
**Information technology —
Telecommunications and information
exchange between systems — Local and
metropolitan area networks — Specific
requirements —**

**Part 11:
Wireless LAN medium access control
(MAC) and physical layer (PHY)
specifications**

AMENDMENT 4

*Technologies de l'information — Télécommunications et échange
d'information entre systèmes — Réseaux locaux et métropolitains —
Exigences spécifiques —*

*Partie 11: Spécifications du contrôle d'accès du milieu sans fil (MAC) et
de la couche physique (PHY)*

AMENDEMENT 4

© IEEE 2013

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from ISO, IEC or IEEE at the respective address below.

ISO copyright office
Case postale 56
CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland
E-mail inmail@iec.ch
Web www.iec.ch

Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York
NY 10016-5997, USA
E-mail stds.ipr@ieee.org
Web www.ieee.org

Published in Switzerland

Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

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

The main task of ISO/IEC JTC 1 is to prepare International Standards. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

Attention is called to the possibility that implementation of this standard may require the use of subject matter covered by patent rights. By publication of this standard, no position is taken with respect to the existence or validity of any patent rights in connection therewith. ISO/IEEE is not responsible for identifying essential patents or patent claims for which a license may be required, for conducting inquiries into the legal validity or scope of patents or patent claims or determining whether any licensing terms or conditions provided in connection with submission of a Letter of Assurance or a Patent Statement and Licensing Declaration Form, 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 ISO or the IEEE Standards Association.

Amendment 4 to ISO/IEC/IEEE 8802-11 was prepared by the LAN/MAN of the IEEE Computer Society (as IEEE 802.11-2013). It was adopted by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 6, *Telecommunications and information exchange between systems*, in parallel with its approval by the ISO/IEC national bodies, under the “fast-track procedure” defined in the Partner Standards Development Organization cooperation agreement between ISO and IEEE. IEEE is responsible for the maintenance of this document with participation and input from ISO/IEC national bodies.

(blank page)

IEEE Standard for Information technology—
Telecommunications and information exchange between systems
Local and metropolitan area networks—
Specific requirements

Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications

Amendment 4: Enhancements for Very High Throughput for Operation in Bands below 6 GHz

IEEE Computer Society

Sponsored by the
LAN/MAN Standards Committee

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

IEEE Std 802.11ac™-2013
(Amendment to
IEEE Std 802.11™-2012,
as amended by IEEE Std 802.11ae™-2012,
IEEE Std 802.11aa™-2012,
and IEEE Std 802.11ad™-2012)

IEEE Std 802.11ac™-2013

(Amendment to
IEEE Std 802.11™-2012,
as amended by IEEE Std 802.11ae™-2012,
IEEE Std 802.11aa™-2012,
and IEEE Std 802.11ad™-2012)

**IEEE Standard for Information technology—
Telecommunications and information exchange between systems
Local and metropolitan area networks—
Specific requirements**

**Part 11: Wireless LAN Medium Access Control
(MAC) and Physical Layer (PHY) Specifications**

**Amendment 4: Enhancements for Very High
Throughput for Operation in Bands below 6 GHz**

Sponsor

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

Approved 11 December 2013

IEEE-SA Standards Board

Abstract: The purpose of this amendment is to improve the IEEE 802.11™ wireless local area network (WLAN) user experience by providing significantly higher basic service set (BSS) throughput for existing WLAN application areas and to enable new market segments for operation below 6 GHz including distribution of multiple multimedia/data streams.

Keywords: 256-QAM, beamforming, IEEE 802.11ac™, multi-user MIMO, noncontiguous frequency segments, very high throughput, wider bandwidth

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

Copyright © 2013 by The Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 18 December 2013. Printed in the United States of America.

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

PDF: ISBN 978-0-7381-8860-7 STD98502
Print: ISBN 978-0-7381-8861-4 STDPD98502

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 upon 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

At the time this standard was completed, the IEEE 802.11 Working Group had the following membership:

Bruce P. Kraemer, *Chair*
Jon W. Rosdahl and Adrian P. Stephens, *Vice-chairs*
Stephen McCann, *Secretary*

The following were officers of Task Group ac:

Osama S. Aboul-Magd, *Chair*
Joonsuk Kim and Menzo M. Wentink, *Vice-chairs*
Robert Stacey, *Technical Editor*
David Xun Yang, *Secretary*

Santosh P. Abraham
 Roberto Aiello
 Carlos H. Aldana
 Thomas Alexander
 Peiman Amini
 Sirikiat Lek Ariyavisitakul
 Lee R. Armstrong
 Yusuke Asai
 Alex Ashley
 Torrey Atcitty
 Kwok Shum Au
 Vijay Auluck
 Stefan Aust
 Geert A. Awater
 David Bagby
 Michael Bahr
 Gabor Bajko
 Raja Banerjea
 Phillip Barber
 John R. Barr
 Tuncer Baykas
 Alan Berkema
 Anirudh Bhatt
 Bijoy Bhukania
 Ted Booth
 Philippe Boucachard
 Andre Bourdoux
 George Bumiller
 George Calcev
 Chris Calvert
 Daniel Camps Mur
 Laurent Cariou
 William Carney
 Philippe Chambelin
 Kim Chang
 Clint F. Chaplin
 Bin Chen
 Minh Cheong
 Inhwan Choi
 In-Kyeong Choi
 Jee-Yon Choi
 Liwen Chu
 John Coffey
 Kenneth Coop
 Carlos Cordeiro

Subir Das
 Rolf J. de Vegt
 Hossein Dehghan
 Yohannes Demessie
 Theodorus Denteneer
 Klaus Doppler
 Offie Drennan
 Roger P. Durand
 Peter Ecclesine
 Richard Edgar
 Marc Emmelmann
 Leonid Epstein
 Vinko Erceg
 Ping Fang
 Fei Qin
 Stanislav Filin
 Matthew J. Fischer
 George Flammer
 Noriyasu Fukatsu
 Patrick Fung
 Chittabrata Ghosh
 James P. K. Gilb
 Reinhard Gloger
 Daning Gong
 Michelle Gong
 David Goodall
 Elad Gottlib
 Sudheer A. Grandhi
 Michael Grigat
 David Halasz
 Mark Hamilton
 Christopher J. Hansen
 Hiroshi Harada
 Dan N. Harkins
 Brian D. Hart
 Ahmadrza Hedayat
 Robert F. Heile
 Guido R. Hiertz
 Garth D. Hillman
 Ken Hiraga
 David Howard
 Jing-Rong Hsieh
 Ju-Lan Hsu
 David Hunter
 Sung Hyun Hwang

Yasuhiko Inoue
 Akio Iso
 Mitsuru Iwaoka
 ByungJang Jang Jeong
 Jorjeta G. Jetcheva
 ZhongYi Jin
 Vince Jones
 Avinash Joshi
 Padam Kaffle
 Carl W. Kain
 Naveen K. Kakani
 Byeongwoo Kang
 Hyunduk Kang
 Assaf Y. Kasher
 Shuzo Kato
 Richard H. Kennedy
 John Kenney
 Stuart J. Kerry
 Prithpal Khakuria
 Thet Khine
 Bonghoe Kim
 Byoung-Hoon Kim
 Eun Sun Kim
 Jinkyong Kim
 Suhwook Kim
 Youhan Kim
 Youngsoo Kim
 Yunjoo Kim
 Shoichi Kitazawa
 Tero Kivinen
 Jarkko Knecht
 Gwangzeen Ko
 Mark M. Kobayashi
 Fumihide Kojima
 Tom Kolze
 Timo Koskela
 Thomas M. Kurihara
 Joseph Kwak
 Paul Lambert
 Zhou Lan
 Leonardo Lanante
 James Lansford
 Daewon Lee
 Donghun Lee
 Jae Seung Seung Lee

Jihyun Lee	James E. Petranovich	James D. Tomcik
Yuro Lee	Albert Petrick	Ichihiko Toyoda
Zhongding Lei	John Petro	Solomon B. Trainin
Wai Kong Kong Leung	Krishna Madhavan Pillai	Ha Nguyen Tran
Honggang Li	Riku Pirhonen	Masahiro Umehira
Huan-Bang Li	Juho Pirskanen	Richard D. J. Van Nee
Lingjie Li	Vishakan Ponnampalam	Allert Van Zelst
Yunzhou Li	Ron Porat	Prabodh Varshney
Erik Lindskog	Henry S. Ptasinski	Ganesh Venkatesan
Jeremy Link	Satish Putta	Sameer Vermani
Lu Liru	Chang-Woo Chang Pyo	Dalton T. Victor
Jianhan Liu	Emily H. Qi	Gabriel Villardi
Siyang Liu	Huyu Qu	Bhupender Virk
Yong Liu	Jim E. Raab	George A. Vlantis
Peter Loc	Harish Ramamurthy	Sanjay Wadhwa
Yi Luo	Jayaram Ramasastry	Chao Chun Wang
Zhendong Luo	Ivan Reede	Haiguang Wang
Kaiying Lv	Edward Reuss	James June Wang
Bradley Lynch	Maximilian Riegel	Junyi Wang
Michael Lynch	Mark Rison	Lei Wang
Jouni K. Malinen	Dongwook Roh	Qi Wang
Hiroshi Mano	Alexander Safonov	Lisa Ward
Avi Masour	Kazuyuki Sakoda	Fujio Watanabe
Simone Merlin	Ruben Salazar Cardozo	Lei Wen
Murat Mese	Hemanth Sampath	Nicholas West
James Miller	Sigurd Schelstraete	Ian Wong
Fanny Mlinarsky	Timothy Schmidl	James Worsham
Apurva Mody	Cristina Seibert	Harry R. Worstell
Emmanuel Monnerie	Yongho Seok	Tianyu Wu
Michael Montemurro	Kunal Shah	Zhanji Wu
Rajendra T. Moorti	Huairong Shao	Akira Yamada
Hitoshi Morioka	Nir Shapira	Huanchun Ye
Andrew Myles	Steve Shearer	James Yee
Yukimasa Nagai	Stephen J. Shellhammer	Jung Yee
Hiroki Nakano	Ian Sherlock	Peter Yee
Sai Shankar Nandagopalan	Wei Shi	Su Khiong Yong
Pradeep Nemavat	Nobuhiko Shibagaki	Christopher Young
Chiu Ngo	Shusaku Shimada	Heejung Yu
Paul Nikolich	Thomas M. Siep	Artur Zaks
Knut Odman	Michael Sim	Dezhi Zhang
Hiroyo Ogawa	Dwight Smith	Hongyuan Zhang
Jong-Ee Oh	Graham Kenneth Smith	Junjian Zhang
Minseok Oh	Ill Soo Sohn	Ning Zhang
David Olson	Chunyi Song	Mu Zhao
Satoshi Oyama	Dorothy Stanley	Qiang Zhao
Santosh G. Pandey	Chin-Sean Sum	Jun Zheng
Anna Pantelidou	Bo Sun	Chunhui Zhu
Thomas Pare	Chen Sun	Lawrence Zuckerman
Jaewoo Park	Mohammad Hossein Taghavi	
Jonghyun Park	Kazuaki Takahashi	
Minyoung Park	Mineo Takai	
Seung-Hoon Park	Joseph Teo	
Sandhya Patil	Jerry Thrasher	
Eldad Perahia	Jens Tingleff	

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

Osama S. Aboul-Magd	Yasuhiko Inoue	Paul Nikolich
Tomoko Adachi	Sergiu Iordanescu	Satoshi Obara
Thomas Alexander	Akio Iso	Robert O'Hara
Nobumitsu Amachi	Atsushi Ito	Satoshi Oyama
Arthur Astrin	Mitsuru Iwaoka	Stephen Palm
Kwok Shum Au	Raj Jain	Sandhya Patil
Phillip Barber	Junghoon Jee	Eldad Perahia
Tuncer Baykas	Vincent Jones	James Petranovich
Mathild Benveniste	Bobby Jose	Brian Phelps
Nancy Bravin	Joe Natharoj Juisai	Juho Pirskanen
William Byrd	Shinkyō Kaku	Clinton Powell
George Calcev	Hyunduk Kang	Venkatesha Prasad
William Carney	Hyunjeong Kang	Michael Probasco
Juan Carreon	Piotr Karocki	Ivan Reede
Douglas Chan	Assaf Kasher	Maximilian Riegel
Xin Chang	Ruediger Kays	Robert Robinson
Hong Cheng	John Kenney	Jon W. Rosdahl
Minho Cheong	Stuart Kerry	Naotaka Sato
Paul Chiuchiolo	Yongbum Kim	Peter Saunderson
Hangyu Cho	Youhan Kim	Bartien Sayogo
Keith Chow	Gwangzeen Ko	Sigurd Schelstraete
Charles Cook	Bruce P. Kraemer	Yongho Seok
Carlos Cordeiro	Thomas Kurihara	Ian Sherlock
Neiyer Correal	Joseph Kwak	Shusaku Shimada
Alessandro De Filippo	Geoff Ladwig	Ju-Hyung Son
Michael de la Garrigue	Jeremy Landt	Myung Sun Song
Michael Denson	Nils Langhammer	Kapil Sood
Hendricus De Ruijter	James Lansford	Manikantan Srinivasan
Wael Diab	Jae Seung Lee	Robert Stacey
Patrick Diamond	Wookbong Lee	Dorothy Stanley
Roger Durand	Hyeong Ho Lee	Thomas Starai
Sourav Dutta	John Lemon	Adrian P. Stephens
Peter Ecclesine	James Lepp	Rene Struik
Richard Edgar	Joseph Levy	Walter Struppler
Marc Emmelmann	Yunbo Li	Chin-Sean Sum
David Evans	Arthur H. Light	Bo Sun
Matthew Fischer	Lu Liru	Mohammad Taghavi
George Flammer	Yi Luo	Rakesh Taori
P. Flynn	Chris Lyttle	Thomas Tetzlaff
Avraham Freedman	Elvis Maculuba	Jens Tingleff
Devon Gayle	Jouni Malinen	Keat Beng Toh
Monisha Ghosh	James Marin	Fei Tong
David Goodall	Roger Marks	Solomon Trainin
Sudheer Grandhi	Jeffery Masters	Ha Nguyen Tran
Randall Groves	W. Kyle Maus	Kazuyoshi Tsukada
Michael Gundlach	Stephen McCann	Mark-Rene Uchida
Chris Guy	Steven Methley	Richard Van Nee
Gloria Gwynne	David Mitton	Allert Van Zelst
Rainer Hach	Michael Montemurro	Dmitri Varsanofiev
David Halasz	Jose Morales	Prabodh Varshney
Hiroshi Hamano	Joseph Moran	John Vergis
Mark Hamilton	Kenichi Mori	George Vlantis
Christopher Hansen	Ronald Murias	Haiming Wang
Jerome Henry	Rick Murphy	James June Wang
Marco Hernandez	Peter Murray	Lei Wang
Dien Hoang	Andrew Myles	Xiang Wang
Werner Hoelzl	Juichi Nakada	Stephen Webb
David Howard	Michael Newman	Hung-Yu Wei
David Hunter	Charles Ngethe	Menzo M. Wentink
Noriyuki Ikeuchi	Nick S.A. Nikjoo	Tianyu Wu
		David Xun Yang

James Yee
Oren Yuen

Hongyuan Zhang
Jiayin Zhang
Daidi Zhong

Mingtuo Zhou
Chunhui Zhu

When the IEEE-SA Standards Board approved this standard on 11 December 2013, it had the following membership:

John Kulick, Chair
David J. Law, Vice Chair
Richard H. Hulett, Past Chair
Konstantinos Karachalios, Secretary

Masayuki Ariyoshi
Peter Balma
Farooq Bari
Ted Burse
Wael William Diab
Stephen Dukes
Jean-Philippe Faure
Alexander Gelman

Mark Halpin
Gary Hoffman
Paul Houzé
Jim Hughes
Michael Janezic
Joseph L. Koepfinger*
Oleg Logvinov

Ron Petersen
Gary Robinson
Jon Walter Rosdahl
Adrian Stephens
Peter Sutherland
Yatin Trivedi
Phil Winston
Yu Yuan

*Member Emeritus

Also included are the following nonvoting IEEE-SA Standards Board liaisons:

Richard DeBlasio, *DOE Representative*
Michael Janezic, *NIST Representative*

Michelle Turner
IEEE Standards Program Manager, Document Development

Kathryn Bennett
IEEE Standards Program Manager, Technical Program Development

Introduction

This introduction is not part of IEEE Std 802.11ac™-2013, IEEE Standard for Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific requirements—Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications—Amendment 4: Enhancements for Very High Throughput for Operation in Bands below 6 GHz.

The purpose of this amendment is to improve the IEEE 802.11 wireless local area network (WLAN) user experience by providing significantly higher basic service set (BSS) throughput for existing WLAN application areas and to enable new market segments for operation below 6 GHz including distribution of multiple multimedia/data streams.

Contents

3.	Definitions, acronyms and abbreviations	2
3.1	Definitions	2
3.2	Definitions specific to IEEE 802.11	2
3.3	Abbreviations and acronyms	8
4.	General description.....	10
4.3	Components of the IEEE 802.11 architecture	10
4.3.4	Distribution system (DS) concepts.....	10
4.3.4.3	Robust security network association (RSNA).....	10
4.3.10a	Very high throughput (VHT) STA	10
4.5	Overview of the services.....	11
4.5.4	Access control and data confidentiality services.....	11
4.5.4.1	General.....	11
4.5.4.7	Replay detection	11
4.5.4.9	Robust management frame protection	11
4.9	Reference model	12
4.9.1	General.....	12
5.	MAC service definition	13
5.1	Overview of MAC services	13
5.1.2	Security services	13
5.2	MAC data service specification.....	13
5.2.2	MA-UNITDATA.request	13
5.2.2.2	Semantics of the service primitive.....	13
6.	Layer management	14
6.1	Overview of management model.....	14
6.3	MLME SAP interface	14
6.3.3	Scan	14
6.3.3.3	MLME-SCAN.confirm.....	14
6.3.4	Synchronize	14
6.3.4.2	MLME-JOIN.request.....	14
6.3.7	Associate.....	15
6.3.7.2	MLME-ASSOCIATE.request	15
6.3.7.3	MLME-ASSOCIATE.confirm	16
6.3.7.4	MLME-ASSOCIATE.indication	17
6.3.7.5	MLME-ASSOCIATE.response	18
6.3.8	Reassociate	19
6.3.8.2	MLME-REASSOCIATE.request	19
6.3.8.3	MLME-REASSOCIATE.confirm	19
6.3.8.4	MLME-REASSOCIATE.indication	20
6.3.8.5	MLME-REASSOCIATE.response	21
6.3.11	Start.....	22
6.3.11.2	MLME-START.request.....	22
6.3.19	SetKeys.....	24
6.3.19.1	MLME-SETKEYS.request.....	24
6.5	PLME SAP interface	24
6.5.4	PLME-CHARACTERISTICS.confirm	24

6.5.4.2	Semantics of the service primitive.....	24
6.5.8	PLME-TXTIME.confirm	26
6.5.8.1	Function	26
6.5.8.2	Semantics of the service primitive.....	27
7.	PHY service specification	28
7.1	Scope.....	28
7.2	PHY functions.....	28
7.3	Detailed PHY service specifications.....	28
7.3.2	Overview of the service.....	28
7.3.4	Basic service and options	28
7.3.4.5	Vector descriptions	28
7.3.5	PHY-SAP detailed service specification	29
7.3.5.2	PHY-DATA.request	29
7.3.5.3	PHY-DATA.indication.....	29
7.3.5.6	PHY-TXSTART.confirm	29
7.3.5.11	PHY-CCA.indication.....	30
7.3.5.13	PHY-RXEND.indication	32
8.	Frame formats.....	33
8.2	MAC frame formats.....	33
8.2.3	General frame format.....	33
8.2.4	Frame fields	33
8.2.4.1	Frame Control field	33
8.2.4.2	Duration/ID field	34
8.2.4.3	Address fields	34
8.2.4.5	QoS Control field.....	34
8.2.4.6	HT Control field	35
8.2.4.7	Frame Body field	40
8.2.5	Duration/ID field (QoS STA)	41
8.2.5.1	General.....	41
8.2.5.2	Setting for single and multiple protection under enhanced distributed channel access (EDCA)	41
8.3	Format of individual frame types.....	42
8.3.1	Control frames	42
8.3.1.2	RTS frame format	42
8.3.1.3	CTS frame format	43
8.3.1.4	ACK frame format.....	43
8.3.1.5	PS-Poll frame format	43
8.3.1.6	CF-End frame format.....	43
8.3.1.8	BlockAckReq frame format.....	43
8.3.1.9	BlockAck frame format	44
8.3.1.20	VHT NDP Announcement frame format.....	44
8.3.1.21	Beamforming Report Poll frame format.....	45
8.3.2	Data frames.....	46
8.3.2.1	Data frame format.....	46
8.3.2.2	Aggregate MSDU (A-MSDU) format	46
8.3.3	Management frames	46
8.3.3.1	Format of management frames	46
8.3.3.2	Beacon frame format	47
8.3.3.5	Association Request frame format	48
8.3.3.6	Association Response frame format	48

8.3.3.7	Reassociation Request frame format	49
8.3.3.8	Reassociation Response frame format.....	49
8.3.3.9	Probe Request frame format	49
8.3.3.10	Probe Response frame format.....	50
8.4	Management and Extension frames body components.....	51
8.4.1	Fields that are not information elements	51
8.4.1.9	Status Code field.....	51
8.4.1.11	Action field	51
8.4.1.27	CSI Report field.....	51
8.4.1.28	Noncompressed Beamforming Report field	51
8.4.1.29	Compressed Beamforming Report field	52
8.4.1.32	Rate Identification field	52
8.4.1.47	VHT MIMO Control field	53
8.4.1.48	VHT Compressed Beamforming Report field.....	55
8.4.1.49	MU Exclusive Beamforming Report field.....	64
8.4.1.50	Operating Mode field.....	68
8.4.1.51	Membership Status Array field.....	69
8.4.1.52	User Position Array field	70
8.4.2	Information elements	71
8.4.2.1	General.....	71
8.4.2.3	Supported Rates element	71
8.4.2.10	Country element	71
8.4.2.17	Power Capability element.....	74
8.4.2.22	Secondary Channel Offset element	75
8.4.2.23	Measurement Request element.....	75
8.4.2.24	Measurement Report element	79
8.4.2.27	RSNE	82
8.4.2.29	Extended Capabilities element	84
8.4.2.31	EDCA Parameter Set element	85
8.4.2.38	AP Channel Report element	85
8.4.2.39	Neighbor Report element.....	86
8.4.2.40	RCPI element.....	87
8.4.2.48	Multiple BSSID element	87
8.4.2.56	Supported Operating Classes element	87
8.4.2.57	Management MIC element	88
8.4.2.58	HT Capabilities element	89
8.4.2.59	HT Operation element	91
8.4.2.69	Event Request element	91
8.4.2.70	Event Report element	91
8.4.2.71	Diagnostic Request element	92
8.4.2.73	Location Parameters element.....	92
8.4.2.88	Channel Usage element	93
8.4.2.160	VHT Capabilities element	93
8.4.2.161	VHT Operation element	98
8.4.2.162	Extended BSS Load element	99
8.4.2.163	Wide Bandwidth Channel Switch element	100
8.4.2.164	VHT Transmit Power Envelope element.....	101
8.4.2.165	Channel Switch Wrapper element	102
8.4.2.166	AID element	103
8.4.2.167	Quiet Channel element	104
8.4.2.168	Operating Mode Notification element.....	104
8.5	Action frame format details	105
8.5.2	Spectrum management Action frames.....	105
8.5.2.6	Channel Switch Announcement frame format	105

8.5.4	DLS Action frame details.....	106
8.5.4.2	DLS Request frame format.....	106
8.5.4.3	DLS Response frame format	106
8.5.8	Public Action details.....	106
8.5.8.3	Measurement Pilot frame format.....	106
8.5.8.7	Extended Channel Switch Announcement frame format	107
8.5.8.16	TDLS Discovery Response frame format	107
8.5.13	TDLS Action frame details.....	108
8.5.13.2	TDLS Setup Request Action field format	108
8.5.13.3	TDLS Setup Response Action field format.....	108
8.5.13.4	TDLS Setup Confirm Action field format.....	109
8.5.13.7	TDLS Channel Switch Request Action field format	109
8.5.14	WNM Action fields	110
8.5.14.24	Channel Usage Response frame format.....	110
8.5.16	Self-protected Action frame details.....	110
8.5.16.2	Mesh Peering Open frame format	110
8.5.16.3	Mesh Peering Confirm frame format.....	111
8.5.23	VHT Action frame details	111
8.5.23.1	VHT Action field.....	111
8.5.23.2	VHT Compressed Beamforming frame format	112
8.5.23.3	Group ID Management frame format.....	112
8.5.23.4	Operating Mode Notification frame format.....	113
8.6	Aggregate MPDU (A-MPDU).....	113
8.6.1	A-MPDU format.....	113
8.6.3	A-MPDU contents	116
9.	MAC sublayer functional description.....	118
9.2	MAC architecture	118
9.2.1	General.....	118
9.2.4	Hybrid coordination function (HCF).....	118
9.2.4.1	General.....	118
9.2.4.2	HCF contention-based channel access (EDCA).....	119
9.2.7	Fragmentation/defragmentation overview.....	119
9.3	DCF.....	120
9.3.1	General.....	120
9.3.2	Procedures common to both DCF and EDCAF.....	120
9.3.2.3	IFS	120
9.3.2.5a	VHT RTS procedure.....	121
9.3.2.6	CTS and DMG CTS procedure	121
9.3.2.7	Dual CTS protection	122
9.3.2.9a	MU acknowledgment procedure	122
9.3.4	DCF access procedure	124
9.3.4.4	Recovery procedures and retransmit limits	124
9.3.7	DCF timing relations	124
9.5	Fragmentation	124
9.7	Multirate support.....	125
9.7.1	Overview	125
9.7.4	Basic Rate Set and Basic MCS Set for mesh STA.....	125
9.7.5	Rate selection for data and management frames	125
9.7.5.3	Rate selection for other group addressed data and management frames ...	125
9.7.5.5a	Rate selection for data frames sent within an FMS stream	125
9.7.5.6	Rate selection for other <u>individually addressed</u> data and management frames	126

9.7.6	Rate selection for control frames.....	127
9.7.6.1	General rules for rate selection for control frames	127
9.7.6.2	Rate selection for control frames that initiate a TXOP	128
9.7.6.4	Rate selection for control frames that are not control response frames.....	128
9.7.6.5	Rate selection for control response frames.....	129
9.7.6.6	Channel Width selection for control frames.....	132
9.7.8	Modulation classes	134
9.7.9	Non-HT basic rate calculation.....	135
9.7.10	Channel Width in non-HT and non-HT duplicate PPDU.....	135
9.7.11	Rate selection constraints for VHT STAs	136
9.7.11.1	Rx Supported VHT-MCS and NSS Set.....	136
9.7.11.2	Tx Supported VHT-MCS and NSS Set	136
9.7.11.3	Additional rate selection constraints for VHT PPDU.....	137
9.9	HT Control field operation	138
9.11	A-MSDU operation.....	138
9.12	A-MPDU operation.....	139
9.12.2	A-MPDU length limit rules	139
9.12.3	Minimum MPDU Start Spacing field.....	140
9.12.4	A-MPDU aggregation of group addressed data frames.....	140
9.12.5	Transport of A-MPDU by the PHY data service.....	141
9.12.6	A-MPDU padding for VHT PPDU	141
9.12.7	Setting the EOF field of the MPDU delimiter.....	142
9.12.8	Transport of VHT single MPDUs	143
9.15	STBC operation	143
9.16	Short GI operation	143
9.17a	Group ID and partial AID in VHT PPDU.....	145
9.18	Operation across regulatory domains	146
9.18.5	Operation with operating classes <u>and the VHT Transmit Power Envelope element</u> ...	146
9.19	HCF.....	147
9.19.2	HCF contention-based channel access (EDCA).....	147
9.19.2.2	EDCA TXOPs	147
9.19.2.3	Obtaining an EDCA TXOP	148
9.19.2.3a	Sharing an EDCA TXOP.....	149
9.19.2.4	Multiple frame transmission in an EDCA TXOP.....	149
9.19.2.5	EDCA backoff procedure	151
9.19.2.6	Retransmit procedures	153
9.19.2.7	Truncation of a TXOP	154
9.19.2.8	EDCA channel access in a VHT BSS	154
9.19.3	HCCA	155
9.19.3.2	HCCA procedure	155
9.19.3.5	HCCA transfer rules	155
9.21	Block Acknowledgment (Block Ack).....	156
9.21.10	GCR Block Ack.....	156
9.21.10.3	GCR Block Ack BlockAckReq and BlockAck frame exchanges	156
9.23	Protection mechanisms	156
9.23.5	L-SIG TXOP protection	156
9.23.5.3	L-SIG TXOP protection rules at the TXOP responder.....	156
9.23.6	Protection Rules for VHT STAs.....	156
9.25	Reverse Direction Protocol.....	156
9.25.1	Reverse direction (RD) exchange sequence	156
9.25.3	Rules for RD initiator	157
9.25.4	Rules for responder.....	157
9.26	PSMP operation.....	157
9.26.1	Frame transmission mechanism during PSMP	157

9.26.1.2	PSMP downlink transmission (PSMP-DTT).....	157
9.27	Sounding PPDU.....	158
9.28	Link adaptation	158
9.28.2	Link adaptation using the <u>HT variant</u> HT Control field	158
9.28.3	Link adaptation using the VHT variant HT Control field	159
9.29	Transmit beamforming	162
9.29.1	General <u>HT steering matrix calculations</u>	162
9.29.2	<u>HT</u> Transmit beamforming with implicit feedback.....	162
9.29.2.1	General.....	162
9.29.2.3	Bidirectional implicit transmit beamforming	164
9.29.2.4	Calibration	164
9.29.3	Explicit feedback beamforming.....	164
9.29.4	VHT MU beamforming.....	165
9.30	Antenna selection (ASEL)	165
9.30.1	Introduction	165
9.31	Null data packet (NDP) sounding	165
9.31.1	NDP rules	165
9.31.2	Transmission of an <u>HT</u> NDP	167
9.31.3	Determination of <u>HT</u> NDP destination	167
9.31.4	Determination of <u>HT</u> NDP source	167
9.31.5	VHT sounding protocol.....	168
9.31.5.1	General.....	168
9.31.5.2	Rules for VHT sounding protocol sequences	168
9.31.5.3	Rules for fragmented feedback in VHT sounding protocol sequences	172
9.31.6	Transmission of a VHT NDP	173
10.	MLME	174
10.1	Synchronization	174
10.1.3	Maintaining synchronization	174
10.1.3.2	Beacon generation in non-DMG infrastructure networks	174
10.2	Power management.....	174
10.2.1	Power management in a non-DMG infrastructure network	174
10.2.1.17	TIM broadcast.....	174
10.2.1.19	VHT TXOP power save	175
10.3	STA authentication and association.....	176
10.3.5	Association, reassociation, and disassociation	176
10.3.5.3	PCP/AP association receipt procedures.....	176
10.3.5.5	PCP/AP reassociation receipt procedures.....	176
10.8	TPC procedures.....	176
10.8.2	Association based on transmit power capability	176
10.8.3a	Interpretation of transmit power capability	177
10.8.4	Specification of regulatory and local maximum transmit power levels	177
10.9	DFS procedures.....	178
10.9.3	Quieting channels for testing	178
10.11	Radio measurement procedures	179
10.11.9	Specific measurement usage.....	179
10.11.9.1	Beacon Report	179
10.11.9.3	Channel Load Report.....	180
10.11.9.4	Noise Histogram Report	181
10.11.18	AP Channel Report.....	181
10.15	20/40 MHz BSS operation.....	181
10.15.2	Basic 20/40 MHz BSS functionality	181
10.15.8	Support for DSSS/CCK in 40 MHz.....	182

10.15.9 STA CCA sensing in a 20/40 MHz BSS	182
10.15.12 Switching between 40 MHz and 20 MHz	182
10.16 Phased coexistence operation (PCO)	182
10.16.1 General description of PCO	182
10.17 20/40 BSS Coexistence Management frame usage	183
10.22 Tunneled direct link setup	183
10.22.1 General	183
10.22.6 TDLS channel switching	184
10.22.6.3 TDLS channel switching and power saving	184
10.22.6.4 Setting up a wide bandwidth off-channel direct link	184
10.25 Quality-of-Service management frame (QMF)	185
10.25.1 General	185
10.25.1.2 Default QMF policy	185
10.39 VHT BSS operation	186
10.39.1 Basic VHT BSS functionality	186
10.39.2 Channel selection methods for a VHT BSS	187
10.39.3 Scanning requirements for VHT STA	188
10.39.4 Channel switching methods for a VHT BSS	188
10.39.5 NAV assertion in a VHT BSS	191
10.39.6 VHT STA antenna indication	191
10.39.7 BSS basic VHT-MCS and NSS set operation	191
10.40 Group ID management operation	191
10.41 Notification of operating mode changes	192
11. Security	195
11.4 RSNA confidentiality and integrity protocols	195
11.4.3 CTR with CBC-MAC Protocol (CCMP)	195
11.4.3.1 General	195
11.4.3.2 CCMP MPDU format	195
11.4.3.3 CCMP cryptographic encapsulation	196
11.4.3.4 CCMP decapsulation	196
11.4.4 Broadcast/Multicast Integrity Protocol (BIP)	196
11.4.4.1 BIP overview	196
11.4.4.5 BIP transmission	197
11.4.4.6 BIP reception	197
11.4.5 GCM with Galois Message Authentication Code (GMAC) Protocol (GCMP)	198
11.4.5.1 GCMP overview	198
11.5 RSNA security association management	198
11.5.3 RSNA policy selection in an ESS	198
11.5.5 RSNA policy selection in an IBSS and for DLS	198
11.5.7 RSNA policy selection in an MBSS	199
11.6 Keys and key distribution	199
11.6.1 Key hierarchy	199
11.6.1.2 PRF	199
11.6.1.3 Pairwise key hierarchy	200
11.6.1.7 FT key hierarchy	202
11.6.2 EAPOL-Key frames	204
11.6.3 EAPOL-Key frame construction and processing	205
11.7 Mapping EAPOL keys to IEEE 802.11 keys	205
11.7.7 Mapping GTK to BIP keys	205
13. MLME mesh procedures	206

13.2	Mesh discovery	206
13.2.4	Mesh STA configuration	206
13.2.7	Candidate peer mesh STA	206
18.	Orthogonal frequency division multiplexing (OFDM) PHY specification	207
18.2	OFDM PHY specific service parameter list	207
18.2.2	TXVECTOR parameters	207
18.2.2.1	General.....	207
18.2.2.7	TXVECTOR CH_BANDWIDTH_IN_NON_HT	207
18.2.2.8	TXVECTOR DYN_BANDWIDTH_IN_NON_HT	207
18.2.3	RXVECTOR parameters	208
18.2.3.1	General.....	208
18.2.3.7	RXVECTOR CH_BANDWIDTH_IN_NON_HT	208
18.2.3.8	RXVECTOR DYN_BANDWIDTH_IN_NON_HT	208
18.3	OFDM PLCP sublayer.....	208
18.3.2	PLCP frame format.....	208
18.3.2.2	Overview of the PPDU encoding process	208
18.3.5	DATA field.....	209
18.3.5.5	PLCP DATA scrambler and descrambler	209
18.3.9	PMD transmit specifications	211
18.3.9.3	Transmit spectrum mask.....	211
18.3.9.7	Modulation accuracy	211
19.	Extended Rate PHY (ERP) specification	212
19.3	Extended Rate PLCP sublayer.....	212
19.3.3	PLCP data modulation and rate change.....	212
19.3.3.4	Long and short DSSS-OFDM PLCP format	212
20.	High Throughput (HT) PHY specification.....	213
20.1	Introduction.....	213
20.1.1	Introduction to the HT PHY	213
20.3	HT PLCP sublayer	213
20.3.10	Transmission of NON_HT format PPDU's with more than one antenna-transmit <u>chain</u>	213
20.3.11	Data field	213
20.3.11.3	Scrambler.....	213
20.3.20	PMD transmit specification	213
20.3.20.1	Transmit spectrum mask.....	213
20.3.20.7	Modulation accuracy	213
22.	Very High Throughput (VHT) PHY specification	214
22.1	Introduction.....	214
22.1.1	Introduction to the VHT PHY	214
22.1.2	Scope	215
22.1.3	VHT PHY functions	215
22.1.3.1	General.....	215
22.1.3.2	PHY management entity (PLME)	215
22.1.3.3	Service specification method.....	215
22.1.4	PPDU formats.....	215
22.2	VHT PHY service interface	216

22.2.1	Introduction	216
22.2.2	TXVECTOR and RXVECTOR parameters	216
22.2.3	Effects of CH_BANDWIDTH parameter on PPDU format	224
22.2.4	Support for NON_HT and HT formats.....	226
22.2.4.1	General.....	226
22.2.4.2	Support for NON_HT format when NON_HT_MODULATION is OFDM	228
22.2.4.3	Support for HT formats	229
22.3	VHT PHY layer	229
22.3.1	Introduction	229
22.3.2	VHT PPDU format	229
22.3.3	Transmitter block diagram.....	230
22.3.4	Overview of the PPDU encoding process	234
22.3.4.1	General.....	234
22.3.4.2	Construction of L-STF.....	234
22.3.4.3	Construction of the L-LTF	235
22.3.4.4	Construction of L-SIG	236
22.3.4.5	Construction of VHT-SIG-A	237
22.3.4.6	Construction of VHT-STF.....	238
22.3.4.7	Construction of VHT-LTF.....	239
22.3.4.8	Construction of VHT-SIG-B	241
22.3.4.9	Construction of the Data field in a VHT SU PPDU	241
22.3.4.10	Construction of the Data field in a VHT MU PPDU.....	243
22.3.5	VHT modulation and coding scheme (VHT-MCS)	243
22.3.6	Timing-related parameters.....	244
22.3.7	Mathematical description of signals	247
22.3.7.1	Notation	247
22.3.7.2	Subcarrier indices in use.....	247
22.3.7.3	Channel frequencies	248
22.3.7.4	Transmitted signal	249
22.3.7.5	Definition of tone rotation	253
22.3.8	VHT preamble	254
22.3.8.1	Introduction	254
22.3.8.2	Non-VHT portion of VHT format preamble	254
22.3.8.3	VHT portion of VHT format preamble	258
22.3.9	Transmission of NON_HT and HT PPDU with multiple transmit chains.....	272
22.3.9.1	Transmission of 20 MHz NON_HT PPDU with more than one transmit chain	272
22.3.9.2	Transmission of HT PPDU with more than four transmit chains	272
22.3.10	Data field	272
22.3.10.1	General.....	272
22.3.10.2	SERVICE field	273
22.3.10.3	CRC calculation for VHT-SIG-B	273
22.3.10.4	Scrambler.....	274
22.3.10.5	Coding	274
22.3.10.6	Stream parser	277
22.3.10.7	Segment parser	278
22.3.10.8	BCC interleaver	279
22.3.10.9	Constellation mapping.....	282
22.3.10.10	Pilot subcarriers	289
22.3.10.11	OFDM modulation	291
22.3.10.12	Non-HT duplicate transmission.....	292
22.3.11	SU-MIMO and DL-MU-MIMO Beamforming.....	293
22.3.11.1	General.....	293

22.3.11.2	Beamforming Feedback Matrix V	294
22.3.11.3	Maximum Number of Total Spatial Streams in VHT MU PPDU	294
22.3.11.4	Group ID	295
22.3.12	VHT preamble format for sounding PPDU	295
22.3.13	Regulatory requirements	296
22.3.14	Channelization	296
22.3.15	Transmit RF delay	297
22.3.16	Slot time	297
22.3.17	Transmit and receive port impedance	297
22.3.18	VHT transmit specification	298
22.3.18.1	Transmit spectrum mask	298
22.3.18.2	Spectral flatness	301
22.3.18.3	Transmit center frequency and symbol clock frequency tolerance	303
22.3.18.4	Modulation accuracy	303
22.3.18.5	Time of Departure accuracy	305
22.3.19	VHT receiver specification	306
22.3.19.1	Receiver minimum input sensitivity	306
22.3.19.2	Adjacent channel rejection	306
22.3.19.3	Nonadjacent channel rejection	307
22.3.19.4	Receiver maximum input level	308
22.3.19.5	CCA sensitivity	308
22.3.19.6	RSSI	310
22.3.20	PHY transmit procedure	310
22.3.21	PHY receive procedure	313
22.4	VHT PLME	318
22.4.1	PLME_SAP sublayer management primitives	318
22.4.2	PHY MIB	318
22.4.3	TXTIME and PSDU_LENGTH calculation	321
22.4.4	PHY characteristics	323
22.5	Parameters for VHT-MCSs	323
Annex B (normative) Protocol Implementation Conformance Statement (PICS) proforma		340
B.2	Abbreviations and special symbols	340
B.2.2	General abbreviations for Item and Support columns	340
B.4	PICS proforma—IEEE Std 802.11-<year>	340
B.4.3	IUT configuration	340
B.4.4	MAC protocol	341
B.4.4.1	MAC protocol capabilities	341
B.4.4.2	MAC frames	341
B.4.12	Spectrum management extensions	342
B.4.18	DSE functions	343
B.4.19	High-throughput (HT) features	345
B.4.19.1	HT MAC features	345
B.4.27	Very high throughput (VHT) features	346
B.4.27.1	VHT MAC features	346
B.4.27.2	VHT PHY features	348
Annex C (normative) ASN.1 encoding of the MAC and PHY MIB		353
C.3	MIB Detail	353
Annex D (normative) Regulatory references		374

D.1	External regulatory references	374
D.2	Radio performance specifications.....	375
D.2.5	CCA-ED threshold	375
Annex E (normative) Country elements and operating classes		376
E.1	Country information and operating classes	376
E.2	Band-specific operating requirements	382
E.2.2	3650–3700 MHz in the United States	382
Annex G (normative) Frame exchange sequences.....		383
G.1	General.....	383
G.4	HT and VHT sequences	384
Annex M (informative) RSNA reference implementations and test vectors.....		388
M.6	Additional test vectors	388
M.6.4	CCMP-128 test vector.....	388
M.7	Key hierarchy test vectors for pairwise keys	389
M.7.1	General	389
M.7.2	CCMP-128 pairwise key derivation.....	389
M.9	Management frame protection test vectors	389
M.9.1	BIP-CMAC-128 with broadcast Deauthentication frame	389
M.9.2	CCMP-128 with unicast Deauthentication frame	390
M.11	GCMP	391
M.11.1	Test vector	391
Annex S (informative) Additional VHT and HT Information.....		392
S.1	VHT and HT waveform generator tool.....	392
S.4	Illustration of determination of NDP addresses.....	392
Annex T (informative) Location and Time Difference accuracy test.....		393
T.2	Time Difference of departure accuracy test.....	393
Annex V (informative) Interworking with external networks		394
V.2	Network discovery and selection.....	394
V.2.4	Sales meeting.....	394
Annex W (informative) Mesh BSS operation.....		395
W.1	Clarification of Mesh Data frame format	395

Tables

Table 7-4—Vector descriptions.....	28
Table 7-5—The channel-list parameter elements.....	30
Table 8-0a—Maximum MSDU and A-MSDU sizes.....	33
Table 8-1—Valid type and subtype combinations	33
Table 8-6—Ack Policy subfield in QoS Control field of QoS data frames	34
Table 8-9—ASEL Command and ASEL Data subfields.....	36
Table 8-13a—VHT variant HT Control field subfields.....	37
Table 8-13b—MFB subfield in the VHT variant HT Control field	39
Table 8-13c—Maximum data unit sizes (in octets) and durations (in microseconds)	40
Table 8-18a—STA Info subfields.....	45
Table 8-20—Beacon frame body.....	47
Table 8-22—Association Request frame body	48
Table 8-23—Association Response frame body	48
Table 8-24—Reassociation Request frame body.....	49
Table 8-25—Reassociation Response frame body	49
Table 8-26—Probe Request frame body	49
Table 8-27—Probe Response frame body	50
Table 8-37—Status codes	51
Table 8-38—Category values	51
Table 8-53c—Subfields of the VHT MIMO Control field.....	54
Table 8-53d—Order of angles in the Compressed Beamforming Feedback Matrix subfield	55
Table 8-53e—Quantization of angles	57
Table 8-53f—VHT Compressed Beamforming Report information.....	58
Table 8-53g—Subcarriers for which a Compressed Beamforming Feedback Matrix subfield is sent back	59
Table 8-53h—Average SNR of Space-Time Stream i subfield.....	64
Table 8-53i—MU Exclusive Beamforming Report information.....	65
Table 8-53j—Number of subcarriers and subcarrier mapping	66
Table 8-53k—Subfield values of the Operating Mode field	69
Table 8-53l—Encoding of User Position subfield.....	70
Table 8-54—Element IDs.....	71
Table 8-55—BSS membership selector value encoding	71
Table 8-60—Optional subelement IDs for Channel Load Request.....	76
Table 8-62—Optional subelement IDs for Noise Histogram Request	77
Table 8-65—Optional subelement IDs for Beacon Report	78
Table 8-68—Optional subelement IDs for frame request.....	79
Table 8-83—Optional subelement IDs for Channel Load Report.....	80
Table 8-85—Optional subelement IDs for Noise Histogram Report	81
Table 8-87—Optional subelement IDs for Frame Report	82
Table 8-99—Cipher suite selectors.....	83
Table 8-100—Cipher suite usage	83
Table 8-101—AKM suite selectors	84
Table 8-103—Capabilities field.....	84
Table 8-105—Default EDCA Parameter Set element parameter values if dot11OCBAActivated is false	85
Table 8-115—Optional subelement IDs for neighbor report.....	86
Table 8-124—Subfields of the HT Capabilities Info field	89
Table 8-127—Subfields of the HT Extended Capabilities field.....	90
Table 8-128—Subfields of the Transmit Beamforming Capabilities field.....	90
Table 8-130—HT Operation element fields and subfields.....	91
Table 8-147—Power Save Mode definition	92
Table 8-183v—Subfields of the VHT Capabilities Info field	94
Table 8-183w—Supported VHT-MCS and NSS Set subfields	97
Table 8-183x—VHT Operation Information subfields	99

Table 8-183y—Meaning of Local Maximum Transmit Power Count subfield	102
Table 8-183z—Definition of Local Maximum Transmit Power Unit Interpretation subfield	102
Table 8-199—DLS Request frame Action field format	106
Table 8-200—DLS Response frame Action field format	106
Table 8-220—Information for TDLS Discovery Response frame	107
Table 8-239—Information for TDLS Setup Request frame	108
Table 8-240—Information for TDLS Setup Response frame	108
Table 8-241—Information for TDLS Setup Confirm frame	109
Table 8-244—Information for TDLS Channel Switch Request frame	109
Table 8-262—Mesh Peering Open frame Action field format	110
Table 8-263—Mesh Peering Confirm frame Action field format	111
Table 8-281ah—VHT Action field values	111
Table 8-281ai—VHT Compressed Beamforming frame Action field format	112
Table 8-281aj—Group ID Management frame Action field format	112
Table 8-281ak—Operating Mode Notification frame Action field format	113
Table 8-282—MPDU delimiter fields	115
Table 8-282a—MPDU delimiter fields (DMG)	115
Table 8-283—A-MPDU Contexts	117
Table 8-288—A-MPDU contents in the VHT single MPDU context	117
Table 9-3—CH_BANDWIDTH control frame response mapping	132
Table 9-4—Modulation classes	134
Table 9-5—Non-HT reference rate	135
Table 9-5a—Example of rate selection for VHT PPDU	137
Table 9-5b—Settings for the TXVECTOR parameters GROUP_ID and PARTIAL_AID	145
Table 9-8a—Channels indicated idle by the channel-list parameter	154
Table 9-9—Transmit beamforming support required with implicit feedback	163
Table 10-12—Default QMF policy	185
Table 10-19—VHT BSS operating channel width	186
Table 11-4—Cipher suite key lengths	204
Table 11-9—Integrity and key-wrap algorithms	205
Table 18-1—TXVECTOR parameters	207
Table 18-2—RXVECTOR parameters	208
Table 18-6a—Contents of the first 7 bits of the scrambling sequence	210
Table 18-6b—TXVECTOR parameter CH_BANDWIDTH_IN_NON_HT values	211
Table 18-6c—RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT values	211
Table 18-6d—DYN_BANDWIDTH_IN_NON_HT values	211
Table 22-1—TXVECTOR and RXVECTOR parameters	216
Table 22-2—PPDU format as a function of CH_BANDWIDTH parameter	224
Table 22-3—Mapping of the VHT PHY parameters for NON_HT operation	228
Table 22-4—Fields of the VHT PPDU	230
Table 22-5—Timing-related constants	244
Table 22-6—Frequently used parameters	245
Table 22-7—Center frequency of the portion of the PPDU transmitted in frequency segment iSeg	250
Table 22-8—Tone scaling factor and guard interval duration values for PHY fields	252
Table 22-9—CH_BANDWIDTH and	253
Table 22-10—Cyclic shift values for L-STF, L-LTF, L-SIG, and VHT-SIG-A fields of the PPDU	254
Table 22-11—Cyclic shift values for the VHT modulated fields of a PPDU	258
Table 22-12—Fields in the VHT-SIG-A field	260
Table 22-13—Number of VHT-LTFs required for different numbers of space-time streams	264
Table 22-14—Fields in the VHT-SIG-B field	268
Table 22-15—VHT-SIG-B bits (before Tail field) in NDP for various channel widths	269
Table 22-16—SERVICE field	273
Table 22-17—Number of rows and columns in the interleaver	280
Table 22-18—J(iSS) values	281

Table 22-19—LDPC tone mapping distance for each bandwidth	287
Table 22-20—Constellation mapper output to spatial mapper input for STBC	288
Table 22-21—Pilot values for 80 MHz transmission	290
Table 22-22—Fields to specify VHT channels	296
Table 22-23—Maximum transmit spectral flatness deviations	302
Table 22-24—Allowed relative constellation error versus constellation size and coding rate.....	304
Table 22-25—Receiver minimum input level sensitivity	306
Table 22-26—Minimum required adjacent and nonadjacent channel rejection levels.....	307
Table 22-27—Conditions for CCA BUSY on the primary 20 MHz	309
Table 22-28—VHT PHY MIB attributes	318
Table 22-29—VHT PHY characteristics	323
Table 22-30—VHT-MCSs for mandatory 20 MHz, NSS = 1	324
Table 22-31—VHT-MCSs for optional 20 MHz, NSS = 2	324
Table 22-32—VHT-MCSs for optional 20 MHz, NSS = 3	325
Table 22-33—VHT-MCSs for optional 20 MHz, NSS = 4	325
Table 22-34—VHT-MCSs for optional 20 MHz, NSS = 5	326
Table 22-35—VHT-MCSs for optional 20 MHz, NSS = 6	326
Table 22-36—VHT-MCSs for optional 20 MHz, NSS = 7	327
Table 22-37—VHT-MCSs for optional 20 MHz, NSS = 8	327
Table 22-38—VHT-MCSs for mandatory 40 MHz, NSS = 1	328
Table 22-39—VHT-MCSs for optional 40 MHz, NSS = 2	328
Table 22-40—VHT-MCSs for optional 40 MHz, NSS = 3	329
Table 22-41—VHT-MCSs for optional 40 MHz, NSS = 4	329
Table 22-42—VHT-MCSs for optional 40 MHz, NSS = 5	330
Table 22-43—VHT-MCSs for optional 40 MHz, NSS = 6	330
Table 22-44—VHT-MCSs for optional 40 MHz, NSS = 7	331
Table 22-45—VHT-MCSs for optional 40 MHz, NSS = 8	331
Table 22-46—VHT-MCSs for mandatory 80 MHz, NSS = 1	332
Table 22-47—VHT-MCSs for optional 80 MHz, NSS = 2	332
Table 22-48—VHT-MCSs for optional 80 MHz, NSS = 3	333
Table 22-49—VHT-MCSs for optional 80 MHz, NSS = 4	333
Table 22-50—VHT-MCSs for optional 80 MHz, NSS = 5	334
Table 22-51—VHT-MCSs for optional 80 MHz, NSS = 6	334
Table 22-52—VHT-MCSs for optional 80 MHz, NSS = 7	335
Table 22-53—VHT-MCSs for optional 80 MHz, NSS = 8	335
Table 22-54—VHT-MCSs for optional 160 MHz and 80+80 MHz, NSS = 1	336
Table 22-55—VHT-MCSs for optional 160 MHz and 80+80 MHz, NSS = 2	336
Table 22-56—VHT-MCSs for optional 160 MHz and 80+80 MHz, NSS = 3	337
Table 22-57—VHT-MCSs for optional 160 MHz and 80+80 MHz, NSS = 4	337
Table 22-58—VHT-MCSs for optional 160 MHz and 80+80 MHz, NSS = 5	338
Table 22-59—VHT-MCSs for optional 160 MHz and 80+80 MHz, NSS = 6	338
Table 22-60—VHT-MCSs for optional 160 MHz and 80+80 MHz, NSS = 7	339
Table 22-61—VHT-MCSs for optional 160 MHz and 80+80 MHz, NSS = 8	339
Table D-1—Regulatory requirement list	374
Table D-2—Behavior limits set	374
Table E-1—Operating classes in the United States	376
Table E-2—Operating classes in Europe	377
Table E-3—Operating classes in Japan	378
Table E-4—Global operating classes	378
Table E-5—Operating classes in China	380
Table G-1—Attributes applicable to frame exchange sequence definition	383
Table M-14—Sample derived CCMP-128 temporal key (TK)	389

Figures

Figure 7-1—The channel-list parameter element for 40 MHz, 80 MHz, and 160 MHz channel width	31
Figure 7-2—The channel-list parameter element for 80+80 MHz channel width	31
Figure 8-1—MAC frame format.....	33
Figure 8-5—HT Control field.....	35
Figure 8-6—Link Adaptation Control subfield	36
Figure 8-5a—HT Control Middle subfield of the HT variant HT Control field	36
Figure 8-8a—HT Control Middle subfield of the VHT variant HT Control field	37
Figure 8-8b—MSI/STBC subfield when the Unsolicited MFB subfield is 1.....	39
Figure 8-8c—MFB subfield in the VHT variant HT Control field	39
Figure 8-29j—VHT NDP Announcement frame format	44
Figure 8-29k—Sounding Dialog Token field	44
Figure 8-29l—STA Info field	45
Figure 8-29m—Beamforming Report Poll frame format	45
Figure 8-30—Data frame.....	46
Figure 8-32—Basic A-MSDU subframe structure	46
Figure 8-34—Management frame format.....	47
Figure 8-70a—MCS Index field format when the MCS Selector field is 3, 4, 5, or 6.....	53
Figure 8-80d—VHT MIMO Control field.....	53
Figure 8-80e—Operating Mode field	69
Figure 8-80g—User Position Array field	70
Figure 8-80f—Membership Status Array field.....	70
Figure 8-90—Country element format	72
Figure 8-90a—Subband Triplet Sequence format	72
Figure 8-90b—Subband Triplet field	72
Figure 8-90c—Triplet field if dot11OperatingClassRequired is true.....	73
Figure 8-90d—Format of m-th Operating/Subband Sequence field	73
Figure 8-216—BSSID Information field.....	86
Figure 8-246—Supported Operating Classes element format.....	87
Figure 8-246a—Current Operating Class Extension Sequence field format.....	88
Figure 8-246b—Operating Class Duple Sequence field format.....	88
Figure 8-247—Management MIC element format.....	88
Figure 8-252—HT Extended Capabilities field.....	90
Figure 8-401bp—VHT Capabilities element format.....	93
Figure 8-401bq—VHT Capabilities Info field	94
Figure 8-401br—Supported VHT-MCS and NSS Set field	97
Figure 8-401bt—VHT Operation element format	98
Figure 8-401bu—VHT Operation Information field.....	98
Figure 8-401bs—Rx VHT-MCS Map and Tx VHT-MCS Map subfields and Basic VHT-MCS and NSS Set field	98
Figure 8-401bv—Extended BSS Load element format.....	99
Figure 8-401bx—VHT Transmit Power Envelope element format	101
Figure 8-401by—Transmit Power Information field.....	101
Figure 8-401bw—Wide Bandwidth Channel Switch element format.....	101
Figure 8-401bz—Channel Switch Wrapper element format	102
Figure 8-401ca—AID element format.....	103
Figure 8-401cb—Quiet Channel element format	104
Figure 8-401cc—Operating Mode Notification element.....	104
Figure 8-436—Channel Switch Announcement frame Action field format.....	105
Figure 8-449—Extended Channel Switch Announcement frame Action field format.....	107
Figure 8-495—Channel Usage Response frame format	110
Figure 8-503—A-MPDU format	113

Figure 8-504—A-MPDU subframe format	114
Figure 8-505—MPDU delimiter (non-DMG)	114
Figure 8-505a—MPDU delimiter (DMG)	114
Figure 8-505a1—MPDU Length field	115
Figure 9-1—MAC architecture	118
Figure 9-9a—An example of a TXOP containing a VHT MU PPDU transmission with an immediate acknowledgment to the VHT MU PPDU	123
Figure 9-9b—An example of a TXOP containing a VHT MU PPDU transmission with no immediate acknowledgment to the VHT MU PPDU	123
Figure 9-20a—Illustration of TXOP sharing and PPDU construction	150
Figure 9-41a—Example of the sounding protocol with a single VHT beamformee	170
Figure 9-41b—Example of the sounding protocol with more than one VHT beamformee	170
Figure 11-16—Expanded CCMP MPDU	195
Figure 18-7—Data scrambler	209
Figure 22-1—PHY interaction on transmit for various PPDU formats	226
Figure 22-2—PHY interaction on receive for various PPDU formats	227
Figure 22-3—PHY-CONFIG and CCA interaction with Clause 18, Clause 20, and Clause 22 PHYs	227
Figure 22-4—VHT PPDU format	229
Figure 22-5—Transmitter block diagram for the L-SIG and VHT-SIG-A fields	231
Figure 22-6—Transmitter block diagram for the VHT-SIG-B field of a 20 MHz, 40 MHz, and 80 MHz VHT SU PPDU	232
Figure 22-7—Transmitter block diagram for the VHT-SIG-B field of a 20 MHz, 40 MHz, and 80 MHz VHT MU PPDU	232
Figure 22-8—Transmitter block diagram for the VHT-SIG-B field of a 160 MHz VHT SU PPDU	233
Figure 22-9—Transmitter block diagram for the VHT-SIG-B field of an 80+80 MHz VHT SU PPDU ...	233
Figure 22-10—Transmitter block diagram for the Data field of a 20 MHz, 40 MHz, or 80 MHz VHT SU PPDU with BCC encoding	234
Figure 22-11—Transmitter block diagram for the Data field of a 20 MHz, 40 MHz, or 80 MHz VHT SU PPDU with LDPC encoding	235
Figure 22-12—Transmitter block diagram for the Data field of a 20 MHz, 40 MHz, or 80 MHz VHT MU PPDU	236
Figure 22-13—Transmitter block diagram for the Data field of a 160 MHz VHT SU PPDU with BCC encoding	237
Figure 22-14—Transmitter block diagram for the Data field of a 160 MHz VHT SU PPDU with LDPC encoding	238
Figure 22-15—Transmitter block diagram for the Data field of an 80+80 MHz VHT SU PPDU with BCC encoding	239
Figure 22-16—Transmitter block diagram for the Data field of an 80+80 MHz VHT SU PPDU with LDPC encoding	240
Figure 22-17—Timing boundaries for VHT PPDU fields	250
Figure 22-18—VHT-SIG-A1 structure	259
Figure 22-19—VHT-SIG-A2 structure	259
Figure 22-20—Data tone constellation in the VHT PPDU pre-VHT modulated fields	262
Figure 22-21—Generation of VHT-LTF symbols per frequency segment	266
Figure 22-22—VHT-SIG-B bits in 20 MHz, 40 MHz, 80 MHz, 160 MHz, and 80+80 MHz transmissions	269
Figure 22-23—VHT-SIG-B and SERVICE field relationship	273
Figure 22-24—Constellation bit encoding for 256-QAM (1st quadrant)	283
Figure 22-25—Constellation bit encoding for 256-QAM (2nd quadrant)	284
Figure 22-26—Constellation bit encoding for 256-QAM (3rd quadrant)	285
Figure 22-27—Constellation bit encoding for 256-QAM (4th quadrant)	286
Figure 22-28—VHT NDP format	295
Figure 22-29—Example transmit spectral mask for a 20 MHz mask PPDU	298
Figure 22-31—Example transmit spectral mask for an 80 MHz mask PPDU	299

Figure 22-30—Example transmit spectral mask for a 40 MHz mask PPDU	299
Figure 22-32—Example transmit spectral mask for a 160 MHz mask PPDU	300
Figure 22-33—Example transmit spectral mask for an 80+80 MHz mask PPDU	301
Figure 22-34—PHY transmit procedure for an SU transmission.....	311
Figure 22-35—PHY transmit state machine for an SU transmission.....	312
Figure 22-36—PHY receive procedure for an SU transmission	316
Figure 22-37—PHY receive state machine	317

**IEEE Standard for Information technology—
Telecommunications and information exchange between systems
Local and metropolitan area networks—
Specific requirements**

**Part 11: Wireless LAN Medium Access Control
(MAC) and Physical Layer (PHY) Specifications**

**Amendment 4: Enhancements for Very High
Throughput for Operation in Bands below 6 GHz**

IMPORTANT NOTICE: IEEE Standards documents are not intended to ensure safety, 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 Std 802.11™-2012, as amended by IEEE Std 802.11ae™-2012, IEEE Std 802.11aa™-2012, and IEEE Std 802.11ad™-2012.)

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 ~~striketrough~~ (to remove old material) and underscore (to add new material). **Delete** removes existing material. **Insert** adds new material without disturbing the existing material. Deletions and 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. Editorial 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.

3. Definitions, acronyms and abbreviations

3.1 Definitions

Delete the following definition from 3.1 (note that the definition is inserted with changes into 3.2):

medium access control (MAC) management protocol data unit (MMPDU)

Insert the following definitions into 3.1 in alphabetic order:

aggregate medium access control (MAC) protocol data unit (A-MPDU) subframe: A portion of an A-MPDU containing a delimiter and optionally containing an MPDU plus any necessary padding.

contiguous transmission: A transmission that uses only one frequency segment.

downlink multi-user multiple input, multiple output (DL-MU-MIMO): A technique by which an access point (AP) with more than one antenna transmits a physical layer (PHY) protocol data unit (PPDU) to multiple receiving non-AP stations (STAs) over the same radio frequencies, wherein each non-AP STA simultaneously receives one or more distinct space-time streams.

frequency segment: A contiguous block of spectrum used by a transmission.

multi-user multiple input, multiple output (MU-MIMO): A technique by which multiple stations (STAs), each with one or more antennas, either simultaneously transmit to a single STA or simultaneously receive from a single STA independent data streams over the same radio frequencies.

NOTE—IEEE 802.11 supports only downlink (DL) MU-MIMO. See DL-MU-MIMO.

multi-user (MU) physical layer (PHY) protocol data unit (PPDU): A PPDU that carries one or more PHY service data units (PSDUs) for one or more stations (STAs) using the downlink multi-user multiple input, multiple output (DL-MU-MIMO) technique.

noncontiguous transmission: A transmission that uses nonadjacent frequency segments.

single-user (SU) physical layer (PHY) protocol data unit (PPDU): A PPDU with a format that is capable of carrying only a single PHY service data unit (PSDU), or no PSDU.

3.2 Definitions specific to IEEE 802.11

Change the following definitions in 3.2:

20 MHz mask physical layer (PHY) ~~convergence procedure (PLCP)~~ protocol data unit (PPDU): A Clause 18 PPDU, a Clause 19 orthogonal frequency division multiplexing (OFDM) PPDU, or a Clause 20 20 MHz high-throughput (HT) PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW20 and the CH_OFFSET parameter equal to CH_OFF_20. The PPDU is transmitted using a 20 MHz transmit spectral mask defined in Clause 18, Clause 19, or Clause 20. One of the following PPDU:

- a) A Clause 18 PPDU transmitted using the transmit spectral mask defined in Clause 18.
- b) A Clause 19 orthogonal frequency division multiplexing (OFDM) PPDU transmitted using the transmit spectral mask defined in Clause 19.

- c) A high-throughput (HT) PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW20 and the CH_OFFSET parameter equal to CH_OFF_20 transmitted using the 20 MHz transmit spectral mask defined in Clause 20.
- d) A very high throughput (VHT) PPDU with TXVECTOR parameter CH_BANDWIDTH equal to CBW20 transmitted using the 20 MHz transmit spectral mask defined in Clause 22.
- e) A Clause 18 PPDU transmitted by a VHT STA using the transmit spectral mask defined in Clause 22.
- f) A HT PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW20 and the CH_OFFSET parameter equal to CH_OFF_20 transmitted by a VHT STA using the 20 MHz transmit spectral mask defined in Clause 22.

20 MHz physical layer (PHY) convergence procedure (PLCP)-protocol data unit (PPDU): A Clause 16 PPDU, Clause 18 PPDU (when using 20 MHz channel spacing), Clause 17 PPDU, Clause 19 orthogonal frequency division multiplexing (OFDM) PPDU, ~~or~~ Clause 20 20 MHz high-throughput (HT) PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW20 or Clause 22 20 MHz very high throughput (VHT) PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to CBW20.

40 MHz mask physical layer (PHY) convergence procedure (PLCP)-protocol data unit (PPDU): One of the following PPDUs:

- 1) ~~a~~ A 40 MHz high-throughput (HT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW40) transmitted using the 40 MHz transmit spectral mask defined in Clause 20.
- 2) ~~a~~ A 40 MHz non-HT duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to NON_HT_CBW40) transmitted by a non-very-high-throughput (non-VHT) STA using the 40 MHz transmit spectral mask defined in Clause 20.
- 3) A 40 MHz non-HT duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW40) transmitted by a very high throughput (VHT) STA using the 40 MHz transmit spectral mask defined in Clause 22.
- 4) ~~a~~ Clause 20 A 20 MHz HT PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW20 and the CH_OFFSET parameter equal to either CH_OFF_20U or CH_OFF_20L transmitted using the 40 MHz transmit spectral mask defined in Clause 20.
- 5) A 20 MHz VHT PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to CBW20 transmitted using the 40 MHz transmit spectral mask defined in Clause 22.
- 6) A 40 MHz VHT PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to CBW40 transmitted using the 40 MHz transmit spectral mask defined in Clause 22.
- 7) A 40 MHz HT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW40) transmitted by a VHT STA using the 40 MHz transmit spectral mask defined in Clause 22.
- 8) A 20 MHz non-HT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW20) transmitted using the 40 MHz transmit spectral mask defined in Clause 20.
- 9) A 20 MHz non-HT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW20) transmitted by a VHT STA using the 40 MHz transmit spectral mask defined in Clause 22.

The PPDU is transmitted using a 40 MHz transmit spectral mask defined in Clause 20 (High Throughput (HT) PHY specification).

40 MHz physical layer (PHY) convergence procedure (PLCP)-protocol data unit (PPDU): A 40 MHz high-throughput (HT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW40), or a 40 MHz non-HT duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to NON_HT_CBW40 or TXVECTOR parameter CH_BANDWIDTH equal to CBW40) as defined in Clause 20, or a 40 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW40).

high-throughput (HT) null data packet (NDP) announcement: A physical layer (PHY) ~~convergence procedure (PLCP)~~-protocol data unit (PPDU) that contains one or more +HTC frames (i.e., frames with an HT (high-throughput) Control field) that have the HT NDP Announcement subfield equal to 1.

modulation and coding scheme (MCS): A specification of the ~~high-throughput (HT)~~ physical layer (PHY) parameters that consists of modulation order (e.g., BPSK, QPSK, 16-QAM, 64-QAM, and 256-QAM) and forward error correction (FEC) coding rate (e.g., 1/2, 2/3, 3/4, 5/6) and, depending on the context, the number of space-time streams.

non-high-throughput (non-HT) duplicate: A transmission format of the physical layer (PHY) that duplicates a 20 MHz non-HT transmission in two ~~adjacent or more~~ 20 MHz channels and allows a station (STA) in a non-HT basic service set (BSS) on ~~either channel~~ any one of the 20 MHz channels to receive the transmission. A non-HT duplicate format is one of the following:

- 1) 40 MHz non-HT duplicate: A transmission format of the PHY that replicates a 20 MHz non-HT transmission in two adjacent 20 MHz channels.
- 2) 80 MHz non-HT duplicate: A transmission format of the PHY that replicates a 20 MHz non-HT transmission in four adjacent 20 MHz channels.
- 3) 160 MHz non-HT duplicate: A transmission format of the PHY that replicates a 20 MHz non-HT transmission in eight adjacent 20 MHz channels.
- 4) 80+80 MHz non-HT duplicate: A transmission format of the PHY that replicates a 20 MHz non-HT transmission in two frequency segments of four adjacent 20 MHz channels where the two frequency segments of channels are not adjacent.

non-high-throughput (non-HT) duplicate physical layer (PHY) ~~convergence procedure (PLCP)~~ protocol data unit (PPDU): A PPDU transmitted by a Clause 20 ~~or Clause 22~~ physical layer (PHY) with the TXVECTOR FORMAT parameter equal to NON_HT and the CH_BANDWIDTH parameter equal to NON_HT_CBW40, CBW40, CBW80, CBW160, or CBW80+80.

non-high-throughput (non-HT) physical layer (PHY) ~~convergence procedure (PLCP)~~ protocol data unit (PPDU): A Clause 20 ~~or Clause 22~~ physical layer (PHY)-PPDU with the TXVECTOR FORMAT parameter equal to NON_HT.

payload protected (PP) aggregate medium access control (MAC) service data unit (A-MSDU): An A-MSDU that is protected with CTR with CBC-MAC Protocol (CCMP) or Galois Counter Mode Protocol (GCMP) but does not include the A-MSDU Present field (bit 7 of the QoS Control field) in the construction of the additional authentication data (AAD).

per-frame sequence counter: For Temporal Key Integrity Protocol (TKIP), the counter that is used as the nonce in the derivation of the per-frame encryption key. For Counter mode with Cipher-block chaining Message authentication code Protocol (CCMP) or Galois Counter Mode Protocol (GCMP), the per-frame initialization vector (IV).

robust-security-network-association- (RSNA-) capable equipment: A device that contains a station (STA) that is able to create RSNAs. Such a device might use pre-RSNAs because of configuration. Notice that RSNA-capable does not imply full compliance with the RSNA Protocol Implementation Conformance Statement (PICS). A legacy device that has been upgraded to support Temporal Key Integrity Protocol (TKIP) might be RSNA-capable, but is not compliant with the PICS if it does not also support Counter mode with Cipher-block chaining Message authentication code Protocol (CCMP) using CCMP-128.

secondary channel: A 20 MHz channel associated with a primary channel used by high-throughput (HT) stations (STAs) for the purpose of creating a 40 MHz channel or used by very high throughput (VHT) stations (STAs) for the purpose of creating the primary 40 MHz channel.

signaling and payload protected (SPP) aggregate medium access control (MAC) service data unit (A-MSDU): An A-MSDU that is protected with CTR with CBC-MAC Protocol (CCMP) or Galois Counter Mode Protocol (GCMP) and that includes the A-MSDU Present field (bit 7 of the QoS Control field) in the construction of the additional authentication data (AAD).

Insert the following definitions in 3.2 in alphabetic order:

80 MHz mask physical layer (PHY) protocol data unit (PPDU): A PPDU that is transmitted using the 80 MHz transmit spectral mask defined in Clause 22 and that is one of the following:

- a) An 80 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80)
- b) An 80 MHz non-high-throughput (non-HT) duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80)
- c) A 20 MHz non-HT, high-throughput (HT), or VHT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW20)
- d) A 40 MHz non-HT duplicate, HT, or VHT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW40)

80 MHz physical layer (PHY) protocol data unit (PPDU): A Clause 22 80 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80) or a Clause 22 80 MHz non-high-throughput (non-HT) duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80).

160 MHz mask physical layer (PHY) protocol data unit (PPDU): A PPDU that is transmitted using the 160 MHz transmit spectral mask defined in Clause 22 and that is one of the following:

- a) A 160 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH set to CBW160)
- b) A 160 MHz non-high-throughput (non-HT) duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW160)
- c) A 20 MHz non-HT, high-throughput (HT), or VHT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW20)
- d) A 40 MHz non-HT duplicate, HT, or VHT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW40)
- e) An 80 MHz non-HT duplicate or VHT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80)

160 MHz physical layer (PHY) protocol data unit (PPDU): A Clause 22 160 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW160) or a Clause 22 160 MHz non-high-throughput (non-HT) duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW160).

80+80 MHz mask physical layer (PHY) protocol data unit (PPDU): A PPDU that is transmitted using the 80+80 MHz transmit spectral mask defined in Clause 22 and that is one of the following:

- a) An 80+80 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH set to CBW80+80)
- b) An 80+80 MHz non-high-throughput (non-HT) duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH set to CBW80+80)

80+80 MHz physical layer (PHY) protocol data unit (PPDU): A Clause 22 80+80 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80+80) or a Clause 22 80+80 MHz non-high-throughput (non-HT) duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80+80).

bandwidth signaling transmitter address (TA): A TA that is used by a very high throughput (VHT) station (STA) to indicate the presence of additional signaling related to the bandwidth to be used in subsequent transmission in an enhanced distributed channel access (EDCA) transmission opportunity (TXOP). It is represented by the IEEE medium access control (MAC) individual address of the transmitting VHT STA but with the Individual/Group bit set to 1.

basic service set (BSS) basic very high throughput (VHT) modulation and coding scheme (MCS) and number of spatial streams (NSS) set (BSS basic VHT-MCS and NSS set): The set of MCS and NSS tuples that are supported by all VHT stations (STAs) that are members of a VHT BSS.

beamforming steering matrix: A matrix that describes the mapping of space-time streams to transmit antennas and for which the values have been determined using knowledge of the channel between transmitter and receiver with the goal of improving reception at the receiver.

dynamic bandwidth operation: A feature of a very high throughput (VHT) station (STA) in which the request-to-send/clear-to-send (RTS/CTS) exchange, using non-high-throughput (non-HT) duplicate physical layer (PHY) protocol data units (PPDUs), negotiates a potentially reduced channel width (compared to the channel width indicated by the RTS) for subsequent transmissions within the current transmission opportunity (TXOP).

end-of-frame (EOF) pad: The 0 to 3 octets used to pad an aggregate medium access control (MAC) protocol data unit (A-MPDU) to the last octet of the associated physical layer convergence procedure (PLCP) service data unit (PSDU) when the A-MPDU is carried in a very high throughput (VHT) physical layer (PHY) protocol data unit (PPDU).

high-throughput (HT) beamformee: An HT station (STA) that receives an HT physical layer (PHY) protocol data unit (PPDU) that was transmitted using a beamforming steering matrix and that supports an HT transmit beamforming feedback mechanism as described in either 9.29.2 or 9.29.3.

high-throughput (HT) beamformer: An HT station (STA) that transmits an HT physical layer (PHY) protocol data unit (PPDU) using a beamforming steering matrix.

medium access control (MAC) management protocol data unit (MMPDU): The unit of data exchanged between two peer MAC entities, using services of the physical layer (PHY), to implement the MAC management protocol. The MMPDU is transported in one or more management MPDUs. The MMPDU might include a Mesh Control field or Management MIC element, but does not include a MAC header, a frame check sequence (FCS), or any other security encapsulation overhead.

NOTE—The MMPDU occupies a position in the management plane similar to that of the MAC service data unit (MSDU) in the data plane. The MMPDU can be fragmented (under certain circumstances) and in that case is carried in multiple management MPDUs. This illustrates the similarity of the MMPDU to the MSDU.

multi-user (MU) beamformee: A non-access-point (non-AP) station (STA) that receives a physical layer (PHY) protocol data unit (PPDU) that was transmitted using a multi-user beamforming steering matrix and that supports the very high throughput (VHT) transmit beamforming feedback mechanism with a VHT null data packet (NDP) Announcement frame that includes more than one STA Info field as described in 9.31.5.

multi-user (MU) beamformer: An access point (AP) station (STA) that transmits a physical layer (PHY) protocol data unit (PPDU) using a multi-user beamforming steering matrix.

non-bandwidth signaling transmitter address (TA): An address in the TA field of an medium access control (MAC) protocol data unit (MPDU) in which the Individual/Group bit has the value 0.

non-high-throughput (non-HT): A modifier meaning neither high-throughput (HT) nor very high throughput (VHT).

non-primary channel: In a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz very high throughput (VHT) basic service set (BSS), any 20 MHz channel other than the primary 20 MHz channel.

physical layer (PHY) protocol data unit (PPDU): The unit of data exchanged between two peer PHY entities to provide the PHY data service. When the PHY is partitioned into physical layer convergence protocol (PLCP) and physical medium dependent (PMD) sublayers, the format of the PPDU is defined by the PLCP.

primary 20 MHz channel: In a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz very high throughput (VHT) basic service set (BSS), the 20 MHz channel that is used to transmit 20 MHz physical layer (PHY) protocol data units (PPDUs). In a VHT BSS, the primary 20 MHz channel is also the primary channel.

primary 40 MHz channel: In an 80 MHz, 160 MHz, or 80+80 MHz very high throughput (VHT) basic service set (BSS), the 40 MHz channel that is used to transmit 40 MHz physical layer (PHY) protocol data units (PPDUs).

primary 80 MHz channel: In a 160 MHz or 80+80 MHz very high throughput (VHT) basic service set (BSS), the 80 MHz channel that is used to transmit 80 MHz physical layer (PHY) protocol data units (PPDUs).

primary access category (AC): The access category (AC) associated with the enhanced distributed channel access function (EDCAF) that gains channel access.

secondary 20 MHz channel: In a 40 MHz very high throughput (VHT) basic service set (BSS), the 20 MHz channel adjacent to the primary 20 MHz channel that together form the 40 MHz channel of the 40 MHz VHT BSS. In an 80 MHz VHT BSS, the 20 MHz channel adjacent to the primary 20 MHz channel that together form the primary 40 MHz channel of the 80 MHz VHT BSS. In a 160 MHz or 80+80 MHz VHT BSS, the 20 MHz channel adjacent to the primary 20 MHz channel that together form the primary 40 MHz channel of the 160 MHz or 80+80 MHz VHT BSS. In a VHT BSS, the secondary 20 MHz channel is also the secondary channel.

secondary 40 MHz channel: In an 80 MHz very high throughput (VHT) basic service set (BSS), the 40 MHz channel adjacent to the primary 40 MHz channel that together form the 80 MHz channel of the 80 MHz VHT BSS. In a 160 or 80+80 MHz VHT BSS, the 40 MHz channel adjacent to the primary 40 MHz channel that together form the primary 80 MHz channel.

secondary 80 MHz channel: In a 160 MHz or 80+80 MHz very high throughput (VHT) basic service set (BSS), the 80 MHz channel not including the primary 20 MHz channel, that together with the primary 80 MHz channel forms the 160 MHz or 80+80 MHz channel of the 160 MHz or 80+80 MHz VHT BSS.

secondary access category (AC): An access category (AC) that is not associated with the enhanced distributed channel access function (EDCAF) that gains channel access.

NOTE—Traffic associated with a secondary AC can be included in a multi-user (MU) physical layer (PHY) protocol data unit (MU PPDU) that includes traffic associated with the primary AC. There could be multiple secondary ACs at a given time.

user: An individual or group of stations (STAs) identified by a single receive address (RA) in the context of single-user multiple input, multiple output (SU-MIMO) or multi-user multiple input, multiple output (MU-MIMO).

very high throughput (VHT) basic service set (BSS): A BSS in which a Beacon frame transmitted by a VHT station (STA) includes the VHT Operation element.

very high throughput (VHT) beamformee: A VHT station (STA) that receives a VHT physical layer (PHY) protocol data unit (PPDU) that was transmitted using a beamforming steering matrix and that supports the VHT transmit beamforming feedback mechanism as described in 9.31.5.

very high throughput (VHT) beamformer: A VHT station (STA) that transmits a VHT physical layer (PHY) protocol data unit (PPDU) using a beamforming steering matrix.

very high throughput modulation and coding scheme (VHT-MCS): A specification of the VHT physical layer (PHY) parameters that consists of modulation order (e.g., BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM) and forward error correction (FEC) coding rate (e.g., 1/2, 2/3, 3/4, 5/6) and that is used in a VHT PHY protocol data unit (PPDU).

very high throughput (VHT) multi-user (MU) physical layer (PHY) protocol data unit (PPDU): A VHT PPDU with a format that is capable of carrying up to four PHY service data units (PSDUs) for up to four users and is transmitted using the downlink multi-user multiple input, multiple output (DL-MU-MIMO) technique.

very high throughput (VHT) physical layer (PHY) protocol data unit (PPDU): A PPDU transmitted with the TXVECTOR parameter FORMAT equal to VHT.

very high throughput (VHT) single medium access control (MAC) protocol data unit (VHT single MPDU): An MPDU that is the only MPDU in an aggregate MPDU (A-MPDU) carried in a VHT physical layer (PHY) protocol data unit (PPDU) and that is carried in an A-MPDU subframe with the EOF subfield of the MPDU delimiter field equal to 1.

very high throughput (VHT) single-user-only (SU-only) beamformee: A VHT beamformee that does not receive VHT multi-user (MU) physical layer (PHY) protocol data units (PPDUs).

very high throughput (VHT) single-user-only (SU-only) beamformer: A VHT beamformer that does not transmit VHT multi-user (MU) physical layer (PHY) protocol data units (PPDUs).

very high throughput (VHT) single-user (SU) physical layer (PHY) protocol data unit (PPDU): A VHT PPDU transmitted with the TXVECTOR parameters FORMAT equal to VHT and GROUP_ID equal to 0 or 63.

3.3 Abbreviations and acronyms

Change the following abbreviation in 3.3:

PPDU	PLCP protocol data unit <u>or PHY protocol data unit</u>
------	--

Insert the following abbreviations into 3.3 in alphabetic order:

BW	bandwidth
DL-MU-MIMO	downlink multi-user multiple input, multiple output
EOF	end-of-frame
GCMP	Galois Counter Mode Protocol
GID	group identifier
MU	multi-user
MU-MIMO	multi-user multiple input, multiple output
NSS	number of spatial streams
STF	Short Training field

FOR VERY HIGH THROUGHPUT FOR OPERATION IN BANDS BELOW 6 GHz

IEEE
Std 802.11ac-2013

SU	single-user
SU-MIMO	single-user multiple input, multiple output
VHT	very high throughput

4. General description

4.3 Components of the IEEE 802.11 architecture

4.3.4 Distribution system (DS) concepts

4.3.4.3 Robust security network association (RSNA)

Change the first paragraph of 4.3.4.3 as follows:

An RSNA defines a number of security features in addition to wired equivalent privacy (WEP) and IEEE 802.11 authentication. These features include the following:

- Enhanced authentication mechanisms for STAs
- Key management algorithms
- Cryptographic key establishment
- Enhanced data cryptographic encapsulation mechanisms, such as Counter mode with Cipher-block chaining Message authentication code Protocol (CCMP), Galois Counter Mode Protocol (GCMP), and, optionally, Temporal Key Integrity Protocol (TKIP).
- Fast basic service set (BSS) transition (FT) mechanism
- Enhanced cryptographic encapsulation mechanisms for robust management frames

Insert the following subclause, 4.3.10a, after 4.3.10:

4.3.10a Very high throughput (VHT) STA

This subclause summarizes the normative requirements for an IEEE 802.11 VHT STA stated elsewhere in this standard.

The IEEE 802.11 VHT STA operates in frequency bands below 6 GHz excluding the 2.4 GHz band.

A VHT STA is an HT STA that, in addition to features supported as an HT STA, supports VHT features identified in Clause 8, Clause 9, Clause 10, Clause 13, Clause 18, and Clause 22.

The main PHY features in a VHT STA that are not present in an HT STA are the following:

- Mandatory support for 40 MHz and 80 MHz channel widths
- Mandatory support for VHT single-user (SU) PPDU
- Optional support for 160 MHz and 80+80 MHz channel widths
- Optional support for VHT sounding protocol to support beamforming
- Optional support for VHT multi-user (MU) PPDU
- Optional support for VHT-MCSs 8 and 9

The main MAC features in a VHT STA that are not present in an HT STA are the following:

- Mandatory support for the A-MPDU padding of a VHT PPDU
- Mandatory support for VHT single MPDU
- Mandatory support for responding to a bandwidth indication (provided by the RXVECTOR parameters CH_BANDWIDTH_IN_NON_HT and DYN_BANDWIDTH_IN_NON_HT) in a non-HT and non-HT duplicate RTS frame
- Optional support for MPDUs of up to 11 454 octets

- Optional support for A-MPDU pre-end-of-frame (pre-EOF) padding (see 9.12.2 (A-MPDU length limit rules)) of up to 1 048 575 octets
- Optional support for VHT link adaptation

Most VHT features, among other benefits, increase the maximum throughput achievable between two VHT STAs over that achievable using HT features alone. The VHT features are available to VHT STAs associated with a VHT AP in a BSS. A subset of the VHT features is available for use between two VHT STAs that are members of the same IBSS. Similarly, a subset of the VHT features is available for use between two VHT STAs that have established mesh peering. A subset of the VHT features is available for use between two VHT STAs that have established a TDLS link.

The support for VHT transmit beamforming sounding and VHT MU PPDU in a VHT AP and more than one VHT STA within a VHT BSS enables the optional use of downlink MU multiple input, multiple output (DL-MU-MIMO). With DL-MU-MIMO the AP can create up to four A-MPDUs, each carrying MPDUs destined for an associated MU-capable STA. The AP uses group identifiers (GIDs) to signal potential recipient STAs. The AP transmits the A-MPDUs simultaneously in separate space-time streams such that each recipient STA is able to demodulate the space-time streams carrying its A-MPDU. The simultaneous transmission of A-MPDUs in a single VHT MU PPDU provides a means to increase aggregate throughput over that achieved by sending the A-MPDUs in separate SU PPDU.

The use of certain HT features, such as RIFS, is not permitted for STAs operating as VHT STAs.

4.5 Overview of the services

4.5.4 Access control and data confidentiality services

4.5.4.1 General

Change the last paragraph of 4.5.4.1 as follows:

An RSNA uses the IEEE 802.1X authentication service along with enhanced data cryptographic encapsulation mechanisms, such as TKIP, ~~and CCMP, and GCMP~~ to provide access control. The IEEE 802.11 station management entity (SME) provides key management via an exchange of IEEE 802.1X EAPOL-Key frames. Data confidentiality and data integrity are provided by RSN key management together with the enhanced data cryptographic encapsulation mechanisms.

4.5.4.7 Replay detection

Change 4.5.4.7 as follows:

The replay detection mechanism defines a means by which a STA that receives a data or protected Robust Management frame from another STA can detect whether the received frame is an unauthorized retransmission. This replay protection mechanism is provided for data frames for STAs that use enhanced data cryptographic encapsulation mechanisms. The replay protection mechanism is also provided for robust management frames for STAs that use CCMP, GCMP, and Broadcast/Multicast Integrity Protocol (BIP).

4.5.4.9 Robust management frame protection

Change the second and third paragraphs of 4.5.4.9 as follows:

Management frame protection protocols in an infrastructure BSS or IBSS apply to robust management frames after RSNA PTK establishment for protection of individually addressed frames is completed and

after delivery of the GTK to protect group addressed frames. Robust management frame protection is implemented by CCMP, GCMP, BIP, and the SA Query procedure.

Management frame protection protocols in an MBSS apply to individually addressed frames after establishment of the RSNA MTK, and to group addressed frames indicated as “Group Addressed Privacy” in Table 8-38. Robust management frame protection is implemented ~~by~~ with CCMP and GCMP.

4.9 Reference model

4.9.1 General

Insert the following paragraph after the first paragraph of 4.9.1:

The description of the VHT PHY in Clause 22 is provided as one layer and is not separated into PLCP and PMD sublayers.

5. MAC service definition

5.1 Overview of MAC services

5.1.2 Security services

Change the first, second, and fifth paragraphs of 5.1.2 as follows:

Security services in IEEE Std 802.11 are provided by the authentication service and the CCMP, GCMP, and BIP mechanisms. The scope of the security services provided is limited to station-to-station data and robust management frame transmissions. When CCMP or GCMP is used, the data confidentiality service is provided for data frames and individually addressed robust management frames. For the purposes of this standard, CCMP and GCMP are ~~is~~ viewed as a logical services located within the MAC sublayer as shown in the reference model, Figure 4-14 (in 4.9). Actual implementations of CCMP and GCMP are transparent to the LLC and other layers above the MAC sublayer.

The security services provided by CCMP and GCMP in IEEE Std 802.11 are as follows:

- a) Data Confidentiality;
- b) Authentication; and
- c) Access control in conjunction with layer management.

BIP provides message integrity and access control for group addressed robust management frames.

During the authentication exchange, both parties exchange authentication information as described in Clause 11 and Clause 12.

The MAC sublayer security services provided by CCMP, GCMP, and BIP rely on information from nonlayer-2 management or system entities. Management entities communicate information to CCMP, GCMP, and BIP through a set of MAC sublayer management entity (MLME) interfaces and MIB attributes; in particular, the decision tree for CCMP, GCMP, and BIP defined in 11.8 is driven by MIB attributes.

5.2 MAC data service specification

5.2.2 MA-UNITDATA.request

5.2.2.2 Semantics of the service primitive

Change the fifth paragraph of 5.2.2.2 as follows:

The data parameter specifies the MSDU to be transmitted by the MAC sublayer entity. ~~For IEEE Std 802.11,~~ ~~the length of the MSDU shall be less than or equal to the value shown in Table 8-0a~~ Table 8-13c.

6. Layer management

6.1 Overview of management model

Insert the following paragraph after the third paragraph of 6.1:

The description of the VHT PHY in Clause 22 is provided as one layer and is not separated into PLCP and PMD sublayers.

6.3 MLME SAP interface

6.3.3 Scan

6.3.3.3 MLME-SCAN.confirm

6.3.3.3.2 Semantics of the service primitive

Insert the following rows at the end of the untitled table describing BSSDescriptions in 6.3.3.3.2:

Name	Type	Valid range	Description	IBSS adoption
VHT Capabilities	As defined in frame format	As defined in 8.4.2.160	The values from the VHT Capabilities element. The parameter is present if dot11VHTOptionImplemented is true and a VHT Capabilities element was present in the Probe Response or Beacon frame from which the BSSDescription was determined. The parameter is not present otherwise.	Do not adopt
VHT Operation	As defined in frame format	As defined in 8.4.2.161	The values from the VHT Operation element. The parameter is present if dot11VHTOptionImplemented is true and a VHT Operation element was present in the Probe Response or Beacon frame from which the BSSDescription was determined. The parameter is not present otherwise.	Adopt

6.3.4 Synchronize

6.3.4.2 MLME-JOIN.request

6.3.4.2.2 Semantics of the service primitive

Change the primitive parameter list in 6.3.4.2.2 as follows:

The primitive parameters are as follows:

MLME-JOIN.request(
 SelectedBSS,
 JoinFailureTimeout,
 ProbeDelay,
 OperationalRateSet,
 HTOperationalMCSSet,

OperationalVHTMCS NSSSet,
VendorSpecificInfo
)

Insert the following row before the VendorSpecificInfo row in the parameter table in 6.3.4.2.2:

Name	Type	Valid range	Description
OperationalVHTMCS_NSSSet	Set of <VHT-MCS, NSS> tuples, constrained so that the MCS values are expressible using the encoding described for the Supported VHT-MCS and NSS Set field in 8.4.2.160.3	As defined in the Rx VHT-MCS Map and Rx Highest Supported Long GI Data Rate subfields in the Supported VHT-MCS and NSS Set field in 8.4.2.160.3	The set of VHT-MCS values for each number of spatial streams that the STA desires to use for communication within the BSS. This set is a superset of the <VHT-MCS, NSS> tuples in the BSS basic VHT-MCS and NSS set (see 10.39.7). The parameter is present if dot11VHTOptionImplemented is true and not present otherwise.

6.3.4.2.4 Effect of receipt

Insert the following paragraph at the end of 6.3.4.2.4:

If the MLME of a VHT STA receives an MLME-JOIN.request primitive with a SelectedBSS parameter containing a BSSDescription with a Basic VHT-MCS and NSS Set field in the VHT Operation element that contains any unsupported <VHT-MCS, NSS> tuple, the MLME response in the resulting MLME-JOIN.confirm primitive shall contain a ResultCode parameter that is not set to the value SUCCESS.

6.3.7 Associate

6.3.7.2 MLME-ASSOCIATE.request

6.3.7.2.2 Semantics of the service primitive

Change the primitive parameter list in 6.3.7.2.2 as follows:

The primitive parameters are as follows:

```
MLME-ASSOCIATE.request(
    PeerSTAAddress,
    AssociateFailureTimeout,
    CapabilityInformation,
    ListenInterval,
    Supported Channels,
    RSN,
    QoSCapability,
    Content of FT Authentication elements,
    SupportedOperatingClasses,
    HT Capabilities,
    Extended Capabilities,
    20/40 BSS Coexistence,
    QoSTrafficCapability,
    TIMBroadcastRequest,
    EmergencyServices,
    DMG Capabilities,
    Multi-band local,
    Multi-band peer,
    MMS,
```

VHT Capabilities,
VendorSpecificInfo
)

Insert the following row before the VendorSpecificInfo row in the parameter table in 6.3.7.2.2:

Name	Type	Valid range	Description
VHT Capabilities	As defined in VHT Capabilities element	As defined in 8.4.2.160	Specifies the parameters in the VHT Capabilities element that are supported by the STA. The parameter is present if dot11VHTOptionImplemented is true and not present otherwise.

6.3.7.3 MLME-ASSOCIATE.confirm

6.3.7.3.2 Semantics of the service primitive

Change the primitive parameter list in 6.3.7.3.2 as follows:

The primitive parameters are as follows:

```
MLME-ASSOCIATE.confirm(
    ResultCode,
    CapabilityInformation,
    AssociationID,
    SupportedRates,
    EDCAPParameterSet,
    RCPI.request,
    RSNi.request,
    RCPI.response,
    RSNi.response,
    RMEEnabledCapabilities,
    Content of FT Authentication elements,
    SupportedOperatingClasses,
    HT Capabilities,
    Extended Capabilities,
    20/40 BSS Coexistence,
    TimeoutInterval,
    BSSMaxIdlePeriod,
    TIMBroadcastResponse,
    QoSMapSet,
    QMFPolicy,
    DMG Capabilities,
    Multi-band local,
    Multi-band peer,
    MMS,
    VHT Capabilities,
    VendorSpecificInfo
)
```