# 2.5 Fast Ethernet

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# Lesestoff im Ethernet Buch

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  - 3.2 100Base-X-Erweiterungen im Ethernet-Standard
  - 3.3 Das 4B/5B-Kodierungsverfahren
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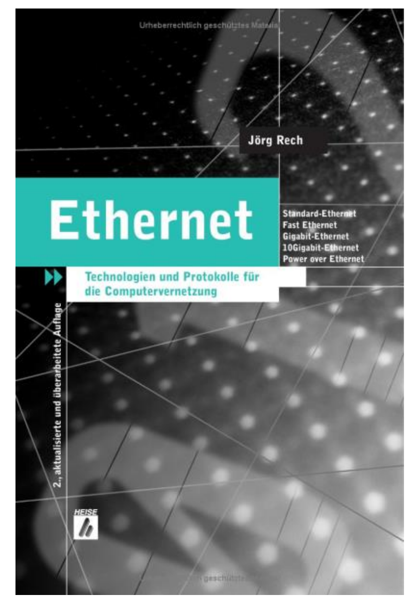
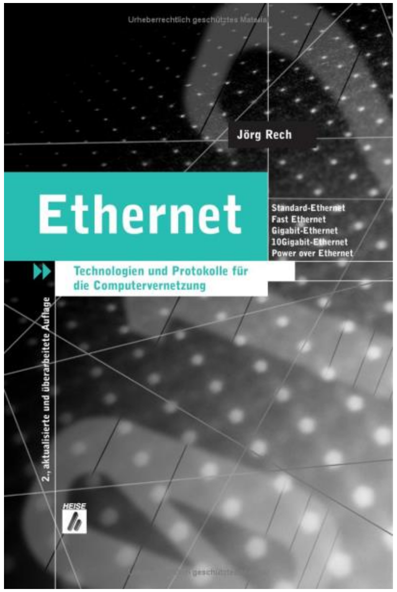


# Selbststudium



- Selbststudium
  Erarbeiten Sie als Vorbereitung für die Übung 3
  selbständig das Thema “Ethernet Frame”
  mit Hilfe von Kapitel 2.10 des Ethernet Buchs und
  des Kapitels 2.9 des CN1 Foliensatzes.



# Fast Ethernet



- In 1995 Fast Ethernet was standardized by the IEEE 802.3u group in competition with FDDI (Fibre Distributed Data Interface) and ATM (Asynchronous Transfer Mode).
- Because of the simplicity (and low cost) of Fast Ethernet, it quickly became the dominant LAN technology for trunks and servers.
- The Ethernet MAC layer is retained without modification
- CSMA/CD stays, but full-duplex connections are supported, too.
  -> 2x100 Mbit/s, collision free.
- Two new physical layer technologies were introduced:
  - 100 Base-TX: 100 Mbps over Cat. 5 copper cable
  - 100 Base-FX: 100 Mbps over Mono- and Multimode Fibers

# Ethernet Technology Overview

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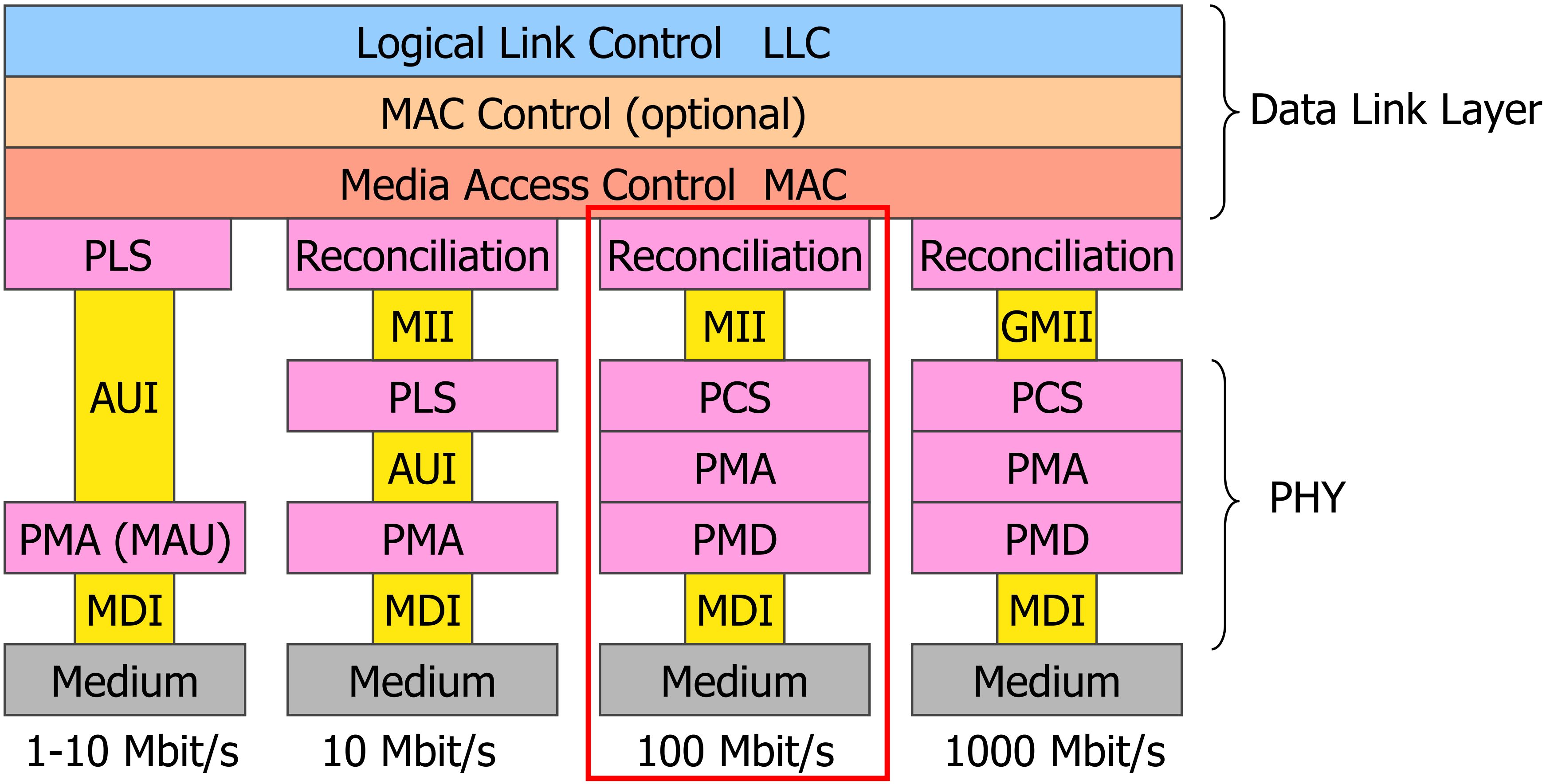


AUI...Attachment Unit Interface, PLS...Physical Line Signaling, MDI...Medium Dependent Interface, PCS...Physical Coding Sublayer, MII...Media Independent Interface, GMII...Gigabit Media Independent Interface, PMA...Physical Medium Attachment, MAU...Medium Attachment Unit, PMD...Physical Medium Dependent

# New Extensions

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- PCS Sublayer
  - Changes 4 bit parallel data from MII interface into 5 bit serial data
  - Generates Carrier Sense / Collision Signal

- Physical Medium Dependent Sublayer (PMD)
  - Defines the two physical standards
    - 100 Base-TX
    - 100 Base-FX
  - Start-of-Stream (JK) and End-of-Stream (TR) delimiters
  - Idle (I) signal allows Link Integrity Test
  - Data is sent with 125 Mbps to compensate 4B/5B coding
  - Differential Non-Return-to-Zero (NRZI) line code saves bandwidth

# 4B/5B Encoding



- Also called "Block Coding".
- Deals with the problem of consecutive 0s.
- Every 4-Bit nibble of data is converted into a 5-bit symbol.
- The conversion table is built in a manner that no more than 3 consecutive 0s can occur in an arbitrary bit stream on the wire.

| 4-bit-nibble | 5-bit-symbol | 4-bit-nibble | 5-bit-symbol |
|---|---|---|---|
| 0000 | 11110 | 1000 | 10010 |
| 0001 | 01001 | 1001 | 10011 |
| 0010 | 10100 | 1010 | 10110 |
| 0011 | 10101 | 1011 | 10111 |
| 0100 | 01010 | 1100 | 11010 |
| 0101 | 01011 | 1101 | 11011 |
| 0110 | 01110 | 1110 | 11100 |
| 0111 | 01111 | 1111 | 11101 |

# 100Base-X Variants



- 100Base-TX:
  - 125 MBaud symbol rate, full duplex, binary encoding
  - Cat. 5 Unshielded Twisted Pair (UTP) cable required
  - RJ45 connector; same pinout as in 10BaseT (transmit on 1 and 2, receive on 3 and 6)
  - In order to halve the spectral bandwidth on copper, data is sent with MLT-3 coding

- 100Base-FX:
  - 125 MBaud symbol rate, full duplex, binary encoding
  - two-strand (transmit and receive) 50/125 or 62.5/125-µm multimode fiber-optic cable
  - SC connector, straight-tip (ST) connector, or media independent connector (MIC)
  - No auto-negotiation on fiber interfaces

# MLT-3 Encoding

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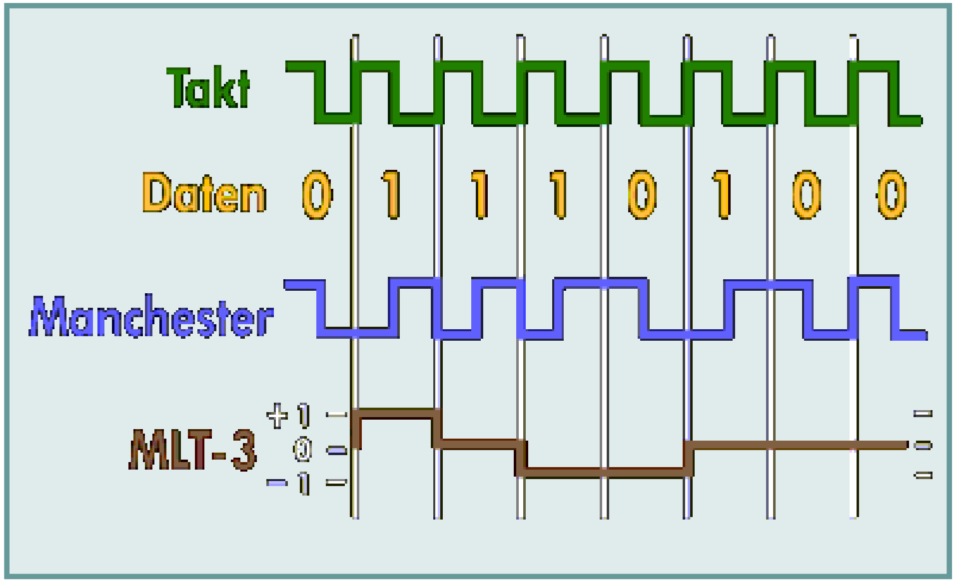
- MLT = "Multi-Level Transition"
  - MLT-3 uses three voltage levels to put a bit stream on the cable (in contrast to the binary NRZ or NRZI codes)
- Advantages
  - Reduction of spectral bandwidth
  - MLT-3 approximates a sine wave with a much lower fundamental frequency than the data rate.
  - Lower bit error rate
- Disadvantage
  - Transmitter and Receiver become more complex.



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# 2.6 Gigabit Ethernet

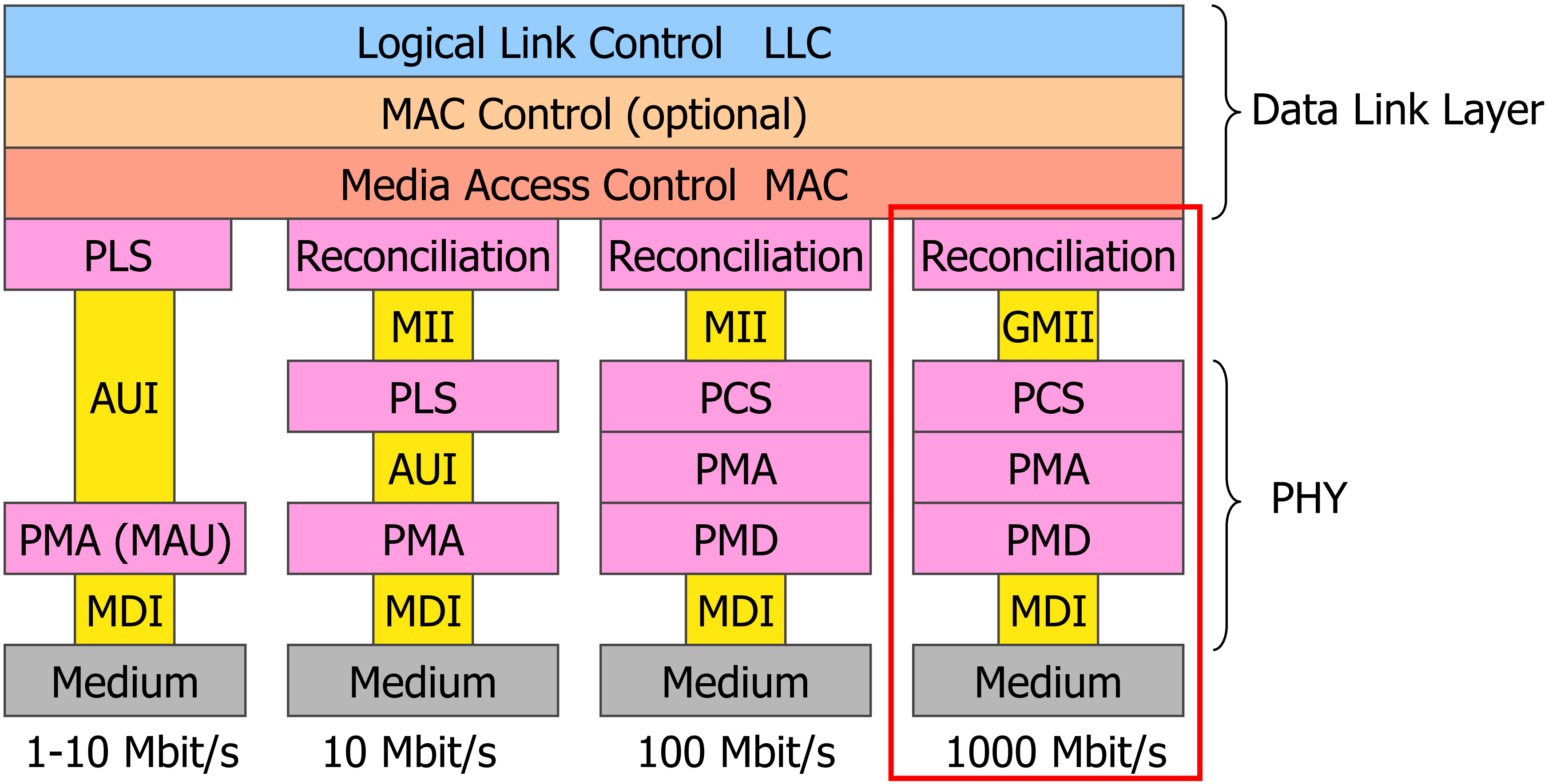
# Gigabit-Ethernet



- Standardization Goals: Easy integration in existing 802.3 LANs
  - Usage of standard Cat 5 Cabling (a huge challenge) and fiber
  - Autonegotiates with 10/100 Mbps Interfaces (not on fibre)
  - Access methods: CSMA/CD or full duplex (no change)
  - Needs some MAC Layer extensions to support longer cables
- Three versions of Gigabit Ethernet available
  - 1000Base-T (802.3ab)
  - 2 Fiber versions (802.3z)
    - Multimode Fiber up to 550 m
    - Single Mode Fiber up to 10 km
- Gigabit Ethernet is increasingly used as a carrier backbone technology; it has also WAN capabilities
  - reaches 100 km length using special fibre optics
  - 2x1 Gbit/s data rate at full duplex mode; no collisions
  - 802.3x MAC-based flow control prevents congestions

# Ethernet Technology Overview



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# Implementations

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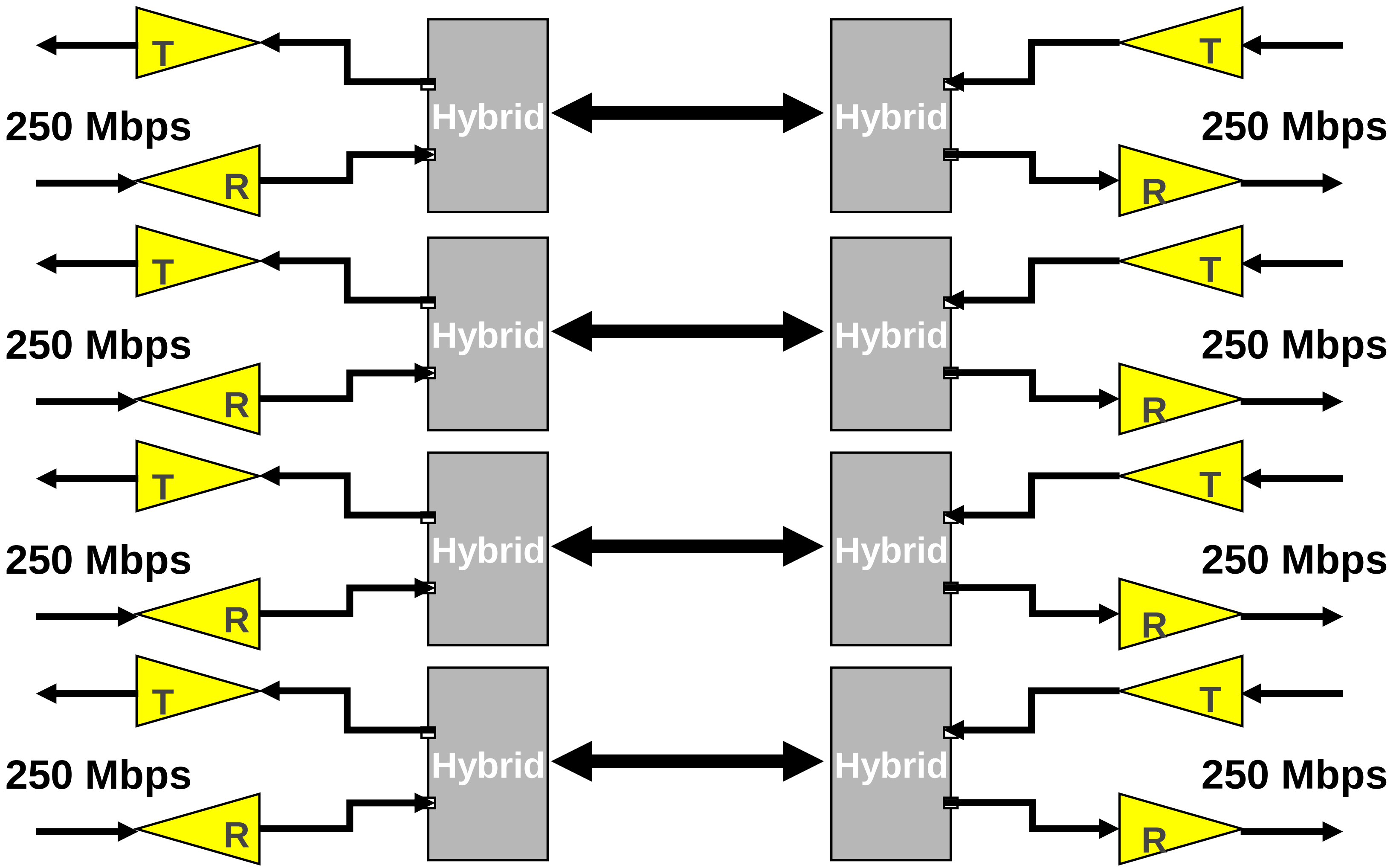
- GMII now sends 8 bits per clock pulse in both directions.
  - Every 8ns the GMII sends 8 bits to the PHY (125 MHz clockrate)
- PCS generates 8B/10B Code
  - Generates words that are DC-free and contain clock information
- PMD implements three Media Dependent Technologies
  - 1000Base-SX: Short wavelength, 850 nm, multimode (cable length of up to 550 m)
  - 1000Base-LX: Long wavelength, 1300 nm multi- or monomode (cable length of up to 5 km)
  - 1000Base-T: Twisted pair, Cat. 5 (cable length of up to 100 m)

# 1000Base-T



- Cat. 5 links, max 100 m; all 4 pairs, cable must conform to the requirements of ANSI/TIA/EIA-568-A
- UTP using all 4 line pairs simultaneously for duplex transmission (using echo-canceling: receiver subtracts own signal); 250 Mpbs
- 5 level PAM coding (-1V, -0.5V, 0V, 0.5V, 1V) = 5^4 = 625 possible Codewords
  - 4 levels encode 2 bits
  - Extra level used for 4D 8-state Trellis Forward Error Correction coding to offset the impact of noise and crosstalk
  - Scrambling to avoid spectral lines
- Only 1 CSMA/CD repeater allowed in a collision domain (should not be used at all !!!)

# 1000BaseT: How It Works



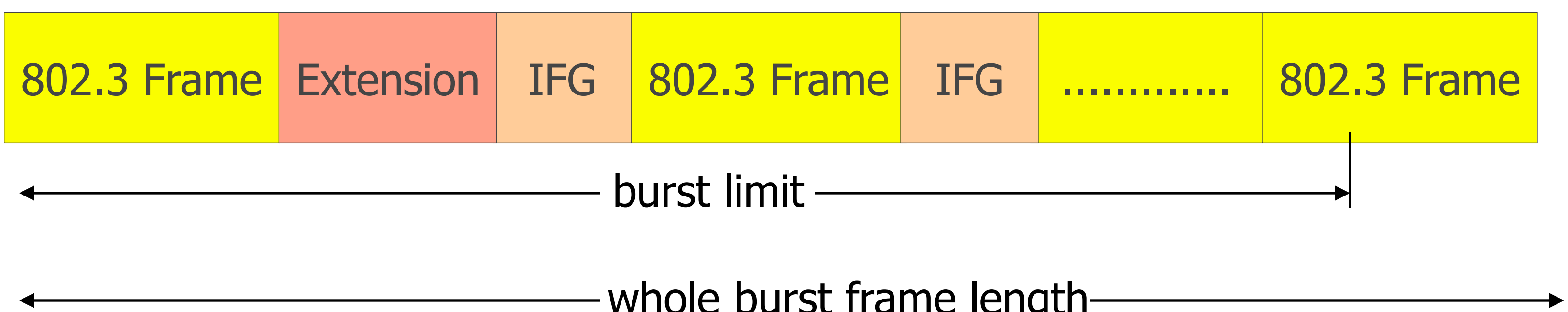
# CSMA/CD Restrictions (Half Duplex Mode)



- The conventional collision detection mechanism CSMA/CD requires that stations have to listen twice the signal propagation time to detect collisions
- Collision window of 512 bit times at a rate of 1Gbit/s would limit the maximal net expansion to 20 m !
- Solutions to increase the maximal net expansion:
  - Carrier Extension: extension bytes appended to (and removed from) the Ethernet frame by the physical layer → frame exists a longer period of time on the medium
  - Frame Bursting: to minimize the extension bytes overhead, station may chain several frames together and transmit them at once ("burst").

# Frame Bursting

- With both methods the minimal frame length is increased from 512 to 4096 bits (512 bytes), the corresponding time is called slot time.
- If a station decides to chain several frames to a burst frame, the first frame inside the burst frame must have a length of at least 512 bytes (by using extension bytes if necessary)
- The next frames (inside the burst frame) can have normal length (at least 64 bytes)
- Station may chain frames up to 8192 bytes (=burst limit) and also may finish the transmission of the last frame even beyond the burst limit
- So the whole burst frame length must not exceed 8192+1518 bytes (incl. inter frame gap of 0.096 µs = 12 bytes)



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# 2.7 10 Gigabit Ethernet

# 10Gigabit Ethernet

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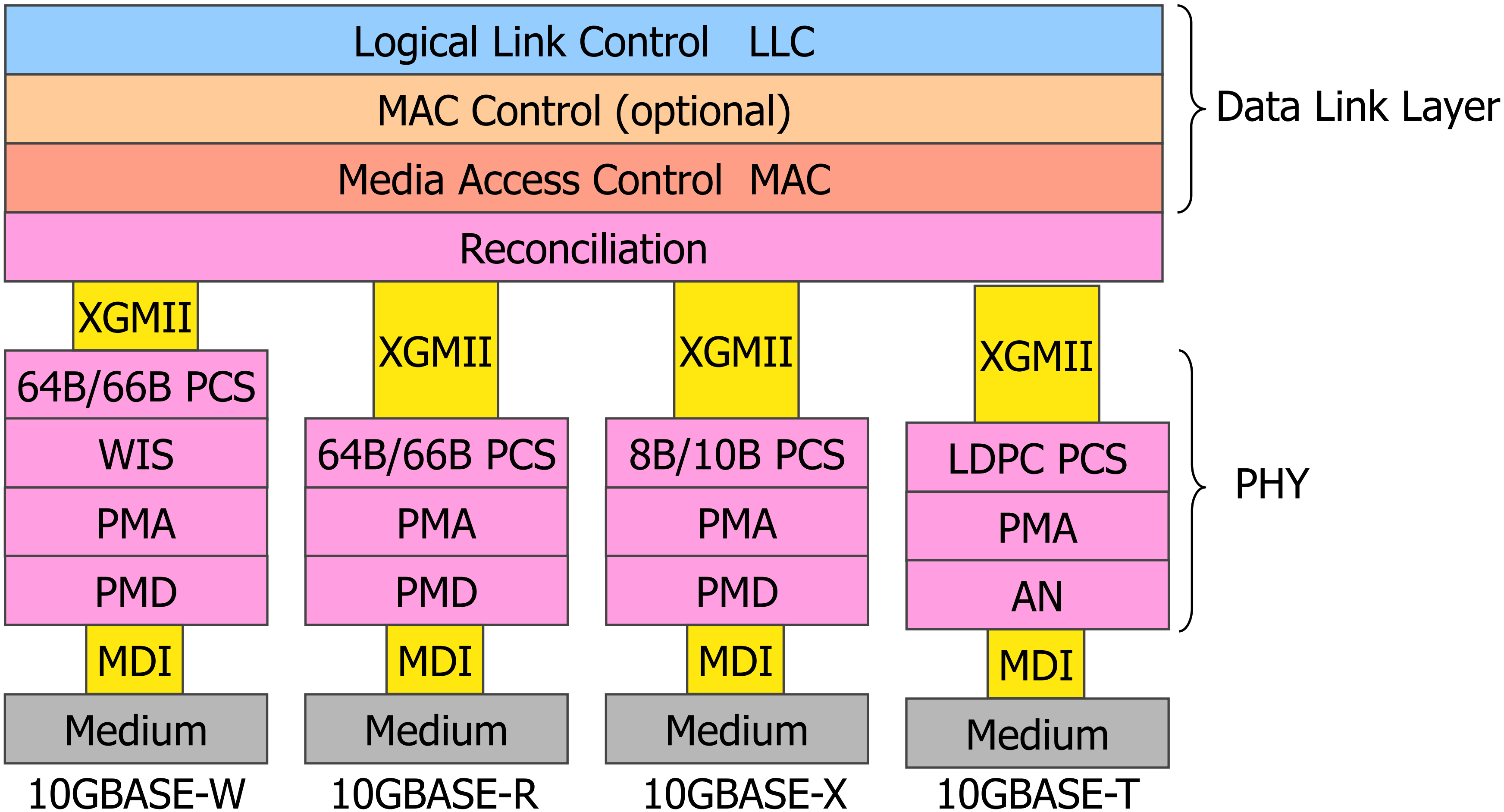
- Only full-duplex mode supported
- Uses the 802.3 Ethernet frame format
- Extensions are made at the physical layer
- Available for LAN and WAN
- Supports fiber with lengths from 55 m up to 40 km
- Supports also copper media
  - Cat 6a
  - Cat 6e (55 m)
  - Cat 7

# Ethernet Technology Overview





# Physical Details



- PMD (Physical Medium Dependent)
  - Lowest layer of the physical view
  - Defines the physical attachment to the medias
  - 3 ranges of the wavelength are defined
    - S: 850nm (short)
    - L: 1310nm (long)
    - E: 1550nm (extra long)
- PMA (Physical Medium Attachment)
  - Serializes the code blocks into the data stream
  - Recovers the clock from the received signal
- WIS (WAN Interface Sublayer)
  - Used for the WAN (SDH/SONET) implementation
  - Synchronizes the 10 Gigabit Ethernet data to the 9,584 Gigabit throughput of SDH/SONET using the stretch function

# Implementations - cont

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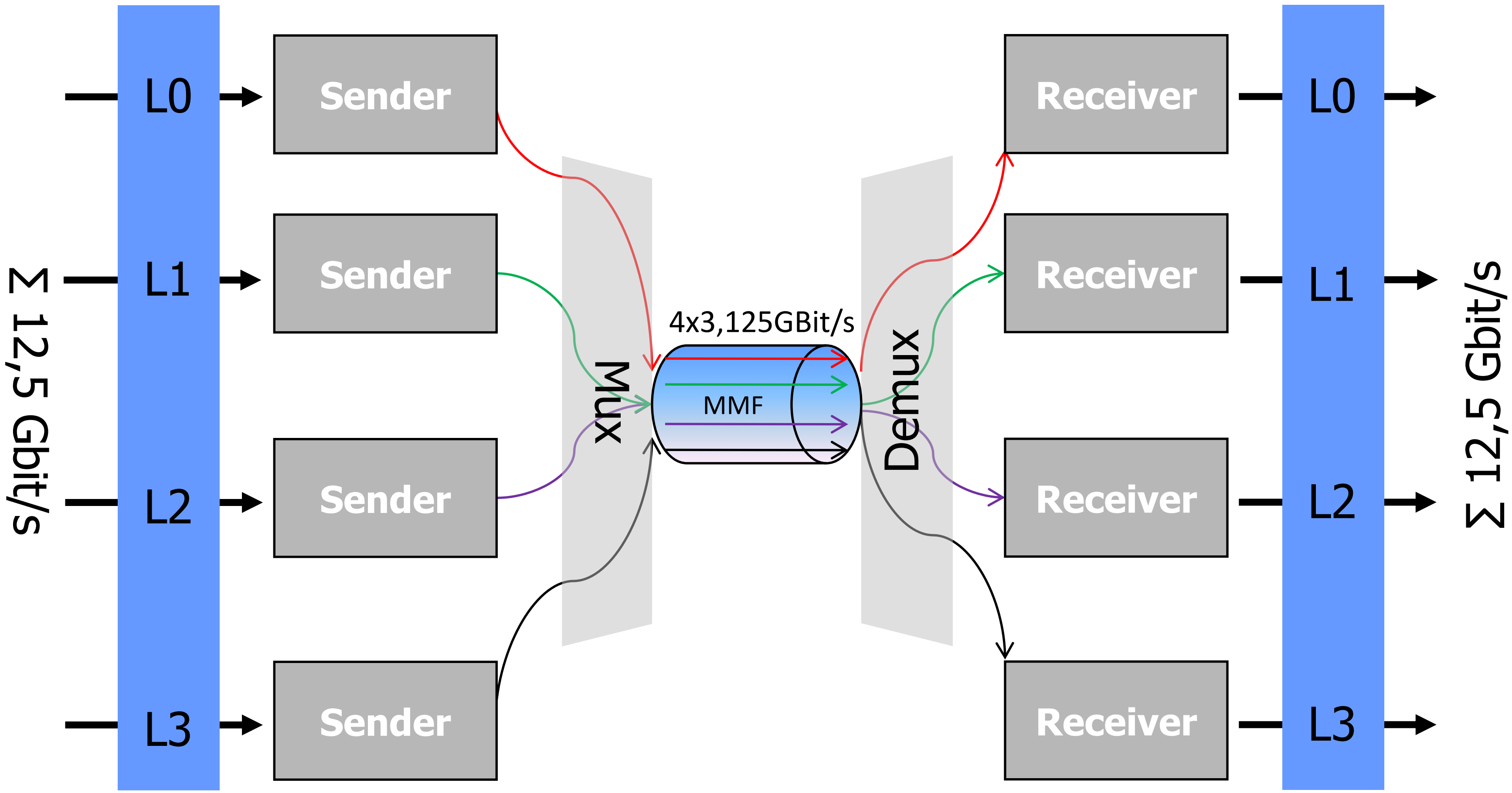
- PCS (Physical Coding Sublayer)
  - Converts the data into a specific coding operation for sending in a serial data format
  - 10GBASE-W, used for WAN coding that the frame is SDH/SONET compatible
  - 10GBASE-R, used for a serial coding where no adaptations for the WAN are necessary
  - 10GBASE-X, used for transmitting the data parallel over multiple channels (typically wavelengths)
  - 10GBASE-T, used for sending the data over copper cable using PAM16 Codes and a scrambler, digital filters, error checks etc.

# Physical Limitations



- There are problem with dispersion on high bandwidths with traditional fiber cabling
- Due to problems with long distances the total bandwidth was split into 4 channels
  - 10GBASE LX4
- Each channel operates at a different wavelength
  - L0 1269,0 nm to 1282,4 nm
  - L1 1293,5 nm to 1306,9 nm
  - L2 1318,0 nm to 1331,4 nm
  - L3 1342,5 nm to 1355,9 nm
- 10GBASE LX4 uses a 8B/10B encoding
  - The transmitted datarate must be increased to 4 x 3,125 Gbit/s
- Up to 300 m with multimode and up to 10 km with monomode fibres can be reached

# 10GBASE-LX-4: How It Works



# 10GBase-R: Traditional LAN approach



- The data will be transmitted on one wavelength with the full bandwith
- 3 different possibilites
  - 10GBASE-SR
    - Using a 850 nm wavelength
    - Up to 82 m with multimode fibre
    - The cheapest lasers
  - 10GBASE-LR
    - Using a 1310 nm wavelength
    - Designed for monomode fibres
    - Up to 10 km
  - 10GBASE-ER
    - Using a 1550 nm wavelength
    - Designed for monomode fibres
    - Up to 40 km

# 2.8 40/100 Gigabit Ethernet

# 40/100 Gbps Ethernet IEEE 802.3ba



| Physical Layer | 40 Gbps | 100 Gbps |
|---|---|---|
| 1m over a backplane | 40GBASE-KR4 | |
| 10m over copper cable | 40GBASE-CR4 | 100GBASE-CR10 |
| 100m over OM3 multi-mode fiber | 40GBASE-SR4 | 100GBASE-SR10 |
| 120m over OM4 multi-mode fiber | 40GBASE-SR4 | 100GBASE-SR10 |
| 10km over single-mode fiber | 40GBASE-LR4 | 100GBASE-LR4 |
| 40km over single-mode fiber | | 100GBASE-ER4 |

- Copper
  - K = Backplane
  - C = Cable Assembly
- Optical
  - S = Short Reach (100m)
  - L = Long Reach (10km)
  - E = Extended Long Reach (40km)
- Coding Scheme
  - R = 64B/66B block coding
- Number of lanes or wavelengths
  - K, C, S n = 4 or 10 lanes
  - L, E n = 4 wavelengths