



Ethernet/IEEE 802.3 evolution

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Based on chapter 3 of:

M. Baldi, P. Nicoletti, "Switched LAN", McGraw-Hill, 2002, ISBN 88-386-3426-2

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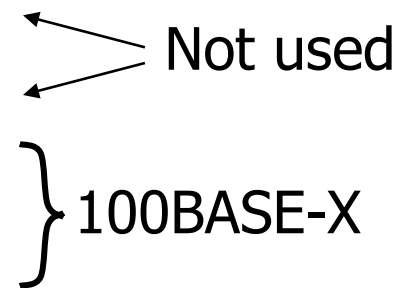
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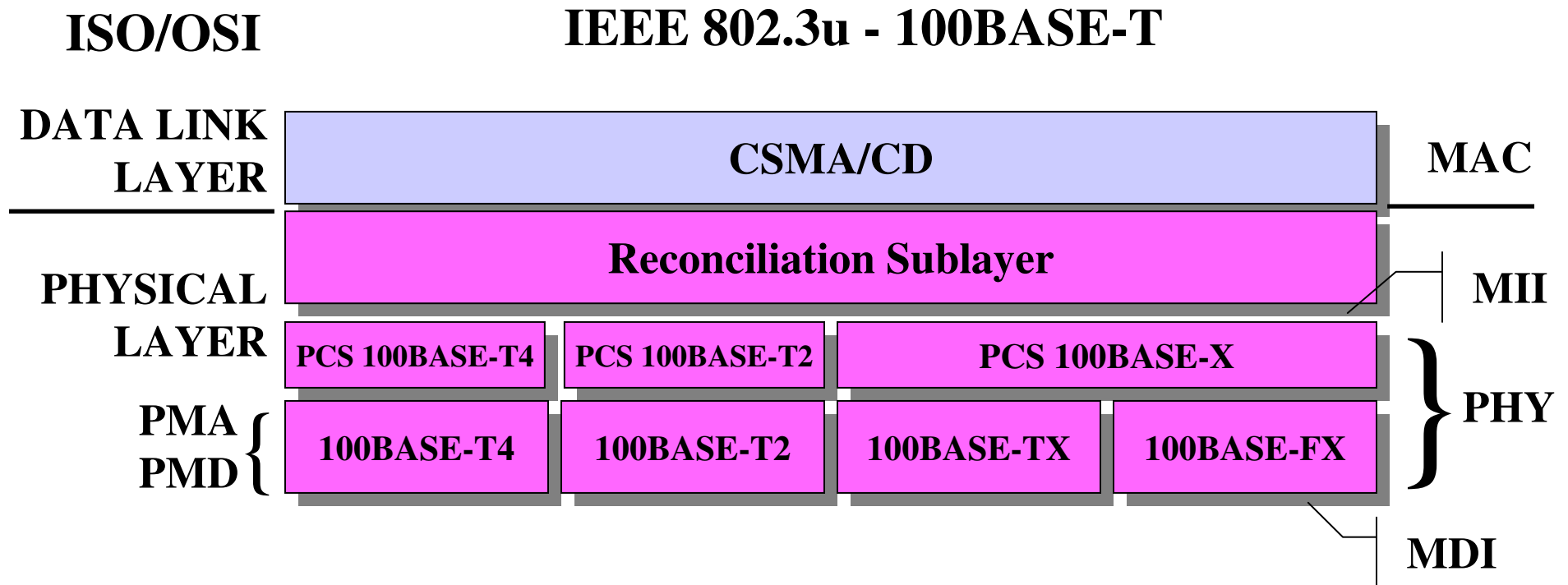
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Fast Ethernet - IEEE 802.3u

- IEEE 802.3u
 - Ethernet 802.3 evolution of 10BASE-T e 10BASE-F
- 4 sub-standard for different cable type:
 - 100BASE-T4 (UTP cat 3, over 4 pairs)
 - 100BASE-T2 (UTP cat 3, over 2 pairs)
 - 100BASE-TX (UTP cat 5, over 2 pairs)
 - 100BASE-FX (fiber optic)
- Same MAC CSMA/CD of IEEE 802.3
- Same frame format of IEEE 802.3
- More than 200 vendors have successfully implemented the 10Base-T standard



Architectural Model



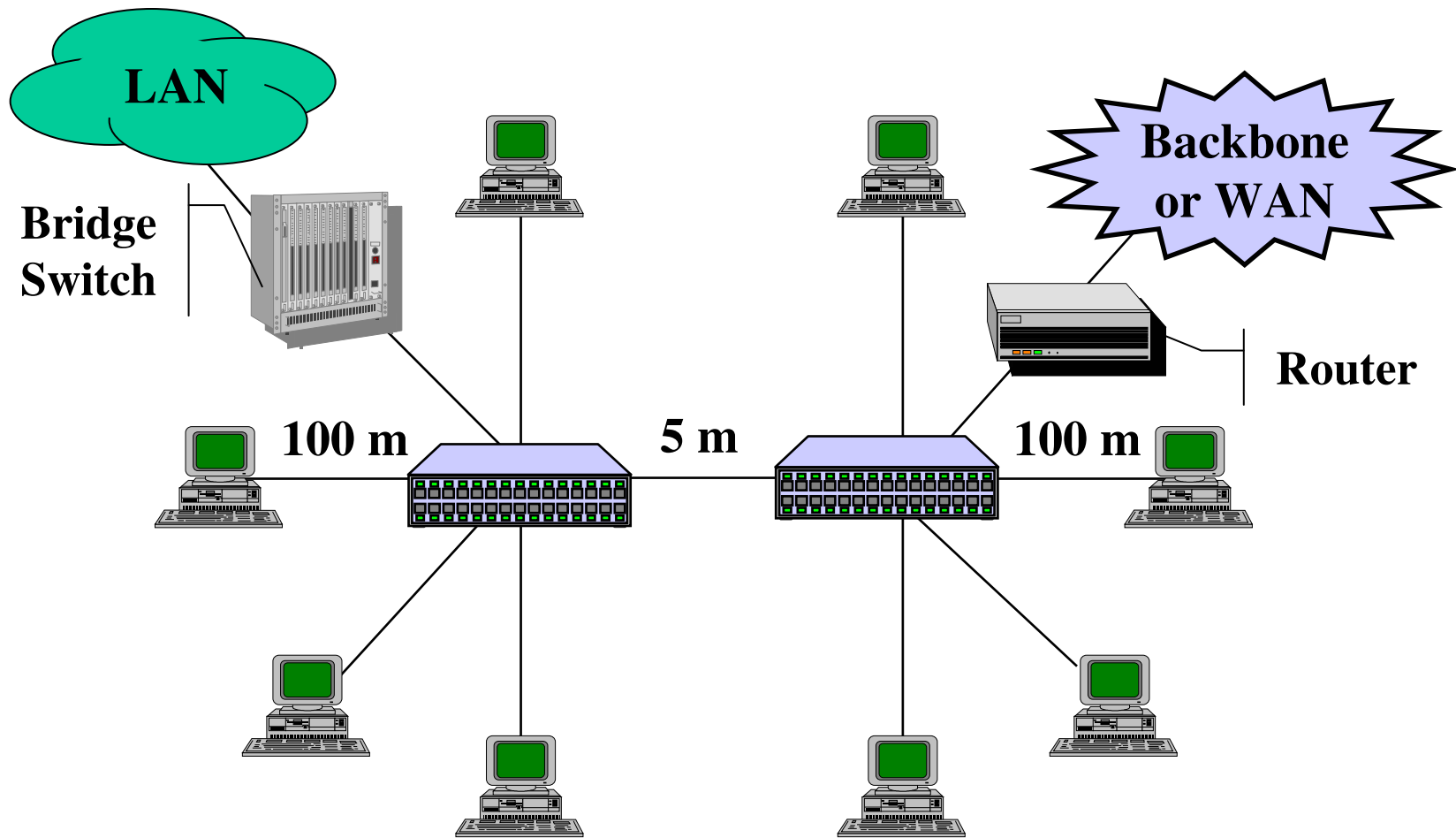
MDI: Medium Dependent Interface
 MII: Medium Independent Interface
 PCS: Physical Coding Sublayer

PHY: Physical Layer Device
 PMA: Physical Medium Attachment
 PMD: Physical Medium Dependent

LAN extension and limits

- Speed 10 times faster
 - Data Rate 100Mb/s
 - Bit time 10ns
 - Interpacket gap 0.96 μ s
 - Slot time 512 bit (5.12 μ s)
- Reduced LAN diameter (200 m + 5 m)
 - This length is enough to implement a star topology (the hub is the central node) with 100m radius (i.e. 200m diameter)

Maximum LAN extension

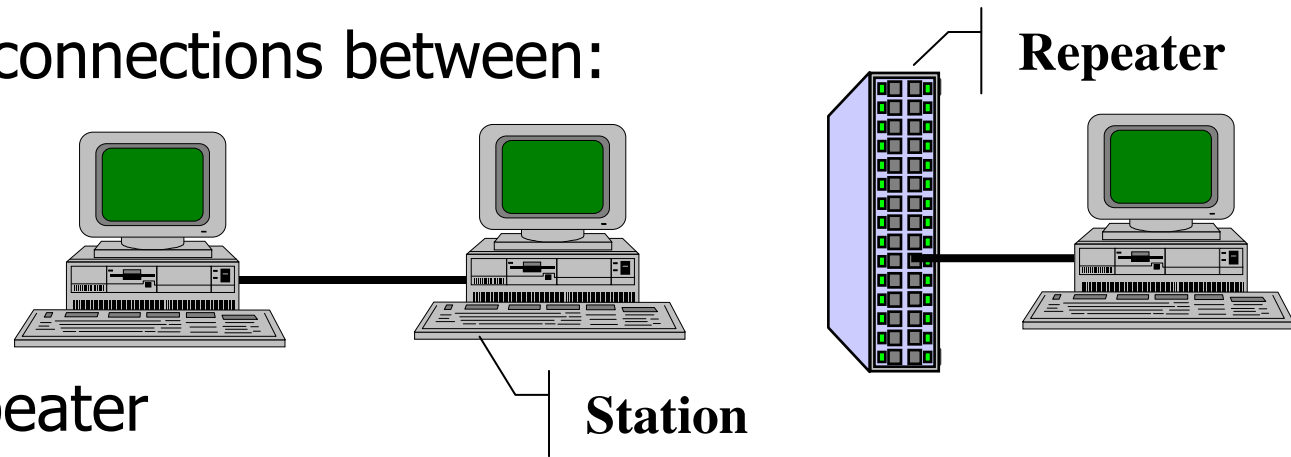


← Collision domain (max 205 m) →

Physical Layer

Point-to-Point connections between:

- stations
- bridge
- switch
- station & repeater

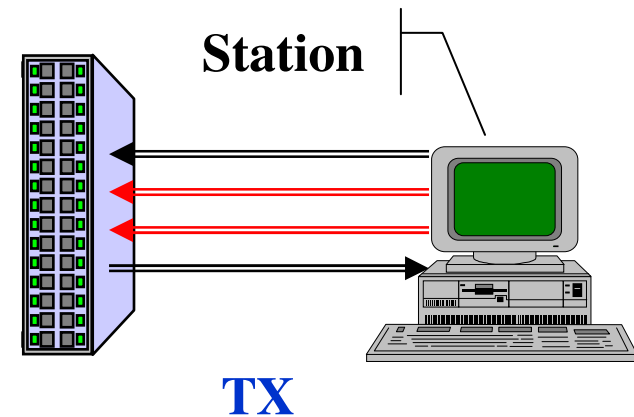
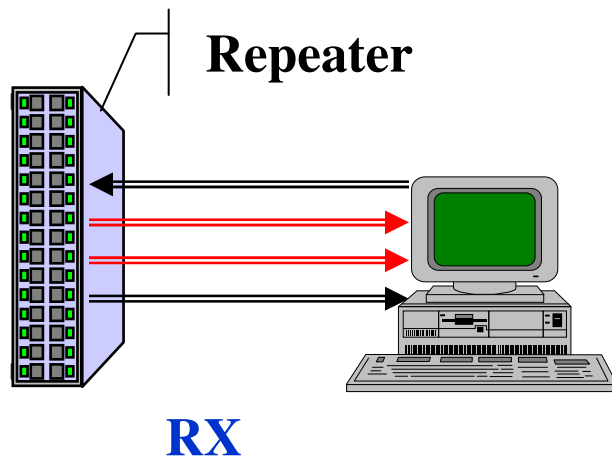


Standard	Media type	use	Max length	Code
100BASE-T4	UTP or STP cat 3 or superior	4 pair	100 m	8B6T
100BASE-T2	UTP or STP cat 3 or superior	2 pair	100 m	PAM5x5
100BASE-TX	UTP or STP cat 5 or superior	2 pair	100 m	FDDI: 4B5B
100BASE-FX	multimode fiber optic (62.5/125 μm)	2 fiber	400 m – HD 2000 m - FD	FDDI: 4B5B

100BASE-T4

4 pairs used

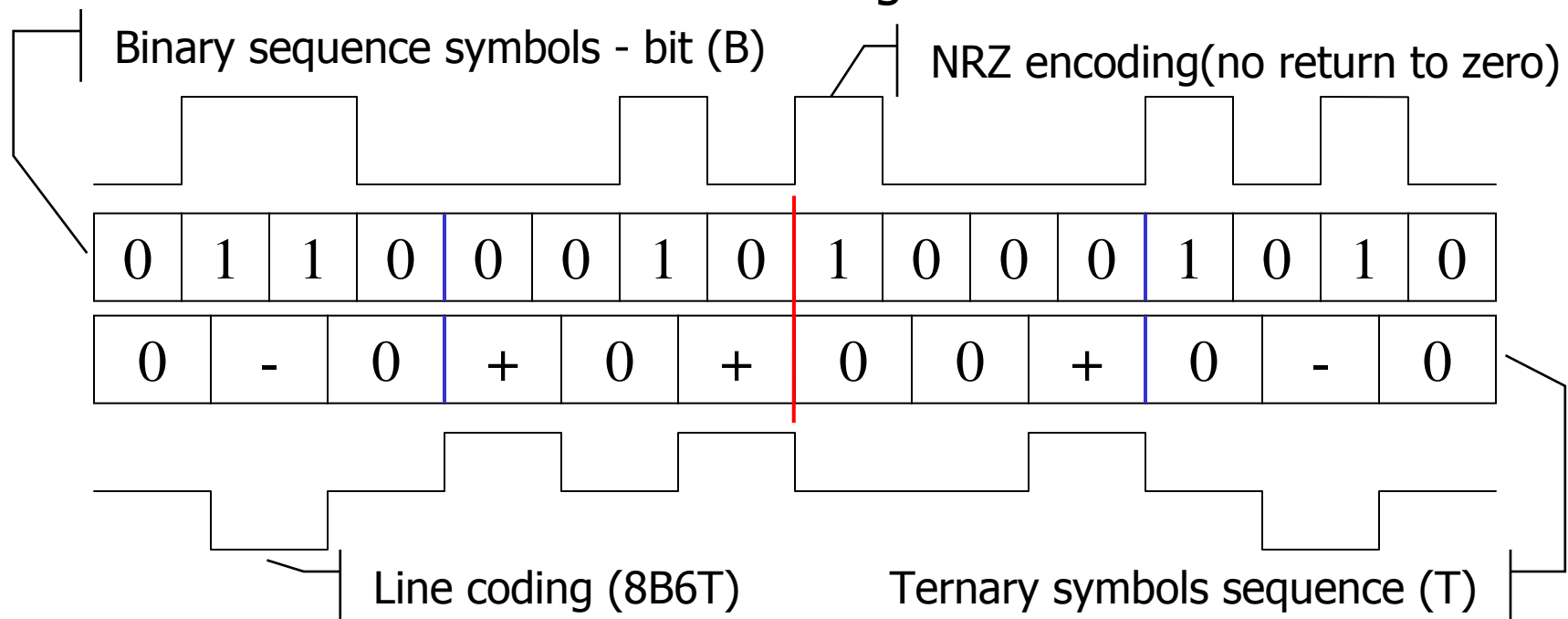
- Half duplex transmission
- 1 for TX
- 1 for RX
- 2 for TX or RX



100BASE-T4

Line coding 8B6T

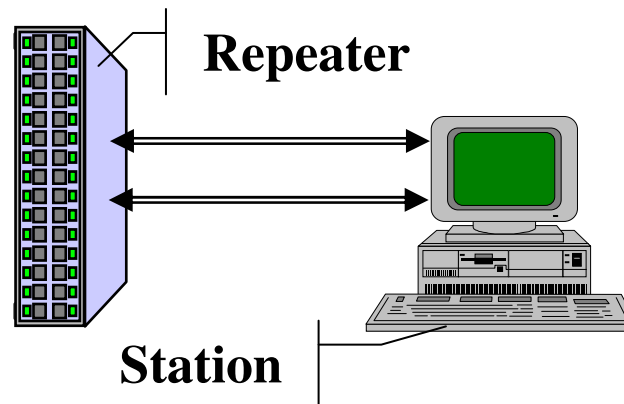
- 8 binary symbols (8B) encoded in 6 ternary symbols (6T)
 - Redundancy used for control symbols
 - DC balance
- Smaller spectral occupancy with same level bit rate
 - 25 MHz → Cat 3 UTP is enough for 100 m



100BASE-T2

2 pairs used

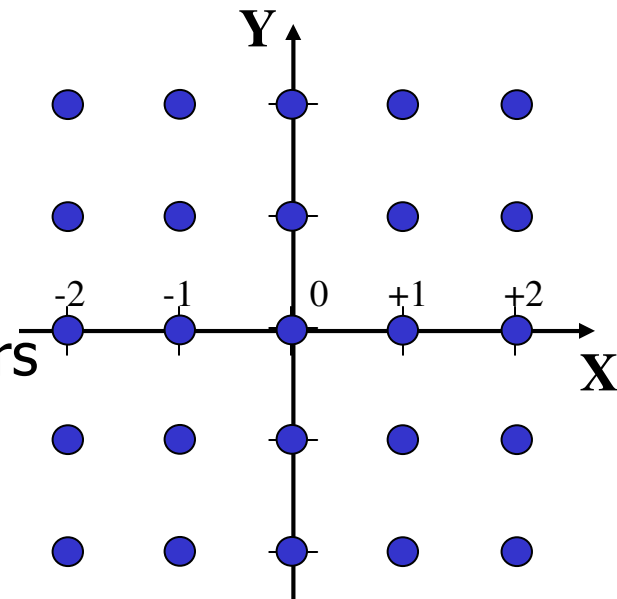
- Full duplex transmission
- Hybrid transformer
- 5-level pulse amplitude modulation PAM 5x5



100BASE-T2

Line coding PAM 5x5

- 5-level pulse amplitude modulation
- Binary symbols sequences (bit) encoded in quinary symbols pairs(X,Y)
- Each symbol is transmitted over the two wire pairs
- Quinary symbols pairs are chosen from the constellation in figure
- Redundancy is used to
 - Define control symbols
 - Reduce interference between pairs



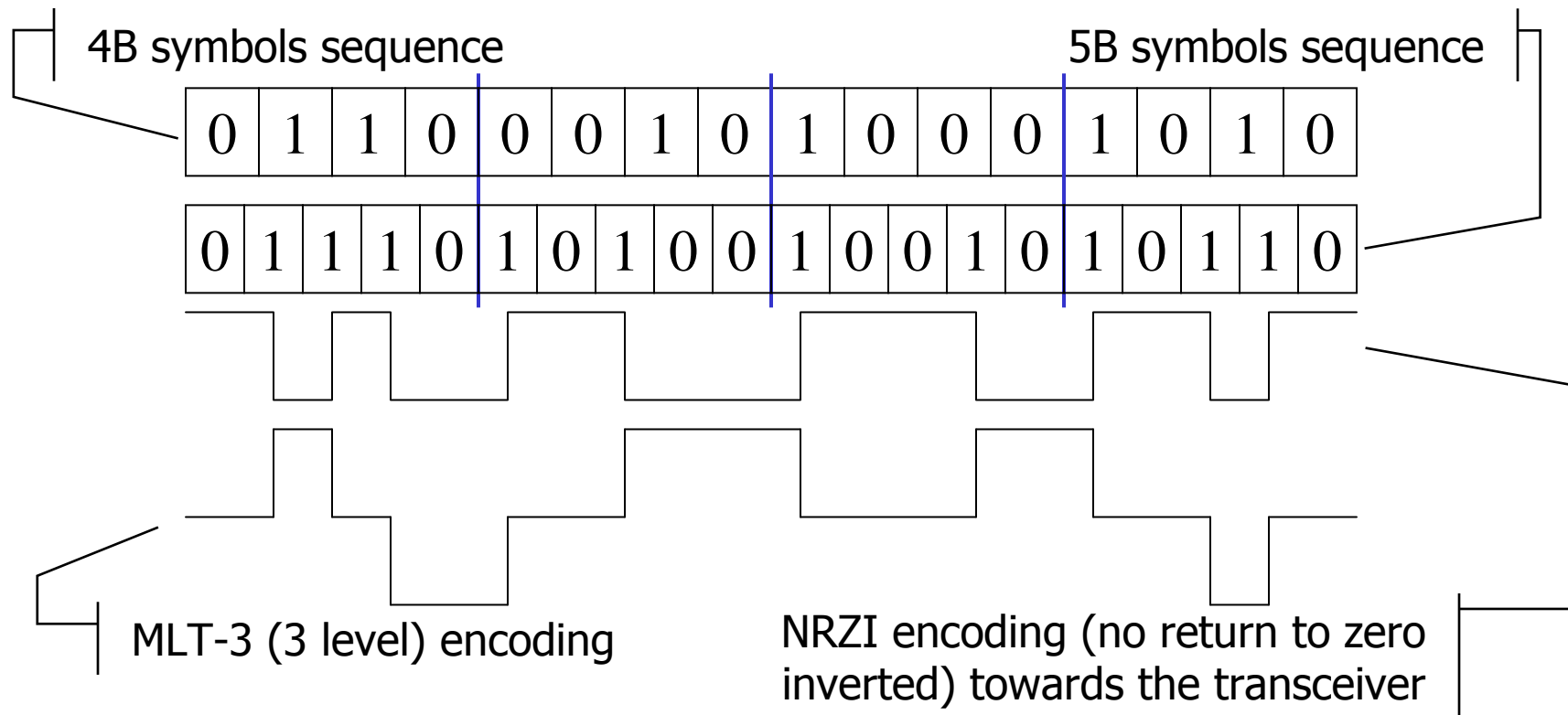
100BASE-X

- Transmission half and full duplex
- 100BASE-X derived from FDDI physical layer specifications (ISO/IEC 9314)
 - 100BASE-TX for copper and 100BASE-FX for fiber
- 100BASE-TX for UTP o STP cables (Shielded Twisted Pair)
 - Maximum segment length: 100 m
 - Maximum LAN diameter 205 m with 2 repeater
- 100BASE-FX for fiber optic cable
 - Maximum segment length (station-to-station): 400 m
 - Limit of CSMA/CD
 - Maximum LAN diameter with 1 repeater 300 m

100BASE-X

Line coding 4B5B

- 4-bit symbols encoded in 5-bit symbols
 - Synchronous transmission at 125 Mb/s
 - Codes guarantee transitions → synchronization
 - Redundancy used for control symbols
 - IDLE code act as Inter-Frame Gap



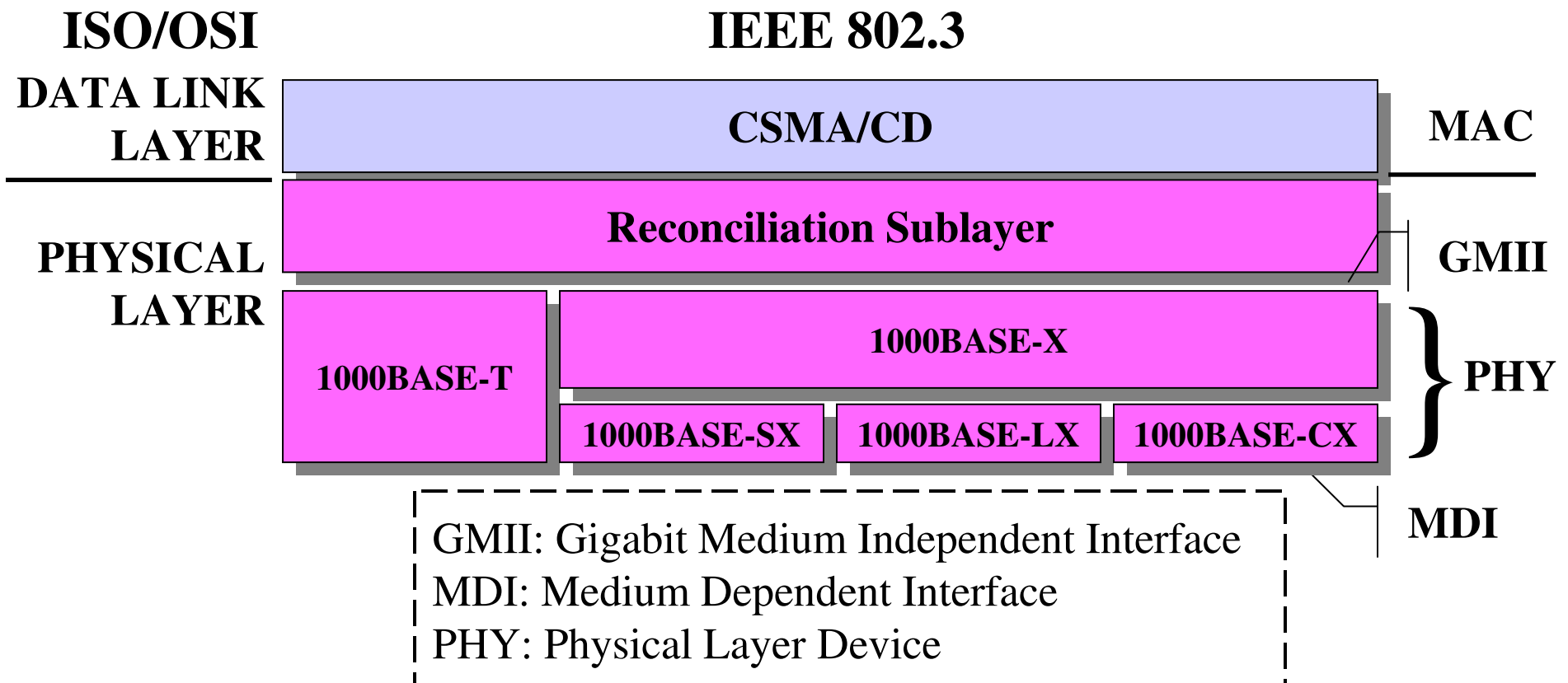
Auto negotiation

- Auto negotiation possibilities:
 - speed (only over copper)
 - half/full duplex (over copper and fiber optic)
- Negotiation sequence:
 - 1 Gb/s full-duplex
 - 1 Gb/s half-duplex
 - 100 Mb/s full-duplex
 - 100 Mb/s half-duplex
 - 10 Mb/s full-duplex
 - 10 Mb/s half-duplex

Gigabit Ethernet

IEEE 802.3z e IEEE 802.3ab

- Protocol extension for collision detection (MAC)
- GMII (Gigabit Media Independent Interface) between Physical and MAC Layers



New functionalities

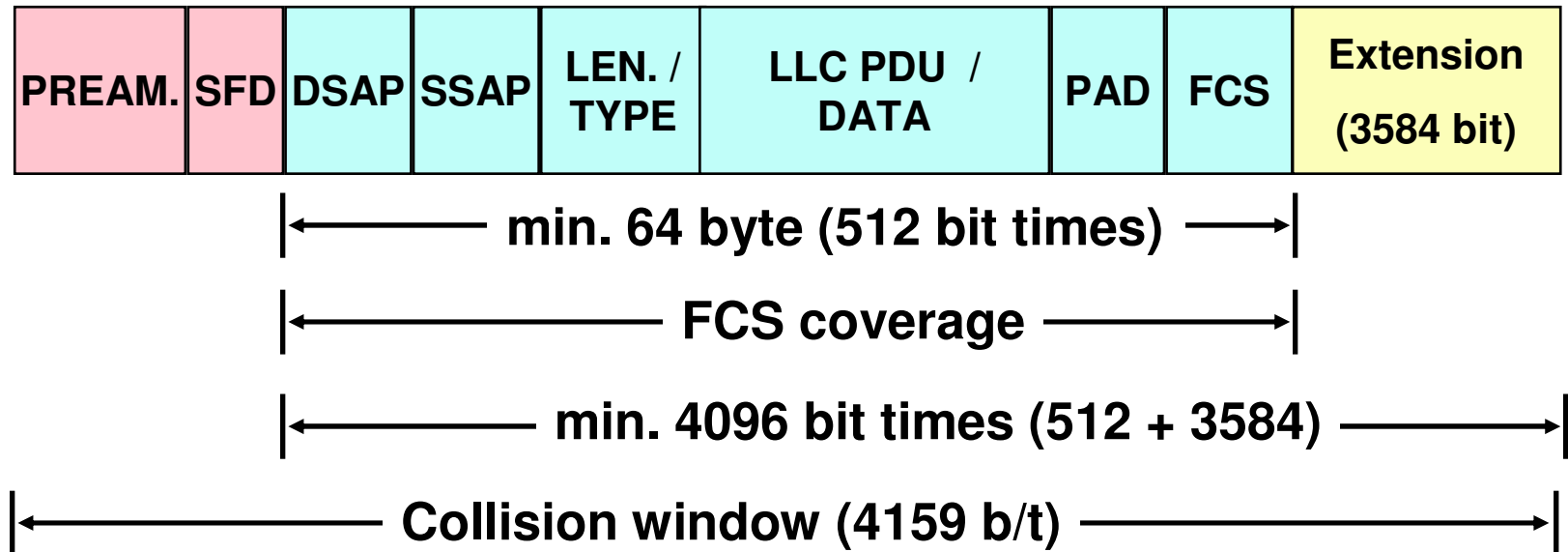
■ *Carrier extension*

- Increase the dimension of frames shortest than 4096 bit
- data + *extension bit* = 4096 bit
- Collision Window = 4.1 μ s
 - Same order of magnitude as Fast Ethernet (5.1 μ s)

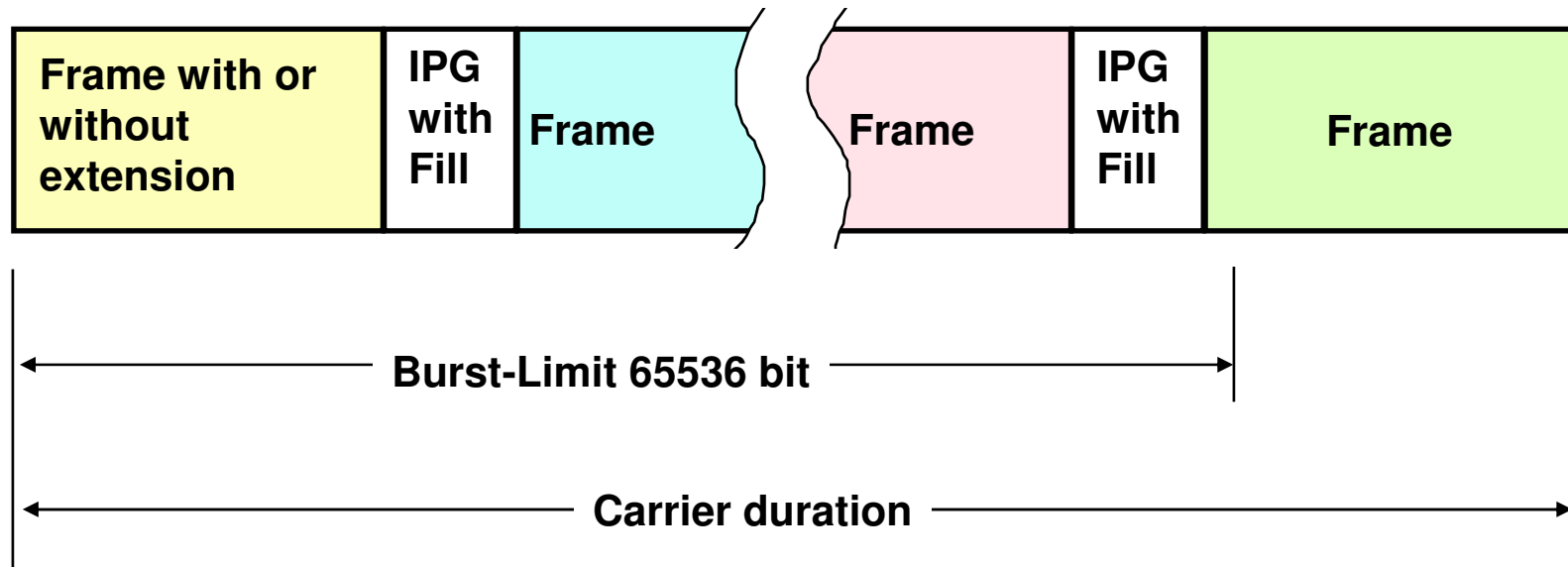
■ *Burst mode*

- Station does not give up the medium until packet transmission is over
- Fill bit transmission instead of Inter Frame Gap between frames during burst window
- Continuous transmission up to 77 Kbit (65 K + 12 K)

Carrier Extension



Frame Bursting



Working modes

- Shared mode to be used with repeaters
 - Not used
 - Not implemented by any commercial products
- Usually used in full duplex mode
 - No carrier extension
 - Collisions does not exist
 - No burst mode
 - Contention does not exist

Gigabit Ethernet Physical layer

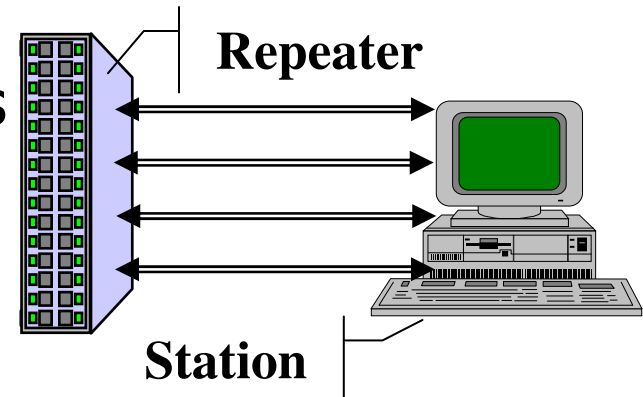


MMF = Multi Mode Fiber
SMF = Single Mode Fiber

Standard	Media	Use	Max leng.	Code
1000BASE-SX	MMF 50/125 μm (400 MHz * Km a 850nm)	2 fibers	500 m	FC: 8B10B
	MMF 50/125 μm (500 MHz * Km a 850nm)		550 m	
	MMF 62.5/125 μm (160 MHz * Km a 850nm)		220 m	
	MMF 62.5/125 μm (200 MHz * Km a 850nm)		275 m	
1000BASE-LX	MMF 50/125 μm (400/500 MHz * Km a 1300nm)	2 fibers	550 m	FC: 8B10B
	MMF 62.5/125 μm (500 MHz * Km a 1300nm)		550 m	
	SMF 10/125 μm		5000 m	
1000BASE-CX	STP (jumper cable) 150 Ω	2 pairs	25 m	FC: 8B10B
1000BASE-T	UTP balanced 100 Ω Cat. 5E	4 pairs	100 m	PAM5

1000BASE-T (IEEE 802.3ab)

- Full-duplex transmission over 4 pairs
 - 250 Mb/s per pair
 - Hybrid transformers
- PAM5 Line coding (5-level Pulse Amplitude Modulation)
 - 6 binary symbols encoded in quinary symbol quadruple
 - Each symbol transmitted over a pair
 - 125 Mbaud per pair
 - Redundancy used for control codes
- Cat 5 UTP has to pass further test in addition to those provided by TIA/EIA TSB95 standard on structured wiring



1000BASE-X

- Sub Standard
 - 1000BASE-CX (copper short range)
 - 1000BASE-SX (short wavelength)
 - 1000BASE-LX (long wavelength)
- Based on Fiber Channel (FC) Physical Layer
 - Code 8B10B
 - Redundancy code: control symbol and transitions

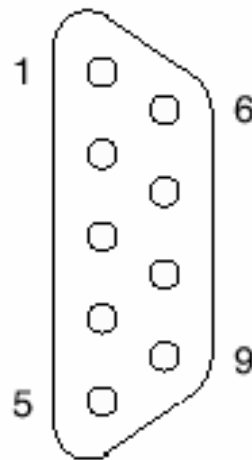
1000BASE-CX connectors

Type 1 connector

1: Transmission +
6: Transmission -

Shell: shield

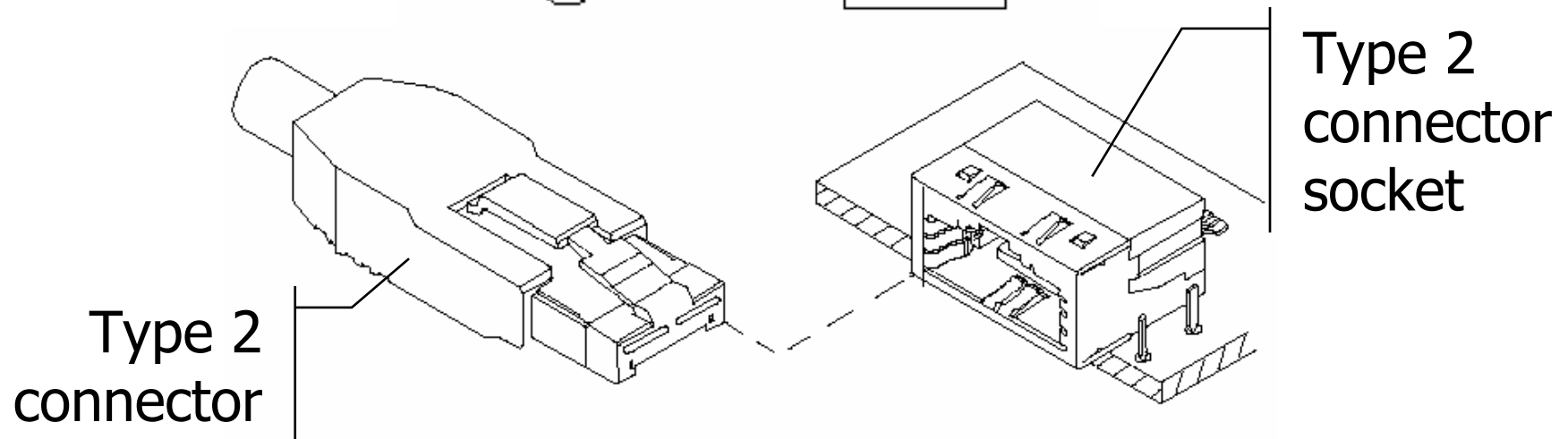
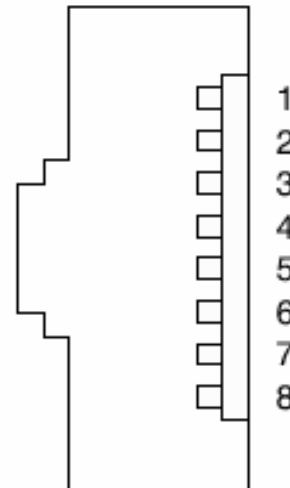
5: Reception -
9: Reception +



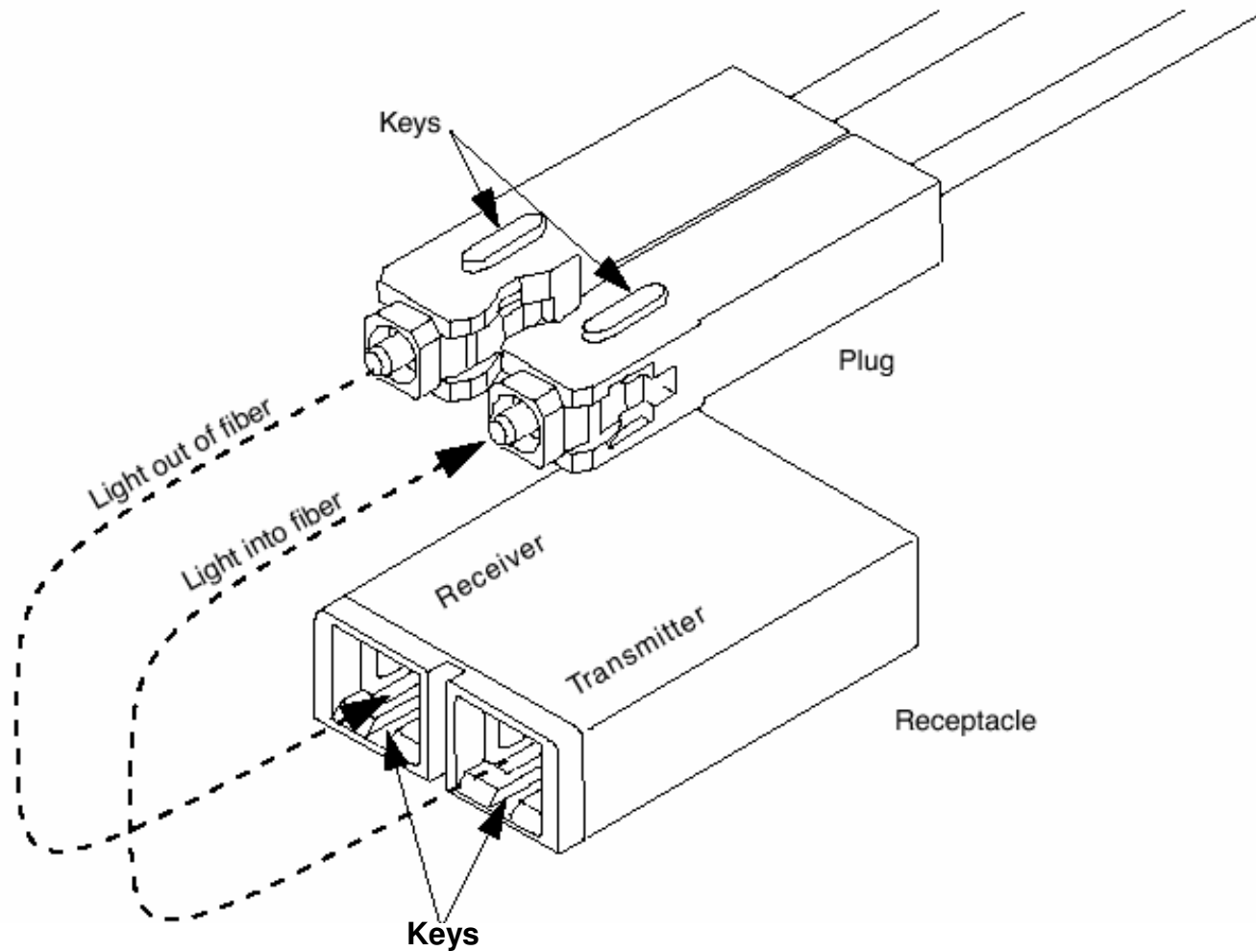
Type 2 connector

1: Transmission +
3: Transmission -

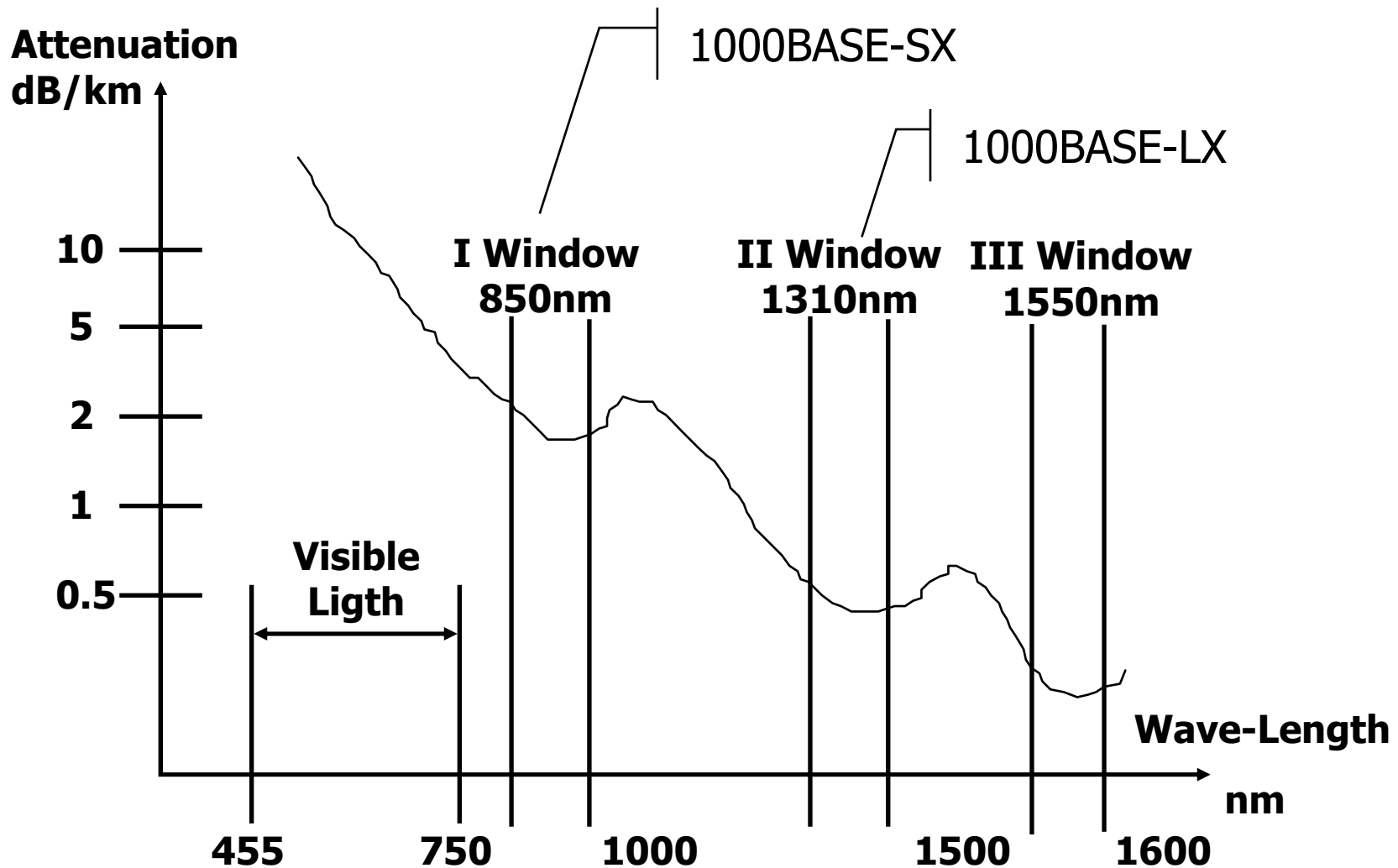
6: Reception -
7: Reception +



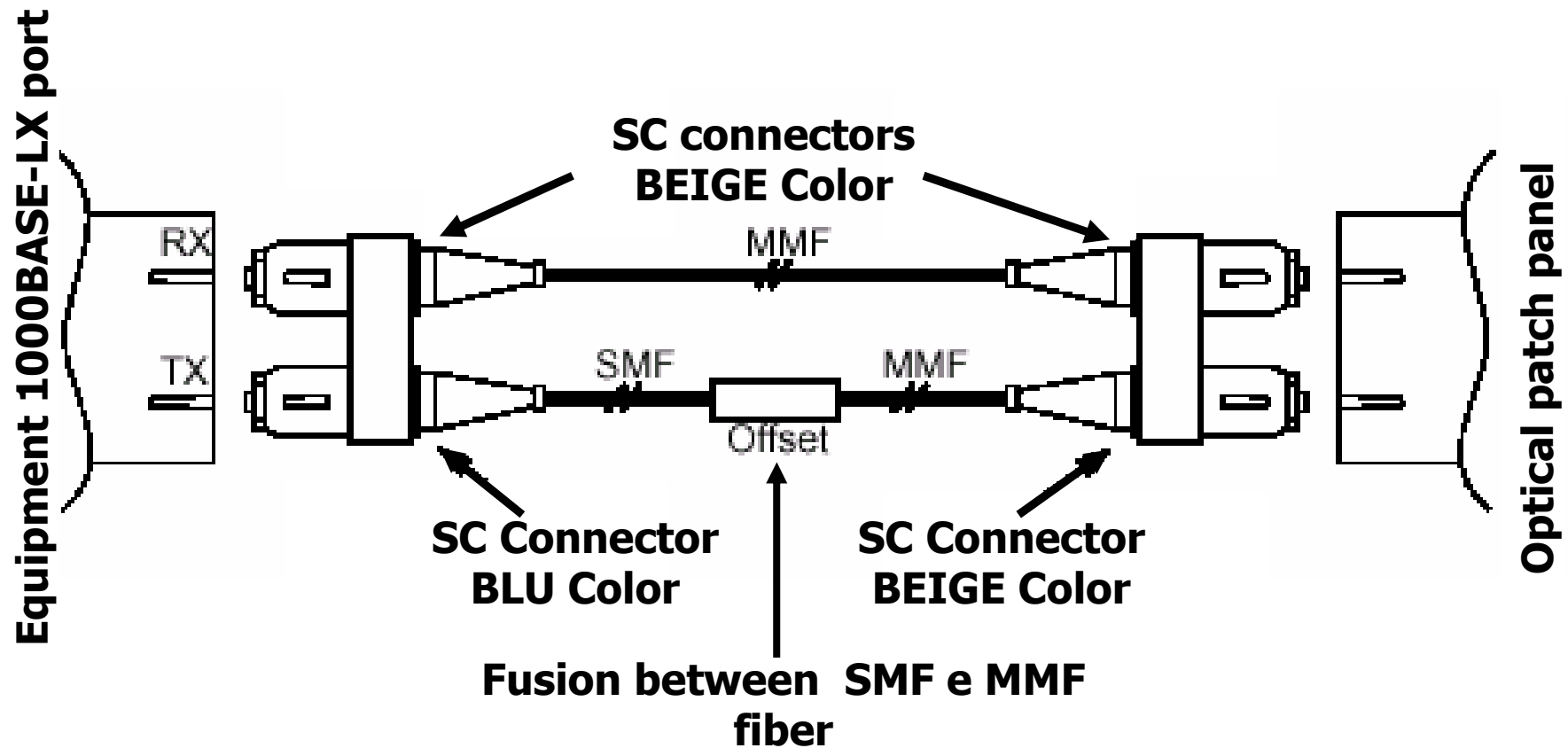
1000BASE-SX e 1000BASE-LX connectors



Wave-Length and standard



1000BASE-LX & multimode fiber: Mode Conditioning Patch Cord



MMF = Multi Mode Fiber
SMF = Single Mode Fiber

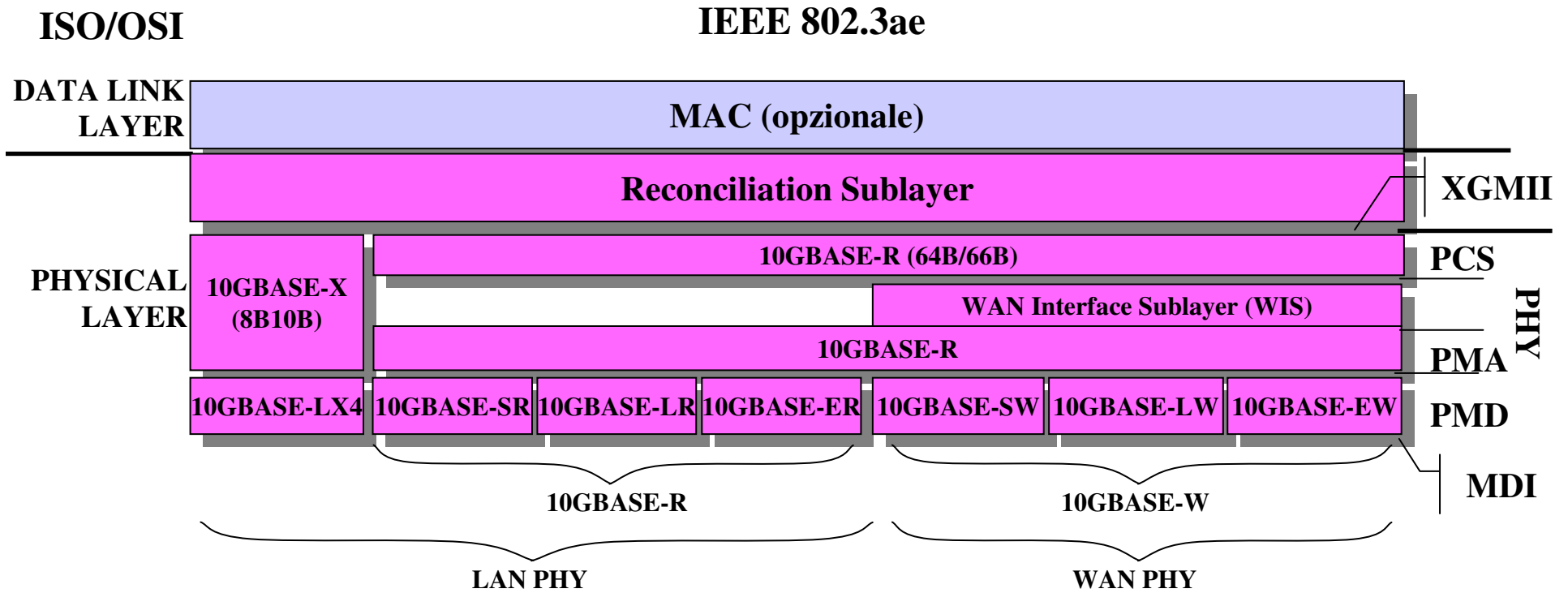
Non standard products

- 1310 nm single-mode fiber: 10 Km
 - Example Cisco GBIC 1000BASE-LX/LH
- 1550 nm single-mode fiber dispersion shift: 100 Km
 - Example Cisco GBIC 1000BASE-LZ
- Interoperability between products of different vendors is not guaranteed

10 Gigabit Ethernet - IEEE 802.3ae

- IEEE 802.3 frame
- Full-duplex mode
 - No repeater
 - No CSMA/CD
 - No carrier extension
- Keep Ethernet's good reputation
 - 10 times more efficient
 - 3 times more expensive
- Break into metropolitan network (MAN) and wide area network (WAN) markets
 - Price/Bandwidth ratio is higher than traditional solutions (SONET/SDH, Frame Relay, ATM)

Architectural model

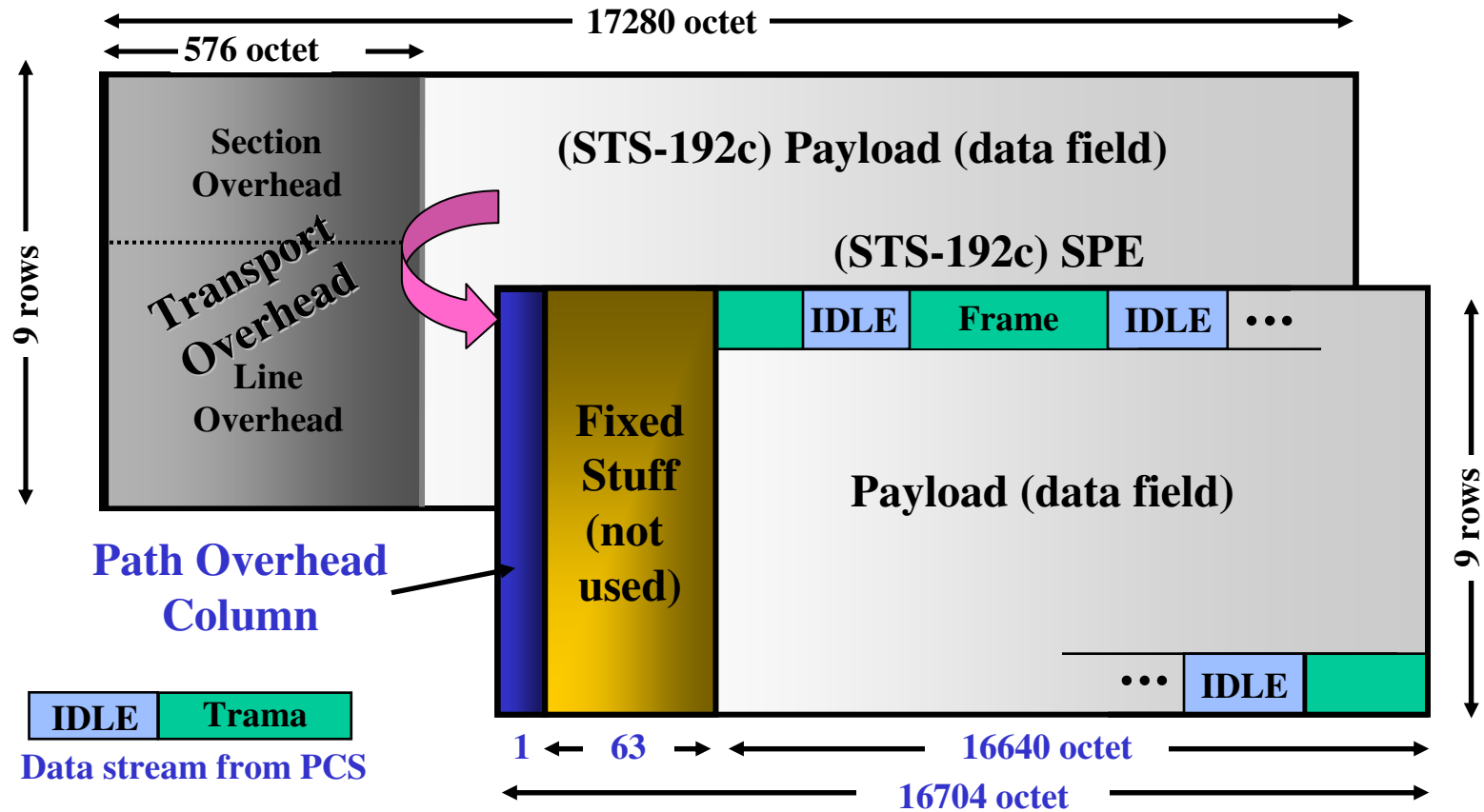


MDI: Medium Dependent Interface PMA: Physical Medium Attachment
 PCS: Physical Coding Sublayer PMD: Physical Medium Dependent
 PHY: Physical Layer Device XGII: 10 Gigabit Medium Independent Interface

WAN PHY

- Enables transport over existent MAN and WAN infrastructure
 - DWDM (Dense Wavelength Division Multiplexing)
- Enables existent MAN and WAN component reuse
 - SONET/SDH transceiver and circuitry
- Different transmission speed (9.6 Gb/s) respect to LAN PHY's speed
- WAN PHY and LAN PHY common properties→ market is waiting for components with both functionalities
 - 10GBASE-R and 10GBASE-W in particular
- WIS (WAN Interface Sublayer) tunes PCS' signal
 - Bit scrambling
 - SONET/SDH headers

10GE frame over SONET/SDH



STS-192c = Synchronous Transport Signal – di livello 192, c = concatenated

SPE = Synchronous Payload Envelope

10GE and SONET/SDH

- Simplified version of SONET/SDH
 - Avoid imposed complexities required by SONET/SDH
 - Limit component cost
- Only some header's fields are used
- High precision synchronization has been removed
 - No Stratum-1 clock (10^{-12} precision)
- Frames are generated and forwarded by 10GE devices in asynchronous mode using
 - SONET/SDH framing
 - Limited SONET/SDH management functionalities

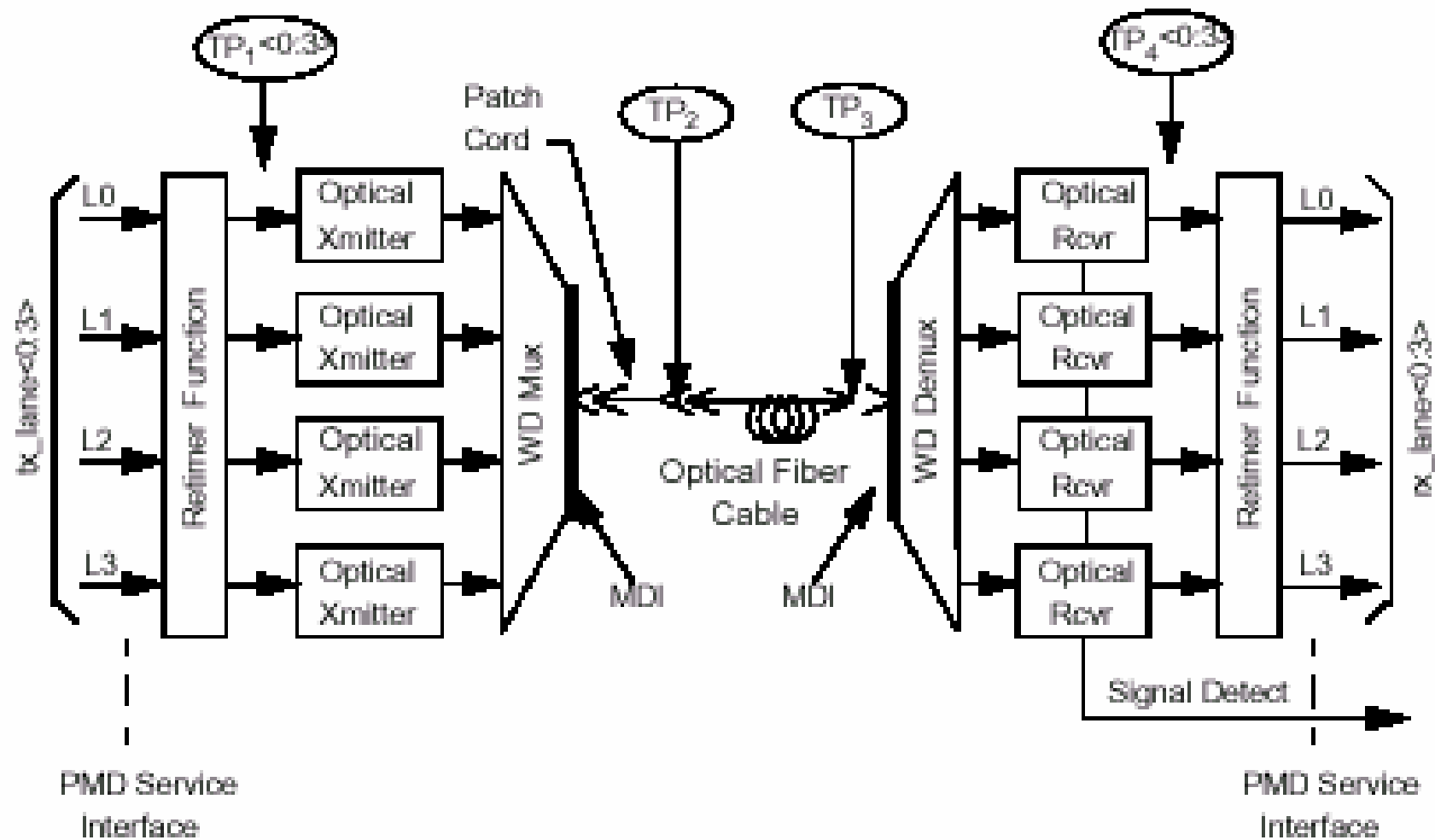
Physical layer

Standard	Fiber	Max lenght	Window	Usage	Coding
10GBASE-SR	Multimode 62.5 μm	26 – 33 m	850 nm	Building (orizontal wiring)	64B/66B
	Multimode 50 μm	66 – 300 m			
10GBASE-LR	Monomode (10 μm)	10 Km	1310 nm	Area	64B/66B
10GBASE-ER	Monomode (10 μm)	40 Km	1550 nm	Metropolitan	64B/66B
10GBASE-LX4	Multimode 62.5 μm	300 m	1310 nm	Building (orizontal wiring)	FC 10G: 8B10B
	Multimode 50 μm	240 – 300 m			
	Monomode (10 μm)	10 Km		Area	
10GBASE-SW	Multimode 62.5 μm	26 – 33 m	850 nm	Building (orizontal wiring)	64B/66B SONET/SDH framing
	Multimode 50 μm	66 – 300 m			
10GBASE-LW	Monomode (10 μm)	10 Km	1310 nm	Area	64B/66B SONET/SDH framing
10GBASE-EW	Monomode (10 μm)	40 Km	1550 nm	Metropolitan	64B/66B SONET/SDH framing

10GBASE-X

- Coding derived from 10G FC (Fiber Channel at 10 Gb/s)
- 32 bit blocks are encoded in 4 blocks of 10 bit each
- Sent over 4 lane
 - 3.125 Gbaud per lane
- Redundancy used for control codes
 - For example idle signal act as inter-frame gap

10GBASE-LX4



WD = Wavelength Division