

Lecture 10: Ethernet Standards and Ethernet Wiring

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EE426: Communication Networks

Classical Ethernet (10 Mbps)

- Classical Ethernet (e.g., 10Base-5 thick coaxial, 10Base-2 thin coaxial, 10Base-T twisted pair) is mostly obsolete .
- Common standards nowadays are Fast Ethernet and Gigabit Ethernet (GbE).
- Classical Ethernet used Manchester encoding.
- *Advantage:* Self-clocking code for any sequence of 1's and 0's, which allows the PLL at the receiver to work properly at all times (after preamble).
- *Disadvantage:* Bandwidth = $2f_0 = 2 \times 10 = 20$ MHz.
- Fast Ethernet and Gigabit Ethernet do NOT use Manchester encoding since they would then require a bandwidth of 200 MHz and 2000 GHz, respectively.

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Fast Ethernet (100 Mbps)

- Fast Ethernet was standardized as **IEEE 802.3u**.
- Approved by IEEE in 1995 as an addendum to the IEEE 802.3 standard.
- Fast Ethernet is backwards compatible with Classical Ethernet: Uses the same frame format (with minimum and maximum frame lengths), same 48-bit MAC address structure and same CSMA/CD rules.
- The main difference is that bit time is reduced from 100 ns to 10 ns.
- In Fast Ethernet, only twisted pairs and optical fibers are allowed (not coaxial cable).
- Half-duplex (with hubs) and full-duplex (with switches) modes are possible.



Main Variants of Fast Ethernet

Name	Cable	Max. Segment	Comments
100 Base-TX	UTP (CAT 5)	100 m	Half-duplex or Full-duplex
100 Base-FX	Fiber optics	2000 m	Full-duplex only; long runs

- CAT 5 (Category 5) cable has 4 pairs (8 wires) of copper. Replaces the older CAT 3 cables.
- Each pair in CAT 5 can carry a bandwidth of about 125 MHz for about 100 m distance.
- To send bits on 100 Base-TX:
 - 4B/5B followed by MLT-3 line encoding.
 - As an example of 4B/5B encoding, let us encode the data stream 0111010000100000.

4B/5B Encoding

	0	1	2	3	4	5	6	7
4-bit Nibble	0000	0001	0010	0011	0100	0101	0110	0111
5-bit Code	11110	01001	10100	10101	01010	01011	01110	01111
	8	9	10	11	12	13	14	15
4-bit Nibble	1000	1001	1010	1011	1100	1101	1110	1111
5-bit Code	10010	10011	10110	10111	11010	11011	11100	11101

Data stream: **0 1 1 1 0 1 0 0 0 0 1 0 0 0 0 0**

4 bit nibbles: 0111 0100 0010 0000

5-bit stream: 01111 01010 10100 11110

- Avoids a long sequence of consecutive 0's in MLT-3.
- Bandwidth = $0.9 \times f_0 = 0.9 \times 5/4 \times 100 = 112.5$ MHz

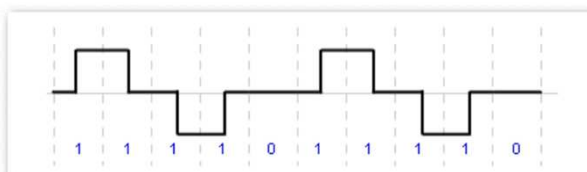
4B/5B Encoding

Data			Data			Control character	5-bit symbols	Purpose
(Hex)	(4-bit Nibble)	5-bit code	(Hex)	(4-bit Nibble)	5-bit code			
0	0000	11110	8	1000	10010	JK	11000 10001	Sync, Start delimiter
1	0001	01001	9	1001	10011	I	11111	100BASE-X idle marker
2	0010	10100	A	1010	10110	TR	01101 00111	100BASE-X end delimiter
3	0011	10101	B	1011	10111	HH	00100 00100	HDLC0
4	0100	01010	C	1100	11010	HI	00100 11111	HDLC1
5	0101	01011	D	1101	11011	HQ	00100 00000	HDLC2
6	0110	01110	E	1110	11100	RR	00111 00111	HDLC3
7	0111	01111	F	1111	11101	RS	00111 11001	HDLC4
						QH	00000 00100	HDLC5

4B/5B encoding with MLT-3

- When applying 4B/5B encoding before MLT-3, we ensure transitions occur even when a long series of 0's are sent.
- As an example let us encode the data stream 00000000.

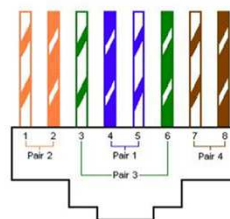
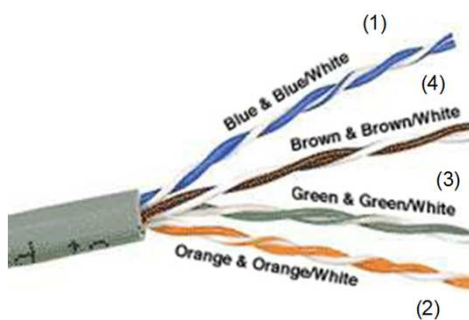
Data stream:	0 0 0 0 0 0 0 0
4 bit nibbles:	0000 0000
4B/5B Stream:	11110 11110
MLT-3 Stream:	+0-00 +0-00



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100Base-TX Wiring



Standard EIA/TIA T568B Wiring Diagram

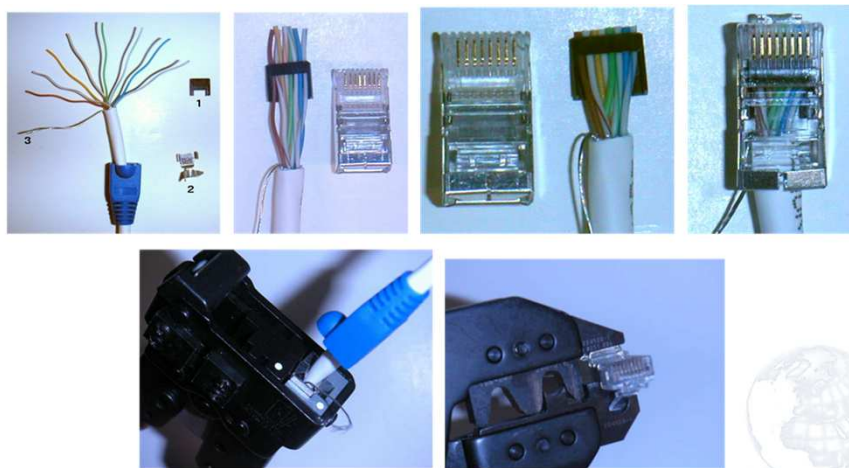
RJ-45 Connector



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How to create a CAT-5 Cable (straight-through or crossover)



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What you need...



RJ45 Crimper



CAT-5 Tester

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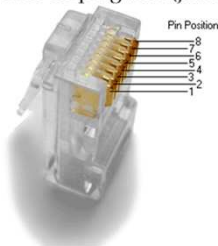
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Ethernet Ports and Cables

- An Ethernet **Cable** can be:
 - Straight-Through (or Patch) cable.
 - Crossover cable.
- An Ethernet **Port** can be:
 - Uplink Port (TX on 1 & 2)
(sometimes called WAN port).
 - Normal Port (TX on 3 & 6)
(sometimes called LAN port).



Pins on plug face (jack is reversed)

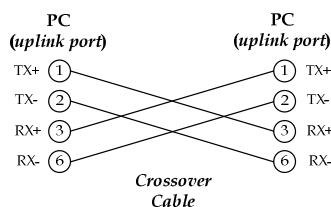
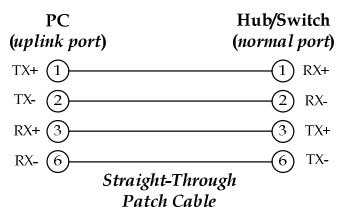


Uplink Port

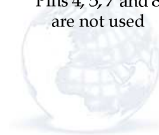
- TX+ (1)
- TX- (2)
- RX+ (3)
- RX- (6)

Normal Port

- (1) RX+
- (2) RX-
- (3) TX+
- (6) TX-




Note:
Pins 4, 5, 7 and 8
are not used




Ethernet Ports

PC/ Laptop




Uplink port

**Modem
ADSL, Cable, etc**




Normal port

Switch




Uplink port **Normal ports**

Hub

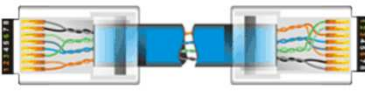


Normal ports

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Pin number	Wire Color	Straight-Through		Pin number	Wire Color
Pin 1 ==>	Orange/White	Wire	Becomes	Pin 1 ==>	Orange/White
Pin 2 ==>	Orange	1	→ 1	Pin 2 ==>	Orange
Pin 3 ==>	Green/White	2	→ 2	Pin 3 ==>	Green/White
Pin 4 ==>	Blue	3	→ 3	Pin 4 ==>	Blue
Pin 5 ==>	Blue/White	6	→ 6	Pin 5 ==>	Blue/White
Pin 6 ==>	Green			Pin 6 ==>	Green
Pin 7 ==>	Brown/White			Pin 7 ==>	Brown/White
Pin 8 ==>	Brown			Pin 8 ==>	Brown

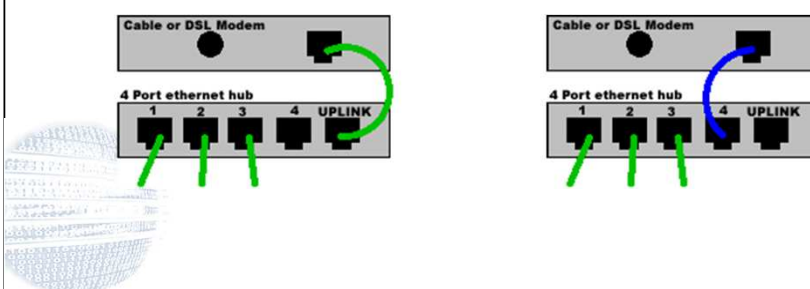


Pin number	Wire Color	Crossed-Over		Pin number	Wire Color
Pin 1 ==>	Orange/White	Wire	Becomes	Pin 1 ==>	Green/White
Pin 2 ==>	Orange	1	→ 3	Pin 2 ==>	Green
Pin 3 ==>	Green/White	2	→ 6	Pin 3 ==>	Orange/White
Pin 4 ==>	Blue	3	→ 1	Pin 4 ==>	Blue
Pin 5 ==>	Blue/White	6	→ 2	Pin 5 ==>	Blue/White
Pin 6 ==>	Green			Pin 6 ==>	Orange
Pin 7 ==>	Brown/White			Pin 7 ==>	Brown/White
Pin 8 ==>	Brown			Pin 8 ==>	Brown

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Ethernet Connections

- Exercise 1: What type of cable do you use to connect a normal port of a switch to a normal port of another switch or router?
- Exercise 2:



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Advanced Switch Ports

- **Auto-sensing:** Automatically sense (negotiate) data rate (100 or 1000 Mbps, etc).
- **Auto-configure:** Automatically negotiate duplexity (half- or full-duplex) using a short circuit in the port (called *loopback*).
- **Auto-uplink:** Automatically adjust the port into normal or uplink port, using built-in analog switches. Also called Auto-MDIX (MDIX: media-dependent interface crossed).

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Exercises

- Modem to a PC/Laptop?
- PC to an Ethernet switch?
- Modem to an Ethernet switch?
- Ethernet core switch to aggregation switch?
- Ethernet core router to aggregation switch?
- PC to PC (If Auto-uplink on at least one of them? If no Auto-uplink but Autoconfig on both? If no Auto-uplink and no Autoconfig)?
- PC to an Ethernet Hub?

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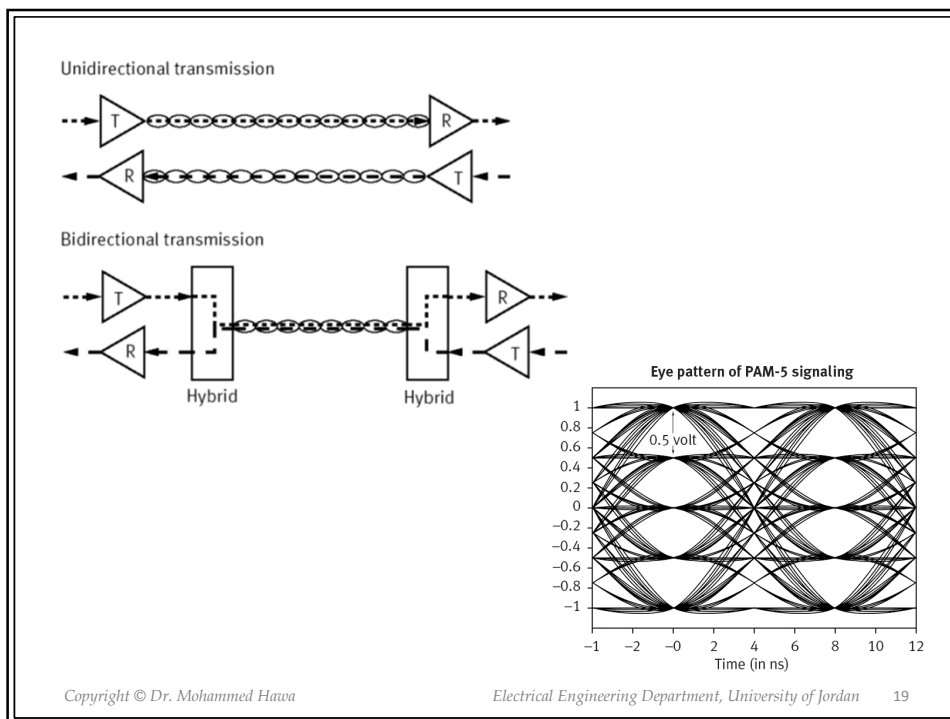
Gigabit Ethernet (GbE) (1000 Mbps or 1 Gbps)

- Gigabit Ethernet was standardized as IEEE 802.3z.
- Ratified by IEEE in 1998.
- Backwards compatible with previous Ethernet standards.
- 1000Base-T is IEEE 802.3ab.

Name	Cable	Max. Segment	Comments
1000 Base-T	UTP	100 m	Deployed CAT 5e or CAT 6 UTP.
1000 Base-SX	Fiber optics	550 m	Multimode fiber.
1000 Base-LX	Fiber optics	5 km	Single or Multimode fiber.
1000 Base-LH	Fiber optics	10 km	Single mode fiber.

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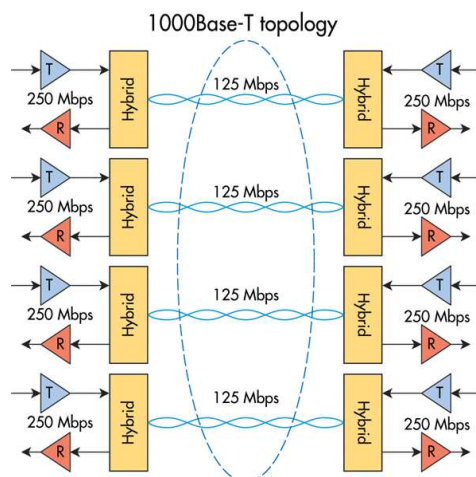
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1000Base-T Encoding

- Uses 8B1Q4 (8-bit to 1 four quinary “five” symbol) combined with 4D-PAM5 (Four-dimensional Pulse Amplitude Modulation 5-levels) encoding method.
- 8B1Q4: divide each group of 8 bits into four 2-bit groups. Each 2-bit group is converted to a 3-bit group to allow for forward error correction. Each 3-bit group is called a quinary symbol.
- The quinary symbols are then line encoded using 4D-PAM5, where each 3-bit group is mapped into one of five possible voltage levels through a non-trivial linear feedback shift register. The mapping varies continuously during transmission. Four symbols are transmitted in parallel in each symbol period.
- A total of 125 Msymbols (4D-PAM5 symbols) is sent per second over the four pairs. This translates into a total of 8 bits per symbol \times 125 Msymbol/s = 1000 Mbps for the cable.

1000Base-T



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10 Gigabit Ethernet (10GbE)

The following three varieties use the LAN PHY:

Name	Max. Segment	Comments
10GBASE-SR	26 m - 82 m	Short Range over deployed multi-mode fiber.
10GBASE-LR	10 km	Long Range over single-mode fiber (1310 nm).
10GBASE-ER	40 km - 80 km	Extended Range over single-mode fiber (1550 nm).

The following use the WAN PHY, designed to interoperate with OC-192/STM-64 SDH/SONET equipment using a light-weight SDH/SONET frame.

Name	Max. Segment	Comments
10GBASE-SW	26 m - 82 m	Short Range over deployed multi-mode fiber.
10GBASE-LW	10 km	Long Range over single-mode fiber (1310 nm).
10GBASE-EW	40 km - 80 km	Extended Range over single-mode fiber (1550 nm).

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10GBASE-T (IEEE 802.3an)

- IEEE 802.3an was released in 2006.
- 10 Gbps over UTP or STP cables over distances up to 100 m.
- Uses Cat-6A (or CAT-7) cable, or 55 m with older Cat-6 cables.
- Encoding: Tomlinson-Harashima precoded (THP) version of pulse-amplitude modulation with 16 discrete levels (PAM-16), encoded in a two-dimensional checkerboard pattern known as DSQ128 (Double Square 128).
- Powerful low-density parity-check (LDPC) linear error correcting code.
- The IEEE 802.3bm standard, released in 2015, defines 100G/40G Ethernet for optical fiber.
- The IEEE 802.3bs standard (December 2017) introduces 200GbE (200 Gbit/s) over single-mode fiber and 400GbE (400 Gbit/s) over optical physical media.



Upgrading your Infrastructure

