WiMAX

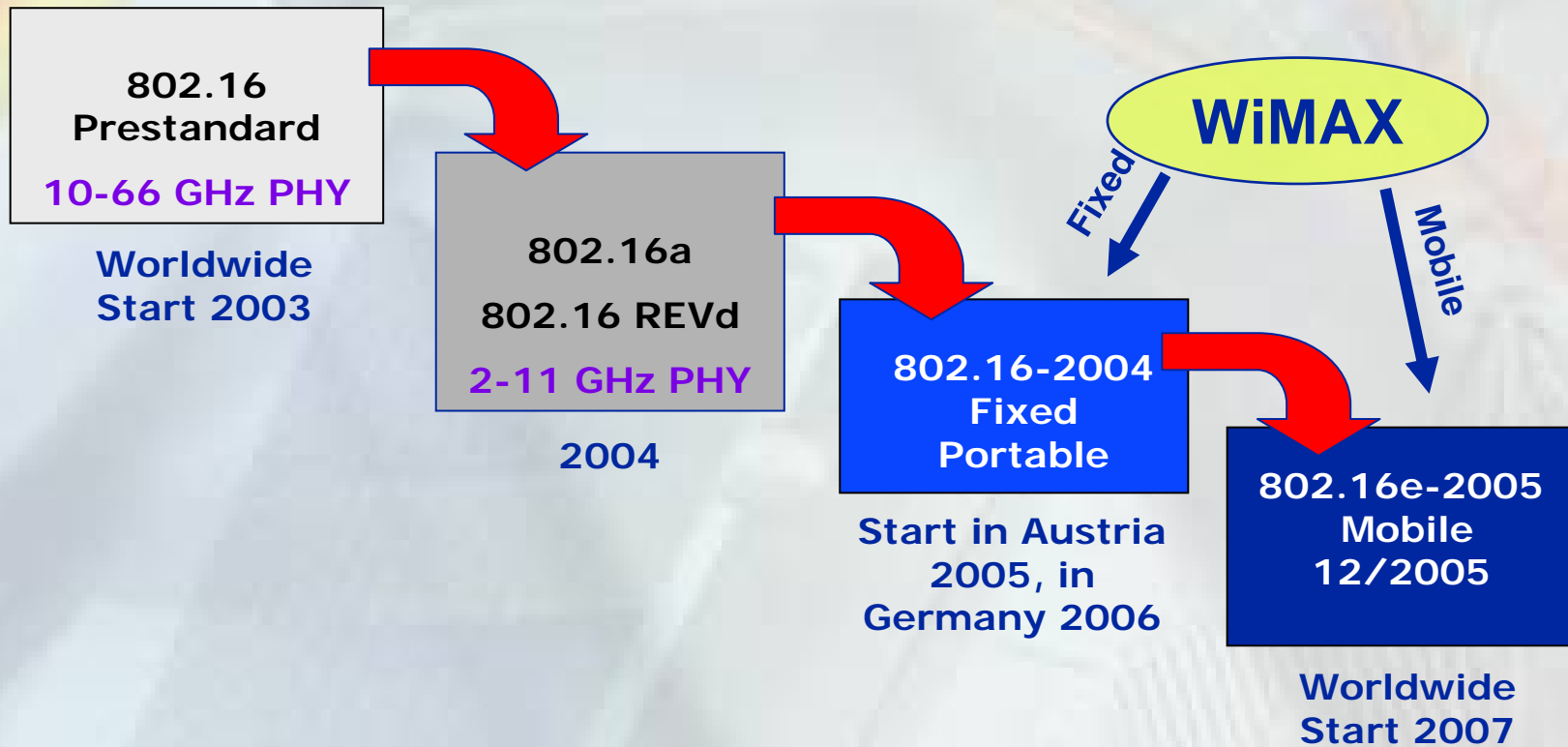## Worldwide Interoperability for Microwave Access
Standards, Technology, Applications and Trends

Hermann Lipfert
Institut für Rundfunktechnik
Broadcast Networks and Servers

WiMAX History

802.16 Prestandard

10-66 GHz PHY

Worldwide Start 2003

802.16a

802.16 REVd

2-11 GHz PHY

2004

802.16-2004 Fixed Portable

Start in Austria 2005, in Germany 2006

WiMAX

Fixed

Mobile

802.16e-2005 Mobile 12/2005
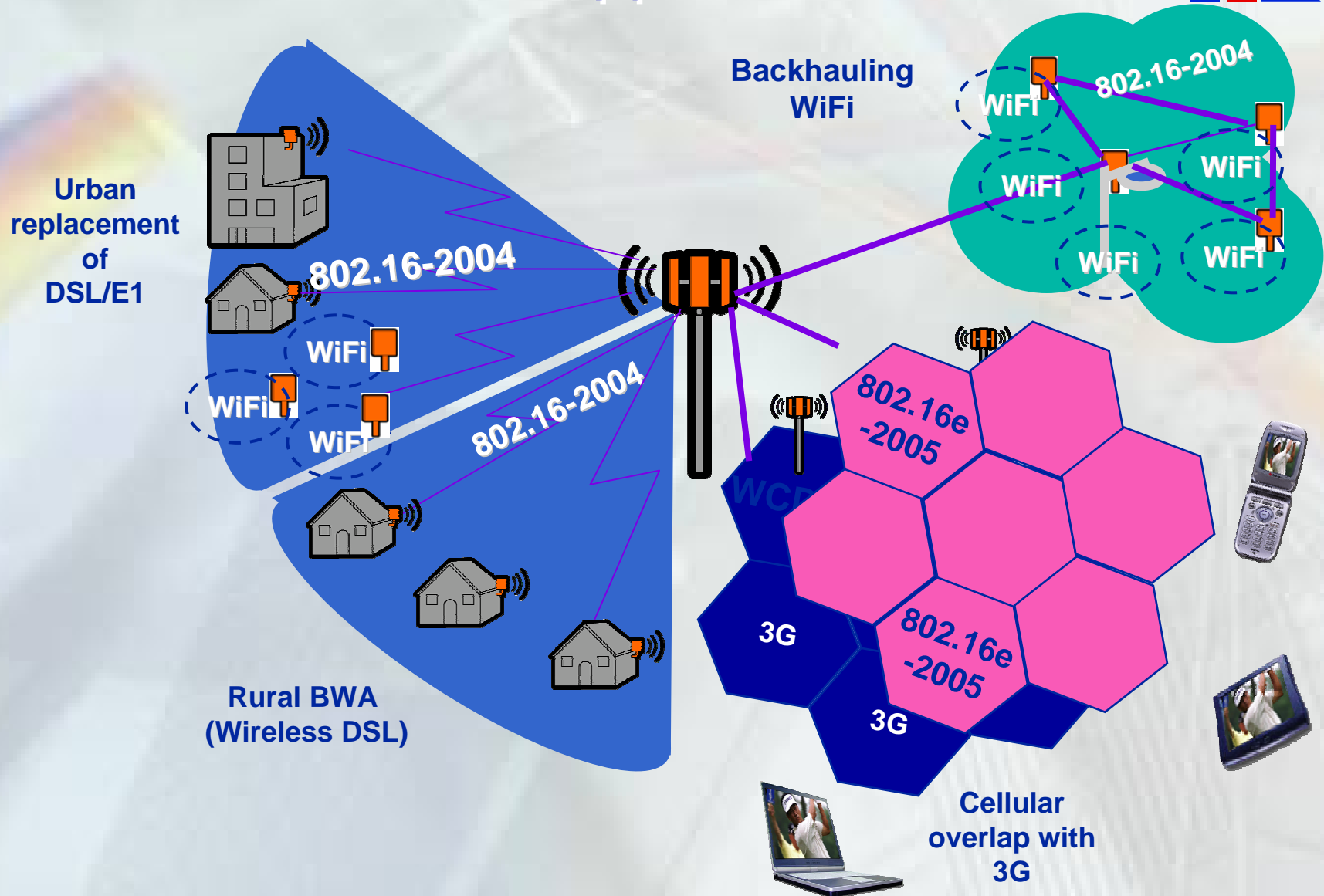
Worldwide Start 2007

WiMAX Forum

- Founded in 2001 by manufacturers
- Heavy growing - May 2007 membership 440+ companies
  (Alcatel, Alvarion, British Telecom, Deutsche Telekom, France Telecom, Fujitsu, IBM, Intel, Nortel, Motorola, Siemens, Samsung ….)
- Commitment to interoperability
- Marketing and Promotion
- Development of systemprofiles for different conditions
  (frequency range and bandwidth, power…)
- Clarification of regulatory conditions (dialog with regulatory authorities)
- Costly test- and certification programm since July 2005 at AT4 wireless (formerly Cetecom Labs Malaga)
- Issue of the label „WiMAX Forum Certified"
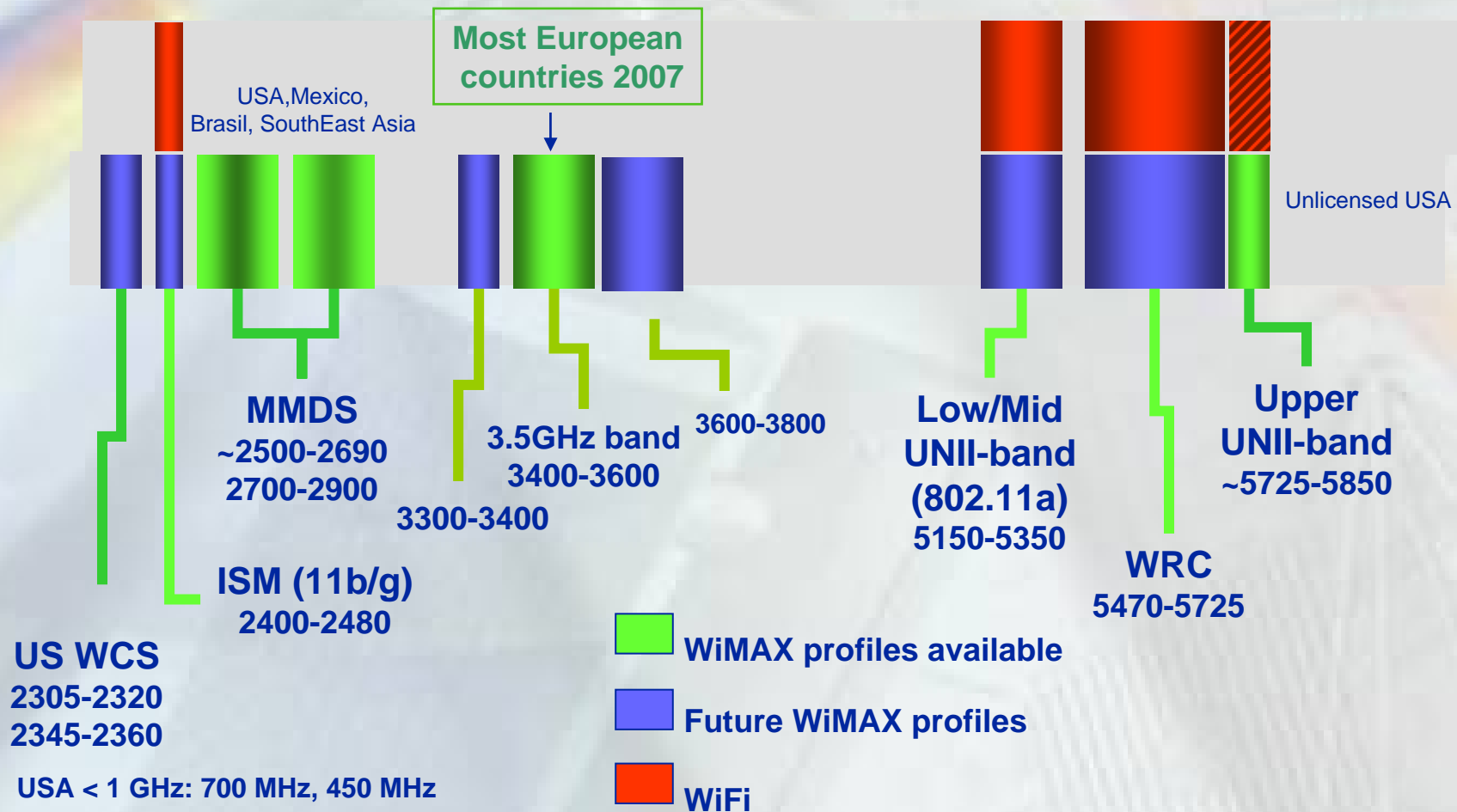- Interoperability and conformity tests

What is WiMAX ?

- Worldwide standard for Broadband Wireless Access (BWA)
- Standardised in Europe by ETSI (BRAN) as HiperMAN
- Korea (Samsung, LG) conforms to the standard IEEE 802.16e WiBro (TTA PG302 BWA)
- Base Station (BS) – Subscriber Station (SS)
- Two possible network topologies defined:
  - PMP (Point-to-Multipoint)
    - traffic takes place only between BS and its SSs
  - Mesh mode
    - traffic also routed between SSs (so-called „nodes")
- Current WiMAX deployments mainly PMP topology
- Uplink ressources for SSs on demand
- Wireless ressources dynamically distributed
- Definition of connections and service flows

WiMAX: Different application models

Backhauling WiFi

802.16-2004

WiFi · WiFi · WiFi · WiFi · WiFi

Urban replacement of DSL/E1

802.16-2004

WiFi · WiFi · WiFi · WiFi

802.16-2004

Rural BWA (Wireless DSL)

WCD

802.16e -2005

802.16e -2005

3G

3G

Cellular overlap with 3G

WiMAX – existing and potential frequency spectrum worldwide

Most European countries 2007

USA, Mexico, Brasil, SouthEast Asia

Unlicensed USA

MMDS
~2500-2690
2700-2900

3.5GHz band
3400-3600

3600-3800

3300-3400

Low/Mid UNII-band (802.11a)
5150-5350

Upper UNII-band
~5725-5850

WRC
5470-5725

ISM (11b/g)
2400-2480

US WCS
2305-2320
2345-2360

USA < 1 GHz: 700 MHz, 450 MHz

- **WiMAX profiles available**
- **Future WiMAX profiles**
- **WiFi**

IEEE 802.16 Family HF-Parameters

	IEEE 802.16a	IEEE 802.16-2004 Fixed WiMAX	IEEE 802.16e-2005 Mobile WiMAX
Completion	January 2003	July 2004	December 2005
Products	Yes, but no relevance for private customers	Since 2005	Since 2006
Frequency range	< 11 GHz	2 bis 11 GHz	0,7 bis 6 GHz
max. Datarate	Up to 75 Mbit/s in 28-MHz-channels	Up to 75 Mbit/s in 20-MHz-channels	Up to 15 Mbit/s in 5-MHz-channels
Bandwidth	1,25 MHz - 28 MHz	Scalable in steps of 250 KHz from 1,25 to 20 (28) MHz (depending on license)	1,25 - 2,5 - 5 - 7 - 10 – 20 - - (28) MHz WiBRO Korea 8,75MHz
Modulation	OFDM-256 with QPSK, 16QAM, 64QAM	SC, 256 FFT OFDM with BPSK, QPSK,16QAM,64QAM OFDMA-2048	S-OFDMA 128, 512, 1024, 2048 FFT
Operation	Fixed with LOS	LOS or NLOS Operation with limited mobility	NLOS and mobility
max. Distance	50 km	Up to 50 km, typically 15 km with external antenna, up to 5 km with internal antenna	Up to 5 km, typically 1,5 km

WiMAX PHY- MAC- Protocol - Layers

MAC Convergence Sublayer (CS) supports ATM- and packet- based network services
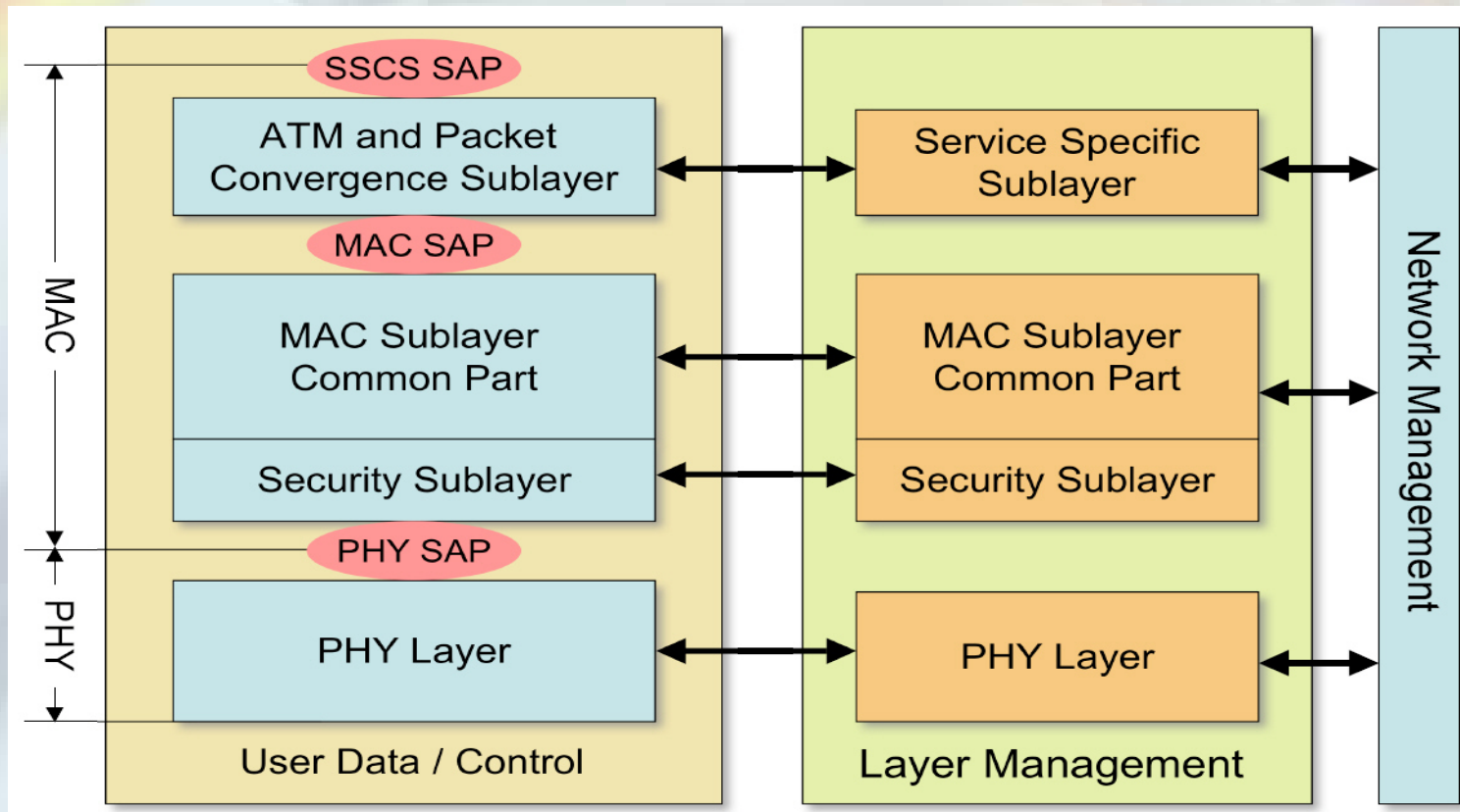
Source: Acterna

ATM/Packet Convergence Sublayer

ATM CS:

Accepts ATM cells – performs classification

– ATM Header Suppression (PHS)

- VP (Virtual Path) switched connections
- VC (Virtual Channel) switched connections

Support of end-to-end signaling for dynamic connections with QoS

- SVCs , soft PVCs

Packet CS:

Used for transport of all packet-based protocols - performs classification

– Payload Header Suppression (PHS)

- Internet Protocol (IP), IPv4, IPv6
- Point-to-Point Protocol (PPP), IEEE 802.3 (Ethernet), MPLS

Although detailed in the standard, for the moment no implementation of the ATM CS is planned !

Convergence Sublayer (CS)

- Implements the basic QoS-functions of WiMAX
- Classifies and maps the Mac Service Data Units (MSDUs) onto appropriate CIDs (Connection Identifiers)
- Classification and mapping based on two fundamental 802.16 Mac layer concepts:
  - Connection – mapping between BS and SS Mac peers (CID)
  - Service Flow – defines QoS parameters for packets (PDUs) exchanged on the connection (SFID)
- Classification allows perfect link adaptation
- Allocation of needed resources

# Mobile WiMAX Applications and Quality of Service

| QoS Category	Applications	QoS Specifications
UGS Unsolicited Grant Service	VoIP	• Maximum Sustained Rate • Maximum Latency Tolerance • Jitter Tolerance
rtPS Real-Time Polling Service	Streaming Audio or Video	• Minimum Reserved Rate • Maximum Sustained Rate • Maximum Latency Tolerance • Traffic Priority
ErtPS Extended Real-Time Polling Service	Voice with Activity Detection (VoIP)	• Minimum Reserved Rate • Maximum Sustained Rate • Maximum Latency Tolerance • Jitter Tolerance • Traffic Priority
nrtPS Non-Real-Time Polling Service	File Transfer Protocol (FTP)	• Minimum Reserved Rate • Maximum Sustained Rate • Traffic Priority
BE Best-Effort Service	Data Transfer, Web Browsing, etc.	• Maximum Sustained Rate • Traffic Priority

WiMAX Forum

Orthogonal Frequency Division Multiple Access   OFDMA

- OFDM: exactly one SS during one time-slot
- OFDMA: several subscribers at allocated Sub-Channels during the same time-slot ➔ Multiple Access
- Coding, Modulation and Amplitude optimized separately for every sub-channel – *Adaptive Modulation and Coding (AMC)*
- S-OFDMA (Scalable OFDMA): possibility to scale amount of carriers (128, 512, 1024, 2048) and Sub-Channels (2, 8, 16, 32)

➔ higher spectral efficiency
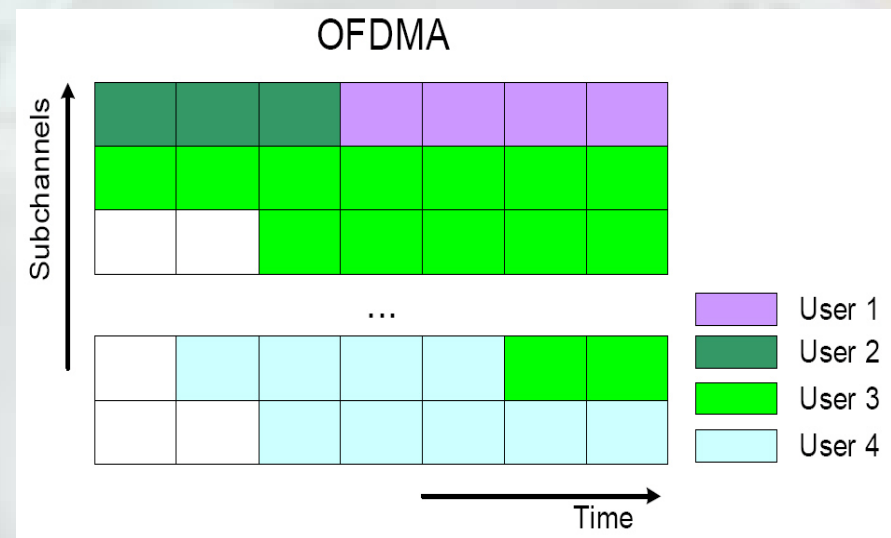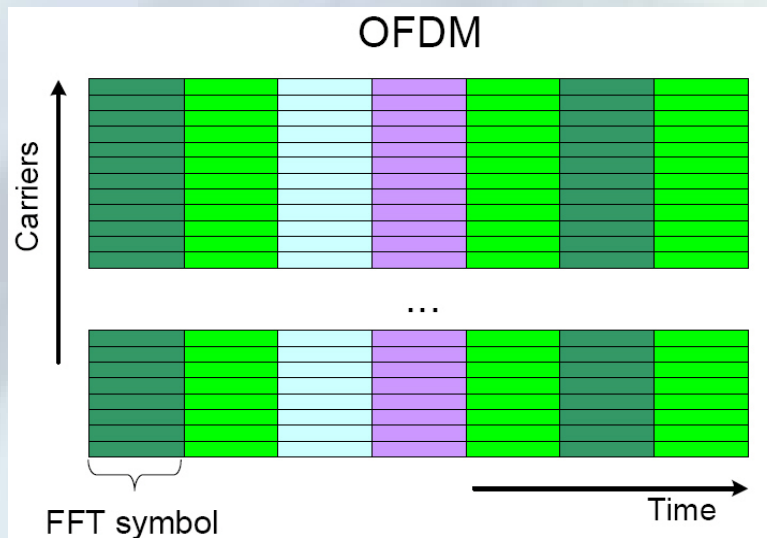
WiMAX OFDMA Frame Structure
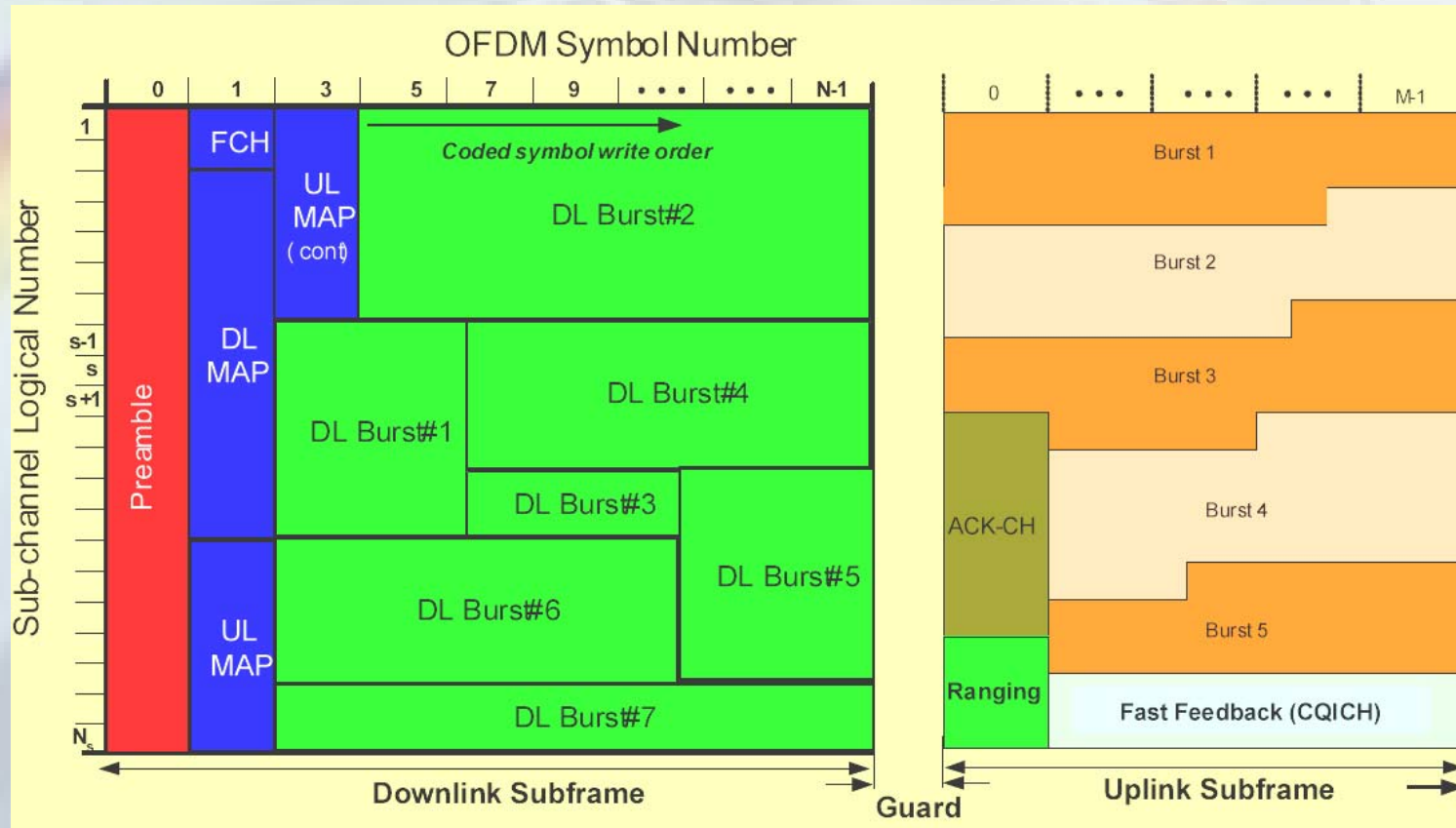
WiMAX Forum

FCH: Frame Control Header
CQICH: Channel Quality Indicator channel
Ranging: Adjustment for Mobile Stations (MS)

DL/UL-MAP: Downlink/Uplink Media Access Protocol
ACK-CH: Acknowledge Channel

Mobile WiMAX Advanced Features

Wave 1

- Adaptive Antenna Systems (AAS) using Beamforming or Transmit Diversity

Wave 2

- Multiple Input Multiple Output (MIMO) using multiple transmit/receive antenna systems

MIMO enhances clearly spectral efficiency (bit/s/Hz)

- multiple datastreams at same frequency via different spatial paths (Spatial Multiplexing)
- MIMO drastically reduces the necessary transmission-sites compared to SISO systems
- Vice versa MIMO can reduce necessary transmitting power to gain adequate coverage

➔ MIMO is business case

Flexible datarates using Sub-Channelization

Advanced Coding and Modulation (ACM)

Mobile WiMAX
Advanced Features (2)

Scalability of spectral ressources (1,25 MHz – 20 MHz)

High security standards integrated (EAP, AES-CCM, SIM)

802.16 MAC-architecture defines Service-Flows with QoS which can be mapped to DiffServ or MPLS

Optimised Hard Handoff (HHO) mandatory, Layer 2 handoff delays < 50ms

Power Management: Sleep Mode, Idle Mode

Scanning for other BSs during Sleep Mode to prepare HO

Multicast and Broadcast Service (MBS)

- Single Frequency Network (SFN)
- Data-Casting, Audio- and Video-Streams

WiMAX Profile 5 MHz and 10 MHz OFDMA Parameter

Parameter	Downlink	Uplink	Downlink	Uplink
System Bandwidth	5 MHz		10 MHz	
FFT Size	512		1024	
Null Sub-Carriers	92	104	184	184
Pilot Sub-Carriers	60	136	120	280
Data Sub-Carriers	360	272	720	560
Sub-Channels	15	17	30	35
Symbol Period, T_S	102.9 microseconds			
Frame Duration	5 milliseconds			
OFDM Symbols/Frame	48			
Data OFDM Symbols	44			

WiMAX Forum

Mobile WiMAX PHY 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	12.67	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*	25.34	*18.82*
	3/4 CTC	14.26	*10.28*	28.51	*21.17*
	5/6 CTC	15.84	*11.42*	31.68	*23.52*

WiMAX Forum

Mesh-based WirelessMAN

WirelessHUMAN (High Speed Unlicensed MAN)
Meshed operation mode defined for license-free frequency bands at 5 GHz and 6 GHz
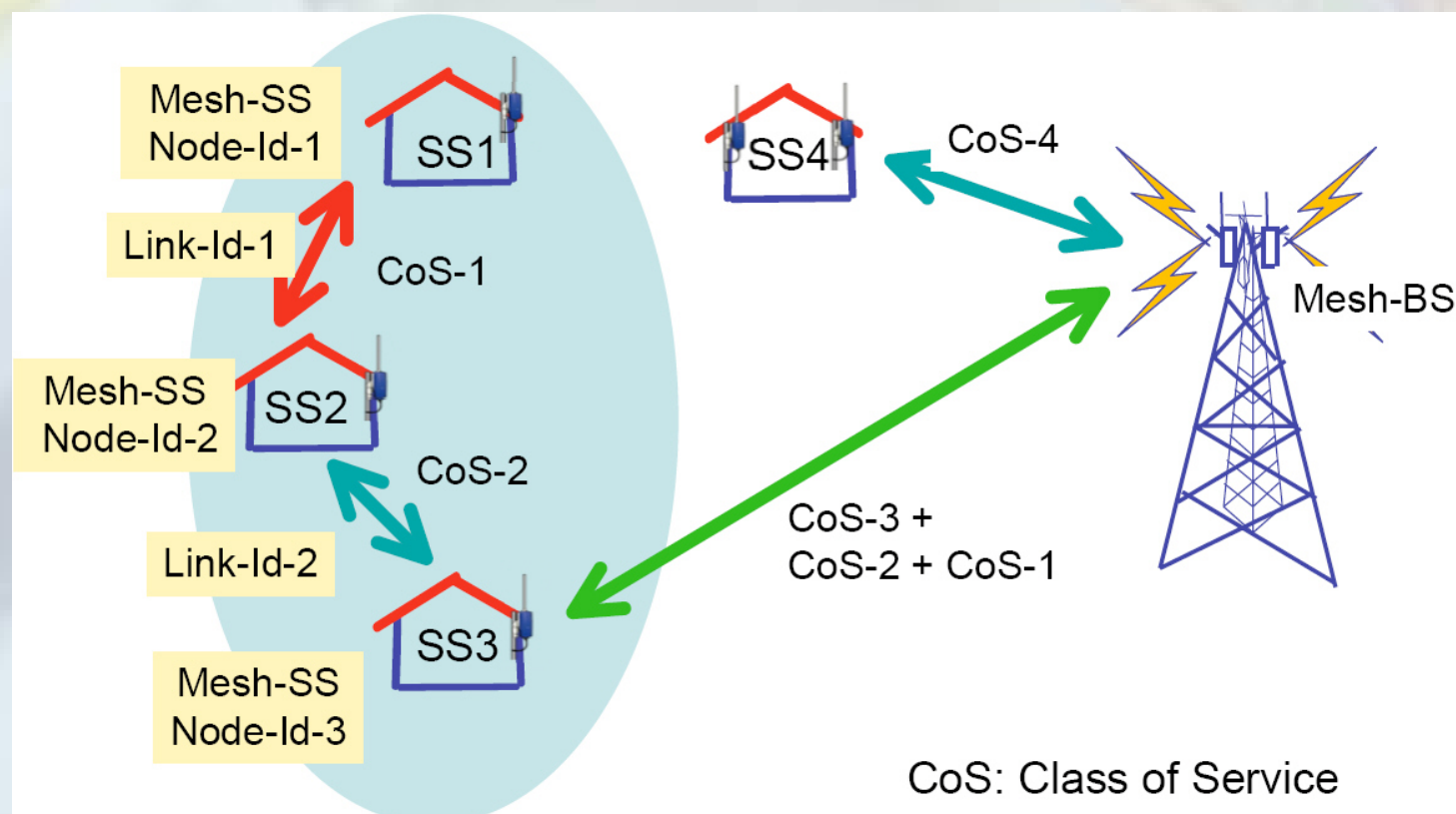
BWA Licenses for the 3.5GHz range in Germany

Revenue of the auction nearly 56 million €

Companies and investors global situated

Clearwire Europe S.a.r.l (Headquarters Europe: Luxembourg

- parent company headquarters: Kirkland, Washington/USA)

Inquam Broadband GmbH (Headquarters: Cologne/Germany)

- joint venture between Next*Wave* Wireless and financial investors

Deutsche Breitbanddienste GmbH (Headquarters: Heidelberg/Germany)

- Investors: Intel Capital and PolyTechnos

Televersa Online GmbH (Headquarters: Töging/Bavaria/Germany)

- Partners: Colt Telecom, MCI Worlcom, BT, Telcat Multicom

MGM Productions Group S.R.L ((Headquarters: Italy

- parent company US Canadian MGM Productions Group Inc.)

On the market WiMAX equipment for the 3.5 GHz range

Airspan:	MacroMAX, MicroMAX, EasyST, ProST
Redline Com.:	RedMAX BS, SS
Axess-pro:	BS, SS
Alvarion:	BreezeMAX, BreezeACCESS, BreezeNET BS, SS
Nortel:	BTS 1080, EasyST, ProST
Aperto:	PacketMAX Family BS, SS
Telsima:	StarMAX Family BS, SS
Telsa:	Freemax CPE System
Navini:	Ripwave Family BS, SS
Motorola:	MOTOwi4 Family
Samsung:	U-RAS Series
Siemens:	WayMAX Family BS, SS
Alcatel+Intel	A9100 Wimax Mobile in 2007
Proxim:	Tsunami Family BS SS

Live News Broadcast over WiMAX BBC -Telabria

Place: From Bristol Millenium Square to BBC Television Studio at center of town

„WiMAX broadcasting vehicle" = LandRover equipped with a 10 m telescopic mast

20 MBit/s bidirectional connection

Live encoding at Landrover site by Tandberg MPEG-4 Equipment

Transmitting-rate of the live streams about 8 MBit/s

Remaining bandwidth usable for positioning of additional camaras in future applications

Examples of available WiMAX Chip-solutions

Fujitsu Microelectronics Europe Mobile WiMAX System-on-Chip (SoC)
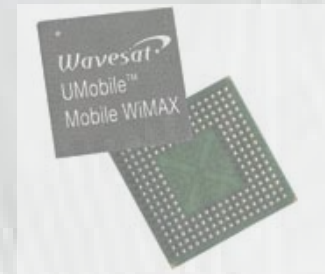
Intel announced WiMAX Connection 2300 at the end of 2007

Beceem offers Chipset "MS120 Mobile Wimax"

Altera Corp. and Sequans Communications (Alcatel)

Runcom RNA 200 "the world's first MIMO-powered WiMAX chipset."

Wavesat UMobile™ WiMAX Series

WiMAX news

Samsung presented
- Mobile WiMAX Equipment with MIMO-Technology
- Mobile WiMAX-Handy (SPH-P9000)
- Mobile WiMAX PDA (SPH-M8100)

Palm announced
- Wimax-Smartphone in autumn 2007

Airspan announced
- Mobile WiMAX USB device (16eUSB) - supports MIMO, Beamforming, Idle- and Sleep-Modi, handover

Nokia announced
- Mobile WiMAX mobile phone in 1Q 2008

Sprint Nextel goes Mobile WiMAX as next generation mobile (4G)
- 3 Billion US-$ order to several companies:
- Intel, Samsung, Motorola, Nokia, LG Electronics
- 100 million users using *Mobile WiMAX Broadband Services* at the end of 2008

Struggled Frequency-range 2.5GHz

IMT-2000 (International Mobile Telecommunications)

Family of 3.Generation (3G) mobile wireless systems

From ITU accepted 3G-Technologies

- W-CDMA and TD-CDMA (UMTS), TD-SCDMA (China), CDMA2000 (EVDO), EDGE

WiMAX tries to get adoption as a 3G technology

GSM Association (GSMA) demands on EU-Commission

- Reservation of frequency-range 2.5 up to 2.69 GHz for UMTS-Technologies

EU-Commission considers to cancel the conjuction of special technologies to individual Frequency-ranges

Conclusion

WiMAX brings together Broadband and Mobility

Mobile Broadband enables the Mobile Internet Anywhere

New Internet Business Models

All-IP conectivity

Puzzeled-out QoS strategy

New entrants will appear to market with diverse business models

Rich possipilities of applications

- Video content streaming
- Mobile IP telephony (VoIP)
- Multimedia messaging
- P2P video/audio sharing
- Multicasting- and broadcasting in the downlink
- Contribution in the uplink

WiMAX could be a complementary technology for Broadcasters

Thank you for your attention

Hermann Lipfert
Broadcast Networks and Servers
Institut für Rundfunktechnik GmbH
Floriansmühlstrasse 60
80939 München

Tel. +49 89 / 32399 367
email: lipfert@irt.de
IRT Blue Report „MIMO-OFDM" at:
http://www.irt.de/IRT/publikationen/BlaueBerichte/Blauer%20Bericht%20197%20Lipfert.pdf