Chapter 2 IEEE 802.16 standards

The working group and documents

BACKGROUND

IEEE Std 802.16, along with related standards and amendments, is developed and maintained by the IEEE 802.16 Working Group on Broadband Wireless Access. In this chapter, we begin with an overview of the umbrella organizations under which the IEEE 802.16 Working Group performs its activities, and we explain the basic process of developing and maintaining IEEE standards. We follow with a history of the IEEE 802.16 Working Group and review the historical development of its projects.

IEEE STANDARDS ASSOCIATION (IEEE-SA)

The Institute of Electrical and Electronics Engineers (IEEE) <http://ieee.org> is a technical professional society with over 350,000 members worldwide. IEEE has many technical and regional activities, most of which take place in a largely independent fashion.

The development of standards in IEEE is assigned to the IEEE-SA <http://standards.ieee.org>. The business of IEEE-SA is directed by an elected board of governors. The development and maintenance of standards are overseen by the IEEE-SA Standards Board, which mandates the process, approves the initiation of new projects, and approves appropriately balloted drafts as IEEE standards. IEEE-SA operates in accordance with the principles of consensus, due process, and openness defined by the American National Standards Institute (ANSI) and the Code of Good Practice for the Preparation, Adoption and Application of Standards produced by the World Trade Organization (WTO) under its Agreement on Technical Barriers to Trade. IEEE-SA is recognized by important international organizations as an international developer of standards, and IEEE standards are, in many cases, recognized as international standards. One example of particular relevance to

IEEE Std 802.16 is IEEE's international Sector Member status in the ITU's Radio Communication Sector (ITU-R), the same status held by the International Organization for Standardization (ISO).

The IEEE-SA leadership sets policy that directly influences not only the development of IEEE-SA standards but also their use. One critical topic is patents. The IEEE-SA patent policy is similar to that of most of the world's other formal standards developing organizations (SDOs). The key statement of IEEE-SA policy on this issue is "IEEE standards may include the known use of essential patents and patent applications provided the IEEE receives assurance from the patent holder or applicant with respect to patents whose infringement is, or in the case of patent applications, potential future infringement the applicant asserts will be, unavoidable in a compliant implementation of either mandatory or optional portions of the standard." The policy goes on to explain that, if the patent will be enforced, this "assurance" shall be "a statement that a license will be made available without compensation or under reasonable rates, with reasonable terms and conditions that are demonstrably free of any unfair discrimination." The IEEE generally avoids offering interpretations of these somewhat ambiguous statements, and any disagreements need to be settled outside of IEEE processes.

IEEE-SA standards are openly developed with consensus in mind. Participation in their development is entirely voluntary, as is their use. However, history has shown that standards developed in an open forum can produce high-quality, broadly accepted results that can focus companies and forge industries.

IEEE-SA charters over 200 "sponsor" groups to oversee the development of specific standards projects. These are typically organized within one or more of IEEE's technical societies.

While the sponsor groups have significant leeway in how they organize their work and prepare draft standards, the IEEE-SA is particularly assertive in the conduct of the ballot process under which drafts are reviewed as part of their consideration as IEEE standards. Before a prospective standard can be considered for approval by the IEEE-SA Standards Board, it must be balloted in a formal process that is defined by IEEE-SA. This process is, rather confusingly, known as "sponsor ballot" although it would more appropriately

be called "IEEE-SA ballot." In any case, balloting is conducted in an open process using a "ballot group" of volunteer individuals. IEEE-SA members are invited to participate in all ballots, regardless of whether they participated in the development of the draft. Balloting is an iterative process in which comments (a polite word for a specific complaint) are solicited and addressed, after which an improved draft is "recirculated" for further comment. As IEEE 802 Executive Committee Member Emeritus Geoff Thompson likes to say, balloting is about "improving" the draft, not about "approving" the draft. More comments lead to a better result. The IEEE 802.16 Working Group seeks comments, and the IEEE 802.16 task groups are experienced at resolving them (up to 500, or 1000, or even 2000 in a weeklong session, if necessary). Provided that a competent, active, and sincere ballot group is engaged in the process, the outcome is a sound and reliable technical document that reflects a broad consensus. While the participants are individual human beings, they often bring with them the technical ideas of their home environments, including national, regional, and corporate viewpoints.

IEEE 802® LAN/MAN Standards Committee (LMSC)

The development of local area network (LAN) and MAN standards with IEEE-SA is assigned to the LMSC, informally known as *IEEE Project 802* or simply *IEEE 802* <http://ieee802.org>. One of the largest, most prolific, and most influential of the IEEE-SA sponsors, IEEE 802 has operated since 1980 under the IEEE Computer Society. It develops and maintains standards addressing the MAC and PHY, each of which fits under a common logical link control (LLC) layer. Taken together, these make up the two lowest layers of the Open System Interconnection (OSI) seven-layer model for data networks (see [B29]).

IEEE 802 oversees a panoply of network standards, using an internal structure based on working groups developing draft standards. IEEE 802's great successes include IEEE 802.3 Ethernet, IEEE 802.11 WLANs, and IEEE 802.15.1 Bluetooth™ personal area networks (PANs). Other significant, although ultimately less successful, projects have included token ring and token bus.

IEEE 802 is a large but tightly managed organization that meets in plenary session each March, July, and November, with recent attendance in the range of 1800 people. The organization is governed by an executive committee composed of the chairs of the active working groups and technical advisory groups (currently 11 individuals) and 7 additional officers.

STANDARDS DEVELOPMENT IN IEEE 802

The IEEE 802 process is designed for quick development of standards with broad consensus. The demand for consensus helps to ensure that standards are technically superior and meet market needs.

The development process in IEEE 802 follows the chronological steps outlined below. The process is overseen by the IEEE 802 Executive Committee and defined by a written set of rules and procedures.

Study group stage

When sufficient interest has been identified in a topic, IEEE 802 may establish a study group to investigate the problem and consider the interest and potential scope of a possible standardization project. Should a study group wish to pursue standardization, it must draft a project authorization request (PAR); this is a form by which all new IEEE-SA projects become authorized. Before the Executive Committee considers approving a PAR for submission to the IEEE-SA Standards Board, it requires a statement addressing IEEE 802's "five criteria for standards development." This statement must demonstrate that the potential standard has broad market potential, compatibility with other IEEE 802 standards, distinct identity within IEEE 802, technical feasibility, and economic feasibility.

Working group development of draft

The Executive Committee assigns each new project to an existing or new working group and charters that group to develop the standard. Technical decisions are made in the working group by vote of at least 75% of its members. Membership in IEEE 802 working groups belongs only to individual people, usually engineering professionals, and is established and

maintained by participation in sessions, according to specific rules. Nonmembers participate actively as well, often with significant influence.

The initial draft development method varies among working groups, but the typical process is to delegate a task group to the problem and issue a public call for contributions requesting documentary input. Eventually, the task group develops a first draft, either by adopting a complete contribution or by assembling a collections of inputs. This process is sometimes contentious, as the competing interests of different companies and technology interests are often reflected in meetings. However, it offers a good opportunity for new participants to come to understand the process and become comfortable in discovering commonality among a group with diverse interests. The fact that professional individuals, not companies, are the recognized entities helps to set a tone of collegiality. New participants continuously enter the process. They sometimes appear aggressive at first, only to discover that this approach can be ineffective. The process demands excellent communication and preparation as well as technical skills. Those most effective at furthering their causes are those who clearly state their intent, present well-documented arguments, and look for opportunities to unite with others who have compatible goals. The system is an excellent training ground for bringing out effective communications skills, and many of the most effective participants learn their skills the hard way.

Once a working group has adopted a draft, the process changes subtly but significantly. At this point, if all goes well, the interest of the participants begins to align with the common goals of improving and completing the draft. The typical process is driven by distributing the draft and requesting comments in the form of specific requests to make changes. A strict IEEE 802 policy, atypical in IEEE-SA, is the requirement of a formal ballot process, modeled after the IEEE-SA ballot, before a draft standard may be forwarded to IEEE-SA for sponsor ballot. This dual ballot process is a key factor in the quality control for which IEEE 802 has become known.

In this "working group letter ballot," as in sponsor ballot (both of which are paperless), any vote against the document must be accompanied by specific comments on what changes are required in order to make it acceptable to the voter. This process forces constructive suggestions of change and helps drive

the process to quick improvement. Members voting to approve, and nonmembers as well, are also solicited for suggestions. An approval rate of 75% is required for draft acceptance. However, changes made in response to comments, and negative comments that have not been accepted by the editorial team, must be "recirculated" for approval by the voters. This allows for additional reviews and additional improvement. Eventually, however, most ballots reach a terminal period in which a large consensus favors closure. The ballot cannot close until those voting negative have had their say and failed to attract significant support for their argument. The approval margin is typically much higher than 75% at closure, but it need not be.

Following approval in working group letter ballot, drafts are forwarded for IEEE-SA sponsor ballot. This is similar to a rerun of the working group letter ballot except that the ballot group is not restricted to members of the working group. When this ballot is complete, the draft, ballot results, and supporting documentation are forwarded for review by the IEEE-SA Standards Board's Review Committee (RevCom). RevCom's recommendation proceeds to the full board for final action.

Once IEEE standards are approved, they are professionally edited and generally published and offered for sale within about two months, depending on size and complexity and the extent of editing required.

Unique to IEEE 802 within IEEE-SA is the "Get IEEE 802" program <http://standards.ieee.org/getieee802> in which published standards are available for download without charge beginning six months after publication. The cost of this program is subsidized by the individual participants, through the session registration fee, along with a few corporate sponsors.

IEEE 802.16 Working Group: Overview

IEEE 802's WirelessMAN work takes place within the IEEE 802.16 Working Group on Broadband Wireless Access <http://WirelessMAN.org>. The working group is a unit of IEEE 802, which serves as sponsor of IEEE 802.16 projects (although, unique to IEEE 802, the IEEE 802.16 projects also have a cosponsor: the IEEE Microwave Theory and Techniques Society).

IEEE 802.16 Working Group: History

The activities of the IEEE 802.16 Working Group were initiated by Roger Marks of the (U.S.) National Institute of Standards and Technology (NIST), who organized a meeting on BWA standardization, attended by 45 people, in August 1998 at the IEEE Radio and Wireless Conference in Colorado Springs, Colorado, USA. Following his visit to the IEEE 802 plenary session in July, Marks forwarded an invitation from IEEE 802 Chair Jim Carlo to convene a meeting on this topic at the IEEE 802 plenary session in November. At that session, IEEE 802 approved the formation of the Study Group on Broadband Wireless Access. That study group met twice and drafted a PAR, limited to 10 GHz to 66 GHz, that was endorsed by the IEEE 802 Executive Committee in March 1999. This action (after approval from the IEEE-SA Standards Board) created the IEEE 802.16 Working Group. Following an organization session (Session #0) in May, 106 people became charter members of the working group at its first official session in Montreal, Canada, in July 1999.

The working group has continued to meet at each IEEE 802 plenary session (in March, July, and November) and to hold a working group interim session each January, May, and September. (An additional interim session in August 1999 caused the even/odd numbering of sessions to reverse; since then, even-numbered sessions correspond to IEEE 802 plenaries.) As shown in Figure 2–1, which includes sessions through #39 of September 2005, attendance has grown and waned. Participation interest depends on the current activity. Interest was very high in 2004-2005 as the IEEE 802.16e amendment was being assembled, and attendance peaked at 367 in November 2004.

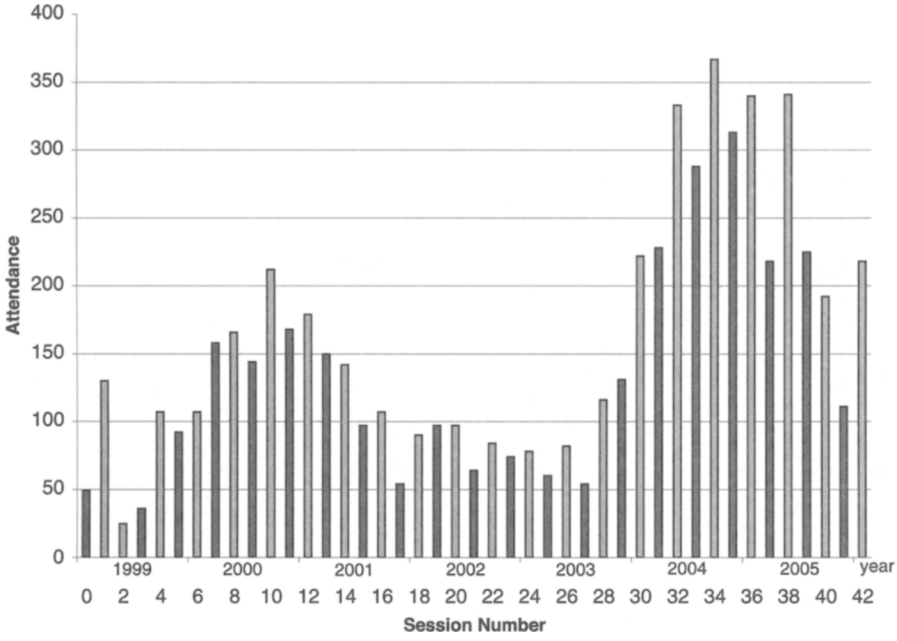

Figure 2–1: IEEE 802.16 Working Group attendance

Beginning in 2004, in recognition of the fact that IEEE 802 plenaries are generally in North America, nearly all sites selected by the working group for its interim sessions have been outside North America, most often in Asia. Like attendance, membership in the working group also fluctuates, lagging behind the attendance figures. As of November 2005, the working group had 310 individual members. According to the addresses they provided, they represent a broad geographical base, as shown in Table 2–1.

Table 2–1: IEEE 802.16 members by geography, as of January 2006

Address	Number of members
Canada	20
China	17
Finland	2
France	3
Germany	7
Ireland	1
Israel	18
Italy	3
Japan	7
Korea	60
Netherlands	4
Romania	1
Singapore	1
Sweden	3
Taiwan	3
UK	11
USA	149

TECHNICAL PROGRESS IN IEEE 802.16 WORKING GROUP

Since 1999, the IEEE 802.16 Working Group has constantly been active in developing standards projects, usually with multiple parallel activities. Although some of its projects have been very large, the group prefers to divide its efforts into specific problems that can be reasonably well-defined and completed within a predictable time. The IEEE process allows for the development of amendments that modify an existing standard. The published

amendment, which is designated by a lowercase letter after the primary standard number, is not an independent specification because it includes only the modifications, not the base material from the original standard. Upon approval of the amendment, the applicable standard is no longer the prior version, but the version defined by the application of the amendment. When appropriate, a revision of the standard may be undertaken; in this case, the base standard and its published amendments are editorially merged and reballoted, with the entire document open to comment.

Figure 2–2 shows a timeline of the past and current projects of the IEEE 802.16 Working Group. The designated start date is that of the approval of the project authorization (PAR); in some cases, the chart shows the date of a previous PAR that was later modified before the project was complete. The end date in each case is the actual or anticipated date of approval.

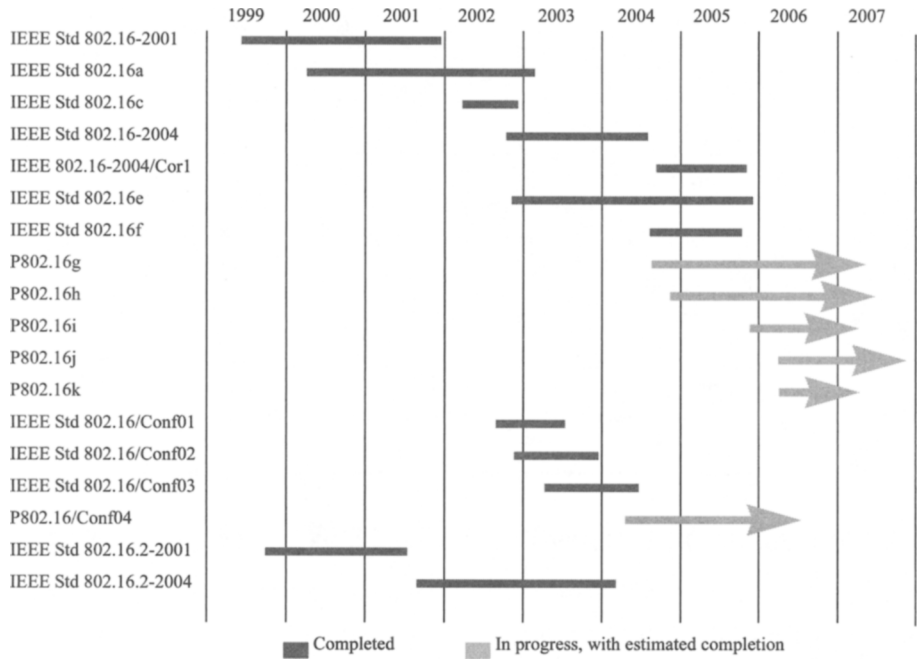

Figure 2–2: IEEE 802.16 project timeline

Air interface: IEEE Std 802.16

Work under the original IEEE 802.16 PAR, to develop an air interface for 10 GHZ to 66 GHz, began in July 1999. By November 1999, 35 PHY and MAC proposals were considered. By March 2000, two consolidated MAC/PHY proposals were still under consideration. In May 2000, agreement was reached to merge these proposals. A working group letter ballot followed soon thereafter. IEEE Std 802.16-2001, IEEE Standard for Local and Metropolitan Area Networks—Part 16: Air Interface for Fixed Broadband Wireless Access Systems, was approved in December 2001. The MAC protocol is fundamentally based on a time division multiplexing/time division multiple access (TDM/TDMA) protocol supporting time division duplexing (TDD), frequency division duplexing (FDD), and half-duplex frequency division duplexing (H-FDD). The PHY, entitled *WirelessMAN-SC*, is a single-carrier system assuming LOS propagation to fixed antenna terminals.

Because the working group believed that IEEE Std 802.16-2001 allowed too many options for easy interoperability testing, it opened up a follow-up amendment project, IEEE P802.16c, to define a set of profiles that would each define a set of options with sufficient specificity to allow for interoperability. With Ken Stanwood's leadership as task group chair, this project both opened and closed in 2002.

In November 1999, while the 35 MAC and PHY proposals were being discussed, IEEE 802.16 created a study group, under the leadership of Brian Kiernan, to develop a PAR for frequencies below 10 GHz. That PAR was approved in March 2000 and began the working group's activities in NLOS PHY technology.

The working group targeted its higher frequency PHY at carrier frequencies above 10 GHz and its lower frequency work at less than 11 GHz. This overlap simply reflected the fact that some available bands (in particular, 10.5 GHz) seemed suitable for either. In fact, this minor overlap was dwarfed, early on, by more fundamental issues regarding the relationship between these two approaches. Initially, many of those interested in the low-frequency applications favored basing the work on a new MAC, believing that the original MAC was too enterprise-centric and not sufficiently suited to basic residential applications. However, upon further discussion, the working group

made the virtually unanimous decision to build all of its PHY specifications upon a single, sophisticated MAC foundation. Another contentious issue was whether to pursue separate PHY projects for licensed and licensed-exempt bands. After starting in this direction, the working group later decided to merge those efforts. As a result of these changing decisions, a number of PARs were revised and renamed in the early years. Eventually, the project became amendment project IEEE P802.16a, and the amendment was approved by IEEE-SA in early 2003.

IEEE Std 802.16a includes three separate PHY specifications:

- WirelessMAN-SCa: single carrier
- WirelessMAN-OFDM: multicarrier with 256 subcarriers
- WirelessMAN-OFDMA: multicarrier with 2048 subcarriers

The debate leading to the decision to include all three modes was long and contentious. The eventual decision was not to everyone's liking, but compromise is a critical element of standardization. In attempting to develop a single standard for worldwide use, it was necessary to recognize a number of different worldwide needs. Since IEEE Std 802.16a was adopted, WirelessMAN-OFDM has become very popular. WirelessMAN-OFDMA, which was more forward-looking at the time of adoption, is increasingly appearing to be the choice of the future, particularly as IEEE Std 802.16 is evolving toward mobile systems. In the meantime, WirelessMAN-SCa has not gained significant industry interest.

Once IEEE Std 802.16a was complete, the working group opened the amendment project IEEE P802.16d. This was intended to parallel the profiles project IEEE Std 802.16c, but oriented toward the lower frequencies. The PAR also allowed for the correction of errors that inevitably plague complex standards such as IEEE Std 802.16. Gordon Antonello agreed to chair the project, which was intended to be short and sweet, like IEEE Std 802.16c™. However, the project quickly grew in complexity, as a number of proposals looked more like enhancements than error corrections. Eventually, the working group decided that it needed to convert the project from an amendment into a revision; this would editorially merge IEEE 802.16-2001, IEEE 802.16a, and IEEE 802.16c, opening the entire result to comments

regarding corrections and improvements. The amendment PAR IEEE 802.16d was abandoned in favor of a revision project IEEE 802.16-REVd, and Antonello ended up with a much larger task than he had expected. The work was finally approved in June 2004 and weighed in at nearly 900 pages. Because it was a revision, IEEE Std 802.16-2004 [B20] made IEEE Std 802.16-2001, IEEE Std 802.16a, and IEEE Std 802.16c obsolete. Some people incorrectly refer to this document as the "16d" standard, but letters are used to identify amendments, not revisions.

Once again, bugs and errors turned up. In September 2004, a PAR was approved for a new project to address them. In IEEE parlance, a project allowing corrections but prohibiting new features is called a *corrigendum*. Under the leadership of Jon Labs, the corrigendum IEEE Std 802.16-2004/Cor1 was completed in September 2005 and approved in November 2005. This document put to rest, for the near term, the definition of the IEEE 802.16 air interface for fixed wireless access.

However, a working group in motion seems to remain in motion. As the amendment project IEEE P802.16a was wrapping up in late 2002, the working group opened up a new PAR, IEEE P802.16e, to expand the IEEE 802.16 fixed access system into a combined fixed/mobile system, allowing a single BS to support both fixed and mobile terminals in licensed bands below 6 GHz. The amendment project IEEE P802.16e, chaired by Brian Kiernan, attracted great interest and a great many participants to the working group. The influx of people tended to keep the project unstable; therefore, many decisions were revisited again and again. However, the work did come to a conclusion, and the final draft, at 684 pages, was approved in December 2005. IEEE Std 802.16e amends IEEE Std 802.16. All of the three lower frequency PHY modes are supported, but the WirelessMAN-OFDMA mode is made "scalable" with the addition of new subcarrier counts: 128, 512, and 1024. The details of IEEE Std 802.16e and its content is beyond the scope of this book.

In March 2006, Brian Kiernan was awarded the IEEE-SA Standards Medallion "for steadfast and exemplary leadership of the Task Groups developing the IEEE 802.16a and 802.16e WirelessMAN standards

specifying wireless metropolitan area networks for fixed and mobile broadband wireless access systems."

As the working group's attention turned to mobility, it decided that network management would be an increasingly critical issue. The Network Management (NetMan) Task Group, chaired by Phil Barber, was initiated to address such concerns. The NetMan group took on two projects: IEEE P802.16f and IEEE P802.16g. IEEE Std 802.16f™, a management information base (MIB) for fixed systems, was approved in September 2005. IEEE P802.16g is a complex activity on "management plane procedures and services." Approval is not expected until 2007. In the meantime, the working group began planning in late 2005 to follow up IEEE Std 802.16f with a new MIB project for the mobile case. This was launched as IEEE P802.16i in December 2005.

The work to amend IEEE Std 802.16-2004 also continues with IEEE P802.16h, which is attempting to address the long-neglected problem of coexistence in license-exempt bands. The License-Exempt Task Group leading the effort is chaired by Mariana Goldhamer.

In July 2005, following a number of presentations and expressions of interest, the working group created the Mobile Multihop Relay Study Group to investigate the initiation of a new project. The existing standard specifies both the BS and the subscriber station (SS). The study group was chartered to consider the additional specification of a relay station, which would offer a valuable new tool to system operators. The study group, chaired by Mitsuo Nohara, proposed an IEEE P802.16j PAR. Following a tutorial on the topic at the IEEE 802 plenary session in March 2006, the PAR was approved later that month.

Conformance: IEEE 802.16/Conformance0*X*

The IEEE 802.16 Working Group, aware that air interface standards alone cannot specify conformance or interoperability, believes in the importance of conformance test documents. The working group has completed and published three stand-alone conformance test standards, all applicable to WirelessMAN-SC systems and all developed by the Conformance Task Group, chaired by Ken Stanwood. IEEE Std 802.16/Conformance01-2003

[B21], IEEE Std 802.16/Conformance02-2003 [B22], and IEEE Std 802.16/Conformance03-2004 [B23] address the protocol implementation conformance statement (PICS) proforma, test suite structure and test purposes (TSS&TP), and radio conformance tests (RCTs), respectively. Work on a PICS for the PHYs operating below 11 GHz is taking place under the IEEE P802.16/Conformance04 project, chaired by Gordon Antonello.

COEXISTENCE: IEEE STD 802.16.2™

Beginning in 1999, the working group took note of the difficulties that would be faced by operators of systems in licensed bands due to co-channel and adjacent channel interference. It opened a PAR to create a stand-alone *recommended practice*, IEEE parlance for a standard that uses the verb "should" instead of "shall" in its normative statements. IEEE Std 802.16.2-2001, addressing the frequencies important to the WirelessMAN-SC PHY, was approved in 2001. A revision, to include the lower frequencies in IEEE Std 802.16a, was approved in 2004 as IEEE Std 802.16.2-2004 [B26]. Phil Whitehead chaired the Coexistence Task Group for both projects.