

Wireless Communications

Text book

**“Wireless Communications: Principles and practice”
2nd edition, Prentice-Hall, By T. S. Rappaport.**

Course Outline

- Chp.1 Introduction to wireless communication systems**
(Evolution of mobile radio, Examples of systems, Comparisons of systems, basic definitions)

- Chp.2 Modern wireless communication systems**
(2G cellular systems, 2.5G systems, 3G, 4G, Wireless Local Area Networks (WLANs), Bluetooth, towards 5G systems)

- Chp.3 The Cellular concept: System design fundamentals**
(frequency reuse concept, Hand off strategies, Interference and system capacity, Trunking and grade of service, Improving coverage and capacity of cellular systems)

Course Outline

- Chp.4 Mobile radio propagation : Large scale path loss**
(free space propagation model, Propagation mechanisms, reflection refraction and scattering, two-ray model, Fresnel zone geometry, Link design using path loss models, practical models (Okumora, Hata models) shadowing, percentage of coverage area)
- Chp.5 Mobile radio propagation: Small scale fading and multipath**
(factors affecting fading, Doppler shift, parameters of mobile multipath channels, , time dispersion, coherence time and bandwidth, types of fading: flat fading, frequency selective fading, fast and slow fading, Rayleigh and Rician distributions of envelope, Clarkes model: spectral shaping due to Doppler spread, level crossing rate and fading statistics)

Course Outline

Chp.6 Digital modulation techniques and spread spectrum systems

Spread spectrum (SS) modulations(Pulse shaping, Digital modulation techniques, factor influencing choice of modulation type, BPSK, DPSK, QPSK, MPSK, QAM, Minimum Shift Keying MSK, GMSK,, performance of digital modulations in slow flat fading channels, Spread spectrum (SS) modulations, performance of SS systems)

Chp.7 Diversity techniques

(Space and antenna diversity, polarization diversity, frequency diversity, time diversity, RAKE receiver in CDMA, Diversity combining techniques, selective combining, maximum ratio combining, equal gain combining, performance of diversity combining techniques)

Chapter 1

Introduction to Wireless Communication Systems

- **Transmitting voice and data using electromagnetic waves in open space**
- **In 1897 Marconi generated the first wireless signals.**
- **In 1946 first mobile phone service was introduced using high-powered TX and large coverage area but serving few users.**
- **Cellular radio concept was developed in early 1960's.**
- **Technology was not available to implement cellular telephony until late 1970's.**
- **The first cellular telephone systems were introduced in early 1980's.**
- **In the past 15 years, huge growth in wireless communication systems market fueled by:**
 - 1- Digital and RF circuit fabrication improvements**
 - 2- Very large scale IC's (DSP's)**
 - 3- miniaturization techniques for portable devices**

The electronics boom

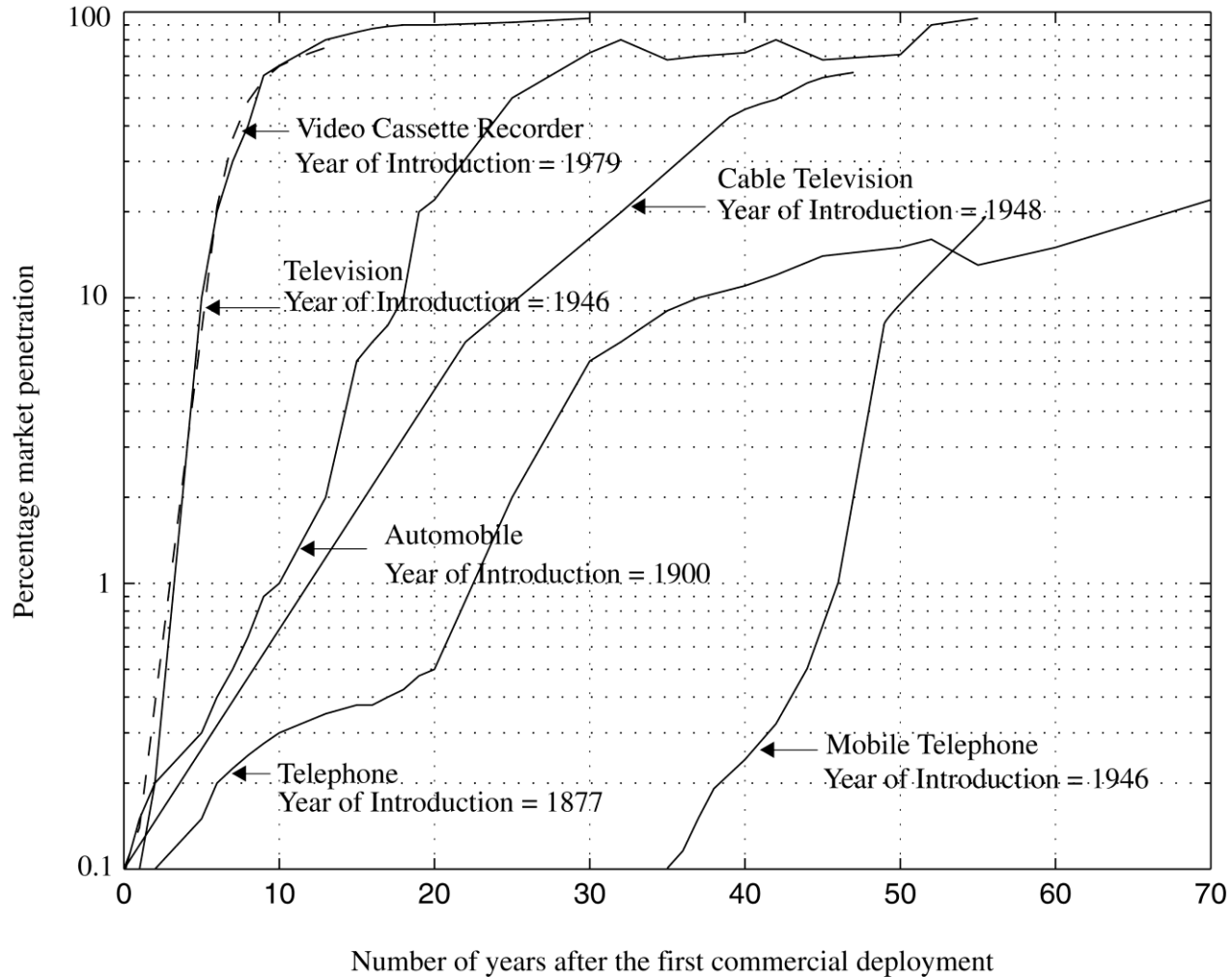


Figure 1.1 The growth of mobile telephony as compared with other popular inventions of the 20th century.

Table 1.1 Major Mobile Radio Standards in North America

| Standard | Type | Year of Introduction | Multiple Access | Frequency Band | Modulation | Channel Bandwidth |
|-----------------------|------------------|----------------------|-----------------|----------------------------|--------------------|-------------------|
| AMPS | Cellular | 1983 | FDMA | 824-894 MHz | FM | 30 kHz |
| NAMPS | Cellular | 1992 | FDMA | 824-894 MHz | FM | 10 kHz |
| USDC | Cellular | 1991 | TDMA | 824-894 MHz | $\pi/4$ -DQPSK | 30 kHz |
| CDPD | Cellular | 1993 | FH/ Packet | 824-894 MHz | GMSK | 30 kHz |
| IS-95 | Cellular/ PCS | 1993 | CDMA | 824-894 MHz 1.8-2.0 GHz | QPSK/ BPSK | 1.25 MHz |
| GSC | Paging | 1970s | Simplex | Several | FSK | 12.5 kHz |
| POCSAG | Paging | 1970s | Simplex | Several | FSK | 12.5 kHz |
| FLEX | Paging | 1993 | Simplex | Several | 4-FSK | 15 kHz |
| DCS-1900 (GSM) | PCS | 1994 | TDMA | 1.85-1.99 GHz | GMSK | 200 kHz |
| PACS | Cordless/ PCS | 1994 | TDMA/ FDMA | 1.85-1.99 GHz | $\pi/4$ - DQPSK | 300 kHz |
| MIRS | SMR/PCS | 1994 | TDMA | Several | 16-QAM | 25 kHz |
| iDen | SMR/PCS | 1995 | TDMA | Several | 16-QAM | 25 kHz |

Table 1.2 Major Mobile Radio Standards in Europe

| Standard | Type | Year of Introduction | Multiple Access | Frequency Band | Modulation | Channel Bandwidth |
|-----------------|------------------|----------------------|-----------------|------------------|------------|-------------------|
| ETACS | Cellular | 1985 | FDMA | 900 MHz | FM | 25 kHz |
| NMT-450 | Cellular | 1981 | FDMA | 450-470 MHz | FM | 25 kHz |
| NMT-900 | Cellular | 1986 | FDMA | 890-960 MHz | FM | 12.5 kHz |
| GSM | Cellular /PCS | 1990 | TDMA | 890-960 MHz | GMSK | 200 kHz |
| C-450 | Cellular | 1985 | FDMA | 450-465 MHz | FM | 20 kHz/ 10 kHz |
| ERMES | Paging | 1993 | FDMA | Several | 4-FSK | 25 kHz |
| CT2 | Cordless | 1989 | FDMA | 864-868 MHz | GFSK | 100 kHz |
| DECT | Cordless | 1993 | TDMA | 1880-1900 MHz | GFSK | 1.728 MHz |
| DCS-1800 | Cordless /PCS | 1993 | TDMA | 1710-1880 MHz | GMSK | 200 kHz |

Table 1.3 Major Mobile Radio Standards in Japan

| Standard | Type | Year of Introduction | Multiple Access | Frequency Band | Modulation | Channel Bandwidth |
|--------------|----------|----------------------|-----------------|----------------|----------------|-------------------|
| JTACS | Cellular | 1988 | FDMA | 860-925 MHz | FM | 25 kHz |
| PDC | Cellular | 1993 | TDMA | 810-1501 MHz | $\pi/4$ -DQPSK | 25 kHz |
| NTT | Cellular | 1979 | FDMA | 400/800 MHz | FM | 25 kHz |
| NTACS | Cellular | 1993 | FDMA | 843-925 MHz | FM | 12.5 kHz |
| NTT | Paging | 1979 | FDMA | 280 MHz | FSK | 12.5 kHz |
| NEC | Paging | 1979 | FDMA | Several | FSK | 10 kHz |
| PHS | Cordless | 1993 | TDMA | 1895-1907 MHz | $\pi/4$ -DQPSK | 300 kHz |

Table 1.4 Wireless Communications System Definitions

| | |
|-------------------------|---|
| Base Station | A fixed station in a mobile radio system used for radio communication with mobile stations. Base stations are located at the center or on the edge of a coverage region and consist of radio channels and transmitter and receiver antennas mounted on a tower. |
| Control Channel | Radio channel used for transmission of call setup, call request, call initiation, and other beacon or control purposes. |
| Forward Channel | Radio channel used for transmission of information from the base station to the mobile. |
| Full Duplex Systems | Communication systems which allow simultaneous two-way communication. Transmission and reception is typically on two different channels (FDD) although new cordless/PCS systems are using TDD. |
| Half Duplex Systems | Communication systems which allow two-way communication by using the same radio channel for both transmission and reception. At any given time, the user can only either transmit or receive information. |
| Handoff | The process of transferring a mobile station from one channel or base station to another. |
| Mobile Station | A station in the cellular radio service intended for use while in motion at unspecified locations. Mobile stations may be hand-held personal units (portables) or installed in vehicles (mobiles). |
| Mobile Switching Center | Switching center which coordinates the routing of calls in a large service area. In a cellular radio system, the MSC connects the cellular base stations and the mobiles to the PSTN. An MSC is also called a mobile telephone switching office (MTSO). |
| Page | A brief message which is broadcast over the entire service area, usually in a simul-cast fashion by many base stations at the same time. |
| Reverse Channel | Radio channel used for transmission of information from the mobile to base station. |
| Roamer | A mobile station which operates in a service area (market) other than that from which service has been subscribed. |
| Simplex Systems | Communication systems which provide only one-way communication. |
| Subscriber | A user who pays subscription charges for using a mobile communications system. |
| Transceiver | A device capable of simultaneously transmitting and receiving radio signals. |

Examples of wireless communication systems

Cordless telephones:

Is a full duplex communication system that connects a portable handset to a dedicated based station.

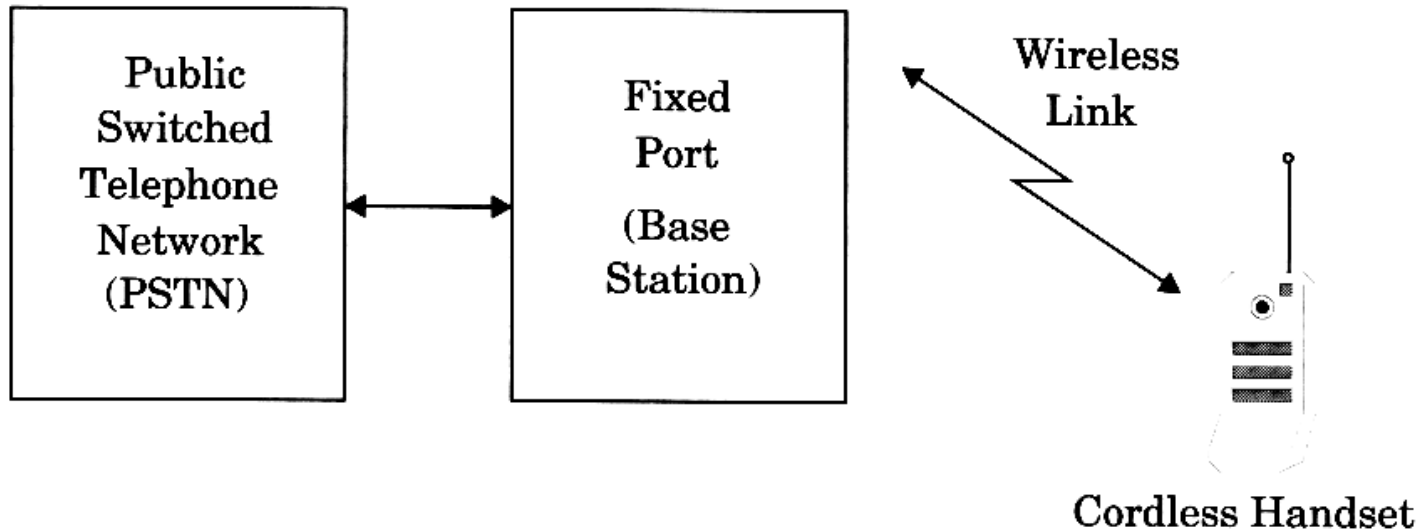


Figure 1.4 A cordless telephone system.

Paging messaging systems

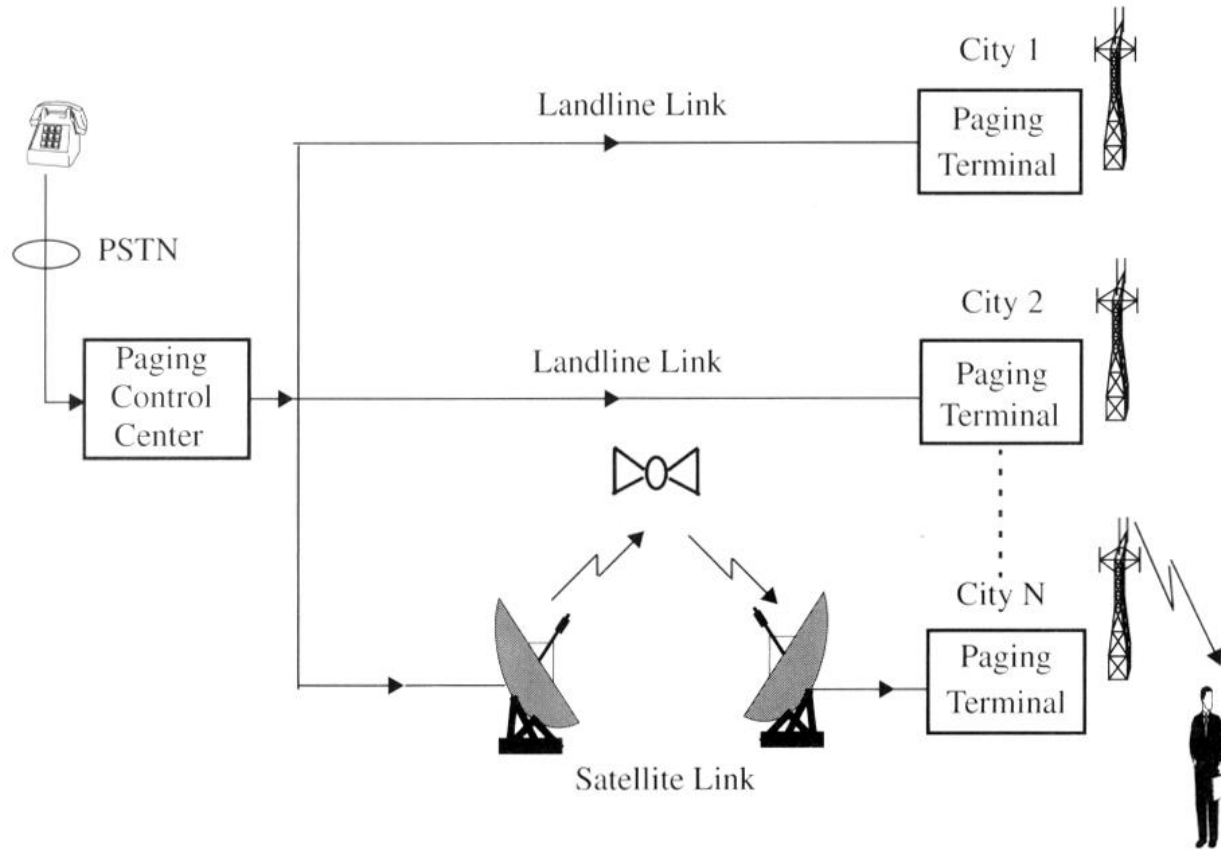


Figure 1.3 A wide area paging system. The paging control center dispatches pages received from the PSTN throughout several cities at the same time.

Cellular Telephone systems

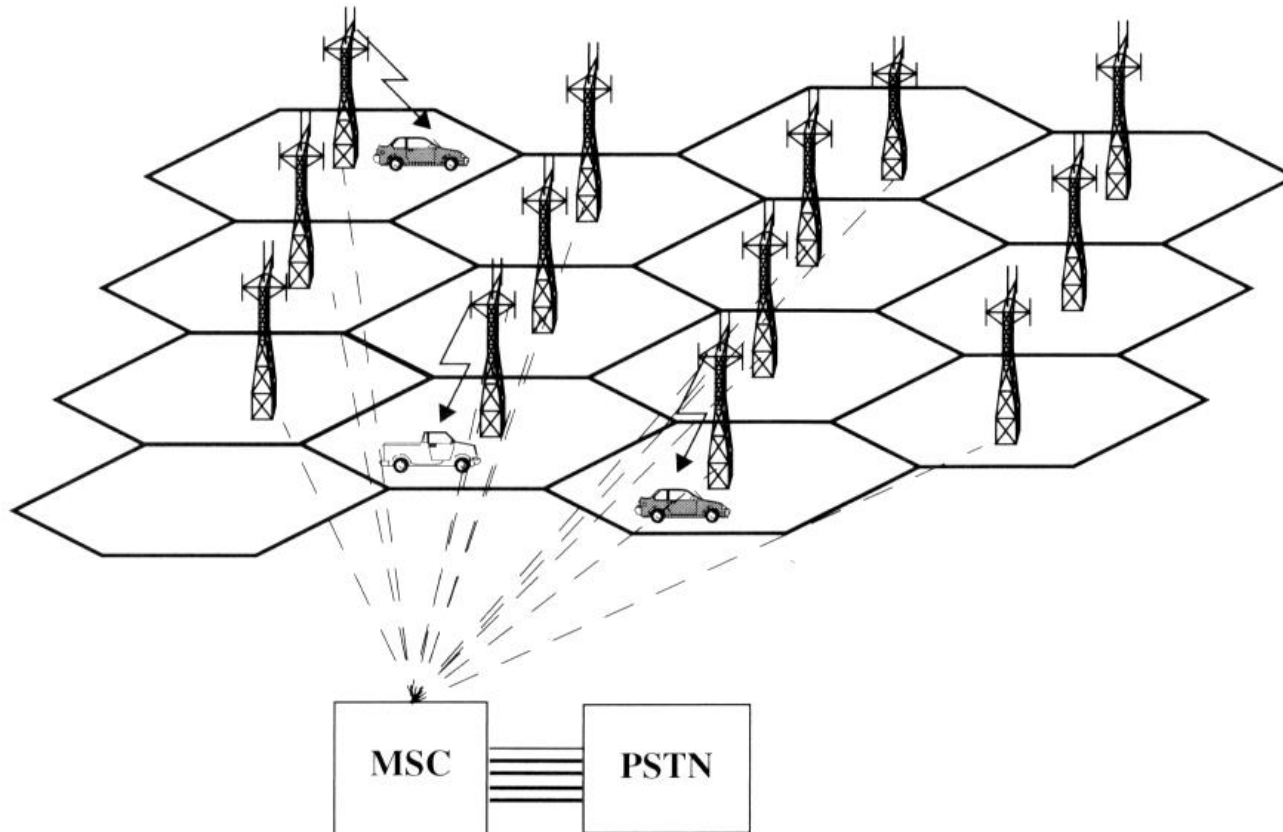


Figure 1.5 A cellular system. The towers represent base stations which provide radio access between mobile users and the mobile switching center (MSC).

| | | | | | | | | |
|--------|--------------|---|---|---|--|--|--|---|
| MSC | | Receives call from PSTN. Sends the requested MIN to all base station. | | | Verifies that the mobile has a valid MIN, ESN pair. | Requests BS to move mobile to unused voice channel pair. | | Connects the mobile with the calling party on the PSTN. |
| | Base Station | FCC | | Transmits page (MIN) for specified user. | | | Transmits data message for mobile to move to specific voice channel. | |
| | | RCC | | | Receives MIN, ESN, Station Class Mark and passes to MSC. | | | |
| | | FVC | | | | | | Begin voice transmission. |
| RVC | | | | | | | Begin voice reception. | |
| Mobile | FCC | | Receives page and matches the MIN with its own MIN. | | | Receives data messages to move to specified voice channel. | | |
| | RCC | | | Acknowledges receipt of MIN and sends ESN and Station Class Mark. | | | | |
| | FVC | | | | | | Begin voice reception. | |
| | RVC | | | | | | Begin voice transmission. | |

time →

Figure 1.6 Timing diagram illustrating how a call to a mobile user initiated by a landline subscriber is established.

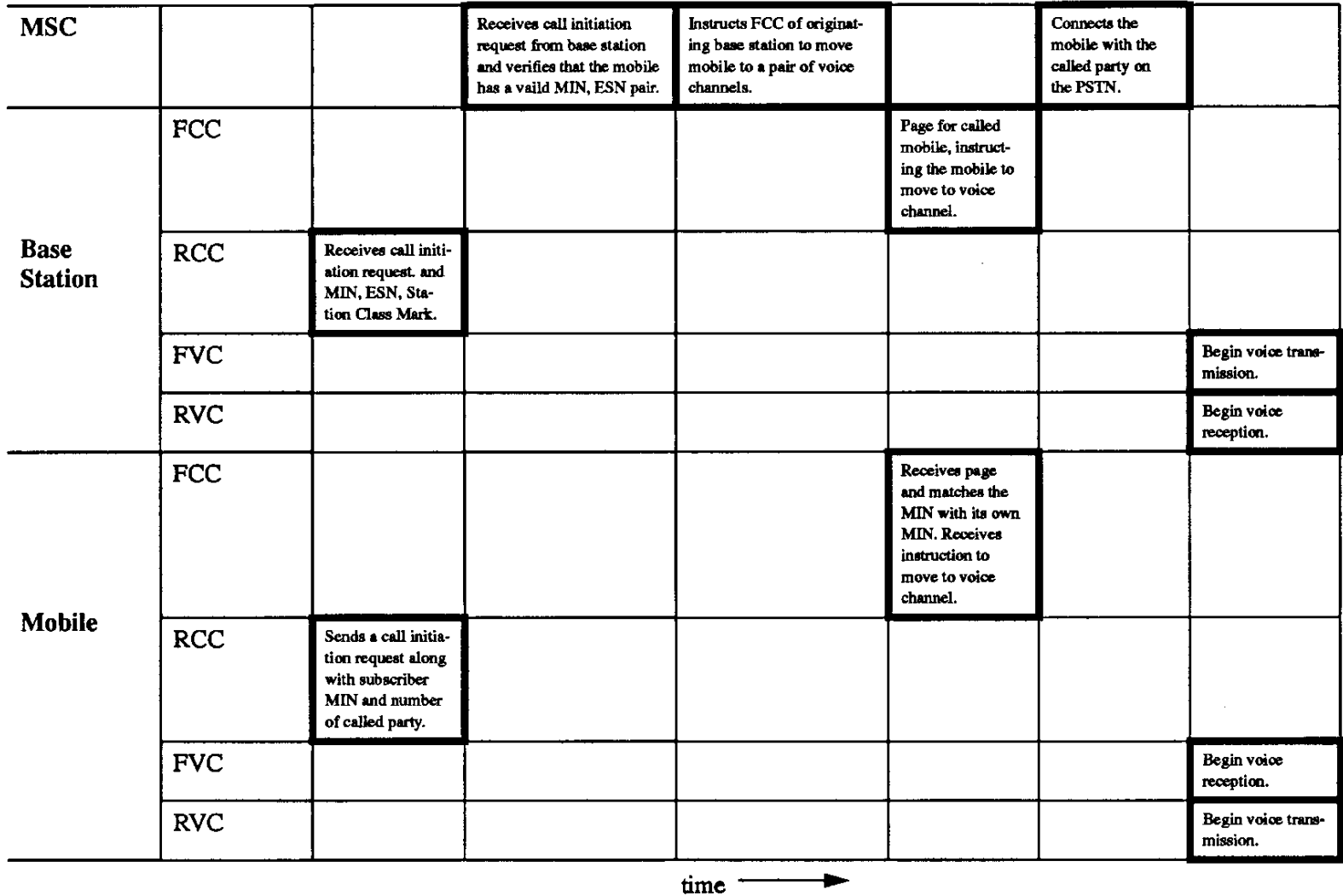


Figure 1.7 Timing diagram illustrating how a call initiated by a mobile is established.

Table 1.5 Comparison of Mobile Communication Systems—Mobile Station

| Service | Coverage Range | Required Infrastructure | Complexity | Hardware Cost | Carrier Frequency | Functionality |
|---------------------------|-----------------------|--------------------------------|-------------------|----------------------|--------------------------|----------------------|
| TV Remote Control | Low | Low | Low | Low | Infrared | Transmitter |
| Garage Door Opener | Low | Low | Low | Low | < 100 MHz | Transmitter |
| Paging System | High | High | Low | Low | < 1 GHz | Receiver |
| Cordless Phone | Low | Low | Moderate | Low | < 1 GHz | Transceiver |
| Cellular Phone | High | High | High | Moderate | < 2 GHz | Transceiver |

Table 1.6 Comparison of Mobile Communication Systems—Base Station

| Service | Coverage Range | Required Infrastructure | Complexity | Hardware Cost | Carrier Frequency | Functionality |
|---------------------------|-----------------------|--------------------------------|-------------------|----------------------|--------------------------|----------------------|
| TV Remote Control | Low | Low | Low | Low | Infrared | Receiver |
| Garage Door Opener | Low | Low | Low | Low | < 100 MHz | Receiver |
| Paging System | High | High | High | High | < 1 GHz | Transmitter |
| Cordless Phone | Low | Low | Low | Moderate | < 1 GHz | Transceiver |
| Cellular Phone | High | High | High | High | < 2 GHz | Transceiver |