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editors

Advances in 3G Enhanced Technologies for Wireless Communications

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Preface

The Fourth IEEE Workshop on Emerging Technologies in Circuits and Systems—Third Generation (3G) Mobile Technologies and Applications was held from November 29 to December 1, 2000, in Hong Kong. It was a very successful workshop with more than 100 participants attending, mainly from industry. Speakers who are working on the development of 3G products in industry were invited. Their presentations, such as WCDMA, EDGE, CDMA2000, wireless Internet, and software radio, were comprehensive and covered different aspects of this important emerging technology. To benefit a larger group of people, we managed to persuade some of the presenters to take time from their busy schedules to write up their presentations. Their efforts enabled us to compile this informative book, which we consider most suitable for both research engineers and postgraduate students.

This book contains seven chapters. In Chapter 1, Dr. Mamoru Sawahashi of NTT DoCoMo comprehensively describes features of the WCDMA air-interface and the essential WCDMA technologies associated with its performance. The chapter describes physical channel and spreading code assignment, transport channel multiplexing (including rate matching), synchronization techniques focusing on the radio interface synchronization, SIR measurement-based fast transmitting power control, and diversity techniques (including rake-time diversity, intercell diversity, and transmitting diversity) in the forward link. Moreover, adaptive antenna array processing, which can further improve system capacity, is also presented.

In Chapter 2, Dr. Hiroshi Furukawa of NEC discusses in detail downlink power control and enhancement of downlink performance. Two proposals to enhance downlink performance are presented: optimum allocation of downlink orthogonal code and site selection diversity transmission power control.

In Chapter 3, Benoist Sébire, Janne Parantainen, and Guillaume Sébire of Nokia provide an overview of GERAN with a focus on release 5 and harmonization with UTRAN. The chapter covers different aspects of GERAN, including 3G services, the GERAN reference architecture, and protocol architectures. Emphasis is placed on the radio protocols that constitute the main change from GSM/EDGE to the Iu-capable GERAN.

In Chapter 4, Dr. Qiang Wu and Dr. Eduardo Esteves of Qualcomm describe the technical details of the CDMA2000 high-rate packet data system, including hybrid ARQ, turbo coding, scheduling, adaptive modulation, and performance simulations.

In Chapter 5, Dr. Vincent Lau of Lucent Technologies analyzes the peak-to-average ratio of a CDMA signal, which determines the backoff factor of a power amplifier allowing for reductions in the clipping of input signals and hence spectral regrowth.

In Chapter 6, Haseeb Akhtar, Dr. Emad Abdel-Lateef Qaddoura, Dr. Abdel-Ghani Daraiseh, and Russ Coffin of Nortel Networks discuss the wireless Internet. This chapter describes the framework of IP mobility, which enables users to gain access to the Web while roaming freely. The framework is designed to extend the mobility management (with centralized directory management), end-to-end security, device independence, and application independence that allow users to use Internet applications on any device and any network.

Finally, in Chapter 7, Yik-Chung Wu, Professor Tung-Sang Ng, and Dr. Kun-Wah Yip of the University of Hong Kong discuss the software radio, which is a promising technique for implementing 3G and future mobile systems incorporating multiple standards. This chapter covers fundamental issues in software radio such as bandpass sampling, decimation filtering, and fractional sampling-rate conversion.

Acknowledgments

We appreciate all authors for providing these important contributions. They spent much time preparing their chapters in addition to their normal busy schedules. The editors also would also like to thank Yik-Chung Wu of the University of Hong Kong for his help in formatting the final manuscripts.

Jiangzhou Wang and Tung-Sang Ng
Hong Kong
February 2002

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WCDMA Enhanced Technologies

Mamoru Sawahashi

After the global-level standardization in the Third Generation Partnership Project (3GPP) and development with enthusiastic efforts of *wideband code-division multiple access* (WCDMA) [1, 2] the commercial service was launched in October 2001 in Japan. Along with the start of IMT-2000 commercial service, the dawn of the genuine era of wireless Internet is upon us. *Direct-sequence CDMA* (DS-CDMA) wireless access, on which WCDMA is based, has numerous advantages over *time-division multiple access* (TDMA) or *frequency-division multiple access* (FDMA) including single-frequency reuse, soft handoff (or site diversity), enhanced radio transmission through RAKE combining, and direct capacity increase through sectored antennas.

A list of the key features of the WCDMA physical layer follows:

- Intercell asynchronous operation and three-step fast cell search;
- Flexible realization of various levels of *quality of service* (QoS) for various transport channels by rate matching associated with channel coding;
- *Signal-to-interference power ratio* (SIR)–based fast *transmission power control* (TPC) to satisfy the required quality level for a physical channel with minimum transmission power;
- Significant gains in link capacity and coverage through the use of many diversity techniques, such as coherent RAKE time diversity using pilot symbol-assisted channel estimation, space diversity,

intercell (sector) diversity, and transmit diversity (only in the forward link);

- A high level of flexibility in offering different multirate services (up to 2 Mbps) through orthogonal variable spreading factor multiplexing and orthogonal multicode transmission;
- Capacity enhanced techniques such as interference cancellation and adaptive antenna array diversity.

This chapter comprehensively describes features of the WCDMA air-interface and the essential WCDMA technologies associated with its performance. This chapter is organized as follows. Section 1.1 explains the physical channel and spreading code assignment. Then, transport channel multiplexing including rate matching is described in Section 1.2. After synchronization techniques focusing on radio interface synchronization are explained in Section 1.3, SIR measurement-based fast TPC is described in Section 1.4. Section 1.5 discusses the various diversity techniques, including RAKE time diversity, intercell (sector) diversity, and transmit diversity in the forward link. Finally, the adaptive antenna array processing technique, which further improves system capacity, is presented.

1.1 Physical Channel and Spreading Code Assignment

1.1.1 Physical Channel

WCDMA has a three-layered channel structure: physical [3, 4], transport, and logical. The physical channels provide several transport channels to the *medium access control* (MAC) layer, which is a sublayer of the data link layer (Layer 2). The MAC layer provides several different logical channels to a higher layer, the *radio link control* (RLC) layer. The physical channels are classified by spreading codes, carrier frequency, and in-phase (I)/quadrature-phase (Q) assignment. One radio frame of a physical channel has a frame length of 10 ms and comprises 15 slots. Thus, the slot length is equal to a basic updating unit of adaptive fast TPC and channel estimation of coherent RAKE combining and is optimized to the value of 0.667 ms taking into account a tradeoff between the frame efficiency and the tracking ability of fast TPC and channel estimation against fast fading variation. The number of channel-coded information bits conveyed by each physical channel differs according to the type of physical channel and spreading factor. The features of the major physical channels are described next:

1. *Primary-common control physical channel (P-CCPCH):* One P-CCPCH is defined for each sector in the forward link. The P-CCPCH has a fixed spreading factor of 256 (15 Ksps) and carries the broadcast channel transport channel. The P-CCPCH is not transmitted during the first 256-chip duration; instead, the P-SCH and S-SCH are transmitted during that period at each slot.
2. *Secondary-common control physical channel (S-CCPCH):* Multiple S-CCPCHs, which are common channels in the forward link, are defined in each cell (sector) and carry paging information and lower data information from a higher layer.
3. *Physical random-access channel (PRACH):* Multiple PRACHs, which are common channels in the reverse link, are defined and used to carry the RACH transport channel comprising lower information data from a higher layer.
4. *Dedicated physical channel (DPCH):* A DPCH is assigned to each *mobile station* (MS) in both the forward and reverse links. It comprises a *dedicated physical control channel* (DPCCH) and a *dedicated physical data channel* (DPDCH). A DPDCH consists of a channel-coded data sequence, and more than one DPDCH can be assigned to one DPCH. A DPCCH is used for Layer 1 control of DPCH and one DPCCH is defined for one DPCH. A DPCCH comprises pilot bits for coherent channel estimation, TPC bits, *transport format combination indicator* (TFCI) bits, and *feedback information* (FBI) bits designating the control information for transmit diversity in the forward link (thus, FBI bits are defined only in the reverse link).
5. *Common pilot channel (CPICH):* A CPICH is the common pilot channel used for channel estimation, path search for RAKE combining (generation of power delay profile), and the third step, that is, scrambling code identification in the three-step cell search method. Two kinds of CPICHs are defined: primary CPICH and secondary CPICH. The primary CPICH has two-symbol data sequences associated with two antennas. Without transmit diversity all symbol sequences with all 1's are transmitted from antenna 1; with transmit diversity, the second primary CPICH with different symbol sequences from those of the first primary CPICH are also transmitted from antenna 2 in addition to the first primary CPICH. In future applications of smart antennas for spot beam transmis-