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Re:	This is a draft of a system requirements document which is a collaborative effort by the 802.16 System Requirements Task Group. The editor has collected contributions from the task group and strove to find consensus on many issues while assimilating this document. Please be sure you are reading the most recent published version of this document (802.16s0-xx/y where xx/y is the version number) which can be found at: http://grouper.ieee.org/groups/802/16/sysreq
Abstract	This document provides system requirements that are guidelines for developing an interoperable 802.16 air interface. The 802.16 committee desired to reach an understanding and consensus for system requirements before proceeding with developing standards for 802.16 MAC and PHY protocols and thus formed a System Requirements Task Group to produce this document.
Purpose	The editor requests the 802.16 System Requirements Task Group review this document and that individuals submit suggested insertions, deletions and changes.
Notice	This document has been prepared to assist the IEEE 802.16. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) reserve(s) the right to add, amend or withdraw material contained herein.
Release	The contributor acknowledges and accepts that this contribution may be made publicly available by 802.16.

Revision History

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1999-07-14	802.16s0-99/2	Brian Petry (editor)	Some changes approved by task group in meeting #0

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The content of this document was collected from 802.16 committee members over the period of several months, based on both written contributions, verbal discussion in meetings and activity on the email reflector. The editor has taken some liberty in discerning consensus and determining compromises on issues dealing with the scope of this document, the extent of requirements, and chosen terminology. While "processing" the contributions by member, the editor did not usually use verbatim text, but attempted to extract the essence of requirements. Many thanks go to the individuals who voiced their opinions and strove for consensus in the IEEE 802.BWA Study Group meetings, the 802.16 System Requirements Task group meetings and on the email reflector. The editor also thanks the following individuals who submitted written contributions (their documents may be found at http://grouper.ieee.org/groups/802/16/sysreq):

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Table of Contents

1 Introduction

[Editor's note: some proposed changes to the document are enclosed by square brackets ([ ]). These comments were received at 802.16 meeting number 1 (Montreal), but were not yet accepted by the sysreq task group. Some comments are additionally noted with a 'U' as "unresolved." The group discussed these comments, but could not come to consensus.]

This document provides system requirements that are guidelines for developing an interoperable 802.16 air interface. The 802.16 committee desired to reach an understanding and consensus for system requirements before proceeding with developing standards for 802.16 MAC and PHY protocols and thus formed a System Requirements Task Group to produce this document.

Please note that this document provides guidelines for the 802.16 working group. Its purpose is to formulate and facilitate consensus on some general issues prior to plunging into MAC and PHY details. As such, the system requirements are subject to change as the 802.16 working group debates the issues, makes revisions, and approves this document as a basis for starting the "Interoperability Standard" [20]. The System Requirements will not be published by the IEEE, and is not binding to forthcoming documents, such as the 802.16 "Interoperability Standard," or other documents set out by 802.16 project authorization requests (PARs). Any 802.16 document developed under an 802.16 PAR takes precedence over this one.

1.1 Scope

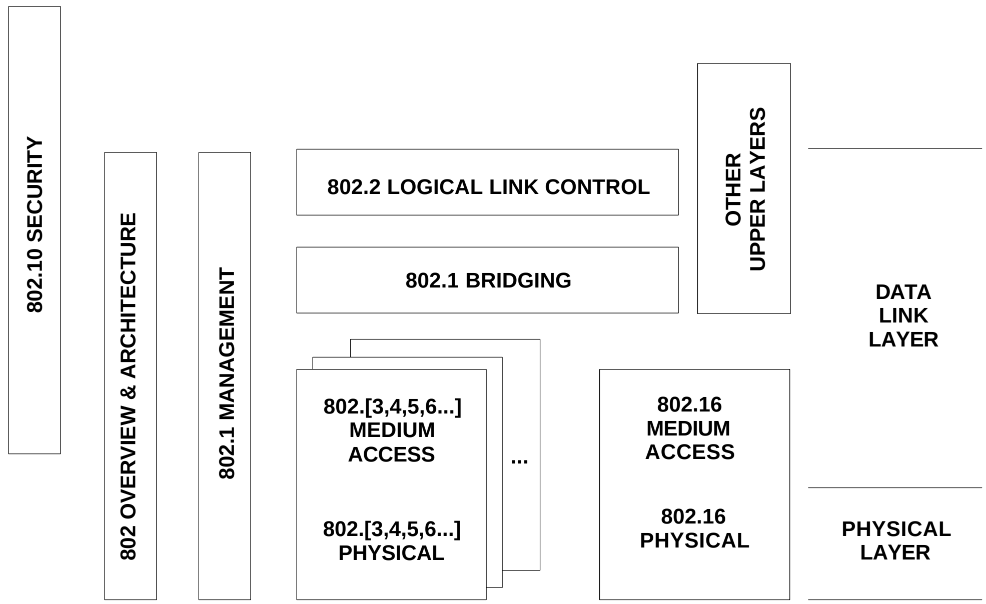
For the purposes of this document, a "system" constitutes: an 802.16 MAC and PHY implementation, in which at least two stations communicate via a point-to-multipoint (P-MP) radio air interface (an 802.16 network), the interfaces to other networks, and services transported by the MAC and PHY protocol layers. So, "system requirements" describes the properties of typical systems in terms of how they affect requirements of interoperable 802.16 MAC and PHY protocols. The system requirements describe 802.16 systems and requirements in broad terms: *what* they are, but not *how* they work. The *how* part is left to the forthcoming 802.16 interoperability standard [20], which will describe in detail the interfaces and procedures of the MAC and PHY protocols.

Since many BWA *systems* are conceivable, with many possible interconnections, inter-working functions [17] and parameters, this document does not specify them all, but focuses on interfaces immediately surrounding an 802.16 network, particularly the services an 802.16 network is required to transport. These *bearer services* impact directly the requirements of 802.16 MAC and PHY protocols. Then, when the 802.16 working group produces an interoperable air interface standard that meets these system requirements, an 802.16 network will interface neatly with many conceivable systems. See section 2.

Other goals of this document are to formulate reference models and terminology for both network topology and protocol stacks that help the 802.16 discuss and develop the MAC and PHY protocols. See sections 3 and 4.

The 802.16 air interface interoperability standard will be part of a family of standards for local and metropolitan area networks. The following diagram illustrates the relationship of 802.16

protocols to other 802 standards, and to the OSI reference model. (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 Modeel (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 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)

2 Supported Services

This section describes the services that an 802.16 system should support. First, typical target markets are described, then the particular bearer services which an 802.16 system is expected to transport.

It may be difficult to comprehend services the system supports without first understanding the system model. Please refer to section 3 if necessary.

2.1 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" [20a].

A broadband wireless access (BWA) system should address markets and offer services similar to wired broadband access technologies, especially those wired technologies with which BWA is expected to compete. This includes current high-speed network access markets served by copper digital subscriber line (DSL) technologies, digital cable TV hybrid fiber/coax (HFC) networks, Integrated Services Digital Network (ISDN) and aggregated telephony-oriented connections (e.g., T1, E1, ISDN-PRI etc.), and the services that such networks carry: data, voice and audio/video [8].

The initial target market likely will be small to large businesses and multi-tenant dwellings [U I. Frigui: delete rest of sentence] which have high (broadband, > ~2Mbps) throughput requirements (see section 5.2). BWA will also address broadband network access for the single-family residential market when technology permits.

BWA systems are not meant to focus on low throughput voice-based access systems such as cellular or digital mobile telephone systems.

A key word in BWA is "access:" *access* to some other network such as the Internet, a private network, a telephony network, etc. An 802.16 network thus provides access to another network, and by itself is not a complete, end-to-end communications system. Furthermore, the thing that's doing the *access*, the subscriber system, is not likely to be a single user terminal, but an interface from some network on the subscriber side, such as an local area network (LAN) or a private branch exchange (PBX) voice network. [U (S. Marin) 802.16 systems are fixed (also nomadic), not mobile.] [Editor note: definitions needed for fixed, transportable, nomadic]

Sometimes, the word *subscriber* is associated with a single customer that is billed for a service. But it is important to note that a BWA system should support more than one paying customer at a single access point to a subscriber BWA radio. In other words, the subscriber access point is for "wholesale" connection of multiple "retail" subscribers [14]. For instance, an office building may be well served by a single BWA radio, but house many tenants who are billed separately. This requirement may for instance affect multiplexing in the MAC layer, security (see section 8 [no pun intended]), and accounting (see section 7.3). [Editor's note: It also affects the choice of terminology---for instance, the traditional telco-ish term customer premise equipment (CPE) may be confusing. So for the purposes of this document, and for lack of a better word, the term *subscriber* is used. Please note that throughout, *subscriber* could be plural.]

The target markets can be further described by Figure 2-1 and Figure 2-2.

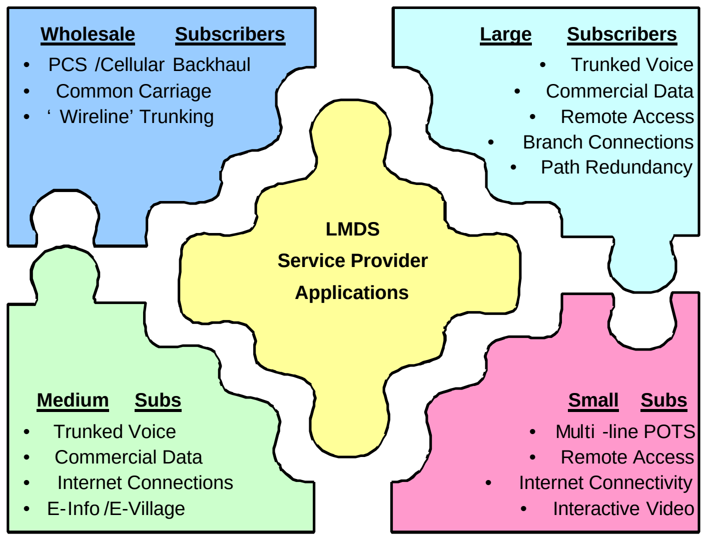


Figure 2-1Summary of 802.16 Applications and Services

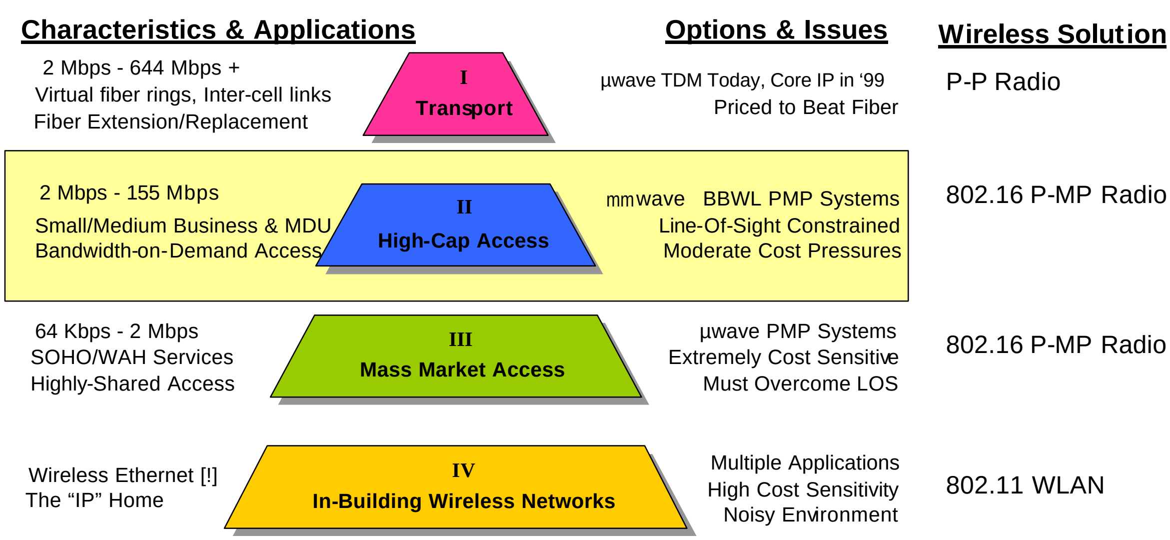


Figure 2-2 A Multi-Tier Perspective of Wireless Transmission and Distribution Systems

2.2 Bearer Services

This section describes typical services, transported by the MAC and PHY protocols, which are important when considering MAC and PHY requirements. The term *bearer service* is borrowed from the Integrated Services Digital Network (ISDN) world, which defines a bearer service to be the capability for information transfer involving lower protocol layers at specific access points in the IDSN reference model. In this document, *bearer service* is used more liberally to mean the next layer up the protocol stack from MAC and PHY layers, and the types of networks that interface to the subscriber-side of BWA systems. [12] [54].

The MAC and PHY protocols may not have explicit support for each and every bearer service, since they should be handled as data streams in a generic fashion. But it is important to consider the bearer services for any particular requirements they may have and extract the "common denominators" that result as generic parameters of MAC and PHY protocols.

2.2.1 Digital Audio/Video Multicast

802.16 protocols should efficiently transport digital audio/video streams to subscribers. This form of digital transport may bypass the MAC protocol layer. The streams flow in the direction of the infrastructure network to subscriber(s) only, and do not originate from subscribers. Digital Audio/Video Multicast service is thus similar to digital video capabilities of digital broadcast cable TV, and digital satellite television service. [I. Frigui: delete this paragraph]

2.2.2 Digital Telephony

802.16 systems should support supplying telephony "pipes" to subscribers in a way that eases the migration of legacy telephony equipment and public switched telephone network (PSTN) access technologies to 802.16 networks. 802.16 protocols should transport any layer in the nationally- and internationally-defined digital telephony service hierarchies: Synchronous Digital Hierarchy (SDH) or Plesiochronous Digital Hierarchy (PDH) (please see the glossary entries in section 10). [I. Frigui, G. Robinson: delete rest of paragraph] For example, any layer from DS0 (64Kbps) through STS-3 (155Mbps) should be accommodated, subject to available bandwidth. However, since an 802.16 network may not cost effectively support single-terminal subscribers, a subscriber radio that supports only one DS0, or a single plain-old telephone service (POTS) analog terminal attached to an 802.16 subscriber radio is a dubious proposition. [(S. Marin) Telephony services are considered toll or wire-line quality at a minimum.]

Note that two forms of digital telephony are possible:

- DS0-channelized PDH/SDH and ISDN

- Cell-based transport using broadband ISDN (B-ISDN) and asynchronous transfer mode (ATM) service.

Also, note that ATM service may be carried using non-channelized links in PDH/SDH. An 802.16 system should manage to efficiently transport both channelized voice circuits and cell-based (ATM) voice traffic.

As mentioned in section 2.1, it is expected that a significant market for 802.16 networks is connecting a business PBX to an 802.16 network. Most PBXs use channelized SDH/PDH telephony circuits for their connection to the public switched telephone network (PSTN), such as T1/E1 or multiples [S. Marin or factions] thereof. Since connecting the PBX to an 802.16 network should not require a prohibitively expensive "channelized-to-ATM" interworking function, an 802.16 system should accommodate an efficient and cost effective means for transporting channelized voice trunks. [18]. A key property of channelized voice trunks is fixed, provisioned, constant bandwidth. The unused channels' bandwidth generally cannot be used by other services. Another property is signaling (see section 2.2.2.2)

An 802.16 network should also efficiently carry ATM-based voice traffic since large corporations use ATM for both voice and data services. These corporations are also a large target market for 802.16 networks. They benefit from flexible bandwidth management, and their ATM systems should integrate well (simple inter-working functions) with 802.16 systems. Also see section 2.2.3.

2.2.2.1 Telephony Service Properties

The properties of telephony services are [12] [54]:

Supervision – monitoring the activity of a user's termination for the ability to accept new incoming calls, or requests from the user to make a new outgoing call.

Call Signaling – sending messages from a user to request a new call, tear down an existing call, or modify an existing call with other end users.

Alerting – informing a user of a new incoming call.

Testing – initiating signals from the central network to troubleshoot possible problems with a user's termination.

Coding – of user information (e.g., analog voice) to the transmission format (e.g., PCM).

Power – basic POTS has traditionally provided power to the end user's terminal equipment (i.e., handset) so that telephone service will still work even when commercial power is interrupted. This allows POTS to support so-called lifeline service, where telephone service is always available to support calls to emergency service such as 911. However, not all services in this category provide network powering (e.g., ISDN BRI in the U.S., and PC telephony).

Bandwidth – in general, the codings used in these services require bandwidths in the range of 64 Kbps or less per call (one exception is ISDN BRI service with both B channels active, which uses 128 Kbps). There are also some 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).

Low delay – as apparent to the end users, 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. Gain, the specific amount of delay can vary based on the quality of the service sold to the end user.

Reliability – the network supporting service among end users can be engineered so that downtime (the time when a user cannot get network service due to a network fault) is limited to minutes a year on average. This is yet another metric that can be varied based on the service sold to the end user.

Supplementary Services – There are a number of supplementary services that enable capabilities such as Caller ID, Call Waiting, special dialing plans, three-way/conference calling, etc. These services require additional user-to-network signaling information above that required to request and terminate calls.

What does these properties mean to BWA system requirements? BWA protocols must support efficient transport of encoded voice data in terms of bandwidth, reliability and delay. Other properties are managed by digital signaling protocols (see section 2.2.2.2).

2.2.2.2 Signaling Systems and Protocols

Telephony and video conferencing signaling protocols may place specific requirements on 802.16 protocols. Some relevant telephony signaling protocols are: Bellcore TR-008, V5.X, Q.931, H.225, H.245, H.323, MGCP, Bellcore GR-303, ISDN PRI, MFC R2, E&M, Q.sig, IETF SIP, etc. [12] [17] [61] [editor's note: protocol references not listed].

In digital telephony hierarchies, periodic bits in the time-division-multiplexed data stream, sometimes "robbed" from encoded voice streams, are used to transport signaling and troubleshooting information [12]. Other signaling protocols (such as those used in ISDN and B-ISDN/ATM) are message-oriented and do not utilize periodic bits in a TDM data stream. The BWA protocols should meet the transport requirements of such telephony signaling, whether TDM- or message-oriented.

2.2.3 ATM Cell Relay Service

Of high speed, connection-oriented services, ATM is the dominant technology. ATM transmits data using small, 53-octet, fixed-length cells which are "routed" by ATM switches along virtual connections with an ATM network. ATM cell relay service is carried over a wide variety of links and bit rates, whether copper, optical fiber or wireless. ATM standards define a rich set of quality of service (QoS) guarantees for various service categories [8]. Although few ATM networks and service providers to date provide all of the ATM QoS features for all ATM service categories, industry has deemed ATM acceptable for transporting QoS-sensitive data. Whether ATM will dominate the future of "QoS-capable" networks is under debate, even within the 802.16 working group; QoS-based services in the Internet Protocol (IP) realm (see section 2.2.4) may someday compete with ATM.

Given the wide deployment of ATM cell relay service within medium to large businesses, even considering the emergence of IP-based QoS, 802.16 protocols should be defined such that an 802.16 network can efficiently transport ATM cell relay service and preserve its QoS features (see section 6). Thus, 802.16 networks will broadly address the target markets mentioned in section 2.1.

Also note that, since ATM cell relay service is circuit-based, it employs message-based signaling protocols to establish, maintain and tear down switched virtual circuits as well as signal QoS-based services and perform network management. 802.16 protocols may need to be cognizant of such ATM signaling to enable an 802.16 network to preserve QoS (see also section 2.2.2.2).

802.16 should provide a means to utilize ATM addresses such as ITU-T E.164 [uncited]. For instance, 802.16 may provide a direct ATM addressing mode for 802.16 nodes, or may provide a means to translate ATM addresses to 802 addresses [10].

2.2.4 Internet Protocol Service

The popularity and importance of Internet Protocol (IP) service needs no argument; 802.16 networks should efficiently transport IP.

The key factors for IP-based service are:

- IP is efficient and cost effective for non-real-time service, such as residential Internet access.
- IP datagrams are variable-length data packets.
- Although not widely deployed, the demand for real-time services and QoS guarantees for IP-based service are emerging.
- Currently, standards for IP-based QoS are lacking, but emerging [8] [42] [43] [44].
- Cable TV access networks, DOCSIS 1.1 [68] provides bandwidth guarantees for IP services [12].

However, IP service can be carried *over* ATM [8], thus leading to the questions: if 802.16 protocols are "tuned" for carrying ATM cell relay service, is the quality of IP service diminished? And: if 802.16 protocols meet a compromise to carry either cell relay service or IP service, are both ATM and IP service diminished? The 802.16 working group for the time being is targeting support for both ATM- and IP-based services. The 802.16 protocols will support either, without requiring IP to be encapsulated in ATM, but a given deployed 802.16 system may chose to carry ATM, IP or both.

The 802.16 protocols should efficiently accommodate IP service that is deemed "best effort delivery." This accommodation may be best made by not forcing bandwidth- and time-consuming procedures for best effort traffic delivery. [S. Marin: delete phrase: that is deemed…] [R. Sanders: delete This accommodation… sentence]

2.2.5 Bridged LAN Service

To an 802.16 network, bridged LAN Service [25] [26] is similar to IP service (section 2.2.4). But whereas IP is classified as a layer 3, "routed" protocol, a bridged LAN is considered layer 2., Bridging is a key component of the IEEE 802 architecture. A bridge connects two or more local area networks (LANs) together, maintaining the concepts of globally addressable nodes, multicast and broadcast procedures. The IEEE 802 has defined protocols (802.1D [25], 802.1Q [28], [26]) to manage topology discovery (Spanning Tree), the concept of virtual LAN membership, "remote" bridging, and multicast domain membership. These protocols allow for the interconnection of 802 LANs, using bridges and switches, regardless of the layer 3 protocols employed.

Whereas an 802.16 network is an *access* network rather than a local area network, bridged LAN service over 802.16 may not be optimal in practice. But since it is expected that bridged LAN services places few, if any, additional requirements on 802.16 than IP service, the 802.16 protocols will support bridged LAN services.

2.2.6 Other Services

Other services that for instance require QoS-based delivery of the MAC services similar to channelized SDH/PDH telephony, cell relay service, IP service or bridging service (see above sections), are envisaged. These services do not place any special requirements on 802.16 networks (MAC and PHY protocols) not already covered in the above sections. Some services are:

- **Back-haul service** for cellular or digital wireless telephone networks. An 802.16 network may be a convenient means to provide wireless trunks for wireless telephony base stations. The channelized SDH/PDH services or ATM cell relay service may be appropriate.

- **Virtual point-to-point connections** for subscriber access to core network services [9]. In the example system described in [9], the Internet-oriented point-to-point protocol (PPP) is employed to make virtual connections between subscribers and service providers and PPP is encapsulated directly in the 802.16 MAC protocol. PPP has some benefits such as simple authentication, privacy/encryption, data compression, and layer 3 network parameter assignment. PPP-over-802.16 should not place any additional requirements on 802.16 protocols, and should be similar to IP or bridged LAN service.

- **Frame Relay Service** Frame Relay is a [I. Frigui: packet/frame-based protocol,] circuit-based data service that uses a simple variable-length frame format. Some basic QoS guarantees are defined for frame relay, but not as rich as ATM. Frame relay networks typically use provisioned permanent virtual circuits (PVCs), although a signaling protocol for switched virtual circuits (SVCs) is defined and in use. Frame Relay also defines a management protocol. [3] [12].

3 System Model

Given the target markets and services described in section 2, this section presents a high level description of a system model that can be used as a framework for developing 802.16 protocol standards. The model describes some of the basic features of an 802.16 system, and terminology that the 802.16 working group can use.

As mentioned in section 1.1, an 802.16 "system" constitutes: an 802.16 MAC and PHY implementation, in which at least two stations communicate via a radio air interface (an 802.16 network), the interfaces to other networks, and services transported by the MAC and PHY protocol layers. An 802.16 system employs point-to-multipoint (P-MP) radios operating in the vicinity of around 30 GHz to connect a base transceiver station (BTS) [S. Marin: terminology association base station, subscriber terminal, customer premises equipment] to one or more subscriber transceiver stations (STS) [4][9]. Radio communications around 30 GHz require line-of-sight (LOS) between a BTS and STS. LOS blocked by foliage also contributes heavily to signal attenuation [cite ??]. Figure 3-1 and Figure 3-2 [13] depict some typical 802.16 systems. Although the range of 802.16 radios varies with transmit power, LOS blockage, and rain fall, it is expected that the maximum usable range of 802.16 radios falls in the region of 5 to 15 Km [cite ??].

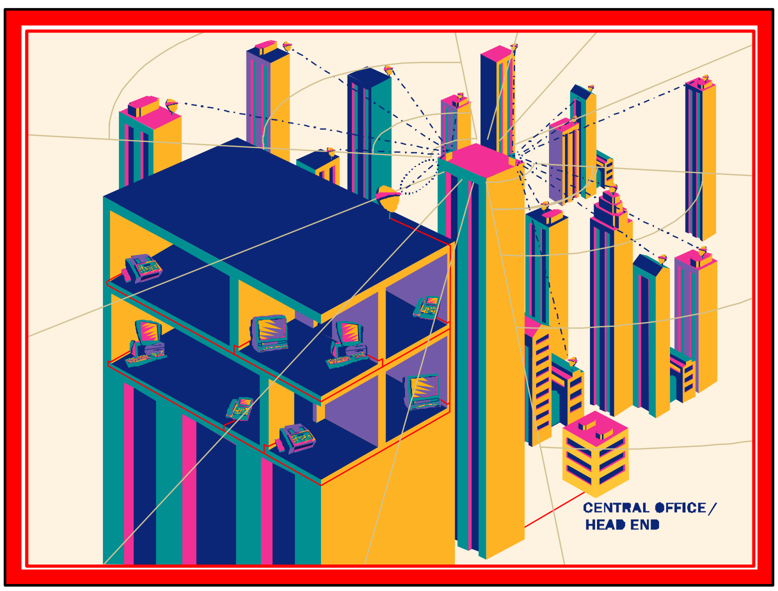


Figure 3-1 System Showing a BTS Mounted on a Tall Bulding

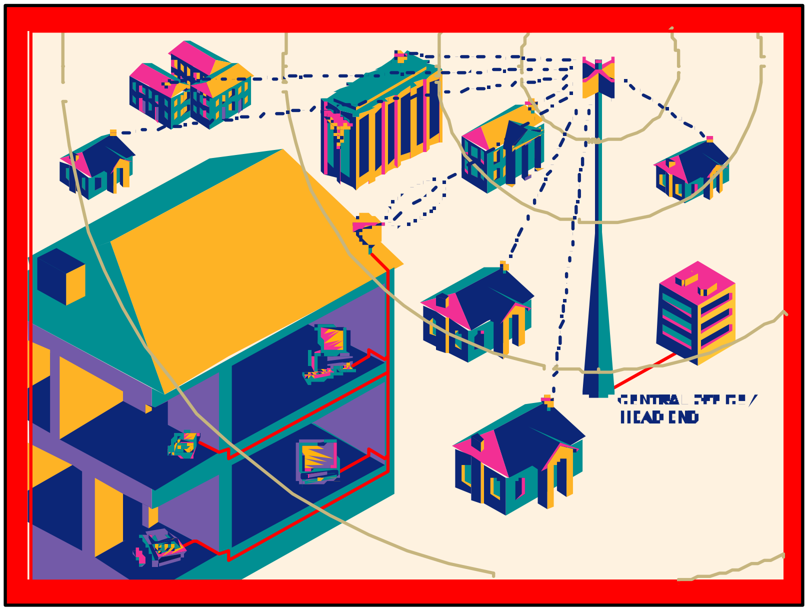


Figure 3-2 System Showing a BTS Mounted on a Tower

Note that, in concern for simple terminology, an 802.16 *network* consists of one BTS radio and one or more subscribers. Thus an 802.16 network also defines 802.16 BTS and STS radios that communicate using the 802.16 MAC and PHY protocols. The BTS radio should be P-MP, radiating its *downstream* signal with a shaped sector antenna achieving broad azimuthal beamwidth to "cover" a prospective number of subscribers. Each STS employs a highly directional radio pointed at the BTS. Note that with this arrangement, direct radio communications between subscriber stations is not possible. Furthermore, the 802.16 system does not define radio communications between base stations. Since the BTS radios are "sector oriented," multiple BTS radios may, in practice, be co-located (subject to frequency re-use requirements), and even share physical hardware. However, 802.16 considers co-located BTS radios belong to separate 802.16 networks. [S. Marin: delete previous sentence.]

The frequency bands used by 802.16 networks varies somewhat among governed geographies [19]. So, to achieve international applicability, 802.16 protocols must be frequency-agile [S. Marin: change to frequency-agnostic]. Typical bands allocated for 802.16 use are very wide, allowing for the bands to be *channelized*. To date, the 802.16 working group has not determined channelization requirements. Neither is it known that a chosen, ubiquitous, channel bandwidth will be applicable to all 802.16 networks. For the time being, 802.16 protocols should remain flexible in their channel parameters. But channels will at least be provisioned in a particular instance of an 802.16 network that allow for:

- Spectrum allocation in adjacent 802.16 networks
- Frequency Division Duplex (FDD) operation: channels designated for downstream or upstream use
- Channel allocation to subscriber(s) based on bandwidth or CoS/QoS requirements

802.16 protocols may allow for Time-Division Duplex (TDD) operation in which a channel is designated to switch between downstream and upstream transmissions.

[S. Marin802.16 systems must have frequency agility to accommodate changes in local markets and mitigate interference.][S. Marin: Fig 3.3: reverse left/right]

3.1 System Reference Model

Figure 3-1 shows the 802.16 system reference points, depicting the relevant elements between a subscriber network and the “core” network (the network to which 802.16 is providing *access*). [F. Chitayat: The air interface may include pereaters to bypas obstructions and extend cell coverage.] A greater system encompassing user terminals, BTS interconnection networks, network management facilities, etc. [1] may be envisaged, but the 802.16 protocols focus on the simplified model shown in the figure. Also not shown are the internal physical characteristics of the BTS and STS: the concepts of “indoor” and “outdoor” units. The description of possible separation of BTS and STS into indoor and outdoor units is beyond the scope of this document. One addition to this model to be considered are security systems (see section 8). Two key interfaces “to the outside world” are shown in the figure: the Base Transceiver Station Network Interface (BNI) and the Subscriber Transceiver Station Network Interface (SNI). A single SNI may support multiple subscriber networks: LANs, Voice PBXs, etc. And recall from section 2.1 that the SNI may support multiple paying subscribers, such as within a multi-tenant office building or dwelling. A BTS interfaces to one or more core networks through one or more BNIs. For the purposes of 802.16, the SNI and BNI are abstract concepts. The details of these interfaces, which are sometimes called inter-working functions (IWFs), are beyond the scope of this document and are not specified by the forthcoming interoperability standard [20] [17]. Since many subscriber and core network technologies are possible, many different IWFs are conceivable. The simplified reference model, serves to discuss the impact of core network technologies and bearer services (see section 2.2) on the requirements of 802.16 protocols by drawing focus to the air interface and the immediate requirements imposed by the surrounding networks. [(G. Fishel) The standard (e.g., MAC/PHY protocols) will describe common access protocol(s) that would be described and common modulation technique(s).] [F. Chitayat: include in igure 3-3: a repeater option between BTS and STS: another box showing that BTS can be connected to STS through repeater]

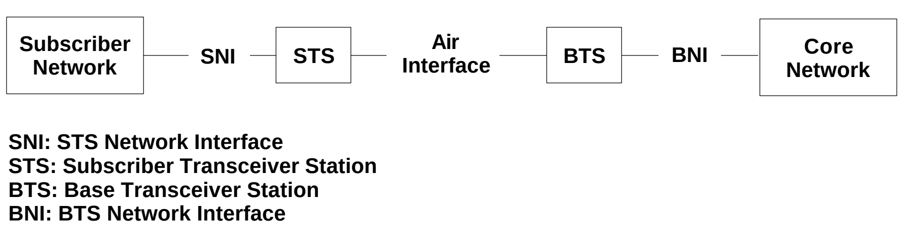


Figure 3-3 System Reference Points

3.2 Topology

Since all data traffic in an 802.16 network must go through the base transceiver station (BTS), it is convenient for the BTS to serve as a radio resource supervisor, which controls the allocation of bandwidth on the radio channel [10]. The STS stations may request bandwidth to achieve QoS obectives (see section 6), but it may be convenient for the BTS to implement the “smarts” of bandwidth allocation.

In the downstream direction, within a channel, the network topology is similar to a contention-less broadcast bus (using LAN terminology), since all transmissions are initiated by the BTS, and more than one STS could share a downstream channel. In the upstream direction, if STSs share a channel, the topology is similar to a contention-oriented bus [(S. Marin) for a given frequency. But, when viewing multiple frequencies simultaneously, the bus can be viewed as a star topology of point-to-point links.] 802.16 protocols must provide the means to multiplex traffic from multiple STS nodes in the downstream direction, and provide for a means to resolve contention and allocate bandwidth in the upstream direction.

The resulting topology is very similar to a Hybrid Fiber Coax (HFC) cable TV network [69][69][3], but with some differences. 802.16 subscribers-per-channel ratio is more flexible and perhaps higher because the BTS can provision its beam width to cover subscribers in a flexible manner. Subscribers with high bandwidth requirements can reside in a narrower beam than subscribers with low bandwidth requirements. Because of the lower subscribers-per-channel ratio, upstream channels may be allocated to achieve higher throughput in the upstream direction.

4 Protocols

Protocols are the heart of the 802.16 standard that, when described well, result in interoperability of multiple vendors’ equipment. Protocol interoperability occurs at each level in the protocol “stack” [16]. 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 as follows (excerpt from 802-1990) :

“The LLC Sublayer (sublayer of layer 2) describes three types of operation for data communication between service access points: unacknowledged connectionless (type 1), connection-oriented (type 2), and acknowledged connectionless (type 3).

With type 1 operation, information frames are exchanged between LLC entities without the need for the prior establishment of a logical link between peers. These LLC frames are not acknowledged, nor are there any flow control or error recovery procedures.

With type 2 operation, a logical link is established between pairs of LLC entities prior to any exchange of information frames. In the data transfer phase of operation, information frames are transmitted and delivered in sequence. Error recovery and flow control are provided.

With type 3 operation, information frames are exchanged between LLC entities without the need for the prior establishment of a loical link between peers. However, the frames are acknowledged to allow error recovery and proper orderin. Further, type 3 operation allows one station to poll another for data.”

“The MAC Sublayer performs access control functions for the shared medium in support of the LLC Sublayer. For different applications, different MAC options may be required. The MAC Sublayer performs the addressing and recognition of frames in support of LLC. MAC also performs other functions, such as frame check sequence generation and checking, and LLC protocol data unit (PDU) delimiting.”

“The Physical Layer provides the capability of transmitting and receiving bits between Physical Layer Entities. A pair of Physical Layer Entities identifies the peer-to-peer unit exchange of bits between to MAC users. The Physical Layer provides the capability of transmitting and receiving modulated signals assigned to specific frequency channels, in the case of broadband, or to a single-channel band, in the case of baseband.”

The 802.16 protocol stack reference diagram is shown in Figure 4-1. In addition to the LLC, MAC and PHY layers suggested by the generic 802 architectures [21] [22], 802.16 protocols transport three other categories of "upper protocols" that correspond to the requirements of the bearer services described in section 2.2. [I. Frigui: delete following sentence.] The "new" upper layers are: ATM, STM and digital audio/video.

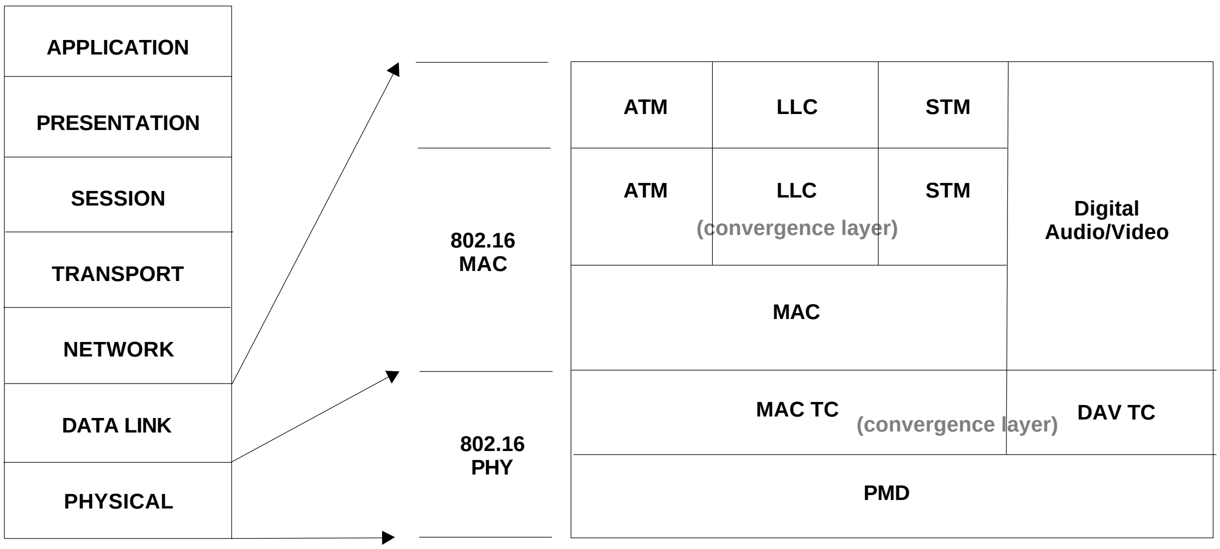


Figure 4-1 Protocol Stack Reference Model

The protocol reference diagram may be getting to far into the "how" part of 802.16 protocols, which should be outside the scope of this document, but this protocol stack reference model should help develop terminology, if not 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 MAC/PHY PDUs. [17] [R Sanders: change PDU to "data unit" (too accommodate "minislots")
- Map an upper layer's addresses into 802.16 addresses
- Translate upper layer CoS/QoS parameters into native 802.16 MAC constructs
- Adapt the asynchronous, synchronous or isochronous (defs) data pattern of the upper layer into the equivalent MAC service
- Reduce the need for complex inter-working functions (IWFs) [17]

For instance, in the ATM world a Transmission Convergence (TC) layer is defined for each link type that carries ATM cells. The purpose of this layer is to delimit cells using the particular link technology, and to signal idle time, or insert idle ATM cells on the link. 802.16 borrows this terminology to accommodate "special" requirements of the multiple upper layer protocols.

Another assumption made in the diagram is that digital audio/video (DAV) service bypasses the MAC protocol layer and accesses the PHY layer directly. This assumption is made because the DAV multicast bearer service (see section 2.2.1) is transmitted in the downstream direction only, and does not require the main service of the MAC: channel contention (access control).

The central purpose of the MAC protocol layer in 802.16 is contention [R. Sanders: change contention to sharing] for radio channel resources. The MAC protocol defines how and when a BTS or STS may initiate transmission on the channel. Since key layers above the MAC, such as ATM and STM, require service guarantees, the MAC protocol must define interfaces and procedures to provide guaranteed service to the upper layers. In the downstream direction, since only one BTS is present, and controls its own transmission, the MAC protocol is simple. But in the upstream direction, if one radio channel is allocated to more than one STS, the MAC protocol must efficiently resolve contention and [R. Sanders: remove "contention and"] bandwidth allocation. Note that the function of the MAC layer is to provide error correction by retransmission, or automatic repeat request (ARQ). 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 and DAV services to generic PMD services. For instance, to best support DAV services, the PHY may provide TDM-based encapsulation of DAV streams TDM MPEG-II frames [14].

Further details, and finalization of the protocol reference model, will be worked out by the 802.16 MAC and PHY task groups while developing the air interface interoperability standard.

5 Performance and Capacity

This section addresses some issues regarding 802.16 network performance and capacity. Specifying protocols such that an 802.16 system can maintain a specified/mandated performance level in the face of rapidly changing channel characteristics (due to rain) will be a difficult problem for the 802.16 working group. This section specifies the target performance levels. Given the target performance levels, planning and provisioning an 802.16 network instance is also a difficult problem. The 802.16 network capacity at the target performance levels for all subscribers, given geographically local LOS obstruction and rain fall will also be difficult. This section also outlines some of the issues for 802.16 capacity planning.

Note that ITU-R (WP 9A) has presented several questions regarding the need for performance objectives for fixed wireless access radio systems. [16]

5.1 Scalability

The 802.16 protocols should allow for different "scales" of capacity and performance for 802.16 network instances. For instance, large businesses with high throughput and CoS/QoS requirements should be accommodated as well as small scale networks in dense, limited LOS environments. For instance, a subscriber with high requirements could be dedicated a narrow beam from the BTS with many radio channels. On the other end of the scale are "pico-802.16-networks" in dense metropolitan areas [6] that implement short-radius beams to a few subscribers (see). Perhaps in the middle of the scale are relatively wide-beam [S. Marin: define] 802.16 networks that serve a large number of subscribers on many radio channels.

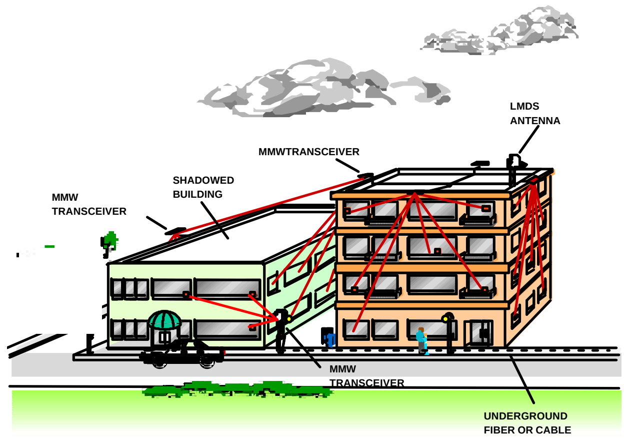


Figure 5-1 802.16 “Pico-cell” Example

5.2 Delivered Bandwidth

[J. Mollenauer: Delete this section]
802.16 networks are expected to deliver approximately 1-50 Mbps [13] to an individual subscriber. But 802.16 protocols should allow the upper range of delivered bandwidth to scale to STS-3 (155 Mbps) rates and beyond for high-capacity subscribers. However, such high rates may be better served by non-802.16 P-P radio links [14]. It should also be possible to scale delivered bandwidth to lower rates, < 1 Mbps. [I Frigui: delete following sentence.] But doing so cost effectively, and competing with other access technologies such as digital cellular may be a dubious proposition (see also section 2.1).

Thus, 802.16 protocols should be optimized for high-bandwidth service (> ~2 Mbps). [I Frigui: delete prev. sentence]

5.3 Flexible Asymmetry

802.16 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---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. If a subscriber’s STS is configured or provisioned into an asymmetrical service class, a lower degree of flexibility is achieved. [S. Marin: delete previous phrase]

5.4 Availability

[S. Marin: change title to “link availability”]An 802.16 network should be available to transport all services at their required maximum error rates (see section 5.4) 99.99% of the time [2, 11] , assuming that the network and radios receive adequate power 100% of the time. This amounts to approximately 53 minutes of outage a year. Note that 99.999% available amounts to approximately 5 minutes of outage a year. [S. Marin change to “from about 99.9 to 99.999”]

[S. Marin: Path redundancy may be used to meet availability requirements]

It is expected that the highest contributor to 802.16 network outage will be excessive attenuation due to rain fall (rain rate and droplet size) [50] [51] [52] [53]. 802.16 MAC and PHY protocols must accommodate rain fall, perhaps consuming more radio bandwidth and/or requiring smaller radio propagation distance (radius) to meet the availability requirements. Since statistical rain rates vary widely in geography, the 802.16 protocols must be flexible in consumed radio bandwidth (spectral efficiency), cell radius, and transmit power to accommodate a rain allowance that varies with geography [11]. Bandwidth and cell radius are critical components of network/cell capacity planning (also see section 5.7).

802.16 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 rain fall.

The telephony world also defines availability in terms of “errored seconds” and “severely errored seconds” [15]. For a service with “stringent” QoS requirements, G.826 defines the errored second ratio to be .04 and the severely errored second ratio .002. [editor’s note: I don’t know what “severely errored” means.] .002 errored seconds is 99.8% availability. Note that this is below the 99.99% goal.

5.5 Error Rates

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 rate (BER) is 10E-9. Additionally, each block of data delivered by the PHY to the MAC layer must allow for detection of errors by the MAC (e.g., by CRC) with 1, 2 or 3 errored bits (a Hamming Distance of 4) [7]. Note that the size of the data block is TBD.

For telephony-oriented bearer services (see section 2.2.2), the 802.16 working group may consider relaxing the 10E-9 BER requirement. ITU requirements for digital voice services are three orders of magnitude less stringent—10E-6 [11] [51] [52]. Thus for digital voice services, 802.16 protocols trade off higher throughput modulation and error correction techniques for less consumed radio bandwidth.

Also, services such as digital audio/video, which may bypass the MAC protocol layer and access the PHY layer directly may have a relaxed BER requirement. The 802.16 working group may consider relaxed BER requirements for this service also, which meets the requirements of digital audio/video delivery. [I Frigui: remove preceding paragraph.]

Other error rate metrics used in the telephony and ATM for what are considered “stringent QoS” are: [15]

- Background block error rate (BBER) [51]. 2E-4. One in 5000 blocks is errored. If the block size is approximately that for Ethernet (1522 octets), BBER is roughly equivalent to 16E-6 bit error rate (BER).
- Cell Loss Ratio (CLR) [cite I.356]. 3E-7. One in 3.333 Mcells is errored. This is rougly equivalent to 5.6E-9 BER. Note that CLR is not always due to transmission error, but ATM switches dropping cells due to capacity limits.

Note that the telephony and ATM bit error rates seem far less stringent than LAN error rates.

5.6 Delay

Network delay requirements come in several categories:

- Medium Access Delay. The delay imposed by the MAC protocol layer between when a BTS or STS becomes ready to transmit and when it actually begins transmission on the channel.
- Transit Delay. The total 802.16 network delay from BNI to SNI and from SNI to BNI (see section 3.2). This includes the Medium Access Delay.
- End-to-End Delay. The total delay between a terminal in the subscriber network, to the ultimate service beyond the core network. For instance, the total delay between two telephony terminals (handsets). This includes the 802.16 Transit Delay.

In addition to the above categories, variation of delay, or jitter, is important to consider. For example, a high variation of delay can severely impact telephony services. But 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. In a telephony network, for example, the maximum acceptable end-to-end delay for the longest path is recommended to be less than 300ms [15] [17] [cite G.114].

The budget for the 802.16 network transit delay and access delay must be derived. [15] [17]. The radio propagation time is 5 μsec/km [cite G.114]. If the distance between STS and BTS is 5km, this propagation time is 25 μsec. 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 LLC layer, if it is to employ an automatic repeat request (ARQ), needs time for additional delay due to responses (acks and nacks) and timeouts. [I. Frigui: delete previous sentence.] The budget for 802.16 transit delay is suggested to be 19.5 ms [15] for "stringent QoS" services. [J. Mollenauer: "stringent" should require a "shall" instead of suggested].

ITU I.356 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 networks be 1.5ms [15] for "stringent QoS" services.

Please refer to section 20 descriptions of QoS parameters.

5.7 Capacity Issues

802.16 network capacity is defined as the product of the number of subscribers, their peak bandwidth requirements and quality of service guarantees. This capacity can vary depending on rain attenuation, LOS blockage, transmit power, etc. In a given 802.16 network instance, capacity must be carefully planned to ensure that subscribers' quality of service guarantees and maximum error rates are met. Given the rain attenuation statistics in a geographic area, and the development of a channel link budget [11], the parameters of an 802.16 network must be chosen [11]:

- Radio range (shaped sector radius)
- Width of the sector
- Upstream/Downstream Channels
- Allocation of prospective subscriber bandwidth to channels [note: the MAC and PHY standards may allow subscribers to hop between channels]

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 networks, the protocols must accommodate them in an automated fashion.

The time-variant impairments, rain fade and multipath interference, are expected to be the most significant contributors 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 equipment (e.g., radios and modems).

6 Class of Service and Quality of Service

This section describes the classes of service and quality of service for 802.16 networks. Terminology is borrowed from the ATM and Internet Engineering Task Force (IETF) worlds.

802.16 protocols must support classes of service (CoS) with various quality of service (QoS) guarantees to support the bearer services (see section 5) that an 802.16 network must transport. Each bearer service defines guarantees that they "expect" to be preserved by an 802.16 network. Thus, 802.16 protocol standards must define interfaces and procedures that accommodate the needs of the bearer services: allocation of prioritization of bandwidth. Additionally, 802.16 protocols must provide the means to enforce QoS contracts and Service Level Agreements [2] (see section 7.1).

The 802.16 protocols must be capable of dedicating fixed, provisioned, bandwidth for bearer services such as SDH/PDH. For instance, the MAC layer may employ TDM allocation of bandwidth within a channel for these services. This form of allocation may be provisioned in advanced, or dynamically "signaled" as virtual circuits are set up.

For QoS-based, connectionless, but not circuit-based, bearer services, the 802.16 protocols must support bandwidth negotiation "on-demand" [9]. For instance, the MAC protocol may allocate bursts of time slots to bearer services that require changes in bandwidth allocation. Such allocation is thus performed in a semi-stateless manner. A connection-oriented bearer service may require "state" information to be maintained for the life of a connection. But the 802.16 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.

6.1 Types and Classes of Service

Traffic may be roughly categorized as follows [2] [8] [4] (ATM terminology):

- Constant Bit Rate (CBR). The bearer service requires a constant, periodic access to bandwidth. SDH/PDH falls into this category.
- Variable Bit Rate: Real-Time (VBR-rt). 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 and other "multimedia" applications.
- Variable Bit: Non-Real-Time Rate (VBR-nrt). 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.
- Available Bit Rate (ABR). The bandwidth varies within a wide range, and is allowed to burst up to the maximum link bandwidth when CBR and VBR traffic are not using bandwidth. Higher variations of delay may be tolerable since applications that fall into this category allow for priority traffic to consume bandwidth they do.
- Unspecified Bit Rate (UBR). The bandwidth and delay requirements are not specified. Bandwidth is delivered on a "best effort" basis.
- [I Frigui: UBR+. (Text coming from Imed)]

The Internet Engineering Task Force (IETF) "Integrated Services" model uses the following terminology to classify network applications [42]:

Elastic. Applications that are tolerant of various bandwidths and/or delay variations:

Interactive burst (Telnet, The X Window System, NFS, Microsoft or Novell File Sharing, etc.)

Interactive bulk (FTP)

Asynchronous bulk (Email, FAX, Remote Printing, Backup, etc.)

Real-Time. Applications that require some level of bandwidth and/or delay variation:

Guaranteed Service. A fixed upper bound on the arrival of data is required. For instance, audio and video conferencing may fall into this category.

Predictive Service. Applications are tolerant of some late data, a higher variation of delay, or may adapt to less available bandwidth. For example, a video playback service may be able to adapt its playback buffer to accommodate variation of delay.

An IETF architecture for differentiated services [43] defines how Internet Protocol-based service classes may be given quality-of-service. Traffic flows are identified in terms of their profiles: rates and burst sizes.

6.2 Parameters

ATM standards describe service categories (see section 6.2) in terms of traffic descriptors [9] [12] [54]:

- Peak Cell Rate (PCR). The maximum rate at which cells will be transmitted.
- Sustainable Cell Rate (SCR). The cell rate which could be sustained for a certain length of time.
- Maximum Burst Size (MBS). The maximum number of cells that could be transmitted "back-to-back."
- Maximum Cell Rate (MCR). The maximum cell rate supported by a link

Other ATM QoS parameters are:

- Cell Loss Ratio (CLR)
- Maximum Cell Transfer Delay (MCTD)
- Cell Delay Variation Tolerance (CDVT)

802.16 protocols will define a set of parameters that preserve the intent of QoS parameters for both ATM- and IP-based services. (TBD)

6.3 Bearer Service QoS Mappings

The classes of service and QoS parameters of bearer services will be translated into a common set of parameters defined by 802.16. A network node that serves as an inter-working function (IWF) between a QoS-capable LAN or WAN and an 802.16 network must participate in signaling protocols to set up QoS parameters for connection-oriented services.

For example, if an ATM network is to be transported over an 802.16 network, ATM switched virtual circuits negotiate QoS parameters for the circuit. The IWF must participate in the ATM signaling protocol that sets up the circuit. It also must utilize 802.16 interface primitives (e.g., MAC layer user interface primitives) to request QoS.

Similarly, 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 is to be a "link" in the IP network, an IWF must interface with 802.16 to negotiate resource allocation.

The specification of how IWFs operate is outside the scope of this document and the forthcoming 802.16 interoperable air interface standard [20] [20a]. However, the QoS parameters for 802.16 must be chosen and interface primitives defined that allow for bearer services' IWFs to negotiate QoS "through" an 802.16 network.

7 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:

- Configuration management
- Fault management
- Performance management (see also section 5)
- Security management (see also section 8)
- Accounting management

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 (CMIP/CMIS). The 802.16 standards will consider ISO 15802 for its network management framework.

7.1 Service Level Agreements

The 802.16 protocol must permit operators (def) to enforce service level agreements (SLAs) with subscribers by restricting access to the air link, discarding data, or other appropriate means. [3]

7.2 Malfunctioning STS

The operator must have means to shut down an STS if necessary, from the BTS, in the face of a malfunction.

7.3 Accounting and Auditing

The 802.16 network management framework, architecture, protocols and managed object 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 that a single STS can interface to multiple subscribers that an operator could bill separately.

8 Security

The 802.16 system will enforce security procedures described in this section. The 802.16 working group may consider the 802.*10 Standard for Interoperable LAN/MAN Security (SILS)* [29] [30] or some other security framework, such as one similar to the Data Over Cable Interface Specifications (DOCSIS) security specification [68] [3].

Since 802.16 employs an air interface and is an access network over which sensitive corporate or personal data will be exchanged, an 802.16 network instance must implement the security system to be specified by 802.16 to claim “802.16 compliance.” In other words, security implementation is mandatory [2][3][10].

Strong cryptographic algorithms must be employed, subject to international use restrictions. Secure protocol transactions must be adequately protected against attacks such as key discovery, replay and denial of service.

The security system chosen by 802.16 will be added to the protocol stack (Figure 4-1) and reference points (Figure 3-3) to include security protocols, and "database" servers for authentication, authorization, key management, etc.

8.1 Authentication

Authentication is a network security mechanism by which a subscriber's identity is established in a secure manner. In 802.16, when an STS "signs on" to an 802.16 network on behalf of a paying subscriber (multiple subscribers per STS are allowed), the STS must be authenticated in a secure manner to establish the identity and credentials (see section 8.2) of the subscriber.

The authentication mechanisms must be secure so that an "enemy" STS is not able to gain access to an 802.16 network, or to the core network beyond. Passwords and secrets must not be passed "in the clear" through the air interface. [I Frigui. Change prev. sentc: passwords and secrets shall be passed encrypted on the air interface.]

8.2 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 standard will 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 network

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

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

Subscriber authorization requests and responses must be transacted securely.

8.3 Privacy

Privacy is a security concept that protects transmitted data from being intercepted and understood by third parties (e.g., an "enemy" STS, BTS 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 networks. Public-key-based mechanisms are in wide use today.

802.16 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.

9 802 Conformance

As mentioned in some earlier sections of this document, 802.16 will strive to fit into the 802 network 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 MAC layer uses 802 “universal” 48 bit addresses

An 802.16 network supports MAC multicast in the downstream direction only, not upstream

The 802.16 protocols support 802.1 bridging services and protocols, including support of the virtual LAN tag and priority ID [25] [26] [28].

The 802.16 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 network management guidelines (see section 1).

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

[I Frigui: Use IEEE 64 bit addresses.]

[M.Goldhammer STS and BTS are identified by the IEEE 48 bit address

ATM support: The VPI/VCI addressing made shouldbe translated to IEEE 802.2 addressing mode, using the source and destinatino 4bit IEEE addresses Layer 3 IWF should take care of connection address resolution and other connection related issues. ATM payload should be incapsulated in the MAC frame.

PDH support: The ITU-T E.164 addressing mode should be translated to IEEE addrfessing mode. Laer 3 IWF should take care of connection address resolutions and other connection related issues.

MAC Primitives: shoud be those defined by 802.2: MA-UNIDATA.request, MA-UNIDATA.indication, MA_UNIDATA_STATUS.indication]

10 Definitions and Abbreviations

BNI – BTS Network Interface. A reference point where one or more core networks interface to a BTS. Also, multiple, co-located BTSs from different 802.16 networks may interface at the BNI.

BTS – Base Transceiver Station. . Equipment that communicates with one or more subscriber transceiver stations (STS) and includes a BNI, MAC and PHY layer implementation, radio and single shaped sector antenna (or antenna array). More than one BTS may be co-located to allow omnidirectional service. A BTS is designated as one system with a single downstream antenna pattern. A BTS is sometimes called a “hub” or “access point.”

CDMA – Code Division Multiple Access. A multiplexing category where each user or application’s signal is “spread” or “scrambled” in a frequency band according to a unique code assigned to the user/application.

Cell – The radio coverage area of 802.16 networks with co-located BTSs.

Core Network – A network on the base-station side of an 802.16 network that interfaces to a BTS. Examples could be an IP-based network, ATM, Frame Relay, or public switched telephone network (PSTN).

Downstream – Flow in the direction of BTS to STS.

FDD – Frequency Division Duplex. Channels and frequency bands are designated for upstream or downstream use only, but not both.

Operator – An administrative entity that is responsible for operating, managing and billing for services of 802.16 networks. The operator may or may not “own” the STS components of an 802.16 network. The administrative reach may extend into the subscriber networks and core networks.

PDH – Plesiochronous Digital Hierarchy. Two signals are plesiochronous if their corresponding significant instants occur at nominally the same rate, any variation in rate being constrained within specified limits. The traditional telephony digital hierarchies in North America (DS0/64Kbps, DS1/1.544Mbps, DS1C/3.152Mbps, DS2/6.312Mbps, DS3/44.736Mbps, DS4/274.176Mbps) and elsewhere (DS0/64Kbps, E1/2.048Mbps, E2/8.448Mbps, E3/34.368Mbps, E4/139.264Mbps) are typically delivered on twisted pair or coaxial cable and are based on plesiochronous clocks in which the user’s data and clock are multiplexed up the digital hierachy.

SDH Synchronous Digital Hierarchy. A telephony network that multiplexes signals, is synchronized to a common clock, and typically delivered on fiber optic cable. In North America, SDH is also refered to as Synchronous Transfer Mode (STM) and implies SONET (Synchronous Optical Network): STS-1/51.840 Mbps, STS-3/155.520 Mbps, STS-9/466.560 Mbps, STS-12/622.080 Mbps, STS-48/2488.320 Mbps). Internationally, the terminology and rates are:

STM-1/155.520 Mbps, STM-3/466.560 Mbps, STM-4/622.080 Mbps, STM-16/16.2488.320 Mbps.

SNI -- STS Network Interface. A reference point where one or more subscriber networks interface to an STS.

Subscriber – an entity that interfaces to an STS. Multiple subscribers may interface to an STS and are uniquely identified by an 802.16 network.

Subscriber Network – A network on the subscriber side of an 802.16 network that interfaces to an STS. Examples could be a telephony private branch exchange (PBX), data LAN (e.g., Ethernet), ATM LAN, integrated voice/data network, etc.

STS – Subscriber Transceiver Station. An 802.16 node that implements the MAC and PHY protocol layers at the subscriber end of an 802.16 network. An STS interfaces with one BTS and one or more subscriber networks through the SNI reference point.

TDD – Time Division Duplex. A channel or frequency band switches between upstream and downstream modes.

TDMA – Time Division Multiple Access. A multiplexing category where the medium is divided into time slots, and slots assigned to users or applications.

Upstream – Flow in the direction of STS to BTS.

11 References

[Editor's note: these references are not in a particular order.]

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