

Wireless MANs

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Slides 19



Wireless Networks



– Wireless Wide Area Networks (WWANs)

- Cellular Networks :
 - GSM, cdmaone (IS-95), UMTS, cdma2000 EVDO
- Satellite Networks:
 - Iridium, Globalstar, GPS, etc.



– Wireless Metro Area Networks (WMANs)

- IEEE 802.16 WiMAX



– Wireless Local Area Networks (WLANs)

- IEEE 802.11, a, b, g, etc. (infrastructure, ad hoc, sensor)

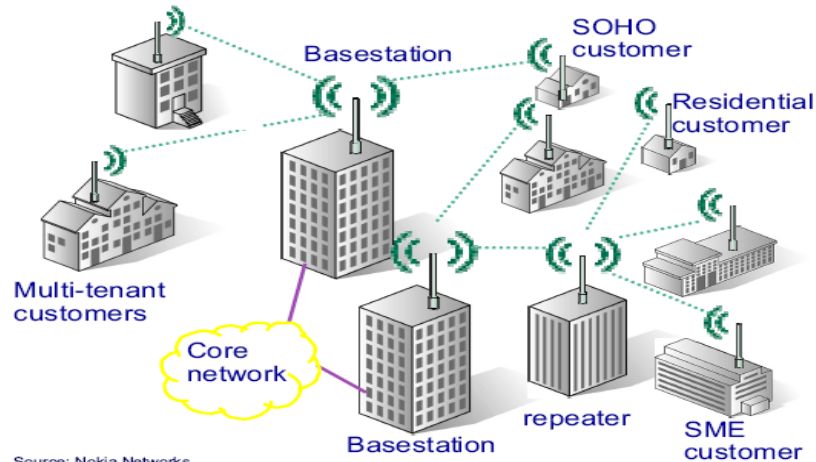
– Wireless Personal Area Networks (WPANs)

- IEEE 802.15 (Bluetooth), IrDa, Zigbee, sensor, etc.

Wireless MANs



- Wireless Metropolitan Area Networks (WMANs) : provide wireless connectivity across a geographical area the size of a city



Source: Nokia Networks

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Wireless MANs



- Wireless MANs
 - Want broadband data rates for last mile connectivity to businesses, homes and network bridging
 - Triple play service (video, voice, data)
 - **Claimed** Advantages: support for QoS, lower cost than cabling, user mobility in future.
 - Currently variety of technologies, speeds, cost, coverage range, spectrum, etc.
 - Market is fragmented among technology and small
 - Proprietary Solutions
 - Free Space Optical
 - LMDS (Local Multipoint Distribution Systems)
 - MMDS (Multipoint Microwave Distribution Systems)
 - Wireless multi-hop mesh networks (based on 802.11)
 - Standards Based Solutions
 - IEEE 802.16 also called WiMAX, WirelessMAN
 - IEEE 802.11 with multi-hop extensions



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Wireless MANs



- Proprietary Solutions

- Free Space Optical:
 - point to point high data rates (100 Mbps -2.5Gbps) over short distances
 - Unlicensed, uses infrared lasers
 - LOS required – severely effected by weather
- LMDS (Local Multipoint Distribution Systems)
 - Bulk of deployment focused on backhaul extension of fiber infrastructure and cellular networks
 - Operates in 28, 29 GHz spectrum
 - Range 3-5 miles, weather effects
- MMDS (Multipoint Microwave Distribution Systems)
 - Operates in 2.5-2.7GHz licensed spectrum
 - Originally intended for wireless cable TV distribution
 - 20MHz spectrum → 99 10Mbps channels
 - Range ~25Km (LOS and NLOS possible)
 - Data rates ~ .5-1 Mbps on 10Mbps channel
- WLAN equipment with mesh routing, scheduling, flow control
 - Use 802.11a/g equipment to build mesh – need many APs
- Proprietary equipment seen as a hindrance to market growth



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IEEE 802.16/WiMAX Standard



- Worldwide Interoperability for Wireless Microwave Access (WiMAX)
- IEEE 802.16 Broadband Wireless Access Standards Working Group
 - Started in 1998 led by NIST
 - Since July 1999 IEEE 802.16 working group meeting bimonthly
 - Suite of WiMAN standards
 - As in WLAN standard focus is Physical and MAC layers only!
- In parallel to IEEE 802.16, European Telecommunication Standards Institute (ETSI) HiperMAN and HiPERACCESS work
 - High performance radio metropolitan area network (HiperMAN)
- IEEE 802.16 and HiperMAN have largely converged
 - Same MAC layer and 802.16a OFDM as Physical layer baseline



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IEEE 802.16/WiMAX Standard



WiMAX
FORUM

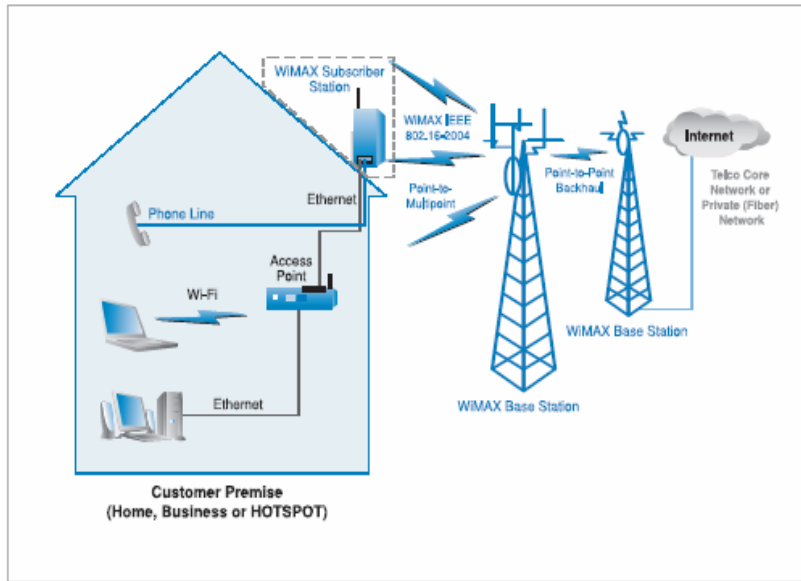
- Worldwide Interoperability for Wireless Microwave Access (WiMAX) industry alliance (WiMAX Forum) started to promote equipment development and interoperability testing/conformance
- <http://www.wimaxforum.org>
 - Interoperable multi-vendor fixed/nomadic/mobile/ wireless access networks using microwaves - line of sight not required
 - Define a set of "profiles" for interoperability/conformance testing
 - Profile specify the physical layer for a frequency band and various MAC layer parameters
- According to In-Stat
 - ~220,000 WiMAX subscribers in 2006
 - predict 19.7 million by 2010 –mostly fixed service in underdeveloped countries/regions - largest announced network build out in Pakistan
- Alvarion dominant equipment vendor, Intel dominant chip set vendor.

IEEE 802.16 /WiMAX Standard



- IEEE 802.16 developed as a Wireless Metropolitan Area Network (MAN) protocol
- Focus wireless alternative to DSL and T1 level services for last mile broadband access and backhaul for other technologies (WiFi, cellular)
- Characteristics of 802.16
 - Point to Multipoint (PMP) and Mesh protocol
 - NLOS wireless broadband services including bandwidth on demand
 - QoS support
 - Security
 - Scope expanded to include mobility and higher data rates
- Focus on both licensed and unlicensed spectrum deployment – supports multiple service providers/licenses in same area
- TDD and FDD duplexing support with flexible channel sizes
- 802.16 Terminology
 - Base Station (BS) is WiMAX cell site/access point
 - Subscriber Station (SS) is customer premise equipment and terminates the wireless link to the user location
 - Mobile Station (MS) is a standalone consumer device equipped with a WiMAX radio

WiMAX Architecture



WiMax Service Architectures



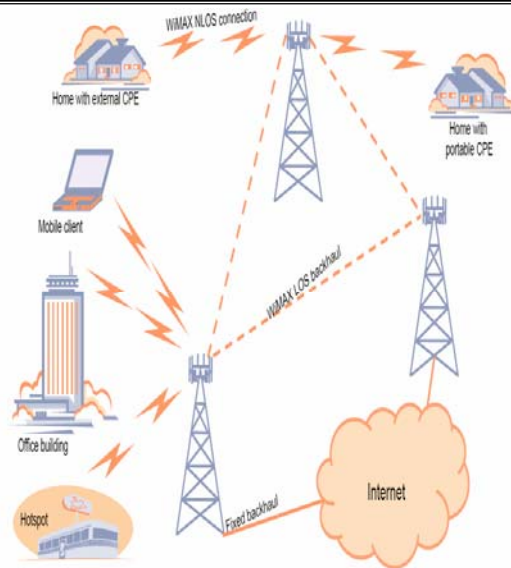
WiMax services

Point to Multi-Point

- Non-LOS, Wi-Fi sort of service, where a small antenna on a computer/ roof top connects to the tower.
- Later upgrade for mobile service to computer/handset

Point to Point

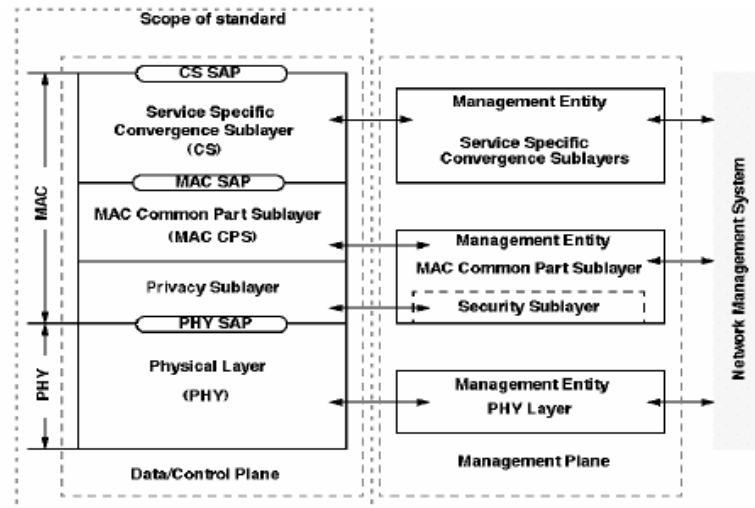
- Focused LOS antennas – high data rates with longer distances



IEEE 802.16 WiMAX Standards



- Scope of standard is bottom two protocol layers same as other 802 standards



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IEEE 802.16 WiMAX Standards



- Suite of standards for WiMANs
- 802.16 : approved 12/2001 10-66GHz range LOS only
- 802.16a-2003 : System for 2-11GHz range NLOS
- 802.16-2004 (802.16d): System for 2-6 GHz range supports nomadic/limited mobility
- In a fashion similar to IEEE 802.11 – multiple physical layers with common MAC layer defined
 - 802.16 a and 2004 define three physical layers
 - SCa – single carrier
 - OFDM – 256 carriers
 - OFDMA – 2048 carriers (OFDM multiple access) (multiple access by assigning a subset to a user)
- Physical layer standards often called “WirelessMAN” standard
 - Most equipment/WiMAX conformance on OFDM 256 carrier 802.15-2004 (802.16d) standard – which is common to ETSI HIPERMAN standard

Main IEEE 802.16 Standards



Dominant standard

	802.16	802.16a	802.16-2004	802.16e-2005
Date Completed	December 2001	January 2003	June 2004	December 2005
Spectrum	10-66 GHz	2-11 GHz	2-11 GHz	2- 6 GHz
Operation	LOS	Non-LOS	Non-LOS	Non-LOS and Mobile
Bit Rate	32-134 Mbps	Up to 75 Mbps	Up to 75 Mbps	Up to 15 Mbps
Omni-directional Cell Radius	1-3 miles	3-5 miles	3-5 miles	1-3 miles

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Techniques used in 802.16-2004



- Orthogonal Frequency Division Multiplexing (OFDM)
 - to reduce multipath effects and provide higher speeds
- Forward error correction rather than ARQ
 - FEC uses an outer RS block code and an inner convolutional code
- Adaptive modulation and coding
 - adjust the modulation/coding depending on the quality of the radio link, subscriber by subscriber, burst by burst, up and downlink
- Admission control
 - Ensures that new flows do not degrade the quality of established flows
- MAC Layer Scheduling:
 - traffic scheduling to provide QoS traffic classes
- Flexible Channel size
 - $n \times 1.25\text{MHz}$, $n \times 1.5\text{MHz}$, $n \times 1.75\text{MHz}$, Max of 20MHz
- TDD and FDD modes supported
- Smart antenna technology

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Physical layers for 802.16a/d



	Sca – single carrier	OFDM	OFDMA
Frequency	2-11 GHz	2-11 GHz	2-11 GHz
Modulation	BPSK, QPSK, 16QAM, 64QAM, 256QAM	BPSK, QPSK, 16QAM, 64QAM	QPSK, 16QAM, 64QAM
No. of subcarriers	N/A	256	2048
Duplexing	TDD, FDD	TDD, FDD	TDD, FDD
Channel Bandwidth	1.75-20 MHz	1.75-20 MHz	1.75-20 MHz

OFDM 256 Carrier option is currently available
 192 Carriers used for data, 8 pilot channels, 56 guard band

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IEEE 802.16d Coding/Modulation



- Table of the maximum data rate in Mbps for the various channel/ coding/modulation options in 802.16d with 256 carrier OFDM physical layer
- Modulation rate used on a set of 256 carriers depends on RSS

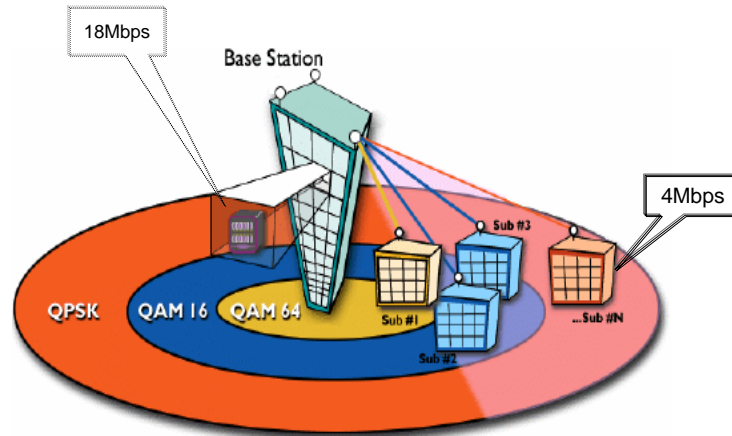
Channel Bandwidth	Modulation FEC Coding					
	QPSK 1/2	QPSK 3/4	16 QAM 1/2	16QAM 3/4	64 QAM 2/3	64 QAM 3/4
1.75 MHz	1.04	2.18	2.91	4.36	5.94	6.55
3.5 MHz	2.08	4.37	5.82	8.73	11.88	13.09
5.0 MHz	3.95	6.00	8.06	12.18	16.30	18.36
7.0 MHz	4.15	8.73	11.64	17.45	23.75	26.18
10.0 MHz	8.31	12.47	16.63	24.94	33.25	37.40
20.0 MHz	16.62	24.94	33.25	49.87	66.49	74.81

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802.16-2004 Data Ranges



- Achievable data rate depends on distance to BS, LOS/NLOS, propagation environment – will vary!



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802.16-2004 Data Ranges



- Achievable data rate depends on distance to BS, LOS/NLOS, propagation environment – will vary!

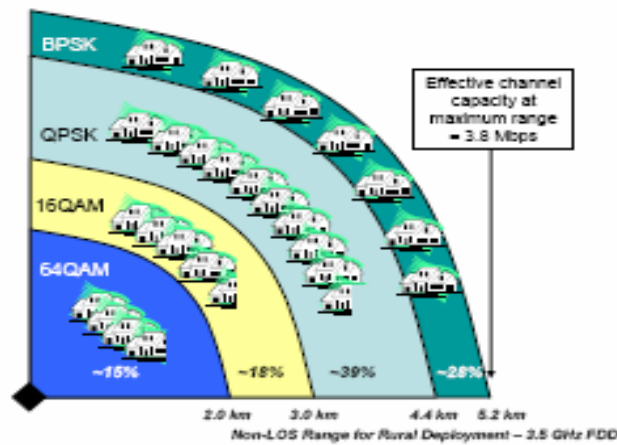
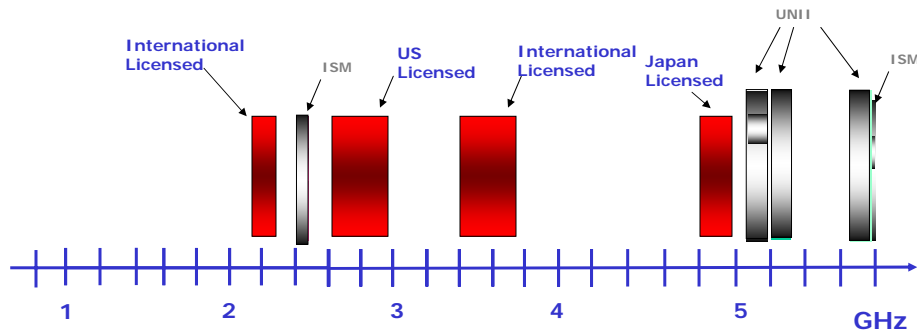


Figure 1: Typical Subscriber Density for a 3.5 GHz Rural Deployment

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802.11/802.16 Spectrum



802.16 has both licensed and license-exempt options

ISM: Industrial, Scientific & Medical Band – Unlicensed band (802.11a,b, g)
UNII: Unlicensed National Information Infrastructure band – Unlicensed band
Licensed band 2.5 GHz US and 3.5 GHz International

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Licensed Systems in U.S.



- U.S. has licensed spectrum 2.459 – 2.69 GHz
- License 22.5 MHz - 8 licenses per geographic area – operator can acquire multiple licenses
- Outside U.S. 3.5 GHz, 4.8GHz and 10.5 GHz bands used for licensed WIMAX
- Main unlicensed band is U-NII 5.725-5.825 GHz
- TDD and FDD options for every band
 - For example ,
 - TDD used with 5 MHz channels in 2.5 GHz band
 - FDD pair of 2.5 MHz channels (one uplink, one downlink) in 3.5 GHz band
 - TDD cheaper implementation and is recommended more for unlicensed spectrum

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IEEE 802.16-2004 MAC Layer



- MAC Layer is independent of physical layer used
- Point to Multipoint
- TDMA Scheduled Uplink/Downlink Frames
- Flexible QoS offerings
- Connection oriented
 - Per Connection QoS
- Integrated Security Sublayer
- Selective ARQ
- Adaptive Modulation and Coding selection
 - Increase capacity and vary data rates
 - Burst by burst, per subscriber station
- Adaptive Power Control

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MAC Addressing



- SS has a 48 bit IEEE 802 MAC address
- BS has a 48 bit BS ID – 24bits are a network operator indicator
- Each flow to a SS is assigned a 16bit connection ID (CID) used in the MAC protocol data units and to provide QoS class identifier

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Multiple Access



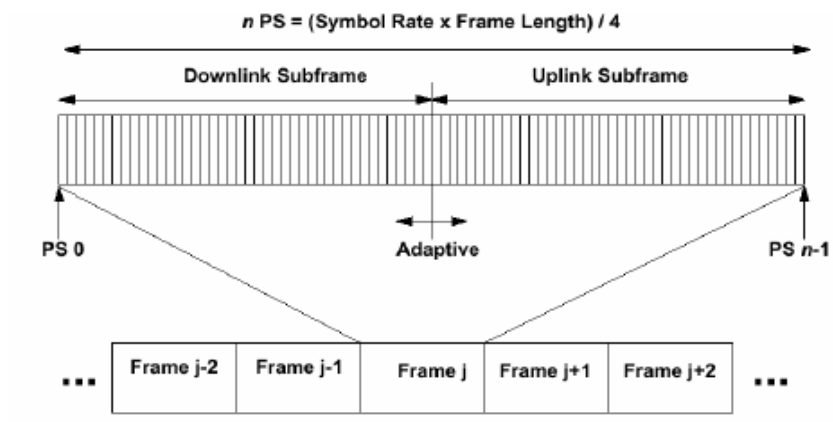
- On DownLink SS addressed in TDM stream
- On Uplink, SS allotted a variable length TDMA slot
- TDD
 - DL & UL time share the RF channel
 - Dynamic asymmetry
 - SS doesn't transmit receive simultaneously (lowers cost)
- FDD
 - DL & UL separate RF channels
 - Static asymmetry
 - Half Duplex SSs supported (lower cost)
- IUC – interval usage code specifies a modulation, rate and FEC for a time interval on DL or UL

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TDD Structure



TDD frames is 1ms durations
adaptively partitioned among up and downlink

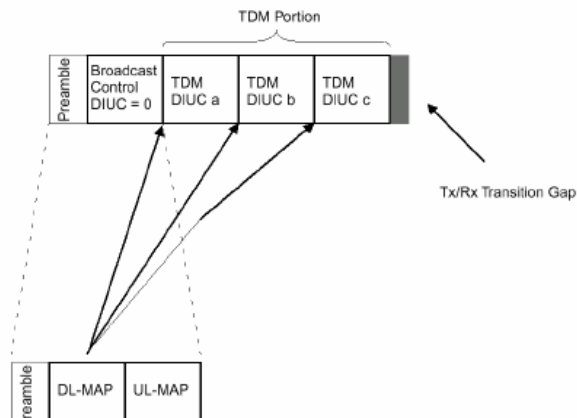


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TDD Structure



DL part of frame contains DL-MAP which specifies the modulation and coding for various TDM slots
 UL-MAP determines which SS gets slots in UL part of frame and modulation and coding used

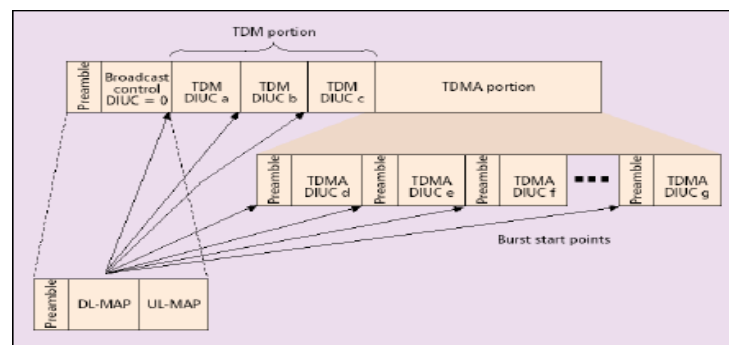


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FDD Structure



DL part of frame contains DL-MAP which specifies the modulation and coding for various TDM slots
 TDMA portion is for support of half duplex users
 UL-MAP determines which SS gets slots in UL part of frame and modulation and coding used

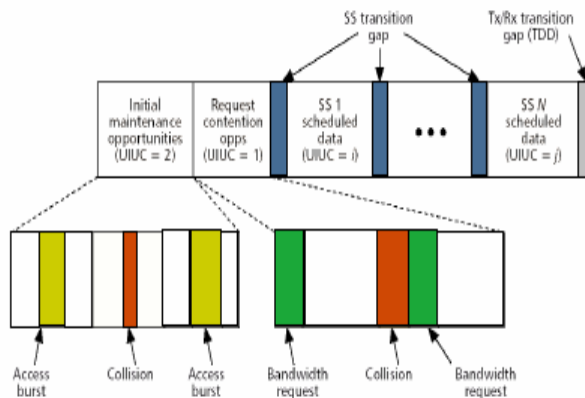


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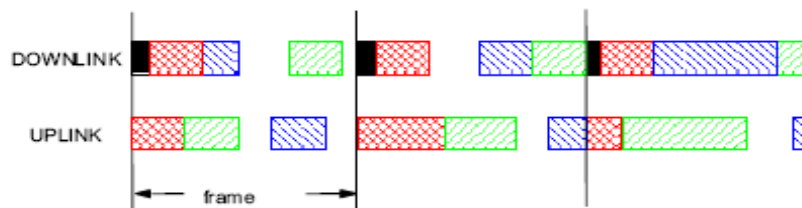
TDD/FDD UL Structure



Contention part for SS to initiate connection followed by TDMA slots

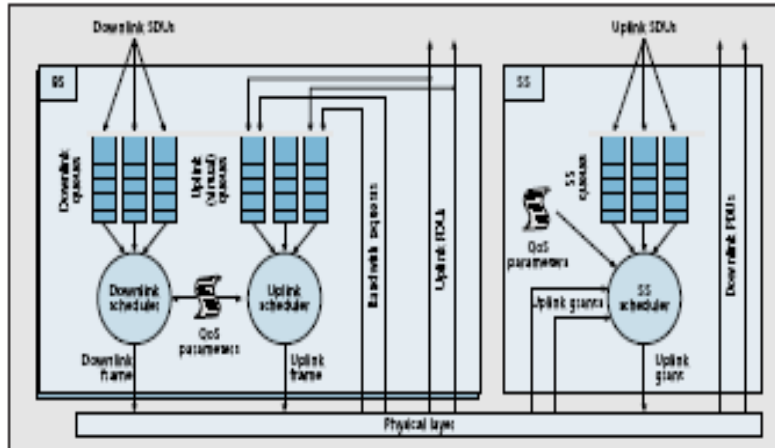


FDD Framing



Allows scheduling flexibility

QoS Services



■ Figure 2. QoS functions within the BS and SS.

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Classes of Uplink Service



- Unsolicited Grant Services (UGS)
 - For constant bit rate (CBR) or CBR like emulation (e.g., leased T1 service)
- Real Time Polling Services (rtPS)
 - For rt-variable bit rate (rt-VBR) flows such as video
- Non-Real Time Polling Services (nrtPS)
 - For non-rt flows that need better than best effort service such as file transfer
- Best Effort (BE)

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WiMax Applications



- According to WiMax Forum it supports 5 classes of applications:
 1. Multi-player Interactive Gaming.
 2. VOIP and Video Conference
 3. Streaming Media
 4. Web Browsing and Instant Messaging
 5. Media Content Downloads
 - Basically the Triple Play
 - These are mapped into QoS requirements for the MAC layer

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Application Requirements



Class	Application	BANDWIDTH		LATENCY		JITTER	
		Guideline		Guideline		Guideline	
1	Interactive Gaming	Low Bandwidth	50 kbps	Low Latency	< 25 msec	N/A	
2	Voice Telephone (VoIP) Video Conference	Low Bandwidth	32064 kbps	Low Latency	160 msec	Low Jittering	<50 msec
3	Streaming Media	Low to High Bandwidth	5 Kbps - 2 Mbps	N/A		Low Jittering	<100 msec
4	Instant Messaging Web Browsing	Moderate Bandwidth	10 kbps - 2 Mbps	N/A		N/A	
5	Media Content Download	High Bandwidth	> 1-2 Mbps	N/A		N/A	

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IEEE 802.16 Security



- Security is a sublayer of the MAC in the standard
- Security Mechanisms
 - Authentication and Registration
 - PKI at the BS with X.509 digital certificates installed by manufacturers in SSs
 - Downloaded to BS with manufacturers public key
 - Access Control
 - (similar to WiFi - WPA)
 - MAC/IP address filtering
 - VPN at higher layers, passwords, etc.
 - Privacy
 - DES with 128 bit key (triple DES)
 - Plans to move to AES
 - PKI for key distribution
 - Key refreshed based on activity max usage 20 hours

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WiMax Rollout



- WiMax Forum anticipates rollout of its technology in 3 phases:
 - Phase 1: Fixed Location, Private Line Services, Hot Spot Backhaul.
 - Phase 2: Broadband Wireless Access/Wireless DSL
 - Phase 3: Fully Mobile/Nomadic Users.

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WiMax Evolution Path



	Fixed access	Limited mobility		Full mobility
Dominating standard	IEEE 802.16-2004	IEEE 802.16e		
Services	Alternative to T1, DSL, cable Backhaul for cellular and Wi-Fi	Plus: VoIP, QoS-based applications; enterprise networking		Plus: mobile access with handoffs (data), some roaming and interworking
CPE form factor	External CPE	Desktop CPE	PCMCIA card	Client built-in
CPE price tag	\$500-\$300			\$100
Residential markets	Underserved areas	Initial deployments in competitive markets		Underserved and competitive markets, mobile users
Business markets	Underserved areas	Underserved and competitive areas		Underserved and competitive markets, mobile users
	2005	2006	2007	2008

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Wireless Networks



Network	Geographic Coverage	Typical Throughput	Standards
WWANs	National, Continent wide	2G: 9.6 – 45 Kbps, 2.5G: 50 -300 Kbps 3G : 50kbsp- 2Mbps 3.5G: .1 – 10 Mbps	2G: GSM, cdmaone 2.5G: GPRS, cdma 2000 1X-rtt 3G: UMTS, cdma2000 1x-EDVO 3.5G: HSPDA
WMANs	Metro, suburb, campus 1-15 km	2-100 Mbps	IEEE 802.16
WLANS	In building, campus wide, subdivision wide, Range ~ 100 M per AP	1-106 Mbps	IEEE 802.11a, b, g, etc.
WPANs	5-10 M around device	.1 – 1Mbps	IEEE 802.15.1rDa, BlueTooth, Zigbee

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Frequency Allocations



	Europe	USA	Japan
WWANs Licensed	Cellular: 453-457MHz, 463-467 MHz; PCS: 890-915 MHz, 935-960 MHz; 1710-1785 MHz, 1805-1880 MHz 3G: 1920-1996 MHz 2110-2186 MHz	Cellular 824-849 MHz, 869-894 MHz; PCS 1850-1910 MHz, 1930-1990 MHz;	Cellular 810-826 MHz, 940-956 MHz; 1429-1465 MHz, 1477-1513 MHz 3G 1918.1-1980 MHz 2110-2170 MHz
WWANs Licensed Unlicensed	IEEE 802.16 3.4-3.6 GHz SAME as WLANs	IEEE 802.16 2.5 – 2.6 GHz, 2.7-2.9GHz Same as WLANs	IEEE 802.16 4.8-5 GHz Same as WLANs
WLANs Unlicensed	IEEE 802.11 2400-2483 MHz 5.7-5.825 GHz HIPERLAN 1 5176-5270 MHz	IEEE 802.11 2400-2483 MHz (b, g) 5.7 – 5.825 GHz (a)	IEEE 802.11 2471-2497 MHz (b, g) 5.7-5.825 GHz (a)
WPANs Unlicensed	IEEE 802.15 2400-2483 MHz	IEEE 802.15 2400-2483 MHz	IEEE 802.15 2471-2497 MHz

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Summary



- Wireless MANs
 - Architecture
 - Standards
 - Protocol

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