

CS 725/825 & IT 725

Lecture 23

**Link Layer**

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December 1, 2025

Link Layer

# Components of Link Layer

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## ▶ Data Link Control

- addressing
- framing
- error detection and correction
- flow control
- QoS

## ▶ Media Access Control (MAC)

- controlling access to the shared medium

# Media Access Control

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- ▶ **Objective**: Arbitration of access to the shared medium - prevention or avoidance of collisions.
- ▶ **Deterministic** - collisions are prevented
  - centralized
  - distributed
- ▶ **Stochastic** - some collisions are permissible - as long as they are detected and transmissions retried

# Stochastic (random) MAC

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## ALOHA

- ▶ Transmit at will...
- ▶ Detect collisions with transmissions of other nodes
- ▶ Random back-off if collision is detected

# ALOHA Improvements

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- ▶ Listen before you talk:
  - Carrier Sense Multiple Access (CSMA)
  - What to do after someone else's transmission is over (Persistence)
- ▶ Stop talking when you detect a collision:
  - Collision Detect (CD)
- ▶ Result: 1-persistent CSMA/CD (a.k.a. Ethernet)

# Ethernet Evolution

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- ▶ Constant: **frame format, 1-persistent CSMA/CD**
- ▶ Medium
  - *(historical)* coaxial cable (thick and thin Ethernet)
  - **twisted pair, fiber**
- ▶ Rate
  - *(historical)* 10M, 100M; currently: 1G, 10G, 40G, 100G, ...
- ▶ Connectivity
  - *(historical)* broadcast and select medium (L1), hub (L1)
  - **bridge/switch (L2)**

# Ethernet

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10BASE5 Ethernet



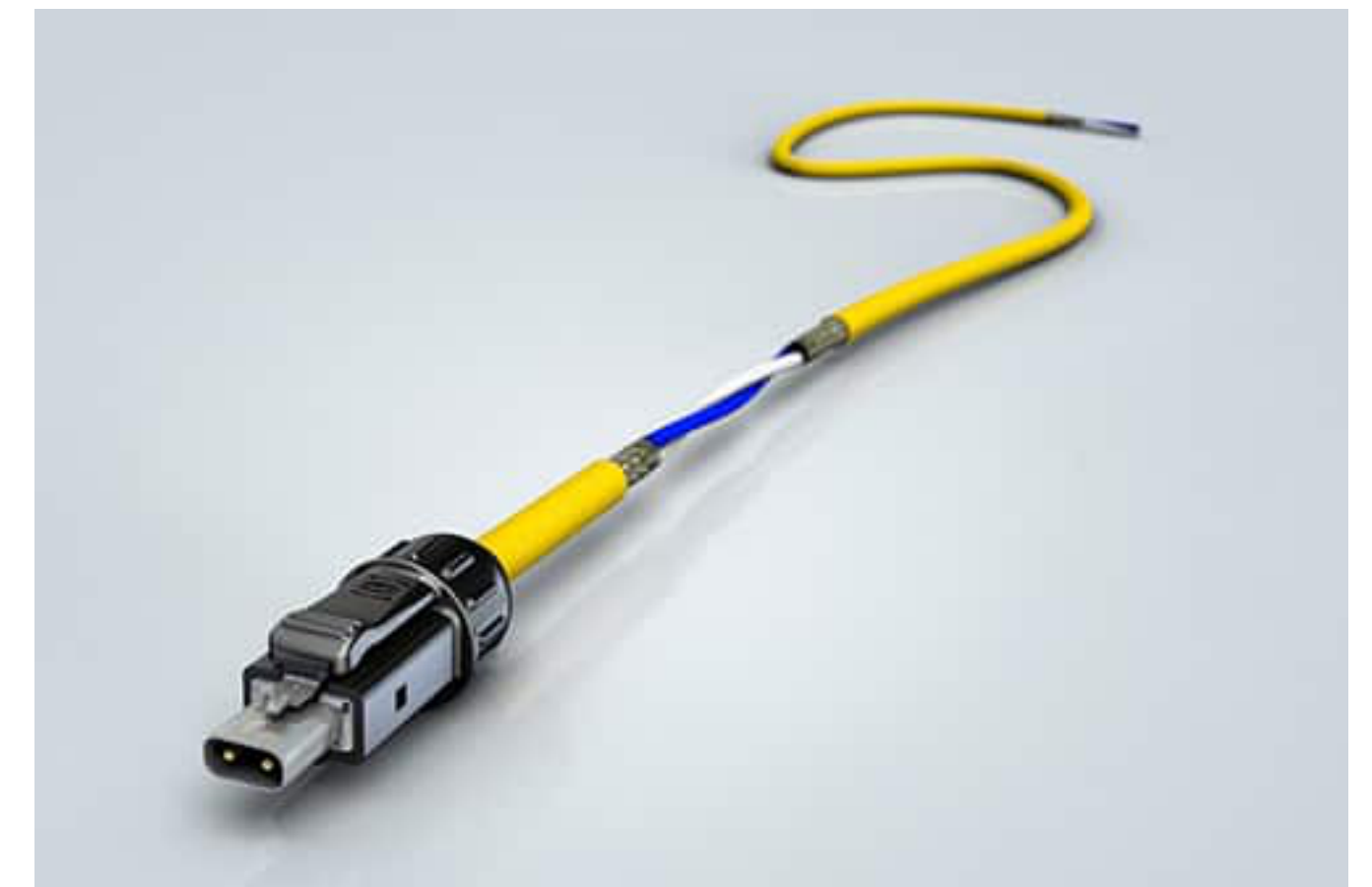
Twisted Pair Ethernet connector



10BASE2 Ethernet connector



25 twisted pairs cable



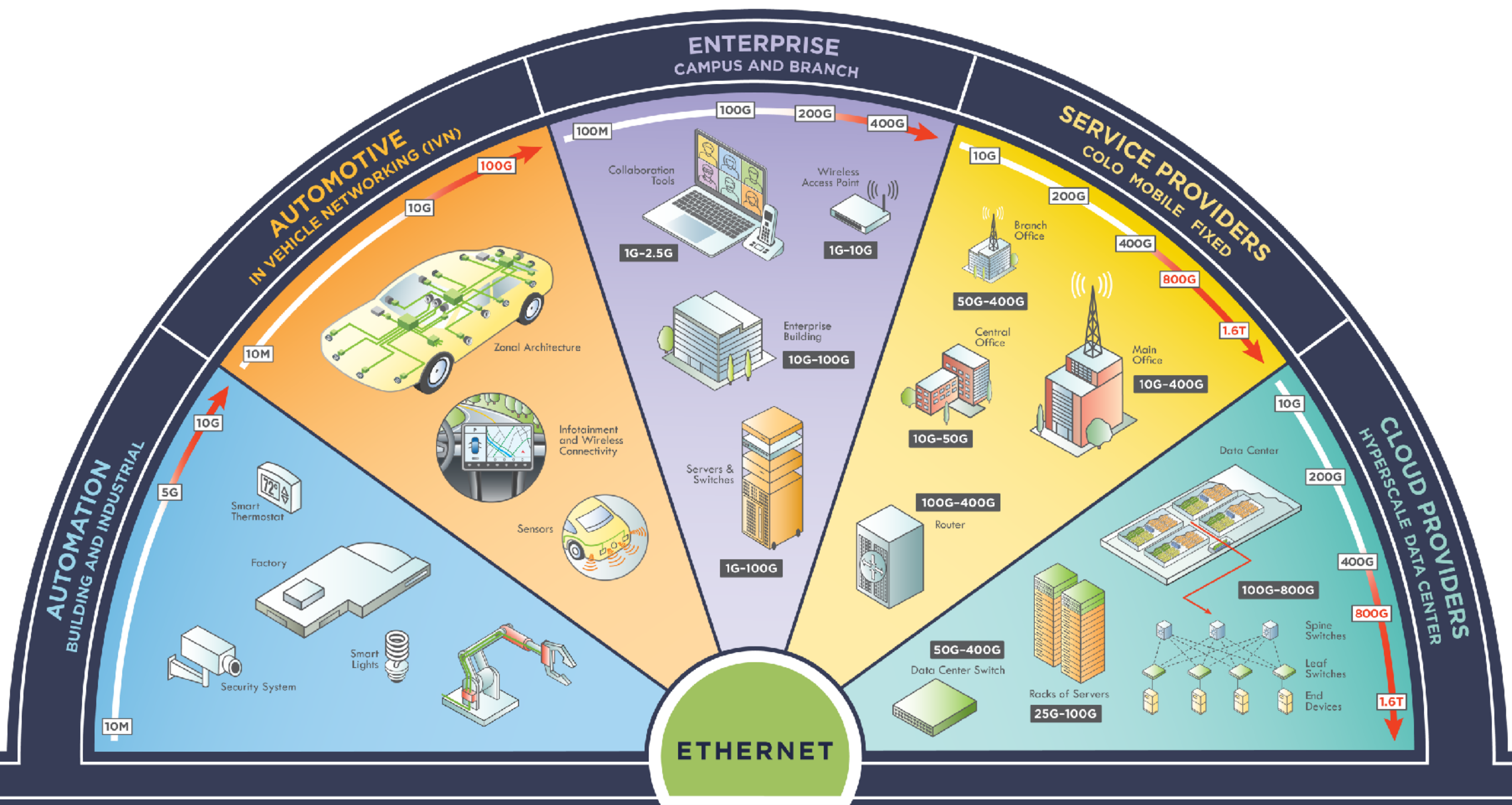
Single Pair Ethernet  
(image source: HARTING)



# Warning/Disclaimer

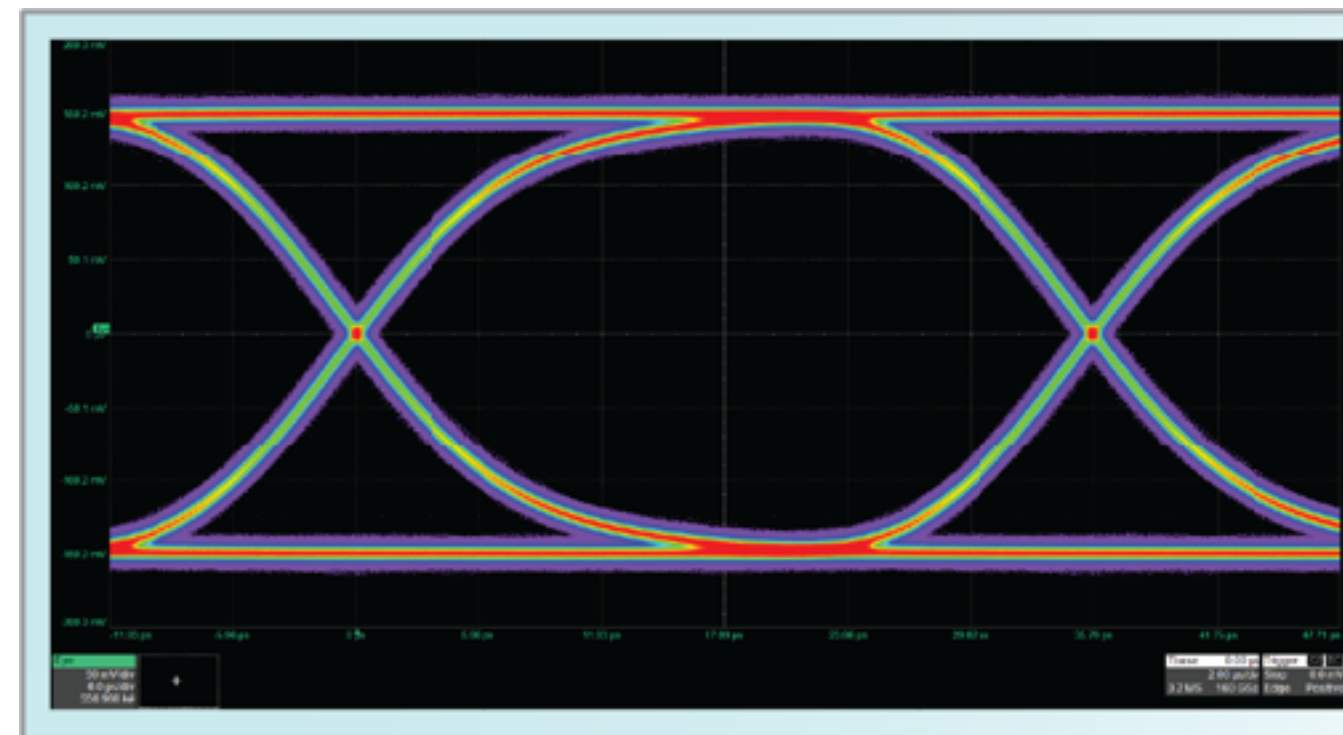
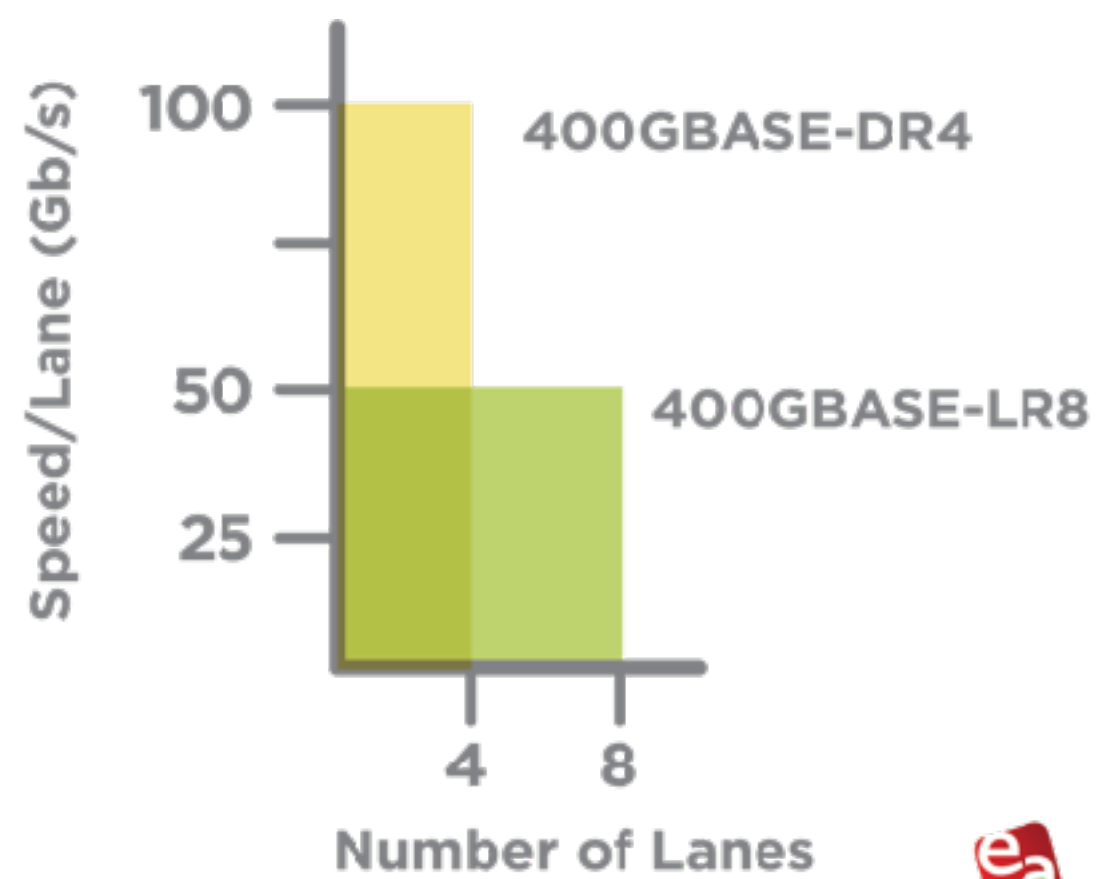
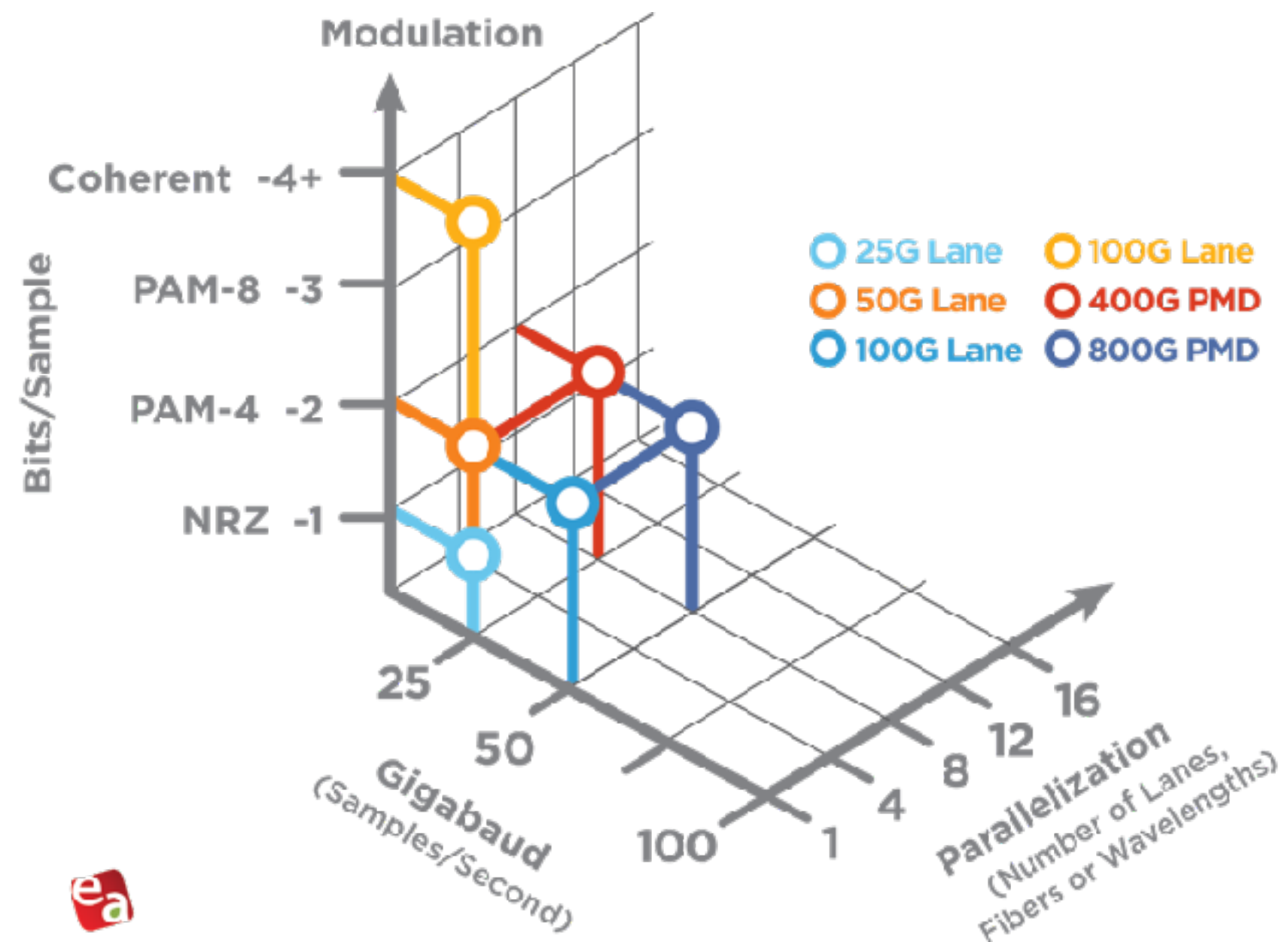
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- ▶ The following three slides are based marketing materials of the Ethernet Alliance (<https://ethernetalliance.org/>), specifically their 2025 Ethernet Road Map

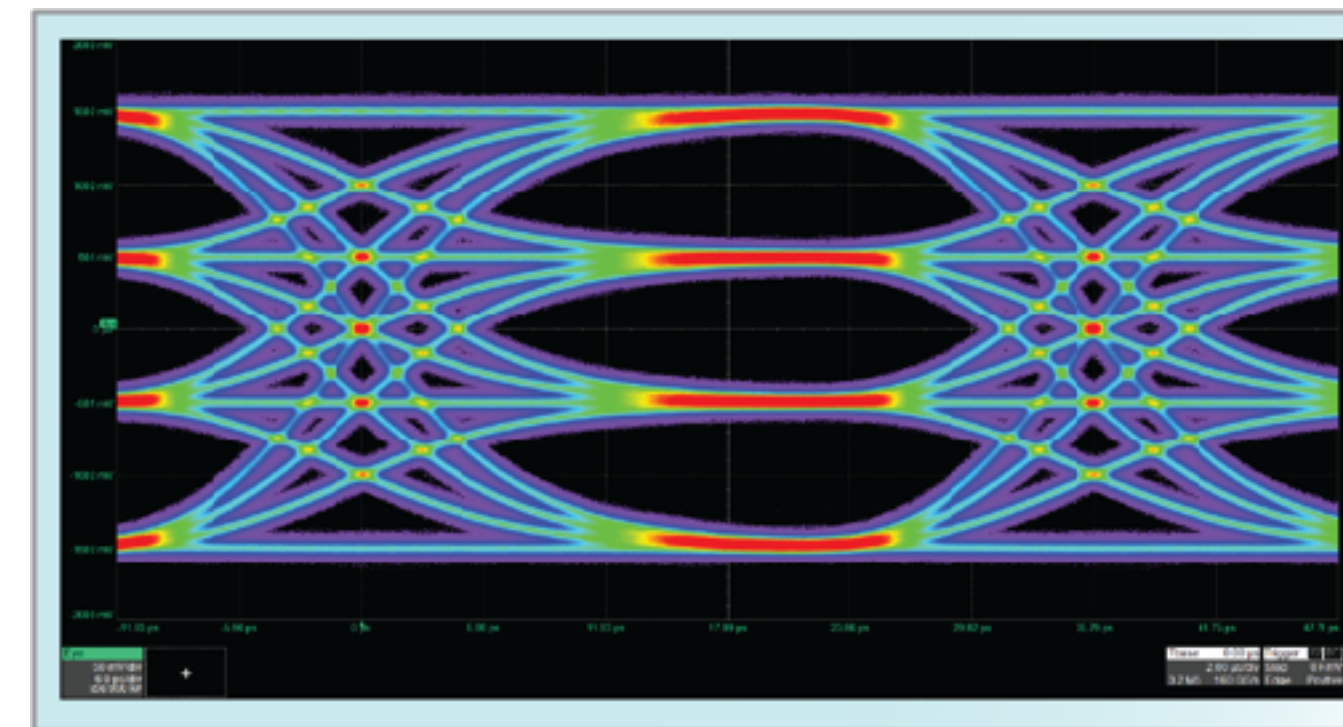


Source: Ethernet Alliance ([www.ethernetalliance.org](http://www.ethernetalliance.org)) 2025 Ethernet Roadmap

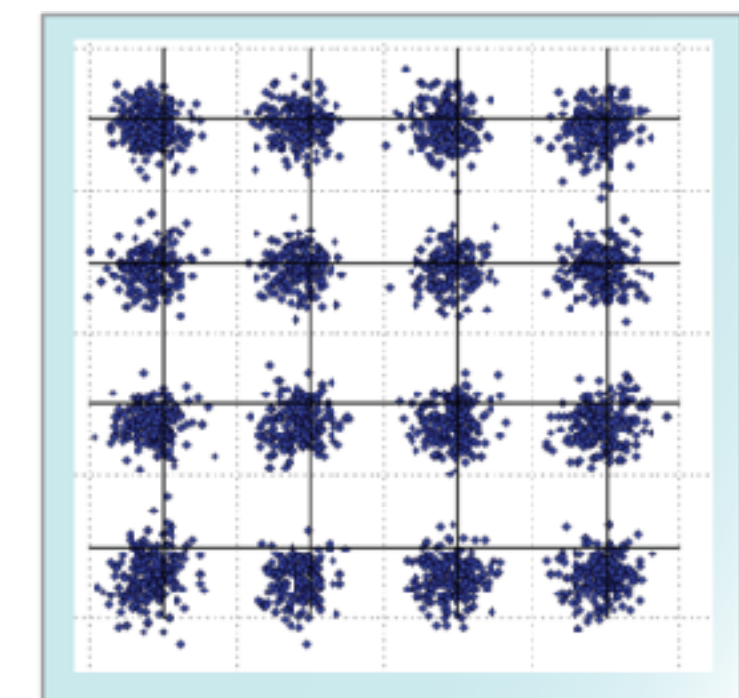
# Fatter Pipes



NRZ



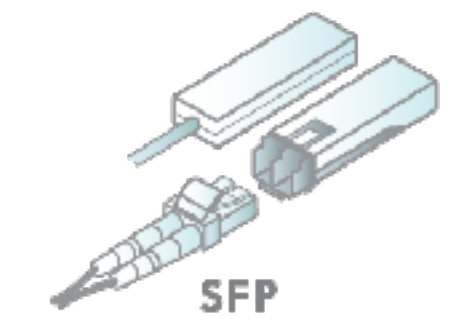
PAM-4



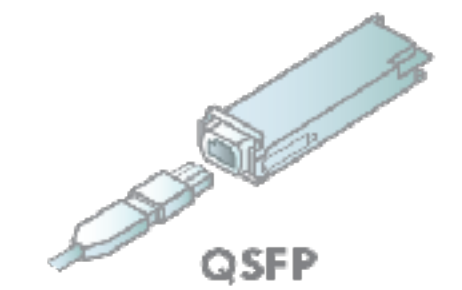
Coherent



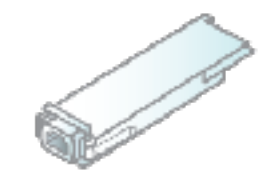
	Backplane	Twinax Cable	15-40m(OT) Single Twisted Pair	>100m (OT) Single Twisted Pair	100m (IT) Twisted Pair (2/4 Pair)	MMF	500m PSM4	2km SMF	10km SMF	20km SMF	40km SMF	80km SMF	Electrical Interface	Pluggable Module
10BASE-	T1S		T1S	T1L	T									
100BASE-			T1	T1L*	T									
1000BASE-			T1		T									
2.5GBASE-	KX		T1		T									
5GBASE-	KR		T1		T									
10GBASE-			T1		T				BIDI Access	BIDI Access	BIDI Access			
25GBASE-	KR1 KR	CR1 CR/CR-S	T1		T (30m)	SR			LR EPON BIDI Access	EPON BIDI Access	ER BIDI Access		25GAUI	SFP
40GBASE-	KR4	CR4			T (30m)	SR4/eSR4	PSM4	FR	LR4				XLAUI XLPP1	QSFP
50GBASE-	KR2 KR	CR2 CR	T2			SR		FR	EPON BIDI Access LxR	EPON BIDI Access	BIDI Access ER		LAUI-2/50GAUI-2 50GAUI-1	SFP/QSFP
100GBASE-	KR4 KR2 KR1	CR10 CR4 CR2 CR1	T4			SR10 SR4 SR2 VR1 SR1	PSM4 DR	CWDM4 FR1	LR4 4WDM-10 LR1	4WDM-20	ER4 4WDM-40	ZR	CAUI-10 CPPI CAUI-4/100GAUI-4 100GAUI-2 100GAUI-1	SFP QSFP/QSFP-DD OSFP
200GBASE-	KR4 KR2	CR4 CR2 CR1*				SR4 VR2 SR2	DR4 1pair*	FR4 1 pair*	LR4		ER4		200GAUI-4 200GAUI-2 200GAUI-1*	QSFP/QSFP-DD SFP-DD
400GBASE-	KR4*	CR4 CR2*				SR16 SR8/SR4.2 VR4 SR4	DR4 2 pair*	FR8 FR4 400G-FR4	LR8 LR4-6 400G-LR4-10		ER8	ZR	400GAUI-16 400GAUI-8 400GAUI-4 400GAUI-2*	QSFP/QSFP-DD OSFP
800GBASE-	ETC-KR8 KR8*	ETC-KR8 CR8* CR4*				VR8* SR8*	8 pair* 4 pair*	8 pair* 4 pair* 4 lambda*	TBD*		TBD*		800GAUI-8* 800GAUI-4*	
1.6TBASE-		CR8*					8 pair*	8 pair*					1.6TAUI-16* 1.6TAUI-8*	QSFP/QSFP-DD OSFP/OSFP-XD



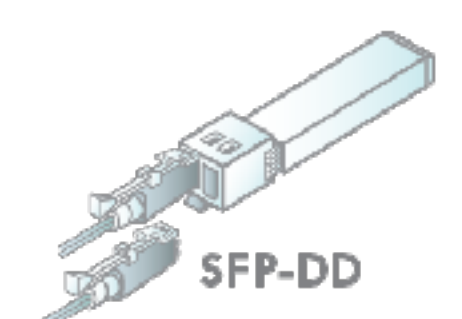
SFP



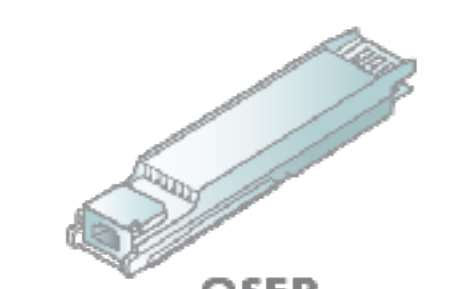
QSFP



QSFP-DD



SFP-DD



OSFP

Gray Text = IEEE Standard    Red Text = In Task Force    Green Text = In Study Group

Blue Text = Non-IEEE standard but complies to IEEE electrical interfaces    \* Note: As of publication, subject to change

