Project	**IEEE 802.16 Broadband Wireless Access Working Group**
Title	**Functional Requirements for the 802.16.3 Interoperability Standard**
Date Submitted	**2000-08-07**
Source	Brian Petry (editor) 3Com 12230 World Trade Dr. San Diego, CA 92128 Voice: (858) 674-8533 Fax: E-mail:brian_petry@3com.com
Re:	This is a collaborative effort by the 802.16.3 Functional Requirements Task Group which started from a contribution by George Fishel and was further revised by the task group by a formal comment/resolution process. Please be sure you are reading the most recent published version of this document (802.16.3-00/02rx where x is the version number) which can be found at: http://ieee802.org/16/sub11/index.html This document is input to 802.16 session #9 (12-15 September, 2000). It contains edits that have been reviewed and resolved by the 802.16.3 task group at session #8.
Abstract	This document provides functional requirements that are guidelines for developing an interoperable 802.16.3 air interface. The 802.16.3 committee desired to reach an understanding and consensus for functional requirements before proceeding with developing standards for 802.16.3 MAC and PHY protocols and thus formed a Functional Requirements Task Group to produce this document. Note that this document contains red-lined edits that have not been approved by the task group. This document has many cross-reference, section numbering and formatting errors. These errors will be fixed by the editor in a subsequent version of this document.
Purpose	This document should be reviewed by the 802.16.3 task group, and once approved by the task group, forwarded to the 802.16 working group for approval. Prior to approval, this document may undergo more comment resolution.
Notice	
Release	
IEEE Patent Policy	

Acknowledgements

George Fishel provided the first draft of this document, based on the 802.16.1 Functional Requirements, 802.16s-99/00r1.

The following people have also contributed by submitting comments on previous versions:

Jose Costa

Adnan Abu-Dayya

Avi Freedman

Marianna Goldhammer

Leif Jansson

Mika Kasslin

Demosthenes Kostas

Adi Nativ

Uzi Padan

Brian Petry

Durga Satapathy

David Trinkwon

Muya Wachira

Revision History

2000-03-02	802.16.3-00/02r0	George Fishel	First Draft; Based on 802.16s-99/00r1
2000-04-29	802.16.3-00/02r1	Brian Petry (editor)	With red-lined, unapproved changes specified by commentors
2000-06-23	802.16.3-00/02r2	Brian Petry (editor)	With changes approved by task group at 802.16 session #7
2000-08-07	802.16.3-00/02r3	Brian Petry (editor)	With changes approved by task group at 802.16 session #8

Table of Contents

1 Introduction

This document provides functional requirements that are guidelines for developing an interoperable 802.16.3 air interface for the licensed microwave frequency bands between 2 and 11 GHz enabling Point to Multipoint (P-MP) Broadband Wireless Access (BWA) . The BWA system provides packet-based transport capabilities that can support a wide range of services (e.g., data, voice and video) to residential, Small and Medium Enterprises (SME) and Small Office/Home Office (SOHO) locations. The 802.16.3 committee desired to reach an understanding and consensus for functional requirements before proceeding with developing standards for 802.16.3 MAC and PHY protocols and thus formed a System Requirements Task Group to produce this document.

For convenience, requirements are itemized in Appendix A.

The Functional Requirements will not be published or sold by the IEEE. The requirements, with possible future amendments, are binding to the future development of 802.16.3 air interface protocols. This means that the forthcoming air interface standard MUST comply with the functional requirements.

Throughout this document, the words that are used to define the significance of particular requirements are capitalized. These words are:

"MUST" or “SHALL” These words or the adjective "REQUIRED" means that the item is an absolute requirement..

"MUST NOT" This phrase means that the item is an absolute prohibition.

"SHOULD" This word or the adjective "RECOMMENDED" means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications should be understood and the case carefully weighed before choosing a different course.

"SHOULD NOT" This phrase means that there may exist valid reasons in particular circumstances when the listed behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label.

"MAY" This word or the adjective "OPTIONAL" means that this item is truly optional. One implementation may include the item because the target marketplace requires it or because it enhances the product, for example; another implementation may omit the same item.

1.1 Scope

For the purposes of this document, a “system” constitutes an 802.16.3 MAC and PHY implementation in which at least one subscriber station communicates with a base station via a point-to-multipoint (P-MP) radio air interface, the interfaces to external networks, and services transported by the MAC and PHY protocol layers. So, “functional requirements” describes the properties of typical systems in terms of how they affect requirements of interoperable 802.16.3 MAC and PHY protocols. The functional requirements describe 802.16.3 systems and requirements in broad terms: *what* they are, but not *how* they work. The *how* part is left to the forthcoming 802.16.3 interoperability standard [20], which will describe in detail the interfaces and procedures of the MAC and PHY protocols.

This document focuses on the service capabilities that an 802.16.3 system is required to transport. These *services* have a direct impact on the requirements of the 802.16.3 MAC and PHY protocols. When the 802.16 working group produces an interoperable air interface standard that meets these functional requirements, resulting 802.16.3-based implementations will provide the services required to neatly interface into many conceivable BWA systems.

Other goals of this document are to formulate reference models and terminology for both network topology and protocol stacks that help the 802.16 working group to discuss and develop the MAC and PHY protocols. As far as possible, these SHOULD be common across 802.16 systems.

The 802.16.3 air interface interoperability standard SHALL be part of a family of standards for local, metropolitan and wide area networks. The 802.16.3 protocols relate to other 802 standards and to the OSI model as shown in Figure 1-1~~Figure 1-1~~.

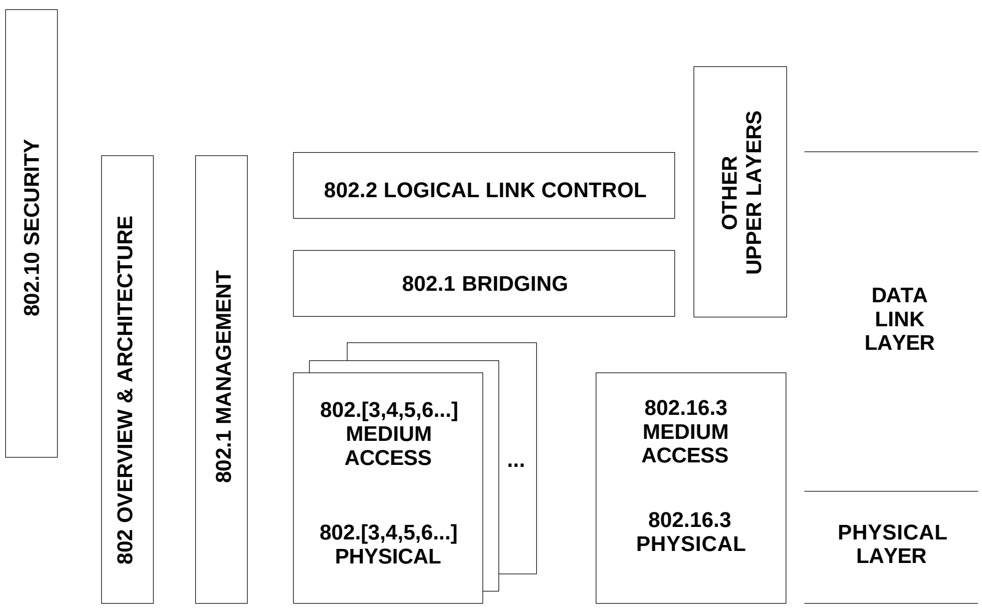

Figure 1-1: Relationship between 802.16.3 and other Protocol Standards (the numbers in the figure refer to IEEE standard numbers)

This family of standards deals with the Physical and Data Link layers as defined by the International Organization for Standardization (ISO) Open Systems Interconnection Basic Reference Model (ISO 7498: 1984). The access standards define several types of medium access technologies and associated physical media, each appropriate for particular applications or system objectives. Other types are under investigation.

The standards that define the technologies noted in the above diagram are as follows:

IEEE Std 802: Overview and Architecture. This standard provides an overview to the family of IEEE 802 Standards. This document forms part of the 802.1 scope of work.

ANSI/IEEE Std 802.1B [ISO/IEC 15802-2]: LAN/MAN Management. Defines an Open Systems Interconnection (OSI) management-compatible architecture, environment for performing remote management.

ANSI/IEEE Std 802.1D [ISO/IEC 10038]: MAC Bridging. Specifies an architecture and protocol for the interconnection of IEEE 802 LANs below the MAC service boundary.

ANSI/IEEE Std 802.1E [ISO/IEC 15802-4]: System Load Protocol. Specifies a set of services and protocols for those aspects of management concerned with the loading of systems on IEEE 802 LANs.

ANSI/IEEE Std 802.2 [ISO/IEC 8802-2]: Logical Link Control

ANSI/IEEE Std 802.3 [ISO/IEC 8802-3]: CSMA/CD Access Method and Physical Layer Specifications

ANSI/IEEE Std 802.4 [ISO/IEC 8802-4]: Token Bus Access Method and Physical Layer Specifications

IEEE Std 802.10: Interoperable LAN/MAN Security, Secure Data Exchange (SDE)

1.2 Target Markets

The target markets described in this section are not an exhaustive set, but serve as guidelines and examples that suffice for meeting the broad applicability goals set forth by the air interface "Five Criteria"

A broadband wireless access (BWA) system based on 802.16.3 protocols is expected to address markets similar to those of certain wired access technologies such as:

- Copper digital subscriber line (xDSL) technologies
- Digital cable TV hybrid fiber/coax (HFC) networks
- Integrated Services Digital Network (ISDN)
- Fiber Access Networks (XXX move up one)
- The services that such legacy systems carry: data, voice and audio/video [8].

The critical parameters for serving these markets using wireless access technology is the combination of coverage / capacity factors that affects access cost per user, the deployability, maintainability and product costs associated with the customer premise installation, and the spectrum efficiency / reuse for economically serving the required number of customer locations with a minimum number of base station locations and backhaul routes.

The target markets to be addressed by the 802.16.3 protocols in BWA networks are single family residential, SOHO, small businesses and multi-tenant dwellings.

[Note from Trinkwon: Proposal : To invite contributions on definitions of these terms (single family residential, SOHO, telecommuters, small businesses and multi-tenant dwellings) and associated traffic model assumptions, demographic density / distribution criteria and typical clutter / propagation implications. Include chapter that discusses traffic models. Note: Task group decided to issue call for contributions.] In accordance with ITU-R [Ref ITU-R F.1399] definitions, Fixed Wireless Access (FWA) (and hence BWA) provides access to one or more (public and private) core networks, rather than forming an end-to-end communication system. 802.16.3 systems serve fixed location customers, but who might be geographically fixed or re-locatable or even nomadic (but not mobile).

2 802.16.3 System Model

This section presents a high level description of a system model to be used as a framework for developing 802.16.3 standards. The model describes some of the main features of an 802.16.3 system, and the terminology to be used by the 802.16-working group in the creation of the standards.

As mentioned in section 1.1, an 802.16.3 "system" constitutes: an 802.16.3 MAC and PHY implementation, in which at least one subscriber station communicates with a base station via a radio air interface (an 802.16.3 system), and services transported by the MAC and PHY protocols. Specific applications of the 802.16.3 point-to-multipoint (P-MP) radios are generally applicable to the range 2 to 11 GHz. Radio communications in the above range may be possible in near- and non-line-of-sight situations between a base station and subscriber station. [XXX: Need definitions in glossary section for Near and Non LOS?] Operation may include partial blockage by foliage which contributes to signal attenuation and multipath effects. Figure 2-1~~Figure 2-1~~ depicts a typical 802.16.3 system. 802.16.3 systems SHALL be deployable in multiple-cell frequency reuse systems and single cell (super cell) frequency reuse systems. The range of 802.16.3 radios varies with transmit power, channel characteristics, availability requirement, local regulations and atmospheric conditions.

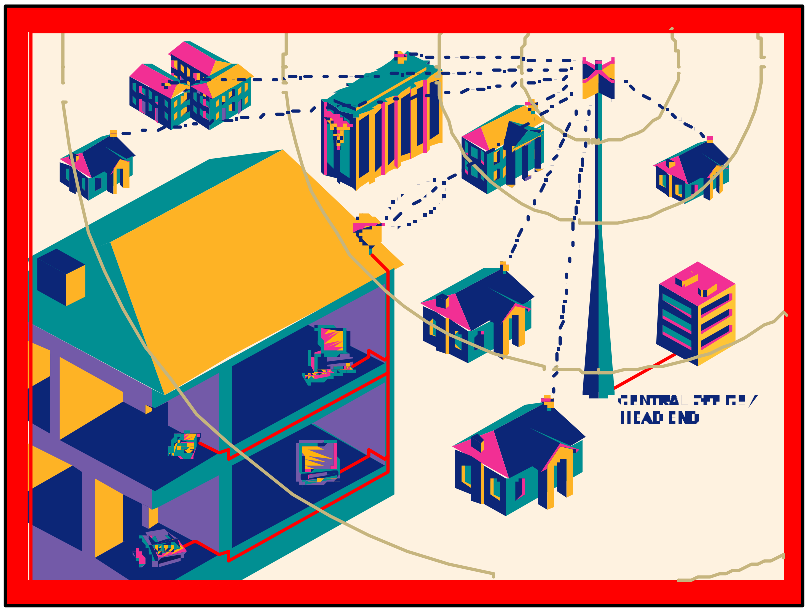

Figure 2-1: System Showing a Base Station Mounted on a Tower [T; Kasslin: Replace figure 2-1 with figure 4-3 from TR 101 177 V1.1.1 (1998-05) by ETSI/BRAN/HIPERACCESS][Note: tabled for next round; Kasslin to rework diagram and text]

Note , in concern for simple terminology, an 802.16.3 *system* consists of one base station radio and one or more subscriber stations. Thus, an 802.16.3 system also defines 802.16.3 base station and subscriber station radios that communicate using the 802.16.3 MAC and PHY protocols. The base station radio SHALL be P-MP, radiating its *downstream* signal with a shaped sector or adaptive array (spatial reuse) antenna achieving broad azimuthal beam width to "cover" a prospective number of subscribers.

Furthermore, the 802.16.3 system does not define radio communications between base stations. Since the base station radios might be "sector oriented," multiple base station radios will likely, in practice, be co-located (subject to frequency re-use requirements), and might share physical hardware.

The frequency bands used by 802.16.3 systems vary among governed geographies [19].

2.1 Wireless Access Reference Model

Figure 2-1~~Figure 2-1~~ shows the 802.16.3 wireless access reference model. The model depicts the relevant points between subscriber networks and "core" networks (the networks that MAY be accessed via 802.16.3 air interface). A greater system encompassing user terminals, base station interconnection networks, network management facilities, etc. may be envisaged but the 802.16.3 protocol focuses on the air interface shown in the model. The Core Network Interface (CNI) and the User Network Interface (UNI) are also shown.

A single SS MAY support multiple customer premises networks that transport data, voice and video through one or more UNIs. Base stations MAY support multiple core networks through one or more CNIs. For the purposes of 802.16.3, the UNI and CNI are abstract concepts. The details of these interfaces are beyond the scope of this document. The standard SHALL specify MAC layer protocols and PHY transmission techniques suitable for providing access between one or more subscriber stations and base stations.

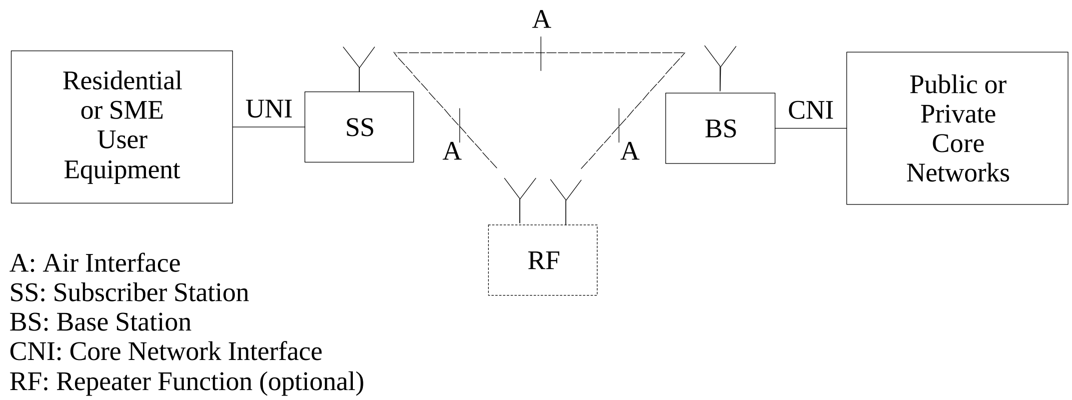

Figure 2-1: Wireless Access Reference Model

2.2 Optional Repeater Function

[TBD: This section is for review by commentors. It was added by editor.]

The 802.16.3 protocols SHALL support the optional deployment of repeater functions. The repeater function SHALL NOT affect the MAC protocol other than the delay which the repeater might introduce into the system. The affect on the PHY protocol SHALL not require data to be re-coded or re-modulated. Thus, the repeater function SHOULD NOT affect the end-to-end operation of 802.16.3 protocols between BS and SS. Also, 802.16.3 protocols SHOULD be defined such that MAC and PHY protocol implementations on the BS and SS need not be aware of the presence of a repeater.

~~2.2~~2.3 Topology

Since all data traffic in a single cell of an 802.16.3 network MUST go through the base station, that station SHALL serve as a radio resource supervisor [10], but the Subscriber Stations may identify the bandwidth needed to achieve the required QoS (see section 7).

In the downstream direction, the multiplexed traffic is transmitted by the base station. In the upstream direction, 802.16.3 protocols MUST provide the means to multiplex traffic from multiple subscriber stations, resolve contention, and allocate capacity.

3 Supported Service Capabilities

This section describes typical service capabilities supported by an 802.16.3 air interface.

The MAC and PHY protocols will not have explicit support for each and every service, due to the fact that generic data streams SHALL be used for transport. The MAC and PHY protocols SHALL provide for QoS service specific support, meaning appropriate BER for data services, limited delay for real time services, etc..

3.1 Voice Transport Service Capabilities

802.16.3 systems SHALL support voice communications for subscribers in a way that eases the migration of legacy voice communications equipment and public switched telephone network (PSTN) access technologies to 802.16.3 systems. The 802.16.3 voice access transport SHALL be packet based (as opposed to circuit-switched based).

802.16.3 systems and protocols MUST support the QoS and signaling requirements of these services.

3.1.1 Voice Service Properties

***

Note: This section is to be reworked into the QoS section by the QoS ad hoc group. Any comments from individuals on this particular section will not be accepted. Please contact George Fishel to participate in the ad hoc group.

***

[T; Kasslin: delete this section] The relevant properties of voice services are:

TBD

- Bandwidth – in general, the codings used in these services require bandwidths in the range of 64 Kbps or less per call. [T; Satapathy: delete following sentence] Voice connectivity ~~will~~ MAY [T; Freedman] be provided via a VoIP protocol and may involve low rate vocoding. There are subjective quality metrics for the clarity of the encoded speech signals, that can vary based on the quality of the services sold to the end user (e.g., residential vs. business). The required bandwidth is minimized with VoIP, the associated codecs providing a very good compression: 8kb/s for G.729, 6.3kb/s for G.723. The compression result is the increase of the delay. [T; Goldhammer]

- ~~Low delay~~Delay [E; Goldhammer] – as apparent to the end users, the amount of delay between a user speaking and another user hearing the speech ~~MUST~~ SHOULD [T; Goldhammer] be kept below a certain level to support two-way conversation. The QoS requirements should take into account the characteristics of the VoIP technology: codec end-to-end delay of 50ms for 10ms frame (G.729), 120ms for 30ms frame (G.723), the possibility to transmit concatenated voice packets, the mandatory use of echo chancellors.[T; Goldhammer] Again, the specific amount of delay can vary based on the quality of the service sold to the end user. Change this bullet to read: "Delay - as apparent to the end user, the amount of delay and delay variation MUST be kept within acceptable limits. Again the specific amount of delay and delay variation acceptable is based on the QoS sold to the end user." [T; Kostas]

- BER level The MAC and PHY protocols SHOULD provide for a reasonable BER Level for voice services. BER of 10-4 is sufficient for voice services and 10-5 for FAX. [T; Goldhammer]

BWA protocols MUST support efficient transport of encoded voice data in terms of bandwidth, reliability and delay.

3.2 Data Transport Service Capabilities – Internet

The 802.16.3 system MUST directly transport variable-length IP datagrams efficiently. Both IP versions 4 and 6 MUST be supported. For efficient transport of IPv6, TCP/IP header compression over the air interface SHOULD be supported. The 802.16.3 IP service MUST provide support for real-time and non-real-time service capabilities. It SHOULD be possible to support the emerging IP Quality of Service (QoS) efforts: Differentiated Services [43, 44] and Integrated Services [42].

3.3 Bridged LAN Service Capabilities

The 802.16.3 protocols SHOULD support bridged LAN service capabilities, whether directly or indirectly, including always on, ad hoc and on-demand communication in either or both directions.

3.4 Other Services

Other services that for instance require QoS-based delivery of the MAC services may be added. These services SHALL NOT place any special requirements on 802.16.3 systems (MAC and PHY protocols) not already covered in the above sections.

4 802.16. Protocols

Protocols are the heart of the 802.16.3 standard that, when described well, result in interoperability of multiple vendors' equipment. Protocol interoperability occurs at each level in the protocol "stack" [16]. In this section, *services* refer to the services provided by the protocols that can appear in the layer sitting directly over the MAC layer. IEEE 802 protocols reside at layer 1 and 2 and consist primarily of Logical Link Control (802.2) [67] and the various MAC and PHY layers for each LAN or MAN standard. The IEEE Std 802-1990 *Overview and Architecture* [21] describes these layers.

The 802.16.3 protocol stack reference diagram is shown in Figure 4-1~~Figure 4-1~~. In addition to the LLC, MAC and PHY layers suggested by the generic 802 architectures [21] [22] [23], 802.16.3 protocols transport other categories of “upper protocols” that correspond to the requirements of the service capabilities described in section 6

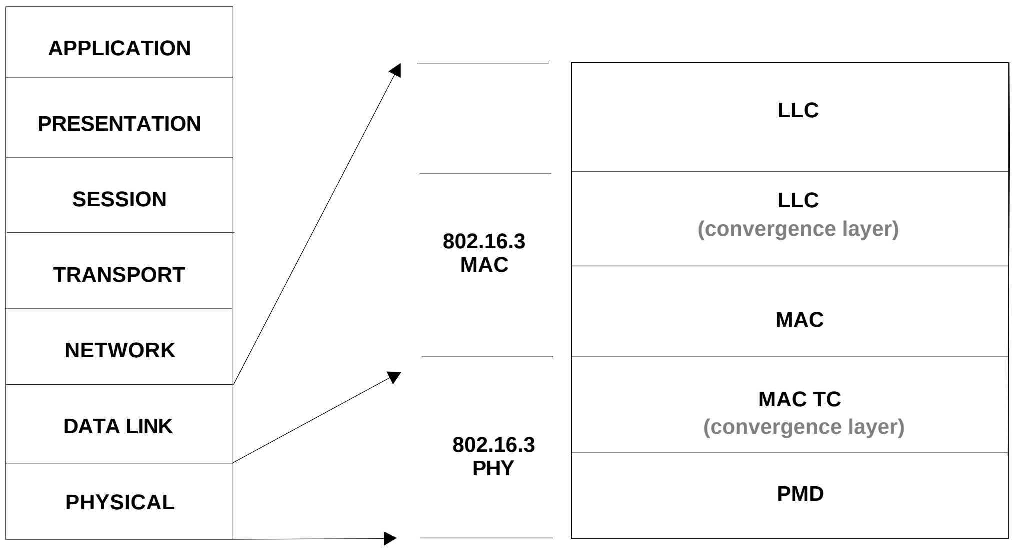

Figure 4-1: Protocol Stack Reference Model

This protocol stack reference model is intended to help develop terminology, and possibly protocol architecture. Each of the “special” protocols above the MAC and PHY are given “convergence sub-layers.”. The convergence sub-layers [2] [17] may be necessary to:

- Encapsulate PDU framing of upper layers into the native 802.16.3 MAC/PHY PDUs. [17]
- Map an upper layer’s addresses into 802.16.3 addresses
- Translate upper layer CoS/QoS parameters into native 802.16.3 MAC constructs
- Adapt the asynchronous, synchronous or isochronous data pattern of the upper layer into the equivalent MAC service
- Reduce the need for complex inter-working functions (IWFs) [17]

The IEEE 802.16.3 protocol stack SHALL be the same for all the supported services. The central purpose of the MAC protocol layer in 802.16.3 is sharing of radio channel resources. The MAC protocol defines how and when a base station or subscriber station may initiate transmission on the channel. Since key layers above the MAC require service guarantees, the MAC protocol MUST define interfaces and procedures to provide guaranteed service to the upper layers. Since customer units will contend for capacity to/from one or more base stations, the MAC protocol MUST efficiently resolve contention and bandwidth allocation. Note that the function of the MAC protocols SHOULD include error correction by retransmission, or Automatic Repeat Request (ARQ), whereas, in the 802 model, those functions if necessary, are provided by the LLC layer.

The PHY layer is similarly subdivided between a convergence layer and a physical medium-dependent (PMD) layer. The PMD is the “main” part of the PHY. Like the MAC convergence layers, the PHY convergence layers adapt/map the “special” needs of the MAC services to generic PMD services. Further details, and finalization of the protocol reference model, SHALL be worked out by the 802.16.3 MAC and PHY task groups while developing the air interface interoperability standard.

5 Performance and Capacity

This section addresses some issues regarding 802.16.3 system performance and capacity. Specifying protocols that can maintain specified/mandatory performance levels in the face of fluctuating and diverse channel characteristics (e.g., due to multipath and atmospheric conditions) is a problem that the 802.16.3 work group has to consider. This section specifies the target performance levels. This section also outlines some of the issues for 802.16.3 capacity planning.

Note that ITU-R has presented several questions regarding the need for performance objectives for fixed wireless access radio systems, in particular, the activities being carried out within the Joint Rapporteur Group (JRG) 8A/9B (Questions ITU-R 140/9, ITU-R 215/8, ITU-R 220/9).

5.1 Scalability

The 802.16.3 protocols SHOULD allow for different “scales” of capacity and performance for 802.16.3 system instances.

5.2 Peak Data Rate

802.16.3 protocols SHALL be optimized to provide the peak data rate up to 10 Mbps in either or both directions to a subscriber station within the specified distance from the base station. The 802.16.3 MAC protocol SHOULD allow the peak data rate to scale beyond 10 Mbps.

5.3 Flexible Asymmetry

802.16.3 protocols SHOULD allow for flexibility between delivered upstream and downstream bandwidth and CoS/QoS. Some target markets utilize naturally asymmetrical bandwidth, such as for generic Internet access where most of the bandwidth is consumed in the downstream direction. Some markets utilize asymmetrical bandwidth, using more in the upstream direction, such as a video multicast from a corporate or distance-learning source. Other markets and applications require symmetrical bandwidth, such as telephony and video conferencing [17].

A high degree of flexibility may be achieved by utilizing the MAC protocol to arbitrate channel bandwidth in either direction, upstream or downstream.

5.4 Radio Link Availability

An 802.16.3 system SHOULD be available to transport all services at better than their required maximum error rates (see section 5.5) from about 99.9 to 99.99 % of the time [2, 11] , assuming that the system and radios receive adequate mains power 100% of the time and not counting equipment availability. The 802.16.3 specifications SHALL NOT preclude the ability of the radio link to be engineered for different link availabilities, based on the preference of the system operator.

A period of unavailable time begins at the onset of ten consecutive SES events based on the following definitions (cite G.826).

- Severely Errored Second (SES) is defined as a one-second period which contains 30% errored blocks.

- Errored Block (EB): A block is defined as a set of consecutive bits associated with the path. Consecutive bits may not be contiguous in time. A block is typified as data block containing an error detection code for service performance monitoring. An errored block is a block in which one or more bits are in error.

It is expected that the highest contributor to 802.16.3 system outage will be excessive attenuation and multipath due to varying path impediments such as reflections and foliage In a multicell environment, intercell interference can not be neglected as an outage increasing factor. 802.16.3 MAC and PHY protocols MUST accommodate these conditions, perhaps consuming more radio bandwidth and/or requiring smaller radio propagation distance (radius) to meet the availability requirements. Since statistical atmospheric and path conditions vary widely in geography, the 802.16.3 protocols MUST be flexible in consumed radio bandwidth (spectral efficiency), cell radius, and transmit power. Bandwidth and cell radius are critical components of system/cell capacity planning (also see section 5.7).

802.16.3 MAC and PHY protocols SHOULD specify functions and procedures to adjust transmitter power, modulation, or other parameters to accommodate rapid changes in channel characteristics.

5.5 Radio Link Error Performance

The error rate, after application of the appropriate error correction mechanism (e.g., FEC), delivered by the PHY layer to the MAC layer SHALL meet IEEE 802 functional requirements with the following exception: the radio link bit error ratio (BER) SHALL be 10E-6 (in accordance with ITU FWA recommendations (see XXX: Need ITU reference) or better. Note that this BER of the recovered payload applies to a BWA system which is only one component of a network's end-to-end BER. Note that the size of the data block is TBD.

5.6 Delay

Variation of delay, or jitter, is important to consider. For example, a high variation of delay can severely impact telephony services. However, generic Internet access can tolerate a high degree of delay variation.

The end-to-end delay is a subjective metric and depends on an entire application-specific network encompassing all 7 layers of the OSI model.

[T; Trinkwon: Change jitter spec to 20ms in following paragraph (apply to wherever applicable)]
[Delete the following two paragraphs, but rework it into QoS table(s)
Note: QoS ad hoc group should address this issue.]
~~The budget for 802.16.3 system transit delay and access delay MUST be derived. [15] [17].~~
~~The MAC layer may have different requirements for each direction, upstream and downstream. In the upstream direction, time MUST be budgeted for requesting bandwidth and contending among nodes. The budget for 802.16.3 transit delay is suggested to be less than 19.5 ms [15] for "stringent QoS" services.~~

~~ITU I.356 [73] recommends end-to-end variation (jitter) for "stringent QoS class" to be less than 3 ms. Multimedia videoconferencing requires delay variation to be less than 200 ms end-to-end to allow for reasonable synchronization of audio and video streams [17]. It is suggested that the budget for 802.16.3 systems be 1.5ms [15] for "stringent QoS" services.~~

Please refer to section 7, descriptions of QoS parameters.

5.7 Capacity

802.16.3 base station capacity requirement is defined as the product of the number of subscribers, their peak bandwidth requirements and load factor based on quality of service guarantees. The standard SHALL support careful planning to ensure that subscribers' quality of service guarantees and minimum error rates are met.

The delivered base station capacity can vary depending on attenuation due to atmospheric conditions, LOS blockage, transmit power, etc., and SHALL be calculated as the aggregate capacity of all sectors supported by a base station. Sector capacity is defined as the product of two factors: the "modulation factor" and the "sector-bandwidth factor" based on quality of service guarantees. The "modulation factor" is defined as the sector's aggregate bit rate divided by the bandwidth. The "sector-bandwidth factor" is defined as the total frequency band available for the BWA service, adjusted by the appropriate frequency re-use factors. [Editor's note: need to define freq. Re-use factor?] This reflects mainly the factor of frequency reallocation and the ability to optimize frequency usage.

- [Editor's note to reviewers: consider more items, numerical examples, bulleted format?]

Given the propagation characteristics in a given frequency band and geographic area, and the development of a link budget [11], the following parameters of an 802.16.3 system SHOULD be addressed by the MAC and PHY protocols [11]:

- Radio range (up to 50 Km)
- Upstream/downstream channels' data rates
- Allocation of prospective subscriber data rate to channels. Note: the MAC and PHY standards MAY allow subscribers to hop between channels
- Types of modulation

The MAC and PHY protocols MUST accommodate channel capacity issues and changes in channel capacity to meet contracted service levels with customers. For example, flexible modulation types, power level adjustment, and bandwidth reservation schemes MAY be employed. Also, as subscribers are added to 802.16.3 systems, the protocols MUST accommodate them in an automated fashion.

The time-variant impairments (multi-path interference) is expected to be the most significant contributor to channel impairments and complexity in cell capacity planning [7] [37] [38] [39] [40] [11] [50] [51] [52] [53]. Common metrics, such as dispersive fade margin (DFM) [7] for frequency-selective fading environments, may be employed to compare the performance of 802.16.3 equipment (e.g., radios and modems).

6 Wireless Media Characteristics

6.1 Duplex Modes

This standard SHALL permit two duplex modes of operation: Frequency Division Duplex (FDD) and Time Division Duplex (TDD). Full duplex operation is used in FDD to maximize spectral efficiency. In TDD, the spectral efficiency is maximized with means to avoid co-location problems and more complex interference scenarios. The PHY and MAC protocols MUST provide for full duplex operation, while preserving the QoS, BER and spectral efficiency requirements for data and voice traffic. The MAC and PHY protocols MUST provide means to resolve the collocation and interference problems in TDD deployment.

6.2 Channelization

The MAC and PHY protocols MUST permit the operation with channel spacing of 1.75, 3.5 and 7MHz when using ETSI masks and 1.5 to 25MHz when using other masks. The typical value for performance analysis SHOULD be 3.5MHz for the ETSI mask and 3MHz for the MDS mask.

7 Class of Service and Quality of Service

Note: This section is to be reworked into the QoS section by the QoS ad hoc group. Any comments from individuals on this particular section will not be accepted. Please contact George Fishel to participate in the ad hoc group.

This section describes the classes of service and quality of service for 802.16.3 systems. Terminology is borrowed from the Internet Engineering Task Force (IETF) worlds.

802.16.3 protocols MUST support classes of service (CoS) with various quality of service (QoS) guarantees to support the service capabilities (see section 3) that an 802.16.3 system MUST support. Thus, 802.16.3 protocol standards MUST define interfaces and procedures that accommodate the needs of the services with respect to allocation of prioritization of bandwidth. Additionally, 802.16.3 protocols MUST provide the means to enforce QoS contracts and Service Level Agreements [2] (see section 8.1). Table 1 provides a summary of the QoS requirements that the PHY and MAC SHALL provide. Note that delay in the table refers to the transmission delay from the MAC input from the upper layer at the transmit station to the MAC output to the upper layer the receiving station for information transmission. It does not include setup time, link acquisition, etc.

For QoS-based, connectionless, but not circuit-based, services, the 802.16.3 protocols MUST support bandwidth negotiation “on-demand” [9]. For instance, the MAC protocol MAY allocate bursts of time slots to services that require changes in bandwidth allocation. Such allocation is thus performed in a semi-stateless manner. A connection-oriented service may require “state” information to be maintained for the life of a connection. However, the 802.16.3 MAC layer interface MAY provide a connection-less service interface that requires a higher-layer “adaptation” to maintain the “state” of a connection and periodically allocate bandwidth. For instance, the MAC may need to maintain “state” information about a QoS data flow only for the duration of an allocation.

Table 1: Services and QoS Requirements

Service			**Maximum**

	MAC Payload Rate	Maximum Ratio	Delay (One way)
Circuit-Based [T; Trinkwon: delete circuit-based params]			
High Quality Narrowband/Voice Frequency Telephony (Vocoder MOS ≥ 4.0)	32 kbps – 64 kbps	10^{-6} BER	~~5~~ 20 [T; Trinkwon] msec
Lower Quality Narrowband/Voice Frequency Telephony (Vocoder MOS < 4.0)	6 kbps – 16 kbps	10^{-4} BER	~~10~~ 20 [T; Trinkwon] ms
Variable Packet [71]			
Time Critical Packet Services	4-13 kbps (voice) and 32-1.5 Mbps (video)	BER 10^{-6}	~~10ms~~1/4 of the VoIP codec end-to-end delay [T; Goldhammer] 100 ms [T; Wachira] 20 ms [T; Trinkwon]
Non- Time Critical Services: IP, IPX, FR… Audio/video streaming, Bulk data transfer etc..	<= 10 Mbps	BER 10^{-8}[-6; T; Trinkwon]	~~N/A~~20 ms [T; Trinkwon]

7.1 Types and Classes of Service

The fundamental direction for the QoS model that will be exported to the BWA endpoints will be IP based and conform to IETF DiffServ QoS model in conjunction with other IP based protocols. The [E; Freedman] DiffServ QoS model defines traffic for all services as follows:

- Expedited forwarding (EF) EF requires a constant, periodic access to bandwidth. The bandwidth requirements vary over time, within a specified range, but delay and delay variance limits are specified. Examples that fall into this category are voice-over-IP (VoIP), videoconferencing, video on demand (VoD), and other “multimedia” applications.
- Assured Forwarding (AF): In AF the bandwidth varies, within a specified range, but has loose delay and delay variance requirements. Applications, which are limited in their bandwidth usage, may fall into this category. In one example, corporate database transactions could be relegated to this category. 'Assured Forwarding' service allows the traffic to be divided into different classes. Using this service, an ISP can offer an "Olympic" service model, which provides three tiers of services: gold, silver and bronze with decreasing quality (i.e., the gold level of service receives a higher share of resources than silver during times of congestion). This service model would support, for example, the ability to provide preferential treatment to subscribers willing to pay a "premium" price for better service. Or it would support more granular priorities such as giving preference to VoIP traffic over other traffic e.g., HTTP).
- Best Effort Service (BES). The bandwidth varies within a wide range, and is allowed to burst up to the maximum link bandwidth when EF and AF traffic are not using bandwidth. The bandwidth and delay requirements may or may not be specified. Higher variations of delay may be tolerable since applications that fall into this category allow for priority traffic to preempt their bandwidth consumption. Bandwidth is delivered on a “best effort” basis. Current Internet service is an example of this type of operation.

7.2 Parameters

The 802.16.3 protocols SHALL define a set of parameters to meet the required QoS parameters for the supported services (e.g., ATM CBR Services and IP)~~802.16.3 protocols SHALL define a set of parameters that preserve the intent of QoS parameters for IP-based services.~~[T; Kostas]

7.3 Service QoS Mappings

The classes of service and QoS parameters of services SHALL be translated into a common set of parameters defined by 802.16.3.
A QoS-based IP network may employ the Resource Reservation Protocol (RSVP) [70] to "signal" the allocation of resources along a routed IP path. If 802.16.3 is to be a "link" in the IP network, an IWF MUST interface with 802.16.3 to negotiate resource allocation.

The basic mechanism available within 802.16.3 systems for supporting QoS requirements is to allocate bandwidth to various services. 802.16.3 protocols SHOULD include a mechanism that can support dynamically-variable-bandwidth channels and paths (such as those required for IP- and ATM-based services)~~(such as those defined for IP environments)~~[T; Kostas].

8 Management

As outlined in IEEE Std 802-1990 [21], The LLC Sublayer, MAC Sublayer and Physical Layer standards also include a management component that specifies managed objects and aspects of the protocol machine that provide the management view of managed resources. The aspect of management considered are (FCAPS):

- Fault management
- Configuration management
- Accounting management
- Performance management (see also section 5)
- Security (see also section 9)

The 802 standards define a framework for LAN/MAN management in ISO/IEC 15802-2: 1995(E) [24]. The framework contains guidelines for managed objects, management protocol, and the relationship to ITU management protocols (SNMP/CORBA). [XXX: Editor will add references]

8.1 Service Level Agreements

The 802.16.3 protocols MUST permit operators to enforce service level agreements (SLAs) with subscribers by restricting access to the air link, discarding data, dynamically controlling bandwidth available to a user or other appropriate means [3]. The 802.16.3 protocols MUST also permit subscribers to monitor performance service levels of the 802.16.3 services being provided at the delivery point.

8.2 Malfunctioning Subscriber Station or Base Station

The operator MUST have means to shut down a subscriber station if necessary, remote from the subscriber station, in the face of a malfunction. The operator also MUST have the means to shut down a base station remotely. The 802.16.3 protocols SHOULD support a function that automatically shuts down transmission from a subscriber station or base station in case of malfunction (e.g., power limits exceeded).

8.3 Accounting and Auditing

The 802.16.3 system management framework, architecture, protocols and managed objects MUST allow for operators to effectively administer accounting and auditing. An operator MUST be able to account for time- and bandwidth-utilization and the various QoS parameters for each subscriber. Also recall from Section that a single subscriber station can interface to multiple subscribers that an operator could bill separately.

9 Security

The 802.16.3 system SHALL enforce security procedures described in this section.

The security system chosen by 802.16.3 SHALL be added to the protocol stack and reference points to include security protocols, and “database” servers for authentication, authorization, key management, etc. [29] [30]

9.1 Authentication

There are two levels of authentication for an 802.16.3 system. The first level of authentication is when the subscriber station authenticates itself with the base station at the subscriber station's network entry. This initial authentication MUST be very strong in order to prevent “enemy” subscriber station from entering the network or an “enemy” base station from emulating a real base station. Once the initial authentication at this level is complete, future authentication at this level can be a little more relaxed. This level of authentication MUST be supported by the 802.16.3 MAC layer.

The second level of authentication is between the subscriber and the BWA system. This may or may not be the responsibility of the 802.16.3 protocols. It MAY be handled by higher layer protocols.

An additional level of authentication may exist between the other two. This additional layer is the authentication of the subscriber with the subscriber station. This is beyond the scope of the 802.16.3 protocols.

The authentication mechanisms MUST be secure so that an “enemy” subscriber station is not able to gain access to an 802.16.3 system, or to the core network beyond. Passwords and secrets MUST NOT be passed “in the clear” through the air interface.

9.2 Authorization

Authorization is a security process that determines what services an authenticated subscriber is permitted to invoke. Each subscriber has a set of credentials that describe what the subscriber is “allowed” to do. The 802.16.3 standard SHALL identify a standard set of credentials and allow for vendors to extend the defined credentials with non-standard credentials. Some possible credentials are:

- Permission to access the 802.16.3 system

- Permission to request up to a defined QoS profile (bandwidth, delay, etc.)

- Permission to operate certain services (IP, Remote Bridging, Digital Audio/Video, etc.)

Subscriber authorization requests and responses MUST be transacted securely.

9.3 Privacy

Privacy is a security concept that protects transmitted data from being intercepted and understood by third parties (e.g., an "enemy" subscriber station, base station or passively "listening" radio). Wire-equivalent privacy (WEP) [10] and shared private key [10] privacy have been suggested as minimum required privacy levels for 802.16.3 systems.

802.16.3 standards SHOULD allow a strong cryptographic algorithm to be employed that is internationally applicable. Facilities SHOULD also be defined in the protocol for the use of alternate cryptographic algorithms that can be used in certain localities and that can replace algorithms as they are obsoleted or "legalized" for international use.

10 802 Conformance

As mentioned in some earlier sections of this document, 802.16.3 SHOULD strive to fit into the 802 system model. Some particulars with the 802 model (see *IEEE Standards for Local and Metropolitan Area Networks: Overview and Architecture* (IEEE Std 802-1990) [21]) are:

- The 802.16.3 MAC supports 802 "universal" 48 bit addresses.

- An 802.16.3 system supports MAC multicast. Note that 802.16.3 protocols support multicast in the downstream direction only, not upstream.

- The 802.16.3 protocols support 802.1 bridging services and protocols, including support of the 802.1q virtual LAN tag and 802.1D priority ID [25] [26] [28].

- The 802.16.3 protocols support encapsulation of 802.2 (LLC) [67] by the MAC protocol .

- Conform to the 802 conventions and structures for "interface primitives:" logical structures that are passed between protocol layers to invoke processes and transact data.

- Address the 802 system management guidelines (see section 8) [27].

- Provide a MAC service interface that complies to 802 conventions [22].

Appendix

A Requirements Summary

[Editor's note: This section will be reworked by the editor prior to the "final" version of this document. All the summaries will reflect the content in the rest of document.]

This section contains tabular summaries or requirements found in the text of this document. Requirements are separated into three categories: required, recommended and optional.

Each requirement is numbered for easy reference. Future revisions of this document will keep the requirement reference numbers intact such that the number for a requirement will not change from revision to revision.

To better discern the meaning and intent of a requirement, please refer to the text.

Editor's note: As additional information for 802.16 task groups, the areas of the standard which a requirement is most likely to affect are also given: MAC, PHY, Management (MGMT), and Security (SEC). This additional information, selected by the editor, is meant as a guideline only: task groups should examine the impact of *all* requirements.

A.1 Mandatory

It is mandatory that the 802.16.3 standard support or specify the items in Table 2.

Table 2: Mandatory Requirements

#	Section	Requirement	Affects Mostly
M1	1	The forthcoming air interface standard MUST comply with the system requirements.	All
M2	1.1	The 802.16.3 air interface interoperability standard SHALL be part of a family of standards for metropolitan area networks.	All
M3	2	802.16.3 systems SHALL be deployable in multiple-cell frequency reuse system configuration and in single super cell frequency reuse system configuration.	MAC PHY
M4	2	The 802.16.3 system SHALL be deployable as a Point-to-Multi-point system.	MAC PHY
M5	2.1	The standard (e.g., MAC/PHY protocols) SHALL describe common access protocol(s) and common modulation technique(s).	MAC PHY
M6	2.2	All data traffic in a single cell of an 802.16.3 network MUST go through the base station.	MAC
M7	2.2	The base station SHALL serve as a radio resource supervisor.	MAC
M8	2.2	802.16.3 protocols MUST provide the means to multiplex traffic from multiple subscriber stations in the downstream direction, and provide for a means to resolve contention and allocate capacity in	MAC

		the upstream direction.	
M9	3.1.2	802.16.3 systems and protocols MUST support the QoS requirements of the telephony services: • POTS via Voice Over IP • NxDS0 via Voice over IP • FT1/FE1 reconfigured from NxDS0 at the CPE.	MAC
M10	3.1.2.1	The amount of delay between a user speaking and another user hearing the speech MUST be kept below a certain level to support two-way conversation.	MAC PHY
M11	3.1.2.1	BWA protocols MUST support efficient transport of encoded voice data in terms of bandwidth, reliability and delay.	MAC PHY
M12	3.1.2.2	MUST meet the pass through requirements of telephony signaling, whether TDM- or message-oriented.(For further study)	MAC
M13	3.1.4	802.16 MUST directly transport variable length IP datagrams efficiently.	MAC
M14	3.1.4	Both IP version 4 and 6 MUST be supported.	MAC
M15	3.1.4	The 802.16.3 IP service MUST provide support for real-time and non-real-time services.	MAC
M16	4	The MAC protocol MUST define interfaces and procedures to provide guaranteed service to the upper layers.	MAC
M17	4	The MAC protocol MUST efficiently resolve contention and capacity allocation.	MAC
M18	4	Further details, and finalization of the protocol reference model, SHALL be worked out by the 802.16.3 MAC and PHY task groups while developing the air interface interoperability standard.	All
M19	5.2	802.16.3 protocols SHALL be optimized to provide the peak capacity up to 2 and enable up to 10 Mbps	MAC PHY
M21	5.4	The 802.16.3 specifications SHALL NOT preclude the ability of the radio link to be engineered for different link availabilities, based on the preference of the system operator.	PHY
M22	5.4	802.16.3 MAC and PHY protocols MUST accommodate atmospheric conditions, perhaps consuming more radio bandwidth and/or requiring smaller radio propagation distance (radius) to meet the availability requirements.	MAC PHY MGMT
M23	5.4	Since statistical atmospheric conditions vary widely in geography, the 802.16.3 protocols MUST be flexible in consumed radio bandwidth (spectral efficiency), cell radius, and transmit power to accommodate a rain allowance that varies with geography.	MAC PHY MGMT
M24	5.5	The error rate, after application of the appropriate error correction mechanism (e.g., FEC), delivered by the PHY layer to the MAC layer SHALL meet IEEE 802 functional requirements: The bit error	MAC PHY

		rate (BER) is 10E-9.	
M26	5.6	The budget for the 802.16.3 system transit delay and access delay MUST be derived. The MAC layer may have different requirements for each direction, upstream and downstream.	MAC PHY
M27	5.6	In the upstream direction, time MUST be budgeted for requesting bandwidth and contending among nodes.	MAC
M28	5.7	In a given 802.16.3 system instance, capacity MUST be carefully planned to ensure that subscribers' quality of service guarantees and maximum error rates are met.	MGMT
M29	5.7	The MAC and PHY protocols MUST accommodate channel capacity issues and changes in channel capacity to meet contracted service levels with customers.	MAC PHY MGMT
M30	5.7	As subscribers are added to 802.16.3 systems, the protocols MUST accommodate them in an automated fashion.	MAC MGMT
M31	6	802.16.3 protocols MUST support classes of service (CoS) with various quality of service (QoS) guarantees to support the services that that support IP protocol.	MAC
M32	6	802.16.3 protocol standards MUST define interfaces and procedures that accommodate the needs of the services with respect to allocation of prioritization of capacity.	MAC
M33	6	802.16.3 protocols MUST provide the means to enforce QoS contracts and Service Level Agreements.	MAC MGMT
M35	6	For QoS-based, connectionless the 802.16.3 protocols MUST support guaranteed bandwidth in provisioning process of the system	MAC
M37	6.2	802.16.3 protocols SHALL define a set of parameters that preserve the intent of QoS parameters for IP-based services.	MAC
M44	7.1	The 802.16.3 protocol MUST permit operators to enforce service level agreements (SLAs) with subscribers by restricting access to the air link, discarding data, dynamically controlling bandwidth available to a user or other appropriate means.	MAC MGMT
M45	7.1	The 802.16.3 protocols MUST permit subscribers to monitor performance service levels of the 802.16.3 services being provided at the delivery point.	MAC PHY MGMT
M46	7.2	The operator MUST have means to shut down a subscriber station if necessary, remote from the subscriber station, in the face of a malfunction.	MAC PHY MGMT
M48	7.3	The 802.16.3 system management framework, architecture, protocols and managed objects MUST allow for operators to effectively administer accounting and auditing via the SNMP protocol.	MAC MGMT
M49	7.3	An operator MUST be able to account for time- and bandwidth-utilization and the various QoS parameters for each subscriber.	MAC

M50	8	The 802.16.3 system SHALL enforce security procedures described in section This will be implemented with the Baseline Privacy Interface (BPI) specification currently available with the IP centric solutions available today.	MAC SEC
M51	8	The security system chosen by 802.16.3 SHALL be added to the protocol stack) and reference points to include security protocols, and "database" servers for authentication, authorization, key management, etc.	SEC
M52	8.1	This initial authentication MUST be very strong in order to prevent an "enemy" subscriber station from entering the network or an "enemy" base station from emulating a real base station.	MAC SEC
M53	8.1	Initial authentication MUST be supported by the 802.16.3 MAC layer.	MAC SEC
M54	8.1	The authentication mechanisms MUST be secure so that an "enemy" subscriber station is not able to gain access to an 802.16.3 system, or to the core network beyond.	MAC SEC
M55	8.1	Passwords and secrets MUST NOT be passed "in the clear" through the air interface.	MAC SEC
M56	8.2	The 802.16.3 standard SHALL identify a standard set of credentials and allow for vendors to extend the defined credentials with non-standard credentials.	MAC SEC MGMT
M57	8.2	Subscriber authorization requests and responses MUST be transacted securely.	MAC SEC

A.2 Recommended (R)

It is recommended that the 802.16.3 standard support or specify the items in Table 3 "Recommended" means that there may exist valid reasons in particular circumstances to ignore an item, but the full implications should be understood and the case carefully weighed before choosing a different course.

Table 3: Recommended Requirements

#	Section	Requirement	Affects Mostly
R1	1.2	802.16.3 SHOULD support more than one paying customer at a single access point to a subscriber BWA radio.	MAC MGMT SEC
R3	3	An 802.16.3 system SHOULD support the services described in section	MAC PHY MGMT
R4	3.1	The MAC and PHY protocols may not have explicit support for each and every service, since they SHOULD be handled as data streams in a generic fashion.	MAC PHY

R5	3.1.1	802.16.3 SHOULD efficiently transport digital audio/video streams to subscribers.	MAC PHY
R6	3.1.2	802.16.3 systems SHOULD support supplying telephony to subscribers in a way that eases the migration of legacy telephony equipment and public switched telephone network (PSTN) access technologies to 802.16.3 systems.	MAC PHY MGMT
R9	3.1.4	For efficient transport of IPv6, TCP/IP header compression over the air interface SHOULD be supported.	MAC
R10	3.1.4	It SHOULD be possible to support the emerging IP Quality of Service (QoS) efforts: Differentiated Services and Integrated Services.	MAC
R11	3.1.6	The 802.16.3 protocols SHOULD NOT preclude the transport of the following services: • Back-haul service • Virtual point-to-point connections • Frame Relay Service	MAC
R12	5.1	The 802.16.3 protocols SHOULD allow for different “scales” of capacity and performance for 802.16.3 system instances.	MAC PHY
R13	5.2	802.16.3 MAC protocol SHOULD allow the upper range of delivered bandwidth to scale beyond 10 Mbps.	MAC PHY
R14	5.3	802.16.3 protocols SHOULD allow for flexibility between delivered upstream and downstream bandwidth and CoS/QoS.	MAC PHY
R15	5.4	An 802.16.3 system SHOULD be available to transport all services at better than their required maximum error rates from about 99.9 to 99.95 % of the time, assuming that the system and radios receive adequate power 100% of the time and not counting equipment availability.	PHY
R16	5.4	802.16.3 MAC and PHY protocols SHOULD specify functions and procedures to adjust power, modulation, or other parameters to accommodate rapid changes in channel characteristics due to atmospheric conditions.	MAC PHY MGMT
R17	5.6	In a telephony network, the maximum acceptable end-to-end delay for the longest path is RECOMMENDED to be less than 300ms.	MAC PHY
R18	5.7	The following parameters of an 802.16.3 system SHOULD be addressed by the MAC and PHY protocols: • Upstream/downstream channels’ data rates • Allocation of prospective subscriber data rate to channels. Note: the MAC and PHY standards may allow subscribers to hop between channels • Types of modulation	MAC PHY MGMT

R19	6.3	802.16.3 protocols SHOULD include a mechanism that can support dynamically-variable-bandwidth channels and paths as defined for IP environments.	MAC
R20	7.2	The 802.16.3 protocols SHOULD support a function that automatically shuts down transmission from a subscriber station or base station in case of malfunction (e.g., power limits exceeded).	MAC PHY MGMT
R21	8.3	Allow for a strong cryptographic algorithm to be employed that is internationally applicable.	SEC
R22	8.3	Facilities SHOULD also be defined in the protocol for the use of alternate cryptographic algorithms that can be used in certain localities and that can replace algorithms as they are obsoleted or "legalized" for international use.	SEC
R23	9	802.16.3 SHOULD strive to fit into the 802 system model.	All

A.3 Optional (O)

It is optional that the 802.16.3 standard support or specify the items in Table 4.

Table 4: Optional Requirements

#	Section	Requirement	Affects Mostly
O4	3.1.5	The 802.16.3 protocols MAY support bridged LAN services, whether directly or indirectly.	MAC
O6	5.7	The MAC and PHY standards MAY allow subscribers to hop between channels.	MAC PHY
O7	5.7	Flexible modulation types, power level adjustment, and bandwidth reservation schemes MAY be employed.	MAC PHY
O9	6	The MAC protocol MAY allocate bursts of time slots to services that require changes in bandwidth allocation.	MAC
O10	8.1	The second level of authentication, between the subscriber and the BWA system, MAY be handled by higher layer protocols.	MAC SEC

B Vocabulary of Terms

Term	Definition	Reference
Access	End-user connection(s) to core networks NOTE 1 - Core networks include, for example, PSTN, ISDN, PLMN, PSDN, Internet, WAN/LAN, CATV, etc. NOTE 2 - The end-user may be a single user or a user accessing the services on behalf of multiple users.	Based on Rec. ITU-R F.1399
Accounting	A function which apportions the revenue obtained by the service providers to network operators in line with commercial arrangements.	Rec. ITU-R M.1224
Air interface	The common boundary between the subscriber station and the radio equipment in the network, defined by functional characteristics, common radio (physical) interconnection characteristics, and other characteristics, as appropriate. NOTE 1 – An interface standard specifies the bi-directional interconnection between both sides of the interface at once. The specification includes the type, quantity and function of the interconnecting means and the type, form and sequencing order of the signals to be interchanged by those means.	Based on Rec. ITU-R M.1224
Authentication	The process of verifying the identity of a user, terminal, or service provider.	Rec. ITU-R M.1224
Authorization	A property by which the rights to resources are established and enforced.	Rec. ITU-R M.1224
Backhaul service	Transport of aggregate communication signals from base stations to the core network.	IEEE 802.16
Bandwidth; communication channel bandwidth	The bandwidth of the information payload capacity of a communication channel available to a user for services (expressed in bit/s or multiples thereof).	
Bandwidth; RF channel bandwidth	The bandwidth of a specified portion of the RF spectrum capable of carrying information over the radio interface (expressed in Hz or multiples thereof).	
Bandwidth; transmission channel bandwidth	The frequency spectrum bandwidth required for the transmission of a specified signal (expressed in Hz or multiples thereof).	
Base station	The common name for all the radio equipment	ITU-R Rec. M.1224

	located at one and the same place used for serving one or several cells. (See also “station”).	
Bearer service	A type of telecommunication service that provides the capability for the transmission of signals between user-network interfaces.	ITU-T Rec. I.112
Broadband wireless access	wireless access in which the connection(s) capabilities are higher than the primary rate.	Rec. ITU-R F.1399
Cell	The radio coverage area of a base station, or of a subsystem (e.g. sector antenna) of that base station corresponding to a specific logical identification on the radio path, whichever is smaller.	Based on Rec. ITU-R M.1224
Cell	A block of fixed length which is identified by a label at the asynchronous transfer mode layer of the B-ISDN protocol reference model.	ITU-T Rec. I.113
Cell delay variation	A component of cell transfer delay, induced by buffering and cell scheduling.	ATM Forum
Cell loss ratio	The proportion of lost cells over the total number of transmitted cells for a connection.	ATM Forum
Channel; communication channel	A specific portion of the information payload capacity, available to the user for services.	ITU-T Rec. I.113
Channel; radio-frequency (RF) channel	A specified portion of the RF spectrum with a defined bandwidth and a carrier frequency and is capable of carrying information over the radio interface.	Rec. ITU-R M.1224
Channel; transmission channel	A means of unidirectional transmission of signals between two points.	ITU-T Rec. I.112
Core network	Core networks include, for example, PSTN, ISDN, PLMN, PSDN, Internet, WAN/LAN, CATV, etc.	Based on Rec. ITU-R F.1399
Customer premises equipment/network	The equipment/network administered by the user.	Based on ITU-T Rec. H.310
Downstream	The direction from base station to subscriber station(s).	IEEE 802.16
Dynamically variable bandwidth	A capability of a system to be able to change the bandwidth of the information payload capacity of a communication channel available to a user for services according to negotiated user requirements.	
Fixed wireless	Wireless access application in which the base	Based on Rec. ITU-R

access	station and the subscriber station are fixed.	F.1399
Frequency Division Duplex	Separation of upstream and downstream transmission in the frequency domain at the same time.	IEEE 802.16
Internet protocol	Networking protocol defined by IETF standards.	IETF
Interoperability	The ability of multiple entities in different networks or systems to operate together without the need for additional conversion or mapping of states and protocols.	Rec. ITU-R M.1124
Inter-working	The means of supporting communications interactions between entities in different networks or systems.	Rec. ITU-R M.1124
Inter-working function	Mechanism which masks the differences in physical, link, and network technologies by converting or mapping states and protocols into consistent network and user services.	Rec. ITU-R M.1124
Network	A set of nodes and links that provides connections between two or more defined points to facilitate telecommunication between them.	Rec. ITU-R M.1224
Nomadic wireless access	Wireless access application in which the subscriber station may be in different places but must be stationary while in use.	Based on ITU-R Rec. F.1399
plesiochronous mode	A mode where the essential characteristic of time scales or signals such that their corresponding significant instants occur at nominally the same rate, any variation in rate being constrained within specified limits.	ITU-T Rec. G.810 (96), 4.3.5
Point-to-multipoint system	a system that establishes connections between a single specified point and more than one other specified points.	ITU-R Rec. F.1399
Privacy	The provision of capabilities to prevent access of information by unauthorized parties.	ANSI T1.702-1995
Quality of service	The collective effect of service performance which determine the degree of satisfaction of a user of the service. NOTE 1 - The quality of service is characterized by the combined aspects of service support performance, service operability performance, serviceability performance, service security performance and other factors specific to each service. NOTE 2 - The term "quality of service" is not used	ITU-T Rec. E.800 (94), 2101

	to express a degree of excellence in a comparative sense nor is it used in a quantitative sense for technical evaluations. In these cases a qualifying adjective (modifier) should be used.	
Radio interface	See air interface	Rec. ITU-R M.1224
Real-Time (adjective)	Pertaining to the processing or transmission of data according to defined time requirements .	Based on ITU-T Rec. Q.9 (88), 6103
Security	The protection of information availability, integrity and confidentiality, as well as authentication and authorization.	Based on Rec. ITU-R M.1224
Service	A set of functions offered to a user by an organization.	Recs. ITU-R M.1224, M.1308
Station	the common name for all the radio equipment at one and the same place. NOTE - The term "station" may refer to any end-user radio equipment (“subscriber station”) or network radio equipment (“base station”).	Rec. ITU-R M.1224
Subscriber	A person or other entity that has a contractual relationship with a service provider on behalf of one or more users. (A subscriber is responsible for the payment of charges due to that service provider.)	Rec. ITU-R M.1224
Subscriber station	the common name for all the radio equipment at one and the same place serving one or more users. (See also “station”).	Based on Rec. ITU-R M.1224
Supplementary service	A service which modifies or supplements a basic telecommunication service. Consequently, it can not be offered to a customer as a standalone service, rather, it must be offered together with or in association with a basic telecommunication service. The same supplementary service may be common to a number of telecommunication services.	Rec. ITU-R M.1224
Synchronous transfer mode	A transfer mode which offers periodically to each connection a fixed-length block.	Based on ITU-T Rec. I.113
System	A regularly interacting or interdependent group of items forming a unified whole technology.	Recs. ITU-R M.1224, M.1308
Time Division Duplex	Separation of upstream and downstream transmission in the time domain using the same frequency.	IEEE 802.16
Upstream	The direction from subscriber station(s) to base station.	IEEE 802.16
User	Any entity external to the network which utilizes	ITU-T Rec. E.600

	connections through the network for communication.	
Virtual point-to-point connections	Providing a point-to-point connection to a subscriber using a point to multipoint system.	IEEE 802.16
Wireless access	end-user radio connection(s) to core networks. NOTE 1 - Core networks include, for example, PSTN, ISDN, PLMN, PSDN, Internet, WAN/LAN, CATV, etc. NOTE 2 - The end-user may be a single user or a user accessing the services on behalf of multiple users.	Rec. ITU-R F.1399

B.1 Acronyms and Abbreviations

Acronym/Abbreviation	**Definition**
BBER	Background block error ratio
BER	Bit Error Ratio
B-ISDN	Broadband aspects of ISDN
BNI	Base station network interface
BWA	Broadband Wireless Access
CDVT	Cell delay variation tolerance
CLR	Cell loss ratio
CPE	Customer premises equipment
DSL	Digital Subscriber Line
FDD	Frequency Division Duplex
HFC	Hybrid fiber coax
IP	Internet protocol
ISDN	Integrated Services Digital Network
IWF	Inter-working function
LAN	Local area network
LLC	Logical link control
MAC	Medium Access Control
MAN	Metropolitan area network
MBS	Maximum burst size
MCR	Maximum cell rate
MCTD	Maximum cell transfer delay
OSI	Open Systems Interconnection
PBX	Private Branch Exchange
PCR	Peak cell rate
PDH	Plesiochronous Digital Hierarchy
PDU	Protocol Data Unit
PHY	Physical layer
P-MP	Point-to-multipoint
PSTN	Public Switched Telephone Network
QoS	Quality of service
SCR	Suitable cell rate
SDH	Synchronous Digital Hierarchy
SNI	Subscriber station network interface
TC	Transmission convergence
TDD	Time Division Duplex
UBR	Unspecified bit rate

C References

[Editor's notes: these references are not in a particular order. Some of these references are not cited in the text of this document. Prior to the "final" version of this document, the editor will confirm all references.]

[2] James Mollenauer, 802.16sc-99/5 Functional Requirements for Broadband Wireless Access Networks.

[3] Jim Mollenauer, 802.16sc-99/7 Functional Requirements for the 802.16 Standard.

[4] Brian Petry, 802.16sc-99/8 System Requirements Agenda and On-the-fly Notes from 5/99 Boulder Meeting.

[5] Brian Petry, 802.16sc-99/9 ITU-R 9B/134E (cable modem over BWA) Requirements.

[7] John Liebetreu, 802.16sc-99/13 Dispersive Fade Margin: A Physical Layer Performance Metric.

[10] Marianna Goldhammer, 802.16sc-99/16 MAC Services.

[13] Scott Marin, 802.16sc-99/19 The Network Topology of Point to Multipoint Radio Systems.

[14] Scott Marin, 802.16sc-99/20 802.16 Services and Applications.

[15] Scott Marin, 802.16sc-99/21 Quality of Service.

[16] George Fishel, 802.16sc-99/22 Interface to MAC and LLC Protocols.

[17] Imed Frigui, 802.16sc-99/23 Services and Performance requirements for Broadband Fixed Wireless Access.

[19] Doug Gray, 802.16cc-99/04 WW Spectrum Allocations for BWA.

[20] 802.16 PAR: Telecommunications and Information Exchange Between Systems - LAN/MAN Specific Requirements - Air Interface for Fixed Broadband Wireless Access Systems.

[20] 802.16 Rationale for a Broadband Wireless Access Air Interface Standard: Meeting the Five Criteria.

[21] IEEE Std 802-1990 "IEEE Standards for Local and Metropolitan Area Networks: Overview and Architecture. IEEE 1990.

[22] ISO/IEC 10039: 1991. Information technology -- Open Systems Interconnection -- Local area networks -- MAC service definition.

[23] ISO 7498-1:1984. Information technology -- Open Systems Interconnection -- Basic Reference Model.

[24] ISO/IEC 15802-2:1995. Information technology -- Telecommunications and information exchange between systems -- Local and metropolitan area networks -- Common specifications -- Part 2: LAN/MAN management.

[25] ISO 15802-3:1998. Information technology -- Telecommunications and information exchange between systems -- Local and metropolitan area networks -- Common specifications -- Part 3: Media Access Control (MAC) bridging.

[26] ISO/IEC 15802-5:1998. Information technology -- Telecommunications and information exchange between systems -- Local and metropolitan area networks -- Common specifications -- Part 5: Remote Media Access Control (MAC) bridging.

[27] IEEE 802.1F-1993. IEEE Standards for Local and Metropolitan Area Networks: Common Definitions and Procedures for IEEE 802 Management Information.

[28] IEEE 802.1Q-1998. IEEE Standards for Local and Metropolitan Area Networks: Virtual Bridged Local Area Networks.

[29] IEEE 802.10-1998. IEEE Standards for Local and Metropolitan Area Networks: Standard for Interoperable LAN/MAN Security (SILS).

[30] IEEE 802.10c-1998. IEEE Standards for Local and Metropolitan Area Networks: Supplement to Standard for Interoperable LAN/MAN Security (SILS) -- Key Management (Clause 3).

[31] J. Costa ITU-R 9B/134E Broadband Wireless Access Draft New Recommendation ITU-R F.BWA Radio Transmission Systems for Fixed Broadband Wireless Access (BWA) Based on Cable Modem Standards" Apr. 1999.

[33] H. D. Graves, "A Detailed Analysis of MMDS and LMDS", February 23-26, 1997 IEEE MTT-S Wireless Technology Symposium, Vancouver, Canada, pp. 7-10, Feb 1997.

[35] H. Izadpanah, D. Gregoire, J. Schaffner, and HP Hsu, "MM-Wave Wireless Access Technology For The Wideband Wireless Local Loop Applications", 1998 IEEE Radio and Wireless Conference (RAWCON'98) Colorado Springs, CO, pp. ,Aug., 1998.

[36] J. Schaffner, H. Izadpanah, and HP Hsu, "MM-Wave Wireless Technology and Testbed Development for Wideband Infrastructure Access", WCC'98, San Diego, CA, Nov. 1998.

[37] C.W. Lundgren and W.D. Rummler, "Digital radio outage due to selective fading observation vs. prediction from laboratory simulation," Bell System Technical Journal, pp.1073-1100, May-June 1979.

[38] M. Emshwiller, "Characterization on the performance of PSK digital radio transmission in the presence of multipath fading," ICC'78 Conference Record, Toronto, Ontario, CANADA, Paper 47.3.

[39] Microwave digital radio systems criteria, Bellcore Technical Reference TR-TSY-000752, October 1989.

[40] W.D. Rummler, R.P. Coutts, and M. Linger, "Multipath fading channel models for microwave digital radio," IEEE Communications Magazine, November 1986, pp.30-42.

[42] R. Braden et al., "Integrated Services in the Internet Architecture: An Overview", RFC 1633, June 1994.

[43] S. Blake et al, "An Architecture for Differentiated Services", RFC 2475, December, 1998.

[44] S. Blake et al, "A Framework for Differentiated Services", Internet Draft, October, 1998.

[45] "Broadband Radio Access Networks (BRAN); Requirements and architectures for broadband fixed radio access networks (HIPERACCESS)", ETSI Technical Report TR 101 177 V1.1.1 (1998-05).

[47] Proc. Of 1999 IMT-2000 3rd Generation Wireless Technology Conference. Feb 10-12, 1999. New Orleans, USA.

[49] Proceedings of 1999 Wireless Symposium. Feb. 22-26, 1999. San Jose, USA.

[50] R. K. Crane, "Prediction of Attenuation by Rain" IEEE, 1980.

[51] ITU-T G.826: Error performance parameters and objectives for international, constant bit rate digital paths at or above the primary rate (2/99).

[52] ITU-R F.1189-1 Error performance objectives for constant bit rate digital paths at or above the primary rate carried by digital radio-relay systems which may form part or all of the national portion of a 27500 km hypothetical reference path. (1995-1997).

[53] CCIR Recommendation 749, Radio-Frequency channels arrangements for radio-relay systems operating in the 36.0 to 40.5 GHz band. (1992).

[54] ITU-T Recommendation I.210 (1993) - "ISDN Service Capabilities Principles of Telecommunications Services Supported by an ISDN and the Means to Describe Them".

[55] W. Stallings, Data and Computer Communications, 5th ed., Prentice Hall, 1996.

[56] G. Almes et. al. "A One-way Delay Metric for IPPM". Internet Draft, May 1999.

[57] G. Almes et. al. "A Round-trip Delay Metric for IPPM". Internet Draft, May 1999.

[58] G. Almes et. al. "A One-way Packet Loss Metric for IPPM". Internet Draft, May 1999.

[59] ITU-T Recommendation I.35IP. Internet Protocol Data Communication Service IP Packet Transfer Performance Parameters.

[60] C. Demichelis. "Packet Delay Variation: Comparison between ITU-T and IETF draft definitions". Draft, carlo.demichelis@cselt.it.

[61] M. Hamdi et. al. "Voice Service Interworking for PSTN and IP Networks". IEEE Comm. Magazine, Vol. 37 No. 5, May 1999.

[63] A. Dutta-Roy. "Cable it's not just for TV". IEEE Spectrum, Vol. 36 No. 5, May 1999.

[65] L. P. Bermejo et. al. "Service Characteristic and Traffic Models in Broadband ISDN". Electrical Communication, Vol. 64-2/3, 1990, pp.132-138.

[67] ISO/IEC 8802-2:1998. Information technology -- Telecommunications and information exchange between systems -- Local and metropolitan area networks -- Common specifications -- Part 2: Logical Link Control.

[68] IEEE P802.14/a Draft 3 Revision 3, Cable-TV access method and physical layer specification Oct. 1998. (unpublished draft)

[69] Data-Over-Cable Service Interface Specifications. Radio Frequency Interface Specification V1.1 SP-RFI-104-980724, Cable Television Labs, 1998.

[70] RFC-2205 Resource ReSerVation Protocol (RSVP) -- Version 1 Functional Specification. R. Braden, Ed., L. Zhang, S. Berson, S. Herzog, S. Jamin. September 1997. Status: PROPOSED STANDARD.

[71] Recommendation ITU-R M.1079 (June 1999). Performance and Quality of Service (QoS) Requirements for International Mobile Telecommunications-2000 (IMT-2000).

[72] Recommendation ITU-R PN530. Propagation of Data and Prediction Methods for Design of Terrestrial Line of Sight Systems.

[73] Recommendation ITU-T I.356 (October 1996) - B-ISDN ATM layer cell transfer performance.

[74] Summary of Recommendation ITU-T E.164 (05/97).