Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Combined Draft IEEE 802.16m Requirements (For Information Only)**
Date Submitted	**2007-03-05**
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Re:	Call for contributions on requirements for P802.16m-Advanced Air Interface, 2007-01-29
Abstract	This document is provided to the working group as a courtesy of the drafting group. The document blindly combines all the contributions responding to the call for requirements for P802.16m-Advanced Air Interface of 29 Jan 2007. The contributor's text is color coded by section. A key is provided at the top of each major section. IEEE 802.16 working group members may use this document as a reference when reviewing the official output of the drafting group IEEE C802.16-07/10r1.
Purpose	For information only.
Notice	
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To Working Group Members:

The 16m requirements drafting group has completed its work consolidating the numerous input contributions received on 23 Feb 2007. We have created two documents. The first is the draft requirements document and what we consider to be our official output. The draft requirements have been uploaded as contribution IEEE C802.16m-07/076. The second is a consolidated version capturing all unedited inputs in one document for informational purposes only. This second information version has been uploaded as IEEE C802.16m-07/058 (this document).

As stated, IEEE C802.16m-07/076 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 some cases, we had multiple contributions capturing similar but conflicting thoughts. In these cases the drafting group created an editor's text proposal, as a baseline, for these areas. The editor's text proposal attempted to capture the requirements that we believe were easily agreeable to all contributors. 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. We were extra careful when we were capturing numerical requirements. We strove not to omit any numerical position. However, we did try to present the various numerical requirements in common units. In several cases, we tried to consolidate the input into common tables capturing all positions. In addition, we avoided any superfluous text that did not communicate a requirement.

IEEE C802.16m-07/076 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 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. Text that is unbracketed represents text that the drafting group felt acceptable to all in the working group. Conversely, the bracketed represents text that the drafting group did not see as universally supported.

The drafting group recommends that the working group accept all unbracketed text. The drafting group further suggests that the working group review all the remaining bracketed text and then make decision as to whether to accept it, accept it with modification or simply reject it.

In Section 1-8, the drafting group did its best to be inclusive and follow the editing guidelines stated above. In Section 9, we were short on time and accepted a more ambitious editorial style. As a result, we have bracketed all of Section 9.0 and leave it for the working group's review.

IEEE C802.16m-07/058 is provided to the working group as a courtesy of the drafting group. The document blindly combines all the contributions responding to the call for requirements for P802.16m-Advanced Air Interface of 29 Jan 2007. As with IEEE C802.16m-07/076, the contributor's text is color coded by section. A key is provided at the top of each major section. IEEE 802.16 working group members may use this document as a reference when reviewing the official output of the drafting group IEEE C802.16m-07/076.

Best Regards,

Mark Cudak
On behalf of 802.16m Requirements Drafting Group

Combined Contributions for IEEE 802.16m Requirements

1.0 Overview

Editor's notes:

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

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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 to meet the requirements of next generation mobile networks. This standard is intended for incorporation into the IMT-Advanced standardization activity being conducted by International Telecommunications Union – Radio Communications Sector (ITU-R). The amendment is based on the WirelessMAN-OFDMA specification and provides continuing support for legacy subscriber stations.

IEEE 802.16m provides an advanced air interface to meet the requirements of next generation mobile networks. This standard is intended for incorporation into the IMT-Advanced standardization activity being conducted by International Telecommunications Union – Radiocommunication Sector (ITU-R). IEEE 802.16m is based on the WirelessMAN-OFDMA specification and provides continuing support inter-operability for legacy WirelessMAN-OFDMA equipment.

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

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

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This document captures the system requirements for 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.

This amendment 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 amendment 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 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).

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

[2] IEEE Std 802.16-2004: IEEE Standard for Local and metropolitan area networks Part 16: 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 for Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands, December 2005.

[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 for Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands, 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

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

[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] WINNER - WIRELESS WORLD INITIATIVE NEW RADIO: Intermediate requirements per scenario, D 1.2, February 2005 (https://www.ist-winner.org/).

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

[7] IEEE C802.16m-07/002: Draft IEEE 802.16m Requirements, January 2007.

[8] IEEE 802.16m PAR

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

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

3.0 Definitions

[Editorial additions]

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 Terminal: 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 802.16m Terminal: 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

[Editorial additions]
[CALEA Communications Assistance for Law Enforcement Act of 1994]

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
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

Editor's notes:

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

Black - Original text

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.

5.1 Legacy Support

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

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

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The amendment provides continuing support for legacy subscriber 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*.

IEEE 802.16m provides continuing support and inter-operable for legacy WirelessMAN-OFDMA equipment. 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*.

IEEE 802.16m is based on the IEEE Standard 802.16 WirelessMAN-OFDMA specification. The amendment provides continuing support for legacy subscriber stations. In order for IEEE 802.16m specification to support legacy subscriber stations, a method to guarantee backward compatibility shall be provided, while satisfying ITU-R requirements. ~~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 profile is defined, for purposes of this document as the *802.16e reference system*.~~ Up to 20MHz within the spectrum band(s), where the IEEE 802.16m might be deployed, shall be IEEE 802.16e backward compatible for legacy IEEE 802.16 terminal support.

The IEEE 802.16m amendment is based on the WirelessMAN-OFDMA specification. The amendment provides continuing support for legacy subscriber stations. This continuing support shall be limited only to 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]. The WiMAX mobile system profile shall serve as the 802.16e reference system.

The amendment provides continuing support for legacy subscriber stations. *[HS1]*

A legacy 16e terminal, compliant with the IEEE 802.16e reference system, shall be able to operate with a new 16m BS with no degradation of performance.

A legacy IEEE 802.16e terminal, compliant with the IEEE 802.16e reference system, should be able to operate with a new 16m BS with no degradation of performance.

An ~~legacy~~IEEE 802.16e terminal~~, compliant with the IEEE 802.16e reference,~~ shall be able to operate with an ~~new~~ IEEE 802.16m Base Station with no degradation of performance.

An IEEE 802.16m BS shall be able to support an IEEE 802.16e terminal if operating in the same band with minimal degradation of performance.

A 802.16m BS shall support an 802.16e terminal with no degradation of performance.

An 802.16m BS shall support an 802.16e terminal with no degradation of performance.

A new 16m terminal shall be able to operate with a 16e BS, compliant with the IEEE 802.16e reference system, at a level of performance that is no worse than the 16e terminal.

A new 16m terminal shall be able to operate with a 16e BS, compliant with the 802.16e reference system, at a level of performance that is no worse than the 16e terminal.

A new IEEE 802.16m terminal should be able to operate with a IEEE 802.16e BS, compliant with the IEEE 802.16e reference system, at a level of performance that is no worse than the IEEE 802.16e terminal.

An ~~new~~ IEEE 802.16m terminal shall be able to operate with an IEEE 802.16e Base Station~~, compliant with the IEEE 802.16e reference,~~ at a level of performance that is no worse than ~~the~~ an IEEE 802.16e terminal.

A 802.16m terminal shall be able to operate with an 802.16e BS, at a level of performance equivalent to that of a 802.16e terminal.

The IEEE 802.16m solution must be able to support migration of actual networks towards IMT-Advanced systems.

The IEEE802.16m should enable the graceful update and evolution of infrastructure from the IEEE 802.16e system to minimize the cost of platform migration.

802.16m and 802.16e systems shall be able to operate on the same RF carrier on a 802.16m BS supporting a mix of 802.16m and 802.16e terminals.

The performance of such a 802.16m system should be proportional to the fraction of 802.16m terminals attached to the BS.

All IEEE 802.16e terminals referred herein in this document shall be compliant with the 802.16e reference system.

The 16m amendment to the “dot 16” standard shall include mechanisms to support operation of 16e OFDMA terminals by “16m” base stations in the same frequency channel used for 16m operation. This requirement should also apply to the case when the 16m terminal operates at a channel bandwidth larger than that of the 16e terminal when both are served by the same BS and the same carrier.

Interoperation between 16m base stations and 16m, or 16e terminals, that have a smaller bandwidth than that of the base station, shall be supported within the same carrier used by the base station.

16e and 16m terminals shall interoperate when served by either a 16m base station or a 16e base station.

To facilitate the above requirements, a 16m terminal should be allowed to be a multimode device.

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

5.2 Complexity

PHY/MAC should enable a variety of hardware platforms with different performance/complexity requirements.

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PHY/MAC should enable a variety of hardware platforms with different performance/complexity requirements. However, it is required to minimize complexity of the architecture and protocols and to avoid excessive complexity of systems and interoperability of access networks. IEEE802.16m should also to enable to support low cost device with total cost of ownership.

IEEE 802.16m system shall satisfy the required performance. In addition, the system complexity shall be minimized by adhering to the following:

a) Minimize the number of options

b) No redundant mandatory features

The IEEE 802.16m Requirements 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-A. 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.

IEEE 802.16m amendment should enable a variety of hardware platforms with different performance/complexity requirements. The system and terminal complexity shall be minimized to decrease the cost of terminals and the RAN.

Therefore, the following shall be taken into account:

- The performance requirements shall be met with mandatory features only
- Minimum number of optional features may be considered only if they provide significant functional and performance improvements over baseline configuration.

- Support of multiple features, mandatory or optional, which are functionally similar and/or have similar impact on performance, shall be avoided.
- Standard changes should focus on areas where the 802.16e reference system can be enhanced to meet the requirements.
- Reduce the number of necessary test cases, e.g. reduce the number of states of protocols, and minimize the number of procedures, appropriate parameter range and granularity.

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 is applicable to enhancements to the downlink/uplink maps, frame structure and message formats.

5.3 Services

IEEE 802.16m architecture shall be flexible in order to support required services from ITU-R.

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

IMT-Advanced QoS requirements shall be supported including end-to-end latency, throughput, and error performance.

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IEEE 802.16m system shall provide powerful and efficient security mechanism to protect the network, system, and user.

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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.

IEEE 802.16m shall be flexible in order to support required services from ITU-R and to ensure QoS levels for different services with secure and reliable security.

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

- VoIP
- IPTV

- Real-time gaming
- Real-time high quality video streaming
- Internet-like Asynchronous Service
  - Fast interactive sessions
  - High priority E-commerce
- Large file exchanges
- Multimedia conferencing
- Multicast Broadcast for TV, news, or advertisement optimized for local area and wide area
- Trust based service such as built in VPN encryption
- MS position locating support and location based service

The system should support existing services more efficiently as well as facilitate the introduction of new/emerging types of services.

5.4 Operating Frequencies

The 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.

5.5 Operating Bandwidths

The IEEE 802.16m shall support scalable bandwidths of 5 to 20 MHz. Support for 802.16e bandwidths of 5, 7, 8.75, 10MHz shall be maintained. Performance for these bandwidths and 20MHz shall be optimized in the 802.16m system. Larger bandwidths such as 40 MHz may also be considered.
For the bandwidths larger than 10MHz, aggregation of multiple contiguous bands may be considered.

5.6 Duplex Schemes

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

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

The 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.
Asymmetric DL/UL bandwidths should be supported for FDD operations (e.g. 10MHz downlink, 5MHz uplink). At the extreme, the IEEE 802.16m system should be capable of supporting downlink-only configurations on a carrier.

5.7 Baseline Antenna Configuration

The IEEE 802.16m standard shall define minimum antenna requirements for the BS and MS. For the BS, 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 DL downlink configuration and a 1x2 UL configuration.

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

6.0 Functional Requirements

Editor's notes:

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

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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

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 two transmit and receive antennas be required of hand-held devices.

[The 802.16 m TG should include enhancements to the 802.16 MIMO and AAS modes within the scope of the project for the explicit purpose of increasing the capacity, aggregate link rates and spectral efficiency]

[Peak useful data rates up to 100 Mbit/sec for mobiles users]

[Peak useful data rates up to 1 Gb/s for stationary users]

[Interference Management/Avoidance]

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 two *RF chains* be required of hand-held devices. 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."

Peak useful data rates up to 100 Mbit/sec for mobiles users

Peak useful data rates up to 1 Gb/s for stationary users

The standard should allow modulation modes that allow stationary users to achieve 1 Gb/s. 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.

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 antenna and two receive antennas be required of hand-held devices. The same considerations impact supportable higher order constellation order.

Accordingly, the minimum peak rate requirement supported by mobile stations compliant with the 802.16m specification, expressed as a peak rate spectral efficiency (i.e. absolute maximum supported data rate divided by the occupied channel bandwidth) is specified in Table X.

Link Direction	**Min. No. of Active MS Antennas**	**Min. No. of Spatial Sub-streams**	**Max. Modulation Order**	**Min. Peak Rate Spectral Efficiency (bps/Hz)**
Downlink (BS->MS)	2 (Receive)	2	64-QAM	6.5
Uplink (MS->BS)	1 (Transmit)	1	64-QAM	2.5

Table X – Requirements of peak spectral efficiencies.

Notes applicable to Table X:

1. The specified requirements of peak spectral efficiencies are not distinguished by duplex mode. Rather, 100% of radio resources are assumed – for the purposes of computing Table X – allocable to downlink and uplink respectively regardless of duplexing mode.
2. Table X specifies requirements of peak spectral efficiencies applicable to all devices supporting 802.16m. Modes offering further enhanced peak spectral efficiencies may, however, be specified.
3. Table X 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.
4. The specified minimum supported peak spectral efficiencies 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.)

The IEEE 802.16m standard 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.

The IEEE 802.16m standard shall provide data rates of at least 100 Mbps for mobile users and 200 Mbps for fixed or portable users. These data rates shall be defined as the sum of the data rates experienced by all active users on a given radio resource or channel in a given cell, exclusive of MAC and PHY overheads and regardless of user distribution within the cell.

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.

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 two transmit and receive antennas be required of hand-held devices.

[The 802.16 m TG should include enhancements to the 802.16 MIMO and AAS modes within the scope of the project for the explicit purpose of increasing the capacity, aggregate link rates and spectral efficiency]

Adaptive switching between different MIMO schemes (diversity and multiplexing, open-loop and close-loop) shall be supported.

[Peak useful data rates up to 100 Mbit/sec for mobiles users]

[Peak useful data rates up to 1 Gb/s for stationary users]

[Interference Management/Avoidance]

The supported peak data rate shall scale according to size of the spectrum allocation and antenna numbers.

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

Peak useful data rates shall be up to 1 Gbit/s for stationary users, if 100MHz bandwidth and 4*4 antennas are used.

Since new applications and new devices supporting high quality video streaming will be available for IMT-Advanced, bandwidth consumption is far more than today's consumption. Requirement of target peak data rate is

- At least 200 Mbit/sec for downlink traffic and at least 100 Mbit/sec for uplink traffic for high mobility
- At least 1 Gbit/sec for downlink traffic and at least 500 Mbit/sec for uplink traffic for fixed or nomadic.

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.

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

The IEEE 802.16m should include enhancements relative to the 802.16e reference system MIMO and AAS modes within the scope of the project for the explicit purpose of increasing the capacity, aggregate link data rates and spectral efficiency.

The requirements for peak data rates in the downlink and uplink are captured in the following table. For These requirements shall be met with the Baseline Antenna Configuration as defined earlier in this document. TDD systems, these requirements shall be calculated for the DL and UL based on 1:0 and 0:1 DL:UL ratios, respectively.

Requirements for peak data rate

Key Performance Characteristic	Required Value	Comments
DL Peak Data Rates		

Peak (stationary/indoor)	> 64 Mbps	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.
Peak (pedestrian)	> 64 Mbps	
Peak (vehicular)	> 40 Mbps	
Peak (stationary/indoor)	> 128 Mbps	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.
Peak (pedestrian)	> 128 Mbps	
Peak (vehicular)	> 80 Mbps	
UL Peak Data Rates		
Peak (stationary/indoor)	> 28 Mbps	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 UL > 10 Mbps, where average instantaneous implies average over the cell area.
Peak (pedestrian)	> 28 Mbps	
Peak (vehicular)	> 18 Mbps	
Peak (stationary/indoor)	> 56 Mbps	Assuming a 20 MHz operating bandwidth. This requirement shall be met with the baseline antenna configuration. Average Instantaneous Data Rate UL > 20 Mbps, where average instantaneous implies average over the cell area.
Peak (pedestrian)	> 56 Mbps	
Peak (vehicular)	> 36 Mbps	

Peak air interface data rates shall meet or exceed the minimum rates to be defined by the ITU-R for IMT-Advanced.
Note: At the present, the ITU-R Recommendation M.1645 [4] §4.2.5 envisions data rates (at the Cellular Level) has high as 100 Mbit/s for high mobility and 1Gbit/s for low mobility such as nomadic/local wireless access. M.1645 also states: "These data rates are targets for research and investigation. They should not be taken as the definitive requirements for systems beyond IMT-2000".

Peak rates

The peak rates depend, among other channel parameters, on the channel bandwidth. For 20 MHz channel, the terminal should be able to achieve a peak data rate in the range of 75 to 150 Mbit/s.. This is considered a maximum requirement in good channel conditions. For other bandwidths, the data rates shall scale accordingly. A base station sector should be able to achieve a peak aggregate data rate of up to 1 Gbit/s.

Duplex mode
Both TDD and FDD operation should be supported. In FDD operation, half-duplex terminals should also be supported.

DL/UL ratio
Symmetrical operation should be supported in addition to asymmetrical operation. To ensure maximum dynamic throughput, the UL/DL ratio should be configurable. In TDD mode, the UL/DL should be adjustable per frame. In FDD mode, the UL and DL channel bandwidths may be different and should be configurable.

Maximum allowed packet reception/transmission outage time
The outage time of user traffic packets, during handoff, shall be specified depending on the type of handoff mechanism and depending on the application type. At least two types of handoff mechanisms should be specified:
- Type-1 allows fast handoff 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 handoff times. Design target for Type-2 is 50 ms.

Trade-off between mobility and data rate
For mobility-performance classification purposes, the required performance values should be established for four mobility speed classes:
- 0 to 5 km/h: optimum performance.
- 5 to 60 km/h: high performance.
- 60 to 120 km/h: medium performance.
- 120 to 350 km/h: basic performance.

The acceptable performance rates for each class are TBD.

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.

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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 deliver of the MAC PDU appears in Table Y.

Link Direction	Max. Latency (ms)
Downlink (BS->MS)	20.0
Uplink (MS->BS)	20.0

Table Y – Maximum data latencies.

6.2.2 State Transition Delay

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.

6.2.3 Handover Delay and Interruption Times

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 1 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.

Handover Type	Max. Interruption Time (ms)
Non-real-time, Intra-Frequency	100.0
Non-real-time, Inter-Frequency	300.0
Real Time, Intra-Frequency	50.0
Real Time, Inter-Frequency	150.0

Table W – Handover maximum interruption times.

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

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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. IEEE 802.16m shall support less than 5 msec of latency for traffic packet and less than 100 msec of latency for signaling message.

Latency should be further reduced as compared to the 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.

Latency requirements for the system

Latency Metric	Requirement	Comments
IDLE_STATE to ACTIVE_STATE	< 100 ms	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).
SLEEP_STATE to ACTIVE_STATE	< 10 ms	
Transmission Latency – Uplink	< 10 ms	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 Latency – Downlink	< 10 ms	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.
Scheduling Latency – Uplink	< 15 ms	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.
Handoff interruption time (intra FA)	< 50 ms	The time between the point when an MS makes connection with a target handoff channel and when it breaks connection with its previous operating channel (Handoff between two sectors operating in the same frequency assignment).
Handoff interruption time (inter FA)	< 150 ms	The time between the point when an MS makes connection with a target handoff channel and when it breaks connection with its previous operating channel (Handoff between two sectors operating in different frequency assignments).
Initial System Entry Time	(a) < 5 s (b) < 60 s	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 (a) when the device is powered on in the same network it was operating last time (including neighboring cells), and (b) when the device is powered on in a new network.

IEEE 802.16m system shall support a considerably reduced latency for signaling or user traffics compared to the IEEE 802.16e system, considering the following latencies:

1) Latency for transition from Power saving mode to normal mode
   - Idle Mode transition latency: Transition delay from Idle Mode to when MS starts exchanging data with BS.
   - Sleep Mode transition latency: Transition delay until MS wakes up from sleep mode.

2) Data transmission latency: Delay between the start of a data packet at IP layer of MS/BS and the arrival of the data packet at IP layer of BS/MS.
3) Handover latency: Delay from when MS break the current connection with Serving BS to when the MS make a new connection with target BS.

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.

6.3 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.

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.

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.

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

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• provide enhanced management of different quality of service levels, and

• provide support for applications requiring IMT-Advanced system end user QoS requirements.

Relative to IEEE 802.16e reference systems, IEEE 802.16m shall

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

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 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]. The 802.16m amendment shall provide

- simultaneous support for a wide range of multimedia services,
- enhanced management of different quality of service levels

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.

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 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
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

- *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 1.

Table 1

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

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

6.4 Radio Resource Management

[IEEE 802.16m amendment shall support functions such as priority and preemption.]

[IEEE 802.16m amendment shall support regional regulatory needs including CALEA.]

The 802.16m amendment shall define methods for optimising base station and network selection, including selection based on application layer requirements, between 802.16 variants (specifically, 802.16e reference systems, and networks and base stations supporting the 802.16m amendment) and other radio access technologies (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 RAT's:

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

The system shall enable advanced radio resource management by enabling the collection of reliable statistics at different "scales", such as system (dropped call statistics), user (terminal capabilities, mobility statistics, battery life), flow, packet, etc.

The system 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.

The IEEE 802.16m standard shall provide MAC and PHY support to enable spatial scheduling techniques (SST). SST enables the allocation of independent spatial channels to multiple users on the same RF channel in the same time interval.

The IEEE 802.16m standard shall provide sufficient access channel (including bandwidth request and ranging) performance and capacity such that all bearer channel capacity can be fully utilized under worst case traffic profile assumptions (i.e. those associated with very bursty and intermittent traffic).

[IEEE 802.16m amendment shall support functions such as priority and preemption.]

[IEEE 802.16m amendment shall support regional regulatory needs including CALEA.]

6.4.1 Frequency Reuse Scheme

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.

6.4.2 Interference Management

IEEE 802.16m shall support advanced interference mitigation schemes.

6.4.3 Multi-cell Joint Resource Optimization

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

6.4.4 B/W Scalability

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

6.4.5 Interworking Between Different Access Systems

As specified in [4], IMT-Advanced expects to support coexistence of different radio access systems connected via flexible core networks. End-user is able to be connected via a variety of different access systems to the networks. Considering the fact, it is required for IEEE 802.16m to support interworking between different access systems in terms of seamless handover not only between intra access system but also between inter access system, QoS management, and efficient load balancing. In addition, IEEE802.16m should support the inter-access-system handoff with minimum interruption time and it should also support the inter-access system measurement for efficient radio resource management.

IEEE 802.16m should aim to optimize inter-networking the IEEE802 based access system, such as IEEE802.11.

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.

Functions such as priority and preemption shall be supported.

Regional regulatory needs including CALEA shall be supported to extent it impacts the air interface.

The 802.16m system shall provide more efficient radio resource allocation mechanism than the 802.16e system. The IEEE 802.16m system capacity should be scalable enough to be expandable easily.

The IEEE 802.16m shall provide radio resource management mechanism to support prioritized system access including emergency service.

6.5 Security

[Requirements for Secrecy and Privacy: More powerful, enhanced (high-speed/small-size and low-power) confidentiality and integrity protection for traffic transmission, control information; More efficient, robust user/device authentication scheme; Location privacy scheme; and Reliable and flexible service availability protection scheme]

[Requirements for Inter-working 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]

The system shall include a security function which provides the necessary means to achieve:

- Protection of system integrity
- Protection and confidentiality of user-generated traffic and user-related data
- Secure access to and secure provisioning of services provided by the system.

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.

[Requirements for Secrecy and Privacy: More powerful, enhanced (high-speed/small-size and low-power) confidentiality and integrity protection for traffic transmission, control information; More efficient, robust user/device authentication scheme; Location privacy scheme; and Reliable and flexible service availability protection scheme]

[Requirements for Inter-working 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]

The supported peak data rate shall scale according to size of the spectrum allocation and antenna numbers.

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

*Peak useful data rates shall be up to 1 Gbit/s for stationary users, if 100MHz bandwidth and 4*4 antennas are used.*

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.

Requirements for secrecy and privacy shall support more efficient, enhanced confidentiality for traffic transmission and integrity protection for control information. It is also required for support efficient, robust user/device authentication scheme, location privacy scheme, and reliable/flexible service availability protection scheme.

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 following are the requirements for Secrecy and Privacy:

- Confidentiality and integrity protection (encryption) for traffic transmission, MAC management messages, and control information;
- Robust user/device authentication scheme; Location privacy scheme; and Reliable and flexible service availability protection scheme.

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.

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 Inter-RAT Mobility

The 802.16m amendment shall fully support ACTIVE mode handover between 802.16e reference base stations, and base stations supporting the 802.16m amendment.

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 820.16m amendments and the RAT's specified above.

6.7 Enhanced Multicast Broadcast Service (MBS)

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.

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

Table Z – MBS channel reselection maximum interruption times.

Note that requirements of Table Z 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 WW 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).

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

Table WW – MBS user-perceived maximum interruption times.

6.8 Location Based Services (LBS)

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 consumed by overhead, including overhead for control signaling procedures as well as overhead related to bearer data transfer, should be minimized.

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

6.12 Improved Location Determination and Broadcast-Multicast Efficiency

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

The 802.16m system should provide optimizations for efficiently delivery of broadcast and multicast services.

The performance requirements for location determination and broadcast and multicast services are captured under performance requirements.

7.0 Performance requirements

Editor's notes:

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

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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

Black	Editor	

[C802.16m-07/018r1]

The performance goal is specified in terms of spectral efficiency performance relative to 802.16e (WiMAX Release-1) baseline 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 1. The performance goals are specified separately for a data only and Voice over IP (VoIP) only system respectively.

Table 1. Performance metrics

Metric	Definitions
Sector throughput	$\frac{\text{good bits in } [0,T]}{T}$
User packet call throughput	$\frac{1}{K}\sum_{k=1}^{K}\frac{\text{bits in packet call k}}{(t_{end_k} - t_{arrival_k})}$
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)	$\frac{\text{Sector (DL/UL) Throughput}}{\text{Sector (DL/UL) BW}}$

[Note: The performance metrics in Table 1 shall be superseded by the definition in the Evaluation Methodology document.]

[C802.16m-07/033r0]

Performance goals should be specified in terms of relative performance relative to that of IEEE 802.16e reference systems.

[C802.16m-07/044r0]

The performance requirements are specified in terms of relative performance with respect to that of the 802.16e reference system. The following sections contain the requirements for mobile and base stations.

7.1 User throughput

[The average user-throughput in the downlink/uplink should be at least 2x enhancement over 802.16e reference system]

[95% of users should receive a 2x greater throughput over the 802.16e reference system]

[C802.16m-07/018r1]

The targets for average user-throughput and cell-edge user throughput of downlink/uplink for data only system for baseline antenna configuration is shown in Table 2. 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 **Error! Reference source not found.**.

Table 2. Data only system

Metric	DL Data (x 802.16e)	UL Data (x802.16e)
Average User Throughput	> 2x	>1.5x
Cell Edge User Throughput	> 2x	>1.5x

Note that the Cell Edge User Throughput is defined as the 5% 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 a 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.

[C802.16m-07/022r0]

The IEEE 802.16m standard shall provide Aggregate User Throughput according to the following table:

User Type	10 MHz Channel Bandwidth	20 MHz Channel Bandwidth
Fixed User	100 Mbps	200 Mbps
Mobile User	50 Mbps	100 Mbps

Aggregate User Throughput shall be defined as the total sustained throughput (uplink + downlink), net of MAC & PHY layer overheads, across all users scheduled on the same RF channel. These throughput requirements must be supported for all distributions of users in all regions 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).

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)

[C802.16m-07/033r0]
The average user-throughput in the downlink/uplink should be at least twice enhancement over IEEE 802.16e reference system.

[C802.16m-07/039r0]

Along with the average user throughput, the target user throughput for cell-edge users required for IEEE 802.16m shall be considered differently due to the potentially limited benefits from the key technologies, which might be deployed in IEEE 802.16m.

- The DL or UL average user throughput over a cell shall be at least 2 times that of the legacy 802.16e system.
- The 5 % point of CDF of user throughput shall be at least 2 times that of the 802.16 reference system in both DL and UL.
- The cell-edge user shall support the peak user throughput described in clause 6.1.

[Editor's Note: Move Definition to the definition part (Section 3.0) of the document]
Definition:

- User throughput : the number of information bits per second that a user can deliver or be received successfully.

[C802.16m-07/044r0]
The average user-throughput in the downlink and in the uplink of IEEE 802.16m system shall be at least 2x relative to that of the 802.16e reference system.

Note that the Cell Edge Throughput is defined as the 5% 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. This metric is separately provided for uplink and downlink.

[C802.16m-07/050r0]

Average rates
In a 20 MHz channel, the achievable average throughput, per terminal, in practical operational conditions (cellular environment, mobility effects, etc.) at typically required cell coverage, shall be at least 10 Mbps. 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).

PHY Improvements

Some improvements over the current 16e standard are required to increase performance in variable mobile user environments, mobility speeds and spectrum/bandwidth allocations. In particular, the service availability at the cell edge should be doubled (relative to "16e") for the 10-percentile of the cell-edge users. Such improvements should be accompanied by increased spectral efficiency. Example solutions include:

- Extended MCS range to support large channel loss
- Waveform adaptation depending on channel multi-path spread and Doppler
- Increase spectrum efficiency by:
    - Enhanced multiple antenna schemes including BF and MIMO.
    - Frequency and time optimised scheduling (water-filling)
    - Interference avoidance, or coordination methods, to achieve higher cell edge throughput, and more uniform service availability

7.1.1 Adaptability to a wide range of user speeds

- High speed need large overhead for reference symbols and signalling
- In low speed environments, higher spectrum efficiency can be achieved
    - By lowering signalling and reference symbols overhead, or increase channel estimate (including channel sounding needed in CL MIMO)
- Cognitive methods should be used to get knowledge of users characteristics, and adapt the transmission format, receiver algorithms and sounding periodicity accordingly

MAC Optimization

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.

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.

[Spectral efficiency in the range of 8-10 bps/second/Hz/cell will 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.]

[Average downlink/uplink sector throughput should be at least 2 x 802.16e reference systems]

[C802.16m-07/013r1]

- Spectral Efficiency (bps/Hz/cell(sector))
  - Effective channel bandwidth
    - The effective bandwidth used in UL and DL
    - Example:

$$\text{DL effective channel bandwidth} = \text{channel bandwidth} \times \frac{\text{DL frame length}}{\text{DL frame length} + \text{UL frame length}}$$

  - M
aximum spectral efficiency
    - The ratio of the maximum throughput (ruling out all PHY/MAC overhead) supported by the BS in a single cell (sector) divided by the effective channel bandwidth

  - Average spectral efficiency
    - The ratio of the average throughput (ruling out all PHY/MAC overhead) supported by a BS in multicell environment divided by the effective channel bandwidth

[C802.16m-07/015]

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.

[Spectral efficiency in the range of 8-10 bps/second/Hz/cell will 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.]

[Average downlink/uplink sector throughput should be at least 2 x 802.16e reference systems]

Comment: Remove brackets around second paragraph above as a spectral efficiency of 8-10 bps/second/Hz/Cell will certainly be required to meet data rate requirements of IMT-Advance**d. **Also I believe this is nearly 2x the efficiency of 16e thus the second bracketed sentence may be removed.

Spectral efficiency in the range of 8-10 bps/second/Hz/cell will 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.

[C802.16m-07/018r1]

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. The targets for data and voice spectral efficiency for baseline antenna configuration over 802.16e (WiMAX Release-1) system is shown in Table 3.

Table 3. Data only system

Metric	DL (x 802.16e)	UL (x802.16e)
Data Spectral Efficiency (bps/Hz/sector)	> 2x	>1.5x
VoIP Spectral Efficiency (Erlangs/MHz/sector)	> 2.5x	>2.5x

[C802.16m-07/022r0]

The IEEE 802.16m standard shall provide spectral efficiency of at least 10 bps/Hz, where spectral efficiency shall be defined as:

Aggregate User Throughput in Mbps (defined above) / Channel Bandwidth (MHz)

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) assuming the following mix of user traffic:

- Fixed and nomadic (no mobility) – 70%
- Low speed mobility (up to 60 km/h) – 20%
- High speed mobility (over 60 km/h) – 10%

These spectral efficiency requirements shall be supported in a network utilizing a frequency reuse pattern of (1, 1, s). Frequency reuse is indicated as (*c, n, s*) where *c* is the number of base station sites per cluster (i.e. 1), *n* is the number of unique RF channels needed for reuse (i.e. 1), and *s* is the number of base station sectors per base station site.

[C802.16m-07/033r0]

IEEE 802.16m 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.

Spectral efficiency of 10 bits/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.

IEEE802.16m shall support the enhanced MBS with spectral efficiency greater than 2bit/sec/Hz at 95% tile coverage. IEEE802.16m shall support the VoIP capacity at 200 VoIP-calls/MHz.

[C802.16m-07/039r0]

The IEEE 802.16m shall at least meet the spectral efficiency in Table 1, which is defined as the ratio of the aggregate throughput excluding any overhead associated with PHY and MAC layer signaling to the system bandwidth under various mobility conditions on the assumption of 2×2 MIMO configuration. The system bandwidth is defined as a bandwidth occupied by the system excluding guard band.

Table 1. Spectral Efficiency for IEEE 802.16m (FFS)

Mobility	DL Spectral efficiency in bps/Hz/Sector	UL Spectral efficiency in bps/Hz/Sector

	Peak	Average*	Peak	Average*
3 km/h	6.0	2.0	3.5	1.2
60 km/h	4.2	TBD	2.5	TBD
120 km/h	2.4	1.5	1.5	0.9
300 km/h or higher	0.5	TBD	0.3	TBD

* : for full loading case

The spectral efficiency at relatively higher vehicular speeds than those shown above will degrade gracefully. Furthermore, it is highly demanded that the L1/L2 signaling overhead shall be optimized in order to achieve the requirements of spectral efficiency.

[C802.16m-07/044r0]

The requirements for the peak, sustained, and equal data spectral efficiencies and sector throughput for the mobile and base stations (whichever applies) are as follows. These requirements shall be met with the baseline antenna configuration. At least 50% improvement over the 802.16e reference system is required.

Performance Metric	Required Value	Comments
DL Data Rates		
Peak Spectral Efficiency/Sector (Full-Buffer Data Traffic)	> 6.4 bps/Hz/Sector	The maximum achievable number of successfully transmitted information bits per second per Hz that a sector can serve in a fully loaded network with full-buffer data traffic. This metric is separately provided for uplink and downlink by only considering the PHY-related (L1) overhead (separately for each link).
Sustained Spectral Efficiency (Full-Buffer Data Traffic)	> 7.5 bps/Hz/Cell	The number of successfully transmitted information bits per second per Hz that a site can serve for a given DL:UL ratio, given number of users, site-to-site distance, and a given fairness and delay criterion in a fully loaded network with full-buffer traffic. This metric is separately provided for uplink and downlink by considering both PHY- and MAC-related (L1+L2) overhead (separately for each link).
Sector Throughput DL:UL=2:1 for TDD duplex scheme, 10 MHz bandwidth	> 16 Mbps	The number of successfully transmitted information bits per second that a sector can serve for a given DL:UL ratio, 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. This metric is separately provided for uplink and downlink by considering both PHY- and MAC-related (L1+L2) overhead (separately for each link).
Equal Data Spectral Efficiency (bps/Hz/Sector)	> 2x the 802.16e reference system	It is the harmonic mean of the throughput divided by the band width. Assume total bandwidth W, # of users *N* with throughput *S1, S2, ... SN,* hence $SE_{ED}=(N/W)*1/(1/S1+1/S2+...+1/SN)$

UL Data Rates		
Peak Spectral Efficiency (Full-Buffer Data Traffic)	> 3 bps/Hz/Sector	The maximum achievable number of successfully transmitted information bits per second per Hz that a sector can serve in a fully loaded network with full-buffer data traffic. This metric is separately provided for uplink and downlink by only considering the PHY-related (L1) overhead (separately for each link).
Sustained Spectral Efficiency (Full-Buffer Data Traffic)	> 3.5 bps/Hz/Cell	The number of successfully transmitted information bits per second per Hz that a site can serve for a given DL:UL ratio, given number of users, site-to-site distance, and a given fairness and delay criterion in a fully loaded network with full-buffer traffic. This metric is separately provided for uplink and downlink by considering both PHY- and MAC-related (L1+L2) overhead (separately for each link).
Sector Throughput DL:UL=2:1 for TDD duplex scheme, 10 MHz bandwidth	> 4 Mbps	The number of successfully transmitted information bits per second that a sector can serve for a given DL:UL ratio, 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. This metric is separately provided for uplink and downlink by considering both PHY- and MAC-related (L1+L2) overhead (separately for each link).
Equal Data Spectral Efficiency (bps/Hz/Sector)	> 2x the 802.16e reference system	It is the harmonic mean of the throughput divided by the band width. Assume total bandwidth W, # of users *N* with throughput *S1, S2, ... SN,* hence $SE_{ED}=(N/W)*1/(1/S1+1/S2+...+1/SN)$

[C802.16m-07/050r0]

7.3 Mobility

[The IEEE 802.16m amendment shall include air-interface features that would enable the Seamless Mobility with legacy 802.16e reference systems. Handoff with other IMT-2000 standards shall also be given consideration. This requirement is intended to address additional air-link requirements beyond those covered by the IEEE 802.21 working group. For example, specific methods for scanning and system discovery should be considered as part of the 16m MAC. Finally, requirements for handoff of broadcast services shall also be defined.]

[IEEE 802.16m system shall provide seamless interworking with legacy radio access systems including legacy 802.16 systems.]

[The expectations for performance should tiered based on mobility speeds and prioritized in order to achieve the optimum overall performance]

[C802.16m-07/018r1]
Section 7
Mobility shall be supported across the 802.16m network. The 802.16m system should be optimized for low speed, and should support higher speeds with reasonable degradation. Table 4 summarizes the mobility performance.

Table 4. 802.16m mobility support

Mobility	Performance
Low (0 – 15 kmph)	Optimized
High (15 – 120 kmph)	Marginal degradation
Higher (up to 350 kmph)	System should be functional

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

Section 6
802.16m shall also support techniques and mechanisms to optimize delay and packet loss during handover between 802.16m and other broadband wireless and cellular systems including the WiMAX Release-1 (IEEE 802.16e), WiFi, cdma-2000-1x, GSM etc..

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.

[C802.16m-07/022r0] Section 6
The IEEE802.16m standard shall provide seamless mobility within and between all cell types in an IEEE802.16m system. The standard shall provide seamless mobility with legacy IEEE 802.16e reference systems. Handoff with other IMT-2000 standards is highly desirable.

[C802.16m-07/033r0] Section 6
IEEE 802.16m shall provide seamless interworking with other radio access systems including legacy IEEE 802.16 systems. Both the inter-networking and intra-networking support for IEEE802.16m shall provide the service continuity at minimum MS speed of 120km/h. The IEEE802.16m shall enable optimize the seamless mobility management and minimize the mobility handover interruption time. The IEEE802.16m shall support the required measurement and signaling for the inter-networking handoff, scanning and network discovery.

[C802.16m-07/039r0]
Section 7
The IEEE 802.16m shall be optimized for low vehicular speeds such as mobility classes from stationary (0 km/hr) to pedestrian (10 km/hr) and provide high

performance for higher mobility classes between 10 and 120 km/h. The performance shall be degraded gracefully at the relatively higher mobility up to 500 km/hr. In addition, the IEEE 802.16m shall be designed to maintain the connection up to 500 km/hr and to support the required spectral efficiency described in clause 7.2. 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.

Section 6

The IEEE 802.16m shall support the interoperability with other radio access technologies and provide the seamless handover in order to improve user experiences of mobile terminals between different types of radio access technologies including the legacy systems.

[C802.16m-07/044r0]
Section 6

The IEEE 802.16m amendment shall include air-interface features that would enable the Seamless Mobility with 802.16e systems. Handoff with other IMT-2000 standards shall also be given consideration. This requirement is intended to address additional air-link requirements beyond those covered by 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 handoff of broadcast services shall also be defined.

Section 7

The expectations for performance should tiered based on mobility speeds and prioritized in order to achieve the optimum overall performance. 802.16m shall support mobile speeds up to 350 km/h. It should provide optimal system performance for vehicular speeds less than 15 km/h, high performance between 15-120 km/h and graceful degradation of performance between 120-350 km/h to maintain session/call connectivity.

Note that the requirements for handover are captured under latency requirements.

[C802.16m-07/050r0]
Section 6

For seamless mobility interoperation with other mobile wireless standards, Event, Command and Information services specified in IEEE 802.21 should be adopted by 802.16m as media-specific support. 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.

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.

7.4 Coverage

[Enhanced cell-edge coverage]

[Support for increased user and service penetration rates]

[C802.16m-07/013r1]

– 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

[C802.16m-07/018r1]

The IEEE 802.16m shall significantly improve the coverage of the current WiMAX-Release1 (IEEE 802.16e) system. The link budget of the limiting link (e.g. DL MAP, UL Bearer) of 802.16e shall be improved by at least 3 dB compared to the WiMAX (IEEE 802.16e) using similar system configurations. Specifically, 802.16m shall support the following deployment scenarios in terms of maximum cell range:

Table 5. 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
30-100 km	System should be functional (noise limited scenario)

[C802.16m-07/022r0]

The IEEE 802.16m standard shall provide PHY and MAC structures that enable significant improvements in system gain through the use of multi-antenna beamforming, higher order MIMO 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 provide performance of control channels (MAPs, etc.) to be equal to or better than that of bearer traffic in all areas of a cell under fully loaded conditions regardless of user distribution.

The IEEE 802.16m standard shall incorporate enhanced MAP techniques to improve MAP reliability in interference limited deployments.

[C802.16m-07/033r0]

IEEE 802.16m shall support legacy cell sizes allowing for co-location of IEEE 802.16m deployments. In addition, larger cell sizes will also be considered. 30 km cells shall be supported with limited degradation. 100 km cells should not be precluded from the standard. Support for these larger cell sizes should not compromise the performance of smaller cells.

Performance at cell edge is an important issue. IEEE 802.16m shall support enhanced cell edge performance through a combination of specified processing including MIMO, SDMA, possibly beamforming, and superposed coding with adaptive interference cancellation. 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.

It is also required to support increased number of simultaneous users and enhanced user penetration rates.

IEEE802.16m should provide the enhancement of IEEE802.16j based multi-hop relay capability.

[C802.16m-07/039r0]

The IEEE 802.16m shall operate at the various cell sizes up to a cell radius of 50 km. 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), the IEEE 802.16m shall be flexible enough to support all users having various coverage requirements in the cellular networks. In addition, it is highly demanded that the PHY- and MAC-related system parameters shall be properly configured by taking into account the large cell environment.

[C802.16m-07/044r0]

The IEEE 802.16m shall provide significant enhancements relative to the 802.16e reference system with respect to coverage. The downlink and uplink link budget shall be improved by at least 3 dB assuming the same baseline antenna configuration and RF channel bandwidth as the 802.16e reference system.

For cell sizes up to 5 km, the user throughput, spectral efficiency, and mobility support requirements should be met. For cell sizes up to 30 km, slight degradations in the achieved user throughput and more significant degradation in spectral efficiency are acceptable; however mobility performance targets should be met. Cell sizes up to 100 km, should not be precluded by the specifications.

[C802.16m-07/050r0]

7.5 Enhanced Multicast-Broadcast (MBS)

[System wide broadcast performance should be evaluated independently of unicast service]

[A specific performance target of 2x appears appropriate]

[C802.16m-07/018r1]
As outlined in Section 6, the 802.16m amendment shall provide support for enhanced Multicast Broadcast Service (E-MBS) performance.

Minimum performance requirements for E-MBS, expressed in terms of spectral efficiency over the coverage area of the service, appear in Table 6.

Table 6. 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

The following notes apply to Table :

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.

[C802.16m-07/022r0]

[C802.16m-07/033r0]
System wide broadcast performance should be optimized independently of unicast service. The enhanced multi-cast and broadcast (E-MBS) support of IEEE802.16m

shall provided fast signalling capability to improve the user surfing reaction time and special MAC/PHY may be optimized to minimize the MS power consumption.

[C802.16m-07/039r0]

The 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. The IEEE 802.16m enhanced MBS shall provide low user power consumption and flexible radio resource allocation mechanism.

[C802.16m-07/044r0]

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

[C802.16m-07/050r0]

[C802.16m-07/044r0]

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:

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	

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:

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

Editor's notes:

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

Black - Original text

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

IEEE 802.16m provides continuing support for legacy WirelessMAN-OFDMA equipment.

Backward compatibility is required in all existing spectrum bands where the 802.16e reference 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.

IEEE 802.16m and the IEEE 802.16e systems shall be deployable on the same RF carriers; i.e., performance should be appropriate for the mix of 802.16e and 802.16m terminals attached to the same RF carrier. The IEEE 802.16m enhancements shall be transparent to the IEEE 802.16e reference-system-based terminals and base stations.

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

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

The 802.16m shall be specified for operation on at least all existing bands where 16e systems are deployed.

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

The IEEE 802.16m standard shall be compatible with existing 802.16e OFDMA modes such that the same base station and RF channel may support both 802.16e and 802.16m compatible mobile stations at the same time.

The IEEE 802.16m standard shall enable 802.16m compatible mobile stations to operate in one or more of the 802.16e OFDMA modes (including the mandatory modes), however it shall not be mandatory that every 16m mobile station also support any or all of the 16e modes.

The IEEE 802.16m standard shall enable 802.16m compatible base stations to operate in one or more of the 802.16e OFDMA modes (including the mandatory modes), however it shall not be mandatory that every 16m base station also support any or all of the 16e modes.

8.2 Greenfield Deployment

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.

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Editor's note following should go to section 6 (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.

8.3 Spectrum Requirements

[Frequency is expected to be decided in WRC07]
[Support the frequency bands within the current 802.16d/e/j framework that do not interfere with the other technologies that are part of IMT.]
[Scalable bandwidth including 5, 7, 8.75, 10 MHz]
[Support for existing bandwidths in both paired and unpaired spectrum.]
[Legacy OFDMA bandwidths described 802.16e reference system should be supported.]
[Larger bandwidths beyond those in the 802.16e reference system should be considered as a 16m specific enhancement.]
[Performance in all bandwidths should be optimized for both TDD and FDD]

IEEE 802.16m shall support scalable bandwidth including 5, 7, 8.75, 10, 20, 40, and 100 MHz.

Terminal shall support 20 MHz bandwidth.

IEEE 802.16m shall support asymmetric bandwidth assignment for downlink and uplink for both TDD and FDD. And the downlink/uplink bandwidth is adaptively assigned depending on channel condition or user capacity.

IEEE802.16m shall support flexible spectrum usage and efficient usage of scattered spectrum.

Legacy OFDMA bandwidths described 802.16e reference system should be supported. In addition the 802.16m shall support channel bandwidth scalability from 1.25 MHz to 100 MHz.

The IEEE 802.16m specification shall allow deployment on any bands specified for IMT-2000 and those to be identified for IMT-A

Capability to share the spectrum with existing primary services in the candidate bands

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

Support frequency sharing between homogeneous 802.16m networks of different operators.

Support frequency sharing with other communication systems, at least other IMT-Advanced networks.

Channel bandwidths

At least the following channel bandwidths should be supported: 1.25, 2.5, 3.5, 5, 7, 8.75, 10, 14, 20, 28, 40, 56, 100 MHz. Bandwidths above 20 MHz should be optional for the terminals.

For channel-bandwidths larger than those currently supported in the "dot16" standard [2], [3], both scaled-up and multi-carrier solutions should be considered.

Channel bandwidth flexibility

16m should offer better frequency assignment support by allowing better 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 shall be possible to operate standalone, i.e. there is no need for any other carrier to be available.

16m should offer better frequency assignment support by allowing better 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 and where possible, between different IMT-Advanced systems.

Support frequency sharing between homogeneous 802.16m networks of different operators.

Support frequency sharing with other communication systems, at least other IMT-Advanced networks.

IEEE802.16m shall support flexible spectrum usage and efficient usage of scattered spectrum.

In order that the IEEE 802.16m effectively supports the functional and performance requirements in section 6 and 7, the spectrum-related requirements below should be taken into consideration.

- The IEEE 802.16m shall support the scalable bandwidth. ←***Editor's note: Move to section 5***
- The IEEE 802.16m shall support sufficient bandwidth that might be considered to achieve the high-level functional/performance requirements in section 6 and 7. ← ***Editor's note: Move to section 5***
- The IEEE 802.16m shall be able to share or reutilize the bandwidth with the legacy systems.
- The IEEE 802.16m shall be able to operate in paired and unpaired spectrum

IEEE802.16m standard shall provide MAC and PHY support to enable efficient spectrum sharing with legacy IEEE802.16 family systems and where practically possible, with other IMT-2000 systems. IEEE802.16m standard shall provide MAC and PHY support to enable efficient spectrum sharing with other IMT-Advanced systems. The IEEE802.16m standard shall support spectrum sharing with these other systems deployed in the overlapping and non-overlapping geographical areas.

Scalable bandwidth including 5, 7, 8.75, 10, 20 MHz, 100MHz

Base stations and terminals supporting the 802.16m amendment shall conform to the following requirements:

1. be optimised to support contiguous spectrum allocations
2. 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)
3. support both unpaired and paired frequency allocations, with fixed duplexing frequency separations when operation in full duplex modes
4. when operating in band, bandwidth and duplexing mode combinations specified by the reference 802.16e system, shall be optimised for radio frequency coexistence with that system
5. be designed to coexist with other IMT radio access technologies likely to be deployed, or already deployed, in spectrum accessible to 802.16m devices

The IEEE 802.16m standard shall enable systems to be deployed in all spectrum bands currently utilized for 802.16e systems.

The IEEE 802.16m standard shall support TDD operation and be deployable in single spectrum blocks enabling channel bandwidths of 5, 10 and 20 MHz.

The IEEE 802.16m standard shall provide MAC and PHY support to enable Flexible Spectrum Use (FSU) between different IEEE802.16m systems and where possible, between different IMT-Advanced systems

8.3.1 Duplexing

Editor's Note: Move to section 5, make a comment in draft that following text does not contain clear requirements, with the possible exception of the last paragraph.

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.

Efficient and flexible duplexing, beyond the traditional paradigm of pure FDD or TDD, allow for alternative options such as hybrid schemes that combine the advantages of both FDD and TDD and enable flexible use of their features.

8.4 System Architecture

[The IEEE 802.16m amendment shall support multi-hop topologies.]
[IEEE 802.16m system shall support different cell sizes which are expected for cellular layer systems.]
[Cell radius and coverage requirements:
16m must support legacy cell sizes allowing for co-location of 16m deployments. In addition, larger cell sizes will also be considered. 30 km cells should be supported with limited degradation. 100 km cells should not be precluded from the standard. Support for these larger cell sizes should **not** compromise the performance of smaller cells
IEEE 802.16m shall support multi-hop topologies. All IP architecture is also supported in 802.16m.

16m must support legacy cell sizes allowing for co-location of 16m deployments. In addition, larger cell sizes will also be considered. 30 km cells should be supported with limited degradation. 100 km cells should not be precluded from the standard.

Support for these larger cell sizes should not compromise the performance of smaller cells

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.

BS Cell size
A wide range of cell radii from tens of meters up to tens of Kilometers should be supported.
The focus shall be on cellular infrastructure deployments with typical cells sizes of 100 meters to several Kilometers.

Architecture
The 802.16m amendment 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 architectures must cover a wide range of deployment scenarios, including macro, micro and femto environments, as well as both out-door and in-building applications.

The 802.16m amendment 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 hand-off, but with fast cell switching capability) options should be supported.

The 802.16m amendment 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.

Support for Multi-hop Relay
Support for scaled-up Multi-hop Relay devices should be included in the 16m architecture.

IEEE 802.16m system shall support different cell sizes which are expected for cellular layer systems. The cell radius and coverage requirements are as follows:
IEEE 802.16m shall support legacy cell sizes allowing for co-location of IEEE 802.16m deployments. In addition, larger cell sizes should be considered. Cell sizes up to 30 km should be supported with limited performance degradation. Cell sizes up to 100 km should not be precluded from the standard. Support for these larger cell sizes should not compromise the performance of smaller cells (see also Section 7.4 for performance requirements).

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
- 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.

The IEEE 802.16m amendment shall support native multi-hop topologies.

IEEE 802.16m system shall support different cell sizes which are expected for cellular layer system. IEEE 802.16m amendment must support legacy cell sizes allowing for co-location of 16m deployments. In addition, larger cell sizes will also be considered. 30 km cells should be supported with limited degradation. 100 km cells should not be precluded from the standard. Support for these larger cell sizes should **not** compromise the performance of smaller cells

The IEEE802.16m standard shall support in-band multi-hop relay technologies. IEEE802.16m standard shall enable IEEE802.16m base station to support legacy IEEE802.16j relay stations without degradation of 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 of the overall radio performance compared to the legacy IEEE802.16j system.

The IEEE 802.16m standard shall support in-band base station backhaul.
The IEEE802.16m standard shall support in-band multi-hop relay radio link in all cell types supported within the IEEE802.16m standard.

The IEEE802.16m standard shall support legacy IEEE802.16j relay stations.

8.4.1 Architecture

The IEEE 802.16m amendment should provide schemes for coverage extension or filling coverage hole such as multi-hop topologies. However, the system requirements described in this document shall be met without the use of the schemes.

IEEE 802.16m system shall support different cell sizes which are expected for cellular layer systems. The cell radius and coverage requirements are as follows:

IEEE 802.16m shall support legacy cell sizes allowing for co-location of IEEE 802.16m deployments. In addition, larger cell sizes should be considered. Cell sizes up to 30 km should be supported with limited performance degradation. Cell sizes up to 100 km should not be precluded from the standard. Support for these larger cell sizes should not compromise the performance of smaller cells (see also Section **Error! Reference source not found.** for performance requirements).

8.4.2 Support for Multi-hop Relay

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.

IEEE 802.16m shall support multi-hop topologies. All IP architecture is also supported in 802.16m

The IEEE 802.16m amendment should provide schemes for coverage extension or filling coverage hole such as multi-hop topologies. 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 technologies. IEEE802.16m standard shall enable IEEE802.16m base station to support legacy IEEE802.16j relay stations without degradation of 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 of the overall radio performance compared to the legacy IEEE802.16j system.

The IEEE 802.16m amendment shall support native multi-hop topologies.

8.5 System Migration

[802.16m and 802.16e reference system shall be deployable on the same RF carriers: performance should be appropriate for the mix of 16e and 16m terminals attached to a RF carrier; and the 802.16m enhancements shall be transparent to 16e terminals and BS.]

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.

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.

8.6 Synchronization

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

8.7 Wi-Fi Coexistence and Interworking

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.

9.0 Usage Models

Section 9 Editor's notes:

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

Black – Edited subsections

Color	Section 9 Source Document Authors	Section 9 Source Document Reference
Blue	San Youb Kim	IEEE C802.16m-07/035
Brown	Sassan Ahmadi, et. al.	IEEE C802.16m-07/046
Red	Jean-Pierre Balech, et. al.	IEEE C802.16m-07/052
Orange	Mark Cudak, et. al	IEEE C802.16m-07/019
Pink	Jianmin Lu et.al.	IEEE C80216m-07/028

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.

Additional suitable usage models are TBD.

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 throughput, 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". RF channels are assigned to different cells (i.e. BS sites) or sectors and this allocation is 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 Z.

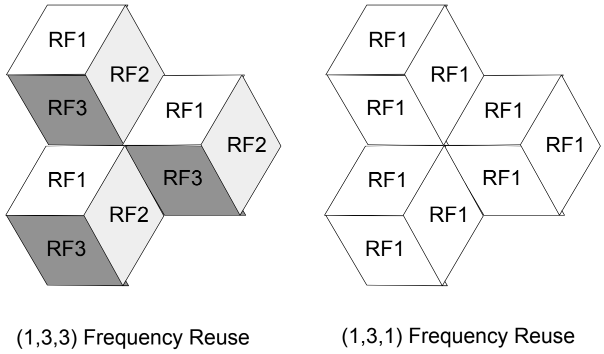

Figure Z — Examples of (1,3,3) and (1,3,1) frequency reuse.

The existing 802.16e reference network allows each sector to use only a non-overlapping subset of OFDM subcarriers, thus creating an equivalent reuse pattern. For example in PUSC permutation, 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, an reuse pattern equivalent to (1,3) will be created. Sometimes, the PUSC frequency reuse is referred to as "in-band" reuse.

It is also possible to have a different reuse pattern in MBS deployment than the reuse pattern for regular data traffic. For example, a (1,1,1) pattern can be used in the so-called "Multicast Broadcast Single Frequency Network" deployment, while the other data service can still use (1,3,1) reuse pattern.

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

The IEEE 802.16m amendment may support the following deployment modes:

- (1,3,1) : Frequency reuse of (1,1) with 3 sectors per BS site (i.e., each cluster comprising one BS site. Each BS site has three sectors and all sectors are assigned the same RF channel)

Scenario I (IEEE 802.16m Systems Only- Single Frequency, Reuse 1)

The physical deployment of the cells and sectors is depicted in Figure 0-1. Each sector is denoted in the figure by two numbers. First is the RF frequency reuse indicator and the second is the segment reuse indicator. This deployment is combined with full use of sub-carriers (meaning that in the FCH all the major groups are assigned to all the segments such that both in the first PUSC zone and in other PUSC zones there will be full collision of sub-carriers from all the sectors, assuming 100% loading of sub-carriers – see the figure for the reuse pattern between the segments).

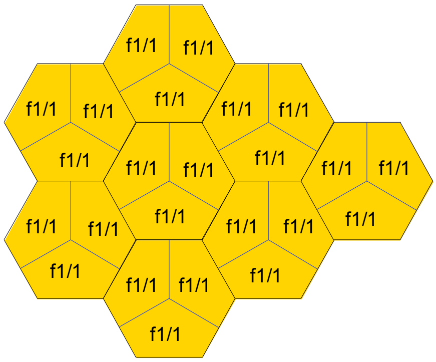

Figure 0-1: Frequency reuse pattern on data sub-carriers for Scenario I.

As far as the preamble (cell search) is concerned, there are two possibilities for preamble deployment in this case. In the first case all the sectors are assigned the same segment number, creating a full collision between all the sectors. In the second case every sector is assigned a different segment number, creating an orthogonal frequency allocation between the preambles of different sectors (see Figure 0-2).

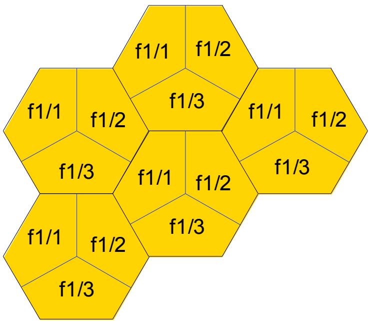

Figure 0-2 : Frequency reuse pattern on preamble sub-carriers for Scenario I with different segment numbers

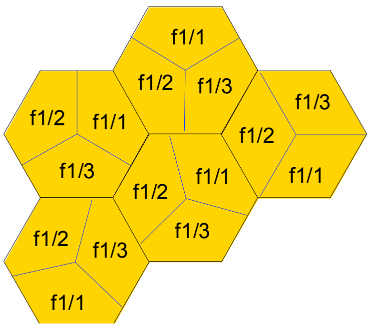

Figure 0-3: Frequency reuse pattern on preamble sub-carriers for Scenario I with different segment numbers in case of spatially unplanned antennas.

Scenario III (IEEE 802.16m Systems Only- Single Frequency, Reuse 3)

The third deployment of the cells and sectors is given in Figure 0-1. This deployment is combined with partial use of sub-carriers (meaning that in the FCH only 1/3 of the major groups are assigned to every segment – to say that in the first PUSC zone and in PUSC zone with Use_all_SC = 0 there will be no collision of sub-carriers between the sectors). This deployment is equivalent to Scenario II deployment with different BW allocated to every BS.

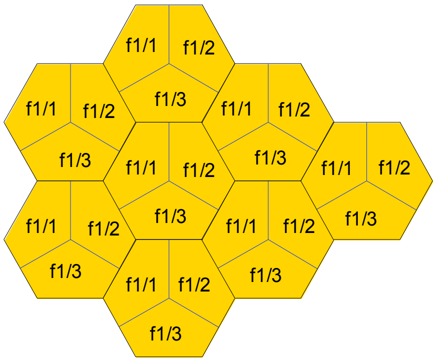

Figure 0-1: Frequency reuse pattern on data sub-carriers for Scenario III

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

- (1,3,3) : Frequency reuse of (1,3) with 3 sectors per BS site (i.e., each cluster comprising one BS site. Each BS site having three sectors where each of the three sectors is assigned a unique RF channel)

Scenario II (IEEE 802.16m Systems Only- Multiple Frequencies)

In this deployment, every sector is transmitting using a different RF frequency, utilizing the full allocation bandwidth. This scenario could be suitable for example in situations where the operator does not have a contiguous spectrum but has several chunks of spectrum (in this case it also possible to deploy a system with reuse factor 3 between the BSs, which would allow utilization of the segmentation mechanism through FCH). In this deployment transfer of a user between two sectors of the same BS would require a change of RF frequency.

This deployment is combined with full use of sub-carriers. (Notice that though in the FCH all the major groups are assigned to all the segments, there is no collision of sub-carriers between the sectors due to different RF frequencies). The physical deployment of the cells and sectors is given in Figure 0-1.

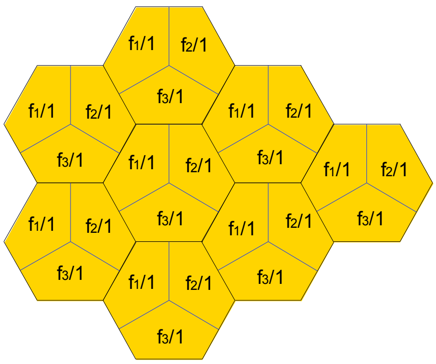

Figure 0-1: Frequency reuse pattern on data sub-carriers for Scenario II.

There are three possibilities for preamble deployment in this scenario. In the first case, all the sectors are assigned the same segment number, creating a full collision between all the sectors with the same RF frequency (It must be noticed that this case is equivalent to 1/3 reuse factor in case of single frequency deployment). In the second scenario, segment numbers are distributed randomly. In the third case, a different segment number is assigned to every BS. In latter case, there will be no interference between the three sectors of the same BS due to the different RF frequencies used and the reuse factor between the BSs will also be 1/3 due to the segment planning. This means that no two neighboring BSs will interfere with each other in the preamble.

For this deployment spatial planning could influence the performance of the algorithms based on preamble, pilots and data (see Figure 0-2 and Figure 0-3).

The expected interference levels in Scenario I and Scenario II deployments are different, but the effect of partial loading on the interference level in this deployment is identical to the one in Scenario I.

There is only one possibility for preamble deployment in this case (the one described in Figure 0-2. For this deployment spatial planning could impact the performance of the algorithms based on preamble, pilots and data (see Figure 0-2 and Figure 0-3).

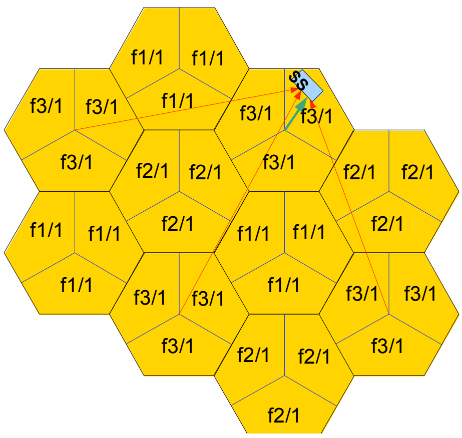

Figure 0-2: An example 3x3x1 deployment

As a convention, it is recommended adding two letters to the deployment description. One in the beginning to describe the spatial planning and the other at the end to separate reuse 3 of RF frequencies between the sectors and reuse 3 due to segmentation in the FCH.

To describe the spatial planning, additional indicator p/u can be used, for example the deployments in Figure 0-2 and Figure 0-3 can be described as p1x3x3s and u1x3x3s, respectively. Note that in practice frequency planning and spatial planning must be performed jointly and cannot be separated into two different tasks.

9.2.1.3 Reuse patterns with 4 and 6 sectors

- (1,6,3) : Frequency reuse of (1,3) with 6 sectors per BS Site
- (1,4,2) : Frequency reuse of (1,2) with 4 sectors per BS Site
- (1,4,1) : Frequency reuse of (1,1) with 4 sectors per BS Site
- (1,6,1) : Frequency reuse of (1,1) with 6 sectors per BS Site

9.2.1.4 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 0-1, 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 preamble (see Figure 0-3 for illustration of spatially unplanned preamble deployment).

Use of partial loading (for example using only first 1/3 of the sub-channels) can help reduce interference in the second PUSC zone for this deployment. Randomization of the actual transmitted carriers due to outer permutation will cause a reduction in mean interference power by a factor of *L* (which is the loading factor). This is true with and without the spatial planning. Notice that this reduction is not possible in the first PUSC zone since the outer permutation seed in this case is 0 for all the base stations thus every MG get the same physical clusters in all the BSs. Since the map is allocated in a frequency first manner, it is almost impossible to obtain partial loading in the first PUSC zone.

Note that the pilots always interfere in any zone, since in this deployment all the major groups are assigned to all the segments.

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.

Scenario IV (Mixed Network - Single Frequency, Reuse 1)

This scenario exemplifies a transitional deployment phase where both IEEE 802.16m and IEEE 802.16e based terminals and base stations are operating on the same RF carrier. The different colors illustrate legacy and the new base stations. Similar to Scenario I, this deployment is combined with full use of sub-carriers (meaning that in the FCH all the major groups are assigned to all the segments such that both in the first PUSC zone and in other PUSC zones there will be full collision of sub-carriers from all the sectors, assuming 100% loading of sub-carriers – see the figure for the reuse pattern between the segments).

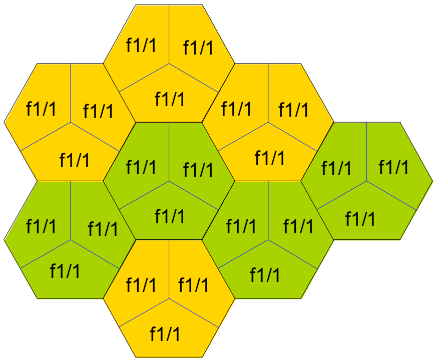

Figure 0-1: Frequency reuse pattern on data sub-carriers for Scenario IV.

As far as the preamble (cell search) is concerned, there are two possibilities for preamble deployment in this case. In the first case all the sectors are assigned the same segment number, creating a full collision between all the sectors. In the second case every sector is assigned a different segment number, creating an orthogonal frequency allocation between the preambles of different sectors (see Figure 0-2).

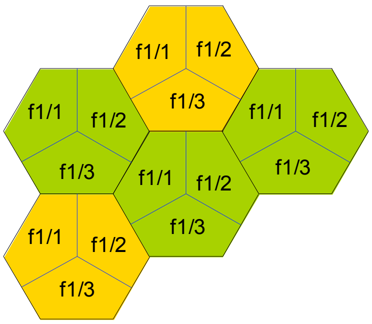

Figure 0-2 : Frequency reuse pattern on preamble sub-carriers for Scenario IV with different segment numbers

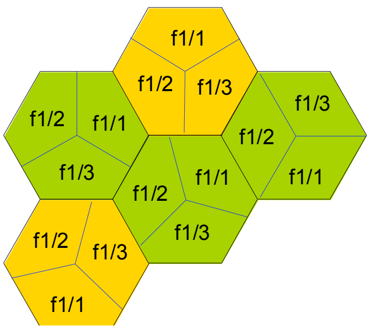

Figure 0-3: Frequency reuse pattern on preamble sub-carriers for Scenario IV with different segment numbers in case of spatially unplanned antennas.

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 0-1, 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 preamble. See Figure 0-2 for illustration of spatially unplanned preamble deployment).

Use of partial loading (for example using only first 1/3 of the sub-channels) can help reduce interference in the second PUSC zone for this deployment. Randomization of the actual transmitted carriers due to outer permutation will cause a reduction in mean interference power by a factor of *L* (which is the loading factor). This is true with and without the spatial planning. Notice that this reduction is not possible in the first PUSC zone since the outer permutation seed in this case is 0 for all the base stations thus every MG get the same physical clusters in all the BSs. Since the map is allocated in a frequency first manner, it is almost impossible to obtain partial loading in the first PUSC zone. It must be noted that the pilots always interfere in any zone, since in this deployment all the major groups are assigned to all the segments.

9.2.3 Deployment with Multi-hop Relay Networks

Scenario V (IEEE 802.16m with Multi-hop Relay Networks)

This scenario (shown in Figure 0-1) 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 are specified by IEEE 802.16m standard (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].

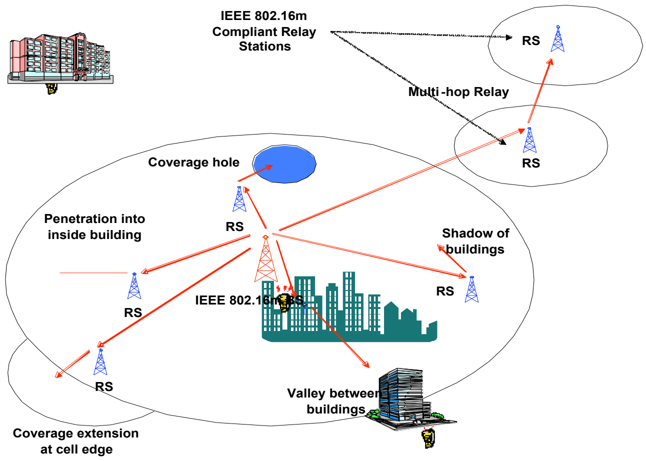

Figure 0-1: IEEE 802.16m with multi-hop relay networks (the RS can be fixed or mobile depending on the usage and deployment specifics).

9.2.4 High Mobility Optimized Scenario

9.x High Mobility Optimized Scenario

The system or one mode of the system needs to provide services to high-speed users. It shall be optimized for speeds ranging from 200 to 300kmph with likely large penetration losses in a large and irregular coverage area. For the high-speed user service environment and even as the speed of the service environment may dynamically and rapidly change, the system should support dynamic link maintenance and burst profile management, with high granularity of differentiated service between subscribers, such that 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

Scenario VI (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.