Workshop on WiMAX Technology

WiMAX Standards Overview

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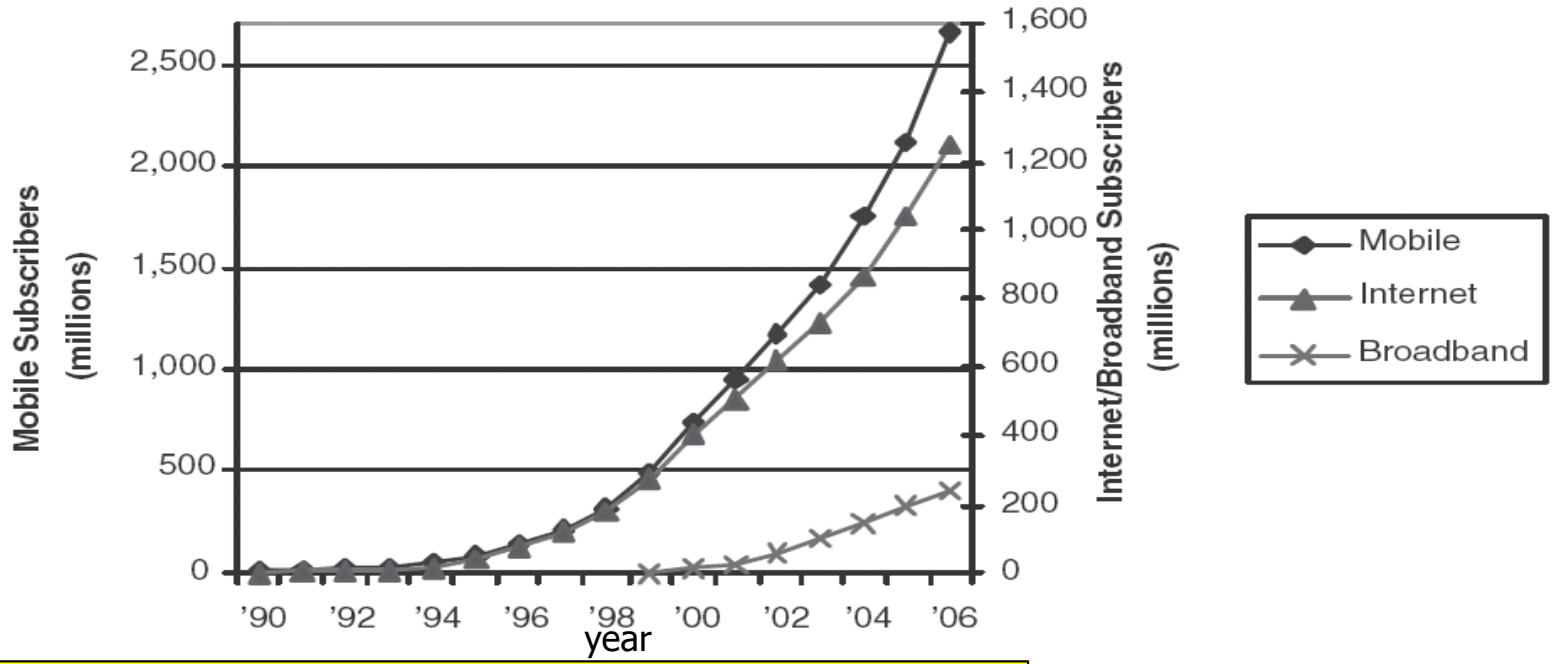
Plan

1. What is WiMAX? Evolution and Drivers
2. Competing Technologies and Standards
3. Overview of Fixed and Mobile WiMAX Standards
4. Physical Layer of WiMAX
5. Medium Access Layer of WiMAX
6. WiMAX Reference Network Architecture

Motivation and Drivers

- Broadband subscribers to double (400 million) by 2010 and close to 1B by 2015
- Driving applications – Multimedia applications
  - Real-time audio/video
  - Conferencing
  - Interactive gaming
  - Video on demand (VoD)



Subscriber growth for Mobile, Internet, and Broadband access

[1] ITU. Telecommunications indicators update—2004. www.itu.int/ITU-D/ict/statistics/.
[2] In-stat Report. Paxton. The broadband boom continues: Worldwide subscribers pass 200 million, No. IN0603199MBS, March 2006.

What is WiMAX?

- World Wide Interoperability for Microwave Access
- Broadband access service for both fixed and mobile applications
- WiMAX is one (current) step along an evolution path of broadband wireless access technologies

Evolution of Broadband Access Technologies

- Narrowband Wireless Local-Loop Systems (WLL)
  - Typically based on DECT and CDMA
  - Originally for telephony – some provided data/internet services (e.g. wireless internet service provider – WISP)
- 1st Generation Broadband Systems
  - Local Multipoint Distribution Systems (LMDS): operated in 2.5 and 3.5 GHz and 24 and 39 GHz bands – 100's of Mb/s and targeted mainly business users
  - Multichannel multipoint Distribution Systems (MMDS): 2.5 GHz band – wireless cable service to include later (1998-1999) two way communication – sold by MCI WordCom and Sprint
  - LMDS and MMDS typical range ~ 50 km with LOS coverage, require aligned CPE antennas, limited tower capacity
- 2nd Generation Broadband Systems
  - Improved coverage (NLOS) and performance – proprietary OFDM and CDMA based systems developed by start-up companies such as SOMA Networks and Navini Networks

Evolution of Broadband Access Technologies – cont'd

- IEEE802.16 and its derivatives
  - 1998 – Group to develop IEEE802.16 (WMAN point-to-multipoint protocol) operating at 10 to 66 GHz band
  - December 2001 – IEEE802.16 approved MAN-SC (single carrier)
  - 2003 – IEEE802.16a (an amendment to IEEE802.16) to extend operation in the 2GHz and 11GHz range – specifies OFDM as a physical layer option and OFDMA as additional MAC layer option
  - **802.16-2004** – additional revisions made to replace the original IEEE802.16, IEEE802.16a and IEEE802.16c – Form also the basis for HIPERLAN developed by ETSI
  - December 2005 – **IEEE802.16e-2005** published to allow vehicular mobility applications
  - 2001-2006 – WiMAX forum certifies products that comply with a subset of IEEE802.16 specifications and test their interoperability – similar role to Wi-Fi Alliance

Milestones in the Development of Wireless Broadband Systems

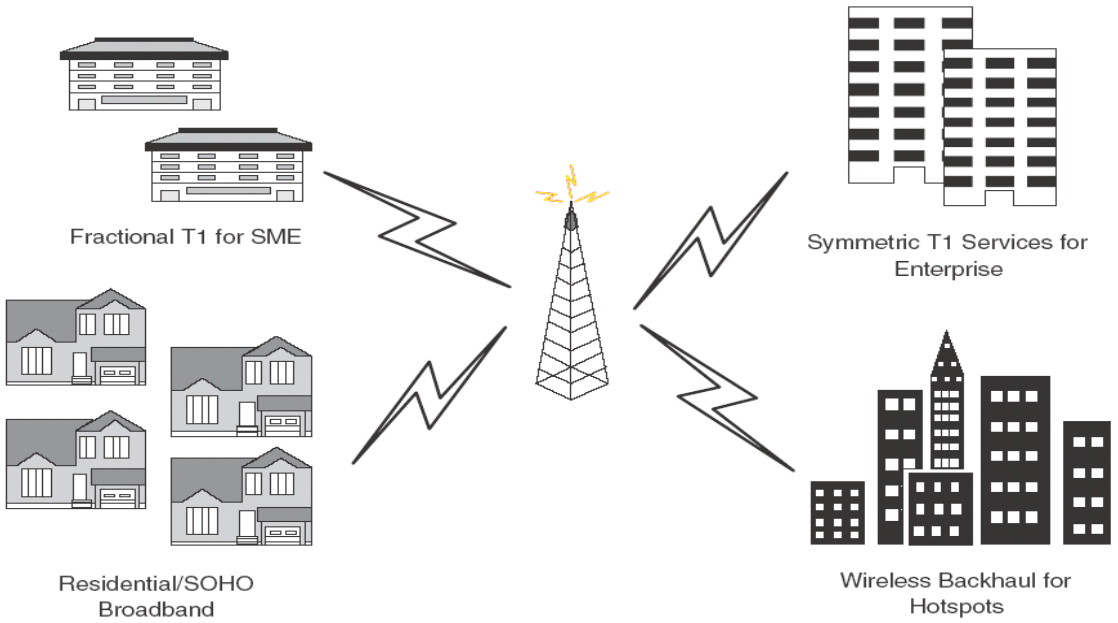
Date	Event
June 2001	WiMAX Forum established
October 2001	Sprint halts MMDS deployments
December 2001	AT&T discontinues fixed wireless services
December 2001	IEEE 802.16 standards completed for > 11GHz.
February 2002	Korea allocates spectrum in the 2.3GHz band for wireless broadband (WiBro)
January 2003	IEEE 802.16a standard completed
June 2004	IEEE 802.16-2004 standard completed and approved
September 2004	Intel begins shipping the first WiMAX chipset, called Rosedale
December 2005	IEEE 802.16e standard completed and approved
January 2006	First WiMAX Forum–certified product announced for fixed applications
June 2006	WiBro commercial services launched in Korea
August 2006	Sprint Nextel announces plans to deploy mobile WiMAX in the United States

Post-WiMAX Events

Table from reference [1].

WiMAX Market Drivers and Applications

- Fixed broadband wireless
  - Residential and small/home office (SOHO)
  - Small- to medium-enterprise (SME) markets
  - T1 or fractional T1-like service for businesses
  - Wireless backhaul for hotspots (Wi-Fi or 3G)
- Mobile broadband wireless
  - Voice, data, video, and mobility services
  - Ideal for operators that do not own 3G spectrum
  - Could complement 3G performance – Korea's WiBro system operating at 2.3 GHz and providing 512 K to 3 Mb/s



Competing Technologies

- Mainly two rivals:
  - 3G cellular/mobile
  - Wi-Fi
- 3G Cellular/Mobile Technology:
  - UMTS/HSPA: HSDPA (release 5) uses 5 MHz to deliver theoretical peak rate of 14.4 Mb/s; HSUPA (release 6) supports theoretical peak rate of 5.8 Mb/s – Practical implementations may provide rates in the 100's of kb/s only!
  - 1xEV-DO (1x evolution data optimized) 3GPP2 standard – an extension of 1xRTT for cdma2000, uses 1.25 MHz to deliver 2.4 Mb/s – Revisions A and B improve the rate to 3.1 Mb/s and 4.9 Mb/s, respectively – allow higher channel bandwidth (up to 20 MHz) to deliver up to 73 Mb/s on downlink and 27 Mb/s on uplink
  - 3G Long Term Evolution (LTE) – next major 3GPP revision providing ~ 100 Mb/s on downlink and ~ 50 Mb/s on uplink – about 3 to 4 time the efficiency of UMTS HSPA.
  - 3GPP2 longer term plans – even higher rates

Likely to utilize OFDM/OFDMA and MIMO technology to achieve these high rates

Competing Technologies – cont'd

- Wi-Fi Technology:
  - Based on 802.11 family of WLAN protocols
  - 802.11a/g provide theoretical peak rates of up to 54 Mb/s
  - Coverage of up to ~ 30 meters
  - Defacto standard for last feet broadband connection
  - Municipalities and cities deployed service in metrozones (such as Riyadh's streets, etc.) – may utilize high power transmitters (~ 300 meters range)
  - IEEE802.11e – QoS support
  - IEEE802.11n – throughput ~ 100 Mb/s
  - Operating in open bands (interference) and inefficiency of CSMA → reduced overall capacity
  - Not designed to support high-speed mobility

Summary of Comparison*

Theoretical throughput Calculations – Not accounting for overhead

Parameter	Fixed WiMAX	Mobile WiMAX	HSPA	1x EV-DO	Wi-Fi
Standards	IEEE802.16-2004	IEEE802.16e-2005	3GPP Release 6	3GPP2	IEEE802.11a/g/n
Peak downlink rate	9.4 Mb/s in 3.5 MHz with 3:1 DL-to-UL ratio TDD; 6.1 Mb/s with 1:1	46 Mb/s with 3:1 DL-to-UL ratio TDD; 32 Mb/s with 1:1	14.4 Mb/s using all 15 codes; 7.2 Mb/s using 10 codes	3.1 Mb/s rev. B will support 4.9 Mb/s	54 Mb/s shared using 802.11a/g; more than 100 Mb/s peak for 802.11n
Peak uplink rate	3.3 Mb/s in 3.5 MHz using 3:1 DL-to-UL ratio; 6.5 Mb/s with 1:1	7 Mb/s in 10 MHz using 3:1 DL-to-UL ratio; 4 Mb/s using 1:1	1.4 Mb/s initially; 5.8 Mb/s later	1.8 Mb/s	
Bandwidth	3.5 MHz and 7 MHz in 3.5 GHz band; 10 MHz in 5.8 GHz band	3.5 MHz, 7 MHz, 5 MHz, 10 MHz, and 8.75 MHz initially	5 MHz	1.25 MHz	20 MHz for 802.11a/g; 20/40 MHz for 802.11n
Modulation	QPSK, 16 QAM, 64 QAM	QPSK, 16 QAM, 64 QAM	QPSK, 16 QAM	QPSK, 8 PSK, 16 QAM	BPSK, QPSK, 16 QAM, 64 QAM
Multiplexing	TDM	TDM/OFDMA	TDM/CDMA	TDM/CDMA	CSMA
Duplexing	TDD, FDD	TDD initially	FDD	FDD	TDD
Frequency	3.5 GHz and 5.8 GHz initially	2.3 GHz, 2.5 GHz, and 3.5 GHz initially	800/900/1800/ 1900/2100 MHz	800/900/1900 MHz	2.4 GHz, 5 GHz
Typical Coverage	5~8 km	< 3 km	1.5~5 km	1.5~5 km	< 30 m (indoors) < 300 m (outdoors)
Mobility Support	NA	Medium	High	High	Low

*Adapted from Table 1.2 of [1].

Throughput Comparison for Mobile Systems – Per Channel per Sector

Simulation Results – Net Throughput Figures

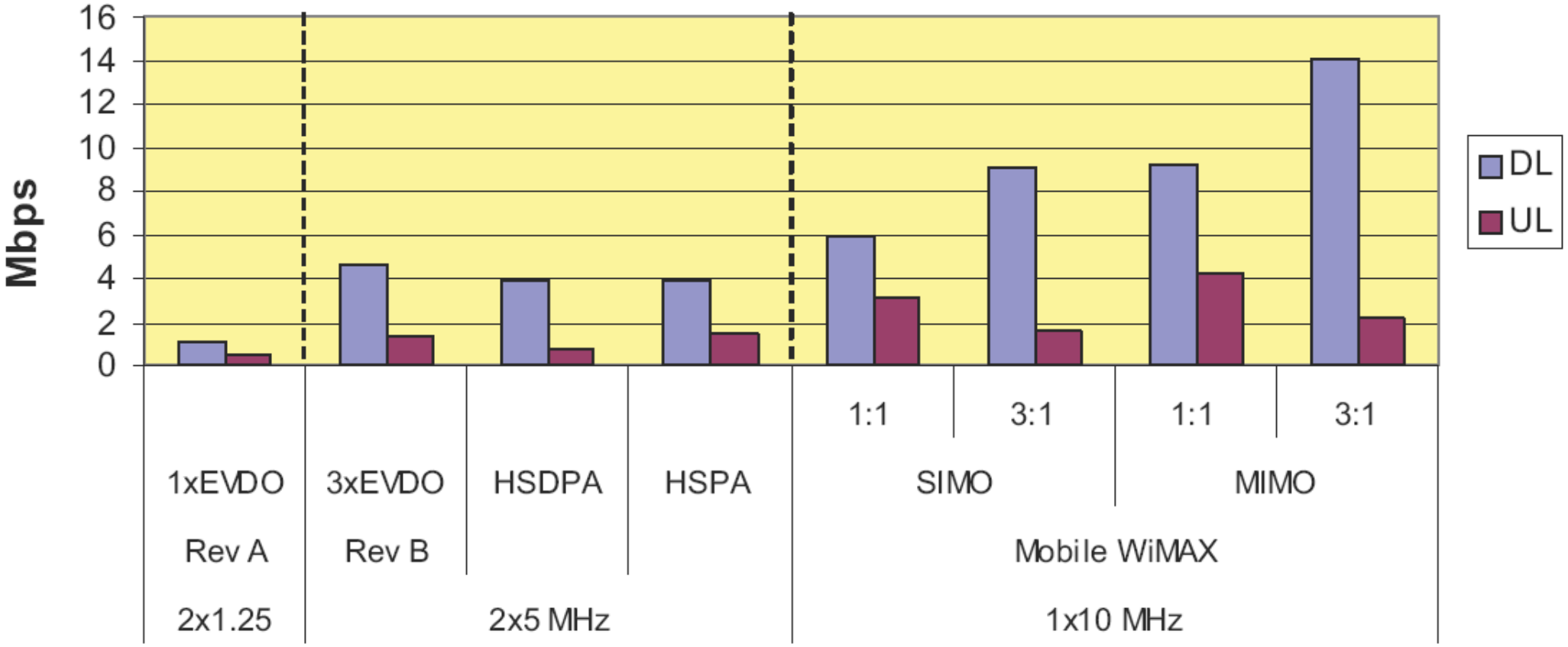


Figure from [3].

HOT From the Press Room on WiMAX and Competing Technologies

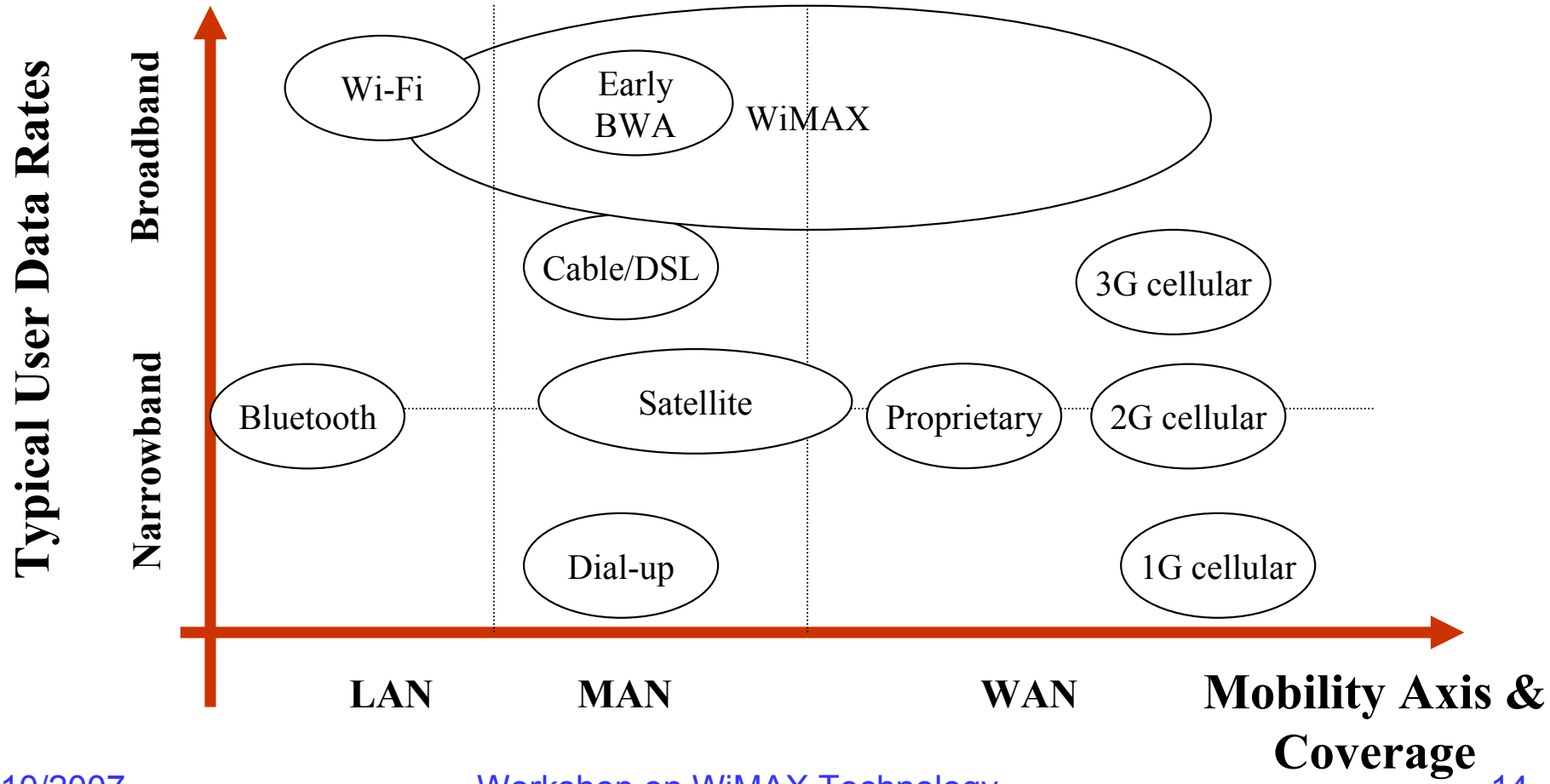
- International Telecommunication Union (ITU-R) to include WiMAX technology in the IMT-2000 set of standards – October 19th, 2007.
  - To provide access operators choices are: W-CDMA, cdma2000, TD-SCDMA, or WiMAX
- Cisco makes its WiMAX move – buys Navini Networks – October 23rd, 2007
- Intel to provide WiMAX chipset for laptops early 2008 – September 19th, 2007
- Qualcomm to introduce the Gobi chip for laptops – October 23rd, 2007
  - Supports cdma2000 and HSPA, with the target of early 2008

sources

http://www.wimaxforum.org/news/pr/view?item_key=993a9f3e2bf2b5b6822364fd90738185f17f2de0
http://blogs.cisco.com/news/2007/10/video_cisco_to_acquire_navini.html
http://www.intel.com/pressroom/archive/releases/20070919corp_a.htm
http://www.qualcomm.com/press/releases/2007/071023_QCT_GOBI_print.html

The Big Picture

- WiMAX provides broadband rates with capacity to operate in fixed and portable/mobile scenarios



WiMAX RF Spectrum

- 2-6 GHz bands available for BWA implementations

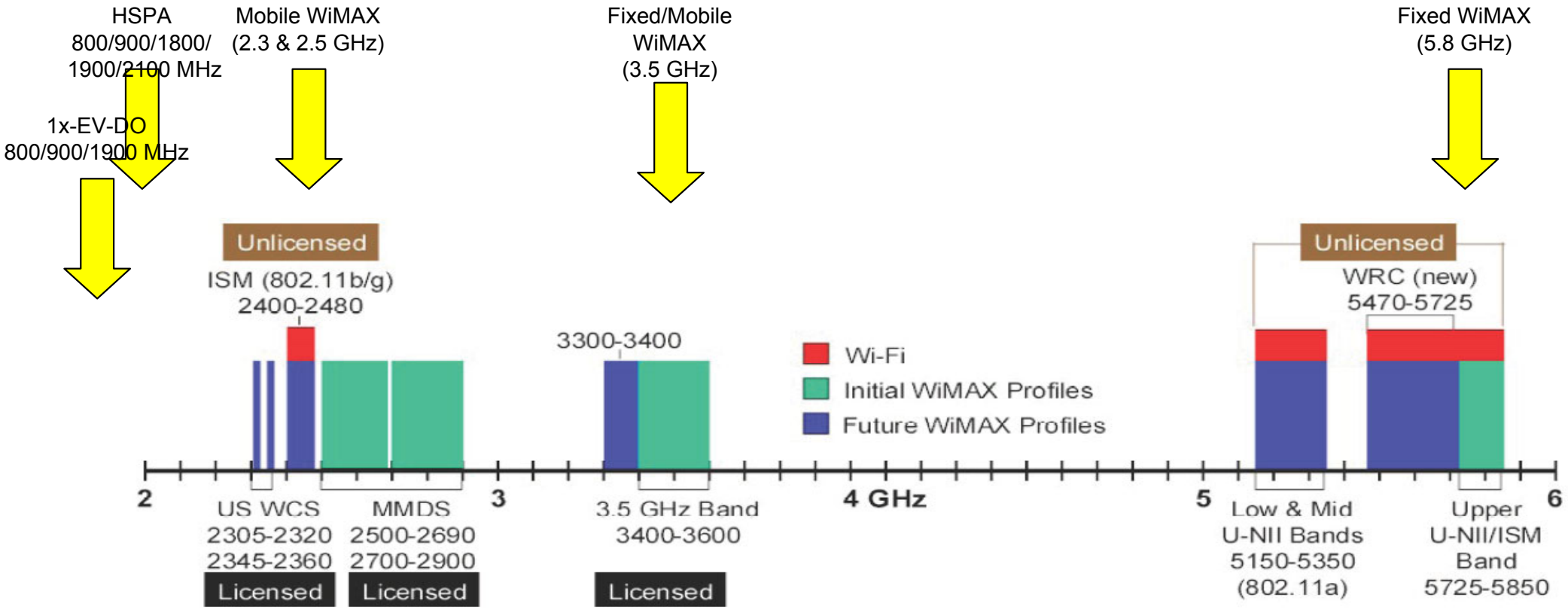


Figure from http://www.fujitsu.com/downloads/MICRO/fme/wimax/whitepapers/wpbwaRF_wp04.pdf

Technical Challenges for WiMAX - Summary

Service Requirement	Technical Challenges	Potential Solutions
NLOS coverage	Mitigation of multipath and interference	Diversity, channel coding, etc.
High data rate and capacity	Achieving high spectral efficiency	Cellular architecture, adaptive modulation and coding, spatial multiplexing, etc.
	Overcoming ISI	OFDM, equalization, etc.
	Interference mitigation	Adaptive antennas, sectorization, dynamic channel allocation, CDMA, etc.
Quality of service	Supporting voice, data, video, etc. on a single access link	Complex MAC layer
	Radio resource management	Efficient scheduling algorithms
	End-to-end QoS	IP-QoS (DiffServe, IntServ, MPLS, etc.)
Mobility	Ability to be reached anywhere	Roaming database, location update, paging
	Session continuity	Seamless handovers
	Session continuity across diverse networks	IP-based mobility solutions (e.g. Mobile IP)
Portability	Reduce battery consumption on portable terminals	Power efficient modulation, sleep, idle modes; low power circuits and efficient DSP
Security	Protect privacy and integrity of user data	Encryption
	Prevent unauthorized access	Authentication and access control
Low cost	Provide efficient and reliable communication using IP architecture and protocols	Adapting IP protocols for wireless link

Fixed and Mobile WiMAX

- IEEE802.16 (and subsequent IEEE802.16-2004) serve as the basis for fixed WiMAX
- IEEE802.16e-2005 serves as the basis for mobile WiMAX
- IEEE802.16 (and its amendments) define multiple choices for the air interface, MAC architecture, duplexing, RF band options, etc.
  - E.g. PHY options – MAN-SCa, WirelesMAN-OFDM, and Wireless-OFDMA

Summary of IEEE802.16 Standards

	802.16	802.16-2004	802.16e-2005
Status	Completed Dec 2001	Completed June 2004	Completed Dec 2005
Frequency band	10GHz–66GHz	2GHz–11GHz	2GHz–11GHz for fixed; 2GHz–6GHz for mobile applications
Application	Fixed LOS	Fixed NLOS	Fixed and mobile NLOS
MAC architecture	Point-to-multipoint, mesh	Point-to-multipoint, mesh	Point-to-multipoint, mesh
Transmission scheme	Single carrier only	Single carrier, 256 OFDM or 2,048 OFDM	Single carrier, 256 OFDM or scalable OFDM with 128, 512, 1,024, or 2,048 subcarriers
Modulation	QPSK, 16 QAM, 64 QAM	QPSK, 16 QAM, 64 QAM	QPSK, 16 QAM, 64 QAM
Gross data rate	32Mb/s-134.4 Mb/s	1Mb/s-75Mb/s	1Mb/s-75Mb/s
Multiplexing	Burst TDMA/TDMA	Burst TDMA/TDMA/OFDMA	Burst TDMA/TDMA/OFDMA
Duplexing	TDD and FDD	TDD and FDD	TDD and FDD
Channel bandwidth	20MHz, 25MHz, 28MHz	1.75MHz, 3.5MHz, 7 MHZ, 14MHz, 1.25MHz, 5MHz, 10MHz, 15MHz, 8.75MHz	1.75MHz, 3.5MHz, 7 MHZ, 14MHz, 1.25MHz, 5MHz, 10MHz, 15MHz, 8.75MHz
Air-interface	WirelessMAN-SC	WirelessMAN-SCa WirelessMAN-OFDM WirelessMAN-OFDMA WirelessMAN-HUMAN	WirelessMAN-SCa WirelessMAN-OFDM WirelessMAN-OFDMA WirelessMAN-HUMAN
WiMAX implementation	**None**	**256 – OFDM as fixed WiMAX**	**Scalable OFDMA as Mobile WiMAX**

WiMAX Forum

- For practicality and interoperability, WiMAX Forum defines limited number of system profiles and certification profiles
  - System profile – subset of the mandatory and optional physical- and MAC-layer features selected by the WiMAX forum from the IEEE802.16-2004 or IEEE802.16e-2005
  - Certification profile – a particular instantiation of a system profile together with operating frequency, channel bandwidth and duplexing modes specified

WiMAX Certification Profiles

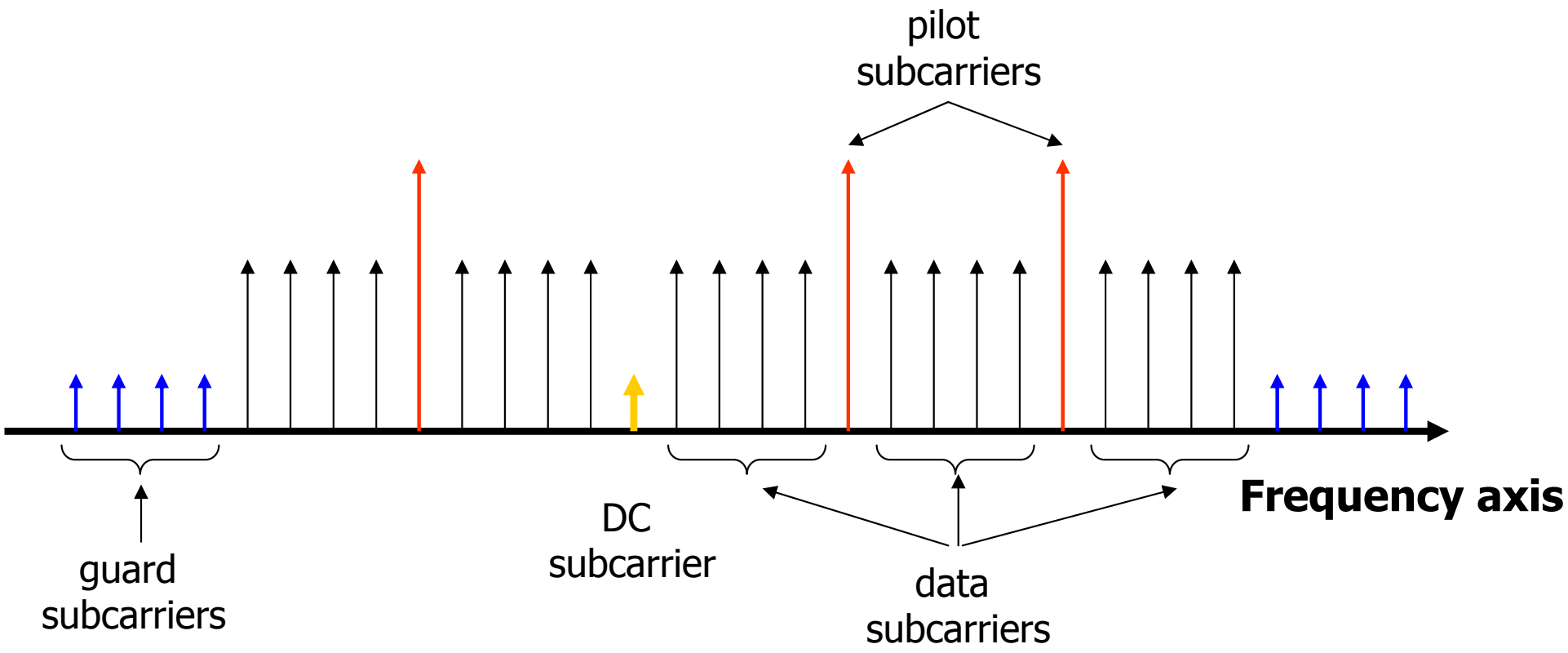
Profile #	Frequency Band	Channel Bandwidth	OFDM FFT Size	Duplexing	Notes
Fixed WiMAX profiles					
1	3.5 GHz	3.5MHz	256	FDD	Products already certified
		3.5MHz	256	TDD	
		7MHz	256	FDD	
		7MHz	256	TDD	
2	5.8 GHz	10MHz	256	TDD	
Mobile WiMAX Profiles					
1	2.3GHz–2.4CHz	5MHz	512	TDD	Both bandwidths *must* be supported by mobile station
		10MHz	1,024	TDD	
		8.75MHz	1,024	TDD	
2	2.305GHz-2,320GHz, 2.345GHz-2.360GHz	3.5MHz	512	TDD	
		5MHz	512	TDD	
		10MHz	1,024	TDD	
3	2.496GHz-2.69GHz	5MHz	512	TDD	Both bandwidths *must* be supported by mobile station
		10MHz	1,024	TDD	
4	3.3GHz-3.4GHz	5MHz	512	TDD	
		7MHz	1,024	TDD	
		10MHz	1,024	TDD	
5	3.4GHz-3.8GHz, 3.4GHz-3.6GHz, 3.6GHz-3.8GHz	5MHz	512	TDD	
		7MHz	1,024	TDD	
		10MHz	1,204	TDD	

WiMAX Physical Layer

- Physical layer is based on OFDM
- OFDM widely used in other broadband systems such as DSL, Wi-Fi, digital video broadcast handheld (DVB-H), etc.
- OFDM Enables NLOS communication and serves to exploit frequency diversity

OFDM Transmitter/Receiver

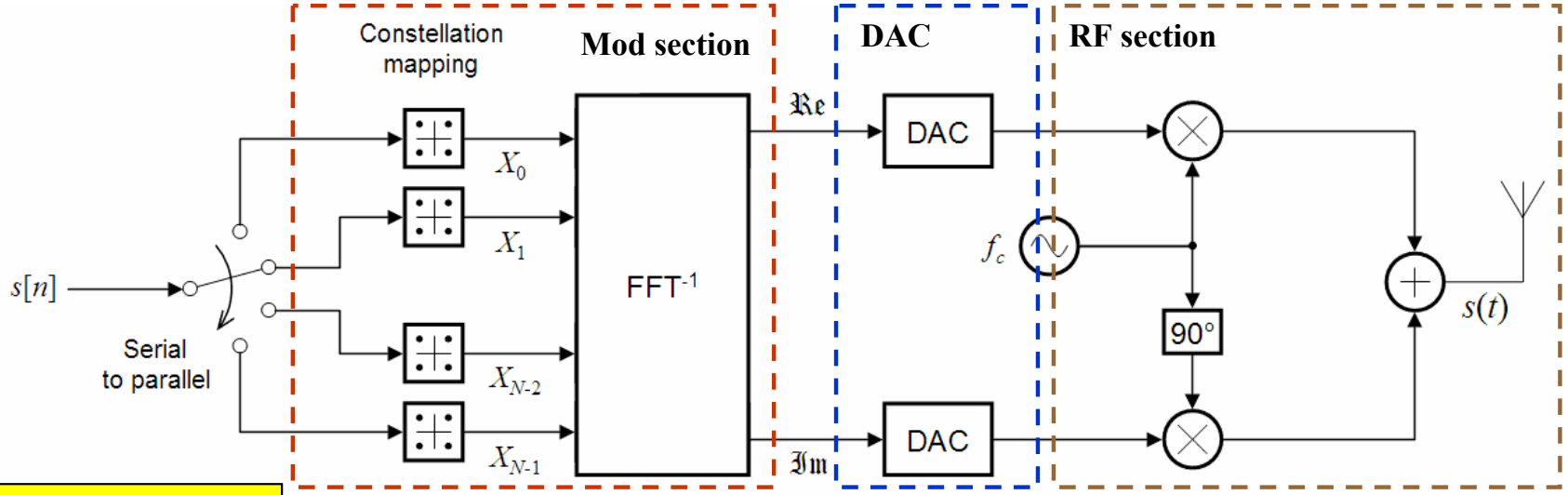
- A typical subcarrier plan (one OFDM symbol representation)



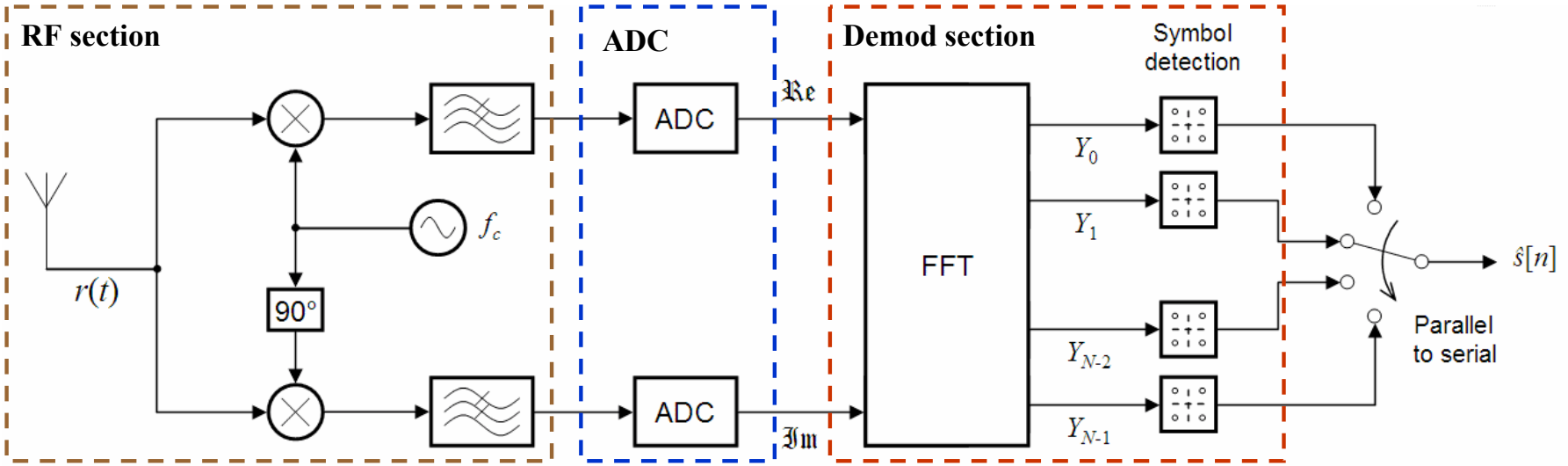
OFDM Parameters for WiMAX

Parameter	Fixed WiMAX OFDM-PHY	Mobile WiMAX Scalable OFDMA-PHY (for downlink partial usage of subscarrier)			
FFT Size	256	128	**512**	1,204	2,048
No of data subcarriers	192	72	**360**	720	1,440
No of pilot subcarriers	8	12	**60**	120	240
Guard subcarriers	56	44	**92**	184	368
Guard time (Tg/Tb)	1/32, 1/16, **1/8**, 1/4				
Oversampling rate (Fs/BW)	Depends on bandwidth: 7/6 for 256 OFDM, 8/7 for multiples of 1.75 MHz, and 28/25 for multiples of 1.25 MHz, 1.5 MHz, 2 MHz, or 2.75 MHz				
Channel bandwidth (MHz)	3.5	1.25	5	10	20
Subcarrier spacing	15.625	**10.94**			
Useful symbol time (μs)	64	**91.4**			
Guard time for 12% (μs)	8	**11.4**			
OFDM symbol time (μs)	72	**102.9**			
No of OFDM symbols in 5 ms frame	69	**48**			

OFDM Transmitter/Receiver – cont'd



Typical OFDM Transmitter

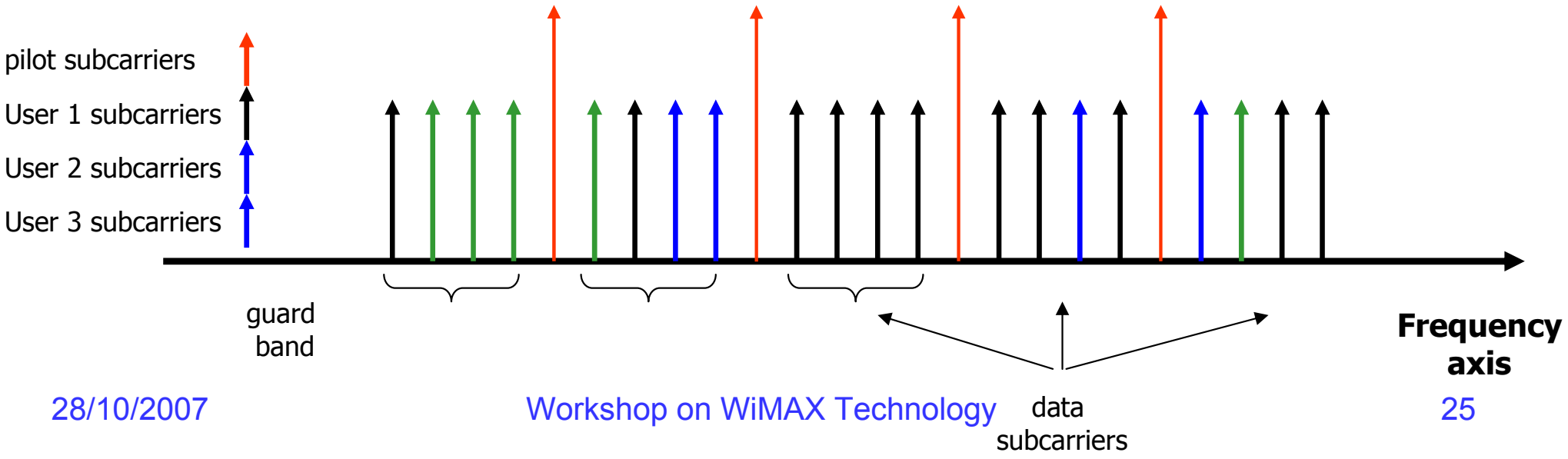


Typical OFDM Receiver

Figures from reference [3]

What is Orthogonal Frequency Division Multiple Access (OFDMA)?

- Definition: OFDMA subsets of the subcarriers are assigned to individual users – Refer to Figure below
  - The subsets are referred to as subchannels
- Fixed WiMAX with OFDM-PHY allows limited form of OFDMA in the uplink
  - 16 subchannels of sizes {1, 2, 4, 8, all} can be assigned to subscriber (subscriber session, SS)
- Mobile WiMAX allows subchannelization on both uplink and downlink
- Subchannels may be comprised of subcarriers that are contiguous or pseudo randomly distributed
- WiMAX defines several methods for distributed subcarriers of a particular channel
  - Partial usage of subcarriers (PUSC) is one mandatory method for Mobile WiMAX implementation
  - E.g: For 5 MHz, PUSC defines 15 and 17 subchannels for downlink and uplink, respectively
- For contiguous subscarriers is WiMAX's form of adaptive modulation and coding (AMC)
  - Most suited for fixed and low-mobility scenarios
- OFDMA is also being considered for LTE



Orthogonal Frequency Division Multiple Access - OFDMA

- Basestation allocates only a fraction of the OFDM tones to the mobile
- Basestation *selects the tones* with good signal quality (i.e. high SINR)
- Selection is aided by feedback from mobile stations
- This improves peak-to-average power ratio (PAPR) for system
  - Critical for uplink and mobile station

An example of contiguous subcarrier allocation

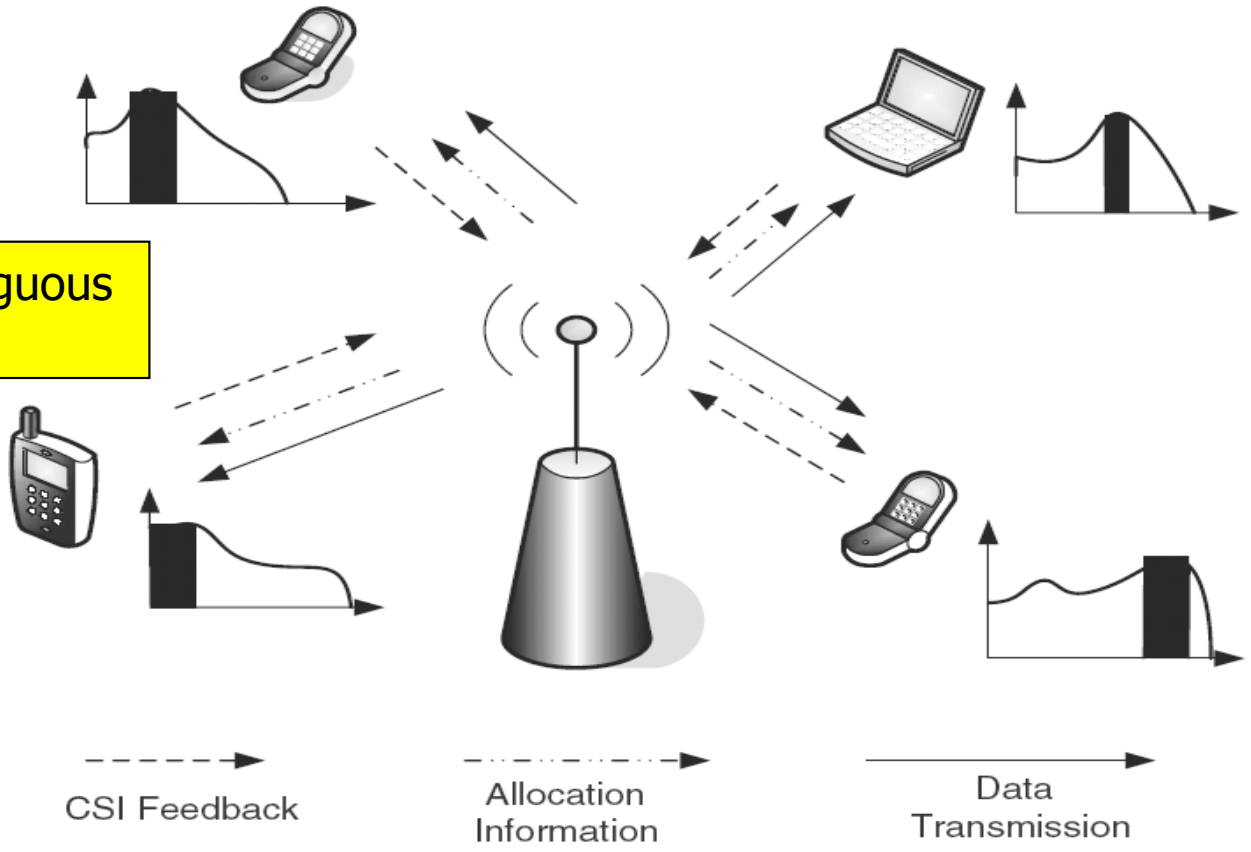


Figure from reference [1].

Adaptive Modulation and Coding (AMC)

- A variety of modulation and coding schemes are supported
  - Can be changed on a burst-by-burst basis per link
- Mobile provides feedback on channel quality (channel quality indicator channel – CQICH)
- The following modulation and coding schemes are supported in WiMAX

	Downlink	Uplink
Modulation	BPSK, QPSK, 16 QAM, 64 QAM; BPSK optional for OFDMA-PHY	BPSK, 16 QAM; 64 QAM optional
Coding	Mandatory: convolutional codes at 1/2, 2/3, 3/4, 5/6 Optional: covolutional turbo codes at 1/2, 2/3, 3/4, 5/6; repetition codes at rate 1/2, 1/3, 1/6, LDPC, RS-Codes for OFDM-PHY	Mandatory: convolutional codes at 1/2, 2/3, 3/4, 5/6 Optional: covolutional turbo codes at 1/2, 2/3, 3/4, 5/6; repetition codes at rate 1/2, 1/3, 1/6, LDPC

Adaptive Modulation and Coding (AMC) – cont'd

- Network varies modulation scheme and coding rate to attain maximum throughput
- Example – depicts network with 6 possible AMC configurations

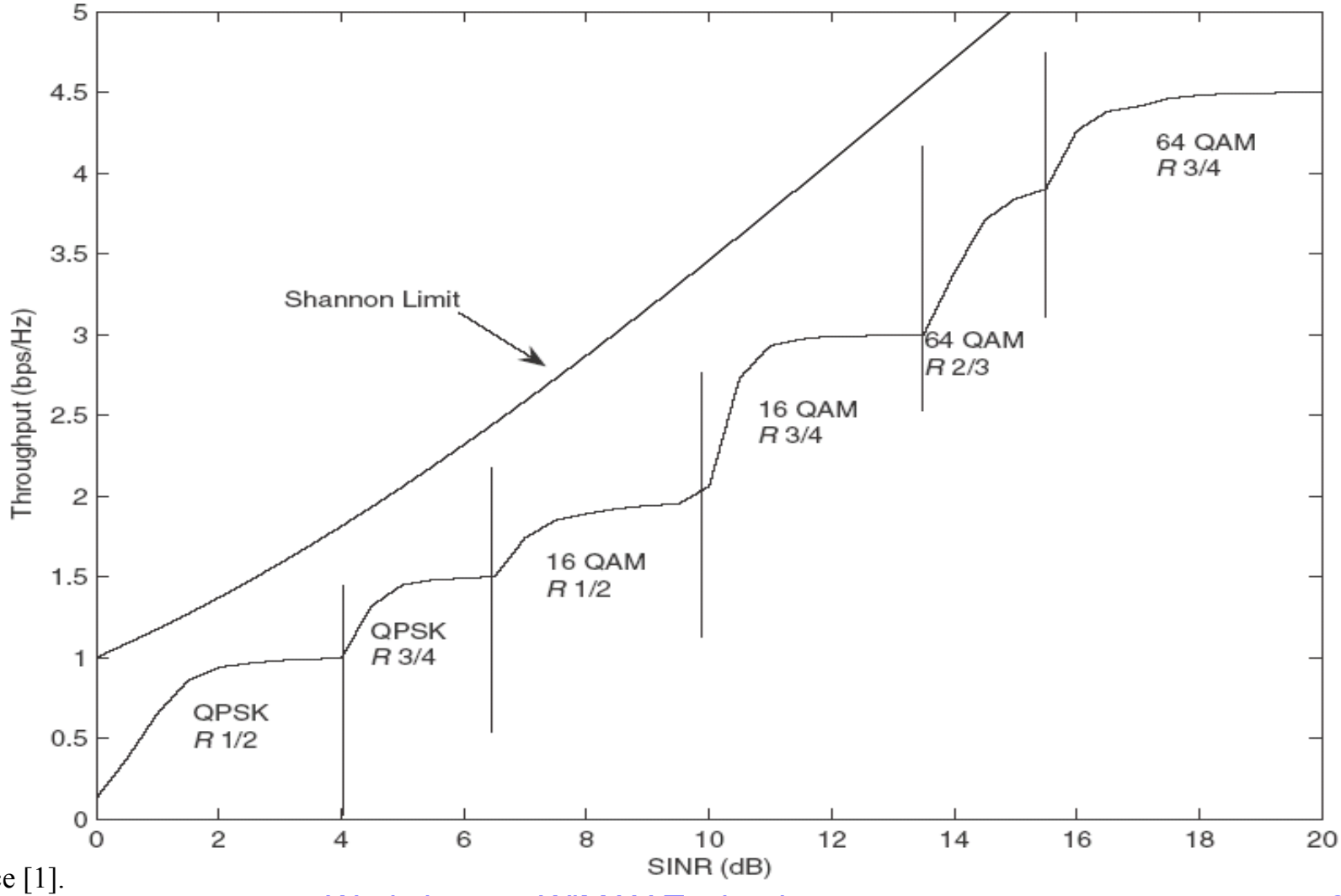
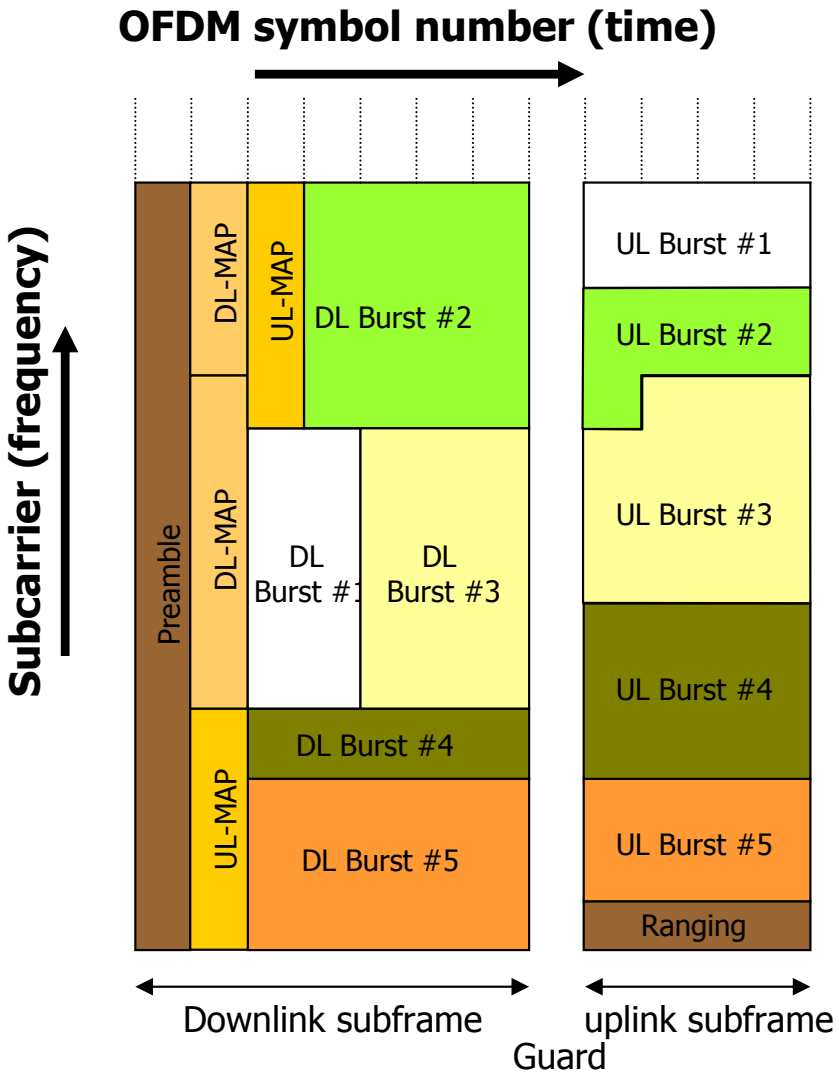
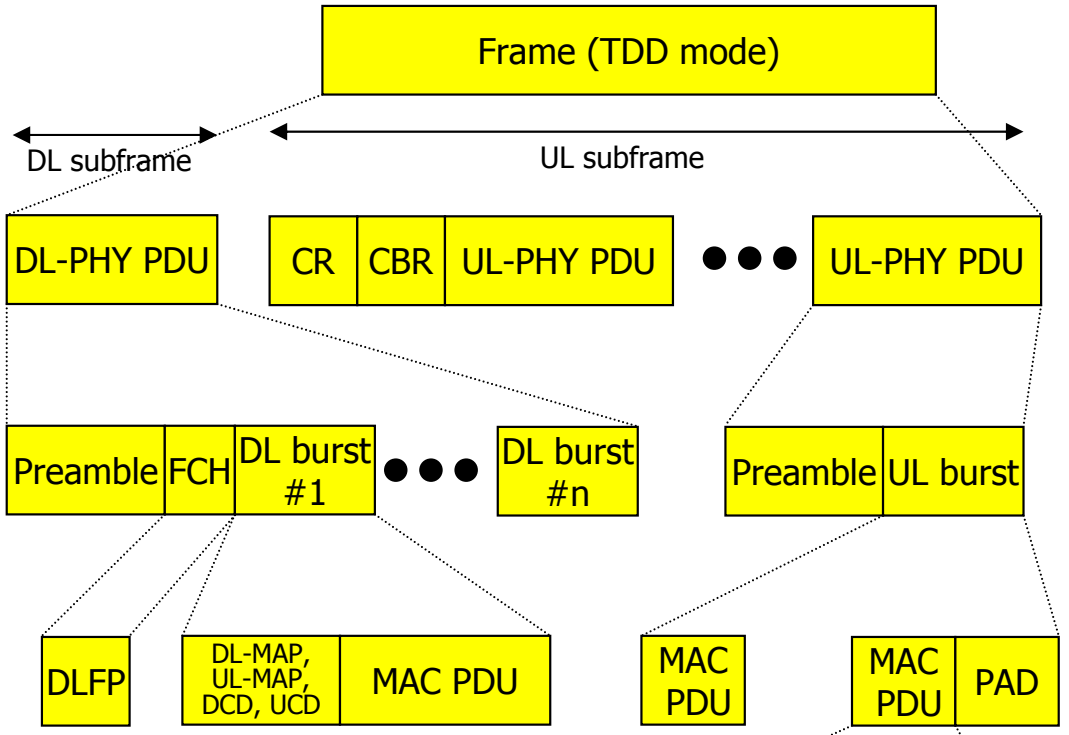


Figure from reference [1].

Frame Structure





CR – Contention region
CBR – Contention for bandwidth request
DLFP – Dnlink frame prefix
DCD – Dnlink channel descriptor
UCD – Uplink channel descriptor

Physical Layer Data Rates

- PHY-layer rates at various channel bandwidths

Channel bandwidth	3.5MHz		1.25MHz		5MHz		10MHz		**8.75MHz[a]**	
PHY mode	256 OFDM		128 OFDMA		512 OFDMA		1,024 OFDMA		1,024 OFDMA	
Oversampling	8/7		28/25		28/25		28/25		28/25	
Modulation and Code Rate	**PHY-Layer Data Rate (kbps)**									
	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL
BPSK, 1/2	946	326	**Not applicable**							
QPSK, 1/2	1,882	653	504	154	2,520	653	5,040	1,344	4,464	1,120
QPSK, 3/4	2,822	979	756	230	3,780	979	7,560	2,016	6,696	1,680
16 QAM, 1/2	3,763	1,306	1,008	307	5,040	1,306	10,080	2,688	8,928	2,240
16 QAM, 3/4	5,645	1,958	1,512	461	7,560	1,958	15,120	4,032	13,392	3,360
64 QAM, 1/2	5,645	1,958	1,512	461	7,560	1,958	15,120	4,032	13,392	3,360
64 QAM, 2/3	7,526	2,611	2,016	614	10,080	2,611	20,160	5,376	17,856	4,480
64 QAM, 3/4	8,467	2,938	2,268	691	11,340	2,938	22,680	6,048	20,088	5,040
64 QAM, 5/6	9,408	3,264	2,520	768	12,600	3,264	25,200	6,720	22,320	**5,600**

a. The version deployed as WiBro in South Korea.

Assumptions:
- Aggregate data rate are reported
- 3:1 dnlink-to-uplink split
- frame size of 5 ms
- 12.5% OFDM guard interval
- PUSC subcarrier permutations

Table from reference [1].

WiMAX MAC Layer

- MAC layer provides interface between physical layer and higher layers
  - Convergence layers for interfacing to ATM, TDM voice, Ethernet, IP are standardized for IEEE802.16-2004 and IEEE802.16e-2005
- WiMAX Forum supports Ethernet and IP so far
- MAC layer at basestation is fully responsible for allocating bandwidth to all users
  - Several mechanisms are provided:
    1. unsolicited bandwidth grants,
    2. contention-based, or
    3. contention-free based (i.e. polling)
  - MS uses dedicated or shared resources to request bandwidth from BS - Polling
- Polling can be unicast or multicast

Quality of Service Provisions

- Strong support through the connection-oriented MAC architecture
  - All downlink and uplink connections are controlled by BS
- A connection is logical unidirectional connection between MAC peer entities in MS and BS identified by CID – used to transport user data
- Three other MAC management connections are also defined: basic, primary, and secondary – used for functions such as ranging
- Service flow is a unidirectional flow of packets with a particular set of QoS parameters – identified by SFID
  - Traffic priority, peak date rate, scheduling type, ARQ Type, maximum delay, jitter, etc.
- Basestation is responsible for issuing SFID and mapping it to unique CIDs
  - SFID can be mapped to DiffServ code points or MPLS flow tables to enable end-to-end IP-based QoS support
- **MAC scheduling** – is the core function responsible for providing the specified QoS profile

Quality of Service Provisions – MAC Scheduling Service

HOT area of RESEACH

- **These services DO NOT define a scheduler** – This is left for vendors
- Features:
  - The protocol defines QoS parameters and mechanisms to allow the design of efficient and QoS-aware scheduler
  - Support for three dimensional dynamic resource management: frequency (subcarrier), time (time slots), and space (multiple antennas)
  - Support for fast channel-quality information feedback
  - Support for contiguous subcarrier permutations, such as AMC – scheduler can exploit multiuser diversity

MAC service	Definition	Application
Unsolicited Grant Service (UGS)	Real-time data streams comprising fixed-size data packets issued at periodic intervals	T1/E1 transport
Extended Real-time Polling Service (ertPS)	Real-time service flows that generate variable-sized data packets on a periodic basis	VoIP
Real-time Polling Service (rtPS)	Real-time data streams comprising variable-sized data packets that are issued at periodic intervals	MPEG Video
Non-real-time Polling Service (nrtPS)	Delay-tolerant data streams comprising variable-sized data packets for which minimum data rate is required	FTP with guaranteed minimum throughput
Best Effort (BE)	Data streams for which no minimum service level is required and therefore may be handled on a space-available basis	HTTP

Other MAC Layer Features

- Power saving support
  - Sleep mode – MS becomes inactive for predetermined period
  - Period negotiated with BS
  - WiMAX defines three classes of power-saving
    - Class I – period exponentially increased from T_min to T_max – appropriate for MS doing non-real-time traffic and best effort
    - Class II – fixed-length sleep window – used for UGS service
    - Class III – one-time sleep window – used for multicast traffic or management traffic when MS knows when the next traffic is expected
  - Idle mode – achieves even greater power saving
    - MS can still receive downlink traffic while not registered with BS
    - Handoff is not supported while in sleep mode
    - Optional for WiMAX

Other MAC Layer Features – cont'd

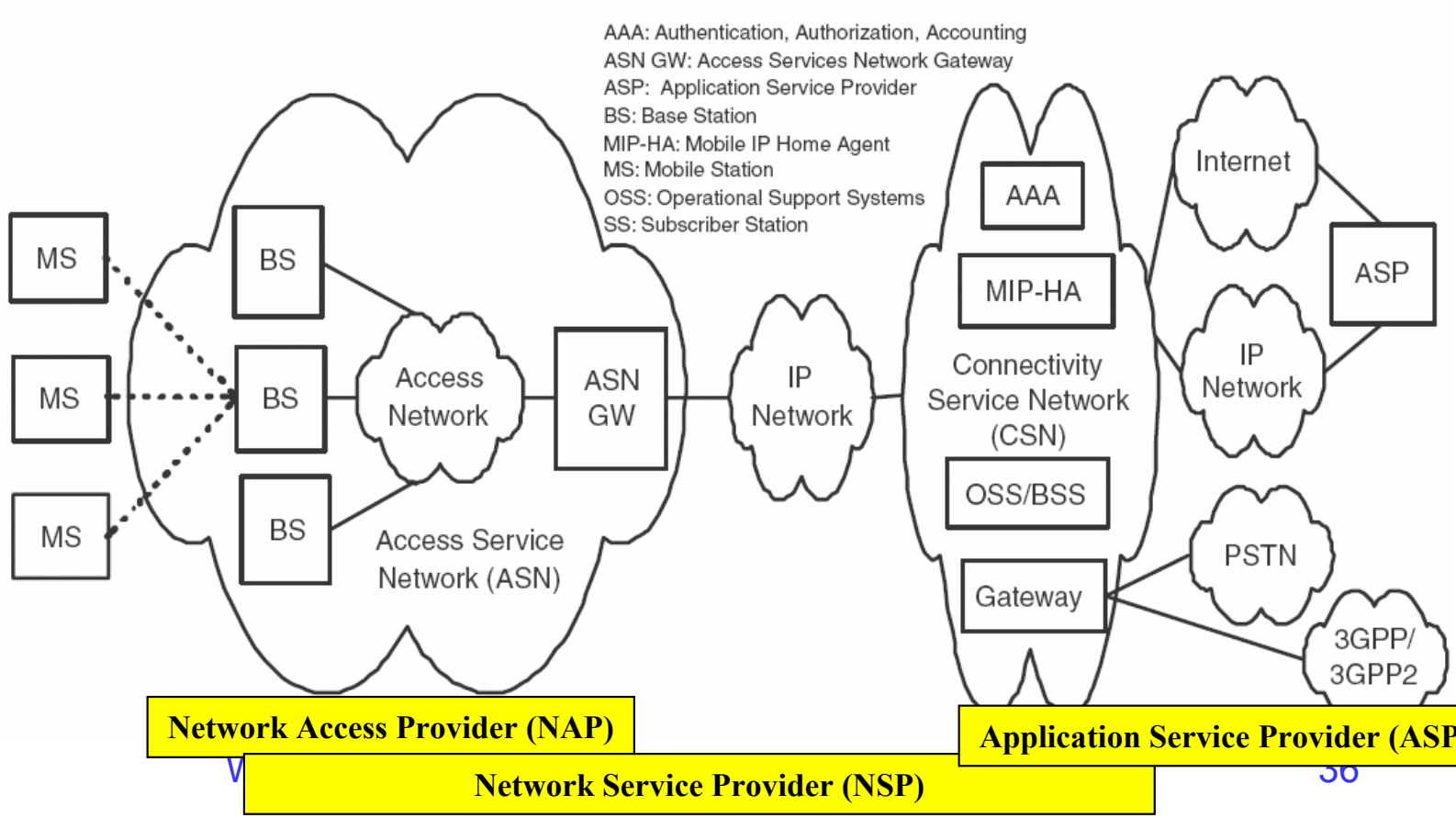
- Mobility support
  - IEEE802.16e-2005 defines the framework to track MS mobility and support handoff
  - Framework adopted and supported by WiMAX forum –through mobility management and Mobile IP support
  - IEEE802.16e-2005 supports three handoff methods
    - Hard handover (HHO) – mandatory {goal ≤ 50 msec}
    - Fast basestation selection (FBSS) – optional – active set
    - Macro diversity handover (MDHO) – optional – diversity set
- Security functions
  - Support for privacy – AES and 3DES are supported
  - Authentication – based on Internet Engineering Task Force EAP
  - Flexible key management – Privacy and Key Management Protocol Version 2 (PKMv2) used to transfer key from BS to MS
  - Protection of control messages – using message digest schemes such AES-based CMAC or MD5-based HMAC
  - Support for fast handovers – to accelerate handovers MS may use pre-authentication with a target BS

WiMAX Reference Network Architecture

- WiMAX defines an end-to-end netwok
  - IEEE802.16e-2005 defines only the air-interface
- Reference model to facilitate interoperability and to support fixed and nomadic/mobile deployments
- Based on IP service model

Three major components:

(1) MS
(2) Access Service Network (ASN)
(3) Connectivity Service Network (CSN)



WiMAX Reference Network Architecture – cont'd

- WiMAX reference network allows non-overlapping business entities to operate and provide services
  - Network access provider (NAP) – owns/operates ASN
  - Network service provider (NSP) – provides IP connectivity and WiMAX services to subscribers using ASN infrastructure provided by one or more NAPs
  - Application service provider (ASP) – provide value-added services such as multimedia using IMS (IP multimedia subsystem) and corporate VPN
- Main network entities
  - Basestation (BS) – provides air-interface to MS; micromobility management functions (handoff triggering, tunnel establishment, RRM, QoS policy enforcement, traffic classification, DHCP, key management, etc.
  - Access service network gateway (ASNG) – layer 2 traffic aggregation point; intra-ASN location management & paging, RRM and CAC; FA for Mobile-IP, etc.
  - Connectivity service network (CSN) – provides connectivity to the internet owned by NSP; authentication; QoS policy and security management; mobility management across NSPs or ASNs; interworking with other networks (PSTN, 3GPP/2, etc.)

References

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