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TELECOMMUNICATIONS TRENDS

by

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Elisha Gray may have had as much a claim on the invention of the telephone as did Alexander Graham Bell. Bell's patents allowed time for the Bell System to be developed and led to AT&T becoming the largest and most organized telephone company in the United States. AT&T, supported by government regulators, enveloped smaller telephone companies and controlled 80% of local service and all toll service by the 1920s. Government regulations supported AT&T's control of the nation's telephone network until the 1950s when the industry began to be deregulated. In 1984 AT&T was divested by court order and today's telecommunications market is characterized by continuing deregulation and increasing competition. Both telephone and data transmission are becoming more digital and service is provided by numerous carriers. New techniques for increasing the speed of data transfer are constantly being developed. Applications in the future will require much larger capacities than at present. Optical fiber will be the media used to bring greater bandwidth to homes and businesses. Communications will develop into a universal, personal, and portable capability.

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TELECOMMUNICATIONS TRENDS

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ABSTRACT

Elisha Gray may have had as much a claim on the invention of the telephone as did Alexander Graham Bell. Bell's patents allowed time for the Bell System to be developed and led to AT&T becoming the largest and most organized telephone company in the United States. AT&T, supported by government regulators, enveloped smaller telephone companies and controlled 80% of local service and all toll service by the 1920s. Government regulations supported AT&T's control of the nation's telephone network until the 1950s when the industry began to be deregulated. In 1984 AT&T was divested by court order and today's telecommunications market is characterized by continuing deregulation and increasing competition. Both telephone and data transmission are becoming more digital and service is provided by numerous carriers. New techniques for increasing the speed of data transfer are constantly being developed. Applications in the future will require much larger capacities than at present. Optical fiber will be the media used to bring greater bandwidth to homes and businesses. Communication will develop into a universal, personal, and portable capability.

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I. INTRODUCTION

A. OBJECTIVES OF THESIS

This thesis is an attempt to understand the direction telecommunications development will take in the future. The outlook for telecommunications is best forecast with a sound knowledge of how it got to its present state. The development of the telephone, telephone network, data transfer, telecommunications technology, and the regulatory environment surrounding them, are all necessary elements to grasp if the future of telecommunications is to be discerned. This thesis will illuminate the past in order to shed light on the future.

B. BACKGROUND

For millennia, the transmission of information was limited by how far the human voice could carry or how fast the written word could be conveyed. The first dramatic variation in this was the invention of the telegraph in the 1800s. The telegraph showed that electricity could be used to transmit a coded representation of writing. The limitations of this form of communication prompted experimentation in using electricity to transmit the spoken word. The desire to speak and be heard from a distance resulted in the invention of the telephone; an achievement which would do no less than shrink the size of the globe. The ability to instantly speak to anyone, anywhere, at anytime, revolutionized the conduct of life everywhere.

As telephone use expanded in the United States, telephone lines were increasingly joined to form one connected system. But these telephone lines were also increasingly operated by a small group of corporations. Being the agent of the means of transmitting information carries with it the perception of holding great power. Power, even when benevolently exercised, always bears with it the suspicion and taint of corruption. An effort was thus made to use government regulations to contain the power inherent in operating the nation's telephone system. Whereas the decisions and actions of businesses are designed to boost profit margins, government regulators make decisions based on intangible criteria which theoretically benefit the public welfare. That portion of the public which receives those benefits is generally known only in hindsight. As regards the telephone industry, over the years, the government has seen fit to regulate from an ideological framework that has ranged from absolute dictatorship to benign neglect.

Regardless of regulations, the network which began as one carrying people's voices was expanded into one carrying the ones and zeroes of digital information. Transforming all information into digital form was found to yield more efficient transmission. As the amount of information to be transmitted grew, the size and scope of the networks used for transmission grew also. Today, at the end of the 20th century, the Earth is criss-crossed with copper and glass cable, and its atmosphere is saturated with man-made emanations in the electromagnetic spectrum.

As the new millennium is entered, the prospect for the further expansion of all forms of telecommunications is indubitable. Not only is there a requirement for more and faster methods of transmitting data, but the technology itself has its own momentum. As long as there is a current top speed at which data can be moved, humans will keep developing new ways to move it even faster. And the faster, more efficient transmission of data will result in services unimagined today.

C. ORGANIZATION OF THE THESIS

This thesis looks at the birth and development of the telephone system in the United States, that system which gave birth to the interlocking, interconnecting, telecommunications network which currently exists. The role of government in shaping the telephone network through regulation is also examined. The government's scrutiny, or lack of it, was a dominating influence in the way the nation's networks developed. The current state of telecommunications technology is then explored and its characteristics are discussed. Lastly, the promise of tomorrow's technology is considered along with the lifestyle it is likely to depend on and help produce.

II. THE DEVELOPMENT OF TELEPHONE SERVICE

The invention of the telegraph ushered in an era of instant communications over distances which before had been restricted by the limitations of the human body. But communication by telegraph was a stilted, foreign, and completely unnatural form of intercourse. It could never substitute for a face to face conversation. The inadequacy of the telegraph would be underscored by the invention of the telephone. It was the telephone, with its accurate reproduction of the familiar human voice, which would produce the greatest change in the link between people that the world had ever encountered. Once unleashed, the expansion of the telephone into all corners of the United States and then the world was an event which could never be halted or recalled and its effects could never be rescinded. This chapter examines the development of the telephone and the system of communications it fostered.

A. INVENTION OF THE TELEPHONE

The actual invention of the telephone was preceded by a host of attempts to achieve it over many years. Many celebrated and otherwise successful people had tried and failed to extend the transmission of the simple dots and dashes of the telegraph into the transmission of the sound of the human voice.

The event itself was to culminate in the conflicting and unresolvable claims of two men.

1. Two Inventors

Many people claimed to have been the source of the telephone but only two had credible reasons to believe that the honor could solely be theirs. These two came from entirely different backgrounds but led lives and had interests which brought them into conflict over a device which would touch the lives of every person on the planet.

a. Elisha Gray

Elisha Gray was born on 2 August 1835 in Barnesville, Ohio. He attended public school while living on his family's farm but was compelled to leave school to find work when his father died. He labored at blacksmithing, carpentry, and boat building before entering Oberlin College at age 22. At Oberlin he studied for five years in the physical sciences and focused especially on electrical mechanisms. From this experience he developed into a life-long inventor. Among his early inventions were an automatic self-adjusting telegraphic relay, a telegraph switch and communicator for hotels, a private telegraph line printer, and a telegraphic repeater. [AMER31 p. 514]

In 1869 Gray cofounded an electric equipment shop in Cleveland called *Gray and Barton* with a partner, Enos N. Barton. The business almost immediately moved to Chicago where it became a manufacturing plant for many inventors of the time. It manufactured the first commercial typewriter, a device which was a predecessor of the mimeograph machine called an electric pen (invented by Thomas Edison), and was involved in Edison's invention of the incandescent lamp. [BROO75 p. 10]

With his background in telegraphic inventions, Gray had gradually migrated to working on the development of a telephone. On 14 February 1876 he filed an explicit description of a telephone as a *caveat* with the U.S. Patent Office. A caveat was a type of document used at the time to give formal notice of an intention to file a patent application and which could be used later as documentary evidence of the priority of an idea [BRIT67 p. 729]. It was technically not a patent application. Gray's caveat described a telephone with a variable-resistance liquid transmitter and an electromagnetic receiver. [TAYL37 p. 246]

b. Alexander Graham Bell

Gray's work on a telephone was paralleled by the work of Alexander Graham Bell. Bell was born on 3 March 1847 in Edinburgh, Scotland. His father was a teacher of elocution who had developed a system called *Visible Speech* which became useful as a tool to train the deaf to speak intelligibly. He attended school in Edinburgh and also worked as a student teacher in music and elocution. Bell later taught and studied at Somersetshire College in Bath. At age 21, he settled in London where he assisted his father in teaching Visible Speech and studied at University College. [BROO75 pp. 38-39]

In 1870 Bell moved with his parents to Brantford, Ontario, Canada, about 60 miles west of Niagara Falls. Bell subsequently went to Boston as a substitute for his father to teach Visible Speech to instructors at a school for the deaf. By 1872 he had opened up his own school of "Vocal Physiology and Mechanics of Speech" and in 1873 he was a professor of physiology at Boston University. [BROO75 pp. 39-40]

In 1872 Bell had begun experimenting on an invention he called a *harmonic telegraph* which would allow simultaneous transmission of several messages over a telegraph wire by distinguishing between several musical notes. These experiments led him to speculate on the possibility of transmitting the human voice over wire. One experiment toward this end involved a *phonautograph* which translated sounds into wave patterns on a piece of smoked glass using the membrane in the ear of a dead person. [BROO75 pp. 40-41]

Bell continued his experiments until, on 14 February 1876, exactly the same day that Elisha Gray had filed his caveat, Bell filed a patent for a telephone with the same U.S. Patent Office that Gray had used in Washington, D.C. Apparently Bell's patent preceded Gray's caveat by just a few hours.

2. Two Patent Office Documents

The two documents are interesting in how they differ in describing the transmitter of a telephone. The transmitter had been the major stumbling block for both Gray and Bell in finally making a telephone work. Half of Gray's caveat was taken up in fully describing and illustrating a liquid, variable-resistance transmitter. Bell's patent was largely a description and illustration of a different type of transmitter, an electromagnetic transmitter, which was in actuality simply an electromagnetic receiver operated in reverse. Figure 1 is the drawing Bell used to illustrate his conception of a telephone in his patent application. It shows both an electromagnetic transmitter and receiver. [TAYL37 p. 246]

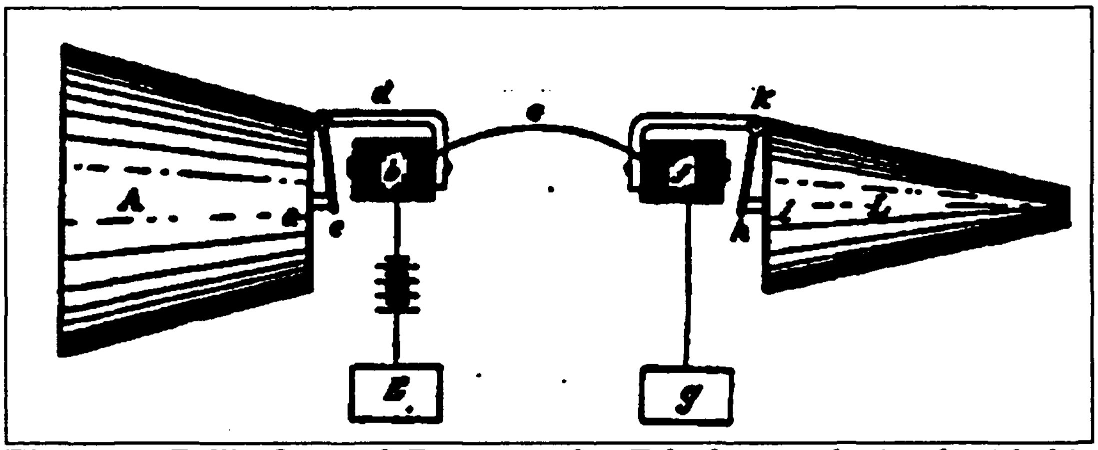

Figure 1: Bell's Original Drawing of a Telephone submitted with his Patent Application

But Bell's patent also mentioned another transmitter. Added in the margin of his application, written sideways, was a suggestion of the possibility that a liquid transmitter (of the type fully described and illustrated in Gray's caveat) might have been built. It occupied less than 4% of Bell's patent application whereas Gray's description of the same thing took up 50% of his caveat. Exactly when Bell added this notation about a liquid transmitter became (and remains) a mystery which has never been adequately addressed in any court. Bell apparently did not deem the possibility of a liquid transmitter being used in a telephone as important enough to even mention in a subsequent patent application for a telephone which he filed in Great Britain. [TAYL37 pp. 245-247]

On 14 February 1876, when both men filed their descriptions of telephones at the Patent Office, neither had yet succeeded in making one work. The fact that both were working on the same invention was not a secret. As early as November 1874 Bell had told others that he and Gray were in "...a neck and neck race...[to see who]...shall complete an apparatus first." [BROO75 p. 43] The same-day filings were confirmed to Bell when the Patent Examiner notified him that his application came into conflict with a caveat filed the same day.

3. Two Descriptions of Patent Office Activity

It is at this point that the historical record does not tell us exactly what happened nor in what order. The day that both Bell's patent application and Gray's caveat were delivered to the Patent Office is shrouded in the fog of the memories of persons whose interest in those events may have colored their recollections.

a. Bell's Version

The popular version, defended by Bell and the companies he helped found, and testified to in court, follows. The Patent Examiner was allowed by regulation to tell Bell and Gray that a conflict existed between the patent and a caveat but not exactly in what area the conflict existed [GRAY78 p. 80]. To ask for more information was not allowed and the Patent Examiner was not allowed to supply any more information. But Bell did ask for more information. Whether he realized it or not at the time, his request was unethical. To compound this violation, the Patent Examiner, who knew the regulations, unethically provided more information to Bell by pointing to Bell's marginal reference to a liquid transmitter. [TAYL37 pp. 246-247]

b. Patent Examiner's Version

The second version of what happened after Bell was notified of the conflict between his patent and a caveat, was supplied ten years later by the Patent Examiner himself, Zenas Fisk Wilber. On 21 May 1886, during a meeting of the Telephone Investigation Committee of the U.S. Congress, an affidavit signed by Wilber was submitted. In this affidavit Wilber announced that he was influenced by his indebtedness to Bell's lawyer to conclude that Bell's patent took precedence over Gray's caveat. He further declared that

> Bell called upon me in person, at the office, and I showed him the original drawing of Gray's caveat and fully explained Gray's method of transmitting and receiving. [POSA86 p. 1]

Wilber finally stated that his meeting with Bell concluded when

> ...Prof. Bell presented me with a $100 bill... [POSA86 p. 1]

for Wilber's services in showing and explaining Gray's caveat to Bell.

c. *Bell's Victory*

The Congressional Committee declined to draw any conclusions from Wilber's statement. However Gray pushed its implications to the U.S. Supreme Court where he argued that Bell had inserted the marginal reference to a liquid transmitter into his patent application *after* its original submission and *after* Wilber had shown and explained Gray's caveat to Bell. In the end, the Supreme Court did not support Gray's contentions because it felt the evidence was "not sufficient" [BROO75 pp. 77-78]. Despite the magnitude of the charges, and their implications, Bell never brought suit against Wilber or Gray for libel. [TAYL37 p. 247]

4. The First Telephone

Regardless of the type of information Bell received from Wilber, within two weeks of being given this information, on 10 March 1876, Bell and his assistant, Thomas Watson, had constructed and successfully operated the first telephone using a liquid transmitter almost exactly as described in Gray's caveat. Figure 2 shows the liquid transmitter Bell used. To transmit, one had to speak down into the large cone. At the bottom of the cone was a diaphragm with a wire attached. The wire extended into acidulated water in a small metal cup. The speaker's voice vibrated the diaphragm, causing the wire's depth in the water to vary, and a variation in electrical resistance to occur in the battery powered circuit. The resulting current variation produced a vibration in a diaphragm in the receiver which then reproduced the sound. [BROO75 p. 49]

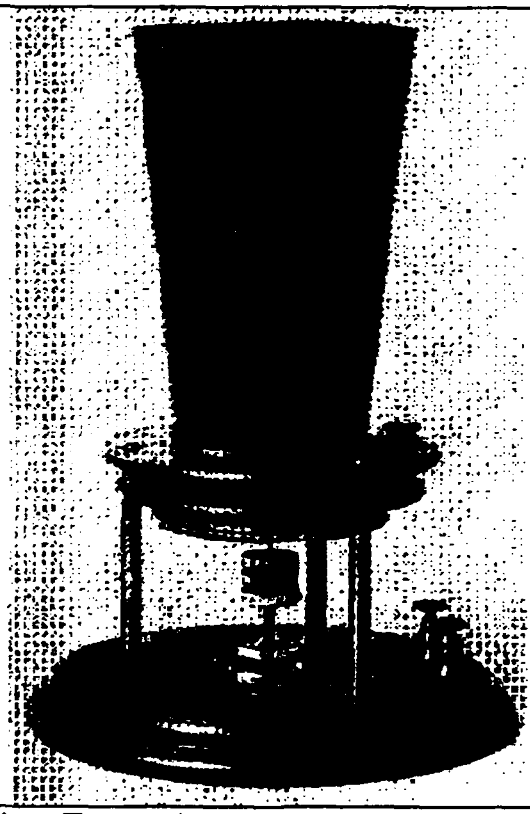

Figure 2: Bell's First Transmitter

Instead of going public with this information, Bell immediately set about modifying the electromagnetic transmitter he had described in his own patent application so that it too could transmit speech. Within three or four weeks he was successful and it was with this device that he finally went public. The fact that he had been first successful with a liquid transmitter was kept secret by Bell for four years, until 1880, when he both admitted it and took credit for it. This was after a number of major lawsuits by and against Bell had been resolved in his favor and he had legally become the sole owner of the rights to the invention of the telephone. [TAYL37 pp. 247-248]

5. Gray's Misgivings

Gray himself had been initially persuaded that Bell had preceded him in the invention of the telephone because Gray had supposed that the first telephone had not used a liquid transmitter. Later he was persuaded just the opposite, as he wrote in 1901,

> It was not till eight or ten years - at least a long time after the telephone was in use - that I became convinced, chiefly through Bell's own testimony in the various suits, that I had shown him *how* to construct the telephone with which he obtained his first results. [TAYL37 p. 249]

6. Gray's Receiver

The telephone which came into general use had a receiver consisting of an electromagnet and a metal diaphragm. Vibrations from an electrical current acting on the diaphragm reproduced transmitted sound. Gray had constructed and publicly demonstrated such receivers since May 1874 and had patented them in July 1874 in England and in July 1875 in the United States.

They were already capable of receiving and reproducing speech at that time although a transmitter capable of sending speech had not been yet been developed.

Gray clearly had an unchallenged patent priority on the metal diaphragm receiver which came to be universally used in telephone systems. Despite this fact, no claims were ever made regarding this receiver by or on behalf of Gray in any of the lawsuits filed against Bell. The point either escaped notice or was not deemed worthy of pursuing. [TAYL37 pp. 249-251]

7. Gray's Obscurity

The nearly universal acclaim which followed Alexander Graham Bell until his death in August 1922 in Cape Breton Island, Nova Scotia, was denied to Elisha Gray [BROO75 pp. 56-57]. Gray continued to invent and eventually held about seventy patents. He wrote technical articles and published technical journals. He was organizing chairman of the first International Electrical Congress in 1893. He received several honorary degrees and was decorated by the French Government. But he never came close to the fame which Bell achieved even though he may have been the true source of that fame [AMER31 p. 514]. Shortly after Gray's death in Newtonville, Massachusetts on 21 January 1901 the following note was found among his belongings.

> The history of the telephone will never be fully written. It is partly hidden away in 20 or 30 thousand pages of testimony and partly dying on

> the heart and consciences of a few whose lips are sealed, - some in death and others by a golden clasp whose grip is even tighter. [TAYL37 p. 251]

One who would apparently agree with Gray is Zenas Fisk Wilber who said,

> I am convinced that, by my action while Examiner of Patents, Elisha Gray was deprived of proper opportunity to establish his right to the invention of the telephone.... [POSA86 p. 1]

B. EARLY TELEPHONE COMPANIES

Businesses are the natural result of the invention of a marketable product. Telephone companies therefore were quick to develop to take advantage of the public's willingness to purchase and use this new technology. The telephone industry which emerged was to result in the creation of the largest corporation in the history of the United States.

1. Bell Companies

The year before filing his patent application, Bell had formed the Bell Patent Association with financial backing he received from the fathers of two of the deaf students he tutored. In addition to being issued a patent for his application of 14 February 1876, the next year he filed and received several other patents for the telephone and demonstrated his telephone widely. It did not however, meet with universal acceptance. Skeptics saw few practical uses for transmitting the human voice over a wire [USTA91 p. 1]. Regardless, on 9 July 1877, Bell and his partners began the commercial exploitation of Bell's patents by changing the Bell Patent Association into the Bell Telephone Company [BROO75 p. 8]. By the end of 1877, using Bell's patents for both transmitter and receiver, they had 600 telephones on line and were manufacturing 25 more per day. [USTA91 p. 1]

To expand their business they appointed regional agents whose job it was to promote the telephone in specific geographical areas. Customers could lease the telephones but were responsible for constructing their own lines, often with the help of the agents, many of whom just happened to own construction firms. Agents received rental commissions as well as any profits from their construction business [BROO75 p. 8]. These first lines were single, bare, copper wires strung along trees and housetops. [HAWL91 p. 24]

2. Exchanges and Switches

Early telephones were directly connected between two users who could only talk to each other. However it soon became clear that this was too limiting. Users wanted to be able to talk to anyone who had a telephone. This need forced the development of the *local exchange* in January 1878. Telephone subscribers' lines were connected directly to the local exchange where their calls could be manually switched to the person to whom they wished to speak. All switching was done by hand by operators who were young men. These males proved to be too boisterous and were soon replaced by young ladies who were thought to have better manners.

The exchange system still exists today in what is known as the *central office* which is operated by a *Local Exchange Carrier*. Most of the early exchanges were installed first by Western Union, the telegraph giant which became an early competitor to the Bell Telephone Company. Western Union would often establish an exchange in a new area and was later followed by a Bell exchange in the same area. This was most often due to Western Union having preexisting telegraph facilities in most areas while Bell had to start from scratch everywhere. [BROO75 pp. 65-66]

3. Bell Franchises

To meet further demand for telephones, Bell Telephone decided to franchise telephone operations. Equipment would be leased to franchisees who would then rent it to their customers. Bell Telephone would retain the rights of ownership and manufacturing of the equipment. Service at this early stage was universally poor and sporadic but demand still increased. By 1878 businessmen in Chicago, Boston, and New York used the telephone regularly for business. [FINK89 p. 154]

4. Western Union Challenge

Although the Bell Telephone Company had been issued numerous patents, their operations did not go unchallenged. Many lawsuits would be filed against Bell Telephone by individuals and companies who claimed that Bell stole their ideas. Conversely, Bell Telephone would file hundreds of lawsuits against those it felt were infringing on its patents for the telephone. The most serious of the latter was a lawsuit Bell Telephone filed against Western Union.

a. Western Union Telephone Company

In 1876, Western Union had rejected an offer from Bell to buy his combined patents for $100,000, evidently deciding not to enter the telephone market. But within two years, in 1878, Western Union had reconsidered and had purchased Elisha Gray's numerous patent rights including many for telephone equipment. With Western Union's existing network of telegraph equipment and facilities throughout the country, it was perfectly positioned to expand in the telephone business. Bell Telephone responded with a patent infringement lawsuit in September 1878 [BROO75 pp. 61-64]. As the suit dragged on, Western Union was busy establishing its own network of telephone companies. Bell Telephone fought back by setting up telephone systems in the same geographical locations thus causing, in many cases, two unconnected telephone systems to exist side by side. A subscriber on one system could not talk to a subscriber on the other system. [FINK89 p. 154]

To gain capital in early 1878, the Bell Telephone Company had split off another company called the New England Telephone Company which was to handle operations in New England. To strengthen its position against

Western Union the two companies reformed into the National Bell Telephone Company in 1879. [BROO75 pp. 8-9]

b. Attack on Western Union

By November 1879, Western Union had 56,000 telephones in 55 cities, about the same as National Bell, but was financially in much better shape [BORN83 p. 9]. However, Western Union's seeming preeminent position in the nascent telephone industry was to come under attack from an entirely different quarter. Since the mid 1870s, Western Union had been besieged by the financial predator Jay Gould. Gould had started his own telegraph network, the Atlantic and Pacific Company, as a rival to Western Union. Gould even considered buying the National Bell Telephone Company as a further means to control competition against Western Union in both the telegraph and telephone business. This competition caused a decline in both Western Union's business and its worth. [BROO75 p. 63]

c. Western Union Settles

Gould's relentless attacks, combined with a chief counsel who predicted that Western Union would lose the ongoing patent infringement suit with Bell, finally convinced Western Union to settle out of court with National Bell. Under the agreement, National Bell bought Western Union's entire system (telephone equipment, exchanges, and facilities), agreed to stay out of the telegraph business, and paid Western Union a royalty of 20% on all Bell telephones. Western Union also agreed to stay out of the telephone business. This agreement remained in force until the expiration of Bell's patents in 1893 and 1894. With the end of the suit, the National Bell Telephone Company became a legal monopoly since they owned the telephone patents. In 1880 its name was changed once more to become the American Bell Telephone Company. [BORN83 p. 9]

5. Western Electric

In a final dealing with Western Union, American Bell bought controlling interest in Western Electric in 1881. This was the company originally cofounded by Elisha Gray as Gray and Barton. Western Union had bought controlling interest in Western Electric in the late 1870s and had used it to manufacture all its telephone equipment. In 1881 American Bell was looking to expand its manufacturing capability and found the plant it needed in Western Electric [BROO75 p. 91]. It quickly became the manufacturing arm for all American Bell equipment and contributed greatly to the standardization of all Bell Telephone facilities. [FINK89 p. 155]

6. Bell Operating Companies

The franchisees (or operating companies) licensed by American Bell were territorial monopolies. They usually had contracts which ran for five or ten years, paid yearly fees to American Bell based on the installed base of telephones, and gave American Bell the opportunity to purchase the franchise at contract expiration. Beginning in about 1881 many of these temporary contracts were renegotiated to become permanent. Under the new contracts, the operating companies still paid licensing fees to American Bell, but also gave Bell a 30% to 50% ownership. American Bell gave up the right to buy out the operating company unless the operating company violated some other terms of the contract. Included in the contracts were the following two important prohibitions.

1. The operating companies could not connect to each other. This was reserved only for the parent company with its long distance division. This meant that there was to be no connection between Bell companies except through American Bell.

2. The operating companies could not connect to any independent (i.e., non-Bell) telephone companies. This included any of the companies or individuals involved in the more than 600 lawsuits Bell was involved in and which centered on the invention of the telephone or key components of it. Many of the litigants had actually started their own small telephone operations. It also looked forward to the time when Bell's patents would run out and Bell companies would no longer be monopolies. [BORN83 pp. 9-10]

C. INDEPENDENTS VERSUS AT&T

The telephone industry was not to remain the monopoly of a single company. Patent law is designed to allow inventors a reasonable period of time to enjoy the fruits of their creativity but then it allows the competitive nature of the marketplace to hold sway.

1. Independents Develop

This, then, described the telephone service that existed when Bell's original patents ran out in 1893 and 1894. Immediately afterward, independent telephone companies began developing and spreading unfettered throughout the United States. Eighty-seven independents were started in 1894 [BORN83 p. 11]. By 1900 there would be about 6000 independent exchanges across the country, with 1000 independents in Iowa alone, and independents would control 44% of all telephones in use. The majority of independents were small, local, rural enterprises started by a few families or businesses. They were typically installed and maintained by the people they served and the exchanges were most often run by a single family. [USTA91 p. 3]

2. AT&T Emerges

The tremendous competition engendered by the startup of the independents spurred American Bell into a period of greater growth. New exchanges were added, older exchanges were expanded, and long distance service between exchanges was extended. This expansion of American Bell required an enormous amount of capital and this was limited by the nature of corporate law in Massachusetts where American Bell had its headquarters. The law limited American Bell to having no more than 30% control of its licensees. It also could not pay stock dividends and was unable to raise the amount of money necessary for the expansion it sought. This situation led

American Bell, in 1899, to transfer its stocks and bonds to its subsidiary in New York where the law was much more hospitable to corporate expansion. The New York subsidiary was called the American Telephone and Telegraph Company (AT&T) and on 30 December 1899 it became the parent company of the Bell family of companies which came to be known as the *Bell System*. [BORN83 p. 11]

AT&T's certificate of incorporation stated that its purpose was to be,

> ...constructing, buying, owning, leasing, or otherwise obtaining, lines of electric telegraph partly within and partly beyond the limits of the State of New York, and of equipping, using, operating, or otherwise maintaining the same. [BROO75 p. 91]

The word *telephone* appeared only in the company name. The use of the word *telegraph* served two purposes.

1. It was a generic term used at the time for any wire communication using electricity.
2. It left a natural opening for AT&T to later enter the telegraph market if the opportunity presented itself. [BROO75 p. 91]

3. Independents Expand

The independent companies (all those not connected to AT&T's Bell System) had, by 1903, controlled 61% of all telephone access lines (i.e., the lines from a subscriber's telephone to his central office) [FINK89 p. 156]. Some larger independents had begun to encroach on the Bell System's territories, especially where Bell's service was relatively poor or expensive. This often resulted in two or three phone companies serving a single area as was the case prior to the settlement of the Bell versus Western Union lawsuit. In general, the telephones belonging to one system in an area could not connect to telephones belonging to another system in the same area because the systems were in competition and were not linked. (Multiple phone systems in a single area would continue to exist until the last one died out in Philadelphia in 1945.) [USTA91 p. 3]

4. Independents Organize Against AT&T

The common problems of the independent telephone companies, along with their common adversary, AT&T's Bell System, led to the establishment of the National Association of Independent Telephone Exchanges in 1897. Toll lines connecting nearly all the independent exchanges were quickly installed. (Toll traffic was any that required an exchange to connect with another exchange to complete a call. This became synonymous with the terms *long distance* or *interexchange* service. The exchange to which a subscriber connected was his central office.) By 1905 the independents had a continuous system which extended from the Rockies to the Atlantic and went coast to coast by 1910. In 1907 they carried 20% of all toll traffic. That would rise to 28% by 1912.

The goal of the independents was to build up a complete system which could compete with AT&T. They even adopted a shield as their nationwide logo to distinguish themselves from the Bell System [BORN83 pp. 16-20]. Optimism was so high that they would succeed that one observer noted in 1906 that the "gouging monopoly" that the Bell Companies had "fastened on the necks of the American people" had been "shaken off." [HINC79 p. 44]

The independent telephone companies used three primary methods in developing a telephone system independent of the Bell System.

1. Independent local exchanges were merged into large regional independent companies which provided toll service between the exchanges.

2. Independent local exchanges formed toll associations which used clearinghouses to divide revenues derived from the toll calls carried over member lines to member exchanges.

3. Toll companies formed to provide long distance service between independent exchanges. [BORN83 pp. 16-20]

Despite its early successes the independent telephone system concept eventually failed. It was made up of many disparate parts, each with its own vision of the future. They were not controlled by a single authority as the Bell System was controlled by AT&T. Defections to the Bell System were commonplace. Independent telephones connected to the Bell System rose from 3% in 1899, to 27% in 1907, to 65% in 1912. [BORN83 pp. 26-27]

5. AT&T Organizes Against the Independents

Although certainly the major player in the telephone industry, AT&T's position was not unassailable. If it was to survive, AT&T had to develop strategies which would carry it through the challenges of the independent telephone companies.

a. Natural Monopoly

Starting in 1907, AT&T, under the leadership of Theodore N. Vail, began stressing its view that telephone service was a "natural" monopoly. Vail said that because of its technical nature, telephone service would be provided most efficiently by a single carrier which operated without competition, i.e., as a monopoly. When regulation of the telephone industry became inevitable AT&T said that telephone service would best be provided by a regulated monopoly. [BROO75 p. 143]

Whether or not any natural monopolies really exist, the number of locations where competition existed between telephone companies was gradually reduced to zero. The causes for this decrease are open to interpretation and Bornholz and Evans have suggested two competing ones. The first affirms Vail's contention regarding telephone service as a natural monopoly.

> ...the fact that the independent telephone companies were unable to provide a competitive nationwide telephone system, the fact that so many independents apparently found it profitable to join the Bell System through acquisition or interconnection, and the fact that the Bell System succeeded in establishing a single, universal, interconnected telephone system suggest that a single firm with common ownership over the pieces of the network can provide telephone service more efficiently than multiple firms. [BORN83 p. 14]

Bornholz and Evans' second interpretation argues against telephone service being a natural monopoly.

> ...the fact that AT&T was unable to impede the independent telephone movement through direct competition in price and quality and the fact that AT&T had to resort to the same kind of merger tactics that created monopolies like Standard Oil suggest that the telephone industry was not a natural monopoly. AT&T circumvented the competitive process in order to establish its unnatural monopoly. [BORN83 p. 14]

b. Long Distance Lines

AT&T had a definite advantage over the independents in that it controlled most of the long distance lines in the country. It had developed these lines as part of a long range plan since before their original telephone patents ran out. It was simply too expensive for an independent to attempt the large scale expansion necessary to compete alone against the Bell System in long distance service. Capitalizing on their advantage, AT&T went from competing directly with the independents to trying to absorb the independents into its own Bell System. AT&T used three techniques to make this happen.

1. AT&T tried to acquire (often secretly) independents that competed directly with AT&T's exchanges.
2. AT&T tried to acquire (often secretly) independents whose exchanges were strategic links in any non-Bell regional systems.
3. AT&T tried to persuade independents which did not compete directly with Bell to interconnect with the Bell System, but with provisions which effectively brought them under the control of AT&T. [BORN83 p. 13]

Largely as a result of these actions by AT&T, the independents saw their share of the nation's telephones decline from 61% in 1903, to 49% in 1907, to 45% in 1912. [BORN83 pp. 12-14]

c. *AT&T Acquires Western Union*

In addition to its success over the independents, AT&T was also moving to consolidate its hold over the nation's communications in general. In 1909 AT&T had acquired enough stock to take control of Western Union and by 1911 the two companies had effectively merged into one. With that merger the United States had a single company which controlled the majority of telephone lines (including virtually all long distance telephones lines through its Bell System) and also controlled the majority of the nation's telegraph lines through Western Union. [BROO75 pp. 133-134]

The size AT&T was becoming began to affect control of the organization. In 1911 the numerous local companies in the Bell System were consolidated into a smaller number of state and regional companies. These companies in large measure still exist today within the Regional Bell Holding Companies. [FINK89 p. 157]

6. Federal Government Forces Changes

The Federal Government had, up to this time, not played a significant role in the development of the telephone industry. That was to change as the importance of the telephone began to affect the nation as a whole.

a. *Independents' Complaints*

The independents, recognizing AT&T's takeover tactics, and understanding their own vulnerabilities, began lobbying the government for the right to connect to the Bell System without becoming beholden to it. As early as 1904 some state legislatures began mandating interconnection between phone companies. AT&T was nearly always able to have such laws rescinded because the concept of the telephone as a public utility had not yet fully developed.

b. *Government Intervention*

Finally, in 1913, at the prodding of the independents and their trade organizations, the U.S. Attorney General informed AT&T that it might be in violation of the Sherman Antitrust Act and in danger of a lawsuit which could bring about the dismantling of the company. At the same time the Interstate Commerce Commission (ICC) started its own investigation as to whether AT&T was attempting to monopolize communications in the United States. [BORN83 p. 13]

c. *AT&T Capitulates*

In 1913, rather than be forced into taking action dictated by the Federal Government, AT&T voluntarily made three policy changes in the way they did business. These changes caused the Federal Government to drop their threatened lawsuits and investigations. The policy changes became known collectively as the Kingsbury Commitment, after the AT&T vice president who wrote it, and required AT&T to do three things.

1. Dispose of its Western Union stock.
2. Purchase no independent telephone companies which competed with AT&T without ICC approval.
3. Allow independent telephone companies to connect with AT&T's long distance lines. [BROO75 p. 136]

The third point made the Kingsbury Commitment one of the most important events in the history of the U.S. telephone industry. It ushered in the availability of what came to be known as *Universal Service*: the ability of any telephone subscriber to be able to connect to any other subscriber, anywhere in the country.

d. Post Office Control

For one year, from 1 August 1918 to 1 August 1919, U.S. telephone systems were under the authority of the U.S. Post Office but were operated by the same people and organizations. In 1921 the *Willis-Graham Act* eased restrictions against telephone company mergers. By 1934, when the Federal Communications Commission (FCC) took over telephone regulatory duties from the ICC, AT&T controlled about 80% of all telephones and independents had the other 20%. This ratio remained relatively steady until

1984. Even today, largely the same local companies provide service to subscribers as they did in 1934 within geographical boundaries approved by regulatory agencies.

D. AT&T LOSES CONTROL

After World War II, AT&T's grip on the nation's telephones began to loosen. In 1956 AT&T agreed to an out-of-court *Consent Decree* from the U.S. Department of Justice. That decree required AT&T to do three things.

1. Restrict its business to "common carrier communications" subject to regulation. [TUNS85 p. 7]
2. Restrict AT&T's subsidiary Western Electric to manufacturing equipment only for the Bell System.
3. Allow any and all AT&T, Western Electric, and Bell Laboratories patents to be licensed by anyone desiring to do so. [BELL85 p. 47]

Few realized it at the time but this Consent Decree (also known as the *Final Judgment*) was the beginning of the return of real competition to the telephone industry.

1. Other Vendors Allowed

Also in 1956 was the *Hush-A-Phone* ruling by a U.S. Court of Appeals which overturned a longstanding FCC prohibition against attaching any non-Bell equipment to the telephone system. This prohibition had been the policy of AT&T and was supported by the FCC to the extent that it had taken on the patina of holy writ. An example with the National Association of Broadc rs (NAB) in the 1930s illustrates just how sacrosanct this prohibition had been.

The NAB was holding a convention in Detroit and had arranged for President Hoover to speak to them from the White House over long distance telephone which would then be amplified for the audience over a public address system. Phil Loucks of the NAB continues the story:

> Everything was great until we called Michigan Bell while setting up the convention arrangements. We told their installers what we wanted, and they flatly refused-it was a violation of the interconnection rules to connect a telephone to a public address system. Nothing I could say made any difference to them. I was getting desperate, and started calling top officials of Michigan Bell. I got the same story from each of them; it didn't make any difference if it was the President, and if no harm was being done to anyone. It was a violation of their tariffs.
>
> As the time approached for the Presidential call, not knowing what else to do, I called AT&T President Walter Gifford at his New York office. I was told he was travelling somewhere in Tennessee, and when I explained the situation, they said they would try to get back to me.
>
> When time was really getting short, I got a call from Gifford. I poured out my problem, and he laughed and said, "Well, in an organization as big as this one, we have to have rules. Leave it with me, and I'll see what I can do." That took care of it and the interconnection was made. We got the call and the broadcasters heard the message. [HENC88 p. 25]

The *Hush-A-Phone* ruling was a major change in the relationship of the public to the telephone system that served them. No longer did AT&T have absolute sway over what the user connected to his own telephone line.

Microwave transmission of telephone traffic had been developed during World War II and was used afterward commercially. In 1959 the FCC allowed businesses to use private microwave systems for internal communication but were not allowed to connect them to the Bell System. [FAUL87 p. 24]

The *Hush-A-Phone* decision in 1956 allowed the connection of user provided equipment (i.e., non Bell-provided equipment) at the subscriber end of the telephone line. However, this allowance was written by AT&T (and approved by the FCC) in such a restrictive manner that almost no user supplied equipment was ever used.

In 1968 the FCC announced its *Carterfone* decision in which all customer supplied equipment would be allowed to be connected. AT&T made its usual argument that the integrity and reliability of the telephone system could only be guaranteed if AT&T had complete responsibility for it from end to end. The FCC rejected AT&T's lament in favor of a new policy requiring AT&T to show that any particular customer provided equipment would harm the network [HINC85 p. 46]. AT&T was successful in delaying the implementation of the *Carterfone* ruling until 1975 while the technical specifications were agreed upon. [FAUL87 p. 30]

2. Toll Market Opens

By FCC edict, until 1971, AT&T had been solely responsible for the nation's long distance traffic. Other groups had tried to compete, especially the independent telephone companies around the beginning of the 20th century, but were unsuccessful. It took an enormous capital investment to construct the lines and install the equipment for a toll system to compete with AT&T. The independents which had attempted this were really a disorganized, loosely aligned cooperative of many smaller telephone systems. AT&T's policy of divide and conquer decimated the cooperative, and FCC support of the Bell System ensured AT&T's control of toll service until the ruling in 1971 when other long distance carriers were allowed into the marketplace. At that time, allowed by the FCC, newcomers typically took a relatively small investment and carved out a niche market from which they could expand into wider operations. Technological innovations like microwave transmission and providing no frills service made this economically feasible.

For example, Microwave Communications Incorporated (MCI) offered telephone service using just 2 Khz of bandwidth per voice channel. This was just half of what AT&T considered the minimum bandwidth needed to produce an acceptable reproduction of the human voice but MCI found customers who did not require or mind a degradation in quality if they could save money. By making this change, MCI was able to put twice as many channels over the same bandwidth, charge less per channel, and still make a profit.

Initially new carriers were allowed to provide customers only point to point toll service. By 1978 this was expanded to include service identical to the service supplied by AT&T. [HENC88 pp. 167-173]

3. AT&T Divested

The action which would lead directly to the end of AT&T's overwhelming dominance in the U.S. telephone industry was the U.S. Justice Department's antitrust suit of 1974. The suit dragged on until 1982 when all sides agreed to settle out-of-court with the *Modification of Final Judgment* which amended the *Consent Decree of 1956*. The result came to be known as *Divestiture* and it accomplished three primary goals which became effective on 1 January 1984.

1. AT&T was divested of its operating companies which would become independent and continue to provide local telephone service.
2. AT&T would keep its long distance service, Western Electric, and Bell Laboratories.
3. AT&T was freed from the restrictions of the *Consent Decree of 1956* and would be allowed to enter other markets, especially the computer field. [CRAN91 pp. 8-9]

The 22 local telephone operating companies owned by Bell and which still provided about 80% of all local exchange service were consolidated into seven separate and distinct Regional Bell Holding Companies (RBHCs). The RBHCs joined the more than 1400 existing independent telephone companies providing just local service within their state regulated geographical boundaries where they all continue to be local service monopolies. The seven RBHCs today still collectively provide about 77.5% of the local service to subscribers while the other 1300+ companies supply the other 22.5%. The number of telephone companies in each state, which offered local exchange service as of 31 December 1990, is listed in Table 1. [USTB91 pp. 19-20]

TABLE 1

LOCAL TELEPHONE COMPANIES BY STATE

AS OF 31 DECEMBER 1990

Alabama	36	Montana	19
Alaska	26	Nebraska	46
Arizona	13	Nevada	16
Arkansas	31	New Hampshire	14
California	26	New Jersey	6
Colorado	28	New Mexico	17
Connecticut	4	New York	53
District of Columbia	2	North Carolina	33
Delaware	2	North Dakota	26
Florida	18	Ohio	49
Georgia	40	Oklahoma	42
Hawaii	2	Oregon	38
Idaho	24	Pennsylvania	48
Illinois	67	Rhode Island	2
Indiana	48	South Carolina	32
Iowa	158	South Dakota	33
Kansas	44	Tennessee	28
Kentucky	23	Texas	63
Louisiana	21	Utah	15
Maine	21	Vermont	11
Maryland	3	Virginia	26
Massachusetts	4	Washington	27
Michigan	43	West Virginia	13
Minnesota	96	Wisconsin	103
Mississippi	20	Wyoming	13
Missouri	48		

Divestiture left AT&T as just another (albeit the largest) of a proliferation of companies offering long distance service. This portion of the telephone industry remains extremely competitive with more than 300 firms offering toll service.

At present subscribers are constrained by their geographical location and their state Public Utilities Commissions as to who provides their local telephone service. Beyond that the choices are many. The equipment used, the toll service selected, and the specialized services provided are limited only by the variation that can be supported in the marketplace.

III. REGULATION IN THE TELEPHONE INDUSTRY

In 1877, the U.S. Supreme Court case of *Munn v. Illinois* established the right of American governmental institutions to regulate economic activity in the United States. Such a right did not meet with universal approval since it violated what most Americans believed to be true, as espoused by Adam Smith, that the marketplace should be free and subject only to the invisible hand of competition. Typical opposition to this right was displayed in the dissent of Supreme Court Justice, Stephen J. Field, who wrote,

> If this be sound law, if there be no protection either in the principles upon which our republican government is founded, or in the prohibitions of the Constitution against such invasion of private rights, all property and all business in the State are held at the mercy of a majority of its legislature. [FAUL87 p. 39]

Nevertheless, at that time, the year following the invention of the telephone, regulation became an entrenched element of government bureaucracy. Independent expert commissions would begin to control industries in which competition did not seem to work, the claim being that this would ensure that the "public interest" (a term without legal definition), and not just private interests, would be better served [BELL85 p. 47]. This chapter examines the role government regulation has played and the power it continues to exert over the telephone industry.

A. EARLY REGULATION

Regulation of the telephone industry was not immediate. Until the expiration of the original Bell telephone patents in 1893 and 1894, the Bell System was able to develop and operate telephone systems relatively unfettered. Almost the only governmental influence was that exerted in the more than 600 telephone lawsuits filed against and on behalf of Bell. Those filed against Bell argued that Bell had infringed on the rights of others who, it was claimed, more properly should have been credited with the invention of key elements of the telephone. Although suits were put forward by such luminaries as Thomas Edison, they were all turned back in court. Those lawsuits filed by Bell against others argued that the defendants had violated Bell's patents for telephone equipment, usually by setting up local telephone companies. Bell won all these lawsuits as well.

1. State Regulation

When Bell's patents expired and entrepreneurs caused telephone service to explode in the late 1800s and early 1900s, many state agencies were created to oversee this burgeoning new enterprise. As early as 1885 (in Indiana) states began passing laws regarding the telephone industry. Indiana's first law fixed the price of telephone service at $3.00 per month. The first state regulatory commissions were established in 1907 [USTA91 p. 6]. By 1915 almost every state had a commission which regulated their state's telephone rates and practices. [BROC83 p. 41]

2. Mann-Elkins Act

In 1910 the U.S. Congress passed the *Mann-Elkins Act* which gave the Interstate Commerce Commission (ICC) the power to regulate interstate telephone service. The ICC almost immediately began an investigation of AT&T which was by far the largest purveyor of service between local exchanges (i.e., long distance telephone service) [BROC83 p. 41]. At this time, AT&T was aggressively forcing independent telephone companies out of business by buying them outright, undercutting their prices, and refusing to let them connect to Bell's long distance lines unless they essentially came under AT&T's control. AT&T's policies were accompanied by a drop in the independent telephone companies' share of U.S. telephones from 61% in 1903 to 45% in 1912. The independents began to complain and, in 1912, the U.S. Justice Department threatened AT&T with a lawsuit which could have broken up the Bell System.

3. Kingsbury Commitment

AT&T responded to these threats from the ICC and the Justice Department with the Kingsbury Commitment in 1913 (see also Chapter II.) Under the terms of this document AT&T agreed to purchase only noncompeting independent telephone companies and to allow any independent telephone company to connect to AT&T's long distance lines [BORN83 p. 13]. These voluntary actions by AT&T effectively headed off further Federal antitrust lawsuits for the next 35 years. (In the minds of AT&T management however, that threat lingered for another nine years until the passage of the *Willis-Graham Act* in 1921.) [HINC85 p. 35]

4. Government Control

By 1912 most European telephone systems had been nationalized. This was a very real threat to the companies which owned the U.S. telephone industry as well. AT&T had the most to lose in nationalization and fought vigorously against it. One method used to fight it was to promote regulation instead. This was emphasized by AT&T President Theodore N. Vail in 1910 when he said,

> A public utility giving good service at fair rates should not be subject to competition at unfair rates. It is not that all competition should be suppressed but that all competition should be regulated and controlled. That competition should be suppressed which arises out of the promotion of unnecessary duplication, which gives no additional facilities or service, which is in no sense either extension or improvement, which without initiative or enterprise tries to take advantage of the initiative and enterprise of others by sharing the profitable without assuming any of the burden of the unprofitable parts or which has only the selfishly speculative object of forcing a consolidation or purchase. [BROC83 p. 42]

Nevertheless, proponents of nationalization finally won a victory when, on 1 August 1918, U.S. telephone systems (as well as telegraph systems) were brought under the governing authority of the U.S. Post Office. This change was justified by the recent U.S. entry into World War I and the need for government control of communication links for national defense purposes. For a year the ICC had no influence over the telephone industry. In reality, telephone companies operated with almost no interference from the Post Office and one year later authority was officially turned back over to the telephone companies. [USTA91 p. 7]

5. Willis-Graham Act

By 1921, the government's hope that the Kingsbury Commitment would foster greater competition in the telephone industry was seen to have failed. The independent telephone companies were just not serious threats to AT&T. From 1912 to 1921 the number of independent telephones had dropped from 45% to 36% and those not connected to the Bell System had dropped from 17% to just 4% [BORN83 p. 14]. Competing telephone companies were so anxious to link with or join the Bell System outright that in 1921 the *Willis-Graham Act* was passed. This act allowed the consolidation of competing telephone exchanges and removed the threat of antitrust suits against AT&T for merging with other companies. [USTA91 p. 7]

B. AT&T MONOPOLY

AT&T's willingness to accept regulation in 1913, with the Kingsbury Commitment, may have contributed to the favorable nature (for AT&T) of the *Willis-Graham Act*. Under *Willis-Graham*, AT&T was able to reduce the few serious competitors it had left and essentially gain complete control of the nation's telephone system. It was a fact that most state regulatory agencies opposed telephone competition. AT&T's willingness to accept regulation in

1913 seems to have resulted in AT&T receiving governmental approval for developing a near monopoly on the telephone industry by 1934 when the U.S. Congress passed a major Communications Act. [BROC83 p. 42]

There were no appreciable regulation changes during the next 13 years and the independents continued to decline while AT&T continued to expand. By 1934 the independent share of telephones was down to 21%, virtually all telephones were connected to the Bell System, and there was no longer any direct competition with the Bell System. State regulatory agencies began to protect telephone companies as monopolies by licensing only single companies within geographical areas (a practice which continues to this day.) This insured that the 80% to 20% split between AT&T and independent telephones would endure until 1984.

1. Communications Act of 1934

The next major change in the regulation of the telephone industry came during the Depression, in 1934, when the *Communications Act of 1934* created the Federal Communications Commission (FCC). The FCC's creation and its dominion over the telephone industry must be considered in light of the concepts of a *common carrier* and a *public utility*.

2. Historical Regulation

Regulation of the telephone industry did not come about in a vacuum but had a long standing precedent extending back before the Western

Hemisphere was discovered by the Europeans. Those precedents continue to guide the regulatory environment of today.

a. Common Carrier

The term *communications common carrier* refers to the business of supplying the transportation of information. Any business supplying such service is known as a common carrier. These terms first developed in the transportation industry in England where English Common Law imposed certain public rights and responsibilities on common carriers. Common carriers were typically businesses licensed to transport people and goods on the public roads of England. English Common Law demanded that nondiscriminatory service be offered in exchange for the right for a common carrier to use public roads and rights of way. [HINC85 pp. 33-34]

b. Public Utility

About the same time, in England, the concept of a public utility developed as well. A public utility was deemed to be a supplied service which was essential to the public's general welfare, e.g., water, gas, and later, electricity. It was believed to be most efficient, safe, and healthful if such services were organized as public or private monopolies within certain geographical areas. Since they would be monopolies, the establishment of institutions to provide continuing oversight over public utilities on behalf of the public was begun. The goal was to ensure that the public which needed these services would get them at a reasonable cost and without discrimination. The government institutions which regulate public utilities are typically at the state level today and are known as Public Utility Commissions (PUCs). [HINC85 p. 34]

c. *Jurisdictions*

Common carriers, public utilities, and the regulation of them, were all present in the laws of the colonies and the states of the United States long before the development of the telephone industry. They were not widely applied however, to this new form of communication, until the first decade of the 20th century. As the telephone grew in importance and the industry became more complex, concerns grew regarding the availability of telephone service and a nondiscriminatory rate structure for it. The refusal of early competing systems to interconnect, thus requiring subscribers to duplicate or even triplicate their equipment in order to connect to all systems, was a powerful incentive for the regulation of the industry on behalf of the public. [HINC85 p. 34]

3. Federal Communications Commission

In light of the fact that early telephone service was primarily local, states often established their own regulatory policies. Common among these was the identification of telephone service providers as common carriers or public utilities and thus under the jurisdiction of the bodies which governed such. There was generally a recognition that telephone service would develop on a monopoly basis within a geographic area [HINC85 p. 35]. At the federal level regulation was more sporadic. What little was done was the responsibility of bodies whose primary duties resided outside the communications industry, e.g., the ICC was most concerned with the trucking and railroad industries and was not especially interested in the telephone industry. When Congress created the FCC it was for the express purpose of regulating all communications common carriers nationwide. The driving force behind its creation was not the telephone but the uncontrolled, uncoordinated expansion of radio. The FCC was to be,

> ...the organization to execute and enforce the provisions of the [Communications] Act [of 1934]; and [establish] the basic policies, definitions, standards, and guidelines for interstate common carrier operations and services, as well as various other telecommunications activities. [HINC85 pp. 35-36]

a. FCC Authority and Charter

The FCC then, assumed all the authority the ICC had over the telephone industry. In addition, the FCC was given new powers to require advance approval for any new facilities and services, to require telephone companies to interconnect, to suspend rates while investigations were conducted, and to allocate frequencies in the electromagnetic spectrum. The members of the FCC took their powers seriously. The attitude within the FCC was summed up by one of its Commissioners, Glen O. Robinson, when he said, "If it moves, regulate it; if it doesn't move, kick it - and when it moves, regulate it." [WEIN86 p. 2] The FCC's power to control entry, connection, and rates gave it the ability to control almost every aspect of telephone competition. [BROC83 p. 12]

By its charter, the FCC was to govern only interstate services while intrastate services would be governed by individual state agencies. The nature of telephone service however, is such that the same end user equipment and local exchange is used for local, intrastate, and interstate calls. Over the years the FCC has used this as a basis for preempting many of the jurisdictional prerogatives of the states. [HINC85 p. 36]

b. Special Telephone Investigation

One of the first orders of business for the FCC was to undertake a *Special Telephone Investigation* and to report its findings to Congress. This was deemed necessary not because of scandal, poor service, or financial impropriety, but because the telephone industry had effectively become a government endorsed monopoly and it was considered imperative to protect the American people from the abuses that monopolies made possible. The investigation cost $1,290,000 and raised questions about the monopolistic position AT&T enjoyed in providing the majority of the nation's telephone service. But the Depression and World War II would combine to serve as enough of a distraction to ward off any potential actions based on the investigation [HENC88 pp. 4-11]. (However, its contention that AT&T

constituted an unfair monopoly would be used as the basis for a lawsuit in 1949) [HENC88 p. 57]. The idea that this was a monopoly which worked was to become almost taken for granted by both the FCC and the country at large. It would result in the FCC almost always acquiescing to anything AT&T claimed was necessary to maintain the integrity of the nation's telephone system and rejecting any objections to those claims.

4. Smith v. Illinois Bell Telephone Company

Through 1930 the telephone system had developed into a network remarkably like it remains today: a local exchange providing local service and access to toll lines, and a long distance company providing toll service (although at that time most local service (80%) and all toll service was provided by AT&T.) A subscriber paid charges to both local and long distance companies separately based on usage. In 1930, the case of *Smith v. Illinois Bell Telephone Company* changed the method used for charging for telephone service and justified it on the basis of the maintenance of universal service.

a. Threat to Universal Service

It had become increasingly expensive over the years to physically connect each subscriber to the local exchange with a pair of copper wires in what is known as the *local loop*. Also expensive for the local exchange was the cost of maintaining the physical plant which supported the local loop. The other part of the nation's telephone system, the toll lines, were becoming increasingly less expensive to operate because of technological advances and the fact that many subscribers shared the use of the same toll lines instead of having to have their own dedicated lines. This cost structure, when passed on to the consumer, was resulting in lower costs per call for heavy toll users (like businesses) and higher costs per call for heavy local users (like most residential subscribers.) This rising rate at the local level was felt to threaten the goal of universal service which had by that time become universally accepted. A situation where some subscribers would have to opt to discontinue the use of the telephone based on economics alone was anathema to the court.

Smith v. Illinois Bell Telephone Company was the government's effort to maintain universal service by redistributing back to the local exchanges, the income charged for toll service. The reasoning was that all toll calls used local equipment and the local exchange at both ends of a call to connect through AT&T's long distance lines. (All telephone equipment was then completely owned by the local telephone company and not by the subscriber.) Therefore AT&T owed the local telephone companies a portion of the charges it made for those toll calls.

b. Separations and Settlements

Based on this decision, AT&T, independent telephone companies, and state and federal regulators adopted the system of *Separations and Settlements*. According to this system, a portion of local calls were *separated* as being part of long distance service. AT&T was then required to *settle* with the local telephone companies by giving them an amount equal to the separated costs. The effect of Separations and Settlements was threefold.

1. It increased the revenue of the local telephone companies (which operated the local exchanges.)
2. It increased the money spent by long distance users.
3. It decreased monthly service charges to users for local service while increasing long distance rates (which was contrary to the actual costs of such services.) [FAUL87 pp. 15-17]

5. AT&T's Absolute Control

Since 1907 AT&T's slogan had been "One Policy, One System, Universal Service." In every court action, in every appearance before a regulatory body, in every public speaking engagement by an AT&T executive, this slogan was never renounced. AT&T's version of the nation's telephone network was the Bell System, controlled and operated by AT&T, which provided all long distance lines and merely allowed independent local telephone companies to connect to it. AT&T was responsible for ensuring that the system worked and that included manufacturing all equipment for it through its subsidiary Western Electric. AT&T claimed that only in this way could it be sure no harm would come to the network .

C. DEREGULATION

The regulatory environment which had enveloped the telephone industry since the 1930s began to unravel in the 1950s. So entrenched and encompassing was that system of regulation that the unraveling has continued for over forty years and will continue into the foreseeable future.

1. Foreign Attachments

Up until the 1950s most regulatory bodies went along with this AT&T gospel of the nation's telephone system. Fully supported was AT&T's contention that the network required the exclusion of all "foreign attachments." *Tariffs* are documents written by common carriers which describe services and charges and are subsequently put to regulators for approval. In the Bell System's tariffs were provisions that said that anyone using a foreign attachment could have their telephone service disconnected. Such provisions had been approved by regulators since 1913 and had been part of AT&T customer contracts since 1899.

a. *Hush-A-Phone*

AT&T's concept of the nation's telephone system was dealt a blow in early 1950 when the foreign attachments rule was challenged by a complaint brought before the FCC by Harry A. Tuttle. Since 1921 Tuttle had made and sold 125,000 units of a device which he called a *Hush-A-Phone*. The *Hush-A-Phone* was a cup shaped device which fit on the end of the telephone handset. Speaking into the *Hush-A-Phone* minimized the risk of the speaker's conversation being overheard, thus providing the speaker with some measure of privacy. Although the *Hush-A-Phone* was certainly a foreign attachment, no user of one had ever had their telephone service disconnected. Tuttle's complaint claimed that he "...had been severely inhibited by telephone companies' reminders to retailers, and to some consumers, about the foreign attachments provisions of the companies' tariffs." [HENC88 p. 33]

The FCC deliberated five years over the case, finally decided against Tuttle, and included the following statement in its decision.

> Where a device has a direct effect upon communication itself, as does the Hush-A-Phone, if we were disposed to do so at all we would require a showing far stronger than that made by Hush-A-Phone herein to warrant departure from the general principle that telephone equipment should be supplied by and under the control of the carrier itself. [HENC88 p. 35]

The FCC went even further by citing the "harm" the Hush-A-Phone could do to the telephone network.

Tuttle appealed to the U.S. Court of Appeals and argued "...that the FCC failed to consider that the antitrust laws are violated by the tariffs" of AT&T [HENC88 p. 36]. The Appeals Court, in November 1956, was unanimous in siding with Tuttle and stated that the foreign attachments provisions "...are unwarranted interference with the telephone subscriber's right to use his telephone in ways which are privately beneficial without being publicly detrimental." [HENC88 pp. 36-37]

b. FCC Acquiescence

The Hush-A-Phone ruling was the first modification made to the belief held by AT&T and supported by most regulators which said that only a monopoly could ensure that the nation's telephone network remained secure, effective, and efficient. This decision marked the beginning of a change in the attitude the FCC would have toward AT&T's monopoly. Since its inception in 1934 the FCC had consistently acquiesced to the will of AT&T as expressed in AT&T's tariffs. The *Hush-A-Phone* ruling was the corner around which the FCC would turn from such acquiescence and the entire atmosphere of telephone regulation would thereafter be transformed.

The fact that this was almost a revolutionary change in the way the FCC operated was expressed well by Bernard Strassburg in 1988 when he made the following statement.

> I served throughout the Hush-A-Phone proceedings as the FCC's staff counsel and recommended against authorizing use of the device. In my view, Tuttle's prospects of winning his case before the FCC were, from the start and without court intervention, virtually nil. This may be somewhat difficult to believe in the context of current FCC policies feverishly promoting deregulation, competition, and maximum free choice for customers.
>
> But the Hush-A-Phone case is a classic illustration of the regulatory values that dominated the entire telephone regulatory community for generations. They were embraced by the FCC from its beginnings in 1934 and into the late 1960s. Thus, it was the conviction of the FCC and its staff that they shared with the telephone company a common responsibility for efficient and economic public telephone service and that this responsibility could only be discharged by the carrier's control of all facilities that made up the network supplying that service. Such control included not only transmission, switching, and the subscriber station used for basic end-to-end service. It also had to extend to any equipment a subscriber might attach to or interface with the basic service. Only by this comprehensive type of control could the quality, safety, and economies of network performance and design be assured.

Hence the blanket ban on a customer's use of foreign attachments without specific authorization was accepted by the regulator as defensible.

The Hush-A-Phone, by itself, posed no threat of any real consequence to the performance of the basic network. Nevertheless, authorization of its use could set a precedent for other, less benign attachments which individually or cumulatively could degrade network performance to the detriment of the public.

This was the litany of the regulator that was Tuttle's impossible burden to overcome at the FCC...Fortunately for Tuttle and the future of regulatory policymaking, the court took a more balanced view of the Hush-A-Phone and its like. In effect, the court's ruling provided a rational reconciliation between the rights of subscribers on the one hand and the limits of telephone company responsibilities in the protection of their networks on the other hand. [HENC88 pp. 38-39]

2. Consent Decree of 1956

A second blow to AT&T also came in 1956 with the settlement of a civil antitrust suit which had been filed by the Justice Department in 1949 against AT&T and its equipment manufacturing subsidiary Western Electric. It had remained virtually unheard of by the public during the seven intervening years. The suit was based on the FCC's *Special Telephone Investigation* in the 1930s and charged the two companies with establishing a monopoly in the manufacture, distribution, and sale of telephone equipment. The government wanted the following three things.

1. AT&T was to divest itself of Western Electric.
2. Western Electric was to divide itself into three regional businesses independent of AT&T and each other.

3. Western Electric was to divest itself of its 50% ownership of Bell Telephone Laboratories (AT&T owned the other 50% and would be allowed to retain it.)

The other parts of AT&T, its long distance service called the Long Lines Department, and the local exchanges which made up the Bell System Operating Companies, would not be required to change.

a. Desire for Competition

The government's case was designed to encourage competition in the manufacture of equipment. Some competition actually did exist already in that other manufacturers besides Western Electric supplied equipment to the independent telephone companies. AT&T's defense was that AT&T could get the equipment cheaper from Western Electric and their subsequent control over manufacture was part of the "vertical integration" of the Bell System which allowed for a smooth running national telephone network. As the years passed in litigation, the case was turning into the biggest antitrust lawsuit in history, topped only by the government's lawsuit against AT&T in 1974. [HENC88 p. 57-59]

b. Final Judgment

In 1956 a settlement was reached out-of-court and came to be known as the *Consent Decree of 1956* or the *Final Judgment*. Under its terms AT&T was required to do the following three things.

1. Restrict its business to "common carrier communications services subject to regulation." This was to prevent AT&T's monolithic size and power from overwhelming the competition in other fields it might enter.

2. Restrict Western Electric from manufacturing equipment other than that for the Bell System.

3. License patents held by AT&T, Western Electric, and Bell Laboratories to all applicants for reasonable fees.

c. *Long Term Results*

These restrictions seem somewhat minor in light of the goals of the original antitrust suit. They would however, come to have long term consequences which would haunt AT&T in the coming years because of a general lack of anticipation regarding the pace of technological advance. Trudy E. Bell (no relation to Alexander Graham Bell) describes the long term results as as being threefold.

[1] ...the decree precluded the Bell System from following its own pioneering technologies into other lines of business - such as selling solid-state components or computers (although AT&T was free to develop Bell Labs technology, such as the transistor, for use within its own system.)

[2] ...the decree's mandate that the Bell System license all its patents to all comers ensured that other companies, both domestic and foreign, could use Bell technology outside of regulated telephone markets against the Bell System.

[3] ...although the decree effectively forbade the Bell System from entering non-telephone markets, it could not prevent other companies from entering AT&T's own market of local and long distance telephone service. [BELL85 p. 47]

3. Above 890 MC and Cross-Subsidies

In 1959, the FCC ruled against Bell in the *Above 890 MC* case. This allowed private concerns to own and use their own microwave transmission facilities for internal communication. Connection to the Bell System however was not allowed. Bell's response to this was a service they called TELPAK. Under TELPAK, AT&T aggressively priced their private line services to businesses at rates which made it more attractive to remain with AT&T rather than for businesses to purchase their own microwave systems. Competitors then claimed that Bell was illegally cross-subsidizing to maintain its monopoly. Under the concept of cross-subsidy, Bell was characterized as willing to temporarily lose money in order to shut out competition in a certain market.

This pattern was to occur many times in the next 25 years of regulation. Faulhaber describes it as follows.

> ...a competitor seeks to enter some peripheral telecommunications market; Bell argues system integrity and economic harms to the telephone ratepayers; after losing, Bell implements a competitive tariff (or product); and finally the competitors and regulators charge Bell with cross-subsidizing competitive services from monopoly markets. Bell counters with the argument that price cutting in the newly competitive market helped them retain at least some of the profits from that market, thus contributing to the goal of universal service. Competitors and regulators continue to voice strong suspicions that Bell's price cuts are too deep and in fact result in predatory pricing via cross-subsidy. [FAUL87 pp. 24-25]

Telephone regulation would increasingly be driven by the goal of preventing a company which operated both as a monopoly and in competitive markets (AT&T) from using the principle of cross-subsidy.

4. Carterfone

In 1968, after three years of consideration, the FCC made its *Carterfone* decision. It was based on a suit filed by Tom Carter of Texas. Carter had invented an acoustical device he called a *Carterfone* to be attached to a telephone receiver which would then allow the telephone to be connected to a private mobile radio system. What made this decision especially notable was the fact that the FCC did not limit itself to just the *Carterfone* but expanded its ruling so that it would apply in general to any type of customer provided terminal equipment, i.e., equipment employed as an interface between the end user and the telephone system. The FCC made it legal for any user to attach whatever he wanted to his end of the telephone. Initially the equipment had to be made to attach through a Bell supplied connecting device but eventually (in 1975) the FCC adopted a set of technical standards which became the only requirement for connection. [FAUL87 pp. 27-30]

5. Toll Services Opened

The complete monopoly AT&T had over long distance service was to finally be successfully challenged in the 1960s. AT&T had been effectively blocking all incursions into this part of its business for over fifty years on the basis of better service to the public, preservation of the network, and security of a national resource. These justifications were to finally fall to the preeminent objective of competition.

a. MCI and Specialized Common Carrier

In 1969 the FCC made a decision in a case it had been considering since 1963. In this case, Microwave Communications Incorporated (MCI) wanted to take the allowed ability for a business to internally use a private line microwave system and expand it into a private line service it could sell to customers on a shared basis between specific locations. The FCC approved this service to be supplied by MCI in 1969 and then expanded it to include any firm in 1971 in its *Specialized Common Carrier* decision [FAUL87 pp. 30-33]. In this decision, the FCC concluded that,

> ...there is a public need and demand for the proposed facilities and services and for new and diverse sources of supply, competition in the specialized communications field is reasonably feasible, there are grounds for a reasonable expectation that new entry will have some beneficial effects, and there is no reason to anticipate that new entry would have any adverse impact on service to the public by existing carriers such as to outweigh the considerations supporting new entry. We further find and conclude that a general policy in favor of the entry of new carriers in the specialized communication field would serve the public interest, convenience and necessity. [HINC85 p. 47]

b. AT&T Responds

AT&T's response was to deny these new toll services access to AT&T's local exchanges. The new toll carriers could provide point-to-point services but were prevented from attaching their customers to the Bell System. In June 1978, after numerous court battles which were appealed to the U.S. Supreme Court several times, the FCC finally mandated access to the Bell System for any long distance carrier requesting it. AT&T's monopoly of the long distance lines in the United States was finally over. [HENC88 pp. 167-173]

6. Computer Inquiries

In 1966 the FCC began a series of studies of the developing computer industry and how it related to the existing telephone industry.

a. Computer Inquiry I

The transmission of data rather than just voice over telephone lines illustrated the growing convergence of the communications and computer industries and motivated the FCC to begin its *Computer Inquiry I* in 1966. It then took five years to establish what distinctions they believed existed b 'ween the regulated communications field and the unregulated data processing field. In 1971 they compromised by concluding that a communications service could have a data processing capability which was incidental to a message switching function and that a data processing service was one in which transmission was subordinate to computing. [CRAN91 p. 90]

b. AT&T Barred

Of greatest import to the telephone industry in this decision was the interpretation of it in regard to the *Consent Decree of 1956*. The *Consent Decree* limited AT&T to business as a communications common carrier. *Computer Inquiry I* concluded that being a communications common carrier did not include the sale of computers nor the offering of data processing services. AT&T was thus barred from entering these natural adjuncts to the telecommunications industry while other firms were free to compete in all of them. [HINC85 p. 42]

c. Computer Inquiry II

Only five years later the inadequacy of the definitions in *Computer Inquiry I* had become obvious and the FCC's *Computer Inquiry II* was begun in 1976. It took four years but resulted in a major deregulatory decision. The FCC decided to distinguish between two types of services: basic and enhanced. Basic services would remain regulated. Enhanced services would be fully deregulated [TUNS85 p. 9]. Basic services would include those offering "transparent transmission capacity for the movement of information." Enhanced services would combine computer processing applications with the basic services [HENC88 p. 142]. Additionally, all new equipment sold to operate on a customer's premises was completely deregulated (beyond meeting FCC technical standards.) AT&T was allowed to offer enhanced services and customer premises equipment only through a fully separated subsidiary. [TUNS85 p. 9]

7. Divestiture of AT&T

The most momentous event in the recent history of U.S. telephone service officially began in November 1974 when the U.S. Department of Justice brought suit against AT&T, Western Electric, Bell Telephone Laboratories, and the 22 Bell Operating Companies (BOCs). It became the most massive civil suit in U.S. history.

a. Justice Department Charges and Goals

The Justice Department asserted,

> ...that AT&T monopolized the long distance telephone business by exploiting its control of the local telephone companies to restrict competition from other telecommunications systems and carriers by denying interconnection with the local phone service. [BELL85 p. 49]

It further claimed,

> ...that since Western Electric supplied substantially all the telecommunications requirements of the Bell System, AT&T restricted competition from other manufacturers and suppliers of customer premises equipment. [BELL85 p. 49]

And finally, as a consequence of these practices, AT&T allegedly,

> ...denied the benefits of a free and competitive market to purchasers of telecommunications service and equipment. [BELL85 p. 49]

This suit was like most government civil antitrust suits in that it did not seek punishment for past wrongdoings but just sought changes which would ensure that the wrongdoings did not recur. At first the redress sought by the government was the divestiture from AT&T of the BOCs and Western Electric, the fragmentation of Western Electric, and an undetermined action against Bell Laboratories. But this was not static and the government modified this several times over the next six years. Both sides used this period of time to gather evidence and prepare for the trial. Attempts by AT&T and the government to reach an out-of-court settlement were all unsuccessful and Judge Harold H. Greene set the trial to begin on 15 January 1981. [BELL85 p. 49]

In February 1981 William Baxter was appointed as the U.S. Assistant Attorney General and effectively took over direction of the case until its completion. By April 1981 he had let AT&T know exactly what he wanted to achieve with the lawsuit.

> ...nothing less than spinning off all the local operating companies to become independent entities, thereby relieving AT&T's hold over 'bottleneck facilities' that could prevent competitors from having access to the system. [BELL85 p. 49]

Included would be the release of AT&T from the *Consent Decree of 1956*.

Before he joined the Justice Department, Baxter had been a professor of antitrust law at Stanford. While there he had actually discussed with his students his view concerning how AT&T should have been broken up. It was this same view guiding him in his prosecution of the Justice Department's antitrust case against AT&T.

b. Dismissal Denied

The government took 130 days to present its case, after which AT&T moved for dismissal on the grounds that the government's case for relief had not been adequately made. Judge Greene, who had been involved in drafting the Civil Rights Act of 1964 and the Voting Rights Act of 1965, could have ended the trial right there by accepting the motion. He chose not to do so and, on 11 September 1981, denied the motion saying,

> The testimony and the documentary evidence adduced by the Government demonstrate that the Bell System had violated the antitrust laws in a number of ways over a lengthy period of time...[T]he burden is on [the] defendants to refute the factual showings....[BELL85 p. 50]

c. AT&T's Assessment

Judge Greene's strongly worded opinion caused AT&T to finally reassess its position in light of six considerations.

1. Judge Greene seemed to be biased in favor of the prosecution.
2. Other similar antitrust suits were being filed by competitors against AT&T at the rate of one every three or four months.
3. Attempts by AT&T to get a special dispensation approving the way it did business, through Congressional legislation, were repeatedly frustrated.

4. The suit was financially draining. At its peak it would occupy 3000 people and it would exhaust $375 million before it was over.

5. The requirements for a separate subsidiary, demanded by the still-in-force *Computer Inquiry II*, were costing AT&T $1 billion per year in duplicate facilities and functions.

6. The suit's possible destruction of AT&T's links to Western Electric and Bell Laboratories would have destroyed its technological capability. [BELL85 pp. 50-51]

d. Modification of Final Judgment

Based on these considerations, AT&T's general counsel, Howard J. Trienens, was authorized to call Baxter and ask him to propose a settlement for the case instead of continuing with the trial. This was done on 16 December 1981. After some negotiations, Trienens and Baxter signed the proposed settlement three weeks later, on 8 January 1982. Judge Greene made some modifications and signed the final settlement on 24 August 1982. It would take effect on 1 January 1984. The settlement was less than nine pages long and was called the *Modification of Final Judgment* (MFJ) because it modified the *Final Judgment* or *Consent Decree of 1956*. It would come to be known simply by the term *Divestiture*.

The conditions of the MFJ were simple in concept but colossal in scope and implementation. Its major provisions included the following.

1. The 22 BOCs were to be separated from AT&T but would continue to offer local exchange services. In implementation they would consolidate

into the seven *Regional Bell Holding Companies* (RBHCs). The BOCs and RBHCs are illustrated in Figure 3.

2. The BOCs would be required to supply access to all long distance carriers which was equal in type, quality, and price to that which they supplied to AT&T.

3. The BOCs could sell but not manufacture customer premises equipment.

4. The BOCs would not be allowed to provide information services which were defined as "...the offering of a capability for generating, acquiring, storing, transforming, processing, retrieving, utilizing, or making available information which may be conveyed via telecommunications...." [USDC82 p. 4]

5. The BOCs would be allowed to produce printed "Yellow Pages" (while AT&T would not.)

6. AT&T would be restricted from engaging in electronic publishing for at least seven years.

7. AT&T would retain its long distance facilities, Western Electric, and Bell Laboratories.

8. A new definition of the local exchange service area was introduced with the creation of the Local Access and Transport Area (LATA). 161 LATAs were created within the 48 contiguous states with no LATA crossing a state border [TUNS p. 95]. Local telephone companies had monopolies on offering services within LATAs. Only long distance carriers could offer inter-LATA services.

9. Only the former BOCs could continue to use the familiar Bell logo or the word "Bell" when referring to their organizations [HENC88 p. 239].

10. Judge Greene's court would retain jurisdiction over the MFJ indefinitely, ruling on modifications to it, compliance with it, and punishment for violations of it. [USDC82 pp. 1-9]

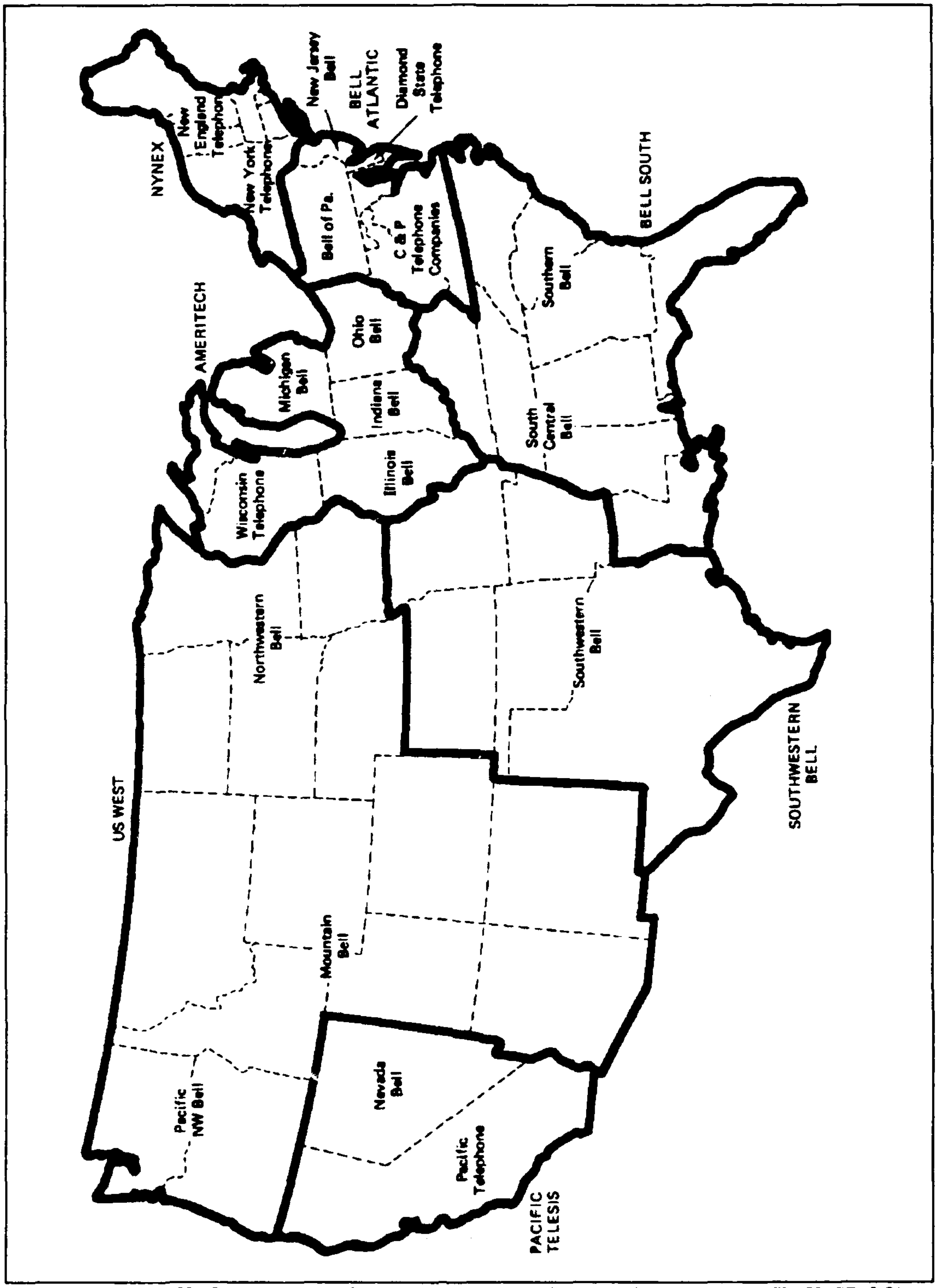

Figure 3: Bell Operating Companies (BOCs) and Regional Bell Holding Companies (RBHCs)

The nine pages which comprised the MFJ were enough to break up the largest corporation in the world; a company larger than General Motors, IBM, General Electric, U.S. Steel, Eastman Kodak, and Xerox combined; a company with assets of $150 billion and annual revenues of $70 billion; and a company whose revenues annually represented 2% of the U.S. gross national product. Its breakup would personally touch the life of every American. [BELL85 p. 48]

e. *Computer Inquiry III*

The MFJ also had an effect on the FCC. It seemed to make obsolete some of the provisions of *Computer Inquiry II* so *Computer Inquiry III* was issued in 1986. This eliminated the requirement that any enhanced services provided by AT&T (and by extension, the seven RBHCs) be through a fully separate subsidiary as long as they could show that no cross-subsidizing was taking place. The RBHCs would also have to show that they offered other enhanced services vendors the same quality and price for access that the RBHCs enjoyed. [BELL88 p. 28]

For the RBHCs *Computer Inquiry III* was really a moot point since the MFJ prohibited them from offering such enhanced services (defined as information services in the MFJ.). This changed in October 1991 when an U.S. Appeals Court overruled Judge Greene and forced him to allow the RBHCs into the information services market. [CARN91 p. B10]

Another major deregulatory change may occur in 1992 when the FCC is expected to allow local telephone companies to enter the cable television market. [NYTA91 p. A1]

D. Regulatory Agencies

One of the problems in deciphering the regulation of an industry like the nation's telephone system is determining who is responsible for regulating it in the first place. We have seen five primary authorities emerge and which seem to hold this power. Rather than there being a strict hierarchy among them, they act as a set of checks and balances on one another. The five authorities are the following.

1. The *U.S. Congress* which enacts legislation and can thus set telecommunications policy. They established the FCC and conceivably could override any decisions made by any other person or agency.

2. The *FCC* which regulates not only telephone communications but also radio and television and all interstate and foreign communications. The FCC is part of the executive branch of the federal government.

3. The state *PUCs* which regulate all intrastate communications unless preempted by higher rulings.

4. The *U.S. Department of Justice*, especially the antitrust division, which enforces the MFJ and is charged with reviewing its provisions every three years and recommending changes.

5. *Judge Greene* who wrote the MFJ to include his jurisdiction over it indefinitely. [BELL88 p. 29]

The history of regulation of the telephone industry is not fixed but constantly changing. The current era of massive deregulation does not mean that a period of hyper-regulation may not be just a few years hence. Regardless, based on the technological advances which drive it, whatever form regulation takes in the future, users are certain to have only more options, more services, and more ways to interact than ever before.

IV. CURRENT TELECOMMUNICATIONS TECHNOLOGY

Capability in the field of telecommunications is no greater than the technology employed to provide it. The technology used at any one moment is really the culmination of years of development to produce that technology. This chapter examines the technology exploited to yield current telecommunications capabilities.

A. TELECOMMUNICATIONS EQUIPMENT

The hardware used in telecommunications is simple in theory. One requires only devices to send and receive signals and the means to transmit those signals. But the complexity behind today's systems belies the seeming simplicity of using them.

1. Equipment in the Local Loop

The local loop provides the ubiquitous end of what is a worldwide connectivity of telecommunications equipment. Without it there would be virtually no communications whatever. Perhaps because of its importance in providing the initial connection, it has remained remarkably unchanged for the last 100 years.

a. The Telephone

The most common of all telecommunications technologies is the telephone itself. From a very young age, most Americans take its presence for granted, giving it no more thought than a pencil and assigning it about an equal usefulness as just another tool for communication. The telephone must convert audible sound into electrical energy and back again. The common telephone accomplishes this with transducers, one to convert sound energy into electrical energy to be transmitted, and one to convert received electrical energy into audible sound energy. Figure 4 illustrates a typical telephone.

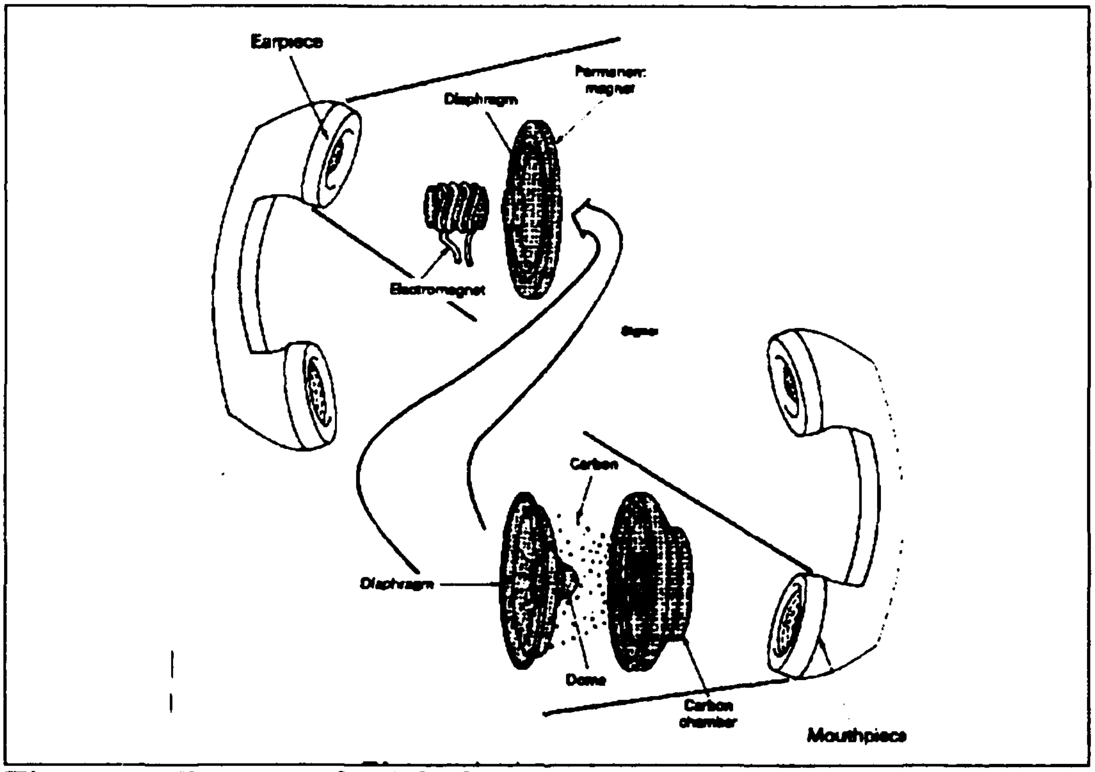

Figure 4: Elements of a Telephone

A thin aluminum diaphragm and a carbon chamber make up the transducer for transmitting voice signals. Sound waves in the air cause the diaphragm to vibrate in and out which in turn compresses and releases the carbon granules in the carbon chamber. These changes in pressure on the carbon granules produce a constantly changing electrical resistance in the carbon chamber. The carbon chamber is part of an electrical circuit whose current is varied by the changes in the electrical resistance of the carbon granules. These changes in electrical current are what are transmitted as electrical energy down the telephone line. Figures 5 and 6 illustrate the principle of telephone transmission.

The receiver of the common telephone uses a diaphragm and an electromagnet to reverse what is done in transmission. The diaphragm is attached to a permanent magnet and is adjacent to the electromagnet. The electrical energy of the incoming transmission is fed to the electromagnet and produces a varying magnetic field. The diaphragm vibrates in accord with the changing magnetic field. The movement of the diaphragm creates waves in the air which are then heard as the transmitted sound. [BLAC89 pp. 149-151]

b. Dial Tone

The electrical energy which flows down telephone lines does not go directly to a receiver. It is first routed by an exchange or *central office* (CO). The CO connects the transmitting telephone with the receiving telephone by means of a switch. The most common connection between a

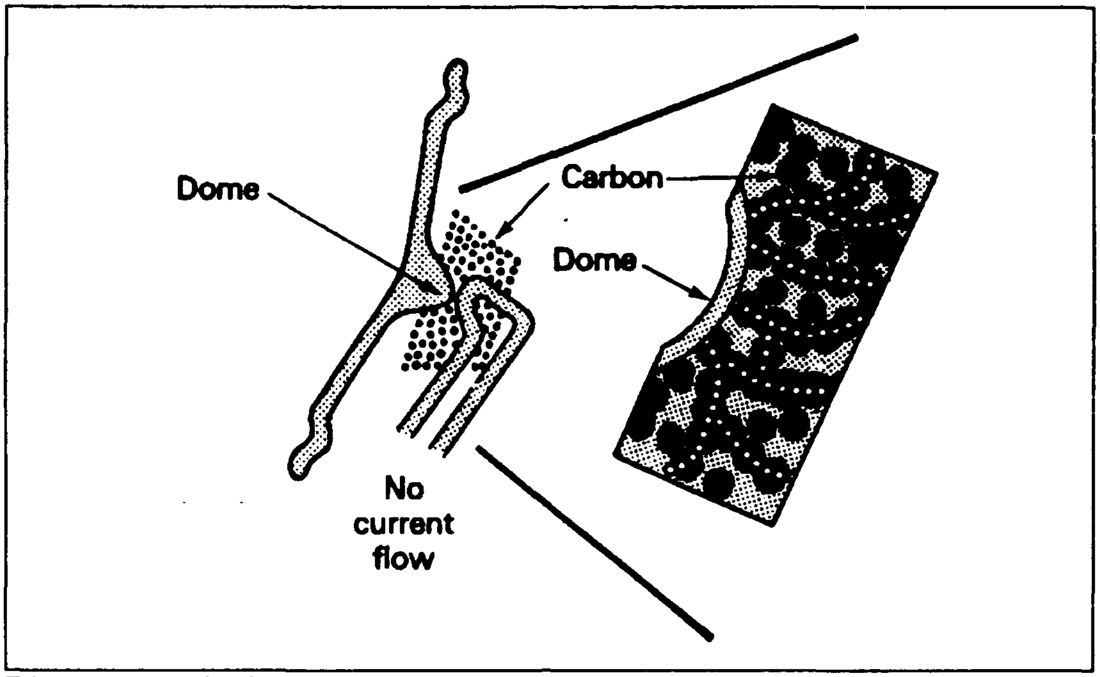

Figure 5: Telephone without Transmission

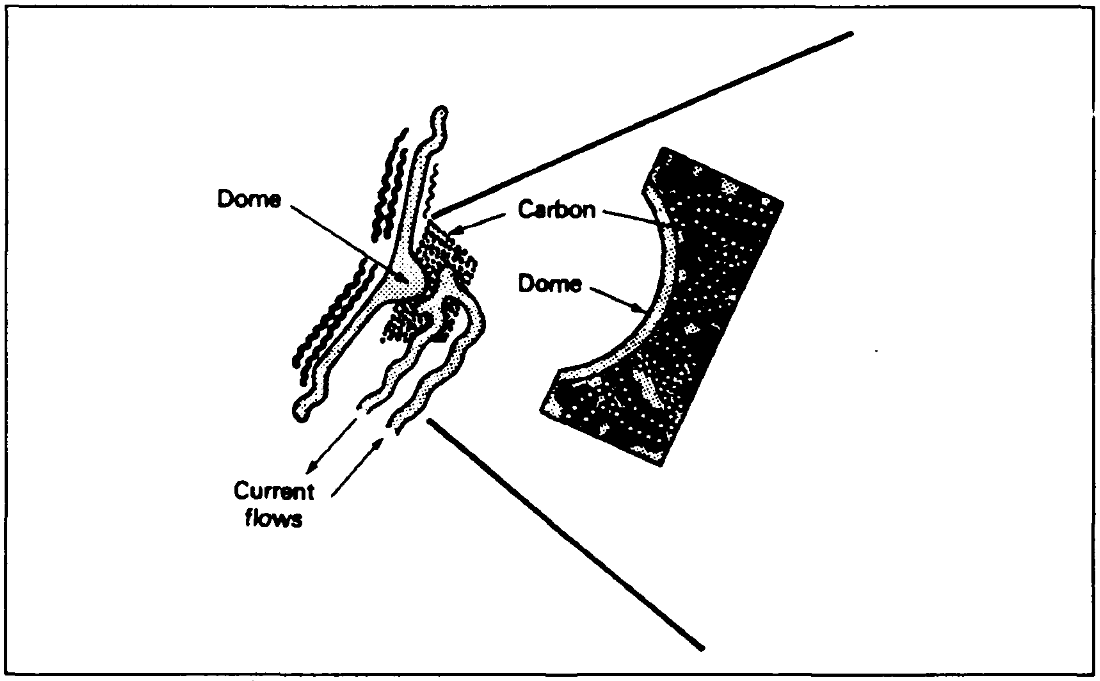

Figure 6: Telephone during Transmission

telephone subscriber and the CO is through a pair of copper wires known as *twisted pair* in a connection known as the *local loop*. The wires are twisted to reduce low frequency interference. [STAL88 pp. 48-49]

The subscriber whose telephone handset is cradled or in the *on-hook* position does not have a completed electrical circuit to the CO. When the telephone handset is lifted it is then *off-hook* and the circuit is complete. This off-hook condition is detected by a current sensor at the CO and a dial tone is sent back to the telephone. The number dialed is then detected and used to establish the connection to the party being called. [BLAC89 pp. 159-160]

c. Power

The power for the local loop was originally supplied by batteries at each subscriber's location [HAWL91 p. 24]. This began to change in 1894 when the CO became the home of common-battery power for its subscribers. A negative voltage of -48 volts has become the standard. A negative voltage was chosen so that the outside equipment (or plant) would have an electrical potential below that of the Earth and thus reduce corrosion problems. [TAYT91 p. 76]

d. T-1

This basic description of the local loop was in place a little more than a decade after the invention of the telephone. For the next six decades the local loop would be refined but not substantively changed. In 1962 the primarily analog telephone system was changed by the introduction of T-1 service. The T-1 line was designed to take 24 analog voice channels, translated into 64 Kbps, Pulse Code Modulated (PCM) digital signals, and send them all multiplexed over two pairs of twisted pair wire. A telephone call which was an analog signal at both transmitter and receiver, was thus transformed into a digital signal for at least a portion of its journey.

e. *Digital Loop Carriers*

The T-1 line was used first for traffic between COs. By 1972 the digital technology of the T-1 line had found its way into the local loop, between the subscriber and the CO, in the form of the *Digital Loop Carrier* (DLC). By 1990 about 8% of all local loops were served by DLCs and over half of all new local loops were being designed and installed with DLCs [HAWL91 pp. 24-25]. By using line concentration and coding techniques, DLCs have been demonstrated which can serve 256 subscribers in a local loop under moderate traffic loads [ANDR91 p. 32]. Other schemes have combined over 672 subscribers [MINO91 p. 21]. Common DLCs generally multiplex between 24 and 96 subscribers.

Preceding the development of the multiplexing of digital signals was the multiplexing of analog signals over a single line. Multiplexing analog signals in the local loop is done using *Frequency Division Multiplexing* (FDM) while multiplexing digital signals is done with *Time Division Multiplexing* (TDM). TDM has become the prevalent method both inside and outside the local loop as digital networks expand faster than analog networks. [MINO91 p. 21]

2. Transmission Media

Besides twisted pair, the most common types of transmission media used include the following.

1. Coaxial Cable
2. Microwave (Terrestrial and Satellite)
3. Radio
4. Optical Fiber

These media can all transmit both analog and digital signals although optical fiber is generally used for just digital.

a. Twisted Pair

Twisted pair, as described previously, is an example of an electrical conductor through which electromagnetic signals are passed. But transmitting at high frequencies over twisted pair is impractical because the signal migrates toward the outer surface of the conductor. To counter this tendency and to take advantage of higher frequencies (and potentially higher transmission rates), transmission can be done using a channel called a waveguide. Coaxial cable and optical fiber are examples of this type of guided transmission medium. A third type of transmission needs no medium. The signal is simply radiated into the atmosphere or into space. Microwave and free-space infrared are examples of unguided transmission.

b. Coaxial Cable

Coaxial cable usually consists of a single copper conducting wire surrounded by a braided copper, concentric, conducting sheath, the two separated by a dielectric material [WEIN86 p. 22]. Coaxial cable can carry far more voice channels than twisted pair and has been used extensively for long distance transmission trunks. It can easily carry more than 10,000 multiplexed voice channels, and as a medium for cable television, can transmit up to 200 standard television channels [NCTA90 p. 6]. Transmission of television signals over coaxial cable is presently analog but voice and data signals delivered by coaxial cable are almost always digital. Other common applications of coaxial cable include communications within buildings or campuses and local area networks. [STAL88 pp. 50-51]

c. Microwave

Microwave transmissions (which fall within the definition of radio transmissions) are line-of-sight and use frequencies from 2 to 40 GHz (Gigahertz, i.e., billions of cycles per second) which allow larger data rates than coaxial cable. Private point-to-point links, voice traffic, and television (including closed circuit television) are all common applications of microwave transmission technologies. Telephone companies often use microwave for connecting COs and a series of microwave hops for longer distances. An additional use is via relay through satellites. Geosynchronous satellites are geostationary over the equator at about 36,000 km [MINO91 p. 270]. Use of satellites induces a quarter second delay in transmission because of the distances travelled. [STAL88 pp. 56-60]

d. Cellular Telephony

Another application of radio transmission is cellular radio, which is used to provide mobile telephony. Cellular telephone service uses a central telephone office which is connected by land lines to a system of antennas which constitute the cellular network. Each antenna tracks any telephone in service within its cell and maintains any active circuits. Active telephones leaving a cell are transferred to an antenna in the new cell which continues to maintain the connection. These systems are currently analog but expected to begin to transition to digital technologies during 1992. The change to digital could expand the ability to serve customers 30-fold within a geographical area. [MINO91 pp. 239-241]

e. Optical Fiber

No media comes close to portending a change in the way we communicate as does optical fiber. Its effects will be felt for at least decades and there is no known successor to it which has the potential to overshadow optical fiber's impact on telecommunications.

(1) Modulation. Optical Fiber is increasingly becoming the medium of choice for transmission of digital signals. For many years it was considered impractical to use light as a carrier wave which could be modulated with an information signal just as was done with radio waves. Light is emitted as a random series of pulses produced by accelerating electrons and by electrons changing their energy levels. Light is not a single simple sinusoidal wave but a collection of waves of different phase and sometimes different frequency.

The development of the laser in the 1960s led to the ability to modulate a light wave. The laser, and later the Light Emitting Diode (LED), can both emit optical radiation as a direct result of applied voltages and electron movement. In addition they can produce *coherent* light which is light of a single frequency with all the waves in phase. It is the coherent light which is transmitted down optical fiber. [LANG86 pp. 60-61]

The light in optical fiber transmits information by undergoing *Intensity Modulation.* This process uses a carrier wave onto which a modulator impresses a digital signal. The optical power being output onto the fiber is modified by the input current coming from the modulator. This variation in optical power is what is interpreted as the digital signal. The modulator simply turns its source on and off at the appropriate times to encode the digital information onto the carrier wave. For this reason, optical fiber is not an intrinsically digital medium, but because of the manner in which it is employed, it can be described as "virtually" digital. [MINO91 pp. 343-346]

The carrier waves used in optical fiber have infrared emitting lasers and LEDs as their sources. Even though lasers and LEDs can produce visible light, the wavelengths whose transmitting characteristics are most suitable for optical fiber (850, 1310, and 1550 nm) are in the infrared range, a little longer wavelength than visible light. Even though the light cannot be seen, they are still called optical systems. [LANG86 p. 60]

(2) Advantages of Optical Fiber. The advantage to using optical fiber is in capitalizing on the very high frequencies of infrared light. In the electromagnetic spectrum, the higher the frequency, the higher the bandwidth, and the more information can be transmitted. The human voice operates in the range of about 10^3 Hz. Twisted pair uses waves of around 10^6 Hz. Coaxial cable and radio use waves in the range of 10^6 to 10^8 Hz. And microwave systems use waves of about 10^{10} Hz. But optical fiber can operate with frequencies up to 10^{13} Hz. The enormous bandwidth which results means a huge increase in the information that can be transmitted [CHOR84 p. 91]. Currently rates of about 2 Gbps are being practically achieved. [STAL88 pp. 47-60]

Minoli has summarized the following intrinsic advantages of optical fiber over other forms of data transmission.

1. Small size - Outer diameter of strand approximately 0.1 mm. Fiber cable: 2 to 5 mm. Copper cable: 3 to 6 mm. Coaxial cable: 10 to 12 mm.

2. Light weight - Specific gravity of silica is 25% that of copper and much less material is used. Weight of the finished fiber cable is 10 to 30% that of copper.

3. Physical flexibility - Optical cable can be bent easily allowing it to be installed in the conduit already in place for other types of cable.

4. Freedom from oxidation - Glass materials are chemically stable and do not rust like metals. Optical fibers can therefore endure adverse environments (such as the bottom of the ocean) better than metal cables.

5. Low loss - The loss of an optical fiber is below 0.5 dB/km, currently allowing unrepeatered links of 60 km for a 30 dB loss. The length of unrepeatered links is expected to vastly increase in the future with newer technologies. By comparison, the loss of coaxial cable is around 20 dB/km (requiring repeaters every 1 to 2 km.)

6. Large bandwidth - This quantity is measured as the product of the bandwidth in hertz and the unrepeatered distance. A commercial single-mode fiber provides several tenfold GHz x km.

7. High density bandwidth - This refers to the bandwidth as a function of the cross-sectional area of the cable. The transmission capacity of fiber per cross-sectional area is about 100 times that of twisted pair and 10 times that of coaxial cable.

8. Bandwidth upgradability - Using Wavelength Division Multiplexing techniques, the transmission rate can be upgraded up to one order of magnitude, while using the existing optical fiber.

9. Electromagnetically robust - Optical fiber is free from electromagnetic induction (glass is a good dielectric and is immune to electromagnetic induction.)

10. Very low crosstalk - Very little light escapes from the fiber or is absorbed through the cladding, implying good crosstalk characteristics.

11. Resistance to high temperature - The melting point of silica is about 1900 C, far above that of copper.

12. Photonic, not electronic - Fibers do not generate sparks, so they can be used in flammable or explosive environments.

13. Difficult to tap - Fibers cannot be tapped easily. A conversion to the electrical domain is typically required to branch a tributary (although this may also be viewed as a disadvantage.)

14. Availability of material - Copper is limited and must be mined. Silica is abundant on the surface of the Earth. [MINO91 p. 344]

B. TELECOMMUNICATIONS TRANSMISSIONS

The techniques for getting a signal from a sender to its intended receiver have undergone tremendous change in the last decade. What once was almost proprietary to a few providers has now become universally available and the opportunities to participate in the conveyance of telecommunications has never been greater.

1. Carriers

The user of telecommunications services must rely on providers of those services to transport their information. In today's open marketplace the consumer is able to choose from an enormous assortment of vendors vying for their patronage.

a. Local Exchange Carriers

Local Exchange Carriers (LECs) are limited to providing telephone service inside their own *Local Access and Transport Areas* (LATAs). The customer must use the local LEC which is granted a monopoly for providing telephone service within a specific geographical area. For telephone service outside a LATA a subscriber must rely on an *Interexchange Carrier* (IXC), more commonly referred to as a long distance carrier.

(1) Private Branch Exchanges. A Private Branch Exchange (PBX) is an on site facility, owned or leased by an organization, which provides many of the functions normally provided by the LEC through the CO. Telephones within the organization may be interconnected with a PBX without recourse to the CO, but access to the CO is still available when needed to connect to sources outside the organization. Originally analog, digital PBXs are now offered which can handle digital data devices directly and use codecs to service analog devices. [STAL88 pp. 234-238]

(2) CENTREX. The Central Exchange (CENTREX) is a service provided by the LEC, usually at the CO. It mirrors what a PBX provides but without the capital investment required for a PBX. The LEC is responsible for maintenance and emergency backup power 24 hours per day. Current CENTREX service can provide from 2 to 30,000 lines in a building or metropolitan area. CENTREX service can be analog, digital, or a combination. [MINO91 pp. 444-445]

b. Interexchange Carriers

There are over 300 IXCs in the United States today. IXCs connect to subscribers by installing a *Point-of-Presence* (POP) in an LEC's CO or similar facility. IXCs pay fees to LECs for connecting a caller from wherever they are in a LATA to the IXC's POP. IXCs then provide the connection to a POP in another LATA in the same state or across the country. The LEC on the receiving end then makes the connection to the called party and receives a fee from the IXC for the service. These fees are not insignificant. Out of each dollar spent on a coast to coast call, about 45¢ goes to the LECs. [ECON91 p. 34]

Before *Divestiture* in 1984, AT&T had almost complete control of the nation's long distance market. It had built up a five-level network hierarchy for routing traffic which selected the first available link at the lowest available level. Most IXCs today (including AT&T) use a dynamic, non-hierarchical structure for routing calls. The non-hierarchical structure bases routing decisions on the pattern of traffic throughout the system. Cost savings of about 15% have resulted from changing the routing schemes. [BLAC89 p. 155]

Not all IXCs are able to provide service to all potential customers in all areas of the country. They are constrained by the cost to build up an infrastructure and the need to make a profit. Many, in fact, have little physical plant of their own. These carriers often lease lines from larger, established IXCs like AT&T, MCI, or US Sprint. By leasing in bulk, at a discount, they can in turn afford to offer their services at a reasonable rate to consumers.

c. *Value Added Carriers*

In addition to LECs and IXCs are the *Value Added Carriers* (VACs), also called *Specialized Common Carriers* (SCCs), which offer their own *Value Added Networks* (VANs). Their uniqueness lies in their enhanced and extensive offerings to users and the sophisticated technologies they employ. By using packet switching, the VAC can extend to any customer the type of data transmission service generally available only in a private network: fast, error free, and low cost. Data communications, video communications, and electronic mail are some of the specialized services the VAC proffers.

The VAC generally leases telecommunications lines from existing carriers thus getting a network only as large as its business will support but flexible enough to expand on short notice. Packet switching allows the VAC to share the same resources among many customers. A limitation of VACs is that they exist generally only in the largest metropolitan areas. A VAC may not be able to provide service out of or into every location a customer needs. [MINO91 p. 63]

d. *Bypass Carriers*

An additional type of carrier offering telecommunications services is the *bypass carrier*. Bypass carriers constitute a means whereby a customer can avoid using the local LEC altogether. Bypass carriers typically provide a direct line from a customer to the POP of an IXC or VAC. The customer may find that this reduces costs, increases available bandwidth, or is more reliable than what is available through the LEC.

2. Networks

The simplicity the user experiences in using telecommunications disguises the enormously complex system of interconnecting networks which actually allows the users connections to be completed.

a. Public Switched Telephone Network

The telephone system which is made up of LECs and IXCs, and blankets the country, is known as the *Public Switched Telephone Network* (PSTN). It is neither owned nor controlled by any one entity although it is regulated primarily by the FCC and state PUCs and is considered a national asset. Computers are employed to handle the switching and routing tasks and keep track of the billing complexities of such an interconnected system.

Cost for access to the PSTN is based predominately on usage. Customers who have a large number of calls can take advantage of bulk services like the *Wide Area Transmission Service* (WATS). With WATS, a volume discount is applied to incoming or outgoing calls from or to certain geographic areas. WATS service is most familiar to the general public in the form of toll free *800* numbers.

b. Public Packet Switched Network

In addition to the PSTN is the *Public Packet Switched Network* (PPSN). This is presently used to transmit data but not voice traffic. Data to be transmitted is formed into standard sized packets which are individually transmitted through the network and reassembled in the correct order at their destination. The path taken for each packe، may differ from every other packet. This allows each packet to be sent along the route which will get is to its destination most efficiently. Later portions of long messages are not obliged to travel along a route that becomes congested simply because earlier portions of the message traveled along that route. [MINO91 pp. 55-56]

c. Dedicated Networks

A third classification of networks can be categorized as dedicated networks. These vary from switched networks in that the path from transmitter to receiver is already determined and dedicated to a certain user or system. These may take the form of voice grade lines over which analog traffic is sent. Either voice, or data which is generally modulated up to 9600 bps, may be sent over voice grade lines.

Dedicated lines may also be devoted to digital data. These lines require transmitters and receivers which can handle digital data directly without transformation to or from analog signals. A variety of dedicated digital data circuits are currently available. The basic standard is the T-1 which was originally copper based but has come to include any medium over which data is transmitted at 1.544 Mbps. The correct nomenclature is DS-1 standing for *Digital System 1* although T-1 has come to be the most generally used term. Since many customers do not have a need for the bandwidth included in full T-1 service, *Fractional T-1* has been developed which allows customers to purchase just that portion of a T-1 line that is required. Services to provide even greater data rates are currently available from carriers including the T-2 (DS-2) at 6.312 Mbps, T-3 (DS-3) at 44.736 Mbps, and T-4 (DS-4) at 274.176 Mbps. [MINO91 pp. 101-107]

d. Common Signaling System #7

As the PSTN grew more complex, more and more information was required to ensure that traffic was handled efficiently. This meant that an increasing amount of overhead was added to each call in the network as signaling information. In 1976 a completely separate digital network began to be used to pass this information. [MINO91 p. 423]

The current state of this "out-of-band" architecture is the *Common Signaling System #7* (SS7). It uses packet switching to multiplex signal information through the network at a much higher rate of speed than the call itself (e.g., T-1.) Specialized computers analyze the call, its destination, and any special services needed, and sends signaling information out to the appropriate switches and nodes to speed the call through.

SS7 allows carriers to offer advanced or intelligent services. This may include transactions that require reference to a database, validation of information, and translation of information. It could also be used to construct marketing information based on parameters like calling area and time of day. 75% of the 120 million access lines in the United States are expected to be using SS7 by 1994. [MINO91 p. 216]

e. *Private Virtual Network*

Another potential service that SS7 can make possible is a *Private Virtual Network* (PVN). PVN is a software defined network which can substitute for an expensive installed private network. PVN can offer a family of software defined services which the customer can control via direct access to the software controlling the PVN. These services can include the following.

1. A uniform numbering plan for telephones regardless of their location (e.g., for a city-wide installation.)
2. Routing incoming calls to different locations based on origin of the call, time of day, day of week, or additional digit dialed by the caller based on prompts.
3. Defining a list of numbers that may not be called from a given number, group of numbers, or location.
4. Specification of types of service to be provided (e.g., voice or data.)

The customer gains the advantage of a certain amount of network control, without the private network management and maintenance costs and responsibilities. [BUCK88 pp. 23-24]

f. LANs

Users and organizations which have a need to transfer data between personal computers (PCs), terminals, and other resources and devices, all within a relatively short distance, commonly use *Local Area Networks* (LANs), *Wide Area Networks* (WANs), and *Metropolitan Area Networks* (MANs). LANs, WANs, and MANs are essentially the same types of networks but are administered differently. LANs generally cover a single department, building, or business. WANs may tie several LANs together and cover a series of buildings in a geographical area. MANs are used over large metropolitan areas and may be part of a public network rather than just a private network. All three types of networks are commonly used as gateways to connect to larger national and international public and private networks as well. [MINO91 p. 601]

LAN installation is currently estimated at over two million networks. LAN use has expanded as PC users discovered that their standalone PCs were not flexible enough. LANs fill the need for a high speed network to pass information among PC users. Transmission speeds of LANs currently range from 1 to 100 Mbps depending on the media used, network configuration, and networking protocols. Transmission media include primarily twisted pair, coaxial cable, and optical fiber.

(1) Configurations. There are three major configurations for LANs: star, ring, and bus.

1. A *Star* network has a central control point with branches out to each individual node.
2. A *Ring* network passes information around a loop to every node in turn (e.g., a Token Ring network which can transfer data at speeds up to about 16 Mbps.)
3. A *Bus* network has a single cable into which each node is tapped. It may be used like a star with central control or like a ring with distributed control (e.g., an Ethernet network which can transfer data at speeds up to about 10 Mbps.) [MINO91 p. 602]

(2) LAN Protocols. A network which carries its signals at their original frequency is called a *baseband* network. If a network uses FDM to divide available bandwidth into separate channels it is known as a *broadband* network. When signals are modulated onto a single carrier frequency it is called *carrierband.* Broadband LANs use multiplexing to derive different transmission channels. Baseband LANs use random access techniques to allow access to the medium. Typical access methods include *contention* and *polling.* With contention, a node waits for a period of non-activity on the network, at which time the node sends data. If a collision occurs with some other node's data then the process is repeated. With polling, a *token* is typically used as the control packet. A node waits until the token is free, retains it while sending data, and then sets the token free again. [MINO91 pp. 603-605]

g. Internet

Many LANs are in turn connected to larger external networks. The *Internet* is the largest interconnection of packet switched networks in the world. It comprises over 2000 networks around the world which use a set of protocols called the *Transmission Control Protocol* and the *Internet Protocol* (TCP/IP) to communicate. [MINO91 p. 95]

h. Standards

The Internet standards are an example of standards which develop from existing technical solutions. They exist because they work and a great number of manufacturers and users employ them. Telecommunications industry standards continue to develop in this de facto manner, but increasingly, standards are set by a variety of national and international organizations. These organizations typically gather representatives from government, industry, and academia to discuss and select standards which are mutually acceptable and serve to advance the industry in general. Unfortunately, the process is often long and slow and can leave users and manufacturers unsure of the technologies in which to invest.

Some of the major organizations involved in telecommunications standards include the following.

1. International Telecommunications Union (ITU)
2. Consultative Committee on International Telephone and Telegraph (CCITT)

3. Consultative Committee on International Radio (CCIR)
4. International Organization for Standardization (ISO)
5. American National Standards Institute (ANSI)
6. Institute of Electrical and Electronics Engineers (IEEE)
7. National Institute of Standards and Technology (NIST) [MINO91 pp. 72-96]

i. Network Connections

Two efforts to standardize high speed, LAN to LAN connections have emerged in the 1990s: the *Fiber Distributed Data Interface* (FDDI) and the *Distributed Queue Dual Bus* (DQDB).

(1) FDDI. FDDI uses a token network with two pairs of fibers passing information at 100 Mbps. FDDI calls for the use of optical fiber to act as a standalone high speed LAN or to interconnect multiple LANs regardless of the individual protocols involved. Its dual ring structure makes it possible for the system to detect failures in the primary ring and bypass them using the counter-rotating secondary ring. If both rings are used to transmit data without the ability to bypass failures, then the throughput doubles to 200 Mbps. There are currently more than 4000 FDDI networks installed [EMME91 p. 30]. The current interoperability of FDDI's standards was demonstrated in October 1991 when more than 40 vendors connected nearly

100 stations in just three days into a single functioning FDDI network. [FAHE91 p. 35]

In 1991 vendors began demonstrating FDDI which would run over twisted pair but at the same speed of 100 Mbps. This is being variously called *Copper Distributed Data Interface* (CDDI) or *Twisted Pair Distributed Data Interface* (TPDDI). This development allow users to take advantage of their existing infrastructure and avoid the higher cost of fiber optic transmission, reception, and connection devices. The major drawback to CDDI is that it works over distances much shorter than FDDI. About 100 m maximum for CDDI and up to 100 km for FDDI. [VERE91 pp. 89-99]

(2) DQDB. Whereas FDDI is being deployed widely, the basic standards for DQDB have only recently been established (about 1990.) DQDB is cabled with a dual ring much like FDDI but is logically a bus. It is also fault tolerant like FDDI in that it can reroute its busing scheme to bypass a line or node failure. Instead of using a token to regulate traffic, DQDB uses a distributed reservation system wherein requests are made to the bus controller for slots in which to transmit data and the slots are doled out in an orderly fashion. This ordered queue means that capacity on the network is not wasted. In addition, access delay is substantially smaller in DQDB than it is in FDDI. [MINO91 pp. 693-696]

(3) HIPPI. Where FDDI serves as a high capacity backbone between LANS, the *High Performance Parallel Interface* (HIPPI) serves as a high capacity backbone for point to point links between supercomputers, high-end workstations, and peripheral devices [EMME pp. 26-30]. It has proven to be a cost effective interconnect technology in a high performance, heterogeneous environment. HIPPI has been standardized as a 32 or 64-bit link operating at 25 MHz with data rates of 800 Mbps to 1.6 Gbps across 25 m of copper cable. [JONE92 pp. 28-29]

LAN communications in general tend to be "bursty" in nature, i.e., large amounts of data are sent at periodic intervals instead of there being a consistent stream of traffic. This means that LAN users are not necessarily best served by a costly dedicated circuit that is always available but only sporadically used. LAN users really need lines which are available on demand. There are some services being developed which would help meet this need and three appear most promising: *Frame Relay*, *Switched Multimegabit Data Service* (SMDS), and *Asynchronous Transfer Mode* (ATM). These services will offer dynamic topologies that can adapt to communications needs in real time, with broader connectivity, and via higher transmission speeds.

(4) Frame Relay. Frame relay is a packet switching technology which is implemented at communications interconnections within bridges and routers. It achieves higher transfer rates by eliminating the error detection

and correction normally done at those interconnections. It offers data rates of 64 Kbps to 1.544 Mbps (DS-1) through statistical multiplexing of multiple data streams over a shared network. [SCOT92 p. 43]

(5) SMDS. Frame relay can accomodate frames (or blocks) of data of varying sizes. SMDS goes one step further by using *cell relay*. Cell relay requires that data be sent in fixed length cells of 53 bytes each. This allows for switching at much higher rates since the switch always knows what size the packets are. SMDS makes use of the DQDB protocol to support speeds of DS-1 to DS-3 (45 Mbps) but speeds up to 600 Mbps are expected in the near future. At present, only two of the BOCs have placed SMDS into service. [SCOT92 p. 46]

(6) ATM. ATM is seen as the next logical step beyond SMDS. It also uses the cell relay technology of 53 byte cell transfers. The term "asynchronous" refers to the ordering of cells during transmission which is not necessarily regular but is done based on actual demand. The term "transfer mode" refers to the process in which cells are identified, switched, and multiplexed according to a label included in the cell header. [MINO91 pp. 219-223]

ATM can support a wide variety of transfer rates varying from the bursty streams characteristic of LANs to the most isochronous (constant) bit rates of other types of data transfer, e.g., multimedia, which may include data, graphics, voice, and video. ATM is expected to support data rates of 45 to 600 Mbps and eventually up to 1 Gbps or more. [SCOT92 p. 46]

j. SONET

The *Synchronous Optical Network* (SONET) is designed to resolve the incompatibility between various fiber optic networks. It includes an interface for global interconnection and a multiplexing hierarchy to ensure compatibility among vendors. SONET optical transmission rates start with OC-1 (Optical Carrier-1) at 51.84 Mbps and goes up to OC-48 at 2.488 Gbps. Plans for rates up to 13 Gbps are being made. OC-1 is the basic building block for higher transmission rates. Basic to OC-1 is an 810 byte frame transmitted every 125 s. This signal is also known as *Synchronous Transport Signal-Level 1* (STS-1). SONET's hierarchy is designed with enough flexibility to allow the transmission of many different capacity signals. Some have predicted that SONET based facilities will carry 40% of interoffice circuits by 1997 and 80% by the year 2000. [MINO91 pp. 153-166]

k. ISDN

The rapid expansion of digital communication services has led to the development of the *Integrated Services Digital Network* (ISDN). ISDN is to provide end-to-end digital connectivity with access to voice and data services over the same digital transmission and switching facilities. The promise of ISDN is more than a decade old but has only just begun to be implemented [MINO91 pp. 167-177]. The RBHCs will have less than 2% of their lines "fully equipped" for ISDN by 1994. [MINO91 p. 216]

(1) Channels. Current standards define three channel types available to the ISDN user.

1. B channel - 64 Kbps for voice, circuit switched data, or packet switched data.
2. D channel - 16 or 64 Kbps for signaling information or packetized customer information.
3. H channel - 384, 1536, or 1920 Kbps for teleconferencing, high speed data, or high quality audio. (Reserved for future ISDN use.)

(2) Interfaces. Two interface structures using these channels have been developed to date.

1. Basic Rate Interface (BRI) - provides access to two B channels and one 16 Kbps D channel (2B + D). May be used over twisted pair.
2. Primary Rate Interface (PRI) - provides access to 23 B channels and one 64 Kbps D channel (23B + D). Requires the use of at least a four-wire copper circuit. [MINO91 pp. 177-179]

The long development lead time into ISDN is causing this rigid concept of ISDN is be replaced by services which better fit the marketplace. Users prefer to be able to obtain service as if they were purchasing fractional T-1 on an as needed basis rather than in terms of 2B + D or 23B + D. LECs are starting to respond with CENTREX services using

ISDN technology. Customers can simply order whatever they need for multiple voice, data, and LAN services without capital expenditures, installations, maintenance, or upgrades to worry about. [CROS92 pp. S63-S65]

(3) Obstacles. The potential capabilities available with ISDN may be outpaced by technology. Frame relay, SMDS, and ATM are all faster digital technologies offering greater bandwidth and flexibility than ISDN and they are already being implemented in vendor equipment [CROS92 p. S65]. Besides the burden of newer technologies, ISDN still faces other hurdles before it can be deemed a success:

1. ISDN specific equipment (like an ISDN interface for a PC) are priced typically an order of magnitude above the equipment needed for other solutions, e.g., modems, LAN adapters, and analog telephones.

2. Vendors will not have interoperable equipment available for ISDN until late 1992. Until 1991 each vendor used a slightly different set of protocols.

3. PBXs are getting cheaper and PBX vendors are claiming that they can provide the same services as ISDN but better and more inexpensively.

4. Producing an ISDN dial tone is expensive and most ISDN service tariffs are only now beginning to be approved.

5. ISDN data rates are higher than twisted pair telephone lines, and lower than that of LANs, but is more expensive than either.

6. ISDN is too slow to handle some media such as multiple channels of full-frame, full-motion video.

7. Deployment of ISDN has been extremely slow with only 45 COs ISDN capable now and only 150 projected to be capable by the end of 1993. Customers outside major metropolitan areas may be waiting for ISDN for years. [CROS92 p. S72]

The glacial pace of the development of ISDN and the emergence of more capable technologies is indicative of the future of telecommunications in general. Products and services which can be adopted quickly and can meet the needs of users will be the ones which will become the standards in fact. Those which merely dangle the promise of future capabilities without being consummated will remain standards in theory only.

V. FUTURE TELECOMMUNICATIONS TECHNOLOGY

The technology to be used in the next two to three decades in the telecommunications industry is largely being planned for today. Existing technologies will be expanded and extended to attempt to meet the demands of tomorrow. Standards are being established which will attempt to guide the direction and pace of innovation. But, regardless of planning, new technologies, techniques, and applications will certainly be forthcoming which are unheard of and unimagined today. This chapter examines some of the telecommunications technologies which are likely to emerge.

A. UNIVERSAL COMMUNICATIONS

The development of these technologies and services are in a symbiotic relationship with society's ever increasing need for information and the transfer of information. The technologies develop to meet the need and the need expands to exploit the technology. The demand for universal communications is the next requirement for technology to satisfy. Stallings has described universal communications as having the following characteristics.

1. Worldwide exchange between any two subscribers in any medium or combination of media.

2. Retrieval and sharing of massive amounts of information from multiple sources, in multiple media, among people in a shared electronic environment.

3. Distribution, including switched distribution, of a wide variety of cultural, entertainment, and educational materials to home or office, virtually on demand. [STAL92 pp. 495-496]

B. BISDN

Planning for ISDN originally began in 1976. Whether or not it is ever fully deployed will depend to some extent on the advancement of more capable technologies. One such technology is an extension of ISDN known as *Broadband ISDN* (BISDN). The impetus to develop BISDN includes services such as image and video processing which require extremely high bit rates, and the development of technologies which support these services such as efficient optical fiber transmission systems and improved microelectronic circuitry.

1. Classes of Service

As envisioned, BISDN will have two classes of service, *Interactive* and *Distribution.*

a. Interactive BISDN

Interactive services are those that allow for two-way communication between a user and a service provider or between two users. Interactive services include *conversational*, *messaging*, and *retrieval* services.

(1) Conversational. Conversational services allow for private, bidirectional, real time dialogue between two or more users. The types of dialogue may be audio, video, data, or documents.

(2) Messaging. Messaging services differ from conversational services in that they are not real time. This places less of a demand on the network carrying the information and does not require both users to even be present. Messaging services use storage to take advantage of functions like store and forward, mailbox, and message handling. One potential use of messaging is video mail wherein a video recording is stored for retrieval by the called party when the called party is ready to view it. An expanded definition of document mail could include text, graphics, voice, and video in a single document.

(3) Retrieval. Retrieval services allow the user to find and obtain information for use from public or private information storage centers. The time of transmission for retrieval should be under the control of the user. The information retrieved might be text or documents. Examples of these include entries from an encyclopedia, reports on consumer products, travel brochures and the ability to schedule travel, and consumer catalogs and the capability to order goods. These services actually already exist via low speed, voice grade telephone lines from vendors such as CompuServe, Prodigy, and America Online. The information retrieved might also be image or video.

Doctors could find this service useful in accessing high resolution X-rays or CAT scans. Businesses could retrieve mixed media documents and large data files. The general public might order movies on demand. [STAL92 pp. 497-507]

b. Distribution BISDN

The second class of BISDN service is distribution service in which information transfer is one way, usually from a service provider to a user. Distribution services are broadcast services and can be presented in two ways, with or without user presentation control.

(1) Without User Control. When the user has no control over the presentation, he merely taps into the flow of information being broadcast by the service provider. Broadcast radio and television are examples of this type of service. With BISDN, more channels with higher resolution will be integrated with other telecommunications services over one network.

(2) With User Control. The other type of distribution service allows the user to control the presentation of information. The information will still be broadcast but is limited to a specific number of frames (pages) which cycle repeatedly. One example might be 10,000 frames of information which could be repeatedly broadcast via BISDN every second. The user could designate what he wanted to access through a hierarchical menu system and the desired frame would be captured and displayed. What appeared to the

user to be interactive would really be the selective display of broadcast information.

(3) Cabletext. The principle behind user controlled presentation services has already been tested in a much more restricted form called *Teletext.* Teletext uses unallocated portions of the bandwidth of a broadcast television signal to distribute such things as news, weather, financial reports, leisure information, and recipes. BISDN would enhance Teletext into *Cabletext* and use not just a portion of the analog signal but a full digital broadband channel. Cabletext could be used in such applications as electronic newspapers and in-house information systems for hospitals, hotels, and trade shows. [STAL92 pp. 498-509]

Teletext should not be confused with *Teletex* which is a slow (2400 bps), direct electronic document exchange system which is part of ISDN. Teletex is designed to replace *Telex*, an even slower (50 bps), primitive interactive text communication system. [STAL92 pp. 211-237]

2. Capacity

BISDN is currently being designed to handle traffic with data rates up to 155.52 Mbps and 622.08 Mbps (multiples of the SONET standard of 51.84 Mbps.) It will easily meet all ISDN requirements and will be compatible with any installed ISDN system. Optical Fiber is the best technology for moving data at such speeds and the introduction of BISDN currently depends on the introduction of optical fiber into the local loop. Fast packet switching is increasingly viewed as the only switching facility capable of dealing with the wide range of data rates expected over BISDN and ATM is expected to be designated as the protocol to be used for the user to network interface. [STAL92 pp. 514-525]

C. SOLITONS

One of the most interesting methods of data transfer in optical fiber currently being researched is by using *solitons*. Solitons (from "solitary" plus the suffix "on") are part of a class of waveform which are observed in a wide variety of natural phenomena. They were first noted by John Scott Russell in 1834 outside Edinburgh, Scotland in the Union Canal [KELL91 p. A1]. Russell recorded his observations as follows.

> I believe I shall best introduce this phenomenon by describing the circumstances of my own first acquaintance with it. I was observing the motion of a boat which was rapidly drawn along a narrow channel by a pair of horses, when the boat suddenly stopped - not so the mass of water in the channel which it had put in motion; it accumulated round the prow of the vessel in a state of violent agitation, then suddenly leaving it behind, rolled forward with great velocity, assuming the form of a large solitary elevation, a rounded, smooth and well-defined heap of water, which continued its course along the channel apparently without change of form or diminution of speed. I followed it on horseback, and overtook it still rolling on at a rate of some eight or nine miles an hour, preserving its original figure some thirty feet long and a foot to a foot and a half in height. Its height gradually diminished, and after a chase of one or two miles I lost it in the windings of the channel. Such, in the month of August 1834, was my first chance interview with that singular and beautiful phenomenon which I have called the Wave of Translation, a name which it now very generally bears. [NEWE85 p. 1]

Russell was convinced that he had observed something no one else had noticed before and he conducted experiments with these waves for the rest of his life. He later wrote the following concerning them.

> This is a most beautiful and extraordinary phenomenon: the first day I saw it was the happiest day of my life. Nobody had ever had the good fortune to see it before or, at all events, to know what it meant. It is now known as the solitary wave of translation. No one before had fancied a solitary wave as a possible thing. When I described this to Sir John Herschel, he said "It is merely half of a common wave that has been cut off." But it is not so, because the common waves go partly above and partly below the surface level; and not only that but its shape is different. Instead of being half a wave it is clearly a whole wave, with this difference, that the whole wave is not above and below the surface alternately but always above it. So much for what a heap of water does: it will not stay where it is but travels to a distance. [NEWE85 p. 1]

1. Light Solitons

The solitary waves which Russell observed in water have a mathematical counterpart as light in a nonlinear medium (one in which the index of refraction changes as the intensity of the light changes.) These solitary light waves are what are known as solitons and describe pulses of light which resist spreading in optical fiber even over great distances.Two classes of solitons have been observed: *temporal* and *spatial*.

a. Temporal

Temporal solitons are pulses of light which resist broadening in time. The tendency of light to broaden in time in optical fiber occurs because no light source produces perfectly monochromatic light. It cannot be monochromatic because its bandwidth is inversely proportional to its width in time. Pulses of light in optical fiber generally require repeaters to regenerate new pulses on the order of every 100 km to counteract this natural spreading. Temporal solitons avoid this problem by balancing the natural broadening of the light with the nonlinearity inherent in optical fiber. By selecting fiber with the right characteristics, the fiber's nonlinearity slows the leading frequencies and speeds up the trailing frequencies, thus producing an ultrastable pulse which does not require repeaters. [BELL90 p. 56]

(1) Amplification. Solitons, like all light, are attenuated by the medium in which they travel and require periodic amplification. It has been found that coating (or doping) optical fiber with the rare earth erbium can turn the fiber into its own amplifier and eliminate the need for more costly amplification equipment [KELL91 p. A11]. The optical amplifier consists of a 10 to 30 meter piece of erbium doped fiber spliced into the regular fiber. AT&T Bell Laboratories has demonstrated systems using such amplifiers which can transmit 5 Gbps over 9000 km and 2.4 Gbps over 21,000 km. Optical amplifiers are being designed into both transatlantic and transpacific cables scheduled for deployment in 1995 and 1996. [REFI91 pp. 30-31]

(2) Multiplexing. Another characteristic of erbium doping is that amplification can take place over a wide band of frequencies. A *Wavelength Division Multiplexing* (WDM) system with multiple channels could

be all be amplified instead of each channel requiring separate equipment. WDM refers to carrying different signals over non-overlapping frequency bands. In non-fiber systems this would be known as FDM but the term WDM is preferred for fiber transmission [STAL92 p. 140]. The number of channels which could be carried is currently at least five but this is expected to grow. [BELL90 pp. 56-57]

(3) Transmission. The data rates and transmission distances possible using soliton technology are constantly stretching. In 1991 AT&T Bell Laboratories demonstrated a soliton transmission of 32 Gbps over 90 km of optical fiber. The 32 Gbps rate is too fast for current electronics to demultiplex and AT&T used an optical filtering scheme to split the data into eight 4 Gbps signals which could be demultiplexed. The demonstration was part of ongoing efforts to develop faster data transfer rates. [HECA91 p. 12]

The transmission of data without repeaters in optical fiber has been most dramatic when the soliton effect is employed. But work continues on non-soliton light transmission as well. Researchers at Hughes Missile Systems Group, also in 1991, reported developing a fiber link which could transmit at 35 Gbps without using the nonlinear soliton effect. They used a specially fabricated fiber link which combined three distinct types of fiber with different dispersion characteristics. Distances of 1800 km were achieved without resorting to repeaters. [LIGN91 p. 3]

Nippon Telegraph and Telephone Corporation (NTT) may have set the current distance record for soliton transmission distance. In 1991 NTT succeeded in sending soliton transmissions at 10 Gbps through one million km of optical fiber. To achieve this however, active pulse regeneration systems were used. Passive systems are generally considered more desirable especially for applications which present access problems such as undersea cables. [HECB91 p. 12]

In late 1991, AT&T Bell Laboratories developed an optical, fiber ring LAN, using solitons and optical logic gates, which was said to be able to handle data at speeds up to 100 Gbps. Such a LAN would most likely be used in MANs or between multiple computer systems. Developers concede that they have no particular application in mind which would require speeds this great in the immediate future. Regardless of the data rate, soliton systems are expected to mature and be routinely deployed within the next decade and speeds on the order of billions of bps (or Terabps) are likely. [LIGD91 p. 3]

b. Spatial

Spatial solitons are continuous beams of light which resist broadening in space. Spatial solitons are mathematically similar to temporal solitons but have a different cause. Spatial solitons occur in specially designed planar waveguides using a medium with a high index of refraction between two mediums with low indices of refraction. In this configuration, the light beam will neither spread nor focus in on itself but maintain parallel edges through the material. This is the spatial soliton effect.

These spatial solitons can interact like particles either attracting or repelling one another. It is hoped that this interaction can be harnessed to produce an efficient optical soliton switch. Most current switching technology is electronic and requires that light be first changed to an electrical signal prior to switching and then be changed back into light. Being able to create all optical switching circuits instead could have enormous impact on networks. Soliton optical switches could also be a key element in the development of optical computing. [BELL90 pp. 56-57]

D. PHOTONICS

Optical switches lie within the realm of *photonic* switching devices.

1. Photonic Switching

Photonic switching is the input, processing, switching, and output of optical information without changing it into another form (usually electrical.) Photonic switching is expected to become commonplace in the next decade, however its form is unclear. For example, pure photonic switching in a telephone company CO is unlikely. It is more likely that applications of photonic switching will take place within environments which also include electronic switching for many years to come. [WARR90 p. 31]

Photonic switching may be done through a waveguide or via free-space optics. Much of the former is done with lithium niobate which is electro-optically active and can operate at a speed of 100 Ghz. More recent experiments with other materials have operated at one THz [LIGD91 p. 8]. These can handle both interconnections and switching. Free-space optics emphasizes getting a maximum amount of data into or out of the processing elements which may be electrical or optical. This is largely driven by the number of pinouts available on a chip. Whereas guided wave optics are limited to about 500 pinouts, free-space optics can support up to 10,000 pinouts per square millimeter chip. [REFI91 p. 31]

2. Optical Computing

The final assault for the integration of photonics into the electronic world is optical computing. This area of photonic technology is still in its infancy and largely speculative, especially when compared to photonic switching which is already being deployed. However, there seems to be no reason to doubt that such technology will be developed and its potential for greater speed and performance harnessed. Ian Ross, president emeritus of AT&T Bell Laboratories, predicted in 1991 that up to 20% of the components in high performance computers could be photonic by the end of the decade, rising to 50% by the year 2010. [LIGN91 p. 3]

E. FIBER IN THE LOOP

As the need for more and more data increases, the need for a physical plant capable of carrying that data also increases. Optical fiber is generally acknowledged as the only means capable of delivering the large data rates expected to be required in the next several decades. The PSTN and the PPSN both use extensive optical fiber for long distance communications and for most trunk routes today. In addition, optical fiber is increasingly being used in a portion of the local loop to carry traffic to DLCs. But it is in the local loop still, where the vast majority of plant remains copper based. If bandwidth is to increase to the user at the end of the local loop, then the advantage of optical fiber must be extended to that user.

1. Distribution

Digital Loop Carriers are commonly used as feeder cables for distribution into the local loop but not for distribution to the end user. Attempts to push optical fiber to the end user fall generally into three categories.

1. *Fiber in the Loop* (FITL) - extending optical fiber systems from the CO to or near the customer premises.
2. *Fiber to the Curb* (FTTC) - terminating optical fiber near but not at the customer premises.
3. *Fiber to the Home* (FTTH) - carrying the optical fiber connection all the way into the customer premises. [HAWL91 p. 27]

2. Economics

The biggest obstacle to implementing FTTH is the installed plant of copper which represents billions of invested dollars. For fiber to be installed requires that the economic advantages of using optical fiber must outweigh the costs of installing new copper or maintaining the existing copper plant. Although previously prohibitive, these costs are expected to reach parity in the mid-1990s. Optical fiber has been projected to completely replace copper in the public telecommunications networks over the next forty years. [ESTY91 p. 26]

3. Bellcore's Model

Bell Communications Research (Bellcore; the research arm of the RBHCs) has devised an outline for the transition to FTTH which has been generally accepted by the telephone industry. Bellcore envisions the mass integration of FITL starting in 1993 with the "challenge...[being to focus]...on the early deployment and long-term evolvability of FITL." Its model is designed having a physical topology along with an information transport capability such that "the methodology that a vendor chooses to utilize to transport signals between the defined interfaces is largely open to innovation." Bellcore's intention is to,

> ...ensure that the distribution fiber infrastructure will be built 'right the first time'...[such that the]...initial fiber layout designs are robust enough to accomodate near-term as well as future transport capability objectives. [BCOR90 pp. 5-6]

Bellcore's model of FTTC includes an *Optical Network Unit* (ONU) which would be fed from the CO and then passively or actively split and fed to between four and eight end users over copper lines. This would allow plant and ONU electronics to be shared by more than one customer and hold down the cost of initial implementation. Planned capabilities for the Bellcore model include the following.

1. Service migration would start with current standard telecommunications capabilities, add video transport capabilities, and then include BISDN.
2. Standard BISDN service would be 622 Mbps initially.
3. An upstream signalling capability (from customer to network) would be included.
4. Actual implementation of services would be driven by economics and service demand.
5. Long term planning should include using the provisions of SONET in the network.
6. The method for powering the system is left to the implementing companies and vendors, however, battery backup must be provided at the ONU.
7. Near term video must deliver 42 to 60 National Television System Committee (NTSC) channels with long term capability expanding to 120 channels. Both analog and digital video would be supported. [BCOR90 pp. 9-16]
8. Fiber systems in general should be expected to be in place and functioning for 20 to 40 years. [ECCL92 p. 32]

Final transition to FTTH may or may not include an ONU on the customer's site but will include an optical fiber interface to the customer premises. One industry analyst predicts that 35% of homes in the United States will have FTTH by the turn of the millennium. [CADO91 p. 22]

F. CABLE TELEVISION

The deployment of fiber is not only of interest to LECs, IXCs, and other traditional public network telecommunications carriers, but is also of vital importance to the *Cable Television* (CATV) industry. Telephone companies have been almost completely restricted by government regulation from entering the CATV business [CARN91 p. B10]. Recent rulings by the FCC and the Justice Department have started to relax those restrictions.

1. Opening the Market

On 7 October 1991, a U.S. Court of Appeals overruled a judgment by Judge Greene regarding the MFJ and allowed the RBHCs to begin offering information services. Typical services may be news, sports, and electronic Yellow Pages, which would put them into competition for the first time with both the publishing and CATV industries. [LATI91 p. D1]

On 24 October 1991, the FCC declared its intent to allow telephone companies to begin carrying a *video dial tone*; in effect, to allow telephone companies to offer television (although regulations still prohibit telephone companies from owning or creating programming in their own service areas) [FAHB91 p. 12]. Within a year, the FCC hopes to publish rules governing the video dial tone. This move is seen by the FCC as a way to encourage the development of new infrastructure (especially the deployment of optical fiber) and increase the competition in the telecommunications industry as a whole by opening up the monopolies held by CATV companies. [DAVI91 p. B1]

2. CATV Response

The CATV industry is using a variety of tactics to offset the damage to CATV as a result of the trend toward deregulation and the competition it engenders. Some are installing optical fiber and are beginning to offer interactive services similar to what the telephone companies are now being allowed to offer [FAHE92 p. 1]. Another tactic is to bypass cabled service with a *direct broadcast service* (DBS). DBS transmits television via satellite to small receivers and can offer more channels than current cable technology. CATV's most powerful weapon, though, is its control of a large portion of television programming through corporate ownership of television production. Some large CATV companies intend to withhold television programming from would be competitors in the television industry and allow it to be offered only by certain carriers. This tactic however may not survive an FCC and a U.S. Congress which support more open competition. [LEWY91 pp. 66-69]

3. End of Monopoly

CATV also may not be able to withstand the general push for more competition in their local operating areas from other CATV companies. The geographic monopolies enjoyed by most CATV providers are being replaced with an open marketplace where any carrier who is able will be allowed to offer CATV services [LEWY91 p. 67].

This same open marketplace is being advocated by some for the local loop. It is declared that the alternatives for consumers, created by the competition allowed in the interexchange market, would also be created in the local loop if the monopoly in the local loop were taken away from the LECs. Such competition might include delivery of services by any available means, for example: optical fiber, satellite, cellular radio, and microwave. Lusa has noted the following regarding this concept.

> The arguments about who will deliver a unified voice, data, and video service to the home will become moot. It will be open to anybody who can muster the resources and technology to develop and implement such a system. [LUSA91 p. 4]

G. PERSONAL COMMUNICATIONS NETWORKS

A logical evolution of current cellular telephone technology may be the *Personal Communications Network* (PCN) [MCCA92 p. 41]. The goal of PCN is to provide individual telephone service, regardless of location, to anyone, through a wallet sized folding telephone. Under the PCN concept, a person might receive a PCN telephone number at birth and keep it until death. [CHIL92 p. 54]

1. Microcells

Where cellular telephony uses cells with radii of about 10 km, PCN uses microcells with radii of only 200 m to 1000 m. Such small cells require a large number of transmitting towers. For example, a 60 square mile city would require 60,000 transmitters if the cell radius were 200 m. The cell sites would be linked most likely with optical fiber or microwave transmitters. [KIMA91 pp. 9-10]

Some microcell PCN systems are already in place in airports, hotels, and business and convention centers. The expense of an all encompassing microcell system will probably dictate a merging of the PCN into the existing cellular telephone network. Vendors are already producing products for that purpose. [KIMA91 p. 10]

2. Routing Options

Another option being developed is to take digital traffic from a PCN and route it to the switching office over existing CATV lines. This design translates the radio frequencies of the PCN into frequencies which can be carried across a CATV network. Developers of such systems say that doing so preserves the "amplitude and phase characteristics of the radio signal" and avoids signal processing. Preliminary estimates project that the cost of using CATV lines could be just 20% of a standalone PCN. [KIMB92 p. 39]

3. Digital PCN

Telephone sets themselves are projected to become more and more digital over the next decade. The emergence of PCNs will allow PCN telephones to transition from analog to digital technology by the late 1990s. Digital portable telephones will exhibit higher quality transmissions and will eliminate the fading and echoing common in current cellular telephones. They will also allow email, facsimile, computer interaction, and file transfer to be possible through the PCN. The access system for these devices will either be *Time Division Multiple Access* (TDMA) or *Code Division Multiple Access* (CDMA). TDMA is older and more established whereas CDMA has better quality, provides three to seven times the capacity, and uses one-third fewer cells than TDMA. [MILE92 pp. 36-37]

H. ENHANCED FDDI

Two improvements to FDDI are already well into the planning stages.

1. FDDI-II

FDDI-II is an enhancement to FDDI that adds a circuit switching capability to the packet switching capability of FDDI. Most packet switched data arrives in various quantities at varying times. Whereas circuit switched (isochronous) data arrives at specific time intervals in specific quantities. FDDI-II will allow a portion of the 100 Mbps bandwidth of FDDI to be used for isochronous data streams. Up to 16 wideband channels of 6.144 Mbps may be so allocated (i.e., up to 98.304 Mbps.) FDDI-II is expected to replace all FDDI installations during the next decade. [ROSS91 pp. 54-58]

2. FDDI Follow-on

FDDI Follow-on is being planned to replace FDDI-II sometime early in the next century. Its primary goal is to increase the data rate from 100 Mbps to between 600 Mbps and 1.2 Gbps, and eventually to 2.4 Gbps, all matching SONET standards. [JONE92 p. 28]

I. DATA COMPRESSION

One technique used in the attempt to move data more quickly is the modification of data before it is transmitted. The most common modification is compression. Most compression schemes replace redundant data with a shorter code which can be interpreted at the receiving end to reproduce the complete set of data again. This technique has worked reasonably well on digital data but is not sufficient to reduce data rates for video.

1. Video Compression

Without compression, an NTSC standard television signal would require 1000 voice grade telephone lines or a 90 Mbps data rate. This is enough to almost fully occupy an FDDI architecture for a single television channel. Video codecs do moderately well at reducing video bandwidths in four ways.

1. Reducing Resolution
2. Reducing Frame Rate
3. Reducing Color Fidelity
4. Reducing Redundancy

The first three methods all have an adverse effect on picture quality and the extent to which they are used must be balanced against the requirements of the application. The fourth reduction technique allows coding to be used to reproduce a compressed signal at the receiver without loss of video quality. [YADO92 pp. 25-29]

Reducing redundancy is generally done in three ways.

1. *Interframe Coding* - Keeps track of picture elements (pixels) and transmits only those pixels which have changed from frame to frame.

2. *Intraframe Coding* - Divides frames into blocks of pixels and transmits only unique blocks plus the location of blocks which are identical to the unique blocks. Deleted blocks are copied back into the frames at the receiving end.

3. *Predictive Coding* - Transmits the first and last frames of a series in which motion has occurred along with a vector which describes the motion which took place between the two frames. At the receiver, the motion vector is used to regenerate the missing frames. [YADO92 p. 29]

Current coding methods will reduce video transport requirements to 20-45 Mbps for NTSC television and to 92-200 Mbps for *High Definition Television* (HDTV) by the mid-1990s. Further reductions are expected as coding schemes continue to improve. [STAL92 p. 512]

2. Wavelets

Another method of compressing data which is currently being developed, and which will have applicability to all types of data, is called *wavelets*. This method has been described as functioning more closely to the way the human eye and ear process data. The eye tends to locate edges between blurry images to produce a picture and so do wavelets. The ear hears in octaves while wavelets split sound frequencies into octaves for storage and recall. The mathematics behind wavelets have been characterized as one of the most important mathematical events of the century. [KOLA91 p. B5]

a. Curves

Wavelets basically use equations to describe data at all points. Wavelets are somewhat similar to Fourier analysis which uses multiple sine and cosine curves to match the curves of a given problem. But Fourier analysis is too cumbersome for the complexities of massive amounts of data, especially when the data consists of images or video. In contrast, wavelets use the mathematics of harmonic analysis to create a more precisely tailored set of curves which fit the data better. The number of wavelets can be tailored to fit the complexity of the data. For images, the amount of resolution can be raised by raising the number of wavelets used. Early results of using wavelets on images has produced a 40:1 compression ratio.

b. Applications

Wavelets have also been shown to be useful to compress human speech without magnifying background noises as in other speech compression schemes. Another application may be in weather satellite imaging. Using wavelets, specific details could be isolated for study by selecting only that data from the information stored in the wavelets. Other data could be added in as necessary. [KOLA91 p. B9]

J. NETWORK STRUCTURE

The networks which constitute the world's interconnected telecommunications systems have undergone radical change in the last two decades. This change has been fueled by advances in technology and will certainly continue into the future.

1. Pyramid

Until about 1970 the telephone network in the United States could be described as a pyramid structure consisting of nodes and links. The nodes were devices such as telephones and switches and the links were the transmission lines between them. They were arranged with the majority of nodes on the bottom layer, each connected to the layer above by a link (e.g., a user's telephone connected to a CO.) Nodes in each layer had many links to nodes below and just a few links to nodes above. The top layer was just a handful of nodes which provided top level coordination and control. [HUBE87 p. 1.2]

2. Geodesic

The pyramid structure developed largely because switching was slow and expensive while transmission tended to be cheap. Using the fewest number of switches was most cost effective. But since the mid 1970s, developments in the electronics field have pushed the cost of switching down to a fraction of what it once was while transmission lines, the majority of which are still in the "last mile" between the CO and the end user, continue to cost about the same. Thus it has become more cost effective to attempt to move switching out closer to the end user. This will result in what was once a pyramid being transformed into more of a geodesic network where nodes tend to be connected to equal numbers of nodes at all levels. Huber has noted the following regarding these two types of networks.

> When switching is expensive and transmission is cheap the efficient network looks like a pyramid...By contrast, when switching is cheap and transmission expensive, the efficient network is a ring. [HUBE87 p. 1.3]

3. Open Architecture

The emerging geodesic network will have an open architecture which has been spurred on by the divestiture of AT&T and continuing deregulation. This open architecture is likely to change telecommunications service at all levels. For example, separate pieces of the telephone connection now provided by the LEC: dial tone, switching, ringing, and busy signals, may all be unbundled and provided in customized packages by alternative providers along with other more advanced services. With the proliferation of technology, and the freedom which vendors have been given in the marketplace, the concept of the geodesic network is apt to continue to expand and include all levels of possible service. [HUBE87 p. 1.5]

K. TRENDS

Given the dynamic nature and the rapid pace of technological innovation, no one can state with a great deal of certainty what the future condition of the telecommunications industry will be. For most people it is difficult enough to stay abreast of the current situation. But certain social, economic, and technological trends would seem to presage certain conditions likely to exist early in the next century.

Based on apparent trends, NTT has gone so far as to publish a description of the trends it believes will guide the bulk of telecommunications development into the next millennium.

According to NTT, service quality will improve based on technological innovation. Service will become more diversified. More activities which require a person to be some place physically today, will be handled remotely, e.g., medical checkups, video conferencing, and shopping. Full wall-size visual services, with thin displays, will be possible along with three-dimensional multi-screen imaging. Remote monitoring and operation of homes, businesses, and installations will become commonplace as standard security procedures. Enormous databases of everything that is typically published as printed material today will be accessible via portable telephones and personal computers. [NTTC90 p. 7]

Service is likely to be enhanced by the advancing capabilities of information processing technology such as recognition and comprehension. Automatic language translation services, voice and handwriting recognition, and Braille output will all make their appearance early in the next century according to NTT. [NTTC90 p. 7]

NTT sees future service falling into three categories: visual, intelligent, and personal. Visual services will take advantage of the higher speeds and greater bandwidths of coming networks such as BISDN to produce images on demand (including HDTV.) Intelligent services will be able to pinpoint information or establish contact with people regardless of location. Personal services will respond to the preferences of individual consumers and tailor output to those preferences. [NTTC90 p. 10]

To meet the requirements of these services NTT plans to deploy optical fiber into every household and business over a 20 year period from 1995 to 2015 [NTTC90 p. 15]. Whether the rest of the world will match or exceed these targets remains to be seen.

VI. CONCLUSIONS

A. SUMMARY

This thesis attempted to ascertain future trends in telecommunications by examining telecommunications of the past and present. The development of telephone service in the United States was discussed within the framework of government regulations. Prevalent telecommunications technologies and expected technologies of the future were addressed.

The exact details of the process Alexander Graham Bell used to build his first working telephone will never be known. Bell himself admitted that he was assisted by an unethical patent examiner. At worst, he was a dishonest, schemer who exploited another man's ideas to produce a watershed device in the Industrial Age and secure the world's acclaim. Bell's protagonist, Elisha Gray, has since faded from memory into a historical footnote.

Bell's patents allowed enough time for the Bell System and AT&T to become the dominant supplier of telephone service in the United States. By the 1930s virtually all telephones were tied into the Bell System and AT&T supplied all long distance traffic. In this they were supported, even encouraged, by state and federal government regulators. This began to change in the 1950s, and through the 1980s government regulators allowed the telephone market to open to competition. Finally, in 1984, the telephone system in the United States was transformed by the divestiture of AT&T. True competition in long distance service began in earnest and a host of new services became available. The further deregulation of all portions of the nation's telephone system continues to unfold.

In the 1950s and 1960s a new type of device and a new method of transmission developed. The computer began to be used extensively and the movement of all varieties of data in digital form became commonplace. Networks evolved which were devoted to digital information. The distinction between types of data began to blur. Moving information expeditiously was paramount. Research into the protocols and physical means to move data advanced to meet the growing needs of users and ushered in the Information Age.

Work on the networks of tomorrow continues apace. Combining voice, data, images, video, and graphics onto a single cable to every home will most likely come about through the use of optical fiber. Data rates in the Terabits per second range will be required to provide services on demand such as high definition television and full-screen video teleconferencing. Personal Communications Networks are apt to free people from the constraints of having to communicate from specific locations and give them the power to locate and use information regardless of where it is stored. An interconnected, geodesic network will give users the power they need and usher in the Age of Universal Communications.

B. RECOMMENDATIONS

Telecommunications technology seems to be developing to make it easier and faster to do things which can actually be done today. While this is certainly useful, emphasis should also be placed on generating new telecommunications applications. Communicating via life-size holographic images in real time is one example. Viewing the world from inside an environment of virtual reality is another. Pushing technology to its limits and taking advantage of all its potential is only sagacious.

But one day, the most advanced technologies will run into the wall of physical limitations. Light can only go so fast. Matter as we know it can only be subdivided so far. These limitations will dictate now miniaturized devices can become and how fast information can move. It is at that point that new ways of thinking and viewing the universe must evolve. It is a common trait of humankind to believe that current technology is at nearly the pinnacle of what is possible. That all that is knowable will be known no later than tomorrow. History has shown this to be false a multitude of times. What is known today is just a fraction of the knowable and what will be known the day after tomorrow is inconceivable today. These are the limits that must be overcome in the advances to come in telecommunications technology.

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