A Short History of Telecommunications

13

Abstract

Telecommunications is a branch of technology concerned with the transmission of information over a distance, where the transmitter sends the information to a receiver. We present a short history of telecommunications and focus on the development of mobile phone technology. The development of the AXE system by Ericsson is discussed, and this was the first fully automated digital switching system. We discuss the concept of a cellular system, which was introduced by Bell Labs, as well as the introduction of the first mobile phone, the DynaTAC, by Motorola. We discuss the Iridium system, which was launched in late 1998 to provide worldwide wireless coverage to its customers, and the coverage included the oceans, airways and polar regions. The existing telecom systems had limited coverage in remote areas, and so the concept of global coverage as provided by Iridium was potentially very useful. In many ways, Iridium was an engineering triumph over common sense, and over $5 billion was spent in building an infrastructure of low Earth orbit (LEO) satellites to provide global coverage.

Key Topics

Telegraph
Telephone
AMPS
AXE
Telephone
Telegraph
Mobile phone system
Iridium

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13.1 Introduction

Telecommunications is a branch of technology concerned with the transmission of information over a distance, where the transmitter sends the information to a receiver. Early societies used fire and smoke signals for visual communication, with drums used for auditory communication. This allowed simple messages (e.g. 'danger') to be communicated to other groups.

The Persian Empire established an early postal system in the sixth century B.C., and other societies such as the Egyptians and Romans later established their own postal systems. A pigeon messaging system, where the homing characteristics of pigeons were employed to send messages, was later introduced.

The Greeks introduced an early semaphore system in the fourth century B.C., and this allowed very simple messages to be exchanged between groups on two different hills (similar in a sense to smoke signals). A ship semaphore system was introduced in the fifteenth century, which allowed two ships to communicate with each other. This system used flags where the position and motion of a flag represented a letter.

The Chappe brothers in France introduced an early optical telegraph system in Europe in the late eighteenth century. It used similar principles as the ship-based semaphore system, and it allowed messages to be sent from one high tower to another. It was used by the French military.

Early electrical telegraph systems were introduced in the early nineteenth century, and Samuel Morse devised a system (the Morse code) that allowed letters to be represented by a series of on-off tones in the late 1830s. This was the foundation for electrical telegraphs and later telephone systems. The first Atlantic telegraph cable was laid between Britain and America in 1858.

The telephone was invented by Alexander Graham Bell in 1876,[1] and early telephones were hardwired to and communicated with a single other telephone (e.g. from a person's business to his home), as initially there were no telephone exchanges. A telephone exchange provides switching or interconnection between two subscriber lines, and the earliest manual commercial telephone exchanges were introduced in the late 1870s. The first mechanical automated exchanges were introduced in the early 1890s. The first North American transcontinental phone call from the east coast to the west coast was made by Bell in 1915, and it made long-distance communication a reality.

The invention of the telephone was a paradigm shift from *face-to-face* communication, where people met to exchange ideas and share information or where individuals wrote letters to each other to exchange information. The telephone was a new medium that provided direct and instantaneous communication between two people. It allowed two individuals to establish and maintain two-way communication irrespective of being at two different physical locations. Initially the business

[1] He was the first person to patent the telephone as an 'apparatus for transmitting vocal or other sounds telegraphically'. There are several other claimants for inventing the telephone.

community and the affluent members of society used the telephone, but this changed rapidly in the years that followed.

Marconi, an Italian engineer, introduced a system for the wireless transmission of sounds in 1896, and the British Marconi Company was established in 1897. It began communication between ships at sea and coastal radio stations. Marconi established an early radio factory in England in 1912.

The first prototype electronic television was developed and demonstrated by Philip Farnsworth in the late 1920s. It was the result of research on ways to transmit images, and it had been determined that radio waves could be encoded with an image and then transmitted back to the screen. Farnsworth's prototype is considered the first electronic television.

The foundations of the mobile cellular industry go back to the introduction of a limited-capacity mobile phone system that was introduced for automobiles in 1946. Martin Cooper of Motorola made the first mobile phone call to Joe Engels at Bell Labs in 1973, and a prototype mobile phone network was operational in the late 1970s with commercial mobile phone networks introduced in the early 1980s. The first global mobile phone system (Iridium) was operational in 1998, and the Iridium system consisted of 66 satellites, with the customers using hand-held satellite phones.

The ARPANET packet switching network was introduced in the late 1960s, and it remained operational until 1990, when the Internet became operational. The Internet has led to almost instantaneous communication, and it has led to electronic mail; the World Wide Web, which was developed by Tim Berners-Lee at CERN; social networking; electronic commerce; and telephone calls over the Internet with the VoIP protocol.

This chapter considers a small number of events in the history of telecommunications including the development of the AXE system, which was the first fully automated digital switching system, the development of mobile phone technology and the development of the Iridium satellite mobile phone system.

13.2 AXE System

Ericsson introduced the AXE (Automatic Exchange Electric) switching system in 1977 (Fig. 13.1). This was the first fully automated digital switching system, and it converted speech into digital (i.e., the binary language used by computers). Ericsson's competitors were still using the slower and less reliable analog systems.

The analog system uses an electric current to convey the vibrations of the human voice, whereas a digital system uses a stream of binary digits to represent sound. The AXE system was an immediate success with telecom companies, and it has been sold in many countries around the world. AXE was originally a digital exchange for landline telephony, but it has been extended for use with mobile telephony systems.

Ellemtel was established in 1970 as a pure research and development company and was a joint venture between Televerket (Sweden's state-owned PTT) and

Fig. 13.1 AXE system (Courtesy of Ericsson)

Ericsson. Its primary task was to develop an electronic and automated switching system for telephone stations that would become the AXE system.

Ericsson had been working to develop a commercial electronic switching system called AKE, while Televerket was working on its own electronic switch. Ericsson realized that its AKE system was not suitable for large switching stations and that it needed to develop a new generation of switching systems. It decided to combine its resources with Televerket and to jointly develop an electronic telephone switching system.

Bengt-Gunnar Magnusson was the project manager for the AXE project, and AXE had a modular system design which made the system flexible. New functionality could be added and existing modules updated or replaced. The modular design enabled the system to be easily adapted to different markets.

The development of AXE also involved the development of hardware and software such as programs and processors to control the AXE stations. The first prototype AXE system was installed at a Televerket station in 1976, and Ellemtel's work in developing the AXE system was complete in 1978.

The AXE system was then commercialized and many of Ellemtel's employees moved to Ericsson. AXE was an immediate success and Ericsson soon had

customers in Sweden, Finland, France, Australia and Saudi Arabia. The Saudi order was the largest that Ericsson had ever received, and it involved increasing the capacity of the Saudi network by 200 % and installing the AXE system.

The introduction of AXE meant that by the early 1980s, Ericsson had the market's most advanced and flexible switching system, and this made it ideally placed for the transition to mobile telephony. It meant that Ericsson had moved from being a minor player in the telecoms business to a major league player. It was now the leader in fixed-line phone technology, and it laid the foundation for Ericsson's future success in mobile telephony, where it became the leader in mobile technology from the late 1980s. Today, AXE has been installed in over 130 countries.

13.3 Development of Mobile Phone Standards

Bell Labs played an important role (with Motorola) in the development of the analog mobile phone system in the United States. It developed a system in the mid-1940s that allowed mobile users to place and receive calls from automobiles, and Motorola developed mobile phones for automobiles. However, these phones were large and bulky and they consumed a lot of power. A user needed to keep the automobile's engine running in order to make or receive a call.

Bell Labs first proposed the idea of a cellular system back in the late 1940s, when they proposed hexagonal rings for mobile communication. Large geographical areas were divided into cells, where each cell had its own base station and channels. The available frequencies could be used in parallel in different cells without disturbing each other (Fig. 13.2). Mobile telephone could now, in theory, handle a large number of subscribers. However, it was not until the late 1960s that Bell Labs prepared a detailed plan for implementing the cellular system.

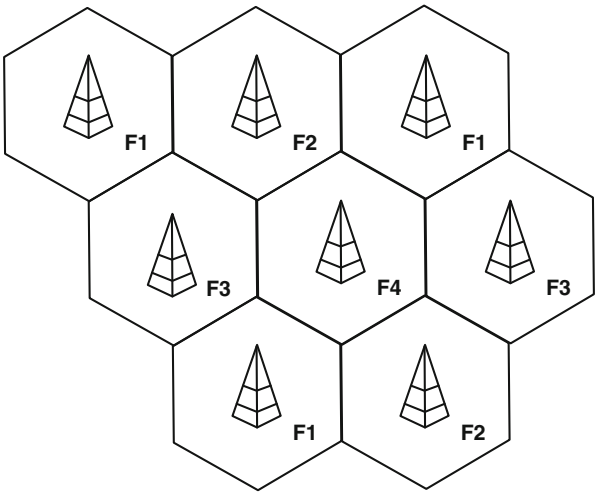

Fig. 13.2 Frequency reuse in cellular networks

Bell Labs developed the Advanced Mobile Phone System (AMPS) standard from 1968 to 1983. Motorola and other telecommunication companies designed and built phones for this cellular system. AMPS uses separate frequencies (or channels) for each conversation and requires considerable bandwidth for a large number of users.

The signals from a transmitter cover an area called a cell. As a user moves from one cell into a new cell, a handover to the new cell takes place without any noticeable difference to the user. The signals in the adjacent cell are sent and received on different channels to the existing cell's signals, and so there is no interference.

The Total Access Communication System (TACS) and Extended TACS (ETACS) were variants of AMPS that were employed in the United Kingdom and Europe. These analog standards employed separate frequencies (or channels) for each conversation using frequency division multiple access (FDMA). However, the analog system suffered from static and noise, and there was no protection from eavesdropping using a scanner.

Ericsson became the leader in the first generation of mobile with Motorola, and the extent of its leadership was clear when its proposed design for digital mobile radio transmission was selected as the US standard for cellular communications over entries from Motorola and AT&T in 1989.

AMPS is the first generation of cellular technology, and it has several weaknesses when compared to today's cellular systems. Mobile technology has evolved from the AMPS analog standard to the digital Global System for Mobile communication (GSM) and code division multiple access (CDMA) technologies; to General Packet Radio Service (GPRS); to third-generation mobile, including 3G and WCDMA; and to fourth-generation (4G) mobile.

13.4 Development of Mobile Phone Technology

The invention of the telephone by Graham Bell in the late nineteenth century was a revolution in human communication, as it allowed people in different geographic locations to communicate instantaneously rather than meeting face to face. However, the key restriction of the telephone was that the actual physical location of the person to be contacted was required prior to communication, as otherwise communication could not take place: i.e. *communication was between places rather than people*.

The origins of the mobile phone revolution dates back to work done on radio technology from the 1940s. Bell Labs had proposed the idea of a cellular communication system back in 1947, and it was eventually brought to fruition by researchers at Bell Labs and Motorola. Bell Labs constructed and operated a prototype cellular system in Chicago in the late 1970s and performed public trials in 1979. Motorola commenced a second US cellular system test in the Washington/Baltimore area. The first commercial systems commenced operation in the United States in 1983.

The DynaTAC (Dynamic Adaptive Total Area Coverage) used cellular radio technology to link people and not places. Motorola was the first company to incorporate the technology into a portable device designed for use outside of an automobile, and it spent $100 million on the development of cellular technology. Martin

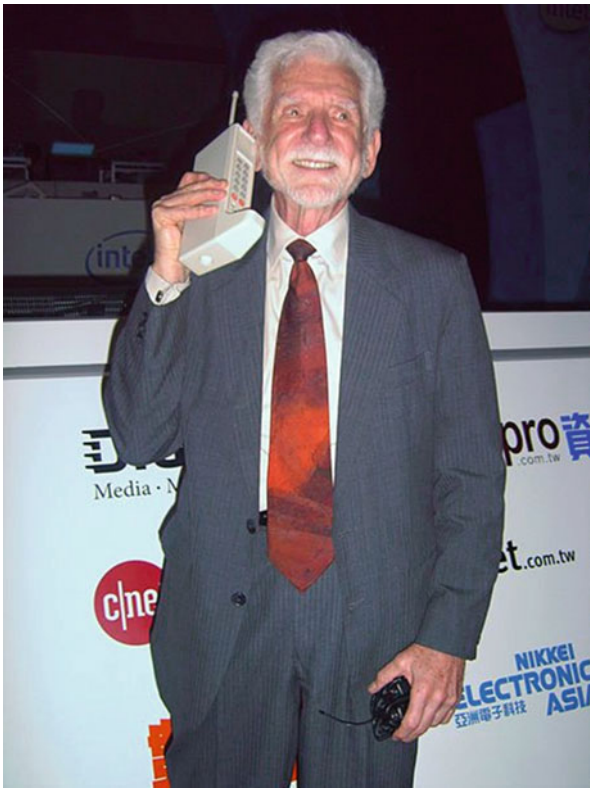

Fig. 13.3 Martin Cooper re-enacts DynaTAC call

Cooper (Fig. 13.3) led the team at Motorola that developed the DynaTAC 8000X, and he made the first mobile phone call on a prototype DynaTAC phone to Joel Engels, the head of research at Bell Labs, in April 1973.

Commercial cellular services commenced in North America in 1983, and the world's first commercial mobile phone went on sale the same year. This was the Motorola DynaTAC 8000X, and it was popularly known as the *brick* due to its size and shape. It weighed 28 ounces (almost 2 lbs); it was 13.5" (over a foot) in length and 3.5" in width. It had a LED display and could store 30 numbers. It had a talk time of 30 min and 8 h of standby, and it took over 10 h to recharge.

The cost of the Motorola DynaTAC 8000X was $3995, and it was too expensive for most people apart from wealthy consumers. Today, mobile phones are ubiquitous, and there are more mobile phone users than fixed-line users. The cost of a mobile phone today is typically less than $100, and a mobile phone typically weighs as little as 3 ounces.

The first-generation mobile phone system introduced into North America in the early 1980s used the 800 MHz cellular band. It had a frequency range between 800 and 900 MHz. Each service provider could use half of the 824–849 MHz range for receiving signals from cellular phones and half the 869–894 MHz range for transmitting to cellular phones. The bands were divided into 30 kHz sub-bands called channels, and a separate frequency (or channel) was used for each conversation. The

division of the spectrum into sub-band channels is achieved by using frequency division multiple access (FDMA).

This first-generation system allowed voice communication only, and it was susceptible to static and noise. Further, it had no protection from eavesdropping using a scanner.

The AXE system (discussed earlier) provided the foundation for Ericsson's growth in mobile telephony. The flexible modular design of AXE allowed new functionality to be added, and by changing a module, AXE could be reconfigured to handle mobile telephone calls. This allowed Ericsson to design the first mobile telephone exchange (MTX) by replacing the subsystem for fixed subscribers with a new subsystem for mobile subscribers. The MTX switch was developed in the late 1970s/early 1980s and was a key part of the Nordic Mobile Telephone (NMT) system which would be used in all Nordic countries.

Ericsson was awarded a large Saudi Arabian contract to deliver a fixed-line and mobile system, and it was agreed that the NMT standard would be used and that Ericsson would supply the entire system. The Saudi mobile phone network became operational from 1981, and Ericsson provided base stations, radio towers and switches. Ericsson had now acquired cell-planning experience, and it was awarded the contract to develop the entire mobile telephone network in the Netherlands. Ericsson was now a total systems supplier in mobile telephony, and it provided the entire infrastructure such as switches and base stations. Today, its base stations range from small picocells to large macrocells.

The second generation (2G) of mobile technology was a significant improvement on the existing analog technology. This digital, cellular technology encrypted telephone conversations and provided data services such as text and picture messages. The two main second-generation technologies were the GSM standard developed by the European Telecommunications Standards Institute (ETSI) and CDMA developed in the United States. The first GSM call was made by the Finnish prime minister in Finland in 1991, and the first short message service (SMS) or text message was sent in 1992.

The subscriber identity module (SIM) card was a new feature in GSM, and a SIM card is a detachable smart card that contains the user's subscription information and phone book. The SIM card may be used in other GSM phones, and this is useful when the user purchases a replacement phone. GSM provides an increased level of security, with communication between the subscriber and base station encrypted.

GSM networks evolved into GPRS (2.5 G), which became available in 2000. Third- and fourth-generation (3G and 4G) mobiles provide mobile broadband multimedia communication. Mobile phone technology has transformed the earlier paradigm of *communication between places* to that of *communication between people*.

Motorola dominated the analog mobile phone market. However, it was slow to adapt to the GSM standard, and it paid a heavy price with a loss of market share to

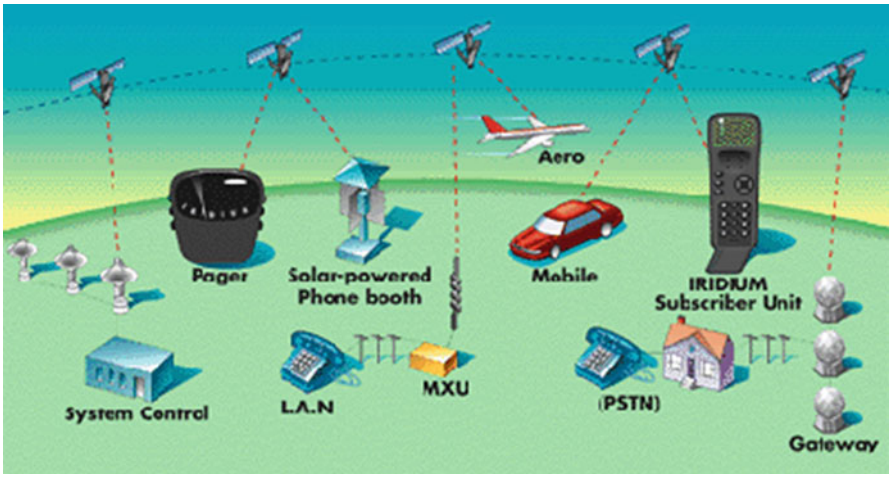

Fig. 13.4 Iridium system (Courtesy of Iridium)

Nokia and Ericsson. The company was very slow to see the potential of a mobile phone as a fashion device,[2] and it was too slow in adapting to smartphones.

13.5 The Iridium Satellite System

Iridium was a global satellite phone company that was backed by Motorola. In many ways it was an engineering triumph over common sense, and over $5 billion was spent in building an infrastructure of low Earth orbit (LEO) satellites to provide global coverage. It was launched in the late 1998 to provide worldwide wireless coverage to its customers, and the coverage included the oceans, airways and polar regions. The existing telecom systems had limited coverage in remote areas, and so the concept of global coverage as provided by Iridium was potentially very useful.

Iridium was implemented by a constellation of 66 satellites (Fig. 13.4). The original design required 77 satellites, and so the name *Iridium* was chosen since its atomic number in the periodic table is 77. However, the later design required just 66 satellites, and so *Dysprosium* may have been a more appropriate name. The satellites are in low Earth orbit at a height of approximately 485 miles, and communication between the satellites is via inter-satellite links. Each satellite contains seven Motorola Power PC 603E processors running at 200 MHz. These machines are used for satellite communication and control.

Iridium routes phone calls through space and there are several Earth stations. As satellites leave the area of an Earth base station, the routing tables change, and

[2] The attitude of Motorola at the time seemed to be similar to that of Henry Ford: i.e. they can have whatever colour they like as long as it is black.

frames are forwarded to the next satellite just coming into view of the Earth base station.

The Iridium constellation is the largest commercial satellite constellation in the world, and it is especially suited for industries such as maritime, aviation, government and the military. Motorola was the prime contractor for Iridium, and it played a key role in its design and development. The satellites were produced at a cost of $5 million each ($40 million each including launch costs), and Motorola engineers were able to make a satellite in a phenomenal time of 2–3 weeks.

The first Iridium call was made by Al Gore in late 1998. However, despite being an engineering triumph, Iridium was a commercial failure, and it went bankrupt in late 1999 due to insufficient demand for its services. It had needed a million subscribers to break even, and as the cost of an Iridium call was very expensive compared to the existing cellular providers, and as the cost of its handsets were much higher and more cumbersome to use than existing mobile phones, there was very little demand for its services.

Specifically, the reasons for failure included:

- Insufficient demand for its services (10,000 subscribers)
- High cost of its service ($5 per minute for a call)
- Cost of its mobile handsets ($3000 per handset)
- Bulky mobile handsets
- Competition from existing mobile phone networks
- Management failures

However, the Iridium satellites remained in orbit, and the service was re-established in 2001 by the newly founded Iridium Satellite LLC. The new business model required just 60,000 subscribers to break even. Today, it has over half a million customers, and it is used extensively by the US Department of Defense.

Iridium was designed in the late 1980s, and so it is designed primarily for voice rather than data. This means that it lacks the sophistication of modern mobile phone networks, and it is not as attractive to users. However, it provides service in remote parts of the world, which is very useful.

13.6 Review Questions

1. Describe the contributions of Bell Labs to mobile technology.
2. What are the advantages of mobile technology over fixed-line technology?
3. Describe the various generations of mobile technology.
4. Describe Motorola's contributions to mobile technology.
5. What factors led to Ericsson's success and leadership in mobile technology?
6. What factors led to the (initial) commercial failure of the Iridium system?

13.7 Summary

The invention of the telephone by Graham Bell in the late nineteenth century was a revolution in human communication, as it allowed people in different geographic locations to communicate instantaneously rather than meeting face to face. The early phones had major limitations, but the development of automated telephone exchanges helped to deal with many of these.

However, the key restriction of the telephone was that the actual physical location of the person to be contacted was needed prior to communication: i.e. communication was between places rather than people.

This led to research by Bell Labs and others into ways in which communication could take place between people (and not places). Bell Labs developed a system in the mid-1940s that allowed mobile users to place and receive calls from automobiles, with Motorola developing the phones for automobiles. However, these phones were large and bulky, and the automobile's engine needed to be running in order to make or receive a call.

Bell Labs proposed the idea of a cellular system back in the late 1940s, and it prepared a detailed plan for the cellular system in the late 1960s. A cellular system is divided into cells, where each cell has its own base station and channels. The available frequencies may be used in parallel in different cells without interference with each other.

Motorola developed the first mobile phone, the DynaTAC, and it made the first mobile phone call in 1973. The first mobile phone systems were analog and based on the AMPS standard. The later generations of mobile technology are digital and are a significant advance on the older cellular technology.

Iridium provides global wireless coverage to its customers including coverage in the oceans, airways and polar regions. It was implemented by a constellation of 66 satellites. For a more detailed account of the contributions of Bell Labs, Ericsson and Motorola, see [Ger:13, MeJ:01, Mot:99, ORe:15].