

# Mobile WiMAX Evolution Toward IMT-Advanced (4G)

**Takashi Shono, Ph.D.**

Technical Policy & Standards

Corporate Technology Group, Intel K.K.

September 7, 2007

Intel and the Intel logo are trademarks or registered trademarks of Intel Corporation or its subsidiaries in the United States and other countries. All dates are preliminary, based on current expectations, and subject to change without notice. \*Third party marks and brands are the property of their respective owners. Copyright © 2007 Intel Corporation. All rights reserved.

# Agenda

- Introduction
- WiMAX Deployment
- 802.16/WiMAX Standards
- PHY/MAC Features
- Mobile WiMAX Performance
- Spectrum & Regulations
- Next-Generation Mobile WiMAX
- Summary



# Introduction

# Computers with Wireless

Wireless (Wi-Fi) implementation ratio on notebooks [%]



Notebooks are  
"WIRELESS"

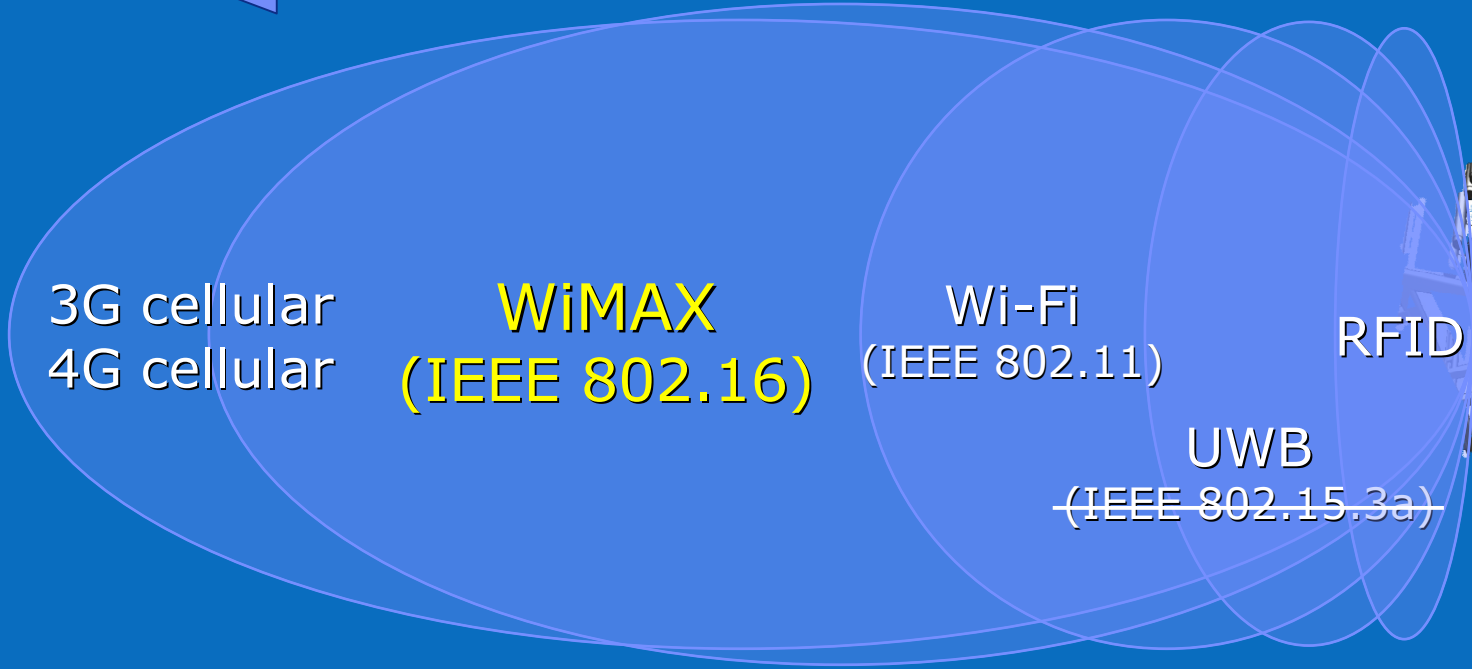


Before  
**Centrino**

Source: IDC, April 2005  
Worldwide WLAN Semiconductor 2005-2009 Forecast (Doc #33257)



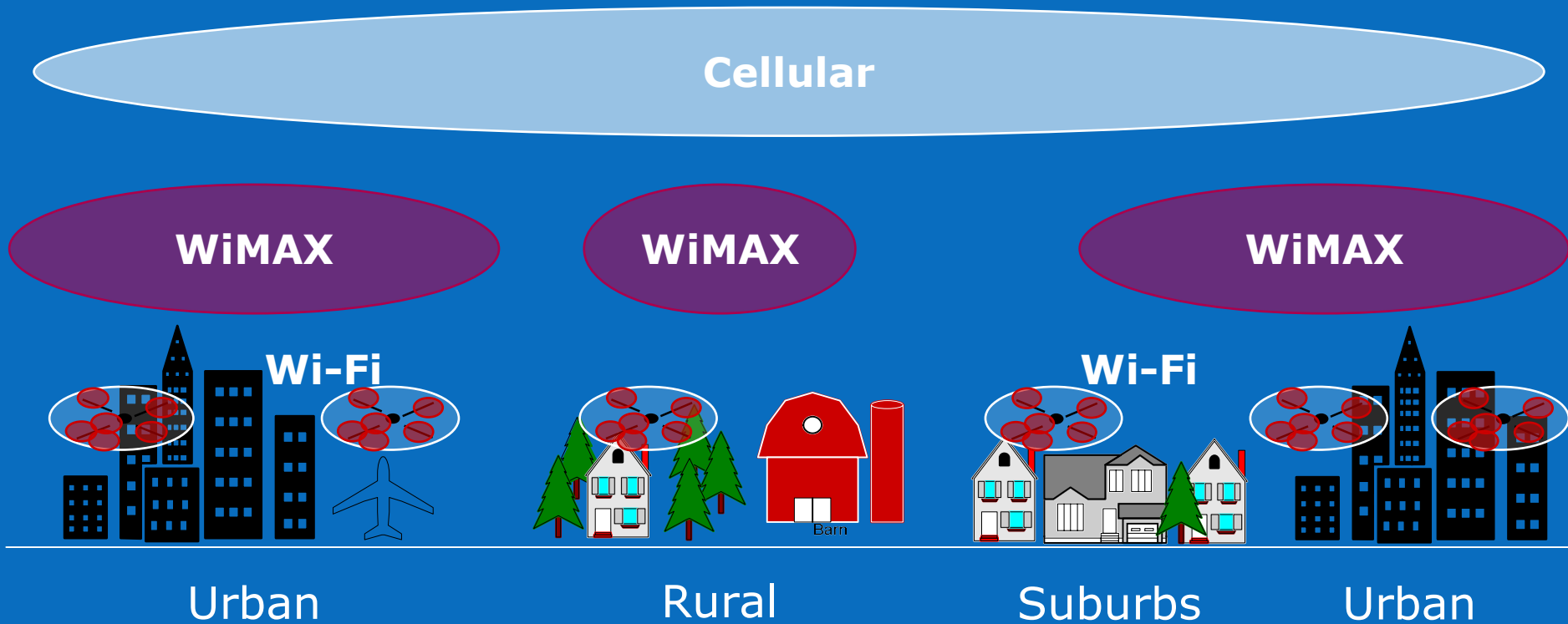
# Always Best Connected



**Coexist: optimal connectivity**



# 2008: Best Connected Model



WiMAX complements Wi-Fi and cellular networks

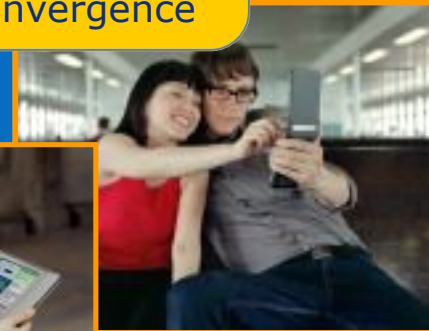
# The World Is Going Wireless



**INFRASTRUCTURE:**  
Voice and Data Last Mile  
Wireless Backhaul  
Wireless Service Convergence



**ENTERPRISE:**  
Unwired Offices and Factories  
Connected Mobile Devices  
Ubiquitous Wireless Connectivity



**CONSUMER:**  
Wireless Broadband (WiMAX)  
Voice / Data / Video  
Inter-Device communications (UWB)  
Streaming Video / 3D Gaming



# Intel's Vision for Mobile Internet

- Success of broadband wireline services (Cable/DSL) and short-range portable wireless data services (Wi-Fi) have created a killer application: "Mobile Broadband Internet"
- Consumers are demanding Mobile Internet (Cable/DSL like) anytime/anywhere
- Wi-Fi and WiMAX are the technologies that will bring us the promise of true "Mobile Internet"





# Mobile Internet Device



- The gateway to the Internet is the PC (desktops, laptops)
- Primary devices for Mobile Internet will be smaller PCs (not larger handsets)
  - PC-like application processing power (service transparency)
  - Full Microsoft/MAC/Linux OS support (application transparency)
  - Always-on experience
- A whole new class of Mobile Internet Devices (MIDs)
  - Small form factor
  - Good battery life
  - Low cost
- Opportunity for other types of specialized devices (music, phone, video, TV, etc.)



# Intel's Commitment to WiMAX




Rosedale, Ofer-R:  
Low-Cost Embedded  
Fixed and Mobile Silicon,  
Wi-Fi/WiMAX Radio




Intel WiMAX Solutions:  
PC Cards, CMT Profiles  
& Design Guide



Centrino:  
Embedded UMPC  
& Notebook Platforms



### Intel Participation in Standards & Regulatory Bodies



### Worldwide Investments for Mobile Internet Ecosystem

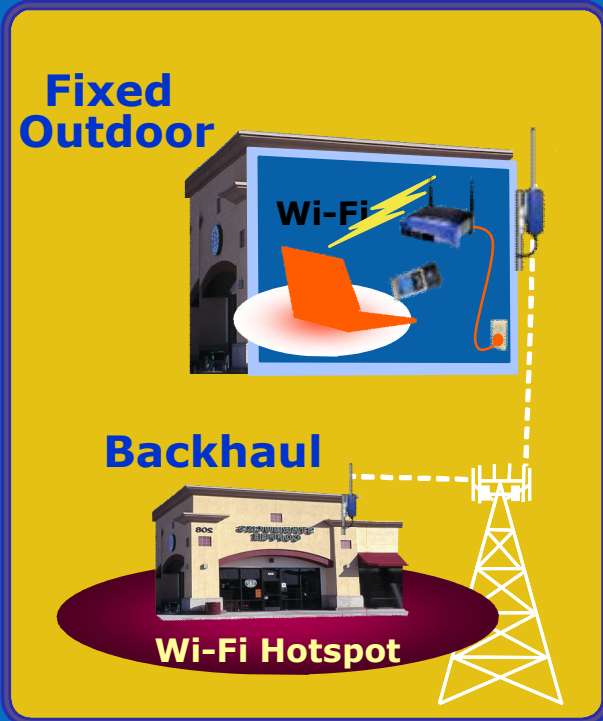


# **WiMAX Deployment**

# WiMAX Deployment Scenarios

## FIXED

802.16-2004 & 802.16e



- Deployable: 2005-2006
- Fixed Access
- Data Focused
- RGs for PC Clients
- Limited Demand

## PORTABLE

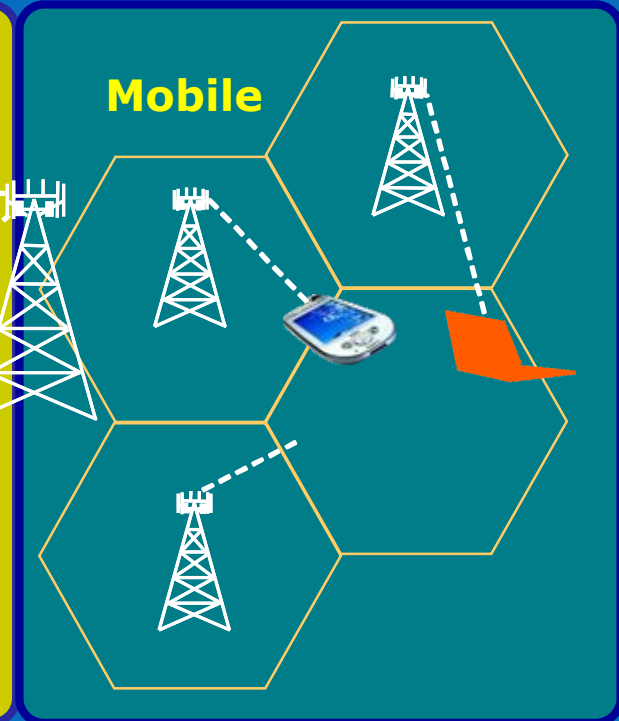
802.16e



- Deployable: 2006-2007
- Fixed and Portable access
- Data, some Voice
- RGs & PC Cards
- High Demand

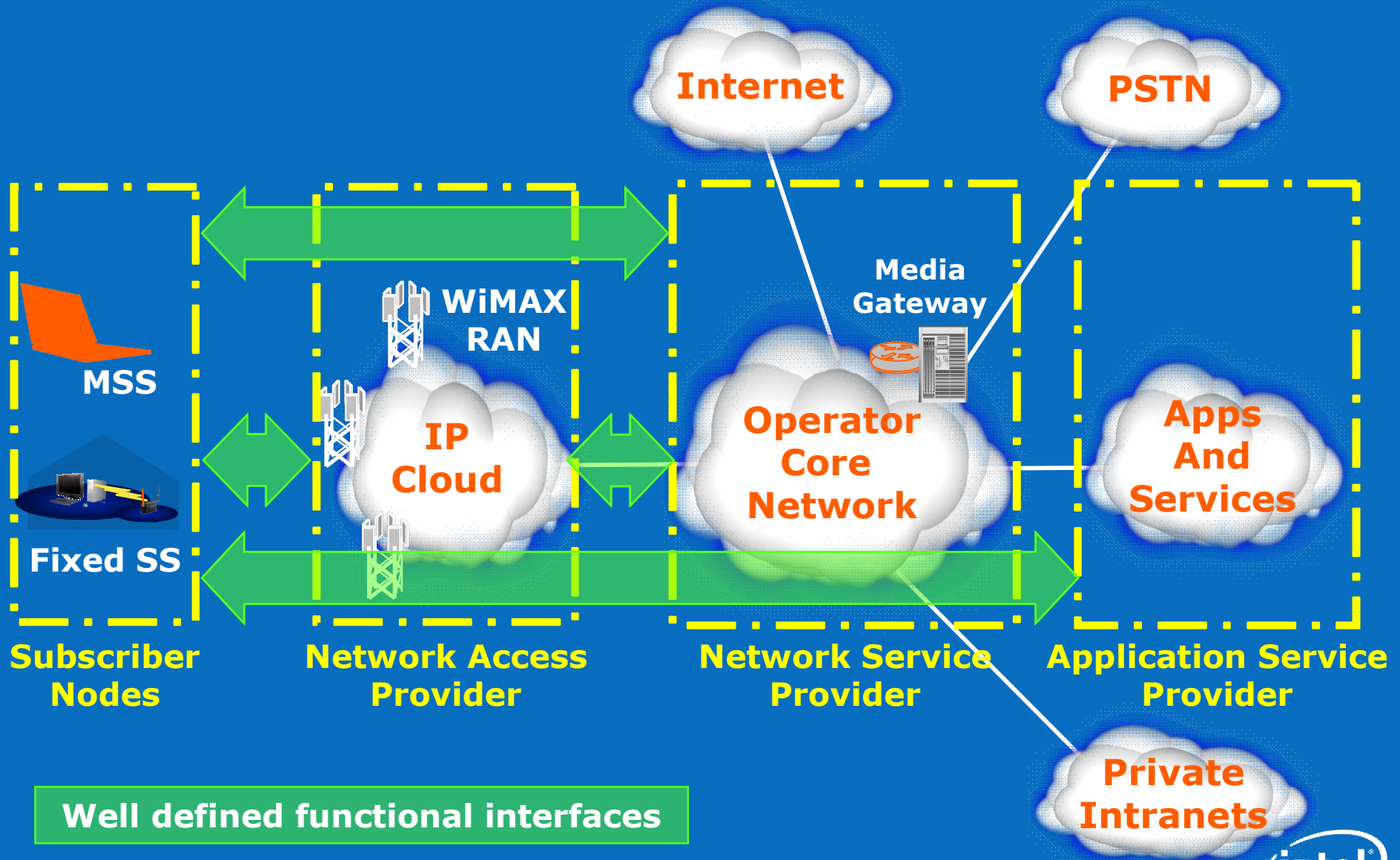
## MOBILE

802.16e



- Deployable: 2007-2008
- Mobile Access
- Data, Audio, Voice, Video
- Client Integration for PC's & Handhelds
- High Demand

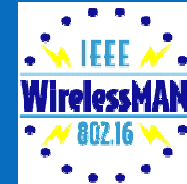
# WiMAX E2E Architecture



# **802.16/WiMAX Standards**

# Standardization Bodies

## IEEE 802.16 Working Group



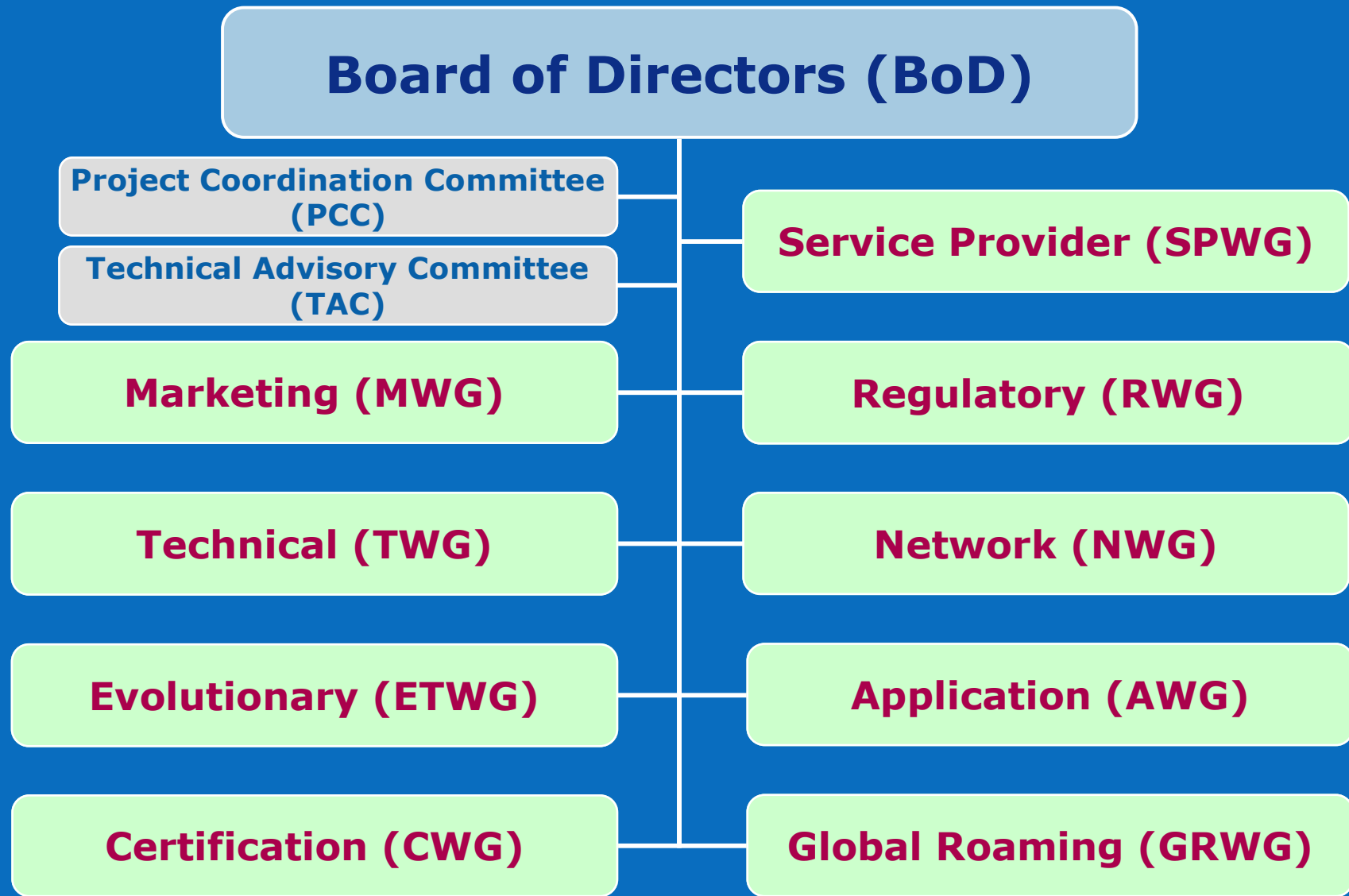
- Develops PHY/MAC standards and recommended practices to support the development and deployment of broadband Wireless Metropolitan Area Networks (WMAN)

## WiMAX Forum



- Non-profit trade organization formed to promote the 802.16 WMAN standard, and to certify 802.16 equipment as interoperable.
- Board Members consist of Intel (President), Alvarion, Airspan, Aperto, Fujitsu, AT&T, ZTE, BT, Sprint, Samsung, KT, Motorola, KDDI, Alcatel-Lucent, Nokia

# WiMAX Forum Organization





# WiMAX Forum Membership 4 Years and Growing

## WiMAX Forum Members

- 28% Content/Ecosystem
- 33% Service Providers
- 22% System Vendors
- 17% Component Suppliers



46



*Spring 2004*

491



*Today*

# WiMAX Forum Japan Office

- Announcement of WiMAX Forum® Japan Office and Its Officers
  - PORTLAND, OR - June 21, 2007 The WiMAX Forum®, an industry-led non-profit organization comprising more than 460 companies committed to promoting and certifying interoperable WiMAX® products, today announced establishment of the WiMAX Forum Japan Office in conjunction with appointment of Japan Director and Vice Directors by the WiMAX Forum.
  - The Japan Director and Vice Directors appointed by the WiMAX Forum are as follows:
    - Japan Director – Dr. Tadao Saito, Professor Emeritus at the University of Tokyo
    - Vice Director of Technology – Dr. Kenji Kohiyama, Professor at Keio University
    - Vice Director of Operations – Dr. Takashi Shono, Executive Researcher of Intel K.K.

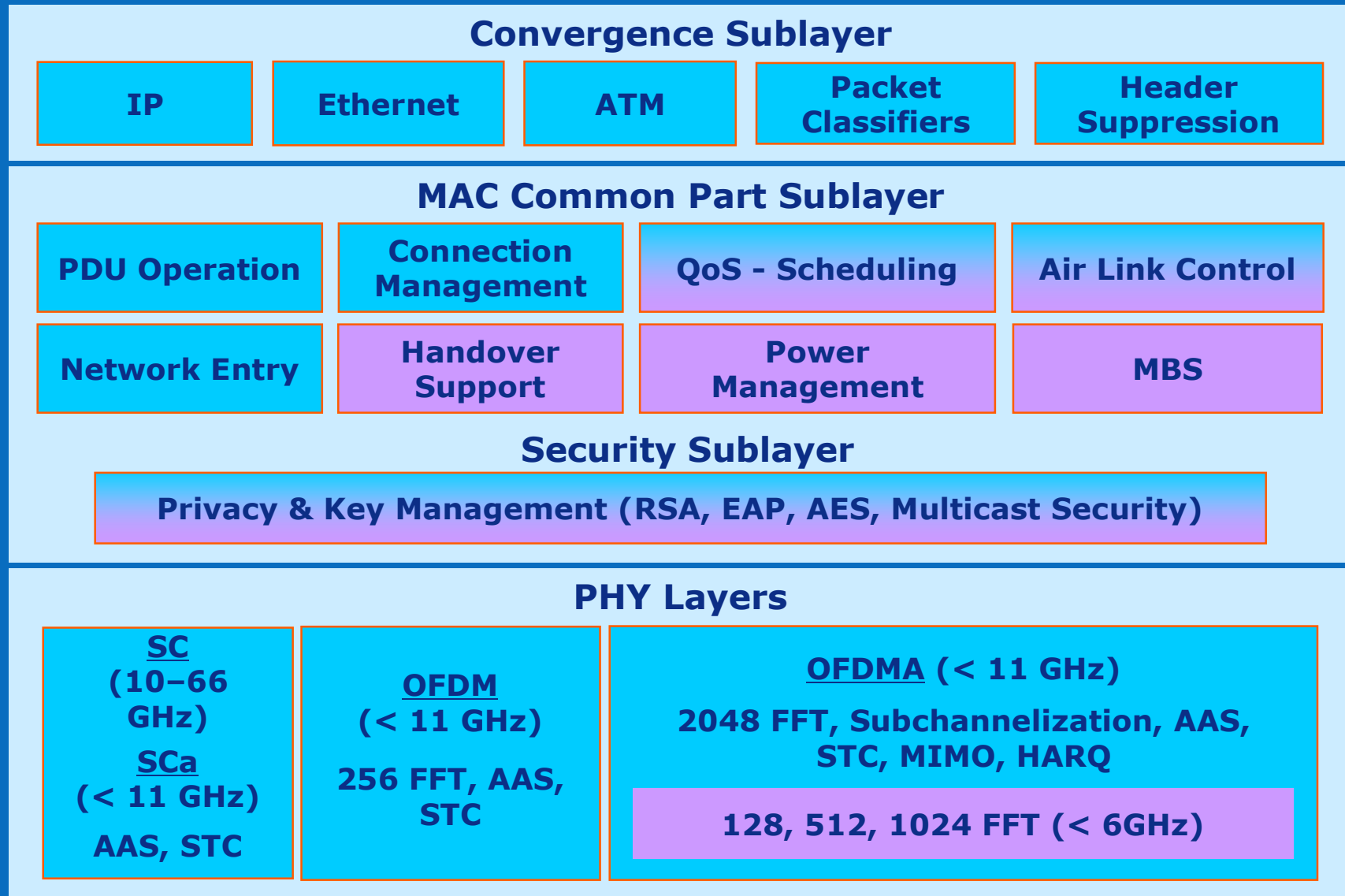


# 802.16 Specifications

	802.16	802.16-2004	802.16e
<b>Ratified</b>	December 2001	June 2004	December 2005
<b>Frequency Band</b>	10-66GHz	<11GHz	<6GHz (Licensed band)
<b>Channel Conditions</b>	LOS Only	NLOS	NLOS
<b>Peak Data Rate</b>	Up to 135 Mbps at 28MHz channelization	Up to 75 Mbps at 20MHz channelization	Up to 75 Mbps at 20MHz channelization
<b>Modulation &amp; Other PHY Technologies</b>	QPSK, 16QAM & 64QAM	<ul style="list-style-type: none"> <li>• OFDM</li> <li>• BPSK, QPSK, 16QAM &amp; 64QAM</li> <li>• AAS(SDMA), STC &amp; MIMO</li> </ul>	<ul style="list-style-type: none"> <li>• OFDMA</li> <li>• QPSK, 16QAM &amp; 64QAM</li> <li>• AAS(SDMA), STC &amp; MIMO</li> </ul>
<b>Mobility</b>	Fixed	Fixed & Nomadic	Fixed, Nomadic, Portable (Walking) & Mobile (120 km/h)
<b>Channel Bandwidth</b>	20, 25 & 28MHz	Selectable channel bandwidths from 1.25 to 20MHz	Selectable channel bandwidths from 1.25 to 20MHz
<b>Typical Cell Radius</b>	3-5 km	<10 km; Max range 50 km based on tower height, antenna gain and power transmit	2-3 km



# 802.16 Protocol Stack



Fixed 802.16-2004 + Cor1 + Mobile 802.16e



# Mobile Certification Profiles

Band Class		1	2	3	4	5		
Frequency Range [GHz]		2.3-2.4	2.305-2.320, 2.345-2.360	2.496-2.690	3.3-3.4	3.4-3.8	3.4-3.6	3.6-3.8
Duplex		TDD	TDD	TDD	TDD	TDD	TDD	TDD
Channel Bandwidth [MHz]	3.5 MHz		2.A					
	5 MHz	1.B	2.B	3.A	4.A	5.A	5L.A	5H.A
	7 MHz				4.B	5.B	5L.B	5H.B
	8.75 MHz	1.A						
	10 MHz	1.B	2.C	3.A	4.C	5.C	5L.C	5H.C



# Successful 1<sup>st</sup> Plugfest for Mobility



# Global Infrastructure for Certification Testing

- **AT4 Wireless (Spain)**
  - Lead Lab for fixed and mobile – Opened August 2005
- **TTA (Korea)**
  - November 2007
- **AT4 Wireless (US)**
  - November 2007
- **CATR (China)**
  - Lab for fixed – April 2007, lab for mobile – November/December 2007
- **ADT (Taiwan)**
  - Lab for fixed and mobile – November 2007
  - 2nd Lab – July 2008

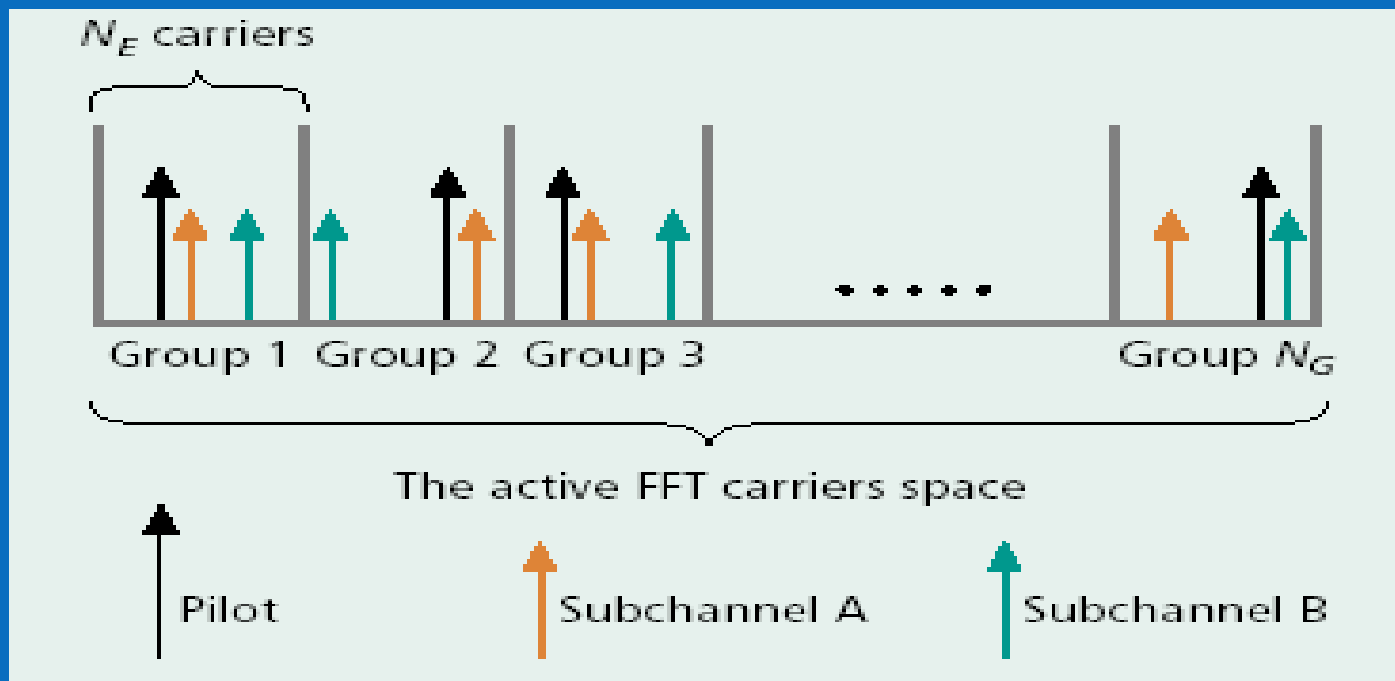


# **PHY/MAC Features**

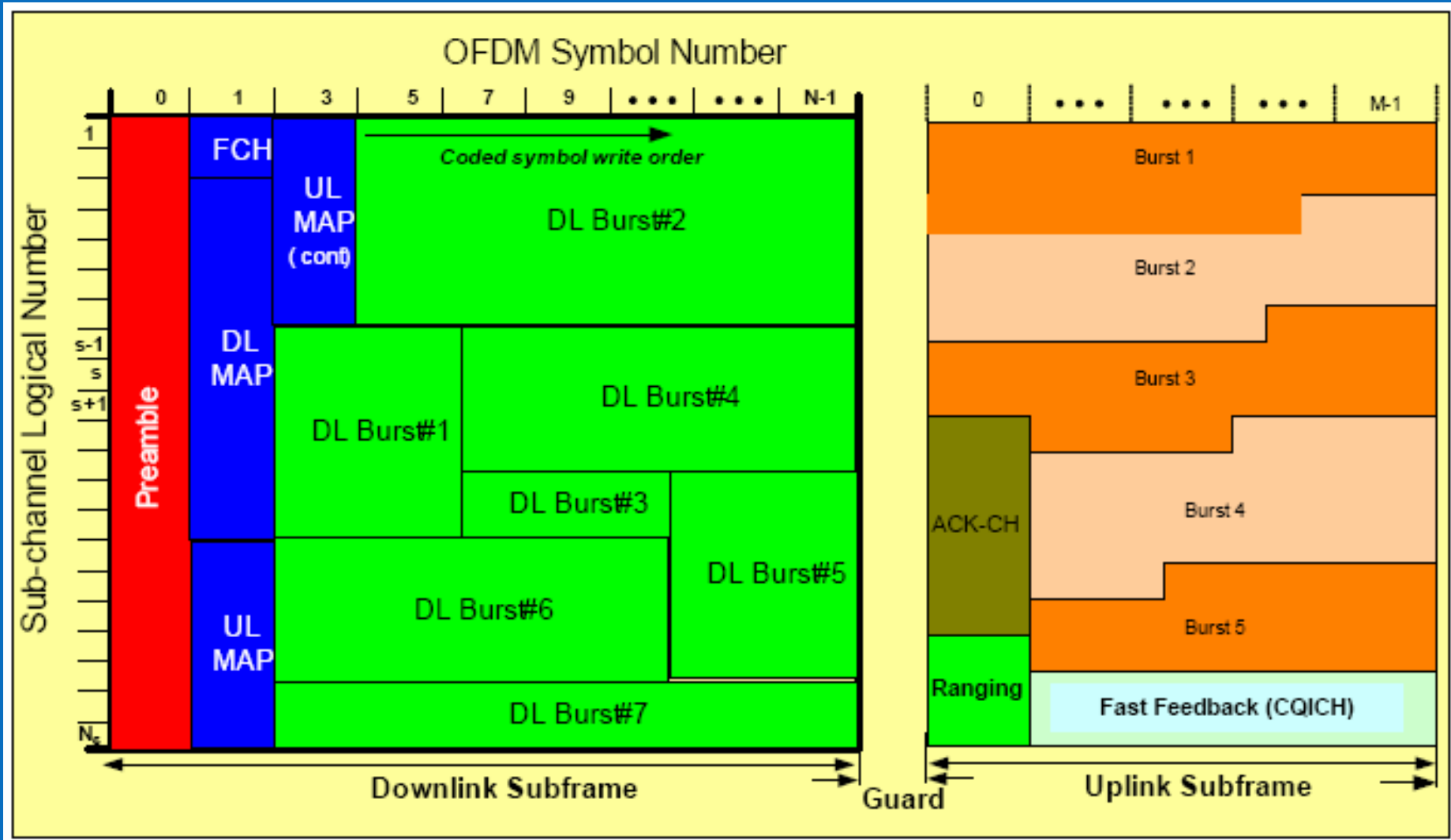


# OFDMA

- The carrier spectrum is divided into multiple **Subchannels** composed of multiple tones
- Subchannels are simultaneously used by multiple transmitters
- Concentration of power on selected subchannel tones adds up to 15dB gain per subchannel relative to OFDM



# OFDMA TDD Frame Structure

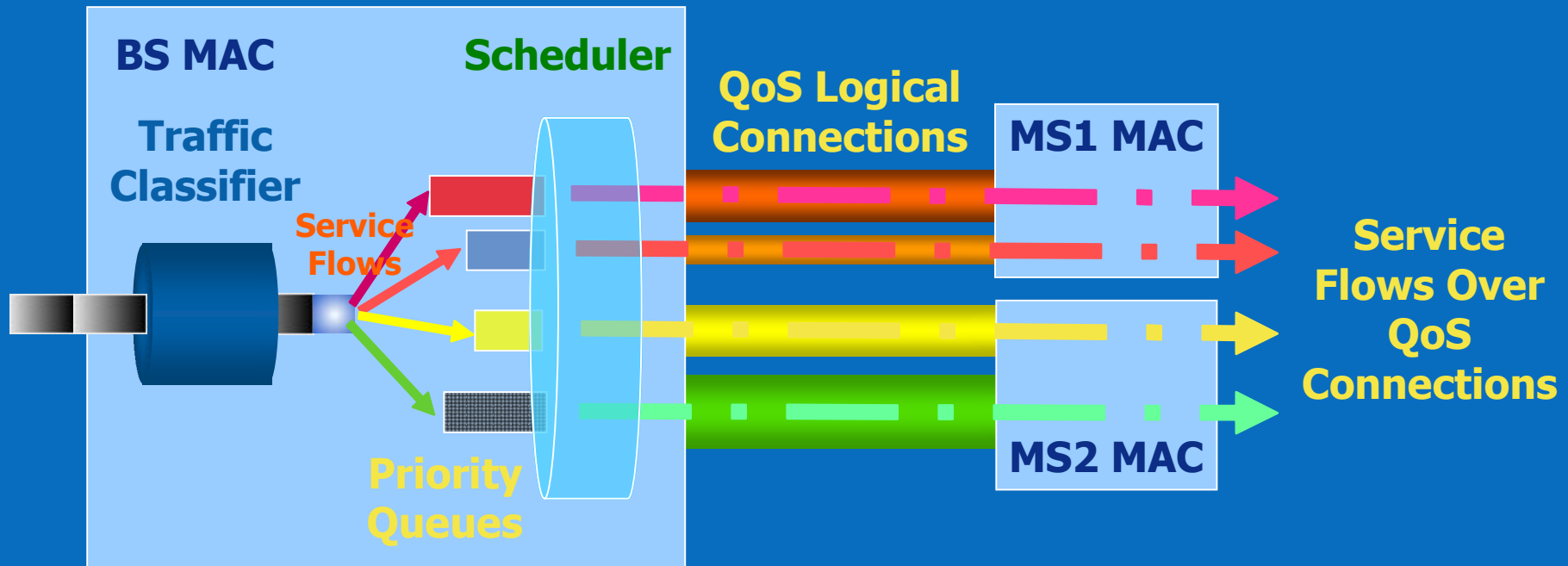


\*Source document: WiMAX Forum White Paper – Mobile WiMAX Part I

# MAC QoS – Data Service Types

QoS Category	Applications	QoS specifications
<b>UGS</b> <b>Un-Solicited Grant Service</b>	<b>VoIP</b>	<ul style="list-style-type: none"> <li>• Maximum sustained rate</li> <li>• Maximum latency</li> <li>• Jitter tolerance</li> </ul>
<b>rtPS</b> <b>Real-Time Packet Service</b>	<b>Stream Audio, Video</b>	<ul style="list-style-type: none"> <li>• Minimum reserved rate</li> <li>• Maximum sustained rate</li> <li>• Maximum Latency</li> </ul>
<b>ErtPS</b> <b>Extended Real-Time Packet Service</b>	<b>Voice with Activity Detection (VoIP)</b>	<ul style="list-style-type: none"> <li>• Minimum reserved rate</li> <li>• Maximum sustained rate</li> <li>• Maximum Latency</li> </ul>
<b>nrtPS</b> <b>Non-Real-Time Packet Service</b>	<b>FTP</b>	<ul style="list-style-type: none"> <li>• Minimum reserved rate</li> <li>• Maximum sustained rate</li> <li>• Traffic priority</li> </ul>
<b>BE</b> <b>Best-Effort Service</b>	<b>Data</b>	<ul style="list-style-type: none"> <li>• Maximum sustained traffic rate</li> <li>• Traffic priority</li> </ul>

# Connection Oriented MAC



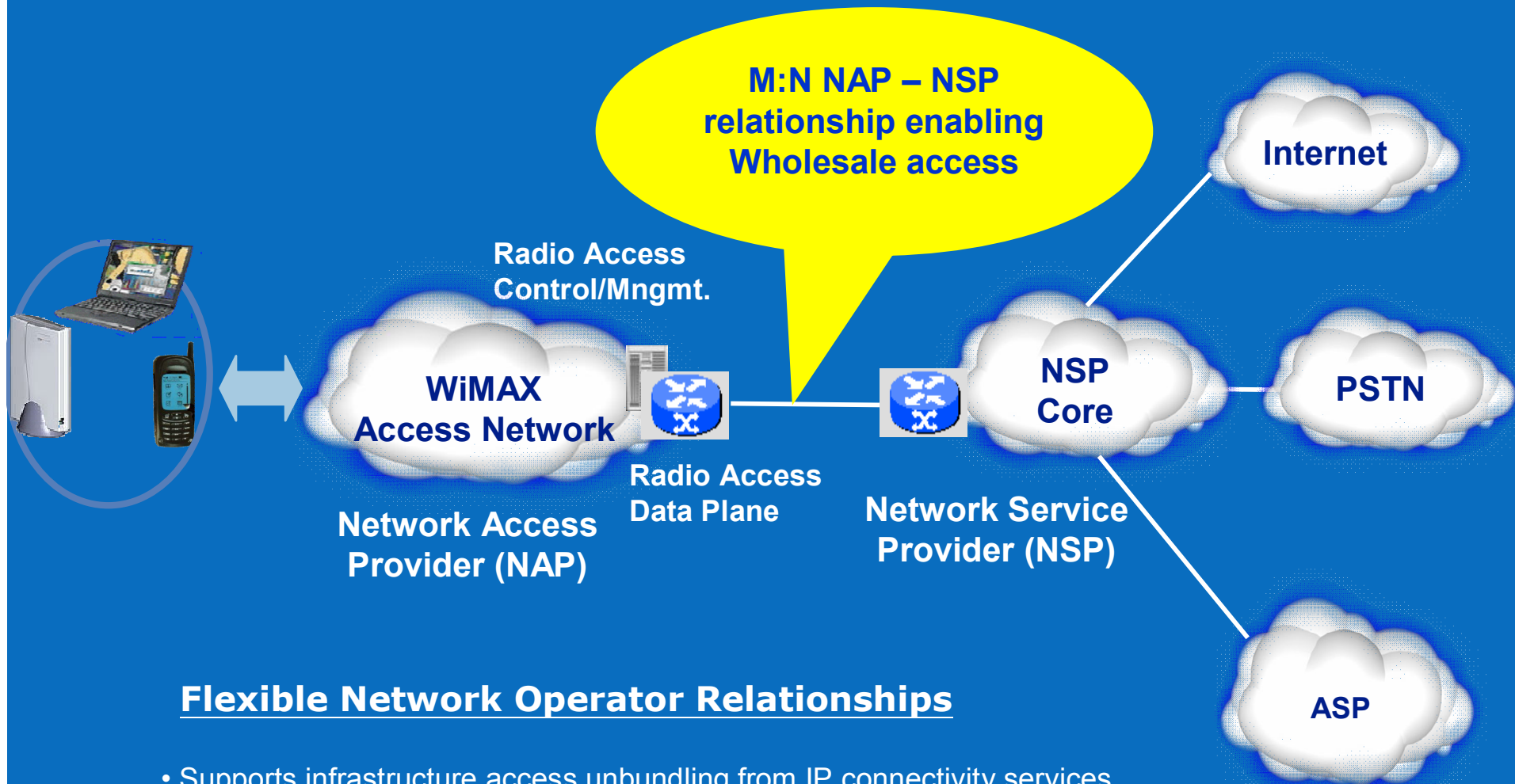
- Define QoS parameters for each service flow
- Associate QoS service flows with logical connections
- Direct packets into service flow
- Determine transmission ordering and scheduling for the air interface
- Dynamically establish new QoS-enabled service flows as required

# Network Architecture Functional Requirements

- Stationary and Fully Mobile
- Standalone and Interworking deployments
  - Multiple operator tiers
- Operator domain agnostic mobile client interfaces
- Multi-vendor network infrastructure interoperability
  - Accommodate vendor differentiation
  - Flexible deployment topologies
- Breaking up of access, connectivity and application service providers



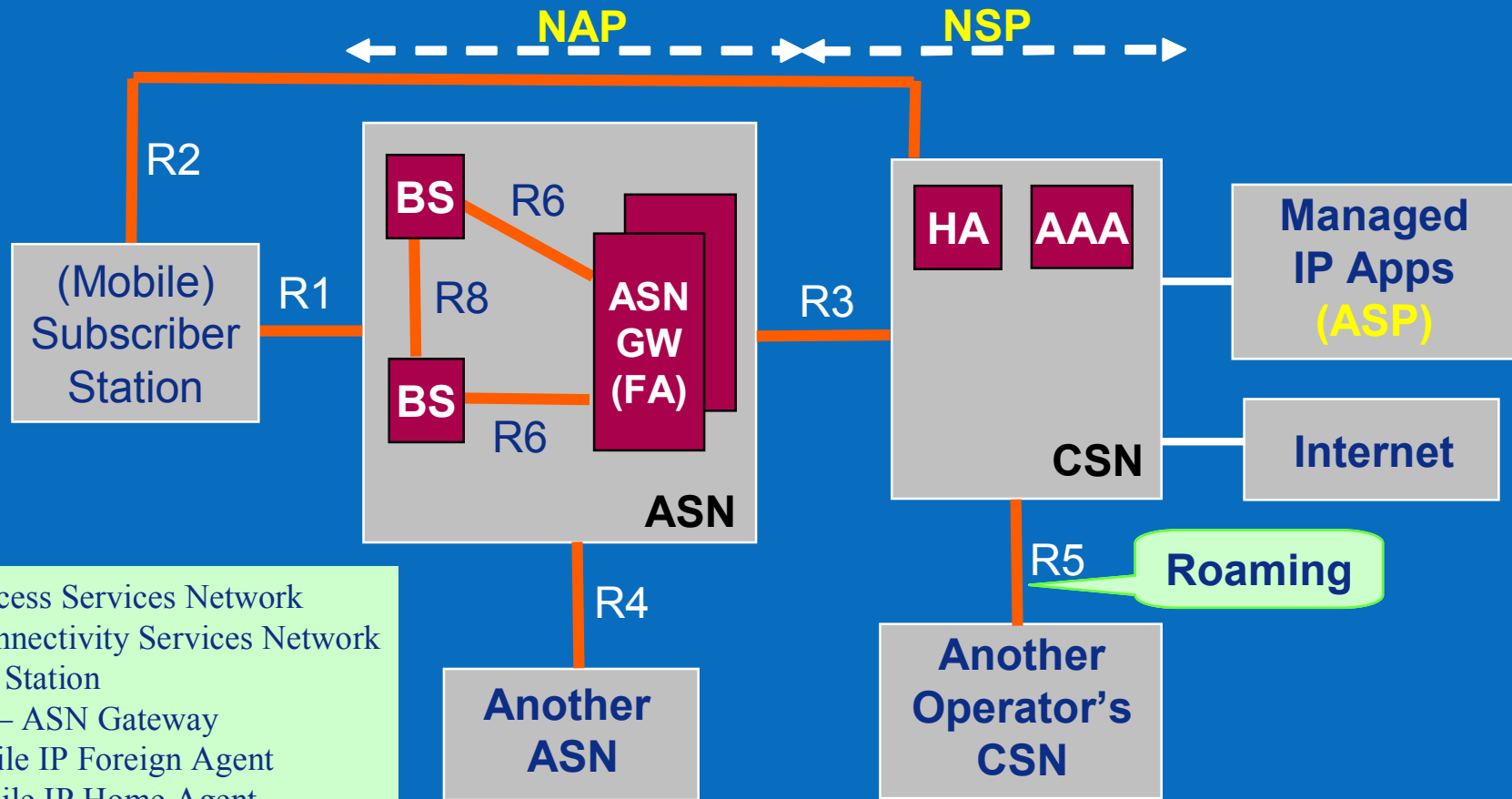
# Generic Mobile WiMAX Architectural Model



## Flexible Network Operator Relationships

- Supports infrastructure access unbundling from IP connectivity services
- Supports Multiple Virtual Network Operator concept

# Network Reference Model (NRM)



ASN – Access Services Network  
 CSN – Connectivity Services Network  
 BS – Base Station  
 ASN GW – ASN Gateway  
 FA – Mobile IP Foreign Agent  
 HA – Mobile IP Home Agent  
 AAA – Authentication, Authorization and Accounting  
 NAP – Network Access Provider  
 NSP – Network Service Provider  
 ASP – Applications Service Provider

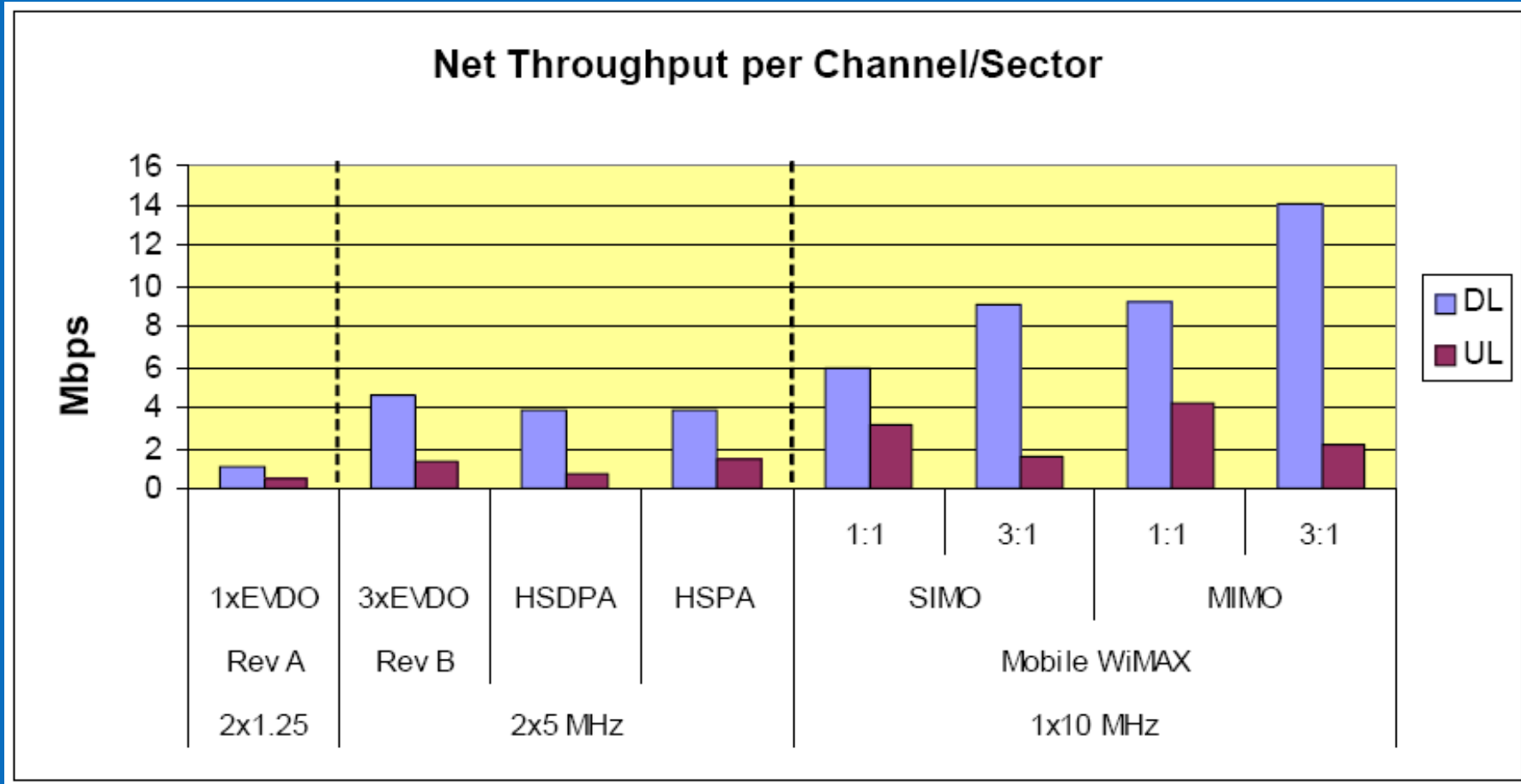
Orange lines represent NRM reference points



# Mobile WiMAX Performance



# Throughput Comparison to 3.5G

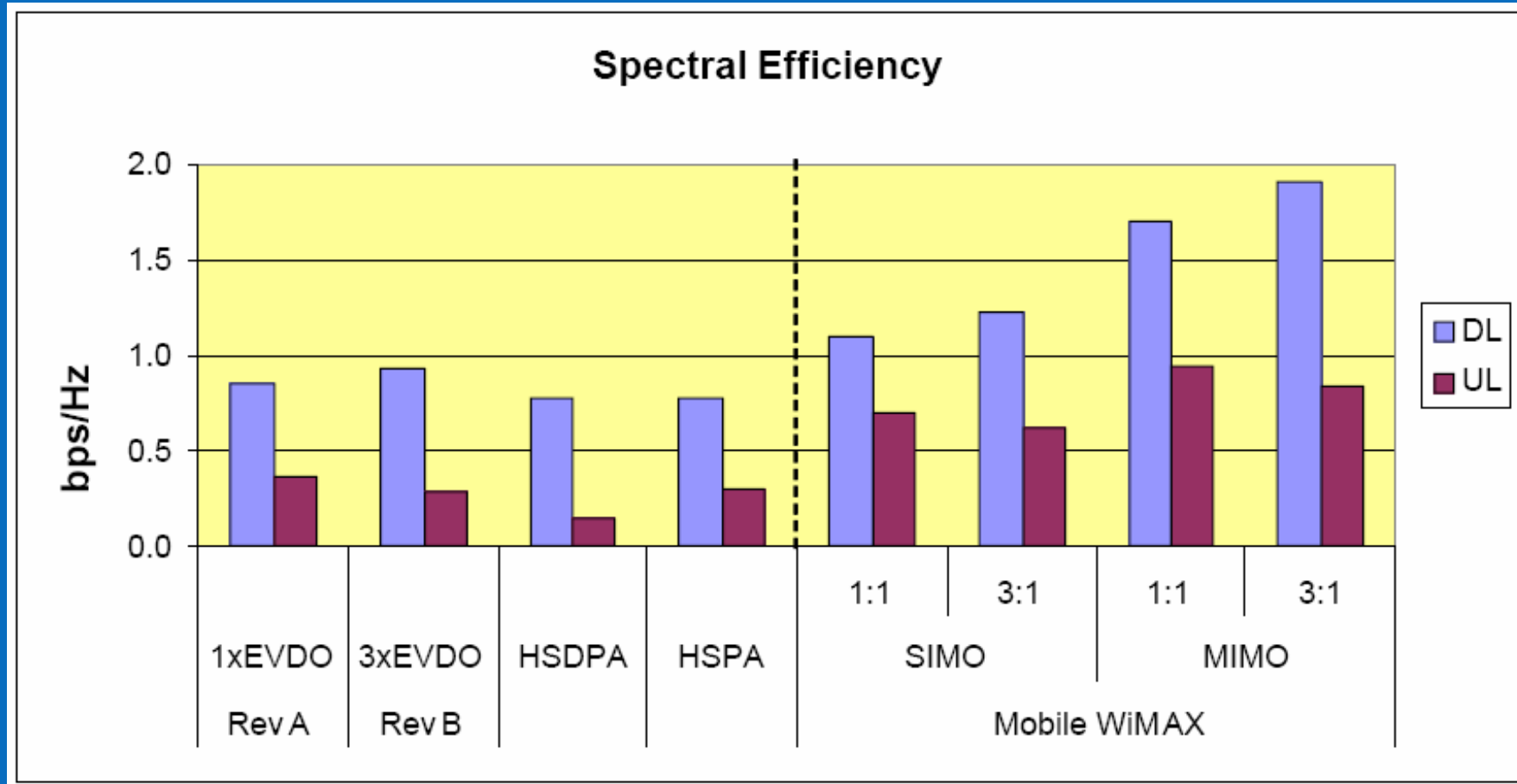


\*Source document: WiMAX Forum White Paper – Mobile WiMAX Part II

**WiMAX throughput is 3X better than 3.5G cellular**



# Spectral Efficiency Comparison to 3.5G



\*Source document: WiMAX Forum White Paper – Mobile WiMAX Part II

**WiMAX spectral efficiency is 3X better than any 3.5G cellular**



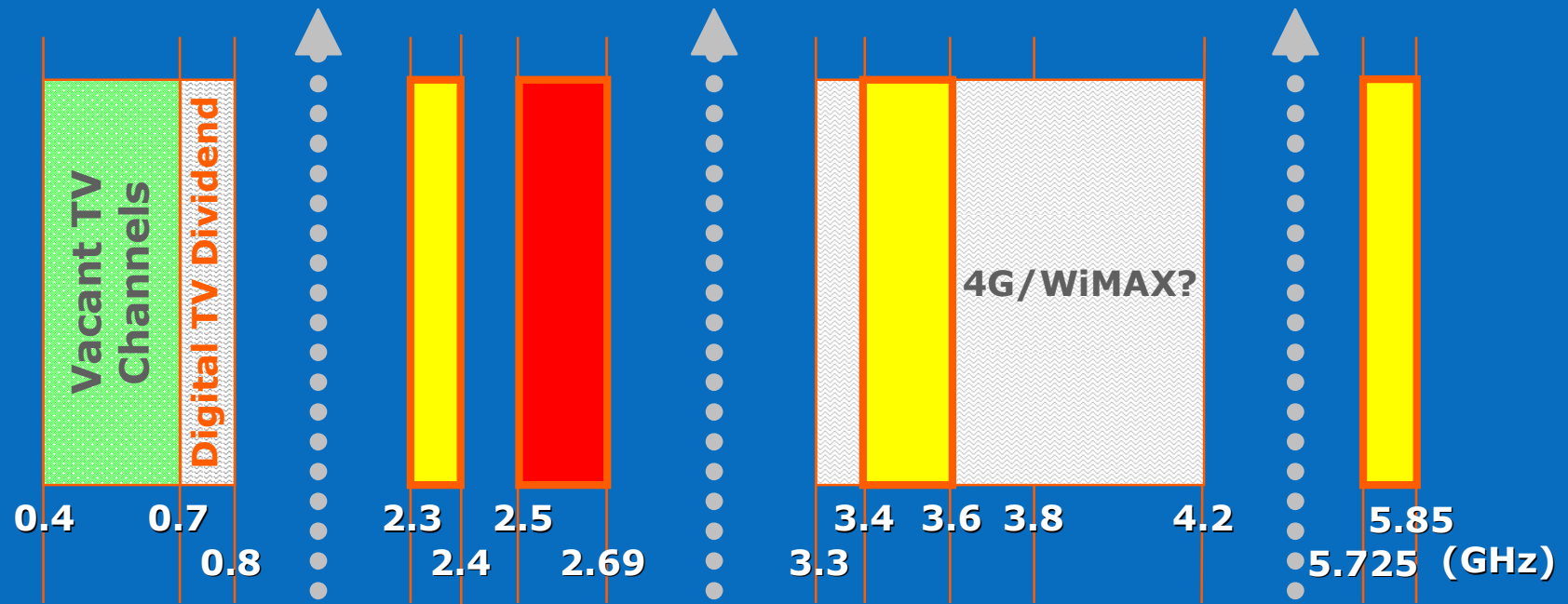
# **Spectrum & Regulations**

# Spectrum by Region

'06-'08 Initial Deployments



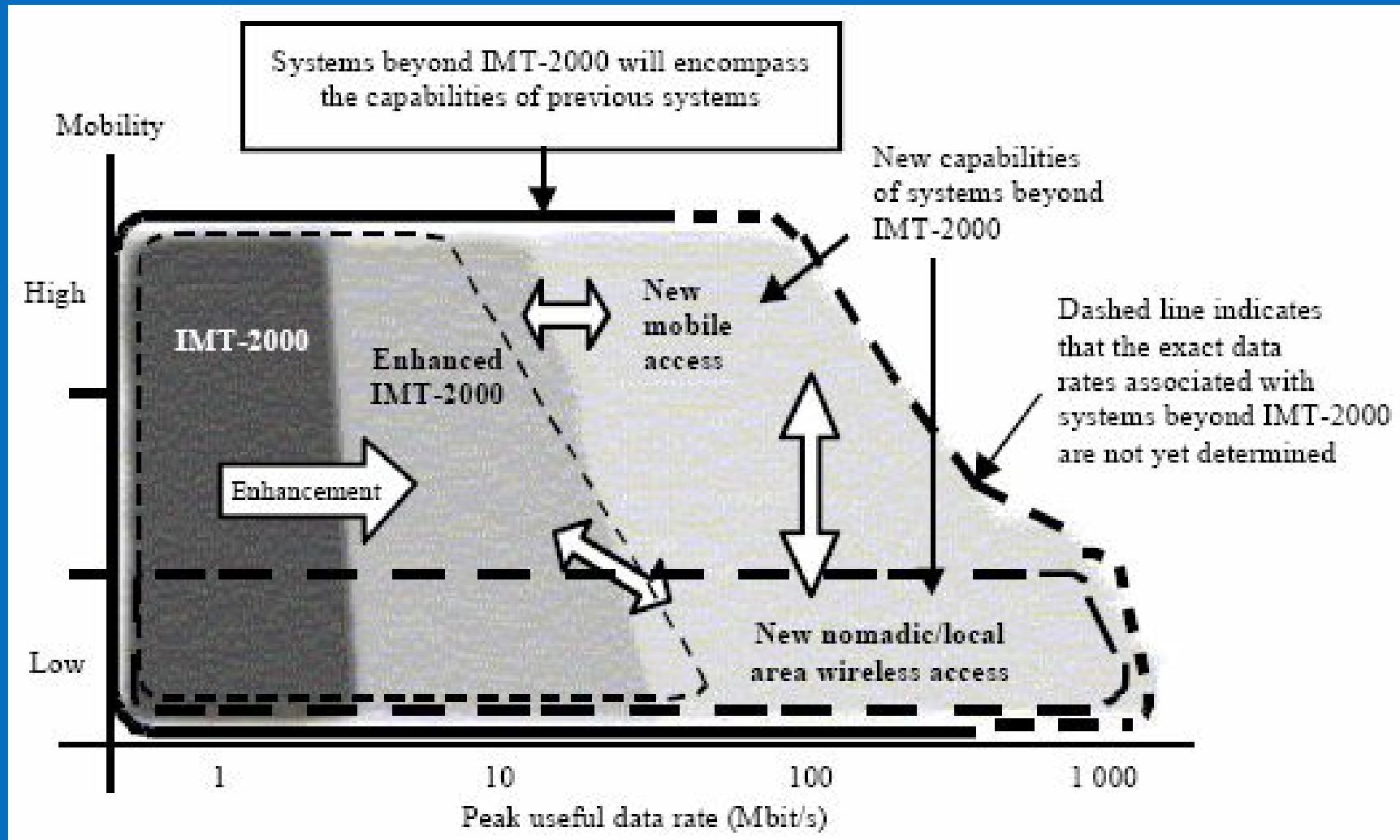
# Target Spectrum and Policy Principles



## Technology Neutrality

- *Flexibility in regulations to encourage competition, technology innovation, and economies of scale*

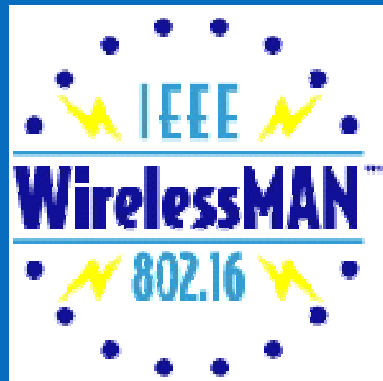
# IMT-Advanced VAN Diagram



\*Source document: Recommendation ITU-R M.1645

# WiMAX within IMT-2000 (IP-OFDMA)

IEEE



WiMAX Forum



- Gaining access to 2.5 – 2.69 GHz
- Leveling the playing field for spectrum

## Japan MIC 2.5 GHz BWA Committee

- MIC established the 2.5 GHz BWA Committee under the Information and Communications Council in February 2006 to define technical requirements for 2.5 GHz BWA systems
- The Information and Communications Council approved in December 2006 the report for mobile usage prepared by the 2.5 GHz BWA Committee, and MIC is now preparing relevant regulations and a licensing policy
- There are four TDD systems described in the committee report:
  - Mobile WiMAX, 802.20 (MBTDD-Wideband, MBTDD-625k MC), and Next-Generation PHS

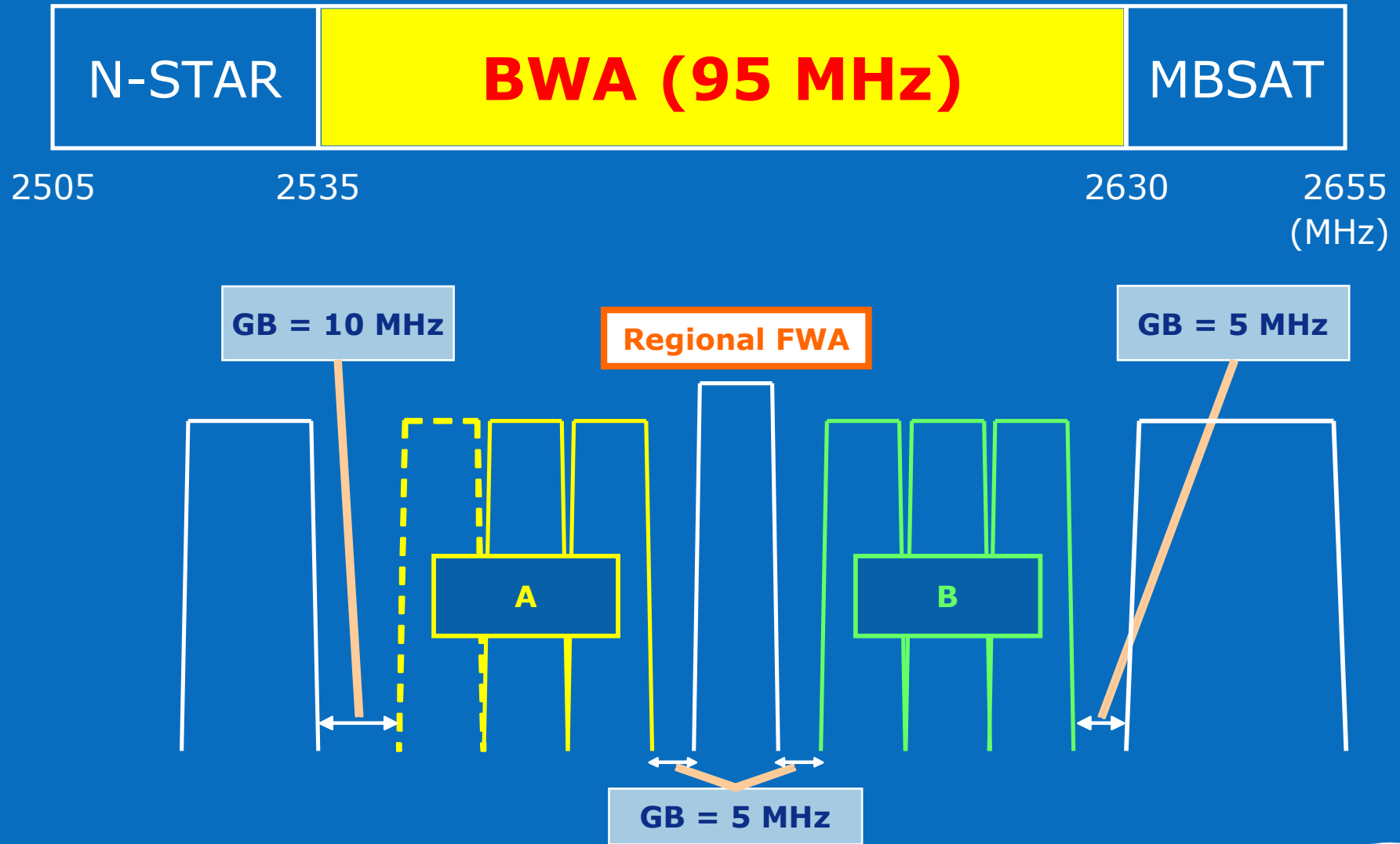




## 2.5 GHz Licensing Policy

- 2 types of licenses: 30 MHz each for 2 nationwide mobile operators and 10 MHz each for regional fixed operators
- Nationwide mobile operators have to deploy the network covering 10% of the population within 3 years and 50% of the population within 5 years from the date when the license is awarded, respectively
- The existing 3G operators cannot apply for the nationwide license by themselves: to limit 3G operator's ownership to 33%
- The plan for leasing the network to MVNO needs to be provided

# 2.5 GHz Spectrum Allocation Plan



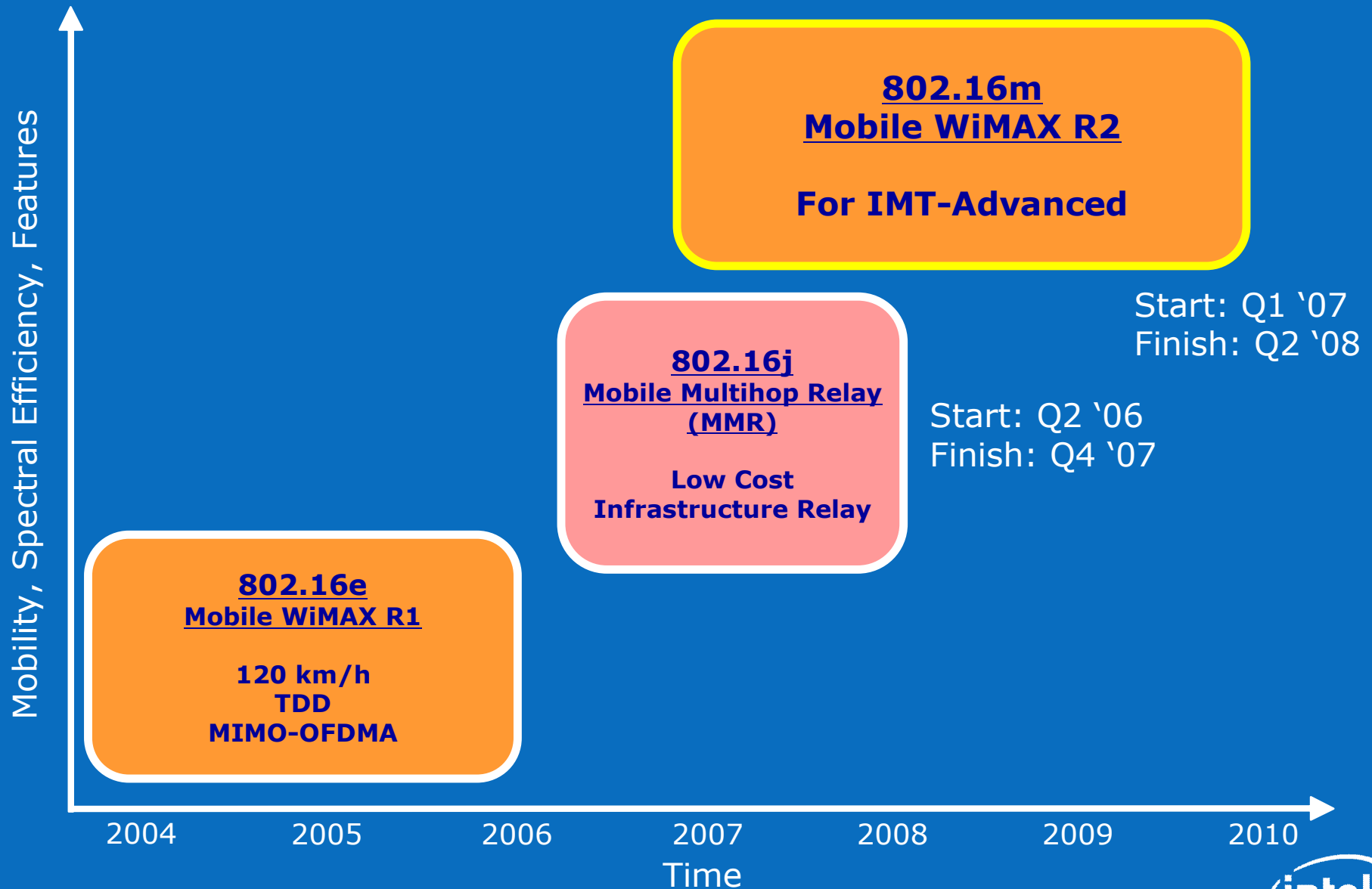
## Envisioned Timeline for 2.5 GHz Operation

- May 15: MIC to issue the draft license policy (DONE)
- From May 15th through June 15: Public consultation process (DONE)
- July 11: MIC to issue an official license policy (DONE)
- September 10 through October 12: MIC to “call for operators”
- Q4 (probably until end of November): MIC to hold a beauty contest
- Q4 (probably in December): MIC to award spectrum to operators
- Q4 2008: Licensed operators to launch services



# **Next-Generation Mobile WiMAX**

# Mobile WiMAX Technology Evolution

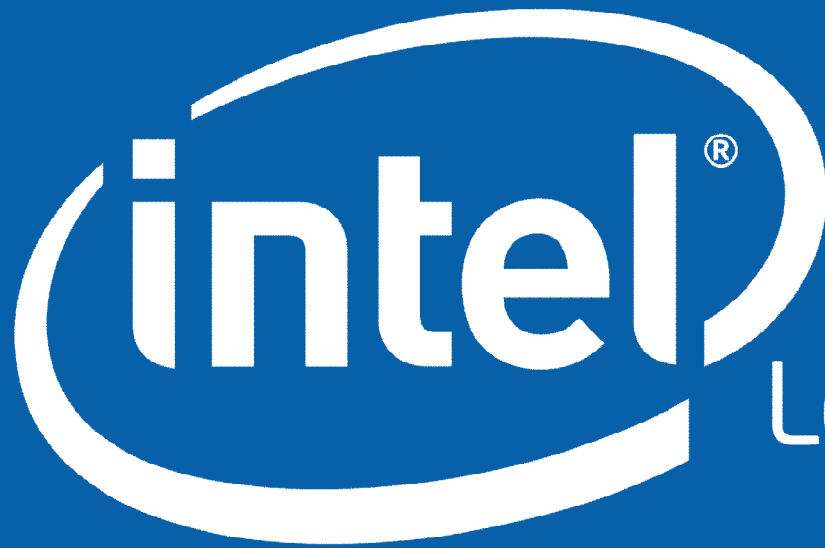


# Summary

## Key Messages

- *Mobile WiMAX = “Mobile Internet”*
- Industry momentum continues to rapidly grow
- Global open standard developed by 100’s of companies over many years in IEEE
- No single company has a disproportionate amount of intellectual property rights
- Wireless technologies are evolving to OFDMA, an ideal foundation for delivering 4G services
- Significant to adopt and promote a “Technology Neutral” approach to spectrum management
- “WiMAX within IMT-2000” will definitely benefit the mobile industry and end users





Leap ahead™