring

Token Ring(3)

MAC frame – for 802.5 protocol

	SD	AC	FC	DA	SA	Data unit	FCS	ED	FS
octets	1	1	1	2 or 6	2 or 6	≥0	4	1	1

(a) General frame format

SD	AC	FC

(b) Token frame format

J	K	1	J	K	1	I	E

(d) Ending delimiter field

P	P	P	T	M	R	R	R

(c) Access control field

A	C	r	r	A	C	r	r

(e) Frame status field

Token Ring(4)

SD – starting delimiter

AC – access control

FC – frame control

DA – destination address

SA – source address

FCS – frame check sequence

ED – end delimiter

Token Ring Priority

802.5 - Includes a specification for an optimal priority mechanism

- priority field – 3bits field
- reservation field – 3 bits field

Variables defined for algorithm explaining:

P_f – priority of frame to be transmitted

P_s – service priority; priority of current token

P_r – value of service P_s as contained in the last token received by this station

R_s – reservation value in current token

R_f – highest reservation value in the frames received by this station during the last token rotation

Token Ring Priority(2)

1. Wait until $P_s \leq P_f$
2. Reservation at P_f if

   (a) $R_s < P_f$ then: $R_s \leftarrow P_f$

   (b) $R_s < P_f$ and $P_f < P_s$ then $R_s \leftarrow P_f$

   this setting has the effect of preempting any lower - priority reservation
3. When a station seizes a token:
   - it sets the token bit to 1 to start a data frame
   - sets the reservation field of the data frame to 0
   - leaves the priority field unchanged
4. Following transmission of one or more data frames a station issues a new token with the priority and reservation fields set as indicated in the table

Token Ring Priority(3)

OBS

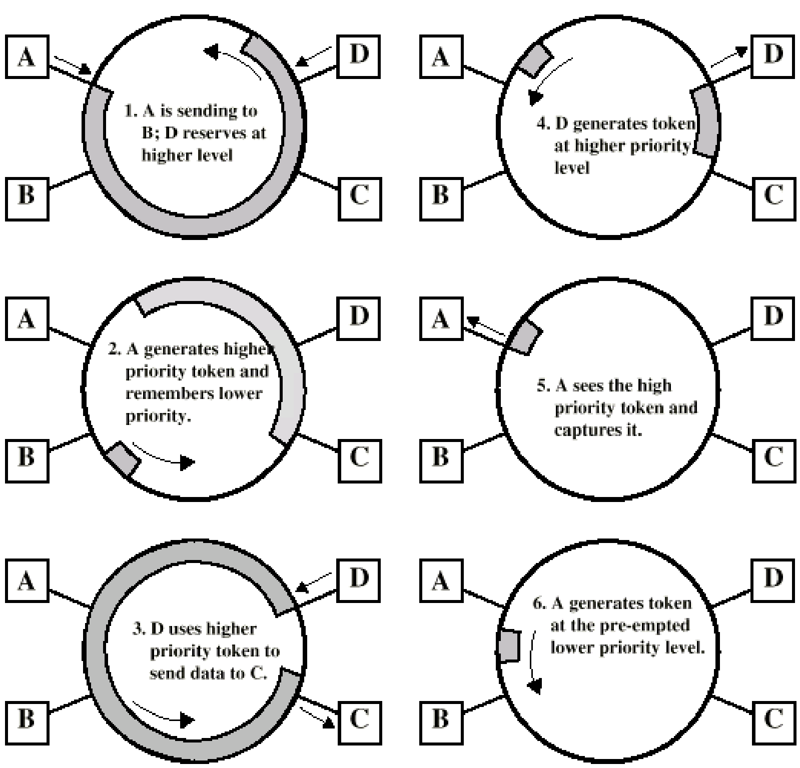
The algorithm has a ratchet effect on priority, driving it to the highest level and keeping it here.

- To avoid this a station that raises the priority has the responsibility of later lowering the priority to its previous level.

- To implement the downgrading mechanism two stacks are maintained by each station:

  - for reservation S_x - store new values of token priority
  - for priorities S_r - store old values of token priority

Token Ring Priority(4)



Early Token Release

If the bit length of the ring is less than that of the frame

- station may issue a token as soon as it has finished frame transmission;

If the frame is shorter than the bit length of the ring:

- some of the potential capacity of the ring is unused;

ETR allows a transmitting station to release a token as soon as it completes frame transmission whether or not the frame header has returned to the station.

Stations that implement ETR are compatible and interoperable with those that do not complete such implementaions.

802.5 Physical Layer Specification

Transmission medium	Shielded twisted pair	Unshielded twisted pair	Fiber chanel
Data Rate	4	16	100
Signaling	Differential Manchester	Differential Manchester	Differential Manchester
Max Frame	4550	18200	18200
Access Control	TP or DTR	TP or DTR	DTR

FDDI Medium Access Control

- 100Mbps
- LAN and MAN applications
- Token Ring

FDDI MAC Frame Format

Bits	64	8	8	16 or 48	16 or 48	≥ 0	32	4	1
	Preamble	SD	FC	DA	SA	Info	FCS	ED	FS

(a) General Frame Format

Preamble	SD	FC	ED

(b) Token Frame Format

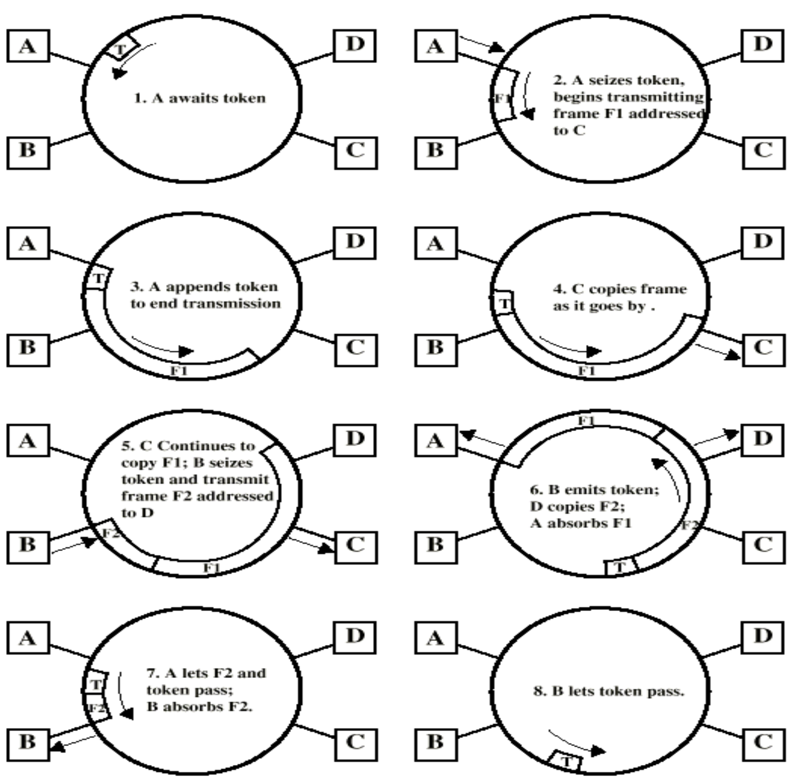
SD = starting delimiter
FC = frame control
DA = destination address
SA = source address
FCS = frame check sequence
ED = ending delimiter
FS = frame status

FDDI MAC Frame Format(2)

As for 802.5 except:

- Station seizes token by aborting token transmission
- Once token captured, one or more data frames transmitted
- New token released as soon as transmission finished (early token release in 802.5)

FDDI Operation



FDDI MAC Frame Format

Frame status field:

Each station can check passing bits for errors and can set the ***E*** indicator if an error is detected.

- If a station detects its own address sets the ***A*** indicator.
- May also copy the frame setting the ***C*** indicator.

Originating station differentiate among 3 conditions:

- Station nonexistent/nonactive
- Station active but frame not copied
- Frame copied

E,A,C indicates results of transmission.

Errors are reported to LLC layer

FDDI Capacity Allocation

- The priority scheme used in802.5 will not work in FDDI
- FDDI is intended to provide for greater control over the capacity of the network than 802.5 due to high speed requirements.
- Capacity allocation scheme seeks to accommodate a mixture of stream and bursty data traffic.
- FDDI defines 2 types of traffic:
  - Synchronous
  - Asynchronous
- Synchronous frames: transmitted during the allocated portion of total capacity
- Asynchronous frames: transmitted during not allocated or allocated but not used portions of time.

802.5 Physical Layer Specification

Transmission medium	Optical fiber	Twisted pair
Data Rate (Mbps)	100	100
Signaling technique	4B/5b/NRZI	MLT-3
Max numbers of repeaters	100	100
Max length between repeaters	2km	100m