7. Physical Layer

7.1 Role

The role of the physical layer is to provide the physical connection between two hosts by a medium and to convert a bit stream of data into a transmittable signal.

medium	signal used
copper	voltage
air or vacuum	electromagnetic wave
optical fiber	light

7.2 Cable types

Project:

Contribute to http://wiki.lte.lu/wiki/Netzwerkkabeltypen by writing a section over one of the following cable types.

twisted pair UTP

twisted pair STP

twisted pair F/STP

Lichtwellenleiter (Stufenindexfaser)

Lichtwellenleiter (Monomodefaser)

Koaxialkabel

Hohlleiter

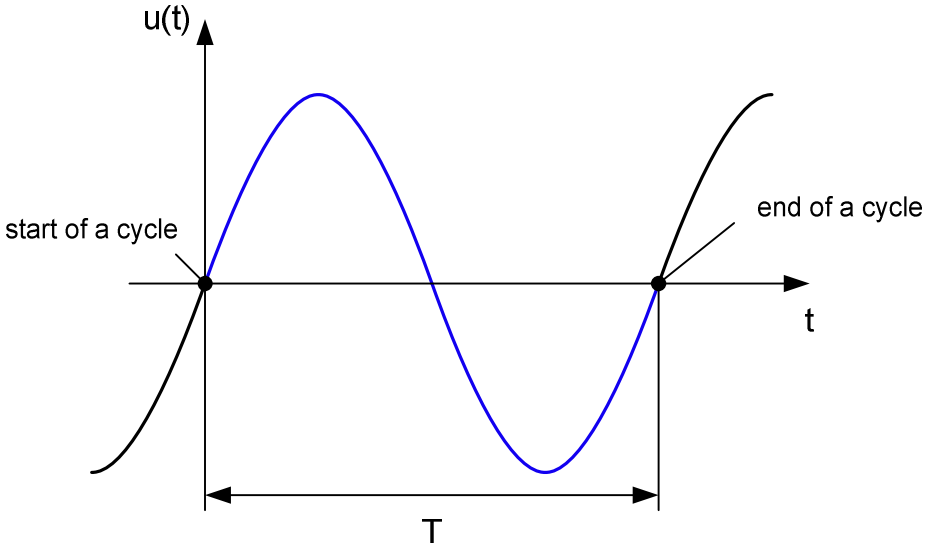
Present your cable type in a week with the help of your wiki. Conditions:

- max. 5 min.
- language: english, german or french
- show structure of the cable (deut: Aufbau des Kabels)
- give indications about the maximum frequency or minimal wavelength of the cable
- give indications about the bandwidth of the cable
- indicate your sources of information
- bring a sample of the cable

7.3 Frequency, bandwidth and throughput

7.3.1 Frequency

The frequency of a signal is the number of repetitions per second. The most basic signal a medium can transport is a sinusoidal signal.



The part of the signal that always repeats is called *cycle*. The time a cycle needs to develop is called *cycle duration T*.

The frequency of a signal can be calculated from the cycle duration as follows:

$$f = \frac{1}{T}$$

f is the frequency in Hertz (Hz)
T is the cycle duration in seconds (s)

Exercise 1:

a) Calculate the frequency of a signal with cycle duration of 2ns.
   ns = nanoseconds = 10^{-9} s
b) Calculate the cycle duration of a signal with a frequency of 5MHz.
   MHz = megahertz = 10^{6} Hz

7.3.2 Bandwidth

In computing the bandwidth is the maximum number of bits that can be transported per second over a certain cable or through a certain medium.

Every cable and every medium has a maximal frequency it can transmit. There is a relation between the maximum frequency and the bandwidth.

The higher the maximum frequency on a cable is, the higher the bandwidth will be.

Note:

In electrics the bandwidth is the difference between the highest and the lowest frequency a line can transmit.

7.3.3 Throughput

The bandwidth is a theoretical maximum that cannot be reached in reality. The throughput is the net data transfer rate that can be reached with a certain protocol. The throughput is also measured in bit/s. Due to additional information (headers & trailers) that needs to be added to the data the throughput will always be lower than the bandwidth.

Exercise 2:

A file with a size of 2GByte is transferred over a line with a throughput of 80Mbit/s. Calculate the time the transmission will take.

7.4 Wavelenght

The frequency of light is so high that we hardly have words for it. Therefore, we mostly talk of the wavelength of a certain color instead of its frequency. The relation between the wavelength and the frequency of light is:

$$\lambda = \frac{C}{f}$$

λ is the wavelength in meters (m)
c is the speed of light in meters per second (m/s)
f is the frequency in Hertz (Hz)

Exercise 3:

Calculate the frequency of a laser with a wavelength of 632,8 nm.

7.5 Ethernet standards

Ethernet is a family of standard that define both the Layer 2 protocols and the Layer 1 technologies. Ethernet is the most widely used wire based LAN technology and supports transmission speed of 10, 100, 1000, or 10.000 Mbps.

Examples of Ethernet standards and characteristics:

standard	speed	cable	Conector	maximum length
10Base-T	10 Mbit/s	4 twisted pair min. cat. 3	RJ-45	100m
100Base-TX	100 Mbit/s	4 twisted pair min. cat. 5	RJ-45	100m
1000Base-T	1000 Mbit/s	4 twisted pair min. cat. 5	RJ-45	100m
10GBase-T	10.000 Mbit/s	4 twisted pair min. cat. 6	RJ-45	100m

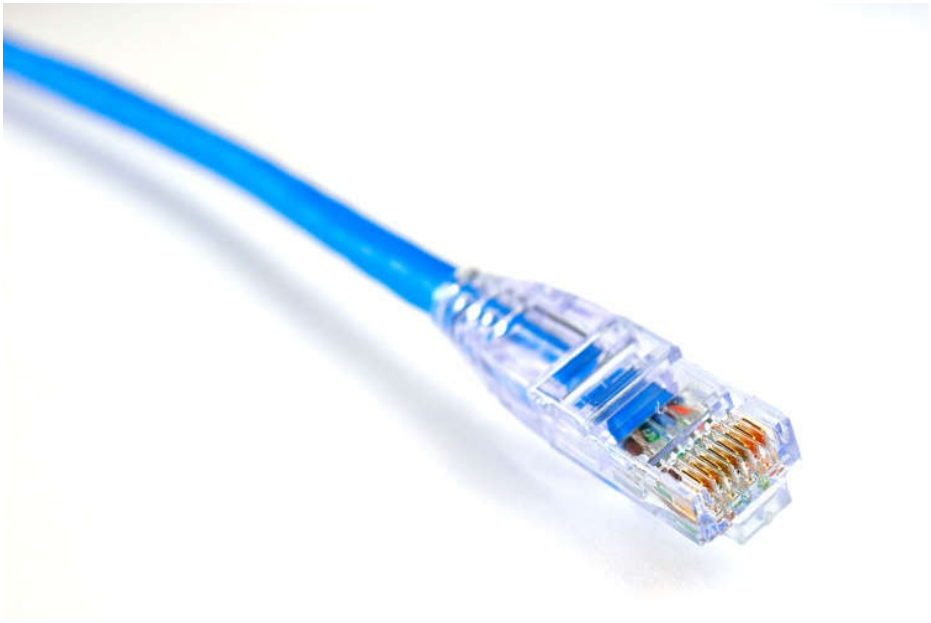
7.6 Layer 1 in the Ethernet standards

The layer 1 is called the physical layer. This layer defines the means of transmitting raw bits rather than logical data packets. Some of the points defined in the physical layer are:

- connector, cable and wiring
- voltage levels
- signal type

7.6.1 The Ethernet connectors

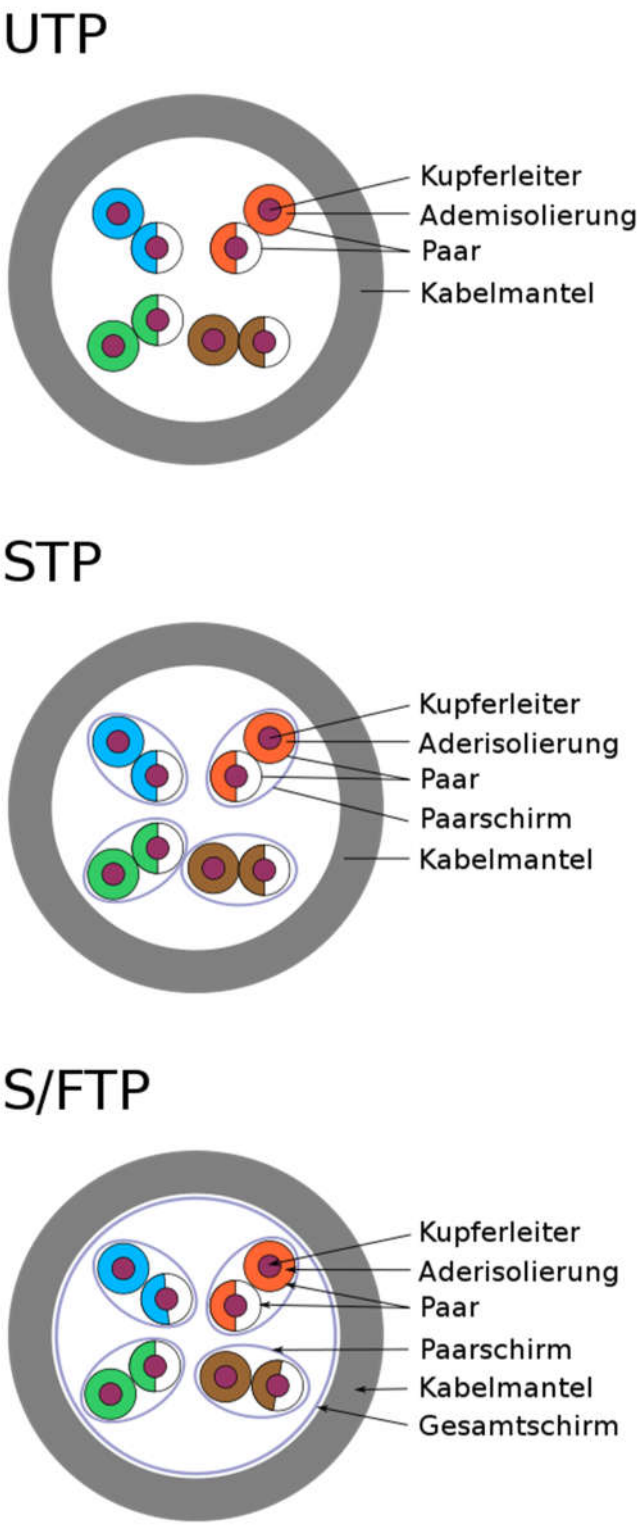
RJ45 connectors can be used up to frequencies of 500MHz. This corresponds to category 6a cables.



For frequencies higher than 500 MHz another connector must be used, for example a *GG45 connector*.

7.6.2 The Ethernet cables

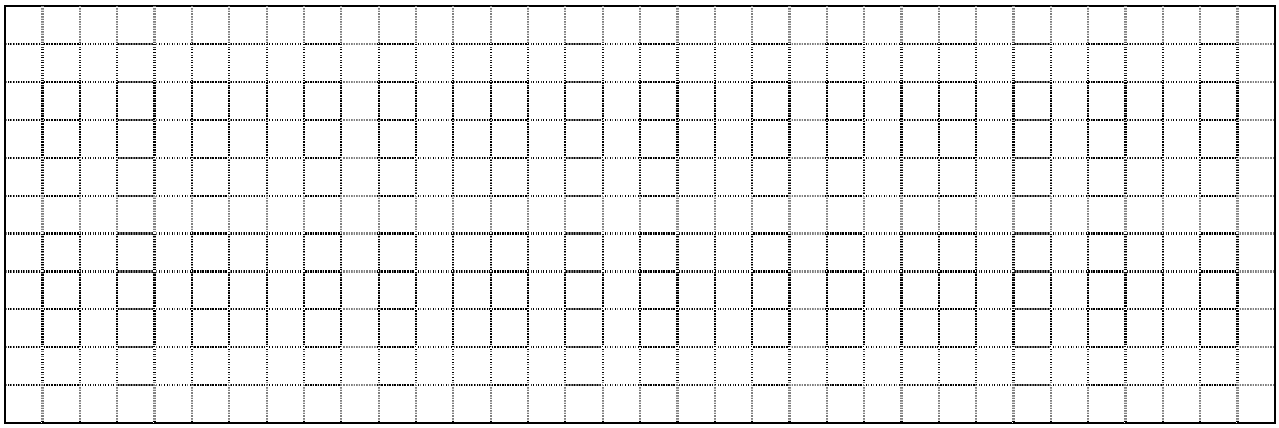
The current Ethernet standards know 3 *types of cables.* All consists of 4 twisted pairs. Twisting the pairs is done in order to eliminate crosstalk (deut.: Übersprechen) and any other type of interference the cable might pick up from nearby electrical sources.



Categories of cables:

name	type	maximum frequency	application
Cat1	UTP	0,4 MHz	Telefon- und Modem-Leitungen
Cat2	UTP	4 MHz	Ältere Terminalsysteme, z. B. IBM 3270
Cat3	UTP	16 MHz	10BASE-T and 100BASE-T4 Ethernet
Cat4	UTP	20 MHz	16 Mbit/s Token Ring
Cat5	UTP	100 MHz	100BASE-TX & 1000BASE-T Ethernet
Cat5e	UTP	100 MHz	100BASE-TX & 1000BASE-T Ethernet
Cat6	UTP	250 MHz	10GBASE-TEthernet
Cat6a	STP	500 MHz	10GBASE-TEthernet
Cat7	STP	600 MHz	10GBASE-TEthernet
Cat7a	STP	1000 MHz	10GBASE-TEthernet
Cat7	S/FTP	600 MHz	Telefon, CCTV, 1000BASE-TX über dasselbe Kabel. 10GBASE-T Ethernet.
Cat7a	S/FTP	1000 MHz	Telefon, CATV, 1000BASE-TX über dasselbe Kabel. 10GBASE-TEthernet.
Cat8	S/FTP	1600 MHz – 2000 MHz	Telefon, PoE, 40GBASE-TEthernet.

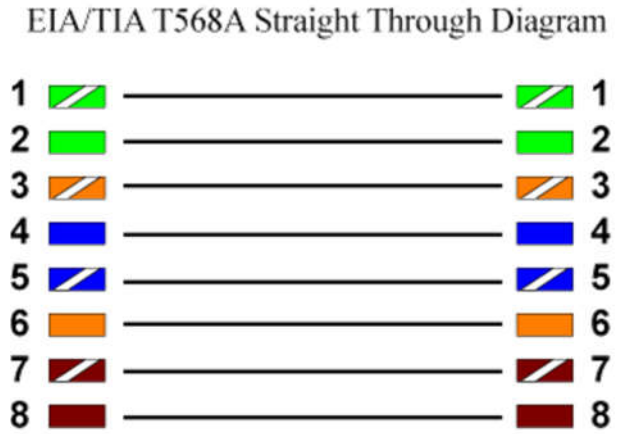
Relation between maximum frequency and bandwidth:



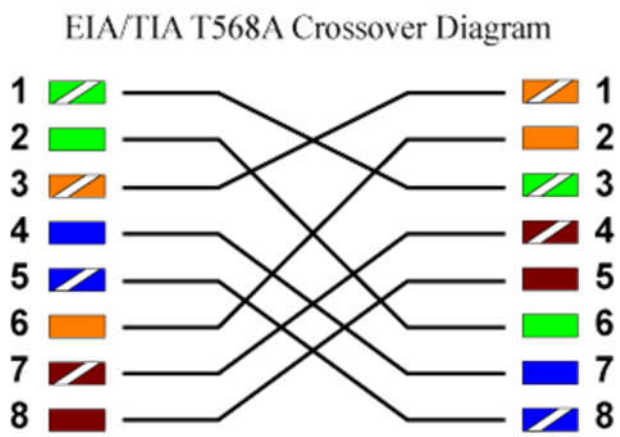
7.6.3 Wiring the RJ45 connector

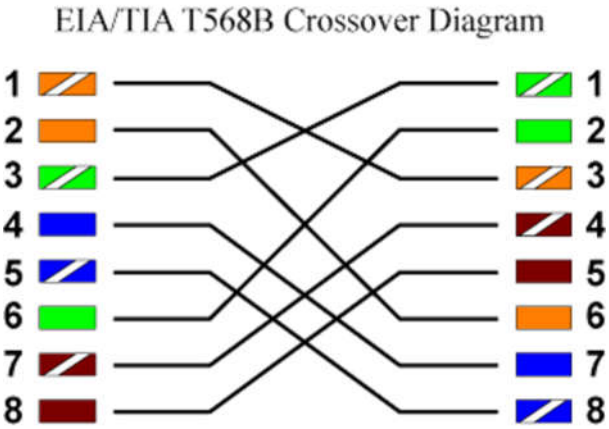
There are two standards for RJ45 connector wiring:

T568A

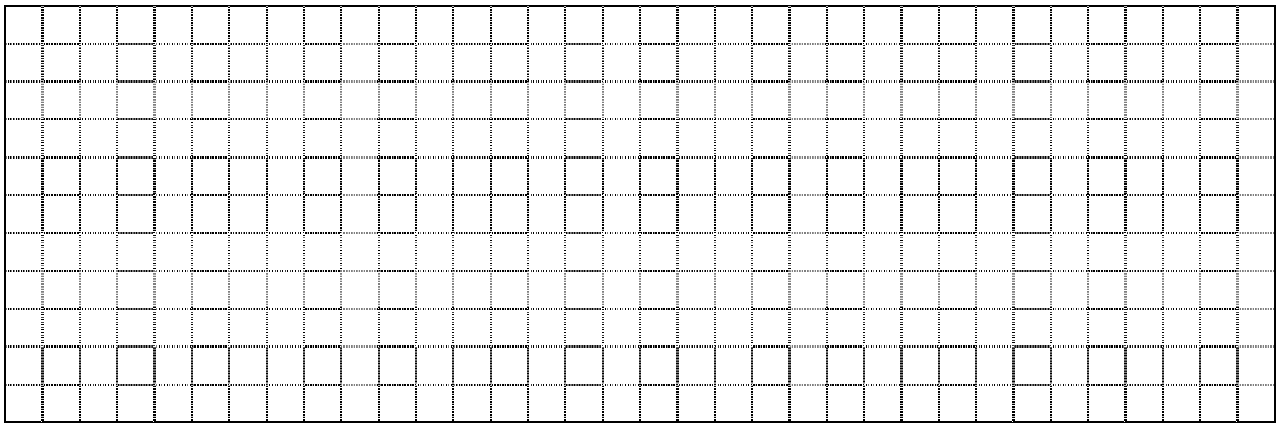


T568B (most commonly used)





Use of crossover cables:

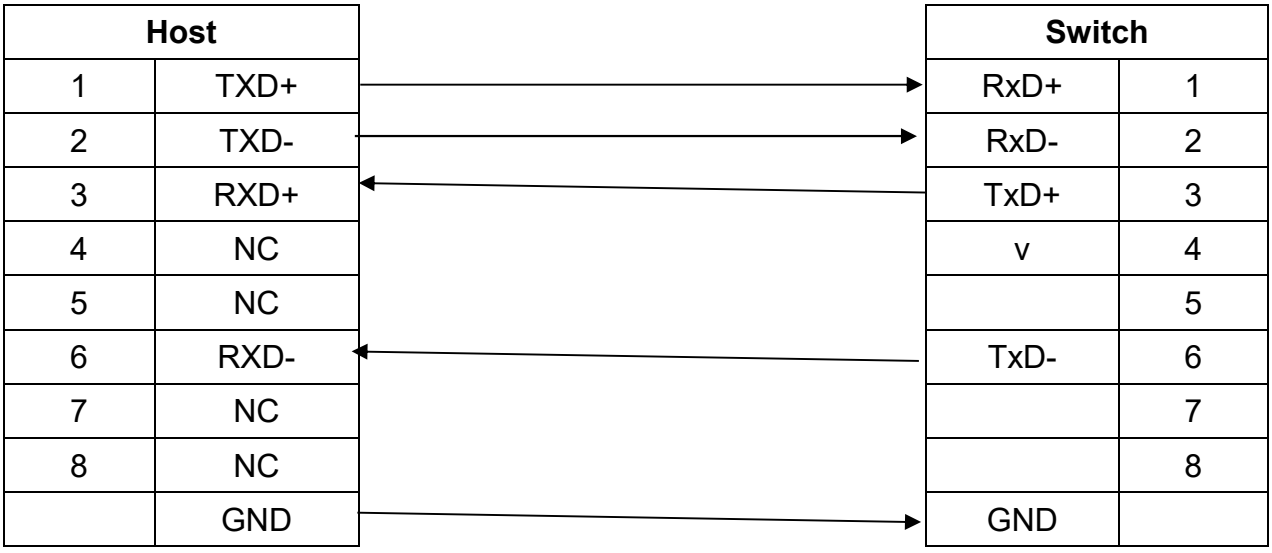


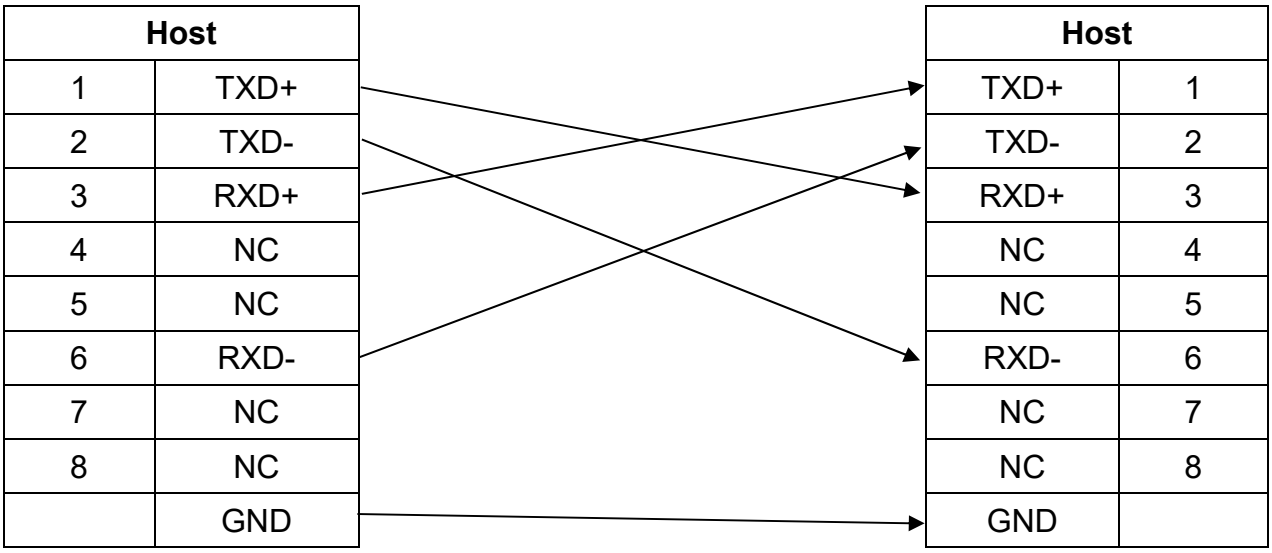
7.6.4 Signals in 100Base-TX

In the 100Base-TX standard only 2 of the 4 twisted pairs are used. On a host pin 1 and 2 are used to transmit and pin 3 and 6 are used to receive data.

Exercise 4:

Complete the following drawings with the pin numbers, signals and connections:





Switch	
1	
2	
3	
4	
5	
6	
7	
8	
	GND

Switch	
	1
	2
	3
	4
	5
	6
	7
	8
GND	

7.6.5 Auto MDI-X

Auto MDI-X is a functionality where hosts detect automatically if pins have to be crossed or not. This makes cross cable obsolete.

7.6.6 Signals in 1000Base-T

1000Base-T uses all 4 twisted pairs for *bidirectional transmission*. As a consequence of the bidirectional transmission 1000Base-T doesn't need crossover cables.

Host	
1	BI_DA+
2	BI_DA-
3	BI_DB+
4	BI_DC+
5	BI_DC-
6	BI_DB-
7	BI_DD+
8	BI_DD-
	GND

Switch	
BI_DA+	1
BI_DA-	2
BI_DB+	3
BI_DC+	4
BI_DC-	5
BI_DB-	6
BI_DD+	7
BI_DD-	8
GND	