Requirements and Recommendations for WiMAX Forum™ Mobility Profiles

November 9, 2005

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1 Introduction and Scope

IEEE 802.16™ is an emerging suite of standards for Broadband Wireless Access (BWA). IEEE Std 802.16e, amendment to the IEEE 802.16 base specification, enables combined fixed and mobile operation in licensed frequency bands under 6 GHz. This combination of IEEE Std 802.16 and the 16e amendment, here forth referred to as IEEE 802.16-2004&E [Ref 1, 2], is designed as a high-throughput packet data network radio capable of supporting several classes of IP applications and services based on different usage/mobility and business models. To allow such a diverse combination of usage, mobility, and deployment models, the IEEE 802.16-2004&E air interface is designed with a high degree of flexibility and an extensive number of options. To ensure interoperability and certification of WiMAX Forum Certified™ products, system profiles and PICs need to be developed within the WiMAX Forum™. [1]

This document provides functional, performance, and operational requirements for a family of air interface profiles that optimize the system performance for mobile performance while supporting other usage scenarios.

The end-to-end Network Requirements for WiMAX networks are separately defined in "Recommendations and Requirements for Networks based on WiMAX Forum Certified™ Products" [Ref 5].

2 Definitions and Conventions

2.1 Conventions

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].[Ref 3]

[1] "WiMAX," "WiMAX Forum," "WiMAX Forum Certified," and "certified" are trademarks of the WiMAX Forum.

All clauses, except for Clause 1 and annexes are normative, unless they are explicitly indicated to be informative.

2.2 Definitions

2.2.1 Basic Mobility Profile Set:

The common set of Required Features that are part of all WiMAX profiles supporting mobility. The Basic Mobility Profile Set is not complete system profile as it does not include power and band class features. This set may be different for BS Profiles and MS Profiles.

2.2.2 Base Station (BS):

A generalized equipment set providing connectivity, management, and control of the subscriber station.

2.2.3 Base Station Cluster:

A collection of Base Stations (BSs) that are physically co-located and typically installed as multiple sectors.

NOTE—This definition is required since per the IEEE 802.16 definition each BS is a single sector with a single carrier, which is different from the definition of BS as used in context of cellular networks.

2.2.4 Certification Profile:

Certification Profile or Certification Parameters refer to a set of RF parameters including spectrum allocation, Channel Bandwidth, and Duplexing modes that must be implemented and supported in all equipments complying with the technology operating in a particular geographical region.

2.2.5 Channel Bandwidth:

The nominal signal bandwidth (BW) as defined in IEEE 802.16-2004&E, which is the spectrum occupied by each RF channel including the internal guard subcarriers and assuming no over-sampling.

2.2.6 Conditionally Certified Feature:

Optional Features in a profile that requires full specification of test procedures and PICS by the WiMAX Forum. WiMAX Forum™ Certification can be obtained without supporting the conditionally certified features; however, if a vendor indicates that the feature is supported, then it becomes part of the suite of tests required to obtain WiMAX Forum™ Certification.

2.2.7 Data Session Setup Time:

The total elapsed time between the first request by the MS (or by the BS) to setup a connection between peer MAC entities and the completion of such request.

2.2.8 Duplexing:

The mechanism of separating the uplink (UL) and downlink (DL) radio frequency (RF) transmissions in a wireless network. Most commonly used duplexing schemes are frequency division duplexing (FDD) and time division duplexing (TDD). In the case of TDD, the UL and DL transmission happen on the same RF channel at two different and non-overlapping intervals of time. In the case of FDD, the UL and DL transmission occur simultaneously over two different RF channels. Also, an FDD Base Station can support both full duplex FDD and half duplex FDD Subscriber Stations. HFDD subscriber stations transmit UL and receive DL at non-overlapping intervals of time but in different RF frequencies.

2.2.9 Delay Spread:

The scattering of signals due to multipath effects, causing multiple copies of the original signal to arrive at the receiver with variable time offsets. Delay spread is defined as the standard deviation of the time offsets of the various paths. This standard deviation may be calculated with weighting factors proportional to the multipath delay power profile.

2.2.10 Embedded Device:

Within this document, this refers to communications devices that will be incorporated into the designs of other electronic equipment.

2.2.11 Extended Mobility Profile:

A complete Mobility System Profile derived from the Basic Mobility Profile Set by including additional Optional Features as well as power and RF features, to meet specific spectrum, device, and deployment scenarios. The extended mobility profile may be implemented in combination with different certification profiles.

2.2.12 Frequency Reuse:

A description of the pattern of RF channel usage in a cellular network. RF channels are uniquely assigned to different cells or sectors in a Cluster (a group of BS Sites) and this allocation is repeated across adjacent clusters throughout the networks. The frequency reuse is indicated as (*c*, *n*, *s*) where *c* is the number of BS Sites per cluster, *n* is the number of unique RF channels needed for reuse, and *s* is the number of sectors per BS Site.

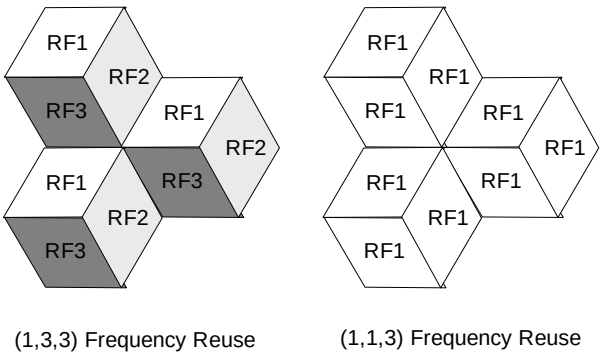

Figure 1—Illustration of (1,3,3) and (1,1,3) Frequency Reuse

For example,

- A (1, 1, 3) pattern implies a RF frequency usage pattern with each cluster comprising of one BS Site. Each BS Sites have three sectors and all sectors are assigned the same RF channel.
- A (1, 3, 3) pattern implies a RF frequency usage pattern with each cluster comprising of one BS Site. Each BS Site having three sectors where each of the three sectors is assigned a unique RF channel.

2.2.13 Full Mobility:

A usage scenario where the user device will continue with an operating network service session as it moves at high vehicular speeds within the network coverage area. Guaranteed handover performance between cells, sectors, and base stations provide this service continuity for all applications.

2.2.14 IEEE 802.16-2004&E:

Includes all IEEE Std 802.16-2004 [Ref 1] specifications as modified by the corrigenda and the IEEE 802.16e amendment [Ref 2].

2.2.15 IETF based L3+:

This refers to documents, published by the Internet Engineering Task Force (IETF), that describe standardized methods of handling IP based addressing, applications support, routing, security and authentication.

2.2.16 Link Budget:

The Link Budget is a measure of coverage efficiency of a system based on Physical and RF layer performance and hardware configuration and environmental factors. Usually, link budget is expressed in terms of the maximum allowable pathloss, which indicates the maximum tolerable loss between the transmitter and the receiver while maintaining certain error rate or data rate criteria, after accounting for various gains and losses at the receiver and the transmitter and other environmental losses such as fade margins, penetration loss, etc.

2.2.17 MAC Signaling Efficiency:

This is the average percentage of total radio resources in frame, symbols x sub-channels, available for Data Transmission, where averaging is performed over large number of frames, e.g., more than 100.

2.2.18 MAC Throughput:

The average rate, measured in bits/sec, at which bits are delivered by the MAC layer to higher layer. (Note that this is measured at the MAC SAP just below the CS Layer so that the effect of PHS is reflected in this definition).

2.2.19 Mobility:

The ability of the network to support terminals that can move with speeds up to 120 km/hr, and experience handovers between different sector, Base Stations Site, and compatible WiMAX networks.

2.2.20 Mobility Management:

Defined as any one of several of the various solutions for seamlessly supporting a mobile client that is operating in a wireless network and traveling between base stations, or possibly between different networks, The Mobility Management may be supported across different networks with the same or different access technologies.

2.2.21 Mobility Profile

In this document Mobility Profile means WiMAX Forum Mobility Profile.

2.2.22 OFDM:

Orthogonal Frequency Division Multiplexing is a modulation technique that divides the data stream into multiple streams and transmits them in parallel over multiple orthogonal frequency tones.

2.2.23 OFDMA:

Orthogonal Frequency Division Multiple Access is a variant of OFDM that uses the multiple orthogonal frequency tones that constitute an OFDM symbol to multiplex different user. Each user is allocated a disjoint set of frequency tones.

2.2.24 Optional Feature:

An air interface feature or attribute that WiMAX Certified equipment MAY support. Some of the Optional Features of IEEE Std 802.16e may be the Optional Features of WiMAX profile. WiMAX Forum™ Certification can be obtained without supporting the conditionally certified features; however, if a vendor indicates on his/her PICS that the feature is supported then it becomes part of the suite of tests required to obtain WiMAX Forum™ Certification.

2.2.25 Packet Error Rate:

The percentage erroneous packets (MAC-PDU) arriving at the receiver. A packet is deemed erroneous if the CRC check fails. If H-ARQ is used, then this is the percentage of post H-ARQ erroneous packets.

2.2.26 PHY burst rate:

The raw transmission rate at the physical layer, excluding the effect of HARQ and packet errors.

2.2.27 PHY Throughput:

The average rate measured in bits/sec at which bits are delivered by the PHY layer to the MAC layer.

2.2.28 Protocol Implementation Conformance Statement (PICS)

A Technical Specification that has to be filled by the WiMAX Forum member who wants to get his/her product certified. A PICS proforma document has been produced by the WiMAX Forum™ and the ETSI BRAN (Broadband Radio Access Network) with the help of the ETSI PTCC (Protocol and Testing Competence Center) in order to be used as a guide for the WiMAX Forum member. This technical specification states which capabilities from the base standard have been implemented in the WiMAX Forum member's product.

2.2.29 Quality of Service (QoS):

QoS refers to various techniques use to differentiate and expedite IP traffic flows.

2.2.30 RAN Transfer Delay:

Time from a request to transfer an IEEE 802.16e SDU from the MAC Service Access Point (SAP) on one end of the BS-MS radio link to its delivery at the corresponding SAP at the other end of the radio link. This delay excludes the scheduling delays, but includes signaling delay associated with traffic allocation. The RAN Transfer Delay is different for DL and UL for different types of service classes.

2.2.31 Realistically Loaded Cell (or Network):

A Network in which all of the BSs are offering the required throughput simultaneously, i.e., the network is uniformly loaded across all BSs.

2.2.32 Required Feature:

An air interface feature or attribute that equipment certified to a particular WiMAX Forum Certified profile must support. This includes all of the mandatory features from IEEE 802.16-2004&E. Additionally, any Optional Features from IEEE 802.16-2004&E that are mandatory in the particular profile also must be supported. Any Optional Feature in IEEE 802.16-2004&E indicated as not to be used, must be unavailable in the WiMAX Forum certified equipment.

2.2.33 Round-Trip MAC Latency:

The elapsed time between the event when a MAC-PDU is transmitted and the event when an acknowledgement (ACK/NACK) for that MAC-PDU is received. The acknowledgement (ACK/NACK) is sent by the peer MAC entity at the receiver.

2.2.34 Simple Mobility:

A usage scenario where the user device will continue with an operating network service session for non-real-time applications as it moves at vehicular speeds within the network coverage area. Handover between cells, sectors, and base stations provide this service continuity for all non-real-time applications.

2.2.35 Space-Time Processing:

This is a general term covering a variety of technologies that leverage the multiple propagation paths a signal may take to improve air-link robustness (diversity), increase capacity (multiplexing), or any combination thereof.

2.2.36 Spectral Efficiency:

An indicator of efficiency of the network to utilize the radio channels to transmit information bits between the BS and the SS in UL and DL. Here, the spectral efficiency is expressed in units of bits/sec/Hz/Sector and is measured as MAC Throughput offered by a single carrier averaged over an entire sector, divided by the total spectrum used for the underlying frequency reuse. Spectral Efficiency is computed in a realistically loaded multi-cellular network setting, with uniform users' distribution and subject to a minimum expected per user data rate.

2.2.37 System Gain:

The technology-dependent part of overall power link budget for each of DL and UL, excluding any deployment and/or RF design-dependent parameters or assumptions, e.g., Fade Margin, In-building/Body Losses, and Hardware Insertion Losses. The system gain does include interference margin imposed by the frequency reuse and loading as well as handover or other diversity gains. The Required System Gain may be separately derived for each of the uplink and downlink and for a given bearer service.

2.2.38 System Profile:

System Profile refers to a WiMAX Forum System profile, which lists sets of features to be used in typical implementation cases. Features specified in the standard as optional may be listed in a profile as "required" or "conditionally required." Profiles do not change "mandatory" status if specified in the standard itself. Any feature that is specified in the standard as optional and does not appear in certain profile is optional for the profile; thus absence of this feature in specific implementation does not affect conformance to the profile. A system profile consists of five components: a MAC profile, a PHY profile, a RF profile, a duplexing selection, and a power class.

2.2.39 Voice over Internet Protocol (VoIP):

VoIP refers, in general, to voice services that are delivered via Internet Protocol.

3 General Requirements and Recommendations for Mobility Profiles

3.1 General Requirements for Profiles

Based on the definition of Basic Mobility Profile Set the following requirements SHALL apply for both Release 1 and Release 2. Note that the Basic Mobility Profile Set is not a complete system profile as it does not include power profiles and band class specific RF requirements, e.g., Spectrum, BW, and Duplexing options.

- The Basic Mobility Profile Set SHALL include all the mandatory features of IEEE802.16-2004&E.
- The Basic Mobility Profile Set SHALL also include all Optional Features and parameters defined in IEEE802.16-2004&E, which are needed to support Simple Mobility and allow seamless migration to Full Mobility.
- The Basic Mobility Profile Set SHALL also include all Optional Features and parameters defined in IEEE802.16-2004&E, which are needed to meet the performance requirements for the Release 1 of WiMAX Forum Mobility Profiles.
- The Basic Mobility Profile Set SHALL also include all Optional Features and parameters defined in IEEE802.16-2004&E, which are needed to allow seamless migration to Full Mobility and meet the performance requirements for the Release 2 of WiMAX Forum Mobility Profiles.
- The Basic Mobility Profile Set SHALL be defined for the BS and the MS separately as some features may be tagged as required for the MS but Optional for the BS and vice versa..
- All Mobile WiMAX Forum Certified™ BSs SHALL support all features in the Basic Mobility Profile that apply to the BS.
- All Mobile WiMAX Forum Certified™ MSs SHALL support all features in the Basic Mobility Profile that apply to the MS.
- Support of Conditionally Certified Optional Features in a profile SHALL NOT impact the compliance with the Required Features of that profile.

All BSs and MSs that comply with WiMAX Forum Mobility Profiles while operating in the same band class SHALL be able to interoperate.

Figure 2 shows the relationship between IEEE 802.16-2004&E features and WiMAX system profiles. Some of the Optional Features of IEEE 802.16-2004&E may not be included in a WiMAX Forum Certified ™ mobility profile but may be implemented by some vendors.

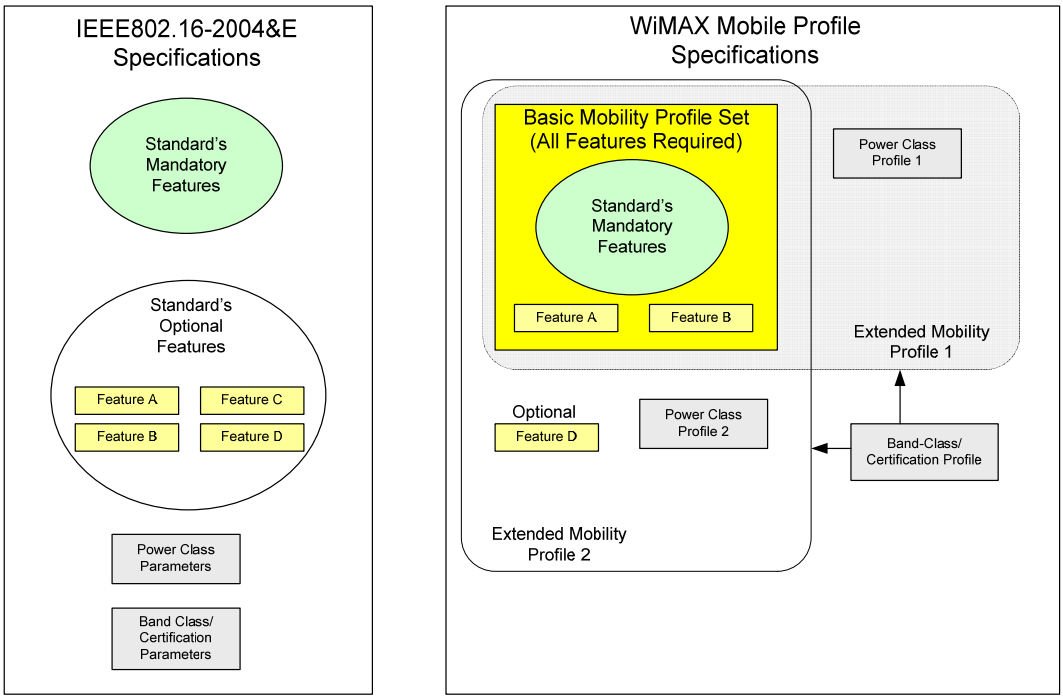

Figure 2—Illustration of Basic Mobility Profile Set and extended profiles

(An extended mobility profile may include some RF and Spectrum features that are not among certification parameters.)

3.2 Requirements for Evolution of Profiles: Forward and Backward Compatibility and Upgrades and Interoperability

The functionality and features needed to support Full Mobility may be realized in two releases, namely Release 1 and 2, to meet the time to market demand. In this case, the following time line SHALL apply.

The initial release of the WiMAX Forum Mobility Profile (Release 1) expected for publication in the first quarter of 2006 for market needs and SHALL support Simple Mobility..

The subsequent release of the WiMAX Forum Mobility Profile (Release 2) expected for publication in the fourth quarter of 2006 SHALL support Full Mobility while maintaining backward compatibility with Release 1.

CAUTION— Care must be taken to ensure compatibility across releases. Some Optional Features may become "Required" in a future release on a case-by-case basis.

- All of the Required Features identified in the profile SHALL be backward compatible.
- Required Features in previous releases SHALL be required in later releases.
- Any feature that is changed from optional to "Required" in a later release needs to be implemented in a backward-compatible mode.
    - Release 1 compliant MSs SHALL seamlessly operate in a BS complying with Release 2

  - Release 2 compliant MSs SHALL operate in a BS Complying with Release 1, but limited to Release 1 capabilities.
- Feature additions and enhancements in new releases SHALL be planned such that upgrades from one release to the next are not disruptive to existing services and operation.
- Release 1 profile selection for TDD SHALL consider support for dual mode TDD/FDD MS operation expected in Release 2.

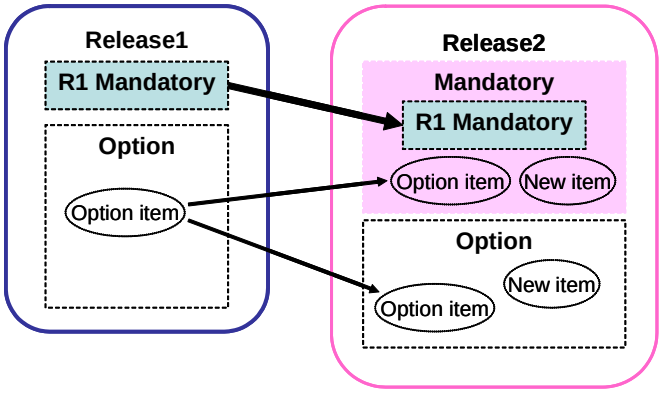

Figure 3—The Phased Approach for Mobility Profiles

4 RF and Spectrum Requirements

The common RF requirements are based on the location and size of the available spectrum allocations as well as range of target data rates offering. The RF and spectrum requirement in this section SHALL apply subject to regulatory requirements and limitations in each region. These requirements specify operating frequency range, channel band width(s), Channel Raster, and duplexing options, and provide for multiple bandwidth and band-class support. The following sections capture the normative requirements for RF and Spectrum, while Table 1.a and Table 1.b summarize some of those requirements for easy reference.

NOTE—The priorities for certification parameters for each band class and region is captured in separate document to be provided to CWG as SPWG input.

All requirements in this section are applicable to both BS and MS unless otherwise stated.

Table 1.a—Common Spectrum Requirements for TDD Systems

Band Class Index	Frequency Range	Recommended BWs (MHz) for Release 1	Additional BWs (MHz) for Release 2	Channel Raster (kHz)
1a	2.3-2.4	5, 8.75, 10	15, 20	250
2a	2.496-2.69	5 and 10, Second Priority: (8.75, 15, 20)	15, 20	250 (200KHz needed for Europe)
3a	3.3-3.8	3.5, 5, 7 or 10 Second Priority: 14 Third Priority: (6, 1.75)	15, 20	250

NOTE 1—Not all recommended bandwidths are required in a bandclass.

NOTE 2—A 3.8-4.2 GHz sub-band may be considered for future releases.

Table 1.b—Common Spectrum Requirements for FDD Systems

Band Class Index	Frequency Range	Recommended BW's (MHz) for Release 1	Additional BW's (MHz) for Release 2	Channel Raster (kHz)	FDD Duplexing Interval
1b	2.3-2.4	N/A	5, 10,	250	Adjustable Range TBD
2b	2.496-2.69	N/A	5, 10, 15, 20 (TBD)	250 (200 Needed for Europe)	Adjustable Range Shall Include 120 MHz
3b	3.3-3.8	N/A	5, 10, 15 and 20	250	Adjustable Range Shall Include 100 MHz

NOTE—A 3.8-4.2 GHz sub-band may be considered for future releases.

4.1 Common RF Requirements for all Band Classes

- The mobility profile SHALL specify a list of recommended center frequencies for each band class and region.
- To facilitate global roaming for TDD systems, all MS in all Band Classes SHALL support 5 MHz and 10 MHz beyond Release 1, if the regulatory rules permit..
- Support for dual mode TDD/FDD at the MS SHALL be a Conditionally Certified Feature.
- The FDD implementation at the MS supporting dual mode TDD/FDD SHOULD be based on HFDD to reduce the cost and complexity.
- Selection of profile features SHALL maximize applicability to both TDD and FDD modes of operation.

New Band classes MAY be added in the future. The common RF requirements in this sub-clause SHOULD apply to new band classes.

4.2 RF Requirement for Each Band Class

4.2.1 RF Requirements for TDD Systems

This section describes the RF requirements specific to each Band Class supported in TDD-based mobile WiMAX networks.

a) Mobility Profile for Band Class 1a:
- Frequency Range of 2.3–2.4 GHz SHALL be supported.
- Recommended RF channel sizes are 5, 8.75, and 10 MHz.
- In Release 1, all MSs SHOULD support 5, 8.75, and 10 MHz channel sizes.
- In Release 2: all MSs SHALL support 5, 8.75, and 10 MHz channel sizes
- In Release 2, 15 and 20 MHz channel sizes SHALL also be supported.
- The frequency raster SHALL allow 250 kHz increments in center frequency.

b) Mobility Profile for Band Class 2a:
- Frequency Range of 2.496–2.69 GHz SHALL be supported.
- Recommended RF channel sizes are 5, 10, and 15 (or 20) MHz.
- All MS SHALL support both 5 and 10 MHz channel sizes.
- In Release 2, 15, and 20 MHz channel sizes SHALL also be supported.
- The frequency raster SHALL allow 250 KHz increments in center frequency,
- When Band Class 2a becomes available in Europe the 200 kHz frequency raster is highly recommended based on expected regulatory requirements in that region.

c) Mobility Profile for Band Class 3a:
- Frequency Range of 3.3–3.8 GHz SHALL be supported.
- Recommended RF channel sizes are 3.5, 7, and 10 MHz. Other lower priority channel sizes for this band class include 14 MHz followed by 5, 5.5, 6 and 1.75 MHz.
- In Release 2, 15, and 20 MHz channel sizes SHALL also be supported.
- The frequency raster SHALL allow 250 kHz increments in center frequency.

4.2.2 RF Requirements For FDD Systems

This section describes the RF requirements specific to each Band Class supported in FDD-based mobile WiMAX networks.

NOTE: Support for FDD may depend on completion of modifications, if required, to 802.16e.

The following requirement for FDD SHALL apply to Release 2.

a) Mobility Profile for Band Class 1b:
- Frequency Range of 2.3–2.4GHz SHALL be supported.
- Recommended RF channel sizes are 5, 10, 15, and 20 MHz.
- The frequency raster SHALL allow 250 KHz increments in center frequency.
- The Frequency Duplexing interval SHALL be flexible with a range TBD.

b) Mobility Profile for Band Class 2b:

- Frequency Range of 2.496–2.69 GHz SHALL be supported.
- Recommended RF channel sizes are 5, 10, 15, and 20 MHz.
- The frequency raster SHALL allow 250 KHz increments in center frequency.
- When this band class is available in Europe the 200KHz channel raster is highly recommended based on expected regulatory requirements in that region
- The Frequency Duplexing interval SHALL be flexible with a range including 120 MHz.

c) Mobility Profile for Band Class 3b:

- Frequency Range of 3.3–3.8GHz SHALL be supported.
- Recommended RF channel sizes are 5, 10, 15, and 20 MHz.
- The frequency raster SHALL allow 250kHz increments in center frequency.
- The Frequency Duplexing interval SHALL be flexible with a range including 100MHz.

4.3 Multiband Support:

- The MSs MAY support multiple band classes.
- Multiband MSs SHALL be able to scan all the supported bands according to the preference set by the operators.

4.4 Radio Configuration and Frequency Reuse:

The Mobility Profile WiMAX Forum Mobility Profiles SHALL allow different frequency reuse and deployment configurations including the following:

- Different Frequency Reuse and Sectorization Scenarios including (1,3,3) and (1,1,3) reuse.

NOTE—(1,1,3) reuse also includes the segmented PUSC implementation for sub-channel reuse.

- Multiple-carrier BS Clusters with a mix of different channel bandwidths, as supported per band class.

5 MAC and PHY Functional Requirements

All requirements in this clause SHALL apply to both BS and MS unless otherwise stated.

Also, all requirements SHALL apply to Release 1 unless otherwise stated.

5.1 Air link QoS and Services Requirements

This section captures the requirements for QoS and Services support for mobility profiles.

5.1.1 Service Class and Applications Support

The Basic Mobility Profile set SHALL include all scheduling services and data delivery services defined in IEEE802.16-2004&E so that the following application types can be supported efficiently:

- Real-Time Applications, One-way Streaming, and Conversational Applications, e.g., Audio/Video Streaming, Video Telephony/Conferencing, Interactive Gaming.
- Non-Real-Time Applications, e.g., Web Browsing, FTP, Email, Instant Messaging.

All the capabilities needed to efficiently support VoIP are required at the MS and at the BS.

- When VoIP is supported the system SHALL use all those features defined in IEEE802.16-2004&E that are needed to ensure the quality of service and capacity for VoIP services.
- When VoIP is supported, specifically silence suppression and header compression and suppression SHOULD be supported.

5.1.2 Multicast and Broadcast Services Support

- In Release 1, all BSs and MSs SHOULD support the Multicast and Broadcast Services (MBS) feature. Also in Release 1, both single BS transmission and multi-BS simulcast transmission SHOULD be supported by the mobility profiles.
- In Release 2 all BSs and MSs SHALL support the Multicast and Broadcast Services (MBS) feature. Also in Release 2, both single BS transmission and multi-BS simulcast transmission SHALL be supported by the mobility profiles.

5.1.3 QoS Control

- The Basic Mobility Profile Set SHALL include all features and parameters needed for applications level QoS differentiation. Such differentiation SHALL apply to different applications and packet flows from the same IP address.
- The Basic Mobility Profile Set SHALL include all features and parameters needed for user-level QoS and Priority differentiation.

5.2 Power Saving, Idle Mode, and Paging Requirements

- The Basic Mobility Profile Set SHALL optimize power saving capabilities for all scheduling services and data delivery services, as enabled by any combination of Sleep and Idle Modes.
- The Basic Mobility Profile Set SHALL include paging capability for all devices.
- The parameters associated with Sleep and Idle modes and Paging SHALL be defined and adjustable over wide ranges to support the needs of different device types and usage models.

5.3 Security Requirements

The WiMAX Forum Mobility Profiles SHALL use security options defined in the IEEE 802.16e draft to meet the following general requirements:

Threat Classes:

The basic assumptions that apply to all security threat classes below include the wide availability of commodity SS/MSs BS systems and components, and the wide availability of knowledge on protocols, security measures, and tools.

- ***Theft of Service:*** Acquisition of network connectivity and other services without proper authorization and without being detected real-time or in auditing.
- ***Privacy Compromise:*** Access to user traffic over wireless links without proper authorization, in real time or via offline analysis.
- ***Man in the Middle (MitM) attack:*** Impersonation of the BS to the Subscriber, or two-way impersonation between the BS and the Subscriber. Although MitM is more of an attack method than a threat, it is listed here for clarity in later sections.

- ***Protocol Denial of Service (DoS):*** Disruption or degradation of correct protocol operation or exhaustion of system resources by injection, shaping, dropping, shuffling or modification of management traffic. Protocol DoS attacks include, for example, water torture" attacks which force the reception and decoding of unnecessary packets to run down system resources, battery power, etc.
- ***Device integrity and compliance compromise:*** Change or violation of device compliance with a certified profile and supported extensions without being detected while or after accessing legitimate network services.

The Mobility Profile WiMAX Forum Mobility Profiles SHALL resist against and/or detect all of the above classes of threats.

Device Authorization:

- The Mobility Profile WiMAX Forum Mobility Profiles SHALL provide device authorization that provides assurance (via an 802.16e x.509 device certificate) that the device has been manufactured by a specific recognized WiMAX vendor. The 802.16e x.509 device certificate SHALL be unique to each MS.

Mobility Profile WiMAX Forum Mobility Profiles:

- In addition to the X.509 device certificate, the MS MAY have other device credentials installed during provisioning for use in network entry. The additional credentials, if installed, SHALL be suitable for PKMv2 secure EAP method satisfying the requirements in IETF RFC 3748 and the mandatory criteria listed in section 2.2 of RFC 4017. [Ref 4, 6]

- The method used by the EAP server SHALL perform mutual authentication in compliance with the PKMv2 specifications. PKMv1 SHALL NOT be supported. EAP methods satisfying the requirements of IETF RFC 3748 and the mandatory criteria listed in section 2.2 of RFC 4017 and PKMv2 SHALL be used.

Network Entry of a Provisioned MS:

- After a device has been provisioned Device and User credentials it SHALL use the provisioned credentials on all subsequent network entries. The credentials SHALL use the EAP-in-EAP method as outlined in the 802.16e draft 10. The EAP-in-EAP method allows for different AAA servers for Device and User authentication allowing flexibility for various business models and roaming agreements. The credentials used SHALL allow key exchange within the authenticator domain and expedited handover in the mobility domain (same AK zone).

Encryption of the Air Link bearer traffic and messages:

- The WiMAX Network SHALL allow CCM-Mode 128-bit AES, AES Key Wrap with 128-bit key to be enabled on any service flow as requested by the MS or BS.. For MBS service the WiMAX Network SHALL allow MBS CTR mode 128 bits AES, no data authentication, AES Key Wrap with 128-bit key to be enabled on any service flow as requested by the MS, or BS SHALL be supported. This means that BS and MSS must support at least the AES methods available in P802.16e so that encryption may be invoked on any or all service flows. CMAC SHOULD be used for control messages.

5.4 Requirement for MAC Convergence Sublayer

- BS and MS SHALL support at least one Convergence Sublayer (CS) [Ref. 1, 2] instance at a time. A BS MAY simultaneously support multiple instances of CSs. Irrespective of the number of CSs supported, at least one of supported CSs at the BS and MS SHALL support the following requirements:
  - All BS SHALL support single host devices.
  - All BS SHALL support multi host devices.
  - Multi-host MSs SHALL support one or more of the following media types on a user facing interface:
    - IEEE 802.3 Ethernet with and without IEEE 802.1Q VLAN tags (See Note 1).
    - IEEE 802.11 With or without a Mobile IP stack on hosts connecting to the gateway.
    - IEEE 802.15 with the ability to manage connectivity to the MS on the device.
  - The hosts behind the multi-host MS SHALL be manageable from the WiMAX network as an option.
  - The hosts behind the multi-host MS SHALL be configurable to authenticate to the network.
  - The MS SHALL be capable of mobile operation even if the form factor favors fixed operation. An example would be a 110 Volt device with Ethernet interface.
  - Nothing in the selected sublayer SHALL impede handover to or from WiMAX/802.11/3G.
  - The Basic Mobility Profile Set, for both MS and BS, SHALL support both IPv4 and IPv6.
  - The CS selected SHOULD conserve airlink resources while supporting all of the requirements.
  - The Basic Mobility Profile Set SHALL support header suppression and compression to maximize throughput efficiency.
  - The header compression selected SHALL reduce the compression-related information feedback across the airlink.
  - The choice of header suppression and compression SHALL support traffic which is forward-link only including broadcast/multicast traffic.

NOTE 1—Support for Ethernet with and without IEEE 802.1Q VLAN is meant to imply the use of Ethernet and IEEE 802.1Q VLAN as a foundation for offering services. These services could typically use IP on top of Ethernet with IEEE 802.1Q VLAN tags.

The above requirements should be interpreted as neither requiring nor prohibiting the instantiation of multiple CS types in a MS at a given instance.

The above requirements should be interpreted as neither requiring nor prohibiting dynamic switching between CS types.

The above requirements should be interpreted as neither requiring nor prohibiting a MS from performing a handover, which involves an instantiation of an additional CS-type that is not already being used before handover.

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5.5 Air Interface Functional Requirement for L2 Handover

- The WiMAX Forum Mobile Release 1 Profile Set SHALL include all features and parameters needed to support QoS during handover for all supported applications at Simple Mobility. The

WiMAX Forum Mobile Release 2 Profile Set SHALL include all features and parameters needed to support QoS during handover for all supported applications at Full Mobility.

- The Basic Mobility Profile Set SHALL include all features and parameters needed to maintain radio link security during the handover process.
- The system SHALL support Handover between different RF channels of the same or different bandwidths.

Note that the performance requirements for handover are captured in the performance requirement section (Section 6.9).

5.6 Diversity and Multiple Antenna Support

For Release 1:

- The MS SHALL support minimum of two branch receive antenna diversity.
- The BS SHALL support minimum of two branch receive and transmit antenna diversity.
- Advanced antenna and/or MIMO based features MAY be supported.

NOTE— Such techniques may be needed to meet or exceed the system and link level performance requirements.

For Release 2:

- Advanced Antenna and MIMO based features SHALL be used to meet or exceed the system and link level performance requirements.

NOTE—Such techniques are expected to be needed to meet or exceed the system and link level performance requirements.

6 System Performance Requirements for TDD Systems

This section provides the WiMAX airlink performance requirements as they relate to PHY and MAC design. Note that

- The requirements listed are based on business and technical considerations to ensure that WiMAX offers the required competitive performance with respect to relevant alternative technologies and their evolution.
- The performance requirements and targets are not meant to be part of a certification test.
- The details in this section are intended to specify a common reference point for discussion of solutions that can address the requirements. While some of the key assumptions are captured in this document, the complete set of parameters and assumptions needed to select profile features are expected to be developed by the respective technical working groups within WiMAX Forum.
- It is NOT the intent of this (stage 1 requirements) document to:
  - Select advanced features that enable the performance targets to be met; nor
  - Arrive at a precise technical analysis; as that is typically done by simulation
    - (Please see requirement for demonstration of performance, below.)
- The Requirements are divided into Release 1 and Release 2, based on the phased approach outlined in Section 3.2:
  - The Release 2 requirements are expected to reflect improved performance that can be achieved as technology matures
  - Any numbers provided here for Release 2 are preliminary estimates and are subject to change upon further study.
- Throughput numbers are based on full buffer traffic model.

Respondent working groups of WiMAX SHALL provide verifiable demonstration of the degree of conformance to those performance requirements in this section that are qualified with a SHOULD, which the specified WiMAX Forum profiles are capable of providing. Substantial performance improvements that can be achieved using specific Optional Features under consideration in the WiMAX Forum as supported by IEEE standards, such as MIMO, SHALL be separately quantified.

6.1 Common Assumptions

The following assumptions SHALL apply to all requirements related to throughput/capacity and latency performance:

NOTE—These assumptions do not imply any recommendations or preference for profiles, and are stated mainly to provide a common framework for performance evaluation.

- Uniform geographic distribution of MSs in the network.
- Fading Channel with Mixed Mobility as detailed in Annex A.
- TDD Frame Structure with 2 to 1 ratio between DL and UL transmission time.
- Three-sector BS Cluster configuration with realistic (e.g., 70 degrees) beamwidth as per the following example equation

$$A(\theta) = -\min\left[12\left(\frac{\theta}{\theta_{3dB}}\right)^2, A_m\right] \quad \text{where } \theta_{3dB} = 70\,\text{degrees, 2 Sided Beam}$$

$$A_m = 18\text{dB}$$

- Realistic System load, such that each BS and its neighbors simultaneously offer the same level of throughput.
- All Latency numbers SHALL be met at 90th percentile under lightly loaded conditions in which scheduling delay is negligible and all messages are assumed to be received with one transmission
- All throughput figures refer to the MAC Layer Throughput unless otherwise states.
- All throughput figures SHALL be met at 90th percentile

  NOTE— At least 90% of base stations in the system shall meet or exceed the sector throughput requirement. At least 90% of mobile stations in the system shall meet or exceed the user throughput requirement.

- All performance figures are based on using two antennas at the MS and two antennas at the BS.
- Frame formation
  a. All BSs have same frame length
  b. All BSs have same DL/UL ratios (TDD)
  c. All BSs are frame time synchronized (frames start simultaneously)
- Frequency
  a. All BSs are frequency synchronized (i.e., same clock reference, all carrier frequencies are derived from same base frequency).
- MS Operating modes - MS may operates in Full Power Mode (FPM) or Power Save Mode (PSM)
- Network topology advertisement - Each BS will be provided the list of neighbor BSs with required parameters

Assumptions for VoIP are as follows:

- A variable rate vocoder, e.g., EVRC or AMR, with full rate of about 8 kbps is in place
- Voice activity factor of 40%.

NOTE—The requirements for coverage efficiency are captured in terms of, previously defined System Gain, so that they do not include deployment specific assumptions such as fade margin and coverage reliability.

6.2 Requirement for System Capacity and Spectral Efficiency

6.2.1 Sector Throughput Requirements (DL/UL)

Table 2 shows the spectral efficiency requirements for releases 1 and 2 for two different frequency reuse scenarios.

Table 2— Spectral Efficiency Requirements for Release 1 and Release 2

Frequency Reuse	Spectral Efficiency at Sector (bits/sec/Hz) for Release 1		Spectral Efficiency at Sector (bits/sec/Hz) for Release 2	
	Downlink	Uplink	Downlink	Uplink
(1,1,3)	1	0.5	2	1
(1,3,3)	0.67	0.33	1.33	0.67

- The average sector throughput and spectral efficiency requirements SHOULD be met while ensuring that at least 90% of the users in each sector exceed the minimum user throughput. The minimum user throughput for each case SHOULD be consistent with the required data rate specified in the System Gain requirements sub-clause.
- For each channel size the effective average sector throughput requirements SHALL be derived by multiplying the required spectrum efficiency by the spectrum utilized for the reuse.

  For example:

  In Release 1 and with (1,1,3) reuse, the mobility profile for 10MHz channel the average sector throughput SHOULD be (1 x 10) = 10Mbps in the downlink and (0.5 x 10) = 5 Mbps in the uplink.

  In Release 1 with (1,3,3) reuse, the mobility profile for 10MHz channel the average sector throughput SHOULD be (0.67 x 3x 10) = 20 Mbps in the downlink and (0.33 x 3 x 10) = 10Mbps in the uplink.

6.2.2 Average User Throughput Requirement (DL/UL)

For (1,1,3) reuse:

The DL user throughput, averaged over a cell area assuming a single user in the target cell and Realistically Loaded neighbor cells and Fading Channel with Mixed Mobility:

- SHOULD be higher than 0.2 bps/Hz times the RF channel size for Release 1.
- SHOULD be higher than 0.5 bps/Hz times the RF channel size for Release 2.

The UL user throughput, averaged over a cell area assuming a single user in target cell and Realistically Loaded neighbor cells under Fading and Mixed Mobility:

- SHOULD be higher than 0.1 bps/Hz times the RF channel size for Release 1.
- SHOULD be higher than 0.25 bps/Hz times the RF channel size for Release 2.

For (1,3,3) reuse:

The DL user throughput, averaged over a cell area assuming a single user in the target cell and Realistically Loaded neighbor cells and Fading Channel with Mixed Mobility:

- SHOULD be higher than 0.4 bps/Hz times the RF channel size for Release 1.

- SHOULD be higher than 1.0 bps/Hz times the RF channel size for Release 2.

The UL user throughput, averaged over a cell area assuming a single user in target cell and Realistically Loaded neighbor cells under Fading and Mixed Mobility:

- SHOULD be higher than 0.2 bps/Hz times the RF channel size for Release 1.
- SHOULD be higher than 0.5 bps/Hz times the RF channel size for Release 2.

6.2.3 Throughput for MBS

- In Release 1: With maximum DL frame allocation, the achievable MBS throughput SHOULD be higher than 0.5 bps/Hz times the RF channel size, with 95% availability.
- In Release 2: With maximum DL frame allocation, the achievable MBS throughput SHOULD be higher than 1 bps/Hz times the RF channel size, with 95% availability.

6.3 VoIP Capacity

- For Release 1: The WiMAX Mobility Profile for TDD System SHOULD support 25 simultaneous VoIP calls per MHz of channel bandwidth at a VoIP packet drop rate of less than 1% where VoIP packets with more than 250msec mouth-to-ear latency are considered dropped. The codecs selected for this capacity measurement SHALL be of a type designed and selected for cellular operation.

6.4 Requirement for System Gain and Coverage Efficiency

The System Gain SHALL include the effect of Power Amplifier (PA) power and Antenna Gains as well as receiver sensitivities for a given data rate at BS and MS. The System Gain SHALL also include other technology specific factors such as handover and diversity gains as well as interference margin associated with realistic loading assuming frequency reuse of (1,1,3). SNR requirements SHALL be based on Pedestrian B model. Note that the System Gain as defined and used in this document does not include shadow fade margin and in-building/body loss.

Table 3 and Table 4**Error! Reference source not found.** show Link Budget examples for System Gain requirements of 160 dB, in the downlink (DL) and uplink (UL), respectively. The numbers in the table show the key assumed (but not necessarily recommended) parameters that are not related to the technology and profile so that requirements specific to profiles can be extracted and referenced consistently.

Table 3—Link Budget (DL) Example for System Gain Requirements

	Parameter	Value	Unit	Formula
A1	Maximum PA Power (Note 4)		dBm	
A2	PA Backoff		dB	
A3	Tx Antenna Gain	18.00	dBi	
A4	Cable/Transmitter Loss	3.00	dB	
A5	**EIRP**		**dBm**	**A1+A3-A2-A4**
A6	Channel Bandwidth		MHz	
A7	**Receiver Noise Level**		**dBm**	**$-174+10\log_{10}(A6*1e6)$**
A8	SS Receiver Noise Figure	8.00	dB	
A9	Required Front End SNR (Note 3)		dB	
A9.1	AAS Diversity Gain		dB	MIMO/Beamforming Gain
A10	Rx Antenna Gain	.00	dB	
A11	Interference Margin		dB	
A12	Hand-Over Gain (Note 1)		dB	
A13	Sub-Channelization Gain (Note 2)		dB	
A14	**Rx Sensitivity**		**dBm**	**A7+A8+A11+A9-A9.1-A10-A12-A13**
A15	**System Gain**	**160.0**	**dB**	**A5 - A14**
A16	Shadow Fading Margin	10.00	dB	
A17	In Building Penetration Loss	10.00	dB	
A18	**Effective Path Loss**	**140.0**		**A15 - A16 - A17**

This color implies this number is required by SPWG

This color implies this number is implementation specific

This color implies this number is calculated

NOTE 1: Handover Gain is used to model macro-diversity gain.

NOTE 2: Sub-Channelization Gain in the DL is to be used with PUSC and segmentation

NOTE 3: The SNR is the static SNR (signal power/noise + interference power) required for a given data rate for Pedestrian B channel model with the assumed modulation and coding scheme and the assumed implementation loss.

NOTE 4: Power per antenna

Table 4—Link Budget (RL) Example for System Gain Requirements

	Parameter	Value	Unit	Formula
A5	**EIRP**	**24.00**	**dBm**	**Assumes 0 dBi SS antenna gain**
A6	Channel Bandwidth		MHz	
A7	**Receiver Noise Level**		**dBm**	**$-174+10\log_{10}(A6*1e6)$**
A8	BS Receiver Noise Figure	4.00	dB	
A9	Required Front End SNR (Note 1)		dB	
A9.1	AAS Diversity Gain		dB	MIMO/Beamforming Gain
A10	Rx Antenna Gain	18.00	dB	
A11	Interference Margin		dB	
A12	Handover Gain (Note 2)		dB	
A13	Sub-Channelization Gain		dB	
A14	**Rx Sensitivity**		**dBm**	**A7+A8+A11+A9-A9.1-A10-A12-A13**
A15	**System Gain**	**160.00**	**dB**	**A5 - A14**
A16	Shadow Fading Margin	10.00	dB	
A17	In Building Penetration Loss	10.00	dB	
A18	**Effective Path Loss**	**140.00**		**A15 - A16 - A17**

This color implies this number is required by SPWG

This color implies this number is implementation specific

This color implies this number is calculated

NOTE 1: The SNR is the static SNR (signal power/noise + interference power) required for a given data rate for Pedestrian B channel model with the assumed modulation and coding scheme and the assumed implementation loss

NOTE 2: Handover Gain is used to model macro-diversity gain.

- For Release 1, the system SHALL allow a system Gain of 160 dB under Realistically Loaded neighbors for the following cell edge data rate:
    a) R = 0.1 bps/Hz times the channel size in the downlink
    b) R = 0.05 bps/Hz times the channel size in the uplink.
- For Release 2, the system SHALL allow a system Gain of 160 dB under Realistically Loaded neighbors for the following cell edge data rate:
    c) R = 0.2 bps/Hz times the channel size in the downlink
    d) R = 0.1 bps/Hz times the channel size in the uplink.

6.5 Requirements for Maximum Delay Spread

Considering a Rayleigh fading channel and a cell size up to 10 km, the air interface SHALL support up to 10 usec maximum delay spread caused by multipath. This value is a measure of systems tolerance to multipath and sets a limit on the maximum range.

6.6 Airlink Data Path Latency Performance

One Way Data Path Latencies	Limits to which WiMAX Mobility Profile SHALL conform
RAN Transfer Delay	DL < 20 msec UL < 20 msec for Real Time Traffic UL < 40 msec for Best Effort
RAN Transfer Mean Delay Variation (Jitter) (for realtime application such as VoIP or video streaming)	< 20 msec (e.g., +/- 10msec) in a system operating at 70% of its maximum throughput capacity

6.7 Airlink Roundtrip Latency

- The Roundtrip MAC Latency, measured at the edge of the radio access network, SHALL be less than 55 msec, assuming that the MS is in the active mode.
- The Round Trip Ping Latency, measured at the edge of the radio access network, using standard MS initiated 32 byte IP packets SHALL be less than 60 msec, assuming that the MS is in the active mode and that the Connection Identifier (CID) [Ref 1, 2] has already been allocated.

6.8 Airlink Signaling Latency Performance

- The E2E data session set up latency from a non-active originating MS to another non-active MS SHALL be 1 sec or less. The Airlink portion of this latency is to be jointly determined by WiMAX Forum working groups.

6.9 L2 Handover Latency

In Release 1:

- The average packet loss during the hand over duration, i.e., between the BS/MS-initiated Handover Request message and the resumption of data transmission from the target BS, SHALL be less than 1%.

- The data path disruption time during handover between two carriers of the same bandwidth SHALL be less than 50 msec. This requirement originates from desire to provide competitive performance.

In Release 2**:**

- The profile SHALL be optimized to improve robustness and reduce handover latency to ensure QoS support for all real time applications under mobility speeds of up to 120km/h.

7 System Performance Requirements for FDD Systems

This section provides the WiMAX airlink performance requirements for FDD systems as they relate to PHY and MAC design. These requirements need to be met to ensure WiMAX's competitive advantage compared with other alternative technologies. The requirements in this section SHALL apply to Release 2.

- The performance requirements for FDD systems SHALL be the same as for the corresponding TDD systems, with comparable channel sizes and PHY and MAC features.
- For FDD system the spectral efficiency and throughput requirements SHALL be normalized to the total Bandwidth used in the downlink and uplink.

Annex A

(Informative)

Fading and Mobility Channel Models

This annex provides recommendations for fading, mobility, and path models to be used for evaluation of different solution and options for WiMAX mobility profiles.

A.1 Channel Models

This annex describes the channel models expected to be part of a unified framework for evaluating the performance of WiMAX Forum Mobile Profiles Appropriate delay spread, Doppler spread, and spatial characteristics that are typical for the licensed bands below 6GHz are captured in the models.

The channel delay profiles comply with the standardized ITU SISO models [Ref 6]. Proposed mobility profiles should be evaluated and compared based on the channel model methodologies described in this document or those adopted by 3GPP/3GPP2 This facilitates a consistent reference for comparison among different proposals and with documented performance results of existing systems using the ITU models.

Table 5—Fading and Mobility Channel Model

Power Delay Profile		**Pedestrian-A**		**Vehicular-A**		**Pedestrian-B**	
Number of Paths		4		6		6	
Power of the each path (dB)	Path Delay (ns)	0, -9.7, -19, -23	0, 110, 190, 410	0,-1, -9,-10,-15,-20	0, 300, 700, 110, 1700, 2500	0, -1, -5, -8, -7.8, -24	0, 200, 800, 1200, 2300, 3700
Speed (km/h)		<=3		60<Speed<=120		<=3	

In Table , “Path Delays” refer to the RMS values of the path delays. Note that the delay profile of a channel is continuous, but for simulation purposes, the rms values are chosen. Also, “Power Profiles” refer to the power (variance) of each path relative to the first path.

A stationary channel model similar to Pedestrian A and B have been considered, where the mobile is stationary or moving at very low speed (portable), and the models could be used with Rician (LOS) components. The simulation description is in the context of a downlink transmission; however the methodology described here can be applied to the uplink as well.

The performance metrics such as data throughputs should be obtained from system level simulation models consisting of multiple cells/sectors, BSs, and MSs (at least two tiers of BSs), as opposed to link level

simulations where only a single BS transmitting to a single MS is considered. During one simulation run, the channel undergoes fast fading due to frequency selectivity and Doppler Fading according to the speed of MSs.

When using multiple antennas, the performance metrics should be adjusted to the situation where there is 50% spatial correlation among the channels constituting the link between each pair of Tx/Rx antennas.

Note that the model outlined in this annex is a proposed framework for the channel models to be used as a test bed for evaluating the performance of different features and profiles. The models are similar to those used in 3GPP/3GPP2 with different parameters. As long as it is consistent with the models described in this section, the 3GPP/3GPP2 channel model may be used [Ref 7,8].

A.2 Model Mixtures

In order to apply the requirements to a realistic modeling of the system, several MSs in random locations in a cell are assumed, while MSs randomly choose the above mentioned channel and mobility speeds, based on the following format:

- 25% of the user population in stationary environment with AWGN channel model.
- 25% of the user population in pedestrian environment with 3Km/h speed, and Ped A channel model.
- 15% of the user population in pedestrian environment with 3Km/h speed using Ped B channel model
- 20% of the user population using Vehicular A channel model with a speed of 60Km/h.
- 15% of the user population using Vehicular A channel model with a speed of 120Km/h.

A.3 Path Loss Models

The channel models described in this Section could be used in different environments for system level simulation.

The environments are Suburban macro-cell, Urban macro-cell, Urban micro-cell, and Indoor pico-cell. All system level simulations are recommended to use the Macro-Cell model.

For each environment, different Log-normal shadow fading standard deviation and path loss models are used. The following summarize these values:

- Macro-cell: 10 dB Log-Normal Shadow Fading, and modified COST231 Hata urban propagation path loss model is assumed for the macro-cell environment. This model is described in the following formula:

$$PL[dB] = (44.9 - 6.55Log_{10}(h_b))Log_{10}\left(d/1000\right) + 45.5 + (35.46 - 1.1h_m)Log_{10}(f_c) - 13.82Log_{10}(h_b) + 0.7h_m + C$$

where h_b and h_m are the mobile and BS antenna heights, f_c is the carrier frequency in MHz, d is the distance between the MS and BS, and C is a parameter which is 0 dB for suburban and 3 dB for urban environments.

- Micro-cell: The micro-cell NLOS path loss is based on the COST 231 Walfish-Ikegami NLOS model with 10 dB Log-Normal shadow fading. Assuming BS antenna height to be 12.5 m, building height 12 m, building to building distance 50 m, street width 25 m, MS antenna height 1.5 m, orientation 30 deg for all paths, and selection of metropolitan center, the equation simplifies to:

$$PL[dB] = -55.9 + 38 * Log_{10}(d) + (24.5 + 1.5 * fc/925) * Log_{10}(f_c)$$

The micro-cell LOS path loss is based on the COST 231 Walfish-Ikegami street canyon model with 4 dB shadow fading. Assuming the same parameters as for the NLOS case, the path loss is

$$PL[dB] = -35.4 + 26 * Log_{10}(d) + 20 * Log_{10}(f_c)$$

where h_b and h_m are the mobile and BS antenna heights, f_c is the carrier frequency in MHz, d is the distance between the MS and BS, and C is a parameter that is 0 dB for suburban and 3 dB for urban environments.

- Indoor Picocell: The indoor path loss is based on the COST 231 model:

$$PL[dB] = 37 + 30 * Log_{10}(d) + 18.3 * n^{\left(\frac{n+2}{n+1} - 0.46\right)}$$

where n is the number of penetrated floor (n = 4 is an average for indoor office environments).

Annex B

(Informative)

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