

**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 2: Sub 1 GHz License Exempt Operation

IEEE Computer Society

Sponsored by the
LAN/MAN Standards Committee

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

IEEE Std 802.11ah™-2016
(Amendment to IEEE Std 802.11™-2016
as amended by IEEE Std 802.11ai™-2016)

**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 2: Sub 1 GHz License Exempt
Operation**

Sponsor

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

Approved 7 December 2016

IEEE-SA Standards Board

Abstract: Modifications to both the IEEE 802.11™ physical layer (PHY) and the medium access control (MAC) sublayer to enable operation of license-exempt IEEE 802.11 wireless networks in frequency bands below 1 GHz, excluding the television (TV) White Space bands, with a transmission range up to 1 km and a minimum data rate of at least 100 Kb/s are defined in this amendment.

Keywords: IEEE 802.11ah™, long transmission range, low power consumption, MAC, medium access control, narrower bandwidth, OFDM, orthogonal frequency division multiplexing, PHY, physical layer, sub 1 GHz, wireless local area network, WLAN

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

Copyright © 2017 by The Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 5 May 2017. 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.

Print: ISBN 978-1-5044-3911-4 STD22509
PDF: ISBN 978-1-5044-3912-1 STDPD22509

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 Notices and Disclaimers Concerning IEEE Standards Documents.” They can also be obtained on request from IEEE or viewed at <http://standards.ieee.org/TPR/disclaimers.html>.

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. IEEE Standards are documents developed through scientific, academic, and industry-based technical working groups. Volunteers in IEEE working groups 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 Standards do not guarantee or ensure safety, security, health, or environmental protection, or ensure against interference with or from other devices or networks. Implementers and users 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.

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> 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 amendment was sent to sponsor ballot, the IEEE 802.11 Working Group had the following officers:

Adrian P. Stephens, *Chair*
Jon W. Rosdahl, *1st Vice Chair*
Dorothy Stanley, *2nd Vice Chair*
Stephen McCann, *Secretary*

The officers and members of the Task Group ah Working Group ballot pool are as follows:

Yongho Seok, *Chair and Co-Technical Editor*
(**David Halasz**, *Former Chair*)
Alfred Asterjadhi, *1st Vice Chair and Technical Editor*
Zander (Zhongding) Lei, *2nd Vice Chair and Secretary*
(**Minyoung Park**, *Former Technical Editor*)

Osama S. Aboulmagd	Li Chia Chia Choo	Ahmadreza Hedayat
Santosh P. Abraham	Sayantan Choudhury	Carolyn Heide
Carlos H. Aldana	Liwen Chu	Robert F. Heile
Thomas Alexander	Jinyoung Chun	Jerome Henry
Yaron Alpert	John Coffey	Guido R. Hiertz
Tsuguhide Aoki	Kenneth Coop	Wei Hong
Sirikiat Lek Ariyavisitakul	Carlos Cordeiro	Jing-Rong Hsieh
Lee R. Armstrong	Neiyer Correal	Chunyu Hu
Yusuke Asai	Subir Das	David Hunter
Alfred Asterjadhi	Rolf J. de Vegt	Yasuhiko Inoue
Arthur W. Astrin	Michael Denson	Koichi Ishihara
Kwok Shum Au	Thomas Derham	Mitsuru Iwaoka
Vijay Auluck	Xiandong Dong	Amin Jafarian
Stefan Aust	Klaus Doppler	Chanyong Jeong
Shahrnaz Azizi	Roger P. Durand	Yangseok Jeong
Eugene Baik	Donald E. Eastlake	Nihar Jindal
Phillip Barber	Peter Ecclesine	Allan Jones
Gwendolyn Barriac	Richard Edgar	V. K. Jones
Alan Berkema	Marc Emmelmann	Seong-soon Joo
Nehru Bhandaru	Iksoo Eo	Kaushik Josiam
Andre Bourdoux	Vinko Erceg	Carl W. Kain
John Buffington	Ping Fang	Naveen K. Kakani
Lin Cai	Yonggang Fang	Hyunduk Kang
George Calcev	Stanislav Filin	Hyunjeong Kang
Chris Calvert	Norman Finn	Richard H. Kennedy
Radhakrishna Canchi	Matthew J. Fischer	John Kenney
Laurent Cariou	P. Flynn	Stuart J. Kerry
William Carney	Dan Gal	Eunkyung Kim
Kim Chang	Chittabrata Ghosh	Hongsoog Kim
Kuor-Hsin Chang	James P. K. Gilb	Jaehwan Kim
Sanghyun Chang	Matthew Gillmore	Jeongki Kim
Xin Chang	David Goodall	Joonsuk Kim
Clint F. Chaplin	Stephen Grau	Sang Gook Kim
Jiamin Chen	Michael Grigat	Sangkyun Kim
Qian Chen	Russell Haines	Suhwook Kim
Minho Cheong	David Halasz	Youhan Kim
George Cherian	Mark Hamilton	Youngsoo Kim
Zhipei Chi	Christopher J. Hansen	Akira Kishida
Francois Chin	Peng Hao	Shoichi Kitazawa
Rojan Chitrakar	Daniel N. Harkins	Jarkko Knecht
Hangyu Cho	Brian D. Hart	Gwangzeen Ko
Jee-Yon Choi	Chris Hartman	Fumihide Kojima
Jinsoo Choi	Victor Hayes	Tom Kolze

Timo Koskela
Igal Kotzer
Bruce P. Kraemer
Maciej Krasicki
G. Rajendra Kumar
Jin-Sam Kwak
Joseph Kwak
Hyoungjin Kwon
Young Hoon Kwon
Paul Lambert
Zhou Lan
James Lansford
Jean-Pierre Le Rouzic
Ilgu Lee
Jae Seung Lee
Jehun Lee
Wookbong Lee
Yuro Lee
Zhongding Lei
James Lepp
Wai Kong Leung
Joseph Levy
Dejian Li
Feng Li
Guoqing Li
Honggang Li
Huan-Bang Li
Jing Li
Liang Li
Yunbo Li
Zhiqiang Li
Dong Guk Lim
Chih-Che Lin
Lu Liru
Dapeng Liu
Jianhan Liu
Pei Liu
Yong Liu
Peter Loc
Hui-Ling Lou
Su Lu
Yi Luo
Zhendong Luo
Kaiying Lv
Michael Lynch
Jouni K. Malinen
Hiroshi Mano
James Marin
Roger Marks
Stephen McCann
Simone Merlin
Filip Mestanov
James Miller
Yasunao Misawa
Apurva Mody
Michael Montemurro
Kenichi Mori
Hitoshi Morioka
Ronald Murias
Rick Murphy
Andrew Myles
Hiroki Nakano

Sai Shankar Nandagopalan
Chiu Ngo
Paul Nikolich
Hiroyo Ogawa
Jong-Ee Oh
Min-Seok Oh
Santosh Pandey
Thomas Pare
Giwon Park
Jaewoo Park
Minyoung Park
Glenn Parsons
Xiaoming Peng
Eldad Perahia
Xavier Perez Costa
James E. Petranovich
Albert Petrick
John Petro
Walter Pienciak
Xu Ping
Juho Pirskanen
Khiam Boon Png
Steve Pope
Ron Porat
Rethnakaran Pulikkoonattu
Chang-Woo Chang Pyo
Emily H. Qi
Fei Qin
Verotiana Rabarijaona
Demir Rakanovic
Harish Ramamurthy
Stephen G. Rayment
Ivan Reede
Edward Reuss
Maximilian Riegel
Mark Rison
Zhigang Rong
Jon W. Rosdahl
Richard Roy
Cheol Ryu
Kiseon Ryu
Bahareh Sadeghi
Kazuyuki Sakoda
Hemanth Sampath
Sigurd Schelstraete
Jean Schwoerer
Jonathan Segev
Cristina Seibert
Yongho Seok
Kunal Shah
Huairong Shao
Stephen J. Shellhammer
Ian Sherlock
Qicai Shi
Nobuhiko Shibagaki
Shusaku Shimada
Tsuyoshi Shimomura
Wooram Shin
Michael Sim
Robert Slater
Graham Kenneth Smith
Ju-Hyung Son

Myung Sun Sun Song
Sudhir Srinivasa
Robert Stacey
Dorothy Stanley
Adrian P. Stephens
Rene Struik
Jung Hoon Suh
Bo Sun
Sheng Sun
Yakun Sun
Kazuaki Takahashi
Mineo Takai
Yasushi Takatori
Sagar Tamhane
Rakesh Taori
Thomas Tetzlaff
Bin Tian
Tong Tian
Jens Tingleff
Fei Tong
Ha Nguyen Tran
Kazuyoshi Tsukada
Masahiro Umehira
Allert Van Zelst
Lorenzo Vangelista
Prabodh Varshney
Ganesh Venkatesan
Sameer Vermani
Dalton T. Victor
George A. Vlantis
Chao Chun Wang
Haiguang Wang
Haiming Wang
James June Wang
Lei Wang
Qi Wang
Xuehuan Wang
Lisa Ward
Fujio Watanabe
Menzo M. Wentink
Leif Wilhelmsson
Christopher Williams
Eun Tae Won
Eric Wong
Tianyu Wu
Mingguang Xu
Akira Yamada
Guang-Qi Yang
Lin Yang
Meng Yang
Rongzhen Yang
Xun Yang
Xun Yang
Yunsong Yang
James Yee
Peter Yee
Hujun Yin
S. K. Yong
Christopher Young
Chang Wahn Yu
Tevfik Yucek
Guangrong Yue

Katsuo D. A. Yunoki
Hongyuan Zhang
Jiayin Zhang
Yan Zhang
Mu Zhao

Jun Zheng
Shoukang Zheng
Mingtuo Zhou
Yuan Zhou
Chunhui Zhu

Hufei Zhu
Yan Zhuang
Lan Zhuo
Wei-Xia Zou
Juan Carlos Zuniga

Major contributions were received from the following individuals:

Alfred Asterjadhi
Stefan Aust
Shahnaz Azizi
Eugene Baik
Raja Banerjee
George Calcev
Minho Cheong
Rojan Chitrakar
Jinsoo Choi
Li-Chia Choo
Liwen Chu
Rolf J. de Vegt
Klaus Doppler
Matthew J. Fischer
Chittabrata Ghosh
Daning Gong
David Halasz
Mark A. Hamilton
Anh Tuan Hoang
Po-Kai Huang
Mitsuru Iwaoka

Amin Jafarian
Jeongki Kim
Young Hoon Kwon
James Lansford
Jae Seung Lee
Zhongding Lei
Jianhan Liu
Yong Liu
Kaiying Lv
Simone Merlin
Kenichi Mori
Ronald Murias
Anna Pantelidou
Minyoung Park
Jaya Shankar Pathmasuntharam
Ron Porat
Yongho Seok
Huairong Shao
Shusaku Shimada
Jae-Hyung Song
Bo Sun

Joseph Teo
Bin Tian
Fei Tong
Masahiro Umehira
Sameer Vermani
Chao Chun Wang
Haiguang Wang
James June Wang
Lin Wang
Xiaofei Wang
Menzo M. Wentink
Eric Wong
Mingguang Xu
Xun Yang
Wai-Leong Yeow
Heejung Yu
Hongyuan Zhang
Wu Zhanji
Mu Zhao
Shoukang Zheng
Yuan Zhou

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

Osama S. Aboulmagd
Tomoko Adachi
Thomas Alexander
Richard Alfvén
Nobumitsu Amachi
Carol Ansley
Butch Anton
Yusuke Asai
Alfred Asterjadhi
Stefan Aust
Gabor Bajko
Tuncer Baykas
Harry Bims
Gennaro Boggia
Nancy Bravin
Jairo Bustos Heredia
William Byrd
Cagatay Capar
William Carney
Juan Carreon
Minho Cheong
Paul Chiuchiolo
Hangyu Cho
Sayantan Choudhury
Keith Chow
Charles Cook
Todor Cooklev
Yezid Donoso
Malcolm Dowse

Sourav Dutta
Richard Edgar
Marc Emmelmann
David Evans
Matthew J. Fischer
Michael Fischer
Avraham Freedman
Devon Gayle
Tim Godfrey
Joel Goergen
Randall Groves
Michael Gundlach
Russell Haines
David Halasz
Mark Hamilton
Jerome Henry
Marco Hernandez
Guido R. Hiertz
Werner Hoelzl
David Hunter
Tetsushi Ikegami
Noriyuki Ikeuchi
Yasuhiko Inoue
Sergiu Iordanescu
Akio Iso
Atsushi Ito
Raj Jain
V. K. Jones
Adri Jovin

Naveen K. Kakani
Shinkyoo Kaku
Hyunjeong Kang
Piotr Karocki
Ruediger Kays
Jeritt Kent
Stuart J. Kerry
Youhan Kim
Patrick Kinney
Bruce P. Kraemer
Yasushi Kudoh
Paul Lambert
Jeremy Landt
Hyeong Ho Lee
Zhongding Lei
James Lepp
Joseph Levy
Arthur H. Light
Ru Lin
William Lumpkins
Michael Lynch
Chris Lytle
Elvis Maculuba
Jouni K. Malinen
Hiroshi Mano
James Marin
Stephen McCann
Michael McInnis
Filip Mestanov

Michael Montemurro
 Jose Morales
 Ronald Murias
 Rick Murphy
 Andrew Myles
 Juichi Nakada
 Michael Newman
 Chiu Ngo
 Nick S. A. Nikjoo
 Paul Nikolich
 John Notor
 Satoshi Obara
 Robert O'Hara
 Yoshihiro Ohba
 Satoshi Oyama
 Stephen Palm
 Arumugam Paventhan
 Clinton Powell
 Venkatesha Prasad
 Verotiana Rabarijaona
 Maximilian Riegel
 Robert Robinson

Benjamin Rolfe
 Jon W. Rosdahl
 Osman Sakr
 Shigenobu Sasaki
 Naotaka Sato
 Bartien Sayogo
 Andy Scott
 Yongho Seok
 Kunal Shah
 Ian Sherlock
 Shusaku Shimada
 Graham Kenneth Smith
 Daniel Smolinski
 Ju-Hyung Son
 Kapil Sood
 Dorothy Stanley
 Thomas Starai
 Adrian P. Stephens
 Rene Struik
 Walter Struppler
 Mark Sturza
 Michael Swearingen
 Jun Ichi Takada

Rakesh Taori
 Payam Torab
 Ha Nguyen Tran
 Kazuyoshi Tsukada
 Mark-Rene Uchida
 Lorenzo Vangelista
 Allert Van Zelst
 Dmitri Varsanofiev
 Prabodh Varshney
 George A. Vlantis
 Khurram Waheed
 Haiming Wang
 James June Wang
 Lei Wang
 Xiaofei Wang
 Hung-Yu Wei
 Menzo Wentink
 Chun Yu Charles Wong
 Oren Yuen
 Hongyuan Zhang
 Shoukang Zheng
 Zhen Zhou

When the IEEE-SA Standards Board approved this amendment on 7 December 2016, it had the following membership:

Jean-Philippe Faure, *Chair*
Ted Burse, *Vice Chair*
John D. Kulick, *Past Chair*
Konstantinos Karachalios, *Secretary*

Chuck Adams
 Masayuki Ariyoshi
 Stephen Dukes
 Jianbin Fan
 J. Travis Griffith
 Gary Hoffman

Ronald W. Hotchkiss
 Michael Janezic
 Joseph L. Koepfinger*
 Hung Ling
 Kevin Lu
 Annette D. Reilly
 Gary Robinson

Mehmet Ulema
 Yingli Wen
 Howard Wolfman
 Don Wright
 Yu Yuan
 Daidi Zhong

*Member Emeritus

Introduction

This introduction is not part of IEEE Std 802.11ah-2016, IEEE Standard for Information technology—Telecommunications and information exchange between systems—Local and metropolitan area network—Specific requirements—Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications—Amendment 2: Sub 1 GHz License-Exempt Operation.

This amendment defines modifications to both the IEEE 802.11™ physical layer (PHY) and the medium access control (MAC) sublayer to enable operation of license-exempt IEEE 802.11 wireless networks in frequency bands below 1 GHz, excluding the television (TV) White Space bands, with a transmission range up to 1 km and a minimum data rate of at least 100 Kb/s.

Contents

3.	Definitions, acronyms, and abbreviations.....	33
3.2	Definitions specific to IEEE 802.11	33
3.4	Abbreviations and acronyms	37
4.	General description	38
4.3	Components of the IEEE 802.11 architecture	38
4.3.13a	Sub 1 GHz (S1G) STA	38
4.3.13a.1	Overview.....	38
4.3.13a.2	S1G Relay	39
5.	MAC service definition	40
5.1	Overview of MAC services	40
5.1.2	Security services	40
5.1.5	MAC data service architecture	40
5.1.5.6	S1G Relay	40
6.	Layer management.....	42
6.3	MLME SAP interface	42
6.3.2	Power management.....	42
6.3.2.2	MLME-POWERMGT.request.....	42
6.3.3	Scan.....	42
6.3.3.2	MLME-SCAN.request.....	42
6.3.3.3	MLME-SCAN.confirm.....	44
6.3.4	Synchronization	47
6.3.4.2	MLME-JOIN.request.....	47
6.3.5	Authenticate.....	47
6.3.5.2	MLME-AUTHENTICATE.request.....	47
6.3.7	Associate.....	47
6.3.7.2	MLME-ASSOCIATE.request.....	47
6.3.7.3	MLME-ASSOCIATE.confirm	49
6.3.7.4	MLME-ASSOCIATE.indication	51
6.3.7.5	MLME-ASSOCIATE.response	53
6.3.8	Reassociate.....	56
6.3.8.2	MLME-REASSOCIATE.request	56
6.3.8.3	MLME-REASSOCIATE.confirm	59
6.3.8.4	MLME-REASSOCIATE.indication	62
6.3.8.5	MLME-REASSOCIATE.response	65
6.3.11	Start.....	68
6.3.11.2	MLME-START.request.....	68
6.3.29	Block Ack	70
6.3.29.3	MLME-ADDBA.confirm	70
6.3.29.5	MLME-ADDBA.response.....	70
6.3.106	Dynamic AID assignment operation.....	71
6.3.106.1	General.....	71
6.3.106.2	MLME-AIDSWITCH.request	71
6.3.106.3	MLME-AIDSWITCH.confirm	72
6.3.106.4	MLME-AIDSWITCH.indication.....	72
6.3.106.5	MLME-AIDSWITCH.response.....	73
6.3.107	Sync Control	74
6.3.107.1	General.....	74
6.3.107.2	MLME-SYNCCONTROL.request	74
6.3.107.3	MLME-SYNCCONTROL.indication.....	75

6.3.108	STA Information Announcement	75
6.3.108.1	General	75
6.3.108.2	MLME-STAINFORMATION.request	75
6.3.108.3	MLME-STAINFORMATION.indication	76
6.3.109	EDCA Parameter Set update	77
6.3.109.1	General	77
6.3.109.2	MLME-EDCAPARAMETERSET.request	77
6.3.109.3	MLME-EDCAPARAMETERSET.indication	77
6.3.110	EL Operation	78
6.3.110.1	General	78
6.3.110.2	MLME-ELOPERATION.request	78
6.3.110.3	MLME-ELOPERATION.indication	79
6.3.111	TWT Setup	79
6.3.111.1	General	79
6.3.111.2	MLME-TWTSETUP.request	79
6.3.111.3	MLME-TWTSETUP.confirm	80
6.3.111.4	MLME-TWTSETUP.indication	81
6.3.111.5	MLME-TWTSETUP.response	82
6.3.112	TWT Teardown	82
6.3.112.1	General	82
6.3.112.2	MLME-TWTTEARDOWN.request	82
6.3.112.3	MLME-TWTTEARDOWN.indication	83
6.3.113	Sectorized Group ID List management	84
6.3.113.1	General	84
6.3.113.2	MLME-SECTORIZEDGROUPID.request	84
6.3.113.3	MLME-SECTORIZEDGROUPID.indication	84
6.3.114	Header Compression procedure	85
6.3.114.1	General	85
6.3.114.2	MLME-HEADERCOMPRESSION.request	85
6.3.114.3	MLME-HEADERCOMPRESSION.confirm	86
6.3.114.4	MLME-HEADERCOMPRESSION.indication	87
6.3.114.5	MLME-HEADERCOMPRESSION.response	87
6.3.115	Reachable Address Update	88
6.3.115.1	General	88
6.3.115.2	MLME-REACHABLEADDRESSUPDATE.request	88
6.3.115.3	MLME-REACHABLEADDRESSUPDATE.indication	89
6.3.116	Control response MCS negotiation operation	90
6.3.116.1	General	90
6.3.116.2	MLME-CONTROLRESPONSEMCS.request	90
6.3.116.3	MLME-CONTROLRESPONSEMCS.confirm	90
6.3.116.4	MLME-CONTROLRESPONSEMCS.indication	91
6.3.116.5	MLME-CONTROLRESPONSEMCS.response	92
6.3.117	S1G Relay (de)activation	92
6.3.117.1	General	92
6.3.117.2	MLME-S1GRELAYACTIVATE.request	93
6.3.117.3	MLME-S1GRELAYACTIVATE.confirm	93
6.3.117.4	MLME-S1GRELAYACTIVATE.indication	94
6.3.117.5	MLME-S1GRELAYACTIVATE.response	95
6.5	PLME SAP interface	95
6.5.4	PLME-CHARACTERISTICS.confirm	95
6.5.4.2	Semantics of the service primitive	95
8.	PHY service specification	97
8.3	Detailed PHY service specifications	97

8.3.4	Basic service and options.....	97
8.3.4.4	Vector descriptions	97
8.3.5	PHY SAP detailed service specification.....	98
8.3.5.8	PHY-TXEND.confirm	98
8.3.5.12	PHY-CCA.indication	98
9.	Frame formats	100
9.2	MAC frame formats	100
9.2.2	Conventions	100
9.2.3	General frame format.....	100
9.2.4	Frame fields	100
9.2.4.1	Frame Control field.....	100
9.2.4.2	Duration/ID field.....	106
9.2.4.5	QoS Control field.....	107
9.2.4.6	HT Control field.....	108
9.2.4.7	Frame Body field	109
9.2.5	Duration/ID field (QoS STA)	110
9.2.5.1	General.....	110
9.2.5.2	Setting for single and multiple protection under enhanced distributed channel access (EDCA)	110
9.2.5.7	Setting for control response frames	112
9.3	Format of individual frame types.....	112
9.3.1	Control frames	112
9.3.1.1	Format of Control frames	112
9.3.1.5	PS-Poll frame format	114
9.3.1.6	CF-End frame format.....	114
9.3.1.20	VHT NDP Announcement frame format.....	115
9.3.1.22	TACK frame format.....	115
9.3.2	Data frames	116
9.3.2.1	Format of Data frames	116
9.3.2.2	Aggregate MSDU (A-MSDU) format	117
9.3.3	Management frames.....	118
9.3.3.1	Format of Management frames.....	118
9.3.3.6	Association Request frame format.....	118
9.3.3.7	Association Response frame format	119
9.3.3.8	Reassociation Request frame format	120
9.3.3.9	Reassociation Response frame format	121
9.3.3.10	Probe Request frame format	122
9.3.3.11	Probe Response frame format.....	123
9.3.4	Extension frames.....	124
9.3.4.3	SIg Beacon frame format	124
9.4	Management and Extension frame body components	126
9.4.1	Fields that are not elements	126
9.4.1.6	Listen Interval field.....	126
9.4.1.8	AID field	127
9.4.1.9	Status Code field	127
9.4.1.11	Action field	128
9.4.1.15a	Originator Preferred MCS field	128
9.4.1.33	Rate Identification field	129
9.4.1.48	VHT MIMO Control field	130
9.4.1.49	VHT Compressed Beamforming Report field	131
9.4.1.53	Operating Mode field.....	133
9.4.1.58	Sync Control field	134
9.4.1.59	Suspend Duration field	135

9.4.1.60	TWT Information field	135
9.4.2	Elements.....	136
9.4.2.1	General	136
9.4.2.6	TIM element	137
9.4.2.29	EDCA Parameter Set element.....	145
9.4.2.31	TCLAS element	147
9.4.2.46	Multiple BSSID element.....	152
9.4.2.79	BSS Max Idle Period element.....	152
9.4.2.82	WNM Sleep Mode element	153
9.4.2.161	Wide Bandwidth Channel Switch element	153
9.4.2.191	SIG Open-Loop Link Margin Index element.....	153
9.4.2.192	RPS element.....	154
9.4.2.193	Page Slice element.....	159
9.4.2.194	AID Request element.....	161
9.4.2.195	AID Response element	163
9.4.2.196	SIG Sector Operation element	164
9.4.2.197	SIG Beacon Compatibility element	166
9.4.2.198	Short Beacon Interval element.....	167
9.4.2.199	Change Sequence element	167
9.4.2.200	TWT element	167
9.4.2.201	SIG Capabilities element.....	173
9.4.2.202	Subchannel Selective Transmission (SST) element	183
9.4.2.203	Authentication Control element.....	185
9.4.2.204	TSF Timer Accuracy element.....	186
9.4.2.205	SIG Relay element	187
9.4.2.206	Reachable Address element	188
9.4.2.207	SIG Relay Activation element	189
9.4.2.208	SIG Relay Discovery element.....	190
9.4.2.209	AID Announcement element	192
9.4.2.210	PV1 Probe Response Option element.....	192
9.4.2.211	EL Operation element.....	197
9.4.2.212	Sectorized Group ID List element	197
9.4.2.213	SIG Operation element.....	198
9.4.2.214	Header Compression element	199
9.4.2.215	SST Operation element.....	201
9.4.2.216	MAD element	201
9.6	Action frame format details	202
9.6.4	DLS Action frame details	202
9.6.4.2	DLS Request frame format	202
9.6.4.3	DLS Response frame format.....	202
9.6.5	Block Ack Action frame details.....	203
9.6.5.1	General	203
9.6.5.2	ADDBA Request frame format	203
9.6.5.3	ADDBA Response frame format.....	203
9.6.5.4	DELBA frame format	204
9.6.8	Public Action details	204
9.6.8.7	Extended Channel Switch Announcement frame format	204
9.6.13	TDLS Action field formats	205
9.6.13.1	TDLS Setup Request Action field format.....	205
9.6.13.3	TDLS Setup Response Action field format	205
9.6.13.4	TDLS Setup Confirm Action field format.....	206
9.6.23	VHT Action frame details.....	206
9.6.23.1	VHT Action field.....	206
9.6.25	Unprotected SIG Action frame details	206

9.6.25.1	Unprotected S1G Action field	206
9.6.25.2	AID Switch Request frame format	207
9.6.25.3	AID Switch Response frame format	207
9.6.25.4	Sync Control frame format	208
9.6.25.5	STA Information Announcement frame format	208
9.6.25.6	EDCA Parameter Set frame format	209
9.6.25.7	EL Operation frame format	209
9.6.25.8	TWT Setup frame format	210
9.6.25.9	TWT Teardown frame format	210
9.6.25.10	Sectorized Group ID List frame format	211
9.6.25.11	Sector ID Feedback frame format	211
9.6.25.12	TWT Information frame format	212
9.6.26	S1G Action frame details	213
9.6.26.1	S1G Action field	213
9.6.26.2	Reachable Address Update frame format	213
9.6.26.3	Relay Activation Request frame format	214
9.6.26.4	Relay Activation Response frame format	214
9.6.26.5	Header Compression frame format	215
9.6.27	Flow Control Action frame details	215
9.6.27.1	Flow Control Action field	215
9.6.27.2	Flow Suspension frame format	216
9.6.27.3	Flow Resumption frame format	216
9.6.28	Control Response MCS Negotiation frame details	217
9.6.28.1	Control Response MCS Negotiation Action field	217
9.6.28.2	Control Response MCS Negotiation Request frame format	217
9.6.28.3	Control Response MCS Negotiation Response frame format	218
9.7	Aggregate MPDU (A-MPDU)	218
9.7.3	A-MPDU contents	218
9.8	MAC frame format for PV1 frames	219
9.8.1	Basic components	219
9.8.2	General PV1 frame format	220
9.8.3	PV1 frame fields	220
9.8.3.1	Frame Control field	220
9.8.3.2	Address fields	222
9.8.3.3	Sequence Control field	223
9.8.3.4	Frame Body field	223
9.8.3.5	Overhead for encryption	223
9.8.3.6	FCS field	223
9.8.4	PV1 Control frames	224
9.8.4.1	General	224
9.8.4.2	STACK frame format	224
9.8.4.3	BAT frame format	225
9.8.5	PV1 Management frames	226
9.8.5.1	Format of PV1 Management frames	226
9.8.5.2	Action and Action No Ack frames	227
9.8.5.3	PV1 Probe Response frame format	227
9.8.5.4	Resource Allocation frame format	229
9.9	NDP CMAC frames	231
9.9.1	General	231
9.9.2	NDP control frame details	232
9.9.2.1	NDP CTS	232
9.9.2.2	NDP CF-End	234
9.9.2.3	NDP PS-Poll	235
9.9.2.4	NDP Ack	237

9.9.2.5	NDP PS-Poll-Ack	238
9.9.2.6	NDP BlockAck	239
9.9.2.7	NDP Beamforming Report Poll	241
9.9.2.8	NDP Paging	241
9.9.3	NDP management frame details	242
9.9.3.1	NDP Probe Request	242
10.	MAC sublayer functional description	245
10.2	MAC architecture	245
10.2.1	General	245
10.2.4	Hybrid coordination function (HCF)	246
10.2.4.1	General	246
10.2.4.2	HCF contention-based channel access (EDCA)	246
10.2.7	Fragmentation/defragmentation overview	247
10.2.8	MAC data service	247
10.3	DCF	248
10.3.2	Procedures common to the DCF and EDCAF	248
10.3.2.1	CS mechanism	248
10.3.2.3	IFS	249
10.3.2.4	Setting and resetting the NAV	250
10.3.2.4a	Setting and resetting the RID	251
10.3.2.6	VHT and S1G RTS procedure	254
10.3.2.7	CTS and DMG CTS procedure	254
10.3.2.8	Dual CTS protection	256
10.3.2.9	Acknowledgment procedure	256
10.3.2.9a	Fragment BA procedure	258
10.3.2.11	Duplicate detection and recovery	259
10.3.2.12	NAV distribution	261
10.3.2.14	Response Indication procedure	261
10.3.6	Group addressed MPDU transfer procedure	263
10.3.7	DCF timing relations	263
10.7	Multirate support	264
10.7.5	Rate selection for Data and Management frames	264
10.7.5.1	Rate selection for non-STBC Beacon and non-STBC PSMP frames	264
10.7.5.3	Rate selection for other group addressed Data and Management frames	264
10.7.5.7	Rate selection for other individually addressed Data and Management frame	264
10.7.6	Rate selection for Control frames	266
10.7.6.1	General rules for rate selection for Control frames	266
10.7.6.4	Rate selection for Control frames that are not control response frames	266
10.7.6.5	Rate selection for control response frames	266
10.7.6.6	Channel Width selection for Control frames	269
10.7.11	Channel Width in non-HT and non-HT duplicate PPDU's	270
10.7.13	Rate selection constraints for S1G STAs	270
10.7.13.1	RX supported S1G-MCS and NSS set	270
10.7.13.2	Tx Supported S1G-MCS and NSS Set	271
10.7.13.3	Additional rate selection constraints for S1G PPDU's	271
10.9	HT Control field operation	272
10.12A	MSDU operation	272
10.13A	MPDU operation	273
10.13.1	A-MPDU contents	273
10.13.2	A-MPDU length limit rules	273
10.13.3	Minimum MPDU Start Spacing field	274
10.13.4	A-MPDU aggregation of group addressed Data frames	274

10.13.5	Transport of A-MPDU by the PHY data service	275
10.13.6	A-MPDU padding for VHT PPDU or SIG PPDU	275
10.13.7	Setting the EOF field of the MPDU delimiter	276
10.14	PPDU duration constraint	276
10.16	LDPC operation	276
10.17	STBC operation	276
10.18	Short GI operation	277
10.20a	SIG dynamic AID assignment operation.....	278
10.20b	Group ID, partial AID, Uplink Indication, and COLOR in SIG PPDU	279
10.22	HCF	282
10.22.1	General	282
10.22.2	HCF contention based channel access (EDCA)	282
10.22.2.1	Reference model	282
10.22.2.2	EDCA backoff procedure	282
10.22.2.3	EDCA TXOPs.....	283
10.22.2.4	Obtaining an EDCA TXOP	283
10.22.2.5a	EDCA channel access in an SIG BSS	283
10.22.2.6	Sharing an EDCA TXOP	284
10.22.2.7	Multiple frame transmission in an EDCA TXOP	285
10.22.2.8	TXOP limits	285
10.22.2.9	Truncation of TXOP	286
10.22.3	HCF controlled channel access (HCCA)	287
10.22.3.1	General	287
10.22.5	Restricted Access Window (RAW) operation	288
10.22.5.1	General	288
10.22.5.2	RAW structure and timing	289
10.22.5.3	Slot assignment procedure in RAW	290
10.22.5.4	Slotted channel access procedure in RAW	291
10.22.5.5	EDCA backoff procedure in generic RAW or triggering frame RAW ...	292
10.22.5.6	EDCA backoff procedure in RAWs other than generic or triggering frame RAW	293
10.22.5.7	RAW Operation with Resource Allocation frame	293
10.22.5.8	Periodic RAW (PRAW) operation	294
10.24	Block acknowledgment (block ack)	295
10.24.1	Introduction.....	295
10.24.2	Setup and modification of the block ack parameters	295
10.24.5	Teardown of the block ack mechanism	297
10.24.6	Selection of BlockAck and BlockAckReq variants	297
10.24.7	HT-immediate block ack extensions.....	298
10.24.7.3	Scoreboard context control during full-state operation	298
10.24.7.4	Scoreboard context control during partial-state operation.....	298
10.24.7.5	Generation and transmission of BlockAck frames by an HT STA, or DMG STA, or SIG STA	298
10.24.7.7	Originator's behavior	299
10.24.8	HT-delayed block ack extensions	300
10.24.8.2	HT-delayed block ack negotiation	300
10.28	Reverse direction protocol	300
10.28.1	General	300
10.28.2	Reverse direction (RD) exchange sequence	300
10.28.3	Rules for RD initiator	300
10.28.4	Rules for RD responder	301
10.29	PSMP operation	301
10.29.1	General	301
10.31	Link adaptation	301

10.31.1	Introduction.....	301
10.31.3	Link adaptation using the VHT variant HT Control field	301
10.34	Null data packet (NDP) sounding.....	303
10.34.5	VHT sounding protocol	303
10.34.5.1	General.....	303
10.34.5.2	Rules for VHT sounding protocol sequences	303
10.34.7	Transmission of an S1G NDP Sounding Frame	303
10.42	S1G BSS operation	304
10.42.1	Basic S1G BSS functionality.....	304
10.42.2	System information update procedure	306
10.42.3	S1G BSS channel selection methods.....	306
10.42.4	S1G BSS channel switching methods.....	307
10.42.5	Scanning requirements for S1G STA	307
10.42.6	NAV and RID assertion in an S1G BSS.....	307
10.42.7	BSS basic S1G-MCS and NSS set operation.....	308
10.42.8	S1G coexistence with non-IEEE-802.11 systems.....	308
10.43	Target wake time (TWT)	309
10.43.1	TWT overview.....	309
10.43.2	TWT acknowledgment procedure	311
10.43.3	Explicit TWT operation	312
10.43.4	Implicit TWT operation	314
10.43.5	TWT grouping	314
10.43.6	NDP Paging Setup	315
10.43.7	TWT Sleep Setup.....	317
10.43.8	TWT Teardown.....	317
10.44	Non-TIM STA operation	317
10.44.1	Resource protection for non-TIM STAs	317
10.44.1.1	General.....	317
10.44.1.2	Resource protection for non-TIM STAs using periodic RAW (PRAW) operation	318
10.44.2	Rescheduling of awake/doze cycle	319
10.45	Synchronization (Sync) frame operation	320
10.45.1	Sync frame transmission procedure for uplink traffic	320
10.46	Bidirectional TXOP	322
10.46.1	Overview.....	322
10.46.2	Rules for BDT.....	322
10.47	Page Slicing	324
10.48	Subchannel Selective Transmission (SST).....	327
10.48.1	SST overview.....	327
10.48.2	Aperiodic SST operation	327
10.48.3	Periodic SST Operation	330
10.49	Sectorized beam operation.....	331
10.49.1	Introduction.....	331
10.49.2	Sector Capabilities Exchange	331
10.49.3	Group sectorization operation.....	332
10.49.4	TXOP-based sectorization operation.....	333
10.49.5	Sector training operation.....	338
10.49.5.1	Introduction.....	338
10.49.5.2	Procedure	338
10.49.5.3	Sector ID feedback.....	340
10.49.5.4	Fast Sector Discovery	340
10.50	S1G Relay operation.....	340
10.50.1	General.....	340
10.50.2	S1G Relay operation	341

10.50.3	Addressing and forwarding of individually addressed relay frames	343
10.50.4	Addressing and forwarding of group addressed relay frames	344
10.50.5	Procedures of TXOP sharing for S1G relay operation	345
10.50.5.1	General	345
10.50.5.2	Explicit Ack procedure	346
10.50.5.3	Implicit Ack procedure	347
10.50.5.4	Relay-shared TXOP protection mechanisms	348
10.50.6	S1G Relay discovery procedure	349
10.51	Group AID	349
10.52	Traveling Pilot Operation	350
10.53	Bitmap Protection for NDP BlockAck frames	351
10.54	Generation of PVI MPDUs and header compression procedure	351
10.55	Transmission of an S1G NDP CMAC frame.....	353
10.56	S1G_Long operation.....	353
10.57	S1G flow control.....	353
10.58	Energy limited STAs operation	354
10.59	S1G BSS type and STA type	356
11.	MLME	357
11.1	Synchronization	357
11.1.2	Basic approach.....	357
11.1.2.1	TSF for an infrastructure BSS or a PBSS	357
11.1.2.2	TSF for an IBSS.....	357
11.1.3	Maintaining synchronization	357
11.1.3.2	Beacon generation in non-DMG infrastructure networks.....	357
11.1.3.5	Beacon generation in an IBSS	358
11.1.3.8	Multiple BSSID procedure	358
11.1.3.10	Maintaining synchronization using S1G Beacon frames.....	359
11.1.4	Acquiring synchronization, scanning	360
11.1.4.3	Active scanning.....	360
11.1.4.4	Initializing a BSS	363
11.1.5	Adjusting STA timers	363
11.1.6	Terminating a BSS.....	364
11.2	Power management.....	364
11.2.3	Power management in a non-DMG infrastructure network.....	364
11.2.3.1	General	364
11.2.3.2	Non-AP STA power management modes.....	366
11.2.3.3	AP TIM transmissions	367
11.2.3.4	TIM types.....	368
11.2.3.6	AP operation during the CP	368
11.2.3.8	Receive operation for STAs in PS mode during the CP	369
11.2.3.20	AP Power management.....	370
11.3	STA authentication and association.....	371
11.3.5	Association, reassociation, and disassociation	371
11.3.5.11	Service characteristic indication during association.....	371
11.3.9	Authentication Control	372
11.3.9.1	General	372
11.3.9.2	Centralized authentication control	372
11.3.9.3	Distributed authentication control	373
11.5	Block ack operation	374
11.5.2	Setup and modification of the block ack parameters.....	374
11.5.2.2	Procedure at the originator.....	374
11.5.2.3	Procedure at the recipient	374
11.5.2.4	Procedure common to both originator and recipient	375

11.7	DLS operation.....	375
11.7.1	General.....	375
11.7.3	Data transfer after setup.....	376
11.14	SA Query procedures.....	376
11.19	RSNA A-MSDU procedures.....	376
11.23	Tunneled direct-link setup.....	376
11.23.1	General.....	376
11.23.6	TDLS channel switching.....	377
11.23.6.5	Setting up a wide bandwidth off-channel direct link.....	377
11.24	Wireless network management procedures.....	378
11.24.13	BSS max idle period management.....	378
11.24.16	Group addressed transmission service.....	379
11.24.16.2	DMS procedures.....	379
11.41	Group ID management operation.....	379
11.42	Notification of operating mode changes.....	380
11.48	Support for energy limited STAs.....	381
12.	Security.....	383
12.5	RSNA confidentiality and integrity protocols.....	383
12.5.3	CTR with CBC-MAC protocol (CCMP).....	383
12.5.3.2	CCMP MPDU format.....	383
12.5.3.2a	Construction of the CCMP header for PV1 MPDUs.....	383
12.5.3.3	CCMP cryptographic encapsulation.....	384
12.5.3.4	CCMP decapsulation.....	389
23.	Sub 1 GHz (S1G) PHY specification.....	392
23.1	Introduction.....	392
23.1.1	Introduction to the S1G PHY.....	392
23.1.2	Scope.....	393
23.1.3	S1G PHY functions.....	393
23.1.3.1	General.....	393
23.1.3.2	PHY management entity (PLME).....	393
23.1.3.3	Service specification method.....	393
23.1.4	PPDU formats.....	394
23.2	S1G PHY service interface.....	394
23.2.1	Introduction.....	394
23.2.2	TXVECTOR and RXVECTOR parameters.....	395
23.2.3	Effect of CH_BANDWIDTH parameter on PPDU format.....	410
23.3	S1G PHY sublayer.....	412
23.3.1	Introduction.....	412
23.3.2	S1G PPDU format.....	412
23.3.3	Transmitter block diagram.....	413
23.3.4	Overview of the PPDU encoding process.....	415
23.3.4.1	General.....	415
23.3.4.2	Construction of the Preamble part in an S1G_LONG PPDU.....	415
23.3.4.3	Construction of the Preamble part in an S1G_SHORT PPDU.....	418
23.3.4.4	Construction of the Preamble part in an S1G_1M PPDU.....	420
23.3.4.5	Construction of Preambles for S1G_DUP_2M and S1G_DUP_1M.....	422
23.3.4.6	Construction of the Data field in an S1G SU PPDU for all cases except 1 MHz MCS10.....	422
23.3.4.7	Construction of the Data field in an S1G SU PPDU (1 MHz MCS10 mode).....	424
23.3.4.8	Construction of the Data field in an S1G MU PPDU.....	425
23.3.5	Modulation and coding scheme (MCS).....	425

23.3.6	Timing-related parameters	426
23.3.7	Mathematical description of signals	430
23.3.8	S1G preamble	436
23.3.8.1	Introduction	436
23.3.8.2	Formats for greater than or equal to 2 MHz	436
23.3.8.3	Format for 1 MHz	458
23.3.9	Data field.....	463
23.3.9.1	General	463
23.3.9.2	SERVICE field	463
23.3.9.3	Scrambler	464
23.3.9.4	Coding.....	464
23.3.9.5	Repetition for 1 MHz MCS10	466
23.3.9.6	Stream parser	466
23.3.9.7	Segment parser.....	466
23.3.9.8	BCC interleaver	466
23.3.9.9	Constellation mapping	467
23.3.9.10	Pilot subcarriers	467
23.3.9.11	OFDM modulation.....	472
23.3.9.12	1 MHz and 2 MHz duplicate transmission	475
23.3.10	SU-MIMO and DL-MU-MIMO Beamforming.....	477
23.3.10.1	General	477
23.3.10.2	Beamforming Feedback Matrix V	477
23.3.10.3	Maximum Number of Total Spatial Streams in S1G MU PPDU	477
23.3.10.4	Group ID	477
23.3.11	S1G preamble format for NDPs.....	477
23.3.12	Regulatory requirements.....	479
23.3.13	Channelization	479
23.3.14	Slot time	479
23.3.15	Transmit and receive port impedance	480
23.3.16	S1G transmit specification.....	480
23.3.16.1	Transmit spectrum mask	480
23.3.16.2	Spectral flatness	483
23.3.16.3	Transmit center frequency and symbol clock frequency tolerance	485
23.3.16.4	Modulation accuracy.....	485
23.3.16.5	Time of Departure accuracy	487
23.3.17	S1G receiver specification	487
23.3.17.1	Receiver minimum input sensitivity	487
23.3.17.2	Adjacent channel rejection.....	488
23.3.17.3	Nonadjacent channel rejection	488
23.3.17.4	Receiver maximum input level	489
23.3.17.5	CCA sensitivity.....	489
23.3.17.6	RSSI	495
23.3.18	PHY transmit procedure	496
23.3.19	PHY receive procedure	498
23.4	S1G PLME.....	506
23.4.1	PLME_SAP sublayer management primitives	506
23.4.2	PHY MIB	508
23.4.3	TXTIME and PSDU_LENGTH calculation	509
23.4.4	PHY characteristics.....	511
23.5	Parameters for S1G-MCSs.....	512

Annex A (informative) Bibliography	520
Annex B (normative) Protocol Implementation Conformance Statement (PICS) proforma.....	521
B.2 Abbreviations and special symbols.....	521
B.2.2 General abbreviations for Item and Support columns.....	521
B.4 PICS proforma—IEEE Std 802.11- <i><year></i>	521
B.4.3 IUT configuration.....	521
B.4.4 MAC protocol	522
B.4.13 QoS enhanced distributed channel access (EDCA)	528
B.4.17 High throughput (HT) features.....	528
B.4.19 WNM extensions.....	530
B.4.25 Very high throughput (VHT) features.....	530
B.4.28 Sub 1 GHz (S1G) features.....	531
B.4.29 S1G Relay features.....	543
Annex C (normative) ASN.1 encoding of the MAC and PHY MIB	544
C.3 MIB detail	544
Annex D (normative) Regulatory references.....	575
D.1 External regulatory references	575
D.2 Radio performance specifications.....	576
D.2.2 Transmit power levels	576
Annex E (normative) Country elements and operating classes	577
E.1 Country information and operating classes	577
Annex G (normative) Frame exchange sequences.....	581
G.1 General.....	581
G.2 Basic sequences	581
G.3 EDCA and HCCA sequences	581
G.4 HT and VHT and S1G sequences	582
Annex J (informative) RSN reference implementations and test vectors.....	585
J.6 Additional test vectors	585
J.6.4 CCMP test vectors.....	585
Annex L (informative) Examples and sample code for encoding a TIM Partial Virtual Bitmap.....	588
L.2 Examples.....	588

Tables

Table 8-4—Vector descriptions	97
Table 8-5—The channel-list parameter elements	98
Table 9-1—Valid type and subtype combinations	102
Table 9-3—To/From DS combinations in Data frames	102
Table 9-4a—Bandwidth Indication subfield encoding	105
Table 9-4b—Dynamic Indication subfield encoding	105
Table 9-4c—Poll Type subfield encoding	105
Table 9-4d—Frame Control field BSS BW setting	106
Table 9-5—Duration/ID field encoding	107
Table 9-9—Ack Policy subfield in QoS Control field of QoS Data frames	107
Table 9-18—MFB subfield in the VHT variant HT Control field	108
Table 9-19—Maximum data unit sizes (in octets) and durations (in microseconds)	109
Table 9-26—Address field contents	116
Table 9-29—Association Request frame body	118
Table 9-30—Association Response frame body	119
Table 9-31—Reassociation Request frame body	120
Table 9-32—Reassociation Response frame body	121
Table 9-33—Probe Request frame body	122
Table 9-34—Probe Response frame body	123
Table 9-41a—Minimum and full set of optional elements	125
Table 9-44a—Unified Scaling Factor subfield encoding	127
Table 9-46—Status codes	127
Table 9-47—Category values	128
Table 9-47a—MCS subfield of the Originator Preferred MCS field	128
Table 9-66—Subfields of the VHT MIMO Control field	130
Table 9-67—Order of angles in the Compressed Beamforming Matrix subfield in a VHT PPDU	131
Table 9-71a—Order of angles in the Compressed Beamforming Feedback Matrix subfield if the Feedback Type field is SU in an S1G PPDU	132
Table 9-71b—Order of angles in the Compressed Beamforming Feedback Matrix subfield if the Feedback Type field is MU in an S1G PPDU	132
Table 9-74—Subfield values of the Operating Mode field	133
Table 9-76a—Subfields of the Sync Control field	135
Table 9-76b—Next TWT Subfield Size subfield encoding	136
Table 9-77—Element IDs	136
Table 9-78a—Block Control field encoding	141
Table 9-137—Default EDCA Parameter Set element parameter values if dot11OCBAActivated is false or the STA is a non-sensor STA	146
Table 9-137a—Default EDCA Parameter Set element parameter values if the STA is a sensor STA	146
Table 9-145—Frame classifier type	147
Table 9-146—Classifier Mask for Classifier Type 6	148
Table 9-146a—Classifier Mask for Classifier Type 7	149
Table 9-146b—Classifier Mask for Classifier Type 8	149
Table 9-146c—Classifier Mask for Classifier Type 9	150
Table 9-262j—Interpretation of RAW Type and RAW Type Options	155
Table 9-262k—TWT Setup Command field values	168
Table 9-262l—TWT Unit subfield encoding	171
Table 9-262m—Action field	173
Table 9-262n—Subfields of the S1G Capabilities Information field	175
Table 9-262o—Supported S1G-MCS and NSS Set subfields	181
Table 9-262p—Mapping between Maximum Transmission Width subfield and maximum permitted PPDU bandwidth	184
Table 9-262q—Hierarchy Identifier subfield	187

Table 9-262r—Enable Relay Function subfield values	189
Table 9-262s—Probe Response Option Bitmap subfield 0 (Default Bitmap).....	194
Table 9-262t—Probe Response Option Bitmap subfield 1	194
Table 9-262u—Probe Response Option Bitmap subfield 2.....	195
Table 9-262v—Probe Response Option Bitmap subfield 3.....	195
Table 9-262w—Probe Response Option Bitmap subfield 4.....	196
Table 9-262x—Probe Response Option Bitmap subfield 5.....	196
Table 9-262y—S1G Operation Information field	198
Table 9-299—DLS Request frame Action field format	202
Table 9-300—DLS Response frame Action field format.....	202
Table 9-302—Block Ack Action field values	203
Table 9-304—ADDBA Response frame Action field format	204
Table 9-343—Information for TDLS Setup Request Action field	205
Table 9-344—Information for TDLS Setup Response Action field.....	205
Table 9-345—Information for TDLS Setup Confirm Action field	206
Table 9-421b—Unprotected S1G Action field values.....	206
Table 9-421c—AID Switch Request frame Action field format	207
Table 9-421d—AID Switch Response frame Action field format	208
Table 9-421e—Sync Control frame Action field format.....	208
Table 9-421f—STA Information Announcement frame Action field format	209
Table 9-421g—EDCA Parameter Set frame Action field format.....	209
Table 9-421h—EL Operation Action field format	209
Table 9-421i—TWT Setup frame Action field format.....	210
Table 9-421j—TWT Teardown frame Action field format.....	210
Table 9-421k—Sectorized Group ID List frame Action field format	211
Table 9-421l—Sector ID Feedback frame Action field format.....	211
Table 9-421m—TWT Information frame Action field format.....	212
Table 9-421n—S1G Action field values	213
Table 9-421o—Reachable Address Update frame Action field format.....	213
Table 9-421p—Relay Activation Request frame.....	214
Table 9-421q—Relay Activation Response frame	214
Table 9-421r—Header Compression Action field format	215
Table 9-421s—Flow Control Action field format	215
Table 9-421t—Flow Suspension frame Action field format	216
Table 9-421u—Flow Resumption frame Action field format	216
Table 9-421v—Control Response MCS Negotiation Action field values.....	217
Table 9-421w—Control Response Negotiation Request frame	217
Table 9-421x—Control Response Negotiation Response frame	218
Table 9-421y—Command Values	218
Table 9-424—A-MPDU contexts	219
Table 9-428—A-MPDU contents MPDUs in the control response context.....	219
Table 9-429—A-MPDU contents in the VHT single S-MPDU	219
Table 9-430—PV1 frame types	220
Table 9-431—From DS values in PV1 frames	221
Table 9-432—Ack Policy subfield in the Frame Control field for PV1 frames.....	222
Table 9-433—PV1 Control frame subtypes	224
Table 9-434—PV1 Management frame subtypes.....	227
Table 9-435—NDP CMAC frame Type field values	232
Table 9-436—Preferred MCS subfield values for NDP_1M PS-Poll frame.....	235
Table 9-437—Preferred MCS subfield values for NDP_2M PS-Poll frame.....	236
Table 10-1a—RESPONSE_INDICATION value for NDP CMAC frames.....	251
Table 10-1b—NormalTXTIME duration based on RXVECTOR's parameters	253
Table 10-3—Transmitter sequence number spaces	260
Table 10-4—Receiver caches	260

Table 10-4a—Setting the TXVECTOR's parameter RESPONSE_INDICATION	261
Table 10-9a—Settings for the TXVECTOR parameter PARTIAL_AID for NDP frames	280
Table 10-9b—Settings for the TXVECTOR parameter PARTIAL_AID for non-1 MHz PPDU and non-NDP frames	280
Table 10-10a—Channels indicated idle by the channel-list parameter	283
Table 10-20—SIG BSS operating channel width	305
Table 11-4—Types of block ack agreement based on capabilities and ADDBA conditions for non-DMG STAs	375
Table 12-1—AAD length for PV0 MPDUs	386
Table 12-1a—AAD length for PV1 MPDUs	387
Table 23-1—TXVECTOR and RXVECTOR parameters	395
Table 23-2—PPDU format as a function of CH_BANDWIDTH parameter	410
Table 23-3—Fields of the SIG PPDU	413
Table 23-4—Timing-related constants	426
Table 23-5—Timing-related constants for SIG/SIG-A field in ≥ 2 MHz PPDU	427
Table 23-6—Frequently used parameters	428
Table 23-7—Tone scaling factor and guard interval duration values for PHY fields	432
Table 23-8—CH_BANDWIDTH and Gamma sub _{k, BW}	434
Table 23-9—Cyclic shift values for the SIG_SHORT preamble PPDU	437
Table 23-10—Number of LTFs required for different numbers of space-time streams	438
Table 23-11—Fields in the SIG field of short preamble	441
Table 23-12—Per antenna cyclic shift values of SIG_LONG preamble PPDU	445
Table 23-13—Fields in the SIG-A field of SIG_LONG preamble SU PPDU	448
Table 23-14—Fields in the SIG-A field of SIG_LONG preamble MU PPDU	450
Table 23-15—Per space-time-stream cyclic shift values of SIG_LONG preamble PPDU	453
Table 23-16—Fields in the SIG-B field for MU PPDU	455
Table 23-17—Cyclic shift values of SIG_1M PPDU	458
Table 23-18—Fields in the SIG field of SIG_1M PPDU	461
Table 23-19—SERVICE field	464
Table 23-20—Number of rows and columns in the interleaver for 1 MHz	466
Table 23-21—Traveling pilot positions for NSTS=1, 1 MHz SIG PPDU	469
Table 23-22—Traveling pilot positions for NSTS=1, 2 MHz SIG PPDU	469
Table 23-23—Traveling pilot positions for NSTS=1, 4 MHz SIG PPDU	469
Table 23-24—Traveling pilot positions for NSTS=1, 8 MHz SIG PPDU	470
Table 23-25—Traveling pilot positions for NSTS=2 and STBC=1, 1 MHz SIG PPDU	471
Table 23-26—Traveling pilot positions for NSTS=2 and STBC=1, 2 MHz SIG PPDU	471
Table 23-27—Traveling pilot positions for NSTS=2 and STBC=1, 4 MHz SIG PPDU	471
Table 23-28—Traveling pilot positions for NSTS=2 and STBC=1, 8 MHz SIG PPDU	472
Table 23-29—Maximum spectral flatness deviations	483
Table 23-30—Allowed relative constellation error versus constellation size and coding rate	486
Table 23-31—Receiver minimum input level sensitivity	488
Table 23-32—Minimum required adjacent and nonadjacent channel rejection levels	489
Table 23-33—Additional conditions for CCA BUSY on the primary 2 MHz in type 1 channelization	492
Table 23-34—Additional conditions for CCA BUSY on the primary 2 MHz in type 2 channelization	493
Table 23-35—Additional conditions for CCA BUSY on the primary 2 MHz in type 2 channelization for 8/16 MHz intended channel width	494
Table 23-36—SIG PHY MIB attributes	506
Table 23-37—SIG PHY characteristics	511
Table 23-38—SIG MCSs for 1 MHz, Nss = 1	513
Table 23-39—SIG MCSs for 1 MHz, Nss = 2	513
Table 23-40—SIG MCSs for 1 MHz, Nss = 3	513
Table 23-41—SIG MCSs for 1 MHz, Nss = 4	514
Table 23-42—SIG MCSs for 2 MHz, Nss = 1	514
Table 23-43—SIG MCSs for 2 MHz, Nss = 2	514

Table 23-44—S1G MCSs for 2 MHz, Nss = 3	515
Table 23-45—S1G MCSs for 2 MHz, Nss = 4	515
Table 23-46—S1G MCSs for 4 MHz, Nss = 1	515
Table 23-47—S1G MCSs for 4 MHz, Nss = 2	516
Table 23-48—S1G MCSs for 4 MHz, Nss = 3	516
Table 23-49—S1G MCSs for 4 MHz, Nss = 4	516
Table 23-50—S1G MCSs for 8 MHz, Nss = 1	517
Table 23-51—S1G MCSs for 8 MHz, Nss = 2	517
Table 23-52—S1G MCSs for 8 MHz, Nss = 3	517
Table 23-53—S1G MCSs for 8 MHz, Nss = 4	518
Table 23-54—S1G MCSs for 16 MHz, Nss = 1	518
Table 23-55—S1G MCSs for 16 MHz, Nss = 2	518
Table 23-56—S1G MCSs for 16 MHz, Nss = 3	519
Table 23-57—S1G MCSs for 16 MHz, Nss = 4	519
Table D-1—Regulatory requirement list	575
Table D-3a—Maximum STA transmit power and maximum BW allowed	576
Table E-4—Global operating classes	577
Table E-4a—S1G Operating classes	578
Table G-1—Attributes applicable to frame exchange sequence definition	581

Figures

Figure 5-7—S1G relay data plane architecture	41
Figure 8-5—The channel-list parameter elements to the 1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz channel width.....	99
Figure 9-2—Frame Control field in non-S1G PPDUs when Type is not equal to 1 or Subtype is not equal to 6	101
Figure 9-3a—Frame Control field in S1G PPDUs when Type is equal to 0 or 2	101
Figure 9-3b—Frame Control field format when Type subfield is equal to 3 and Subtype subfield is equal to 1	101
Figure 9-15a—MFB subfield in the VHT variant HT Control field when carried in S1G PPDUs	108
Figure 9-19—Frame Control field subfield values within Control frames carried in a non-S1G PPDUs ...	112
Figure 9-19a—Frame Control field in S1G Control frames when Subtype is not equal to 3 and not equal to 10.....	113
Figure 9-19b—Frame Control field in S1G Control frame when Subtype subfield is equal to 3	113
Figure 9-19c—Frame Control field in S1G Control frames when Subtype subfield is equal to 10.....	113
Figure 9-23—PS-Poll frame	114
Figure 9-51a—STA Info field in an S1G STA.....	115
Figure 9-52a—TACK frame format	115
Figure 9-52b—Next TWT Info/Suspend Duration field format.....	116
Figure 9-57a—Dynamic A-MSDU subframe structure.....	117
Figure 9-57b—Subframe Control field.....	117
Figure 9-63a—S1G Beacon frame format.....	124
Figure 9-71—Listen Interval field carried in a non-S1G PPDUs	126
Figure 9-71a—Listen Interval field carried in an S1G PPDUs	126
Figure 9-80a—Originator Preferred MCS field.....	128
Figure 9-118—Operating Mode field when it is carried in a non-S1G PPDUs	133
Figure 9-118a—Operating Mode field when it is carried in an S1G PPDUs	133
Figure 9-121a—Sync Control field format.....	134
Figure 9-121b—Suspend Duration field format.....	135
Figure 9-121c—TWT Information field format	135
Figure 9-127a—Bitmap Control field (when TIM is carried in a non-S1G PPDUs).....	138
Figure 9-127b—Bitmap Control field (when TIM is carried in an S1G PPDUs).....	138
Figure 9-127c—Hierarchical structure of traffic-indication virtual bitmap	139
Figure 9-127d—Partial Virtual Bitmap field.....	141
Figure 9-127e—Encoded Block subfield	141
Figure 9-127f—Block Control subfield.....	141
Figure 9-127g—Encoded Block Information (Block Bitmap mode)	142
Figure 9-127h—Encoded Block Information (Single AID mode)	142
Figure 9-127i—Encoded Block Information (OLB mode)	143
Figure 9-127j—Encoded Block Information (ADE Block)	143
Figure 9-261—EDCA Parameter Set element.....	145
Figure 9-261a—Update EDCA Info field	145
Figure 9-280—Frame Control Match Specification subfield of Classifier Type 6, 7, 8, 9	150
Figure 9-282—Address 1 Match Specification subfield of Classifier Type 6, 8, 9	150
Figure 9-283—Address 2 Match Specification subfield of Classifier Type 6, 7, 9	150
Figure 9-284—Address 3 Match Specification subfield of Classifier Type 6, 7, 8	150
Figure 9-285—Sequence Control Match Specification subfield of Classifier Type 6, 7, 8, 9	150
Figure 9-286—Address 4 Match Specification subfield of Classifier Type 6, 7, 8	150
Figure 9-286a—Frame Classifier field of Classifier Type 7	150
Figure 9-286b—Address 1 (SID) Match Specification subfield of Classifier Type 7	151
Figure 9-286c—Frame Classifier field of Classifier Type 8	151
Figure 9-286d—Address 2 (SID) Match Specification subfield of Classifier Type 8	151
Figure 9-286e—Frame Classifier field of Classifier Type 9	151

Figure 9-589ac—S1G Open-Loop Link Margin Index element format.....	153
Figure 9-589ad—RPS element format	154
Figure 9-589ae—RAW Assignment subfield format	154
Figure 9-589af—RAW Control subfield format	155
Figure 9-589ag—RAW Slot Definition subfield.....	157
Figure 9-589ah—RAW Group subfield	158
Figure 9-589ai—Channel Indication subfield	158
Figure 9-589aj—Periodic Operation Parameters subfield.....	159
Figure 9-589ak—Page Slice element format.....	159
Figure 9-589al—Page Slice Control field format.....	159
Figure 9-589am—AID Request element format	161
Figure 9-589an—AID Request Mode field format.....	162
Figure 9-589ao—Service Characteristic field format.....	163
Figure 9-589ap—AID Response element format	163
Figure 9-589aq—S1G Sector Operation element (sectorization type is group sectorization).....	164
Figure 9-589ar—S1G Sector Operation element (sectorization type is TXOP-based sectorization operation).....	166
Figure 9-589as—S1G Beacon Compatibility element format.....	166
Figure 9-589at—Short Beacon Interval element format	167
Figure 9-589au—Change Sequence element format	167
Figure 9-589av—TWT element format	167
Figure 9-589aw—Control field format	168
Figure 9-589ax—Request Type field format.....	168
Figure 9-589ay—TWT Group Assignment field format	170
Figure 9-589az—NDP Paging field format.....	172
Figure 9-589ba—S1G Capabilities element format	173
Figure 9-589bb—S1G Capabilities Information field	174
Figure 9-589bc—Supported S1G-MCS and NSS Set field format	181
Figure 9-589bd—Rx S1G-MCS Map, Tx S1G-MCS Map and Basic S1G-MCS and NSS Set	183
Figure 9-589be—Subchannel Selective Transmission element format.....	183
Figure 9-589bf—Channel Activity Schedule subfield format (Sounding Option = 0)	183
Figure 9-589bg—Channel Activity Schedule subfield format (Sounding Option = 1).....	183
Figure 9-589bh—Authentication Control element format (Control subfield equal to 0).....	185
Figure 9-589bi—Centralized Authentication Control Parameters format.....	186
Figure 9-589bj—Authentication Control element format (Control subfield equal to 1).....	186
Figure 9-589bk—Distributed Authentication Control Parameters format	186
Figure 9-589bl—TSF Timer Accuracy element format	187
Figure 9-589bm—S1G Relay element format.....	187
Figure 9-589bn—Relay Control field format	187
Figure 9-589bo—Reachable Address element format.....	188
Figure 9-589bp—Reachable Address subfield format	188
Figure 9-589bq—S1G Relay Activation element format.....	189
Figure 9-589br—Relay Function field format.....	189
Figure 9-589bs—S1G Relay Discovery element format.....	190
Figure 9-589bt—UL/DL Data Rate field format	190
Figure 9-589bu—Relay Discovery Control field format.....	191
Figure 9-589bv—AID Announcement element format.....	192
Figure 9-589bw—AID Entry field format.....	192
Figure 9-589bx—PV1 Probe Response Option element format	193
Figure 9-589by—EL Operation element format	197
Figure 9-589bz—Sectorized Group ID List element format.....	197
Figure 9-589ca—S1G Operation element format.....	198
Figure 9-589cb—S1G Operation Information field	198
Figure 9-589cc—Basic S1G-MCS and NSS Set	199

Figure 9-589cd—Header Compression element format.....	199
Figure 9-589ce—Header Compression Control field.....	199
Figure 9-589cf—CCMP Update field.....	200
Figure 9-589cg—BPN subfield.....	200
Figure 9-589ch—SST Operation element format.....	201
Figure 9-589ci—MAD element.....	201
Figure 9-740b—TWT Flow field format.....	211
Figure 9-740c—Sector ID Index format.....	212
Figure 9-740d—Receive Sector Bitmap format.....	212
Figure 9-748—PV1 frame format.....	220
Figure 9-749—Frame Control field.....	220
Figure 9-750—SID field.....	223
Figure 9-751—Frame Control field subfield values within PV1 Control frames.....	224
Figure 9-752—STACK frame format.....	224
Figure 9-753—BAT frame format.....	225
Figure 9-754—Starting Sequence Control field.....	226
Figure 9-755—PV1 Management frame format.....	226
Figure 9-756—PV1 Probe Response frame format.....	227
Figure 9-757—Frame Control field of PV1 Probe Response frame format.....	228
Figure 9-758—Resource Allocation frame format when Slot Assignment Mode field is 0.....	229
Figure 9-759—Resource Allocation frame format when Slot Assignment Mode field is 1.....	229
Figure 9-760—Slot Assignment Indication field for MU group when Slot Assignment Mode field is 0 and the Group Indicator field is 1.....	229
Figure 9-761—Slot Assignment Indication field for a STA when Slot Assignment Mode is 0 and the Group Indicator field is 0.....	229
Figure 9-762—Slot Assignment Indication field when Slot Assignment Mode field is 1.....	230
Figure 9-763—Frame Control field format for Resource Allocation frame.....	230
Figure 9-764—NDP CMAC frame body field of the NDP_1M CTS frame.....	232
Figure 9-765—NDP CMAC frame body field of the NDP_2M CTS frame.....	233
Figure 9-766—NDP CMAC frame body field of the NDP_1M CF-End frame.....	234
Figure 9-767—NDP CMAC frame body field of the NDP_2M CF-End frame.....	234
Figure 9-768—NDP CMAC frame body field of the NDP_1M PS-Poll frame.....	235
Figure 9-769—NDP CMAC frame body field of the NDP_2M PS-Poll frame.....	236
Figure 9-770—NDP CMAC frame body field of the NDP_1M Ack frame.....	237
Figure 9-771—NDP CMAC frame body field of the NDP_2M Ack frame.....	237
Figure 9-772—NDP CMAC frame body field of the NDP_1M PS-Poll-Ack frame.....	238
Figure 9-773—NDP CMAC frame body field of the NDP_2M PS-Poll-Ack frame.....	239
Figure 9-774—NDP CMAC frame body field of the NDP_1M BlockAck frame.....	239
Figure 9-775—NDP CMAC frame body field of the NDP_2M BlockAck frame.....	240
Figure 9-776—NDP CMAC frame body field of the NDP_2M Beamforming Report Poll frame.....	241
Figure 9-777—NDP CMAC frame body field of the NDP_1M Paging frame.....	241
Figure 9-778—NDP CMAC frame body field of the NDP_2M Paging frame.....	242
Figure 9-779—NDP CMAC frame body field of the NDP_1M Probe Request frame.....	243
Figure 9-780—NDP CMAC frame body field of the NDP_2M Probe Request frame.....	243
Figure 10-1a—SIG STA MAC architecture.....	245
Figure 10-5a—Data/Ack with RID setting.....	253
Figure 10-23a—Illustration of dynamic AID assignment.....	278
Figure 10-30a—Restricted Access Window (RAW).....	290
Figure 10-30b—Illustration of the RAW slot assignment procedure (RAW restricted to STAs whose AID bits in the TIM element are equal to 1).....	291
Figure 10-30c—Illustration of the RAW slot assignment procedure (RAW not restricted to STAs whose AID bits in the TIM element are equal to 1).....	291
Figure 10-30d—Backoff procedure for restricted channel access control.....	292
Figure 10-90—Example of PRAW operation.....	319

Figure 10-91—Example of uplink sync frame transmission procedure in RAW	322
Figure 10-92—Example of BDT exchange	324
Figure 10-93—Illustration of Page Slicing with Page Slice element	325
Figure 10-94—Selective Subchannel Transmission channel transmission permission allocations from SST element	328
Figure 10-95—Sectorized BSS operation	333
Figure 10-96—SO frame exchange sequence 1	335
Figure 10-97—SO frame exchange sequence 2	336
Figure 10-98—SO frame exchange sequence 3	336
Figure 10-99—SO frame exchange sequence 4	337
Figure 10-100—CTS-to-self preceding SO frame exchange sequence	338
Figure 10-101—Sector training	339
Figure 10-102—SIG Relay Architecture	341
Figure 10-103—EL STA operation	355
Figure 11-5a—NDP Probing Procedure	362
Figure 12-16a—Expanded PV1 CCMP MPDU	383
Figure 12-18—AAD construction for PV0 MPDUs	385
Figure 12-18a—AAD construction for PV1 MPDUs	387
Figure 12-19—Nonce construction	388
Figure 12-20—Nonce Flags subfields	388
Figure 23-1—SIG_SHORT format	412
Figure 23-2—SIG_LONG format	412
Figure 23-3—SIG_1M format	413
Figure 23-4—Transmitter block diagram for the Data field of an SIG_1M PPDU with BCC or LDPC encoding and MCS10	415
Figure 23-5—Timing boundaries for SIG PPDU fields	431
Figure 23-6—Generation of LTF symbols	439
Figure 23-7—SIG-1 structure	440
Figure 23-8—SIG-2 structure	440
Figure 23-9—Data constellation in SIG field of SIG_SHORT	442
Figure 23-10—4-bit CRC calculation	444
Figure 23-11—SIG-A1 structure for SU PPDU	446
Figure 23-12—SIG-A2 structure for SU PPDU	447
Figure 23-13—SIG-A1 structure for MU PPDU	447
Figure 23-14—SIG-A2 structure for MU PPDU	447
Figure 23-15—Data constellation in SIG-A field of SIG_LONG	451
Figure 23-16—Structure of the 6 symbol SIG field of SIG_1M PPDU	461
Figure 23-17—SIG NDP for Sounding Format	478
Figure 23-18—SIG NDP CMAC frame for ≥ 2 MHz	478
Figure 23-19—SIG NDP CMAC frame for 1 MHz	478
Figure 23-20—SIG field format for 1 MHz NDP CMAC frame	478
Figure 23-21—SIG field format for ≥ 2 MHz NDP CMAC frame	479
Figure 23-22—Transmit spectral mask for 1 MHz channel	480
Figure 23-23—Transmit spectral mask for 2 MHz channel	481
Figure 23-24—Transmit spectral mask for 4 MHz channel	481
Figure 23-25—Transmit spectral mask for 8 MHz channel	482
Figure 23-26—Transmit spectral mask for 16 MHz channel	482
Figure 23-27—PHY transmit procedure for a SU transmission using SIG_1M preamble	496
Figure 23-28—PHY transmit procedure for a SU transmission using SIG_SHORT preamble	497
Figure 23-29—PHY transmit procedure for a SU transmission using SIG_LONG preamble	497
Figure 23-30—PHY transmit state machine for a SU transmission	499
Figure 23-31—PHY Receive procedure for a SU transmission, SIG_1M preamble	500
Figure 23-32—PHY Receive procedure for a SU transmission, SIG_SHORT preamble	500
Figure 23-33—PHY Receive procedure for a SU transmission, SIG_LONG preamble	501

Figure 23-34—PHY receive state machine	502
Figure L-8—Partial Virtual Bitmap example #7 for S1G STAs, Block Bitmap mode	588
Figure L-9—Partial Virtual Bitmap example #8 for S1G STAs, Single AID mode	589
Figure L-10—Partial Virtual Bitmap example #9 for S1G STAs, OLB mode	589
Figure L-11—Partial Virtual Bitmap example #7 for S1G STAs, ADE mode	590
Figure L-12—Partial Virtual Bitmap example #10 for S1G STAs, Inverse Bitmap + Block Bitmap mode.....	590
Figure L-13—Partial Virtual Bitmap example #11 for S1G STAs, Inverse Bitmap + Single AID mode ..	591
Figure L-14—Partial Virtual Bitmap example #12 for S1G STAs, Inverse Bitmap + OLB mode.....	592
Figure L-15—Partial Virtual Bitmap example #10 for S1G STAs, Inverse Bitmap + ADE mode	592

**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 2: Sub 1 GHz License Exempt
Operation**

[This amendment is based on IEEE Std 802.11™-2016, as amended by IEEE Std 802.11ai™-2016.]

NOTE—The editing instructions contained in this amendment define how to merge the material contained therein into the existing base standard and its amendments to form the comprehensive standard.

The editing instructions are shown in ***bold italic***. Four editing instructions are used: change, delete, insert, and replace. ***Change*** is used to make corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed by using ~~strike through~~ (to remove old material) and underscore (to add new material). ***Delete*** removes existing material. ***Insert*** adds new material without disturbing the existing material. Insertions may require renumbering. If so, renumbering instructions are given in the editing instruction. ***Replace*** is used to make changes in figures or equations by removing the existing figure or equation and replacing it with a new one. 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

3.2 Definitions specific to IEEE 802.11

Change the following definition in 3.2 as shown:

~~very high throughput (VHT) single medium access control (MAC) protocol data unit (VHT single S-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.

Insert the following definitions into 3.2:

1 MHz mask physical layer (PHY) protocol data unit (PPDU): A PPDU that is transmitted using the 1 MHz transmit spectral mask defined in Clause 23 and that is a 1 MHz sub 1 GHz (S1G) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW1).

1 MHz physical layer (PHY) protocol data unit (PPDU): A Clause 23 1 MHz sub 1 GHz (S1G) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW1).

2 MHz mask physical layer (PHY) protocol data unit (PPDU): A PPDU that is transmitted using the 2 MHz transmit spectral mask defined in Clause 23 and that is one of the following:

- a) A 1 MHz sub 1 GHz (S1G) non-duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW1)
- b) A 2 MHz S1G non-duplicate or S1G 1 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW2)

2 MHz physical layer (PHY) protocol data unit (PPDU): A Clause 23 2 MHz sub 1 GHz (S1G) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW2) or a Clause 23 2 MHz S1G 1 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW2).

4 MHz mask physical layer (PHY) protocol data unit (PPDU): A PPDU that is transmitted using the 4 MHz transmit spectral mask defined in Clause 23 and that is one of the following:

- a) A 1 MHz sub 1 GHz (S1G) non-duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW1)
- b) A 2 MHz S1G non-duplicate or S1G 1 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW2)
- c) A 4 MHz S1G non-duplicate, or S1G 1 MHz duplicate, or S1G 2 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW4)

4 MHz physical layer (PHY) protocol data unit (PPDU): A Clause 23 4 MHz sub 1 GHz (S1G) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW4), a Clause 23 4 MHz S1G 1 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW4), or a Clause 23 4 MHz S1G 2 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW4).

8 MHz mask physical layer (PHY) protocol data unit (PPDU): A PPDU that is transmitted using the 8 MHz transmit spectral mask defined in Clause 23 and that is one of the following:

- a) A 1 MHz sub 1 GHz (S1G) non-duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW1)
- b) A 2 MHz S1G non-duplicate or S1G 1 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW2)

- c) A 4 MHz S1G non-duplicate, or S1G 1 MHz duplicate, or S1G 2 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW4)
- d) An 8 MHz S1G non-duplicate, or S1G 1 MHz duplicate, or S1G 2 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW8)

8 MHz physical layer (PHY) protocol data unit (PPDU): A Clause 23 8 MHz sub 1 GHz (S1G) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW8), a Clause 23 8 MHz S1G 1 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW8), or a Clause 23 8 MHz S1G 2 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW8).

16 MHz mask physical layer (PHY) protocol data unit (PPDU): A PPDU that is transmitted using the 16 MHz transmit spectral mask defined in Clause 23 and that is one of the following:

- a) A 1 MHz sub 1 GHz (S1G) non-duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW1)
- b) A 2 MHz S1G non-duplicate or S1G 1 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW2)
- c) A 4 MHz S1G non-duplicate, or S1G 1 MHz duplicate, or S1G 2 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW4)
- d) An 8 MHz S1G non-duplicate, or S1G 1 MHz duplicate, or S1G 2 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW8)
- e) An 16 MHz S1G non-duplicate, or S1G 1 MHz duplicate, or S1G 2 MHz duplicate (TXVECTOR parameter CH_BANDWIDTH equal to CBW16)

16 MHz physical layer (PHY) protocol data unit (PPDU): A Clause 23 16 MHz sub 1 GHz (S1G) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW16), a Clause 23 16 MHz S1G 1 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW16), or a Clause 23 16 MHz S1G 2 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW16).

centralized authentication controller (CAC) access point (AP): A sub 1 GHz (S1G) AP with dot11S1GCentralizedAuthenticationControlActivated equal to true. A CAC AP is able to alleviate wireless medium contention when a large number of stations (STAs) are trying to, or are expected to, reconnect to the AP at about the same time.

centralized authentication controlled (CAC) station (STA): A sub 1 GHz (S1G) non-access point (non-AP) STA with dot11S1GCentralizedAuthenticationControlActivated equal to true. A CAC STA supports a CAC access point (AP) to alleviate wireless medium contention when a large number of STAs are trying to, or are expected to, reconnect to the AP at about the same time.

energy limited (EL) station (STA): A sub 1 GHz (S1G) STA whose limited energy supply requires the STA to transmit or receive in certain intervals of time determined by an EL Operation element.

non-sensor station (STA): A sub 1 GHz (S1G) non-access point (non-AP) STA transmitting or receiving data frames not subject to limitation of payload size. A non-sensor STA might not have the power and traffic volume limitation expected for a sensor STA.

non-traffic indication map (non-TIM) mode: A sub 1 GHz (S1G) non-access point (non-AP) station (STA) power save mode in which an S1G non-AP STA need not listen for traffic indication map (TIM) Beacon frames but transmits at least one PS-Poll or trigger frame to the associated AP every listen interval.

non-traffic indication map (non-TIM) station (STA): A sub 1 GHz (S1G) non-access point (non-AP) station (STA) that has entered the non-TIM mode.

null data packet (NDP) 1M (NDP_1M): An NDP carrying medium access control (MAC) information (CMI) frame that is transmitted using the S1G_1M format.

null data packet (NDP) 2M (NDP_2M): An NDP carrying medium access control (MAC) information (CMI) frame that is transmitted using the S1G_SHORT format.

null data packet (NDP) carrying medium access control information (CMAC) frame: A physical layer (PHY) protocol data unit (PPDU) with no Data field used by the PHY to provide to the medium access control (MAC) the service of carrying MAC information in the SIGNAL field of the sub 1 GHz (S1G) PPDU.

paged association identifier (AID): An AID of a sub 1 GHz (S1G) non-access point (non-AP) station (STA) whose corresponding bit value in a transmitted traffic indication map (TIM) encoded in AID with differential encoding (ADE) mode is 1.

primary 1 MHz channel: In a 2 MHz, 4 MHz, 8 MHz, or 16 MHz sub 1 GHz (S1G) basic service set (BSS), the 1 MHz channel that is used to transmit 1 MHz physical layer (PHY) protocol data units (PPDUs).

primary 2 MHz channel: In a 4 MHz, 8 MHz, or 16 MHz sub 1 GHz (S1G) basic service set (BSS), the 2 MHz channel that is used to transmit 2 MHz physical layer (PHY) protocol data units (PPDUs).

primary 4 MHz channel: In an 8 MHz or 16 MHz sub 1 GHz (S1G) basic service set (BSS), the 4 MHz channel that is used to transmit 4 MHz physical layer (PHY) protocol data units (PPDUs).

primary 8 MHz channel: In a 16 MHz sub 1 GHz (S1G) basic service set (BSS), the 8 MHz channel that is used to transmit 8 MHz physical layer (PHY) protocol data units (PPDUs).

protocol version 0 (PV0) medium access control (MAC) protocol data unit (MPDU): An MPDU that has the Protocol Version field of the Frame Control field of the MPDU header equal to 0.

protocol version 1 (PV1) medium access control (MAC) protocol data unit (MPDU): An MPDU that has the Protocol Version field of the Frame Control field of the MPDU header equal to 1.

restricted access window (RAW): A medium access interval for a group of stations (STAs) during which a STA in the RAW group indicated by the RAW parameter set (RPS) element is allowed to contend for access to the medium.

secondary 1 MHz channel: In a 2 MHz sub 1 GHz (S1G) basic service set (BSS), the 1 MHz channel adjacent to the primary 1 MHz channel that with the primary 1 MHz channel forms the 2 MHz channel of the 2 MHz S1G BSS. In a 4 MHz, 8 MHz, and 16 MHz S1G BSS, the 1 MHz channel adjacent to the primary 1 MHz channel that together form the primary 2 MHz channel of the S1G BSS.

secondary 2 MHz channel: In a 4 MHz sub 1 GHz (S1G) basic service set (BSS), the 2 MHz channel adjacent to the primary 2 MHz channel that with the primary 2 MHz channel forms the 4 MHz channel of the 4 MHz S1G BSS. In an 8 MHz and 16 MHz S1G BSS, the 2 MHz channel adjacent to the primary 2 MHz channel that together form the primary 4 MHz channel of the S1G BSS.

secondary 4 MHz channel: In an 8 MHz sub 1 GHz (S1G) basic service set (BSS), the 4 MHz channel adjacent to the primary 4 MHz channel that with the primary 4 MHz channel forms the 8 MHz channel of the 8 MHz S1G BSS. In a 16 MHz S1G BSS, the 4 MHz channel adjacent to the primary 4 MHz channel that together form the primary 8 MHz channel.

secondary 8 MHz channel: In an 16 MHz sub 1 GHz (S1G) basic service set (BSS), the 8 MHz channel adjacent to the primary 8 MHz channel that with the primary 8 MHz channel forms the 16 MHz channel of the 16 MHz S1G BSS.

sensor station (STA): A sub 1 GHz (S1G) non-access point (AP) STA that has certain traffic and device characteristics (e.g., limited payload size, limited traffic volume, battery operated device) and is allowed to associate with an AP that transmits an S1G Beacon, a Probe Response, or a PV1 Probe Response frame containing the S1G Capabilities element with the STA Type Support subfield indicating a sensor basic service set (BSS) or a mixed BSS.

short beacon interval: The interval between the consecutive target short beacon transmission times (TSBTTs) of beacons containing a minimal set of information elements.

sub 1 GHz (S1G) physical layer (PHY) protocol data unit (PPDU): A PPDU transmitted with the TXVECTOR parameter FORMAT equal to S1G, S1G_DUP_1M, or S1G_DUP_2M. The PPDU is transmitted with the S1G_SHORT, S1G_LONG, or S1G_1M preamble.

sub 1 GHz 1M (S1G_1M) physical layer (PHY) protocol data unit (PPDU): A 1 MHz PPDU or 1 MHz duplicate PPDU that is transmitted with S1G_1M preamble.

sub 1 GHz long (S1G_LONG) physical layer (PHY) protocol data unit (PPDU): A 2 MHz, 4 MHz, 8 MHz, or 16 MHz PPDU with long preamble format.

sub 1 GHz modulation and coding scheme (S1G-MCS): A specification of the S1G 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 rep2, 1/2, 2/3, 3/4, 5/6) that is used in an S1G PHY protocol data unit (PPDU).

sub 1 GHz short (S1G_SHORT) physical layer (PHY) protocol data unit (PPDU): A 2 MHz, 4 MHz, 8 MHz, 16 MHz, or 2 MHz duplicate PPDU with short preamble format.

subchannel selective transmission (SST) channel: A channel that is permitted for the subchannel selective transmission indicated by either an SST element or an RPS element.

target wake time (TWT): A specific time or set of times for individual stations (STAs) to wake in order to exchange frames with other STAs.

target wake time (TWT) responder: A station (STA) that has accepted a TWT agreement that was requested by another STA and that assigns TWT service period (SP) start times to the requesting STA.

target wake time (TWT) service period (SP): A period of time during which a TWT station (STA) is awake to transmit and/or receive frames.

target wake time (TWT) service period (SP) start time: The value of the timing synchronization function (TSF) at the beginning of a TWT SP.

target wake time (TWT) requester: A station (STA) that has had a requested TWT agreement accepted by another STA and that receives TWT service period (SP) start times from that STA.

3.4 Abbreviations and acronyms

Insert the following abbreviations into 3.4 in alphabetical order:

ADE	AID with differential encoding
BAT	block acknowledgment TWT
BDT	bidirectional TXOP
BPN	base packet number
CAC	centralized authentication controller (for access points) or controlled (for stations)
EL	energy limited
EOM	end of multi-user
MAD	maximum away duration
OLB	offset length bitmap
PRAW	periodic restricted access window
PV0	protocol version 0
PV1	protocol version 1
RAW	restricted access window
RID	response indication deferral
RPS	RAW parameter set
S1G	sub 1 GHz
SC	sequence counter
SID	short identifier
S-MPDU	single MAC protocol data unit
SST	subchannel selective transmission
STACK	short TWT acknowledgment
TACK	TWT acknowledgment
TSBTT	target short beacon transmission time
TWT	target wake time
USF	unified scaling factor

4. General description

Change the following phrase throughout IEEE Std 802.11:

from “[a] VHT Single MPDU” to “[an] S-MPDU”

4.3 Components of the IEEE 802.11 architecture

Insert the following subclauses (4.3.13a through 4.3.13a.2) after 4.3.13:

4.3.13a Sub 1 GHz (S1G) STA

4.3.13a.1 Overview

The IEEE 802.11 S1G STA operates in frequency bands below 1 GHz excluding the TV White Space bands.

An S1G STA supports S1G features identified in Clause 9, Clause 10, Clause 11, Clause 12, and Clause 23.

The main PHY features in an S1G STA are the following:

- Mandatory support for 1 MHz and 2 MHz channel width
- Mandatory support for S1G_1M, S1G_SHORT PPDU
- Mandatory support for S1G_LONG PPDU if ≥ 4 MHz channel width is supported
- Mandatory support for detection and decode of SIG-A field of the S1G_LONG preamble
- Mandatory support for single spatial stream S1G-MCS 0 to S1G-MCS 2 and S1G-MCS 10 (for 1 MHz PPDU only)
- Mandatory support for single spatial stream S1G-MCS 3 to S1G-MCS 7 for an S1G AP
- Mandatory support for binary convolutional coding
- Mandatory support for normal guard interval
- Mandatory support for fixed pilots
- Optional support for 2, 3 and 4 spatial streams (transmit and receive)
- Optional support for S1G_LONG PPDU if only 2 MHz channel width is supported
- Optional support for beamforming sounding (by sending an S1G NDP frame)
- Optional support for compressed beamforming feedback
- Optional support for STBC, LDPC (transmit and receive)
- Optional support for S1G MU PPDU (transmit and receive)
- Optional support for 4 MHz, 8 MHz, or 16 MHz channel width
- Optional support for S1G-MCSs 8 and 9 (transmit and receive)
- Optional support for short guard interval
- Optional support for traveling pilots

The main MAC features supported for S1G STA are the following:

- Mandatory support for NDP Ack, NDP BlockAck, and NDP CTS frames; mandatory support for the reception of NDP Probe Request frame for S1G AP; optional support for other NDP CMAC frames
- Mandatory support for the reception of PV1 MPDUs but optional support for the transmission of PV1 MPDUs
- Mandatory support for the second virtual carrier sensing - RID
- Mandatory support for the hierarchical structure of TIM element by an S1G AP

- Mandatory support for extended BSS max idle periods and extended listen intervals with USF
- Optional support for RAW
- Optional support for Relay
- Optional support for grouping of non-AP STAs and group AID
- Optional support for TWT
- Optional support for BDT
- Optional support for sectorization
- Optional support for non-TIM STA operation
- Optional support for asymmetric block ack operation, fragment block ack operation
- Optional support for page slicing, dynamic AID assignment for an S1G AP
- Optional support for authentication control
- Optional support for SST
- Optional support for rescheduling STA's doze/awake cycle
- Optional support for either a sensor STA or a non-sensor STA
- Optional support for an EL STA

NOTE—Some NDP CMAC frames are mandatory under certain conditions as indicated in B.4.4.2.

Most S1G features help either reduce a STA's energy consumption or increase the usable range between an AP and a non-AP STA.

An S1G STA is a non-mesh STA, and a QoS STA that does not support HCCA.

4.3.13a.2 S1G Relay

The S1G relay is a mechanism for expanding the coverage area of an AP. The AP is referred to as the root AP. An S1G relay consists of an S1G relay AP and an S1G relay STA. An S1G relay forwards frames between STAs associated to its S1G relay AP and the AP to which its S1G relay STA is associated.

5. MAC service definition

5.1 Overview of MAC services

5.1.2 Security services

Insert the following paragraph at the end of 5.1.2:

An S1G STA shall not use the pairwise cipher suite selectors WEP-40, WEP-104, TKIP, or “Use group cipher suite”.

5.1.5 MAC data service architecture

Insert the following subclause (5.1.5.6, including Figure 5-7) after 5.1.5.5:

5.1.5.6 S1G Relay

An S1G relay comprises a relay AP, a relay STA and a relay function (see Figure 5-7).

A relay STA is a non-AP STA associated to a root AP or the relay AP of another relay. A relay AP is an AP that offers the relay function to its associated non-AP STAs, and provides access to the DS indirectly through the relay STA’s path to the root AP. The relay function performs local reception or selective forwarding of MSDUs between the relay STA and relay AP, based on the destination address, as described in 10.50.

The MAC data plane architecture of an S1G relay is shown in Figure 5-7.

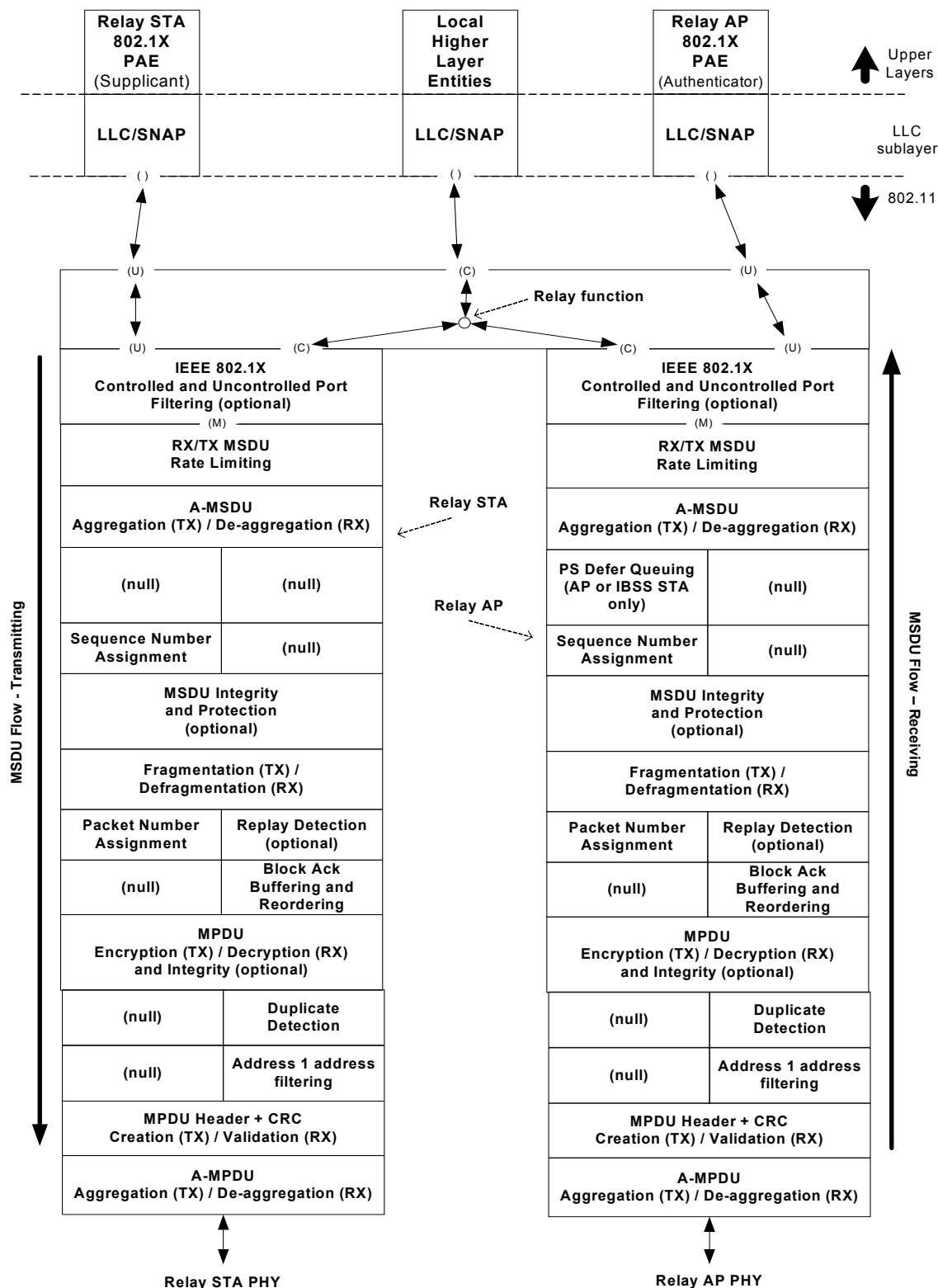


Figure 5-7—S1G relay data plane architecture

6. Layer management

6.3 MLME SAP interface

6.3.2 Power management

6.3.2.2 MLME-POWERMGT.request

6.3.2.2.2 Semantics of the service primitive

Change the primitive parameter list in 6.3.2.2.2 as follows:

The primitive parameters are as follows:

```
MLME-POWERMGT.request(  
    PowerManagementMode,  
    ReceiveDTIMs,  
    ReceiveTIMs  
)
```

Insert the following row at the end of the parameter table in 6.3.2.2.2:

Name	Type	Valid range	Description
ReceiveTIMs	Boolean	true, false	The parameter is present if dot11S1GOptionImplemented is true; otherwise not present. This parameter is set to the boolean complement of dot11NonTIMModeActivated. When true, this parameter causes the S1G STA to awaken to receive a Beacon frame, as determined by the STA's ListenInterval and the ReceiveDTIMs parameter. When this parameter is false, the S1G STA transmits at least one frame every listen interval without receiving a Beacon frame.

6.3.3 Scan

6.3.3.2 MLME-SCAN.request

6.3.3.2.2 Semantics of the service primitive

Change the primitive parameter list in 6.3.3.2.2 as follows:

The primitive parameters are as follows:

```
MLME-SCAN.request(  
    BSSType,  
    BSSID,  
    SSID,  
    ScanType,  
    ActiveScanType,  
    ProbeDelay,  
    ChannelList,  
    MinChannelTime,  
    MaxChannelTime,
```

RequestInformation,
SSID List,
ChannelUsage,
AccessNetworkType,
HESSID,
MeshID,
DiscoveryMode,
FILSRequestParameters,
ReportingOption,
APConfigurationSequenceNumber,
S1GRelayDiscovery,
PV1ProbeResponseOption,
S1GCapabilities,
ChangeSequence,
ELOperation,
MaxAwayDuration,
VendorSpecificInfo
)

Insert the following row into the parameter table in 6.3.3.2.2 after the “ScanType” row:

Name	Type	Valid range	Description
ActiveScanType	Enumeration	FRAME, NDP	Indicates active scanning type by the transmission of either Probe Request frames or NDP Probe Request frames. This parameter is optionally present if dot11S1GOptionImplemented is true and if ScanType is ACTIVE; otherwise not present.

Insert the following rows into the parameter table in 6.3.3.2.2 before the “VendorSpecificInfo” row:

Name	Type	Valid range	Description
S1GRelayDiscovery	S1G Relay Discovery element	As defined in 9.4.2.208	Indicates link budget information and QoS requirements for relay discovery. This element is optionally present if dot11RelaySTAImplemented is true; otherwise not present.
PV1ProbeResponseOption	PV1 Probe Response Option element	As defined in 9.4.2.210	Indicates which optional information is requested to be included in the PV1 Probe Response frame. This element is optionally present if dot11PV1ProbeResponseOptionImplemented is true; otherwise not present.
S1GCapabilities	S1G Capabilities element	As defined in 9.4.2.201	Indicates S1G capabilities of an S1G STA. The S1G Capabilities element is present if dot11S1GOptionImplemented is true; otherwise not present.
ChangeSequence	Change Sequence element	As defined in 9.4.2.199	Specifies the parameters within the Change Sequence element that are supported by the MAC entity. The parameter is optionally present if dot11S1GOptionImplemented is true; otherwise not present.

Name	Type	Valid range	Description
ELOperation	EL Operation element	As defined in 9.4.2.211	Specifies the parameters within the EL Operation element that are supported by the MAC entity. The parameter is present if dot11S1GELOperationActivated is true; otherwise not present.
MaxAwayDuration	Integer	0–65 535 inclusive	Indicates the maximum duration, in TUs, that the AP is unavailable for communications with the STA. The parameter is optionally present if dot11MaxAwayDuration is nonzero; otherwise not present.

6.3.3.3 MLME-SCAN.confirm

6.3.3.3.2 Semantics of the service primitive

Change the second paragraph in 6.3.3.3.2 as follows:

Each BSSDescription consists of the parameters shown in the following table, in which the term *peer STA* refers to the STA transmitting the Beacon frame, S1G Beacon frame, or Probe Response frame, or PV1 Probe Response frame from which the BSSDescription was determined and the term *local STA* refers to the STA performing the scan, and in which the “IBSS adoption” column indicates whether

- This parameter is adopted by a STA that is joining an IBSS.
- This parameter is adopted by a STA that is a member of an IBSS that receives a beacon or S1G Beacon from a STA that is a member of the same IBSS and that has a timestamp value that is greater than the local TSF value (see 11.1.5).

Change the following row in the BSSDescriptionSet table in 6.3.3.3.2 as shown:

Name	Type	Valid range	Description	IBSS adoption
Timestamp	Integer	N/A	The timestamp of the received frame (Probe Response/ Beacon, <u>or PV1 Probe Response/S1G Beacon</u>) from the found BSS. <u>When a PV1 Probe Response or an S1G Beacon frame is received, the timestamp is reconstructed as described in 11.1.3.10.3.</u>	Adopt

Insert the following rows at the end of the BSSDescriptionSet table in 6.3.3.3.2:

Name	Type	Valid range	Description	IBSS adoption
Compressed SSID	Integer	N/A	The Compressed SSID of the received frame (PV1 Probe Response or S1G Beacon) from the found BSS. This parameter is optionally present if dot11S1GOptionImplemented is true; otherwise not present.	Adopt

Name	Type	Valid range	Description	IBSS adoption
Next TBTT	Integer	N/A	Highest 3 octets of the 4 least significant octets of the next TBTT. This parameter is optionally present if dot11S1GOptionImplemented is true; otherwise not present.	Adopt
S1G Relay Discovery	As defined in frame format	As defined in 9.4.2.208	The values from the S1G Relay Discovery element if such an element was present in the Probe Response, PV1 Probe Response, or S1G Beacon frame. More description is provided in 10.50.6.	Do not adopt
RPS	RPS element	As defined in 9.4.2.192	The parameter set for group-based restricted medium access, if such element was present in the S1G Beacon, PV1 Probe Response, or Probe Response frame, else null. The support of the feature is described on RAW-based medium access (10.22.5).	Do not adopt
Page Slice	Page Slice element	As defined in 9.4.2.193	The set of page slices present in DTIM interval, if such element was present in the S1G Beacon, or Probe Response, or PV1 Probe Response frame, else null. The support of the feature is described 10.47.	Do not adopt
S1G Capabilities	As defined in frame format	As defined in 9.4.2.201	The values from the S1G Capabilities element. The parameter is present if dot11S1GOptionImplemented is true and an S1G Capabilities element was present in the S1G Beacon, or Probe Response, or PV1 Probe Response, frame from which the BSSDescription was determined; otherwise not present.	Adopt
TSF Timer Accuracy	TSF Timer Accuracy element	As defined in 9.4.2.204	The values from the TSF Timer Accuracy element if such an element was present in the Probe Response, PV1 Probe Response, or S1G Beacon frame, else null. The parameter is optionally present if dot11TSFTimerAccuracyImplemented is true; otherwise not present.	Adopt
Change Sequence	As defined in frame format	As defined in 9.4.2.199	A Change Sequence element indicates the change of system information within a BSS. The support of the feature is described 10.42.2.	Do not adopt

Name	Type	Valid range	Description	IBSS adoption
S1GRelay	As defined in frame format	As defined in 9.4.2.205	The S1G Relay element is present in the S1G Beacon if dot11RelayAPOperationActivated is true or if dot11RelayAPIImplemented is true; otherwise not present. The S1G Relay element is optionally present in Probe Response, or PV1 Probe Response, if dot11RelayAPIImplemented is true. More description is provided in 10.50.	Do not adopt
S1GOperation	As defined in frame format	As defined in 9.4.2.213	The values from the S1G Operation element if such an element was present in the Probe Response, PV1 Probe Response, or S1G Beacon frame, else null. The parameter is optionally present if dot11S1GOptionImplemented is true; otherwise not present.	Adopt
ShortBeaconPeriod	As defined in frame format	As defined in 9.4.2.198	The short beacon period, in TUs, of the found BSS if the Short Beacon Interval element was present in the Probe Response, PV1 Probe Response, or S1G Beacon frame, else null. The parameter is optionally present if dot11S1GOptionImplemented is true; otherwise not present.	Adopt
ShortBeaconDTIM Period	As defined in frame format	As defined in 9.4.2.6	The values from the TIM element if such an element was present in the S1G Beacon frame, else null. The parameter is optionally present if dot11S1GOptionImplemented is true; otherwise not present.	Adopt
MaxAwayDuration	Integer	0–65 535 inclusive	Indicates the maximum duration, in TUs, that the AP is unavailable for communications with the STA. The parameter is optionally present if dot11MaxAwayDuration is nonzero; otherwise not present.	Do not adopt

6.3.4 Synchronization

6.3.4.2 MLME-JOIN.request

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 an S1G STA receives an MLME-JOIN.request primitive with a SelectedBSS parameter containing a BSSDescription with a Basic S1G-MCS and NSS Set field in the S1G Operation element that contains any unsupported <S1G-MCS, NSS> tuple, the ResultCode parameter in the MLME's responding invocation of the MLMEJOIN.confirm primitive shall contain a value that is not SUCCESS.

6.3.5 Authenticate

6.3.5.2 MLME-AUTHENTICATE.request

6.3.5.2.3 When generated

Insert the following paragraph at the end of 6.3.5.2.3:

When dot11S1GCentralizedAuthenticationControlActivated is true and a STA's local MAC variable AuthenticationRequestTransmission is false, then the STA shall not invoke this primitive.

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,
BSSMaxIdlePeriod,
ListenInterval,
Supported Channels,
RSN,
QoSCapability,
Content of FT Authentication elements,
SupportedOperatingClasses,
SM Power Save,
QoSTrafficCapability,
TIMBroadcastRequest,
EmergencyServices,
DMG Capabilities,
Multi-band local,
Multi-band peer,
MMS,
FILSHLPContainer,
FILSIPAddressAssignment,
AID Request,
S1G Capabilities.)

TWT,
MaxAwayDuration,
SIGRelayActivation,
ReachableAddress,
VendorSpecificInfo
)

Insert the following row into the parameter table in 6.3.7.2.2 before the “ListenInterval” row:

Name	Type	Valid range	Description
BSSMaxIdlePeriod	BSS Max Idle Period element	As defined in 9.4.2.79	Indicates the preferred BSS Max idle period parameters. This parameter is optionally present if dot11SIGOptionImplemented is true; otherwise not present.

Insert the following rows into the parameter table in 6.3.7.2.2 before the “VendorSpecificInfo” row:

Name	Type	Valid range	Description
AID Request	AID Request element	As defined in 9.4.2.194	Indicates the device characteristic of the non-AP STA requesting AID assignment. This parameter is optionally present if dot11SIGOptionImplemented is true; otherwise not present.
SIG Capabilities	As defined in frame format	As defined in 9.4.2.201	Specifies the parameters in the SIG Capabilities element that are supported by the STA. The parameter is present if dot11SIGOptionImplemented is true; otherwise not present.
TWT	TWT element	As defined in 9.4.2.200.	Specifies the parameters in the TWT element. This parameter is optionally present if dot11TWTOptionActivated is true; otherwise not present.
MaxAwayDuration	Integer	0–65 535 inclusive	Indicates the maximum duration, in TUs, that the AP is unavailable for communications with the STA. The parameter is optionally present if dot11MaxAwayDuration is nonzero; otherwise not present.

Name	Type	Valid range	Description
SIGRelayActivation	SIG Relay Activation element	As defined in 9.4.2.207	Indicates if the STA with dot11RelaySTAImplemented equal to true requests to operate as a relay (in a request) and the AP with dot11RelayAPIImplemented equal to true requests/ confirms operation as a relay. The parameter is optionally present if dot11RelaySTAImplemented is true; otherwise not present.
ReachableAddress	Reachable Address element	As defined in 9.4.2.206	The Reachable Address element is optionally present if dot11RelaySTAImplemented is true; otherwise not present.

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,
 EDCAPParameterSet,
 RCPI of Request,
 RSNI of Request,
 RCPI of Response,
 RSNI of Response,
 RMEnabledCapabilities,
 Content of FT Authentication elements,
 SupportedOperatingClasses,
 Extended Capabilities,
 20/40 BSS Coexistence,
 TimeoutInterval,
 BSSMaxIdlePeriod,
 TIMBroadcastResponse,
 QoSMapSet,
 QMFPolicy,
 DMG Capabilities,
 Multi-band local,
 Multi-band peer,
 MMS,
 FILSHLPContainer,
 FILSIPAddressAssignment,
 KeyDelivery,
 SIG Sector Operation.