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Introduction

This chapter will introduce the aim and positioning of Mobile WiMAX in relation to other telecommunication technologies and will provide a presentation of the specification structure and document identifier applied for Mobile WiMAX. The chapter concludes with an overview of the intention and content of each of the chapters of this book.

1.1 WiMAX in the Telecommunication Markets

Mobile WiMAX has left its phase of 'superhype' and converted to real network operation and successful telecommunication business. The roots of Mobile WiMAX go back to springtime 2002, when startup companies appeared in the IEEE 802 standardization arena and introduced the idea of multi-megabit broadband Internet access over a cellular infrastructure.

The promise was that a new mobile radio access technology would outperform the highly developed 3G radio technologies. It took some time and quite a number of disputes both inside and outside the IEEE 802 standardization committees until two projects were established, one known as the IEEE 802.20 Mobile Broadband Wireless Access (MBWA) Working Group and the other finally leading to the Mobile WiMAX radio standard by creating the IEEE 802.16e amendment to the IEEE 802.16 metropolitan area network interface specification. About a year after the standardization work was initiated, adoption of the IEEE 802.16e specification by the Korean WiBro initiative caused enormous public awareness resulting in huge hype around Mobile WiMAX. Many believed that Mobile WiMAX would become the preferred fourth generation (4G) radio technology superseding all the CDMA-based 3G technologies of the UMTS.

Despite the similarities of the radio interface, Mobile WiMAX follows a different paradigm of telecommunications (Figure 1.1).

From the beginning, the Mobile WiMAX technology aimed at a different deployment model, similar to the 'Digital Subscriber Line' model introduced on the wire-line networking area by cable and xDSL technologies.

1.1.1 Integrated Services Digital Networks

Traditionally all telecommunication networks were specially designed for particular services, and there were quite a number of them. The PSTN is the biggest example. It is a huge network

Deploying Mobile WiMAX Max Riegel, Dirk Kroeselberg, Aik Chindapol and Domagoj Premec

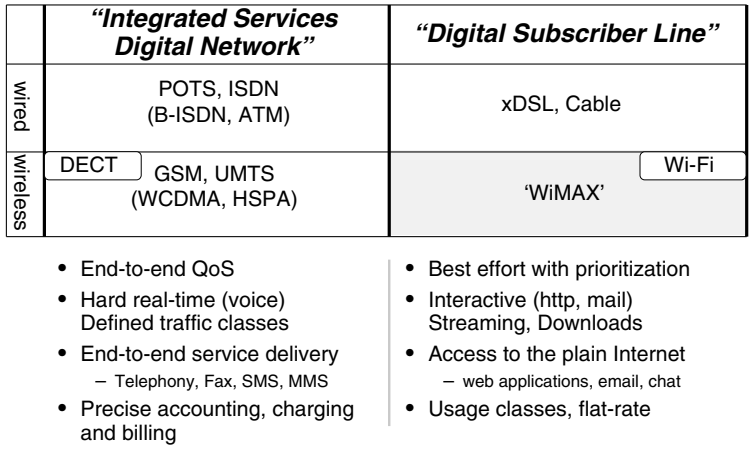

Figure 1.1 Telecommunication market segmentation

which is highly optimized to the telephony service by providing circuit-switched connections between customers. Other dedicated networks were constructed, e.g. for the TELEX service or for packet data services. All the networks were designed to ensure perfect delivery of their particular services, and these services built the economic base for operation of the network. Service-specific sophisticated accounting, charging and billing models were implemented to generate revenues for telecommunications operators based on the usage and value of the services provided to customers. The more the services were 'consumed' by the customers, the higher the income generated for the operators. The model did not change when telecommunications converted from analog transmission to digital transmission. Digitization of analog signals like voice or facsimile enabled the replacement of the analog networks by a digital counterpart. Moreover, with everything becoming digital, a single digital network became capable of providing all kinds of services over a common digital transmission system. ISDN became the ubiquitous wire-line telecommunication system in the world, even when for economic reasons the last mile of the network, aka the subscriber line, remained analog in most parts of the world.

To untie the terminal from the subscriber line, allowing usage of telecommunication services at any time at any place, was a huge desire of both the telecommunication operators and the customers. Cordless telephony by replacing the telephone cord by a local short-range radio transmission system was an intermediate step toward full mobility of terminals. DECT is the most advanced technology for cordless systems and resembles many of the concepts of ISDN. Full mobility of terminals and services was finally reached by GSM and its sibling IS-95 leading to an explosion of the mobile telecommunication market. UMTS and its ancestor GSM form today the technical base of most of the traditional cellular telecommunication services represented mainly by telephony and short-message service (SMS).

1.1.2 The Digital Subscriber Line to the Internet

Apart from traditional paradigms, the Internet introduced in the 1990s a disruptive telecommunication model. Primarily being an interconnection system of data networks, the Internet introduced a connectionless global telecommunication network based on the concept of

best-effort delivery. Best effort means that the end-to-end network does not guarantee delivery of information. If transmission fails, e.g. due to congestion in transmission nodes, the end systems have to detect it and take countermeasures to correct these transmission failures.

Such a communication system became feasible by the increasing computing power in the terminals. By shifting the reliability to the edge of the network, the place to create and to provide communication services was also shifted to the edge, moving it essentially out of the domain of the network operator. Every user of the Internet is able to become a service provider as well, and that feature was and is the foundation of the World Wide Web, which put an attractive graphical user interface with ubiquitous linking and embedding facilities on top of the Internet. The World Wide Web was the application which brought the Internet into everyone's daily life and since then the Internet has been used for all kinds of communication and information including telephony and television.

Access to the Internet can be established through the traditional ISDNs, but the connection and service delivery model does not fit well with the nature of the Internet. Much more appropriate for access to the Internet is the DSL model, which provides a broadband leased-line service to the Internet. Data can be sent and received at any time without taking care of the connection and the user gets the feeling of instant access to all resources on the Internet. According to the cost structure of the underlying network infrastructure, a monthly flat fee, sometimes combined with some transfer volume restrictions, replaced the strict usage-based charging of the traditional telecommunication networks.

DSL-type networks are widely deployed based on cable or xDSL technologies with a transmission speed of multiple megabits per second (Mbit/s) and high competition among network providers to provide ever higher speed connectivity to their customers. Having experienced the comfort of mobile telephony, customers are looking also for mobility for their broadband Internet access. Wi-Fi, aka WLAN, based on IEEE 802.11, became a huge success by allowing people to just sit down and connect to the Internet wirelessly without being tied by an Ethernet cable to the modem of the DSL.

1.1.2.1 Mobile WiMAX, the Wireless Subscriber Line to the Internet

Providing broadband Internet connectivity wirelessly over a much wider range than a couple of meters around a Wi-Fi access point is the driving idea behind Mobile WiMAX. It is intended to become the wireless counterpart to the cable and xDSL networks and to enable a new area of telecommunication by opening up the Internet for mobile terminals as well as new kinds of mobile applications.

The technology is designed to cope with the biggest challenge for operation of a mobile DSL: the huge growth of data volumes as experienced so far in the wired networks and now also appearing in the mobile networks. Starting mainly from wireless DSL deployments, the support of mobility functions like network detection and selection, handover, roaming and paging allows for the evolution toward nomadic and mobile service offerings for notebook computers and handheld devices.

1.2 Mobile WiMAX Specifications

IEEE 802.16 as well as the WiMAX Forum [2] create the technical specifications of Mobile WiMAX. IEEE 802.16 is a working group of the IEEE 802 LMSC, which is in charge of the

PHY and MAC specifications of the radio interface. The remaining parts of the access network functionalities are specified by the standardization activities in the WiMAX Forum, which refers not only to IEEE 802.16 but also to appropriate specifications of other standardization organizations, e.g. the IMS system of 3GPP. In addition to the technical specifications, the WiMAX Forum also develops the certification process for Mobile WiMAX equipment to ensure interoperability between different implementations.

Apart from its technical work, the WiMAX Forum is active in the promotion, marketing and regulatory areas to support the worldwide acceptance of the Mobile WiMAX technology.

1.2.1 Specification Areas

Mobile WiMAX technical specifications cover three main areas: radio, network and roaming. For each of the areas one or more interfaces are defined, which provide reference points for interoperability. Figure 1.2, a schematic figure of an access network, shows the location and the relation of the interfaces to each other.

The three areas of interoperability in Mobile WiMAX consist of:

- **Radio interface**: The radio interface denoted by R1 in Figure 1.2 defines the interface between the mobile terminal or subscriber equipment and the base station (BS) of the access network. The interface consists of three parts: the PHY and MAC according to the IEEE 802.16 specification as well as network layer functions, which are defined as part of the Mobile WiMAX network specification.

  Certification is provided for all the three parts defining the air interface R1, the PHY layer, the MAC layer and the network functions for establishing the IP configuration and carrying user payload over the air.
- **Network interfaces**: Mobile WiMAX defines distinct logical network entities for the access serving network, called ASN, as well as for the connectivity serving network, called CSN.

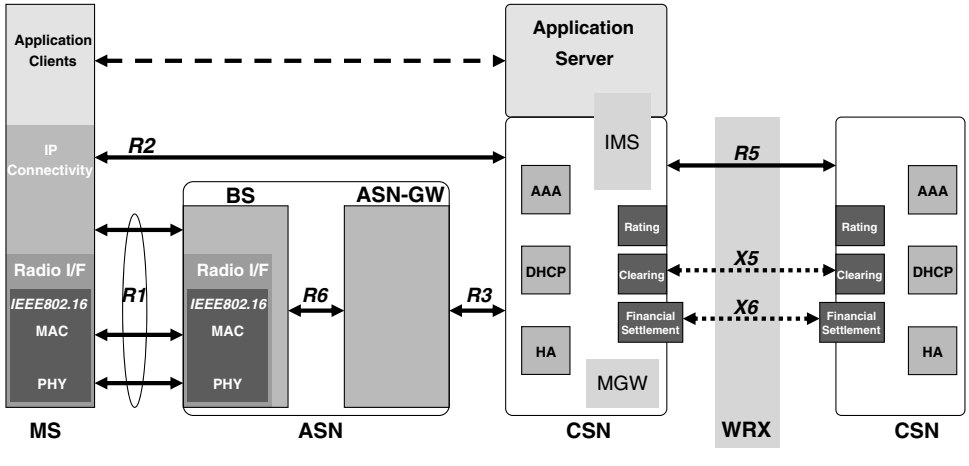

Figure 1.2 WiMAX specification areas

The ASN consists of a number of base stations (BSs) connected to at least one ASN gateway (ASN-GW), which also anchors the interface to the CSN. A standardized interface between CSNs exists for roaming purposes. The interfaces denoted R2, R3, R5 and R6 in Figure 1.2, as well as R4 and R8 (not depicted in the figure), denote reference points for interoperability in the network.

Network interoperability tests are provided for all network interfaces to ensure the proper operation of network equipment from different manufacturers.

- **Roaming interfaces**: In addition to the radio and network interfaces, Mobile WiMAX supports standardized roaming interfaces to facilitate worldwide roaming support among the WiMAX operators. Roaming is supported by a WiMAX roaming exchange (WRX) network, which mediates standardized procedures and messages between WiMAX operators to enable connectivity provisioning for subscribers in foreign networks. The roaming architecture is defined by the interfaces X2–X6 as well as R5. Figure 1.2 only depicts X5, X6 and R5, which pass through the WRX.

  Interoperability testing is provided across all specified interfaces to ensure proper operation of the Mobile WiMAX roaming exchange.

1.2.2 Development Process for WiMAX Interoperability

WiMAX interoperability relies on certification and interoperability testing, which is the final outcome of the standardization work in the WiMAX Forum in addition to the radio interface specification stemming from IEEE 802.16. In an extension of the commonly used three-stage standardization process, the WiMAX Forum is creating the necessary documentation for interoperability and certification in six stages, depicted in Figure 1.3.

The stages define distinct steps for the development of the WiMAX Forum specifications:

- **Stage 1: Requirements**: First, the functional requirements for the WiMAX terminals and the access network are specified. As usual, new functional requirements are add-ons to the existing specifications; the specifications are published in releases, with each new release comprising a number of functional enhancements to the previous release.
- **Stage 2: Architecture**: The development of new functions starts with the design of the overall architecture of the solution and the definition of basic message flows.
- **Stage 3: Protocols and procedures**: Based on the Stage 2 results, protocols and detailed procedures of the solution are specified in Stage 3. Implementation of functions in products can start with the completion of this stage, which provides all the necessary information.

  While Stage 2 and Stage 3 specifications provide a choice of implementation options for particular functions, as in the case of the IEEE 802.16 radio interface specification, a profile document lists the selected options for certification and interoperability testing.
- **Stage 4: Conformance statements**: For the development of the interoperability tests a conformance statements document details and lists all the functions which are subject to the tests. The implementation conformance statements are captured in a derived document, which allows manufacturers to specify which of the listed functions are supported by their implementations.

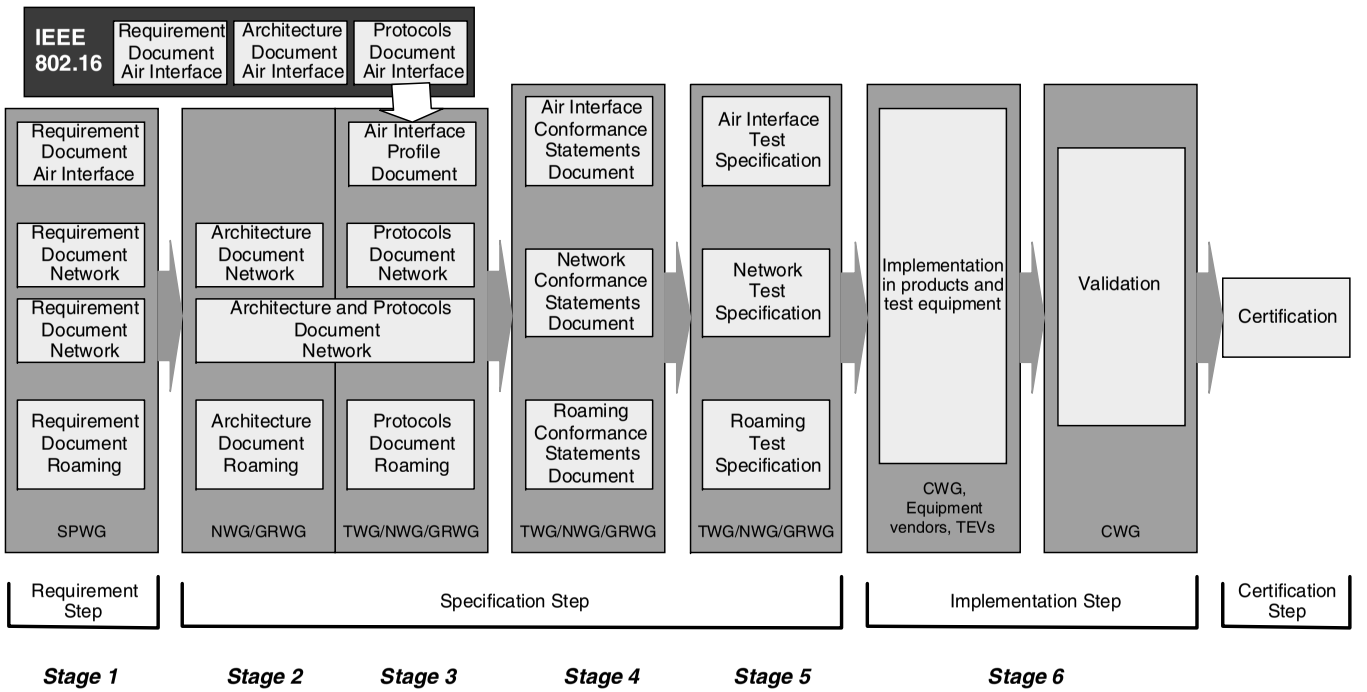

Figure 1.3 WiMAX Forum six-stage development process

- **Stage 5: Test procedures**: This stage of the development process defines all the test purposes and procedures for each of the functions listed in the conformance statements.
- **Stage 6: Certification process**: This stage consists of the detailed processes of the certification and interoperability testing based on the results of Stage 5 as well as the templates for capturing and documenting the outcome of the certification and interoperability testing.

The six-stage development process of the WiMAX Forum generates all the paperwork necessary to develop and verify interoperable implementations of the Mobile WiMAX technology.

1.2.3 Documentation Structure of the WiMAX Forum

The documentation structure of the WiMAX Forum is closely aligned to the six-stage development process. It defines a separate series for each of the stages of the specification areas (Figure 1.4).

All the technical specifications are captured in the series starting with the capital 'T'. The first digit of the series number denotes the technical area – air interface, network, roaming – while the second digit reflects the particular stage to which the documents belong. The series number starts with a capital 'C' for the certification documents. Figure 1.5 shows the complete set of series numbers currently defined by the WiMAX Forum.

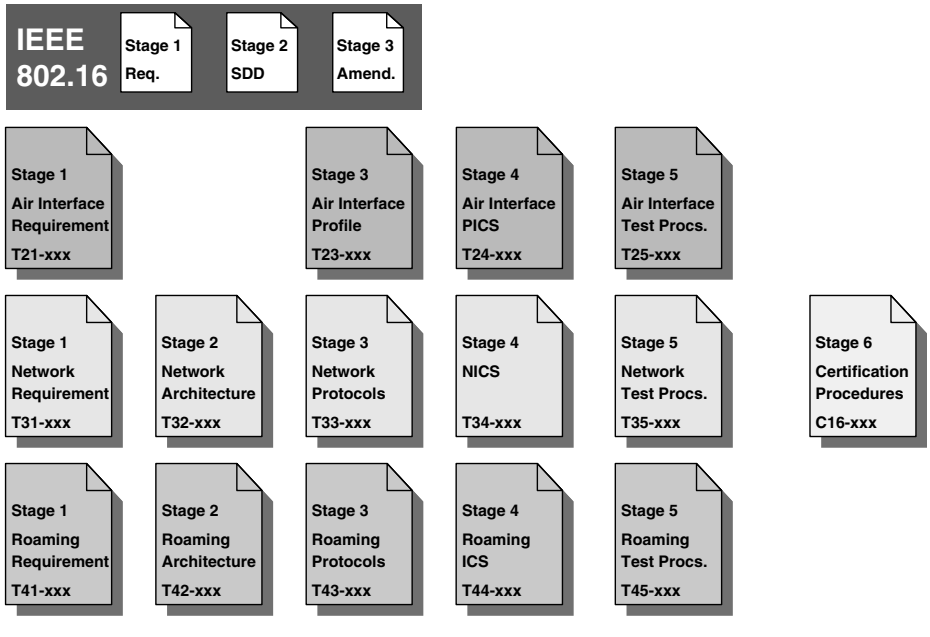

Figure 1.4 Documentation structure

A1x WiMAX Forum Processes Administrative Aspects	C1x Certification Aspects	T1x Overall Deployment, Application and OAM
A11: Policies and Procedures A12: Release Plans	C11: Instructions C12: Policies C16: Procedures	T11: End-to-end Requirements T12: WMF Credentials (X.509) T13: Application level issues T14: Spectrum policies issues
T2x Air Interface	**T3x Network**	**T4x Roaming**
T20: Air Interface Guidelines T21: Air Interface Requirements T22: Air Interface Stage 2 T23: Air Interface Specifications T24: Conformance Statements T25: Test Procedures T26: Reserved T27: Spectrum Issues and Coexistence	T30: Network Guidelines T31: Network Requirements T32: Architecture T33: Protocol Specifications T34: Conformance Statements T35: Test Procedures T36: Reserved T37: Interworking Specifications	T40: Roaming Guidelines T41: Roaming Requirements T42: Architecture T43: Protocol Specification T44: Conformance Statements T45: Test Procedures T46: Reserved T47: Interworking Specifications T48: Agreements T49: Information

Figure 1.5 WiMAX Forum documentation: series numbers

The series numbers form the base of the document identifiers used by the WiMAX Forum. Within a series, each document is identified by a serial number, the release number to which it belongs, as well as a version number indicating maintenance updates of the document. Document identifiers of approved WiMAX Forum documents are preceded by the string 'WMF-', work in progress contains 'DRAFT-' instead of 'WMF-'.

Figure 1.6 explains the anatomy of document identification in the WiMAX Forum.

The document identifier of approved specifications starts with the letters 'WMF' in front of the series number and the serial number of the specification within its series, followed by the release number it was created for, and concludes with a version number, indicating the maintenance cycles it stems from. Initial editions of specifications carry the version number 'v01'.

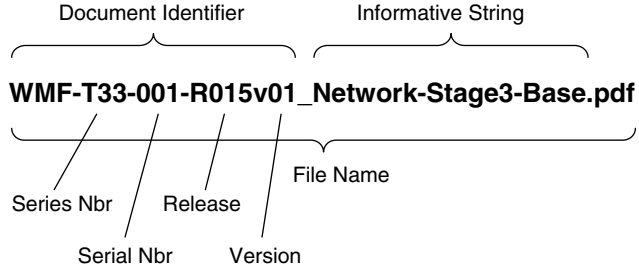

Figure 1.6 Anatomy of the WiMAX Forum document identification

An informative string indicating the title of the specification is appended to the document identifier to form the file name of the document. The informative string is added to enable easier browsing and searching in file archives for particular specifications. The document identifier would be sufficient, as it is unique and concise, but human beings often appreciate additional information which is more meaningful to them.

The complete specification of the WiMAX Forum documentation structure and identification, as well as the release structure and process, is available from [112] and [113].

1.3 About This Book

The structure of this book is guided by the aim to provide an overview of the technology and a foundation for stepping deeper into specifications and deployment planning. It follows a top-down approach by providing first the big picture and general principles and then delving deeper into technical issues throughout the course of the book.

The book mostly covers what is contained in Release 1.5 of the WiMAX Forum. It consists of eight chapters starting with the positioning of Mobile WiMAX in the telecommunication landscape and an introduction to the overall structure of the specifications, and concludes with a look at future enhancements of the network and radio architecture as visible in the release planning of the WiMAX Forum and accompanying specifications in IEEE 802.16.

Chapter 2 provides an introduction to the Mobile WiMAX network architecture as a result of the design of a mobile network fully aligned to the Internet network and business model for offering broadband IP services. In addition to the presentation of the WiMAX roaming architecture and the wireless DSL deployment option, the chapter contains a comparison between Mobile WiMAX and the enhanced system architecture evolution of the 3GPP.

The following chapter addresses the security and subscription-related aspects of Mobile WiMAX starting with an explanation of the authentication procedures for devices, as well as for subscriptions, in addition to an overview of the EAP methods and the certificates and public key infrastructure which are used for it. The chapter comprises as well considerations about the overall security design in WiMAX and the identities which are part of or involved in the security procedures. The chapter concludes with a description of the AAA protocols and the AAA routing issues.

Services and the management of services from a Mobile WiMAX network are the topics of Chapter 4. After an introduction to the AAA-related aspects of accounting and charging, the QoS concept and QoS management with and without the involvement of a dedicated PCC function are explained. After laying the foundation of service provisioning, the chapter presents the supporting location information, IMS and emergency services in more detail.

Chapter 5 provides an introduction to the mobility support in Mobile WiMAX, which is composed of ASN-anchored mobility functions and CSN-anchored Mobile IP support. The chapter elaborates all the PMIP and CMIP versions used in the architecture, and also explains the network architecture option without Mobile IP support and functions in the ASN to restrict mobility support for particular subscribers to particular regions, as needed to fulfill regulatory requirements for fixed wireless access from a mobile network.

The basics of the WiMAX radio interface are covered in Chapter 6. It addresses the functions in the PHY layer as well as in the MAC layer, and provides insights into MAC layer

functionality for network entry and initialization, for connection management and QoS support, and for mobility support comprising handover functions as well as the extensions dealing with the sleep mode and the idle mode. Throughout the whole chapter, detailed references are made to the Release 1.0 profile of the IEEE 802.16 radio specification.

The extensions of the radio interface in the system profile Release 1.5 are the topics of Chapter 7. It presents the additional features which were added to build the radio interface specification for Release 1.5. Finally, Chapter 8 provides future perspectives of Mobile WiMAX.