

IEEE Standard for Information Technology—
Telecommunications and information exchange
between systems
Wireless Regional Area Networks (WRAN)—
Specific requirements

Part 22: Cognitive Wireless RAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications: Policies and Procedures for Operation in the TV Bands

Amendment 2: Enhancement for Broadband Services and Monitoring Applications

IEEE Computer Society

Sponsored by the
LAN/MAN Standards Committee

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

IEEE Std 802.22b™-2015
(Amendment to
IEEE Std 802.22™-2011
as amended by IEEE Std 802.22a™-2014)

IEEE Std 802.22b™-2015
(Amendment to
IEEE Std 802.22™-2011
as amended by IEEE Std 802.22a™-2014)

**IEEE Standard for Information Technology—
Telecommunications and information exchange
between systems
Wireless Regional Area Networks (WRAN)—
Specific requirements**

**Part 22: Cognitive Wireless RAN
Medium Access Control (MAC) and
Physical Layer (PHY) Specifications:
Policies and Procedures for
Operation in the TV Bands**

**Amendment 2: Enhancement for Broadband
Services and Monitoring Applications**

Sponsor

**LAN/MAN Standards Committee
of the
IEEE Computer Society**

Approved 3 September 2015

IEEE-SA Standards Board

Abstract: Alternate physical layer (PHY) and necessary medium access control layer (MAC) enhancements to IEEE Std 802.22-2011 are specified in this amendment for operation in very high frequency/ultra-high frequency (VHF/UHF) television broadcast bands between 54 MHz and 862 MHz to support enhanced broadband services and monitoring applications. The amendment supports aggregate data rates greater than the maximum data rate supported by the IEEE Std 802.22-2011. This amendment defines new classes of IEEE 802.22™ devices to address these applications and supports more than 512 devices in a network. This amendment also specifies techniques to enhance communications among the devices and makes necessary amendments to the cognitive, security, and parameters and connection management clauses. This amendment supports mechanisms to enable coexistence with other IEEE 802® systems in the same band.

Keywords: broadband wireless access network, enhanced broadband services, high capacity, high throughput, IEEE 802.22™, IEEE 802.22b™, monitoring applications, WRAN standard

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

Copyright © 2015 by The Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 30 October 2015. Printed in the United States of America.

IEEE and IEEE 802 are registered trademarks in the U.S. Patent & Trademark Office, owned by The Institute of Electrical and Electronics Engineers, Incorporated.

PDF: ISBN 978-0-7381-9838-5 STD20318
Print: ISBN 978-0-7381-9839-2 STDPD20318

IEEE prohibits discrimination, harassment and bullying.

For more information, visit <http://www.ieee.org/web/aboutus/whatis/policies/p9-26.html>.

No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without the prior written permission of the publisher.

Important Notices and Disclaimers Concerning IEEE Standards Documents

IEEE documents are made available for use subject to important notices and legal disclaimers. These notices and disclaimers, or a reference to this page, appear in all standards and may be found under the heading “Important Notice” or “Important Notices and Disclaimers Concerning IEEE Standards Documents.”

Notice and Disclaimer of Liability Concerning the Use of IEEE Standards Documents

IEEE Standards documents (standards, recommended practices, and guides), both full-use and trial-use, are developed within IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (“IEEE-SA”) Standards Board. IEEE (“the Institute”) develops its standards through a consensus development process, approved by the American National Standards Institute (“ANSI”), which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of the Institute and participate without compensation from IEEE. While IEEE administers the process and establishes rules to promote fairness in the consensus development process, IEEE does not independently evaluate, test, or verify the accuracy of any of the information or the soundness of any judgments contained in its standards.

IEEE does not warrant or represent the accuracy or content of the material contained in its standards, and expressly disclaims all warranties (express, implied and statutory) not included in this or any other document relating to the standard, including, but not limited to, the warranties of: merchantability; fitness for a particular purpose; non-infringement; and quality, accuracy, effectiveness, currency, or completeness of material. In addition, IEEE disclaims any and all conditions relating to: results; and workmanlike effort. IEEE standards documents are supplied “AS IS” and “WITH ALL FAULTS.”

Use of an IEEE standard is wholly voluntary. The existence of an IEEE standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard.

In publishing and making its standards available, IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity nor is IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing any IEEE Standards document, should rely upon his or her own independent judgment in the exercise of reasonable care in any given circumstances or, as appropriate, seek the advice of a competent professional in determining the appropriateness of a given IEEE standard.

IN NO EVENT SHALL IEEE BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO: PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE PUBLICATION, USE OF, OR RELIANCE UPON ANY STANDARD, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE AND REGARDLESS OF WHETHER SUCH DAMAGE WAS FORESEEABLE.

Translations

The IEEE consensus development process involves the review of documents in English only. In the event that an IEEE standard is translated, only the English version published by IEEE should be considered the approved IEEE standard.

Official statements

A statement, written or oral, that is not processed in accordance with the IEEE-SA Standards Board Operations Manual shall not be considered or inferred to be the official position of IEEE or any of its committees and shall not be considered to be, or be relied on as, a formal position of IEEE. At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that his or her views should be considered the personal views of that individual rather than the formal position of IEEE.

Comments on standards

Comments for revision of IEEE Standards documents are welcome from any interested party, regardless of membership affiliation with IEEE. However, IEEE does not provide consulting information or advice pertaining to IEEE Standards documents. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments. Since IEEE standards represent a consensus of concerned interests, it is important that any responses to comments and questions also receive the concurrence of a balance of interests. For this reason, IEEE and the members of its societies and Standards Coordinating Committees are not able to provide an instant response to comments or questions except in those cases where the matter has previously been addressed. For the same reason, IEEE does not respond to interpretation requests. Any person who would like to participate in revisions to an IEEE standard is welcome to join the relevant IEEE working group.

Comments on standards should be submitted to the following address:

Secretary, IEEE-SA Standards Board
445 Hoes Lane
Piscataway, NJ 08854 USA

Laws and regulations

Users of IEEE Standards documents should consult all applicable laws and regulations. Compliance with the provisions of any IEEE Standards document does not imply compliance to any applicable regulatory requirements. Implementers of the standard are responsible for observing or referring to the applicable regulatory requirements. IEEE does not, by the publication of its standards, intend to urge action that is not in compliance with applicable laws, and these documents may not be construed as doing so.

Copyrights

IEEE draft and approved standards are copyrighted by IEEE under U.S. and international copyright laws. They are made available by IEEE and are adopted for a wide variety of both public and private uses. These include both use, by reference, in laws and regulations, and use in private self-regulation, standardization, and the promotion of engineering practices and methods. By making these documents available for use and adoption by public authorities and private users, IEEE does not waive any rights in copyright to the documents.

Photocopies

Subject to payment of the appropriate fee, IEEE will grant users a limited, non-exclusive license to photocopy portions of any individual standard for company or organizational internal use or individual, non-commercial use only. To arrange for payment of licensing fees, please contact Copyright Clearance Center, Customer Service, 222 Rosewood Drive, Danvers, MA 01923 USA; +1 978 750 8400. Permission to photocopy portions of any individual standard for educational classroom use can also be obtained through the Copyright Clearance Center.

Updating of IEEE Standards documents

Users of IEEE Standards documents should be aware that these documents may be superseded at any time by the issuance of new editions or may be amended from time to time through the issuance of amendments, corrigenda, or errata. An official IEEE document at any point in time consists of the current edition of the document together with any amendments, corrigenda, or errata then in effect.

Every IEEE standard is subjected to review at least every ten years. When a document is more than ten years old and has not undergone a revision process, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE standard.

In order to determine whether a given document is the current edition and whether it has been amended through the issuance of amendments, corrigenda, or errata, visit the IEEE-SA Website at <http://ieeexplore.ieee.org/xpl/standards.jsp> or contact IEEE at the address listed previously. For more information about the IEEE-SA or IEEE's standards development process, visit the IEEE-SA Website at <http://standards.ieee.org>.

Errata

Errata, if any, for all IEEE standards can be accessed on the IEEE-SA Website at the following URL: <http://standards.ieee.org/findstds/errata/index.html>. Users are encouraged to check this URL for errata periodically.

Patents

Attention is called to the possibility that implementation of this standard may require use of subject matter covered by patent rights. By publication of this standard, no position is taken by the IEEE with respect to the existence or validity of any patent rights in connection therewith. If a patent holder or patent applicant has filed a statement of assurance via an Accepted Letter of Assurance, then the statement is listed on the IEEE-SA Website at <http://standards.ieee.org/about/sasb/patcom/patents.html>. Letters of Assurance may indicate whether the Submitter is willing or unwilling to grant licenses under patent rights without compensation or under reasonable rates, with reasonable terms and conditions that are demonstrably free of any unfair discrimination to applicants desiring to obtain such licenses.

Essential Patent Claims may exist for which a Letter of Assurance has not been received. The IEEE is not responsible for identifying Essential Patent Claims for which a license may be required, for conducting inquiries into the legal validity or scope of Patents Claims, or determining whether any licensing terms or conditions provided in connection with submission of a Letter of Assurance, if any, or in any licensing agreements are reasonable or non-discriminatory. Users of this standard are expressly advised that determination of the validity of any patent rights, and the risk of infringement of such rights, is entirely their own responsibility. Further information may be obtained from the IEEE Standards Association.

Participants

When this amendment went to sponsor ballot, the IEEE 802.22 Working Group had the following officers:

Apurva Mody, Chair
Chang-woo Pyo, Vice Chair

When this amendment was sent to sponsor ballot, the Task Group b had the following membership:

Chang-woo Pyo, Chair and Editor
Sung Hyun Hwang, Vice Chair
Gabriel Villardi, Secretary

Gregory Buchwald
Winston Caldwell
Gerald Chouinard
Subir Das
Peter Flynn
Thomas Gurley
Hiroshi Harada
Bob Heile
Dien Hoang
Byung Jang Jeong

Jerome J. Kalke
Hynduk Kang
Gwangzeen Ko
Bruce Kraemer
Donghun Lee
PinHsun Lin
Liru Lu
Michael Lynch
Apurva Mody
Paul Nikolich

Masayuki Oodo
Ranga K. Reddy
Ivan Reede
Shigenobu Sasaki
Steve Shellhammer
Chunyi Song
Keat-Beng Toh
Xin (Amy) Zhang
Bing Xuan Zhao
Lei Zhongding

Major contributions were received from the following individuals:

Sung Hyun Hwang
Masayuki Oodo
Chang-woo Pyo
Aziz Rahman

Ranga K. Reddy
Shigenobu Sasaki
Chunyi Song

Keat-Beng Toh
Gabriel Villardi
Xin (Amy) Zhang
Bing Xuan Zhao

The following members of the individual balloting committee voted on this amendment. Balloters may have voted for approval, disapproval, or abstention.

Iwan Adhicandra
Nobumitsu Amachi
Butch Anton
Madhusudan Banavara
Tuncer Baykas
Harry Bims
Nancy Bravin
William Byrd
Edgar Callaway
Juan Carreon
Keith Chow
Charles Cook
Carlo Donati
Sourav Dutta
Richard Edgar
Charles Einolf
Stanislav Filin
Devon Gayle
Alexander Gelman
Tim Godfrey
Randall Groves
Michael Gundlach
Thomas Gurley
Chris Guy

Werner Hoelzl
Sung Hyun Hwang
Noriyuki Ikeuchi
Akio Iso
Atsushi Ito
Raj Jain
Shinkyu Kaku
Jerome J. Kalke
Piotr Karocki
Stuart Kerry
Adrian Kliks
Bruce Kraemer
Yasushi Kudoh
Paul Lambert
Arthur H. Light
Daniel Lubar
William Lumpkins
Elvis Maculuba
James Marin
Jeffery Masters
Michael McInnis
Apurva Mody
Nabil Nasser
Michael Newman
Nick S. A. Nikjoo

Paul Nikolich
Masayuki Oodo
Satoshi Oyama
Subburajan Ponnuswamy
Venkatesha Prasad
Chang-woo Pyo
Verotiana Rabarijaona
Robert Robinson
William Rose
John Santhoff
Shigenobu Sasaki
Naotaka Sato
Chunyi Song
Kapil Sood
Thomas Starai
Walter Struppler
Keat-Beng Toh
Ha-Nguyen Tran
David Trejo Pizzo
Mark-Rene Uchida
Gabriel Villardi
Hung-Yu Wei
Oren Yuen
Mingtuo Zhou

When the IEEE-SA Standards Board approved this amendment on 3 September 2015, it had the following membership:

John Kulick, *Chair*
Jon Walter Rosdahl, *Vice Chair*
Richard H. Hulett, *Past Chair*
Konstantinos Karachalios, *Secretary*

Masayuki Ariyoshi
Ted Burse
Stephen Dukes
Jean-Phillippe Faure
J. Travis Griffith
Gary Hoffman
Michael Janezic

Joseph L. Koepfinger*
David J. Law
Hung Ling
Andrew Myles
T. W. Olsen
Glenn Parsons
Ronald C. Peterson
Annette D. Reilly

Stephen J. Shellhammer
Adrian P. Stephens
Yatin Trivedi
Phillip Winston
Don Wright
Yu Yuan
Daidi Zhong

*Member Emeritus

Introduction

This introduction is not part of IEEE Std 802.22b™-2015, IEEE Standard for Information Technology—Telecommunications and information exchange between systems—Wireless Regional Area Networks (WRAN)—Specific requirements—Part 22: Cognitive Wireless RAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications: Policies and Procedures for Operation in the TV Bands—Amendment 2: Enhancement for Broadband Services and Monitoring Applications.

This amendment specifies alternate physical layer (PHY) and necessary medium access control layer (MAC) enhancements to IEEE Std 802.22-2011 for operation in very high frequency/ultra high frequency (VHF/UHF) television broadcast bands between 54 MHz and 862 MHz to support enhanced broadband services and monitoring applications. PHY specifications (i.e., Operation Mode 1 and Operation Mode 2) in Clause 9 and Clause 9a are designed to meet the needs required by channel models. A multi-channel operation (7.24), high modulation and coding (9.2 and 9a.2), and multiple-input, multiple-output (MIMO) (9.15 and 9a.15) provide higher throughput (compared to the IEEE Std 802.22-2011), which may be achieved by individual use or combinational use. Point-to-multipoint connections and relay connections are specified in Clause 7.

Contents

1. Overview	2
1.3 Reference application	2
3. Definitions	2
4. Abbreviations and acronyms	4
7. MAC Common Part sublayer	5
7.1 General.....	5
7.2 Addressing and connections	6
7.3 General superframe structure.....	7
7.4 General frame structure (on PHY-OM1).....	7
7.4a General frame structure (on PHY-OM2).....	8
7.4a.1 General frame structure for normal mode.....	8
7.4a.2 General frame structure for self-coexistence mode	8
7.4a.3 Frame format.....	8
7.4b General frame structure for a relay network.....	12
7.4b.1 General frame structure for a centralized scheduling mode	12
7.4b.2 General frame structure for a distributed scheduling mode.....	13
7.4b.3 Detail of zones	15
7.4b.3.1 Access zone (AZ).....	15
7.4b.3.2 Centralized relay zone (CRZ).....	16
7.4b.3.3 Distributed relay zone (DRZ)	17
7.4b.3.4 Application of PHY Operation Mode to Zone Type	18
7.5 Control header	18
7.5.1 Superframe Control header	18
7.5.2 Frame Control header.....	18
7.5.2a Frame control header for PHY-OM2.....	19
7.5.2a.1 General.....	19
7.5.2a.2 Extended frame control header (Ex-FCH).....	20
7.5.2b Distributed relay zone (DRZ) Frame Control header (DRZ-FCH).....	23
7.6 MAC PDU formats.....	24
7.6.1 MAC headers	24
7.6.1.1 Generic MAC header	24
7.6.1.2 MAC subheaders and special payloads	25
7.6.1.2.5 Extended subheader types	26
7.6.1.3 CBP MAC PDU format.....	27
7.6.1.3.1 CBP information elements	28
7.7 Management messages	30
7.7.1 Downstream Channel Descriptor (DCD).....	30
7.7.1.1 DCD Channel information elements.....	32
7.7.2 Downstream MAP (DS-MAP).....	34
7.7.2.1 DS-MAP IE.....	35
7.7.2.1.1 DIUC allocations	35
7.7.2.1.2 DS-MAP Extended DIUC IE	37
7.7.3 Upstream Channel Descriptor (UCD).....	42
7.7.3.1 UCD Channel IEs	44
7.7.4 Upstream MAP (US-MAP).....	45
7.7.4.1 US-MAP IE.....	46
7.7.4.1.1 UIUC allocations	49
7.7.4.1.4 US-MAP Extended UIUC IE	50

7.7.7	REG-REQ/RSP	60
7.7.7.3	REG-REQ/RSP information elements	60
7.7.7.3.4	CPE capability	60
7.7.7.3.6	Local SID Group	61
7.7.8.9	Service Flow encodings	61
7.7.8.9.19	Per-RS QoS	61
7.7.11	CPE Basic Capability Request/Response (CBC-REQ/RSP)	62
7.7.11.3	CBC-REQ/RSP information elements	62
7.7.11.3.2	Physical parameters supported	62
7.7.11.3.4	Relay CPE Mode	63
7.7.11.3.5	Multi-channel operation supported	64
7.7.24	Confirmation codes	64
7.7.25	Local Cell Update messages	64
7.7.25.1	Local Cell Update Indication (LCU-IND) message	64
7.7.25.2	Local Cell Update Acknowledgment (LCU-ACK) message	65
7.7.26	Container message	66
7.7.26.1	Message format	66
7.7.26.2	Container ACK message	66
7.7.27	Downstream Transmit Test (DTT) messages	67
7.7.27.1	DTT Request (DTT-REQ) message	67
7.7.27.1.1	Message format	67
7.7.27.1.2	DTT-REQ information element	67
7.7.27.2	DTT Response (DTT-RSP) message	67
7.7.27.2.1	Message format	67
7.7.27.2.2	DTT-RSP information element	68
7.7.27.3	DTT Report (DTT-RPT) message	68
7.7.27.3.1	Message format	68
7.7.27.3.2	DTT-RPT information element	68
7.7.27.4	DTT Confirmation (DTT-CFM) message	69
7.7.27.4.1	Message format	69
7.7.27.4.2	DTT-CFM information element	69
7.7.28	Relay-Schedule (Relay-SCHE) message	69
7.7.29	Channel Allocation Manager management messages	70
7.7.29.1	Overview	70
7.7.29.2	Add new operating channel (CAM-ADD) message	70
7.7.29.3	Stop operating channel (CAM-STP) message	71
7.7.29.4	Stop operating channel acknowledgment (CAM-STP-ACK) message	71
7.7.29.5	Switch operating channel (CAM-SWH) message	71
7.7.29.6	Switch operating channel acknowledgment (CAM-SWH-ACK) message	72
7.7.30	Group Resource Allocation management messages	72
7.7.30.1	Group Resource Allocation Configuration (GRA-CFG) message	72
7.7.30.2	Group Resource Allocation Update (GRA-UPD) message	73
7.7.31	Ranging Report (RNG-RPT) message	75
7.8	Management of MAC PDUs	75
7.8.4	Packing	75
7.8.4.3	ARQ Feedback IEs	75
7.8.7	MAC PDU construction for relay	76
7.8.7.1	General	76
7.8.7.2	MAC PDU construction for distributed scheduling A-CPE on non-ARQ connections	76
7.8.7.2.1	Overview	76
7.8.7.2.2	Procedure 1 on non-ARQ connections	76
7.8.7.2.3	Procedure 2 on non-ARQ connections	77
7.8.7.2.4	Procedure 3 on non-ARQ connections	78

7.8.7.2.5	Procedure 4 on non-ARQ connections	78
7.8.7.3	MAC PDU construction for distributed scheduling A-CPE on ARQ connections	79
7.8.7.3.1	Overview	79
7.8.7.3.2	Procedure 1 for ARQ connections	79
7.8.7.3.3	Procedure 2 for ARQ connections	80
7.8.7.3.4	Procedure 3 on ARQ connections	83
7.8.7.3.5	Procedure 4 on ARQ connections	84
7.8.8	MAC PDU transmission for relay	87
7.8.8.1	Overview	87
7.8.8.2	US through a distributed scheduling A-CPE	87
7.8.8.3	US through a centralized scheduling A-CPE	87
7.8.8.4	DS through a distributed scheduling A-CPE	88
7.8.8.5	DS through a centralized scheduling A-CPE	88
7.9	ARQ mechanism	89
7.9.6	ARQ operation	89
7.9.6.4	ARQ for a relay network	89
7.9.6.4.1	Overview	89
7.9.6.4.2	Two-link ARQ mode	89
7.9.6.4.3	ARQ state machine	91
7.10	Scheduling services	91
7.10.2	Upstream request/grant scheduling	91
7.10.2.1	UGS	91
7.10.2.2	rtPS	92
7.11	Bandwidth management	92
7.11.1	Bandwidth Requests	92
7.11.1.3	Bandwidth Request for a relay network	92
7.11.1.3.1	Overview	92
7.11.1.3.2	Bandwidth Request by a distributed scheduling A-CPE	92
7.11.1.3.3	Bandwidth Request by a centralized scheduling A-CPE	93
7.11.2	Grants	93
7.11.2.1	Grants for a relay network	93
7.11.2.1.1	Bandwidth grant for relay with a distributed scheduling A-CPE	93
7.11.2.1.2	Bandwidth grant for relay with a centralized scheduling A-CPE	94
7.11.3	Polling	94
7.11.3.4	Polling for a relay network	94
7.13	Contention resolution	96
7.13.1	Transmission opportunities	96
7.14	Initialization and network association	97
7.14.3	A-BS initialization	97
7.14.3.1	General	97
7.14.3.2	Professional installation	97
7.14.3.3	A-BS antenna gain information acquisition	97
7.14.3.4	Determine geographic location	99
7.14.3.5	Access TV bands database service and receive list of available channels	99
7.14.3.6	Operator disallows channels	99
7.14.3.7	Perform incumbent detection and synchronize network with neighboring networks ..	99
7.14.3.8	Present the available channel list to the higher layers	99
7.14.3.9	Commence single channel operation or multi-channel operation	100
7.14.4	CPE initialization for relay	100
7.14.4.1	General	100
7.14.4.2	CPE performs self test	103
7.14.4.3	CPE antenna gain information acquisition	103
7.14.4.4	CPE senses for and identifies A-WRAN services and incumbents	103
7.14.4.5	Present sensing results to the higher layers	103

7.14.4.6 CPE chooses an A-WRAN service for single channel operation or for multi-channel operation	103
7.14.4.7 CPE performs satellite-based geolocation	103
7.14.4.8 Acquire DS and US parameters	104
7.14.4.8.1 Overview	104
7.14.4.8.2 Obtaining DS parameters from an A-BS	104
7.14.4.8.3 Obtaining DS parameters from a distributed scheduling A-CPE	104
7.14.4.8.4 Obtaining US parameters from an A-BS	106
7.14.4.8.5 Obtaining US parameters from a distributed scheduling A-CPE	107
7.14.4.9 CPE transmits ranging/CDMA burst	108
7.14.4.9.1 General	108
7.14.4.9.2 CDMA initial ranging and automatic adjustments to an A-BS	109
7.14.4.9.3 CDMA initial ranging and automatic adjustments to a distributed scheduling A-CPE (Local initial ranging)	110
7.14.4.9.4 CDMA initial ranging and automatic adjustments by relaying on a centralized scheduling A-CPE (Relay initial ranging)	112
7.14.4.9.5 Ranging parameter adjustment	114
7.14.4.10 CPE transmit basic capabilities for a relay network	114
7.14.4.10.1 CPE transmit basic capabilities to a distributed scheduling A-CPE	114
7.14.4.10.2 CPE transmit basic capabilities relaying on a centralized scheduling A-CPE	115
7.14.4.11 CPE authentication and key exchange	116
7.14.4.12 Registration for a relay network	117
7.14.4.12.1 Overview	117
7.14.4.12.2 Local cell management on relay	117
7.14.4.13 A-BS transmits channel sets to CPE	119
7.14.4.14 Establish IP connectivity	120
7.14.4.15 Establish time of day	120
7.14.4.16 Transfer operational parameters	120
7.14.4.17 Establish dynamic service flows	120
7.14.4.18 Neighboring network discovery	120
7.15 Ranging	121
7.15.1 DS management	121
7.15.1.1 DS management (A-BS and CPE)	121
7.15.1.2 Local DS management (distributed scheduling A-CPE and S-CPE)	121
7.15.1.3 Relay DS management (A-BS and S-CPE via centralized scheduling A-CPE)	123
7.15.2 US management	126
7.15.2.3 CDMA initial ranging and automatic adjustments for a relay network	127
7.15.2.3.1 CDMA initial ranging and automatic adjustments (A-BS and CPE)	127
7.15.2.3.2 CDMA local initial ranging and automatic adjustments (distributed scheduling A-CPE and S-CPE)	127
7.15.2.3.3 CDMA relay initial ranging and automatic adjustments (centralized scheduling A-CPE and S-CPE)	128
7.15.2.4 CDMA Periodic ranging and automatic adjustments for a relay network	129
7.15.2.4.1 CDMA periodic ranging and automatic adjustments (A-BS and CPE)	129
7.15.2.4.2 CDMA local periodic ranging and automatic adjustments (distributed scheduling A-CPE and CPE)	129
7.15.2.4.3 CDMA relay periodic ranging and automatic adjustments (centralized scheduling A-CPE and CPE)	130
7.16 Channel descriptor management	131
7.18 QoS	131
7.18.9 Service Flow Management	131
7.18.9.3 Dynamic Service Addition	131
7.18.9.3.1 CPE-initiated DSA	131

7.18.9.3.2	BS-initiated DSA	132
7.18.9.4	Dynamic Service Change.....	132
7.18.9.4.1	CPE-initiated DSC	132
7.18.9.4.2	BS-initiated DSC	133
7.18.9.5	Dynamic Service Deletion.....	133
7.18.9.5.1	CPE-initiated DSD	133
7.18.9.5.2	BS-initiated DSD	134
7.19	Incumbent protection.....	134
7.19.2	Measurements management.....	134
7.19.2.1	Measurements management for a relay network.....	134
7.19.4	Measurement report and notification.....	135
7.19.4.2	Measurement report and notification for a relay network.....	135
7.20	Self-coexistence.....	136
7.20.1	Coexistence Beacon Protocol (CBP).....	136
7.20.1.1	CBP packet structure	136
7.20.4	Self-coexistence for a relay network.....	137
7.20.4.1	General.....	137
7.20.4.2	Mechanism for inter-A-BS self-coexistence on a relay network.....	138
7.20.4.3	CBP-based neighboring network discovery	139
7.20.4.3.1	Overview	139
7.20.4.3.2	Discovery with SCW	139
7.21	Quiet periods and sensing.....	140
7.21.2	Synchronization of overlapping quiet periods	140
7.21.2.1	Intra-frame quiet period synchronization	140
7.21.2.2	Inter-frame Quiet Period Synchronization.....	141
7.21.4	Quiet periods and sensing for a relay network.....	141
7.21.4.1	Quiet period synchronization for an A-BS's cell.....	141
7.21.4.2	Quiet period synchronization for a local network	141
7.22	Channel management	142
7.22.3	Channel management on a relay network.....	142
7.22.3.1	Overview.....	142
7.22.3.2	Initialization and channel sets updating.....	143
7.22.3.3	Scheduling of channel switching time.....	144
7.23	Synchronization of the IEEE 802.22 base stations and IEEE 802.22b base stations.....	145
7.24	Multi-channel operation	145
7.24.1	General.....	145
7.24.2	Channel allocation manager.....	147
7.24.2.1	General.....	147
7.24.2.2	Add new operating channel operation	148
7.24.2.2.1	General	148
7.24.2.2.2	BS-CAM selects a specific BS-CHU	149
7.24.2.2.3	BS-CAM commences operation request	149
7.24.2.2.4	BS-CHU commences operation acknowledgment	149
7.24.2.2.5	BS-CAM sends management information notification to BS-CHU	150
7.24.2.2.6	BS-CHU memorizes management information	150
7.24.2.2.7	BS-CHU performs frequency setting	150
7.24.2.2.8	BS-CHU performs synchronization	150
7.24.2.2.9	BS-CHU sends operation preparation completed notification to BS-CAM	150
7.24.2.2.10	BS-CHU broadcasts SCH on PHY-OM1 or FCH on PHY-OM2	150
7.24.2.2.11	BS-CAM checks unused BS-CHU	150
7.24.2.2.12	CPE-CAM selects a specific CPE-CHU	150
7.24.2.2.13	CPE-CAM sends BS search command (All or specific channel) to the specific CPE-CHU	151
7.24.2.2.14	CPE-CHU performs BS search	151

7.24.2.2.15	CPE-CHU sends BS detected notification to CPE-CAM	151
7.24.2.2.16	CPE-CAM determines other operating CPE-CHU	151
7.24.2.2.17	CPE-CAM performs BSID matching	151
7.24.2.2.18	CPE-CAM sends BSID mismatch notification to CPE-CHU	151
7.24.2.2.19	CPE-CAM sends proceed notification to CPE-CHU	151
7.24.2.2.20	CPE-CHU performs synchronization	152
7.24.2.2.21	CPE-CHU sends synchronization completed notification to CPE-CAM	152
7.24.2.2.22	CPE-CAM checks unused CPE-CHU	152
7.24.2.2.23	CPE-CAM sends registration request to CPE management unit	152
7.24.2.2.24	CPE management unit sends registration completed notification to CPE-CAM	152
7.24.2.3	Add new operating channel operation by using BS search command (specific channel).....	152
7.24.2.3.1	General	152
7.24.2.3.2	BS-CAM sends aggregation information to BS-CHU1	153
7.24.2.3.3	BS-CHU1 forwards aggregation information to CPE-CHU1	153
7.24.2.3.4	CPE-CHU1 forwards aggregation information to CPE-CAM	153
7.24.2.3.5	BS-CAM selects a specific BS-CHU	153
7.24.2.3.6	BS-CAM commences operation request	154
7.24.2.3.7	BS-CHUn commences operation acknowledgment	154
7.24.2.3.8	BS-CAM sends management information notification to BS-CHUn	154
7.24.2.3.9	BS-CHUn memorizes management information	155
7.24.2.3.10	BS-CHUn performs frequency setting	155
7.24.2.3.11	BS-CHUn performs synchronization	155
7.24.2.3.12	BS-CHUn sends operation preparation completed notification to BS-CAM ..	155
7.24.2.3.13	BS-CHUn broadcasts SCH on PHY-OM1 or FCH on PHY-OM2	155
7.24.2.3.14	BS-CAM checks unused BS-CHU	155
7.24.2.3.15	CPE-CAM selects a specific CPE-CHU	155
7.24.2.3.16	CPE-CAM sends BS search command (specific channel) to the specific CPE-CHUn	155
7.24.2.3.17	CPE-CHUn performs BS search	156
7.24.2.3.18	CPE-CHUn sends BS detected notification to CPE-CAM	156
7.24.2.3.19	CPE-CAM determines other operating CPE-CHU	156
7.24.2.3.20	CPE-CAM performs BSID matching	156
7.24.2.3.21	CPE-CAM sends BSID mismatch notification to CPE-CHUn	156
7.24.2.3.22	CPE-CAM sends proceed notification to CPE-CHUn	156
7.24.2.3.23	CPE-CHUn performs synchronization	156
7.24.2.3.24	CPE-CHUn sends synchronization completed notification to CPE-CAM	156
7.24.2.3.25	CPE-CAM checks unused CPE-CHU	157
7.24.2.3.26	CPE-CAM sends registration request to CPE management unit	157
7.24.2.3.27	CPE management unit sends registration completed notification to CPE-CAM	157
7.24.2.4	Stop operating channel operation	157
7.24.2.4.1	General	157
7.24.2.4.2	BS-CAM sends stop operation request to BS-CHU	157
7.24.2.4.3	BS-CHU starts stop operation timer	157
7.24.2.4.4	BS-CHU sends stop operation request acknowledgment to BS-CAM	158
7.24.2.4.5	BS-CHU sends stop operation request to CPE-CHU	158
7.24.2.4.6	CPE-CHU starts stop operation timer	158
7.24.2.4.7	CPE-CHU sends stop operation notification to CPE-CAM	158
7.24.2.4.8	CPE-CAM sends stop operation approval/command to CPE-CHU	158
7.24.2.4.9	CPE-CHU sends stop operation request acknowledgment to BS-CHU	159
7.24.2.4.10	CPE-CHU checks stop operation timer expired and stops operation	159
7.24.2.4.11	CPE-CHU sends stop operation completed notification to CPE-CAM	159

7.24.2.4.12	BS-CHU checks stop operation timer expired and stops operation	159
7.24.2.4.13	BS-CHU sends stop operation completed notification to CPE management unit	159
7.24.2.5	Switch operating channel operation.....	159
7.24.2.5.1	General	159
7.24.2.5.2	BS-CAM sends channel switch request to BS-CHU	160
7.24.2.5.3	BS-CHU starts channel switch timer	160
7.24.2.5.4	BS-CHU sends channel switch request acknowledgment to BS-CAM	161
7.24.2.5.5	BS-CHU sends channel switch request to CPE-CHU	161
7.24.2.5.6	CPE-CHU starts channel switch timer	161
7.24.2.5.7	CPE-CHU sends channel switch notification to CPE-CAM	161
7.24.2.5.8	CPE-CAM sends channel switch approval/command to CPE-CHU	161
7.24.2.5.9	CPE-CHU sends channel switch request acknowledgment to BS-CHU	161
7.24.2.5.10	BS-CHU checks channel switch timer expired and performs channel switch	161
7.24.2.5.11	CPE-CHU checks channel switch timer expired and performs channel switch	161
7.24.2.5.12	BS-CHU sends channel switch completed notification to BS-CAM	162
7.24.2.5.13	BS-CHU broadcasts SCH on PHY-OM1 or FCH on PHY-OM2	162
7.24.2.5.14	BS-CHU sends DS-MAP/DCD/US-MAP/UCD to CPE-CHU	162
7.24.2.5.15	CPE-CHU sends channel switch completed notification to CPE-CAM	162
7.24.2.5.16	CPE-CHU sends channel switch completed notification to CPE management unit	162
7.24.3	Multi-channel operation at A-BS	162
7.24.4	Multi-channel operation at A-CPE	163
7.25	Group Resource Allocation	164
8.	Security mechanism in IEEE 802.22	166
8.1	Security Architecture for the Data/Control and Management Planes	167
8.1.2	Key management and authentication overview	167
8.2	SCM protocol	167
8.2.2	Authentication state machine	167
8.2.2.7	Security capabilities negotiation	167
8.2.3	TEK exchange overview	168
8.2.3.1	TEK exchange overview for PMP topology	168
8.2.3.2	TEK state machine	168
8.3	Key usage	168
8.3.1	BS key usage	168
8.3.1.5	BS usage of TEX and GTEK	168
8.4	Cryptographic methods.....	169
8.4.1	Selection of Data Encryption and Authentication methods	169
8.4.2	Data Encryption and Authentication with AES GCM	170
8.4.2.1	PDU format.....	170
8.4.2.1.1	Packet number (PN)	170
8.4.2.1.2	PDU format—Authentication only	172
8.4.2.1.3	PDU format—Authentication and encryption	173
8.4.2.1.4	PDU format—Encryption only	174
8.4.2.2	GCM algorithm constraints	175
8.4.2.3	Receive processing rules	176
8.6	Security sublayer 2—Security mechanisms for the cognitive functions	176
8.6.2	CBP Authentication mechanisms.....	176
8.6.2.4	ECQV implicit certificate generation, processing, and validation requirements	177
8.6.2.4.1	ECQV certificate generation requirements	177
8.6.2.5	Signature generation, processing, and validation requirements	177

8.6.2.5.1	Signature generation requirements	177
8.6.2.6	BS Implicit Certificate Exchange	178
9.	PHY Operation Mode 1 (PHY-OM1)	178
9.2	Data rates	179
9.4	Superframe and frame structure.....	192
9.4.1	Preamble.....	192
9.4.1.5	Local frame preamble	192
9.4.1.6	Local CBP preamble.....	193
9.7	Channel coding.....	194
9.7.2	Forward Error Correction (FEC).....	194
9.7.2.1	Binary Convolutional code (BCC) mode (mandatory).....	194
9.7.2.1.2	Puncturing	194
9.7.2.1.3	OFDM slot concatenation	195
9.7.2.5	Multidimensional trellis coded modulation (MD-TCM) mode (optional)	196
9.7.2.5.1	Overview of multidimensional trellis coded modulation (MD-TCM)	196
9.7.2.5.2	Coset selection	197
9.7.2.5.3	Region pair selection	198
9.7.2.5.4	Symbol selection	200
9.8	Constellation mapping and modulation.....	200
9.8.1	Data modulation.....	200
9.9	Control mechanisms	203
9.9.4	Power control	203
9.9.4.2	Transmit Power Control mechanism	203
9.14	Receiver requirements	205
9.14.1	Receiver minimum sensitivity	205
9.15	Multiple-input, multiple-output (MIMO).....	205
9.15.1	Overview.....	205
9.15.2	MIMO pilot allocation	205
9.15.2.1	Overview.....	205
9.15.2.2	Pilot allocation for two antennas	205
9.15.2.3	Pilot allocation for four antennas.....	206
9.15.3	Space time coding (STC).....	207
9.15.3.1	Overview.....	207
9.15.3.2	Transmit diversity using two antennas (Alamouti O-STBC)	208
9.15.3.3	Transmit diversity with array-interference gain	208
9.15.3.3.1	Overview	208
9.15.3.3.2	Transmit diversity with array-interference gain for two antennas	209
9.15.3.3.3	Transmit diversity with array-interference gain for four antennas	210
9.15.4	Spatial multiplexing.....	212
9.15.4.1	Overview.....	212
9.15.4.2	Spatial multiplexing using two antennas	212
9.15.4.3	Spatial multiplexing using four antennas.....	213
9a.	PHY Operation Mode 2 (PHY-OM2)	213
9a.1	Symbol description	214
9a.1.1	OFDM symbol mathematical representation	214
9a.1.1.1	Time domain description	215
9a.1.1.2	Frequency domain description.....	215
9a.1.2	Symbol parameters.....	215
9a.1.2.1	Subcarrier spacing.....	215
9a.1.2.2	Symbol duration for different cyclic prefix modes.....	216
9a.1.2.3	Transmission parameters	216
9a.1.3	OFDMA basic terms definition.....	217

9a.1.3.1	Tile, slot, and data region.....	217
9a.1.3.2	Data mapping.....	219
9a.2	Data rates.....	221
9a.3	Functional block diagram applicable to the PHY.....	233
9a.4	Frame structure.....	234
9a.4.1	Preamble.....	235
9a.4.1.1	Frame preamble and local frame preamble.....	235
9a.4.1.2	CBP preamble.....	237
9a.4.2	Control header and MAP definitions.....	237
9a.4.2.1	Frame control header (FCH).....	237
9a.4.2.2	DS-MAP, US-MAP, DCD, and UCD.....	238
9a.5	CBP packet format.....	238
9a.6	OFDM subcarrier allocation.....	238
9a.6.1	Pilot pattern.....	238
9a.6.1.1	Downstream (DS).....	238
9a.6.1.2	Upstream (US).....	239
9a.6.2	DS subcarrier allocation.....	239
9a.6.2.1	Symbol structure for subchannel in the DS.....	239
9a.6.2.2	Subcarrier allocation and data mapping onto subcarriers.....	240
9a.6.3	Upstream subcarrier allocation.....	242
9a.6.3.1	Symbol structure for subchannel in the upstream.....	242
9a.6.3.2	Subcarrier allocation and data mapping onto subcarriers.....	243
9a.6.3.3	Data subchannel rotation scheme.....	245
9a.6.4	Bit interleaving.....	246
9a.7	Channel coding.....	246
9a.7.1	Data scrambling.....	246
9a.7.2	Forward error correction (FEC).....	246
9a.7.2.1	BCC mode (mandatory).....	247
9a.7.2.1.1	Binary convolutional coding.....	247
9a.7.2.1.2	Puncturing.....	247
9a.7.2.1.3	OFDM slot concatenation.....	247
9a.7.2.2	Multidimensional trellis coded modulation (MD-TCM) mode (optional).....	249
9a.8	Constellation mapping and modulation.....	249
9a.8.1	Data modulation.....	249
9a.8.2	Pilot modulation.....	250
9a.9	Control mechanisms.....	250
9a.9.1	DS synchronization.....	250
9a.9.2	US synchronization.....	250
9a.9.3	Opportunistic US bursts.....	250
9a.9.3.1	CDMA bursts.....	250
9a.9.3.1.1	CDMA codes.....	251
9a.9.3.1.2	Initial-ranging transmission.....	251
9a.9.3.1.3	CDMA periodic-ranging, BW-request, and UCS notification transmission.....	252
9a.9.3.1.4	Ranging, BW request, and UCS notification opportunity windows.....	253
9a.9.4	Power control.....	254
9a.9.4.1	Transmit power control boundaries and EIRP limits.....	254
9a.9.4.2	Transmit power control mechanism.....	254
9a.10	Network synchronization.....	255
9a.11	Frequency control requirements.....	255
9a.12	Antenna.....	255
9a.13	RF mask.....	255
9a.14	Receiver requirements.....	255
9a.15	MIMO pilot allocation.....	256
9a.15.1	Overview.....	256

9a.15.2 Pilot allocation for two antennas.....	256
9a.15.3 Pilot allocation for four antennas.....	257
9a.15.4 Space time coding (STC).....	257
10. Cognitive radio capability	257
10.1 General.....	257
12. Parameters and connection management	258
12.1 Parameters, timers, message IEs.....	258
12.1.1 MAC (dynamic service flow, multicast, ARQ, capability, and bandwidth management).....	258
12.1.1.1 MAC (Relay, Multi-channel).....	258
12.1.2 PHY (initialization, operation, and DS/US synchronization).....	258
14. Management plane interfaces and procedures	263
14.2 Primitive definitions	263
14.2.1 Management SAP (M-SAP).....	263
14.2.1.4 BS configuration and monitoring primitives	263
14.2.1.4.1 M-AVAIL-TV-CH-REPORT REQUEST	263
14.2.1.4.2 M-AVAIL-TV-CH-REPORT-INDICATION	264
14.2.1.4.5 M-OPERATING-TV-CHS-CONFIRMATION	264
14.2.1.5 CPE reports the resulting available WRAN services list.....	266
14.2.1.5.4 M-WRAN-SERVICES-INDICATION	266
Annex G (informative) Bibliography	268
Annex H (informative) Multiple-input, multiple-output (MIMO)—Receiver side implementation	269

**IEEE Standard for Information Technology—
Telecommunications and information exchange
between systems
Wireless Regional Area Networks (WRAN)—
Specific requirements**

**Part 22: Cognitive Wireless RAN
Medium Access Control (MAC) and
Physical Layer (PHY) Specifications:
Policies and Procedures for
Operation in the TV Bands**

**Amendment 2: Enhancement for Broadband
Services and Monitoring Applications**

IMPORTANT NOTICE: IEEE Standards documents are not intended to ensure safety, security, health, or environmental protection, or ensure against interference with or from other devices or networks. Implementers of IEEE Standards documents are responsible for determining and complying with all appropriate safety, security, environmental, health, and interference protection practices and all applicable laws and regulations.

This IEEE document is made available for use subject to important notices and legal disclaimers. These notices and disclaimers appear in all publications containing this document and may be found under the heading “Important Notice” or “Important Notices and Disclaimers Concerning IEEE Documents.” They can also be obtained on request from IEEE or viewed at <http://standards.ieee.org/IPR/disclaimers.html>.

(This amendment is based on IEEE 802.22™-2011 as amended by IEEE Std 802.22a™-2014.)

NOTE—The editing instructions contained in this amendment define how to merge the material contained therein into the existing base standard and its amendments to form the comprehensive standard. The editing instructions are shown in **bold italic**. Four editing instructions are used: change, delete, insert, and replace. **Change** is used to make corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed by using ~~strike through~~ (to remove old material) and underscore (to add new material). **Delete** removes existing material. **Insert** adds new material without disturbing the existing material. Insertions may require renumbering. If so, renumbering instructions are given in the editing instruction. **Replace** is used to make changes in figures or equations by removing the existing figure or equation and replacing it with a new one. Editing instructions, change markings, and this NOTE will not be carried over into future editions because the changes will be incorporated into the base standard.¹

¹Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.