华章教育

全美经典
学习指导系列

计算机网络习题与解答

(英文版)

Schaum's Outhines of Computer Networking

Complete coverage of hardware and software involved in networking solutions

Real-world scenarios explained step-by-step

142 review questions

92 solved problems

Perfect for professionals refreshing core concepts

Ed Tittel 著

Schaum's 系列 全球销售超过 3000 万册!

机械工业出版社
China Machine Press

全美经典
学习指导系列

计算机网络习题与解答

（英文版）

Schaum's Outlines of Computer Networking

Ed Tittel 著

机械工业出版社
China Machine Press

本书版权登记号：图字：01-2002-4780

图书在版编目（CIP）数据

计算机网络习题与解答：英文版/蒂特尔（Tittel, E.）著. –北京：机械工业出版社，2003.1

（全美经典学习指导系列）

书名原文：Computer Networking

ISBN 7-111-10970-8

Ⅰ. 计…　Ⅱ. 蒂…　Ⅲ. 计算机网络-解题-英文　Ⅳ. TP393

中国版本图书馆CIP数据核字（2002）第076046号

机械工业出版社（北京市西城区百万庄大街22号　邮政编码　100037）

责任编辑：华　章

北京市密云县印刷厂印刷 · 新华书店北京发行所发行

2003年1月第1版第1次印刷

787mm × 1092mm 1/16 · 20.75印张

印　数：0 001- 3 000册

定　价：38.00元

凡购本书，如有倒页、脱页、缺页，由本社发行部调换

PREFACE

Today, the subject of computer networking embraces an ever-increasing body of knowledge. It spans a broad range of functions and capabilities, from the basic kinds of signaling and circuitry used to permit computers to exchange data, to the kinds of cables or wireless broadcast techniques used to transport data from sender to receiver.

Networking also embraces various sets of rules for communication between sender and receiver at various abstract levels of data exchange. These range from simple, limited streams of bits used to ferry data from a sender to a receiver, to various schemes for identifying, addressing, routing, and handling messages as they travel across various types of networking media. Likewise, protocols also apply to the kinds of services or activities that motivate data transmission across a network, be it to exchange e-mail messages, access remote files or file systems, access distributed databases of many kinds, and even to manage and monitor the behavior and characteristics of the networks that enable such communication to occur.

At first learning about networking involves mastering basic terminology and concepts. One a basic vocabulary is in place, it's a truism that the monolithic "big problem" of networking is best understood by breaking it down into a set of well-separated and mutually interdependent tasks and technologies. At this stage of learning, it's essential to understand various models for networking such as the International Standards Organization's Open Systems Interconnect (ISO/OSI) Network Reference model, as well as other models related to specific types of networking protocols. Likewise, important networking standards and technologies must also be digested and understood.

With a working understanding of how solving the problems inherent in networking depends on understanding how networking can be decomposed into a layered set of related (but technically and terminologically distinct) layers, it's possible to begin digging into some of the details involved in making networks really work. At this point, information about network naming and addressing schemes, network routing models and behaviors, and networked applications and services will begin to make sense. Thus, this represents the kind of developmental and evolutionary model that drives this book, and most of the networking textbooks, which this book seeks to supplement.

All students come to technical subjects with greater or lesser degrees of knowledge and understanding. Some may have to work harder to master basic concepts and vocabulary than others; likewise, some may have to spend more time and effort decoding and absorbing the structures and functions of the various networking models explored here. But all readers will benefit from the following networking resources online, no matter what their prior knowledge and backgrounds might be:

1. For good basic descriptions of terminologies and technologies, please visit `www.whatis.com`; this site provides encyclopedic listings for information technology terms, including most networking terms you'll encounter in this book and its companion texts.
2. For more detailed tutorials and overviews of general networking topics, tools, and technologies, please visit `www.techfest.com`; this site provides ample coverage of a broad range of networking topics from local area networks (LANs) to network cabling and management.
3. For middling levels of detail and information, and pointers to additional resources on networking terms and concepts, please visit `www.techweb.com/encyclopedia`.

Other networking resources and information is widely available on the Internet. Don't neglect to use your favorite search engines, such as Yahoo, Google, AskJeeves, AltaVista, and so forth, to find more information on topics where you might benefit from additional detail.

Ed Tittel

CONTENTS

CHAPTER 1

Data Communications

The technologies used in moving data among computers involve many different components and methodologies. One primary goal of data communications is to allow different hardware and operating systems to communicate and understand each other. To accomplish these objectives, the transmission media involved in data communications have to meet certain hardware specifications. The software used by the computer's operating system to access the transmission media must also conform to standards. These are just two examples of the many components that come into play to allow data to be transmitted between devices. In this chapter, we introduce some of the terms and techniques used in data communications for networks, which range from telephones to the Internet.

Multiplexing

The transmission *media*, or link, refers to the devices used to carry information from one device to another. For example, the telephone line or cable that brings telephone service to your house is the transmission media for carrying voice communications. There may be different types of transmission media used between your house and the telephone company. Your house and the surrounding houses typically use copper wires encased in protective materials to carry the signals into and out of your house. Thus, for each house in your immediate neighborhood, there is a separate cable going to each house that carries the phone conversations for that house. Imagine there are 50 houses in your neighborhood and outside the neighborhood is a junction box or switch managed by the phone company. Switch boxes are used to connect adjacent junction boxes along the physical path or route to the phone company's central office. For our 50-house neighborhood example, the phone company would have to lay 50 individual cables between each of the junction boxes to carry the conversations from the houses to the central office. In addition, if other neighborhoods between yours and the central office use the same junction boxes, then additional cables would need to be added to handle all the neighborhoods' conversations. By the time the cables reached the central office there may be hundreds or even thousands of cables! To say nothing of the expense of all these cables, imagine the work involved when a new house is built or when one or more of the cables physically fails. To eliminate the need and cost of all these cables, conversations from several houses are *multiplexed*, or bundled, together and then transmitted over a single cable between the junction boxes.

Multiplexing technology is used on computer networks and especially over *wide area network* (WAN) exchanges. On computer networks, different carrier frequencies enable the use of multiple, simultaneous computer conversations over the same transmission media. When different carrier frequencies are used to carry different signals, they can use the same transmission media without interfering with each other. The techniques used to modulate the carrier wave for different frequencies are similar to how television stations modulate the carrier wave to broadcast video. Let's take a closer look at how television transmissions work to handle multiple channels at the same time.

Each television station that transmits a signal is assigned a channel number over which the station can broadcast its information. The numbers assigned to channels are actually an abbreviation of the frequency at which the television station's carrier oscillates. To receive a television station's signal, the receiving hardware must be able to select or tune to the same frequency or channel. Thus, when you change channels on your television, you are changing the frequency of the receiver component of the television. By using different channels, or frequencies, for different television stations, several television stations can transmit at the same time in the same geographic region. Cable television uses the same principle except the transmission media is wire instead of the atmosphere. Each cable station is assigned a different frequency, and many different channels can be transmitted simultaneously on the same transmission media. Computer networks use these same types of principles by using different frequencies or channels to carry multiple conversations over the same transmission media.

FREQUENCY DIVISION MULTIPLEXING

Techniques must be used to allow the simultaneous transmission of different carrier frequencies to travel through the media. One method, called *Frequency Division Multiplexing* (FDM), is designed for networks that use multiple carrier frequencies to permit the independent signals to pass through the transmission media. Because the *bandwidth* of the transmission media exceeds the needed bandwidth for a single signal, FDM is designed to take advantage of this bandwidth difference. FDM technology is used on networks that send signals over wire, radio frequencies, or optical fiber. The end of the network that generates the data to be transmitted uses a hardware device called a *multiplexor*, which combines the different frequencies so they can be transmitted along the single channel. At the destination, a *demultiplexor* device separates the different frequencies and routes them to the proper recipient.

For two-way conversations where each end can both transmit and receive, a multiplexor and demultiplexor pair are required at each end. Another hardware requirement for the multiplexor may be the ability to generate the carrier waves that will be propagated down the transmission media. Although multiplexing provides the capability of transmitting signals of different frequencies at the same time, there are problems if the frequencies used are too close or are multiples of another frequency. In these situations, interference between the different signals exists, which makes the transmitted data useless. To prevent these types of issues, the engineers who design FDM networks specify a minimum frequency separation between the different carriers. This minimum frequency difference also applies to radio and television station broadcasts.

A common usage of FDM is AM radio broadcasts. The permitted range of frequencies for AM radio is 500 to 1500 kHz. Different frequencies are assigned to the different logical channels, or stations. There is sufficient separation between the different frequencies to prevent interference between the various stations. Another area where FDM is used is on voice-grade telephone channels. The usable bandwidth is about 3000 Hz per voice-grade channel, and these limits are controlled by filters. When several of these voice-grade channels are multiplexed, 4000 Hz is assigned to each channel to provide sufficient separation, so interference does not occur between the channels. Before transmission, each of the voice-grade channels is raised in frequency by different amounts with a 4000-Hz frequency separation. The FDM schemes used around the world are somewhat standardized where twelve 4000-Hz voice channels are multiplexed into the 60- to 108-kHz band. This collection of voice channels on a specified range of frequencies is called a group. Each of the 12 voice channels includes 3000 Hz for the user plus two 500-Hz guard bands for each voice channel. These guard bands help reduce the interference from items such as spikes because the filters do not produce waves with sharp edges. In some environments, another group exists in the 12- to 60-kHz band. Five groups, or 60 voice channels, can be multiplexed together to form what is called a supergroup. A mastergroup is the collection of five supergroups for the CCITT standard or the assembly of 10 supergroups for the Bell system standard. Other standards exist that allow up to 230,000 voice channels.

Another purpose for using FDM is to provide high throughput on the transmission media. To allow a higher throughput, the hardware is designed to use a large part of the electromagnetic spectrum. Using a larger part of the electromagnetic spectrum generates a larger bandwidth, which gives more "space" for signals to travel. The term *broadband* is used to define technology methods that use larger portions of the electromagnetic spectrum. Methodologies that use small parts of the electromagnetic spectrum and only permit one signal at a time over the medium are referred to as *baseband* technologies.

An example of FDM usage is the phone system, which uses full-duplex *frequency-shift keying* (FSK) transmission. FSK transmission encodes the binary values with different frequencies near the carrier frequencies. *Full-duplex* means that the voice conversation can occur in both directions at the same time on the transmission media.

WAVE DIVISION MULTIPLEXING

Wave Division Multiplexing (WDM) is the term used to specify multiplexing techniques on optical transmission systems. Instead of using different frequencies, different optical wavelengths are used for different signals on the same transmission media. As with electrical signals, light signals at different wavelengths or frequencies do not interfere with each other. When many different wavelengths are used, *Dense Wave Division Multiplexing* (DWDM) is used. Engineers working on WDM systems sometimes use the term *color division multiplexing* and humorously refer to red, purple, orange, and other colors for the carriers. These informal terms arise from the fact that humans see visible light as colors. WDM functions by sending multiple light waves on a single optical fiber. A prism, or diffraction grating device, at the transmission source combines the different light waves and transmits the combined signal over the fiber-optic cable. At the receiving end, another prism is used to separate the light into separate wavelengths, which are then passed on to the recipient.

An issue that is important on multiplexing systems is reliability. Over the course of time, there may be sporadic interference that affects some, but not all, of the frequencies. For example, radio broadcasts can be affected by the movement of large objects in the space between the transmitter and the receiver. Across the available frequencies, broadcast of the radio signal may be better on one frequency at certain times of the day and better at other frequencies during other time frames. The special technique of using FDM on multiple carriers or frequencies to transmit data is called *spread spectrum*. The transmitter using spread spectrum transmits the same signal on different frequencies, and the receiver is designed to check the different frequencies and choose one that is presently working. A form of spread-spectrum technologies is used on some *analog* modems to improve reliability. These modems use a range of carrier frequencies and send the data on all the frequencies. The receiver uses one of the frequencies and, if interference occurs, the data can be "read" from the other frequencies.

One of the reasons why WDM is popular on long-distance fiber-optic lines is that the energy used is typically only a few gigahertz wide. In addition, because the bandwidth of a single fiber band is about 25,000 GHz, the possibility exists for multiplexing many channels together over long-distance runs. Figure 1-1 illustrates a typical WDM system.

In Fig. 1-1, the information coming from Computer A on Fiber A and from Computer B on Fiber B at the source end are multiplexed together and transmitted over the shared fiber-optic cable. At the receiving end, the signal from Computer A is extracted and placed on Fiber Y and the signal from Computer B is placed on Fiber Z. In this type of system, the signal from Computer A will always end up on Fiber Y, and Fiber Z will always carry the signal from Computer B. WDM systems can also be built that incorporate switching technologies. In a switched WDM system, the signal from Computer A on Fiber A can be placed on any of the fibers at the receiving end. In fact, any signal from any device at the source end can be put on any of the input fibers and can arrive on any of the output fibers. Spreading the signals across multiple fibers may reduce the amount of the signal's energy.

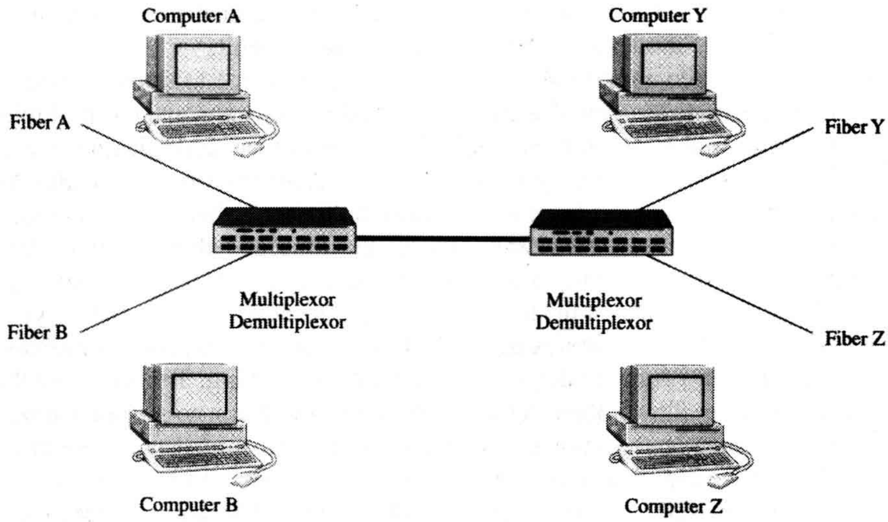

Fig. 1-1. Typical Wave Division Multiplexing system.

However, these types of switched WDM systems are useful in environments that need hundreds of channels.

TIME DIVISION MULTIPLEXING

Time Division Multiplexing (TDM) is an alternative to FDM. In TDM, the transmitting sources use *time* slices, or take turns at using the transmission media. Each chunk of data for each time slice device is referred to as a frame. TDM methodology takes advantage of the fact that the bit rate of the transmission media is greater than the needed rate of a single transmission. There are two forms of TDM: *Synchronous Time Division Multiplexing* (STDM) and *Statistical Multiplexing*. STDM is also referred to as Slotted Time Division Multiplexing.

In STDM, each transmitting source gets access to the transmission media for a specific time where each time slice is the same size. Each transmitting device gets a turn at the transmission media and does not get another turn until all the other devices have had their turns to transmit. For example, imagine there are three devices that need to transmit: Computer A, Computer B, and Computer C. The first device that has access to the transmission media is Computer A. When Computer A is finished transmitting, Computer B gets its time and when Computer B is finished, Computer C gets access. Sometimes this type of media access is referred to as *round-robin*. The interleaving of data at different times can be done in bits, bytes, or for other groupings of data. TDM multiplexing is well-suited for telephone conversations because each telephone call on the shared transmission media generates data at the exact same rate. One problem with STDM is that even if Computer A and Computer B do not have any information to transmit, Computer C still must wait until the allocated time has passed for Computer A and Computer B before it can transmit. To use the media more efficiently, statistical multiplexing can be used when some systems don't have anything to transmit.

Statistical multiplexing still allocates time for each device to transmit, and each device must go in order. But if a device has nothing to transmit, the multiplexor skips the device and goes on to the next device. Statistical multiplexing is a very cost-effective way for multiple systems to share the same transmission media. Most computer networks use some form of statistical multiplexing because the devices on the network do not need to transmit data all the time and they generate data at different rates. Communicating devices on a network tend to transmit for a short period of time and then wait for a response. Because of this burst type of transmission, statistical multiplexing is preferred over synchronous multiplexing because time is not wasted on devices that are not transmitting. To make sure that a transmitting device allows other devices that want to transmit to get their time, an upper limit is placed on the amount of data that can be transmitted at a given time. In statistical multiplexing, this limited amount of data is referred to as a *packet*.

An example of TDM usage is the method in which AM radio is broadcast in some countries. In addition to each channel using an assigned frequency, each channel has two logical subchannels. One of the subchannels is used for music, and the other is used for advertising. Using TDM, the two subchannels alternate in time on the same channel.

On individual computer systems, TDM is not practical for copper wire or microwave channel transmissions because of the overhead of the needed analog circuitry. Instead, performing TDM can be done entirely by *digital* electronics and has become much more widespread in use. However, when digital techniques are used for TDM, it can only be used for digital data.

When modems are used to communicate between two different systems across the telephone company's transmission media, the analog signals on the copper wires must be converted to a digital form so they can be multiplexed by TDM. The multiplexed signal is then transmitted over fiber-optic cables used by the telephone companies between junction locations. The analog signals are digitized by a device called a *codec* (coder-decoder). The codec takes 8000 samples per second to produce a 7- or 8-bit number. The Nyquist theorem states that 8000 samples per second are sufficient to capture all the information from a 4-kHz telephone channel. If the sampling rate were lower, data would be lost and if the sampling rate were higher, no additional information would be gathered from the analog signal. The main concept in digitization is to compare the amplitude of an analog signal with a small set of numbered amplitude thresholds called *quantization levels*. The spacing between the quantization levels is logarithmically spaced because this scheme produces better resolution at low signal levels. The digital representation of the amplitude of an analog signal is the number of the quantization level closest to the sample. The 8000 sampled amplitudes per second are compared against 256 quantization levels to produce 8-bit samples. This results in the standard voice bandwidth of 64 Kbps. There are two implementations of quantization levels that are in common use. The μ-law form is used in the United States and Japan, and the A-law variant is used throughout the rest of the world. Unfortunately, this does not allow direct connections between different quantization levels so telephone conversations have to be remapped to fit the sender's and receiver's quantization scheme.

On telephone systems, the sampling of analog data is called *pulse code modulation* (PCM). The 8000 samples per second translate to a 125 μsec/sample and because of this, essentially all time intervals within the telephone system are multiples of 125 μsecs. When PCM was being developed, the CCITT organization was not able to reach an agreement on an international standard. As a result, PCM exists in different implementations in different countries, which does not allow a seamless connection between different PCM systems. To permit international hookups, expensive "black boxes" are used to convert the signals between different PCM systems.

One implementation of PCM that is used a lot in North America and Japan is *T1*. The T1 carrier is composed of 24 voice channels that are multiplexed together. When T1 is being used entirely for data, 23 channels are used for data and the twenty-fourth channel is used for a special synchronization pattern to allow recovery of the information if the transmission gets out of synchronization. The analog signals at the source end are sampled on a round-robin basis to produce an analog stream of data that is processed through the codec. The purpose of the round-robin approach is to reduce the need for 24 separate codecs at the source end. During creation of the round-robin analog data stream, each device inserts 8 bits of data, in which 7 bits are for data and 1 bit is for control. If you multiply 7 bits of data by the sample rate of 8000 samples per second, you arrive at the value of 56,000 bps (bits per second). Taking into account that a frame of information consists of 192 bits (24 channels × 8 bits) plus an additional bit for framing, there are 193 bits every 125 μsecs. These values produce a data rate of 1.544 Mbps. The *framing bit*, 193, uses the pattern of 0101010101 . . ., which the receiver checks periodically to make sure transmission is synchronized. If things do get out of synchronization, the receiver can scan for the framing bit and get back into sync. The framing bit is added by the digital circuitry because if the pattern were in the analog signal, it would produce a sine wave at 4000 Hz, which would be filtered out.

The CCITT did finally come to an agreement about PCM and decided that the sampling rate of 8000 was too high. Consequently, the CCITT 1.544 Mbps standard is based on 8 bits for data instead of the 7 bits of data described previously. Because of these differences, there exists two incompatible variations. To handle these differences, one method, called *common-channel signaling*, assigns the extra bit the value of 10101010... in the odd frames and contains signaling information in the even frames for all the channels. The other approach for handling the differences is called *channel associated signaling*. In this technique, each channel has its own private signaling subchannel. This private subchannel is created by allocating one of the 8 data bits in every sixth frame for signaling purposes. Therefore, five out of six samples are 8 bits in length and the remaining sample is 7 bits in length.

The CCITT also specifies a PCM standard for 2.048 Mbps, which is referred to as *E1*. Usage of E1 is widespread outside of Japan and North America. The E1 carrier has thirty-two 8-bit data samples per 125 μsec frame. Two of the channels are used for signaling and the remaining 30 channels are used for data. Sixty-four signaling bits are provided by each group of four frames where 32 bits are used for channel-associated signaling and the remaining 32 are used for either frame synchronization or are reserved by each country to use as they wish.

TDM multiplexing also allows multiple T1 carriers to be multiplexed onto a *T2* or *T3* channel. Multiplexing T1s into T2s or T3s is done bit-for-bit instead of byte-for-byte for the 24 channels in each T1. Four T1s at 1.544 Mbps each would generate 6.176 Mbps, but the T2 implementation is actually 6.312 Mbps. The difference is caused by the addition of extra bits used for framing and synchronization recovery. In the United States, the T3 level is composed of six T2s that are multiplexed bit-by-bit and seven T3s are *bitwised* multiplexed to form a T4. The CCITT standard defines multiplexing of four carriers for each level—that is, four T2s combine for a T3 and four T3s combine for a T4. The CCITT specifications are listed in Table 1-1.

Table 1-1 CCITT Channel Specifications

Number of Channels	Mbps
32	2.048
128	8.848
512	34.304
2048	139.264
8192	565.148

Signaling

When discussing data communications, the terms analog and digital are frequently encountered. Analog refers to information that is in a continuous form, and digital refers to information that has discrete states. For example, an analog clock that has hour, minute, and second hands reports the information in a continuous form by the constant movement of the clock hands. A digital clock has discrete units of information. Digital clocks that report the hours and minutes will suddenly change from 29 minutes past the hour to 30 minutes past the hour. The minute value in the digital clock does not gradually change from 29 to 30 but instead makes a discrete change from 29 to 30.

The terms *analog* and *digital* are used in three different contexts when referring to data communications: data, signaling, and transmission. The word *data* when used in the context of networks refers to information that conveys or contains something of meaning to the source and/or the recipient. The information in the data may be the raw information or contain the interpreted results from raw data. Data is encoded in some electrical or electromagnetic form to produce analog or digital signals. The process by which a computer interacts with the network transmission media and sends the signal down the media is referred to as *signaling*. In addition to the data that will be transmitted, signaling also requires the transmission of network control messages. These control messages are sent as units of information across the same connection used by the transmission of the data. Typically, the control information is sent on a separate channel from the data or voice and may be referred to as *out-of-band signaling*. Telephone networks typically use out-of-band signaling that is called the *Common Channel Interoffice Signaling* (CCIS) network. Transmission is the propagation and processing of signals down the transmission media so that exchange of information occurs.

Transmission of data over transmission media can be propagated in analog or digital energy forms and the type of energies used can be electrical or optical. A continuously changing electromagnetic wave that is propagated over the transmission media is an analog signal. For example, a signal of varying frequencies traveling down an unshielded twisted-pair cable, a coaxial cable, a fiber-optic cable, or through the atmosphere, is an analog signal. If the signal is a series of voltage pulses traveling down the communication hardware, the form is a digital signal. Digital signaling has some advantages over analog signaling. Digital systems are usually more cost-effective and suffer less from noise interference. However, digital signals tend to attenuate more than analog signals. *Attenuation* is the reduction or loss of the signal strength as the distance of the transmitted signal increases. Furthermore, signals at higher frequencies suffer more from attenuation than lower frequencies. As digital signals travel farther and farther down the media, the strength of the wave is not as distinct as the initial signal. The wave shapes begin to become more rounded and it becomes more difficult for the receiver to differentiate between high and low values.

Analog data transmitted over analog hardware is typically expressed as a function of time within a limited frequency range. A good example of analog data is voice data. The frequency range of the human voice is between 20 Hz and 20 kHz, but most of the speech energy is in a small portion of that range. Typically, a 300- to 3400-Hz electromagnetic signal is quite sufficient to adequately propagate speech so that it is clear and understandable. This range of frequencies is what the standard telephone uses for both the speaker and microphone components. Information that is in digital form, such as from a computer, can be represented by analog signals. A good example of using analog signals to transmit digital data is a modem. The modem converts the binary voltage pulses from the computer into an analog signal that uses different frequencies to represent the digital data. The frequencies that are used by the modem occupy a certain range around the frequency of the carrier or channel. Thus, the modem uses a range of frequencies in the human voice range to send the signals down a voice-grade telephone line. Analog data can also be represented by digital signals with a codec (coder-decoder). In addition, digital signals can be used to carry digital data.

The techniques used to allow signaling on a computer network are often the most complex portion of the entire network. Take, for example, the telephone system with all the telephone switches located around the world and all the conversation features such as conference calls, call screening, and accounting. Each of these takes many lines of code to produce all the features and functions, but a good portion of the code is involved in handling the signaling requirements. The software must provide the services in a fast and reliable environment, and updating the software is a major undertaking involving hundreds of programmers on a daily basis.