



The Evolution of IEEE 802.16 and Mobile WiMAX
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We Are **Wireless 2.0™**

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Outline

- ❖ Value of standards
- ❖ IEEE 802
- ❖ IEEE 802.16 Working Group
 - Organization and process
 - Participants
- ❖ IEEE 802.16 Standards and Projects
 - Existing standards
 - Projects in progress

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High-Level Global Issues in Broadband Wireless

- ❖ Access to spectrum on a technology-neutral basis
 - Harmonized spectrum is best!
- ❖ Global standards
 - Developed by global industry to meet global needs

Value of Standards in Broadband Wireless

- ❖ Reduced costs due to mass production
- ❖ Reduced operator risk
 - Multiples vendors competing to provide technological elements
- ❖ Opportunities for roaming
- ❖ Stimulate adoption of technology
- ❖ Platform for technical innovation
- ❖ Basis of harmonized spectrum and regulatory treatment
- ❖ Global standards benefit the **users** and the **producers**.

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Standards Cultures: Telecom vs Datacom

Telecom Standardization

- National
- Political

Datacom Standardization

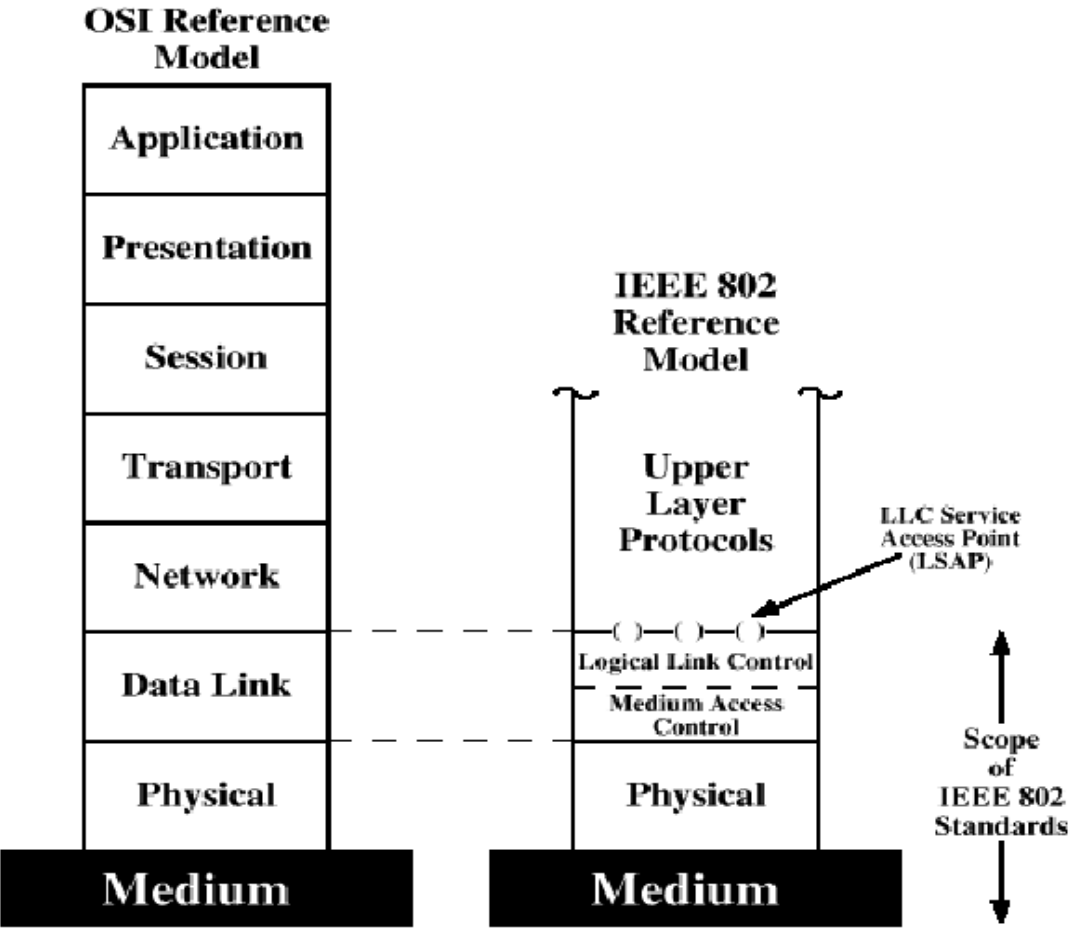
- Global
- Open
- Industry-Driven
- Key players
 - IETF
 - IEEE 802: LAN/MAN Standards Committee

Who are the Members?

- ❖ Telecom Standardization Bodies
 - Governmental Representatives
 - Companies

- ❖ IEEE
 - Engineers

Scope of IEEE 802 Standards



IEEE 802 Standards for Broadband Wireless

- ❖ IEEE 802.15 (personal range: ~10 m):
 - Wireless Personal Area Networks
- ❖ IEEE 802.11 (building range: ~100 m):
 - Wireless Local Area Networks
 - Often called “Wi-Fi” for “Wi-Fi Alliance”
- ❖ IEEE 802.16 (metro range: ~10 km):
 - Wireless Metropolitan Area Networks
 - Often called “WiMAX” for “WiMAX Forum”

Related IEEE 802 Activities

- ❖ Working Group (WGs) with standards
 - 802.1 WG: Upper-layer
 - 802.3 WG : Ethernet
- ❖ WGs without standards
 - 802.20: “Mobile Broadband Wireless Access”
 - 802.21: “Media-Independent Handover”
 - 802.22: “Wireless Regional Area Networks”
- ❖ Technical Advisory Groups (TAGs)
 - 802.18: Radio Regulatory
 - 802.19: Coexistence

IEEE 802 Process

- ❖ Call for Contributions
 - Specific topics for discussion at next meeting
- ❖ Receive and post written contributions
- ❖ Discuss and debate at meeting
- ❖ Create draft by 75% vote
- ❖ Working Group Ballot
- ❖ IEEE "Sponsor Ballot"
- ❖ Ballot Responses:
 - "Approve" (can include comments)
 - "Disapprove": indicate what needs to be changed to bring about an "Approve" vote

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IEEE 802. 16 Foundations: 1998

- ❖ Telecom vs. Datacom: distinct
- ❖ 3G discussions unsettled
- ❖ Broadband access expanding slowly
 - cable modem networks & DSL
- ❖ IEEE 802
 - Data networks dominated by Ethernet (802.3)
 - New 802.11 Wireless LAN standard
 - approved in 1997 (802.11a/b in 1999)
- ❖ 1998: IEEE 802 Study Group (SG) on Broadband Wireless Access (BWA)

First IEEE 802.16 Project: 1999

- ❖ Scope: Physical and MAC layer of the air interface of interoperable fixed point-to-multipoint broadband wireless access systems. The specification enables transport of data, video, and voice services. It applies to systems operating in the vicinity of 30 GHz but is broadly applicable to systems operating between 10 and 66 GHz.
- ❖ Purpose: To enable rapid worldwide deployment of innovative, cost-effective, and interoperable multivendor broadband wireless access products. To facilitate competition in broadband access by providing alternatives to wireline broadband access. To facilitate coexistence studies, encourage consistent worldwide allocation, and accelerate the commercialization of broadband wireless access spectrum.

Carrier-class wireless access

- Provide service competitive with wired broadband access
- Full QoS for full multimedia
 - From the ground up
- Fully support for IP and ATM

IEEE 802.16 Principle #2

❖ Fully exploit spectrum

- Spectrum is the most valuable resource
- Use every technological trick to maximum spectrum use
- Flexible support for multiple allocations
 - TDD, FDD, Half-duplex FDD, etc.
 - Multiple frequencies and bandwidths

IEEE 802.16 Principle #3

❖ Evolve

- Ethernet (802.3) development model
- Ethernet had evolved into 802.11
- Carry on that tradition (LAN -> MAN)
- Evolve for an evolving user base
 - Begin with fixed, line-of-sight antennas
 - Move to non-line-of-sight, portable, mobile
 - Support evolution of customer systems

IEEE 802.16 Principle #4

❖ Network model: Datacom

- Specify Layers 1&2 only
- Open interface to support any higher-layer network
- Radical compared to vertically-integrated telecom network
- Stimulates innovation
- Highly beneficial to users

❖ Standards model: Datacom

- Seek global applications
- Single global technical project
 - Avoid national politics
 - Balance technical and business needs
 - » Success requires both
- Open forum
 - No dominance; many contributors

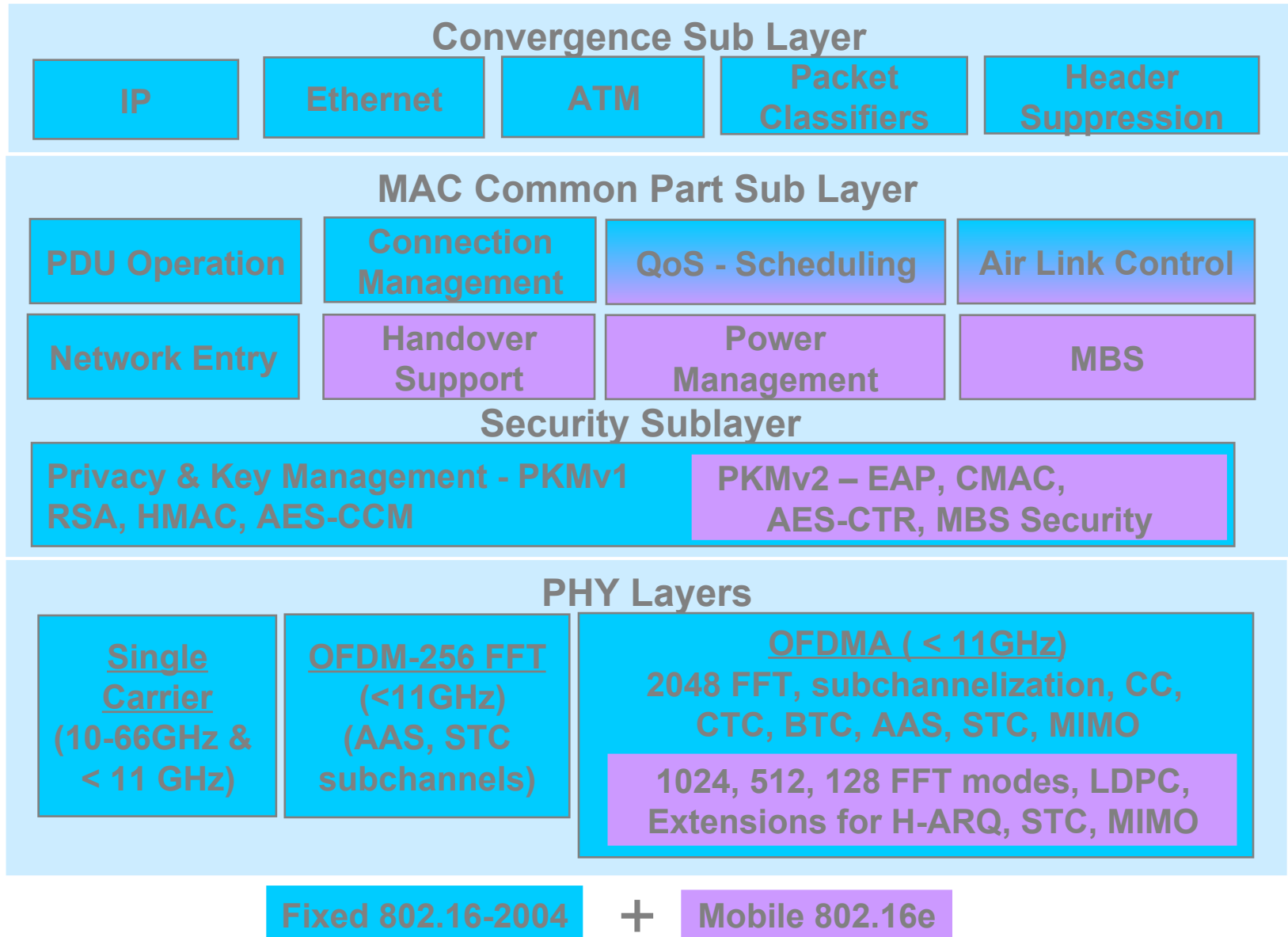
802.16 Wireless MAN: not a LAN

- ❖ Base Station (BS) connected to public networks
- ❖ BS serves Subscriber Stations (SSs)
- ❖ Provide SS with access to networks
 - SS can serve a building (business or residence)
 - SS can serve a Wireless LAN AP
 - SS can serve a mobile handset, PDA, etc.
- ❖ Compared to a Wireless LAN:
 - Multimedia QoS, not contention-based
 - Centrally scheduled
 - Many more users
 - Much higher data rates
 - Much longer distances

IEEE 802.16: Properties

- ❖ Lower network layers interface with multiple higher layers
- ❖ Supports multiple services simultaneously with full QoS
 - Efficiently transport IPv4, IPv6, Ethernet, ATM, etc.
- ❖ Broadband
- ❖ Bandwidth on demand (frame by frame)
- ❖ MAC designed for efficient use of spectrum
- ❖ Comprehensive, modern, and extensible security
- ❖ Supports multiple frequency allocations
 - OFDM and OFDMA for non-line-of-sight applications
- ❖ TDD and FDD (full-duplex and half-duplex)
- ❖ Link adaptation: Adaptive modulation and coding
 - Subscriber by subscriber, burst by burst, uplink and downlink
- ❖ Point-to-multipoint topology, with mesh extensions
- ❖ Support for adaptive antennas, space-time coding, MIMO
- ❖ Mobility
- ❖ New enhancements underway
 - license-exempt coexistence; multihop relay

IEEE 802.16 Features



IEEE 802.16: Myths and Facts

- ❖ Note: Myths may be true, or partially true.

Myth #1: An IEEE Project leads to an IEEE Standard

Reality:

- The identification “IEEE Standard” needs to be earned.
- “802.16” is the name of Working Group. And a standard.
- New project gets a number (e.g., P802.16j).
- If successful, an approved standard results (e.g., IEEE 802.16e). Requires many steps, including demonstrable consensus
- Not every standards project leads to a standard; e.g. P802.14
- 14 projects from IEEE 802.16 have been approved.

IEEE 802.16 standards as of 2004

Air Interface

802.16-2001
MAC
10-66 GHz PHY
Pub: Apr 2002

802.16c
>10 GHz Profiles
Pub: Jan 2003

802.16a
2-11 GHz PHY
Pub: Apr 2003

802.16-2004
Revision
Pub: Oct 2004

Conformance

802.16/Conf01
>10 GHz PICS
Pub: Aug 2003

802.16/Conf02
>10 GHz TSS&TP
Pub: Feb 2004

802.16/Conf03
>10 GHz RCT
Pub: Jun 2004

Coexistence

802.16.2-2001
Coexistence
Pub: Sep 2001

802.16.2-2004
Revision
Pub: Mar 2004



Recent & Active 802.16 Projects

Air Interface

802.16e
Mobile
Pub: Feb 2006

P802.16h
LE Coexistence

P802.16j
Relay

P802.16m
Advanced AI

P802.16/Rev2
Revision

Conformance

802.16 /Conf04
<11 GHz PICS
Pub. Jan 2007

Management

802.16f
MIB (fixed)
Pub: Dec 2005

802.16k
Bridging
Appr: Mar 2007

P802.16g
Management

P802.16i
MIB (mobile)

Myth #2: IEEE 802.16 is Company X's technology

Reality:

- ❖ Standards-development efforts conducted under the auspices of the IEEE must be conducted in a manner consistent with the principles of openness, balance, and the absence of domination.
- ❖ The IEEE 802 Executive Committee and the IEEE Standards Association's Standards Board ensure that standards meet the conditions.
- ❖ Like other IEEE 802 standards, IEEE 802.16 are broadly developed, with the participation of many individuals from many companies.
- ❖ Membership roster is 263; peak: 310.
- ❖ Domination by an organization contradicts the procedures.

Participation in IEEE 802.16

❖ *Open process and open standards*

❖ Anyone can participate in meetings

Anyone can participate outside of meetings

Subscribe to mailing lists and read list archives

Post to mailing lists

Examine documents

Contribute and comment on documents

Join the Sponsor Ballot Pool

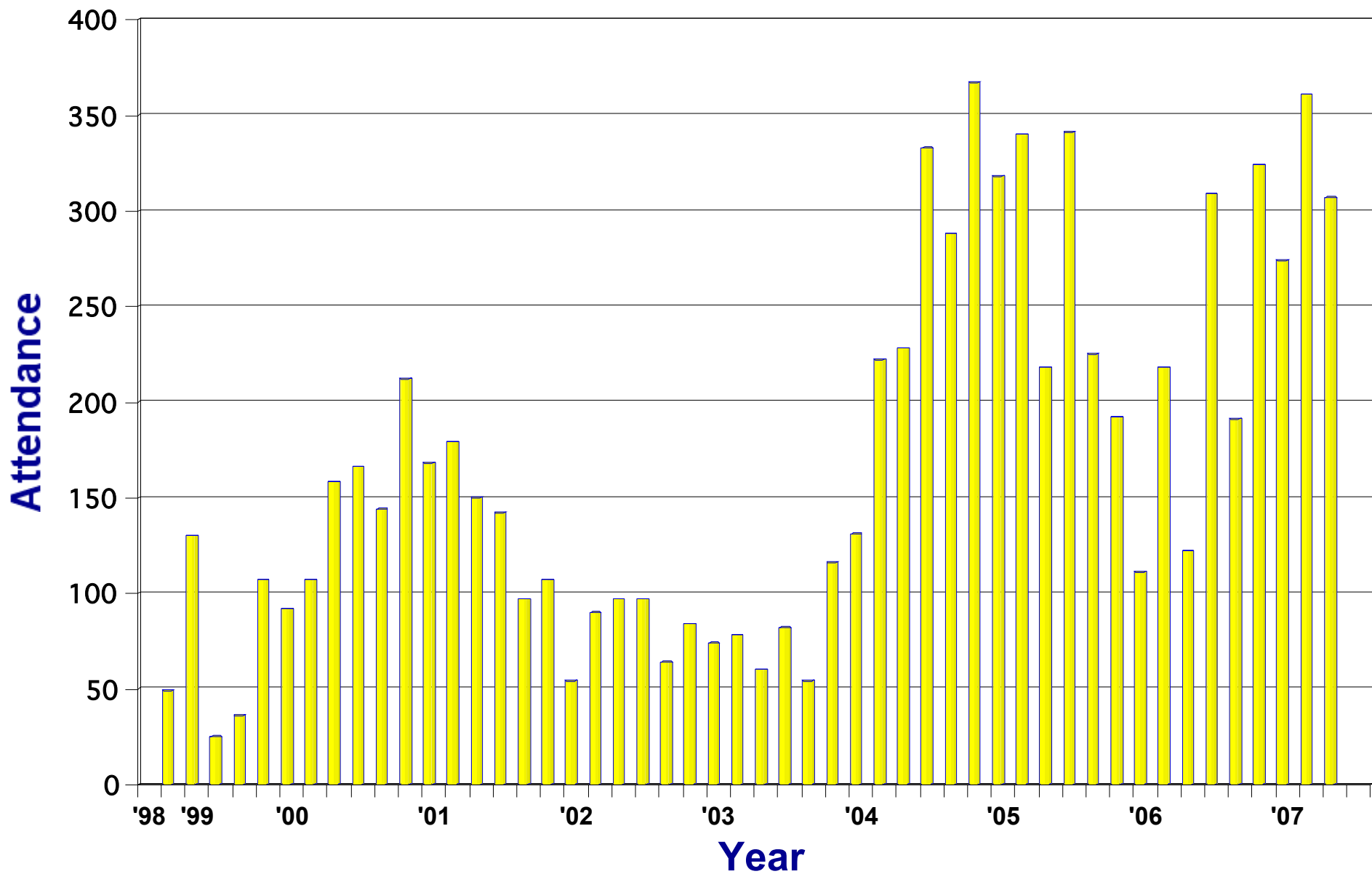
- Vote and comment on draft standards
- Must join the IEEE Standards Association to vote
- Producers and Users must both be in ballot group

Myth #3: 802.16 is “home-grown” in Country Y

Reality:

- ❖ IEEE 802.16 Working Group has made a conscious effort to be applicable worldwide.
- ❖ Therefore, we made a conscious effort to attract worldwide participation. Attendees from Australia, Belgium, Brazil, Canada, China, Finland, France, Germany, Greece, Hong Kong, India, Ireland, Israel, Italy, Japan, Korea, Netherlands, Norway, Pakistan, Romania, Russia, Singapore, Spain, Sweden, Taiwan, Thailand, USA, UK.
- ❖ Major coordination efforts:
 - Europe, Korea, China, Japan; ITU-R

IEEE 802.16 Session Attendance



IEEE 802.16 Session History

#31/May'04:	Shenzhen	China	228
#32/Jul'04:	Portland	USA	332
#33/Sep'04:	Seoul	Korea	287
#34/Nov'04:	S. Antonio	USA	367
#35/Jan'05:	Sanya	China	313
#36/Mar'05:	Atlanta	USA	330
#37/May'05:	Sorrento	Italy	218
#38/Jul'05:	San Francisco	USA	341
#39/Sep'05:	Taipei	Taiwan	225
#40/Nov'05:	Vancouver	Canada	225
#41/Jan'06:	New Delhi	India	111
#42/Mar'06:	Denver	USA	218
#43/May'06:	Tel Aviv	Israel	122
#44/Jul'06:	San Diego	USA	309
#45/Sep'06:	Mt Tremblant	Canada	191
#46/Nov'06:	Dallas	USA	324
#47/Jan'07:	London	UK	274
#48/Mar'07:	Orlando	USA	361
#49/May'07:	Portland	USA	307

IEEE 802.16 Members by Address

- ❖ 110 USA
- ❖ 56 Korea
- ❖ 18 Canada
- ❖ 14 Japan
- ❖ 13 China (PRC)
- ❖ 12 Taiwan
- ❖ 11 Israel
- ❖ 6 UK
- ❖ 6 France
- ❖ 6 Germany
- ❖ 3 Netherlands
- ❖ 3 Sweden
- ❖ 2 Italy
- ❖ 2 Finland
- ❖ 1 Singapore

- ❖ 263: TOTAL

Myth #4: The Korean “WiBro” competes with 802.16

Reality:

- ❖ Korean Ministry of Information and Communication announced (29 July 2004) that Portable Internet Service (WiBro) using the 2.3 GHz spectrum “must comply with IEEE 802.16-2004 and IEEE 802.16e/Draft3 or later versions.”
- ❖ WiBro is a service
- ❖ WiBro is not a technology
- ❖ WiBro is not a standard

Myth #5: 802.16 is not an “International” Standard

Reality:

- ❖ IEEE 802 standards are developed by individual people, not by nations, so are not “Inter-National”.
- ❖ The WTO refers to “appropriate international standardizing bodies” but does not restrict the definition to organizations that are “one country, one vote”.

Internationalization of IEEE 802.16

International Telecommunication Union (ITU)

- organized under United Nations
- membership by national governments
- Radiocommunications Sector (ITU-R)
- private organizations are “sector members”
- IEEE: Sector Member of ITU-R
 - “Regional and other International Organizations”

IEEE 802.16 and ITU

ITU-R:

- WP 9B: fixed wireless access
 - ITU-R Recommendation F.1763 (published 4 Sept 2006) recommends the use of IEEE 802.16-2004 for broadband wireless access systems in the fixed service
- WP 8A: land mobile radio:
 - M.1801 (8 March 2007) recommends the use of IEEE Std 802.16 (inc 802.16e) in the mobile service
- WP 8F:
 - IMT-2000: contribution on IP-OFDMA
 - IMT-Advanced: participation

IMT-2000: “International Mobile Telecommunications”

Under ITU-R Study Group 8/Working Party 8F

The primary standard for “3G” cellular

- significant impact on spectrum allocations

Since 1998, 5 evolving terrestrial air interfaces

- inc. 3GPP (W-CDMA) & 3GPP2 (cdma2000)

Nov 2007: IEEE applied to join IMT-2000

- Proposed “IP-OFDMA” based on IEEE 802.16
- Supported by WiMAX Forum

IMT-2000 Progress and Status

Working Party 8F: Jan 2007 in Cameroon

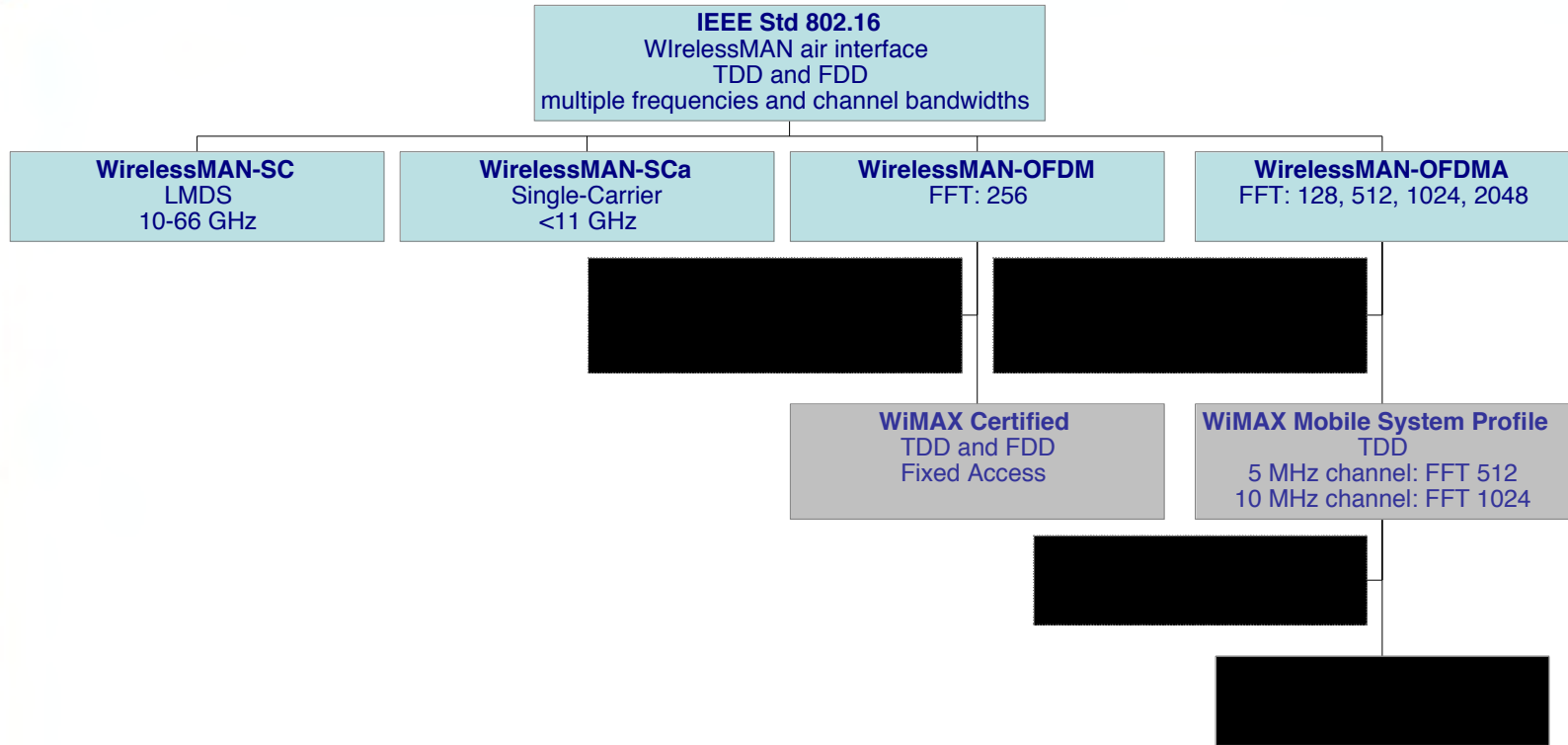
- invited “Evaluation Groups
- eight reports, from Brazil, Canada, China, Israel, Japan, Korea, USA (ATIS); and WCA

Working Party 8F: May 2007 in Kyoto

- strong support by many govts. to include *now*
- strong opposition from a few companies
- Drafted new IMT-2000 rev. including IP-OFDMA
 - renamed “IMT-2000 OFDMA TDD WMAN”
- Forwarded to Study Group 8 (25-26 June)
 - decided to arrange “special meeting” in August 2007

IEEE Standard 802.16 and its Derivatives

WirelessMAN Standard for Wireless Metropolitan Area Networks



IMT-Advanced

Plan to develop “Beyond IMT-2000” recommendations

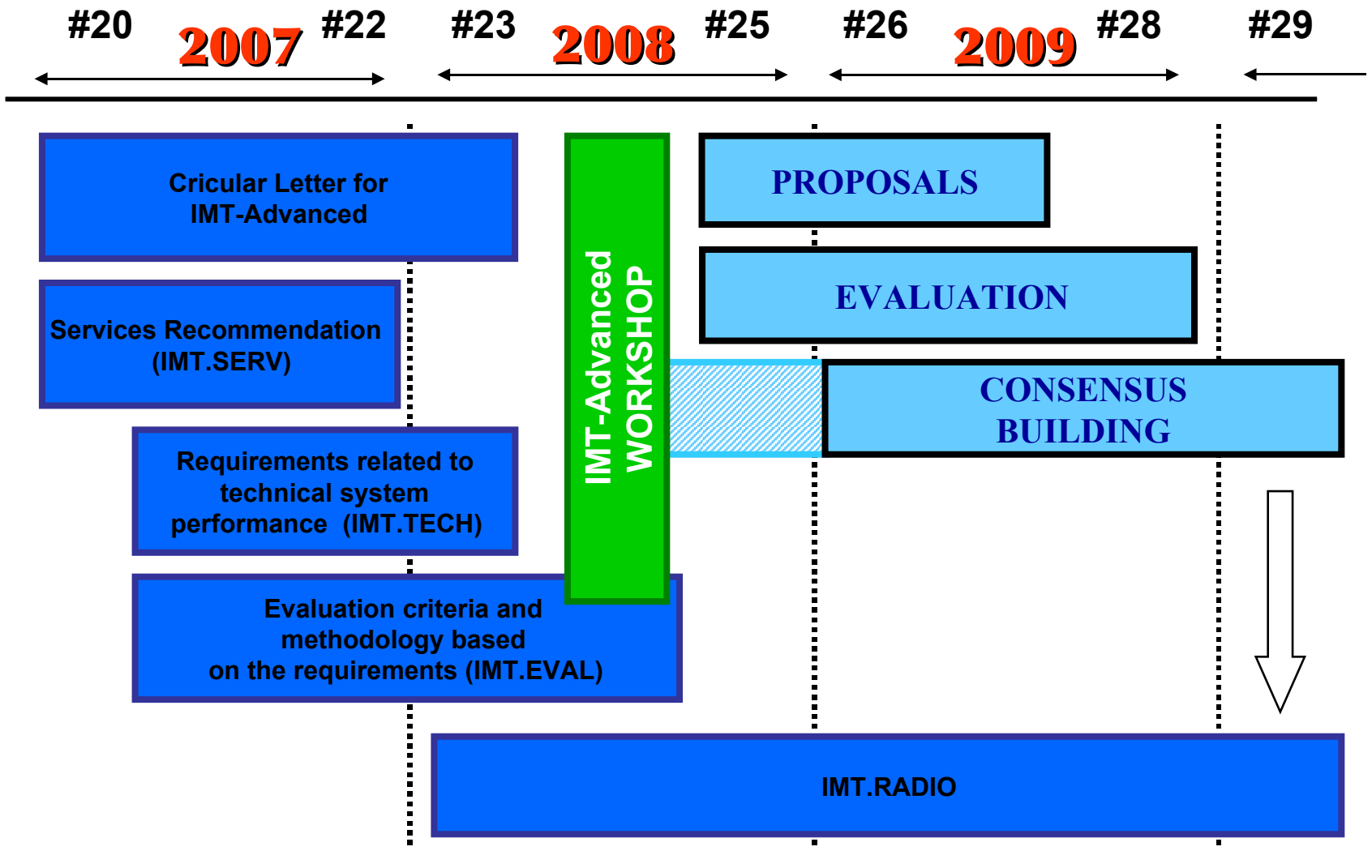
Working Party 8F drafting background materials

- intent to initiate development in Jan 2007

IEEE 802.16 plans to participate:

- developing 802.16m draft standard
- advanced air interface suitable for IMT-Advanced

IMT-Advanced (obsolete timeline)



Myth #6: IEEE 802.16 is “The WiMAX Standard”

Reality:

- ❖ The WiMAX Forum is a private entity, independent of IEEE, that supports certification of compliance to IEEE 802.16, with demonstrated interoperability.
- ❖ The WiMAX Forum certifies compliance based on “profiles” that specify mandatory and optional features as subsets of IEEE 802.16.
- ❖ IEEE 802.16 does not “ratify the WiMAX standard”. IEEE 802.16 develops standards that are used by the WiMAX Forum.
- ❖ The scope of IEEE 802 is limited to network layers 1 (physical) and 2 (medium access control), to support any higher network. The WiMAX Forum is developing higher-layer specs.
- ❖ The WiMAX Forum is a “user” of IEEE 802.16 standards
 - Other compliant implementations and other uses are possible.

Myth #7: 802.16 is “Wi-Fi on steroids”

Reality:

- ❖ 802.16 and 802.11 are completely different, by design.
- ❖ IEEE 802 technologies are distinguished by medium access control (MAC).
- ❖ The 802.11 MAC uses CSMA (“listen before talk”)
 - Connectionless
- ❖ The carrier-class 802.16 MAC is:
 - Full QoS, bandwidth-on-demand (since Day 1): multimedia
 - Connection-oriented
 - Centralized controlled and scheduled
- ❖ No regimen of steroids would grow 802.11 into 802.16.
- ❖ 802.16 and 802.11 technologies are complementary
 - Need to be brought into a common network architecture

Myth #8: 802.16 was Originally Point-to-Point

Reality:

- ❖ IEEE 802.16-2001 included the basic 802.16 medium access control (MAC) and a physical layer for 10-66 GHz.
- ❖ Due to these high frequencies, the physical layer assumed line-of-sight propagation.
- ❖ The original standard specified a point-to-multipoint system.
- ❖ Subsequent changes have not altered this topology, but:
- ❖ A mesh-mode option was added for WirelessMAN-OFDM.
- ❖ P802.16j is a mobile multihop relay project.

Myth #9: Fixed BWA uses 802.16d

Reality:

- ❖ IEEE 802.16 is an evolving standard. Changes come by:
 - Amendment (change document); e.g. IEEE 802.16a
 - Revision (consolidated updated document)
- ❖ IEEE 802.16-2001 came first (followed by amendments)
- ❖ IEEE 802.16-2004 (revision) addresses fixed BWA
 - “802.16d” does not exist, and never will.
- ❖ Two amendments (802.16e and 802.16f) have since been approved, plus Corrigendum 1 (published along with 802.16e)
- ❖ The current version of IEEE Std 802.16 is IEEE 802.16-2004, as amended by IEEE 802.16e and 802.16f and by Corrigendum 1

Myth #10: Mobile BWA uses 802.16e

Reality:

- ❖ IEEE 802.16e-2005 (802.16e, for short) is called “Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands”
- ❖ IEEE 802.16e changes the title of IEEE Std 802.16 to “... Air Interface for Fixed and Mobile Broadband Wireless Access Systems”
- ❖ Compliance to 802.16e alone is impossible, since it’s just an amendment.
- ❖ Note: There is no “802.16-2005”, and there never will be. However “802.16, as of the end of 2005” is a reasonable shorthand way to describe the standard following the approval of the 802.16e amendment.

Myth #11: 802.16 is for License-Exempt Bands Only

Reality:

- ❖ [Other versions of this myth:
- ❖ 802.16 is only for licensed bands only
- ❖ 802.16 was originally for licensed bands only
- ❖ 802.16 was originally for license-exempt bands only]

- ❖ 802.16 was originally for 10-66 GHz (licensed or not)
- ❖ 802.16a added frequencies below 10 GHz, mainly for licensed bands but with some special features specified for LE bands.
- ❖ The mobile enhancements in 802.16e are specified for licensed bands below 6 GHz.
- ❖ The current P802.16h project is working to specify “Improved Coexistence Mechanisms for License-Exempt Operation”.

Myth #12: 802.16e is not compatible with “802.16d”

- ❖ (Myth: “.16d is OFDM; .16e is OFDMA”)
- ❖ 802.16a-2003 includes three modes for < 11 GHz:
 - ❖ WirelessMAN-OFDM
 - ❖ WirelessMAN-OFDMA
 - ❖ WirelessMAN-SCa (single-carrier)
- ❖ All three modes still exist.
- ❖ Mobile specifications are all backward compatible.

Reality:

Myth #13: 802.16e is evolving

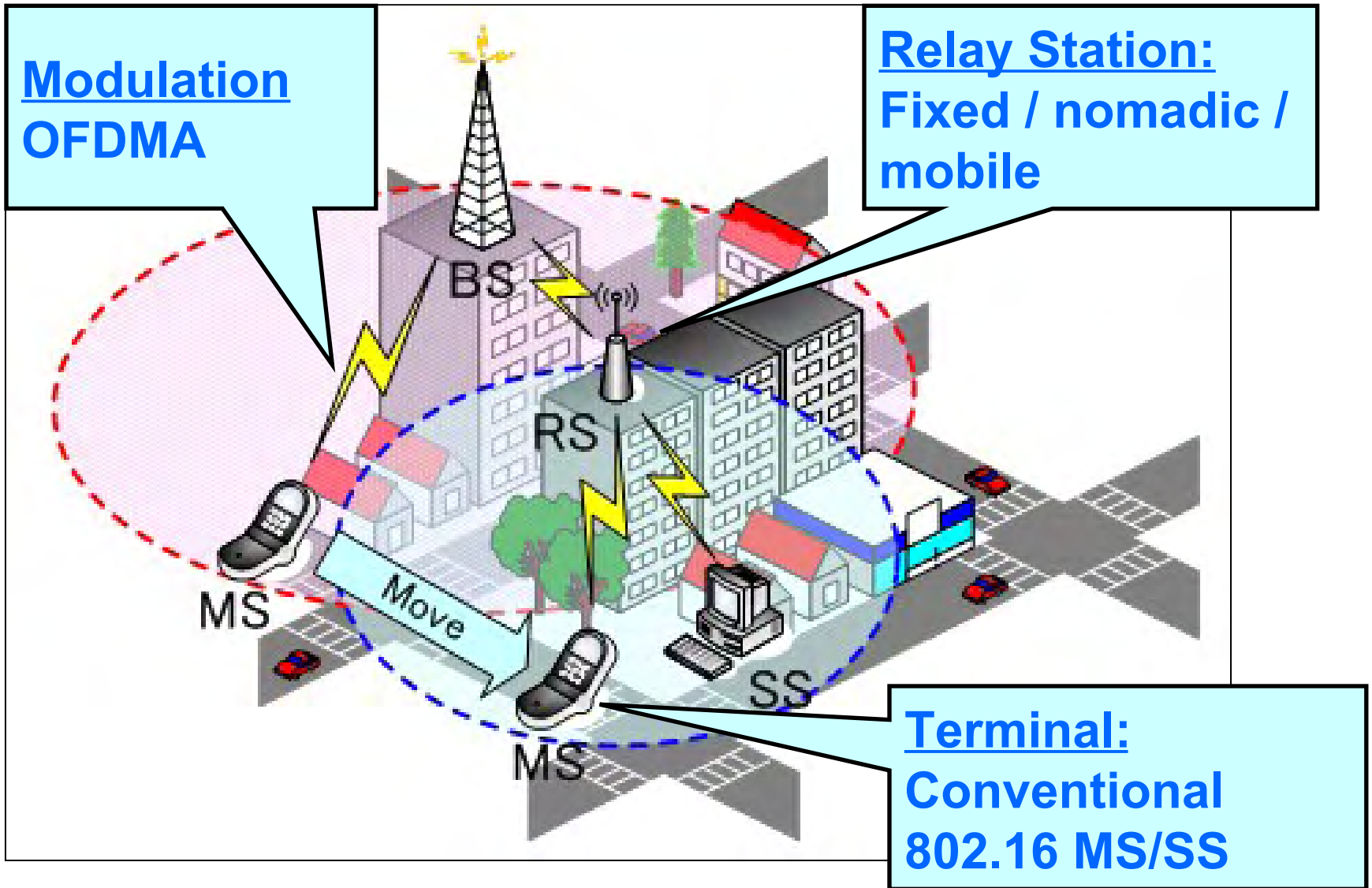
Reality:

- ❖ IEEE Std 802.16 is evolving and will continue to evolve.
- ❖ There can never be a new version of IEEE 802.16e
- ❖ Five amendment projects are in progress:
 - ❖ P802.16g, P802.16h, P802.16i, P802.16j, P802.16m
 - ❖ A revision project is in progress
- ❖ The IEEE 802.16 air interface will evolve with new standardization projects.

P802.16m

- ❖ New amendment project, as of 6 December 2006
- ❖ Scope:
 - amend the IEEE 802.16 WirelessMAN-OFDMA specification to provide an advanced air interface for operation in licensed bands
 - meet the cellular layer requirements of IMT-Advanced next generation mobile networks... with continuing support for legacy WirelessMAN-OFDMA equipment
- ❖ “target” of 100 Mbit/s
 - high mobility
 - Newest Myth: P802.16m is “Gbit WiMAX”
- ❖ intended as a candidate for IMT-Advanced

P802.16j Relay Project



Myth #14: 802.16 has range of “31 miles”

Reality:

- ❖ Q: What is the range of an 802.16 base station?
- ❖ A: What range do you want to service? And what spectrum do you have?
- ❖ Cells supporting mobile broadband in a dense metro area will be limited in practice, in most cases, to around a mile.

Resources

- ❖ IEEE 802.16 Working Group
- ❖ <http://WirelessMAN.org>

- ❖ WirelessMAN: Inside the IEEE 802.16 Standard for Wireless Metropolitan Area Networks
- ❖ Carl Eklund, Roger Marks, Subbu Ponnuswamy, Ken Stanwood, and Nico van Waes
- ❖ IEEE Press, May 2006