3.1 INTRODUCTION

In this chapter we describe transmission technologies, which have been adopted in many of the developing standards and products for wireless networks. In principle these techniques are applicable to all wired and wireless modems because the basic design issues are common to both systems. In general we would like to transmit data with the highest achievable data rate with the minimum expenditure of signal power, channel bandwidth, and transmitter and receiver complexity. In other words we usually want to maximize both bandwidth efficiency and power efficiency and minimize the transmission system complexity. However, the emphasis on these three objectives varies according to the application requirement and medium for transmission, and there are certain details that are specific to particular applications and media of transmission. Also these design objectives are often conflicting and the trade-offs decide what factors are considered more important than others. We start this chapter with a brief description of specific characteristics of the wireless medium that affect the design of transmission techniques. Then we provide a comprehensive overview of applied wireless transmission techniques, followed by a review of coding techniques and a brief description of software implementation of these radios.

3.1.1 Wired Transmission Techniques

In most wired data applications, such as LANs, transmission schemes over TP, coaxial cable, or optical fiber are very simple. The received data from the higher layers are line coded (e.g., Manchester coded on Ethernet) and the voltages (or optical signals) are applied directly to the medium. These transmission techniques are often referred to as baseband transmission schemes. In voice-band modems, DSL, and coaxial cable modem applications, the transmitted signal is modulated over a *carrier.* The amplitude, frequency, phase of the carrier, or a combination of these is used to carry data. These digital modulation schemes are correspondingly called amplitude shift keying (ASK), frequency shift keying (FSK), phase shift keying (PSK), or quadrature amplitude modulation (QAM). In voice-band modems, this carrier is around 1,800 Hz which is the center of the passband of 300–3,300 Hz of the telephone channels. The purpose of modulation here is to eliminate the DC component from the transmission spectrum and to allow the usage of more bandwidth-efficient modulation to support higher data rates over the telephone channel. For DSL services, the spectrum that is utilized is shifted away from the lower frequencies used for voice applications. Discrete multitone transmission, a form of OFDM, is employed there. In cable modems, modulation is employed to shift the spectrum of the signal to a particular frequency channel and to improve the bandwidth efficiency of the channel to support higher data rates. In the data networking industry, cable modems are referred to as broadband modems because they provide a much higher data rate (broader band) than the voice-band modems. High bandwidth efficiency in the voice-band modems has a direct economic advantage to the user, as it can reduce connect time and avoids the necessity for leasing additional circuits to support the application at hand. The typical telephone channel is less hostile than a typical radio channel, providing a fertile environment for examining and employing complex modulation and coding techniques such as QAM and *trellis coded modulation* (TCM) and signal processing algorithms such as equalizers and echo cancellers. Specific impairments seen on telephone channels are amplitude and delay distortion, phase jitter, frequency offset, and effects of nonlinearity. Many of the practical design techniques of wired modems have been developed to efficiently deal with these categories of impairments.

3.1.2 Considerations in the Design of Wireless Modems

Radio channels are characterized by multipath fading and Doppler spread, and a key impediment in the radio environment is the relatively high levels of average signal power needed to overcome fading. However, there are other considerations that impact the selection of a modem technique for a wireless application. For example, in radio systems, bandwidth efficiency is an important consideration, because the radio spectrum is limited, and many operational bands are becoming increasingly crowded. There are a number of considerations that enter into the choice of a modulation technique for use in a wireless application, and here we briefly review the key requirements. These requirements can vary somewhat from one system to another, depending on the type of system, the requirements for delivered services, and the users' equipment constraints.

3.1.2.1 Bandwidth Efficiency

Most wireless networks that support mobile users have a need for bandwidth-efficient modulation, and this requirement steadily grows in importance each year. One of the major incentives of the cellular telephone industry for moving from analog to digital and then from TDMA to CDMA was to increase the bandwidth efficiency and consequently the number of users. A cellular carrier company is assigned a specified amount of licensed bandwidth in which to operate their system, and therefore an increase in system capacity leads directly to increased revenues.