Chapter 5
The Physical Layer Aspects of Wireless Networks

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ABSTRACT

The modern era belongs to wireless communication systems. The cellular networks, which were originally designed for voice services, have now been upgraded to accommodate Internet services. Wi-Fi and Wi-Max systems have been explicitly developed for delivering data services over wireless channels. Just like wired systems, wireless systems also follow the layered architecture for developing or accessing various Internet services; still, there exist significant differences between the technologies used at various layers for the similar purpose. Special design requirements of physical layer due to distinct properties of wireless channel have caused these differences. Low bandwidth supported by the channel, poor equipment capabilities, et cetera, features require special attention in developing various Internet services intended to be accessed by wireless devices. This chapter addresses various aspects of the physical layer of a wireless channel for developing a basic understanding of the problems, existing solutions, and proposals for future networks.

INTRODUCTION

The breakthrough in the physical layer technologies over the last few decades enables portable mobile terminals to achieve very high data rates and avail any kind of Internet based service besides traditional voice services. Increased data rate and anytime anywhere service feature of wireless networks are used by modern society in reframing its existing business and social activities besides creating several new activities. Data rate of wireless networks is still incomparable with wired network technology but the freedom of moving and doing the work simultaneously gives them

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an upper edge. Significant modifications in upper layers of Internet protocol stack has been done for accessing Internet services using wireless devices but without solving the bottlenecks associated with physical layer technologies, it would not have been possible. The evolution of physical layer technologies for wireless systems took more than a century. Over this period many ups and downs have been observed in radio technology. Specifically it underwent a golden age during 1890-1940. It had attracted best engineers for developing new technologies for building efficient and robust wireless communication systems. The popularity of amplitude modulation (AM) based systems, the struggle of Armstrong in establishing superiority of frequency modulation (FM) based systems, Invention of television (TV) etc. are some of the memorable happenings belonging to this golden age (Calhoun, 2003). At the same time several simplex type (one way) and stationary duplex type (two ways) wireless communication systems were deployed for different applications. Development of a mobile duplex communication system was a dream for wireless engineers of that era. Realization and commercialization of this dream took a long time due to two major reasons. First was the transfer of wireless technologies to military during Second World War, thus leaving no technical development was available in commercial domain. Second reason lies in the fundamental limitations of available technologies at that time. Specifically physical layer technologies of that era were not able to overcome the typical characteristic features of the wireless channels. First generation cellular network (1G) was frequency modulation (FM) based analog system which had very poor spectral efficiency and service performance. Deployment of second Generation (2G) cellular network in 1990 brings another golden age for wireless communication which is also known as 'digital radio revolution'. It is still continuing, by getting boosted from the deployment of third generation (3G) and emergence of fourth generation (4G) wireless networks. 2G networks are optimized for voice traffic but perform poorly on data traffic. A new air interface called radio transmission technology (RTT) was defined as 3G - a cellular system which is equally good for both voice as well as data traffic. But the supported data rate is still not sufficient for running some applications. Since wireless LAN technology has been improved to support very high data rates, thus a common platform has been defined where different air interfaces should converge and is now called 4G networks. This chapter addresses the evolution of various physical layer technologies from 1st generation to 4th generation cellular networks. The physical layer of other modern wireless networks has also been covered in this chapter.

Fundamentals of Communication Systems

The channel, transmitter and receiver are the three essential modules of any electrical communication system. If conducting wires or optical fiber cables are used as a channel, then it is called wired communication systems, when space itself is used as channel then it is called wireless communication system. Channel is the most important part of a communication system because it connects source with destination units and governs their design specifications. These units are required for overcoming the undesired effects produced by the channel and achieving efficient communication. The wired channels are engineerable because appropriate manufacturing technology may be used and at least in principle a given set of characteristic features can be easily achieved. On the other hand, wireless channel is known to be nonengineerable because we can't do any modification in characteristic features of the channel itself. Thus all the engineering intelligence should be applied in transceiver designing for getting faithful communication over wireless channel. Higher transmission power requirement due to unguided power spreading, fading and interference due to extreme environment conditions, etc.