40/100 Gigabit Ethernet Overview

The IEEE 802.3 working group is concerned with the maintenance and extension of the Ethernet data communications standard.

The speeds chosen by 802.3ba were 40 and 100 Gbit/s to support both end-point and link aggregation needs. This was the first time two different Ethernet speeds were specified in a single standard. The decision to include both speeds came from pressure to support the 40 Gbit/s rate for local server applications and the 100 Gbit/s rate for internet backbones. The standard was announced in July 2007 and was ratified on June 17, 2010.

The 40/100 Gigabit Ethernet standards encompass a number of different Ethernet physical layer (PHY) specifications. A networking device may support different PHY types by means of pluggable modules. Optical modules are not standardized by any official standards body but are in multi-source agreements (MSAs). One agreement that supports 40 and 100 Gigabit Ethernet is the C Form-factor Pluggable (CFP) MSA which was adopted for distances of 100+ meters. QSFP and CXP connector modules support shorter distances.

The standard supports only full-duplex operation. Other electrical objectives include:

- Preserve the 802.3 / Ethernet frame format utilizing the 802.3 MAC
- Preserve minimum and maximum FrameSize of current 802.3 standard
- Support a bit error rate (BER) better than or equal to 10−12 at the MAC/PLS service interface
- Provide appropriate support for OTN
- Support MAC data rates of 40 and 100 Gbit/s
- Provide physical layer specifications (PHY) for operation over single-mode optical fiber (SMF), laser optimized multi-mode optical fiber (MMF) OM3 and OM4, copper cable assembly, and backplane.

The following nomenclature is used for the physical layers:

Physical layer	40 Gigabit Ethernet	100 Gigabit Ethernet
Backplane		100GBASE-KP4
Improved Backplane	40GBASE-KR4	100GBASE-KR4
7 m over twinax copper cable	40GBASE-CR4	100GBASE-CR10 100GBASE-CR4
30 m over "Cat.8" twisted pair	40GBASE-T	

100 m over OM3 MMF	40GBASE-SR4	100GBASE-SR10 100GBASE-SR4
125 m over OM4 MMF		
2 km over SMF, serial	40GBASE-FR	100GBASE-CWDM4
10 km over SMF	40GBASE-LR4	100GBASE-LR4
40 km over SMF	40GBASE-ER4	100GBASE-ER4

The 100m laser optimized multi-mode fiber (OM3) objective was met by parallel ribbon cable with 850 nm wavelength 10GBASE-SR like optics (40GBASE-SR4 and 100GBASE-SR10). The backplane objective with 4 lanes of 10GBASE-KR type PHYs (40GBASE-KR4). The copper cable objective is met with 4 or 10 differential lanes using SFF-8642 and SFF-8436 connectors. The 10 and 40 km 100 Gbit/s objectives with four wavelengths (around 1310 nm) of 25 Gbit/s optics (100GBASE-LR4 and 100GBASE-ER4) and the 10 km 40 Gbit/s objective with four wavelengths (around 1310 nm) of 10 Gbit/s optics (40GBASE-LR4).

➢ **100G Port Types**

<table>
<tr><th>Name</th><th>Media</th><th>Lanes</th><th>Gigabaud per lane</th><th>Notes</th></tr>
<tr><td>100GBASE-CR10</td><td rowspan="2">Twin-ax copper cable</td><td>10</td><td>10.3125</td><td>CXP connector, center 10 out of 12 channels</td></tr>
<tr><td>100GBASE-CR4</td><td>4</td><td>25.78125, RS-FEC</td><td></td></tr>
<tr><td>100GBASE-SR10</td><td rowspan="2">Multi-mode fiber, 850 nm</td><td>10</td><td>10.3125</td><td>MPO/MTP connector, center 10 out of 12 channels</td></tr>
<tr><td>100GBASE-SR4</td><td>4</td><td>25.78125, RS-FEC</td><td></td></tr>
<tr><td>100GBASE-LR4</td><td rowspan="3">Single-mode fiber, WDM: 1295.56 nm, 1300.05 nm, 1304.59 nm, 1309.14 nm</td><td rowspan="3">4</td><td rowspan="2">25.78125</td><td>10 km reach</td></tr>
<tr><td>100GBASE-ER4</td><td>30–40 km reach</td></tr>
<tr><td>100GBASE-CWDM4</td><td>25.78125, RS-FEC</td><td>2 km reach, multi-vendor non-IEEE Standard</td></tr>
<tr><td>100GBASE-PSM4</td><td>4×Single-mode fiber 1310 nm</td><td>4</td><td>25.78125</td><td>500m, multi-vendor non-IEEE Standard</td></tr>
<tr><td>100GBASE-ZR</td><td>Single-mode fiber, 1546.119 nm</td><td>1</td><td>120.579, DP-QPSK</td><td>80+ km reach, non-IEEE Standard</td></tr>
<tr><td>100GBASE-KR4</td><td rowspan="2">Copper backplane</td><td rowspan="2">4</td><td rowspan="2">25.78125, RS-FEC</td><td></td></tr>
<tr><td>100GBASE-KP4</td><td>additional four level amplitude modulation</td></tr>
</table>

All variants listed in the table share the 64b/66b Physical Coding Sublayer, and the media count is given per direction (i.e. double the count is required to form a link.) RS-FEC refers to the Reed-Solomon Layer defined in Clause 91, introduced in IEEE 802.3bj. DP-QPSK refers to Dual polarization-quadrature phase shift keying.

- **40G port types**

40GBASE-CR4

40GBASE-CR4 ("copper") is a port type for twin-ax copper cable. Its 64b/66b PCS is defined in IEEE 802.3 Clause 82 and its PMD in Clause 85. It uses four lanes of twin-axial cable delivering serialized data at a rate of 10.3125 Gb/s per lane.

40GBASE-KR4

40GBASE-KR4 is a port type for backplanes. Normally backplanes are board traces, such as Megtron6 or FR4 materials. Its Physical Coding Sublayer 64b/66b PCS is defined in IEEE 802.3 Clause 82 and its Physical Medium Dependent PMD in Clause 84. It uses four lanes of backplane delivering serialized data at a rate of 10.3125 Gbit/s per lane.

40GBASE-SR4

40GBASE-SR4 ("short range") is a port type for multi-mode fiber and uses 850 nm lasers. Its Physical Coding Sublayer 64b/66b PCS is defined in IEEE 802.3 Clause 82 and its Physical Medium Dependent PMD in Clause 86. It uses four lanes of multi-mode fiber delivering serialized data at a rate of 10.3125 Gbit/s per lane. 40GBASE-SR4 has a reach of 100 m on OM3 and 150m on OM4. There is a longer range variant 40GBASE-eSR4 with a reach of 300 m on OM3 and 400 m on OM4. This extended reach is equivalent to the reach of 10GBASE-SR.

40GBASE-LR4

40GBASE-LR4 ("long range") is a port type for single-mode fiber and uses 1300 nm lasers. Its Physical Coding Sublayer 64b/66b PCS is defined in IEEE 802.3 Clause 82 and its Physical Medium Dependent PMD in Clause 87. It uses four wavelengths delivering serialized data at a rate of 10.3125 Gbit/s per wavelength.

40GBASE-ER4

40GBASE-ER4 ("extended range") is a port type for single-mode fiber being defined in P802.3bm and uses 1300 nm lasers. Its Physical Coding Sublayer 64b/66b PCS is defined in IEEE 802.3 Clause 82 and its Physical Medium Dependent PMD in Clause 87. It uses four wavelengths delivering serialized data at a rate of 10.3125 Gbit/s per wavelength.

40GBASE-FR

40GBASE-FR is a port type for single-mode fiber. Its Physical Coding Sublayer 64b/66b PCS is defined in IEEE 802.3 Clause 82 and its Physical Medium Dependent PMD in Clause 89. It uses 1550 nm optics, has a reach of 2 km and is capable of receiving 1550 nm and 1310 nm wavelengths of light. The capability to receive 1310 nm light allows it to inter-operate with a longer reach 1310 nm PHY should one ever be developed. 1550 nm was chosen as the wavelength transmission to make it compatible with existing test equipment and infrastructure.

40GBASE-T

40GBASE-T is a port type for 4-pair balanced twisted-pair Cat.8 copper cabling defined in IEEE 802.3bq. IEEE 802.3bq-2016 standard was approved by The IEEE-SA Standards Board on June 30, 2016.