

# Overview of IEEE 802.16 Broadband Wireless Access Standards

Timo Smura 24.02.2004

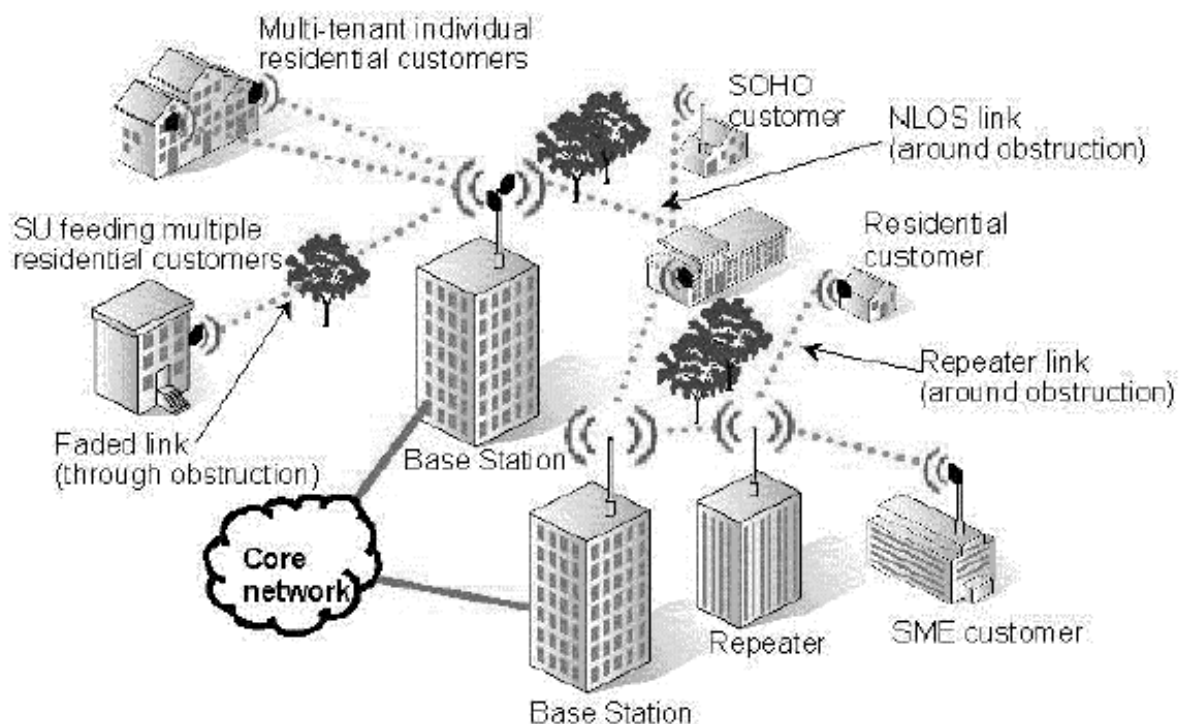
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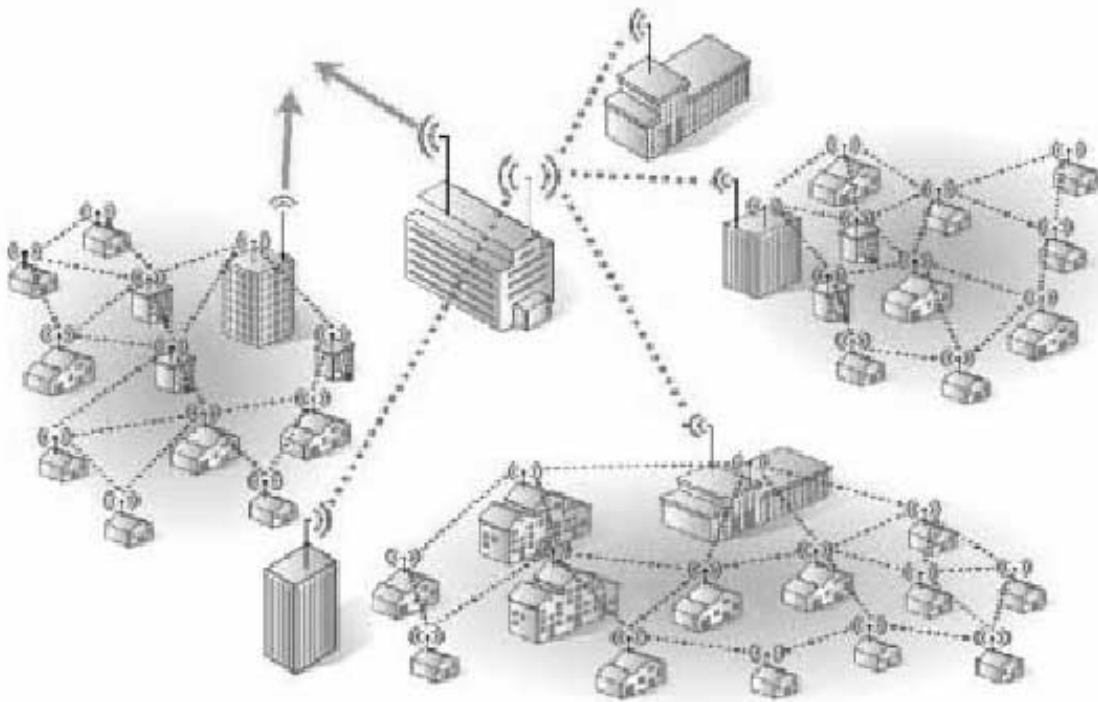
# Fixed Wireless Access Networks

- Fixed broadband access to Internet
  - competitor to DSL, cable modems etc.
- Fixed customer premises equipment (CPE)
  - CPE portability possible in some cases
- FWA = Wireless MAN, not LAN
  - Higher range, more users, guaranteed QoS
- Point-to-multipoint and mesh topologies
- Licensed and unlicensed frequency bands
- Line-of-sight vs. non-line-of-sight deployment
- Standardized in IEEE 802.16 and ETSI BRAN

## Topologies: Point-to-multipoint



# Topologies: Mesh



Source: ETSI TR 101 856

## Frequency bands for FWA

Name	Frequency band (bandwidth)	Type	ETSI Standards, ERC Decisions and Recommendations
<b>2.4 GHz ISM band</b>	2.400 – 2.4835 GHz (83.5 MHz)	Unlicensed	EN 300 328-1. ERC/REC/70-03, ERC/DEC/(01)07.
<b>3.5 GHz FWA band</b>	3.410 – 3.600 GHz (190 MHz)	Licensed	EN 301 753, EN 301 124, EN 301 253, EN 301 021, EN 301 080, EN 302 085. ERC/REC 14-03, ERC/REC 13-04
<b>5 GHz RLAN band</b>	5.470 – 5.725 GHz (255 MHz)	Unlicensed	ETS 300 836-1. ERC/REC70-03, ERC/DEC/(99)23.
<b>10.5 GHz FWA band</b>	10.150 – 10.300 GHz, 10.500 – 10.650 GHz (2 x 150 MHz)	Licensed	EN 301 751, EN 301 753, EN 301 124, EN 301 253, EN 301 080, EN 301 021, EN 302 085. ERC/REC/12-05, ERC/REC 13-04.
<b>26 GHz FWA band</b>	24.577 – 25.417 GHz, 25.585 – 26.425 GHz (2 x 840 MHz)	Licensed	EN 301 753, EN 301 213-1, EN 301 213-2, EN 301 213-3, EN 301 215-2, EN 301 751. ERC/REC 13-04, ERC/REC 00-05, T/R 13-02 Annex B, ERC/REC/(00)05.

# IEEE Working Groups

## 802.11 WG Wireless Local Area Network

802.11a ... 802.11n

## 802.15 WG Wireless Personal Area Network

802.15.1 ... 802.15.5

## 802.16 WG Broadband Wireless Access

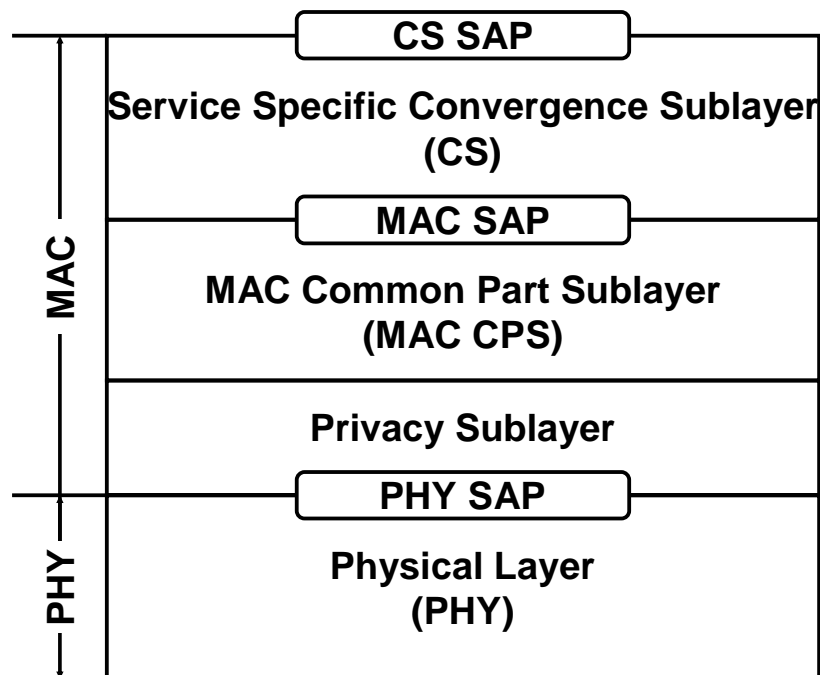
802.16a ... 802.16e

## 802.20 WG Mobile Wireless Access

# IEEE 802.16 standards and drafts

- Air interface standards
  - IEEE Std 802.16-2001: MAC + 10-66 GHz PHY
  - IEEE Std 802.16a-2003: 2-11 GHz PHY
  - IEEE Draft P802.16e: Mobile WirelessMAN
- Conformance standards
  - IEEE Std 802.16c-2002: System profiles for 10-66 GHz
  - IEEE Std 802.16/Conformance01-2003: PICS for 10-66 GHz
  - IEEE Std 802.16/Conformance02-2003: TSS&TP for 10-66 GHz
  - IEEE Draft P802.16/Conformance03: RCT for 10-66 GHz
  - IEEE Draft P802.16d: System profiles for 2-11 GHz
- Coexistence standards
  - IEEE Std 802.16.2-2002: 10-66 GHz
  - IEEE Std 802.16.2a-2004: 2-11 GHz

# IEEE 802.16 Protocol Stack



## Physical layer specifications x 5

PHY layer designation	Applicability	Options	Duplexing
WirelessMAN-SC	10-66 GHz Licensed		TDD FDD
WirelessMAN-SCa	2-11 GHz Licensed	AAS, ARQ STC	TDD FDD
WirelessMAN-OFDM	2-11 GHz Licensed	AAS, ARQ Mesh, STC	TDD FDD
WirelessMAN-OFDMA	2-11 GHz Licensed	AAS, ARQ STC	TDD FDD
WirelessHUMAN	2-11 GHz License-exempt	AAS, ARQ Mesh, STC	TDD

# WirelessMAN-SC

- 10-66 GHz licensed bands, line-of-sight operation
- TDD / FDD, TDM / TDMA
- Single carrier modulation
- Adaptive burst profiles
  - = modulation and FEC
  - QPSK, 16-QAM, 64-QAM
- Channel bandwidths of 20, 25, or 28 MHz
  - Large frequency allocations
  - Negligible multipath

Source: IEEE Std 802.16a-2003

# WirelessMAN-SCa

- 2-11 GHz licensed bands
- Non-line-of-sight operation
- TDD / FDD, TDM / TDMA
- Single carrier modulation
- Adaptive burst profiles
  - BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM
- Channel bandwidths of e.g. 1.75, 3.5, and 7 MHz
  - Smaller allocations per operator
  - Multipath fading

Source: IEEE Std 802.16a-2003

# WirelessMAN-OFDM

- 2-11 GHz licensed bands
- Non-line-of-sight operation
- Orthogonal Frequency Division Multiplexing
  - FFT size 256, 200 subcarriers in use
- Adaptive burst profiles
  - QPSK, 16-QAM, 64-QAM modulation
  - FEC with code rates of 1/2, 3/4, and 2/3
- Channel bandwidths of e.g. 1.75, 3.5, and 7 MHz

Source: IEEE Std 802.16a-2003

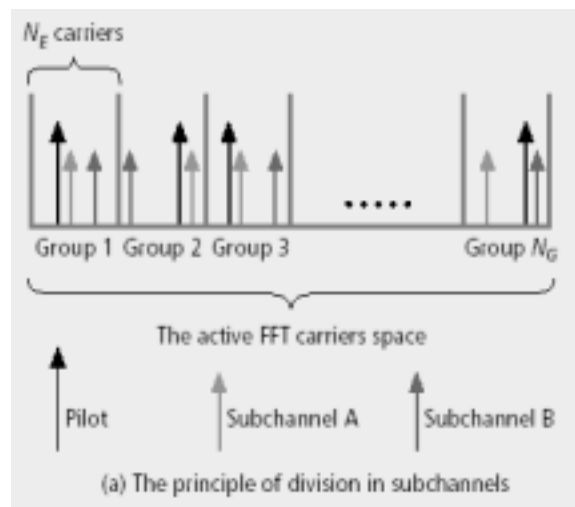
# WirelessHUMAN

- Wireless High-speed Unlicensed MAN
- 2-11 GHz unlicensed bands
  - primarily 5-6 GHz
- Channel bandwidth of 10 MHz or 20 MHz
- Dynamic Frequency Selection (DFS)
- Otherwise similar to WirelessMAN-OFDM
  - although lower transmit powers for interference mitigation

Source: IEEE Std 802.16a-2003

# WirelessMAN-OFDMA

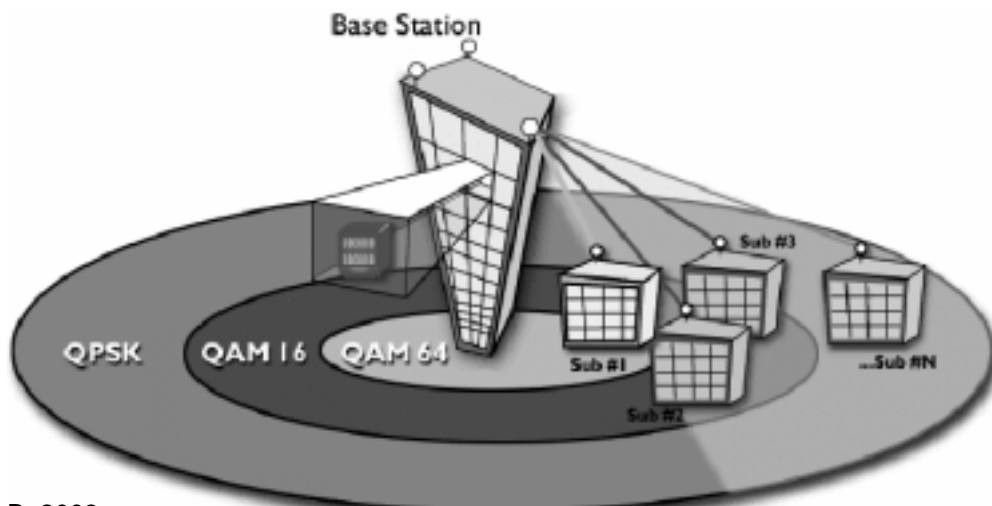
- 2-11 GHz licensed bands
- Non-line-of-sight operation
- TDD / FDD duplexing
- Orthogonal Frequency Division Multiple Access
  - FFT size 2048
  - Active carriers divided into subsets of carriers, i.e. subchannels
- In downlink, a subchannel may be intended for different receivers
- In uplink, a transmitter may be assigned one or more subchannels



Source: Koffman & Roman, 2002

## PHY: Adaptive burst profiles

- Burst profile = Modulation + FEC
- Dynamically assigned according to link conditions
  - Burst by burst, per subscriber station



Source: Marks, R.B. 2003.



# 802.16 MAC layer

- Point-to-multipoint and mesh topologies
- Protocol independent core
  - Convergence sublayers for ATM, IP, Ethernet
- Connection-oriented
- Many QoS classes
  - CBR, rt-VBR, nrt-VBR, BE
- Support for different PHYs
  - TDD/FDD, single carrier, OFDM, OFDMA
- Privacy sublayer
  - Secures over-the-air transmissions
  - Authentication, data encryption

# Coexistence standards

- 802.16.2-2001 and 802.16.2a-2004  
Recommended Practices
- Guidelines for minimizing interference
  - For manufacturers: equipment design parameters
  - For operators: deployment and coordination
- Scenarios:
  - Co-channel, adjacent area
  - Adjacent-channel, same area

# WiMAX Forum



- Worldwide Interoperability for Microwave Access Forum
- A non-profit organization formed in 2001 in order to:  
*“promote the wide-scale deployments of fixed broadband wireless access networks operating above 2 GHz by using a global standard and certifying the interoperability of products and technologies“*
- Enables interoperability between equipment manufacturers that base their products on the IEEE 802.16 and ETSI HIPERMAN standards
- Has been developing conformance standards for IEEE
- Certification to begin in early 2005

## Future of 802.16

- Many vendors have announced support for the 802.16a OFDM version of the standard
  - Interoperable products expected in late 2004
- Intel has been a strong proponent of the technology
  - Mass production of 802.16a-chipsets expected
- Fixed >> Portable >> Mobile
  - Fixed CPEs with directional antennas
  - Non-line-of-sight user installable and movable CPEs
  - PC-card CPEs for laptops
  - Integrated radios
- Extensions for mobility developed in 802.16e
- What is the number one target market?

# Summary

- 802.16 standards for FWA networks
  - alternative for DSL, cable
- A plethora of options exists
  - 5 different PHYs, Mesh vs. PMP, different frequency bands
- WiMAX-certified interoperability a key issue
- Products expected in late 2004
- Evolution towards portability and mobility

# References

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- IEEE 802.16-2001. IEEE Standard for Local and Metropolitan Area Networks. Part 16: Air Interface for Fixed Broadband Wireless Access Systems.
- IEEE 802.16a-2003. IEEE Standard for Local and metropolitan area networks. Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Amendment 2: Medium Access Control Modifications and Additional Physical Layer Specifications for 2-11 GHz.
- ETSI TR 101 856 V1.1.1 (2001-03). Broadband Radio Access Networks (BRAN); Functional Requirements for Fixed Wireless Access systems below 11 GHz: HIPERMAN.

# Thank You! Questions?

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## Homework

- The table below shows the raw bitrates and required receiver sensitivity thresholds for different modulations and code rates in a 802.16a-based OFDM system using 7 MHz channels.
- Using a log-distance path loss model with path loss exponent  $n = 4$ , calculate the average bitrate in a cell with uniformly distributed receiver terminals.
- Assume the PHY/MAC overheads to be zero.

Modulation	Code Rate	Raw bitrate (Mbps)	Receiver sensitivity (dBm)
QPSK	1/2	5.76	-84
QPSK	3/4	8.65	-82
16-QAM	1/2	11.53	-77
16-QAM	3/4	17.29	-75
64-QAM	2/3	23.06	-71
64-QAM	3/4	25.94	-69