Convergence Technologies for 3G Networks

IP, UMTS, EGPRS and ATM

Jeffrey Bannister, Paul Mather and Sebastian Coope

at Orbitage Consultants

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About the Authors

The three authors form part of the senior management team of Orbitage, a high-technology consultancy firm offering specialised expertise in many aspects of the telecommunication and information technology fields. Originally founded in 1998 and based in Kuala Lumpur, Malaysia, it has expanded to primarily cover the Asia-Pacific region, and has regional offices in Cyberjaya and Petaling Jaya, Malaysia, Singapore and Hong Kong. Orbitage is numbered among those companies to be awarded the prestigious Malaysian MSC status. In addition, Orbitage has a development team in the UK, and representatives in Finland and Ireland, as well as a regional office in Europe. Orbitage is also a distributor of NetHawk 2G/3G analysis tools.

Orbitage is highly regarded in Asia, and has provided consultancy and training services to a number of major organizations, including Nokia, Ericsson, Motorola, Singapore Telecom, Mobile One Singapore, StarHub Singapore, Telekom Malaysia, Maxis Malaysia, Celcom Malaysia, Telstra Australia, KGT Taiwan, TCC Taiwan, AIS and DTAC in Thailand, Vodaphone Ireland, and NetHawk Finland. Orbitage has been providing services to Nokia in Asia for a number of years as well as projects in China and Europe. Orbitage specialises in cross-training of professionals between the IT and telecommunications fields to enable them to become proficient Convergence Engineers.

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DEDICATION

To my family, Canjoe, Siobhán, Avril and Norman, for their love, support and encouragement-J.B.

To Vivian, my wife and best friend for her unbridled love and support and also to my dad for ensuring I was suitably equipped for this journey-P.M.

I would like to dedicate my contribution in this book to Carole and little Al-S.C.

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1

Introduction

1.1 BACKGROUND TO CONVERGENCE

The telecommunications industry, and particularly the cellular industry, is currently going through a state of enormous transition. Many of the major cellular operators are now deploying a network to support packet switched data services and lead them to third generation (3G). This step to 3G involves a major change in the network infrastructure with the introduction of complex technologies such as asynchronous transfer mode (ATM), code division multiple access (CDMA) and the Internet protocol (IP). For forward-looking operators, this transition also requires a clear, strategic transformation of their business model to grasp and maximize on the benefits of the next generation's lucrative revenue streams. An operator requires both highly motivated staff with a substantial skill set as well as comprehensive, dynamic information systems. Also crucial is a clear understanding of the role the operator will play in this new model on the continuum from mere provision of a bit-pipe, to an organization offering full Internet service provider (ISP) capabilities and value-added services. This revised business model needs to incorporate integrated solutions for charging and billing, and provide a clear understanding of the new revenue streams available. Smooth convergence of network and telecommunications technologies and a proactive business strategy are pivotal to the success of the future mobile operator.

Many telecoms engineers have little experience in the new packet and IP technologies. To remain competitive it is essential that they learn the new packet switched skills quickly. The circuit switched skills will be required for a long time as circuit switching is not expected to disappear overnight and will probably be around for decades. However, new network components for telecoms networks will be based around packet switched technology.

Second generation cellular systems have been implemented commercially since the late 1980s. Since then, the systems have evolved dramatically in both size and reliability to achieve the level of quality subscribers expect of current networks. Mobile

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network operators have invested heavily in the technology and the infrastructure, and it is unreasonable to expect this to be simply discarded when a new 3G system is proposed.

As a term, *convergence* has been coined by both the telecoms and datacoms industries. From a telecoms perspective, it is the expansion of the public switched telephone network (PSTN) to offer many services on the one network infrastructure. For Internet advocates, it is the death of the PSTN as its role is largely replaced by technologies such as voice over IP (VOIP). In reality, the truth lies somewhere in the middle, and it is here that the cellular industry takes the best of both worlds to create an evolved network, where the goal is the delivery of effective services and applications to the end user, rather than focusing on a particular technology to drive them. That said, the economy of scale and widespread acceptance of IP as a means of service delivery sees it playing a central role in this process.

1.2 THIRD GENERATION (3G)

Third generation or 3G is now the generally accepted term used to describe the next wave of mobile networks and services. First generation (1G) is used to categorize the first analogue mobile systems to emerge in the 1980s, such as the advanced mobile phone system (AMPS) and nordic mobile telephony (NMT). These systems provided a limited mobile solution for voice, but have major limitations, particularly in terms of interworking, security and quality. The next wave, second generation (2G), arrived in the late 1980s and moved towards a digital solution which gave the added benefit of allowing the transfer of data and provision of other non-voice services. Of these, the global system for mobile communication (GSM) has been the most successful, with its global roaming model. 3G leverages on the developments in cellular to date, and combines them with complementary developments in both the fixed-line telecoms networks and from the world of the Internet. The result is the development of a more general purpose network, which offers the flexibility to provide and support access to any service, regardless of location. These services can be voice, video or data and combinations thereof, but, as already stated, the emphasis is on the service provision as opposed to the delivery technology. The motivation for this development has come from a number of main sources, as follows:

- subscriber demand for non-voice services, mobile extensions to fixed-line services and richer mobile content;
- operator requirements to develop new revenue sources as mobile voice services and mobile penetration levels reach market saturation;
- operators with successful portfolios of non-voice services now unable to sustain the volume of traffic within their current spectrum allocation;
- equipment vendor requirements to market new products as existing 2G networks become mature and robust enough to meet current consumer demand.

It is arguable which of these weigh most heavily on the big push for the introduction of 3G networks, and which of these are justifiable. Certainly in Japan and Korea, where operators

are now generating more traffic and revenue from non-voice services, the business case for 3G is present. These operators are no longer able to meet the subscriber demand for such applications, and have been a major impetus in 3G development, particularly NTT DoCoMo, arguably the most successful, and a pioneer in non-voice services. However, the situation in Japan and Korea is somewhat different to the rest of the world. There are a number of key factors that led to the growth of data services there:

- low Internet penetration, due largely to language factors;
- high existing mobile penetration (in Japan, the high cost and low efficiency of fixed-line services has partially fuelled this);
- large urban conurbation with sizeable proportion of the working population commuting on public transport, often for a long duration;
- low relative cost of mobile services.

This is evident in Japan, where the first driving application of DoCoMo's iMode service was provision of email.

However, the current situation outside of these exceptions is that thus far, consumer demand for data services has been limited, even now when there is widespread availability of data-capable mobile devices. Cost of new services has been a significant factor in this poor uptake as bandwidth charges are unrealistically high when compared to fixed-line equivalents, particularly now with the widespread availability of economical consumer digital subscriber line (DSL) services.

1.3 WHY UMTS?

The 3G standard proposed by the European Telecommunications Standards Institute (ETSI) with much joint work with Japanese standardization bodies is referred to as the universal mobile telecommunications system (UMTS). UMTS is one of a number of standards ratified by the International Telecommunications Union–Telecommunication Standardization Sector (ITU-T) under the umbrella of International Mobile Telephony 2000 (IMT2000), as discussed in the next section. It is currently the dominant standard, with the US CDMA2000 standard gaining ground, particularly with operators that have deployed cdmaOne as their 2G technology. At the time of writing, Japan is the most advanced in terms of 3G network deployment. The three incumbent operators there have implemented three different technologies: J-Phone is using UMTS, KDDI has a CDMA2000 network, and the largest operator NTT DoCoMo is using a system branded as FOMA (Freedom of Multimedia Access). FOMA is based around the original UMTS proposal, prior to its harmonization and standardization.

The UMTS standard is specified as a migration from the 2G GSM standard to UMTS via the general packet radio service (GPRS) and enhanced data rates for global evolution (EDGE), as shown in Figure 1.1. This is a sound rationale since as of December 2002, there were over 780 million GSM subscribers worldwide,[1] accounting for 71% of the

[1]Source: GSM Association, www.gsmworld.com.

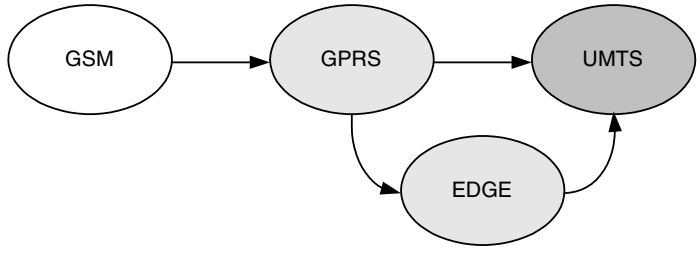

Figure 1.1 GSM evolution to UMTS

global cellular subscriber figures. The emphasis is on enabling as much of the GSM network as possible to continue to operate with the new system.

The goal of 3G is to provide a network infrastructure that can support a much broader range of services than existing systems so the changes to the network should reflect this. However, many of the mechanisms in the existing networks are equally applicable to supporting new service models, for example mobility management. For a successful migration, the manufacturers and suppliers of new 3G equipment understand that most licences granted for 3G network operation will be to existing 2G operators and thus the next step must be an evolution rather than a revolution. Operators in the main are expected to introduce GPRS functionality before taking the step to 3G. This will allow them to educate and develop the consumer market for these new services prior to major investment in new technology. This means that the Core Network will comprise the GSM circuit switched core and the GPRS packet switched core. The first release (Release 99) specification for UMTS networks is focused on changes to the Radio Access Network rather than the Core Network. This allows the Core Network to continue in functionality although changes will be made in areas of performance due to the higher data rates required by subscribers in the future networks. Maintaining this functionality allows the mobile network operators to continue using their existing infrastructure and progress to 3G in steps. The handover between UMTS and GSM offering worldwide coverage has been one of the main design criteria for the 3G system.

1.4 IMT2000 PROCESS

The IMT2000 is a global process, coordinated by the ITU-T to develop next generation mobile networks, and covers both the technical specifications and the frequency allocations. It was started in 1995 under the original heading of Future Plans for Land Mobile Telecommunications System (FPLMTS). IMT2000 is not a particular technology, but rather a system which should allow seamless, ubiquitous user access to services. The task is to develop a next generation network fulfilling criteria of ubiquitous support for broadband real-time and non-real-time services. The key criteria are

- high transmission rates for both indoor and outdoor operational environments;
- symmetric and asymmetric transmission of data;

- support for circuit and packet switched services;
- increased capacity and spectral efficiency;
- voice quality comparable to the fixed line network;
- global, providing roaming between different operational environments;
- support for multiple simultaneous services to end users.

The process is intended to integrate many technologies under one roof. Therefore, it should not be seen that wireless technologies from different regional standardization bodies, or supported by different manufacturers, are competing with each other, but rather that they can be included in the IMT2000 family. This is evident with the development of such interworking models as wireless LAN and 3G. A major enabler of the ITU-T vision is the emergence of software defined radio (SDR). With SDR, the air interface becomes an application, which enables a single mobile device to be able to operate with a variety of radio technologies, dynamically searching for the strongest signal, or the most appropriate network to connect to.

Thus far, the ITU-T has given the imprimatur of 3G to five different radio access technologies, as shown in Figure 1.2.

ITU-DS is the UMTS frequency division duplex (FDD) standard, ITU-MC is CDMA-2000, and ITU-TC covers both UMTS time division duplex (TDD) and time division synchronous CDMA. All these technologies are explained in Chapter 6. The IMT-SC system, UWC-136, is the EDGE standard (Chapter 4). The ITU-FT incorporates the European standard for cordless telephones, digital enhanced cordless telecommunications (DECT). DECT provides a local access solution which may be used, for example, in a home environment. The handset can automatically handover to a subscriber's domestic access point, providing dedicated resources. While the integration of DECT with GSM has been standardized, it has yet to see any exposure.

The development of these standards is under the control of two partnership organizations formed from a number of regional standardization bodies. The Third Generation Partnership Project (3GPP, www.3gpp.org) is responsible for UMTS and EDGE, while the Third Generation Partnership Project 2 (3GPP2, www.3gpp2.org) deals with CDMA2000 (Figure 1.3). DECT is the exception to this, with its standards developed solely by ETSI.

As can be seen, there is considerable overlap in terms of the bodies involved in the two organizations. The various bodies are described in Table 1.1.

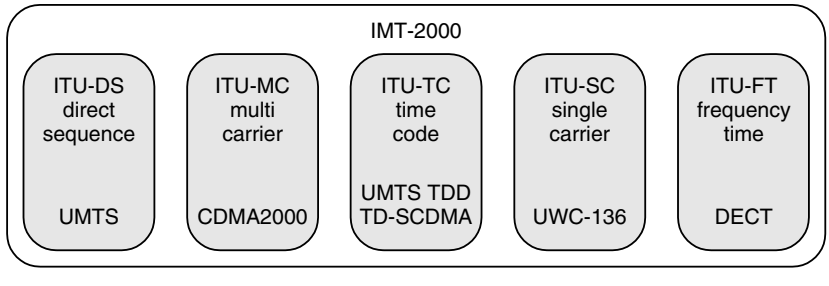

Figure 1.2 IMT2000 technologies

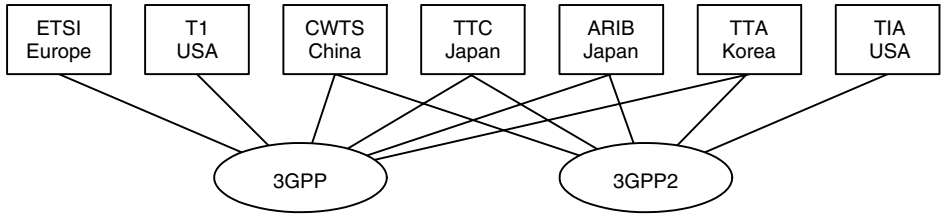

Figure 1.3 3G partnerships

Table 1.1 Standardization bodies

Body	Description
ETSI	The European Telecommunications Standards Institute is responsible for the production of standards for use principally throughout Europe, but standards may be used worldwide
T1	Committee T1 develops technical standards and reports in the US with regard to the interconnection and interoperability of telecommunications networks at interfaces with end user systems
CWTS	The China Wireless Telecommunication Standard group has the responsibility to define, produce and maintain wireless telecommunication standards in China
TTC	The Telecommunication Technology Committee is a Japanese organization whose role is to contribute to the standardization and dissemination of standards in the field of telecommunications
ARIB	The Association of Radio Industries and Businesses conducts investigations into new uses of the radio spectrum for telecommunications and broadcasting in Japan
TTA	The Telecommunications Technology Association is an IT standards organization that develops new standards and provides testing and certification for IT products in Korea
TIA	The Telecommunications Industry Association is the leading US trade association serving the communications and information technology industries

One of the tasks was to allocate a band of the frequency spectrum for this new system. Figure 1.4 shows the bands allocated, and compares this to the bands being used in both the US and Europe/Asia-Pacific regions, with the exception of Japan and Korea.

As can be seen, the allocated frequency is already extensively used in North America, and this presents deployment issues for 3G technologies. This is expanded in more depth in Chapter 6. In this frequency use chart, MSS is the mobile satellite system, which is the satellite component of 3G. Europe/Asia-Pacific has allocated all of the IMT2000 frequency to UMTS, with the exception of 15 MHz, which is already being used for DECT. The UMTS allocation is as follows:

- *UMTS FDD*: uplink: 1920–1980 MHz; downlink: 2110–2170 MHz
- *UMTS TDD*: uplink: 1900–1920 MHz; downlink: 2010–2025 MHz.

Most countries have now completed the licensing of these new bands for 3G services, many of them opting for an auction process. For UMTS, the basic carrier frequency is 5 MHz, and since it is a CDMA system it is possible to use only one frequency throughout

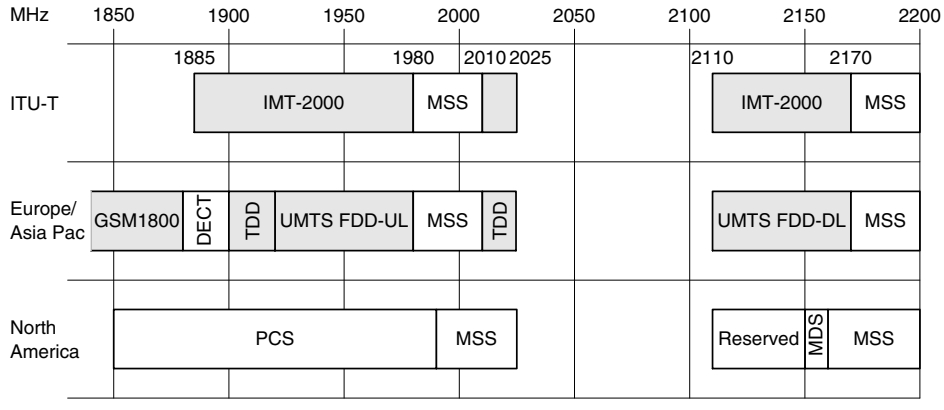

Figure 1.4 Cellular frequency usage

the system (see Chapter 2). For UMTS FDD, since there is 60 MHz of bandwidth available in UL/DL, this equates to 12 carriers. However, it is recommended that an operator be allocated three carrier frequencies. This is to tie in with the ITU-T principle of cell hierarchies, which provides for the following cell types:

- *Macro cell*: large area, outdoor general coverage
- *Micro cell*: small area, densely populated urban coverage
- *Pico cell*: indoor coverage.

Each cell type could be allocated a different carrier frequency, allowing for an overlay model. However, the decision of how to allocate frequencies is the remit of the national regulatory authority in a country. As an extreme example, consider the situation in the United Kingdom, which opted for the auction method. Five licences were allocated, as shown in Figure 1.5.

Licence A is allocated 15 MHz of FDD plus 5 MHz of TDD, and was reserved for a greenfield operator. Licence B consists of 15 MHz of FDD spectrum, and licences C–E 10 MHz of FDD plus 5 MHz of TDD each. After a controversial auction which concluded on 27 April 2000, the licences were sold as shown in Table 1.2.

Greenfield operator TIW UMTS (UK) Ltd is owned by the Canadian operator Telesystem International Wireless Inc. and is deploying UMTS in the UK as a joint venture with Hong Kong's Hutchison Whampoa, under the brand name 3. Commercial operation commenced at the end of December 2002. This rather cynical auctioning process worldwide has done little to aid the development of 3G, and has been widely criticized

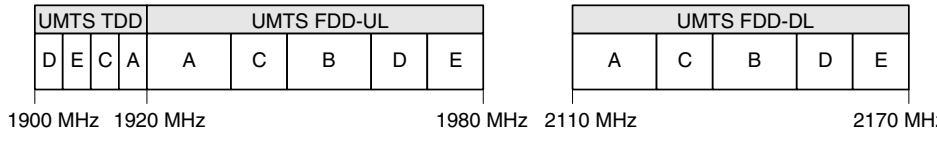

Figure 1.5 UK 3G spectrum licences

Table 1.2 UK 3G auction results

Licence	Operator	Fee (£ bn)
A	TIW UMTS (UK) Ltd	4.38
B	Vodaphone Ltd	5.96
C	BT (3G) Ltd	4.03
D	One2One Ltd	4.00
E	Orange 3G Ltd	4.10
Total		**22.47**

by many sources for the amount of capital it has taken out of the market. However, the various regulatory authorities have argued that the fees reflect the potential that the applicants expect from 3G in the long term.

1.5 ORGANIZATION OF THE BOOK

This book is intended to provide detailed and relevant information on the technologies related to the deployment of 3G systems, and focuses on UMTS. It is designed to cover the requisite knowledge to a reader coming from either a telecommunications or a computer networking background, examining how the different technologies are implemented in a UMTS context, and how the system evolves to deliver the service model. Throughout the text, examples of procedures are illustrated using trace files captured from UMTS networks to demonstrate their operation in practice.

Chapter 2 discusses the general principles on which packet-based networks are built, highlighting their use for the transport of real-time traffic. Added to this is the complication of a wireless interface to the network, and the mechanisms for providing multiple access are also explored. In particular, an overview of the principles and operation of the CDMA technique is presented, as this forms the central basis of the wireless physical layer of most 3G technologies.

Chapter 3 begins the description of cellular systems with a detailed explanation of the operation of the GSM. Aside from the access network, much of the existing GSM network is reused in UMTS, particularly at the higher layers such as connection and mobility management. In particular, the model for support of roaming within GSM and the basic security architecture are important components carried forward and expanded upon in UMTS. GSM is built around the signalling system 7 (SS7) protocol suite as used in the fixed-line PSTN, with extensions to support users accessing through a wireless interface.

Chapter 4 introduces the first major evolutionary step of GSM, the general packet radio service (GPRS). The GSM network has been designed and optimized for the delivery of one application, voice calls. Other services offered are considered supplementary. Chapter 2 explains why this type of network is not well suited for data transport, due to the vastly different requirements of the traffic. GPRS adds a network infrastructure based around the IP protocol which is designed with the needs of this data traffic is mind. It is also an essential building block of the UMTS network. Also described here is EDGE, which builds on GSM/GPRS to create a relatively high-speed network, without the major