Fixed and Mobile WiMAX Overview

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Scope of Presentation

- Broadband Wireless Access
- Overview of 802.16 Standards & Features
- OFDM Basics
- Overview of WiMAX
  - WiMAX Forum
  - Vision & Benefits
  - Certification
  - Applications
- Conclusion / Q&A
Business and residential customers demand:
- Data
- Voice
- Video distribution
- Real-time videoconferencing

Service providers need new value-added services such as:
- Video on Demand (VOD)
- Mobile video telephony
- Online gaming
- VoIP
- TV broadcasting

The “last mile”
- Fast local connection to network

Broadband technologies can be fixed, limited mobility or mobile
Market Segments for Wireless Access

Addressable Markets

- Residential SOHO
- Small Business
- Medium Business
- Mobile Backhaul
- Multi-Tenant Residential
- Large Business

Data Rate

- 1 Gbps
- 150 Mbps
- 50 Mbps
- 20 Mbps
- 10 Mbps
- 2 Mbps
- 500 Kbps
- 56 Kbps

Frequency Bands

- <11 GHz
- 10-40 GHz

Communication Technologies

- PtP
- FSO
- Fiber

Network Protocols

- xDSL, Cable
Global Wireless Standards

- WiMAX 802.16
- Wi-Fi 802.11
- UWB 802.15.3
- Bluetooth 802.15.1
- ZigBee 802.15.4
- WiMobile 802.20
- 802.22

IEEE
802.16 Standards Evolution

- **802.16c (Dec 2001)**
  - Original fixed wireless broadband air interface for 10-66 GHz
  - Line-of-sight only, point-to-multi-point applications

- **802.16a (Jan 2003)**
  - Extension for 2-11 GHz
  - Targeted for non-line-of-sight, point-to-multi-point applications like “last mile” broadband access

- **802.16d (Jun 2004)**
  - 802.16 Revision PAR for 802.16 & 802.16a to add WiMAX System Profiles and Errata for 2-11 GHz in support of 802.16e requirements

- **802.16e (Dec 2005)**
  - Amendment for mobile wireless broadband up to vehicular speeds in licensed bands from 2-6 GHz
  - Enables roaming for portable clients (laptops) within & between service areas
802.16 Layer Characteristics

Service Specific Convergence Sublayer (CS) provides mapping or transformation of external network data received through the CS Service Access Point (SAP) into MAC Service Data Units received by the MAC CPS through the MAC SAP. This includes classifying external network SDUs and associating them to the proper MAC service flow and Connection Identifier, payload header suppression, etc.

MAC CPS provides the core MAC functions, such as, uplink scheduling, bandwidth request & grant, connection establishment, connection maintenance, ARQ and ranging. Receives data through MAC SAP classified to particular MAC connections. QoS is applied to the transmission and scheduling of data over PHY. MAC contains a separate Privacy Sub-layer providing authentication, secure key exchange and encryption.

Data, PHY control and statistics are transferred between the MAC CPS and the PHY via the PHY SAP. The PHY may include multiple specifications, each appropriate to a particular frequency range and application.
802.16 General Characteristics (1)

- Four physical layers (SC, SCa, OFDM, OFDMA)
  - Wireless Metropolitan Area Networks operation in 2-11 GHz spectrum
  - Non-line-of-sight (NLOS) operation designed to address multi-path
    Eliminates need for directional LOS propagation
  - Greater range and higher data rates
- Multiple options for:
  - Flexible channel bandwidths from 1.75 to 20MHz
  - Flexible frame lengths: frame sizes ranging from 2.5 to 20ms
  - Duplexing modes: Time Division Duplex (TDD) and Frequency Division Duplex (FDD)
  - Flexible channel coding & FEC
- Support for multiple antenna technology
  - Adaptive and smart antennas (AAS)
  - TX diversity (STC)
  - Beamforming and spatial multiplexing (MIMO)
802.16 General Characteristics (2)

- Link adaptation (per subscriber, burst by burst, uplink and downlink)
  - Adaptive Modulation and Coding BPSK to QAM64 across all channel bandwidths
  - Trade off capacity and robustness in real time
  - Adaptive burst profiles dynamically assigned modulation and FEC for each burst
- Point-to-multipoint topology, with mesh extensions
- Protocol independent supporting ATM and packet-based protocols
- **True** Quality of Service (QoS) supports multiple services simultaneously, with different QoS priorities
- Scalable system capacity allows more efficient use of available spectrum than other wireless technologies
- Supports both licensed and licensed-exempt frequencies
- Supports a variety of services such as IP, voice over IP and streaming video
- Bandwidth on demand (frame by frame)
- Comprehensive and extensible security (DES and AES CCM)
Why Is the Focus on OFDM?

- The OFDM signal is able to support NLOS performance while maintaining a high level of spectral efficiency, maximizing the available spectrum.
- Superior NLOS performance enables significant equalizer design simplification.
- Supports operation in multi-path propagation environments.
- Scalable bandwidths provide flexibility and potentially reduce capital expense.
OFDM Basic Concepts

- A conventional transmission uses only a single carrier, which is modulated with all the data to be sent
- OFDM is a multi-carrier amplitude modulation scheme that transmits data over a number of orthogonal sub-carriers
- OFDM breaks the data into small chunks, allocating each sub-data stream to a sub-carrier
- The data is sent in parallel orthogonal sub-carriers

![Diagram of OFDM concepts](image-url)
OFDM Fundamentals

- **OFDM Sub-carrier Organization**
  - **Data Sub-carriers**
    - Transport BPSK, QPSK, 16QAM, 64QAM symbols
  - **Pilot Sub-carriers**
    - Transport known pilot symbol sequence (frequently at an elevated power level) to permit channel estimation and coherent demodulation at receiver
  - **Guard Sub-carriers**
    - Suppressed – permits spectrum shaping
  - **DC Sub-carrier**
    - Frequently suppressed to support direct-conversion receivers
OFDM and OFDMA

Available data sub-carriers divided into N contiguous groups
Each sub-channel assigned one data sub-carrier from each group
OFDM Transceiver

OFDM Transmitter

01000111010101
Serial Tx Data

Serial To Parallel
Sub-carrier Modulation
I FFT
Cyclic Prefix Insertion
Frame Sync Insertion
RF Modulator Amplifier

Carrier Phase
Carrier Amplitude

OFDM Receiver

01000111010101
Serial Rx Data

Parallel To Serial
Sub-carrier Demodulation
FFT
Cyclic Prefix Removal
RF Amplifier Demodulator

Carrier Phase
Carrier Amplitude

Time Synchronization
Frame Detection

Frequency Correction
Time Division Duplex (TDD) and Frequency Division Duplex (FDD) modes

- Frame duration from 2.5 to 20ms
- Channel bandwidths ranging from 1.75 to 20MHz
- Guard times (cyclic prefix) 1/4, 1/8, 1/16 or 1/3
Adaptive Modulation

Modulation changes dynamically to match propagation path

- Adaptive Modulation maximizes both air-link capacity and coverage
- Adaptive TDMA: True bandwidth on demand and variable packet sizes provide differentiated, bursty services to multiple users
- Adaptive TDD: Variable asymmetry in a single broadband channel best matches bandwidth to demand
Modulation and Coding

- BPSK, QPSK, 16QAM and 64QAM
- Concatenated Reed-Solomon/Convolution Code (RS-CC) FEC
- Convolutional Turbo Code (CTC)
  - CTC encoder adopted from DVB-RCT specification – similar performance to 3GPP
- Optional LDPC code under study
Channel Quality Indicator

- Base Station uses Adaptive Modulation and Coding (AMC) to send data to the subscriber stations to optimize throughput
- A Channel Quality Indicator (CQI) channel is utilized to provide channel-state information from the user terminals to the base station scheduler

“T’ve got data to send you, measure my preamble and send me CQI in the next UL subframe”

“Here’s what I see; doesn’t look good”

“We’ll go slow; the MAP will tell you where to find your data”
Frame Structure
Smart Antenna Technology

- **Beamforming**
  - Multiple-antennas transmit weighted signals to improve coverage and capacity

- **Transmit Diversity: Space-Time Code (STC)**
  - Provides spatial diversity and reduce fade margin

- **Spatial Multiplexing (SM)**
  - Multiple streams are transmitted over multiple antennas
  - Receiver can have single or multiple antennas. Receiver separates different streams to achieve higher throughput compared to a single antenna
  - Examples: 2x2 MIMO, 1x2 SIMO

![Diagram of MIMO](image)
QoS Support

- QoS is provided via service flows. This is a unidirectional flow of packets with a particular set of QoS parameters.
- Base Station and user terminal first establish a unidirectional logical link between the peer MACs called a connection.
Hybrid Automatic Repeat-Request (HARQ)

- Self-optimizing and adjusts automatically to channel conditions
  - Adds redundancy only when needed
  - Receiver saves failed transmission attempts to help future decoding (Chase Combining)
  - Every transmission helps to increase the packet success probability

- Enabled by $N$-Channel Stop-and-Wait ARQ
  - Receiver sends an ACK or NAK in response to each transmission
WiMAX
What is WiMAX?

Worldwide Interoperability for Microwave Access
WiMAX Forum Charters

- Industry-led, non-profit corporation
- More than 350 members: Service providers, system vendors, semiconductor suppliers, and eco-system
- To promote a common broadband wireless standard
- To develop reduced scope “profiles” to ease development
- To act as a certification body
WiMAX Vision

End 2005
Fixed, Outdoor

End Customers

2006
Consumer, Indoor

Backhaul

2006/7
Portable

2007
Mobile
WiMAX Benefits

Pre-Standard: Discrete Components
- Proprietary, vertical solutions
- No volume silicon market

Post-Standard: Integrated Solution
- Equipment interoperability
- Economies of scale
- Superior price/performance

Service Providers
- System Integration
- Network Software
- System Design & Architecture
- Custom MAC
- Custom, 802.11 or DOCSIS PHY
- Custom Radio

Large revenue opportunities

Service Providers
- System Integrator
- Network Mgmt Software Supplier
- Equipment Manufacturers
- Volume Integrated MAC/PHY Silicon Solutions
- Volume Radio Supplier

Large revenue opportunities
## WiMAX Frequency Bands

<table>
<thead>
<tr>
<th>Service</th>
<th>Frequency (GHz)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>WCS</td>
<td>2.3</td>
<td>Wireless Communication Service</td>
</tr>
<tr>
<td>ISM</td>
<td>2.4 – 2.4</td>
<td>Industrial, Scientific and Medical Bands</td>
</tr>
<tr>
<td>MMDS</td>
<td>2.5 – 2.7</td>
<td>Multi-channel Multipoint Distribution Service</td>
</tr>
<tr>
<td>International</td>
<td>3.4 – 3.7</td>
<td>Licensed Bands – Europe, Latin America, Asia</td>
</tr>
<tr>
<td></td>
<td>4.8 – 5</td>
<td>Licensed Bands – Japan</td>
</tr>
<tr>
<td>UNII</td>
<td>5.15 – 5.35 &amp; 5.75 – 5.85</td>
<td>Licensed-exempt National Information Infrastructure Band</td>
</tr>
<tr>
<td>New Spectrum</td>
<td>5.470 – 5.725</td>
<td>FCC NPRM 03-110 Part 15</td>
</tr>
</tbody>
</table>

Note: 4.3Ghz (emergency band), 4.9Ghz (public safety band)
WiMAX Certification Process

Vendor returns to self-testing upon failure

Vendor Self-Testing ➔ WiMAX Certification Testing ➔ Vendor passed all tests

- WiMAX PICS
- PIXIT

WiMAX Approved Test Plans

- PICS Proforma: Protocol Implementation Conformance Statement
- TSS & TP: Test Suite Structure and Test Purposes
- ATS: Abstract Test Suite
- Standardized (Protocol) Implementation eXtra Information for Testing

Publish WiMAX Certified Equipment List

Vendor’s responsibility
WiMAX Forum’s responsibility
Certification lab’s responsibility
- Required path
- Optional path

Service Provisioning Standard (802.16f) MIB, etc.
WiMAX Forum Certification Program

- **WiMAX Certification Services**
  - CETECOM, a WiMAX Forum designated certification laboratory (located in Spain), provides a one-stop service for the certification of WiMAX systems

- **Mission**
  - Evaluate testing options
  - Recommend test lab(s) selection
  - Manage test lab and vendor relationships
  - Manage WiMAX Forum Certification program
  - Maintain open process for WiMAX Forum Certification program
  - Provides system profiles, PICS, TSS & TP
What is Certified?

WiMAX certification is for the system, not for components.
WiMAX Timeline

802.16-2004
Fixed Applications
10-66GHz Single Carrier, LOS, Licensed
2-11GHz OFDM, Non-LOS, Licensed & Unlicensed

WiMAX Profiles & Certification
Testing
OFDM
3.5 GHz
5.8 GHz

Fixed WiMAX/802.16-2004-Compliant Deployments for Broadband Wireless Fixed and/or Nomadic Services

802.16e
Fixed & Mobile Applications
< 6 GHz SOFDMA, Non-LOS, Licensed

WiMAX Profiles & Certification
Testing
2.3 GHz
2.5 GHz
3.5 GHz

Mobile WiMAX/802.16e-Compliant Deployments for Mobile Services

Other Mobile WiMAX Profiles:
Frequency bands, Channel BWs, FDD, etc. (based on markets and opportunities)

2004  2005  2006  2007  2008/9
The WIMAX-based applications are related to two different PHY supports: OFDM256 and OFDMA.
## Key Features

<table>
<thead>
<tr>
<th>Fixed/Nomadic (802.16-2004)</th>
<th>Mobile (802.16e-2005)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>256 - OFDM</strong></td>
<td><strong>Scalable OFDMA 128 – 2048</strong></td>
</tr>
<tr>
<td>Uplink sub-channelization (optional)</td>
<td><strong>Full uplink &amp; downlink sub-channelization</strong></td>
</tr>
<tr>
<td>Channel BW: up to 10MHz</td>
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</tr>
<tr>
<td>TDD and FDD support</td>
<td>TDD</td>
</tr>
<tr>
<td><strong>Space Timing Coding (optional)</strong></td>
<td><strong>Adaptive antenna systems, Beamforming, Space Timing Coding &amp; Spatial Multiplexing (MIMO)</strong></td>
</tr>
<tr>
<td>Per-connection QoS support</td>
<td><strong>QoS support: UGS, rtPS, ErtPS, nrtPS, BE</strong></td>
</tr>
<tr>
<td><strong>Automatic Retransmission Request (ARQ)</strong></td>
<td><strong>HARQ</strong></td>
</tr>
<tr>
<td><strong>Security and encryption (DES)</strong></td>
<td><strong>AES CCM</strong></td>
</tr>
<tr>
<td><strong>Coding: Reed-Solomon/Convolution Code (RS-CC) FEC</strong></td>
<td><strong>Coding: CTC and LDPC FEC</strong></td>
</tr>
<tr>
<td>Licensed &amp; license-exempt bands</td>
<td>Licensed bands</td>
</tr>
<tr>
<td>NA</td>
<td><strong>Mobility management (sleep and idle mode)</strong></td>
</tr>
<tr>
<td>NA</td>
<td><strong>Handover (HO)</strong></td>
</tr>
<tr>
<td></td>
<td>-Hard handover (HHO)</td>
</tr>
<tr>
<td></td>
<td>-Soft handover (SHO)</td>
</tr>
<tr>
<td></td>
<td>-Macro diversity handover (MDHO)</td>
</tr>
</tbody>
</table>
BWA Evolution (Fixed / Portable / Mobile)

OUTDOOR CPE

802.11

802.16

Non Line-of-Sight Point-to-Multi-point

INTERNET BACKBONE
Telco Core Network or Private (Fiber) Network

802.16 PCMCIA Form Factor

INDOOR CPE

Portable Device Connected Through 802.16

802.16
Vision – Wireless Multimedia Distribution

- Cordless Phones
- HDTV
- Gaming
- Tablet PC with Camera
- Set Top Box 802.16/11 AP
- WIMAX 802.16/11
- Broadband Service 802.16, Cable, DSL, IP
- Real-Time Video 2xHDTV
- Guaranteed Data Access
- Guaranteed and Best Effort Access
- Real-Time Video 2xHDTV
- CBR TDM Voice
- Best Effort Access
- Pocket PC
- 802.16/11
- 802.16d
- 802.16/11
- 802.16d
- 802.16d
Other WiMAX Applications

- WSP (Wireless Service Provider) Backhaul
- Banking Networks
- Education Networks
- Hot Zone
- Public Safety
- Rural Connectivity
- Enterprise Private Networks
- Alternative to DSL / Cable
- Cellular Backhaul
Conclusion

- WiMAX, a single technology can deliver fixed, portable & mobile services with scalable bandwidths & higher data rates

- WiMAX is a well-supported, cost-effective, standards-based, flexible, broadband technology that is ready to deliver significant benefits for:
  - Operators in a wide range of markets (enterprise, consumer, emerging, public service)
  - Over a wide range of geographies and demographics (urban, suburban, rural)

- Advantages of WiMAX
  - Large coverage
  - Higher capacity
  - Scalable
  - Faster to implement
  - Performs well in high delay spread environments
  - Supports multiple antenna technologies
Fujitsu

The possibilities are infinite