Voice/Data Telecommunications Systems

An Introduction to Technology

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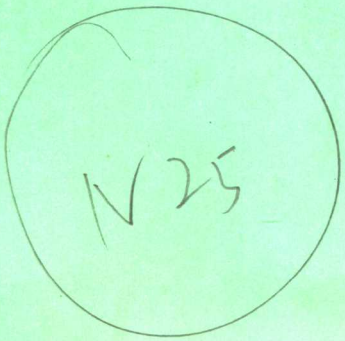

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Preface

The telecommunications industry is changing at an increasing rate, and as a result, the demand for "telecommunications-literate" people has outstripped the supply. *You* may be one of the people who will fill that demand, or you may be someone who needs to read this book before you can deal with the new generation of telecommunications equipment.

"What's that?", you say, "Everyone just went crazy over computers, and they told me I had to be 'computer literate,' until I've got digital depression! I've used telephones all my life. How can I be a 'telephone illiterate'!"

Well, probably, you're not. Unlike computers, which were out of reach of most people until a few years ago, telephones have been within reach—often very close to hand—for almost everybody. That is why the new developments in telecommunications technology are likely to catch you napping; the telephone is an old, familiar acquaintance and hasn't changed much in your lifetime. The computer is *clearly* new and different, and everybody is pretty much aware that a "computer revolution" is going on. As a result, everyone's getting "hyper" about computers and computer literacy, while equally awesome changes are taking place behind the mouthpiece of their telephones. What is the "telecommunications revolution," and why are so many people unprepared for it?

Three major reasons for this exist. First, there are more complicated uses for telecommunications today than there ever were in the past; as the capabilities of these systems get better, the performance that is expected of them also increases. As business expects, and demands, "smarter" telecommunications equipment, the people working with the equipment must be "smarter," too.

Second, competition has been introduced into the telecommunications industry. Where previously only one telecommunications company served a particular locality, there now are a variety of choices. Business demands for high-quality telecommunications equipment and services have literally forced the organization of companies to manufacture, install, and service this equipment. This brings about diversity through competition, and means that as time goes by, a telecommunications expert must know about many more kinds of equipment with more complex features than ever before.

Third, integration of the computer into the telecommunications network has been responsible in large part for the increased capabilities of the "smart" telecommunications system. The increased speed and abilities of these systems requires a technician with increased knowledge of the computer technology they contain.

What problems face you as someone who works with telecommunications equipment? One problem is maintaining "telecommunications literacy"—that is, to keep pace with the industry, supply the information needed to make full use of these systems, or to have the skill to install and service them promptly. This book is written to help you understand all you will need to know, to overcome the problems you may encounter.

Technicians, communications managers, and other professionals will find this book useful because of its real-world applications. We have intentionally steered clear of highly technical theory so that the reader can quickly obtain the pertinent information. Little previous experience is assumed. The reader will be taken through a progression from early developments through the most recent technology. We avoid emphasizing old or obsolete material, except where it helps to make a point concerning current techniques. Both detailed and necessary technical information and general background information needed by the newcomer are included in this book.

Personal growth and advancement in this field will require you to keep pace with new developments. Making your business advance beyond its competition will also require that it employ telecommunications-literate people who know what advantages accrue to the latest developments in equipment and services. The communications industry has proven itself as highly profitable for all concerned. With increased competition, it may also serve as a source of bankruptcy to those businesses which *aren't* concerned. Through the application of current telecommunications technology, manufacturers and suppliers have increased sales and production, and users have cut costs while increasing the efficiency of their businesses. "Aware" readers of this book will have the background to "read between the lines" to see the implications future developments have for their business. Whether you work with telecommunications equipment or manage those people who do, after reading this book you will not have to rely completely on the supplier's staff for all information.

This book presents an overall view of the telecommunications industry with emphasis on the systems and methods used by business. A telecommunications system might be installed by AT&T or one of their competitors, even by yourself. Systems like those used by large corporations require personnel to manage and maintain their use. Too often, people working with these systems find that they have difficulties

because they don't see "the big picture" of telecommunications. Both newcomers and persons experienced in a specific segment of the industry will find that the material in this book gives them a broader view of the entire field.

To the reader: End of chapter review questions provided in this book include a number of "discussion" type questions that do not have a single "correct" answer. In some cases, there may not even be a "best" answer. We have made no effort to tell the reader what all the answers are, here or in any other publication, because we feel that a concensus arrived at through discussion and debate is a better learning tool than a solutions manual.

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An Overview of the Industry

If you use a telephone, you are a part of the global communications network. Every time you converse with someone else by phone, you link into the most complex switching network ever devised. Since you are reading this book, you must be interested in the system and how it works. This chapter will give you some of the background and origins of the telecommunications system, a description of the organizations that it contains, and a look at some of the parts you don't see when you're just talking to someone across town.

1.1 BACKGROUND

1.1.1 Origins

Few industries are as important to our lives and economy as telecommunications services. It isn't easy to imagine how our lives would be without them.

Back in 1876, when Alexander Bell was getting the first telephone company started, many people were completely against the idea. For instance, there were those who felt the telephone was an instrument of the devil (some still do!). These are probably the same people, who, a few years later, were saying, "If God had meant men to fly, he would have given them wings." Others felt that the telephone was an amusing toy but of little real importance, and expected that the "fad" would soon fade. Bell displayed his invention to the Western Union company, hoping to sell it as a new type of telegraph receiver/transmitter to be attached to existing telegraph lines. The telegraph company was thus presented with a golden opportunity to get into the telephone business as a logical extension of the telegraph system.

You would think that the Western Union company would have snapped up such an obvious improvement on its existing communications equipment—that's what you would think—but in fact the general manager to whom Bell proposed his idea scoffed at it and said, "No future in it, sorry!" Too bad. Bell had to go and start his own company, being unable to get backing from Western Union. Western Union's manager lived to regret his mistake, but it was too late, and the telegraph company, because of their tunnel vision, missed out on the business deal of the century—of several centuries, in fact. Were he alive today, that same manager would have been even less happy to see AT&T/Bell become one of the largest single corporate entities in the world. He would have been amused, perhaps, to see what the government did to it once they decided it was *too* large, and broke it up. That never happened to Western Union.

1.1.2 Later Developments

In the middle 1870s, Alexander Graham Bell was a special-education teacher working with the deaf. In seeking to understand sound and sound communication better, he learned enough about the theory of sound to get the idea for a "speaking telegraph" that could transmit sound over long distances. The actual invention involved a lot of false starts, but ultimately, it was ready for demonstration in time for the Philadelphia Centennial Exhibition in 1876. Bell first exhibited his working telephone in this exposition, and soon had orders and potential subscribers in sufficient numbers to form a company and start a communications system.

By 1880, the telephone system had hundreds of subscribers and a network (in New York alone) large enough to require some sort of switching system to sort out the circuits and make the connections between sender and receiver. Thus the switchboard, telephone operator, and switching system began.

By the turn of the century, telephone interchanges in major cities had spread to the extent that the number of circuits outnumbered the Western Union telegraph system's, and "forests" of telephone poles with hundreds of wires supported by each filled the air above street intersections (see Figure 1-1).

As early as the May 1884 issue of *Scientific American,* it was reported that "wires . . . like threads in a huge web, hold the New York streets in a mesh-like tangle" and that one branch of the legislature had declared that "both electric-light and telephone wires must be underground by June 1, 1885, in cities of 50,000 or more." It appears to have been an optimistic deadline.

It soon became evident that the human operators were needed in larger numbers than the work force could supply. This fact, coupled with the astronomically growing number of possible interconnections between circuits, forced the development of the automatic switching system and dial-telephone device.

Today, telephones with rotary dials are being replaced by new technology. The Touch-Tone® pad has taken over the function of the mechanical switch, but still performs the same function: addressing the other circuits in the system without human intervention.

Figure 1-1 New York street scene from 1880s depicting "forests" of telephone poles and wires. From James Martin, TELECOMMUNICATIONS AND THE COMPUTER, 2nd ed., ©1976, p. 425. Reprinted by permission of Prentice-Hall, Inc., Englewood Cliffs, N.J.

1.2 ORGANIZATIONS

1.2.1 Network Today

The world telecommunications network is a complex linkage of different communications media. Everything from wires to satellite microwave links is used to carry the word from one place to another. The information carried on the global telecommunications system is conveyed by the largest assemblage of transistors, switches, wires, waveguides, fiber-optic light pipes, and other signal conductors that ever existed. It could be said without exaggeration that the global telecommunications network is one vast machine—the largest machine of any kind ever built.

The functions of this vast machine are divided into two parts. One part is a **public** network, and the other consists of **private** systems. The public network links together all the private systems (with the possible exception of the *really* private ones, such as intercoms). The dividing line between what's a **public** and what's a **private** system is not all that clear.

Public network

The public network is composed of numerous organizations, called **common carriers**, that provide telecommunications services to the general public. These common carriers can be owned and operated by business or government. In the United States, the largest of these was the Bell System, which included AT&T and other subsidiaries, a publicly owned corporation. In most other countries the public telephone system is operated by the government—in England, it is a division of the General Post Office—so that the public network is just another one of the public utilities. The facilities of all these telecommunications organizations are interconnected, allowing communications between any two places in the world.

Private systems and networks

Private systems are generally owned and operated by individuals or companies for their own use. A private system can be of any size. It can be anything from a small office with a couple of keyphones, up to the IBM network, which is international but comprises lines and switching circuits dedicated solely to IBM's use. A private system can deny access to anyone except users the owner authorizes, while a public network cannot deny services to any person without good reason.

1.2.2 Common Carriers

Local telephone companies (we will refer to them hereafter as **telcos**) may be either Bell or some other company, but once established, have traditionally had an exclusive "lock" on telephone operations in their service area. Of the 1500 or so telcos, about 85% of the business is controlled by Bell companies. Having the lion's share of the telco business in this country, Bell had an effective, although regulated, monopoly on telephone communications in the United States.

1.2.3 Deregulation and Divestiture

In 1934, the Federal Communications Commission (FCC) was established by the federal government. Its goal was to provide communications service to all Americans, and to regulate that service—especially radio broadcast communications—but all interstate communications media came under its jurisdiction. There was a perception that a "radio trust" or "telephone trust" might arise that would stifle all competition and hinder development in this field (still in its infancy at the time).

The Communications Act of 1934 (as amended) still governs the interstate communications of the United States. One thing it does is regulate the common carriers to protect the consumer from unfair prices for communications services.

Descriptions of services and rates are called **tariffs** and are filed with the FCC. Any changes or additions to the tariffs must be approved by the FCC. Similarly, state commissions regulate the common carriers within each state. Because of the two regulatory bodies, state and federal, it could cost more to call long distance within a state than it costs to call across the country.

By government order, AT&T has been divested of its interest in the Bell operating companies. AT&T still provides long-distance services through the AT&T Communications division. Money made by AT&T can no longer be used to subsidize the local telcos, or money from the local telcos used to subsidize production of telephones by a manufacturer. Before deregulation, phones could only be *rented* from Bell. That's like your power company saying, "Don't buy bulbs from Jones or we will shut off your power." Now you can buy (or rent) your telephones from the vendor of your choice. The cost of these systems is limited only by the pressures of the marketplace.

The Bell operating companies across the country have been split into seven independent groups. A holding company has been formed for each of those seven groups. For instance, Illinois Bell, Wisconsin Bell, Michigan Bell, Indiana Bell, and Ohio Bell are affiliated with a Midwestern-region holding company called Ameritech. The AT&T system's public network, for instance, no longer has any connection with the holding company, Ameritech, and Ameritech isn't allowed to make its own telephone equipment. This split was necessary to allow fair competition between Bell and the smaller companies. As a result, profits from the public network (still a monopoly, and still regulated) could not be used to subsidize a private (nonmonopoly, nonregulated) equipment division. However, Ameritech is not regulated and can charge whatever the market will bear for products and services of its deregulated private equipment division. Since Ameritech does not manufacture its own equipment, they buy it from other companies, such as Nippon Electric (NEC) or any other company whose equipment and price is suitable to their needs.

1.2.4 Specialized Common Carriers and Other Common Carriers

Specialized common carriers (SCCs) provide services that are not offered by the local telco or duplicate its services at a lower cost. MCI and SPC (Microwave Communications, Inc. and Southern Pacific Communications) are two examples of specialized common carriers that offer attractive rates for long-distance calls to certain metropolitan areas. Many SCCs can reach any location in the continental United States. They also allow you to communicate with other companies offering similar services, or may provide data communication links from computer to computer. Specialized common carriers may produce their own network links like microwave or satellite, or they may lease lines from other common carriers, including telco services.

As an example, let's suppose that a long-distance voice communication SCC, the Com Company, has a fiber-optic link between Chicago and Milwaukee. There is a lot of business traffic between Chicago and Milwaukee, since they are both major Midwestern centers of commerce. If a call placed through AT&T, via the local

telco, costs $0.52, and Com charges $0.34, they should easily be able to attract business calls.

Suppose that a business in Chicago, the Harts Company, has a branch office in Milwaukee and must stay in touch regularly. They make enough calls to Milwaukee to warrant using the services of a SCC such as Com. Harts could use three methods to access the Com services:

1. **Dial-up service.** Harts could call up Com Company through the local telco and be charged for a local call only. Com would then use their link to Milwaukee to connect the call to the Milwaukee local telco. If the local costs are $0.09 and this cost is added to the $0.34 charge from Com, the call costs $0.43, still less than the alternative charge of $0.52.
2. **Specified common carrier.** Harts could "specify," that is, stipulate, that their common carrier on long-distance calls is Com, not AT&T. This is okay if Com reaches all the places that AT&T reaches, and if all the calls are priced lower than AT&T charges. If this is *not* true for Com, Harts may not be able to specify this option.
3. **Tie trunk.** Harts may choose to have a tie trunk put in between themselves and Com. The tie trunk is a private link provided at a flat rate—let's say $100—per month. If Harts makes 1000 calls to its Milwaukee office per month, this would be $0.10 per call allocated for tie-trunk use. This brings the cost of each call up to $0.44, a penny more than the cost of dial-up service. Now that Harts has a tie trunk, though, they may not need as many local lines—perhaps they can take out two local lines—thus offsetting the penny difference. Harts has also simplified its dial-up procedure to the Milwaukee office. Instead of dialing Com through the local telco, then giving Com their account number, then dialing the Milwaukee number, they have a dedicated line to Com, and have only the Milwaukee number to dial, saving dialing time and reducing errors.[1] If the management at Harts believes the old saying that "time is money," the extra penny for tie-trunk service is no loss at all.

Some problems arise from the tie trunk. Since Harts has only one tie trunk, only one call can be made to Milwaukee at a time. A second caller either has to wait or must make the call over the telco at a cost of $0.52. The amount of traffic on the tie trunk will determine whether Harts will need one, or two, or more tie trunks. Let's look at Com Company's side of the picture. The fiber-optic link cost them $12 million to put in and $56 thousand a year to operate and maintain. Selling calls at $0.34 each requires that a lot of calls be made before Com can show a profit.

Actually, a SCC such as Com would charge $0.34 for the first minute and $0.03 for each additional tenth of a minute. This is similar to the way telcos charge. Since the SCC charges in fractional minutes, and some telcos charge by the whole minute

[1]By law, "equal access" will make the number of digits dialed by all common carriers the same by about 1986.

(no matter how little of it you've used), there could be an additional price break for using Com's service compared to that of some other telco.

AT&T offer special lines called WATS, which are used only for long-distance calls. The charges for using these lines is substantially less than calling over the regular local lines. A call over a WATS line may cost the Harts Company $0.43, the same as Com Company's charge plus the local call. The office bean-counters might be happier with the WATS arrangement, since there is only one bill to pay, not two.[2]

1.2.5 Interconnect Companies

The local telco was, at one time, the only place you could go for a phone or system. State and federal tariffs would not permit you to connect anything to telco equipment unless they provided it. Being the only vendor of equipment, and also the only vendor of services, the telcos could enforce their monopoly by withdrawing service to anyone who violated these tariffs. For some reason, this autocratic attitude was ignored until the Carterfone decision in 1968. The ruling that a Carterfone (a non-Bell piece of equipment) could be connected to Bell lines without Bell having a "right" to "pull the plug" on the Carterfone user was a landmark decision in telecommunications.

Equipment connected to telco lines must still fulfill FCC regulations, and if directly connected, must still be compatible with telco signals and voltage levels, and could be purchased from AT&T or any other supplier.

Following the Carterfone decision, new tariffs were filed establishing how non-telco equipment should be connected to the telcos' lines. The Bell System began to get alarmed that some of this nonstandard equipment might damage, degrade, or otherwise compromise their lines and equipment. Data connections to telephone company equipment, for instance, required an interface, or **direct-access arrangement** (DAA)—a piece of coupling equipment used to protect telco systems from possible harm due to "unorthodox" equipment. For voice connections, such as PBXs and telephones, a **protective coupling attachment** (PCA) was required. You leased the interface from the telco to connect "that weird stuff" to the telco's lines. These interfaces are still needed to connect equipment not approved by the FCC and for "foreign" equipment that uses incompatible signaling.

The term **interconnect company** was coined by the Bell System. Interconnect companies do not particularly like to be grouped together under this heading; they don't call *themselves* interconnect companies. But there is a lot of Bell and not very much of them, so in the trade language, companies that provide equipment to be connected to the telcos' lines are called interconnect companies. Let's refer to these companies as **intercos** for the balance of this discussion.

Intercos sell, lease, install, and service private systems. These systems are then interconnected to the public network through lines leased from the local telco. These lines are run by the telco to a terminal block inside the customer's premises. Then

[2]Soon, AT&T will be billing separately for interstate WATS.

the interco connects its equipment to this mutual tie point. Since this terminal block represents the line of demarcation where the telco's responsibility ends and the interco's responsibility begins, it is referred to as a **demarc**.

There are around 2000 intercos in the country today. Small companies in this business may be located in one city or area only. Larger intercos may serve areas that encompass many states. The largest may be not merely nationwide, but international in scope. ROLM Telecommunications, for example, has major operating divisions in most large metropolitan areas, and markets their systems overseas as well.

Most intercos do not manufacture the equipment that they install. Because of this, they can offer equipment made by many different manufacturers. This can result in a flexible system, where every product line is second-sourced by alternate suppliers, ensuring a steady supply to consumers. A company that deals in a variety of different types of equipment, however, can have shortages when alternate suppliers of the same device do not exist. Equipment for a specific purpose may come from many different manufacturers. Where the equipment from one manufacturer is not interchangeable with that from another supplier, small companies do have difficulty keeping a stock of all possible items on hand.

Most intercos have their own service departments and rarely make arrangements for other companies to do the servicing. The majority install their own equipment; a few also delegate some tasks, such as cabling, to subcontractors.

If you are seeking a telecommunications system, you have several choices: You can lease or purchase equipment from many intercos. These include former divisions of the Bell System which are now completely separate subsidiaries that do not provide telephone service, such as trunks, operators, and so on, and are, in fact, interconnect companies. Whereas in the past you could pick up a phone and order telephone equipment from "the phone company," you can no longer lease or purchase equipment from your local telco. The law now requires that there be two groups, one for basic services such as telephone numbers, and the other for the equipment. You can no longer rent telephone equipment under a tariff on a month-to-month basis, except for equipment already installed as of January 1, 1984 (which was taken over from the local telcos by AT&T Information Systems). You should base your decision not only on the prices and options available, but also on the supply capability and service reputation of the interconnect company.

1.3 HARDWARE

1.3.1 Telephones

That funny little critter that sits on your telephone stand is such a taken-for-granted item that you probably haven't thought very much about what's in it or what it's connected to. At the beginning, the telephone was an intercom without a dial, telephone numbers, or even a microphone in the true sense of the word. Bell's original 1876 equipment used the same mechanism for both microphone and speaker. The speaker mechanism was a moving permanent magnet pushed back and forth in the

middle of a coil by a diaphragm. Pressure waves from the voice moved the diaphragm, and the changing magnetic field in the coil induced electric currents in the coil. At the other end of the circuit, the current reversed the process and pulled the magnet in the earpiece half back and forth, moving the diaphragm and producing sound waves. In 1877, Thomas Alva Edison invented the carbon microphone, permanently separating the functions of mouthpiece (transmitter) from earphone (receiver). The "carbon mike," still used today, is capable of producing much stronger current signals from a voice input (it *does* need a battery to run, which the "dynamic mike" system didn't). Early in the twentieth century, the telephone network had been extended to all parts of the nation, but you had to shout to be heard over a long-distance call. This was due to the fact that no effective amplifier existed for voice signals. (An amplifier for telegraph signals, called a relay or "repeater," had been invented in the 1840s—this is what made Morse's telegraph commercially successful.) The development of the vacuum-tube triode made it possible to "repeat" (amplify) audio signals (voice waves) as the relay had earlier made "repeating" of telegraph dots and dashes possible. Invented in 1908 by Lee De Forest, the "audion" tube was also the backbone of the radio telecommunications system later.

Recent modifications, such as the Touch-Tone® keypad and solid-state switching, have modified the appearance and action of the telephone, but inside each one, you'll still find the carbon microphone **transmitter**, electromagnetic speaker **receiver**, and the switchhook (even though the earpiece no longer hangs on a hook). These basic parts are still the same as in the 1880s, and newer telephone system equipment still retains compatibility with the older models. Early dial telephones (rotary dials) can still be attached to the present system.

The "electronic" telephones of today, incorporating digital logic and microprocessors into their composition, have a lot more "smarts" than did phones of the recent past. They can display the numbers being dialed, store and retrieve frequently used phone numbers (and dial them for you), and even display the cost of a call as it's in progress. The capabilities of microprocessor-based telephones are limited only by the imagination of designers.

1.3.2 Links

The first telecommunications links were used by the telegraph companies, which connected the key and sounder with wires. Most telephone communications links also use wires for at least part of the signal path, but the longer the distance covered, the less likely it becomes that the *total* signal path will be wires. Long distance may use such media as coaxial cable, waveguides, or fiber optics to communicate high-frequency "RF," microwaves, or light waves. Some links may be designed to convey voice signals, digital data communications, or both. **Multiplex** communication allows use of a link to carry more than one channel of information at a time. Each type of link is named according to its purpose and/or its physical characteristics. Your long-distance call may travel via any combination of methods that is available to reach your intended destination.