Token Ring and Fiber Distributed Data Interface (FDDI)
IEEE 802.5 Token Ring

- Proposed in 1969 and initially referred to as a Newhall ring.

**Token ring**: a number of stations connected by transmission links in a ring topology. Information flows *in one direction along the ring* from source to destination and back to source.

Medium access control is provided by a small frame, the *token*, that circulates around the ring when all stations are idle. *Only the station possessing the token is allowed to transmit at any given time.*
Token Ring Operation

• When a station wishes to transmit, it must wait for token to pass by and seize the token.
  – One approach: change one bit in token which transforms it into a “start-of-frame sequence” and appends frame for transmission.
  – Second approach: station claims token by removing it from the ring.

• The data frame circles the ring and is removed by the transmitting station.

• Each station interrogates passing frame. If destined for station, it copies the frame into local buffer. 
  {Normally, there is a one bit delay as the frame passes through a station.}
Token Ring Network with star topology

Figure 6.58
Token Insertion Choices

1. **multi-token**: insert token after station has completed transmission of the last bit of the frame.

2. **single-token**: insert token after last bit of busy token is received and the last bit of the frame is transmitted.

3. **single-frame**: insert token after the last bit of the frame has returned to the sending station.

*Performance is determined by whether more than one frame is allowed on the ring at the same time and the relative propagation time.*
(a) Low Latency Ring

\[ t=0, \text{A begins frame} \]

\[ t=90, \text{return of first bit} \]

\[ t=400, \text{transmit last bit} \]

\[ t=490, \text{reinsert token} \]

(b) High Latency Ring

\[ t=0, \text{A begins frame} \]

\[ t=400, \text{last bit of frame enters ring} \]

\[ t=840, \text{return of first bit} \]

\[ t=1240, \text{reinsert token} \]
Single token operation

(a) Low Latency Ring

\[ t=0, \text{ A begins frame} \]

(b) High Latency Ring

\[ t=0, \text{ A begins frame} \]

\[ t=400, \text{ transmit last bit} \]

\[ t=210, \text{ return of header} \]

\[ t=400, \text{ last bit enters ring, reinsert token} \]

\[ t=840, \text{ arrival of first frame bit} \]

\[ t=960, \text{ reinsert token} \]
IEEE 802.5 Token Ring

• 4 and 16 Mbps using twisted-pair cabling with differential Manchester line encoding.
• Maximum number of stations is 250.
• 4 Mbps 802.5 token ring uses *single frame operation*.
• 4 Mbps IBM token ring uses *single token operation*.
• Both 802.5 and IBM 16Mbps token rings use *multi-token operation*.
• 802.5 has 8 priority levels provided via two 3-bit fields (priority and reservation) in data and token frames.
• Permits 16-bit and 48-bit addresses (same as 802.3).
Token Ring

- Under light load – delay is added due to waiting for the token \{on average delay is one half ring propagation time\}.
- Under heavy load – ring is “round-robin”.
  - \textit{Performance is fairer and better than Ethernet}!!
- The ring must be long enough to hold the complete token.
- Advantages – fair access, no collisions.
- Disadvantages – ring is single point of failure, ring maintenance is complex due to token malfunctions.
Token Maintenance Issues

*What can go wrong?*

- Loss of token (no token circulating)
- Duplication of token (forgeries or mistakes)
- The need to designate one station as the *active ring monitor*.
- Persistently circulating frame
- Deal with active monitor going down.
IEEE 802.5 Token and data frame structure

<table>
<thead>
<tr>
<th>Token Frame Format</th>
<th>SD</th>
<th>AC</th>
<th>ED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Data Frame Format</td>
<td>2 or 6</td>
<td>2 or 6</td>
<td>Information</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>FCS</td>
</tr>
<tr>
<td>Starting delimiter</td>
<td>J, K 0 J K 0 0 0</td>
<td>J, K non-data symbols (line code)</td>
<td></td>
</tr>
<tr>
<td>Access control</td>
<td>PPP T M R R R</td>
<td>PPP Priority; T Token bit</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>M Monitor bit; RRR Reservation</td>
<td></td>
</tr>
<tr>
<td>Frame control</td>
<td>FF ZZ ZZ ZZ ZZ</td>
<td>FF frame type</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>ZZZZZZ control bit</td>
<td></td>
</tr>
<tr>
<td>Ending delimiter</td>
<td>J K 1 J K 1 1 E</td>
<td>I intermediate-frame bit</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>E error-detection bit</td>
<td></td>
</tr>
<tr>
<td>Frame status</td>
<td>A C xx A C xx</td>
<td>A address-recognized bit</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>xx undefined</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>C frame-copied bit</td>
<td></td>
</tr>
</tbody>
</table>
Fiber Distributed Data Interface (FDDI)

- **FDDI** uses a ring topology of multimode or single mode optical fiber transmission links operating at 100 Mbps to span up to 200 kms and permits up to 500 stations.
- Employs *dual* counter-rotating rings.
- 16 and 48-bit addresses are allowed.
- In FDDI, token is absorbed by station and released as soon as it completes the frame transmission. *{multi-token operation}*. 
Figure 6.62

FDDI – Dual Token Ring
FDDI Repair

(a) Normal Operation

(b) Reconfigured After Link Failure

(c) Reconfigured After Station Failure

$\bullet$ = MAC Entity

FIGURE 6.7 FDDI Dual-Ring Operation
FDDI Ring Operation

1. A awaits token.
2. A seizes token, begins transmitting frame F1 addressed to C.
3. A appends token to end of transmission.
4. C copies frame F1 as it goes by.
5. C continues to copy F1; B seizes token and transmits frame F2 addressed to D.
6. B emits token; D copies F2; A absorbs F1.
7. A lets F2 and token pass; B absorbs F2.
8. B lets token pass.
• To accommodate a mixture of stream and bursty traffic, FDDI is designed to handle two types of traffic:
  – *Synchronous* frames that typically have tighter delay requirements (e.g., voice and video)
  – *Asynchronous* frames have greater delay tolerances (e.g., data traffic)

• FDDI uses TTRT (Target Token Rotation Time) to ensure that token rotation time is less than some value.
FDDI Data Encoding

• Cannot use differential Manchester because 100 Mbps FDDI would require 200 Mbaud!

• Instead each ring interface has its own local clock.
  – Outgoing data is transmitted using this clock.
  – Incoming data is received using a clock that is frequency and phase locked to the transitions in the incoming bit stream.
FDDI Data Encoding

• Data is encoded using a **4B/5B encoder**.
  – For each four bits of data transmitted, a corresponding 5-bit **codeword** is generated by the encoder.
  – There is a maximum of two consecutive zero bits in each symbol.

• The symbols are then shifted out through a NRZI encoder which produces a signal transition whenever a 1 bit is being transmitted and no transition when a 0 bit is transmitted.

• Local clock is 125MHz. This yields 100 Mbps (80% due to 4B/5B).
FDDI

From MAC unit

- 4B/5B encoder
- NRZI encoder
- Optical transmitter

125 MHz local clock

Clock synchronizer

To MAC unit

- 5B/4B decoder
- Latency buffer
- Optical receiver

TCU

Outgoing fiber

Incoming fiber
Figure 7.15

FDDI line coding and framing detail:
(a) 4B5B codes;
(b) frame formats.

<table>
<thead>
<tr>
<th>Data symbols</th>
<th>Control symbols</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-bit data group</td>
<td>5-bit symbol</td>
</tr>
<tr>
<td>0000</td>
<td>11110</td>
</tr>
<tr>
<td>0001</td>
<td>01001</td>
</tr>
<tr>
<td>0010</td>
<td>10100</td>
</tr>
<tr>
<td>0011</td>
<td>01011</td>
</tr>
<tr>
<td>0100</td>
<td>10110</td>
</tr>
<tr>
<td>0101</td>
<td>01111</td>
</tr>
<tr>
<td>0110</td>
<td>11100</td>
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<tr>
<td>1000</td>
<td>10010</td>
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<tr>
<td>1001</td>
<td>10111</td>
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<tr>
<td>1010</td>
<td>11010</td>
</tr>
<tr>
<td>1011</td>
<td>11111</td>
</tr>
<tr>
<td>1100</td>
<td></td>
</tr>
<tr>
<td>1101</td>
<td></td>
</tr>
<tr>
<td>1110</td>
<td></td>
</tr>
<tr>
<td>1111</td>
<td></td>
</tr>
</tbody>
</table>

(b) Table of FCS coverage

<table>
<thead>
<tr>
<th>PA</th>
<th>SD</th>
<th>FC</th>
<th>DA</th>
<th>SA</th>
<th>INFORMATION</th>
<th>FCS</th>
<th>ED</th>
<th>FS</th>
</tr>
</thead>
</table>

PA = Preamble (16 or more symbols)
SD = Start delimiter (2 symbols)
FC = Frame control (2 symbols)
DA = Destination address (4 or 12 symbols)
SA = Source address (4 or 12 symbols)
FCS = Frame check sequence (8 symbols)
ED = End delimiter (1 or 2 symbols)
FS = Frame status (3 symbols)
FDDI frame structure

Token Frame Format

Data Frame Format

<table>
<thead>
<tr>
<th>8</th>
<th>1</th>
<th>1</th>
<th>2 or 6</th>
<th>2 or 6</th>
<th>4</th>
<th>1</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRE</td>
<td>SD</td>
<td>FC</td>
<td>Destination Address</td>
<td>Source Address</td>
<td>Information</td>
<td>FCS</td>
<td>ED</td>
</tr>
</tbody>
</table>

Preamble

Frame Control CLFFZZZZ
C = Synch/Asynch
L = Address length (16 or 48 bits)
FF = LLC/MAC control/reserved frame type

Leon-Garcia & Widjaja: Communication Networks

Networks: Token Ring and FDDI 21
More FDDI Details

• FDDI Transmission on optical fiber requires ASK.
• The simplest case: coding is done via the absence or presence of a carrier signal \textit{Intensity Modulation}.
• Specific 5-bit codeword patterns chosen to guarantee no more than \textbf{three zeroes in a row} to provide for adequate synchronization.
• 1300 nm wavelength specified.
• Dual rings (primary and secondary) – transmit in opposite directions.
• Normally, second ring is \textbf{idle} and used for redundancy for automatic repair (self-healing).
Differences between **802.5** and **FDDI**

**Token Ring**
- Shielded twisted pair
- 4, 16 Mbps
- No reliability specified
- Differential Manchester
- Centralized clock
- Priority and Reservation bits
- All three token operations possible

**FDDI**
- Optical Fiber
- 100 Mbps
- Reliability specified (dual ring)
- 4B/5B encoding
- Distributed clocking
- Timed Token Rotation Time
- Multi-token operation