universal personal communications

Ramjee Prasad

OFDM for Wireless Communications Systems

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OFDM for Wireless Communications Systems

For a listing of recent titles in the *Artech House Universal Personal Communications Series,* turn to the back of this book.

To my and my wife Jyoti's lovely granddaughters Sneha and Ruchika, whose innocent, smiling faces keep us energetic

Preface

सहजं कर्म कौन्तेय सदोषमपि न त्यजेत् ।
सर्वारम्भा हि दोषेण धूमेनाग्निरिवावृताः ॥

saha-jaṁ karma kaunteya
sa-doṣam api na tyajet
sarvārambhā hi doṣeṇa
dhūmenāgnir ivāvṛtāḥ

Every endeavor is covered by some fault, just as fire is covered by smoke. Therefore one should not give up the work born of his nature, even if such work is full of fault.

—*The Bhagvad-Gita* (18.48)

My wireless (mobile) garden is full of flowers with varieties of flavors, for example, CDMA, OFDM, and so forth.

Last year I realized my "OFDM flower" has become a "paragon" with the successful completion of the work of of several masters, doctoral, and postdoctoral candidates, for example Mohindar Jankiraman, Dusan Matic, Klaus Witrisal, Uma Jha, Richard van Nee, Shinsuke Hara, Hiroshi Harada, and so on. Therefore, I decided to put together in one place their interesting and valuable contributions, particularly of those of Klaus, Jankiraman, Uma, and Richard.

Although I coauthored *OFDM for Wireless Multimedia Communications* with Richard and *Multicarrier Techniques for 4G Mobile Communications* with Shinsuke, this book is very different in that it presents an overview of the wireless local area network (WLAN), wireless personal area network (WPAN), frequency-domain channel model, a novel hybrid OFDM concept, and a practical OFDM system.

Figure P.1 illustrates the coverage of this book. This book illustrates the role of OFDM in developing an adaptive system by designing OFDM-based wireless wide area networks (WWANs), WLANs, and WPANs. It is based on the contributions of several researchers who had or have been actively involved in growing the OFDM flower in the wireless (mobile) garden under my gardenership.

As a gardener, I have tried my best to provide enough water and energy to nurture the OFDM flower up until this point. In the future, it will sow several other interesting colors, which I will bring to you at that time.

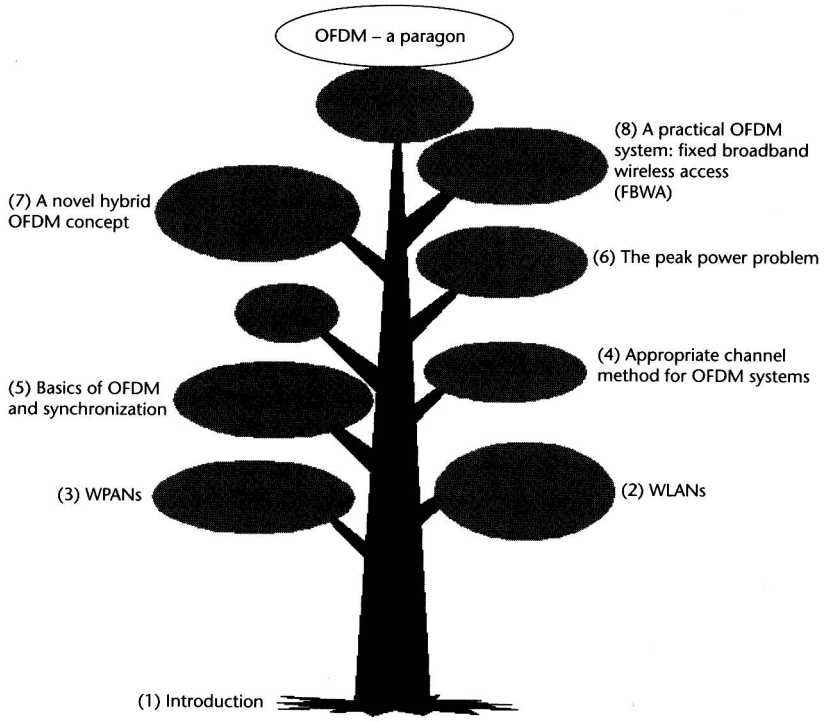

Figure P.1 Coverage of this book.

I would greatly appreciate it if readers would provide extra water and energy in improving the quality by pointing out any errors. I strongly believe nothing is errorless.

Acknowledgments

I would like to express my heartfelt gratitude to colleagues and students without whom this book would have never been completed, namely, Mohindar, Dusan, Klaus, Uma, Richard, Petar, Hiro, Carl, Liljana, Shinsuke, Hiroshi, and Anand.

Junko gave her support in preparing the typescript of the book.

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CHAPTER 1

Introduction

"It is dangerous to put limits on wireless data rates, considering economic constraints," I said in 1999. Data rates are really what broadband is about. Broadband wireless communications will support applications up to 1 Gbps and will probably operate in the 60-GHz frequency [1–5]. However, many people argue whether there is a need for such high-capacity systems, bearing in mind all of the compression algorithms developed and the types of applications that require tens of megabits per second. One can look at this issue from another perspective. There is a need for high-capacity systems to give a perspective of what should be the "hot topics" in the area of telecommunications for research. In this visionary perspective of the road to follow, in order to go along with the needs of society in the year to come as far as communications is concerned, capacity is one of the major issues to be developed due to the foreseen increase in demand for new services (especially those based on multimedia). Together with this, personal mobility will impose new challenges to the development of new personal and mobile communications systems.

A conclusion can be drawn from this: Even if at a certain point it may look "academic" to develop a system for a capacity much higher than what seems reasonable (in the sense that there are no applications requiring such high capacity), it is worthwhile to do it since almost certainly in the future (which may not be very far off) applications will come out that need a capacity of even more than 1 Gbps. The story of fiber optics is elucidative on that. Rapid development will shrink the world into a global information multimedia communication village (GIMCV) by 2020. Figure 1.1 illustrates the basic concept of a GIMCV, which consists of version components of different scales ranging from global to picocelluar in size. Figure 1.2 shows a family tree of the GIMCV system [6–21].

1.1 Wireless Technology in the Future

Today, basically five wireless technologies have made an impact, namely, wireless global area networks (WGANs), wireless wide area networks (WWANs), wireless local area networks (WLANs), wireless personal area networks (WPANs), and wireless broadband–personal area networks (WB-PANs), as illustrated in Figure 1.3.

These five technologies will not compete with, but will complement, each other.

Another set of technologies is fixed wireless access (FWA) or broadband wireless access (BWA). Current standardization trends show that the FWA technologies will get mobility functionalities; if this happens, then FWA could become a threat to

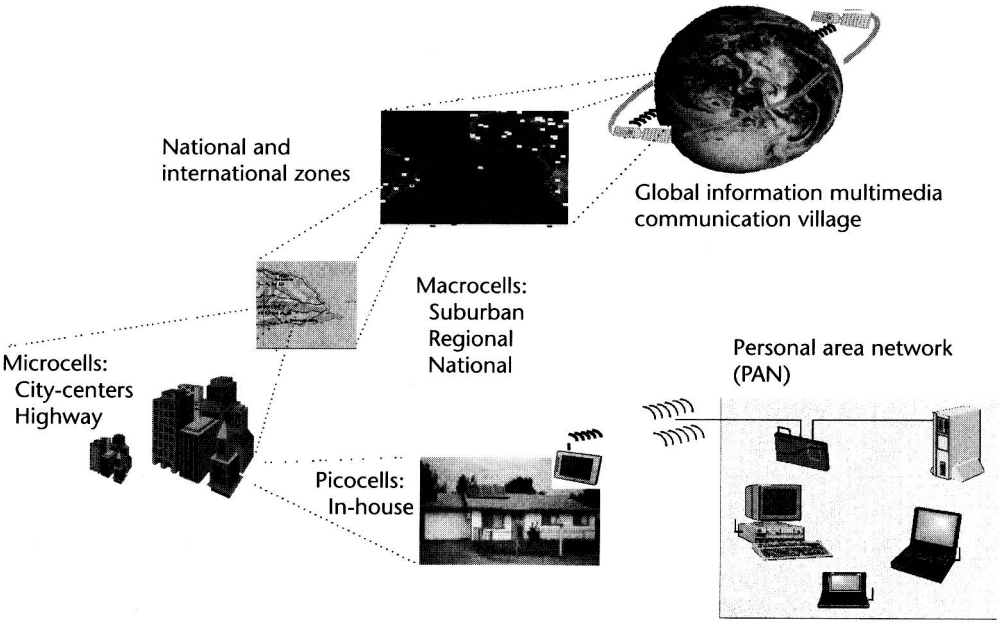

Figure 1.1 GIMCV.

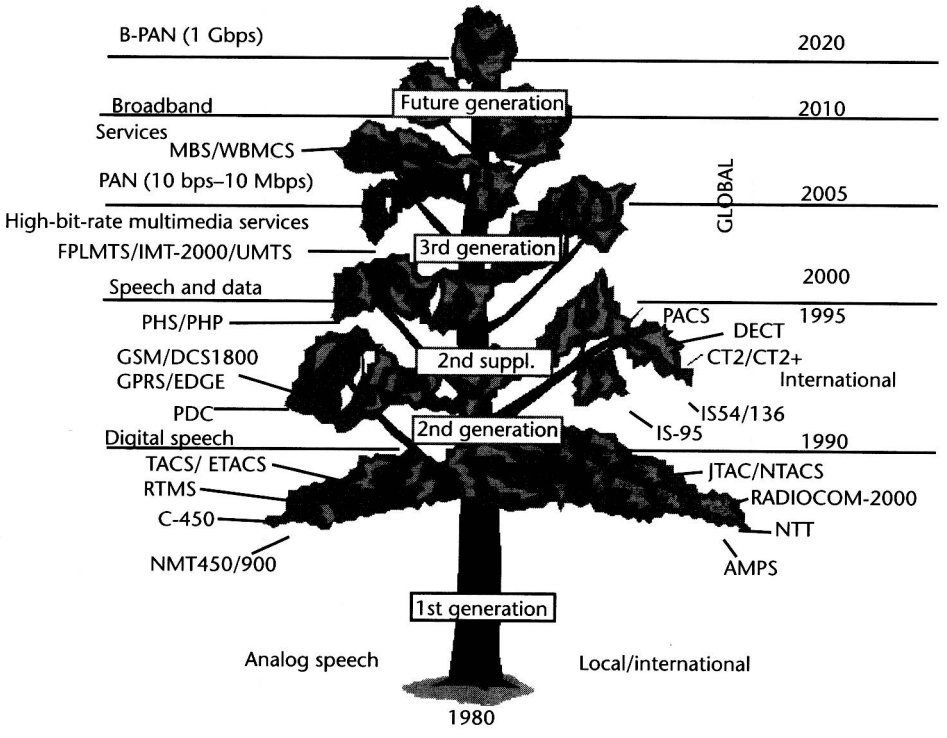

Figure 1.2 Family tree of the GIMCV. Branches and leaves of the GIMCV family tree are not shown in chronological order.

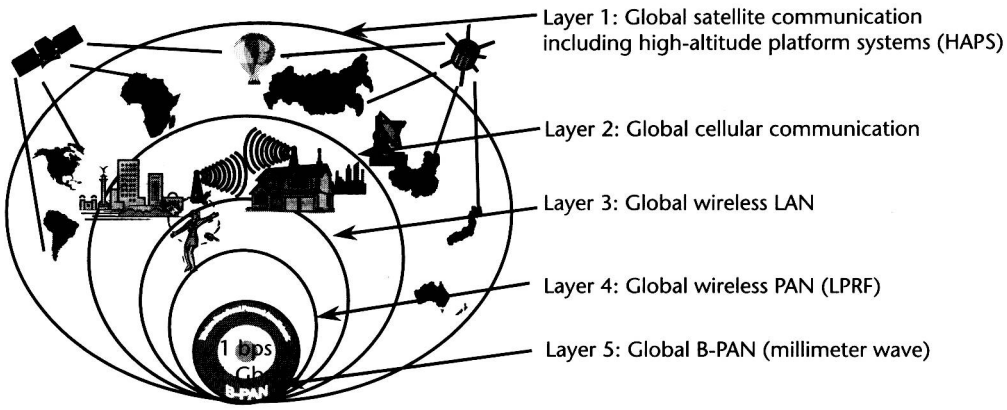

Figure 1.3 Five-layer wireless communications provide mobile everywhere and complement each other.

WWANs. Development of 802.20, a mobile BWA (MBWA), could surely become a threat for WWANs in the future. In the following the future direction of WLANs, WWANs and WPANs is presented; Table 1.1 presents an overview of wireless technology standards. Figure 1.4 shows the partitioning among WWAN, WLAN, and WPAN.

1.1.1 WWANs

Growth in the WWAN field, more commonly known as mobile communications, has been tremendous over the past decade. Second generation (2G), 2.5G, and third generation (3G) standards of mobile systems are being used, while efforts are ongoing toward development and standardization of beyond 3G (B3G) systems. The existing 2G systems are mainly for voice purposes. Due to the tremendous growth of the Internet, some support for data services like Wireless Application Protocol (WAP) and I-mode have been developed [22, 23]. Further, 2G supplement systems, 2.5G,

Table 1.1 Wireless Technologies

Cellular Technology	*WLAN*	*WPAN*	*Cordless Technology*	*FWA/BWA*
GSM-HCSD, GPRS, EDGE-(WAP)	IEEE 802.11	IEEE 802.15	PHS	IEEE 802.16, IEEE 802.20 (MBWA)
IS-95	HIPERLAN/2	Bluetooth	DECT	HIPERACCESS
IS-54/IS-136	MMAC Ethernet WG and ATM WG (HiSWAN)	HIPERPAN	CT2/CT2+	High-speed wireless access
PDC (I-mode)	MBS			BWIF
3G	MMAC wireless homelink			LMDS
				MMDS