

# Overview of Mobile WiMAX Technology and Evolution

*Kamran Etemad, Intel Corporation*

## ABSTRACT

Mobile WiMAX is a fast growing broadband access technology that enables low-cost mobile Internet applications, and realizes the convergence of mobile and fixed broadband access in a single air interface and network architecture. Mobile WiMAX combines OFDMA and advanced MIMO schemes along with flexible bandwidth and fast link adaptation, creating a highly efficient air interface that exceeds the capacity of existing and evolving 3G radio access networks. WiMAX networks, built on all-IP network architecture for plug and play network deployments, can support a mix of different usage and service models. While some consider mobile WiMAX as a candidate for the fourth generation of mobile networks, others view it as the first generation of mobile Internet technologies emerging from a wider ecosystem targeting to extend the success of WiFi over wide area networks supporting mobility. This article provides a high-level overview of mobile WiMAX technology and its evolution roadmap from both radio and network perspectives.

## INTRODUCTION

The increasing demand for mobile broadband access to multimedia and Internet applications and services over the last few years has created new interest among existing and emerging operators to explore new technologies and network architectures to offer such services at low cost to operators and end users.

It is also well understood by industry leaders that the move to next-generation mobile networks cannot be made just through offering higher data rates and greater system efficiencies. A paradigm shift in traditional cellular architecture, service offering, and ecosystem is needed to allow an Internet friendly framework and open access to innovative applications and services using novel business models. Along with increased and scalable data capacity and IP friendly architecture, the new frameworks also need to support new device distribution and subsidy models to bootstrap faster adoption of mobile Internet devices and services among users. This should be achieved while ensuring successful interoperability and roaming of retail devices across different networks. Motivated by

the success of WiFi and considering the need for such a paradigm shift, many vendors and operators joined forces in the WiMAX Forum and IEEE 802.16 to develop a new end-to-end (e2e) solution to address the new demands and opportunities.

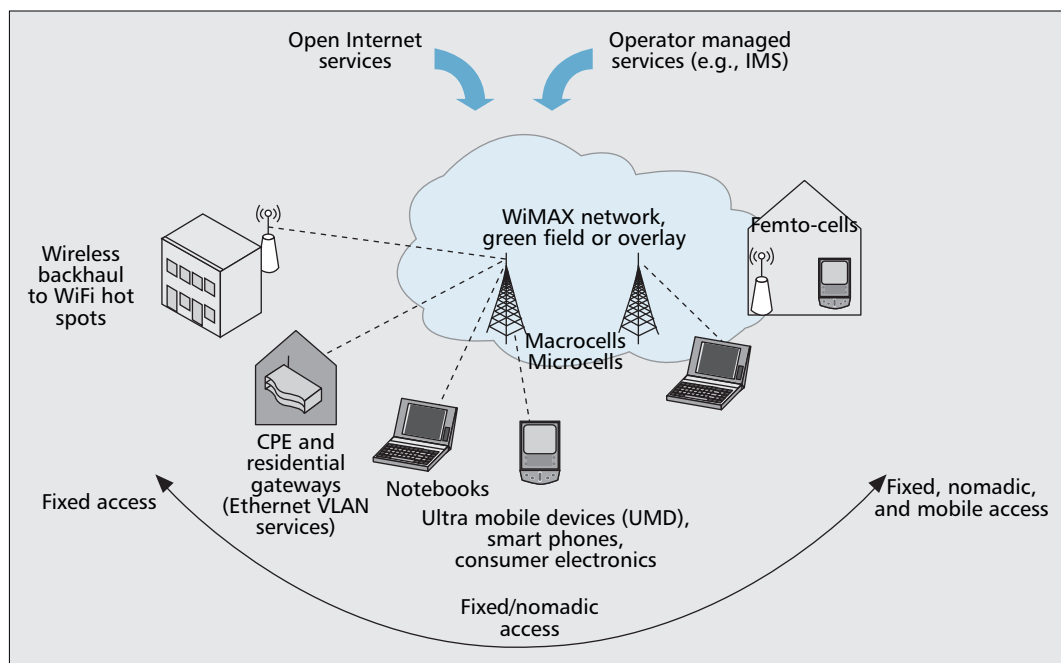
The industry quickly came to the conclusion that such a solution should be built around the following key technical concepts and objectives:

- Orthogonal frequency-division multiple access (OFDMA)-based multiple access with scalable bandwidth in downlink and uplink
- Advanced antenna technologies allowing beamforming and diversity through space-time coding and spatial multiplexing (SM)
- Adaptive physical layer (PHY) design using fast link adaptation combined with fast time and frequency scheduling
- All-IP flat network architecture supporting different deployment models and enabling both traditional operator-managed as well as new open Internet services
- Open standard interfaces enabling over-the-air as well as network interoperability in multivendor deployments

The IEEE 802.16 Working Group established by the IEEE Standards Board in 1999 has developed and published several versions of air interface standards for wireless metropolitan area networks (WMANs) with focus on medium access control (MAC) and PHY. While the initial versions of 802.16/a/d focused on fixed applications, the latest versions — 802.16-2005 (16e) amendment [1] and 802.16-REV2 — include many new features and functionalities needed to support enhanced quality of service (QoS) and mobility. The 802.16 Working Group is currently focusing on the specification for next-generation systems in the 802.16m Task Group.

The IEEE 802.16 standards define the structure of the PHY and link layer operations that occur between subscriber stations and base stations (BSs). However, the over-the-air upper layer signaling as well as network architecture and protocols behind the base stations required for an e2e specification are considered outside the scope of this standard. In addition, 802.16 MAC and PHY specifications, defined with a focus on flexibility, leave many options and allow various implementations of BS and mobile station (MS) features, which, unless coordinated

The WiMAX architecture enables open access to Web based applications and enhanced Internet services as well as operator managed "Walled Garden" services in the same network, allowing operators to explore creative service offerings and Internet friendly business models.



■ Figure 1. Mobile WiMAX enabling a variety of usage models in the same network.

for interoperability, can result in incompatible products.

The WiMAX Forum was established in 2003 to promote and enable deployment of WiMAX as a new broadband access technology based on 802.16 standards. To achieve this goal, the WiMAX Forum initiated several technical specification efforts to complement IEEE 802.16 standardization by defining minimum product interoperability requirements or system profiles as well as protocol and radio conformance testing specifications to be used as a basis for industry-wide certification of devices and BSs. In addition to developing testing specifications, the WiMAX Forum has also established certification laboratories, and manages the conformance and interoperability testing to ensure that all WiMAX Certified products across different implementations work seamlessly with one another.

To extend the scope of interoperability beyond the air interface and based on service providers' requirements, the WiMAX Forum also defines e2e network architectures and protocols specification [2] based on, and consistent with, IEEE 802.16 and WiMAX system profile air interface definitions. The network specification efforts in WiMAX Forum involve interactions with other standard organizations such as the Internet Engineering Task Force (IETF), Third Generation Partnership Project (3GPP), 3GPP2, DSL Forum, and Open Mobile Alliance (OMA).

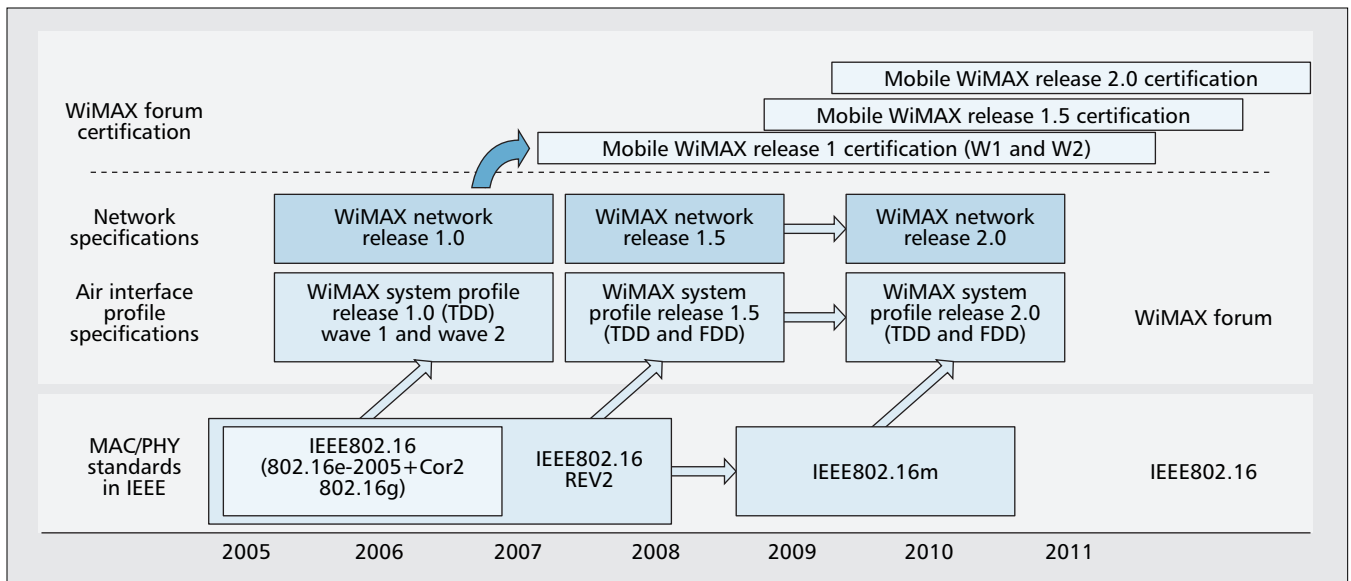
Mobile WiMAX, based on 802.16 standards, which is also approved by the International Telecommunication Union (ITU) for IMT2000 technology as OFDMA-time-division duplex (TDD)-WMAN, is designed and now well positioned to realize the convergence of fixed and mobile broadband access in one simple network. While the technology is primarily focused on IP protocols and solutions, it also supports Ether-

net as an option, which is important for some fixed access deployments.

A WiMAX network can be deployed as a green field network without any unnecessary complexity due to legacy circuit-switched system support. It can also be deployed as an overlay to existing fixed or mobile access networks such as 2.5G/3G cellular systems or cable/digital subscriber line (DSL) networks by supporting different levels of interworking to ensure service continuity. The same network can be used for a variety of usage models such as wireless backhaul to WiFi hot spots, fixed/nomadic access to customer premises equipment (CPE) and residential gateways (RGs), and mobile access to notebooks, smart phones, and next-generation WiMAX embedded ultra-mobile devices (Fig. 1).

The WiMAX architecture also enables open access to Web-based applications and enhanced Internet services as well as operator managed "walled garden" services in the same network, allowing operators to explore creative service offerings and Internet friendly business models. To complement that, the over-the-air activation protocols and associated network conformance testing and certification in the WiMAX Forum are structured to ensure successful network entry and provisioning of a variety of mobile Internet devices, including embedded communications devices and consumer electronics distributed through retail channels.

In the following sections we present a high-level overview of mobile WiMAX technology and its roadmap from both the radio and network perspectives. We provide a high-level overview of standardization roadmap and timelines in IEEE 802.16 and the WiMAX Forum. We present an overview of WiMAX network architecture and evolution, and then summarize the protocol structure as well as key MAC/PHY features of the air interface and system profile. We provide some concluding remarks about the



■ **Figure 2.** Mobile WiMAX technology and network evolution roadmap.

technology and its prospects for enabling mobile Internet. This article does not address the issue of mobile WiMAX performance, which requires careful elaboration on various assumptions.

## WiMAX TECHNOLOGY ROADMAP AND TIMELINES

WiMAX technology development and evolution rely on cooperative and complementary efforts in the WiMAX Forum and IEEE 802.16. In this article we skip discussions on early versions of WiMAX technology, which primarily addressed fixed network applications, and focus instead on mobile WiMAX systems and their evolution in the near and long term. Figure 2 shows a high-level view of this evolution, and captures different key elements of mobile WiMAX standardization and certification. Note that the standardization and certification timelines presented are projections and subject to change due to different factors.

The Mobile WiMAX Release 1.0 System Profile [3], based on 802.16e or 802.16-2005, was completed in late 2006, and the radio-level certification of products began in 2007. The certification follows a phased approach to address deployment priorities and vendor readiness.

System Profile Release 1.0 includes all 802.16-2005 mandatory features, and also requires some of the optional features needed for enhanced mobility and QoS support. This system profile is based on OFDMA, and enables downlink and uplink multiple-input multiple-output (MIMO) as well as beamforming (BF) features. The release 1.0 system profile is defined only for the TDD mode of operation, with more focus on 5 and 10 MHz bandwidths in several band classes in 2.3 GHz, 2.5 GHz, and 3.5 GHz bands, but it also includes 8.75 MHz specifically for Korea.

The WiMAX certification for the release 1.0 profile started with a Wave 1 subset, excluding MIMO and a few optimization features, to

enable early market deployments. This was followed by Wave 2, which progressively adds more and more feature tests over time based on vendors and testing tool availability. The early phases of certification were also limited to MAC and PHY layer conformance and interoperability testing, which will be expanded to add network-level testing.

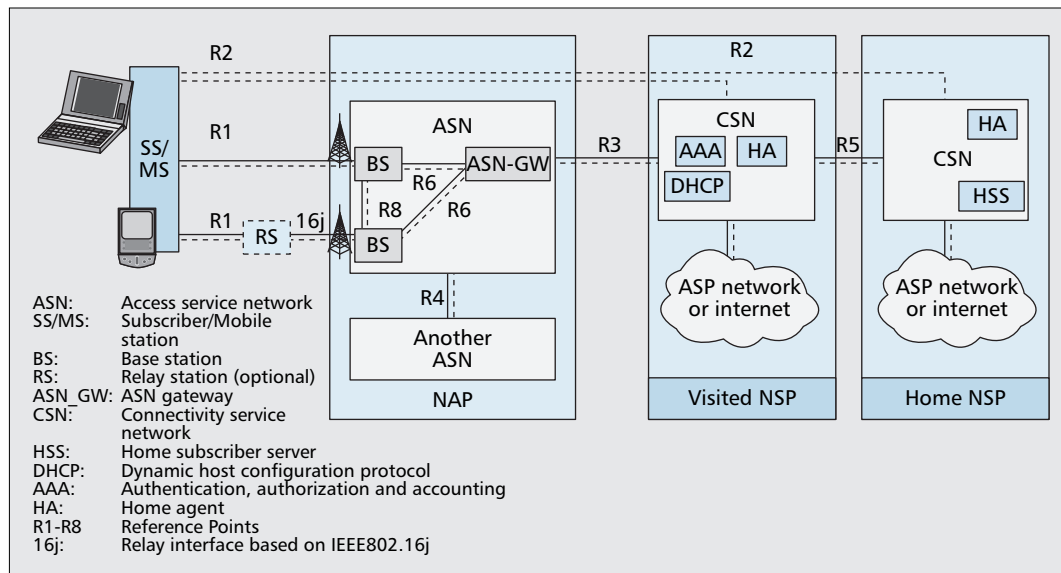
Meanwhile, the development of WiMAX Forum Network Release 1.0 was completed in 2007, based on which the specific network-level device conformance testing as well as infrastructure interoperability testing projects were initiated. The goal was to ensure e2e interoperability of WiMAX devices with networks and also ensure multivendor plug and play network infrastructure deployments. Release 1.0 defines the basic architecture for IP-based connectivity and services while supporting all levels of mobility.

Based on operators' requirements for advanced services and new market opportunities to be more competitive with evolved 3G systems, the WiMAX Forum initiated interim releases for both the system profile and network without major modifications to the IEEE 802.16 standard.

The work on network release 1.5 network specifications was started in parallel, aimed primarily at enabling dynamic QoS and provisioning of open retail device and support for advanced network services as well as commercial grade VoIP.

The release 1.5 system profile work item was initiated to enable mobile WiMAX in new spectrum including frequency-division duplex (FDD) bands, address a few MAC efficiency improvements needed for technology competitiveness, and align the system profile with advanced network services supported by network release 1.5. All required fixes and minor enhancements needed to support release 1.5 are incorporated in IEEE 802.16 REV2, which combines the IEEE 802.16-2004 base standard plus IEEE 802.16e/f/g amendments and related corrigenda into one specification document.

The network architecture allows one NSP to have a relationship with multiple NAPs in one or different geographical locations. It also enables NAP sharing by multiple NSP's. In some cases the NSP may be the same business entity as the NAP.



■ Figure 3. WiMAX network reference model.

Following Release 1.5, the next major release of mobile WiMAX, Release 2.0, will be based on the next generation of IEEE 802.16, which is being developed in the 16m technical group (TGM) of 802.16. WiMAX Release 2 targets major enhancements in spectrum efficiency, latency, and scalability of the access technology to wider bandwidths in challenging spectrum environments. Currently the expected timeline for the formal completion of 802.16m and WiMAX Certification of Release 2 products are early 2010 and early 2011, respectively. In parallel with developments in IEEE on the stage 2 system-level description of 802.16m, the requirements for network release 2.0 are being discussed in the WiMAX Forum, where stage 2/3 specifications are expected to be completed by 2010.

## WIMAX NETWORK ARCHITECTURE AND EVOLUTION

The WiMAX network architecture is designed to meet the requirements while maximizing the use of open standards and IETF protocols in a simple all-IP architecture. Among the design requirements are supports for fixed and mobile access deployments as well as unbundling of access, connectivity, and application services to allow access infrastructure sharing and multiple access infrastructure aggregation.

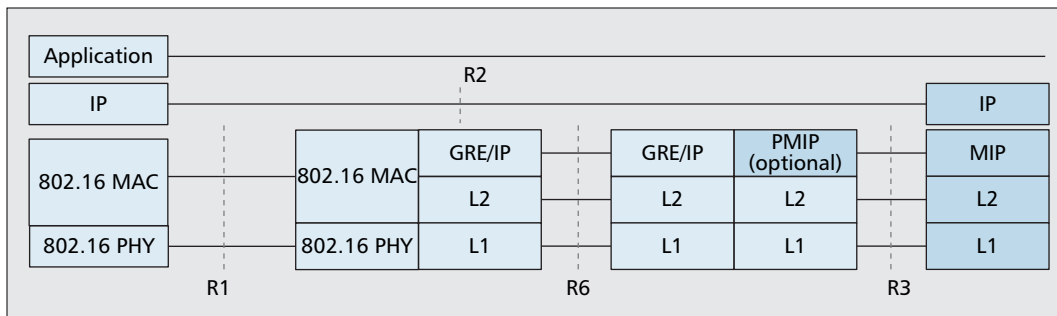
### BASILINE NETWORK REFERENCE MODEL

The baseline WiMAX network architecture can be logically represented by a network reference model (NRM), which identifies key functional entities and reference points over which the network interoperability specifications are defined [2]. The WiMAX NRM differentiates between network access providers (NAPs) and network service providers (NSPs). The NAP is a business entity that provides WiMAX radio access infrastructure, while the NSP is the business entity

that provides IP connectivity and WiMAX services to WiMAX subscribers according to some negotiated service level agreements (SLAs) with one or more NAPs. The network architecture allows one NSP to have a relationship with multiple NAPs in one or different geographical locations. It also enables NAP sharing by multiple NSPs. In some cases the NSP may be the same business entity as the NAP.

The WiMAX NRM, as illustrated in Fig. 3, consists of several logical network entities: MSs, an access service network (ASN), and a connectivity service network (CSN), and their interactions through reference points R1–R8. Each MS, ASN, and CSN represents a logical grouping of functions as described in the following:

- Mobile station (MS): generalized user equipment set providing wireless connectivity between a single or multiple hosts and the WiMAX network. In this context the term MS is used more generically to refer to both mobile and fixed device terminals.
- Access service network (ASN): represents a complete set of network functions required to provide radio access to the MS. These functions include layer 2 connectivity with the MS according to IEEE 802.16 standards and WiMAX system profile, transfer of authentication, authorization, and accounting (AAA) messages to the home NSP (H-NSP), preferred NSP discovery and selection, relay functionality for establishing layer 3 (L3) connectivity with MS (i.e., IP address allocation), as well as radio resource management. To enable mobility, the ASN may also support ASN and CSN anchored mobility, paging and location management, and ASN-CSN tunneling.
- Connectivity service network (CSN): a set of network functions that provide IP connectivity services to WiMAX subscriber(s). The CSN may further comprises network elements such as routers, AAA proxy/servers, home agent, and user databases as well as interworking gateways or enhanced



■ **Figure 4.** *WiMAX network uses IP based simple protocol structure.*

*The initial release of WiMAX Network Release 1.0 targeted basic mobile Internet services using an all IP architecture supporting both integrated and decomposed ASN profiles. This release supports all basic features needed to enable early WiMAX deployments.*

network servers to support multicast and broadcast services and location-based services. A CSN may be deployed as part of a green field WiMAX NSP or part of an incumbent WiMAX NSP. The following are some of the key functions of the CSN:

- IP address management
- AAA proxy or server
- QoS policy and admission control based on user subscription profiles
- ASN-CSN tunneling support
- Subscriber billing and interoperator settlement
- Inter-CSN tunneling for roaming
- CSN-anchored inter-ASN mobility
- Connectivity to Internet and managed WiMAX services such as IP multimedia services (IMS), location-based services, peer-to-peer services, and broadcast and multicast services
- Over-the-air activation and provisioning of WiMAX devices

The network supports two tiers of mobility architecture. ASN anchored mobility occurs on every BS handover, irrespective of IP subnet/prefix or Mobile IP foreign agent changes. This handover is completely transparent to the core network (CSN) as the ASN functions manage data path changes within or between ASNs to maintain uplink (UL) and downlink (DL) bearer paths for the MS. The CSN anchored handover is triggered when the foreign agent or IP subnet/prefix changes. This handover procedure is based on client or proxy Mobile IP for IPv4 or IPv6.

The ASN may be implemented as an integrated ASN where all functions are collocated in the same logical entity, or it may have a decomposed configuration in which the ASN functions are selectively mapped into two separate nodes, a BS and an ASN gateway (ASN-GW) (Figs. 3 and 4). A decomposed ASN may consist of one or more BSs and at least one instance of an ASN-GW. The BS and ASN-GW functions can be described as follows:

- Base station (BS): a logical network entity that primarily consists of the radio related functions of an ASN interfacing with an MS over-the-air link according to MAC and PHY specifications in IEEE 802.16 specifications subject to applicable interpretations and parameters defined in the WiMAX Forum system profile. In this definition each BS is associated with one sector with one frequency assignment but may incorpo-

rate additional implementation-specific functions such as a DL and UL scheduler.

- ASN gateway (ASN-GW): a logical entity that represents an aggregation of centralized functions related to QoS, security, and mobility management for all the data connections served by its association with BSs through R6t. The ASN-GW also hosts functions related to IP layer interactions with the CSN through R3 as well as interactions with other ASNs through R4 in support of mobility.

Typically multiple BSs may be logically associated with an ASN. Also, a BS may be logically connected to more than one ASN-GW to allow load balancing and redundancy options.

The WiMAX network specification defines a single decomposed ASN profile (ASN C) with an open R6 interface as well as an alternative ASN profile B that may be implemented as an integrated or a decomposed ASN in which R6 is proprietary or not exposed.

The normative definitions of intra-ASN reference points (R6 and R8) are only applicable to profile C. Note that in release 1.5 profile A has been removed to reduce the number of implementation options and create a better framework for network interoperability.

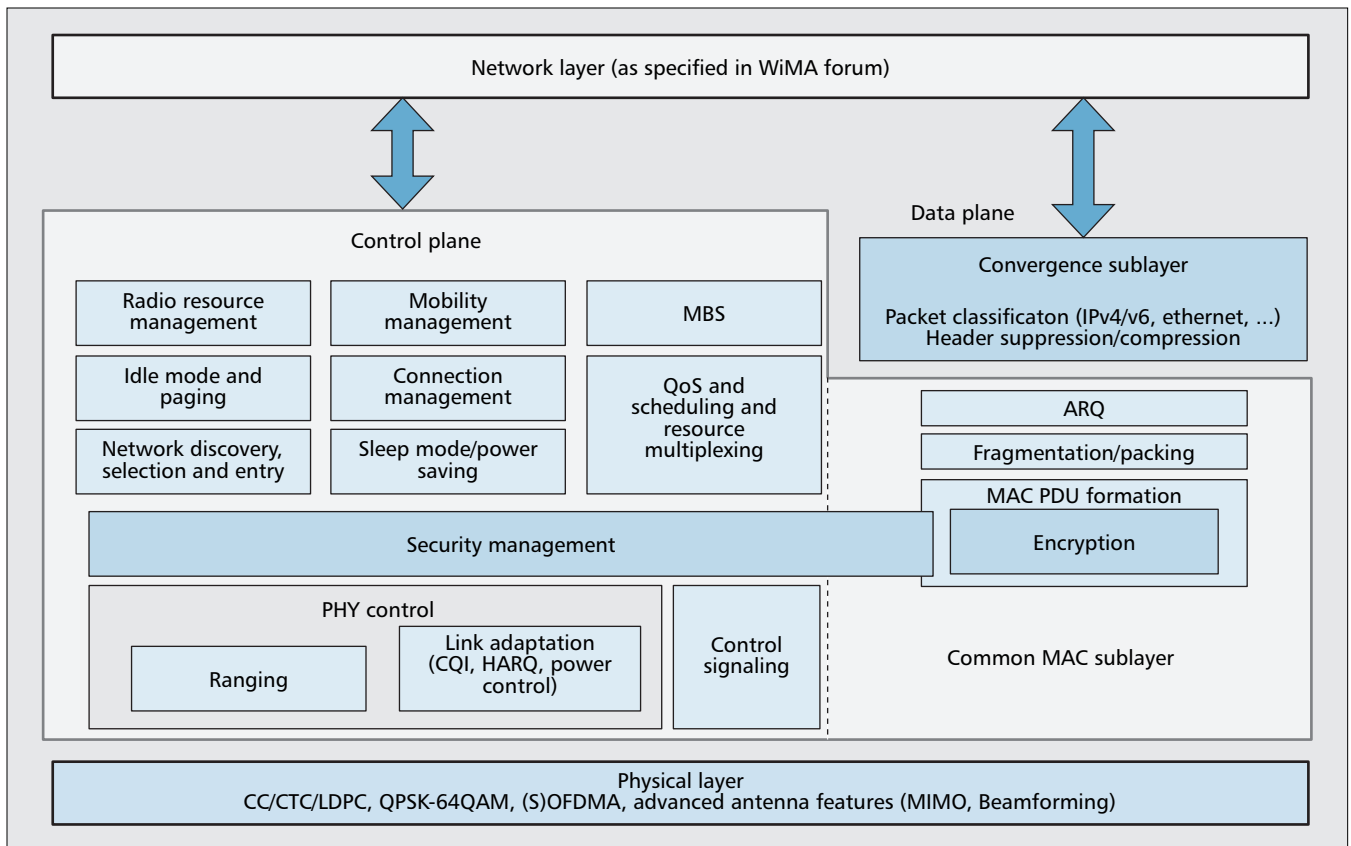
#### WIMAX NETWORK EVOLUTION

The mobile WiMAX roadmap currently shows three releases of the network specifications: 1.0, 1.5 and 2.0.

The initial release, 1.0, targeted basic mobile Internet services using an all-IP architecture supporting both integrated and decomposed ASN profiles. This release supports all basic features needed to enable early WiMAX deployments, including:

- ASN and CSN mobility (for mobility support)
- Paging and location management
- IPv4 and IPv6 connectivity
- Preprovisioned/static QoS
- Optional radio resource management (RRM)
- Network discovery/selection
- IP/Ethernet CS support
- Flexible credentials, pre- and postpaid accounting
- Roaming (RADIUS only)
- 3GPP I-WLAN compatible interworking

The WiMAX Network Release 1.5 development started in 2007 with a focus on enabling retail distributed devices, advanced managed IP



■ **Figure 5.** MAC/PHY protocol structure in mobile WiMAX release 1.0.

services, and 3G interworking as well as commercial grade VoIP. The following are some of the key features of network release 1.5:

- Over-the-air (OTA) activation and provisioning
- Location-based services (LBS)
- Multicast broadcast service (MBS)
- IMS integration
- Dynamic QoS and policy and charging (PCC) compatible with 3GPP Release 7
- Telephony VoIP with emergency call services and lawful interception
- Full NAP sharing support
- Handover data integrity
- Multihost support
- Ethernet services, VLAN, DSL IWK
- Enhanced open Internet services
- Diameter-based AAA

Release 1.5 also defines the normative R8 between BSs and discontinues ASN profile A, leaving only one R6 definition in a single decomposed ASN configuration (profile C).

#### PLANS FOR WIMAX NETWORK RELEASE 2.0

The full scope of WiMAX network release 2.0 has not been finalized, and it is expected to enable e2e features to complement enhancements made in System Profile Release 2.0 based on IEEE 802.16m. However, some features have already been identified by the WiMAX Forum driven by new deployment requirements to be considered following release 1.5, which may be integrated as part of release 2.0. The following are examples of such features:

- Multimedia session continuity

- 3GPP/2 interworking (optimized handover)
- Network management, including self-organized/optimized networks (SONs)
- Seamless WiFi-WiMAX handover
- Roaming enhancements
- Support for multihop relay stations
- Support for femto-cells
- Device reported metrics

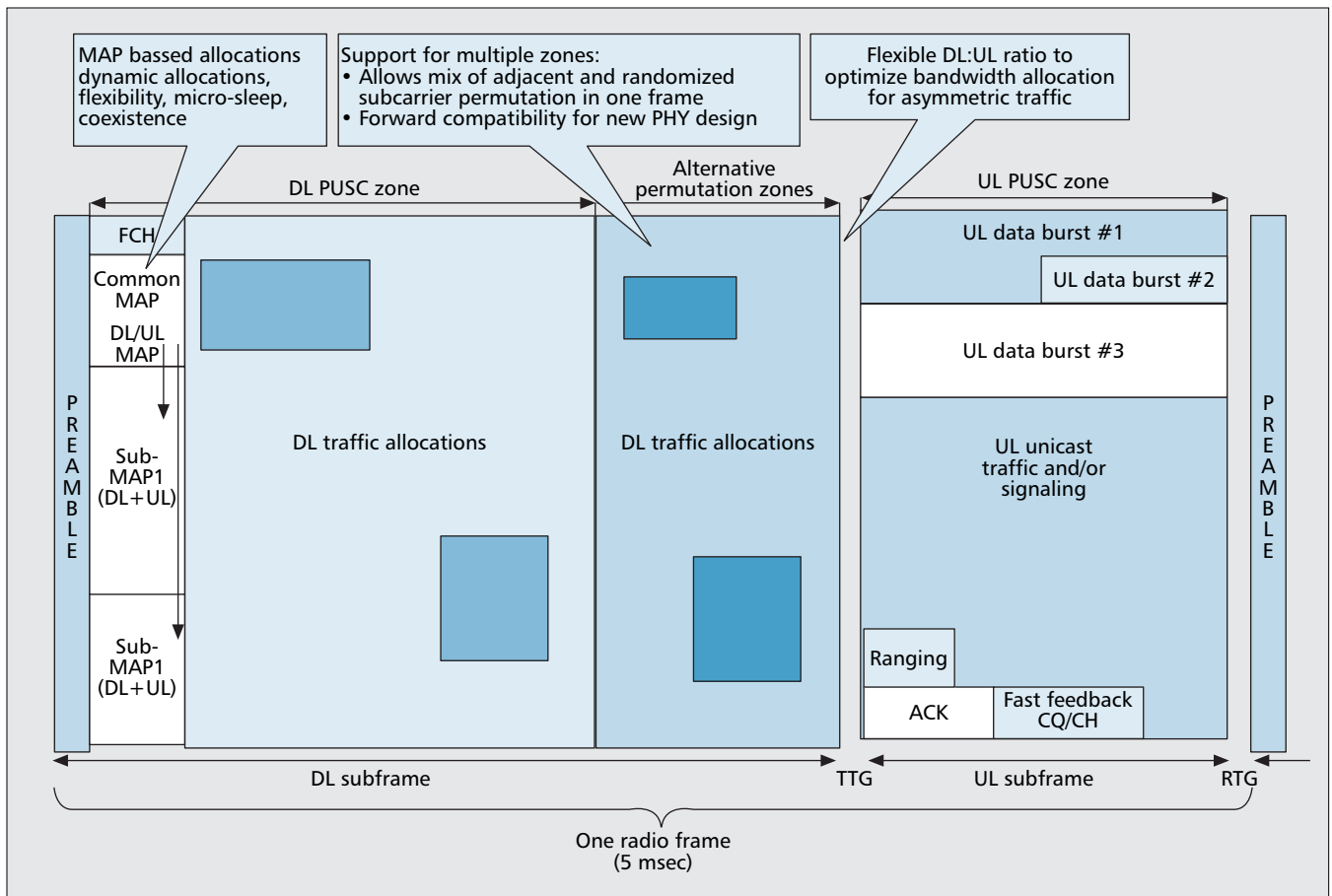
Some of features considered for release 2.0 may slightly change the baseline NRM by adding a few optional elements.

## WIMAX AIR INTERFACE AND EVOLUTION

The IEEE 802.16 standard in general defines several PHY modes; however, mobile WiMAX uses only the OFDMA PHY, which has also been the main focus of standardization since 2004. A convergence sublayer (CS) allows multiplexing various types of network traffic into the MAC layer. 802.16 MAC supports link layer security (encryption and message authentication), QoS differentiation among flows, connected mode mobility (handover), and idle mode mobility (location updates, paging).

#### BASIC PROTOCOL STRUCTURE

The high-level MAC/PHY protocol structure for mobile WiMAX as specified in IEEE 802.16-2005 is shown in Fig. 5. This structure is built on a simple OFDMA-based PHY and a MAC layer composed of two sublayers: the CS and MAC common part sublayer (MAC CPS).



■ Figure 6. Frame structure and channelization for TDD system in release 1.0.

The functional blocks in the CPS may be logically classified into upper MAC functions responsible for mobility control and resource management, and lower MAC functions that focus on control and support for the physical channels defined by the PHY. Although not formally separated in the standard, one may also classify functions into control plane and data plane functions.

The upper MAC functional group includes protocol procedures related to radio resource control and mobility related functions such as:

- Network discovery, selection, and entry
- Paging and idle mode management
- Radio resource management
- Layer 2 mobility management and handover protocols
- QoS, scheduling, and connection management
- Multicast and broadcast services (MBS)

On the control plane, the lower MAC functional group includes features related to layer 2 security and sleep mode management as well as link control and resource allocation and multiplexing functions.

The PHY control block handles PHY signaling such as ranging, measurement/feedback (CQI), and hybrid automatic repeat request (HARQ) acknowledgment (ACK)/negative ACK (NACK). The control signaling block generates resource allocation messages.

On the data plane, the ARQ block handles MAC ARQ function. For ARQ-enabled connec-

tions, the ARQ block logically splits MAC signaling data units (SDUs) into ARQ blocks and numbers each logical ARQ block. The fragmentation/packing block performs fragmenting or packing MSDUs based on scheduling results from the scheduler block.

### FRAME STRUCTURE AND PHYSICAL CHANNELIZATION

The IEEE802.16e PHY supports both TDD and (FDD) operation. The FDD mode also defines a half duplex FDD mode to support lower-complexity terminals in which one radio front unit is time-shared between UL and DL. While Mobile WiMAX Release 1.0 includes only the TDD profile, in Release 1.5 both TDD and FDD systems are supported.

Figure 6 illustrates the OFDMA frame structure for TDD mode, where each 5 ms radio frame is flexibly divided into DL and UL subframes. The DL and UL subframes are separated by small transmit/receive and receive/transmit transition gaps (TTG and RTG, respectively) to prevent DL and UL transmission collisions.

This frame structure defines the following physical channels:

- Preamble: broadcast in the first orthogonal frequency-division multiplexed (OFDM) symbol of the frame in DL and used by the MS initial and handover related scanning as well as PHY synchronization with the BS.

The IEEE 802.16e PHY supports both TDD and FDD operation. The FDD mode also defines Half Duplex FDD mode to support lower complexity terminals in which one radio front unit is time-shared between uplink and downlink.

Band class	Spectrum range (GHz) bandwidth (MHZ)	Bandwidth certification group code (BCG)
1 (Korea, South Asia)	2.3–2.4	
	8.75	1.A
	5 AND 10	1.B
2 (United States/Canada)	2.305–2.320, 2.345–2.360	
	3.5	2.A
	5	2.B
	10	2.C
3 (International: United States/Europe, IMT2000)	2.496–2.69	
	5 AND 10	3.A
4 (China/India)	3.3–3.4	
	5	4.A
	7	4.B
	10	4.C
5 (International: Europe/Asia)	3.4–3.8	
	5	5.A
	7	5.B
	10	5.C

■ **Table 1.** Mobile WiMAX TDD band classes for release 1.0.

- Frame control header (FCH): follows the preamble and provides the frame configuration information, such as MAP message length and coding scheme and usable sub-channels.
  - DL-MAP and UL-MAP: provide resource allocation and other control information for the DL and UL subframes, respectively. The MAP is typically broadcast across the cell using a robust modulation and coding scheme (MCS). To reduce the MAP overhead, the system may also define one or more multicast sub-MAPs that can carry traffic allocation messages at higher MCS levels for users closer to the BS and with higher CINR conditions.
  - UL ranging: The UL ranging subchannel is allocated for an MS to perform closed-loop time, frequency, and power adjustment as well as bandwidth requests.
  - UL CQICH: The UL CQICH channel is allocated for the MS to feedback channel state information.
  - UL ACK: The UL ACK is allocated for the MS to feedback DL HARQ ACKs.
- In IEEE 802.16-2005, the scalable OFDMA PHY defines channels ranging from 1.25 to 10 MHz and also includes a 20 MHz OFDMA chan-

nel with 2K fast Fourier transform (FFT). In the WiMAX Forum, however, based on market requirements and spectrum suitability, specific channel bandwidths are selected for product support and certification. Table 1 summarizes the channel sizes and band classes for TDD in release 1.0.

In mobile WiMAX the PHY layer defines various combinations of modulation and coding rates providing a fine resolution of data rates to be used as part of link adaptation. The 802.16 standard specified multiple channel coding schemes, including convolutional coding, convolutional turbo coding, and LDPC coding combined with both HARQ Chase and IR. The system profile, however, requires only convolutional and convolutional turbo coding combined with asynchronous HARQ Chase.

Table 2 shows the data rates for the 5 MHz channel with 512 FFT and the 10 MHz channel with 1K FFT assuming partial utilized subchannels (PUSC). The frame duration is 5 ms. Each frame has 48 OFDM symbols, with 44 OFDM symbols available for data transmission. The highlighted values indicate data rates for optional 64-quadrature amplitude modulation (QAM) in the UL.

Modulation	Code rate	5 MHz channel		10 MHz channel	
		Downlink rate (Mb/s)	Uplink rate (Mb/s)	Downlink rate (Mb/s)	Uplink rate (Mb/s)
QPSK	1/2 CTC, 6x	0.53	0.27	1.06	0.56
	1/2 CTC, 4x	0.79	0.41	1.59	0.84
	1/2 CTC, 2x	1.59	0.82	3.17	1.68
	1/2 CTC, 1x	3.17	1.63	6.34	3.36
	3/4 CTC	4.75	2.45	9.50	5.04
16-QAM	1/2 CTC	6.34	3.26	12.67	6.72
	3/4 CTC	9.50	4.90	19.01	10.08
64-QAM	1/2 CTC	9.50	4.90	19.01	10.08
	2/3 CTC	12.67	6.53	25.34	13.44
	3/4 CTC	14.26	7.34	28.51	15.12
	5/6 CTC	15.84	8.16	31.68	16.80

**Table 2.** Mobile WiMAX PHY data rates (PUSC, DL:UL [22:15], 11-symbol overhead, MIMO 2 × 2).

While the combination of mobility and Internet enables new killer applications and low cost service models, making such services available to a wide range of embedded retail devices including consumer electronics is expected to bootstrap the global adoption of technology in the next few years.

The initial scope of Mobile WiMAX Release 1.0 was limited to TDD systems. This was motivated by several technical advantages of TDD over FDD such as flexibility of DL/UL resource allocations to support variable traffic; channel reciprocity, which allows better support of closed loop link adaptation; and MIMO/beamforming and lower-complexity/cost transceiver designs.

Considering the significant market opportunities for FDD deployments and potential interference scenarios when TDD systems are deployed as overlay networks in the same or adjacent spectrum as/to traditional 3G systems, the industry decided to extend the system profile to include the FDD mode of operation starting with release 1.5.

### SYSTEM PROFILE EXTENSION IN RELEASE 1.5

Following the completion of System Profile Release 1.0 and based on new requirements for advanced network services and potential market opportunities in FDD spectrum, the WiMAX Forum started the development of an interim release 1.5 profile. System Profile Release 1.5 is simply an extension of release 1.0 without requiring major changes in the underlying IEEE 802.16 standards to address the following high-level strategic goals:

- To enable WiMAX deployment in paired spectrum by extending the TDD-based system profile to FDD mode of operation
- To add new system profile features and improvements needed to enable advanced services, such as location-based services and multicast/broadcast services enabled in network release 1.5
- To improve MAC layer efficiency with focus

on lowering MAP overhead especially for VoIP traffic and reducing latencies

- To explore other optional enhancements, such as closed loop MIMO, to further improve coverage and capacity for low-mobility usage

Despite the fact that 802.16-2005 had already defined FDD mode of operation standards, enabling FDD and the special case of half duplex FDD required some fixes and optimization features which are included in 802.16REV2.

### IEEE802.16M AND MOBILE WIMAX RELEASE 2

The system profile for the next generation of mobile WiMAX is expected to be based on IEEE 802.16m, which is targeted for completion in 2010 and certification/deployment in 2011/2012.

The following are some of the key enhancements expected in 802.16m:

- Higher spectrum efficiency through more advanced and higher-order MIMO solutions, including multiuser MIMO as well as lower MAC and PHY overhead
- Higher peak and user data rates using wider-band carriers (including 20 MHz) and multicarrier aggregation
- Enhanced coverage in high interference environments with improved preamble and control channel
- Lower latency through faster MAC/signaling
- Support for higher mobility through a faster feedback mechanism and link adaptation
- Flexible spectrum deployments (both FDD and TDD support in contiguous and non-contiguous bands)

- Optimizations for improved interworking and coexistence with other access technologies such as 3G systems, WIFI, and Bluetooth
  - Support for integrated multihop relay and femtocells
  - Improved power saving operation
- All features and enhancements in 802.16m/WiMAX release 2 are required to be backward compatible with previous releases.

## CONCLUSIONS

Mobile WiMAX technology has been developed and promoted by a large ecosystem of operators and vendors aimed at low-cost and scalable realization of fixed and mobile network convergence. The technology utilizes advanced PHY and MAC techniques in radio to provide high spectrum efficiency and QoS control as well as IP-based flat network architecture supporting multivendor plug and play deployments. Mobile WiMAX has defined the technology evolution roadmap for the next few years, which includes, but goes beyond, further improvements in system efficiency and user experience. The next generation of mobile WiMAX is expected to provide flexible deployment solutions such as multihop, femtocell, and multicarrier support as well as optimized coexistence and interworking with other access technologies such as WiFi, Bluetooth, and 3G systems. While the combination of mobility and Internet enables new killer applications and low-cost service models, making

such services available to a wide range of embedded retail devices including consumer electronics is expected to bootstrap the global adoption of technology in the next few years.

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## BIOGRAPHY

KAMRAN ETEMAD (kamran.etemad@intel.com) received his B.S. degree in electronic engineering from Sharif University of Technology, and M.S. and Ph.D. degrees in electrical engineering from the University of Maryland. Currently, he is the director of technology standards at Intel Corporation, where he leads various technical and strategic initiatives related to WiMAX technology. He has also served as the chair of the Technical Advisory Committee of the WiMAX Forum. Prior to Intel, he held senior technical and management positions with Sprint-Nextel as an executive technology consultant, WFI as vice president of advanced technology, and Hughes Network Systems as a senior member of technical staff. His current focus is on advanced development and standardization of the next generation of mobile broadband technologies and networks. He also actively contributes to IEEE 802.16m and various working groups of the WiMAX Forum. Some of his key areas of focus are network architecture/protocols for enhanced mobility, location, and multicast/broadcast services as well as advanced MAC and PHY design in 16m and other OFDMA systems. Prior to his involvement in WiMAX he also made many contributions in the development of cdma2000 technology in 3GPP2 and authored a book, *CDMA2000 Evolution*.