INTRODUCTORY CONCEPTS

1.1 WHAT IS TELECOMMUNICATION?

Many people call *telecommunication* the world's must lucrative industry. In the United States, 110 million households have telephones and 50% of total households in the U.S. have Internet access and there are some 170 million mobile subscribers. Long-distance service annual revenues as of 2004 exceeded 100×10^9 dollars.[1]

Prior to divestiture (1983), the *Bell System* was the largest commercial company in the United States. It had the biggest fleet of vehicles, the most employees, and the greatest income. Every retiree with any sense held the safe and dependable Bell stock. Bell System could not be found on the "Fortune 500" listing of the largest companies. In 1982, Western Electric Co., the Bell System manufacturing arm, was number seven on the "Fortune 500." However, if one checked the "Fortune 100 Utilities," the Bell System was up on the top. Transferring this information to the "Fortune 500" put Bell System as the leader on the list.

We know it is big business; but what is *telecommunications*? *Webster's* (Ref. 1) calls it *communications at a distance*. The *IEEE Standard Dictionary* (Ref. 2) defines telecommunications as *the transmission of signals over long distance, such as by telegraph, radio, or television*. Another term we often hear is *electrical communication*. This is a descriptive term, but of somewhat broader scope.

Some take the view that telecommunication deals only with voice telephony, and the typical provider of this service is the local telephone company. We hold a wider interpretation. Telecommunication encompasses the electrical communication at a distance of voice, data, and image information (e.g., TV and facsimile). These media, therefore, will be major topics of this book. The word *media* (*medium*, singular) also is used to describe what is transporting telecommunication signals. This is termed transmission media. There are four basic types of medium: wire pair, coaxial cable, fiber optics, and radio.

1.2 TELECOMMUNICATION WILL TOUCH EVERYBODY

In industrialized nations, the telephone is accepted as a way of life. The telephone is connected to the public switched telecommunications network (PSTN) for local, national, and international voice communications. These same telephone connections may also carry data and image information (e.g., television). In the United States the connection to the PSTN may be via a *local exchange carrier* (LEC) or by a *competitive local exchange carrier* (CLEC).

The personal computer (PC) is beginning to take on a role similar to that of the telephone—namely, being ubiquitous. Of course, as we know, the two are becoming married. In many situations, the PC uses telephone connectivity to obtain Internet and e-mail services. Cable television (CATV) offers another form of connectivity providing both telephone and Internet service. In the case of Internet access, CATV can be shown to be more efficient than a telephone line for data rate capacity. Then there are the radio adjuncts to the telephone, typically cellular and PCS, which are beginning to offer similar services such as data communications (including Internet) and facsimile (fax) as well as voice. The popular press calls these adjuncts *wireless*. Can we consider wireless in opposition to *being wired*?

Count the number of devices one has at home that carry out some kind of controlling or alerting function. They also carry out a personal communication service. Among these devices are television remote controls, garage-door openers, VCR and remote radio and CD player controllers, certain types of home security systems, pagers, and cordless telephones. We even take cellular radios for granted.

In some countries, a potential subscriber has to wait months or years for a telephone. Cellular radio, in many cases, provides a way around the problem, where equivalent telephone service can be established in an hour—that is, the amount of time it takes to buy a cellular radio in the local store and sign a contract for service.

The PSTN has ever-increasing data communications traffic where the network is used as a conduit for data. PSTN circuits may be leased or used in a dial-up mode for data connections. Of course the Internet has given added stimulus to data circuit usage of the PSTN. The PSTN sees facsimile as just another data circuit, usually in the dial-up mode. Conference television traffic adds still another flavor to PSTN traffic and is also a major growth segment. The trend for data is upwards where today data connectivity greatly exceeds telephone usage on the network.

There is a growing trend for users to bypass the PSTN partially or completely. The use of satellite links in certain situations is one method for PSTN bypass. Another is to lease capacity from some other provider. *Other provider* could be a power company with excess capacity on its microwave or fiber-optic system. There are other examples such as a railroad with extensive rights-of-way which may be used for a fiber-optic network.

Another possibility is to build a private network using any one or a combination of fiber optics, copper wire line, line-of-sight microwave, and satellite communications. Some private networks take on the appearance of a mini-PSTN.

1.3 INTRODUCTORY TOPICS IN TELECOMMUNICATIONS

An overall telecommunications network (i.e., the PSTN) consists of local networks interconnected by one or more long-distance networks. The concept is illustrated in Figure 1.1. This is the PSTN, which is open to public correspondence. It is usually regulated by a government authority or may be a government monopoly, although there is a notable trend toward privatization. In the United States the PSTN has been a commercial enterprise since its inception.

1.3.1 End-Users, Nodes, and Connectivities

End-users, as the term tells us, provide the inputs to the network and are recipients of network outputs. The end-user employs what is called an I/O, standing for input/output

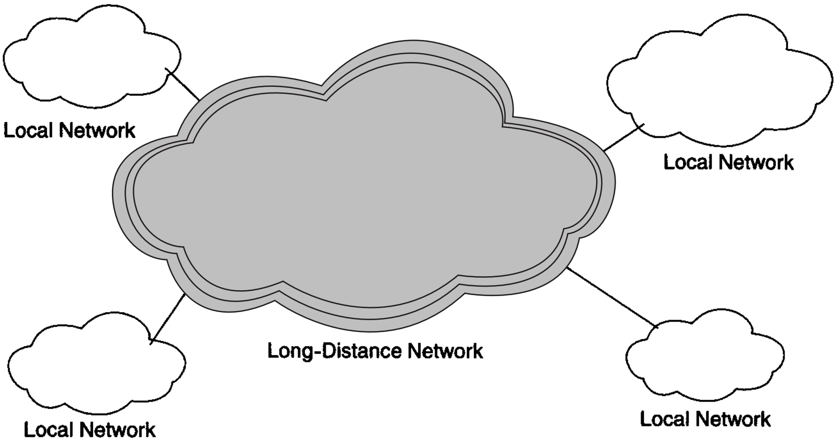


Figure 1.1 The PSTN consists of local networks interconnected by a long-distance network.

(device). An I/O may be a PC, computer, telephone instrument, cellular/PCS telephone or combined device, facsimile, or conference TV equipment. It may also be some type of *machine* that provides a stimulus to a coder or receives stimulus from a decoder in say some sort of SCADA[2] system.

End-users usually connect to *nodes*. We will call a node a point or junction in a transmission system where lines and trunks meet. A node usually carries out a switching function. In the case of the local area network (LAN), we are stretching the definition. In this case, a network interface unit is used, through which one or more end-users may be connected.

A *connectivity* links an end-user to a node, and from there possibly through other nodes to some final end-user destination with which the initiating end-user wants to communicate. Figure 1.2 illustrates this concept.

The IEEE (Ref. 2) defines a *connection* as "an association of channels, switching systems, and other functional units set up to provide means for a transfer of information

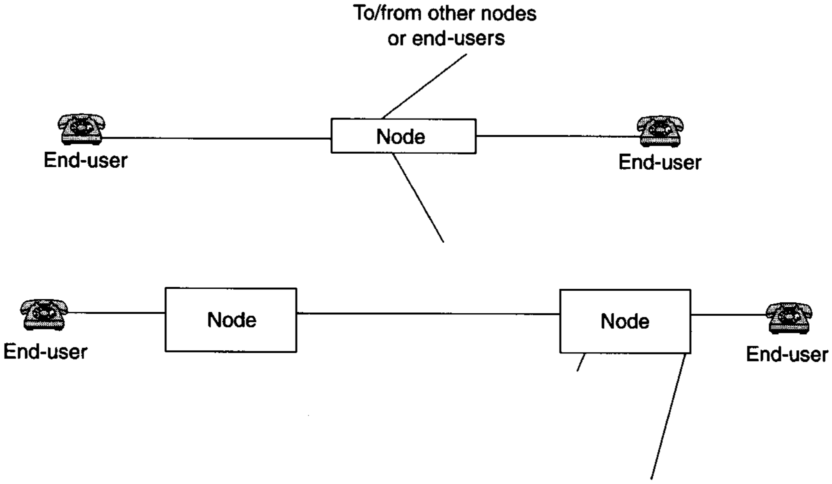


Figure 1.2 Illustrating the functions of end-users, nodes, and connectivity.

---

[2] *SCADA* stands for supervisory control and data acquisition.

between two or more points in a telecommunications network." There would seem to be two interpretations of this definition. First, the equipment, both switching and transmission facilities, are available to set up a path from, say, Point A to Point B. Assume A and B to be user end-points. The second interpretation would be that not only are the circuits available, but also they are connected and ready to pass information or are in the information-passing mode.

At this juncture, the end-users are assumed to be telephone users, and the path that is set up is a speech path (it could, of course, be a data or video path). There are three sequential stages to a telephone call.

1. Call setup
2. Information exchange
3. Call takedown

Call setup is the stage where a circuit is established and activated. The setup is facilitated by *signaling*,[3] which is discussed in Chapter 7. It is initiated by the calling subscriber (user) going *off-hook*. This is a term that derives from the telephony of the early 1900s. It means "the action of taking the telephone instrument out of its cradle." Two little knobs in the cradle pop up, pushed by a spring action causing an electrical closure. If we turn a light on, we have an electrical closure allowing electrical current to pass. The same thing happens with our telephone set; it now passes current. The current source is a "battery" that resides at the local serving switch. It is connected by the *subscriber loop*. This is just a pair of copper wires connecting the battery and switch out to the subscriber premises and then to the subscriber instrument. The action of current flow alerts the serving exchange that subscriber requests service. When the current starts to flow, the exchange returns a dial tone, which is audible in the headset (of the subscriber instrument). The calling subscriber (user) now knows that she/he may start dialing digits or pushing buttons on the subscriber instrument. Each button is associated with a digit. There are 10 digits, 0 through 9. Figure 1.3 shows a telephone end instrument connected through a subscriber loop to a local serving exchange. It also shows that all-important *battery* (battery feed bridge), which provides a source of current for the subscriber loop.

If the called subscriber and the calling subscriber are in the same local area, only seven digits need be dialed. These seven digits represent the telephone number of the called subscriber (user). This type of signaling, the dialing of the digits, is called *address signaling*. The digits actuate control circuits in the local switch, allowing a connectivity to be set up. If the calling and called subscribers reside in the serving area of that local switch, no further action need be taken. A connection is made to the called subscriber line, and the switch sends a special ringing signal down that loop to the called subscriber,

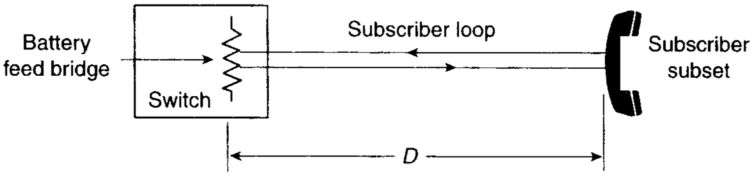


Figure 1.3 A subscriber set is connected to a telephone exchange by a subscriber loop. Note the battery feed in the telephone serving switch. Distance *D* is the loop length discussed in Section 5.4.

---

[3] *Signaling* may be defined as the exchange of information specifically concerned with the establishment and control of connections, along with the transfer of user-to-user and management information in a circuit-switched (e.g., the PSTN) network.

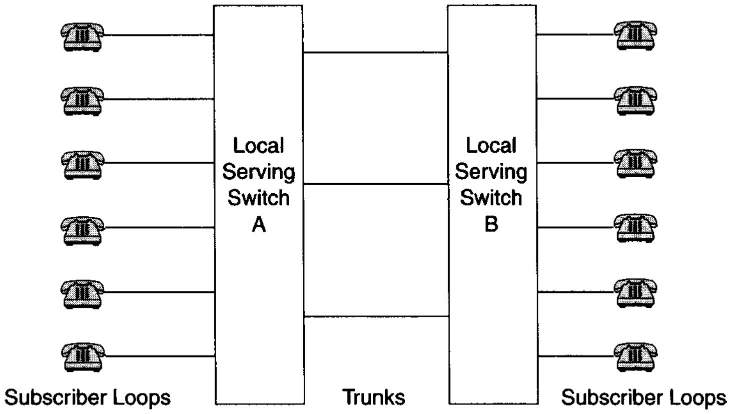


Figure 1.4 Subscriber loops connect telephone subscribers to their local serving exchange; trunks interconnect exchanges (switches).

and her/his telephone rings, telling her/him that someone wishes to talk to her/him on the telephone. This audible ringing is called *alerting*, another form of signaling. Once the called subscriber goes off-hook (i.e., takes the telephone out of its cradle), there is activated connectivity, and the call enters the information-passing phase or phase 2 of the telephone call.

When the call is completed, the telephones at each end are returned to their cradle, breaking the circuit of each subscriber loop. This, of course, is analogous to turning off a light; the current stops flowing. Phase 3 of the telephone call begins. It terminates the call, and the connecting circuit in the switch is taken down and is then freed-up for another user. Both subscriber loops are now *idle*. If a third user tries to call either subscriber during stages 2 and 3, she/he is returned a *busy-back* by the exchange (serving switch). This is the familiar "busy signal," a tone with a particular cadence. The return of the busy-back is a form of signaling called *call-progress* signaling.

Suppose now that a subscriber wishes to call another telephone subscriber outside the local serving area of her/his switch. The call setup will be similar as before, except that at the calling subscriber serving switch the call will be connected to an outgoing *trunk*. As shown in Figure 1.4, trunks are transmission pathways that interconnect switches. We repeat: Subscriber loops connect end-users (subscriber) to a local serving switch; trunks interconnect exchanges or switches.

The IEEE (Ref. 2) defines a *trunk* as "a transmission path between exchanges or central offices." The word *transmission* in the IEEE definition refers to one (or several) transmission media. The medium might be wire-pair cable, fiber-optic cable, microwave radio, and, stretching the imagination, satellite communications. In the conventional telephone plant, coaxial cable has fallen out of favor as a transmission medium for this application. Of course, in the long-distance plant, satellite communication is fairly widely employed, particularly for international service. Our reference above was for local service.

1.3.2 Telephone Numbering and Routing

Every subscriber in the world is identified by a number, which is geographically tied to a physical location.[4] This is the *telephone number*. The telephone number, as we used it

---

[4] This will change. At least in North America, we expect to have telephone number portability. Thus, whenever one moves to a new location, she/he takes their telephone number with them. Will we see a day when telephone numbers are issued at birth, much like social security numbers?

above, is seven digits long. For example:

234−5678

The last four digits identify the subscriber line; the first three digits (i.e., 234) identify the serving switch (or exchange).

For a moment, let's consider theoretical numbering capacity. The subscriber number, consisting of the last four digits, has a theoretical numbering capacity of 10,000. The first telephone number issued could be 0000; the second number, if it were assigned in sequence, would be 0001, the third would be 0002, and so on. At the point where the numbers ran out, the last number issued would be 9999.

The first three digits of the example above contain the exchange code (or central office code). These three digits identify the exchange or switch. The theoretical maximum capacity is 1000. If again we assign numbers in sequence, the first exchange would have 001, the next 002, then 003, and finally 999. However, particularly in the case of the exchange code, there are blocked numbers. Numbers starting with 0 may not be desirable because in North America 0 is used to dial the operator.

The numbering system for North America (United States, Canada, and Caribbean islands) is governed by the North American Numbering Plan (NANP). It states that central office codes (exchange codes) are in the form *NXX*, where N can be any number from 2 through 9 and X can be any number from 0 through 9. Numbers starting with 0 or 1 are blocked numbers in the case of the first digit N. This cuts the total exchange code capacity to 800 numbers. Inside these 800 numbers there are five blocked numbers such as 555 for directory assistance and 958/959 for local plant test.

When long-distance service becomes involved, we must turn to using still an additional three digits. Colloquially we call these area codes. In the official North American terminology used in the NANP is "NPA" for numbering plan area, and we call these area codes *NPA codes*. We try to assure that both exchange codes and NPA codes do not cross political/administrative boundaries. What is meant here are state, city, and county boundaries. We have seen exceptions to the county/city rule, but not to the state. For example, the exchange code 443 (in the 508 area code, middle Massachusetts) is exclusively for the use of the town of Sudbury, Massachusetts. Bordering towns, such as Framingham, shall not use that number. Of course, the 443 exchange code number is meant for Sudbury's singular central office (local serving switch).

There is similar thinking for NPAs (area codes). In this case, these area codes may not cross state boundaries. For instance, 212 is for Manhattan and may not be used for northern New Jersey.

Return now to our example telephone call. Here the calling party wishes to speak to a called party that is served by a different exchange (central office[5]). We will assign the digits 234 for the calling party's serving exchange; for the called party's serving exchange we assign the digits 447. This connectivity is shown graphically in Figure 1.5. We described the functions required for the calling party to reach her/his exchange. This is the 234 exchange. It examines the dialed digits of the called subscriber, 447−8765. To route the call, the exchange will only work upon the first three digits. It accesses its local look-up table for the routing to the 447 exchange and takes action upon that information. An appropriate vacant trunk is selected for this route, and the signaling for the call advances to the 447 exchange. Here this exchange identifies the dialed number as its own and connects it to the correct subscriber loop, namely the one matching the 8765

---

[5] The term *office* or *central office* is commonly used in North America for a switch or exchange. The terms switch, office, and exchange are synonymous.

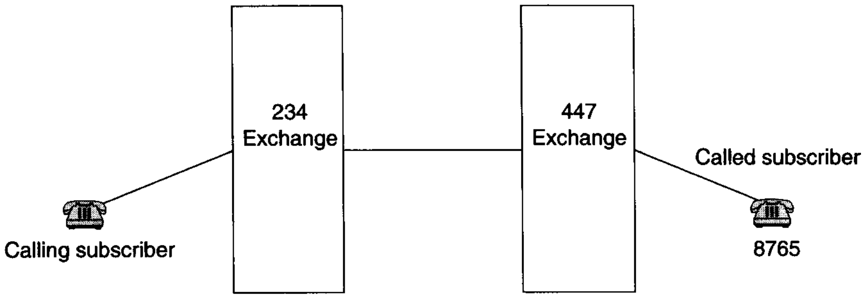


Figure 1.5 Example connectivity subscriber-to-subscriber through two adjacent exchanges.

number. Ringing current is applied to the loop to alert the called subscriber. The called subscriber takes her/his telephone off hook, and conversation can begin. Phases 2 and 3 of this telephone call are similar to our previous description.

1.3.3 The Use of Tandem Switches in a Local Area Connectivity

Routing through a tandem switch is an important economic expedient for a telephone company or administration. We could call a tandem switch a *traffic concentrator*. Up to now we have discussed direct trunk circuits. To employ a direct trunk circuit, there must be sufficient traffic to justify such a circuit. One reference (Ref. 3) suggests a break point of 20 erlangs.[6] For a connectivity with traffic intensity under 20 erlangs for the busy hour (BH), the traffic should be routed through a tandem (exchange). For traffic intensities over that value, establish a direct route. Direct route and tandem connectivities are illustrated in Figure 1.6.

1.3.4 Introduction to the Busy Hour and Grade of Service

The PSTN is very inefficient. This inefficiency stems from the number of circuits and the revenue received per circuit. The PSTN would approach 100% efficiency if all the circuits were used all the time. The facts are that the PSTN approaches total capacity utilization for only several hours during the working day. After 10 P.M. and before 7 A.M., capacity utilization may be 2% or 3%. The network is dimensioned (sized) to meet the period of maximum usage demand. This period is called the *busy hour* (BH). There are

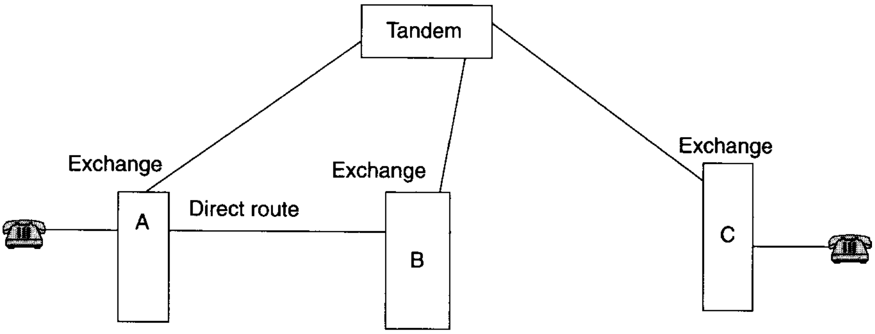


Figure 1.6 Direct route and tandem connectivities.

---

[6] The *erlang* is a unit of traffic intensity. One erlang represents one hour of line (circuit) occupancy.

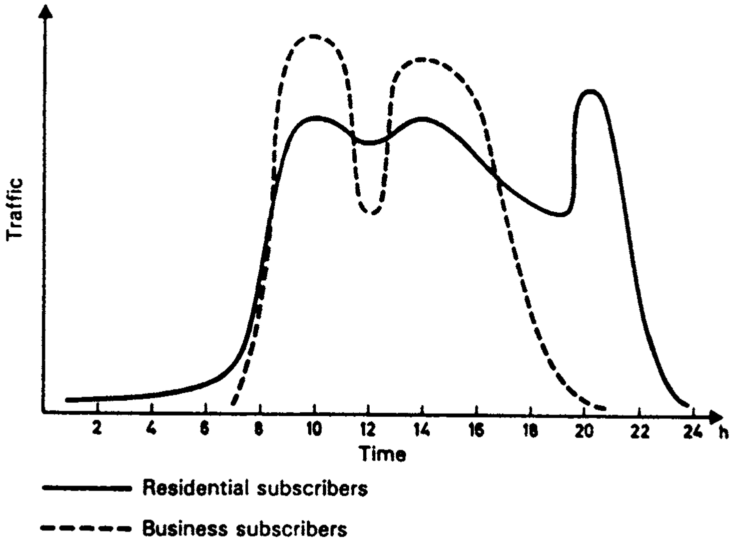


Figure 1.7 The busy hour.

two periods where traffic demand on the PSTN is maximum: one in the morning and one in the afternoon. This is illustrated in Figure 1.7.

Note the two traffic peaks in Figure 1.7. These are caused by business subscribers. If the residential and business curves were combined, the peaks would be much sharper. Also note that the morning peak is somewhat more intense than the afternoon busy hour. In North America (i.e., north of the Rio Grande), the busy hour (BH) is between 9:30 A.M. and 10:30 A.M. Because it is more intense than the afternoon high-traffic period, it is called the busy hour. There are at least four distinct definitions of the busy hour. The IEEE (Ref. 2) gives several definitions. We quote only one: “That uninterrupted period of 60 minutes during the day when the traffic offered is maximum.” Other definitions may be found in Ref. 4.

BH traffic intensities are used to dimension the number of trunks required on a connectivity as well as the size of (a) switch(es) involved. Now a PSTN company (administration) can improve its revenue versus expenditures by cutting back on the number of trunks required and making switches “smaller.” Of course, network users will do a lot of complaining about poor service. Let’s just suppose the PSTN does just that, cuts back on the number of circuits. Now, during the BH period, a user may dial a number and receive either a voice announcement or a rapid-cadence tone telling the user that all trunks are busy (ATB) and to try again later. From a technical standpoint, the user has encountered *blockage*. This would be due to one of two reasons, or may be due to both causes. These are: insufficient switch capacity and not enough trunks to assign during the BH. There is a more in-depth discussion of the busy hour in Section 4.2.1.

Networks are sized/dimensioned for a traffic load expected during the busy hour. The sizing is based on probability, usually expressed as a decimal or percentage. That probability percentage or decimal is called the *grade of service*. The IEEE (Ref. 2) defines grade of service as “the proportion of total calls, usually during the busy hour, that cannot be completed immediately or served within a prescribed time.”

Grade of service and *blocking probability* are synonymous. Blocking probability objectives are usually stated as $B = 0.01\%$ or 1%. This means that during the busy hour, 1 in 100 calls can be expected to meet blockage.

1.3.5 Simplex, Half-Duplex, and Full Duplex

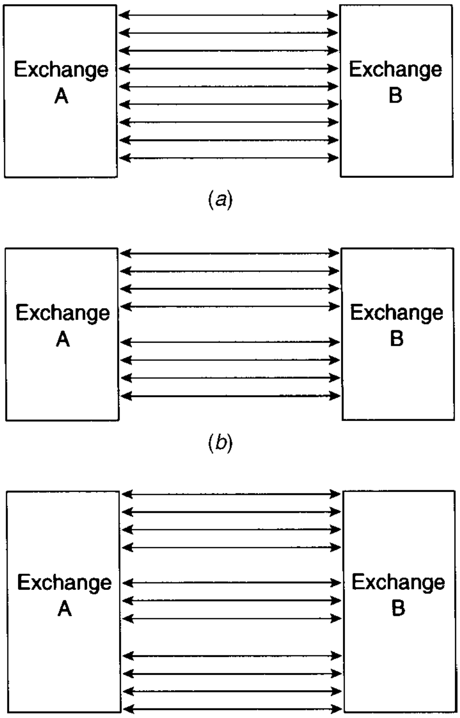
These are operational terms, and they will be used throughout this text. *Simplex* is one-way operation; there is no reply channel provided. Radio and television broadcasting are simplex. Certain types of data circuits might be based on simplex operation.

Half-duplex is a two-way service. It is defined as transmission over a circuit capable of transmitting in either direction, but only in one direction at a time.

Full duplex or just *duplex* defines simultaneous two-way independent transmission on a circuit in both directions. All PSTN-type circuits discussed in this text are considered using full-duplex operation unless otherwise specified.

1.3.6 One-Way and Two-Way Circuits

Trunks can be configured for either one-way or two-way[7] operation. A third option is a hybrid where one-way circuits predominate and a number of two-way circuits are provided for overflow situations. Figure 1.8*a* shows two-way trunk operation. In this case, any trunk can be selected for operation in either direction. The incisive reader will observe that there is some fair probability that the same trunk can be selected from either side of the circuit. This is called *double seizure*. It is highly undesirable. One way to reduce this probability is to use normal trunk numbering (from top down) on one side of the circuit (at exchange A in the figure) and to reverse trunk numbering, from the bottom up at the opposite side of the circuit (exchange B).



(*a*)

(*b*)

(*c*)

Figure 1.8 Two-way and one-way circuits: two-way operation (*a*), one-way operation (*b*), and a hybrid scheme, a combination of one-way and two-way operation (*c*).

---

[7] Called *both-way* in the United States and in ITU-T documentation.

Figure 1.8*b* shows one-way trunk operation. The upper trunk group is assigned for the direction from A to B; the lower trunk group is assigned for the opposite direction, from exchange B to exchange A. Here there is no possibility of double seizure.

Figure 1.8*c* illustrates a typical hybrid arrangement. The upper trunk group carries traffic from exchange A to exchange B exclusively. The lowest trunk group carries traffic in the opposite direction. The small, middle trunk group contains two-way circuits. Switches are programmed to select from the one-way circuits first, until all these circuits become busy; then they may assign from the two-way circuit pool.

Let us clear up some possible confusion here. Consider the one-way circuit from A to B, for example. In this case, calls originating at exchange A bound for exchange B in Figure 1.8*b* are assigned to the upper trunk group. Calls originating at exchange B destined for exchange A are assigned from the pool of the lower trunk group. Do not confuse these concepts with two-wire and four-wire operation discussed in Chapter 4, Section 4.4.

1.3.7 Network Topologies

The IEEE (Ref. 2) defines *topology* as "the interconnection pattern of nodes on a network." We can say that a telecommunications network consists of a group of interconnected nodes or switching centers. There are a number of different ways we can interconnect switches in a telecommunication network.

If every switch in a network is connected to all other switches (or nodes) in the network, we call this "pattern" a *full-mesh* network. Such a network is shown in Figure 1.9*a*. The figure has eight nodes.[8]

In the 1970s, Madrid (Spain) had 82 switching centers connected in a full-mesh network! A full-mesh network is very survivable because of a plethora of possible alternative routes.

Figure 1.9*b* shows a *star network*. It is probably the least survivable. However, it is one of the most economic nodal patterns both to install and to administer. Figure 1.9*c* shows a *multiple star network*. Of course we are free to modify such networks by adding direct routes. Usually we can apply the 20-erlang rule in such situations. If a certain *traffic relation* has 20 erlangs or more of BH traffic, a direct route is usually justified. The term *traffic relation* simply means the traffic intensity (usually the BH traffic intensity) we can expect between two known points. For instance, between Albany, NY,[9] and New York

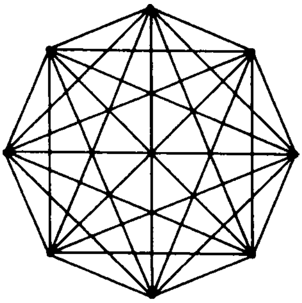


Figure 1.9*a* A full-mesh network connecting eight nodes.

---

[8] The reader is challenged to redraw the figure, adding just one node for a total of nine nodes. Then add a tenth, and so on. The increasing complexity becomes very obvious.

[9] Albany is the capital of the state of New York.

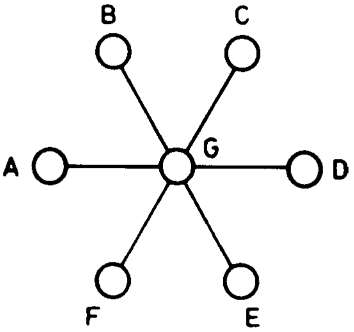


Figure 1.9*b* A star network.

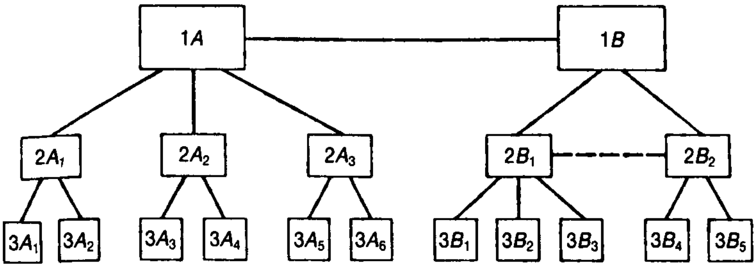


Figure 1.9*c* A higher-order or multiple-star network. Note the direct route between $2B_1$ and $2B_2$, and note another direct route between $3A_5$ and $3A_6$.

City there is a traffic relation. On that relation we'd probably expect thousands of erlangs during the busy hour.

Figure 1.9*d* shows a hierarchical network. It is a natural outgrowth of the multiple star network shown in Figure 1.9*c*. The PSTNs of the world universally used a hierarchical network; CCITT recommended such a network for international application. Today there is a trend away from this structure, or, at least, there will be a reduction of the number of levels. In Figure 1.9*d* there are five levels. The highest rank or order in the hierarchy is the class 1 center (shown as 1 in the figure), and the lowest rank is the class 5 office (shown as 5 in the figure). The class 5 office (switch), often called an *end office*, is the local serving switch, which was discussed above. Remember that the term *office* is a North American term meaning switching center, node, or switch.

In a typical hierarchical network, *high-usage* (HU) routes may be established, regardless of rank in the hierarchy, if the traffic intensity justifies. A high-usage route or connectivity is the same as a direct route. We tend to use direct route when discussing the local area, and we use high-usage routes when discussing a long-distance or toll network.

1.3.7.1 Rules of Conventional Hierarchical Networks. One will note the backbone structure of Figure 1.9*d*. If we remove the high-usage routes (dashed lines in the figure), the backbone structure remains. This backbone is illustrated in Figure 1.10. In the terminology of hierarchical networks, the backbone represents the *final route* from which no *overflow* is permitted.

Let us digress and explain what we mean by overflow. It is defined as that part of the offered traffic that cannot be carried by a switch over a selected trunk group. It is that type of traffic that met congestion, which we called *blockage* above. We also can have overflow of a buffer (a digital memory), where overflow just spills, and is lost.

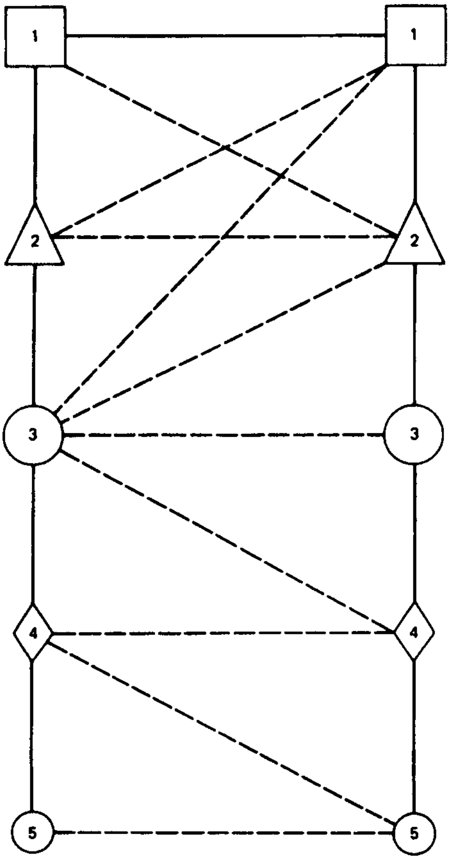


Figure 1.9*d* A typical hierarchical network. This was the AT&T network around 1988. The CCITT recommended network was very similar.

In the case of a hierarchical network, the overflow can be routed over a different route. It may overflow on to another HU route or to the final route on the backbone. See Figure 1.10.

A hierarchical system of routing leads to simplified switch design. A common expression used when discussing hierarchical routing and multiple-star configurations is that lower-rank exchanges *home* on higher-rank exchanges. If a call is destined for an exchange of lower rank in its chain, the call proceeds down the chain. In a similar manner, if a call is destined for another exchange outside the chain (the opposite side of Figure 1.9*d*), it proceeds up the chain and across. When high-usage routes exist, a call may be routed on a route additional or supplementary to the pure hierarchy, proceeding to the distant transit center[10] and then descending to the destination. Of course, at the highest level in a pure hierarchy the call crosses from one chain over to the other. In hierarchical networks, only the order of each switch in the hierarchy and those additional links (high-usage routes) that provide access need be known. In such networks, administration is simplified, and storage or routing information is reduced when compared to the full-mesh type of network, for example.

---

[10] A transit center or transit exchange is a term used in the long-distance network for a tandem exchange. The term *tandem exchange* is reserved for the local network.

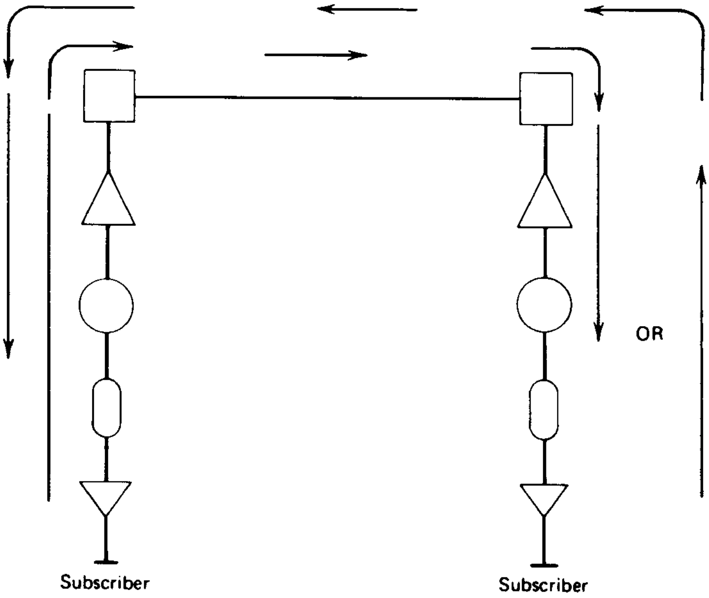


Figure 1.10 The backbone of a hierarchical network. The backbone traces the final route.

1.3.7.2 The Trend Away from the Hierarchical Structure. There has been a decided trend away from hierarchical routing and network structure. However, there will always be some form of hierarchical structure into the foreseeable future.

The change is brought about due to two factors: transmission and switching. Since 1965, transmission techniques have taken leaps forward. Satellite communications allowed direct routes some one-third the way around the world. This was followed by the introduction of fiber-optics transmission providing nearly infinite bandwidth, low loss, and excellent performance properties. These transmission techniques are discussed in Chapter 9.

In the switching domain, the stored program control (SPC)[11] switch had the computer brains to make nearly real-time decisions for routing. This brought about dynamic routing such as AT&T DNHR (dynamic nonhierarchical routing). The advent of CCITT Signaling System No. 7 (Chapter 7) working with high-speed computers made it possible for optimum routing based on real-time information on the availability of route capacity and shortest routes. Thus the complex network hierarchy started to become obsolete.

Nearly all reference to routing hierarchy disappeared from CCITT in the 1988 Plenary Session (Melbourne) documents. International connectivity is by means of direct/high-usage routes. In fact, CCITT Rec. E. 172 (Geneva 10/92) states that "In the ISDN[12] era, it is suggested that the network structure be non-hierarchical,. . . ." Of course, reference is being made here to the international network.

1.3.8 Variations in Traffic Flow

In networks covering large geographic expanses and even in cases of certain local networks, there may be a variation of the time of day of the BH or in a certain direction of traffic flow. It should be pointed out that the busy hour is tied up with a country's culture. Countries have different working habits and standard business hours vary. In Mexico, for

---

[11] SPC stands for stored program control. This simply means a switch that is computer-controlled. SPC switches started appearing in 1975.

[12] ISDN stands for Integrated Services Digital Network(s). This is discussed in Section 12.4.

instance, the BH is more skewed toward noon because Mexicans eat lunch later than do people in the United States.

In the United States, business traffic peaks during several hours before and several hours after the noon lunch period on weekdays, and social calls peak in early evening. Traffic flow tends to be from suburban living areas to an urban center in the morning, and the reverse occurs in the evening.

In national networks covering several time zones where the difference in local time may be appreciable, long-distance traffic tends to be concentrated in a few hours common to BH peaks at both ends. In such cases it is possible to direct traffic so that peaks of traffic in one area (time zone) fall into valleys of traffic of another area. This is called taking advantage of the *noncoincident busy hour*. The network design can be made more optimal if configured to take advantage of these phenomena, particularly in the design of direct routes and overflow routes.

1.4 QUALITY OF SERVICE

Quality of service (QoS) appears at the outset to be an intangible concept. However, it is very tangible for a telephone subscriber unhappy with his or her service. The concept of service quality must be covered early in an all-encompassing text on telecommunications. System designers should never once lose sight of the concept, no matter what segment of the system they may be responsible for. Quality of service means *how happy* the telephone company (or other common carrier) is keeping the customer. For instance, we might find that about half the time a customer dials, the call goes awry or the caller cannot get a dial tone or cannot hear what is being said by the party at the other end. All these have an impact on quality of service. So we begin to find that QoS is an important factor in many areas of the telecommunications business and means different things to different people. In the old days of telegraphy, a rough measure of how well the system was working was the number of service messages received at the switching center. In modern telephony we now talk about *service observation*.

The transmission engineer calls QoS *customer satisfaction*, which is commonly measured by how well the customer can hear the calling party. The unit for measuring how well we can hear a distant party on the telephone is *loudness rating*, measured in decibels (dB). From the network and switching viewpoints, the percentage of lost calls (due to blockage or congestion) during the busy hour certainly constitutes another measure of service quality. Remember, this item is denominated *grade of service*. One target figure for grade of service is 1 in 100 calls lost during the busy hour. Other elements to be listed under QoS are:

- Can connectivity be achieved?
- Delay before receiving dial tone (*dial tone delay*).
- Post dial(ing) delay (time from the completion of dialing the last digit of a number to the first ring-back[13] of the called telephone). This is the primary measure of signaling quality.
- Availability of service tones [e.g., busy tone, telephone out of order, time out, and all trunks busy (ATB)].
- Correctness of billing.
- Reasonable cost of service to the customer.

---

[13] *Ring-back* is a call-progress signal telling the calling subscriber that a ringing signal is being applied to the called subscriber's telephone.

- Responsiveness to servicing requests.
- Responsiveness and courtesy of operators.
- Time to installation of a new telephone, and, by some, the additional services offered by the telephone company.

One way or another, each item, depending on the service quality goal, will have an impact on the design of a telecommunication system.

1.5 STANDARDIZATION IN TELECOMMUNICATIONS

Standardization is vital in telecommunications. A rough analogy is that it allows worldwide communication because we all "speak a standard language." As the reader progresses through this book, he/she will find that this is not strictly true. However, a good-faith attempt is made in nearly every case.

There are international, regional, and national standardization agencies. There are at least two international agencies that impact telecommunications. The most encompassing is the ITU (International Telecommunication Union) based in Geneva, Switzerland, which has produced literally over 2000 standards. Another is the International Standardization Organization (ISO) that has issued a number of important data communication standards.

Unlike other standardization entities, the ITU is a treaty organization with more treaty signatories than the United Nations. Its General Secretariat produces the *Radio Regulations*. This document set is the only one that is legally binding on the nations that have signed the treaty. In addition, two of the ITU's subsidiary organizations prepare and disseminate documents that are recommendations, reports, or opinions and are not legally binding on treaty signatories. However, they serve as worldwide standards.

The ITU went through a reorganization on January 1, 1993. Prior to that, the two important branches to us were the CCITT, standing for International Consultative Committee for Telephone and Telegraph; the second was the CCIR, standing for International Consultative Committee for Radio. After the reorganization, the CCITT became the *Telecommunication Standardization Sector of the ITU*, and the CCIR became the *ITU Radiocommunication Sector*. The former produces ITU-T Recommendations and the latter produces ITU-R Recommendations. The ITU Radiocommunications Sector essentially prepares the Radio Regulations for the General Secretariat.

We note one important regional organization, ETSI, the European Telecommunication Standardization Institute. For example, it is responsible for a principal cellular radio specification, GSM or Ground System Mobile (in the French). Prior to the 1990s, ETSI was the Conference European Post and Telegraph or CEPT. CEPT produced the European version of digital network PCM, previously called CEPT30+2 and now called E-1.

There are numerous national standardization organizations. There is the American National Standards Institute based in New York City that produces a wide range of standards. The Electronics Industries Association (EIA) and the Telecommunication Industry Association (TIA), both based in Washington, DC, are associated with one another. Both are responsible for the preparation and dissemination of telecommunication standards. The Institute of Electrical and Electronic Engineers (IEEE) produces the 802 series specifications, which are of particular interest to enterprise networks. The Advanced Television Systems Committee (ATSC) standards for video compression produce CATV (cable television) standards, as does the Society of Cable Telecommunication Engineers. Another important group is the Alliance for Telecommunication Industry Solutions. This group prepares standards dealing with the North American digital network. Bellcore (Bell Communications Research, now called Telcordia) is an excellent source for standards with a North American flavor. These standards were especially developed for the Regional Bell Operating Companies (RBOCs). There are also a number of *Forums*. A forum, in this context, is a group of manufacturers and users that band together to formulate standards. For example, there is the Frame Relay Forum, the ATM Forum, and so on. Often these ad hoc industrial standards are adopted by CCITT, ANSI, and the ISO, among others.