Lecture Computer Networks
Ethernet and FDDI

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Institut für Organisation und Management von Informationssystemen

Thomas Nau, kiz
Ethernet and FDDI

• Ethernet
  – History, Evolution, Overview
  – OSI-Model
    • Physical Layer: Coding Schemes
    • MAC-Layer: CSMA/CD
  – Ethernet Principles
    • Versions and Parameters
    • Topologies
    • Communication Modes
    • Collision Domain
    • Framing
  – Standards up to Gigabit Ethernet
  – Gigabit Ethernet
  – VLAN

• FDDI
History - Ethernet and DIX Consortium

Creation of Ethernet

• by Dr. Robert Metcalfe
• at Xerox Corporation in Palo Alto, California, 1973
• operated at 2.94Mbps
• goal was to improve the connection speed between computers and printers

DEC-Intel-Xerox (DIX) Consortium

• developed the standard for 10Mbps Ethernet, 1980
• thick multi-drop coaxial cable

IEEE 802 standards, 1980

• IEEE 802.3 for Ethernet
• IEEE 802.4 for Token Bus
• IEEE 802.5 for Token Ring
In the beginning

1976 R. Metcalfe presented Ethernet for the first time; he used this diagram
Evolution

- Ethernet 10Mb/s (1973)
- Fast Ethernet 100Mb/s (1980)
- Gigabit Ethernet 1000Mb/s (1995)
- 10 Gigabit Ethernet 10000Mb/s (1998)
- 10 Gigabit Ethernet 10000Mb/s (2002)
IEEE Standards

802.10 Security
802.1 Overview
802.2 Logical Link
802.1 Bridging
802.3 Ethernet LAN
802.4 Token Bus
802.5 Token Ring
802.6 DQDB
802.7 Broadband Tag
802.8 Fiber Optic Tag
802.9 Integrated Services
802.11 Wireless LAN
Ethernet and FDDI

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• FDDI
OSI Layers

- Application
- Presentation
- Session
- Transport
- Network
- Data Link
- Physical
  - LLC
  - MAC
  - PHY
  - PMD
Sub-Layers

LLC  Logical Link Control
(de)multiplexing packets from the network layers

MAC  Media Access Control
frame formats, addressing, sharing of the medium

PHY  physical medium independent layer
encoding/decoding bits into pulses, synchronization of the transceiver clocks

PMD  Physical Medium Dependent Layer
handling with electrical components
Inter-Layer Connections

![Diagram showing inter-layer connections between MAC, PHY, and PMD layers with data flow indicated by Frames, Symbols, and Pulses.]
Bandwidth Sharing (Half Duplex Mode)

For a bus or any other half duplex topology a method for bandwidth sharing is mandatory.

In the development days of the Ethernet the following methods were tested:

- Pure Aloha
- Slotted Aloha
- CSMA
- CSMA/CD
CSMA/CD

Carrier Sense Multiple Access with Collision Detection

- Wait until medium is available
  - medium must be idle for the Interframe Gap (IFG) time before sending

- Start transmission

- If a collision is detected while transmitting,
  - transmit a jam signal
  - wait for a random time and retry (up to 16 times)

- Collision detection is done by comparing transmitted and received signals
CSMA/CD

1. Host wants to transmit
2. Is carrier sensed?
3. Assemble frame
4. Start transmitting
5. Is a collision detected?
6. Keep transmitting
7. Is the transmission done?
8. Transmission completed
9. Broadcast jam signal
10. attempts = attempts + 1
11. attempts > too many?
12. Too many collisions; abort transmission
13. Algorithm calculates backoff
14. Wait for t seconds
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- FDDI
Ethernet Versions

Two incompatible versions:

• Ethernet II (DIX - consortium of the companies DEC, Intel and Xerox)

• Ethernet 802.3 (standard of IEEE)
  • PMD, PHY, and MAC layers are covered in the standard IEEE 802.3
  • LLC - covered in the standard IEEE 802.2 (general standard, not only for Ethernet)
Ethernet II Principles

- Fixed 10Mbps Manchester coded signals
- CSMA/CD used for bandwidth sharing
- Frame size range 64 to 1518 bytes
- Truncated binary back-off algorithm used for retransmission
- Little-endian bit-order
- 64 bit preamble at front and 9.6μs delay between frames
- Bus topology
- Ethernet is a passive network, only transmitting stations can be detected
Example for a Bus Topology (very obsolete by now)

10Mb/s
Example for a Star/Tree Topology
Example for a Star Topology
Half-duplex Mode

- Stations share a single Ethernet channel by using a medium access control protocol (see CSMA/CD)
- Only one station can send data over the channel at any given time
- Disadvantage: segment length is limited by timing requirement caused by requirements of collision detection mechanism
Physical Extension

- Ethernet cards detect collisions only while transmitting. A collision that occurs at the far end of the medium must reach the sender before it stops transmitting.
Collision Domain
Separate Collision Domains

Diagram showing a network with a switch in the middle and Repeaters connected to the switch and to servers in separate collision domains.
Full-duplex Mode

- Point-to-point links over twisted pair or fiber optic media
- Both devices may send data at any time
  - Disable the carrier sense function
  - Disable collision detect
  - Disable the looping back of transmitted data onto the receiver input
- Advantages:
  - Segment length is limited by the signal-carrying capabilities of the segment media
  - The multiple access algorithm (CSMA/CD) is unnecessary
- Standard IEEE 802.3x
Framing

- Layer 2 encapsulation
- Breaking the stream into fields
  - Start and stop indicator fields
  - Naming or addressing fields
  - Data fields
  - Quality control fields
IEEE MAC Address

<table>
<thead>
<tr>
<th>I/G</th>
<th>U/L</th>
<th>OUI</th>
<th>assigned by OUI owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Bit</td>
<td>1 Bit</td>
<td>22 Bit</td>
<td>24 Bit</td>
</tr>
</tbody>
</table>

I/G  Individual/Group
U/L  Universal/Local
OUI  Organizationally Unique Identifier
specifies the manufacturer of the Ethernet card
Ethernet II Frame

- **Preamble**: 8 Byte, for synchronization of the stations
- **Type**: 2 Byte, specifies Layer 3 Protocol
- **FCS**: Frame Check Sequence

![Ethernet II Frame Diagram]
Ethernet and FDDI

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Some of the (very old) Standards for 10Mbit/s

<table>
<thead>
<tr>
<th>Standard-first released</th>
<th>Topology</th>
<th>Medium</th>
<th>Max Cable Segment [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>half-duplex</td>
<td>full-duplex</td>
</tr>
<tr>
<td>10Base5</td>
<td>DIX-1980</td>
<td>Bus</td>
<td>single 50 Ohm coaxial cable (10mm thick) - thicknet</td>
</tr>
<tr>
<td>10Base2</td>
<td>802.3a-1985</td>
<td>Bus</td>
<td>single 50 Ohm RG 58 coaxial cable (5mm thick) - thinnet</td>
</tr>
<tr>
<td>10Base-T</td>
<td>802.3i-1990</td>
<td>Star</td>
<td>two pairs of 100 Ohm Cat3 or better UTP cable</td>
</tr>
<tr>
<td>10Base-F</td>
<td>802.3j-1993</td>
<td>Star</td>
<td>two optical fibres</td>
</tr>
</tbody>
</table>

10 stands for 10Mbit/s
Base stands for Baseband
## Standards for 100Mbit/s

<table>
<thead>
<tr>
<th>Standard</th>
<th>Standard-first released</th>
<th>Top.</th>
<th>Medium</th>
<th>Max Cable Segment [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>100Base-TX</td>
<td>802.3u-1995</td>
<td>Star</td>
<td>two pairs of 100 Ohm Cat5 UTP cable</td>
<td>100</td>
</tr>
<tr>
<td>100Base-FX</td>
<td>802.3u-1995</td>
<td>Star</td>
<td>two optical fibres</td>
<td>412</td>
</tr>
<tr>
<td>100Base-T4</td>
<td>802.3u-1995</td>
<td>Star</td>
<td>four pairs of 100 Ohm Cat3 or better UTP cable</td>
<td>100</td>
</tr>
<tr>
<td>100Base-T2</td>
<td>802.3y-1997</td>
<td>Star</td>
<td>two pairs of 100 Ohm Cat3 or better UTP cable</td>
<td>100</td>
</tr>
</tbody>
</table>
## Standards for 1Gbit/s

<table>
<thead>
<tr>
<th>Standard</th>
<th>Topology</th>
<th>Medium</th>
<th>Max Cable Segment [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000Base-LX</td>
<td>Star</td>
<td>long wavelength laser:</td>
<td></td>
</tr>
<tr>
<td>802.3z-1998</td>
<td></td>
<td>- 62.5μm multi-mode fiber</td>
<td>316</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- 50μm multi-mode fiber</td>
<td>316</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- 10μm single-mode fiber</td>
<td>316</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>550</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5000</td>
</tr>
<tr>
<td>1000Base-SX</td>
<td>Star</td>
<td>short wavelength laser:</td>
<td></td>
</tr>
<tr>
<td>802.3z-1998</td>
<td></td>
<td>- 62.5μm multi-mode fiber</td>
<td>275</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- 50μm multi-mode fiber</td>
<td>316</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>275</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>550</td>
</tr>
<tr>
<td>1000Base-CX</td>
<td>Star</td>
<td>specialty shielded balanced copper jumper cable assemblies (“twinax”)</td>
<td>25</td>
</tr>
<tr>
<td>802.3z-1998</td>
<td></td>
<td></td>
<td>25</td>
</tr>
<tr>
<td>1000Base-T</td>
<td>Star</td>
<td>four pairs of 100 Ohm Cat5 or better cable</td>
<td>100</td>
</tr>
<tr>
<td>802.3ab-1999</td>
<td></td>
<td></td>
<td>100</td>
</tr>
</tbody>
</table>
## Encodings used by the IEEE Standards

<table>
<thead>
<tr>
<th>Technology</th>
<th>Standards</th>
<th>Encodings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethernet</td>
<td></td>
<td>Manchester coding</td>
</tr>
<tr>
<td>Fast Ethernet</td>
<td>100Base-FX</td>
<td>NRZI and 4B/5B encoding</td>
</tr>
<tr>
<td></td>
<td>100Base-TX</td>
<td>MLT-3 (or NRZI-3) and 4B/5B encoding</td>
</tr>
<tr>
<td></td>
<td>100Base-T4</td>
<td>8B/6T encoding</td>
</tr>
<tr>
<td>Gigabit Ethernet</td>
<td>1000Base-LX</td>
<td>8B/10B encoding</td>
</tr>
<tr>
<td></td>
<td>1000Base-SX</td>
<td>8B/10B encoding</td>
</tr>
<tr>
<td></td>
<td>1000Base-CX</td>
<td>8B/10B encoding</td>
</tr>
<tr>
<td></td>
<td>1000Base-T</td>
<td>PAM5</td>
</tr>
</tbody>
</table>
## Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>10MBit/s</th>
<th>100MBit/s</th>
<th>1GBit/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>nominal Bit Time</td>
<td>0,1 μs</td>
<td>0,01 μs</td>
<td>0,001 μs</td>
</tr>
<tr>
<td>Slot Time [Bit Times]</td>
<td>512</td>
<td>512</td>
<td>4096</td>
</tr>
<tr>
<td>Interframe Gap</td>
<td>9,6 μs</td>
<td>0,96 μs</td>
<td>0,096 μs</td>
</tr>
<tr>
<td>Max Frame Size</td>
<td>1518 Byte</td>
<td>1518 Byte</td>
<td>1518 Byte</td>
</tr>
<tr>
<td>Min Frame Size</td>
<td>64 Byte</td>
<td>64 Byte</td>
<td>64 Byte</td>
</tr>
<tr>
<td>Extended Size</td>
<td>0 Bit</td>
<td>0 Bit</td>
<td>Slot-Time-MinFrameSize</td>
</tr>
<tr>
<td>Burst Limit</td>
<td>no</td>
<td>no</td>
<td>65536 Bit</td>
</tr>
</tbody>
</table>
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• **FDDI**
Gigabit Ethernet Standards

Media Access Control (MAC)
- full duplex / half duplex

Gigabit Media Independent Interface (GMII) optional

8B/10B encoding/decoding

1000BASE-LX
- LWL Fiber Optic

1000BASE-SX
- SWL Fiber Optic

1000BASE-CX
- Shielded Balanced Copper

1000BASE-T encoder/decoder

1000BASE-T
- UTP
- Category 5

802.3z physical layer

802.3ab physical layer
Migration to Gigabit Ethernet

- Gigabit Ethernet looks identical to Ethernet from data link layer upwards
- Changes are made to physical interface
  - Gigabit Ethernet Physical Media Attachment (PMA) is identical to Fiber Channel PMA
- Standard takes advantage of
  - High speed physical interface of fiber channel
  - IEEE 802.3 Ethernet frame format
  - Full or half duplex CSMA/CD
IEEE 802.3z Gigabit Ethernet

GMII: Gigabit Media Independent Interface
PMA: Physical Media Attachment
PMD: Physical Media Dependent

Reconciliation: Mapping between:
- Physical layer signaling primitives &
- Signals on GMII
Frame Formats

IEEE 802.3 frame format

- Preamble: 7 octets
- Start-of-Frame Delimiter: 1 octet
- Destination Address: 6 octets
- Source Address: 6 octets
- Length/Type: 2 octets
- Data: 46-1500 octets
- Frame Check Sequence: 4 octets

Gigabit Ethernet frame format

- Preamble: 7 octets
- Start-of-Frame Delimiter: 1 octet
- Destination Address: 6 octets
- Source Address: 6 octets
- Length/Type: 2 octets
- Data: 46-1500 octets
- Frame Check Sequence: 4 octets
- Extension: 0-448 octets
Problems with Gigabit Ethernet

In half-duplex mode, the physical extension would - without further measures - be less than 20 meters.

Reason: dependence between minimum sized frames, speed and physical extension

- The minimum CSMA/CD carrier time and the Ethernet slot time have been extended to 512 bytes.

- Packets \( \geq 512 \text{ bytes} \) are not modified.

- Packets \( < 512 \text{ bytes} \) have a carrier extension field following the CRC field.
Frame with Extension Field

Packets smaller than 512 Byte will be extended with an additional field:

<table>
<thead>
<tr>
<th>Destination Address (6 Byte)</th>
<th>Source Address (6 Byte)</th>
<th>Type/Length (2 Byte)</th>
<th>Data</th>
<th>FCS (4 Byte)</th>
<th>Extension</th>
</tr>
</thead>
</table>

512 Byte
Packet Bursting

Mechanism to improve the performance of the small sized packets:
the devices are allowed to send some small packets together
but a burst limit is defined too:
one transmission of a station must not be longer than 65,536 bit
times

![Diagram of Packet Bursting](image)
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VLANs (Virtual Local Area Network)

- VLAN A
- VLAN B
- VLAN C

H: Host
Benefits of VLANs

• Facilitating network administration
• Allowing formation of work groups
• Enhancing network security
• Providing a means of limiting broadcast domains
VLAN Standards

- IEEE 802.3ac (1998) defines frame format extensions to support Virtual Local Area Network (VLAN) Tagging on Ethernet networks.

- IEEE 802.1Q defines the general VLAN protocol.
VLAN Tag

The VLAN protocol permits the insertion of an identifier, or "tag", into the Ethernet frame format to identify the VLAN to which the frame belongs. It allows frames from stations to be assigned to logical groups.

<table>
<thead>
<tr>
<th>Destination Address (6 Byte)</th>
<th>Source Address (6 Byte)</th>
<th>Length/Type 802.1Q Tag Type (2 Byte) 0x8100</th>
<th>Tag Control Information (2 Byte)</th>
<th>Length/Type (2 Byte)</th>
<th>Data (46 - 1500 Byte)</th>
<th>FCS (4 Byte)</th>
</tr>
</thead>
</table>

- **FCS**: Frame Check Sequence.
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- FDDI
FDDI (Fiber Distributed Data Interface)

• 100Mbps bandwidth
• Up to 500 stations in one network
• Up to 60km between two stations
• Total length 200km
• Guaranteed waiting time
• Redundancy in topology
FDDI Summary

• Fixed 125Mbps 4b/5b coded signals
• Timed token rotation used for bandwidth sharing
• Frame size 3...4500 bytes
• Topology: dual ring of trees
• Big-endian bit order
• Offers synchronous and asynchronous transmissions
• Stations have station-management duties
FDDI Topology

Dual Ring

Ring with Trees

Tree
FDDI Stations

DAS: Dual Attachment Station
DAC: Dual Attachment Concentrator
SAS: Single Attachment Station
A: Primary Port
B: Secondary Port
M: Master Port
S: Slave Port
Wrapped Ring

Dual Ring

Wrapped Ring
FDDI Frame

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starting Delimiter</td>
<td>(2 symbols)</td>
</tr>
<tr>
<td>Frame Control</td>
<td>(2 symbols)</td>
</tr>
<tr>
<td>Destination Address</td>
<td>(12 symbols)</td>
</tr>
<tr>
<td>Source Address</td>
<td>(12 symbols)</td>
</tr>
<tr>
<td>Information</td>
<td>(&lt;= 8956)</td>
</tr>
<tr>
<td>Ending Delimiter</td>
<td>(1 symbol)</td>
</tr>
<tr>
<td>Frame Status</td>
<td>(3 symbols)</td>
</tr>
<tr>
<td>Error Detected</td>
<td>(1 symbol)</td>
</tr>
<tr>
<td>Address Recognized</td>
<td>(1 symbol)</td>
</tr>
<tr>
<td>Frame Copied</td>
<td>(1 symbol)</td>
</tr>
</tbody>
</table>

Type of Frame

- **C**: Length of Address
  - 0 = 16 bits, 1 = 48 bits
- **L**: Class of Service
  - 0 = asynchronous, 1 = synchronous
Access Method

For a right to initialize the token: 8ms, 8ms, 8ms, ...
Do I hear any 7?
FDDI Access Method

- There are 2 types of transfers: synchronous and asynchronous
- Synchronous transfers can be done whenever the station gets the token; was never really used
- Asynchronous traffic can be started whenever the station gets a token that is not late
- The last frame is always allowed to complete
- The token is immediately released after transmission
- The transmitting station removes its own data
Token Release Methods

Immediate Release

Delayed Release

Wasted Time
FDDI Error Detection

- A station suspects a fault in the ring
- It starts sending beacon frames
- Every station that receives a beacon frame stops sending beacons
- If a station receives its own beacon everything is OK
- Else the ring is broken right before the station
- The SMT takes action
FDDI Ring Wrapping and Hold

Wrapping results in partitions

global hold maintains primary ring