FDDI

- Fiber Distributed Data Interface (FDDI)
- Metropolitan Area Network (MAN) *or*

  Local Area Network (LAN) ?

Metropolitan Area Networks

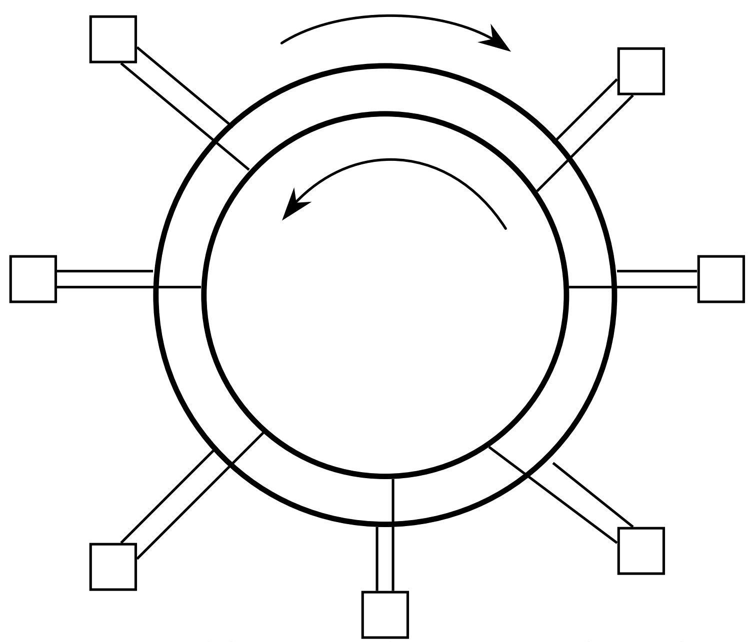
- MANs are like LANs, only bigger and faster
- MANs are typically used as campus-wide or regional computer networks
- LAN < MAN < WAN

FDDI Characteristics

- 100 Mbps data rate
- Distances of up to 200 km
- Up to 1000 hosts attached
- Based on fiber optic cabling

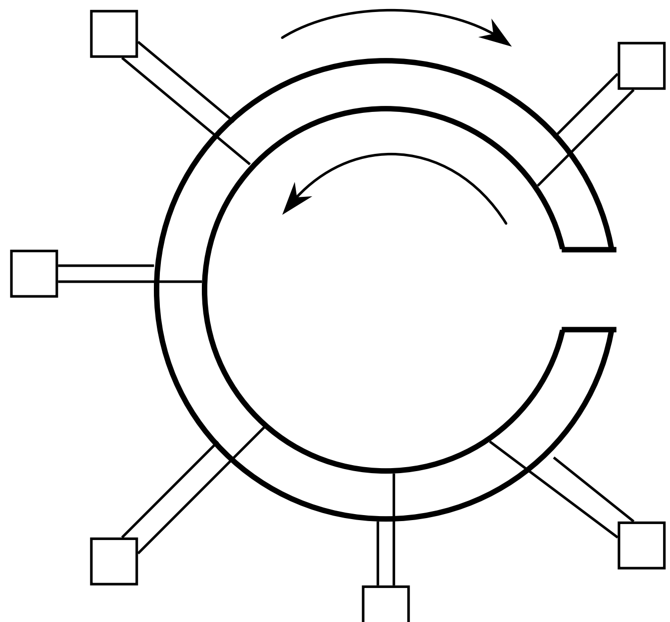
FDDI Dual Ring Topology

- Two fiber rings:
  - Fiber channels are unidirectional, so 2 are needed



FDDI Fault Tolerance

- Fault Tolerance
  - Two rings can be merged into one after failure



FDDI Physical Layer Coding

- 4B5B (4 out of 5) coding is used
  - Each 4-bit data message requires 5 bits to send
  - Some of the unused 5-bit codes are used for controlling the fiber rings or for synchronization
  - To obtain a 100 Mbps data rate, a 125 Mbps physical layer rate must be achieved

- Each group of 4 bit MAC symbols is encoded as a group of 5 bits
  - 16 (of 32 combinations) are for date
  - 3 are for delimiters
  - 2 are for control
  - 3 are for hardware signaling
  - 8 are unused (reserved for future use)

FDDI Frame Format

- Similar to Token Ring

≥8	1	1	2/6	2/6	unlimited	4	1	1
Preamble	SD	FC	**Destination Address**	**Source Address**	Data	**Checksum**	ED	FS

FDDI token and data frame formats

Token

PA	SD	FC	ED

PA *Preamble (16 or more* I *symbols)*
SD *Starting Delimiter (2 symbols:* JK*)*
FC *Frame Control (1 octet)*
ED *Ending Delimiter (2* T *symbols)*

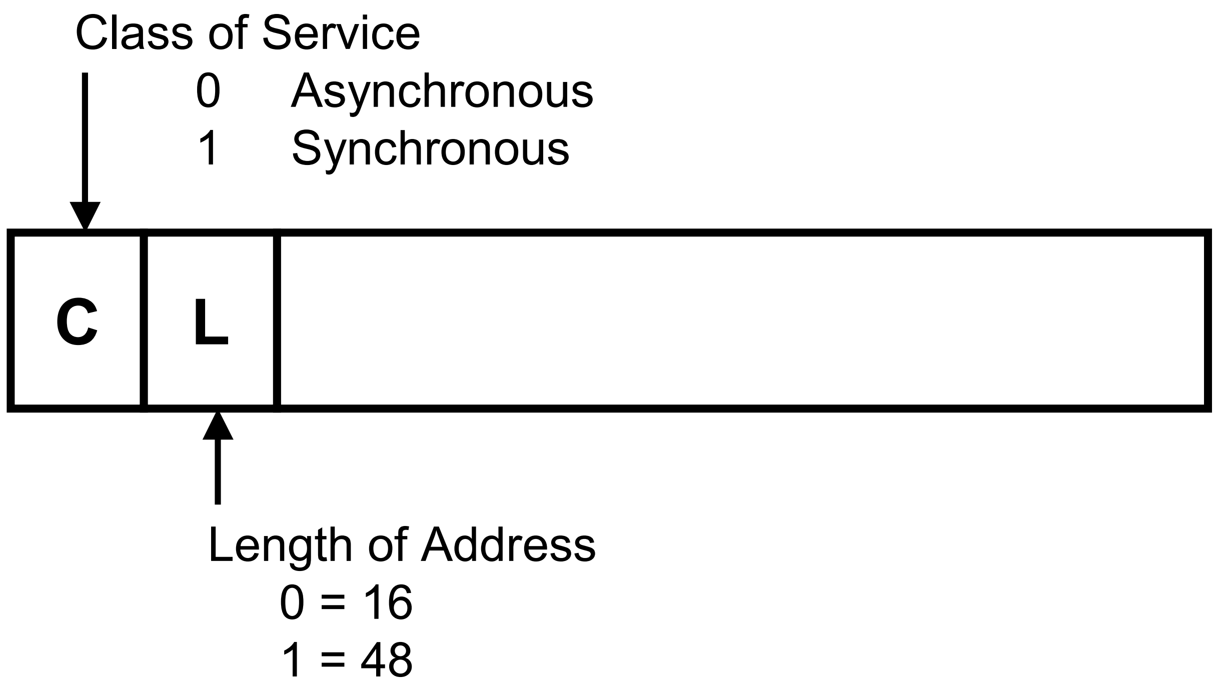
Data Frame

SFS		FCD coverage					EFS	
PA	SD	FC	DA	SA	INFO	FCS	ED	FS

SFS *Start of Frame Sequence*
PA *Preamble (16 or more* I *symbols)*
SD *Starting Delimiter (2 symbols:* JK*)*
FC *Frame Control (1 octet)*
DA *Destination Address (2 or 6 octets)*
SA *Source Address (2 or 6 octets)*

INFO *Information (0 or more octets)*
FCS *Frame Check Sequence (4 octets)*
EFS *End of Frame Sequence*
ED *Ending Delimiter (1* T *symbol)*
FS *Frame Status (3 or more* R *or* S *symbol*

Some Frame Control (FC) values



Valid frames: (1) Integral number of bytes between JK & T;

(2) Number of bytes within limits for type of frame;

(3) Valid FCS (where appropriate);

(4) E should be reset (R), false.

FDDI Token Passing Protocol

- In Token Ring, a new token is not generated until the frame is received again at the transmitting host
- In FDDI, multiple tokens may be on the ring simultaneously.
  - After an FDDI host transmits a frame, it may put another token on the ring
- Timers used to implement priority
  - If a token is ahead of schedule (target token rotation time), all priorities may transmit. If it is behind schedule, only the highest ones may send.

- Other FDDI timers
  - Token Holding Timer
    - determines how long a station may continue to transmit once it has acquired the token.
  - Token Rotation Timer
    - is restarted every time a token is seen.
    - If this timer expires, it means that the token has not been sighted for too long an interval; possibly it has been lost. Token recovery procedure is initiated.

- Transmission mechanism
  - Token captured (not repeated)
  - Data frame transmitted
  - Token released
  - Receiver copies the frame
  - Sender absorbs the frame
  - More than one frame are possible on the ring.
- Station latency delay : 60 bits

- Supports
  - Synchronous traffic (guaranteed bandwidth)
  - Asynchronous traffic (best effort)
    - Eight priority classes
    - Extended dialog between a pair of stations
- Synchronous Traffic
  - Target token-rotation time (TTRT) defined
  - Token is guaranteed in 2 x TTRT
  - SA(i) – Synchronous allocation for ith station

D(Max) + F(Max) + Token time + $\sum SA(i) \leq TTRT$

D(Max) = Ring Latency

F(Max) = Transmission time of largest frame (4500 Bytes)

Token Time = Transmission time of token

- Timers and counter at each station
  - Token-rotation Timer (TRT)
  - Token-holding Timer (THT)
  - Late Counter (LC)

- Initialize

  TRT = TTRT

  LC = 0

  - TRT counts down
  - Token arrives *before* TRT=0

  (a) TRT $\rightarrow$ THT

  (b) TTRT $\rightarrow$TRT

  © Enable TRT

  (d) LC = 0

  (e) Transmit SA(i)

  (f) Enable THT

  (g) Transmit Async data till THT = 0

  (h) Release token

- Token arrives *after* TRT = 0

  (a) When TRT = 0

  – TTRT $\rightarrow$ TRT, LC=1

  (b) Enable TRT

  © Token arrives, LC=0

  (d) TRT remains enabled

  (e) Transmit SA(i), no async data transfer

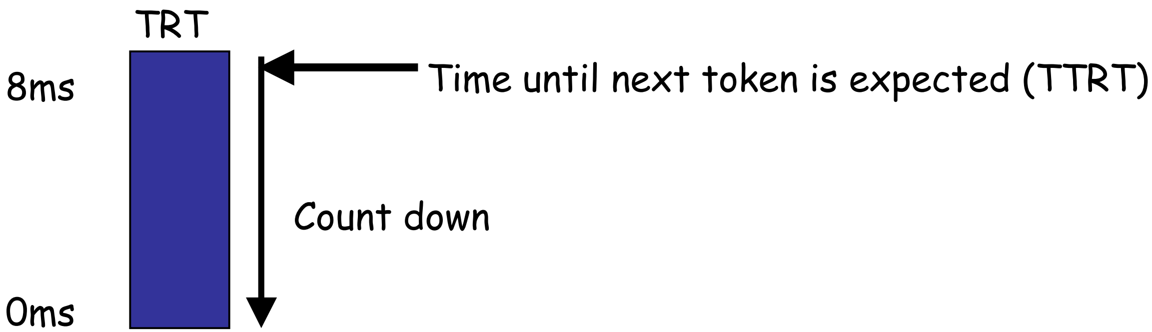
- Token does not arrive before two consecutive expiry of TRT : LC=2, token is lost.

FDDI Timed Token Rotation Protocol

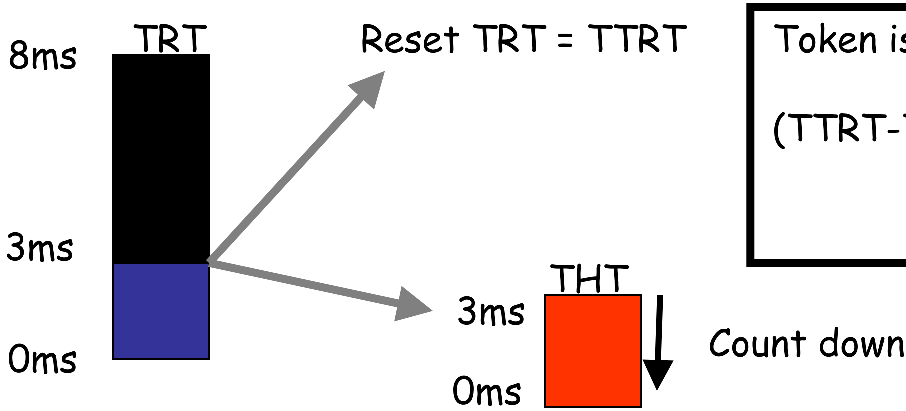
1. All hosts agree on a common Target Token Rotation Time (TTRT). They will aim to make the token rotate around the network at least once per TTRT. Hence, they can each expect to see the token once TTRT.
2. Each host on the network maintains a timed token Rotation (TRT) timer, that indicates when the token is next expected to arrive.
3. If the token arrives before TRT expires, we say it is "Early". If the token arrives after TRT expires, we say it is "Late".
4. A host can only transmit if it receives the token, AND the token is Early.

FDDI Timed Token Rotation Protocol

Time 0: Host receives Token and sets TRT = TTRT (= 8ms in this example)



Time = 5ms: Token arrives & host wants to transmit one or more packets



Token is Early

Host is allowed to transmit up to 3ms (TTRT-TRT) is transferred to a new counter

Token Holding Timer (THT) keeps track of the amount of time host can transmit

When THT reaches 0ms host cannot start new packet

FDDI performance

– Choose TTRT and synchronous allocations so that:

$T = \text{TTRT} \quad T \geq D + F_{\max} + \sum S_i$

D = token rotation time for idle ring (including time to transmit token)

$F_{\max}$ = maximum frame size

S_i = synchronous allocation for station I

– $\text{TRT} \leq 2 \times \text{TTRT}$

– Average token cycle time, $\text{TRT}_{\text{avg}} \leq \text{TTRT}$

– For a ring with N active stations, no synchronous allocations, and every station always with a frame to transmit, i.e., fully loaded, utilization, U, given by

$$U = \frac{N(T-D)}{NT+D}$$

$$= (N-1)T + 2D$$

–and maximum access delay

FDDI: Timed Token Example

Assume: 4 hosts, all have full buffers to send.
TTRT = 3ms

	Host 1	Host 2	Host 3	Host 4
	Frames 3ms	No Tx TRT expired	No Tx TRT expired	No Tx TRT expired
> 3ms	No Tx TRT expired	Frames	No Tx TRT expired	No Tx TRT expired
	No Tx TRT expired	No Tx TRT expired	Frames	No Tx TRT expired

FDDI: Timed Token Example

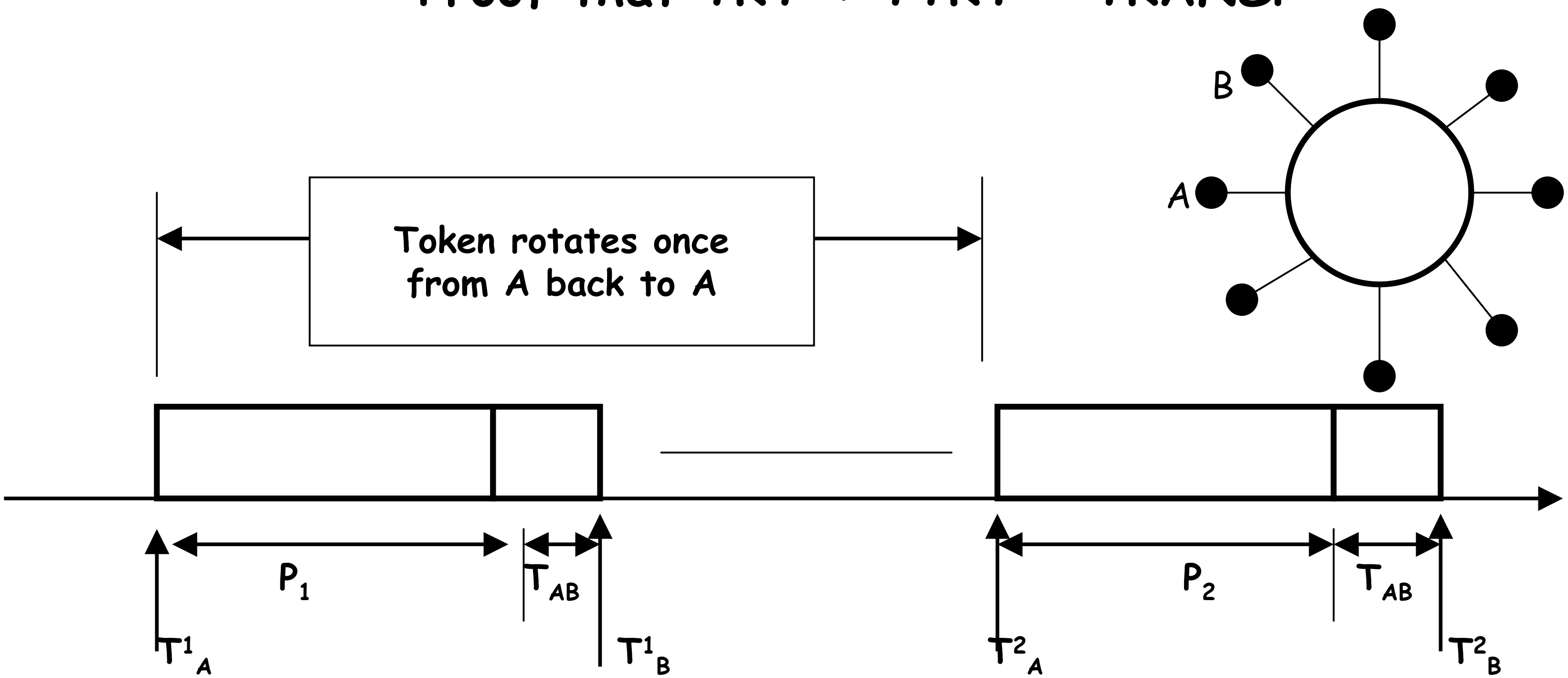
Assume: not all transmit buffers are full.

< 3ms

Host 1	Host 2	Host 3	Host 4
Frames 1.0ms	No Tx Nothing to Tx	Frames 0.5ms	Frames 0.8ms
Frames 0.7ms	Frames 1.0ms	No Tx TRT expired	Frames 0.5ms
No Tx Nothing to Tx	Frames 1.5ms	Frames 0.5ms	No Tx Nothing to Tx

FDDI Timed Token Protocol

Proof that TRT < TTRT + TRANSP



Claim:

IF $T^2_A - T^1_A < TTRT + TRANSP$

THEN $T^2_B - T^1_B < TTRT + TRANSP$

Proof:

Early Token at A

1. IF **TTRT** > $T^2_A - T^1_A$ THEN

   $(T^2_A + P_2) - (T^1_A + P_1) <$ **TTRT** + TRANSP

Hence

$T^2_B - T^1_B = T^2_A - T^1_A + P_2 + P1 <$ **TTRT** + TRANSP

Late Token at A

2. IF TTRT < $T^2_A - T^1_A$ < TTRT + TRANSP

   THEN $P_2 = 0$

   HENCE

   $T^2_B - T^1_B = T^2_A - T^1_A - P_1 <$ TTRT + TRANSP

FDDI MAC Protocol: “Synchronous” Traffic

- So why do we want to guarantee the token rotation time?
- Answer: to support special traffic (called “synchronous traffic that requires a guaranteed access time to the network.

- Each time it receives the token, station $_i$ can send S_i synch traffic.
- S_i’s are picked so that: $\text{sum}(S_i) < \text{TTRT} - \text{TRANSP}$, which adds an extra TTRT to maximum TRT.

$$\boxed{\text{Therefore: } \text{TRT} < 2 \times \text{TTRT}}$$

FDDI MAC Protocol: Asynch Traffic Efficiency

$$\eta \sim= \frac{\text{TTRT - PROP}}{\text{TTRT}}$$

Example: **10km, 100Mbps FDDI ring with 20 nodes**
Assume: **TTRT = 5ms**

$$\eta \sim= \frac{5 \times 10^{-3} - 10^{4} / 2.5 \times 10^{8}}{5 \times 10^{-3}}$$

$= 99.2\%$

FDDI – II

- Can operate in *hybrid mode*
  - Packet switched mode
  - Circuit switched mode
- Provides 16 wideband channels (WBCs) of 6.144 Mbps.
- Provides a minimum of 768 kbps channel for packet switched data (Dedicated Packet Group).
- WBCs can be used to transfer asynchronous data

N Channels of Circuit Switched data = N x 6.144 Mbps

Packet Switched Data = 0.768 + (16-N) x 6.144 Mbps

Overhead (preamble + Cycle header) = 0.928 Mbps