

The Mobile WiMAX Technology

Dr. Hikmet Sari*

Chief Scientist

SEQUANS Communications

Bat. CitiCenter, 19 Le Parvis

F-92073 Paris La Défense, France

(*) Professor and Department Head at SUPELEC



Presentation Outline

- ❑ From fixed to mobile WiMAX
- ❑ WiMAX Forum and IEEE 802.16 specifications
- ❑ Mobile WiMAX PHY and MAC
- ❑ Basic features of mobile WiMAX
- ❑ Advanced multiple antenna (MIMO) Technologies
- ❑ Positioning w.r.t. WiFi and 3G cellular
- ❑ Technology roadmap
- ❑ Summary and conclusions

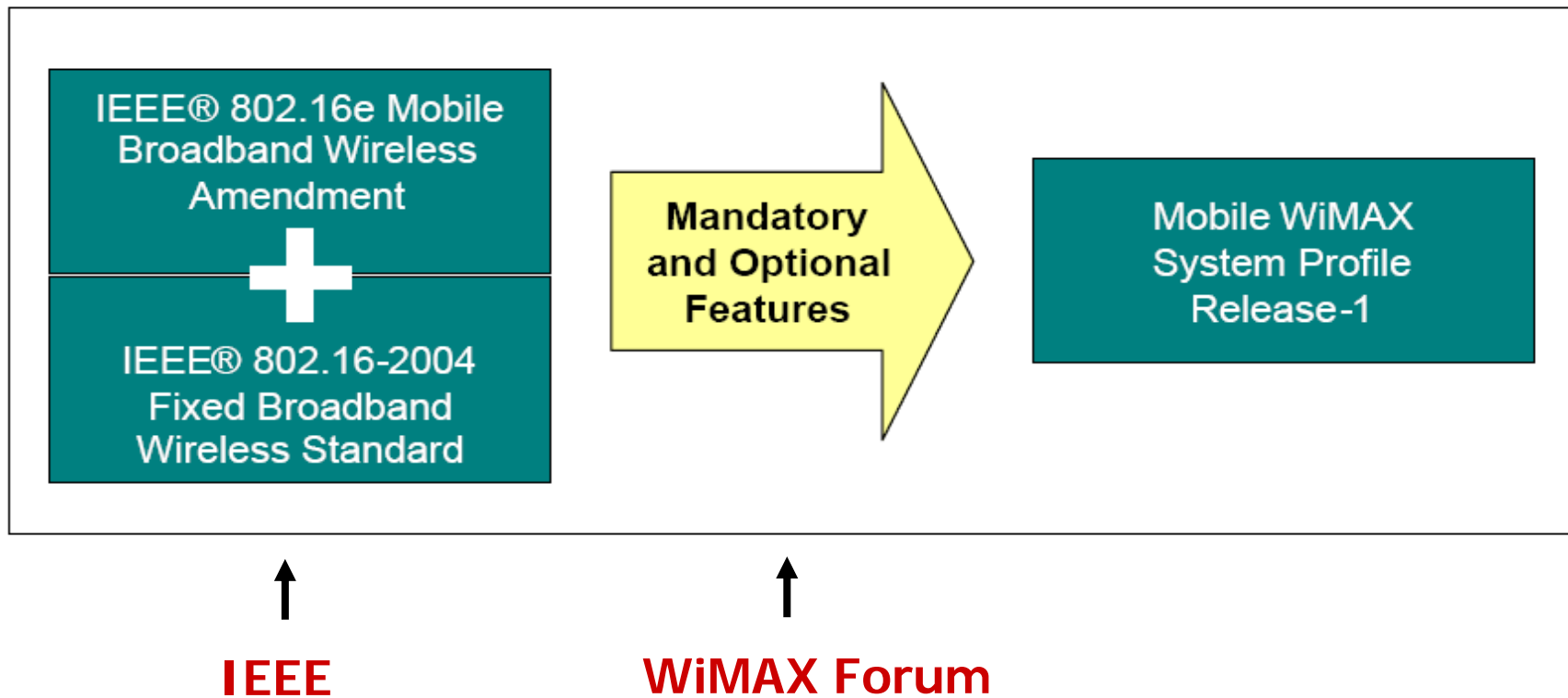
Introduction

- ❑ WiMAX refers to a broadband wireless access (BWA) technology adopted by the WiMAX Forum and based on the IEEE 802.16x specifications.
- ❑ WiMAX technology uses only a subset of the IEEE 802.16 specifications, those specifications being a tool box which contains a number of different technologies and many options.
- ❑ The WiMAX Forum also defines certification procedures and interoperability tests for WiMAX products.
- ❑ Today, there are two sets of IEEE 802.16 specifications, one for fixed wireless access and one for mobile services.

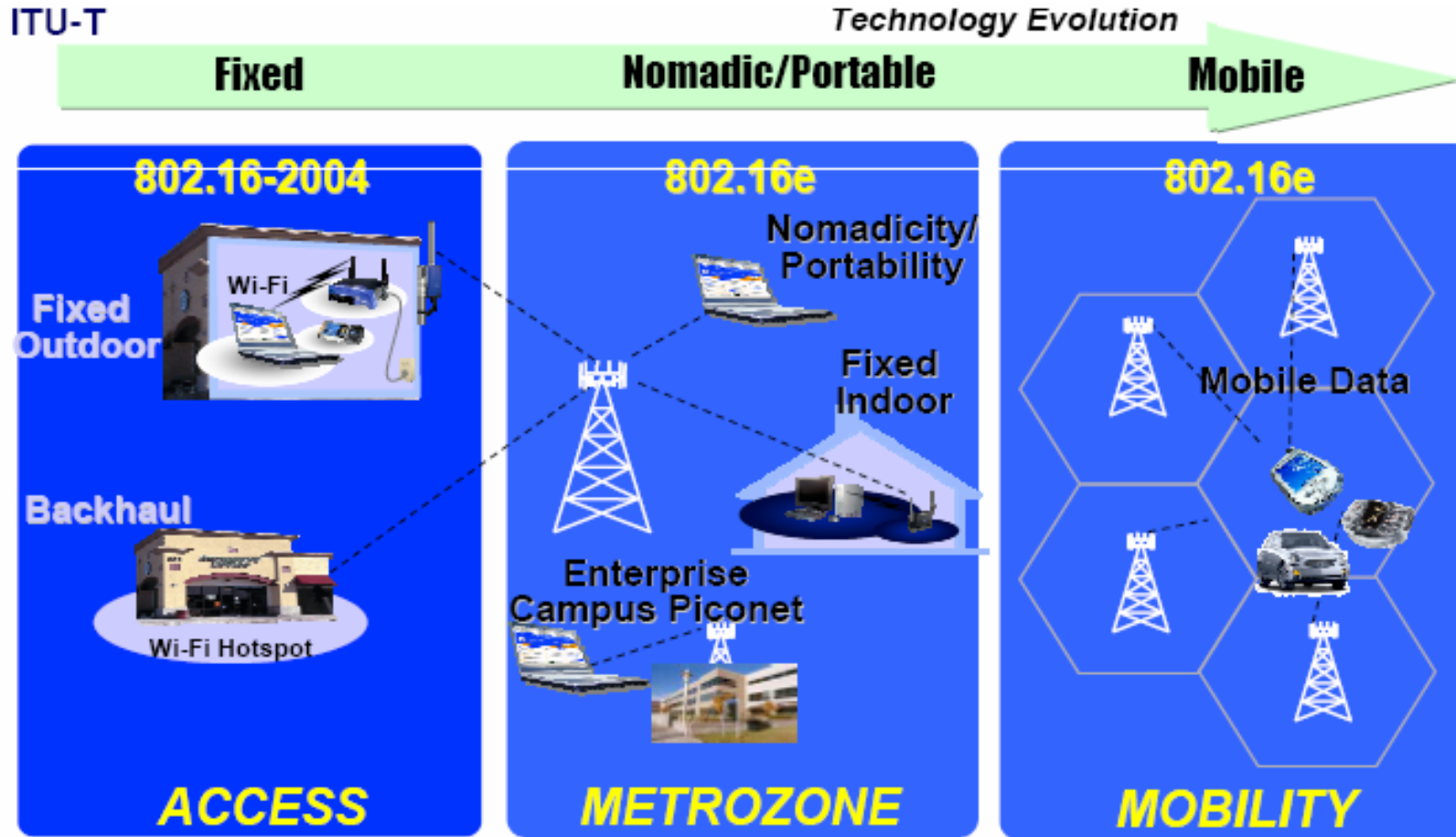
IEEE 802.16/WiMAX Forum technologies

- ❑ The IEEE 802.16 – 2004 specifications define the physical layer (PHY) and the medium access control (MAC) layer for fixed BWA systems operating on licensed frequency bands between 2 and 11 GHz. They include 3 PHY layers: OFDM, single-carrier (SCT) and OFDMA, but from those, the WiMAX Forum has only selected the OFDM PHY.
- ❑ Similarly, the IEEE 802.16e – 2005 specifications define the PHY and MAC layers for mobile BWA systems operating on licensed frequency bands between 2 and 6 GHz. Here too, 3 PHY layers are included, but the WiMAX Forum has only selected the OFDMA PHY for mobile applications.

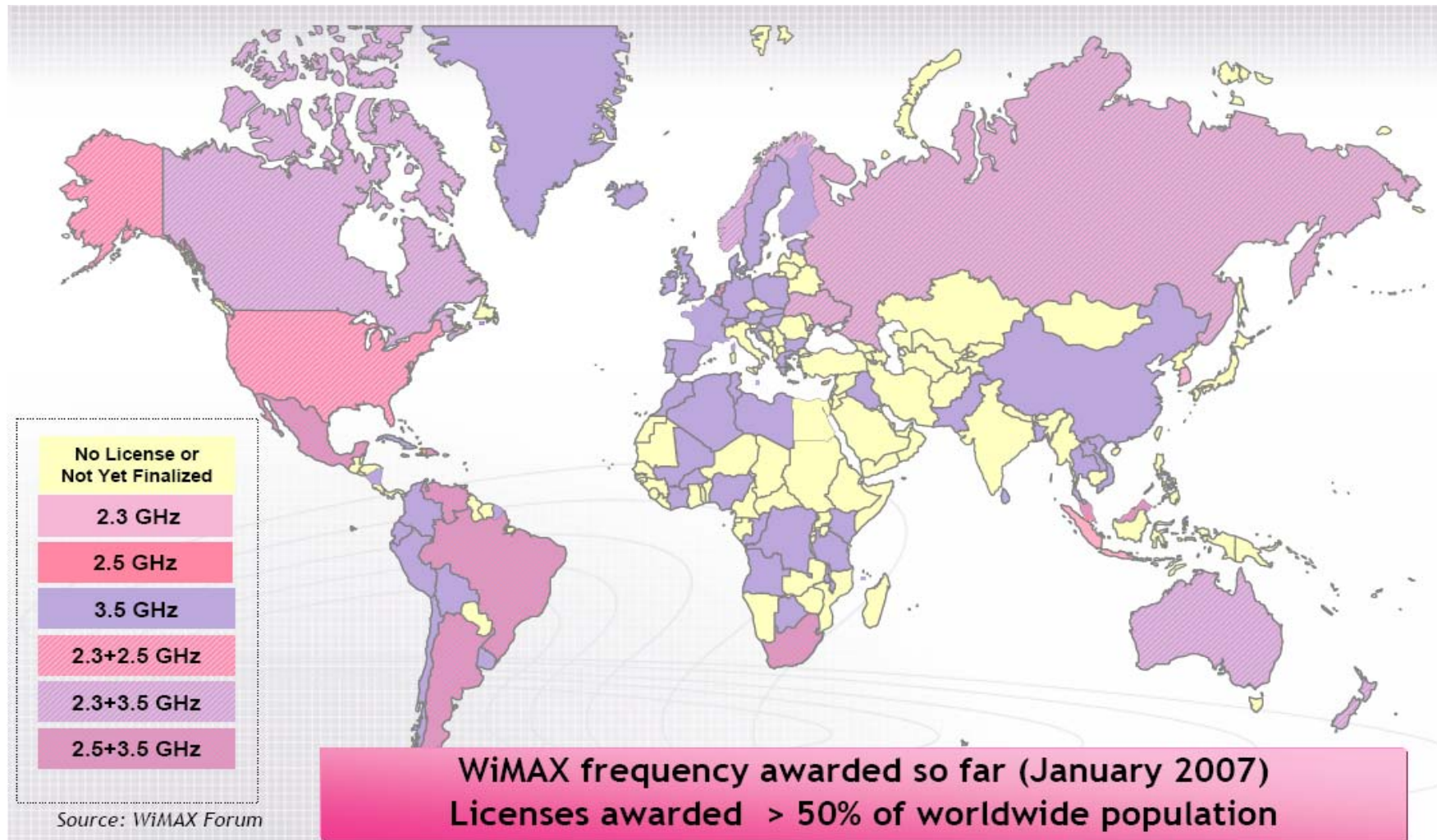
From Fixed to Mobile WiMAX



WiMAX Applications



Radio Spectrum Availability



Mobile WiMAX Features

- ❑ High Data Rates:

Peak data rates of 63 Mbps on the downlink and 28 Mbps on the uplink using MIMO technology, flexible sub-channelization, adaptive modulation and coding, and other advanced features.

- ❑ Quality of Service (QoS):

End-to-end IP-based quality of service; IEEE 802.16 MAC based on the DOCSIS MAC.

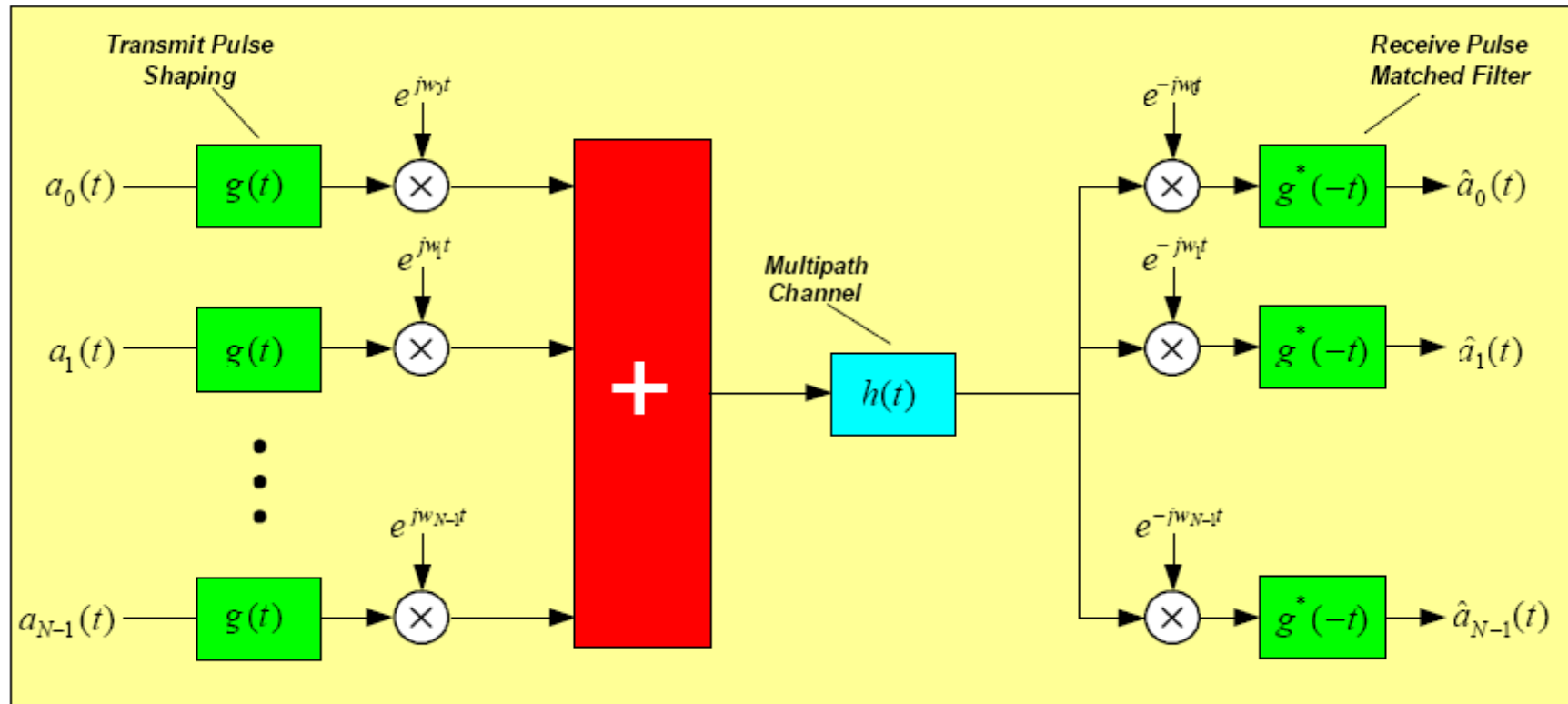
- ❑ Scalability:

Mobile WiMAX systems are designed to work in channel bandwidths ranging from 1.25 MHz up to 20 MHz to comply with various national and regional frequency allocations and requirements.

Mobile WiMAX Physical Layer

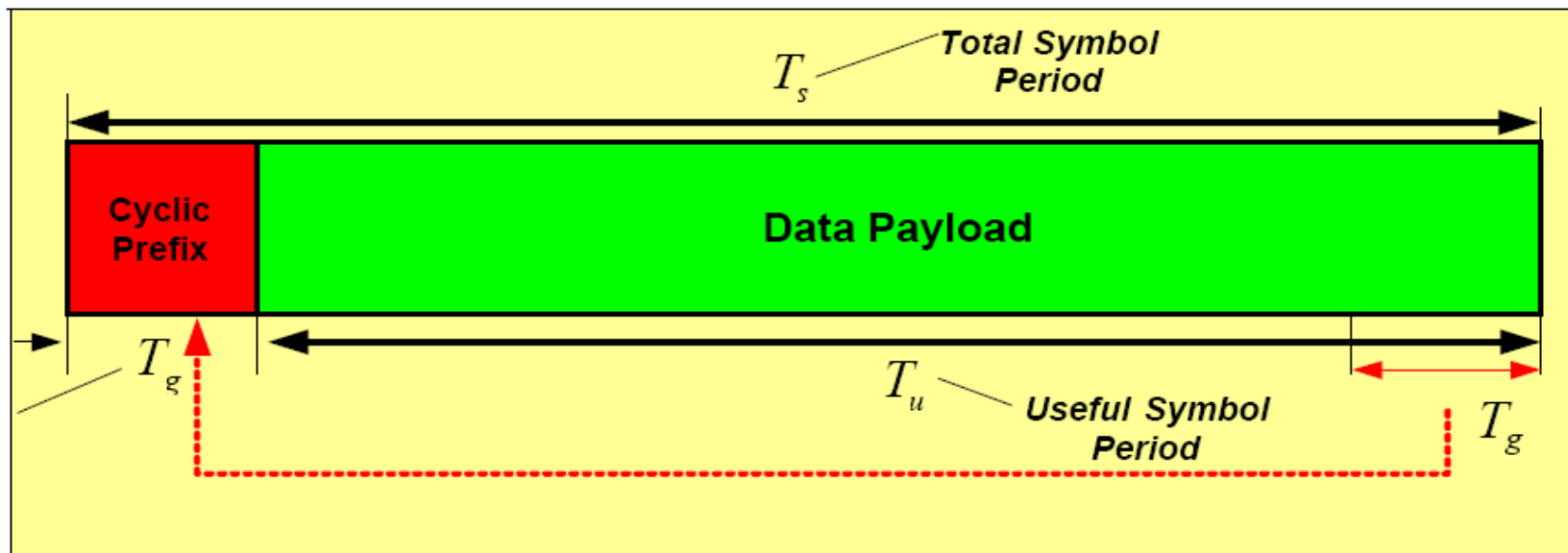
- ❑ The physical layer is based on orthogonal frequency-division multiple access (OFDMA), which consists of using OFDM for transmission and allocating groups of subcarriers to different users.
- ❑ OFDM is also the transmission technology used in the IEEE 802.11a specifications, which form the basis of WiFi, but those specifications use TDMA for multiple access.
- ❑ Similarly, the IEEE 802.16 – 2004 for fixed WiMAX are based on OFDM and TDMA.
- ❑ OFDMA uses the subscriber station energy more efficiently than TDMA, and this helps to extend the cell range and the battery power of mobile terminals.

Basic Architecture of OFDM



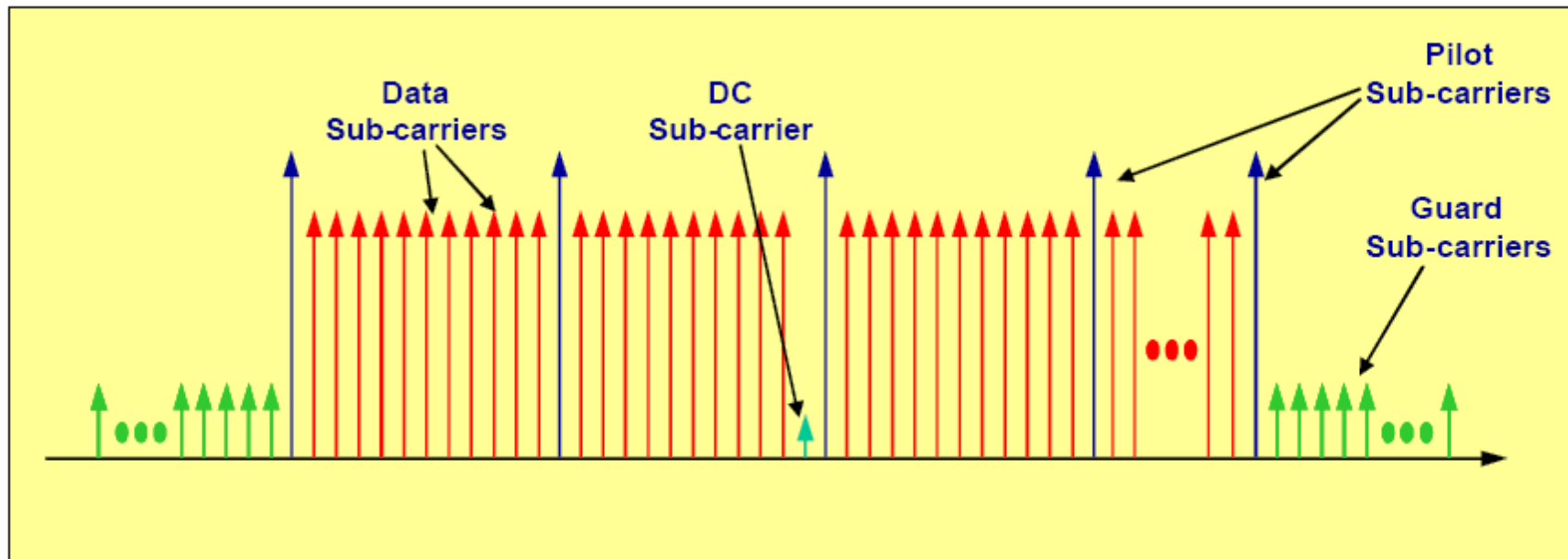
Cyclic Prefix Insertion

OFDM and OFDMA signals are generated using an Inverse Fast Fourier Transform (IFFT). A cyclic prefix is inserted between successive OFDM symbols (IFFT blocks) to cancel intersymbol interference.



OFDMA Symbol Structure

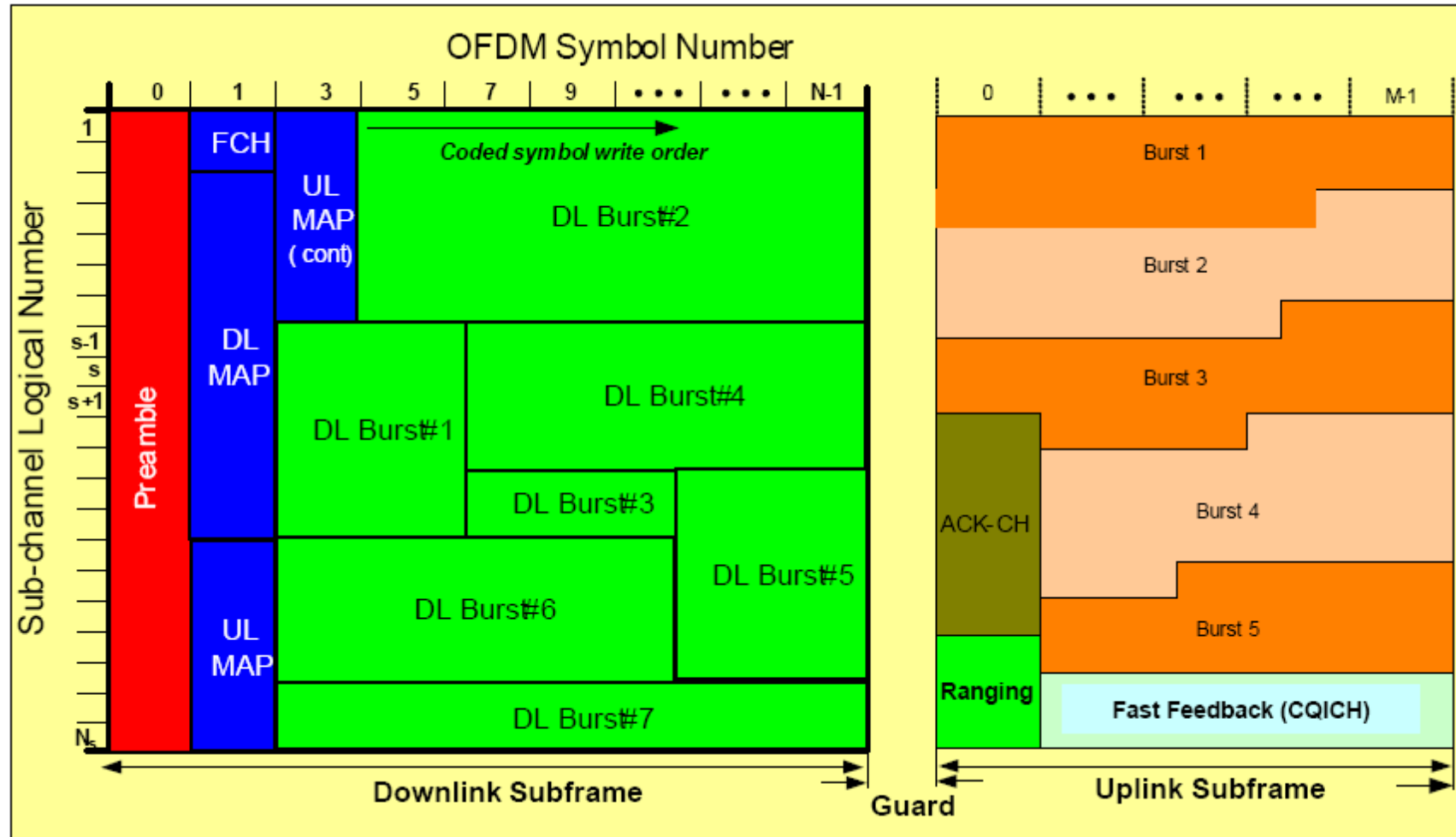
The OFDMA symbol structure consists of 3 types of sub-carriers
As shown below:



Basic Features

- ❑ WiMAX OFDMA is scalable: It supports a wide range of channel bandwidths by scaling the number of subcarriers accordingly. The subcarrier spacing remains fixed (10.24 kHz).
- ❑ Subchannelization is used in both the downlink (DL) and uplink (UL), the minimum frequency-time resource unit of subchannelization is one slot, which is composed of 48 data subcarriers.
- ❑ Subcarrier permutation is used to gain frequency diversity and average interference between adjacent cells.

WiMAX OFDMA Frame Structure



Scalable OFDMA Parameters

Parameters	Values			
System Channel Bandwidth (MHz)	1.25	5	10	20
Sampling Frequency (F_p in MHz)	1.4	5.6	11.2	22.4
FFT Size (N_{FFT})	128	512	1024	2048
Number of Sub-Channels	2	8	16	32
Sub-Carrier Frequency Spacing	10.94 kHz			
Useful Symbol Time ($T_b = 1/f$)	91.4 microseconds			
Guard Time ($T_g = T_b/8$)	11.4 microseconds			
OFDMA Symbol Duration ($T_s = T_b + T_g$)	102.9 microseconds			
Number of OFDMA Symbols (5 ms Frame)	48			

Adaptive Modulation and Coding

Adaptive modulation and coding (AMC), Hybrid Automatic Repeat Request (HARQ) and Fast Channel Feedback were introduced in mobile WiMAX specifications to enhance coverage and capacity.

The supported modulation and coding schemes are:

		DL	UL
Modulation		QPSK, 16QAM, 64QAM	QPSK, 16QAM, 64QAM
Code Rate	CC	1/2, 2/3, 3/4, 5/6	1/2, 2/3, 5/6
	CTC	1/2, 2/3, 3/4, 5/6	1/2, 2/3, 5/6
	Repetition	x2, x4, x6	x2, x4, x6

Other Advanced Features

- ❑ Hybrid ARQ

HARQ is a physical layer ARQ stop-and-wait protocol, which improves transmission performance on wireless channels. Mobile WiMAX supports HARQ with Chase combining.

- ❑ Fast Scheduling

Fast scheduling enables rapid response to variations of traffic and channel conditions. Mobile WiMAX uses fast scheduling on both uplink and downlink and performs it on a per-frame basis. This is particularly suited to burst traffic and rapidly time-varying channels.

- ❑ Bandwidth-Efficient Handoff

Mobile WiMAX supports network-optimized handoff and achieves a handoff delay less than 50 ms.

Mobile WiMAX Data Rates

Mod.	Code Rate	5 MHz Channel		10 MHz Channel	
		Downlink Rate, Mbps	Uplink Rate, Mbps	Downlink Rate, Mbps	Uplink Rate, Mbps
QPSK	1/2 CTC, 6x	0.53	0.38	1.06	0.78
	1/2 CTC, 4x	0.79	0.57	1.58	1.18
	1/2 CTC, 2x	1.58	1.14	3.17	2.35
	1/2 CTC, 1x	3.17	2.28	6.34	4.70
	3/4 CTC	4.75	3.43	9.50	7.06
16QAM	1/2 CTC	6.34	4.57	12.07	9.41
	3/4 CTC	9.50	6.85	19.01	14.11
64QAM	1/2 CTC	9.50	6.85	19.01	14.11
	2/3 CTC	12.67	9.14	26.34	18.82
	3/4 CTC	14.26	10.28	28.51	21.17
	5/6 CTC	15.84	11.42	31.68	23.52

MAC Layer Description

- ❑ The IEEE 802.16 standard was developed from the outset for the delivery of broadband services including voice, data and video.
- ❑ The MAC layer is based on the time-proven DOCSIS standard and can support bursty data traffic with high peak rates while simultaneously supporting streaming video and latency-sensitive voice traffic on the same channel.
- ❑ The resource allocated to one terminal can vary from a single time slot to the entire frame providing a very large dynamic range of throughput to a given user terminal.
- ❑ The MAC scheduler can change the resource allocation on a frame-by-frame basis to adapt to the bursty nature of traffic.

Quality of Service (QoS) Support

- ❑ In the Mobile WiMAX MAC layer, QoS is provided via service flows. Before providing a particular type of data service, the base station and user terminal establish a logical channel between the peer MACs, called a connection.
- ❑ The outbound MAC layer then associates packets traversing the MAC interface into a service flow to be delivered over the connection.
- ❑ Since the air interface is usually the bottleneck, the connection-oriented QoS of mobile WiMAX can effectively lead to end-to-end QoS control.
- ❑ Mobile WiMAX supports unsolicited grant service for VoIP, real-time packet service for audio and video streaming, non-real-time packet service for FTP as well as best-effort traffic.

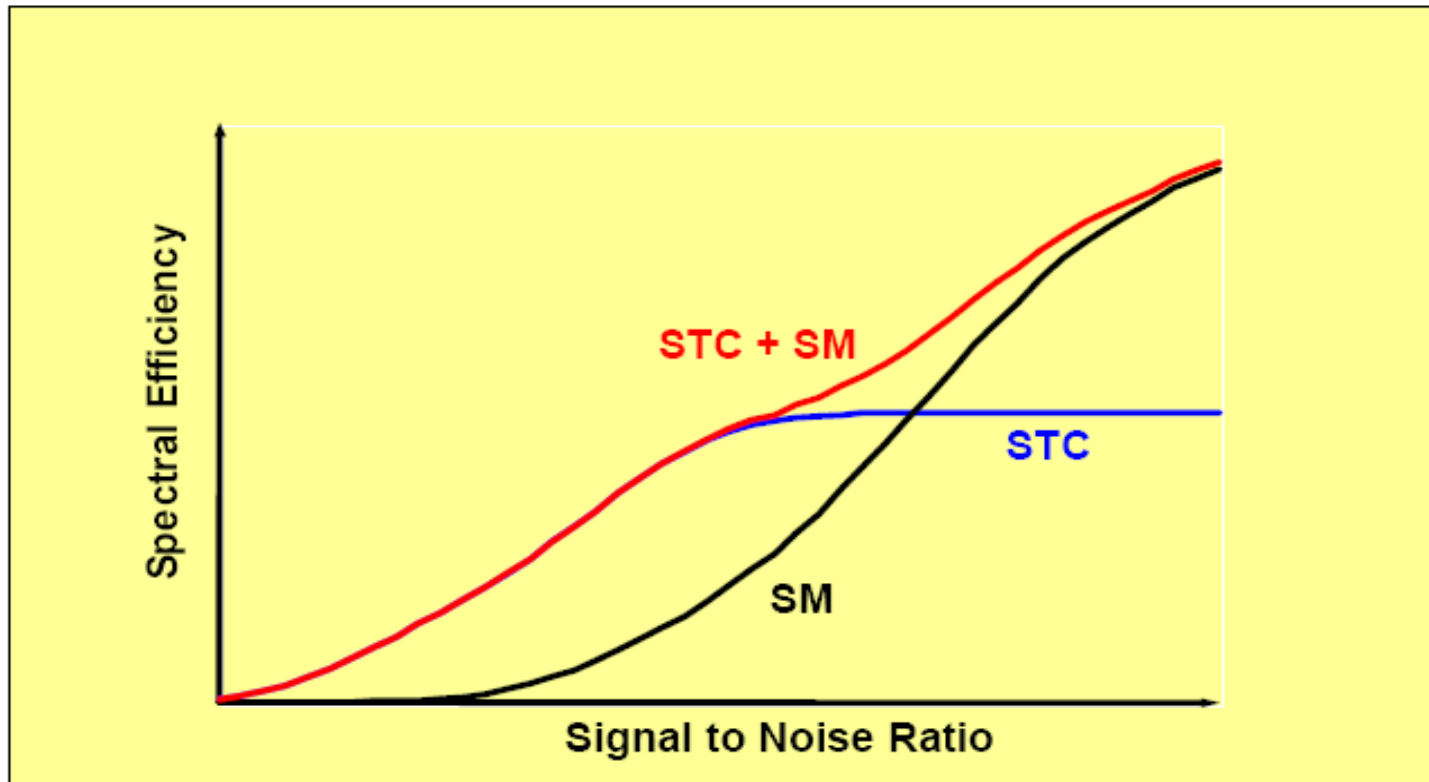
Multiple Antenna Technologies

- ❑ Multiple antennas at the transmitter or at the receiver can be used to provide spatial diversity and improve robustness to fading, or to make beam forming (smart antennas).
- ❑ When multiple antennas are used at both transmitter and receiver, the resulting system is called MIMO (multiple-input multiple-output). In addition to diversity, MIMO systems can also increase cell throughput and make the desired tradeoff between them.
- ❑ WiMAX specifications define two mandatory MIMO profiles for the downlink. Both of them are only optional for the uplink.
 - Matrix A: Alamouti's space-time code (STC)
 - Matrix B: Spatial Multiplexing (SM)

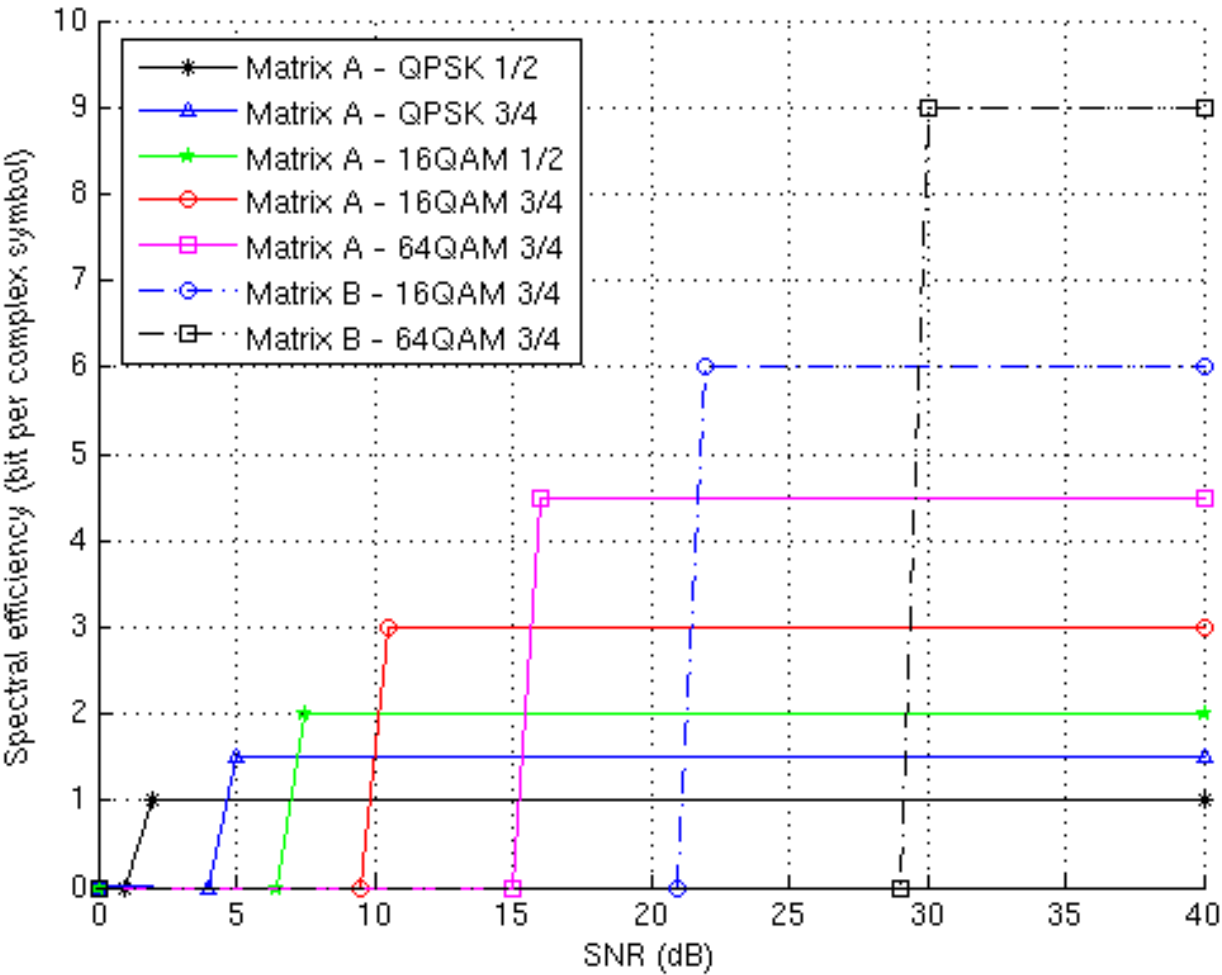
Comparison of MIMO Profiles

- ❑ Alamouti's STC inherently provides second-order transmit diversity. When combined with two antennas and maximum-ratio combining (MRC) at the receiver, it leads to 4th-order diversity and excellent performance.
- ❑ 2x2 spatial multiplexing (SM) has only a 2nd-order diversity and therefore it cannot achieve the performance of Matrix A. But spatial multiplexing offers a doubled bit rate when it uses the same modulation scheme as the Alamouti/MRC system.
- ❑ An objective comparison of the two schemes shows that Matrix A should be used at low signal-to-noise ratio (SNR) values and Matrix B at high SNR values.
- ❑ MIMO profile switching can be combined with adaptive modulation and coding.

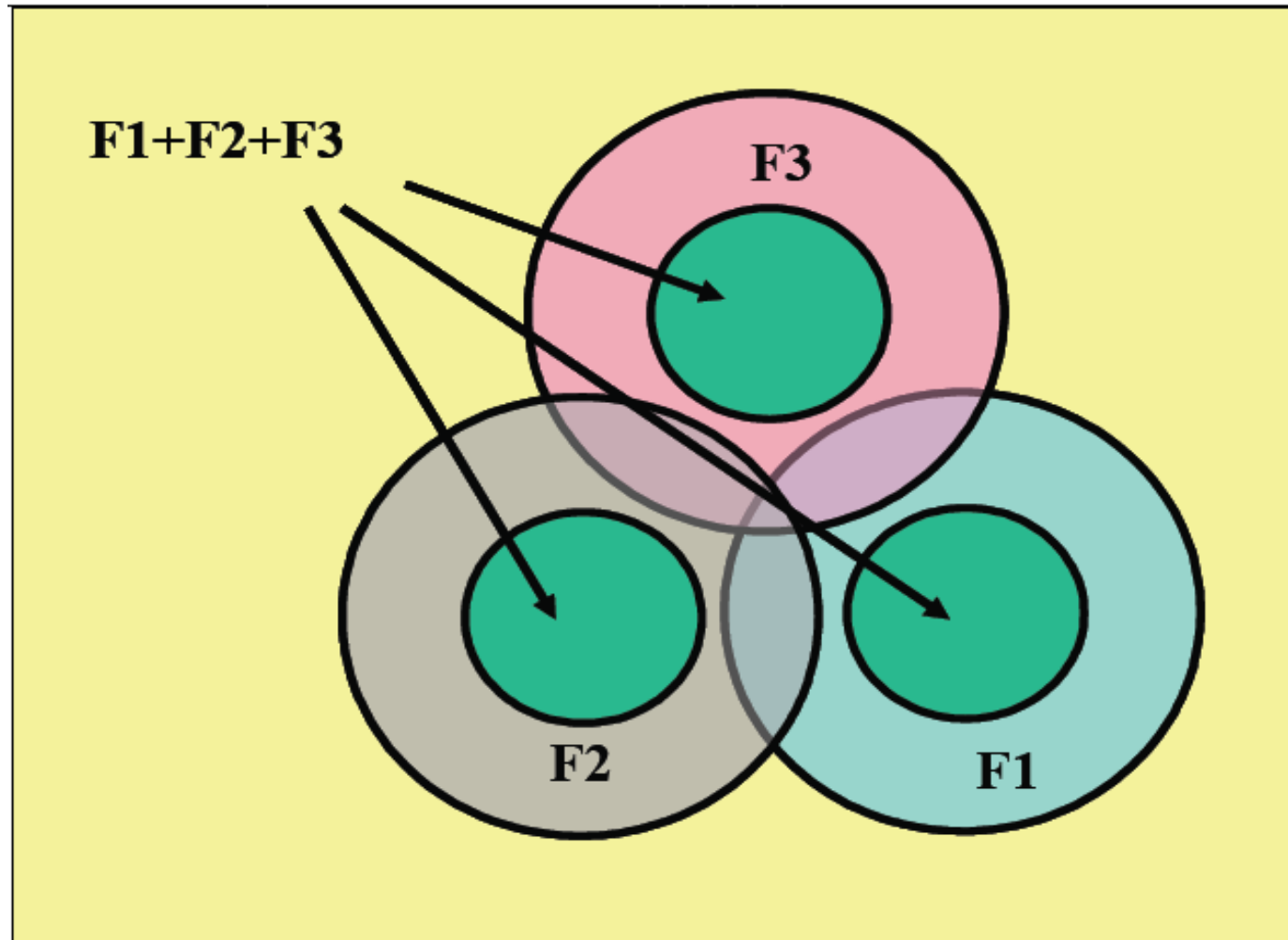
MIMO Option Switching



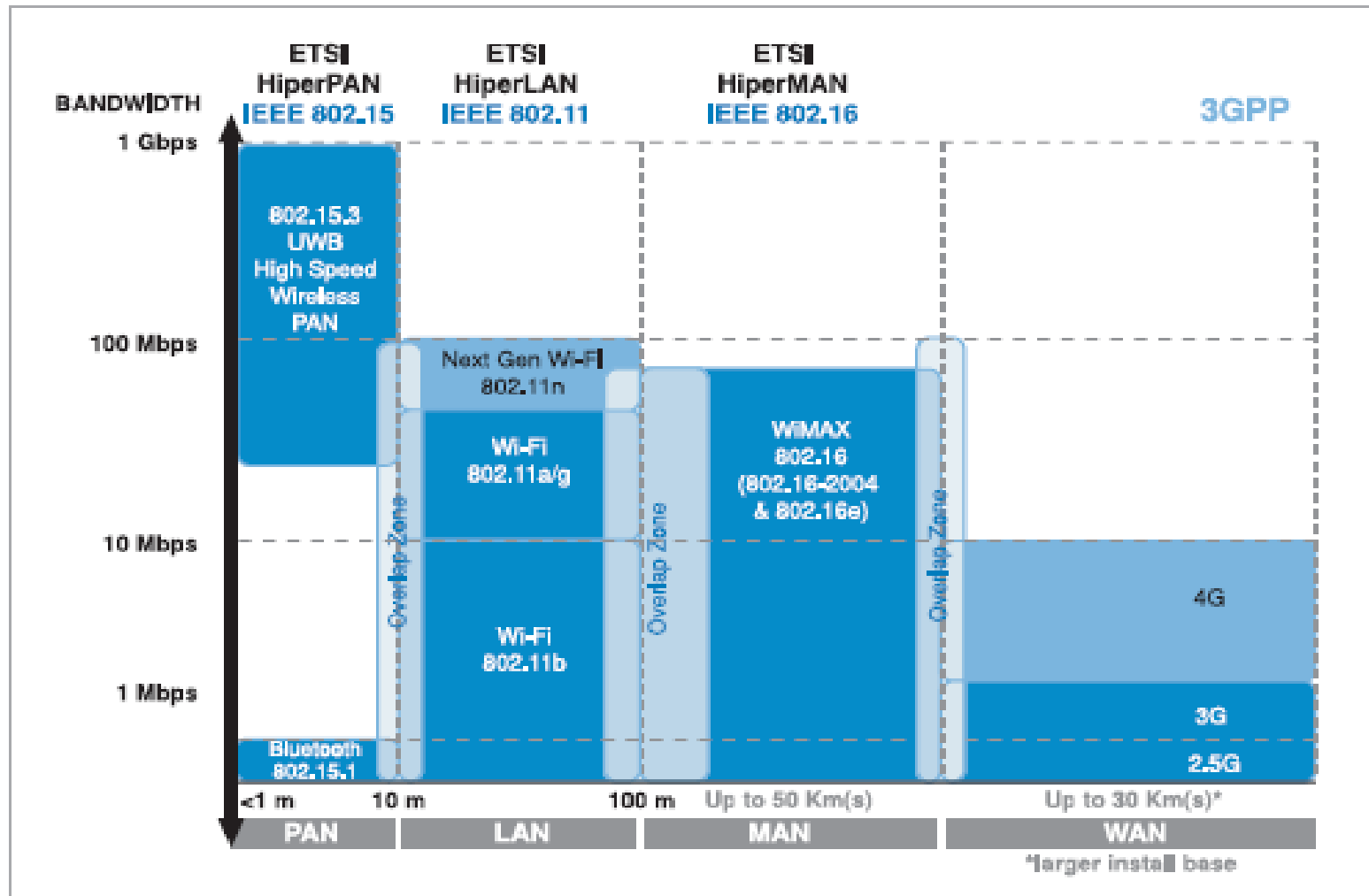
MIMO Option Switching



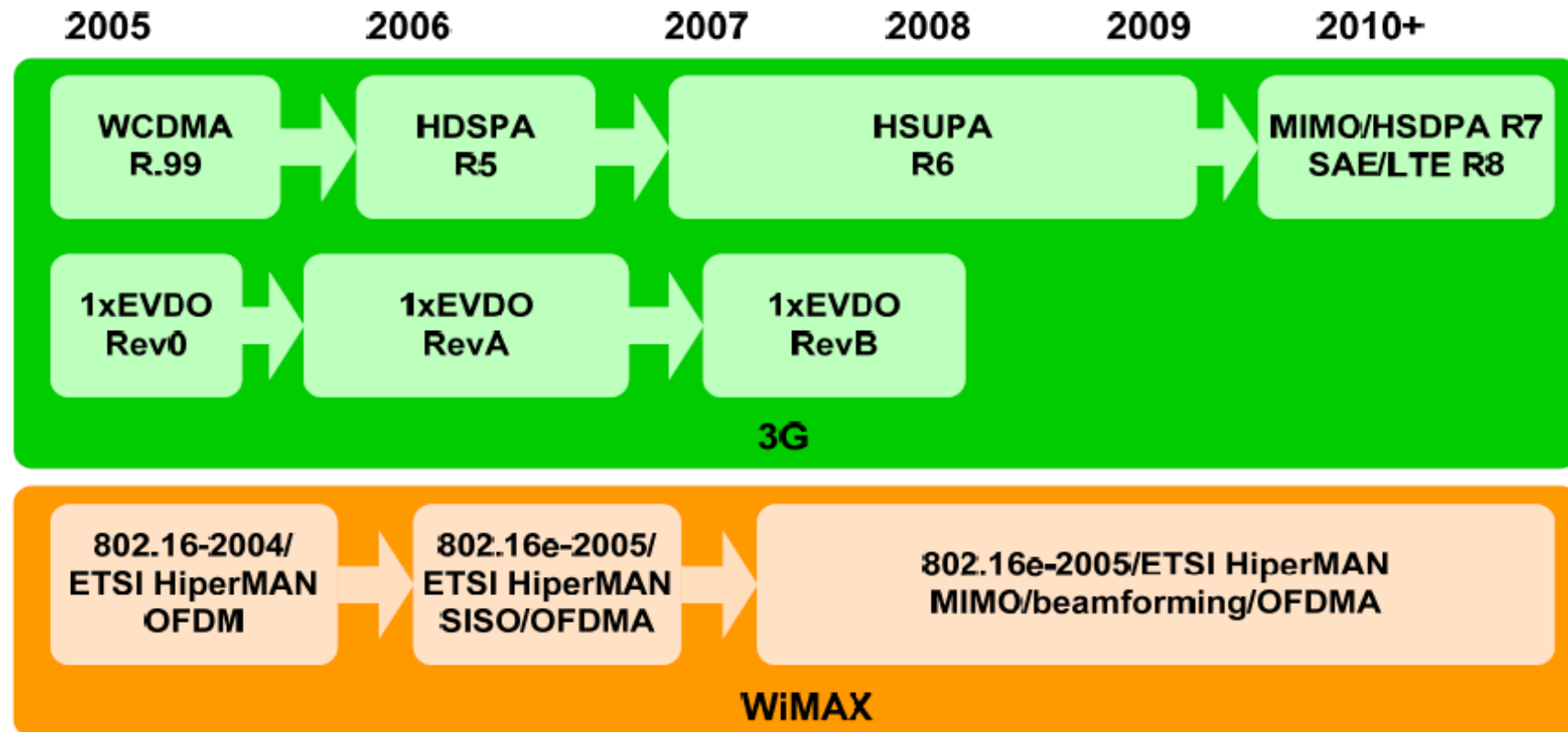
Fractional Frequency Reuse



WiMAX and WiFi



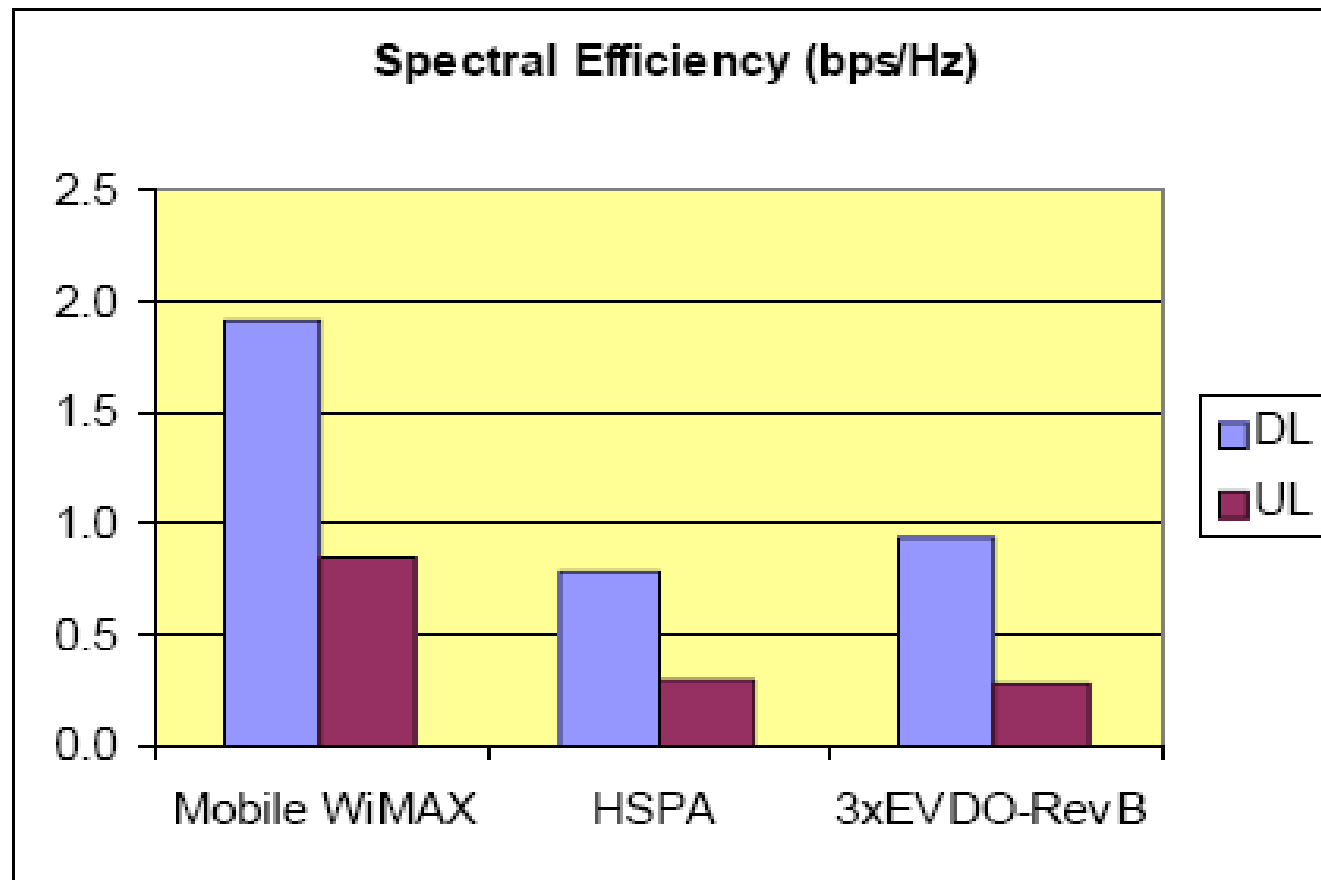
WiMAX and 3G Evolutions



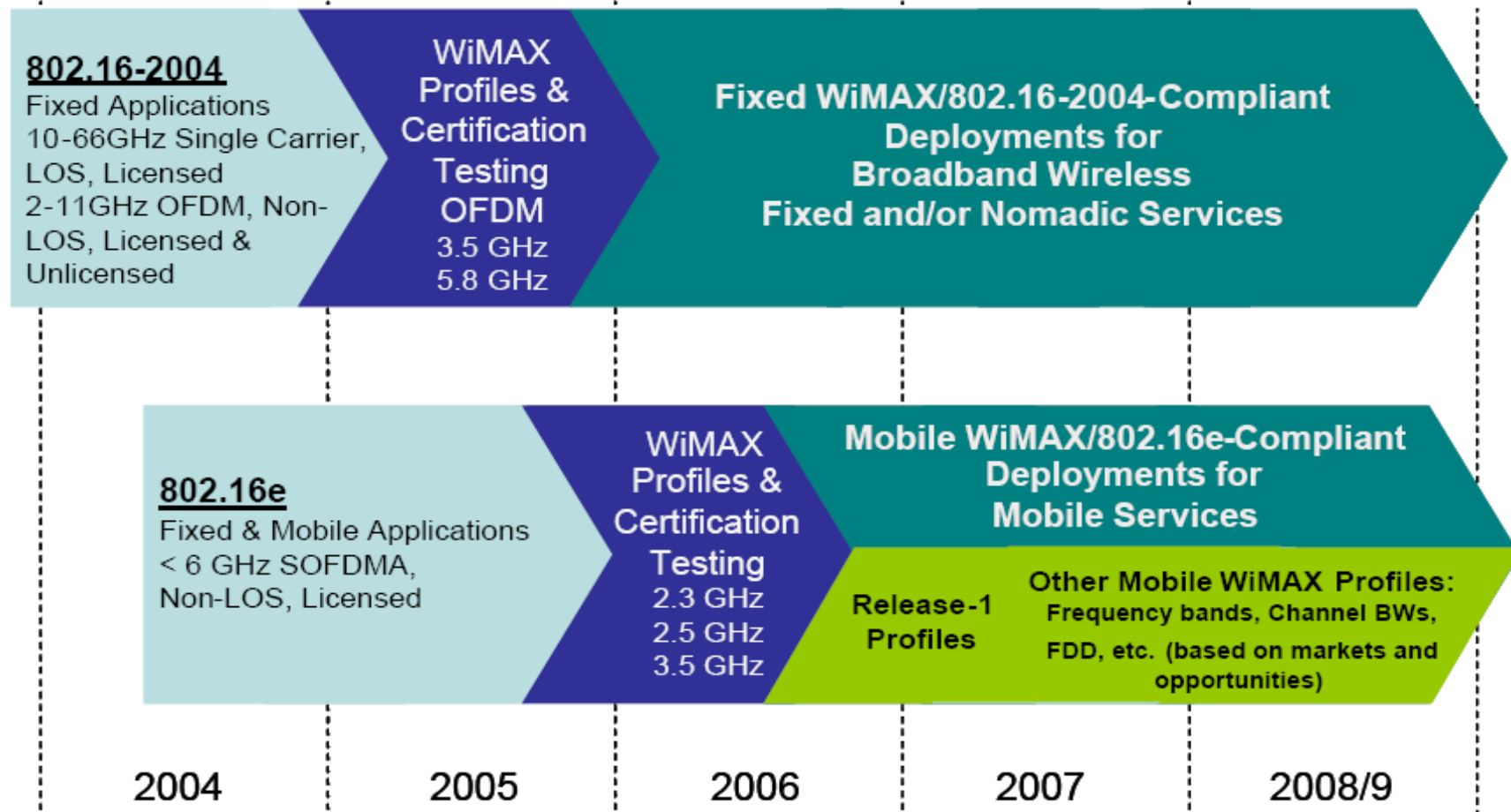
WiMAX and 3G Features

Technology	DL Modulation	DL Code Rate	UL Modulation	UL Code Rate
HSDPA	16QAM, QPSK	Turbo, CC: 1/4, 2/4, 3/4, 4/4	Fixed (BPSK)	Fixed
HSPA (HSDPA+HSUPA)			BPSK, QPSK	Turbo, CC: 2/3, 3/4, 4/4
Mobile WiMAX	64QAM, 16QAM, QPSK	Turbo, CC, Repetition: 1/12, 1/8, 1/4, 1/2, 2/3, 3/4, 5/6	16QAM, QPSK, 64QAM <i>Optional</i>	Turbo, CC, Repetition: 1/12, 1/8, 1/4, 1/2, 2/3, 3/4, 5/6 <i>Optional</i>

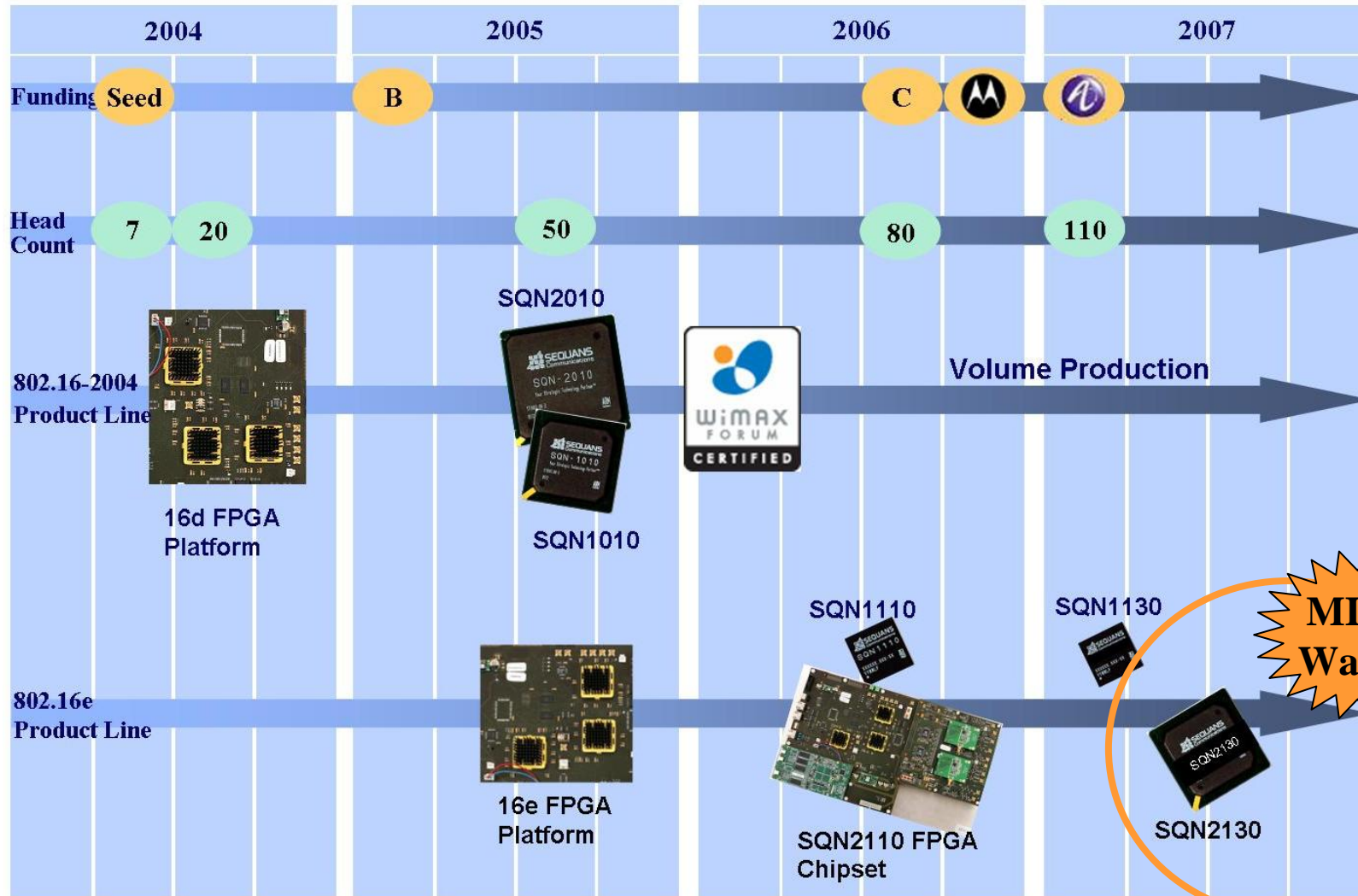
WiMAX and 3G Spectral Efficiencies



WiMAX Technology Roadmap



SEQUANS Communications Chips



Summary and Conclusions

- ❑ We have given an overview of Mobile WiMAX systems and of the IEEE 802.16e specifications on which they are based.
- ❑ Mobile WiMAX employs a transmission and multiple access technique well-suited for mobile broadband access as well as advanced multiple antenna technologies. It also features a time-proven MAC supporting services with different QoS requirements.
- ❑ Mobile WiMAX products are in the certification phase today, and mass deployment is expected within the next few months.