Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Draft IEEE 802.16m Requirements**
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Source(s)	802.16 m Requirements Drafting Group: Mark Cudak, Motorola — mark.cudak@motorola.com Michael Webb, BRN Phoenix Inc. — mwebb@brnphoenix.com Phil Orlik, Mitsubishi Electric Research Laboratories — porlik@merl.com Avi Freedman, Hexagon System Engineering Ltd — avif@hexagonltd.com Ronny (Yong-Ho) Kim, LG Electronic Inc. — ronnykim@lge.com
Re:	IEEE 802.16m-07/004r1(Call for contributions on requirements for P802.16m-Advanced Air Interface)
Abstract	This document is considered by the drafting group to be its official output. The drafting group did its best to create consensus draft from the text we found in the various contributions. In many cases, there were multiple contributions capturing similar but conflicting thoughts. In these cases, the drafting group created an editor's text proposal, as a baseline. Where the contributions conflicted or introduced unique requirements, the editor's text proposal included the conflicting positions as bracketed text without necessarily copying the source text verbatim. The drafting group made every effort to include all numerical positions expressed in the input contributions.
Purpose	Output of the 802.16m Requirements Drafting Group
Notice	
Release	
Patent Policy and Procedures	

Contents

This document has been both color-coded and encoded using bracketed text. The color-coding is used to identify input from the various contributions. At the top of each major section you will find a table assigning a color to particular contribution. Colors have been reused from one major section to another. We have attempted to give like authors the same color throughout the document; however, this was not possible in all cases. All colored-coded text is sourced from the contributions with only minor edits. Black text represents editor's proposed text. In addition to the color coding, the drafting group has marked some text with brackets and left other text unbracketed. Square brackets [ ] identify text that requires further harmonization. This may include situations where the specified text is proposed for removal by one or more contributors or there are contradictory contributions related to that text.

1.0 Overview

Color	Section 1-4 Source Document Authors	Section 1-4 Source Document Reference
Blue	San Youb Kim, et, al.	IEEE C802.16m-07/030
Brown	Sassan Ahmadi, et. al	IEEE C802.16m-07/041
Green	Kiseon Ryu, et. al	IEEE C802.16m-07/037

The IEEE 802.16m amendment provides an advanced air interface which includes enhancements and extensions to IEEE STD 802.16-2004 and 802.16e-2005 in order to meet the requirements of next generation mobile networks.

[IEEE 802.16m is based on the WirelessMAN-OFDMA specification and provides continuing support for legacy WirelessMAN-OFDMA equipment, including base stations and subscriber stations.]

[IEEE 802.16m is based on the WirelessMAN-OFDMA specification and defines a backward compatible evolution of the standard providing interoperability with legacy subscriber stations and base stations.]

The purpose of this standard is to update the WirelessMAN-OFDMA air interface in accordance with the requirements defined for the internationally agreed radio interface standards for next generation mobile networks such as IMT-Advanced.

This standard is intended to be a candidate for consideration in the IMT-Advanced standard evaluation process being conducted by the International Telecommunications Union – Radio Communications Sector (ITU-R).

This document captures the high-level system requirements for the proposed IEEE 802.16m amendment as envisioned by the working group.

The system requirements for the IEEE 802.16m are defined to ensure competitiveness of the evolved air-interface with respect to other mobile broadband radio access technologies, and to ensure support and satisfactory performance for the emerging services and applications. The IEEE 802.16m system requirements also call for significant gains and improvements relative to the IEEE 802.16e reference system to justify the creation of a new standard revision/amendment.

[IEEE 802.16m is further required to maintain backward compatibility with the existing deployment of IEEE 802.16e standard. A reference system is defined that includes all mandatory features and a subset of optional features of IEEE 802.16e standard as specified by the Mobile System Profile [1] and is used as the reference for backward compatibility.]

This document further describes possible deployment scenarios for IEEE 802.16m standard. These scenarios include topologies consisting of new and legacy mobile and base stations as well as combinations of fixed and mobile relays.

[While IEEE 802.16m is expected to further facilitate the use of mobile multi-hop relays, the baseline architecture of the IEEE 802.16m does not include relays and the system requirements shall be met without inclusion of the relay stations.]

Some of the requirements in this document are separated for the mobile and the base station. Such requirements shall be construed as minimum performance requirements for the mobile and base stations. It must be noted that the system requirements described in this document shall be met with a system comprising of all new IEEE 802.16m compliant mobile and base stations.

[To accelerate the completion and evaluation of the standard, and in order to improve the clarity and reduce complexity of the standard specification, and to further facilitate the deployment of the IEEE 802.16m systems, the number of optional features shall be limited to a minimum.]

2.0 References

[1] WiMAX Forum™ Mobile System Profile, Release 1.0 Approved Specification (Revision 1.2.2: 2006-11-17) (see http://www.wimaxforum.org/technology/documents).

[2] IEEE Std 802.16-2004: Part 16: IEEE Standard for Local and metropolitan area networks: Air Interface for Fixed Broadband Wireless Access Systems, June 2004

[3] IEEE Std. 802.16e-2005, IEEE Standard for Local and metropolitan area networks, Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems, Amendment 2: Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands, and IEEE Std. 802.16-2004/Cor1-2005, Corrigendum 1, December 2005.

[4] Recommendation ITU-R M.1645: Framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000, January 2003

[5] Multi-hop Relay System Evaluation Methodology (Channel Model and Performance Metric), http://ieee802.org/16/relay/docs/80216j-06_013r2.pdf, November 2006.

[6] IEEE 802.16m PAR, http://standards.ieee.org/board/nes/projects/802-16m.pdf

[7] ITU-R Document 8F/TEMP/495-E: Draft Guidelines for Evaluation of Radio Transmission Technologies for IMT-Advanced, January 2007.

[8] ITU-R Document 8F/TEMP/496-E: Draft [Report on] Requirements Related to Technical System Performance for IMT-Advanced Radio Interface(s), January 2007.

[9] 3rd Generation Partnership Project 2, "cdma2000 Evaluation Methodology", http://www.3gpp2.org/Public_html/specs/C.R1002-0_v1.0_041221.pdf , 3GPP2 C.R1002-0 Version 1.0, December 2004

[10] WiMAX Forum System Performance White Paper, http://www.wimaxforum.org/technology/downloads/Mobile_WiMAX_Part1_Overview_and_Performance.pdf

3.0 Definitions

Sector	This term refers to physical partitioning of the base station (BS). When there are N transmitting directional antennas in the BS, each of them is named a sector.
Cell	A collection of sectors (typically 3) belonging to the same base station.
[IEEE 802.16e Mobile Station	Compliant with the IEEE 802.16 WirelessMAN-OFDMA specification specified by IEEE 802.16-2004 and amended by IEEE 802.16e-2005.]
IEEE 802.16e Base Station	Compliant with the IEEE 802.16 WirelessMAN-OFDMA specification specified by IEEE 802.16-2004 and amended by IEEE 802.16e-2005]
[IEEE 802.16e Reference System	A system compliant with a subset of the IEEE 802.16 WirelessMAN-OFDMA capabilities specified by IEEE 802.16-2004 and amended by IEEE 802.16e-2005, where the subset is

	defined by the WiMAX Forum™'s Mobile System Profile, Release 1.2 Approved Specification [1].
IEEE 802.16e Mobile Station	A mobile station compliant with a subset of the IEEE 802.16 WirelessMAN-OFDMA capabilities specified by IEEE 802.16-2004 and amended by IEEE 802.16e-2005, where the subset is defined by the WiMAX Forum™'s Mobile System Profile, Release 1.2 Approved Specification [1].
IEEE 802.16e Base Station	A base station compliant with a subset of the IEEE 802.16 WirelessMAN-OFDMA capabilities specified by IEEE 802.16-2004 and amended by IEEE 802.16e-2005, where the subset is defined by the WiMAX Forum™'s Mobile System Profile, Release 1.2 Approved Specification [1].]
IEEE 802.16m Mobile Station	Compliant with the IEEE 802.16 WirelessMAN-OFDMA specification specified by IEEE 802.16-2004 and amended by IEEE 802.16e-2005 and IEEE 802.16m
IEEE 802.16m Base Station	Compliant with the IEEE 802.16 WirelessMAN-OFDMA specification specified by IEEE 802.16-2004 and amended by IEEE 802.16e-2005 and IEEE 802.16m

4.0 Abbreviations and Acronyms

Abbreviation	Description
AAS	Adaptive Antenna System
BS	Base Station
CALEA	Communications Assistance for Law Enforcement Act of 1994
CDF	Cumulative Distribution Function
DL	Downlink
FCH	Frame Control Header
FDD	Frequency Division Duplexing
FER	Frame Error Rate
FTP	File Transfer Protocol
L2/L3	Layer 2/Layer 3
LAN	Local Area Network
LBS	Location Based Services
MAC	Medium Access Control
MBS	Multicast and Broadcast Service
MG	Major Group
MIMO	Multiple-Input Multiple-Output

MS	Mobile Station
OFDMA	Orthogonal Frequency Division Multiple Access
PAN	Personal Area Network
PHY	Physical Layer
PoC	Push over Cellular
PUSC	Partial Use of Sub-Carriers
QoS	Quality of Service
RAT	Radio Access Technique/Technology
RRM	Radio Resource Management
RS	Relay Station
TCP	Transport Control Protocol
TDD	Time Division Duplexing
UL	Uplink
VoIP	Voice over Internet Protocol
VPN	Virtual Private Network
WAN	Wide Area Network

5.0 General Requirements

Color	Section 5 Source Document Authors	Section 5 Source Document Reference
Blue	San Youb Kim, et. al.	IEEE C802.16m-07/031
Brown	Sassan Ahmadi, et. al.	IEEE C802.16m-07/042
Violet	Xin Qi, et. al.,	IEEE C802.16m-07/024
Grey	John Humbert, et. al.	IEEE C802.16m-07/027r1
Green	Kiseon Ryu, et. al.	IEEE C802.16m-07/037
Red	Dan Gal, et. al.	IEEE C802.16m-07/056
Orange	Mark Cudak, et. al	IEEE C80216m-07/019
Gold	Michael Webb et. al.	IEEE C80216m-07/023

This section contains general requirements for IEEE 802.16m systems. These requirements are intended to supplement the requirements specified by the ITU-R for IMT-Advanced systems.

5.1 Legacy Support

The IEEE 802.16m amendment is based on the IEEE Standard 802.16 WirelessMAN-OFDMA specification.

IEEE 802.16m shall provide continuing support and interoperability for legacy WirelessMAN-OFDMA equipment, including base stations and mobile stations.

[This continuing support shall be limited to only a "harmonized sub-set" of IEEE 802.16e OFDMA features. This harmonized sub-set is captured by the WiMAX Forum™ definition of OFDMA mobile system profiles [1]. These WiMAX mobile system profiles shall serve as the IEEE 802.16e reference system.]

A new IEEE 802.16m mobile station [should] [shall] be able to operate with a IEEE 802.16e base station at a level of performance that is equivalent to an IEEE 802.16e mobile station.

An IEEE 802.16m base station shall support:

- operation of IEEE 802.16e mobile stations with performance equivalent to an IEEE 802.16e base station, and
- concurrent operation of both IEEE 802.16m and 802.16e mobile stations on the same RF carrier.

[An IEEE 802.16m base station should also support:

- concurrent operation of IEEE 802.16e and 802.16m mobile stations on the same RF carrier where the 802.16m base station operates at a channel bandwidth larger than that of the 802.16e mobile station, and

- concurrent operation of two 802.16m mobile stations on the same RF carrier in different channel bandwidths.[1]]

[IEEE 802.16m base stations operating in bandwidths greater than 20 MHz shall only be required to support 802.16e mobile stations operating with bandwidths of 20 MHz or less.]

The performance of an IEEE 802.16m system supporting concurrent operation of IEEE 802.16e and 802.16m mobile stations should be proportional to the fraction of 802.16m mobile stations attached to the base station.

[Legacy support requirements shall apply to both TDD and FDD duplexing modes, respectively, with a minimal degradation of performance in backward compatibility operational configurations.][2]

IEEE 802.16m shall enable the efficient upgrade of existing IEEE 802.16e (reference system) base stations to 802.16m compliance and enable graceful migration of IEEE 802.16e systems to fully capable 802.16m systems.[3]

IEEE 802.16m shall operate and support backward compatibility in all bands where existing IEEE 802.16e systems are deployed or could be deployed by the time 802.16m technology is available. [This requirement shall not be construed as different modes of operation for different frequency bands; rather to reduce the number of optional features and the complexity of the standard, a unified baseband system with configurable parameters shall be used for operation in different frequency bands.]

[It shall not be mandatory that every IEEE 802.16m mobile station also support any or all of the IEEE 802.16e modes.]

[It shall not be mandatory that every IEEE 802.16m base station also support any or all of the IEEE 802.16e modes on all channels.]

[In view of continuing support for legacy 802.16 systems, the legacy 802.16 terminals shall be able to be supported within the spectrum band(s) where the IEEE 802.16m might be deployed.]

[IEEE 802.16m system shall meet the IMT-Advanced performance/capability requirements and support legacy terminals simultaneously.]

[The IEEE 802.16m enhancements shall be transparent to the IEEE 802.16e reference-system-based terminals and base stations.]

[IEEE 802.16m may also be deployed on a separate RF carrier as an overlay to legacy IEEE 802.16e reference system.]

Editor's note: choose one of the following:

[The IEEE 802.16m system shall support seamless handover to and from legacy IEEE 802.16e reference system.]

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[1] This probably belongs in a different section.
[2] Legacy requirements only apply to TDD per WiMAX profile??
[3] Maybe move this to a different section??

[An IEEE 802.16m base station shall support seamless handover of IEEE 802.16e mobile stations to and from legacy IEEE 802.16e base stations.]

5.2 Complexity

The IEEE 802.16m PHY/MAC should enable a variety of hardware platforms with differing performance and complexity requirements.

IEEE 802.16m shall minimize complexity of the architecture and protocols and avoid excessive system complexity. It should enable interoperability of access networks , support low cost devices and minimize total cost of ownership.

[Standard changes should focus on areas where the 802.16e reference system can be enhanced to meet the requirements.]

[IEEE 802.16m should only provide enhancements in areas where the IEEE 802.16e reference system does not meet the requirements.]

[The IEEE 802.16m system shall satisfy the performance requirements in Section 7.0. In addition, the complexity of base stations and mobile stations shall be minimized by adhering to the following:

a) The performance requirements shall be met with mandatory features only.
b) The number of optional features shall be minimized.
c) Optional features may be considered only if they provide significant functional and performance improvements over mandatory features.
d) Support of redundant [mandatory] features which are functionally similar and/or have similar impact on performance shall be avoided.
e) The number of necessary test cases shall be minimized, e.g. reduce the number of states of protocols, and minimize the number of procedures, appropriate parameter range and granularity.]

[IEEE 802.16m should minimize the complexity of the 802.16m mobile station in terms of size, weight, battery life (standby and active) consistent with the provision of the advanced services of the IMT-Advanced. For this, the following steps shall be followed;

a) The mobile station complexity in terms of supporting multiple radio access technologies (e.g. IEEE 802.16e, IEEE 802.11, GERAN, UTRAN, EV-DO etc.) should be considered when considering the complexity of 802.16m features.
b) The mandatory features for the mobile station only shall be kept to the minimum.
c) There shall be no redundant or duplicate specifications of mandatory features, or for accomplishing the same task.
d) The number of options shall be minimized.]

All enhancements included as part of the IEEE 802.16m amendment should promote the concept of continued evolution, allowing IEEE 802.16 to maintain competitive performance as technology advances beyond 802.16m. For example, this concept suggests that enhancements to the downlink/uplink maps, frame structure and message formats should be extensible.

5.3 Services

[IEEE 802.16m should support existing services more efficiently as well as facilitate the introduction of new/emerging types of services.

IEEE 802.16m and its services architecture shall be flexible in order to support services required for next generation mobile networks, including those identified by IMT-Advanced.

IEEE 802.16m shall support different QoS levels for different services. IMT-Advanced QoS requirements shall be supported including end-to-end latency, throughput, and error performance.

IEEE 802.16m shall provide reliable, powerful, secure and efficient security mechanisms to protect the network, system and user.][4]

[End users anticipate new services, new features, and new devices for IMT-Advanced. For example, HDTV plasma screens will be popular for notebook type of devices. Real-time gaming or real-time video streaming service over high definition screens will be a typical service in the future. High priority E-commerce, telemetric, Broadcast/Multicast for TV, news, and advertisement over the handheld will be popular services as well.

A list of services that IEEE 802.16m shall support is as follows:

a) VoIP
b) IPTV
c) Real-time gaming
d) Real-time high quality video streaming
e) Internet-like Asynchronous Service
   - Fast interactive sessions
   - High priority E-commerce
f) Large file exchanges
g) Multimedia conferencing
h) Multicast Broadcast for TV, news, or advertisement optimized for local area and wide area
i) Trust based service such as built in VPN encryption
j) MS position locating support and location based service]

5.4 [Operating Frequencies]

[IEEE 802.16m systems shall operate in RF frequencies less than 6 GHz and be deployable in licensed spectrum allocated to the mobile and fixed broadband services and shall be able to operate in frequencies identified for IMT-Advanced.]

[4] Could take either of two sets of bracketed text or both.

[IEEE 802.16m shall allow deployment on any bands specified for IMT-2000 and those to be identified for IMT-Advanced]

5.5 [Operating Bandwidths]

IEEE 802.16m shall support scalable bandwidths [5 to 20 MHz] [1.25 to 100 MHz]. [Support for 802.16e bandwidths of 5, 7, 8.75, 10MHz shall be maintained.] In addition, IEEE 802.16m should be optimized for [1.25, 2.5, 3.5, 5, 7, 8.75, 10, 14, 20, 28, 40, 56, 100 MHz.] [5, 7, 8.75, 10, 20 MHz] [5, 10 and 20 MHz] [5, 7, 8.75, 10, 20, 40, and 100 MHz] [Larger bandwidths such as 40 MHz may also be considered.].

[Bandwidths above 20 MHz should be optional for terminals.]

[For bandwidths larger than 10 MHz aggregation of multiple contiguous bands may be considered.]

5.6 Duplex Schemes

IEEE 802.16m shall be designed to support both TDD and FDD operational modes. The FDD mode shall support both full duplex and half duplex mobile station operation. Specifically, a half-duplex FDD mobile station is defined as a mobile station that is not required to transmit and receive simultaneously.

IEEE 802.16m shall support both unpaired and paired frequency allocations, with fixed duplexing frequency separations when operating in full duplex FDD mode.

System performance in the desired bandwidths specified in Section 5.5 should be optimized for both TDD and FDD independently while retaining as much commonality as possible.

The UL/DL ratio should be configurable. In TDD mode, the DL/UL ratio should be adjustable per frame. In FDD mode, the UL and DL channel bandwidths may be different and should be configurable (e.g. 10MHz downlink, 5MHz uplink). In the extreme, the IEEE 802.16m system should be capable of supporting downlink-only configurations on a given carrier.

Symmetrical operation should be supported in addition to asymmetrical operation.

[IEEE 802.16m shall support adaptive assignment of downlink/uplink bandwidth depending on channel condition or user capacity.]

Editor's Note: The following text does not contain clear requirements, so has been left bracketed for further harmonization.

[The potential outcome of WRC 2007 may affect the duplexing schemes, which may be applied in the following way:

- Traffic symmetry / or asymmetry: TDD enables asymmetric allocation of degrees of freedom between uplink and downlink.

- Need for link reciprocity to support channel estimation at the transmitter: TDD or hybrid schemes such as band switching support channel reciprocity. However, there the difference in the transmitter/receiver RF chain may limit the link reciprocity and should be carefully considered.
- TDD is typically used for local / metropolitan area while FDD is typically for wide area coverage, although there may be merits in some circumstances in reversing these arrangements. Hybrid schemes, such as hybrid division duplexing can be considered for flexible coverage of both scenarios.
- Synchronization and link continuity requirements.
- Distributed control e.g. terminal to terminal.]

Editor's Note: The following text has been reworded into the form of a requirement.

[IEEE 802.16m shall support efficient and flexible duplexing, beyond the traditional paradigm of pure FDD or TDD in order to enable alternative hybrid schemes that combine the advantages of both FDD and TDD and enable flexible use of their features.]

5.7 Baseline Antenna Configuration

The IEEE 802.16m standard shall define minimum antenna requirements for the base station and mobile station.

[For the base station, a minimum of two transmit and two receive antennas will be supported. For the MS, a minimum of one transmit and two received antennas will be supported. This minimum is consistent with a 2x2 downlink configuration and a 1x2 uplink configuration.]

[Other antenna configurations such as DL: 4x2, 2x4, 4x4 and UL: 1x4, 2x2, 2x4, 4x4 may also be optionally supported.]

5.8 [Regulatory Requirements]

IEEE 802.16m shall not preclude support of regional regulatory requirements such as CALEA, E911, etc.]

6.0 Functional Requirements

Editor's notes:

Source text is shown in color in this document as shown below:

Black - Original text

Color	Section 6 Document Source	Section 6 Document Reference
Olive	Phil Orlik	IEEE C802.16m-07/014
Orange	Mark Cudak, et. al	IEEE C80216m-07/017r1
Gold	Michael Webb et. al.	IEEE C802.16m-07/021
Violet	Xin Qi, et. al.	IEEE C80216m-07/025
Pink	Ronald Mao et. al.	IEEE C802.16m-07/029
Blue	San Youb Kim, et. al.	IEEE C80216m-07/032
Green	Aeran Youn, et. al	IEEE C80216m-07/038
Brown	Sassan Almadi, et. al.	IEEE C80216m-07/043
Red	Dan Gal, et. al.	IEEE C80216m-07/049

This section contains system level functional requirements targeting higher peak rates, lower latency, lower system overhead as well as PHY/MAC features enabling improved service security, QoS and Radio Resource Management.

6.1 Peak Data Rate

[This section defines the peak data rate achievable per link between base station and mobile station under the best of channel of conditions.]

State of the art modulation, coding, scheduling and multiplexing should be employed to achieve higher spectral efficiency at a reasonable complexity

Additional transmit and receive antennas may be considered but should not be required of subscriber devices.

[Size and power considerations continue to dictate that no more than one transmit and receive antennas be required of hand-held devices.]

[Size and power considerations continue to dictate that no more than two *RF chains* be required of hand-held devices.]

The same considerations impact supportable higher order constellation order.

[The standard should allow and specify the efficient training of AAS/MIMO systems to enable the optimum set of BS and subscriber station antenna elements to be discovered.]

[The standard should not preclude a single user from obtaining the entire aggregate bitrate/capacity of a BS in order to meet this requirement.]

[The standard shall provide for the development of cross-layer (PHY/MAC) methods and techniques that enable the cooperation among BSs and relays, specifically, the sharing of information between BSs for the purpose of mitigating self interference.]

[Accordingly, the minimum peak rate requirement supported by mobile stations compliant with the 802.16m specification, expressed as a normalized peak rate (i.e. absolute maximum supported data rate divided by the occupied channel bandwidth) is specified in Table 1. Normalized Peak Data RateTable 1.

Table 1. Normalized Peak Data Rate

Link Direction	Mobility	Min. No. of Active MS Antennas	Min. No. of Spatial Sub-streams	Max. Modulation Order	Normalized Peak Rate (bps/Hz)
Downlink (BS->MS)	Mobile	2 (Receive)	2	[64-QAM]	[6.5] , [1][5], [10][6], [4][7], [4][8]
Uplink (MS->BS)	Mobile	1 (Transmit)	1	[64-QAM]	[2.5], [5][9], [1.8][10]
Downlink (BS->MS)	Stationary	2 (Receive)	2		[10][11], [6.4][12]
Uplink (MS->BS)	Stationary	1 (Transmit)	1		[2.8][13]
Downlink (BS->MS)	Stationary	4 (Receive)	4		[10][14], [50][15]
Uplink (MS->BS)	Stationary				[25][16]

Notes applicable to Table 1. :

1. The specified requirements of normalized peak rates are not distinguished by duplex mode. Rather, 100% of radio resources are assumed – for the purposes of computing Table 1– allocable to downlink and uplink respectively regardless of duplexing mode.
2. Table 1. specifies requirements of normalized peak rate applicable to all devices supporting 802.16m. Modes offering further enhanced normalized peak rates may, however, be specified.
3. Table 1. considers overhead due to provisioning of radio resources for essential functions such as synchronisation, common control channel signalling, guard intervals, etc. which would be expected to reduce achievable peak spectral efficiency.

[5] Peak useful data rates shall be up to 100 Mbit/sec for mobile users, if 100MHz bandwidth is used.

[6] At least 200 Mbit/sec for downlink traffic for high mobility. Terminal shall support 20 MHz bandwidth.
[7] 40 Mbps with a 10 MHz bandwidth..

[8] For 20 MHz channel, the terminal should be able to achieve a peak data rate in the range of 75 to 150 Mbit/s.

[9] At least 100 Mbit/sec for uplink traffic for high mobility. Terminal shall support 20 MHz bandwidth.
[10] 18 Mbps with a 10 MHz bandwidth.

[11] 1 Gbps divided by 100 MHz bandwidth
[12] 64 Mbps with a 10 MHz bandwidth

[13] 28 Mbps with a 10 MHz bandwidth.

[14] Peak useful data rates shall be up to 1 Gbit/s for stationary users, if 100MHz bandwidth and 4*4 antennas are used.
[15] At least 1 Gbit/sec for downlink traffic for fixed or nomadic. Terminal shall support 20 MHz bandwidth.
[16] At least 500 Mbit/sec for uplink traffic for fixed or nomadic. Terminal shall support 20 MHz bandwidth.

4. The specified minimum supported normalized peak rates are applicable to all bandwidths specified in Section 5. For example, for mobile stations supporting a 20MHz bandwidth, the minimum supportable peak rate (excluding overhead) is > [130Mbps].

(Further peak rate requirements, such as coverage-averaged sustainable peak rates, may be further studied and could be specified following agreement on usage scenarios.)]

[Peak air interface data rates shall meet or exceed the minimum rates to be defined by the ITU-R for IMT-Advanced.]

6.2 Latency

Latency should be further reduced as compared to the IEEE 802.16e reference system for all aspects of the system including the air link, state transition delay, access delay, and handover.

[The following latency requirements shall be met by the system, under light loading assuming no signaling/MAC message retransmission.]

6.2.1 [Data Latency]

[Requirements for air link data latency are specified in terms of the time for delivery of a MAC PDU, transmissible as a Layer 1 codeword (i.e. without fragmentation), from the MAC interface of a base station or mobile station entity to the MAC interface of the corresponding mobile station or base station entity, excluding any scheduling delay at the base station. A single Layer 1 re-transmission of the codeword is included in the definition. The corresponding maximum latency for delivery of the MAC PDU appears in Table 2.]

[IEEE 802.16m shall support less than 100 msec of latency for signaling message.]

[Transmission Uplink Latency is the one-way transit time between the start of a small IP data packet transmission from the MS MAC layer and its arrival at the BS MAC layer for a high priority service assuming all radio resources have been previously assigned.]

[Transmission Downlink is the one-way transit time between the start of a small IP data packet transmission from the BS MAC layer and its arrival at the MS MAC layer for a high priority service assuming all radio resources have been previously assigned.]

Table 2. Maximum Data Latency

Link Direction	Max. Latency (ms)
Downlink (BS->MS)	[20],[5][17], [10]
Uplink (MS->BS)	[20],[10]

]

[17] IEEE 802.16m shall support less than 5 msec of latency for traffic packet

[PHY-MAC roundtrip delay

The requirement for the PHY-MAC roundtrip delay should respect the different types of services. Different values may be specified for:

- VoIP and other real-time-services
- Audio/video streaming
- Broadcast/multicast services
- HARQ.

The specific values of acceptable roundtrip delay, for each case, are TBD. These values may differ slightly from TDD to FDD modes.

High bandwidth real-time services and gaming applications shall be supported.]

6.2.2 [Scheduling Latency]

[Uplink Scheduling Latency is the time between the arrival of a data packet at the MS and the start of its transmission for a high priority service assuming all radio resources have been previously assigned.

Table 3. Maximum Scheduling Latency

Link Direction	**Max. Latency (ms)**
Uplink (MS->BS)	[15]

]

6.2.3 [State Transition Latency]

[Performance requirements for state transition delay may be divided into transition delay requirements for transition from SLEEP mode to ACTIVE mode and from IDLE mode to ACTIVE mode. The following requirements apply.

1. Delay performance requirements for mobile stations transitioning from SLEEP mode to ACTIVE mode shall be aligned with the reference system.
2. The 802.16m specification shall support mobile station transition times from IDLE mode to ACTIVE mode less than or equal to 100ms.

]

[IDLE to ACTIVE_STATE is defined as the time it takes for a device to go from an idle state (fully authenticated/registered and monitoring the control channel) to when it begins exchanging data with the network on a traffic channel or timeslot measured from the paging indication (i.e. not including the paging period).]

Table 4. State Transition Latency

Metric	Max. Latency (ms)
[IDLE_STATE to ACTIVE_STATE]	[100 ms]
[SLEEP_STATE to ACTIVE_STATE]	[10 ms]

]

6.2.4 [Handover Latency]

[Handover performance requirements, and specifically the interruption times applicable to handovers, are differentiated according to real-time and non-real-time service handover, handover between base stations supporting 802.16e and 802.16m, and intra- and inter-frequency handover.

The maximum service interruption times specified in Table 5 apply to handover of mobile stations supporting 802.16m between base stations supporting 802.16m and operating in the absence of 802.16e-2005 mobile stations.

Table 5. Maximum Handover Interruption.

Handover Type	Max. Interruption Time (ms)
Non-real-time, Intra-Frequency	100.0
Non-real-time, Inter-Frequency	300.0
Real Time, Intra-Frequency	50[18]
Real Time, Inter-Frequency	150[19]

]

[Maximum allowed packet reception/transmission outage time

The outage time of user traffic packets, during handover, shall be specified depending on the type of handover mechanism and depending on the application type. At least two types of handover mechanisms should be specified:

- Type-1 allows fast handover times through usage of additional MAC and radio resources. Design target for Type-1 is 20 ms or better outage time.
- Type-2 is more efficient with respect to radio resource usage but leads to longer handover times. Design target for Type-2 is 50 ms.]

[18] 50 ms is also supported by contribution IEEE C80216m-07/043
[19] 150 ms is also supported by contribution IEEE C80216m-07/043

6.2.5 [Channel State Feedback Latency]

[IEEE 802.16m shall provide methods to reduce channel estimation latency by at least 50% in order to enable higher speed mobility.]

6.2.6 [Initial System Entry Latency]

[IEEE 802.16m shall provide low-latency initial system entry for both intra-network and inter-network entry]

[The Initial System Entry Latency is defined as the time for a new device to complete network entry with probability > 0.9, including scanning, receiving DL signal and required management messages, and performing system entry for "intra-network" when the device is powered on in the same network it was operating last time (including neighboring cells), and "inter-network" when the device is powered on in a new network.

The following latency requirements shall be met by the system, under light loading assuming no signaling/MAC message retransmission.]

Table 6. Initial System Entry Latency

Metric	Max. Latency (sec)
Intra-Network Entry	[5]
Inter-Network Entry	[60]

6.3 QoS

[Relative to IMT-2000 systems, the 16m amendment shall:

- have a greater ability to simultaneously support a wide range of multimedia services,
- provide enhanced management of different quality of service levels, and
- provide support for applications requiring IMT-Advanced system end user QoS requirements.]

[IEEE 802.16m shall support QoS classes, enabling an optimal matching of service, application and protocol requirements (including higher layer signaling) to RAN resources and radio characteristics. This includes enabling new applications such as interactive gaming [5].]

[Further, support shall be provided for preserving QoS when switching between networks associated with other radio access technologies (RAT's).]

[The system shall support the necessary mechanisms and fields to enable content-awareness and definition of flow priorities and packet priorities within a flow at the lower (MAC/PHY) layers.]

[Supporting high priority service in wireless network is one of important issues from government operator perspective and end-user perspective.]

- [End-user: IEEE 802.16m shall provide high priority for emergency service calls (such as 911). Such high priority service shall be protected by proper assignment of radio resources.]
- [Government/Operator: In emergency situations, wireless networks can experience severe congestion due to large call volumes. This causes damage to network facilities and further more prohibits emergency callings from Federal, state, and local government personnel. IEEE 802.16m shall support management of and response to emergency callings from government personnel in emergency situations.]

[IEEE802.16m shall ensure the QoS mechanism can provide the required data integrity, response time and throughput applicable to the MS to deliver carrier grade level service.]

[IEEE 802.16m shall provide optimal and stable resource allocation mechanism to support QoS for IMT-Advanced service classes, Conversational, Interactive, Streaming, and Background services. IEEE 802.16m shall also provide QoS mechanism for low multimedia, medium multimedia, high multimedia, and high multimedia. Their definitions are given below.

- *Low Multimedia*: The data speed of the service reaches up to 144 kbit/s. Services include e.g. VoIP, video telephony and file sharing
- *Medium multimedia*: The data speed of the service reaches up to 2 Mbit/s. Services include e.g. video conference, mobile TV, broadcast IP TV, video/audio streaming, photo messages and business intranet/extranet.
- *High multimedia*: The data speed of the service reaches up to 30 Mbit/s. Services include e.g. high quality video conference, video streaming and messaging, application sharing, mobile internet/intranet/extranet and navigation.
- *Super high multimedia*: The data speed of the service reaches up to 100 Mbit/s or even 1 Gbit/s. Services include e.g. high volume streaming, e-newspaper and game data download, and mobile internet/intranet/extranet.]

[Quality of Service profiles for IMT-Advanced and the future development of IMT-2000 are given in the Table 7.

Table 7. Quality of Service profiles for IMT-Advanced and the future development of IMT-2000

Traffic class / Service type	Conversational	Streaming	Interactive	Background
Super High Multimedia (30Mbit/s to 100M/1Gbit/s)	Layer 2 throughput: TBD Delay: TBD Delay jitter: TBD Asymmetry: TBD	Layer 2 throughput: TBD Delay: TBD Delay jitter: TBD Asymmetry: TBD	Layer 2 throughput: TBD Delay: TBD Delay jitter: TBD Asymmetry: TBD	Layer 2 throughput: TBD Delay: TBD Delay jitter: TBD Asymmetry: TBD
High multimedia (<30 Mbit/s)	Layer 2 throughput: TBD	Layer 2 throughput: TBD	Layer 2 throughput: TBD	Layer 2 throughput: TBD

	Delay: TBD Delay jitter: TBD Asymmetry: TBD	Delay: TBD Delay jitter: TBD Asymmetry: TBD	Delay: TBD Delay jitter: TBD Asymmetry: TBD	Delay: TBD Delay jitter: TBD Asymmetry: TBD
Medium multimedia (<2 Mbit/s)	Layer 2 throughput: TBD Delay: TBD Delay jitter: TBD Asymmetry: TBD	Layer 2 throughput: TBD Delay: TBD Delay jitter: TBD Asymmetry: TBD	Layer 2 throughput: TBD Delay: TBD Delay jitter: TBD Asymmetry: TBD	Layer 2 throughput: TBD Delay: TBD Delay jitter: TBD Asymmetry: TBD
Multimedia & Low rate data (<144kbit/s)	Layer 2 throughput: TBD Delay: TBD Delay jitter: TBD Asymmetry: TBD	Layer 2 throughput: TBD Delay: TBD Delay jitter: TBD Asymmetry: TBD	Layer 2 throughput: TBD Delay: TBD Delay jitter: TBD Asymmetry: TBD	Layer 2 throughput: TBD Delay: TBD Delay jitter: TBD Asymmetry: TBD
Very low bit rate (<16kbit/s)	Layer 2 throughput: TBD Delay: TBD Delay jitter: TBD Asymmetry: TBD	Layer 2 throughput: TBD Delay: TBD Delay jitter: TBD Asymmetry: TBD	Layer 2 throughput: TBD Delay: TBD Delay jitter: TBD Asymmetry: TBD	Layer 2 throughput: TBD Delay: TBD Delay jitter: TBD Asymmetry: TBD

Note: QoS parameters in the table are expected to be defined by ITU-R. (IMT.SERV).
]

6.4 Radio Resource Management

[While Radio Resource Management (RRM) is outside the scope of IEEE 802.16m standard necessary messages and parameters to enable RRM at the network layer shall be supported.]

6.4.1 [Idle Mode Cell Selection]

[IEEE 802.16m shall define methods for optimising base station and network selection by multimode terminals, including selection based on application layer requirements. This should include selection between IEEE 802.16 variants (specifically, IEEE 802.16e reference systems, and networks and base stations supporting the 802.16m amendment) and other RAT's. Such support shall include initial network access and IDLE mode procedures.

Further, support shall be provided for optimised network selection with respect to at least the following RATs:

- IEEE 802.11x networks
- 3GPP GSM/EDGE, UMTS WCDMA, and LTE networks
- 3GPP2 CDMA2000 networks

]

6.4.2 [Reporting]

[IEEE 802.16m shall enable advanced radio resource management by enabling the collection of reliable statistics over different timescales, including system (e.g. dropped call statistics), user (e.g. terminal capabilities, mobility statistics, battery life), flow, packet, etc.]

6.4.3 Scheduling

[IEEE 802.16m shall provide enhanced uplink transmission efficiency by expanding the freedom on the part of the MS to decide on the exact scheduling of uplink data packets on a micro time scale.]

[IEEE 802.16m shall enable the MAC and PHY to schedule independent spatial streams to multiple users on the same RF channel in the same time interval.]

[IEEE 802.16m shall provide sufficient access channel (including bandwidth request and ranging) capacity such that all bearer channel capacity can be fully utilized.]

[IEEE 802.16m shall provide radio resource management mechanisms to support preemption and prioritized system access.]

[IEEE 802.16m should increase spectrum efficiency by:

- Frequency and time optimised scheduling (water-filling)
- Interference avoidance, or coordination methods, to achieve higher cell edge throughput, and more uniform service availability]

6.4.4 [Flexible Frequency Reuse]

IEEE 802.16m shall support very flexible frequency reuse schemes with or without network wide frequency planning, such as soft frequency reuse or adaptive frequency reuse to improve cell edge performance and overall throughput.]

6.4.5 [Interference Management]

IEEE 802.16m shall support advanced interference mitigation schemes.]

[IEEE 802.16m shall provide support for active interference cancellation techniques. The purpose of active interference cancellation is to minimize degradation of user data rates in all regions of a fully loaded cell in an interference limited, full frequency reuse environment. Performance of interference cancellation shall be such that SINR degradation in all regions of a cell is less than 3 dB between the unloaded cell case and a fully loaded cell case.]

6.4.6 [Multi-cell Joint Resource Optimization]

IEEE 802.16m shall support multi cell joint resource allocation schemes to enable load balancing and maximize network capacity.]

6.4.7 [B/W Scalability]

IEEE 802.16m shall support enhanced B/W scalability and agility including seamless initial access and H/O.]

6.5 Security

Editors Note: Further harmonization of the text in this section is desperately required!

IEEE 802.16m shall include a security function which provides the necessary means to achieve:

- [protection of system integrity, including control information and MAC management messages;
- protection and confidentiality of user-generated traffic and user-related data (e.g. location privacy),
- secure access to and secure provisioning of services provided by the system,
- efficient, robust user and device authentication, and
- reliable/flexible service availability protection.]

[The following are the requirements for Service Security

- Authentication and authorization of subscribers to each service shall be provided
- All signaling and user traffic related to services shall be confidentiality- and integrity- protected
- It shall be possible to apply different levels of security to different sessions after some negotiation during the signaling setup
- A single sign-on solution that minimizes the number of times that protection is applied when a user is accessing a service, without reducing the security level, is highly desirable.]

[The following are the requirements for Interworking Security:

- Delay constrained handover and roaming support without changing the security level (Especially, seamless mobility across heterogeneous networks with the negotiation of security mechanisms/algorithms); and Minimum performance/capacity degradation due to the security feature provisioning.]

[IEEE 802.16m shall also support inter-working security which includes delay constrained handover and roaming without changing the security level and minimum performance/capacity degradation due to the security feature provisioning and the delay due to the re-establish the security context shall not affect the real time service.]

[The security function shall be self-contained and capable of maintaining security without relying on specific behaviors on the part of algorithms/protocols at any other functions or layers outside the security function. Such assumptions, if and when necessary, shall be explicitly specified.]

[The impact of security procedures on the performance of other system procedures, such as handover procedures, shall be minimized.]

[Roaming users and users performing inter-technology handover shall not be prevented from accessing the maximum level of security provided by the system.]

[802.16m key derivation hierarchy should include a new optional branch allowing the use of a HOKEY based PMK derivation (using per authentication master keys, such as MDMSK) in addition to the use of an EAP based PMK derivation (using MSK). This will provide great flexibility and less complex WiMAX architecture design, while at the same time providing great deal of backward compatibility with 802.16e MS and BS, since no portion of the 802.16e key hierarchy below the PMK needs to be changed.]

[The security sublayer currently defined in IEEE 802.16 provides the function of authentication, confidentiality and integrity. In the design of IEEE 802.16m, optimizations and enhancements for the security of legacy IEEE 802.16e system shall be further highlighted. For this, the security for IEEE 802.16m shall satisfy the followings.

1) Support delay constrained handover/roaming: Seamless mobility shall be ensured without changing the security level. For this, security mechanisms/algorithms shall be negotiated across heterogeneous networks.

2) Reduce cost and complexity : The EAP intrinsic complexity, message size overhead, many round trips and high end-to-end packet transmission delay shall be minimized. For this, new security services shall be offered without degrading the performance and capacity

3) Enhance security : The security flaws of 802.16 shall be resolved in a cost effective way at MAC layer. For this, new cryptographic methods shall be used to treat various attacks on MAC messages. Also, more robust and enhanced function of confidentiality/integrity protection shall be considered.]

6.6 Handover

IEEE802.16m shall provide seamless mobility within and between all cell types in an IEEE802.16m system. IEEE802.16m shall provide seamless mobility with legacy IEEE 802.16e systems. Handover with other IMT-2000 standards is highly desirable.

[High performance handover algorithms should be designed by taking into consideration all relevant system aspects and costs, such as over-the-air overhead and algorithmic security.]

[IEEE802.16m shall provide the service continuity at minimum MS speed of 120kmph for both the inter-RAT and intra-RAT handover.]

[IEEE 802.16m standard shall enable optimized L2 (and/or L3) handoff between Wi-Fi and 802.16m air interfaces to enable seamless connectivity for upper layer applications.]

[IEEE 802.16m should adapt Event, Command and Information services specified in IEEE 802.21 as media-specific support to enable seamless mobility interoperation with other mobile wireless standards. Event services in the 802.16m PHY and MAC should be supported by triggering link events when configurable thresholds are crossed, enabling the MIH (Media Independent Handover) function to react expeditiously to the changing channel conditions. Similarly, the MAC and PHY layers should be able to accept local and remote commands as specified in IEEE 802.21.]

[IEEE 802.16m shall also give consideration to additional beyond those features specified in the IEEE 802.21 working group. For example, specific methods for scanning and system discovery should be considered as part of the 802.16m MAC. Finally, requirements for handover of broadcast services shall also be defined.]

[The 802.16m amendment shall specify means of reporting ACTIVE mode measurement of additional radio access technologies (RAT's) including at least the following RAT's:

- IEEE 802.11x networks
- 3GPP GSM/EDGE, UMTS WCDMA, and LTE networks
- 3GPP2 CDMA2000 networks

In addition, the 802.16m amendment shall provide support for optimised ACTIVE mode handover procedures between base stations supporting the 802.16m amendments and the RAT's specified above.

]

[Mobility procedures should be fully compatible with the Network Control and Management Services (NCMS) procedures described in the IEEE 802.16g amendment. At a minimum, 802.16m shall support all the NCMS functional entities, described in IEEE 802.16g, which may be centrally located or distributed across the network.]

6.7 Enhanced Multicast Broadcast Service (MBS)

[The 802.16m system should provide optimizations for efficient delivery of broadcast and multicast services.]

[The 802.16m amendment shall provide support for an evolved Multicast Broadcast Service (E-MBS). As well as providing enhanced multicast and broadcast spectral efficiency (Section 7), E-MBS shall provide the following functional enhancements with respect to the reference 802.16e system:

- Optimised scheduling and resource allocation overhead reduction
- Reduced mobile station power consumption while monitoring
- Enhanced broadcast quality of service (QoS) and coverage optimization
- MS MBS decoding of pre-defined MBS channel(s) without requiring network registration

The 802.16m amendment shall be structured in such a way that dedicated carrier modes of operation (i.e. where most, or all, of the radio resources on a specific carrier frequency are assigned for MBS use) may be applied as a means of achieving the goals above.

The system shall support seamless switching between broadcast and unicast services, including the case when broadcast and unicast services are deployed on different frequencies.]

6.7.1 [MBS Channel Reselection Delay and Interruption Times]

E-MBS functionality defined as part of the 802.16m amendment shall support the following requirements for maximum MBS channel change interruption times when applied to broadcast streaming media.

Table 8. MBS channel reselection maximum interruption times.

MBS Channel Reselection Mode	Max. Interruption Time (s)
Intra-frequency	1.0
Inter-frequency	1.5

Note that requirements of Table 8 apply to the interruption time between terminating delivery of MAC PDU's from a first MBS service to the MAC layer of the mobile station, and the time of commencement of delivery of MAC PDU's from a second MBS service to the mobile station MAC layer.

In addition, the requirements of Table 9 specify the maximum user-perceived channel reselection time (i.e. the time from channel re-selection by the user to the start of media stream rendering by the mobile station).

Table 9. MBS user-perceived maximum interruption times.

MBS Channel Reselection Mode	Max. Interruption Time (s)
Intra-frequency	2.0
Inter-frequency	3.0

]
[

6.8 [Location Based Services (LBS)]

[The IEEE 802.16m system shall support PHY and MAC measurements and reporting mechanisms needed to enable high resolution location determination.]

[The 802.16m amendment shall provide optimised support for assisted modes of global navigation satellite systems (A-GNSS). 802.16m shall also support location based services using only native 802.16m transmissions.]

6.9 [Reduction of User Overhead]

[The system shall provide mechanisms for reducing overhead already present in a bearer stream, by natively supporting improved and efficient header compression schemes, capable of suppressing overhead caused by IP/TCP layers, as well as other vital applications, such as VPN, PPPoE etc.]

6.10 [System Overhead]

[The percentage of system resources consumed by overhead, including overhead for control signaling procedures as well as overhead related to bearer data transfer, should be minimized.
]

[The IEEE 802.16m standard shall support the required throughput with a minimum downlink efficiency of 80%, where airlink efficiency shall be defined as:

1 - (Number of downlink MAC and PHY overhead slots (Preamble, MAP, sub-MAP, FCH, etc.) per frame / Total number of downlink slots per frame)

The IEEE 802.16m standard shall support the required throughput with a minimum uplink efficiency of 80%, where airlink efficiency shall be defined as:

1 - (Number of uplink MAC and PHY overhead slots (ranging allocations, HARQ Ack-Nack, CQICH, etc.) per frame / Total number of uplink slots per frame)
]

[Further optimization of the MAC should be considered for "16m". Overhead for critical real-time, latency-sensitive applications, should be reduced as far as feasible without compromising other performance criteria. More specifically, 802.16m should support various FEC-block, MAC-PDU and other protocol layer block sizes, optimized for typical applications by minimizing padding bits, i.e., matching payload to block sizes for the key application that need to be supported (VoIP, Gaming, Video, etc)]

[Although backward compatible 802.16m should be able to receive the legacy DCD/UCD messages, as well as the DL and UL MAPs, other non compatible operating modes shall be supported where the overhead of the layer 2 maps is significantly reduced.]

6.11 [Enhanced Power Saving]

[The 802.16m amendment shall provide support for enhanced power saving functionality to help reduce power consumption in client devices during multimedia services such as push-to-X and also when the device is idle. The following functional enhancements with respect to the reference 802.16e system are possible:

- Optimized sleep to scan and scan to sleep mode switching
- Automatic sleep mode reactivation provided by the BS
- Optimized sleep mode deactivation/reactivation by MS
- Optimized paging message indication and decoding]

7.0 Performance requirements

Color	Section 7 Source Document Authors	Section 7 Source Document Reference
Torquise	In-Kyeong Choi, et. al.	IEEE C80216m-07/013r1
Olive	Philip Orlik, et. al.	IEEE C80216m-07/015
Orange	Mark Cudak, et. al.	IEEE C80216m-07/018r1
Gold	Michael Webb, et. al.	IEEE C80216m-07/022
Blue	Sang Youb Kim, et. al.	IEEE C80216m-07/033
Green	Jin Sam Kwak, et. al.	IEEE C80216m-07/039
Brown	Sassan Ahmadi, et. al.	IEEE C80216m-07/044
Red	Jean-Pierre Balech, et. al.	IEEE C80216m-07/050

The performance requirements are specified in terms of absolute performance and relative performance with respect to that of the IEEE 802.16e reference system.

[For relative performance requirement, the performance goal is specified in terms of spectral efficiency performance relative to IEEE 802.16e reference system using 2 transmit and 2 receive antennas at the base station and 1 transmit and 2 receive antennas at the mobile station. [The performance metrics are average sector throughput, average user throughput and five percentile user throughput (cell edge throughput) defined in Table 12.]
[The performance goals are specified separately for a data only and Voice over IP (VoIP) only system respectively.]

Table 10. Performance metrics

Metric	Definitions
Sector throughput[20]	$\frac{\sum_{k=1}^{K}\text{bits to/from user k in [0,T]}}{T}$
Average user throughput	$\frac{1}{K}\sum_{k=1}^{K}\frac{\text{bits in user session k}}{(t_{end_k}-t_{start_k})}$
Cell edge user throughput	5% user throughput
Sector spectral efficiency (TDD)	$\frac{\text{Sector (DL/UL) Throughput}}{\text{Total Sector BW} \times \text{\%(DL/UL) Split}}$
Sector spectral efficiency (FDD)	$\frac{\text{Sector (DL/UL) Throughput}}{\text{Sector (DL/UL) BW}}$
Harmonic Spectral Efficiency (bps/Hz/Sector)	It is the harmonic mean of the throughput divided by the band width. Assume total bandwidth W, # of users *N* with throughput *S1,*

[20] There is some ambiguity as to whether this metric includes overhead associated with MAC headers. This metric clearly excludes PHY and MAP overheads. This should be clarified in the evaluation methodology.

	S2, ... SN, hence $SE_{ED}=(N/W)*1/(1/S1+1/S2+...+1/SN)$
VoIP Capacity	Erlangs/MHz/Sector
Cell Edge Spectral Efficiency	TBD

[Note: The performance metrics in Table 10 shall be superseded by the definition in the Evaluation Methodology document.]

7.1 User throughput

7.1.1 [Relative performance]

The targets for average user-throughput and cell-edge user throughput of downlink/uplink for data only system for baseline antenna configuration are shown in Table 11. Both targets should be achieved assuming 802.16e reference performance as per antenna configuration defined above and using an MMSE receiver and assumptions in the WiMAX white paper [10].

Table 11. Data only system

Metric	Relative Throughput	
	DL Data (x 802.16e)	UL Data (x 802.16e)
Average User Throughput	> 2x	>[1.5x] >[2x][21]
Cell Edge User Throughput	> 2x	>[1.5x] >[2x]

Note that the Cell Edge User Throughput is defined as the [5%] [10%] point of the cumulative distribution function (CDF) of the user throughput for a given DL:UL ratio (in TDD duplex mode), a given number of users, site-to-site distance, and a given fairness and delay criterion in a fully loaded network with full-buffer traffic.

[The reference VoIP system should support an 8 kbps codec with a 50% activity factor such that the percentage of users in outage is less than 5% where outage is defined such 98% of the VoIP packets are delivered successfully to the users within the delay bound of *x* msec.]

[21] From contributions, IEEE C80216m-07/033, IEEE C80216m-07/039, IEEE C80216m-07/44

7.1.2 [Absolute performance]

[IEEE 802.16m standard shall provide average throughput , per terminal, in practical operational conditions (cellular environment, mobility effects, etc.) at typically required cell coverage, shall be at least 10 Mbps in a 20MHz channel. The definition of average throughput per user terminal should be consistent with the definition and measurement specifics specified in the TGm Evaluation Criteria document (TBD).]

Table 12. Absolute throughput of Data only system

Metric	DL Data	UL Data
Average User Throughput	[2 bits/Hz][22]	TBD
Cell Edge User Throughput	[5 Mbps][23]	TBD

[A base station sector should be able to achieve a peak aggregate data rate of up to 1 Gbit/s.]

7.2 Spectrum efficiency

The IEEE 802.16m amendment shall provide enhancements to the existing standard to reduce the amount of PHY and MAC layer overhead, particularly in cases of large numbers of users with small or sporadic bandwidth demands, in order to make more efficient use of available capacity.

802.16m should deliver significantly improved spectrum efficiency and increased cell edge bit rate while maintaining the same site locations as deployed for current 802.16e system.

Spectral efficiency of 10 bps/second/Hz/cell shall be required to achieve the subscriber penetration rates and aggregate data rates needed to ensure commercial success for these networks, given the bandwidth-intensive multimedia services they must support.

Sector Throughput is defined as the total unidirectional sustained throughput (downlink/uplink), excluding MAC & PHY layer overheads, across all users scheduled on the same RF channel. Sector throughput requirements must be supported for realistic distributions of users of a fully loaded cell surrounded by other fully loaded cells using the same RF channel (i.e. an interference limited environment with full frequency reuse).

---

[22] Assuming a 10 MHz operating bandwidth (unpaired) consistent with the IEEE 802.16e reference system. This requirement shall be met with the baseline antenna configuration. Average Instantaneous Data Rate DL > 20 Mbps, where average instantaneous implies average over the cell area.
Assuming a 10 MHz operating bandwidth (unpaired) consistent with the IEEE 802.16e reference system This requirement shall be met with the baseline antenna configuration. Average Instantaneous Data Rate DL > 20 Mbps, where average instantaneous implies average over the cell area.
Assumes a 20 MHz operating bandwidth This requirement shall be met with the baseline antenna configuration. Average Instantaneous Data Rate DL > 40 Mbps, where average instantaneous implies average over the cell area

[23] The IEEE802.16m standard shall be capable of supporting cell edge data rate per link of at least 5 Mbps in all supported cell types exclusive of MAC and PHY overheads.

[These spectral efficiency requirements shall be supported in all regions of a fully loaded cell surrounded by other fully loaded cells using the same RF channels (i.e. an interference limited environment).
]

7.2.1 [Relative spectral efficiency]

Table 13. Spectral Efficiency (bps/Hz/sector)

Scheduling Policy	Speed (km/h)	DL	UL
Average	TBD	[2x]	[1.5x]

Table 14. VoIP Capacity

Scheduling Policy	Speed (km/h)	Capacity (Erlangs/MHz/sector)	
TBD	TBD	[2.5x]	[2.5x]

Table 15. Harmonic Spectral Efficiency (bps/Hz/sector)

Scheduling Policy	Speed (km/h)	DL	UL
TBD	TBD	[2x]	[2x]

Table 16. Cell Edge Spectral Efficiency (bps/Hz/sector)

Scheduling Policy	Speed (km/h)	DL	UL
TBD	TBD	TBD	TBD

7.2.2 [Absolute spectral efficiency]

Table 17. Spectral Efficiency (bps/Hz/sector)

Scheduling Policy	Speed (km/h)	DL	UL
Peak	TBD	[6.4][24]	[3]

[24] We assume that the "peak spectral efficiency" defined in contribution IEEE C80216m-07/044 is equivalent to the "peak spectral efficiency" in IEEE C80216m-07/039

	[3]	[6.0]	[3.5]
	[60]	[4.2]	[2.5]
	[120]	[2.4]	[1.5]
	[300] higher	[0.5]	[0.3]
Average	TBD	[7.5] [25]	[3.5]
	[3]	[2.0]	[1.2]
	[60]	TBD	TBD
	[120]	[1.5]	[0.9]
	[300] or higher	TBD	TBD
TBD	TBD	[2.4][26]	[1.2]
TBD	TBD	[10]	[10]
TBD	no mobility– 70% up to 60 km/h–20% over 60 km/h – 10%	[10]	[10]

Table 18. VoIP Capacity

Scheduling Policy	Speed (km/h)	Capacity (Erlangs/MHz/sector)
TBD	TBD	[200][27]

Table 19. Harmonic Spectral Efficiency (bps/Hz/sector)

Scheduling Policy	Speed (km/h)	DL	UL
TBD	TBD	TBD	TBD

Table 20. Cell Edge Spectral Efficiency (bps/Hz/sector)

Scheduling Policy	Speed (km/h)	DL	UL
TBD	TBD	[1-4][28]	TBD

[25] We assume that the "sustained spectral efficiency" defined in contribution IEEE C80216m-07/044 is equivalent to the "average spectral efficiency" in IEEE C80216m-07/039

[26] "Sector throughput" in IEEE C80216m-07/044 has been converted into spectral efficiency using given bandwidth and DL/UL ratio.

[27] IEEE802.16m shall support the VoIP capacity at 200 VoIP-calls/MHz

[28] The target spectral efficiency at cell edge shall be on the order of at least in the range of 1-4 bits/sec/Hz/cell.

7.3 Mobility

Mobility shall be supported across the 802.16m network. IEEE 802.16m shall be optimized for low vehicular speeds such as mobility classes from stationary to pedestrian and provide high performance for higher mobility classes. The performance shall be degraded gracefully at the highest mobility. In addition, the IEEE 802.16m shall be designed to maintain the connection up to highest supported speed and to support the required spectral efficiency described in clause 7.2. Table 21 summarizes the mobility performance.

Table 21. IEEE 802.16m mobility support

Mobility	Performance
Low (0 – [5][10][15] km/h)	Optimized
[Medium (5-60 km/h)]	[High performance]
High ([10][15] [60]– 120 km/h)	[Marginal degradation] [High performance] [Medium performance]
Highest (up to [350] [500] km/h)	[System should be functional] [Graceful degradation of performance to maintain session/call connectivity] [Basic performance]

It may be noted that speeds above 250 km/h are applicable for special cases such as high speed trains.

7.4 Coverage

IEEE 802.16m shall provide significantly improved coverage with respect to the IEEE 802.16e reference system.

The link budget of the limiting link (e.g. DL MAP, UL Bearer) of 802.16m shall be improved by at least [3 dB] compared to the IEEE 802.16e reference system using similar system configurations.

[Along with achieving the requirements of cell-edge user throughput (clause 7.1) and spectral efficiency (clause 7.2) with various mobility classes (clause 7.3), IEEE 802.16m shall be flexible enough to support all users having various coverage requirements in the cellular networks. In addition, IEEE 802.16m shall properly configure the range of PHY and MAC system parameters to take into account the large cell environment.]

[IEEE 802.16m shall support legacy cell sizes allowing for co-location of IEEE 802.16m deployments. Support for larger cell sizes (30km, 100km cells) should not compromise the performance of smaller cells. It is also required to support increased number of simultaneous users and enhanced user penetration rates. Specifically, 802.16m shall support the following deployment scenarios in terms of maximum cell range:]

Table 22. 802.16m Deployment Scenarios

Cell Range	Performance target
Up to 5 km	Optimized Performance targets defined in clause 7.1-7.3 should be met
5-30 km	[Graceful degradation in system/edge spectral efficiency] [slight degradations in the achieved user throughput and more significant degradation in spectral efficiency are acceptable; however mobility performance targets should be met.]
30-100 km	System should be functional (noise limited scenario)

The IEEE 802.16m standard shall provide PHY and MAC structures that enable significant improvements in coverage, relative to the 802.16e reference system, through the use of techniques such as multi-antenna beamforming, higher order MIMO, SDMA, [superposed coding with] adaptive interference cancellation and enhanced diversity techniques. System gain improvements shall be obtained in a fully loaded cell in an interference-limited environment regardless of user distribution within the cell. The IEEE 802.16m standard shall improve the performance of control channels (MAPs, etc.) such that it is equal to or better than that of bearer traffic in all areas of a cell under fully loaded conditions regardless of user distribution (i.e. interference limited deployments).

[Especially, it is required that at least 1% packet error rate for common control channel shall be given for 95% users in the cell over a variety of cell layouts (clause 7.4) and mobility classes.]

[The standard shall support the use of multi-hop/relay transmission to improve a subscriber station's bit-rate when at a cell edge.]

[IEEE802.16m should provide enhancement to IEEE802.16j based multi-hop relay capability.]

[Example of cell types and their sizes are given in the Table 23.

Table 23. Example of typical cell type parameters

Cell type	Radio environment	Cell radius (km)	Mobile speed (km/h)
Macro	Rural	5 ~ 35	0 ~ 500
	Suburban	~ 5	0 ~ 120
Micro	Urban	~ 1	0 ~ 100
Hot-spot	Business area	~ 0.1	0 ~ 10
Personal	Wireless personal area	~ 0.01	0 ~ 10

]

7.5 Enhanced Multicast-Broadcast Service

As outlined in Section 6, IEEE 802.16m shall support enhanced multicast-broadcast service for IMT-Advanced multimedia multicast broadcast services in a spectrally efficient manner.
The IEEE 802.16m enhanced multicast-broadcast shall support the coverage up to [50km] of a cell radius.

[Minimum performance requirements for E-MBS, expressed in terms of spectral efficiency over the coverage area of the service, appear in Table 24.

Table 24. MBS minimum spectral efficiency vs. inter-site distance

Inter-Site Distance (km)	Min. Spectral Efficiency (bps/Hz)
0.5	2.0
1.5	1.0
TBD	2.0[29]

The following notes apply to Table 24:

1. The performance requirements apply to a wide-area multi-cell multicast broadcast single frequency network (MBSFN).
2. The specified spectral efficiencies neglect overhead due to ancillary functions (such as synchronization and common control channel) and apply to both mixed unicast-broadcast and dedicated MBS carriers, where the performance is scalable with carrier frequency bandwidth.

]

7.6 [Voice over IP]

[IEEE 802.16m VoIP capacity shall be significantly higher than that of the 802.16e reference system. The VoIP capacity and call setup latency for the 802.16m systems shall satisfy the following requirements:

Table 25. VoIP Requirements

Feature	Requirement	Comments
Number of VoIP Users/Sector (per MHz) Number of concurrent VoIP sessions/sector/MHz in a system fully loaded only with VoIP users	> 100 users/sector/FDD MHz > 50 users/sector/TDD MHz	System outage and FER shall be less than 3% and 3%, respectively. AMR shall be used as the default codec and 12.2 kbps with DTX enabled shall be considered as the default source rate.
VoIP (and PTT) call setup latency	< 1s	

[29] IEEE802.16m shall support the enhanced MBS with spectral efficiency greater than 2bit/sec/Hz at 95% tile coverage.

]

7.7 [Data Services]

[IEEE 802.16m aggregate TCP capacity shall be at least 2x relative to that of the 802.16e reference system. The aggregate TCP capacity is defined as the sum of the TCP goodputs of all the users in a sector. It is measured above the TCP layer.]

7.8 [Enhanced Location-Based Services (LBS)]

[IEEE 802.16m systems should provide support for enhanced LBS. The IEEE 802.16m should satisfy the following requirements:

Table 26. VoIP Requirements

Feature	Requirement	Comments
Location based services	Location Determination Latency < 1 s	To maintain session/call connectivity at high vehicular speeds
	Position Accuracy 50-250 m	Need to meet E911 Phase II Requirements

]

8.0 Deployment-related requirements

Color	Section 8 Source Document Authors	Section 8 Source Document Reference
Blue	San Youb Kim, et. al.	IEEE C802.16m-07/034
Brown/Dk Red	Sassan Ahmadi, et. al.	IEEE C802.16m-07/045
Violet	Xin Qi, et. al.,	IEEE C802.16m-07/026
Rose	Sunil Vadgama et. al.	IEEE C802.16m-07/047r1
Green	Jin Sam Kwak et.al	IEEE C802.16m-07/040
Red	Dan Gal, et. al.	IEEE C802.16m-07/011
Orange	Mark Cudak, et. al	IEEE C802.16m-07/019
Dark Yellow	Phil Orlik	IEEE C802.16m-07/016
Gold	Michael Webb et. al.	IEEE C802.16m-07/023

8.1 Legacy Support – All Legacy support items moved to section 5

8.2 Spectrum Requirements

[IEEE 802.16m should be optimised to support contiguous spectrum allocations]

[IEEE 802.16m should be suitable for deployment both in spectrum already identified for IMT radio access technologies (RATs), and for any additional spectrum identified for IMT RATs by ITU (e.g. at WRC 2007)]

[The IEEE 802.16m shall be possible to operate standalone, i.e. there is no need for any other carrier to be available.]

[IEEE 802.16m should offer better frequency assignment support by allowing [better] finer granularity. This would facilitate an optimized utilization of variable spectrum block sizes. Optimization/adaptation of channel bandwidth should also utilize the OFDMA capability to switch off channel-edge sub-carriers.]

[The IEEE 802.16m standard shall provide MAC and PHY support to enable Flexible Spectrum Use (FSU) between different IEEE802.16m systems e.g., frequency sharing between homogeneous 802.16m networks of different operators and be able to share or reutilize the bandwidth with the legacy systems. [Where possible, IEEE 802.16m should support frequency sharing with other communication systems, at least other IMT-Advanced networks.]
Flexible Spectrum Use should enable the use of [paired and unpaired spectrum] and [scattered spectrum].

8.3 System Architecture

Modern standards are global in scope and aim at serving a variety of market environments, each with its own set of individual requirements, characteristics and limitations. The requirements imposed by different markets, often result in a variety of deployment situations, such as:

- Small-scale to large-scale (sparse to dense radio coverage and capacity)
- Urban, suburban and rural deployments [including macro, micro and femto environments]
- both out-door and in-building applications
- Hierarchical, flat, or mesh network topologies, and their variants
- Co-existence of fixed, nomadic, portable and mobile usage models

In order to allow the greatest flexibility to accommodate such a broad range of deployments, specific requirements on the network architecture imposed by PHY/MAC shall be minimized.

[IEEE 802.16m should support, and be optimized for, an All IP and Ethernet architecture. It should support the various flavors of IP and Ethernet architecture: One-node and two nodes Radio Access Network (RAN) architecture.]

[The 802.16m shall provide a protocol-independent packet convergence sublayer that supports multiple protocols over 802.16m air interface.]

[Furthermore, where feasible and not excessively complex, in order to maximize system performance, both inter-BS diversity and simplex (no soft handover, but with fast cell switching capability) options should be supported.]

[The 802.16m should be able to support advanced Macro Diversity techniques such as Network MIMO, if practical ways can be devised to incorporate them.]

[The 802.16m amendment shall support all the Network Control and Management Services (NCMS) network elements and procedures described in the IEEE 802.16g amendment.]

8.3.1 BS Cell size

Editor's note: Exact deployed cell size should match cell coverage numbers in Section 7.4, once these values are decided

A wide range of cell radii from [tens of meters] up to [tens of Kilometers] [30 km] should be supported. [The focus shall be on cellular infrastructure deployments with typical cells sizes of 100 meters to several Kilometers.] Larger cell sizes,[10 - 30 km] should be supported with limited degradation to the performance of smaller cells. Cell sizes up to 100 km should not be precluded from the standard. In Addition, IEEE 802.16m shall support legacy cell sizes allowing for co-location of IEEE 802.16m deployments.

8.3.2 Support for Multi-hop Relay

The IEEE 802.16m amendment should provide schemes for coverage extension or filling coverage holes. Support for [scaled-up] [native] Multi-hop Relay devices should be included in the IEEE 802.16m architecture.[However, the system requirements described in this document shall be met without the use of the schemes.][The IEEE802.16m standard shall support in-band multi-hop relay radio link in all cell types supported within the IEEE802.16m standard.]

[The IEEE 802.16m standard shall support in-band base station backhaul.]

[The IEEE802.16m standard shall support legacy IEEE802.16j relay stations.] . [IEEE802.16m standard shall enable IEEE802.16m base stations to support legacy IEEE802.16j relay stations without degradation to the performance of the multi-hop relay radio links. IEEE802.16m standard shall enable IEEE802.16m relay stations to efficiently operate with legacy IEEE802.16j base stations and IEEE802.16e mobile stations without degradation to the overall radio performance compared to the legacy IEEE802.16j system.]

[The Physical and MAC layer design of the 802.16m must allow for the deployment of relays including multi-hop relay. Communication between different relay nodes in the same tier (in a tree-like topology) shall not be precluded]

8.4 System Migration

[The IEEE 802.16m amendment shall provide for a smooth migration from legacy IEEE 802.16e systems to IEEE 802.16m deployments. To achieve this goal, the following requirements are applicable:

- IEEE 802.16m and IEEE 802.16e mobiles shall be able to coexist on the same RF carrier.
- All IEEE 802.16m enhancements shall be transparent to a legacy IEEE 802.16e terminal.
- IEEE 802.16m cell sites shall be able to operate in a 16m mode while adjacent to legacy IEEE 802.16e cell sites.
- IEEE 802.16m cell sites shall not cause significant degradation to the performance of the adjacent IEEE 802.16e cell.
- Handoff between legacy IEEE 802.16e cell sites and IEEE 802.16m cell sites shall be supported and efficient. The efficiency should be equivalent to legacy IEEE 802.16e handoffs.
- IEEE 802.16m amendment shall allow the handoff from an IEEE 802.16e operating mode on a legacy BS directly into an IEEE 802.16m operating mode on IEEE 802.16m BS.

The above requirements provide for a smooth cell-site by cell-site migration strategy.]

[The IEEE 802.16m system may be deployed without an underlying legacy network. In this case, while the standard and implementations remain fully backward compatible, the deployment may be optimized for the new IEEE 802.16m terminals.]

8.5 [Synchronization]

[Synchronization between different BSs shall be required, at least for TDD mode.]

9.0 Usage Models

Color	Section 9 Document Source	Section 9 Document Reference
Red	Jean-Pierre Balech et. al	IEEE C802.16m-07/52
Orange	Mark Cudak et. al.	IEEE C802.16m-07/020
Blue	Sang Youb Kim	IEEE C802.16m-07/035
Pink	Jianmin Lu et.al.	IEEE C80216m-07/028
Brown	Sassan Ahmedi et. al	IEEE C802.16m-07/46

.

[The IEEE 802.16m air interface, as an amendment to the existing IEEE 802.16-2004 and IEEE 802.16e-2005 standards, shall support a wide range of deployment scenarios and usage models including

a) those considered during formulation of the existing standards and b) as envisioned by IMT-Advanced requirements. The examples provided in this section are informative only.

The Standard should support different usage models. More specifically, it should cover (but not be restricted to)

1) Higher data rates and improved performance (compared to 802.16e) in legacy cell sizes (of several kilometers radius).
2) Very high data rates in smaller cells
3) High mobility optimized scenarios
4) Deployment with Multi-hop Relay Networks
5) Co-Deployment with Other Networks
6) Provision for PAN/LAN/WAN Collocation / Coexistence

This section is informative only. It includes service and application scenarios and deployment scenarios. The deployment scenarios described in the following sections include topologies networks and frequency reuse schemes where 802.16m terminals and base stations are exclusively used, where a mix of 802.16m and 802.16e (migration from legacy to new systems), a scenario where fixed and mobile relay stations (used for coverage and throughput enhancements) are used and a scenario optimized for high mobility. It also describes deployments with other systems.]

9.1 [Service and Application Scenarios]

[The types of services that can be provided by IEEE802.16m-based packet-switched network can include:

- Voice services (e.g., VoIP)
- Data services (e.g., Email, IMS, web browsing, file transfer, internet gaming)
- Multimedia services (e.g., Audio and/or video streaming, broadcast, interactive conferencing)

Section 5.7 provides details on the class of services for next generation of mobile networks.

The type of end users can include:

- Personal use (e.g., mobile internet)
- Business/Enterprise use (e.g., backhaul, VPN)
- Special use (e.g., dedicated network for public safety needs)

End users anticipate new services, new features, and new devices for IMT-Advanced. For example, HDTV plasma screens will be popular for notebook type of devices. Real-time gaming or Real-time video streaming service over high definition screens will be a typical service in the future. High priority E-commerce, telemetric, Broadcast/Multicast for TV, news, and advertisement over the handheld will be popular services as well.]

9.2 [Deployment Scenarios]

[The IEEE 802.16m radio access technology shall be suitable for deployment in a number of propagation environments including

- Outdoor environments including outdoor-to-indoor environments (e.g., rural, urban, suburban)
- Indoor environments (e.g., hot-spot, overlay for improved coverage and/or capacity)

The end users in an IEEE80.16m-based network also shall be supportable with different levels of mobility including

- Fixed/Stationary (e.g., CPE with fixed antenna)
- Pedestrian or quasi-static (e.g., portable devices)
- Mobile (e.g., handsets)]

9.2.1 [Frequency Reuse]

[In the usage model example of cellular networks, a network coverage area can be served by a number of Base Stations (BS), each of which may further contain a certain number of sectors. For areas that need enhanced coverage or require additional throughout, additional IEEE 802.16m-based BS's can be overlaid onto existing 802.16e reference system topologies.

Cellular deployment scenarios specify the pattern of RF channel (or carrier) usage in terms of a "frequency reuse factor" which is a factor of the total spectrum size allocated to it. RF channels are assigned to different cells (i.e. BS sites) or sectors and this allocation can be repeated across adjacent sites or adjacent cluster of sites throughout the network. The resulting frequency reuse can be indicated as the triplet (*c, s, n*) where *c* is the number of BS sites per cluster, *s* is the number of sectors per BS site and *n* is the number of unique RF channels needed for reuse. Typical examples of reuse (1,3,1) and (1,3,3) are shown in Figure 9.1 and 9.2.

As in the existing 802.16e reference network, the 802.16m system may allow each sector to use only a non-overlapping part of the spectrum thus creating an equivalent reuse pattern. For example in PUSC permutation of 802.16e, the whole band is divided into six major groups and the FCH (Frame Control Header) message of each sector contains a bitmap that indicates the major groups usable to that sector. If the major groups are divided equally to three sets, a reuse pattern equivalent to (1,3,3) will be created. Sometimes, the PUSC frequency reuse is referred to as "in-band" reuse.

In the reference system it is also possible to have a different reuse pattern in different zones. For example for MBS (Multicast and Broadcast Service) deployment a (1,3,1) pattern can be used while the other data service can still use (1,3,3) reuse pattern.

The 802.16m system may offer a similar degree of flexibility.

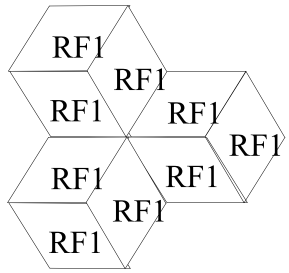
As a convention, it is recommended to describe the patterns of the channel and the different zones by a notation (*c,s,n/k*), with *k* indicates the effective reuse factor of each zone. Thus (1,3,1/1) indicates a full re-use pattern of all zones, while (1,3,1/3) indicates 1 unique RF channels segmented to 3 to produce an effective re-use 3 in a given zone.

It is expected that tight spectrum constraints may limit the number of unique frequency channels allocated to a given deployment, thus the IEEE 802.16m amendment may support the deployment modes as described in the following subsections, all are of a very small spectrum allocation:]

9.2.1.1 [Single RF channel allocation, (1,3,1) frequency re-use pattern]

[(1,3,1) : In this allocation each cluster comprising one BS site. Each BS site has three sectors and all sectors are assigned the same RF channel

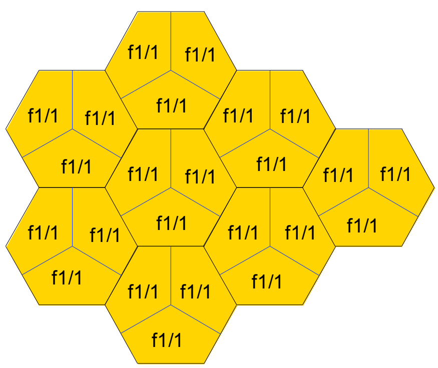
Examples of (1,3,1) Frequency Reuse is given in Figure 9.1.



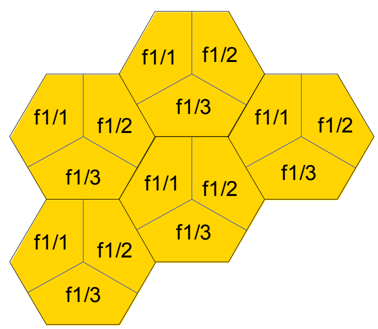
(1,3,1) Frequency Reuse

Figure 9.1 — Example of (1,3,1) frequency reuse.

A comparison of an in-band reuse (1,3,1/3) to a full band re-use (1,3,1/1) pattern is given in Figure 9.2, where in each cell the notation f_i/s_i indicates the RF channel (f_i) and the segment number s_i of the particular sector. Fig. 9.2a shows a (1,3,3) re-use with the same segment allocated to each sector, while Fig. 9.3b shows the same re-use pattern with different segments allocated to each sector.



(a) Full re-use 1 identical segments (1,3,1/1)



(b) Full re-use 1 different segments (1,3,1/3)

Figure 9.2 : (1,3,1) Frequency Reuse Patterns

]

9.2.1.2 [Three RF channels allocation, (1,3,3) and (3,3,3) frequency re-use pattern]

[With three RF channels allocated, one can distinguish between two different patterns:

- (1,3,3) : in which each cluster comprising one BS site. Each BS site having three sectors where each of the three sectors is assigned a unique RF channel, as depicted in Figure 9.3

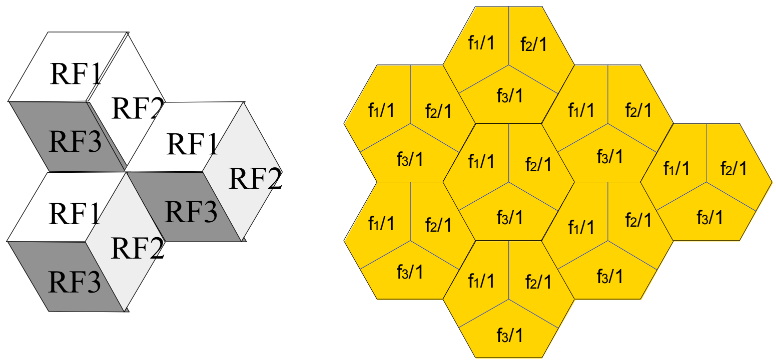


Figure 9.3 — Examples of (1,3,3) frequency reuse, with different sector orientations.

- (3,3,3) 3 BS per cluster, 3 sectors per BS and 3 unique RF channels. Each BS is assigned a single RF channel, as depicted in figure 9.4

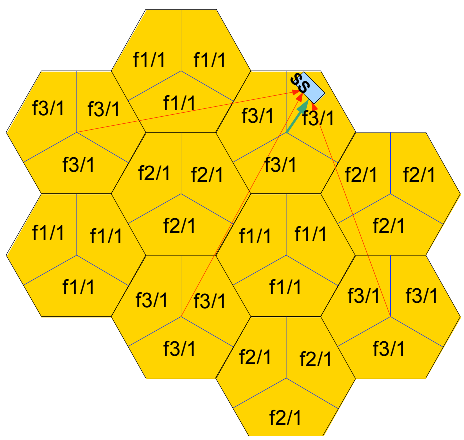


Figure 9.4: Frequency reuse pattern (3,3,3) with no segmentation in each BS]

9.2.1.3 [Reuse patterns with 4 and 6 sectors]

[Increasing the number of sector may improve the system performance and reduced interference between a sector and a close by cell. It however adds burden to the handover process. Still, multiple sector base stations may be of use. Thus one can define the following re-use patterns.

(1,6,3) :1 BS per cluster, 6 sectors per BS Site, 3 unique RF channels
(1,4,2) : 1 BS per cluster, 4 sectors per BS Site, 2 unique RF channels
(1,4,1) :1 BS per cluster, 4 sectors per BS Site, 1 unique RF channel
(1,6,1) : 1 BS per cluster 6 sectors per BS site, 1 unique RF channel]

9.2.1.3 [Additional consideration for frequency reuse pattern selection]

[Another factor that should be taken into account is the spatial planning. Even though a reuse 1 deployment with full use of sub-carriers that is described in this section does not require frequency planning, it could be impacted by the antenna's orientation of different sectors. In case of frequency deployment shown in Figure 9.1, the number of interfering sectors for every tone is not influenced by the BS's orientation, but the interference power per tone could be influenced by it. This effect is much

more significant for the interference levels for the zones which have a higher re-use factor (see Figure 9.5 for illustration of spatially unplanned preamble deployment).
As a convention, it is recommended adding an additional letter, 'p' or 'u', at the beginning of the notation. indicating weather the deployment is spatially planned or not For example the deployments in Figure 9.1 and Figure 9.5 can be described as p(1,3,1) and u(1,3,1/3) respectively. Note that in practice frequency planning and spatial planning must be performed jointly and cannot be separated into two different tasks.

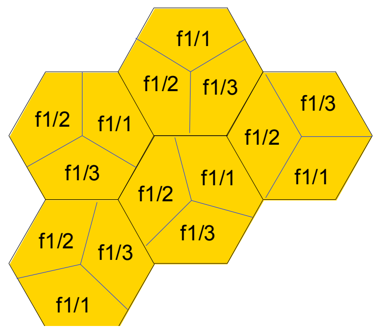


Figure 9.5: Frequency reuse pattern on preamble sub-carriers for Scenario I with different segment numbers in case of spatially unplanned antennas.

In the existing IEEE 802.16e reference system, use of partial loading (for example using only 1/3 of the sub-channels) can help reduce interference in zones which use different permutation base. Similarly, the IEEE 802,16m air interface should be considered as a function of the system load.]

9.2.2 [Co-Deployment with Other Networks]

[The IEEE 802.16m amendment is anticipated to be deployed in the same RF carrier as the legacy network (refer to the Section 5.1 and 8.1). Moreover, it is also envisioned that the IEEE 802.16m air interface can be deployed in the same or overlapping geographical areas with other wireless networks based on different RAT (Radio Access Technologies). These non-802.16 networks may operate in the neighboring licensed frequency bands such as CDMA2000, 3GPP (e.g., GSM, UMTS, LTE) or in unlicensed bands such as 802.11x networks. They may or may not have the same network topology. Coexistence of networks specified on the basis of the IEEE 802.16m amendment with these networks must be guaranteed from the perspective of being both an interferer and being a victim. Inter-working in the form of handoff as described in Section 7 is also expected. A possible deployment of IEEE 802.16m with legacy system is depicted in figure 9.5

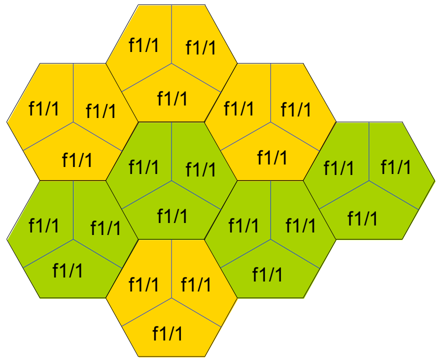


Figure 9.5: Possible deployment of 802.16m with legacy systems, with a similar re-use pattern]

9.2.3 [Deployment with Multi-hop Relay Networks]

[This scenario (shown in 9.6 is an example of IEEE 802.16m deployments (network topologies) that include fixed and/or mobile relays for coverage extensions and filling coverage holes and throughput improvement. The air-interface between the mobile stations and the relay stations will be in the IEEE 802.16m amendment (some deployment scenarios may include IEEE 802.16e based air-interface). The performance evaluation of the proposals containing fixed or mobile relay stations shall follow the evaluation methodology defined by IEEE 802.16j Relay Task Group for mobile multi-hop relay networks [6].

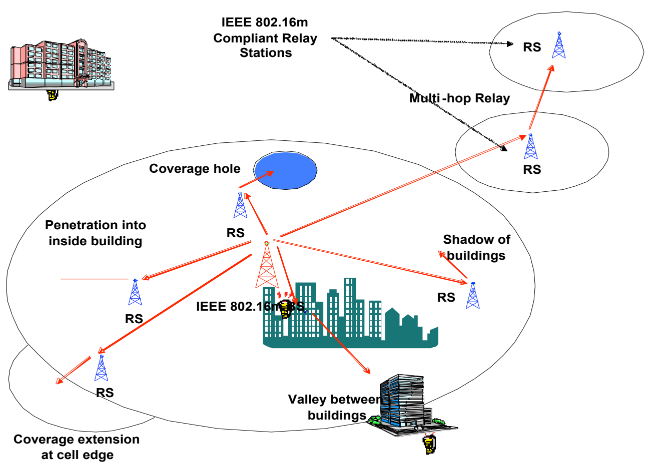


Figure 9.6: IEEE 802.16m with multi-hop relay networks (the RS can be fixed or mobile depending on the usage and deployment specifics).

]

9.2.4 [High Mobility Optimized Scenario]

[The system or one mode of the system needs to provide services to high-speed users. In this scenario mobile terminal speeds range from 200 to 300kmph with likely large penetration losses in a large and irregular coverage area. The service environment may dynamically and rapidly change and differentiated service with high granularity may be required. The air interface shall be optimized and balanced between reducing link level maintenance overhead and providing optimized burst profile and handover performance.]

9.2.5 [Provision for PAN/LAN/WAN Collocation / Coexistence]

[As a provision for proper operation of various wireless access technologies on multi-radio terminals, the IEEE 802.16m should provide (measurement / report / radio resource allocation) methods to mitigate interference from other wireless radios on the same (collocated) device given minimum adjacent channel isolation. As a result, IEEE 802.16m radio will not suffer from interference from other wireless devices, or cause destructive interference to other wireless devices. Currently, Wi-Fi and Bluetooth radios are likely to coexist/collocate with an IEEE 802.16m radio.]