Introduction to mobile WiMAX Radio Access Technology: PHY and MAC Architecture

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Outline

- What is mobile WiMAX?
- Salient features of mobile WiMAX
- IEEE 802.16 Reference Model
- Air-Interface Protocol Stack
- WiMAX Network Reference Model
- Review of mobile WiMAX Physical Layer
- Review of mobile WiMAX MAC Layer
- Performance of mobile WiMAX
- Next Generation of mobile WiMAX
- Back up
  - mobile WiMAX system profile feature set
What is mobile WiMAX?

- Mobile WiMAX is a rapidly growing broadband wireless access technology based on IEEE 802.16-2004 and IEEE 802.16e-2005 air-interface standards.
- The WiMAX Forum* is developing mobile WiMAX system profiles that define the mandatory and optional features of the IEEE standard that are necessary to build a mobile WiMAX compliant air interface which can be certified by the WiMAX Forum.
- mobile WiMAX is not the same as IEEE 802.16e-2005, rather a subset of the IEEE STD 802.16 standard features and functionalities.

* [http://www.wimaxforum.org](http://www.wimaxforum.org)
Salient Features of mobile WiMAX

- The mobile WiMAX air interface utilizes Orthogonal Frequency Division Multiple Access (OFDMA) as the radio access method for improved multipath performance in non-line-of-sight environments.

- **High Data Rates:** The use of multiple-input multiple-output (MIMO) antenna techniques along with flexible sub-channelization schemes, adaptive modulation and coding enable the mobile WiMAX technology to support peak downlink (DL) data rates up to 128 Mbps per sector and peak uplink (UL) data rates up to 56 Mbps per sector in 20 MHz bandwidth (DL 2x2 MIMO, UL 1x2 Virtual MIMO).

- **Quality of Service (QoS):** The fundamental premise of the IEEE 802.16 medium access control (MAC) architecture is QoS. It defines service flows which can be mapped to fine granular IP sessions or coarse differentiated-services code points to enable end-to-end IP based QoS. Additionally, sub-channelization and medium access protocol (MAP) based signaling schemes provide a flexible mechanism for optimal scheduling of broadcast and unicast traffic using space, frequency, and time physical resources over the air interface on a frame-by-frame basis.
Salient Features of mobile WiMAX

- **Scalability**: The mobile WiMAX technology utilizes scalable OFDMA (SOFTDMA) and has the capability to operate in scalable bandwidths from 1.25 to 20 MHz to comply with various spectrum allocations worldwide.

- **Security**: The mobile WiMAX incorporates the most advanced security features that are currently used in wireless access systems. These include Extensible Authentication Protocol (EAP) based authentication, Advanced Encryption Standard (AES) based authenticated encryption, and Cipher-based Message Authentication Code (CMAC) and Hashed Message Authentication Code (HMAC) based control message protection schemes.

- **Mobility**: The mobile WiMAX supports optimized handover schemes with latencies less than 50 ms to ensure real-time applications such as Voice over Internet Protocol (VoIP) are efficiently supported without service degradation. Flexible key management schemes assure that security is maintained during handover.
IEEE 802.16 Reference Model

- **Service specific convergence sublayer (CS)**
  - Mapping of external network data received through the CS SAP into MAC SDUs received by the MAC CPS through the MAC SAP
  - Classifying external network SDUs and associating them to MAC SFID and CID
  - Payload header suppression/compression (PHS)

- **MAC common part sublayer (MAC CPS)**
  - Core MAC functionality of system access (idle/sleep/active mode protocols)
  - Connection establishment and maintenance
    - **Basic connection** for transfer of time-critical MAC messages
    - **Primary management connection** for transfer of more delay tolerant MAC messages
    - **Secondary management connection** for transfer protocol messages such as DHCP
    - **Transport connections** for transfer of service (data, voice, etc.) traffic
  - Quality of Service (QoS)
  - Scheduling of users for both DL and UL
  - Control and signaling

- **Security sublayer**
  - Authentication (user authentication is part of core network services)
  - Secure key exchange and Encryption

- **Physical layer**
  - Physical layer protocol and functions
Air-Interface Protocol Stack

Network Functionalities and Services

Convergence Sub-Layer (ROHC)

Upper MAC Sub-Layer

ARQ
Handoff
Idle Mode Protocol

Sleep Mode Protocol
MBS
Session/Connection Management

RRM/RLC
QoS
Security

Lower MAC Sub-Layer

H-ARQ
Ranging (Access)
Scheduling

Framing, Control & Signaling
QoS
MBS

Network Functionalities and Services

Physical Layer

PHY Protocol (FEC Coding, Signal Mapping, Modulation, MIMO processing, etc.)

MAC/RLC

SAPs

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WiMAX Network Reference Model

- Reference Points
- Network Components Needed for Attachment to 3G Cellular Core Networks (New R2, R3, R4 must be defined)
- Air-interface
- Access Service Network (BS + Gateway)

Network Service Provider

Application Service Provider

Network Access Provider

Access Service Provider

Evolved RAN

GERAN

UTRAN

SGSN

GPRS Core

MME

S1

S2a

S2b

ePDG

WLAN Access NW

WLAN 3GPP IP Access

3GPP Anchor

SAE Anchor

Evolved Packet Core

PCRF

Rx+

Op. IP Serv. (IMS, PSS, etc...)

HSS

S5a

S5b

S3

S4

S6

S7

SGi

S1

S2a

S2b

S3

S4

S5a

S5b

S6

S7

SGi

S1

S2a

S2b

S3

S4

S5a

S5b

S6

S7

SGi
WiMAX Network IP-Based Architecture

User Terminals

- Mobile WiMAX Terminal
- Portable WiMAX Terminal
- Fixed WiMAX Terminal

Access Service Network

- Mobile WiMAX Base Station
- Access Service Network Gateway (ASN-GW)

Core Service Network

- Service Provider IP Based Core Networks
  - AAA Server
  - MIP HA
  - IMS Services
  - Billing Support Systems
  - Operation Support Systems

Network Interoperability Interfaces

Air Interface

Roaming Interface

COTS Components

WiMAX Components
Review of mobile WiMAX Physical Layer
The IEEE 802.16e-2005 air-interface supports both Time Division Duplexing (TDD) and Frequency Division Duplexing (FDD) modes; however, the initial release of mobile WiMAX profiles only includes the TDD mode of operation.

The TDD mode is preferred for the following reasons:

- It enables dynamic allocation of DL and UL resources to efficiently support asymmetric DL/UL traffic (adaptation of DL:UL ratio to DL/UL traffic).
- It ensures channel reciprocity for better support of link adaptation, MIMO and other closed-loop advanced antenna techniques such as transmit beam-forming.
- Unlike FDD, which requires a pair of channels, TDD only requires a single channel for both downlink and uplink providing greater flexibility for adaptation to varied global spectrum allocations.
- Transceiver designs for TDD implementations are less complex and therefore less expensive (restrictions in the number of DL/UL switching points).
OFDMA Concept

- In OFDMA multiple access is two dimensional (time and frequency)
- Multiple users use separate subchannels for multiple access
  - Improved capacity
  - Improved scheduling and QoS support
  - Reduced interference (no intra-cell interference)
  - Improved link margin (subchannelization gain)
- Flexible subchannelization
  - Pseudo-random permutation (PUSC) for frequency diversity, or
  - Contiguous assignment (AMC) to enable beamforming
- Scalable structure to support variable bandwidths
## OFDMA Numerology

<table>
<thead>
<tr>
<th>Transmission Bandwidth (MHz)</th>
<th>1.25</th>
<th>5</th>
<th>10</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sampling Frequency (MHz)</td>
<td>1.4</td>
<td>5.6</td>
<td>11.2</td>
<td>22.4</td>
</tr>
<tr>
<td>( f_s = \frac{8000 \cdot \text{BW}}{8000} )</td>
<td>( n = 28 / 25 )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FFT Size</td>
<td>128</td>
<td>512</td>
<td>1024</td>
<td>2048</td>
</tr>
<tr>
<td>Sub-Carrier Spacing (kHz)</td>
<td>10.94</td>
<td>10.94</td>
<td>10.94</td>
<td>10.94</td>
</tr>
<tr>
<td>( \text{Tu} ) (us)</td>
<td>91.4</td>
<td>91.4</td>
<td>91.4</td>
<td>91.4</td>
</tr>
</tbody>
</table>

### Cyclic Prefix (CP)

<table>
<thead>
<tr>
<th>Cyclic Prefix (CP)</th>
<th>( \text{Ts} ) (us)</th>
<th>Number of OFDM Symbols per Frame</th>
<th>Idle Time (us)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( T_g=1/4 \text{ Tu} )</td>
<td>91.4 + 22.85 = 114.25</td>
<td>43</td>
<td>87.25</td>
</tr>
<tr>
<td>( T_g=1/8 \text{ Tu} )</td>
<td>91.4 + 11.42 = 102.82</td>
<td>48</td>
<td>64.64</td>
</tr>
<tr>
<td>( T_g=1/16 \text{ Tu} )</td>
<td>91.4 + 5.71 = 97.11</td>
<td>51</td>
<td>47.39</td>
</tr>
<tr>
<td>( T_g=1/32 \text{ Tu} )</td>
<td>91.4 + 2.86 = 94.26</td>
<td>53</td>
<td>4.22</td>
</tr>
</tbody>
</table>

Frame Size = (Number of OFDM Symbols) * \( \text{Ts} \)

The idle time in FDD mode may be used for channel or noise measurements.
Subchannelization and Slots

- OFDMA symbol is made up of sub-carriers
  - Data sub-carriers
  - Pilot sub-carriers
  - Null sub-carriers – guard bands and DC sub-carrier
- Standard supports multiple schemes for dividing the frequency/time resources between users – call these subchannelization schemes (PUSC, AMC, FUSC, TUSC, etc.)
- Subchannelization schemes define slots/sub-channels
- Slot is the basic unit of allocation in the time-frequency grid
  - Slot is a (logical) n x m rectangle where
    - n is a number of sub-carriers and m is a number of contiguous symbols
  - Slot contains 48 data carriers for all subchannelization schemes, but their arrangement is different in different schemes
  - Number of pilot carriers in a slot is different for different subchannelization schemes
- The term “subchannel” has a confusing definition in the standard
  - Subchannel is defined as a grouping of sub-carriers
  - Subchannels really refer to the frequency dimension of slots
- The number of used sub-carriers over the entire spectrum is different for various permutation schemes.
Subchannelization Schemes

TILE in UL-PUSC Zone
Slot = 6 tiles over 3 symbols

CLUSTER in DL-PUSC Zone
Slot = 4 clusters over 2 symbols

BIN in DL/UL AMC Zone
slot = m bin x n symbols
m x n = 6

Dedicated Pilots

Data Sub-carriers

After assigning 83 common pilots, the remaining sub-carriers are divided into 48 groups of 16 sub-carriers. Slots are formed by taking one sub-carrier from each group.
Localized and Distributed Resource Allocation

Signal level for the subchannel
Loading gain
Average signal level for all channel
Subcarriers allocated to user #1

Subcarriers allocated to user #1

Subcarriers allocated to user #2

Combined OFDMA signal

Channel characteristics are different for each user
Adjacent subcarrier allocation (AMC)

Combined OFDMA signal

Some subcarriers fade more than the others, overall packet can be recovered with FEC
Distributed subcarrier allocation (FUSC, PUSC)
mobile WiMAX Frame Structure

- DL: Downlink
- UL: Uplink
- Bin: Binary
- TTG: Time To Group
- Tile: Tiling
- RTG: Return To Group

- Band 0
- Band 1
- Band 2
- Band 3

Preamble

- PUSC zone
- AMC zone
- UL control symbols
- Diversity zone
- AMC zone

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Zones in TDD Mode

- First zone in DL/UL subframe
  - DL PUSC is mandatory
  - UL PUSC is default, but O-PUSC can be located at the first zone in UL
- Zone switch IE in DL/UL-MAP
  - DL: symbol offset, zone length, permutation, PermBase, STC type AMC type
  - UL: symbol offset, zone length, permutation, PermBase, AMC type
FCH and DCD/UCD
System Configuration Information

- **Frame Control Header Contents**
  - **Used Subchannels bitmap**
    Maps the used subchannel in the segment
    Allocated subchannel are renumbered logically
  - **Ranging Change Indication**
  - **DL-Map Coding parameters**
    - Repetition Coding Indication (1,2,4,6)
    - Coding Indication CC and CTC (mandatory) and LDPC optional
    - **DL-MAP Length**
  - **Total 24 bits**

- **Fixed Location and Coding:**
  - First 4 slots of the segment
  - QPSK rate ½ with repetition coding of x4

- **DCD (Downlink Channel Descriptor)**
  - Downlink burst profile – CINR for each DIUC (MCS type), BS EIRP, Maximum RSS for initial ranging, TTG and RTG, H-ARQ ACK delay for DL burst, HO type and parameters, etc.

- **UCD (Uplink Channel Descriptor)**
  - Uplink burst profile – CINR for each UIUC (MCS type), Uplink center frequency, UL allocated subchannel bitmap, Ranging parameters, Band AMC parameters, H-ARQ ACK delay for UL burst, UL OLPC parameters, etc.
Medium Access Protocol (MAP)
Message-Based Control and Signaling

MAP Contains
- Information on DL/UL burst allocation
- Physical layer control message (IE: Information Element)

Normal MAP: DL-MAP & UL-MAP
- Management Messages (GMH and CRC)
- DL-MAP IEs and UL-MAP IEs
- Burst Profile (DIUC and UIUC)
Medium Access Protocol (MAP)
Message-Based Control and Signaling

Compressed MAP: Compressed DL-MAP & UL-MAP
- No GMH and one CRC
- DL-MAP IEs and UL-MAP IEs
- Burst Profile (DIUC and UIUC)
Normal MAP Extension for H-ARQ
- The following modes of H-ARQ are supported by the HARQ DL/UL MAP IE:
  - Chase combining H-ARQ for all FEC types (H-ARQ Chase Combining). In this mode the burst profile is indicated by a DIUC.
  - Incremental redundancy H-ARQ with CTC (H-ARQ IR). In this mode the burst profile is indicated by the parameters $N_{EP}$ (Encoded Packet Size), $N_{SCH}$ (Number of Allotted Subchannels).
  - Incremental redundancy H-ARQ for convolutional code (H-ARQ CC-IR)
Medium Access Protocol (MAP)  
Message-Based Control and Signaling

**DL/UL Sub-MAPs**
- Different modulation and channel coding with MAP
- HARQ for downlink and uplink
- Incremental Redundancy (IR) HARQ and Chase HARQ
- HARQ DL-MAP IEs and HARQ UL-MAP IEs
- $N_{EP}$ & $N_{SCH}$ / DIUC & UIUC
DL-MAP IE

- Optional CID
  - Number of CIDs included (0-255)
  - CIDs List

- Burst Allocation
  - OFDMA Symbol offset
  - Subchannel offset
  - Number of Subchannels
  - Number of OFDMA Symbols
  - Boosting (+6 to -9 dB)
  - Repetition Coding Indication (1/2/4/6)
UL-MAP Allocations

Constant Parts

CDMA BW Request / Ranging

PAPR / Safety

Burst #1

Burst #2 (Duration=30)

End of Map IE

UL-MAP Message

Basic Allocation = 1 Subchannel X 3 Symbols

GMH
Mgmt Msg Type
Uplink Ch. ID
UCD Count
Allocation Start

UIUC = 12
Rectangle Allocation:
OFDMA Symbol Offset
Subchannel Offset
No. OFDMA Symbols
No. Subchannels
Ranging method
PAPR reduction / Safety zone
End of Map
IE

CID
UIUC = 11
Duration
Repetition Coding Indication

CDMA BW Request / Ranging

UL Subframe

CID
UIUC (1-10 = Burst Profiles)
Duration
Repetition Coding Indication

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Interval Usage Codes

• DIUC (Downlink Interval Usage Code)
  – 0~12 DL Burst Profiles   MCS schemes used in the burst
  – 13 Gap/PAPR   PAPR and Safety zones
  – 14 Extended DIUC 2   Control IE
  – 15 Extended DIUC   Control IE

• UIUC (Uplink Interval Usage Code)
  – 0   Fast feedback channel  Zone for CQI etc.
  – 1~10 UL Burst Profiles   MCS schemes used in the burst
  – 11 Extended DIUC 2   Control IE
  – 12 CDMA ranging/BW   Ranging / BW request zone
  – 13 PAPR/Safety   PAPR and Safety zones
  – 14 CDMA allocation IE   for CDMA BW request
  – 15 Extended DIUC   Control IE
# Adaptive Modulation and Coding

<table>
<thead>
<tr>
<th></th>
<th>DL</th>
<th>UL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Modulation</strong></td>
<td>QPSK, 16QAM, 64QAM</td>
<td>QPSK, 16QAM, 64QAM (optional)</td>
</tr>
<tr>
<td><strong>Code Rate</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CC</strong></td>
<td>1/2, 2/3, 3/4, 5/6</td>
<td>1/2, 2/3, 5/6</td>
</tr>
<tr>
<td><strong>CTC</strong></td>
<td>1/2, 2/3, 3/4, 5/6</td>
<td>1/2, 2/3, 5/6</td>
</tr>
<tr>
<td><strong>Repetition</strong></td>
<td>x2, x4, x6</td>
<td>x2, x4, x6</td>
</tr>
</tbody>
</table>
MIMO Schemes

The mobile WiMAX air-interface supports a number of MIMO technologies

- **Beamforming (closed-loop):** The system uses multiple-antennas to transmit weighted signals to improve coverage and capacity of the system and reduce outage probability.

- **Space-Time Coding (STC; open-loop):** Transmit diversity techniques such as Alamouti scheme is supported to provide spatial diversity and to reduce fade margin.

- **Spatial Multiplexing (SM; open-loop):** To take advantage of higher peak rates and increased throughput. With spatial multiplexing, multiple streams are transmitted over multiple antennas. If the receiver also has multiple antennas, it can separate the different streams to achieve higher throughput compared to single antenna systems. With a 2x2 MIMO, SM approximately doubles the peak data rate by transmitting two data streams.
UL Collaborative MIMO (Virtual MIMO)

- Multiple mobile stations transmit simultaneously creating a “virtual” multi-antenna transmitter, resulting in increased network capacity.
- Mobile stations have one or two antennas, BS has multiple antennas.
- BS stores CSI from mobile stations and based on certain criteria; e.g., CQI chooses two or more mobile stations whose UL transmissions can be spatially multiplexed (using the same time-frequency resources).
Adaptive MIMO Switching (AMS)
AMS overcomes the deficiencies of STBC and SM and leads to an spectral efficiency very close to the ideal one at both low and high SNR regions (across the cell)
Ranging

- The process in which the MS acquires frequency, time and power adjustments, after which all MS transmissions are aligned with the UL sub-frame received by the BS
- Process is based on MS transmitting a signal and BS responding with required adjustments (close-loop)

**Power and Frequency Adjustments**

- Gain offset (Dynamic Range)
- Frequency offset (Orthogonality)

_Uplink OFDMA symbols as received by the BS_

Before ranging

After ranging
Ranging

- Ranging types
  - Initial ranging/Handoff ranging
  - Periodic ranging
  - BW request ranging

### Time Adjustment

<table>
<thead>
<tr>
<th>MS #1</th>
<th>R1</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS #2</td>
<td>R2 &gt; R1</td>
</tr>
<tr>
<td>MS #3</td>
<td>R3 &gt; R2</td>
</tr>
</tbody>
</table>

**Before Ranging**

- $T_1 = \frac{2R_1}{c}$
- $T_2 = \frac{2R_2}{c}$
- $T_3 = \frac{2R_3}{c}$
Frequency Reuse Schemes
Reuse One and Three with PUSC

Reuse 1x3x1

Reuse 1x3x3

F1 = 10MHz

S1 = SubCh (0-1)
S2 = SubCh (12-13)
S3 = SubCh (20-21)
Fractional Frequency Reuse (FFR)

- Support frequency reuse 1/3/1 near cell center and utilize frequency reuse 1/3/3 near cell edges
- No frequency planning
- Frequency reuse one at cell center to maximize spectral efficiency
- Higher reuse factor at cell edge to reduce interference
- Flexible reconfiguration

\[ F = F_1 + F_2 + F_3 \]
Review of mobile WiMAX MAC Layer
Generic MAC Header (GMH)

**Generic MAC Header Format**

- **Header Type**: `HT` = 0 (1)
- **Payload Length**: `LEN msb` (3)
- **CID msb**: (8)
- **CID lsb**: (8)
- **HCS**: (8)

**BW Request MAC Header Format**

- **Header Type**: `HT` = 1 (1)
- **Payload Length**: `BR MSB` (11)
- **CID MSB**: (8)
- **CID LSB**: (8)
- **HCS**: (8)

- **CRC Indicator**
- **Encryption Type**
- **Encrypted Key Sequence**
- **Payload Type**
- **BW Request Type**
- **Connection ID**
- **Header Check Sequence**
- **Encryption Control**
- **BW Request**
MAC PDU Construction

- Bandwidth Request PDU
  - BR Header
- Management PDU
  - MAC Header
  - Management Message Type
  - MAC Management Payload
- User PDU
  - MAC SDU
  - MAC SDU
  - MAC Header
  - Fragmentation Sub-header
  - MAC SDU f1
  - MAC Header
  - Fragmentation Sub-header
  - MAC SDU f2
- Aggregation
- Fragmentation
- Packing
  - MAC Header
  - Packing Sub-header
  - MAC SDU
  - Packing Sub-header
  - MAC SDU
# QoS–Data Service Types

<table>
<thead>
<tr>
<th>QoS Class</th>
<th>Applications</th>
<th>QoS Specifications</th>
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<tbody>
<tr>
<td>UGS</td>
<td>VoIP</td>
<td>Maximum sustained rate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maximum latency tolerance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jitter tolerance</td>
</tr>
<tr>
<td>rtPS</td>
<td>Streaming Audio, Video</td>
<td>Minimum Reserved Rate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maximum Sustained Rate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maximum Latency Tolerance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Traffic Priority</td>
</tr>
<tr>
<td>ErtPS</td>
<td>Voice with Activity Detection (VoIP)</td>
<td>Minimum Reserved Rate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maximum Sustained Rate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maximum Latency Tolerance</td>
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<td></td>
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<td>Jitter Tolerance</td>
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<td>nrtPS</td>
<td>FTP</td>
<td>Minimum Reserved Rate</td>
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<td></td>
<td>Maximum Sustained Rate</td>
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<tr>
<td></td>
<td></td>
<td>Traffic Priority</td>
</tr>
<tr>
<td>BE</td>
<td>Data Transfer, Web Browsing</td>
<td>Maximum Sustained Rate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Traffic Priority</td>
</tr>
</tbody>
</table>
QoS: Connection-Oriented MAC

- Define QoS parameter for each connection
- Dynamically establish QoS-enabled connections
- Associate packets to service flows
- Associate service flows with QoS logical connections
Handoff

- Handover Schemes
  - Optimized Hard Handover (OHHO)
  - Fast Base Station Switching (FBSS)
  - Macro Diversity Handover (MDHO)

- Handover Control
  - Mobile initiated
  - BS initiated
  - Network initiated

- Cell Selection
  - Neighbor Advertisements from Serving BS
  - Periodic intervals for scanning neighbor base stations

- Security for Handover
  - 3-way handshake for authentication key validation
  - TEK sharing for FBSS scheme
Idle Mode, Multicast/Broadcast, Paging

- MS uses special mode called “Idle Mode” to receive broadcast/multicast service without UL transmission
- MS associates to broadcast region formed by paging group
- DL traffic received but no UL transmission within broadcast region
- Cell selection may occur but no handover required (no idle mode HO support)
- MS can be paged for DL traffic alerting
- Paging controller in the network coordinates DL traffic and paging
- A SFN network and multi-BS combining is used for Multicast and Broadcast service.
Power Management

Frames received and MS states

- **Active**
  - MS Normal Tx or Rx
  - MS requests BS to enter sleep mode to save power.
  - Sleep mode ‘start frame’ is indicated.

- **Sleeps**
  - MS sleeps for integer # of frames called sleep interval.
  - No MS Tx or Rx during this interval.
  - Power saving classes supported provide flexible wake up methods.

- **Listens**
  - MS Listens for integer number of frames called listening interval.
  - Paging detected in this interval.
  - If Data traffic waiting on BS it is indicated.

Periodic listening Intervals

Periodic sleep Intervals
Network Entry and Connection Management

- Downlink Scan and Synchronization (Preamble, DL-MAP)
- Uplink Parameter Acquisition (UL-MAP)
- UL Ranging & Time Sync. (RNG-REQ/RSP)
- Basic Capability Negotiation (SBC-REQ/RSP)

- MS Authorization & Key Exchange (PKMv2)
- Registration with Serving BS (REG-REQ/RSP)

- Active DL/UL Data Transmission with Serving BS
- Neighbor Scanning /Handover

- IP Data Transport Connection Established
- Sleep Mode

- Security Traffic
- Non-Secured Traffic
- Secured Traffic
## Performance of mobile WiMAX

<table>
<thead>
<tr>
<th>User Peak Rate (Mbps)</th>
<th>DL/UL Ratio</th>
<th>1:0</th>
<th>3:1</th>
<th>2:1</th>
<th>3:2</th>
<th>1:1</th>
<th>0:1</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIMO (1x2)</td>
<td>DL</td>
<td>31.68</td>
<td>23.04</td>
<td>20.16</td>
<td>18.72</td>
<td>15.84</td>
<td>0</td>
</tr>
<tr>
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<td>DL</td>
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<td>46.08</td>
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For 10 MHz channel, 5 ms frame, PUSC sub-channel, 44 data OFDM symbols DL 64QAM 5/6 CTC x 1 and UL 16QAM CTC 3/4 x1
Next Generation of mobile WiMAX

New capabilities of Systems Beyond IMT-2000

Peak Useful Data Rate (Mb/s)

Mobility

High

Low

IMT-2000

Enhanced IMT-2000

3G Evolution mobile WiMAX

New Mobile Access 4G

Next Generation of mobile WiMAX

New Nomadic / Local Area Wireless Access
Back up
# mobile WiMAX MS Certification Profiles

<table>
<thead>
<tr>
<th>Band Class</th>
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<td>2.305-2.320 GHz</td>
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# mobile WiMAX MS
## Release 1 PHY Profile and Certification

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<tr>
<th>Release 1 PHY Profile</th>
<th>Wave 1*</th>
<th>Wave 2</th>
<th>Comments</th>
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<td><strong>DL Subcarrier Allocation</strong></td>
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<td>AMC 2x3</td>
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<td><strong>UL Subcarrier Allocation</strong></td>
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<td><strong>Ranging &amp; Bandwidth Request</strong></td>
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# mobile WiMAX MS
## Release 1 PHY Profile and Certification

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<td><strong>CINR Measurement</strong></td>
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<td><strong>MIMO (IO-MIMO for BS)</strong></td>
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