Practical Exercises in Computer Networks

CSMA Ethernet network deployment with 10BASE-T hubs (WIP)

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So far, among other things, we have learned the basic network configuration commands and the UDP Java network programming APIs; in this lab we aim to setup and deploy the simplest network, a CSMA Ethernet network based on HUBs. This LAB assumes that the students already have taken up Ethernet as in the initial paragraphs of textbook section 2.6 (Ethernet and Multiple Access Networks).

Transmission media and basic LAN equipment

Different transmission media are used in the various types of networks in use today. In this LAB we will study a few of them, the most relevant to Local Area Networks (LAN). Recall that the LAN, MAN, and WAN classification of computer networks is somewhat arbitrary but very useful for us now. LANs are networks which geographical extent is around 1 Km, but, depending on the specific LAN technology used, LANs, today can cover very large geographical areas. The technology that we are going to study in this chapter is Ethernet in its most basic form, for, in today's networks the level of sophistication and performance of Ethernet are very high.

The LANs in our laboratory use copper cables, optical fibers and radio as transmission media. In this LAB exercise we will cover only wired media, specifically we will use either structured twisted-pair cables (TP) or coaxial cables, most of the time we will use TP. A twisted-pair cable contains 8 pairs of stranded copper wires all of them confined into a soft plastic tube, the electrical properties of these cables turn them in an excellent transmission medium which can support very high data rates: 1Gbps (Gigabit Ethernet) can be transmitted over those cables if they comply with 5e category, for example.

The original Ethernets originally used coaxial cables of different thicknesses for transmission, data rates at that time were around the 10Mbps. The coaxial cabling was difficult to install and manage due to its mechanical properties and subject to accidental damage which in many cases could divide a network into two disconnected segments. Eventually the TP technologies won and, today we can state that coaxial-cabling is not used at all. It is necessary to stress the idea that coaxial and TP technologies were shared among all network hosts, that, for this LAB we will use only shared media and will not use any switched media or equipment.

One of the most acute problems of the coaxial cable, as we mentioned before, is that if the cable is cut, then, the LAN gets divided into two disconnected segments. The first step in solving this problem came when coaxial-cable LANS were migrated to concentrator-based TP (Concentrators are normally known as Hubs in English). This solution implied a change in the LAN topology from the bus topology (Coaxial) to the star topology (Hub).

Hubs somewhat stand in a sort of topological center in the LAN: every host has a direct connection to it by means of a TP structured cable, thereby avoiding the division of the LAN into two disconnected segments in case the cable suffered some damage. With a hub, if one cable suffers some damage or a cut, the intervening host will be disconnected from the network, but the rest of them will continue to operate normally. Observe that the hub-based star topology still constitutes a shared medium, actually we can imagine the hub as sort of electronic cable that repeats and amplifies the *digital* signal received on any one of its ports. This is the technology that we will use in this lab.

The Ethernet hub technology 10BASE-T best resembles that of the coax-cable original Ethernet that is explained in the textbook (Section 2.3, pg. 119 on ed. 5 of the textbook). We must highlight that the access protocol (CSMA/CD) for the original 10Mbps Ethernet based on thin coaxial cable is exactly the same as that for TP structured cabling. One of the differences between coax and TP electronics is the signaling and encoding, in coax, Manchester is used, in TP 10BASE-T, differential Manchester is used, in 100BASE-TX 4B/5B encoding is used alongside with NRZI signaling. It's important to highlight that the same CSMA/CD access protocol is used in 10-BASE-T as in the old coax-based 10-BASE-5 (Thick coaxial cable) and 10-BASE-2 (Thin coaxial cable), therefore, the textbook discussion of CSMA/CD applies in our experiments with 10BASE-T hubs.

In our short review of transmission media, we will not cover optical fibers, we leave this for when we take up Ethernet Switching and LAN switches with fiber uplinks or even Optical Switching in ch. 3.

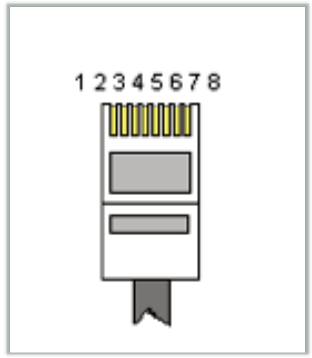
Twisted-pair cables

TP cables come in a variety of qualities tha we summarize in the following table. The connectors used with the TP cables are normally of the RJ-45 type and surprisingly, those used for CAT 6 for GBe (Gigabit Ethernet over copper, 1000BASE-T) have a gold coating around the physical conductor pins.

TP technology name	Max nominal bandwidth	Comments
STP		· Shielded Twisted Pair Cable · Has a wrapping shielding that provides better noise immunity
UTP		· Unshielded Twisted Pair · No wrapping shielding
CAT 3	30 Mbps	
CAT 5	100Mbps	
CAT 5e	100Mbps, up to 1000Mbps	
CAT 6	1000 Mbps	

Physical transmission media

- Twisted Pair cables (Copper)
  - Inexpensive
  - Between 10 y 1000 Mbps
  - STP (Shielded Twisted Pair)
  - UTP (Unshielded)
  - Categories:
    - Cat 3 (30 Mbps)
    - Cat 5 (100 Mbps)
    - Cat 5 (100 Mbps or 1 Gbps at limited distance)
    - Cat 6 (1 Gbps)



RJ-45 connector, male

Exercise 1. In this exercise you are asked to connect your two computer hosts *directly, i.e.,* without a hub or other lan equipment; depending on the capabilities of the involved NIC (Network Interface Cards), you will have to build a *cross-over* TP cable. The NICs of today, contain electronics that is capable of automatically crossing the TD/RD pins (The name of this technology is MDI-X), thereby avoiding the need to use a crossover cable for connecting two host NICs. If using a common TP cable doesn't provide the needed connection between the two hosts, then, you will have to use a crossover cable or build it. For the time being, use a common TP cable, assuming that your NIC's electronics does support MDI-X. Checking that the connection is successful consists of observing the activity LEDs at each NIC: if they light, that indicates the connection is functional.

a) Assuming your physical link is successfully established, configure the NICs so that you can check TCP/IP is also operational. Use the ifconfig command before the connection has been carried out, what state is the interface in (UP/DOWN, RUNNING)?

b) Now, connect both computers. Again, use the ifconfig command. What state is the interface in now (UP/DOWN, RUNNING)?

c) Since we are connecting two hosts directly, we can assume that the hosts won't be able to contact a DHCP server for fetching their IP addresses, then, we need to configure those IPs manually. Build an ifconfig that applies the following IP parameters (Consult the man page or search the Internet for "Ubuntu ifconfig", for example:

IP address:	192.168.0.10 on host no. 1 and 192.168.0.20 on host no. 2
IP mask:	255.255.255.0

d) Check that the interface is UP and RUNNING, now, after the physical connection is operational and IP parameters have been successfully applied

e) Check TCP/IP is operational

In a host-hub connection the 4-pair cable connection is built by connecting hub pins to host pins with equal numbers. In this case, the hub, internally routes the TD pins to the RD pins; by contrast, If you want to connect *two hosts* by using a TP cable, you will have to provide the crossing yourself by connecting the TD (Transmit Data) pins to the RD (Receive Data) pins and conversely. Take care not to flip the polarities in each case. Use the cabling diagrams that follow for establishing your strategy and write it down on your notes. *If you want* to use the standard wire color assignment, consult EIA standard T568A and B (Simply search the Internet for "T568A").

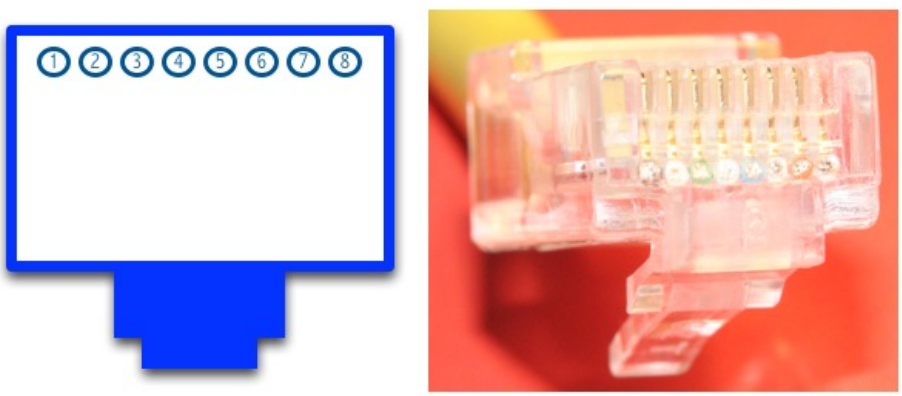


Fig. x. RJ-45 connector pin numbers (Front side)

Pin number	Signal name and polarity
1	TD+ (Transmit Data, polarity +)
2	TD-
3	RD+ (Receive Data, polarity +)
4	Not used in 10BASE-T
5	Not used
6	RD-
7	Not used
8	Not used

Table. x. RJ-45 connector pin numbers and signal functions

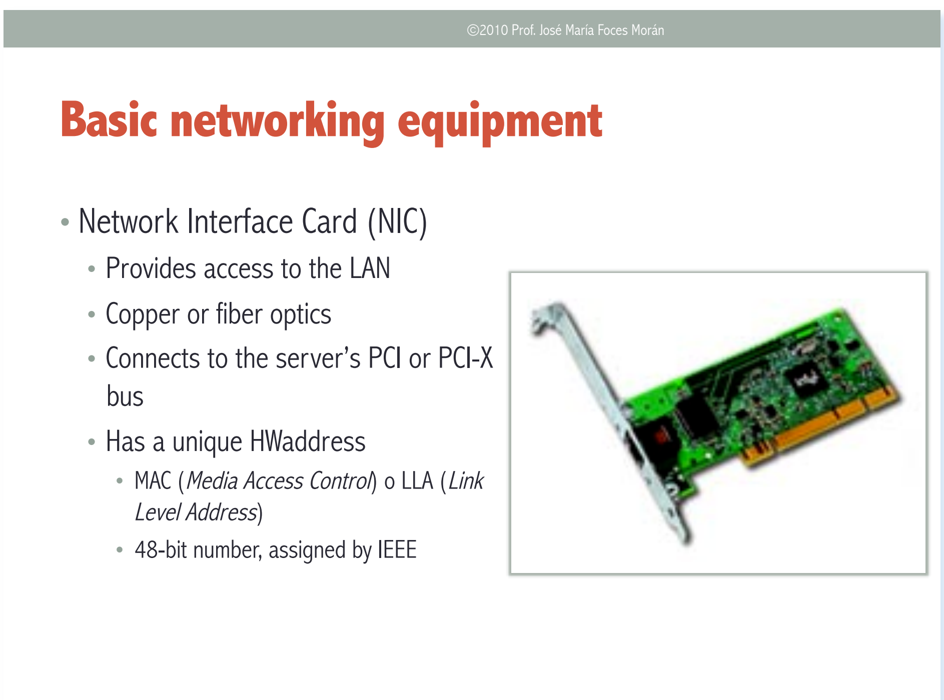
Today's network interface electronics is intelligent enough to determine whether it is necessary to crossover or not, depending on whether we are connecting a host to the LAN equipment (Ethernet switch) or we are connecting a host interface to another host interface. In conclusion, with the appropriate NIC, you can use the TP cable that connects it to a switch in a host-to-host connection with no intervention on your part. Next section explores more technical detail of common NICs today.

Exercise 2. The laboratory instructor will build a fully functional CAT 5e cable along with the two RJ-45 connectors; follow their instructions, observe how they use the crimping tool. Every student team must test their cable with their computers and their assigned hub.

Network Adapters

In Lab 1 we introduced the Network Interface Adapters that are connected to the backplane bus of a system for providing LAN connectivity. In today's computers these devices are part of the machine's chipset and are normally installed on the motherboard; more powerful systems such as internet servers usually include several NICs (Network Interface Cards). The NIC is connected to one of the PCI or PCI-X slots and provides Fast Ethernet or Gigabit Ethernet (GBe) connectivity via a RJ-45 connector if the GBe technology is 1000-BASE-T.

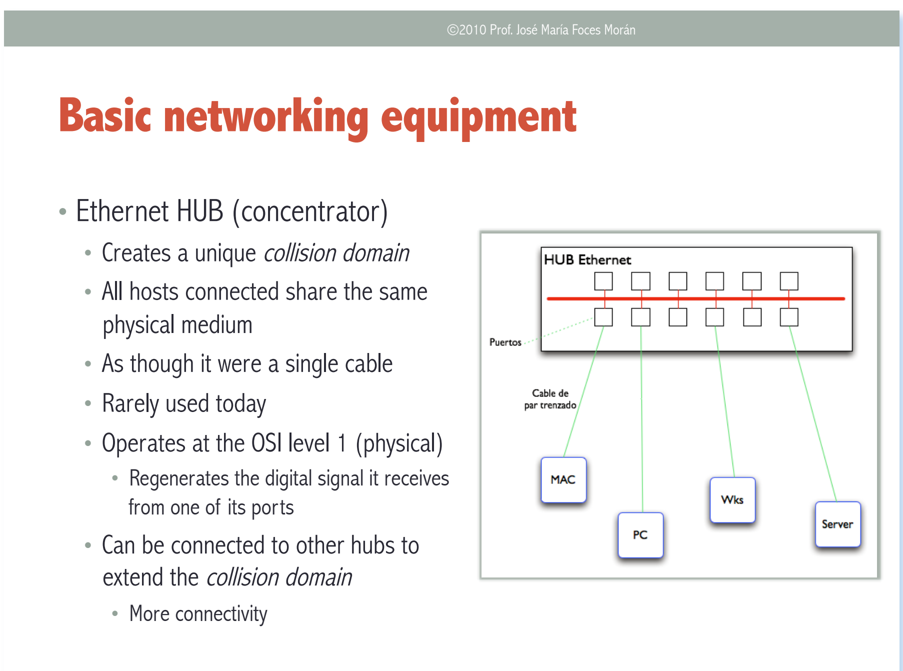
Each NIC has a MAC address, a 48-bit, unique, Medium Access Control address. MAC addresses have a simple logical structure specified by the IEEE; their structure represents the chip manufacturer in the high byte, it is supposed to be unique, therefore guaranteeing that no other device will get the same MAC address. IP addresses have a hierarchical structure of Network-SubNetwork-Host. By contrast, MAC addresses are not hierarchical and therefore they are not appropriate for addressing in large networks as we will study in chapters 3 and 4. The MAC address is also known as Link Level Address or LLA.



Collision domains

A fully functional ethernet network can be built by using hubs, a network equivalent to the initial coax-based ethernets. When using coaxial cables, if the network must be physically extended, repeaters must be used and the total resulting distance must not be greater than 100 m in the case of 10BASE-2 (ThinLan) or 2500 m in the case of 10BASE5 (ThickLan). In our case, using 10BASET hubs in case that the connectivity offered by a single device does not satisfy our needs, we can connect one more hub to our initial hub by using the same cabling with the Transmit/Receive pairs swapped, obviously. This hub-to-hub connection scheme has limitations regarding the maximum resulting distance and the maximum interconnected devices at the nominal speed of 10Mbps so that CSMA/CD will function properly.

Ethernet delivery of information belongs to the *broadcast* type since any frame sent by host A in the set of interconnected hubs is in fact delivered to all the connected hosts. We summarize the situation defining the interconnection of hubs mentioned as a collision domain, since any host connected to any of the hubs can collide with any other host connected to any of the same hubs, as though all those hosts were connected to a coax-cable Ethernet. In the latter case it's easy to understand the shared nature of the transmission medium, however, despite our increased difficulty, all the interconnected hubs behave the same as the cable -at least functionally. In summary, the set of interconnected hubs is known as *collision domain*.



Exercise 3. We can observe the signal-regenerating action of hubs by using a digital oscilloscope and the test circuit in fig. 2. As you can see, these devices only operate at the OSI physical level (Layer 1) since they only regenerate the signal coming from the host that got hold of the medium in the latest competition for it

governed by the CSMA/CD distributed algorithm. We are testing the signal retransmission capability of a 10BASE-T hub. For a better understanding of this topic, you must recall the inherent broadcast-delivery nature of 10BASE-T.

- We have a single digital oscilloscope, therefore, the instructor will provide you specific instructions for carrying out this experiment with his assistance. Make any questions or comments you like. Take your time to reflect and take your notes.
- The test should be performed with a single hub and also with a group of hubs interconnected, the results should be the same: the original signal is regenerated at each successive hub and retransmitted over all ports.

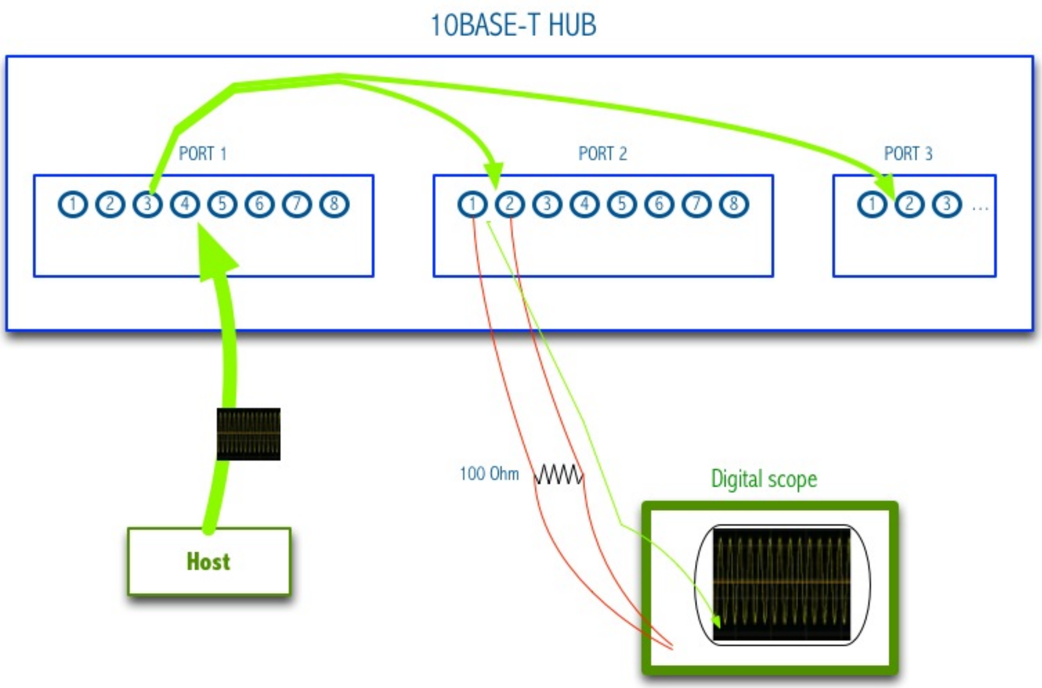


Fig. 2. Oscilloscope tracing a Differential Manchester signal from a 10BASE-T Hub

Exercise 4. Join one of the five three-student groups working concurrently in the lab. Now we want to build an example Ethernet network based on 10BASE-T hubs. Each group should perform the following sequence of steps to accomplish this exercise:

a) Connect both hosts to different Hub ports. Since the hosts will be configured to fetch a dynamic IP from a DHCP server, you can not perform any IP connectivity test (ping) since your host has not an IP yet.

b) Connect your hub to next group's Hub, use an appropriate cable or else, configure the special uplink port as uplink, not as normal.

c) The instructor will connect a DHCP server to your newly-setup Ethernet. Boot your hosts, then login as estudiante, you will be given the necessary password. Check your interface configuration for a 192.168.1.* IP. If your interface has been successfully configured, send pings to your partner host.

d) Request other students' IPs and check connectivity and RTTs.

e) Download a big file from the web server at 192.168.1.2. Instead of a browser, use the wget command and type the following URL: http://192.168.1.2/bigfile.txt. Measure the time consumed by issuing the $ time wget http://192.168.1.2/bigfile.txt command which will print out the real time elapsed since wget started its execution. Repeat several times the same file download. Take detailed note of the results in tabular form.

f) Now, disconnect your the hosts from the Hub and reconnect to the switch that provides service to your group of tables, normally, you will simply use the TP cables that belong to the wiring underneath the tables.

g) Make sure your host has gotten a new IP from the general laboratory network that provides you connectivity to Internet. The aforementioned lab network is based on another form of Ethernet technology named Fast Ethernet or 100BASE-TX that is much faster than 10BASE-T. Repeat the file download against the same URL and take note of the results. Is the throughput increase noticeable? We will be able to interpret these results more correctly when we take up Lan Switching in chapter 3. For the time being, it suffices that you know that there are other faster Ethernets that are not based on Hubs but on another networking equipment named Switch. See the slide titled "basic networking equipment" for some characteristics of Switches.

h) As in step 4, request other students' IPs and check connectivity and RTTs. Compare with the results of step 4.

Basic networking equipment

- Ethernet Switch
  - Functionally equivalent to a Hub
  - Can sustain several parallel communications among the hosts connected: higher aggregated throughput
  - Any communication host A – host B receives the full nominal bandiwdth
    - 100BASE-TX: 100Mbps
    - 10BASE-T: 10Mbps
  - The most used today
  - Learns the hosts MAC addresses, creates path A – B *on the fly*
  - Must understand the Ethernet frame
    - Operates at levels 1 and 2 OSI