Introduction to WiMAX
Contents

- Overview of WiMAX
- WiMAX Network Architecture
- WiMAX Basics
- WiMAX Physical Layer Basics
Overview of WiMAX
OUTLINE

- Wired or Wireless: The Future
- Components of Wireless Networks
- Classification of Wireless Networks
- Problems in Wireless Links
- Overview of Wi-Fi
- Overview of WiMAX
- WiMAX Strengths
Objectives

• The main objectives of this session are:
  • To understand the need and history for wireless networks.
  • To comprehend salient features of different wireless networks.
  • To compare different standards of wireless networks.
  • To understand the key aspects of WiMAX standard.
Ideal Network

Faster

More

Secure

Manageable

Seamless connectivity to all networks, applications, & services

Anytime Anywhere
Wired or Wireless: The Future

• Portability

• Mobility
  • Ability to be reached regardless of location (Roaming)
  • Session continuity while traversing between BS and across diverse networks (Handover)

• Coverage
  • Extend to rural subscribers
  • Areas where wired networks not available
Components of Wireless Network

• **Wireless hosts**
  • Laptops, palmtops, PDA, desktop computer, phone
  • WiMAX calls wireless host ‘Customer Premises Equipment (CPE)’

• **Access Points**
  • The base station (BS)
  • Responsible for sending and receiving data
  • A wireless host is associated with a BS
Components of Wireless Network

• Wireless link
  • Communication link between wireless host and access point/BS and/or among wireless hosts.
  • The link characteristics depend upon the wireless technology.

• Network Infrastructure
  • A larger network with which a wireless host wishes to communicate.
  • Service providers e.g. Wi-Tribe, Wateen, Mobilink etc.
Classification of Wireless Networks

• Single Hop / Multiple Hop
  • Number of hops a packet undergoes in the wireless network

• Infrastructure Based / Infrastructure Less
  • BS present or absent
  • Adhoc – no BS

• Examples
  • Single Hop Infrastructure based: Wi-Fi in classroom/library/cafe, cellular networks and Wimax
  • Single Hop Infrastructure less: Bluetooth

• Fixed / Mobile
  • Nomadicity
  • Ability to be reached regardless of location - Roaming
  • Session continuity while traversing between BS - Handover
Problems in Wireless Links

• **Decreasing Signal Strength**
  • In free space, the signal will disperse that results in decreased signal strength.

• **Interferences from other Sources**
  • Radio sources transmitting in the same frequency band will interfere with each other.

• **Multipath Propagation**
  • Reflection of electromagnetic waves off objects and ground
  • Results in blurring of the received signal at the receiver.
Standards of Wireless Technology

- Bluetooth
- IEEE 802.11 (Wi-Fi)
- IEEE 802.16d (Fixed WiMAX)
- IEEE 802.16e (Mobile WiMAX)

Layers:
- PAN
- LAN
- MAN
- WAN
Wi-Fi: The Predecessor of WiMAX

- Wi-Fi (Wireless Fidelity) is a set of technologies that are based on the IEEE 802.11a, b, and g standards.
- Wi-Fi is considered to be one of the first widely deployed fixed broadband wireless networks.
- The Wi-Fi architecture consists of a base station that wireless hosts connect to in order to access network resources.
- As long as the users remain within 300 feet of the fixed wireless access point, they can maintain broadband wireless connectivity.
Wi-Fi Standards

<table>
<thead>
<tr>
<th>Standard</th>
<th>Throughput</th>
<th>Range</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>802.11a</td>
<td>Up to 54 Mbps</td>
<td>Up to 300 ft</td>
<td>5 Ghz</td>
</tr>
<tr>
<td>802.11b</td>
<td>Up to 11 Mbps</td>
<td>Up to 300 ft</td>
<td>2.4 Ghz</td>
</tr>
<tr>
<td>802.11g</td>
<td>Up to 54 Mbps</td>
<td>Up to 300 ft</td>
<td>2.4 Ghz</td>
</tr>
</tbody>
</table>

Find about the latest 802.11n standard?
IEEE 802.11n

- IEEE 802.11n is the next-generation standard enhancements to the current 802.11 standard to provide improvements in throughput.
- IEEE 802.11n Task Group (TGn) established in September 2003.
- Salient Features include
  - Data rate of 300 Mbps
  - Works in both 2.4/5GHz band
  - Multiple Input Multiple Output (MIMO)
  - Backward Compatibility.
Wi-Fi Issues

• **Effective range**
  • Limited level of mobility

• **Interference from other sources**
  • Operate in unlicensed spectrum

• **Signal strength decreases with distance**

• **Multipath propagation**
  • Waves reflect off ground and objects
What is WiMAX?

- WiMAX (Worldwide Interoperability for Microwave Access) is a standards-based technology enabling the delivery of last mile wireless broadband access as an alternative to cable and DSL.

- The technology is specified by the Institute of Electrical and Electronics Engineers, as the IEEE 802.16 standard.

- WiMAX eliminates the constraints of Wi-Fi.
WiMAX Strengths

• Effective range
  • 2-5 miles
  • Full mobility
  • Broad operating range – unlicensed (5 GHz), licensed (3.5 GHz)

• Interference from other sources
  • Operates in licensed spectrum

• Signal strength decreases with distance

• Multipath propagation
  • Wave reflects of ground and objects

Efficient signal processing schemes, e.g. OFDM/OFDMA etc
# WiMAX Vs Wi-Fi

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Fixed WiMAX</th>
<th>Mobile WiMAX</th>
<th>Wi-Fi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standards</td>
<td>IEEE 802.16d-2004.</td>
<td>IEEE802.16e-2005.</td>
<td>IEEE 802.11a/b/g</td>
</tr>
<tr>
<td>Coverage (Non-line-of-site)</td>
<td>3-5 miles</td>
<td>&lt; 2 miles</td>
<td>&lt;100 ft.</td>
</tr>
<tr>
<td>Mobility</td>
<td>Not applicable</td>
<td>Supported</td>
<td>Supported</td>
</tr>
<tr>
<td></td>
<td>UL: 3.3 – 6.5 Mbps</td>
<td>UL: 4-7 Mbps</td>
<td>IEEE 802.11 a &amp; g: 54 Mbps</td>
</tr>
<tr>
<td>Frequency Range</td>
<td>10 – 66 GHz (Line-of-site)</td>
<td></td>
<td>IEEE 802.11.b: 2.4GHz</td>
</tr>
<tr>
<td></td>
<td>2-11 GHz (Non-line-of-site)</td>
<td></td>
<td>IEEE 802.11.a: 5GHz</td>
</tr>
</tbody>
</table>
WiMAX accommodates both fixed and mobile deployments.

**Fixed Profiles**

- Point To Point (PTP) applications include microwave backhaul.
- Point To Multipoint (PTM) applications include broadband for residential, small office/home office and small-to-medium-enterprise markets, wireless backhaul for Wi-Fi hotspots.
WiMAX Frequency Allocation

International Frequency Allocation

Canada:
• 2.3 GHz
• 2.5 GHz
• 3.5 GHz

Europe:
• 3.5 GHz
• possibly 2.5 GHz

Russia:
• 3.5 GHz
• possibly 2.3, 2.5 GHz

USA:
• 2.5 GHz

Central & South America:
• 2.5 GHz
• 3.5 GHz

Middle East & Africa:
• 3.5 GHz

Asia Pacific:
• 2.3 GHz
• 3.3 GHz
• 3.5 GHz
• possibly: 2.5 GHz
## WiMAX Technical Challenges

<table>
<thead>
<tr>
<th>Service Requirements</th>
<th>Technical Challenge</th>
<th>Potential Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Line-Of-Site coverage</td>
<td>Multipath fading and interference</td>
<td>Diversity, channel coding etc.</td>
</tr>
<tr>
<td>High data rate</td>
<td>High spectral efficiency</td>
<td>Adaptive Modulation Coding (AMC) etc.</td>
</tr>
<tr>
<td></td>
<td>Inter Symbol Interference (ISI)</td>
<td>OFDM, OFDMA etc.</td>
</tr>
<tr>
<td>Quality of Service (QoS)</td>
<td>Multiplexing voice, data and video on a single access network</td>
<td>Complex MAC layer</td>
</tr>
<tr>
<td></td>
<td>Radio Resource Management</td>
<td>Efficient scheduling algorithms</td>
</tr>
<tr>
<td>Security</td>
<td>Privacy and integrity of data</td>
<td>Encryption</td>
</tr>
<tr>
<td></td>
<td>Prevent unauthorized access to the network</td>
<td>Authentication and access control</td>
</tr>
</tbody>
</table>
Summary: WiMAX Is....

- IEEE 802.16 standard
  - Fixed, Mobile
- High speed
- Broader coverage
- Licensed Frequency band
- Lower layer technology- Standard defined at PHY and MAC Layers
Long Term Evolution (LTE)

- Competing with WiMAX.
- 3GPP’s LTE standard evolved from the High-Speed Packet Access (HSPA) cellular standards.
- Single Carrier Frequency Division Multiple Access (SCFDMA) in the uplink.
  - Increase battery life
- Higher data rates: (100Mbps downlink, 60Mbps uplink)
- Lower latency (~10ms)
- The LTE standard can be used with many different frequency bands.
  - 700 and 1700 MHz in North America.
  - 900, 1800, 2600 MHz in Europe
## Difference Between WiMAX and LTE

<table>
<thead>
<tr>
<th></th>
<th>LTE</th>
<th>WiMAX 802.16e</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Layer</td>
<td>DL: OFDMA</td>
<td>DL: OFDMA</td>
</tr>
<tr>
<td></td>
<td>UL: SC-FDMA</td>
<td>UL : OFDMA</td>
</tr>
<tr>
<td>Duplex Mode</td>
<td>FDD and TDD</td>
<td>TDD</td>
</tr>
<tr>
<td>VoIP Capacity</td>
<td>80 users/sector</td>
<td>20 users/sector</td>
</tr>
<tr>
<td>Channel Bandwidth</td>
<td>5, 10, 15, 20 MHz</td>
<td>5, 7, 10 MHz</td>
</tr>
<tr>
<td>Peak data rates</td>
<td>DL: 302 Mbps (4 × 4) UL : 75 Mbps (2 × 4)</td>
<td>DL: 46 Mbps (2 × 2) UL : 4 Mbps (1 × 2)</td>
</tr>
<tr>
<td>Latency</td>
<td>Link layer &lt; 5 ms Handoff &lt; 50 ms</td>
<td>Link layer ~ 20 ms Handoff ~ 35 to 50 ms</td>
</tr>
<tr>
<td>Frame Length</td>
<td>0.5 ms</td>
<td>5ms</td>
</tr>
</tbody>
</table>
WiMAX Network Architecture
Objectives

Main Objectives of this session are:

• To understand different profiles used by WiMAX network.
• To explain the architecture of a typical WiMAX network.
• To understand the functionality of different servers used in a WiMAX network.
• To explain the architecture provided by Motorola for the WiMAX network.
Contents

• WiMAX Network Architecture
  • What is Access Service Network (ASN) and Connectivity Service Network (CSN)?
  • Functions of ASN and CSN
• WiMAX Interfaces
• Motorola WiMAX Network Architecture
  • ASN
    • Base Controller Unit (BCU) and its functions
    • ASN-GW
      • Functions of Carrier Access Point Controller (CAPC)
      • Functions of Redback Router
    • Element Management System (EMS)
  • CSN
    • Authentication Accounting and Authorization (AAA) Server
    • Other CSN Servers e.g. DNS, NTP etc
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  • Profile A, B, C
  • Merits and Demerits of Difference profiles
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WiMAX Networks Architecture

- WiMAX split the system into three areas:
  - Network Service Provider (NSP)
  - Network Access Provider (NAP)
  - Customer Premises Equipment (CPE)

Fig 1: WiMAX architecture
WiMAX is an Access Network

<table>
<thead>
<tr>
<th>Network</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSP</td>
<td>Network service Provider</td>
</tr>
<tr>
<td></td>
<td>Provide all of the services and features being offered by the carrier</td>
</tr>
<tr>
<td>CSN</td>
<td>Connectivity Service Network</td>
</tr>
<tr>
<td></td>
<td>Responsible for subscribers IP connectivity</td>
</tr>
<tr>
<td>ASN</td>
<td>Access Service Network</td>
</tr>
<tr>
<td></td>
<td>Provide network access and mobility</td>
</tr>
<tr>
<td>CPE</td>
<td>Customer Premises Equipment</td>
</tr>
<tr>
<td></td>
<td>Provides the customer interface</td>
</tr>
</tbody>
</table>

Table 1: Functions of Network Elements
## Functions of ASN and CSN

### ASN
- **Network discovery**
  - Selecting the service provider
  - Wateen, Wi-tribe, Mobilink Infinity
- **Network entry**
  - Providing mechanism to CPE for accessing the network resources and services
- **Radio Resource Management**
- **Accounting assistance**
  - Records the duration of user session
- **Quality-of-Service**

### CSN
- **Provides access to Internet**
  - Assigns IP addresses to CPEs for internet access
- **AAA server**
  - Provides authentication, accounting and authorisation services to network provider
- **Manages Quality of service for each subscriber**
  - Policies for each subscriber are defined – subscription profiles
  - Admission to network and access to various services
- **WiMAX subscriber billing**
Network Service Provider (NSP)

• The NSP network provides
  • Services and features being offered by the carrier.
  • Authentication, authorization and allocation of IP addresses.
  • Broadband access services.

• These may include:
  • Voice over IP (VoIP)
  • Streaming audio or video programs
  • Internet access
  • E-mail
  • Instant Messaging
  • Access to databases
Network Service Provider (NSP)

Fig 3: Logical Elements of the NSP
Network Service Provider (NSP) & Operators in Pakistan

- NSP may establish roaming agreement with other NSPs and contractual agreements with the third party application providers for providing WiMAX services to SS.

- Few Network Service Providers are
  - NayaTel
  - Micronet
  - PTCL
  - Wateen

- Few WiMAX operators are
  - Mobilink Infinity
  - Wateen
  - Wi-Tribe
  - Qubee
Connectivity Service Network (CSN)

- **Authorization, Authentication and Accounting (AAA) Server**
  - Responsible for managing CPE authentication.
  - Providing the network with the profile information of each subscriber.

- **Domain Name Server (DNS)**
  - Responsible for translating domain names into IP addresses.

- **Dynamic Host Configuration Protocol (DHCP) Server**
  - Responsible for providing dynamic IP address to devices on a network.
  - Using DHCP allows IP addresses to be added to a computer automatically.

- **Home Agent (HA)**
  - Use for mobility feature.

- **Gateways**
  - Added to the network to provide access to other systems outside of the CSN.
Connectivity Service Network (CSN)

Fig 4: Logical Elements of the CSN
Access Service Network (ASN)

• The ASN provides the radio connection to the SS from the network.
  • Radio Resource Management (RRM)
  • Mobility Management (MM)

• The ASN contains two main functional areas:
  • ASN Gateway
  • Base Station(BS)

• The ASN gateway is connected to the Base Stations and the CSN.
Access Service Network (ASN)
Summary of WiMAX Architecture

Fig 6: WiMAX Architecture
Interfaces in WiMAX

• The elements that make up the WiMAX network are connected by physical connections carrying many logical interfaces.

• The WiMAX Forum defines the following Interfaces for its network architecture.
  • R1 → SS—BS.
  • R2 → SS—CSN.
  • R3 → ASN — CSN.
  • R4 → ASN — ASN.
  • R5 → CSN — CSN.
  • R6 → BS—ASN-GW.
  • R7 → ASN-GW.
  • R8 → BS—BS.
Interfaces in WiMAX

Air Interface between SS & BS

SS-ASN mobility

BS – ASN-GW Management

Inter-CSN mobility

BS-BS Handover

ASN-CSN allowing AAA, policy enforcements, mobility management etc

Internal interface to the ASN-GW

Fig 8: WiMAX Interfaces
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    • Other CSN Servers e.g. DNS, NTP etc
Motorola WiMAX Network Architecture

- The ASN elements provided by Motorola are as follows:
  - WiMAX Base Station (BS) or Access Point (AP)
  - Carrier Access Point Controller (CAPC)
  - Redback Router
  - Element Management Server (EMS)
  - Customer Premise Equipment (CPE)
Motorola WiMAX Network Architecture

• The CSN elements provided by Motorola are as follows:
  
  • Authentication, Authorization and Accounting (AAA) Server
  • Dynamic Host Configuration Protocol (DHCP) Server
  • Domain Name Service (DNS) Server
  • Network Time Protocol (NTP) Server
  • Routers/Switches/Firewall
ASN Elements

• Motorola has chosen the following equipment within its ASN solution:

  • Base Station
    • Diversity Access Point (DAP)
  • ASN-GW
    • CAPC
    • Router (Redback-SmartEdge)
Diversity Access Point (DAP)

• The DAP consists of two major subsystems:

1. RF Modules
   • Performs all RF transmit and receive processing to deliver signals to Base Controller Unit (BCU).

2. The BCU
   • Perform signal processing
   • Site synchronization
   • Power distribution
   • Network interfacing
RF Modules

- WAP 400, WAP 600 etc.
- It features multiple transmit and receive paths.
- Supports 4 sectors.
- 20 Watts of power per sector.
- Supports 256 active users per sector.

RF Module installed at NUST

- WAP 35450.
- Operating Frequency 3.5GHz.
- Support Bandwidth Up to 200MHz.
- Single Sector (Omni directional).
- 5 Watts of power.
Base Controller Unit (BCU)

- Pluggable slots for up to two site controllers.
- Four modems support a four sector site configuration.
- BCU contains:
  - Alarm I/O board.
  - Fans and heating system.
  - Power distribution system for the entire site.
Functions of Base Controller Unit (BCU)

- Site synchronization
  - GPS Module is installed for Atomic clock.

- Power distribution
  - Distribute the equal powers in all defined sectors.

- Network interfacing
  - Provide interfacing and access control to the backhaul network and external alarms.
Base Controller Unit (BCU)

Fig 11: BCU Internal View
Base Controller Unit (BCU)

**External view**
- BCU door
- AP control
- Customer I/O
- Ethernet ports
- Remote GPS

**Internal view**
- BCU FAN
- Power Supply 1
- Power Supply 2
- Power Supply 3
- Modem Card 1
- Modem Card 2
- Controller Card

**802.16e MAC and PHY processing.**
- Digital programming
- Ethernet switch
- Interfaces for backhaul
- Site alarms
- I/O

Fig 12: BCU Internal & External View
Function of CAPC

- CAPC performs security related functions and network mobility in Motorola WiMAX architecture. Some functions are:
  - Authentication / Security liaison.
    - Acts as AAA client
    - User and service profiles, equipment credentials and authentication keys storage.
  - QoS Policy Decision Point.
    - Admission control on CSN level.
    - Interfacing with billing.
    - Achieved by the co-ordination of message and lease management during handovers.
  - Handover Decision Point.
    - CSN temporary user database handling.
    - DHCP IP allocation.
  - Location Management.

Fig 13: CAPC with 14 Payload cards
Carrier Access Point Controller (CAPC)

- The CAPC chassis provides total 14 slots:
  - 2 System Controller Cards.
    - Microprocessor
    - Ram
    - Hard disk
  - 2 Reserved for future use.
  - 10 available for CAPC Payload cards.
    - Host individual Base Stations
    - Run applications for data and billing

Fig 14: CAPC Internal Structure
Carrier Access Point Controller (CAPC)

• CAPC installed in NUST lab is
  • Emerson
  • 1 Payload CAPC card
  • 2 Controller cards
  • Fan

Fig 15: Emersion CAPC
Red Back Router

• The Redback SmartEdge is a multipurpose smart router which may be configured to perform the different services:
  • It routes the incoming traffic towards DHCP for IP Assignment, provides interface to DNS and EMS.

• Redback router components include the following:
  • Up to two controller cards.
  • Up to twelve traffic cards.
  • Two power supplies.
  • Fan tray containing 6 fans.

Fig 17: Red Back Router
Element Management System (EMS)

- A web based interface that is used for maintenance of the all the network elements.

- The functions it provides are as follows:
  - Fault Management
    - Provides for real-time alarm views.
    - Alarm management.
    - Event logging.
    - Network element availability reporting and diagnostics.
  - Security Management
    - Employs Access Control and Security logging procedures.
Element Management System (EMS)

• Configuration Management
  • Software and configuration data distribution.
  • Configuration reports.
  • Auto discovery of network elements.

• Performance Management
  • Provides processing of real-time and historical statistics.
LOCAL MAINTENANCE TERMINAL (LMT)

• A web based interface that is used for maintenance of the specific network elements.

• LMT available are:
  1) Carrier Access Point Controller (CAPC) LMT
  2) Access Point (AP) LMT
CAPC LMT

• Assists the operator in management of the CAPC
• Provides following functions:
  • Alarm Logs
  • Event Reports
  • Link Management
  • Security
  • Activity Logging
  • Session Management
  • State Management
  • User Management
AP LMT

- Assist the operator in management of the AP
- Provides following functions:
  - View/Modify Ethernet Network Configuration.
  - View Active Alarms.
  - View Connected MSs.
  - View Daily Log File.
  - Add/Remove a New LMT User Account.
  - Reset Modem.
  - View Running Configuration.
  - Deploy New Configuration.
  - View/Modify IP Network Configuration.
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    - Other CSN Servers e.g. DNS, NTP etc
Authentication Accounting and Authorisation (AAA) Server

• AAA server provides the following core functions in WiMAX:
  – Authentication - involves verifying an identity associated with the device or service.
  – Authorisation - involves decision-making, related to granting or denying the request from the device or service.
  – Accounting - involves maintaining the record of resource consumption by the device or service and billing.
Other Core Servers in CSN

• Domain Name Server (DNS)
  • Resolve Fully Qualified Domain Name/IP address of the network elements.

• Dynamic Host Configuration Protocol (DHCP) server
  • The DHCP server within the CSN will be used to allocate IP addresses to SS.

• Network Time Protocol (NTP) Server
  • Signals which Network Elements use to synchronize their timing clocks with network time.
LTE Network Architecture

- **Mobility Management Entity (MME)**
  - Paging procedures
  - Retransmission of Data
  - Bearer activation/deactivation
  - Authentication of UE

- **User Equipment (UE)**
  - Header compression
  - Radio Resource Management
  - Admission Control
  - Scheduling
  - Enforcement of QoS

- **eNodeB (eNB)**
  - Forward user data packets
  - Inter eNB Handover
  - Anchor for mobility between LTE & other 3GPP technologies

- **Serving Gateway**
  - Paging procedures
  - Retransmission of Data
  - Bearer activation/deactivation
  - Authentication of UE

- **Packet Data Network Gateway (PDN GW)**
  - Policy enforcement
  - Packet filtering
  - Billing
  - Anchor for mobility between 3GPP and non-3GPP technologies

- **Internet**
Questions ?