Networking Fundamentals

A network comprises two or more computers that have been connected in order to enable them to communicate with each other, and share resources and files.

1. Parts of a network

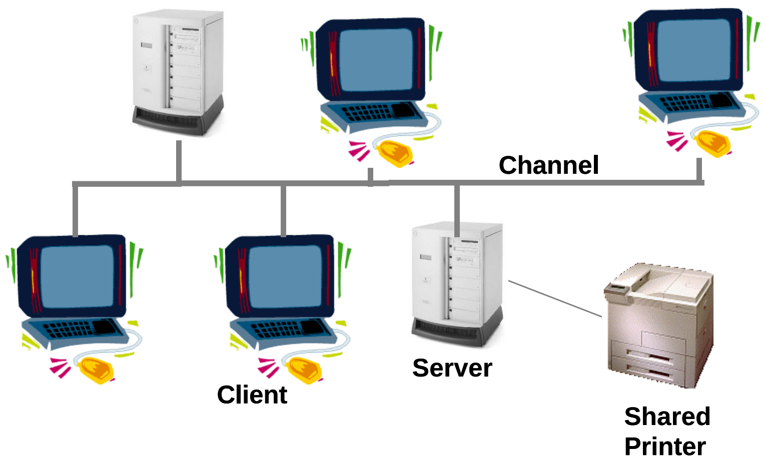
There are five basic components of a network: clients, servers, channels, interface devices and operating systems.

Servers: Sometimes called ***host computers***, servers are powerful computers that store data or applications and connect to resources that are shared by the users of a network.

Clients: These computers are used by the users of the network to access the servers and shared resources (such as hard disks and printers). These days, it is typical for a client to be a personal computer that the users also use for their own non-network applications.

For example, the personal computers in the Tisch labs are clients, while the computers that store our H: drive files and all of our web pages are servers.

Channels: Also called the network ***circuit***, the channel is the pathway over which information travels between the different computers (clients and servers) that comprise the network.



Interface devices: These are hardware devices that connect clients and servers (and sometimes other networks) to the channel. Examples include ***modems*** and ***network interface cards***.

Operating systems: The network operating system is the software of the network. It serves a similar purpose that the operating system serves in a ***stand-alone*** computer.

2. Understanding network channels

Network channels come in a variety of types, speeds and capabilities. For our purposes, there are four important dimensions of channels:

Transmission medium: This is the actual physical medium of the channel. Computer network channels use either ***wireline*** or ***wireless*** media.

- **Wireline media:** Also called ***guided media*** and ***line-based media***. In networks that use wireline media, the transmission of information takes place on a wire or cable. The three types of wireline media are ***twisted-pair wire***, ***coaxial cable*** and ***fiber-optic cable***. (Try and find examples of each of these media, and their relative speeds). While twisted-pair and coaxial cable are more commonly used today, fiber optic cables are becoming increasingly popular.
- **Wireless media:** Also called ***radiated media***. As the name indicates, in networks that use wireless media, there is no physical wire along which information travels; instead, information is transmitted through the air, from one transmission station to the next. Networking examples include radio, cellular, microwave and satellite. Broadcast TV and FM radio use wireless transmission as well (though the underlying engineering is a little different).

Transmission rate or bandwidth: This property of a network channel describes how fast information can be transmitted over the channel. It is measured in ***bits per second (bps)***[1]. People very commonly use the term ***bandwidth*** to mean transmission rate.

Transmission directional capability: The direction in which information can be transmitted over a channel depends on whether the channel is ***simplex***, ***half-duplex*** or ***full-duplex***.

- **Simplex:** Information can be transmitted only in one direction
- **Half-duplex:** Information can be transmitted in both directions, but only in one direction at a time
- **Full-duplex:** Information can be transmitted in both directions simultaneously

Signal type: There are two signal types – ***analog*** and ***digital***. It is a little hard to understand the exact difference without discussing a lot of electrical engineering and physics, so we won't go there. What you need to take away is that:

- Analog signals are ***'continuous'*** (they take on a wide range of values) and digital signals are '***discrete',*** and binary (take on only two values).
- Digital signals are more 'natural' for computer networks, since, as we know, computers represent all information in binary.

[1] 1000 bps = 1 Kbps (kilobit per second); 1000Kbps = 1 Mbps (megabit per second); 1000Mbps = 1Gbps (gigabit per second).

- The reason why we have to worry about analog signals is because the communications channels that predated computer networks (like telephone lines, cable TV lines and radio transmitters) were all designed to carry analog signals.

We'll discuss this a little more when we talk about convergence. Meanwhile, we use the term 'digital communications channel' to refer to a channel which can transmit binary digital signals.

3. LANs, MANs, WANs and backbones.

The simplest (and least exact) way of classifying networks is on the basis of the geographic scope of the network. Under this classification, there are four types of networks:

Local Area Networks (LANs): A LAN is confined to a fairly small geographic area. The clients and servers on a LAN are connected to the same channel, and are typically in the same building or in neighboring buildings.

Backbone Networks: These are high-bandwidth channels that typically connect LANs with each other, and are often referred to as ***backbones***.

Metropolitan Area Networks (MANs) and **Wide Area Networks (WANs):** A MAN spans a wider geographic area, like a corporate campus or a university, while a WAN is spread over a large geographic area, such as a country or a state.

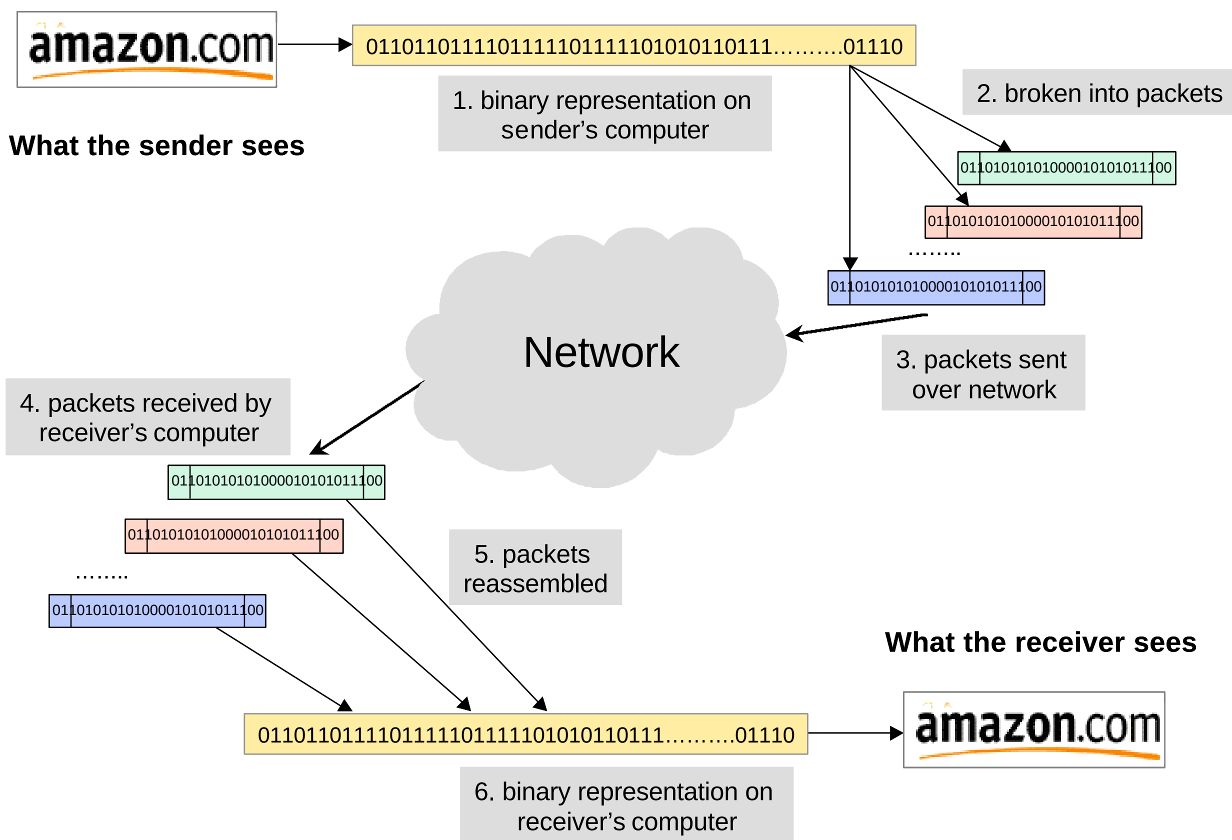
4. Networking protocols

Most networks have one feature in common: they transmit information by breaking the original information into a set of ***messages*** (called ***packets***), transmitting these packets sequentially, and then reassembling these packets back into the original information. Each packet is a string of bits. However, these packets sometimes have to travel a long way, over a bunch of different networks, there are typically lots of computers sending and receiving information over the same network, and the information getting sent can often get altered during transmission (this is called a ***transmission error***). In order to make sure that the original information gets transmitted correctly, efficiently, and to the right place, computer networks use a set of rules, called ***networking protocols***.

By itself, the study of networking protocols could constitute an entire course, so we will not go into too much detail here. The primary tasks that protocols are responsible for fall into two categories: ***network-layer*** tasks and ***data-link layer*** tasks, and the rules associated with each category are called ***network-layer protocols*** and ***data-link layer protocols***.

Network-layer protocols: Also called ***layer-3 protocols***. These rules specify how a network does the following three tasks:

- **Packetizing:** breaking up the information into packets, and reassembling the packets at the receiving end.



Sending information over a computer network

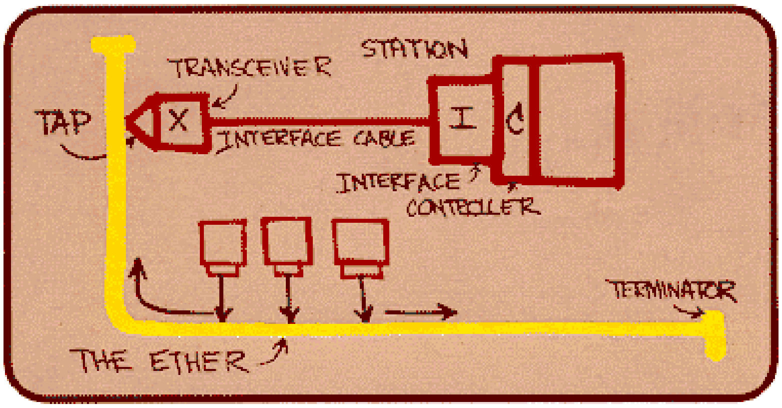
- **Addressing:** Determining which computer and network the packets are headed to.
- **Routing:** Determining the best way for the packets to get to where they are headed.

TCP/IP is a network-layer protocol (and currently the most common one). Another one is IPX/SPX, which was very popular until a few years ago.

Data-link layer protocols: Also called ***layer-2 protocols***. These rules specify how a network does the following three tasks:

- **Delineation:** Figuring out when a message (packet) begins and ends.
- **Error control:** Figuring out when a transmission error has occurred, and correcting it.
- **Channel access:** Controlling when a particular client or server accesses the channel.

There are a wide variety of data-link layer protocols. The most common in organizations and universities is ***Ethernet*** (which was the first network protocol – try and find out who invented it, where and when); another common one is the ***token ring*** protocol, developed by IBM. The networks that we connect to from home using a telephone line typically use one of two data link protocols: ***SLIP*** or ***PPP***.



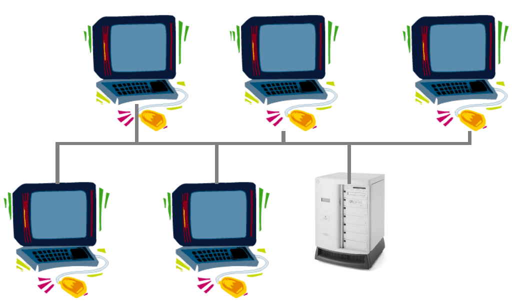
Picture of the first Ethernet schematic, drawn by its inventor

It's important to remember that any particular LAN uses exactly one network-layer protocol, and one data-link layer protocol. For instance, the Stern school network uses TCP/IP and Ethernet.

5. Network topologies:

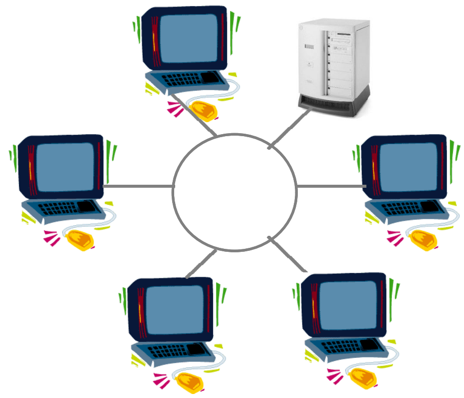
The ***topology*** of a network is the basic geometric layout of how clients and servers are connected to the channel (and hence to each other). The three common network topologies are ***star, bus*** and ***ring***. Topology is associated with ***channel access*** (refer to the notes on layer-2 protocols), since the way we connect computers to a channel restricts, to some extent, how they can access the channel. Each method of channel access (and hence, each layer-2 protocol), therefore, requires a particular topology.

Bus topology: This is the most common LAN topology – all clients, servers and shared resources are connected directly to a single channel, called the bus, which runs from one end of the network to the other.



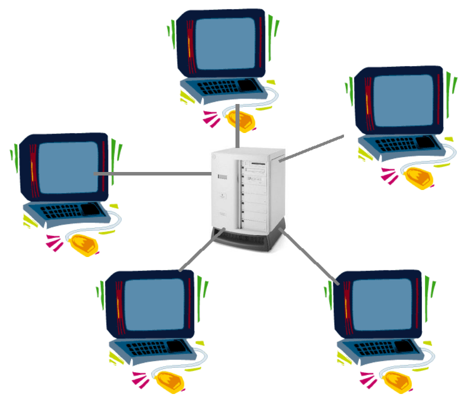
All networks that use ***Ethernet*** use the bus topology.

Ring topology: The ring topology connects all the computers in the LAN in one closed-loop circuit, with each computer linked to the next.



Networks that use the ***token ring*** protocol use the ring topology.

Star topology: In this type of topology, all the clients are connected individually to a central server, using a direct channel for each client. This was common in the mainframe era (and is used in some wide area networks now) but is not a common LAN topology.



6. Modems and Ethernet cards

In every LAN, one needs ***network interface devices*** to connect the clients and servers to the channel. In organizational and university LANs, the most common such device is the ***network interface card (NIC),*** which is commonly called an ***Ethernet card*** (since most such networks are Ethernet networks – in fact, the LAN is often simply referred to as the Ethernet). For people connecting to their Internet service provider or online service networks from their homes, the ***modem*** is the most common network interface device. A modem's basic purpose is to enable a computer to reconcile the fact that computers transmit digital signals while telephone lines carry analog signals.

Currently, traditional modem speeds range from 14.4 Kbps to 53.3 Kbps. It currently isn't possible to use an analog telephone line to receive data at speeds higher than 53.3 Kbps, or to transmit data at speeds higher than 33.6 Kbps.

7. Convergence and residential broadband

Recall from our session on information that text, images, sound and video can all be represented as digital information. This means that the three most common communications activities of residential customers – ***Internet*** access, ***telephone*** conversations and receiving ***television*** programs – can all, in theory, be done through a single digital communications channel. This idea – that ***data***, ***voice*** and ***video*** communications are converging towards being transmitted over the same channel – is commonly called ***media convergence***[2].

There are three primary challenges when a company attempts to deliver on this vision of a single, converged channel (or 'pipe') into people's homes:

- **The need for high bandwidth:** When voice and video are converted into digital information, it takes a large number of bits to represent each second of the audio or video (if you've downloaded even small video clips off the Web, you'll know what we're talking about here). Hence, if one is going to use a single digital channel, this channel has to have very high bandwidth.
- **The last mile problem:** It is tremendously expensive for any one company to create a new set of channels into every home. The actual cost of the cables is not that significant – it's the effort involved in digging up the roadside, laying these cables so that they run into each home, the problems associated with getting permission to do this (getting 'right of way'), and the added problems of getting people to let you into their homes to install the new cables. This fact – the almost insurmountably high expense of rapidly deploying new digital wires into people's homes – is called the problem of the ***'last mile'***.
- **Legacy analog networks:** The existing channels into most homes – cable TV wires and telephone wires – are designed for ***analog signals***, and so are parts of the ***networks*** that they connect to – the cable TV transmission network and the local telephone network. Besides, the cable TV network had been designed for ***one-way*** communication, involving ***broadcasting*** the same information into multiple homes. Evidently, this kind of network isn't of much use for Internet access or telephone conversations (these are two-way, and each sender and receiver may be sending and receiving different information).

In response to the latter challenge, the telephone companies and the cable TV companies have been rapidly upgrading their networks from analog to digital (literally, by ripping out existing wires and equipment and installing new stuff). The problem of bandwidth still exists, but there are two emerging high-bandwidth digital communications technologies developed for residential access that are beginning to become more popular – ***cable modems*** and ***DSL*** (digital subscriber line). Together, they are often referred to as ***residential broadband***.

[2] The term 'convergence' is used in many ways – some people use it to refer to the convergence of computers and consumer electronics.

- **Cable Modems:** These are communications devices that are used along with to residential TV cables to set up a residential broadband channel. Once the cable TV provider has upgraded their network, and a cable modem is installed in one's home, one can use a standard Ethernet card to get high speed Internet access. The bandwidth of cable modems can be as high as 10Mbps; however, in neighborhoods with a number of cable modem users, people experience much lower bandwidth when many people are using their connections simultaneously.
- **DSL:** Digital subscriber lines are the telephone companies' answer to cable modems. DSL is a technology that allows one to connect a ***DSL modem*** and a traditional analog telephone line, and get a high-speed digital channel, which one can connect, to using an Ethernet card. It is only available in areas where telephone companies have upgraded their networks. The maximum bandwidth a residence can get depends a great deal on how far it is from the nearest telephone ***central office***. Download speeds of up to 7 Mbps are currently available. Also, the performance of DSL does not degrade significantly when there are multiple users in the same neighborhood. If we have time in class, we'll discuss why.

Residential broadband is the first step towards making convergence a reality. A number of companies are planning towards a future with converged media – perhaps the most active being AT&T. Spend some time searching the Web for news of corporate acquisitions by AT&T over the last 12-15 months. See any patterns?