CPS 422
Computer Networks

DATA LINK LAYER

IEEE 802 STANDARD

This part will be covered from Computer Networks by Andrew S. Tenenbaum 3rd Edition

IEEE has produced several standards for LANs, collectively known as IEEE-802 standards. The most common ones include CSMA/CD, Token Bus, Token Ring and Wireless LAN standards (IEEE 802.3, 802.4,
802.5 and 802.11 respectively)

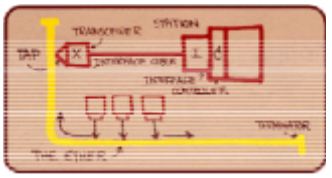
IEEE 802.3 and Ethernet

- We have studied the evolution of CSMA/CD (ALOHA -> CSMA -> CSMA/CD)
- IEEE 802.3 is 1-persistent CSMA/CD
- The name Ethernet was derived from the concept of Ether (medium through which em waves were thought to travel)
- Here Ether refers to the cable
- First Ethernet system was designed and developed by Metcalfe and Boggs in 1976, which connected 100 workstations at a max distance of 1 Km @ 2.94 Mbps

Difference between 802.3 and Ethernet

- Although very similar, IEEE 802.3 is incorrectly referred to as Ethernet
- Xerox Ethernet was the first
- Due to the success of Ethernet, Xerox, DEC and Intel drew up a standard that formed the basis for 802.3 which gave the parameters for a 10 Mbps system using 50-ohm coaxial cable
- 802.3 standard refers to a complete family of 1-persistent CSMA/CD systems

Metcalfe's Ethernet sketch



802.3 CABLING (Variants)

10Base5

- Commonly known as Thick Ethernet or ThickNet
- Connections are made using vampire taps
- Cable is 0.4 inch thick (and hard) coaxial cable
- Had markings every 2.5 meters showing where taps could be inserted
- Complex electronics in transceiver at tap
- 10Base5 notation

10Base2

- Commonly known as Thin Ethernet or ThinNet
- Connections are made using BNC connectors to form T-junctions
- Uses 0.25 inch thick (thinner than the previous one) coaxial cable
- Advantage of simple and cheap connectors and flexible thin cable
- Transceiver electronics shifted to the motherboard of computer
- Disadvantage of lesser segment length
- 10Base2 notation

10BaseT

- The problem of cabling with coaxial cable and existence of twisted pair wires for telephones lead to the evolution of 10BaseT (T stands for twisted pair)
- Complex electronics shifted to the Hub
- Segment length reduced to 100m (150 at best)
- 10BaseT later evolved into 100BaseT or "Fast Ethernet"

10BaseF

- Uses Fiber Optics at Physical Layer
- Expensive cable, connectors, jointing, electronics and equipment
- Noise immunity
- Longer segments
- Segment length depends upon type of OFC used, however 10BaseF has segment length of 2000m.

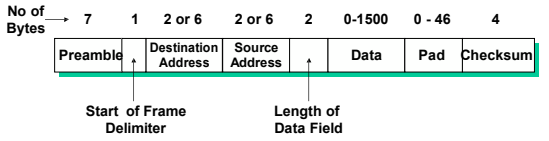
For comparison of 802.3 variants see fig 4-17 of computer networks by Tenenbaum 3rd ed

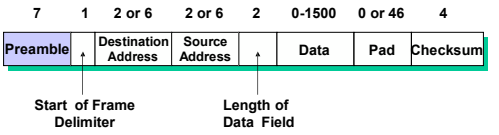
Fast Ethernet and Gigabit Ethernet

- Ethernet standards later reached 100 Mbps and are called "Fast Ethernet"
- Even higher data rates of 1 Gbps evolved to be called "Gigabit Ethernet", with fol variants:-

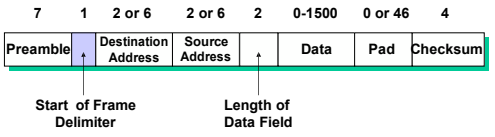
name	medium	specified distance
1000BASE-T	unshielded twisted pair	100 meters
1000BASE-SX	multi-mode fiber	500 meters
1000BASE-LX	single-mode fiber	2 km
1000BASE-LX10	single-mode fiber	10 km
1000BASE-BX10	single-mode fiber, over single-strand fiber: 1490 nm downstream 1310 nm upstream	10 km
1000BASE-CX	balanced copper cabling	25 meters
1000BASE-ZX	single-mode fiber at 1550 nm wavelength	~ 70 km

802.3 FRAME FORMAT

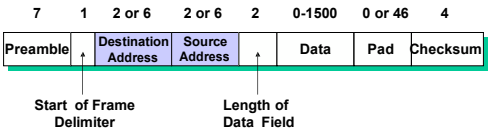




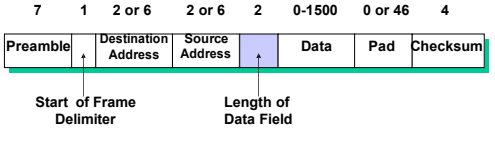
- Has a fixed bit pattern 10101010 of 7 bytes
- With Manchester encoding this pattern produces a 10MHz square wave for 5.6 micro sec for receiver to synchronize its clock



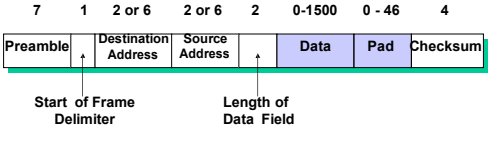
- Has a fixed bit pattern 10101011 of 1 byte
- Denotes start of frame



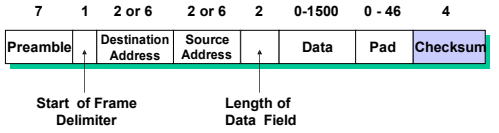
- The standard allows 2 or 6 bytes for addresses
- However 10 Mbps baseband standard allows only 6 byte addresses
- MSB if 0 means ordinary (single) address
- MSB if 1 means group address (multicast)
- All 1s mean a broadcast address
- Second bit from the left indicates a global (0) or a local(1) address
- Total bits available for addressing are 46



- Represents the number of bytes present in data field, from 0 to 1500.



- Although zero bytes in Data are allowed, but causes problems in collision detection.
- Therefore a minimum of 64 bytes from destination to checksum should be there in a frame
- If data field has less than 46 bytes, Pad field of 46 bytes will be used



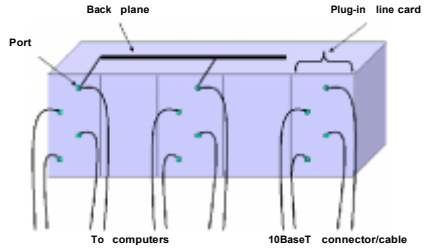
- Uses CRC as discussed earlier.

Recall Binary Exponential Backoff Technique.

802.3 uses it.

Switching in LANs

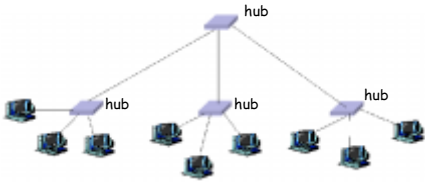
LAN Switches



LAN Switches

Interconnecting with hubs

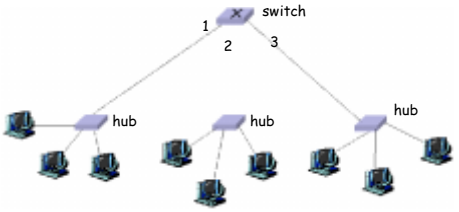
- Backbone hub interconnects LAN segments
- Extends max distance between nodes
- But individual segment collision domains become one large collision domain
- Can't interconnect 10BaseT & 100BaseT



Switch

- Link layer device
  - stores and forwards Ethernet frames
  - examines frame header and selectively forwards frame based on MAC dest address
  - when frame is to be forwarded on segment, uses CSMA/CD to access segment
- plug-and-play, self-learning
  - switches do not need to be configured

Forwarding



• How do determine onto which LAN segment to forward frame?

Self learning

- A switch has a switch table
- entry in switch table:
  - (MAC Address, Interface, Time Stamp)
  - stale entries in table dropped (TTL can be 60 min)
- switch learns which hosts can be reached through which interfaces
  - when frame received, switch "learns" location of sender: incoming LAN segment
  - records sender/location pair in switch table

Filtering/Forwarding

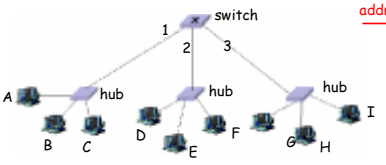
When switch receives a frame:

index switch table using MAC dest address
if entry found for destination
then{
if dest on segment from which frame arrived
then drop the frame
else forward the frame on interface indicated
}
else flood

forward on all but the interface on which the frame arrived

Switch example

Suppose C sends frame to D

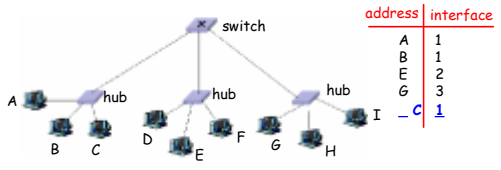


address	interface
A	1
B	1
E	2
G	3

- Switch receives frame from C
  - notes in bridge table that C is on interface 1
  - because D is not in table, switch forwards frame into interfaces 2 and 3
- frame received by D

Switch example

Suppose D replies back with frame to C.

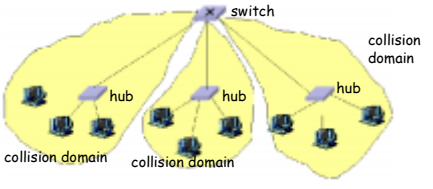


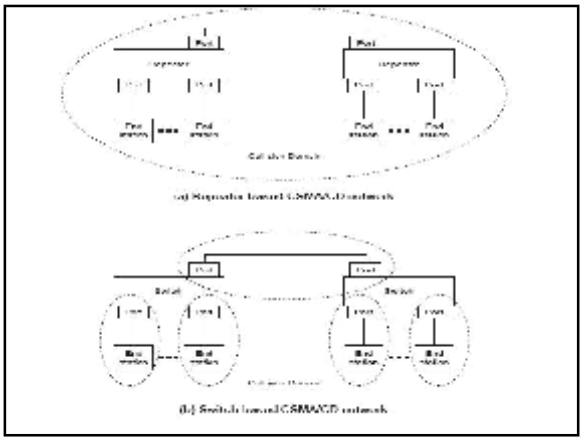
address	interface
A	1
B	1
E	2
G	3
C	1

- Switch receives frame from from D
  - notes in bridge table that D is on interface 2
  - because C is in table, switch forwards frame only to interface 1
- frame received by C

Switch: traffic isolation

- switch installation breaks subnet into LAN segments
- switch filters packets:
  - same-LAN-segment frames not usually forwarded onto other LAN segments
  - segments become separate collision domains

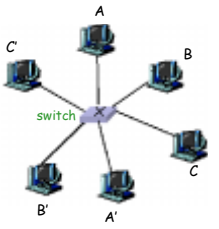




Switches: dedicated access

- Switch with many interfaces
- Hosts have direct connection to switch
- No collisions; full duplex

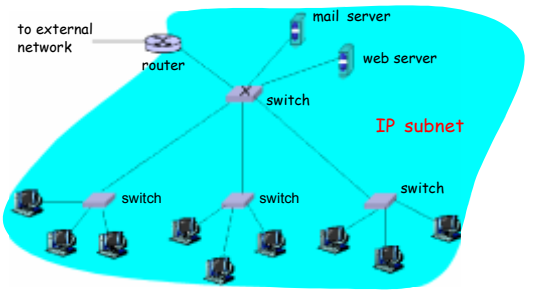
Switching: A-to-A' and B-to-B' simultaneously, no collisions



More on Switches

- cut-through switching: frame forwarded from input to output port without first collecting entire frame
  - slight reduction in latency
- combinations of shared/dedicated, 10/100/1000 Mbps interfaces

Institutional network

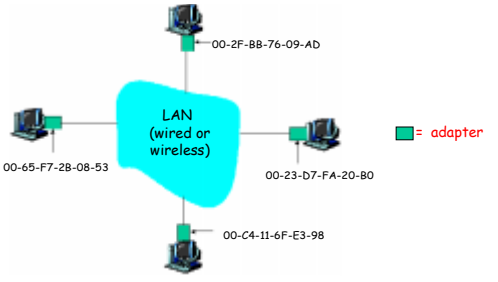


MAC Addresses

- MAC (or LAN or physical or Ethernet) address:
  - used to get datagram from one interface to another physically-connected interface (same network)
  - 48 bit (6-byte) MAC address (for most LANs) burned in the adapter ROM

LAN Addresses

Each adapter on LAN has unique LAN address



LAN Address (more)

- MAC address allocation administered by IEEE
- manufacturer buys portion of MAC address space (to assure uniqueness)
- Analogy:
  - (a) MAC address: like CNIC Number
  - (b) IP address: like postal address
- MAC flat address → portability
  - can move LAN card from one LAN to another

IP hierarchical address NOT portable

- depends on IP subnet to which node is attached

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Computer Networks

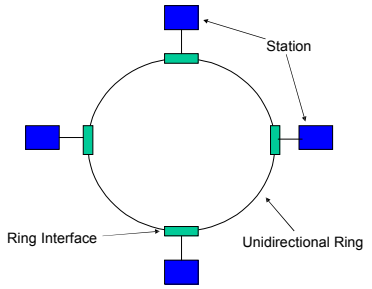
DATA LINK LAYER

IEEE 802.4 (TOKEN BUS) AND IEEE 802.5 (TOKEN RING) STANDARDS

TEXT BOOK:- Andrew S. Tenenbaum 3rd Edition

IEEE 802.5 (TOKEN RING) STANDARD

A Token Ring Layout



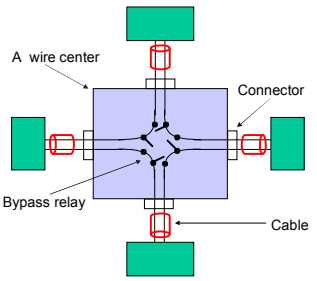
TOKEN RING

- Ring is not a broadcast medium but a collection of point-to-point links forming a circle
- Rings can be based on twisted pair, coaxial or a fiber optics cable
- Fair operation with an upper bound on channel access
- Channel access problem is solved with the help of a special frame called a "Token"
- Also, shutting down of stations should not impair ring functionality

TOKEN RING

- Bits of the frame that have traversed the ring must be removed from the ring by the sender
  - Since the entire frame does not appear on the ring at one time, there is no limit on frame size. It only needs to be pre-decided. The only limit is the token holding time.
- Acknowledgements are sent by the receiver in the same received frame, by setting an Acknowledgement bit in the received frame.

Four Stations connected to a wire center

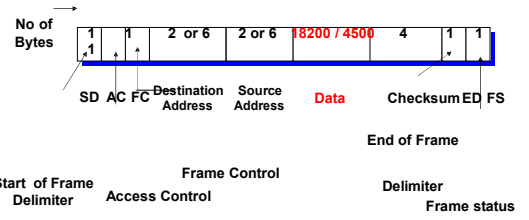


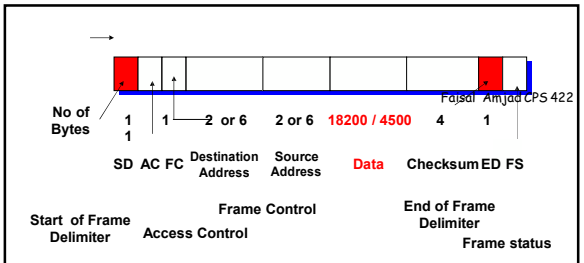
Station

USE OF WIRE CENTERS

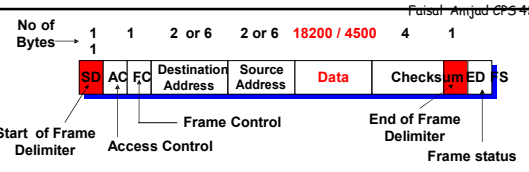
- Cable breaks can lead to ring failure
- This problem can be resolved with the help of a Wire Center.
- A wire center has bypass relays which draw current from the station
- If a station is powered down the relays close thereby removing the station from the ring and maintaining the ring
- Relays can be operated by software for network management
- wire centers make the ring a star-shaped ring.

802.5 FRAME FORMAT

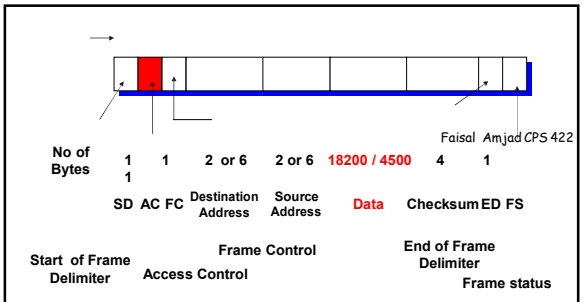




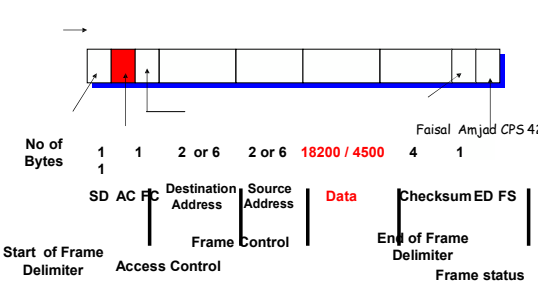
- Mark the frame boundaries
- Contain analog encoding of symbols other than 0s and 1s (code violations)
- So it cannot accidentally occur in data
- End delimiter contains two special bits
  - One to mark an error in frame (E bit)
  - Other to mark the last frame of a logical sequence



- J,K,0,J,K,0,0,0 are bits of Start Delimiter, where J and K are "code violations"
- J,K,1,J,K,1,I,E are bits of End delimiter, where I represents the last frame of a sequence of transmissions and E represents an error in the frame

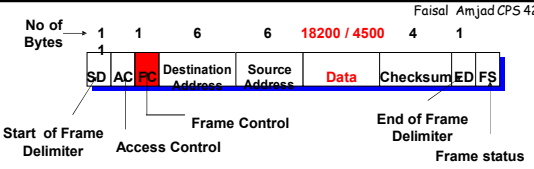


- Contains token, monitor, priority and reservation bits
- Changing the token bit changes a token frame into the first three bytes of a data frame
- Monitor bit is used for ring maintenance
- Priority bits give the current priority of token
- To transmit a frame of priority n, a station has to capture a token of priority less than or equal to n.
- In a passing-by data frame, any station can try to reserve the next token, by writing the priority of its frame in the data frame's reservation bits.

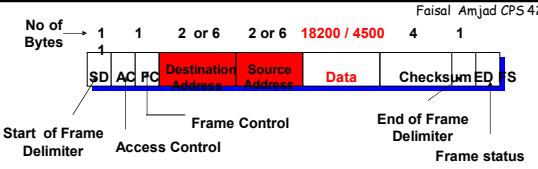


- bits (MSB to LSB): 0-2 3 4 5-7
- Purpose: Priority Token Monitor Reservation
- When it is a token (token bit=0) Reservation bits have no meaning, since reservation bits are used for "booking" future claim as per priority of frames to be sent

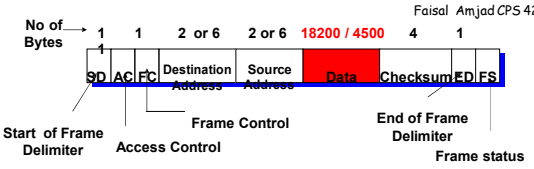
http://www.uandiStar.org



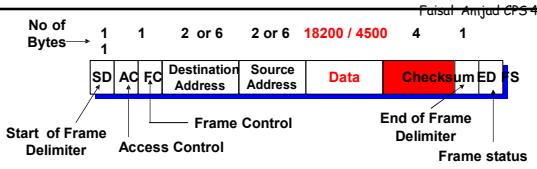
- Used to distinguish data and control frames
- MSB '00' : MAC Control frame
- MSB '01' : LLC Control frame
- MSB '1x' : Undefined, Reserved



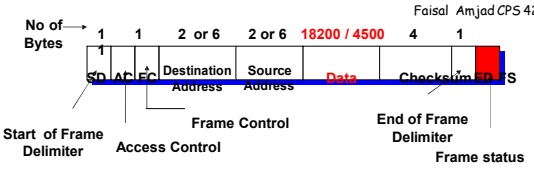
- Identical to 802.3 addressing



- Contains the data, 18200 or 4500 bytes
- Only limited by token holding time



- Same as 802.3



- Contains A and C bits (A,C,0,0,A,C,0,0)
- When a frame arrives at its destination, the station's interface sets the A bit to 1
- If the frame is correctly copied to the station , the C bit is also changed to 1
- A=0, C=0 -> dest not present or powered down
- A=1, C=0 -> dest present but frame not accepted
- A=1, C=1 -> dest present and frame accepted

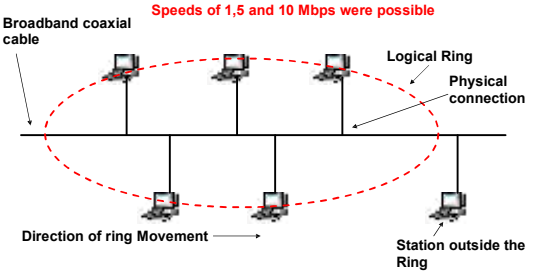
IEEE 802.4 (TOKEN BUS) STANDARD

Evolution of 802.4

- People interested in factory automation were opposed to 802.3
- A station might have to wait arbitrarily to send a frame and
- 802.3 frames do not have priorities, so unsuited for real-time systems
- A ring topology has a known worst-case wait time of nT
- But a ring has a single point of network breakdown
- Also, ring is a poor fit to the linear topology of an assembly line
- 802.4 was developed having robustness of a 802.3 broadcast cable and a known worst-case behavior of a ring

A Token Bus Layout

Speeds of 1,5 and 10 Mbps were possible



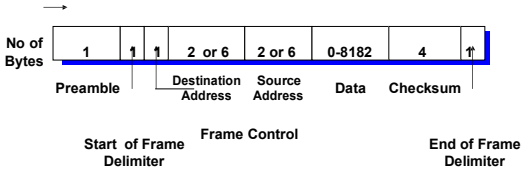
802.4 Ring Operation

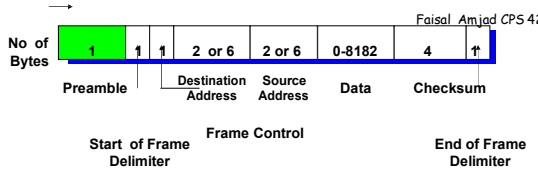
- Token is a special Frame which gives the holder station the "Right to Transmit"
- All stations are connected to a linear cable (Bus) but organized in a Logical ring
- Frames are passed from the Predecessor to the successor after a specified time interval
- When there is no data to be sent the token circulates around the logical ring
- Whenever a station has data to send, it waits for a token to arrive
- Station then captures the token and keeps transmitting data until allocated time for keeping the token expires
- After the specified time the token must be passed on to the successor

Token Bus MAC Protocol

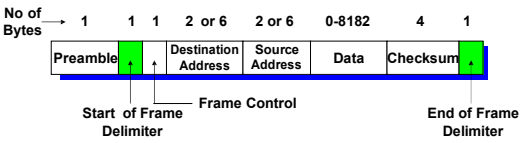
- Stations inserted into the ring in the order of descending addresses
- Token passing also done from high to low addresses
- Defines 4 priority classes 0,2,4 and 6 for traffic, 0 being the lowest
- The token holding time can be sub-divided for frames with different priority classes
- A station may have frames with different priorities
- High priority frames get transmitted first and if token time remains lower priority frames get transmitted in the left over time

802.4 FRAME FORMAT





- Has a fixed bit pattern 10101010 of 1 byte, used to synchronize the receiver's clock.



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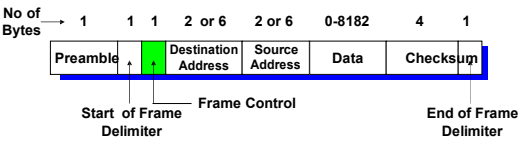
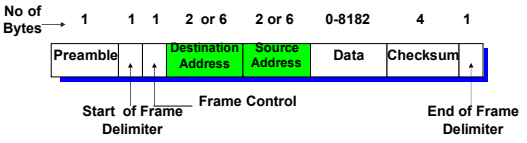
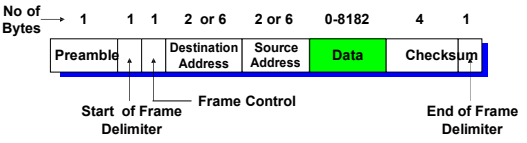


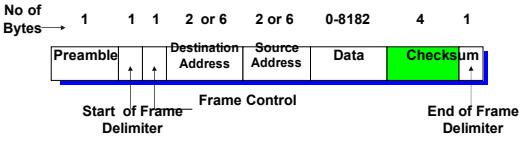
- Used to distinguish data and control frames
- For data frames, it carries frame's priority
- It can also contain an indicator for the receiver to acknowledge a correctly received frame, immediately, since it cannot otherwise do so.
- For control frames, it specifies frame types, e.g. Token, frames for ring maintenance (addition/removal) fig 4-27 for details



- Identical to 802.3 addressing



- Contains the data, max 8182 bytes when 2-byte addresses used
- When 6-byte addresses used data can be a max of 8174 bytes
- All 2-byte or 6-byte addresses used on a LAN, no mixture



- Same as 802.3

Logical Ring Maintenance

Joining the Ring (adding new stations to ring)

- Predecessor and successor addresses maintained by all
- Periodically token holder sends a SOLICIT_SUCCESSOR frame giving its successor's address
- Any station wishing to join the ring with address within the range of sender's and its successor's address can do so, becoming the predecessor of sender's successor
- Ring initialization is special case of adding new stations to the ring
- Descending order of stations is maintained thereby
- If no station bids to enter the ring, the response window closes and token holder continues its operation

Joining the Ring (Contd……)

- If two or more stations bid to enter the ring, their frames will collide
- To reduce the collisions, stations must wait for a random number of time slots between 0,1,2 or 3 for next bidding
- Previous bidding activity is recorded through timers and when the new token is captured, new bidding may not be done if too much time has already been spent on bidding for new stations
- No guarantees on how long a station may have to wait to join the ring. A weakness of the protocol

Leaving the Ring

- Much easier than joining the ring
- Leaving station X, with predecessor P and successor S, sends a SET_SUCCESSOR frame to P
- It tells P to reset its successor to S, rather than X

Reading Assignment

- Study the Ring Maintenance section of the Token Bus and Token Ring, and find out the detail of problems and their solutions for various possibilities of transmission errors in ring / token frame or any hardware failure