10 Terabit Ethernet, T1, OC3, and Document Transmission Speeds

In Pages per Second
Over Various Types of Links

Pages per Second (Internet Communications)

DSL (Digital Subscriber Line) = 100 Kilobits (Kbits) to 8 Megabits (Mbits) per second = 1 to 15 pages per second (about ~ US$ 50.00 per month)

Modem = 56 Kbit (Kilobits) per second = 3 pages per minute (about ~ US$ 30.00 per month for a standard phone line) (2 bytes per baud (cycle))

ISDN (2 voice channels) = 128 Kilobit per second = 10 pages per minute (~ US$ 100.00 per month) (ISDN charge)

Cable (TV) modem =~ 500 Kilobits per second = 1 page per second (about ~ US$ 50.00 per month)

T1 (24 voice channels, 64 Kilobits/sec each) = 1.544Megabit per second = 3 pages per second (~ US$ 1,000.00 per month)

Ethernet (CSMA/CD) = 1 Megabit per second (effective) or 10 Megabit per second (nominal) = 2 pages per second

100 Base T = 100 Megabit Ethernet (usually switched) = 100 Megabits per second = 200 pages per second

Gigabit Ethernet = 1 Gigabit per second = 2 thousand pages per second [http://www.Cisco.com] (best with category 7 cable, works with category 5 cable)

10 Gigabit Ethernet = 10 Gigabits per second = 20 thousand pages per second (OC192 over SONET, Synchronous Optical Network) or STS192 (Synchronous Transport Signal) [http://www.NortelNetworks.com] [http://www.nortelnetworks.com/products/library/collateral/56358.02-05-01.pdf] [http://www.nortelnetworks.com/corporate/news/topnews/2001b/collateral/10_gig_backgrounder.pdf]

OC3 ATM (Optical Carrier, Asynchronous Transfer Mode) = 155 Megabit per second = 300 pages per second (1 1/2 books per second)

OC192 (SONET: Synchronous Optical NETwork fiber) = 10 Gigabit per second = 20,000 pages (2 file cabinets) per second (1,000 books per second)

Dense Wavelength Division Multiplexing (DWDM) with 32 OC192 channels = 320 Gigabits per second = 64 file cabinets per second

Dense Wavelength Division Multiplexing (DWDM) with 80 OC1536 channels = 6.4 Terabits per second = 1,600 file cabinets per second. Announced by Nortel Networks On October 12, 1999: [http://www.NortelNetworks.com/corporate/news/newsreleases/1999d/10_12_9999633_80gigabit.html]

Optical carrier frequency (1,300 nm) (single-mode dark fiber) = 230 THz (TeraHertz) (about 2,000 cycles (baud) are used for every OC1536 bit transmitted)

Optical carrier frequency (1,550 nm) (coaxial dark fiber) = 193 THz (~1 Petabit per second per fiber at 1 byte per baud); see [http://www.Omni-Guide.com]

1 Petabit per second = ~2 billion pages per second = ~200 thousand file cabinets per second = ~10 million books per second (1 Petabit per second is the transmission rate per second per fiber, and Intercity fiber cables often have 144 fibers) See also ITU (International Telecommunications Union) [http://www.ITU.int] TIA (Telecommunications Industry Association) [http://www.TIAonline.org] The Internet Society (ISoc) [http://www.ISoc.org] The Internet Corporation for Assigned Names and Numbers (ICANN) [http://www.ICANN.org] The next Internet: [http://www.Internet2.edu]

Packet switch: 256 Gigabits per second for 384 Gigabit Ethernet ports [http://www.Cisco.com] 192 by 192 Gigabit Ethernet ports, non-blocking (handles full traffic on all ports simultaneously = 500 thousand pages per second. [http://www.cisco.com/warp/public/cc/pd/si/casi/ca6000/prodlit/index.shtml]

Optical switch 2016 x 2016 (1008*2 x 1008*2) nonblocking optical switch (micro-mirrors) of 4,032 DWDM 6.4 Terabit channels (160 OC768 40 GigaBit per second channels) for a switch capacity of 12.8 PetaBits per second. (Each channel requires 1 port in and 1 port out.) [http://www.nortelnetworks.com] [http://www.nortelnetworks.com/products/01/optera/connect/px/index.html] [http://www.nortelnetworks.com/products/library/collateral/56335.02-05-01.pdf] For IP (Internet Protocol) on optics: see [http://www.nortelnetworks.com/products/library/collateral/56023.25-01-01.pdf] For MEMS (micro electro-mechanical systems) technology micro-mirrors see [http://www.omminc.com]

Data Link Nomenclature and Speeds (for Current Optical Cables and Traditional Wire and Coaxial Cables)

1 **Voice Channel** = 64 Kilobits per second (8 thousand 8-bit samples per second) (8 bits = 256 sound levels) (but, effectively 7-bit in the US for 56Kbps)

T1 = 1.544 Megabits per second = 24 voice lines, Trunk Level 1, Developed by Bell Labs in 1957 to eliminate party lines in rural areas.
Also known as (aka) DS-1 (Digital Signal Level 1) (non-optical) Aka Time division multiplexing and as T in the lettered multiplexing system series started with A in 1917. [http://www.dcbnet.com/notes/9611t1.html] and [http://www.dcbnet.com/notes/0103t.html]

T3 = 45 Megabits per second (28 T1 lines)(44.736 Mbs)(Developed in analog for first US nationwide television transmission) Also know as DS-3 (non-optical)

OC1 (Optical Carrier) = 52 Megabits per second

OC3 = 155 Megabits per second (3 times OC1)

OC12 = 622 Megabits per second (12 time OC1)

OC48 = 2.5 Gigabits per second (2,500 Megabits per second) (48 times OC1)

OC192 = 10 Gigabits per second (10Gbase for 10 Gigabit Ethernet)

OC768 = 40 Gigabits per second (6.4 Terabits per second = 160 DWDM 40 Gigabit links)

OC1536 = 80 Gigabits per second (6.4 Terabits per second = 80 DWDM 80 Gigabit links)

100 Gigabit Ethernet: Is poised to replace the OC (Optical Carrier) series in 2006 (projected)

10 Terabit Ethernet: from 10 Gigabit Ethernet, to 100 Gigabit Ethernet, to 1 Terabit Ethernet

Ethernet Timeline

10 Megabit Ethernet	1990*
100 Megabit Ethernet	1995
1 Gigabit Ethernet	1998
10 Gigabit Ethernet	2002
100 Gigabit Ethernet	2006**
1 Terabit Ethernet	2008**
10 Terabit Ethernet	2010**

*Invented 1976, 10BaseT 1990 **projected

Every kind of networking is coming together: LANs (Local Area Networks), SANs (Storage /System Area Networks), MANs (Metropolitan Area Networks) telephony, cable TV, inter-city optical fiber links, etc., but if you don't call it Ethernet you cannot sell it. Your networking must also include a reference to IP (Internet Protocol) to be marketable.

Above 10 Gigabit Ethernet lies 100 Gigabit Ethernet. The fastest commercial bit rate on a fiber transmitter/receiver pair is 80 Gigabits per second. Each Ethernet speed increase must be an order of magnitude (a factor of 10) to be worth the effort to incorporate a change, and 100 Gigabit Ethernet has not been commercially possible with a simple bit multiplexing solution, but NTT has now solved this problem (announced December 4, 2002) and has the first 100 Gigabit per second chip to begin a 100 Gigabit system [http://www.ntt.co.jp/news/news02e/0212/021204.html]. Currently, Nortel Networks offers DWDM (Dense Wavelength Division Multiplexing) where 160 of the 40 Gigabit transmitter/receiver pairs are used to transmit 160 wavelengths (infrared colors) on the same fiber yielding a composite, multi-channel, bandwidth of 6.4 terabits per second.

Because it is now impossible to sell networking unless it is called Ethernet (regardless of the actual protocols used), it is likely that 1 Terabit Ethernet and even 10 Terabit Ethernet (using 100 wavelengths used by 100 gigabit per second transmitter / receiver pairs) may soon be announced. Only a protocol name change is needed. And, the name change is merely the acknowledgement that Ethernet protocols can tunnel through other protocols (such as DWDM) (and vice versa). In fact, Atrica has been advertising such a multiplexed version of 100 Gigabit Ethernet since 2001. [http://www.atrica.com/products/a_8000.html]

Now that NTT has announced a reliable 100 Gigabit per second transmitter/receiver pair, the progression may be 1 wavelength for 100 Gigabit Ethernet, 10 wavelength (10 x 100 Gigabits per second) CWDM (Coarse Wavelength Division Multiplexing) for 1 Terabit Ethernet, and 100 wavelength (100 x 100 Gigabits per second) DWDM for 10 Terabit per second Ethernet in the near future.

iSCSI (Internet SCSI) over Ethernet is replacing: *SCSI (Small Computer Systems Interface, which, in 1979 it was Shugart Associates Systems Interface: *SASI), *FC (Fibre Channel), and even *ATA (IBM PC AT Attachment) aka (also known as) *IDE (Integrated Drive Electronics) for desktop computers. *see [http://www.pcguide.com]. Ethernet is replacing ATM (Asynchronous Transfer Mode), Sonet (Synchronous Optical NETwork), POTS (Plain Old Telephone Service, which is being replaced with Gigabit Ethernet to the home in Grant County, Washington,USA, 1999)[http://www.cisco.com/warp/public/cc/so/neso/efmsol/grant_cp.pdf] [wwp.com], *PCI (Peripheral Component Interconnect local bus), Infiniband [http://www.nwfusion.com/news/2002/1219infiniband.html], and every other protocol, because, as described above, if you don't call it Ethernet you cannot sell it. And, everything, in every type of communications, must now also include a reference to IP (Internet Protocol) for the same reason.

At the same time that the transmitter / receiver pairs are getting faster, and DWMD is adding channels, the capacity of fibers (to carry the analog digital signals that represent the digital analogs of documents) is increasing, as is the transmission distance available without repeaters. Omni-Guide [http://www.omni-guide.com/Pages/mission.html] is working on fibers that "could substantially reduce or even eliminate the need for amplifiers in optical networks. Secondly it will offer a bandwidth capacity that could potentially be several orders of magnitude greater than conventional single-mode optical fibers". Eliminating amplifiers greatly reduces the cost of fiber optic cables (and reduces maintenance costs, especially when the cables are under the ocean). If today's cables can carry 10 Gigabits per second easily and 100 Gigabits to about 10 terabits per second with CWDM and DWDM, then "a bandwidth capacity that could potentially be several orders of magnitude greater" (Omni-Guide, above) could mean fiber optic transmission rates from 100 Gigabits per second to 1 Petabit per second (1 Petabit per second is 10**15 bits per second and is 10**5 times the speed of a 10 Gigabit link and 10**3 times the speed of a 1 Terabit link). The 1.3 micron wavelength used in communications has a frequency of about 230 TeraHertz. At one bit per baud (transition through zero, eponymous for Emile Baudot) this would support a theoretical maximum data rate of 230 Terabits per second. At 8 bits per baud (256 detectable light levels) (256 = 2**8) this would be 1.84 Petabits per second. And, a 56 kilobit per second modem achieves over 16 bits per baud on a 3 kilohertz voice grade line.