High-Speed LANs

Class 4
Layer-2 Switching
Where we are

Data Flow

Application
Presentation
Session
Transport
Network
Data Link
Physical

Application
Presentation
Session
Transport
Network
Data Link
Physical

User application, process
And management functions
Data interpretation, format
And control transformation
Administration and control
Of session between two nodes
Network transparent data transfer and transmission control
Routing, switching and flow control
Control over a network
Maintain and release data:
Link, error and flow control
Electrical and mechanical characteristics

Communication subnet
Standardisation & protocol stacks

- IEEE 802.x normally defines the **Media Access Control (MAC) layer**
  - controlled by the 802.2 Logical Link Control (LLC) layer

<table>
<thead>
<tr>
<th>Network layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>802.2 Logical Link Control (LLC)</td>
</tr>
<tr>
<td>802.3 CSMA/CD</td>
</tr>
<tr>
<td>802.5 Token ring</td>
</tr>
<tr>
<td>802.11 Wireless LAN</td>
</tr>
<tr>
<td>802.16 Wireless MAN</td>
</tr>
<tr>
<td>Various physical layers</td>
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</table>
# IEEE 802 LAN standards (CONT)

<table>
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<tr>
<th>Standard</th>
<th>Description</th>
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<tbody>
<tr>
<td>802.1</td>
<td>The highest level interface standard.</td>
</tr>
<tr>
<td>802.1: LLC Protocol</td>
<td>Provides Point-to-Point link control between devices at the protocol level; equivalent to second layer of the OSI Model</td>
</tr>
<tr>
<td>802.3: CSMA/CD Base band Bus</td>
<td>Describes techniques for a device on a bus to transmit when no other device is transmitting</td>
</tr>
<tr>
<td>802.4: Token Passing Bus</td>
<td>As per this standard, a device on a bus topology transmits only when it receives a token passed along in a predetermined sequence, guaranteeing network access to all users</td>
</tr>
<tr>
<td>802.5 Token Ring</td>
<td>Here too, a token is used for medium access in the ring topology. It is based on IBM’s Token Ring LAN</td>
</tr>
<tr>
<td>802.6 MAN Standard</td>
<td>This was meant to create standards for networks whose stations were more than five Kilometers apart</td>
</tr>
<tr>
<td>802.7 Broadband</td>
<td>This committee is engaged in incorporating broadband and technology standards for use in existing networks.</td>
</tr>
</tbody>
</table>
## IEEE 802.2 LAN/MAN Stds

<table>
<thead>
<tr>
<th>Logical link control (LLC)</th>
<th>Medium access control (MAC)</th>
<th>IEEE 802.2</th>
<th>Reservation</th>
</tr>
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<tr>
<td></td>
<td>Contention</td>
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<tr>
<td></td>
<td>IEEE 802.3</td>
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<td>IEEE 802.4</td>
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<td></td>
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<td></td>
<td>IEEE 802.6</td>
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<tr>
<td></td>
<td>IEEE 802.11</td>
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</tr>
</tbody>
</table>

### Logical link control (LLC)
- Unacknowledged connectionless service
- Connection-mode service
- Acknowledged connectionless service

### Medium access control (MAC)
- **Contention**
  - CSMA/CD
- **Reservation**
  - Round robin
  - Token bus
  - Round robin: priority
  - Token ring
  - Token ring

### Physical
- **IEEE 802.3**
  - Baseband coaxial: 10 Mbps
  - Unshielded twisted pair: 10, 100 Mbps
  - Shielded twisted pair: 100 Mbps
  - Broadband coaxial: 1, 5, 10 Mbps
- **IEEE 802.4**
  - Carrierband coaxial: 1, 5, 10 Mbps
- **IEEE 802.5**
  - Optical fiber: 5, 10, 20 Mbps

### IEEE 802.6
- Optical fiber: 100 Mbps
- Shielded twisted pair: 4, 16 Mbps
- Unshielded twisted pair: 100 Mbps

### IEEE 802.11
- Optical fiber: 100 Mbps
- Infrared: 1, 2 Mbps
- Spread spectrum: 1, 2 Mbps

### Topologies
- Bus/tree/star topologies
- Ring topology
- Dual bus topology
- Wireless
Layers at An Interface

Layer $N+1$

**IDU**

**ICI**

**SDU**

Layer $N$

**ICI**

**SDU**

**SAP**

Layer $N$ entities exchange $N$-PDUs in their layer $N$ protocol.

- **SAP** = Service Access Point
- **IDU** = Interface Data Unit
- **SDU** = Service Data Unit
- **PDU** = Protocol Data Unit
- **ICI** = Interface Control Information
Taxonomy of an 802 Standard

Data Link Layer

Logical Link Control

Medium Access Control

Physical Layer

PHYsical layer

MAC_SAP

PHY_SAP

MLME_SAP

PHY Layer Management Entity

MLME_PLME_SAP

MAC Layer Management Entity

KEY

Component

Service Access Point

Station Management Entity
Why High-speed LANs?

- **Rationale**
  - to solve speed / topology limitations imposed by conventional *shared media* LANs

- **Driving force**
  - More users
  - New high speed applications
High-speed LANs - solutions

• **Solutions**
  - Bridging can solve problem to a certain extent
  - Better solution is to adopt star/hub topology
    • (in contrast to shared media topology)

• **Competing technologies**
  - In the long term - ATM
  - In the short / medium term
    • Fast Ethernet (100BaseT)
      - 100Base-TX (copper)
      - 100Base-FX (multimode optical fiber)
      - 100Base-T4 (copper)
    • 100VG-AnyLAN (802.12)
    • Gigabit Ethernet
100Base-T

- The 100BASE-T standard can be defined based on the physical medium used
- 100BASE-T defines several physical mediums

<table>
<thead>
<tr>
<th>Physical Medium</th>
<th>100BASE-TX</th>
<th>100BASE-FX</th>
<th>100BASE-T4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission Medium</td>
<td>Two Pair STP</td>
<td>Two Pair Cat. 5 UTP</td>
<td>Two optical Fibers</td>
</tr>
<tr>
<td>Signaling</td>
<td>4B/5B, NRZI, MLT-3</td>
<td>4B/5B, NRZI</td>
<td>4B/5B, NRZI</td>
</tr>
<tr>
<td>Data Rate</td>
<td>100mb/s</td>
<td>100mb/s</td>
<td>100mb/s</td>
</tr>
<tr>
<td>Maximum Length</td>
<td>100m</td>
<td>100m</td>
<td>100m</td>
</tr>
</tbody>
</table>
100BaseT

• aka *Fast Ethernet* - Upgrade of 10Base-T
  - Star / hub topology - *typically* star topology
  - Each station has its own 4 wire connection to hub

• **Characteristics**
  - Can use UTP (evolutionary considerations)
  - IEEE 802.3 frame format
  - 100-Base-TX - Cat 5 UTP
  - 100-Base-T4 - Cat 3,4,5 UTP & Cat 1 STP
  - 100-Base-Fx - Fiber
100BASE-T

- Uses two UTP pairs $\Rightarrow$ 100Mbps is achieved using
  - 4B/5B signaling
  - imposed on the NRZI encoding scheme

- The 4B/5B encoding is used for two reasons.
  1. The problem with using NRZI alone is the lack synchronization (only fixes 1s transitions)
  2. The use of another encoding scheme such as Manchester would be inefficient since there may be up two transitions per bit time.

- This would give 50 percent efficiency meaning we would need to transmit the signal at 200MHz (baud rate) to achieve 100Mbps data transmission.

- With 4/5 efficiency, we obtain a 100Mbps data transmission rate by using a baud rate of 125 MHz.
100BASE-TX

- When STP cabling is used the 4B/5B NRZI is sufficient for signal encoding
- For transmission of 100Mbps over UTP Cat5 additional encoding must be done
  - 4B/5B NRZI is not suitable as is for use over twisted pair
    - Because the signal energy is concentrated in such a way as to produce undesirable radiated emissions from the wire.
  - Steps
    - NRZI to NRZ conversion
    - Scrambling
    - Encoding (MLT-3)
  - MLT-3 scheme concentrates most of the energy in the transmitted signal below 30 MHz, which reduces radiated emissions.
100BASE-TX

• MLT-3 is specifically designed to keep most of the signal energy below the 30Mhz range
  - using three voltage levels instead of the standard two
  - +V, 0 and -V instead of just 0 and V+
MLT-3 Encoding

- If 0 is next bit, remain at the same level
- If 1 is next bit
  - “remember previous transition direction
  - Transition accordingly
MLT-3 Encoding

- Note transitions can go above and below 0V
- Result is “sinusoidal”
  - The sinusoidal wave reduces DC component
  - Effectively eliminates higher-frequency harmonics \(\rightarrow\) hence keeps under 30MHz range
100BASE-FX

- Runs on optical fiber
- The timing, frame format, and transmission are all common to both versions of 100Mbps Fast Ethernet
- 100BASE-FX also uses 4B/5B encoding
- 200 Mbps transmission is possible because of the separate Transmit and Receive paths in 100BASE-FX optical fiber
100BASE-T4

- For transmission of 100Mbps signal over UTP Cat3 (voice (low) grade UTP; 4 pair) a 100BASE-T4 is used
- Half-duplex transmission
- Does not transmit a continuous signal between packets → useful in battery-powered applications
- Transmission Scheme
  - splits the data stream into 4 separate transmissions
  - each at a rate of 33 1/3 Mbps per stream
  - places these streams on separate pairs of UTP
- Hence net transmission is 100Mbps
100BASE-T4

- This is accomplished by using a scheme called block-coding known as 8B6T
- Is collision detection needed?
- If so, how done
100BASE-T4

- **In 8B6T**
  - 8 bit blocks are mapped onto 6 ternary symbols (similar to the 4B/5B logic)
    - Each ternary symbol has 3 states (+1, 0, -1) \(3^6 = 729\)
    - Which is more than \(2^8 = 256\) bits
    - At least two transitions within a block (avoid 1s or 0s block)
  
- **The effective transmission rate of the ternary symbols is** \(6/8 \times 33.33 = 25\) Mbaud per stream

- **As in 4B/5B patterns were chosen to**
  - *maximize the number of transitions* per pattern group
  - *maintain a DC balance* - meaning an average voltage of zero on the line
Collision Detection for T4

- Detected by detecting a signal on pair two while the station is transmitting
- Near-end-crosstalk (NEXT) may be misconstrued as a collision
- To minimize NEXT, preamble (high-range amplitude $+1 \rightarrow -1$) at the start of each frame is encoded as a string of 2-level symbols
100VG-AnyLAN

• **Main objectives of 802.12**
  - Use Unshielded Twisted Pair (UTP)
  - Support new applications
  - Compatible with existing LAN software
    • Evolutionary technology

• **Characteristics**
  - Allows 802.3/802.5 (token ring) frame formats
  - Requires new MAC \( \rightarrow \) 802.12
  - Hierarchical Star topology
  - Uses round-robin scheme rather than contention
  - Implements two priority classes
100VG-AnyLAN

- **Demand Priority MAC Protocol – Consider Single-Hub:**
  - Each node is connected to Hub by 4 UTP cables
  - Transmission of data is spread across all 4 pairs @ **30Mbps**
  - Data encoded - 5 data bits across 6 transmission bits (5B/6B)
  - Gives $\frac{5}{6} \times 30Mbps \times 4 = 100Mbps$

- **Signaling:**
  - Only 2 of 4 pairs used for signaling
  - QoS served by 2 priority queues (REQ-N / REQ-H)

![Figure 1. 100VG-AnyLAN example topology.](image)
802.12 MAC

- Central (Root) hub continually scans all of its ports.
- Round robin scheme with two priority levels.
- Hub maintains two pointers: high priority and low priority.
- Hub grants each high priority requests in the order they are encountered.
- If no high-priority requests, grants the normal requests in the same round robin fashion.
- If low-priority request is in queue >250ms it is moved to high-priority queue.
Fast Ethernet - Assessment

• **Less Promising**
  - **100VG-Anylan**
    • + Has built-in priority queues
    • 100Mbps over cat3
    • - Still over shared media
  - **100base-T4**
    • 100Mb over cat3, 4 wire pairs (8 wires)

• **Most Promising**
  - **100base-TX**
    • 100Mb over 2 wire-pairs (just like 10base-T)
    • Very small price difference with 10Mbps-only equipment these days
Gigabit Ethernet

- **Upgrade of 100Base-T**
  - Similar to other Ethernet standards
  - No CSMA/CD is needed in full-duplex
  - Transmit / receive are on different wire pairs

- **Characteristics**
  - Max network diameter is 200-250m
  - No QoS capability
  - Modified MAC layer
  - Requires fiber as medium
  - Minimum frame size is 512 bytes (v. 512 bits)
  - Network utilization can be low so introduces Frame bursting (concatenates smaller frames)
Fast Ethernet & Gb Ethernet

**Fast Ethernet** (typical case now)
- 100 Mbits/s over twisted pair (UPT Cat 5) or fibre optic

<table>
<thead>
<tr>
<th>Name</th>
<th>Cable</th>
<th>Max. segment</th>
<th>Advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>100Base-T4</td>
<td>Twisted pair</td>
<td>100 m</td>
<td>Uses category 3 UTP</td>
</tr>
<tr>
<td>100Base-TX</td>
<td>Twisted pair</td>
<td>100 m</td>
<td>Full duplex at 100 Mbps</td>
</tr>
<tr>
<td>100Base-FX</td>
<td>Fiber optics</td>
<td>2000 m</td>
<td>Full duplex at 100 Mbps; long runs</td>
</tr>
</tbody>
</table>

**Gigabit Ethernet**
- 1000 Mbits/s or more over short UTP/STP or fibre optic
- Cable limit reduced to shorten 2T for fixed 64-Byte min. packet size (transmission time must be < or = (propagation time)/2 \( \Rightarrow T \))

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<tbody>
<tr>
<td>1000Base-SX</td>
<td>Fiber optics</td>
<td>550 m</td>
<td>Multimode fiber (50, 62.5 microns)</td>
</tr>
<tr>
<td>1000Base-LX</td>
<td>Fiber optics</td>
<td>5000 m</td>
<td>Single (10 ( \mu )) or multimode (50, 62.5 ( \mu ))</td>
</tr>
<tr>
<td>1000Base-CX</td>
<td>2 Pairs of STP</td>
<td>25 m</td>
<td>Shielded twisted pair</td>
</tr>
<tr>
<td>1000Base-T</td>
<td>4 Pairs of UTP</td>
<td>100 m</td>
<td>Standard category 5 UTP</td>
</tr>
</tbody>
</table>
High-speed LANs

- **FDDI**—Fiber distributed data interface
  - 100 Mbps; up to 100 km dual ring
  - up to 2km between stations (multimode fiber)
  - can be used as a backbone to connect copper LANs

- **1 Gbps Ethernet** - 802.3z
- **10 Gbps Ethernet** - 802.3ae

**Fiber:**
- 1000 BASE SX  \textit{short wavelength}
- 1000 BASE LX  \textit{long wavelength}

**Copper:**
- 1000 BASE CX  \textit{shielded twisted pair}
- 1000 BASE T   \textit{unshielded twisted pair}
FDDI

• FDDI is a high speed token ring fiber optical cable technology
• This technology can 'self-heal', which means that the hardware can automatically detect and correct hardware problems
• FDDI consists of two independent rings to connect each computer.
  - Data flows in opposite direction in each ring
• FDDI can have two types of Network Interface Cards, A and B, that connect to it
  - Class A Network Interface Cards connect to both rings - Dual Attached Stations (DAS)
  - Class B Network Interface Cards connect to only one ring - Single Attached Stations (SAS)
FDDI

- Only Class A cards can be used to heal broken rings.
  - Thus the number of class A cards define the fault tolerant characteristics of the network.

- When an error occurs the nearest computer routes frames from the inner ring to the outer ring.
FDDI

• FDDI MAC Protocol
  - Token ring protocol similar to IEEE 802.5
  - Differences due to high speed (100 Mbps when compared to 2-16 Mbps)
• 4B/5B code
• Distributed clocking
• Timed token rotation
• New token after transmit
• Synchronous (Delay-sensitive) and Asynchronous traffic
FDDI MAC Protocol

- Waiting station seizes the token as soon as it recognize one
- Once the token is completely captured, node may send one or more data frames
- Releases the token as soon as done with transmission
- Capacity Allocation
  - Reservation similar to 802.5 will not work → node issues a token before its own transmitted frame returns
  - Support for mixture of stream and bursty traffic (sync & async traffic)
  - Support for multi-frame dialogue (dedicated (token) to communicate between two nodes, e.g., File Server & W/S)
FDDI Token Timing

**SA scheme**

\[ \text{DMax} + \text{FMax} + \text{TokenTime} + \sum \text{SA}_i \leq \text{TTRT} \]

- **DMax** → propagation time around the circuit
- **FMax** → time to transmit a max-sized frame (Target Token Rotation Time)
- **TokenTime** → time to transmit a token
- **SA}_i \rightarrow synchronous allocation for node (i)
  - All stations start with \( \text{SA}=0 \)

**Other parameters:**
- Token-rotation timer (TRT)
- Token-holding timer (THT)
- Late counter (LC)
HIPPI
High Performance Parallel Interface

Bandwidth hierarchies:
- 800 Mbps (parallel) HIPPI to
- 800 Mbps serial HIPPI to
- 800 Mbps switched HIPPI to
- 1600 Mbps switched HIPPI to
- 6400 Mbps switched HIPPI

HIPPI is a specialized high performance LAN technology that is used primarily in high performance computer LAN environments.

More devices and emerging multimedia applications require the network bandwidth to scale. This is being addressed by going from shared to switched media networks → evolving network standards such as gigabit ethernet, OC-12, OC-48 and OC-192 ATM and HIPPI-6400.
Wireless LANs
Wireless LANS

Application Areas:
• LAN extension
• Cross-building interconnect
• Nomadic access
• Ad hoc networks
LAN Extension

• Wireless LAN linked into a wired LAN on same premises
  - Wired LAN
    • Backbone
    • Support servers and stationary workstations
  - Wireless LAN
    • Stations in large open areas
    • Manufacturing plants, stock exchange trading floors, and warehouses
Cross-Building Interconnect

- Connect LANs in nearby buildings
  - Wired or wireless LANs
- Point-to-point wireless link is used
- Devices connected are typically bridges or routers
Nomadic Access

- **Wireless link between LAN **\textit{hub}** and mobile data terminal**
  - Laptop computer or notepad computer
- **Uses:**
  - Transfer data from portable computer to office server
  - Extended environment such as campus
Ad Hoc Networking

- Temporary peer-to-peer network set up to meet immediate need

- Example:
  - Group of employees with laptops convene for a meeting; employees link computers in a temporary network for duration of meeting
Requirements

- **MAC** should ensure *efficient* use of capacity
- Battery power consumption
- Transmission robustness and security
- Dynamic configuration
  - Additions
  - Deletions
  - Relocations
WLAN Technologies

- **Infrared (IR) LANs**
  - Subject to heat/sun interference
  - Requires line-of-sight

- **Spread spectrum**
  - DSSS and FHSS
  - Uses lower frequency microwaves.
  - Most common.

- **Narrowband microwave**
  - Higher frequencies require line-of-sight
  - Problems with noise and security
IR LANs

Advantages:
- **Unregulated**, virtually unlimited spectrum
- **Broadcast** possibilities through diffusion
- **More secure**, simple, and inexpensive
IR LANs

Disadvantages:
- Ambient noise
- Eye safety concerns
- Power consumption
IR Transmission Techniques

- Directed-beam
- Omni-directional
- Diffused
Directed Beam Infrared

• Used to create point-to-point links
• Range depends on emitted power and degree of focusing
• Focused IR data link can have range of kilometers
  – Cross-building interconnect between bridges or routers
Ominidirectional

• Single base station within line of sight of all other stations on LAN
• Station typically mounted on ceiling
• Base station acts as a multiport repeater
  - Ceiling transmitter broadcasts signal received by IR transceivers
  - IR transceivers transmit with directional beam aimed at ceiling base unit
Diffused

• All IR transmitters focused and aimed at a point on diffusely reflecting ceiling

• IR radiation strikes ceiling
  - Reradiated omnidirectionally
  - Picked up by all receivers
Multiple Access with Collision Avoidance

Range of A's transmitter

Range of B's transmitter

(a)

(b)
Spread Spectrum LANs

• Frequency hopping
  - Periodically switch frequency
  - Both ends must switch at the same time
    • Normally a fixed switch time
  - New frequency is selected pseudo-randomly.
  - Receiver reverses the process
Spread Spectrum LANs

- **Direct-sequence spread spectrum**
  - Turn each bit into a multi-bit pattern
  - Each bit in pattern transmitted on a different frequency
  - Each bit in the original signal is transmitted as multiple bits of *chipping code*
  - Pattern is selected pseudo-randomly
  - Spread is directly correlated to the data rate of the random pattern
Spread Spectrum LANs

Pseudo-random sequence:
10100001001100101000

XOR:
0101001110000101000

Data: 10100

Direct Sequence Spread Spectrum:
- Data is XOR-ed with a pseudo-random \( n \)-bit “Chip” (or chipping code)
- Spreads the spectrum by a factor of \( n \)
- All transmitters and receivers use same chipping code
- (In CDMA, multiple transmitters and receivers talk simultaneously using different chipping codes)
- To other receivers, signal looks like low-level white noise
Narrowband Microwave LANs

- Use of a microwave radio frequency band for signal transmission
- Relatively narrow bandwidth
- Licensed
- Unlicensed
Licensed Narrowband RF

- Licensed within *specific geographic areas* to avoid potential interference
- Motorola - 600 licenses in 18-GHz range
  - Covers all metropolitan areas
  - Can assure that independent LANs in nearby locations don’t interfere
  - Encrypted transmissions prevent eavesdropping
Unlicensed Narrowband RF

- RadioLAN introduced narrowband wireless LAN in 1995
  - Uses unlicensed ISM spectrum
  - Used at low power (0.5 watts or less)
  - Operates at 10 Mbps in the 5.8-GHz band
  - Range = 50 m to 100 m
Wireless LAN Standards

• **IEEE 802.11**
• **Services:**
  - Association, re-association, and disassociation
  - Authentication
  - Privacy
IEEE 802.11b

- Originally 2 Mbps with 802.11
- Up to 11 Mbps
- Range 20 – 300
- Operates on ISM band (915 MHz, 2.4 GHz, 5.7 GHz), globally available
- Support for 128 bit Wired Equivalent Privacy (WEP) encryption
802.11 Protocol Stack

• **MAC Sublayer**
  - Standard Ethernet frame format and addressing
  - Distributed or Centralized access control
    - Distributed uses CSMA/CA + ACK
      - Optional RTS/CTS
    - Centralized uses polling

• **LLC Sublayer**
  - Any LLC can be used, typically LLC1
    - LLC1 - connectionless, unacknowledged
End of Class 4