CHAPTER 1

INTRODUCTION

1.1 GROWTH OF WIRELESS COMMUNICATION

There has been tremendous growth in the field of wireless communication over the past two decades, both in establishing the wireless telecommunications market and in the enhancements made in digital communications technology. This has been backed up by the ongoing development of digital baseband technology that allows a significant amount of signal processing power to be fitted in a small portable device. Evolution of standards from 2G to 4G (Erik Dahlman et al 2007), combined with the progress in device technology and newly developed ideas in signal processing, have all helped improve the efficiency and capacity of cellular networks. This leads to the introduction of a wide variety of mobile services to the end user. Figure 1.1 shows the technological evolution of Wireless Communication.

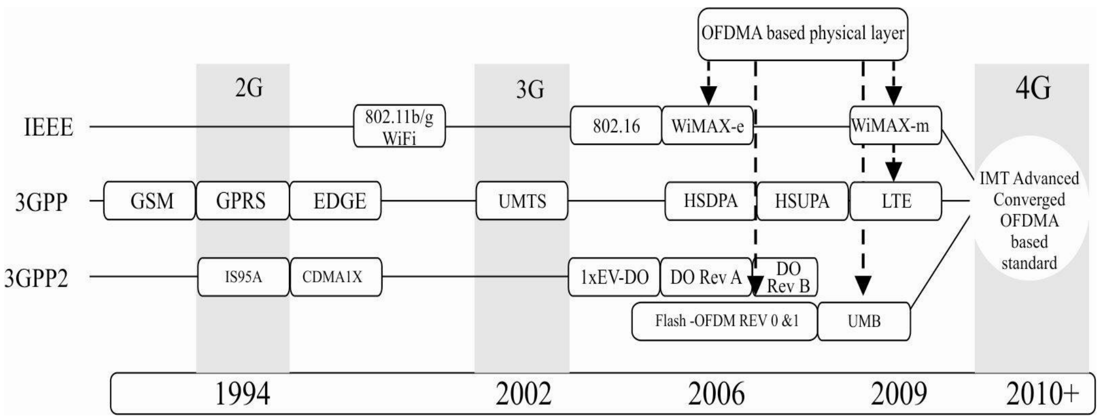

Figure 1.1 Evolution of wireless communication technology

Existing Code Division Multiple Access (CDMA) based 3G cellular technologies are CDMA 2000, 1X Evolution-Data Optimized (1X/EV-DO), Wide-band CDMA (WCDMA), High Speed Packet Access (HSPA) and Time Division-Spatial Division Multiple Access (TD-SCDMA). Since their inception into the market, they have evolved to deliver higher capacities, throughputs and efficiencies according to the growing demand for increased bandwidth-intensive data services. In narrow bandwidth allocations (up to 5 MHz), Rev.A and Rev.B, HSPA and HSPA+ can achieve the highest data throughputs possible in a given amount of spectrum. With wider radio channels (more than 10 MHz), OFDM-based technologies such as Long Term Evolution (LTE) and Mobile Worldwide Interoperability for Microwave Access (WiMAX) have emerged as viable options (Mustafa Ergen 2009) to deliver high data rate mobile broadband services.

Both 3G CDMA and OFDM-based technologies provide the spectral efficiencies, network capacities and latencies necessary to support mobile television and rich broadband services for the immediate future and is still evolving. Yet, depending upon the market scenario they can either complement or compete against each other. Each technology has its own technical merits. As there is no single network technology that is a perfect fit for all user situations, services and environments, Intellectual property Multimedia Subsystem (IMS) will enable operators to interconnect their various wireless and fixed network systems to improve the delivery and economics of convergent services. The following sections provide examples for illustration.

1.2 CONVERGENCE IN COMMUNICATION

1.2.1 The Convergence of Networks

In addition to 3G networks, in most developed countries there is an abundance of Wireless Fidelity (Wi-Fi) access points in residential homes, coffee shops, campuses and enterprises. In all instances, Wi-Fi is used to provide a short range wireless extension of a broadband wireline connection, such as xDSL, to a small group of people who are within range of the signal. There is also a growing availability of wide area broadcast networks dedicated to the delivery of television, rich multimedia multicasting and datacasting services to mobile devices (Gour Karmakar and Laurence 2008). A large number of 3G CDMA operators are using OFDM-based Wi-Fi and forward link only broadcast networks such as Digital Video Broadcast-Handheld (DVB-H), Terrestrial-Digital Multimedia Broadcast (T-DMB), and Integrated Services Digital Broadcasting-Terrestrial television (ISDB-T) to complement their existing portfolio of services, provide extra broadband capacity and offload traffic from their wide area networks in home, campus and office environments. This allows 3G operators to leverage their existing mobile communications networks to become ubiquitous Internet Service Providers (ISPs) and broadcasters.

1.2.2 The Convergence of Services

The introduction of a wide selection of services defines the competitiveness of a service provider (Tony Wakefield et al 2007). A single operator's ability to deliver voice, video, broadband Internet access, location based services and a plethora of mobile data services maximizes their revenue opportunity across a diverse subscriber base (where each user has unique needs) and leverages existing capital expenditures. These services are used to supplement and extend services across multiple industries including entertainment, education, transportation, banking, advertising, broadcasting and information technology. Even for a casual industry follower, it is evident that no single telecommunications delivery mechanism is currently capable of fulfilling all these multi-varied requirements. Instead, operators typically use IMS implementation to provide subscribers with a seamless user experience by assigning the most appropriate access technology among 3G WCDMA, Bluetooth, 802.11, Near Field Communication (NFC), OFDM, etc. to deliver the requested service.

Due to its huge economies of scale, cost advantage is exemplified by the availability of affordable 3G CDMA handsets. 3G CDMA will retain a significant cost advantage for the time being over OFDM-based technologies when it comes to delivering mobile telephone and broadband services. While CDMA-based technologies offer compelling performance and economic advantages that will support service providers well into the next decade, there are situations and applications where OFDM-based technologies may be more attractive to operators. Figure 1.2 shows the bandwidth allocation for CDMA and OFDM based technologies.

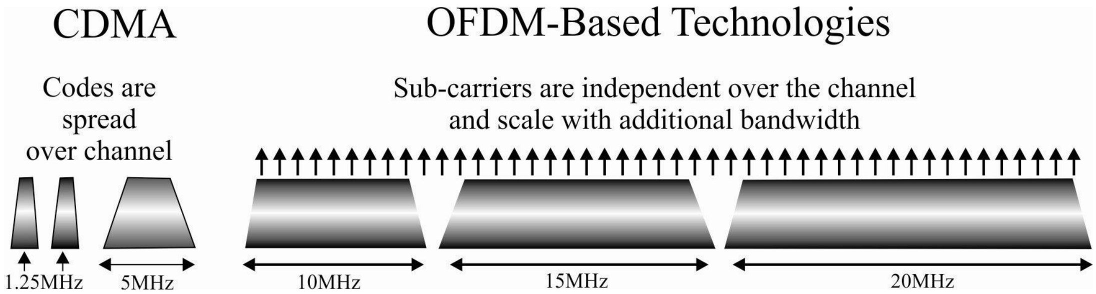

Figure 1.2 Bandwidth allocation for CDMA and OFDM based technologies

For service providers with existing or a limited amount of spectrum, CDMA-based technologies are the best option since they are more spectrally efficient in bandwidths up to 5 MHz. For a service provider to provide a service that has access to a large amount of bandwidth (e.g., more than 10 MHz of spectrum), OFDM-based technologies are a suitable option to introduce new bandwidth-intensive broadband services. Existing 2G or 3G solutions with additional broadband capacity is suitable in densely-populated metro-zones, also referred to as "hot-zones." This is because wider radio channels support higher data throughputs in capacity constrained areas such as busy or dense data traffic areas. For larger bandwidths, greater than 2 x 5MHz Frequency Division Duplex (FDD) or 10MHz Time Division Duplex (TDD), OFDM-based technologies offer a simpler implementation than CDMA technologies. Outside of high traffic metro areas, OFDM-based systems may not be economical since the spectrum and network will most likely remain under utilized, this can be overcome by making the cell sizes larger in such a way that the number of subscribers in each cell remains the same irrespective of their sizes. When new OFDM based technologies like LTE and WiMAX are deployed, it may take many years to provide service in every geographical area without any coverage holes.

IMS can be used to combine the economic advantages of the ubiquitous 3G network with a complementary wider-bandwidth OFDM broadband network in high-traffic areas or "hot-zones" within the network. In this overlay scenario, an operator would retain the 3G network for wide area broadband coverage while the consumer will need to own a dual-mode (CDMA + OFDM) handheld device to access the higher bandwidth broadband services inside and outside of the OFDM coverage zones.

Fixed, line-of-sight, OFDM-based technologies such as IEEE 802.16 d based WiMAX are also well-suited to provide backhaul connectivity to 2G/3G mobile broadband networks. Several CDMA2000 networks use WiMAX (IEEE 802.16d) for their backhaul. To some extent, the relationship between 2G/3G and mobile OFDM networks is very similar to the relationship between 2G/3G and Wi-Fi. Just as Wi-Fi complements 3G, mobile OFDM technologies will complement the services, features and network capacity provided by 3G. The role and deployment of OFDM systems will be ultimately determined by the business case, which in turn will depend on the availability of revenue-generating applications, affordable devices, the market demand for bandwidth-intensive applications and the economic benefits they offer to the operator. The industry is yet to develop a clear business model for these services, and as the experience with 3G demonstrates that it will take time for a sustainable business model to evolve. Thus, the mass market adoption time of OFDM-based solutions in providing broad-band services is uncertain. OFDM-based solutions are in the initial stages and cost effective solutions will be built-out over time as the demand for high-capacity broadband services grows and wider bandwidth spectrum becomes available. Meanwhile, 3G CDMA solutions will coexist with these higher-bandwidth OFDM based solutions until OFDM-based technologies are fully capable of delivering an equivalent or better value proposition to the end user, including ubiquitous coverage, compelling broadband services, carrier-grade Voice over Internet Protocol (VoIP) replacing circuit-switched voice services, affordable devices, global roaming and an improved profitability for operators. It is expected that CDMA and OFDM-based solutions will coexist in the future networks.

1.2.3 Device Convergence

As more capabilities and features are introduced into handheld devices, Moore's Law is enabling more wireless technologies to be incorporated within them. Presently, these wireless technologies include Interim Standard-95 (IS-95), Global System for Mobile communications (GSM), General Packet Radio Services (GPRS), Enhanced Data rate for Global Evolution (EDGE), CDMA2000 1X, WCDMA, CDMA2000 1xEV-DO and HSPA for wide area network access, Wi-Fi for the local area network, GPS for location-based services, NFC for mobile commerce, and Bluetooth for personal area network connectivity. Mobile WiMAX and LTE are expected to be available in the near future mobile devices.

As consumers become accustomed to the presence of multiple access technologies, they will expect their handheld device to support the technologies that they use the most wherever they go. Carrying a separate device for each access technology is not the preferred option. 3G CDMA handsets that support multiple radio technologies already exist. In the coming years, CDMA2000 devices will include support for WCDMA/HSPA, WiMAX and LTE. Bluetooth is becoming very common due to consumer interest in wireless headsets and various government regulations which strictly limit holding a cell phone while driving. NFC-enabled handsets are being used for transportation and mobile commerce solutions. Likewise, Wi-Fi is integrated into a number of CDMA handsets to provide high-speed access to the Internet/VPN in the home, campus or office that has a high bandwidth wireless communication

1.3 4G MOBILE COMMUNICATION

The 4G network is expected to serve mobile subscribers under dynamic network conditions and offer any-type service, such as anytime, anywhere and anyhow, in a seamless manner. Users carrying an integrated open terminal can use a wide range of applications provided by multiple wireless networks and access to various air interface technologies. The continuous evolution of wireless networks and the emerging variety of different heterogeneous, wireless network platforms with different properties require integration into a single platform. The handoff mechanism allows a network connection on a mobile node to operate over multiple wireless access networks in a way that is completely transparent to end user. But there is no single system that is good enough to support all the wireless communication technologies. Instead of putting efforts in developing new radio interface standards and technologies for 4G systems, establishing 4G systems that integrate existing and newly developed wireless systems into one open platform is the more feasible option.

This thesis paves the path towards 4G mobile communications by introducing mobility in heterogeneous IP networks with both 3G cellular systems and WLANs, which is seen as one of the central issues of 4G telecommunications networks and systems. So the goal of future mobile communication systems is to incorporate and integrate different wireless access technologies and mobile network architectures in a complementary manner so as to achieve a seamless wireless access infrastructure.

1.4 DIGITAL SYSTEM REALIZATION

Digital Signal Processing systems for implementing multistandard communication can be realized using programmable processors or custom designed hardware circuits fabricated using Very Large Scale Integrated (VLSI) circuit technology. The goal of this digital system design is to maximize performance while keeping the cost low. In the context of digital system design, performance is measured in terms of the amount of hardware circuitry, resources required, the speed of execution and the amount of power dissipation or the total energy required to perform a given task.

1.5 DESIGN CHALLENGES

This multistandard functionality imposes several challenges for network and mobile terminal implementations. The main challenge is to provide seamless user mobility between networks with same/different air interface standards. So users have to be equipped with mobile handsets that can inter-work with multiple wireless technologies. Designing various architectures for each of the multiple standards in the same mobile equipment would result in an intolerable increase in physical size, weight, and power consumption. Therefore area and power consumption become another two challenges in the design of multistandard mobile equipments. The continuous evolution of wireless standards forces manufacturers to release new products at shorter time and with lower prices. So developing low price devices at shorter time is another design challenge.

To support this seamless user mobility across different wireless access technologies, it is important to design reconfigurable multistandard receiver architectures which meet the above design challenges. The idea of the reconfigurable architecture is that it should be possible to alter the functionality of a mobile device at run-time by simply reusing the same hardware for different wireless technologies and ultimately for users to connect to any system that happens to be available at any given time and place. This means that the same hardware should be able to handle many different modulation types as well as different demands on data rate and mobility.

The need to support several standards in the same handheld device, associated with the power consumption and area restrictions, created the necessity to develop a portable, power efficient, integrated solution. Two such technologies that can respond to the above said services discussed in this thesis are WCDMA and OFDM based WiFi.

1.6 THESIS OBJECTIVES AND CONTRIBUTIONS

The main contribution of this thesis is to present the system-level design of the baseband architecture of a wireless receiver for WCDMA technology and OFDM based WiFi standard. An efficient implementation of FFT algorithm for WiFi and RAKE receiver design for WCDMA are proposed and these two algorithms are tested separately. The common resources for both FFT and RAKE receiver implementation are identified and a new resource sharing reconfigurable architecture is also proposed. This architecture efficiently shares the resources needed for these two standards while reconfiguring. Then a dedicated hardware module that can reconfigure itself either to WiFi or WCDMA standard on demand is designed. The simulation results show that the proposed architecture efficiently shares the resources needed for implementing these two standards, and there is a significant reduction in the number of computational resources. The proposed implementation requires fewer FPGA resources, and therefore not only reduces area, but also reduces the total power consumption.

1.7 THESIS ORGANIZATION

The organization of the thesis is as follows:

Chapter 1 briefs about the evolution of wireless communication technology, the need of reconfigurable architecture for the multistandard wireless communication system, design challenges for implementing the system and then the objectives of this thesis.

Chapter 2 discusses the related works in this area. Numerous system architectures, which proposed various ways of organizing and interfacing configurable logic, are discussed in this chapter.

Chapter 3 first briefly explains the motivation of reconfigurable architecture. This chapter then goes on describing the design of the proposed reconfigurable architecture to implement WCDMA and OFDM based WiFi standard.

Chapter 4 is devoted to present digital baseband processing of WCDMA and OFDM based WiFi standards. The RAKE Receiver is the key component of WCDMA receivers. In OFDM demodulation is performed by applying N-tap Discrete Fourier Transform (DFT) to the samples within a symbol window. Typically the FFT algorithm is used to compute of the DFT efficiently. This chapter discusses efficient design techniques exploiting multiplier-less technique for implementing the RAKE receiver and algorithmic strength reduction transformation technique for implementing the FFT algorithms on the proposed architecture.

Chapter 5 presents the overall architecture of the work. In this chapter, a resource sharing technique to share the computational resources among the RAKE receiver and the FFT algorithm is explained. A framework of mapping applications on this reconfigurable architecture is also discussed in this chapter.

Chapter 6 discusses the results and observations obtained from this work.

Chapter 7 gives the conclusions on this work and presents possible future scope.