King Fahd University of Petroleum and Minerals

Electrical Engineering Department

EE 400, Experiment # 2

Transmission Media & Networking Components

Objectives:
Study different types of networking cables, connectors and other network components.

Transmission Media (refer to text book, sec 3.7)
Computers communicate data in a network over a medium. The choice of the medium is very critical since it affects the network cost, maximum operating speed, and error rates. Network media should be durable, rodent-proof, reliable, inexpensive, immune to noise, and easy to install, maintain, and reconfigure. The longer the transmission distance, the lower the maximum speed.

Transmission Media Types:

***Air*:** The transmission of data is performed using radio waves, infrared, or laser light. The advantage of this medium is that it eliminates cabling. The disadvantages are:

- Need of an unobstructed line-of-sight path between nodes.
- Light signal are susceptible to interference from fog, and smoke.
- Data can be intercepted (security problems).

***Twisted-Pair (TP)*:** It consists of two insulated wires twisted together. Most of the telephone lines use TP. The twisting tends to expose each wire in the pair to the interference uniformly. Wires have an American Wire Gauge (AWG) number based on their diameter. For network purposes, 22-and 24-gauge are two most common types of twisted-pair cabling. Twisted-pair cable is bundled in groups of pairs, many LANs use 25 pairs. The advantages of TP is that they are:

- Available in many forms at low prices.
- Relatively easier to install.
- Used extensively in telephone lines.

***Shielded Twisted-Pair (STP)*:** It has improved noise immunity and crosstalk and has better system security.

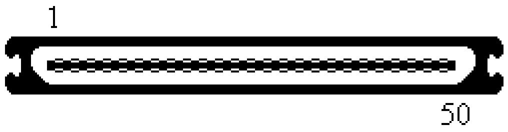
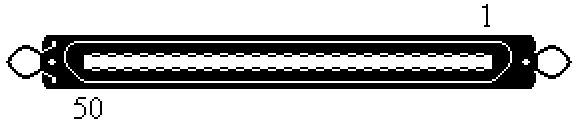
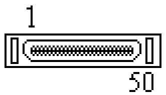
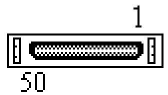
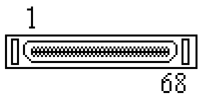
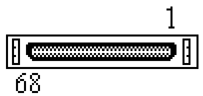
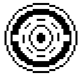
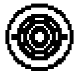
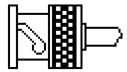
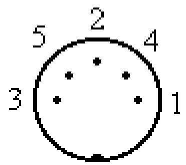
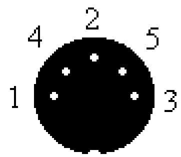
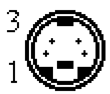
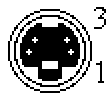
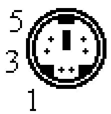
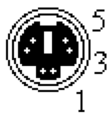
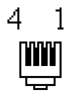
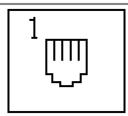
***Coaxial Cable (CO)*:** It is used in commercial TV networks. It is the third mostly used cable (power lines, TP) with a bandwidth second only to that of fiber-optic cable. A coaxial cable is composed of a copper conductor surrounded by insulation. An outer jacket composed of copper or aluminum acts as conductor, and also provides protection, While more expensive than TP, it can transmit data significantly faster over a much longer distance.

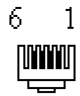
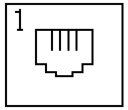
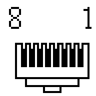
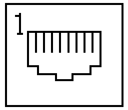
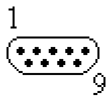
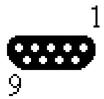
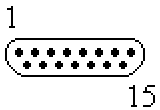
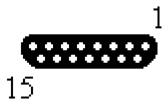
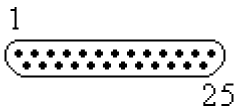
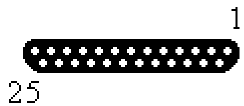
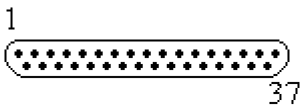
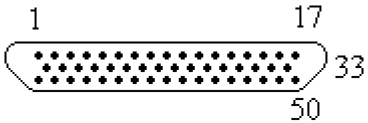
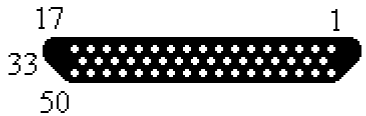
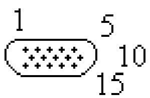
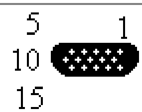
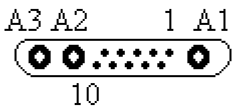
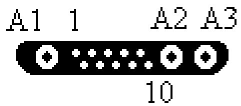
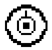
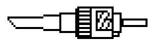
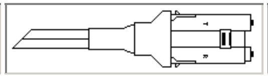
***Fiber-optic*:** It has extremely low rates of signal loss and high immunity to radiation, crosstalk, lighting, and corrosion. The transmission capability of fiber-optic cable is virtually unlimited. Its bandwidth is constrained only by its ability to generate light signals of uniform frequency. The light is generated by lasers or by LEDs. The cabling can consist of a single fiber (monomode), several fibers (multimode), or a variation of multimode (graded index) in which the index of refraction drops slowly from the center of the fiber towards the outside.

Physical-Layer Media Specifications

Specifications	10Base5	10Base2	10Base-T	10Base-TX (Fast Ethernet)	10Base-TX (Gigabit Ethernet)	FDDI
Cable Type	Thick coaxial cable	Thin coaxial cable	Twisted-pair	Twisted-pair (two pairs)	Twisted-pair (four pairs)	Fiber optic
Cable Impedance	50 ohms	50 ohms	85-110 ohms	85-110 ohms	85-110 ohms	-
Signaling techniques	Baseband (Manchester)	Baseband (Manchester)	Baseband (Manchester)	Baseband (Manchester)	Baseband (Manchester)	Baseband
Data Rate	10 Mbps	10 Mbps	10 Mbps	100 Mbps	1 Gbps	100 Mbps
Maximum cable segment length	500 m	185 m	100 m	205 m	200 m	2 km
Maximum network length	2500 m	925 m	2500 m	2500 m	2500 m	10 km
Attachments per segment	100	30 (29 with a repeater)	1	1	1	-
Attachments spacing	2.5 m	0.5 m				-
Connector type	DB-15 connector	BNC	RJ 45 (8 pin)	RJ 45 (8 pin)	RJ 45 (8 pin)	MIC, ST
Topology	Linear Bus	Linear Bus	Star-wired bus	Star-wired bus	Star-wired bus	Ring
Maximum number of stations per network	1024	1024	1024	1024	1024	1000

Connector Reference Chart

Description	Male	Female	Side View	Common Applications
Amphenol 50 Pin				Telco, SCSI
Half Pitch Centronics 50 pin				SCSI
Half Pitch Centronics 68 pin				SCSI
BNC				LAN, Video
DIN 5 Pin				AT Keyboard, Audio, MIDI
Mini-DIN 4 Pin				Apple Destop Bus, SVHS, S-Video
Mini-DIN 6 Pin				PS/2 Keyboard/Mouse
RJ10				Telephone

RJ11				Telephone
RJ45				ISDN, LAN
Sub-D 9 Pin				RS232, RS449, EGA, CGA
Sub-D 15 Pin				X.21, Mac Video
Sub-D 25 Pin				RS232, Centronics
Sub-D 37 Pin				RS449
Sub-D 50 Pin				SCSI
Sub-D 15 Pin High-Density				VGA, SVGA, XGA
13C3				Sun Work Station
ST				FDDI
MIC				FDDI

Cabling Categories:

- *Category 1*: suitable for voice only (1950s)
- *Category 2*: suitable for voice and low data rates (less than 4 Mbps). (1960s)
- *Category 3:* suited for voice and data rates up to 10 Mbps (frequency bandwidth 16 MHz). Uses 4 twisted-pairs. May support data rates up to 100 Mbps like 100Base-T4. Standard for most telephone installations. (1991)
- *Category 4:* consists of 4 twisted-pairs. Suitable for data rates up to 16 Mbps (frequency bandwidth 20 MHz). Support fast Token Ring networks. (1993)
- *Category 5:* consists of 4 twisted-pairs. Suitable for data rates up to 100 Mbps (frequency bandwidth 100 MHz). Supports 100Base-TX. (1994)
- *Category 6:* consists of 4 twisted-pairs. Suitable for data rates up to 1 Gbps). Supports 1000Base-TX. (1994)

Topologies:

Bus: All devices connect to a common, shared cable (or backbone).

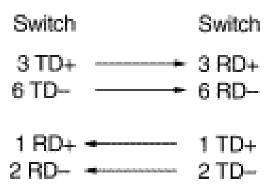
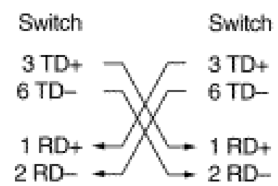
Ring*:* Nodes are wired in circle. Each node is connected to its neighbors on either side and data passes around the ring in one direction only.

Star*:* All devices connect to a central hub. The hub receives signals from other networks devices and routes the signals to the proper destinations.

Straight-Through and Crossover Cable Pin outs:

Cables ending in RJ45's may be wired up in two ways: straight through and crossover. A straight through cable connects pins N at both ends, whereas a crossover cable has the various pairs crossed over. Whether a straight through or crossover cable is required will depend on the types of network equipment and how they are interlinked.

The schematics of crossover and straight-through cables are shown in below.

<table>
<tr><th>Straight-Through Cable Schematic</th><th>Crossover Cable Schematic</th></tr>
<tr><td>
</td><td>
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LAN Devices:

Network Interface Cards (For further reading on the subject, refer to Text book, sec 6.2)

Network interface cards, commonly referred to as NICs, are used to connect a PC to a network. The NIC provides a physical connection between the networking cable and the computer's internal bus. NICs come in three basic varieties: 8-bit, 16-bit, and 32-bit. The larger the number of bits that can be transferred to the NIC, the faster the NIC can transfer data to the network cable.

Many NIC adapters comply with Plug-n-Play specifications. On these systems, NICs are automatically configured without user intervention, while on non-Plug-n-Play systems, configuration is done manually through a setup program and/or DIP switches.

Cards are available to support almost all networking standards, including the latest Fast Ethernet environment. Fast Ethernet NICs are often 10/100 capable, and will automatically set to the appropriate speed. Full duplex networking is another option, where a dedicated connection to a switch allows a NIC to operate at twice the speed.

Repeaters :

A repeater is a device used to extend the network length and topology beyond what can be achieved by a single cable segment. It is used to re-time and amplify the individual signals and has no concept of packets.

Repeaters, also called hubs or concentrators, are bit level devices. What this means that they do not examine the data packets that travel through them. They have no knowledge of addresses associated with the source or the destination. The basic operation of a repeater is to repeat traffic. Any data arriving on one port will be amplified and repeated out all ports (except the port on which it was received).

Repeaters were originally designed with only two ports and were used to increase the size of coax cable-based networks. This way, different lengths of coax cable coulds be attached to the repeater to extend the size of the network. This would allow the network to reach all areas of large or tall buildings. Data would be repeated from one cable segment to the other.

When the coax cabling was replaced by concentrators or hubs, the concentrators were, in fact, just repeaters with many more ports. Now, data reeived on one port would be replicated anywhere from twice to hundreds of times and transmitted to attached stations. The repeater also had the ability to track how much traffic was crossing through it.

Repeaters may also be linked together for even greater distances, but it is recommended that the data should not need to cross more than four repeaters. This is because each time the data gets repeated it may be slightly distorted. If there are too many distortions, original signal may be unreadable.

A very important fact to note about hubs is that they only allow users to shared Ethernet. A network of hubs/repeaters is termed a "shared Ethernet," meaning that all members of the network are contending for transmission of data onto a single network (collision domain).

This means that individual members of a shared network will only get a percentage of the available network bandwidth

Repeaters support all standard LAN protocols and cabling types, and a repeater can translate between different cabling. Today, repeaters are being replaced called a bridge.

Bridges :

A bridge operates at layer 2 of the OSI model and offers several functions, including expansion of networks beyond normal physical limitation, overcoming station count limitations, packet storage and forwarding, and keeping local traffic local by building an address table (SAT) of where devices are located within the network.

Bridges offer several advantages over repeaters, including:

- **Expansion of network** - because of regeneration issues, packets can only be repeated a limited number of times. Bridges eliminate the problem by copying and recreating new packets before forwarding them.
- **Overcoming station count limitations** - each type of LAN (Ethernet, token ring, FDDI) has a maximum number of users allowed on one segment. Bridges allows for the creation of multiple bridging segments.
- **Packet storage and forwarding** – bridges receive the packet, examine it, and then determine where it needs to go. If there is other traffic on the destination port, the bridge buffers (stores) the packet until the port is able to accept more traffic.
- **Keeping local traffic local** – the bridge's ability to read packets and identity addresses enables it to determine where a destination is located. This eliminates sending packets to segments that do not contain the destination.
- **Translating between different speeds** – bridges are required to interface between networks of different speeds (e.g., Ethernet's 10, 100, and 1000 Mbps)

- **Translating traffic between LAN protocols** – bridges, acting as interpreters, have the ability to translate packets between other LAN protocols such as Ethernet, token ring, FDDI, and ATM.

Bridges fit into the network in a similar fashion as repeaters and they support all the capabilities of repeaters (amplifications of signals, etc.) However, bridges have increased intelligence and can perform additional functions.

The repeater repeats all traffic that goes through it, so if I had a 24-port repeater and a packet came in one port, it would be repeated out 23 other ports. This is because the repeater does not know where to send it. A bridge, though, is aware of the individual packets and the addressing that is used. A bridge that receives that same packet examines it and resends it only to the port that has the diestination address attached to it. Obviously, this is a better way to handle traffic.

Besides having the ability to examine packets and forward based on addresses, bridges have the ability to learn where the different addresses are located on the network. This means the bridge will learn which PC is located on which port, and it also keep track of this address if the PC is moved. Bridges can also be used to separate repeated networks.Bridges support all protocol and media types, and even have the ability to translate one LAN protocol to another.

Routers :

Routers perform their function at layer 3 of the OSI Model and are used to forward messages across an extended network based on network layer addresses (logical addressing), not MAC layer addresses. They route messages from end-station to end station, allowing multiple paths between them. Routeres can also be used to provide better traffic isolation and security by using access lists that control who can communicate through the router. Routers are used to forward traffic on the internet.

Routers offers several advantages over repeaters and bridges. These include:

- **Isolation of broadcast traffi**c – routers prevent the flow of broadcast traffic from one LAN to another.
- **Path selection** – routers can use the best path that physically exists between source and destination. Some routers allows for load balancing over redundant paths.
- **Flexibility** – routers can support any desired protocol or network topology.
- the total size of the network interconnected with routers is, for all practical purposes, unlimited (e.g., the Internet)
- Routers supports layer 1,2,and 3 functionality.

Note : Routers are more intelligent than bridges, but they are not plug-and –play- routers must be configured by a human.

Routers are designed to separate different parts of the network into what are called sub-nets, which are subdivisions of the the total network. This division of the network is done to support the different requirements of the organization, and it allows a network manager to separate and control traffic in the different sub-nets. Routers are often used to separate the network for the purpose of security. Doing this allows a network manager to keep some traffic inside a sub-net and allows other traffic to cross sub-net boundaries. An example of using routers and sub-nets would be a large company that has divided their network up based on departments. Sales might be one sub-net, marketing on another sub-net, and engineering on another sub-net. All these sub-nets would form the complete network, and within each sub-net is a collection of users connected to bridges or repeaters.

Routers support all the capabilities of bridges and repeaters along with network layer (layer3) protocols.

Switches :

Networks started as a collection of computers connected by a single cable.

The next evolution of networks was the introduction of the repeater. The repeater allowed the larger networks (Distance and size) and eliminated the cable as a single point of failure. The problem was that traffic was flooded everywhere.

The next evolution was the bridge. Originally, bridges were designed to separate networks into different sections, and this cut down on the amount of flooded traffic. Bridges could then used to interconnect groups of users connected to repeaters.

Next came the router. With the routers, logical groupings could be defined, traffic could be better controlled. Now you had networks with users connected to repeaters, the repeater connected to bridges and the bridges connected to routers, with each network network device doing its own thing.

A switch operates at layer 1, layer 2, and layer 3 (sometimes layer 4) and allows users to use a single device to support multiple capabilities. Now, using one device, some traffic can be repeated, some bridged, and some routed, all based on where the traffic needs to go. This is called switching.

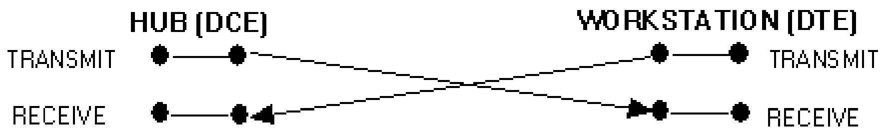
Switches combine the intellegence of repeaters, bridges, and routers into one networking device. Some of the advantages to using single box for all three functions are listed as follows:

- Save time – one device to manage
- Single device reqiured for spare
- Reconfigure instead of move/replace
- Single version of software need for uipgrading network.

Switches look like repeaters or bridges and allow direct connection to the PCs or to other switches, bridges, or routers, These devices are designed with much more intelligence built in, and the netwirk manager can configure any port, or groups of ports , to act as repeaters, bridges, or routers. the idea here is that you do not need to purchase and manage three different types of devices in your network – you can purchase one type of device and configure it the way you need it.

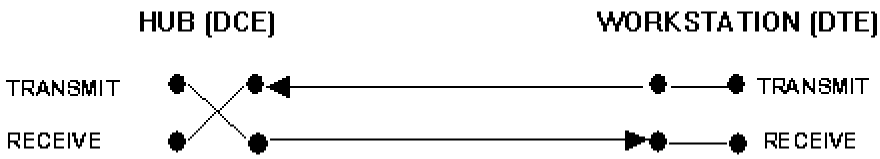
MDI / MDI-X ports:

Consider the connection between a hub (DCE) and a workstation (DTE), shown in the figure below



The connection between a DCE and a DTE using a crossover cable.

There must be a point of crossover between the DCE and DTE for data to be successfully exchanged. Figure above shows a cable with the transmit and receive pairs crossed over. On a hub most of the ports will connect to DTE's (workstations, PCs etc.) and at some point a signals crossover must be effected. Equipment manufacturers are aware of this situation so the industry accepted standard is that all ports on hubs and switches which do not have a media conversion capability have crossovers already built in. In such cases (the vast majority) only a straight-through cable is required to connect to a DTE. Figure below shows the DCE (hub) with a built in crossover port. Visually it is not easy to distinguish between straight-through and crossover cables so it is preferable to avoid having both types of cable in an installation. Using hubs and switches with crossover ports built in is a way of eliminating the need for crossover cables altogether. Ports on such equipment are often marked MDI-X. Uplink ports (e.g. 100BaseT) will not usually have built-in crossover and may be marked MDI.



The connection between a DCE and DTE using a straight through cable because the port of the DCE is already crossed over internally. Many hubs and switches feature ports which are switchable between crossover for DTE connection and straight-through for cascading or uplinking, all others being MDI-X only, or unmarked

MODEMS

The modem is a device that converts digital information to analog by MODulating it on the sending end , and DEModulating the analog information into digital information at the receiving end. They act as textual and voice mail systems, facsimiles, and are connected or integrated into cellular phones and in notebook computers enabling sending data from anywhere. Modem speeds are not expected to be increased much over today's 56 kbps. Further dramatic speed increases will require digital phone technology such as ISDN, xDSL and fiber optic lines.

xDSL

DSL stands for Digital Subscriber Line:

- ***Digital*** - means a line able to carry data traffic in its original form, as opposed to analog (see below)
- ***Subscriber Line*** - the line connecting the individual subscriber (e.g. a household) to the local exchange

The use of digital lines makes transmission of computer information faster and more reliable. It also allows much faster connect and disconnect, eliminating the slow process required for modems to establish a connection and start handling traffic. Over time its expected that all future telephony will be digital. The "x" in xDSL simply means there are several variations, eg ADSL, VDSL

DSL Summary Table

DSL Type	Description	Data Rate Down/Upstream	Distance Limit	Application
G.Lite (same as DSL Lite)	"Splitterless" DSL "	From 1.544 Mbps to 6 Mbps , depending on the subscribed service	18,000 feet on 24 gauge wire	The standard ADSL; sacrifices speed for not having to install a splitter at the user's home or business
HDSL	High bit-rate Digital Subscriber Line	1.544 Mbps duplex on two twisted-pair lines; 2.048 Mbps duplex on three twisted-pair lines	12,000 feet on 24 gauge wire	T1/E1 service between server and phone company or within a company; WAN, LAN, server access
SDSL	Symmetric DSL	1.544 Mbps duplex (U.S. and Canada); 2.048 Mbps (Europe) on a single duplex line downstream and upstream	12,000 feet on 24 gauge wire	Same as for HDSL but requiring only one line of twisted-pair
ADSL	Asymmetric Digital Subscriber Line	1.544 to 6.1 Mbps downstream; 16 to 640 Kbps upstream	1.544 Mbps at 18,000 feet; 2.048 Mbps at 16,000 feet; 6.312 Mpbs at 12,000 feet; 8.448 Mbps at 9,000 feet	Used for Internet and Web access, motion video, video on demand, remote LAN access
RADSL	Rate-Adaptive DSL from Westell	Adapted to the line, 640 Kbps to 2.2 Mbps downstream; 272 Kbps to 1.088 Mbps upstream	Not provided	Similar to ADSL
VDSL	Very high Digital Subscriber Line	12.9 to 52.8 Mbps downstream; 1.5 to 2.3 Mbps upstream; 1.6 Mbps to 2.3 Mbps downstream	4,500 feet at 12.96 Mbps; 3,000 feet at 25.82 Mbps; 1,000 feet at 51.84 Mbps	ATM networks; Fiber to the Neighborhood