

IEEE P802.11ba™/D0.0, October 2017

(amendment to IEEE Std 802.11-2016
as amended by IEEE Std 802.11ai™-2016,
IEEE Std 802.11ah™-2016,
IEEE P802.11aq™/D12.0,
IEEE P802.11ak™/D4.3,
IEEE P802.11aj™/D8.0,
IEEE P802.11ax™/D2.0,
IEEE P802.11ay™/D0.5,
and IEEE P802.11az™/D0.0)

IEEE P802.11ba™/D0.0

**Draft Standard for Information technology— Tele-
communications 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 9: Wake-Up Radio Operation

Prepared by the 802.11 Working Group of the

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

Copyright © 2017 by the IEEE.
Three Park Avenue
New York, New York 10016-5997, USA
All rights reserved.

This document is an unapproved draft of a proposed IEEE Standard. As such, this document is subject to change. **USE AT YOUR OWN RISK!** Because this is an unapproved draft, this document must not be utilized for any conformance/compliance purposes. Permission is hereby granted for IEEE Standards Committee participants to reproduce this document for purposes of international standardization consideration. Prior to adoption of this document, in whole or in part, by another standards development organization permission must first be obtained from the IEEE Standards Activities Department (stds.ipr@ieee.org). Other entities seeking permission to reproduce this document, in whole or in part, must also obtain permission from the IEEE Standards Activities Department.

IEEE Standards Activities Department
445 Hoes Lane

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

Abstract: This amendment defines modifications to both the IEEE 802.11 physical layer (PHY) and the medium access control (MAC) sublayer for wake-up radio operation.
Keywords: wake-up radio, wake-up receiver, PHY, physical layer, MAC, medium access control, primary connectivity radio

1 Piscataway, NJ 08854, USA
2
3

4 This introduction is not part of IEEE P802.11ba /D0.0, October 2017, IEEE Standard for Information
5 technology—Telecommunications and information exchange between systems—Local and metropoli-
6 tan area network—Specific requirements—Part 11: Wireless LAN Medium Access Control (MAC)
7 and Physical Layer (PHY) Specifications—Amendment 9: Wake-Up Radio Operation.
8
9

10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

1 Introduction

2
3
4
5
6
7
8
9
10
11 This amendment defines modifications to both the IEEE 802.11 physical layer (PHY) and the medium
12 access control (MAC) sublayer for wake-up radio operation.
13

14 Laws and regulations

15
16
17 Users of these documents should consult all applicable laws and regulations. Compliance with the
18 provisions of this standard does not imply compliance to any applicable regulatory requirements.
19 Implementers of the standard are responsible for observing or referring to the applicable regulatory
20 requirements. IEEE does not, by the publication of its standards, intend to urge action that is not in
21 compliance with applicable laws, and these documents may not be construed as doing so.
22
23

24 Copyrights

25
26
27 This document is copyrighted by the IEEE. It is made available for a wide variety of both public and private
28 uses. These include both use, by reference, in laws and regulations, and use in private self-regulation,
29 standardization, and the promotion of engineering practices and methods. By making this document
30 available for use and adoption by public authorities and private users, the IEEE does not waive any rights in
31 copyright to this document.
32
33

34 Updating of IEEE documents

35
36
37 Users of IEEE standards should be aware that these documents may be superseded at any time by the
38 issuance of new editions or may be amended from time to time through the issuance of amendments,
39 corrigenda, or errata. An official IEEE document at any point in time consists of the current edition of the
40 document together with any amendments, corrigenda, or errata then in effect. In order to determine whether
41 a given document is the current edition and whether it has been amended through the issuance
42 of amendments, corrigenda, or errata, visit the IEEE Standards Association website at [http://](http://ieeexplore.ieee.org/xpl/standards.jsp)
43 ieeexplore.ieee.org/xpl/standards.jsp, or contact the IEEE at the address listed previously.
44
45
46

47 For more information about the IEEE Standards Association or the IEEE standards development process,
48 visit the IEEE-SA website at <http://standards.ieee.org>.
49
50

51 Errata

52
53
54 Errata, if any, for this and all other standards can be accessed at the following URL: [http://](http://standards.ieee.org/findstds/errata/index.html)
55 standards.ieee.org/findstds/errata/index.html. Users are encouraged to check this URL for errata
56 periodically.
57
58

59 Patents

60
61
62 Attention is called to the possibility that implementation of this standard may require use of subject matter
63 covered by patent rights. By publication of this standard, no position is taken with respect to the existence or
64 validity of any patent rights in connection therewith. A patent holder or patent applicant has filed a statement
65

1 of assurance that it will grant licenses under these rights without compensation or under reasonable rates,
2 with reasonable terms and conditions that are demonstrably free of any unfair discrimination to applicants
3 desiring to obtain such licenses. Other Essential Patent Claims may exist for which a statement of assurance
4 has not been received. The IEEE is not responsible for identifying Essential Patent Claims for which a
5 license may be required, for conducting inquiries into the legal validity or scope of Patents Claims, or
6 determining whether any licensing terms or conditions are reasonable or non-discriminatory. Further
7 information may be obtained from the IEEE Standards Association.
8
9

10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

1 **Participants**

2
3
4 At the time this revision was sent to sponsor ballot, the IEEE 802.11 Working Group had the following
5 officers:

6
7
8 **Adrian P Stephens, Chair**
9 **Jon W. Rosdahl, 1st Vice Chair**
10 **Dorothy Stanley, 2nd Vice Chair**
11 **Stephen McCann, Secretary**
12
13
14

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

16
17
18 **Minyoung Park, Chair**
19 **Yunsong Yang, 1st Vice Chair**
20 **Eunsung Park, 2nd Vice Chair**
21 **Leif Wilhelmsson, Secretary**
22
23
24
25

26
27 *Editor's Note: A 3-column list of working group voters at the time the working group first approved the*
28 *draft will be inserted here.*
29

30 Major contributions were received from the following individuals:

31
32
33 *Editor's Note: A 3-column list of those who made major contributions will be inserted here.*
34
35

36 The following members of the individual balloting committee voted on this revision. Balloters may have
37 voted for approval, disapproval, or abstention.
38
39

40 *Editor's Note: A 3-column list of sponsor ballot voters will be inserted here.*
41
42

43 *Editor's Note: The date of approval will be inserted on the following line.*
44

45 When the IEEE-SA Standards Board approved this revision on <date>, it had the following membership:
46

47
48 *Editor's Note: The officers of the IEEE-SA Standards board will be inserted here.*
49

50
51 *Editor's Note: A 3-column list of the IEEE-SA Standards board members will be inserted here.*
52
53

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

55
56
57
58 *Editor's Note: The Standards Program Manager and Staff liaison will be inserted below.*
59

60 <name>
61 IEEE Standards Program Manager, Document Development
62
63 <name>
64 IEEE Standards Program Managers, Technical Program Development
65

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

Contents

1		
2		
3		
4	Editorial Notes	15
5		
6	3. Definitions, acronyms, and abbreviations.....	17
7		
8	3.2 Definitions specific to IEEE 802.11	17
9	3.4 Abbreviations and acronyms	17
10		
11		
12	4. General description	19
13		
14	4.3 Components of the IEEE Std 802.11 architecture	19
15	4.3.15a Wake-up radio (WUR) STA	19
16		
17		
18	9. Frame formats	21
19		
20	9.1 General requirements	21
21	9.4 Management and Extension frame body components	21
22	9.4.1 Fields that are not elements	21
23	9.4.1.11 Action field	21
24	9.4.2 Elements.....	21
25	9.4.2.262 WUR Mode element	21
26	9.4.2.263 WUR Capabilities element	21
27	9.6 Action frame format details	21
28	9.6.31 WUR Action details.....	21
29	9.10 WUR frame formats.....	21
30		
31	31. Wake-Up Radio (WUR) MAC specification.....	23
32		
33		
34		
35	31.1 Introduction.....	23
36	31.2 Channel access.....	23
37	31.3 Maintaining synchronization	23
38	31.4 WURx duty cycle operation	23
39	31.5 Power management with WUR mode	23
40	31.6 Wake-up operation.....	23
41		
42		
43		
44		
45		
46	32. Wake-Up Radio (WUR) PHY specification	25
47		
48	32.1 Introduction.....	25
49	32.2 WUR PHY service interface.....	25
50	32.3 WUR PHY	25
51	32.3.1 Introduction.....	25
52	32.3.2 WUR PPDU format	25
53	32.3.3 Transmitter block diagram.....	25
54	32.3.4 Overview of the PPDU encoding process.....	25
55	32.3.5 WUR data rate	25
56	32.3.6 Timing related parameters	25
57	32.3.7 Mathematical description of signals	25
58	32.3.8 WUR preamble	25
59	32.3.9 WUR payload	25
60	32.3.10 WUR transmit procedure	25
61	32.3.11 WUR receive procedure.....	26
62		
63		
64		
65		

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

List of figures

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

List of tables

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

Table 1—Draft Status 16

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

IEEE P802.11ba™/D0.0

Draft 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 9: Wake-Up Radio Operation

[This amendment is based on IEEE Std 802.11-2016 amended by IEEE Std 802.11ai-2016, IEEE P802.11ah-2016, IEEE P802.11aq/D12.0, IEEE P802.11ak/D4.3, IEEE P802.11aj/D8.0, IEEE P802.11ax/D2.0, IEEE P802.11ay/D0.5, and IEEE P802.11az/D0.0]

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 ~~strikethrough~~ (to remove old material) and underline (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.

Editorial Notes

Editor's Note: Editorial Notes in the body of the standard appear like this. They will be removed before publication. They may highlight some issue that the editor has had to address during the implementation of a change. Where there may be any technical impact from an editing issue, the editor will raise a tech-

1 *nical letter ballot comment. There is no need for voters to comment on such issues unless they have a spe-*
 2 *cific resolution they wish to present.*
 3

4
 5 *Editor’s Note: Headings with empty content or Headings preceding editing instructions that modify the*
 6 *contents of the referenced subclause are there to provide context to the reader of this document, they have*
 7 *no other significance.*
 8

9
 10
 11 *Editor’s Note: The default IEEE-SA style for tables is to "float". This means that they be repositioned*
 12 *later, usually at the head of the next page, to avoid splitting the table and reduce the amount of blank*
 13 *space. The table can appear to move out of the subclause it is referenced first from, and can even split a*
 14 *paragraph. This is the intended IEEE-SA behavior, please do not report it as a defect in the draft. In*
 15 *many cases, additional line feeds have been inserted to force tables to follow text, rather than float beyond*
 16 *sequential text. The additional line feeds will be removed before publication, please do not report them as*
 17 *a defect in the text.*
 18

19
 20
 21 *Editor’s Note: Line numbering is only approximate. This is a limitation of the FrameMaker tool.*
 22 *Whitespace between paragraphs is part of the IEEE-SA style, as defined in their templates. The combina-*
 23 *tion of these two facts leads to the appearance of blank lines in the draft between every paragraph. Please*
 24 *do not report this as an editorial defect as it is the unavoidable behavior.*
 25

26
 27
 28
 29
 30 Tags:

31
 32
 33 Tags are placed in this draft near changes to identify the source of the change. Changes resulting from incor-
 34 poration of an approved proposal are shown like this: (#<number>), where <number> identifies the submis-
 35 sion/revision that introduced that change.
 36

37 These tags will be hidden in versions of the draft sent out to letter ballot - i.e., they are present only to assist
 38 the editorial review panel in checking that changes have been properly applied.
 39

40
 41 Tags are shown close to the point of change. When a whole subclause is new, the heading is tagged.
 42

43 Otherwise, when a whole paragraph is new, the paragraph is tagged. Otherwise tags are placed after a section
 44 of changes within a paragraph or at the end of the paragraph if the changes are substantial.
 45

46
 47 New tables are tagged in the table caption (if there is one), or in the introductory paragraph. Otherwise, new
 48 rows in existing tables are tagged only in the first column, to avoid distraction. Otherwise, a modified cell is
 49 tagged.
 50

51 Finally, any other changes made by the editor (e.g., for grammar, language, style & consistency with other
 52 comment resolutions, baseline, etc.) are tagged (#Ed).
 53

54
 55
 56
 57
 58 *Editor’s Note: A cumulative status of the versions of this draft is shown below.*
 59

60 **Table 1—Draft Status**

Draft	Date	Status
D0.0	2017-10-23	Proposed draft specification

3. Definitions, acronyms, and abbreviations

3.2 Definitions specific to IEEE 802.11

Insert the following definitions maintaining alphabetical order:

primary connectivity radio (PCR): A radio with the capability to transmit and receive 20 MHz non-HT PPDU.

wake-up radio (WUR): A companion radio to a primary connectivity radio with the capability to transmit or receive WUR PPDU.

wake-up receiver (WURx): A companion receiver to a primary connectivity radio with the capability to receive WUR PPDU.

wake-up radio (WUR) physical layer (PHY) protocol data unit (PPDU): A PPDU transmitted with the TXVECTOR parameter FORMAT equal to WUR.

3.4 Abbreviations and acronyms

Insert the following acronym definitions (maintaining alphabetical order):

OOK	on-off keying
PCR	primary connectivity radio
TD	type dependent
WUR	wake-up radio
WURx	wake-up receiver

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

4. General description

4.3 Components of the IEEE Std 802.11 architecture

Insert a new subclause after subclause 4.3.15 as follows:

4.3.15a Wake-up radio (WUR) STA

The main PHY features in a WUR STA are the following:

- <Texts to be filled>

The main MAC features in a WUR STA are the following:

- <Texts to be filled>

A WUR non-AP STA can receive a wake-up frame from a WUR AP STA to trigger a transition of the corresponding primary connectivity radio to the awake state.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

9. Frame formats

9.1 General requirements

Change the paragraph as follows:

The format of the MAC frames is specified in this clause. WUR frame format is defined in Subclause 9.10, and other MAC frame formats are defined in Subclauses 9.2 to 9.9. A STA shall be able to properly construct a subset of the frames specified in this clause for transmission and to decode a (potentially different) subset of the frames specified in this clause upon validation following reception. The particular subset of these frames that a STA constructs and decodes is determined by the functions supported by that particular STA. A STA shall be able to validate every received frame using the frame check sequence (FCS) and to interpret certain fields from the MAC headers of all frames.

A STA shall transmit frames using only the frame formats described in Clause 9.

9.4 Management and Extension frame body components

9.4.1 Fields that are not elements

9.4.1.11 Action field

<Texts to be modified>

9.4.2 Elements

Insert the following new subclauses after the last subclause in 9.4.2:

9.4.2.262 WUR Mode element

<Texts to be filled>

9.4.2.263 WUR Capabilities element

<Texts to be filled>

9.6 Action frame format details

Insert the following new subclause after the last subclause in 9.6:

9.6.31 WUR Action details

<Texts to be filled>

Insert the following new subclause after the last subclause in 9:

9.10 WUR frame formats

<Texts to be filled>

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

1 *Insert new Clauses 31 and 32 following Clause 30 as follows:*
2
3

4 **31. Wake-Up Radio (WUR) MAC specification**
5
6

7 **31.1 Introduction**
8
9

10 <Texts to be filled>
11
12

13 **31.2 Channel access**
14
15

16 <Texts to be filled>
17
18

19 **31.3 Maintaining synchronization**
20
21

22 <Texts to be filled>
23
24

25 **31.4 WURx duty cycle operation**
26
27

28 <Texts to be filled>
29
30

31 **31.5 Power management with WUR mode**
32
33

34 <Texts to be filled>
35
36

37 **31.6 Wake-up operation**
38
39

40 <Texts to be filled>
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

32. Wake-Up Radio (WUR) PHY specification

32.1 Introduction

<Texts to be filled>

32.2 WUR PHY service interface

<Texts to be filled>

32.3 WUR PHY

32.3.1 Introduction

<Texts to be filled>

32.3.2 WUR PPDU format

<Texts to be filled>

32.3.3 Transmitter block diagram

<Texts to be filled>

32.3.4 Overview of the PPDU encoding process

<Texts to be filled>

32.3.5 WUR data rate

<Texts to be filled>

32.3.6 Timing related parameters

<Texts to be filled>

32.3.7 Mathematical description of signals

<Texts to be filled>

32.3.8 WUR preamble

<Texts to be filled>

32.3.9 WUR payload

<Texts to be filled>

32.3.10 WUR transmit procedure

<Texts to be filled>

32.3.11 WUR receive procedure

<Texts to be filled>

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65