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ISO/ IEC/IEEE 8802-11

Third edition
2022-07

Telecommunications and information exchange between systems — Specific requirements for local and metropolitan area networks —

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

Télécommunications et échange entre systèmes informatiques — Exigences pour les réseaux locaux et métropolitains —

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

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IEEE Std 802.11™-2020
(Revision of IEEE Std 802.11-2016)

**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

Developed by the

LAN/MAN Standards Committee
of the
IEEE Computer Society

Approved 3 December 2020

IEEE SA Standards Board

Abstract: Technical corrections and clarifications to IEEE Std 802.11 for wireless local area networks (WLANs) as well as enhancements to the existing medium access control (MAC) and physical layer (PHY) functions are specified in this revision. Amendments 1 to 5 published in 2016 and 2018 have also been incorporated into this revision.

Keywords: 2.4 GHz, 256-QAM, 3650 MHz, 4.9 GHz, 5 GHz, 5.9 GHz, 60 GHz, advanced encryption standard, AES, audio, beamforming, carrier sense multiple access/collision avoidance, CCMP, channel switching, clustering, contention based access period, Counter mode with Cipher-block chaining Message authentication code Protocol, confidentiality, CSMA/CA, DFS, direct link, directional multi-gigabit, dynamic allocation of service period, dynamic extension of service period, dynamic frequency selection, dynamic truncation of service period, E911, EDCA, emergency alert system, emergency services, fast session transfer, forwarding, GCMP, generic advertisement service, high throughput, IEEE 802.11™, international roaming, interworking, interworking with external networks, LAN, local area network, MAC, management, measurement, medium access control, media-independent handover, medium access controller, mesh, MIS, millimeter-wave, MIMO, MIMO-OFDM, multi-band operation, multi-hop, multi-user MIMO, multiple input multiple output, network advertisement, network discovery, network management, network selection, noncontiguous frequency segments, OCB, path-selection, personal basic service set, PHY, physical layer, power saving, QoS, quality of service, quality-of-service management frame, radio, radio frequency, RF, radio resource, radio management, relay operation, spatial sharing, SSPN, subscriber service provider, television white spaces, TPC, transmit power control, video, wireless access in vehicular environments, wireless LAN, wireless local area network, WLAN, wireless network management, zero-knowledge proof

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Introduction

This introduction is not part of IEEE Std 802.11-2020, 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.

This revision gives users, in one document, the IEEE 802.11 standard for wireless local area networks (WLANs) with all of the amendments that have been published to date.

Incorporating published amendments

The original standard was published in 1997, revised in 1999 with MIB changes, and reaffirmed in 2003.

A revision was published in 2007, which incorporated into the 1999 edition the following amendments:

- IEEE Std 802.11a™-1999: High-speed Physical Layer in the 5 GHz Band (Amendment 1)
- IEEE Std 802.11b™-1999: Higher-Speed Physical Layer Extension in the 2.4 GHz Band (Amendment 2)
- IEEE Std 802.11b-1999/Corrigendum 1-2001: Higher-speed Physical Layer (PHY) extension in the 2.4 GHz band (Corrigendum 1 to Amendment 2)
- IEEE Std 802.11d™-2001: Specification for operation in additional regulatory domains (Amendment 3)
- IEEE Std 802.11g™-2003: Further Higher Data Rate Extension in the 2.4 GHz Band (Amendment 4)
- IEEE Std 802.11h™-2003: Spectrum and Transmit Power Management Extensions in the 5 GHz band in Europe (Amendment 5)
- IEEE Std 802.11i™-2004: Medium Access Control (MAC) Security Enhancements (Amendment 6)
- IEEE Std 802.11j™-2004: 4.9 GHz–5 GHz Operation in Japan (Amendment 7)
- IEEE Std 802.11e™-2005: Medium Access Control (MAC) Quality of Service Enhancements (Amendment 8)

A revision was published in 2012, which incorporated into the 2007 revision the following amendments:

- IEEE Std 802.11k™-2008: Radio Resource Measurement of Wireless LANs (Amendment 1)
- IEEE Std 802.11r™-2008: Fast Basic Service Set (BSS) Transition (Amendment 2)
- IEEE Std 802.11y™-2008: 3650–3700 MHz Operation in USA (Amendment 3)
- IEEE Std 802.11w™-2009: Protected Management Frames (Amendment 4)
- IEEE Std 802.11n™-2009: Enhancements for Higher Throughput (Amendment 5)
- IEEE Std 802.11p™-2010: Wireless Access in Vehicular Environments (Amendment 6)
- IEEE Std 802.11z™-2010: Extensions to Direct-Link Setup (DLS) (Amendment 7)
- IEEE Std 802.11v™-2011: Wireless Network Management (Amendment 8)
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- IEEE Std 802.11ae™-2012: Prioritization of Management Frames (Amendment 1)
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- IEEE Std 802.11ac™-2013: Enhancements for Very High Throughput for Operation in Bands below 6 GHz (Amendment 4)
- IEEE Std 802.11af™-2013: Television White Spaces (TVWS) Operation (Amendment 5)

This revision is based on IEEE Std 802.11-2016, into which the following amendments have been incorporated:

- IEEE Std 802.11ai™-2016 (second printing): Fast Initial Link Setup (Amendment 1)
- IEEE Std 802.11ah™-2016: Sub 1 GHz License Exempt Operation (Amendment 2)
- IEEE Std 802.11aj™-2018: Enhancements for Very High Throughput to Support Chinese Millimeter Wave Frequency Bands (60 GHz and 45 GHz) (Amendment 3)
- IEEE Std 802.11ak™-2018: Enhancements for Transit Links Within Bridged Networks (Amendment 4)
- IEEE Std 802.11aq™-2018: Preassociation Discovery (Amendment 5)

Technical corrections, clarifications, and enhancements

In addition, this revision specifies technical corrections and clarifications to IEEE Std 802.11 as well as enhancements to the existing medium access control (MAC) and physical layer (PHY) functions. In addition, this revision removes some features previously marked as obsolete and adds new indications of other obsolete features.

Generally, features that are marked deprecated or obsolete are not maintained; there might be technical errors in the material describing these features.

Renumbering of clauses and annexes

The numbering of certain clauses and annexes has been modified since IEEE Std 802.11-2007.

The evolution of this numbering is shown in Figure 1.

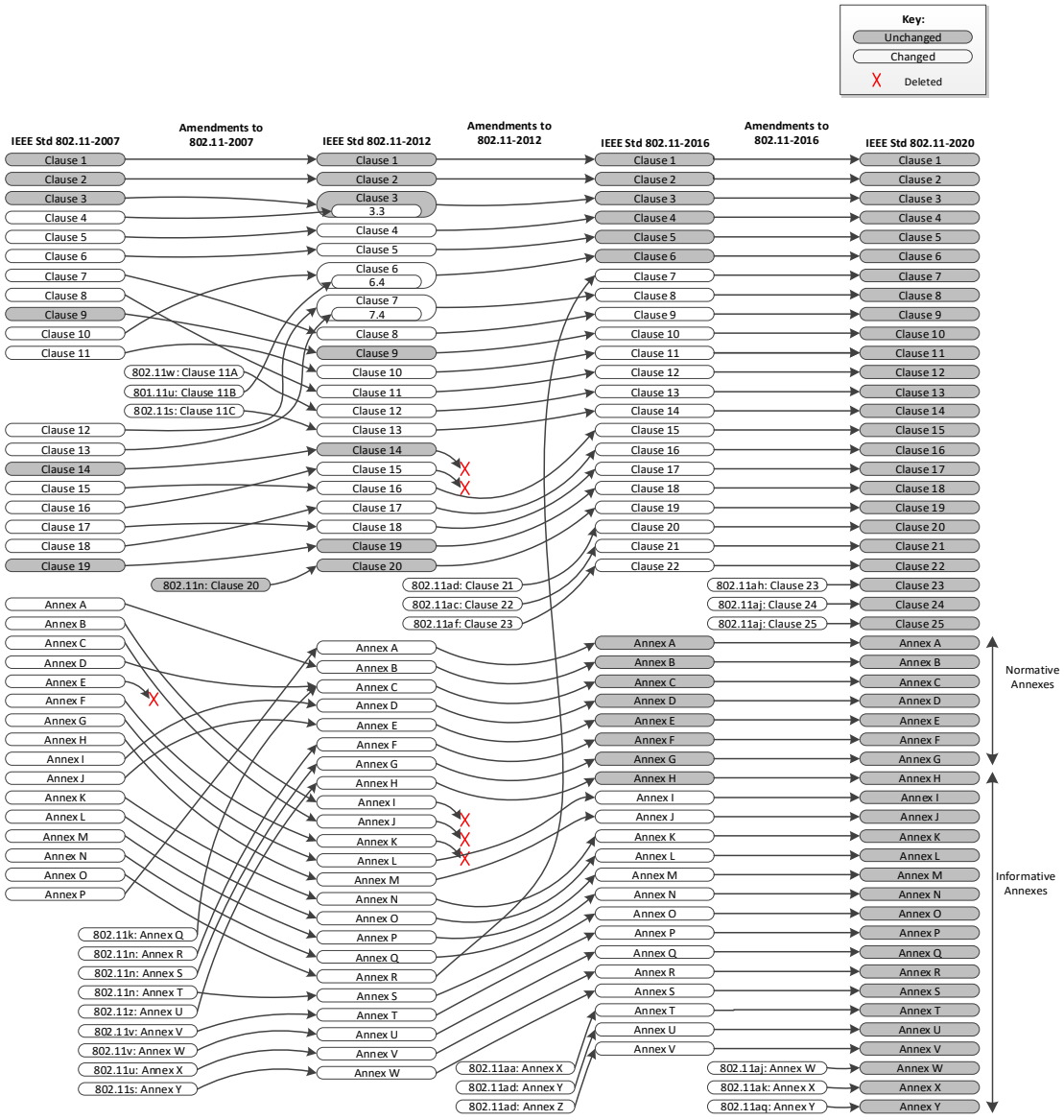

Figure 1—The evolution of numbering in IEEE Std 802.11

Contents

Tables

Figures

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

1. Overview

1.1 Scope

The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area.

1.2 Purpose

The purpose of this standard is to provide wireless connectivity for fixed, portable, and moving stations within a local area. This standard also offers regulatory bodies a means of standardizing access to one or more frequency bands for the purpose of local area communication.

1.3 Supplementary information on purpose

Specifically, in the context of IEEE 802.11™-compliant devices, this standard

- Describes the functions and services required by a device to operate within independent, personal, and infrastructure networks as well as the aspects of device mobility (transition) within those networks.
- Describes the functions and services that allow a device to communicate directly with another such device outside of an independent or infrastructure network.
- Defines the MAC procedures to support the MAC service data unit (MSDU) delivery services.
- Defines several PHY signaling techniques and interface functions that are controlled by the MAC.
- Permits the operation of a device within a wireless local area network (WLAN) that coexists with multiple overlapping IEEE 802.11 WLANs.
- Describes the requirements and procedures to provide data confidentiality of user information and MAC management information being transferred over the wireless medium (WM) and authentication of devices.
- Defines mechanisms for dynamic frequency selection (DFS) and transmit power control (TPC) that may be used to satisfy regulatory requirements for operation in any band.

— Defines the MAC procedures to support local area network (LAN) applications with quality-of-service (QoS) requirements, including the transport of voice, audio, and video.
— Defines mechanisms and services for wireless network management of devices that include BSS transition management, channel usage and coexistence, collocated interference reporting, diagnostic, multicast diagnostic and event reporting, flexible multicast, efficient beacon mechanisms, proxy ARP advertisement, location, timing measurement, directed multicast, extended sleep modes, traffic filtering, and management notification.
— Defines functions and procedures aiding network discovery and selection by devices, information transfer from external networks using QoS mapping, and a general mechanism for the provision of emergency services.
— Defines the MAC procedures that are necessary for wireless multi-hop communication to support wireless LAN mesh topologies.
— Defines medium access control mechanisms to support the prioritization of Management frames.
— Defines mechanisms to improve audio video (AV) streaming QoS while maintaining data and voice performance.
— Defines the PHY signaling, MAC, and beamforming procedures required for operation with directional antenna patterns.
— Defines the PHY and MAC enhancements to enable operation in the Chinese millimeter wave frequency bands (60 GHz and 45 GHz).
— Defines the mechanisms for communications over the wireless medium used as a link in an IEEE 802.1Q™ bridged network.
— Defines mechanisms to enable delivery of preassociation service discovery information to IEEE 802.11 stations (STAs).

1.4 Word usage

In this document, the word *shall* is used to indicate a mandatory requirement. The word *should* is used to indicate a recommendation. The word *may* is used to indicate a permissible action. The word *can* is used for statements of possibility and capability.

The construction "between *x* and *y*", "*x* to *y*" or "*x*-*y*" represents an inclusive range (i.e., the range includes both values *x* and *y*).

The construction "up to *y*" represents an inclusive upper bound (i.e., the range includes the value *y).*

Any action specified as relating to a SAP primitive is to be interpreted as an action on an invocation or instance of that primitive.

If <x> represents a scalar field, scalar subfield, scalar parameter or scalar MIB attribute:
— if "<x> is" is used in a context that relates to the testing or setting the value of "<x>" this usage is to be interpreted as though written "the value of <x> is"
— "<x> indicate(s)" is to be interpreted as though written "the value of <x> indicate(s)"
— "indicated by <x>" is to be interpreted as though written "indicated by the value of <x>"
— "<x> that indicate" is to be interpreted as though written "<x> whose value indicates"

If <x> represents a frame, element, subelement, structured field, structured subfield, structured parameter or structured MIB attribute:
— "<x> indicate(s)" is to be interpreted as though written "the contents of <x> indicate"
— "indicated by <x>" is to be interpreted as though written "indicated by the contents of <x>"
— "<x> that indicate" is to be interpreted as though written "<x> whose contents indicate"

If <x> represents a SAP primitive:

— "<x> indicate(s)" is to be interpreted as though written "the (or an) invocation of <x> indicates"

— "indicated by <x">" is to be interpreted as though written "indicated by the (or an) invocation of <x>"

The construction of descriptions for uses of the SHA family of hash algorithms [HMAC-]SHA-<1,256,384>[-*n*] is used to refer to hash algorithms/HMACs where square brackets indicate optional information, and *n* is an integer indicating the length, in bits, of the output when truncating.

A construction of the form "the x element can be included in a, b and c frames" or "the x element can be present in a, b and c frames" is not to be understood as being a complete list of frames in which the element might be present.

Constructions of the form that a frame, MPDU or A-MPDU is transmitted with a certain TXVECTOR parameter, or received with a certain RXVECTOR parameter, are to be understood as referring to the TXVECTOR or RXVECTOR parameter, respectively, corresponding to the PSDU containing the frame, MPDU or A-MPDU. Similarly, constructions of the form that a PPDU is transmitted with a certain TXVECTOR parameter, or received with a certain RXVECTOR parameter, are to be understood as referring to the TXVECTOR or RXVECTOR parameter, respectively, corresponding to the PSDU contained in the PPDU.

References in this standard to a "<name> frame", where <name> corresponds to one of the Management frame subtypes, are to be understood as being to a "<name> MMPDU, where the MMPDU is carried in the frame body of one or more Management frames with the Subtype field value corresponding to <name>, plus information from the MPDU headers (the Management frame subtype and the addresses)".

References in this standard to a "<name> request", where <name> corresponds to one of the Measurement Types in Table 9-98 is equivalent to (according to context) a) "a Spectrum Measurement Request frame or Radio Measurement Request frame carrying a Measurement Request element with the Measurement Type field equal to <name>" or b) "a Measurement Request element with the measurement type field equal to <name>".

An ASCII or UTF-8 string is a sequence of ASCII or UTF-8 encoded code points, respectively, without a terminating null.

References in this standard to "<adjective> STA" correspond to a specific instance of a STA implementation that will statically support and execute the <adjective> feature or role for the lifetime of the instance. Such a STA implementation may be capable of a different configuration where <adjective> is not supported (or even a mutually exclusive state is supported instead), but the switch from support to nonsupport of <adjective> is beyond the scope of this standard. The <adjective> support is to be understood as static for the lifetime of the instance, unless explicitly discussed otherwise.

References in this standard to "FILS authentication frame" or "SAE authentication frame" are to be understood as references to an Authentication frame that contains fields and elements for FILS or SAE (respectively) operation per Table 9-41.

1.5 Terminology for mathematical, logical, and bit operations

Floor (x), also written as $\lfloor x \rfloor$, is the largest integer smaller than or equal to x. For example, Floor (2.3) is 2 and Floor (–2.3) is –3. The two parameter form, Floor (x, y), is the largest multiple of y smaller than or equal to x; this operator is not used in this standard if y is negative. For example, Floor (3.3, 2) is 2 and Floor (–3.3, 2) is –4.

Ceil (x), also written as $\lceil x \rceil$ is the smallest integer larger than or equal to x. For example, Ceil (2.3) is 3 and Ceil (–2.3) is –2. The two parameter form, Ceil (x, y), is the smallest multiple of y larger than or equal to x; this operator is not used in this standard if y is negative. For example, Ceil (2.3, 2) is 4 and Ceil (–2.3, 2) is –2.

Round (x) is the integer closest to x, rounding values with a fractional part of 0.5 away from zero. For example, Round (2.3) is 2, Round (2.5) is 3, Round (–2.3) is –2 and Round (–2.5) is –3.

x mod y is the remainder when x is divided by y; this operator is not used in this standard if y is negative; the result is positive even if x is negative. For example, 5 mod 3 is 2 and –5 mod 3 is 1.

The symbol ⊕ represents bitwise exclusive OR (XOR).

log2 (x) is the logarithm of x to the base 2. For example, log2 (32) is 5.

Re (z) is the real part of complex number z. Im (z) is the imaginary part of complex number z (not including the factor i). For example, Re ($1 – 2i$) is 1 and Im ($1 – 2i$) is –2.

x && y is the short-circuiting Boolean AND.

x || y is the concatenation of x and y, except in code, where it sometimes is the short-circuiting Boolean OR (as determined by the context).

!x is the Boolean NOT.

x >> y is x logically shifted right (i.e., zeros are inserted at the most significant end) by y; this operator is not used in this standard if y is negative.

x << y is x shifted left (i.e., zeros are inserted at the least significant end) by y; this operator is not used in this standard if y is negative.

x == y is Boolean equality.

x != y Boolean inequality.

x & y, where x and y are numbers, is the bitwise AND of x and y.

x | y, where x and y are numbers, is the bitwise OR of x and y.

0x introduces a hexadecimal number. For example, 0x12 is 18 decimal.

L(S, F, N) is bits F to F+N–1 of the bit string S starting from the left, using the IEEE 802.11 bit conventions from 9.2.2.

Truncate-N(S) is bits 0 to N–1 of the bit string S starting from the left, using the IEEE 802.11 bit conventions from 9.2.2). Other bits are irretrievably deleted.

exp(x) is e to the power x, where e is the base of natural logarithms.

A[b:c] is the bit string consisting of bits b to c of A, where bit 0 of the output is the value of bit b. This operator is not used in this standard with b larger than c.

int(*S*) is the numeric value of bit string *S*, where bit 0 of S is the least significant bit, using the IEEE 802.11 bit conventions from 9.2.2.

NOTE—The *int* operator applied to a (portion of a) MAC address implies that octet 0 of the MAC address is the least significant octet under this operator.[1]

bin[*x*, *k*] is the operator that casts decimal value *x* into *k* bits binary vector, where *x* is less than 2^k.

[1] NOTEs in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement the standard. Lettered footnotes to tables and figures, however, are normative.

2. Normative references

The following referenced documents are indispensable for the application of this standard (i.e., they must be understood and used; therefore, each referenced document is cited in the text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) at the time of publication of this standard applies.

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ETSI EN 301 893, Broadband Radio Access Networks (BRAN); 5 GHz high performance RLAN (latest Official Journal of the European Union published version).[3]

FIPS 180-4, Secure Hash Standard.[4]

FIPS 186-4, Digital Signature Standard.

FIPS 197, Advanced Encryption Standard (AES).

IANA EAP Method Type Numbers, http://www.iana.org/assignments/eap-numbers.

IEEE Std 754™-2008, IEEE Standard for Binary Floating-Point Arithmetic.[5,6]

IEEE Std 802®, IEEE Standards for Local and Metropolitan Area Networks: Overview and Architecture.

IEEE Std 802c™-2017, IEEE Standard for Local and Metropolitan Area Networks: Overview and Architecture—Amendment 2: Local Medium Access Control (MAC) Address Usage.

IEEE Std 802.1AC™-2016, IEEE Standard for Local and Metropolitan Area Networks—Media Access Control (MAC) Service Definition.

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IEEE Std 802.1X™-2010, IEEE Standard for Local and Metropolitan Area Networks—Port-Based Network Access Control.

IEEE Std 802.3™-2018, IEEE Standard for Ethernet.

IEEE Std 802.21™-2017, IEEE Standard for Local and metropolitan area networks—Part 21: Media Independent Services Framework.

[2] 3GPP™ documents are available from the 3rd Generation Partnership Project Web site (http://www.3gpp.org).
[3] ETSI documents are available from the European Telecommunications Standards Institute (http://www.etsi.org).
[4] FIPS publications are available from the National Technical Information Service (NTIS) (http://csrc.nist.gov).
[5] The IEEE standards or products referred to in this clause are trademarks owned by The Institute of Electrical and Electronics Engineers, Inc.
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IETF RFC 3315, Dynamic Host Configuration Protocol for IPv6 (DHCPv6), July 2003.

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IETF RFC 3447, Public-Key Cryptography Standards (PKCS) #1: RSA Cryptography Specification Version 2.1, Feb. 2003.

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IETF RFC 3610, Counter with CBC-MAC (CCM), Whiting, D., R. Housley, and N. Ferguson, Sept. 2003 (status: informational).

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IETF RFC 4776, Dynamic Host Configuration Protocol (DHCPv4 and DHCPv6) Option for Civic Addresses Configuration Information, Nov. 2006.

[7] IEFT documents (i.e., RFCs) are available from the Internet Engineering Task Force (http://tools.ieft.org/).

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[8] ISO publications are available from the ISO Central Secretariat (http://www.iso.ch/).

ISO 4217, Currency codes.[9]

ISO/IEC 7498-1:1994, Information technology — Open Systems Interconnection — Basic Reference Model: The Basic Model.[10]

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[9] See http://www.currency-iso.org/en/home/tables/table-a1.html

[10] ISO/IEC publications are available from the ISO Central Secretariat (http://www.iso.ch/). ISO/IEC publications are also available in the United States from the American National Standards Institute (http://www.ansi.org/).

[11] The numbers in brackets correspond to the numbers of the bibliography in Annex A.

[12] ITU publications are available from the International Telecommunications Union (http://www.itu.int/).

[13] NIST publications are available from the National Institute of Standards and Technology (http://csrc.nist.gov/).