Information Technology: Transmission, Processing, and Storage

Wireless Communications Systems and Networks

Edited by

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PREFACE

Since the early 1990s, the wireless communications field has witnessed explosive growth. The wide range of applications and existing new technologies nowadays stimulated this enormous growth and encouraged wireless applications. The new wireless networks will support heterogeneous traffic, consisting of voice, video, and data (multimedia). This necessitated looking at new wireless generation technologies and enhance its capabilities. This includes new standards, new levels of Quality of Service (QoS), new sets of protocols and architectures, noise reduction, power control, performance enhancement, link and mobility management, nomadic and wireless networks security, and ad-hoc architectures. Many of these topics are covered in this textbook.

The aim of this book is research and development in the area of broadband wireless communications and sensor networks. It is intended for researchers that need to learn more and do research on these topics. But, it is assumed that the reader has some background about wireless communications and networking. In addition to background in each of the chapters, an in-depth analysis is presented to help our readers gain more R&D insights in any of these areas. The book is comprised of 22 chapters, written by a group of well-known experts in their respective fields. Many of them have great industrial experience mixed with proper academic background.

The first chapter discusses peer-to-peer networking in mobile communications based on SIP. J. Huber of Siemens, Germany, describes the evolution path of the Global System for Mobile Communications towards UMTS that integrates Internet technologies and provides a platform for the development of new mobile specific services. These services include new developments that will incorporate mobility and person-to-person communications with real-time video, sound, and voice, describing the evolutionary path in achieving this objective.

The second chapter, written by A. Boukerche from the University of Ottawa, Canada, discusses some protocols for data propagation in wireless sensor networks. These protocols cover large numbers of these sensors that can be deployed in areas of interest, such as inaccessible terrains or disaster places, and

use self-organization and collaborative methods to form a network. Their wide range of applications is based on the possible use of various sensor types. Thus, sensor networks can be used for continuous sensing, event detection, location sending, as well as micro-sensing. This is a challenging technological and algorithmic task. Features, including the huge number of sensor devices involved, the severe power shortage, computational and memory limitations, their dense deployment and frequent failures, pose new design analysis and implementation challenges. This chapter aims to present certain important aspects of the design, deployment, and operation of sensor networks, as well as some evaluation of their performance analysis.

The third chapter, by A. Safwat of Queen's University, Canada, talks about the design of a novel architecture for 4G and 4G+ wireless networks called "A-CELL." The A-Cell relay is used to reduce power consumption and enhance coverage and throughput. A-Cell increases spatial reuse via directive antennas and GPS. The author derives an analytical model for A-Cell based on multi-dimensional Markov chains. The model is then used to formulate A-Cell call blocking. This is the first time that directive antennas are used as a means to reduce interference, conserve energy, and enhance spatial reuse in a multi-hop UMTS wireless network.

H. Holma and A. Toskala from Nokia, Finland discuss third generation WCDMA radio evolution. They discuss technologies including: 2 Mbps data rate with variable bit rate capability, support of multi-service, QoS differentiation, and efficient packet data. These technologies also contain downlink packet data operation enhancement, high speed downlink packet access (HSDPA). HSDPA utilizes Hybrid ARQ and higher order modulation for improving data spectral efficiency and for pushing bit rates beyond 10 Mbps. The further 3GPP releases will study the enhancements of packet data performance in uplink. Other important features in future 3GPP releases include advanced antenna technologies and WCDMA standard for new spectrum allocations. The chapter also describes the main solutions of 3GPP WCDMA standard in more detail.

Next, H-H. Chen from National Sun Yat-Sen University, Taiwan, discusses the evolution of CDMA from interference-limited to noise-limited. The chapter covers various new CDMA-based wireless standards—such as TD-SCDMA and LAS-CDMA, etc., as well as those on other commonly referred CDMA-based standards, such as IS-95A/B, cdma2000, UTMS-UTRA, W-CDMA, etc.—providing a rather comprehensive coverage of the evolution of CDMA technologies from interference-limited to noise-limited. The discussions on various features of state-of-the-art CDMA technologies lead to the introduction of a new concept on *isotropic CDMA air-link technology,* which consists of two related sectors: isotropic spreading codes and isotropic spreading modulation. This can offer a homogenous performance in both synchronous and asynchronous CDMA channels. Based on the discussion on conventional CDMA technologies and introduction of two novel CDMA architectures, the author concludes that the

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evolution of CDMA technologies will eventually make a CDMA system offer a noise-limited performance.

Then, B. Hashem from Nortel Networks of Ottawa, Canada, describes a power control implementation in third generation CDMA systems. The inner loop and the outer loop algorithms are explained whereby the power commands are sent at a high rate, and uncoded, resulting in high error rate in receiving them. The problem of errors in the power control commands becomes worse during soft handoff where the terminal communicates simultaneously with more than one base station. A few algorithms are introduced during soft handoff to increase the system capacity, like power control rate reduction and the adjustment loop. Adjusting the transmission rate is also discussed as another scheme to achieve the required quality.

F. Gunnarsson of Linköping University, Sweden, discusses the characteristics and fundamentals of power control in wireless networks. He describes power control fundamentals, including both theoretical and practical limitations. The relationship to session management, such as admission and congestion control, is also addressed. Concepts and algorithms are illustrated with simple examples and simulations.

L. Yang and M-S. Alouini of the University of Minnesota present their results on the average outage duration of wireless communication systems. More specifically they discuss generic results for the LCR and AOD: (1) of maximal ratio combining systems subject to CCI operation over independent identically distributed Rician and/or Nakagami fading environments when a minimum desired signal power requirement is specified for satisfactory reception; and (2) of various selection combining diversity scheme in presence of multiple CCI and with both minimum SIR and desired signal power constraints over independent, correlated, and/or unbalanced channels. Corresponding numerical examples and plots illustrating the mathematical formulation are also provided and discussed.

A transport level approach in enhancing TCP performance in wide area cellular wireless networks are discussed by E. Hossain and N. Parvez from the University of Manitoba, Canada. They present a comprehensive study on the performances of the basic TCP variants (e.g., TCP Tahoe, TCP Reno, TCP New-Reno, SACK TCP, FACK TCP) in wide-area cellular wireless networks. For the basic TCP variants, an in-depth analysis of the transport-level system dynamics is presented based on computer simulations using *ns-2*. Impacts of variations in wireless channel error characteristics, number of concurrent TCP flows, and wireless link bandwidth on the average TCP throughput and fairness performances are investigated. The maximum achievable throughput under window-based end-to-end transmission control is also evaluated and the throughput performances of TCP New-Reno, SACK TCP, and FACK TCP are compared against this ideal TCP throughput performance. To this end an overview of the major modifications to the basic TCP variants based on transport-level approaches to enhance TCP performance in wireless networks is presented.

The deployment of several real-time multimedia applications over the Internet has motivated a considerable research effort on the provision of multiple services on the Internet. In order to extend this work over wireless links however, we must also take into account the performance limitations of wireless media. G. Xylomenos and G. Polyzos from the Athens University of Economics and Business in Greece survey various related approaches and conclude that link layer schemes provide a universal and localized solution. Based on simulations of application performance, over many link layer schemes, they show that different approaches work best for different applications by concurrently supporting multiple link layer schemes. Simulations of multiple applications executing simultaneously show that this approach dramatically improves performance for all of them. They finally consider embedding this approach into a Quality of Service oriented Internet, discussing the traditional best-effort architecture, the Differentiated Services architecture, and an advanced dynamic service discovery architecture.

A value added service to broadband wireless network is the remote access virtual private network (VPN). The corporate legitimate portable users can connect to their users through a wireless network from different locations and get secure services as if they were connected to the corporate local area network. One of the main challenges is to block illegitimate wireless users' requests. Registration and authentication functions should be implemented with highly secured wireless connections. These functions are accomplished by tunnelling the user information, in a secured form, to the corporate authentication server through the Internet traffic. The Corporate Authentication Server then grants or denies the user access. M. Matalgah from the University of Mississippi, J. Qaddour, from Illinois Institute of Technology, and their colleagues O. Elkeelany and K. Sheikh from Sprint Inc. have designed a portability architecture for nomadic wireless Internet access users and security performance evaluation to solve these challenges. This chapter addresses various portability scenarios, architectures, implementation, and requirement issues for portable wireless Internet access systems. Moreover, performance evaluation and comparison are presented for the state-of-the-art security and authentication techniques.

V. W-S Feng and Y-B Lin, of National Chiao Tung University and Industrial Technology Research Institute (ITR) of Taiwan, describe the design and implementation of a softswitch for Third Generation UMTS Mobile All-IP Network developed by Computer and Communication Research Laboratory (CCL) of ITRI. This softswitch can be utilized as call agent (media gateway controller) for the third generation mobile all-IP network such as UMTS. The CCL Softswitch follows the reference architecture proposed by International Softswitch Consortium. In this approach, the Intelligent Network (IN) call model is implemented to interwork with existing IN devices. They design protocol adapter modules and service provider interface to ensure that multiple VoIP protocols can be supported without modifying the core of the softswitch.

Furthermore, the message flows of call setup, call transfer, and inter-softswitch call are described to show the feasibility of the softswitch.

Then, in Chapter 13, E. Hossain et al., from the University of Manitoba, Canada, discuss issues and approaches of clustering in mobile wireless ad hoc networks. In a multi-hop ad hoc wireless network, which changes its topology dynamically, efficient resource allocation, energy management, routing, and end-to-end throughput performance can be achieved through adaptive clustering of the mobile nodes. Impacts of clustering on radio source management and protocol performance in a multi-hop ad hoc network are described and a survey of the different clustering mechanisms is presented. A comparative performance analysis among the different clustering mechanisms based on the metrics such as cluster stability, load distribution, control signaling overhead, energy-awareness is performed.

The maximum capacity of a CDMA cellular system's radio interface depends on the time varying radio environment. This makes it hard to establish the amount of currently available capacity. The received interference power is the primarily resource in the uplink. Ability to predict how different resource management decisions affect this spatial quality is therefore of utmost importance. The uplink interference power is related to the uplink load through the pole equation. In this chapter, E. Lundin and F. Gunnarsson of Ericsson Research and Linköping University, Sweden, discuss both theoretical and practical aspects of uplink load estimation concentrating on concepts and algorithms.

In Chapter 15, end-to-end performance analysis of multi-hop transmissions over Rayleigh fading channels is presented. Several types of relays for both regenerative and non-regenerative systems are considered. In addition, optimum power allocation over these hops is investigated as it is considered a scarce resource in the context of relayed transmission. Numerical results show that regenerative systems outperform non-regenerative systems especially at low average signal-to-noise ratios, or when the number of hops is large. The authors, M. Hasna and M-S. Alouini of Qatar University and the University of Minnesota, also show that power optimization enhances the system performance, especially if the links are highly unbalanced in terms of their average fading power or if the number of hops is large. Interestingly, they also show that non-regenerative systems with optimum power allocation can outperform regenerative systems with no power optimization.

Mobility management plays a significant role in current and future wireless mobile networks in effectively delivering services to the mobile users on the move. Many schemes have been proposed and investigated extensively in the past. However, most performance analyses were carried out either under simplistic assumptions on some time variables or via simulations. Recently, Y. Fang and W. Ma of the University of Florida have developed a new analytical approach to investigate the modeling and performance analysis for mobility management schemes under fairly general assumptions. In this chapter, they present the

techniques they have developed for this approach and summarize major results obtained for a few mobility management schemes such as movement-based mobility management, pointer forwarding scheme (PFS), Two-level location management scheme, and two-location algorithm (TLA).

Pervasive computing environments present entirely new set of challenges because of the fact that data may be acquired and disseminated at various stages within the system. Therefore, novel caching mechanisms are needed that take into account demand-fetched and prefetched (or pulled), as well as broadcast (or pushed) data. In addition, cached maintenance algorithms should consider such features as heterogeneity, mobility, interoperability, proactivity, and transparency that are unique to pervasive environments. Pervasive computing applications require continual and autonomous availability of 'what I want' type of information acquisition and dissemination in a proactive yet unobtrusive way. Mobility and hererogeneity of pervasive environments make this problem even more challenging. Effective use of middleware techniques—such a caching—can overcome the dynamic nature of communication media and the limitations of resource-poor devices. These and other challenging issues in this area are discussed by M. Kumar and S. Das, of the University of Texas at Arlington, in Chapter 17. Das *et al.* also present issues of security in wireless mobile and sensor networks in Chapter 18. In particular, they discuss security issues and challenges in wireless mobile ad hoc and sensor networks as well as in pervasive computing infrastructures. They also describe security protocols for such environments.

H-H. Chen discusses various issues on pulse shaping waveform design for bandwidth efficient digital modulations in Chapter 19. He starts with an overview on the evolution of pulse shaping technologies from early digital modulation schemes to recently emerging new carrier modulations such as quadrature-overlapped modulations. The impact of the pulse shaping technologies on both bandwidth-efficiency and power-efficiency, which are two essential merit parameters of a digital modem, are also discussed with an emphasis on shaping pulse design methodology as well as performance analysis of a pulse-shaped digital modem. Several new pulse shaped QO modulation schemes, which adopt various novel pulse shaping waveforms generated by time-domain convolution method, are presented and their performance analysis will be carried out in comparison with other traditional digital modems, such as QPSK, OQPSK and MSK.

In chapter 20, E. Biglieri and G. Taricco of Politecnico di Torino, Italy, investigate transmission systems where more than one antenna is used at both ends of the radio link. The use of multiple transmit and receive antennas allows one to reach capacities that cannot be obtained with any other technique using present-day technology. After computing these capacities, the authors show how "space-time" codes can be designed and how sub-optimum architectures can be employed to simplify the receiver.

In Chapter 21, a group of researchers (R. Schober, L. Lampe, S. Pasupathy, and W. Gerstacker) from the University of British Columbia and the University of Toronto, Canada, as well as the University of Wrlangen-Nuernberg, Germany, designed and optimized matrix-symbol-based space-time block codes (STBC's) for transmission over fading intersymbol interference (ISI) channels. They show that STBC's employing diagonal code matrices exclusively facilitate the successful application of suboptimum equalization techniques for the practically important case when only a single receive antenna is available. Three different types of diagonal STBC's are optimized for fading ISI channels and their performances are compared for decision-feedback equalization (DFE) and decision-feedback sequence estimation (DFSE), respectively. The robustness of the designed codes against variations of the characteristics of the fading ISI channel and the dependence of the equalizer performance on the STBC structure is investigated.

Last, but not least, M. Bassiouni, W. Cui, and B. Zhou of the University of Central Florida, present a fast routing and recovery protocols in hybrid ad-hoc cellular networks. They present and evaluate efficient recovery and routing protocols for mobile routers in HACN (hybrid ad-hoc cellular network). In the dual backup recovery protocol, a standby router is dedicated to each primary router. A more flexible protocol, called the distributed recovery protocol, is obtained by relaxing this one to one mapping and scattering the backup routers geographically among the primary routers. The effectiveness of the distributed recovery protocol is demonstrated by simulation results. A simple analytical model is also presented for computing the blocking probability of new calls in the presence of router failures. Chapter 22 is concluded by presenting an efficient location–based routing protocol for HACN mobile routers.

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CONTENTS

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Chapter 1

PEER-TO-PEER NETWORKING IN MOBILE COMMUNICATIONS BASED ON SIP

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Abstract The mobile Internet, ubiquitous computing and universal mobile communications are key words related to the integration of information technology and communications. Until today, the Internet has been dominated by non-realtime services based on client-server relations. As its continued developments encompass realtime voice and video, peer-to-peer communications will emerge. Consequently, the take-up of Internet technologies in mobile networks leads to new innovations there. This chapter describes the evolution path of mobile networks and services in the framework of the universal mobile telecommunication system UMTS.

Keywords: Mobile Internet, Next Generation Networks, IP Multimedia, SIP, 3G Services and Networks, UMTS, Ubiquitous Computing

1. Why Mobile NGN's?

What are the targets of mobile next generation networks (NGN's)? This is the key question when we discuss the evolution of hardware and software technology in the field of mobile communications. One target could be computing anywhere, anytime, another one personalisation, or let us summarise and say ubiquitous computing.

The discussion about ubiquitous computing (UC, or ubicomp) has been going on for many years. UC describes the evolution of computing towards the so-called third era of computing. Mobile computing will be a main contributor to this development. The main aim of UC is to embed many small and highly specialised devices within the everyday environment in such a way that they operate seamlessly and become transparent to the person using them. They will operate either off-line or on-line. UC products aim to be everywhere (e. g., by being portable), to be small, and to be aware (of their environments, users, the contexts). Products and devices embodying these characteristics will provide a physical entity with complete freedom of movement as well as freedom of interaction [1].

The cornerstones of this vision are that computers as they are known today will be replaced by a multitude of networked computing devices embedded in our environments and that these devices will be invisible in the sense of not being perceived as computers. Wireless connectivity is a key contributor to this vision.

In order to facilitate UC, mobile NGN's have to fulfil such requirements like providing flexible bit rates and wide area coverage outdoor and indoor, as well as intelligent support encompassing location and situation of the computing devices.

2. Enabling Technologies for Mobile NGN's

With the evolution from second generation (2G) to third generation (3G) mobile networks, wideband radio access and Internet-based protocols will prepare the way from a mobile handset today to a mobile multimedia device in the future. Providing wireless access to the wireline Internet brings, of course, more flexibility and facilitates penetration. New services come with new enabling functions – like mobility, personalisation, and localisation capabilities – which are the characteristics of 3G mobile systems. This is the motivation for the industry to evolve the wireline Internet to a mobile Internet with new capabilities and applications. Key enabling functions for the mobile NGN are as follows:

- *IP-transparency:* All elements involved in the end-to-end communications path have to support IP, both in the fixed and in the mobile parts of the network.
- *Mobility management:* It has to function in a globally networked environment for roaming.
- *Addressing:* It must allow every user a unique address capability, which is independent from the user's location.
- *Personalisation of information and positioning:* There must be means to provide such functionality.
- *Positioning:* The individual must be positioned to enable location-dependent services.

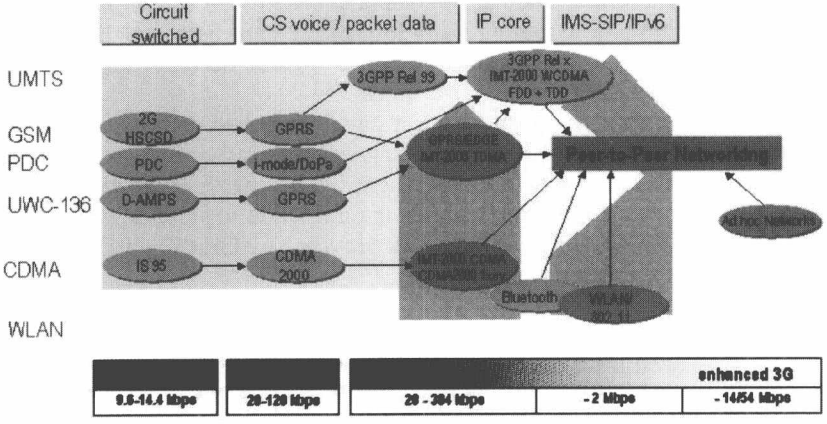
- *Security:* It has to be provided end-to-end for fixed and mobile devices.

Such functionality will make the mobile Internet different from a wireless access to the Internet, like wireless LANs (WLAN) offer today.

3. New Infrastructures

Many mobile operators are currently in the process of evolving their networks to 3G services, from current voice and data bearer services to high bit rate IP-based services. To do so, they must upgrade their networks from second generation 2G to evolved 2G (2.5G) and third generation systems (3G).

The major 2G mobile networks are based on four technologies: Global System for Mobile Communications (GSM), Universal Wireless Communications (UWC-136), Personal Digital Cellular (PDC) and Code Division Multiple Access (CDMA), also called cdma One. As illustrated, the generally accepted 3G migration path for the GSM technology is GPRS/EDGE/WCDMA, for cdmaOne it is CDMA2000 and for PDC it is WCDMA.



Legend:

HSCSD	...	High Speed Circuit Switched Data
D-AMPS	...	Digital AMPS
GPRS	...	General Packet Radio Service
TDMA	...	Time Division Multiple Access
CDMA	...	Code Division Multiple Access
FDD	...	Frequency Division Duplex
TDD	...	Time Division Duplex
PDC	...	Personal Digital Cellular
UWC	...	Universal Wireless Communications

Fig. 1 Migration of Mobile Networks

These same paths are also available for UWC-136. It is clear that the GSM operators and the majority of UWC-136 operators are preferring the GSM path to 3G. There are a number of reasons for example the present worldwide GSM footprint with a market share of beyond 75 % (1 bio. users in first half of 2004). Thus, it is obvious that the GSM technology path GPRS – EDGE – WCDMA will become the most widely accepted standard for 3G services.

The evolution begins with an upgrade of the GSM network to GPRS technology, which provides more effective mobile data capabilities.

GPRS

GPRS (General Packet Radio Service) is a 2.5G radio system, but a 3G system in terms of the core network. It enhances GSM data services significantly by providing genuine end-to-end packet-switched data connections, offers data transmission speeds up to 171.2 kbps (peak data rate) and supports the leading Internet protocols TCP/IP and X.25.

The integration of GPRS into GSM is a rather straightforward process. A subset of time slots on the air interface are defined for GPRS allowing scheduled packet data multiplexing of several mobile stations. The radio subsystem needs a minor modular upgrade associated with the packet control unit (PCU) to provide a routing path for packet data between the mobile terminal and gateway node. A minor software upgrade becomes necessary to employ the different channel coding schemes.

The GSM core network constructed for circuit-switched connections has to be extended with new packet data switching and gateway nodes, the so-called GGSN (Gateway GPRS Support Node) and SGSN (Serving GPRS Support Node). However this acquisition endures the migration towards 3G, since the high-speed packet switching core network provided by GPRS and EDGE can be used for UMTS almost completely.

EDGE

EDGE (Enhanced Data rates for Global Evolution) is an approved 3G radio transmission technique that can be deployed in existing spectrum of TDMA and GSM operators. EDGE reuses the GSM carrier bandwidth and time slot structure. Thus, EDGE-capable infrastructure and terminals are fully compatible with GSM and GPRS (EGPRS).

Due to adaptive modulation/coding schemes optimal bit rates are achieved for all channel qualities. The maximum user peak data rate that can be achieved in a 200 kHz carrier with the most sensitive modulation/coding scheme and combining of all 8 time slots is 473.6 kbps.

W-CDMA or UMTS/FDD

W-CDMA (Wideband Code Division Multiple Access) is the UMTS radio access (UTRA) technology for paired band operation. It operates in separated

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