INTERNATIONAL STANDARD

ISO/IEC 8802-11

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AMENDMENT 6
2006-12-15

**IEEE STD 802.11i-2004
(Amendment to
IEEE Std 802.11-1999)**

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 6: Medium Access Control (MAC) Security Enhancements

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

Partie 11: Spécifications pour le contrôle d'accès au support et la couche physique

AMENDEMENT 6: Perfectionnements de la sécurité de moyens de contrôle d'accès (MAC)

Reference number
ISO/IEC 8802-11:2005/Amd.6:2006(E)
IEEE Std 802.11i-2004
(Amendment to IEEE Std 802.11-1999)

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IEEE Std 802.11i™-2004
[Amendment to IEEE Std 802.11™, 1999 Edition (Reaff 2003)
as amended by
IEEE Stds 802.11a™-1999, 802.11b™-1999,
802.11b™-1999/Cor 1-2001, 802.11d™-2001,
802.11g™-2003, and 802.11h™-2003]

IEEE Standards

802.11i™

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 6: Medium Access Control (MAC) Security Enhancements

IEEE Computer Society

Sponsored by the
LAN/MAN Standards Committee

This amendment is an approved IEEE Standard. It will be incorporated into the base standard in a future edition.

IEEE

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Abstract: Security mechanisms for IEEE 802.11 are defined in this amendment, which includes a definition of WEP for backward compatibility with the original standard, IEEE Std 802.11, 1999 Edition. This amendment defines TKIP and CCMP, which provide more robust data protection mechanisms than WEP affords. It introduces the concept of a security association into IEEE 802.11 and defines security association management protocols called the 4-Way Handshake and the Group Key Handshake. Also, it specifies how IEEE 802.1X may be utilized by IEEE 802.11 LANs to effect authentication.
Keywords: AES, authentication, CCM, CCMP, confidentiality, countermeasures, data authenticity, EAPOL-Key, 4-Way Handshake, Group Key Handshake, IEEE 802.1X, key management, key mixing, Michael, RC4, replay protection, robust security network, RSN, security, security association, TKIP, WEP

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Introduction

[This introduction is not part of IEEE Std 802.11i™-2004, IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements—Part 11: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications—Amendment 6: Medium Access Control (MAC) Security Enhancements.)]

Enhanced security services and mechanisms for the IEEE 802.11 medium access control (MAC) beyond those features and capabilities provided by the wired equivalent privacy (WEP) mechanism of the base standard, IEEE Std 802.11, 1999 Edition, are defined in this amendment. This amendment retains the WEP feature for purposes of backwards compatibility with existing IEEE 802.11 devices, but WEP is deprecated in favor of the new security features provided in this amendment.

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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 6: Medium Access Control (MAC) Security Enhancements

[This amendment is based on IEEE Std 802.11™, 1999 Edition (Reaff 2003), as amended by IEEE Stds 802.11a™-1999, 802.11b™-1999, 802.11b™-1999/Cor 1-2001, 802.11d™-2001, 802.11g™-2003, and 802.11h™-2003.]

NOTE—The editing instructions contained in this amendment define how to merge the material contained herein 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 small corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed either by using ~~strikethrough~~ (to remove old material) or 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 instructions. ***Replace*** is used to make large changes in existing text, subclauses, tables, or figures by removing existing material and replacing it with new material. Editorial notes will not be carried over into future editions.

1. Overview

1.2 Purpose

Change the fifth bullet of 1.2 as follows:

— Describes the requirements and procedures to provide ~~privacy~~confidentiality of user information being transferred over the wireless medium (WM) and authentication of IEEE 802.11 conformant devices.

End of changes to Clause 1.

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2. Normative references

Insert the following references at the appropriate locations in Clause 2:

FIPS PUB 180-1-1995, Secure Hash Standard.[1]

FIPS PUB 197-2001, Advanced Encryption Standard (AES).

IEEE P802.1X™-REV, Draft Standard for Local and Metropolitan Area Networks: Port-Based Network Access Control.[2, 3, 4]

IETF RFC 1321, The MD5 Message-Digest Algorithm, April 1992.[5]

IETF RFC 1750, Randomness Recommendations for Security, December 1994.

IETF RFC 2104, HMAC: Keyed-Hashing for Message Authentication, February 1997.

IETF RFC 2202, Test Cases for HMAC-MD5 and HMAC-SHA-1, September 1997.

IETF RFC 3394, Advanced Encryption Standard (AES) Key Wrap Algorithm, September 2002.

IETF RFC 3610, Counter with CBC-MAC (CCM), September 2003.

IETF RFC 3748, Extensible Authentication Protocol (EAP), March 2004.

End of changes to Clause 2.

3. Definitions

Delete the definition "3.40 privacy."

Change the definition for "wired equivalent privacy (WEP)" as follows:

3.49 wired equivalent privacy (WEP): ~~The~~ An optional cryptographic confidentiality algorithm specified by IEEE 802.11 <u>that may be</u> used to provide data confidentiality that is subjectively equivalent to the confidentiality of a wired local area network (LAN) medium that does not employ cryptographic techniques to enhance ~~privacy~~ <u>confidentiality</u>.

Insert the following definitions in alphabetical order into Clause 3, renumbering as necessary:

3.63 additional authentication data (AAD): Data that are not encrypted, but are cryptographically protected.

[1]FIPS publications are available from the National Technical Information Service (NTIS), U. S. Dept. of Commerce, 5285 Port Royal Road, Springfield, VA 22161 (http://www.ntis.org/).

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3.64 authentication, authorization, and accounting (AAA) key: Key information that is jointly negotiated between the Supplicant and the Authentication Server (AS). This key information is transported via a secure channel from the AS to the Authenticator. The pairwise master key (PMK) may be derived from the AAA key.

3.65 authentication and key management (AKM) suite: A set of AKM suite selectors.

3.66 Authentication Server (AS): An entity that provides an authentication service to an Authenticator. This service determines, from the credentials provided by the Supplicant, whether the Supplicant is authorized to access the services provided by the Authenticator. (IEEE P802.1X-REV[6])

3.67 Authenticator: An entity at one end of a point-to-point LAN segment that facilitates authentication of the entity attached to the other end of that link. (IEEE P802.1X-REV)

3.68 Authenticator address (AA): The IEEE 802.1X Authenticator medium access control (MAC) address.

3.69 authorized: To be explicitly allowed.

3.70 big endian: The concept that, for a given multi-octet numeric representation, the most significant octet has the lowest address.

3.71 cipher suite: A set of one or more algorithms, designed to provide data confidentiality, data authenticity or integrity, and/or replay protection.

3.72 counter mode (CTR) with CBC-MAC [cipher-block chaining (CBC) with message authentication code (MAC)] (CCM): A symmetric key block cipher mode providing confidentiality using CTR and data origin authenticity using CBC-MAC.

NOTE—See IETF RFC 3610.

3.73 decapsulate: To recover an unprotected frame from a protected one.

3.74 decapsulation: The process of generating plaintext data by decapsulating an encapsulated frame.

3.75 EAPOL-Key confirmation key (KCK): A key used to integrity-check an EAPOL-Key frame.

3.76 EAPOL-Key encryption key (KEK): A key used to encrypt the Key Data field in an EAPOL-Key frame.

3.77 encapsulate: To construct a protected frame from an unprotected frame.

3.78 encapsulation: The process of generating the cryptographic payload from the plaintext data. This comprises the cipher text as well as any associated cryptographic state required by the receiver of the data, e.g., initialization vectors (IVs), sequence numbers, message integrity codes (MICs), key identifiers.

3.79 4-Way Handshake: A pairwise key management protocol defined by this amendment. It confirms mutual possession of a pairwise master key (PMK) by two parties and distributes a group temporal key (GTK).

3.80 group: The entities in a wireless network, e.g., an access point (AP) and its associated stations (STAs), or all the STAs in an independent basic service set (IBSS) network.

[6]Information on references can be found in Clause 2.

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3.81 Group Key Handshake: A group key management protocol defined by this amendment. It is used only to issue a new group temporal key (GTK) to peers with whom the local station (STA) has already formed security associations.

3.82 group master key (GMK): An auxiliary key that may be used to derive a group temporal key (GTK).

3.83 group temporal key (GTK): A random value, assigned by the broadcast/multicast source, which is used to protect broadcast/multicast medium access control (MAC) protocol data units (MPDUs) from that source. The GTK may be derived from a group master key (GMK).

3.84 group temporal key security association (GTKSA): The context resulting from a successful group temporal key (GTK) distribution exchange via either a Group Key Handshake or a 4-Way Handshake.

3.85 IEEE 802.1X authentication: Extensible Authentication Protocol (EAP) authentication transported by the IEEE 802.1X protocol.

3.86 key counter: A 256-bit (32-octet) counter that is used in the pseudo-random function (PRF) to generate initialization vectors (IVs). There is a single key counter per station (STA) that is global to that STA.

3.87 key data encapsulation (KDE): Format for data other than information elements in the EAPOL-Key Data field.

3.88 key management service: A service to distribute and manage cryptographic keys within a robust security network (RSN).

3.89 little endian: The concept that, for a given multi-octet numeric representation, the least significant octet has the lowest address.

3.90 liveness: A demonstration that the peer is actually participating in this instance of communication.

3.91 message integrity code (MIC): A value generated by a symmetric key cryptographic function. If the input data are changed, a new value cannot be correctly computed without knowledge of the symmetric key. Thus, the secret key protects the input data from undetectable alteration. This is traditionally called a *message authentication code* (MAC), but the acronym MAC is already reserved for another meaning in this amendment.

3.92 Michael: The message integrity code (MIC) for the Temporal Key Integrity Protocol (TKIP).

3.93 nonce: A value that shall not be reused with a given key, including over all reinitializations of the system through all time.

3.94 pairwise: Two entities that are associated with each other, e.g., an access point (AP) and an associated station (STA), or a pair of STAs in an independent basic service set (IBSS) network. This term is used to describe the key hierarchies for keys that are shared only between the two entities in a pairwise association.

3.95 pairwise master key (PMK): The highest order key used within this amendment. The PMK may be derived from an Extensible Authentication Protocol (EAP) method or may be obtained directly from a preshared key (PSK).

3.96 pairwise master key security association (PMKSA): The context resulting from a successful IEEE 802.1X authentication exchange between the peer and Authentication Server (AS) or from a preshared key (PSK).

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3.97 pairwise transient key (PTK): A value that is derived from the pairwise master key (PMK), Authenticator address (AA), Supplicant address (SPA), Anthenticator nonce (ANonce), and Supplicant nonce (SNonce) using the pseudo-random function (PRF) and that is split up into as many as five keys, i.e., temporal encryption key, two temporal message integrity code (MIC) keys, EAPOL-Key encryption key (KEK), EAPOL-Key confirmation key (KCK).

3.98 pairwise transient key security association (PTKSA): The context resulting from a successful 4-Way Handshake exchange between the peer and Authenticator.

3.99 pass-phrase: A secret text string employed to corroborate the user's identity.

3.100 per-frame encryption key: A unique encryption key constructed for each medium access control (MAC) protocol data unit (MPDU), employed by some IEEE 802.11 security protocols.

3.101 per-frame sequence counter: For Temporal Key Integrity Protocol (TKIP), the counter that is used as the nonce in the derivation of the per-frame encryption key. For CCM [counter mode (CTR) with cipher-block chaining (CBC) with message authentication code (MAC)] Protocol (CCMP), the per-frame initialization vector (IV).

3.102 pre-robust security network association (pre-RSNA): The type of association used by a pair of stations (STAs) if the procedure for establishing authentication or association between them did not include the 4-Way Handshake.

3.103 pre-robust security network association (pre-RSNA) equipment: A device that is not able to create robust security network associations (RSNAs).

3.104 preshared key (PSK): A static key that is distributed to the units in the system by a method outside the scope of this amendment, always by some out-of-band means.

3.105 pseudo-random function (PRF): A function that hashes various inputs to derive a pseudo-random value. To add liveness to the pseudo-random value, a nonce should be one of the inputs.

3.106 robust security network (RSN): A security network that allows only the creation of robust security network associations (RSNAs). An RSN can be identified by the indication in the RSN Information Element (IE) of Beacon frames that the group cipher suite specified is not wired equivalent privacy (WEP).

3.107 robust security network association (RSNA): The type of association used by a pair of stations (STAs) if the procedure to establish authentication or association between them includes the 4-Way Handshake. Note that the existence of a RSNA by a pair of devices does not of itself provide robust security. Robust security is provided when all devices in the network use RSNAs.

3.108 robust-security-network-association- (RSNA-) capable equipment: A station (STA) that is able to create RSNAs. Such a device can use pre-RSNAs because of configuration. Notice that RSNA-capable does not imply full compliance with the RSNA Protocol Implementation Conformance Statement (PICS). A legacy device that has been upgraded to support Temporal Key Integrity Protocol (TKIP) can be RSNA-capable, but will not be compliant with the PICS if it does not also support CCM [counter mode (CTR) with cipher-block chaining (CBC) with message authentication code (MAC)] Protocol (CCMP).

3.109 robust-security-network-association- (RSNA-) enabled equipment: A station (STA) when it is RSNA-capable and `dot11RSNAEnabled` is set to TRUE.

3.110 robust security network association (RSNA) key management: Key management that includes the 4-Way Handshake, the Group Key Handshake, and the STAKey Handshake.

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3.111 security network: A basic service set (BSS) where the station (STA) starting the BSS provides information about the security capabilities and configuration of the BSS by including the robust security network (RSN) information element in Beacon frames.

3.112 selector: An item specifying a list constituent in an IEEE 802.11 Management Message information element.

3.113 STAKey: A symmetric key used to protect direct station-to-station (STA-to-STA) communication in an infrastructure basic service set (BSS).

3.114 STAKey Handshake: A STAKey key management protocol, used to issue a new STAKey to stations (STAs) that have a pairwise transient key security association (PTKSA) with an access point (AP).

3.115 STAKey security association (STAKeySA): The security context for direct station-to-station (STA-to-STA) communication in an infrastructure basic service set (BSS). A STAKeySA includes a STAKey.

3.116 Supplicant: An entity at one end of a point-to-point LAN segment that is being authenticated by an Authenticator attached to the other end of that link. (IEEE P802.1X-REV)

3.117 Supplicant address (SPA): The Supplicant's medium access control (MAC) address**.**

3.118 temporal encryption key: The portion of a pairwise transient key (PTK) or group temporal key (GTK) used directly or indirectly to encrypt data in medium access control (MAC) protocol data units (MPDUs).

3.119 temporal key: The combination of temporal encryption key and temporal message integrity code (MIC) key.

3.120 temporal message integrity code (MIC) key: The portion of a transient key used to ensure the integrity of medium access control (MAC) service data units (MSDUs) or MAC protocol data units (MPDUs).

3.121 transition security network (TSN): A security network that allows the creation of pre-robust security network associations (pre-RSNAs) as well as RSNAs. A TSN can be identified by the indication in the robust security network (RSN) information element of Beacon frames that the group cipher suite in use is wired equivalent privacy (WEP).

End of changes to Clause 3.

4. Abbreviations and acronyms

Insert the following abbreviations in alphabetical order into Clause 4:

AA	Authenticator address
AAA	authentication, authorization, and accounting
AAD	additional authentication data
AES	advanced encryption standard
AKM	authentication and key management
AKMP	Authentication and Key Management Protocol
ANonce	Authenticator nonce
ARP	Address Resolution Protocol
AS	Authentication Server
CBC	cipher-block chaining
CBC-MAC	cipher-block chaining with message authentication code

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CCM	CTR with CBC-MAC
CCMP	CTR with CBC-MAC Protocol
CTR	counter mode
EAP	Extensible Authentication Protocol (IETF RFC 3748)
EAPOL	Extensible Authentication Protocol over LANs (IEEE P802.1X-REV)
GMK	group master key
GNonce	group nonce
GTK	group temporal key
GTKSA	group temporal key security association
ICMP	Internet Control Message Protocol
KCK	EAPOL-Key confirmation key
KDE	key data encapsulation
KEK	EAPOL-Key encryption key
LFSR	linear feedback shift register
MIC	message integrity code
NTP	Network Time Protocol (IETF RFC 1305 [B12][7])
OUI	organizationally unique identifier
PAE	port access entity (IEEE P802.1X-REV)
PMK	pairwise master key
PMKID	pairwise master key identifier
PMKSA	pairwise master key security association
PN	packet number
PRF	pseudo-random function
PRNG	pseudo-random number generator
PSK	preshared key
PTK	pairwise transient key
PTKSA	pairwise transient key security association
RADIUS	remote authentication dial-in user service (IETF RFC 2865 [B14])
RSC	broadcast/multicast transmit sequence counter
RSN	robust security network
RSNA	robust security network association
SNAP	Sub-Network Access Protocol
SNonce	Supplicant nonce
SPA	Supplicant address
TKIP	Temporal Key Integrity Protocol
TSC	TKIP sequence counter
TSN	transition security network
TTAK	TKIP-mixed transmit address and key
UCT	unconditional transfer

End of changes to Clause 4.

[7]The numbers in brackets correspond to the numbers of the bibliography in Annex E.

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5. General description

5.1 General description of the architecture

5.1.1 How wireless LAN systems are different

5.1.1.4 Interaction with other IEEE 802® layers

Insert the following paragraph at the end of 5.1.1.4:

In a robust security network association (RSNA), IEEE 802.11 provides functions to protect data frames, IEEE 802.1X provides authentication and a Controlled Port, and IEEE 802.11 and IEEE 802.1X collaborate to provide key management. All stations (STAs) in an RSNA have a corresponding IEEE 802.1X entity that handles these services. This amendment defines how an RSNA utilizes IEEE 802.1X to access these services.

After 5.1.1.4, insert 5.1.1.5:

5.1.1.5 Interaction with non-IEEE 802 protocols

An RSNA utilizes non-IEEE 802 protocols for its authentication and key management (AKM) services. Some of these protocols are defined by other standards organizations, such as the Internet Engineering Task Force (IETF).

5.2 Components of the IEEE 802.11 architecture

5.2.2 Distribution system (DS) concepts

After 5.2.2.1, insert 5.2.2.2:

5.2.2.2 RSNA

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

— Enhanced authentication mechanisms for STAs

— Key management algorithms

— Cryptographic key establishment

— An enhanced data encapsulation mechanism, called CTR [counter mode] with CBC-MAC [cipher-block chaining (CBC) with message authentication code (MAC)] Protocol (CCMP), and, optionally, Temporal Key Integrity Protocol (TKIP)

An RSNA relies on several components external to the IEEE 802.11 architecture.

The first component is an IEEE 802.1X port access entity (PAE). PAEs are present on all STAs in an RSNA and control the forwarding of data to and from the medium access control (MAC). An access point (AP) always implements an Authenticator PAE and implements the EAP Authenticator role, and a STA always implements a Supplicant PAE and implements the Extensible Authentication Protocol (EAP) peer role. In an independent basic service set (IBSS), each STA implements both an Authenticator PAE and a Supplicant PAE and both the EAP Authenticator and EAP peer roles.

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A second component is the Authentication Server (AS). The AS may authenticate the elements of the RSNA itself, i.e., the non-AP STAs; and APs may provide material that the RSNA elements can use to authenticate each other. The AS communicates through the IEEE 802.1X Authenticator with the IEEE 802.1X Supplicant on each STA, enabling the STA to be authenticated to the AS and vice versa. An RSNA depends upon the use of an EAP method that supports mutual authentication of the AS and the STA. In certain applications, the AS may be integrated into the same physical device as the AP, or into a STA in an IBSS.

5.3 Logical service interfaces

Change item g) in the list of architectural services in 5.3 as follows:

g) ~~Privacy~~Confidentiality

5.3.1 Station service (SS)

Change item c) in the list of SSs in 5.3.1 as follows:

c) ~~Privacy~~Confidentiality

5.4 Overview of the services

5.4.2 Services that support the distribution service

5.4.2.2 Association

Insert the following paragraph after the second paragraph of 5.4.2.2:

Within a robust security network (RSN), this is different. In an RSNA, the IEEE 802.1X Port determines when to allow data traffic across an IEEE 802.11 link. A single IEEE 802.1X Port maps to one association, and each association maps to an IEEE 802.1X Port. An IEEE 802.1X Port consists of an IEEE 802.1X Controlled Port and an IEEE 802.1X Uncontrolled Port. The IEEE 802.1X Controlled Port is blocked from passing general data traffic between two STAs until an IEEE 802.1X authentication procedure completes successfully over the IEEE 802.1X Uncontrolled Port. Once the AKM completes successfully, data protection is enabled to prevent unauthorized access, and the IEEE 802.1X Controlled Port unblocks to allow protected data traffic. IEEE 802.1X Supplicants and Authenticators exchange protocol information via the IEEE 802.1X Uncontrolled Port. It is expected that most other protocol exchanges will make use of the IEEE 802.1X Controlled Ports. However, a given protocol may need to bypass the authorization function and make use of the IEEE 802.1X Uncontrolled Port.

NOTE—See IEEE P802.1X-REV for a discussion of Controlled Port and Uncontrolled Port.

5.4.2.3 Reassociation

Insert the following paragraph at the end of 5.4.2.3:

No facilities are provided to move an RSNA during reassociation. Therefore, the old RSNA will be deleted, and a new RSNA will need to be constructed.

Change the title of 5.4.3 as follows:

5.4.3 Access control and confidentiality ~~control~~services

Change the second paragraph of 5.4.3 as follows:

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Two services are provided to bring the IEEE 802.11 functionality in line with wired local area network (LAN) assumptions: authentication and ~~privacy~~confidentiality. Authentication is used instead of the wired media physical connection. ~~Privacy~~ Data confidentiality is used to provide the confidential aspects of closed wired media.

Insert the following paragraphs at the end of 5.4.3:

In a wireless LAN (WLAN) that does not support RSNA, two services, authentication and confidentiality, are defined. IEEE 802.11 authentication is used instead of the wired media physical connection. WEP encryption was defined to provide the confidentiality aspects of closed wired media.

An RSNA uses the IEEE 802.1X authentication service along with TKIP and CCMP to provide access control. The IEEE 802.11 station management entity (SME) provides key management via an exchange of IEEE 802.1X EAPOL-Key frames. Confidentiality and data integrity are provided by RSN key management together with the TKIP and CCMP.

5.4.3.1 Authentication

Replace the text of 5.4.3.1 with the following:

IEEE 802.11 authentication operates at the link level between IEEE 802.11 STAs. IEEE 802.11 does not provide either end-to-end (message origin to message destination) or user-to-user authentication.

IEEE 802.11 attempts to control LAN access via the authentication service. IEEE 802.11 authentication is an SS. This service may be used by all STAs to establish their identity to STAs with which they communicate, in both extended service set (ESS) and IBSS networks. If a mutually acceptable level of authentication has not been established between two STAs, an association shall not be established.

IEEE 802.11 defines two authentication methods: Open System authentication and Shared Key authentication. Open System authentication admits any STA to the DS. Shared Key authentication relies on WEP to demonstrate knowledge of a WEP encryption key. The IEEE 802.11 authentication mechanism also allows definition of new authentication methods.

An RSNA also supports authentication based on IEEE 802.1X, or preshared keys (PSKs). IEEE 802.1X authentication utilizes the EAP to authenticate STAs and the AS with one another. This amendment does not specify an EAP method that is mandatory to implement. See 8.4.4 for a description of the IEEE 802.1X authentication and PSK usage within an IEEE 802.11 IBSS.

In an RSNA, IEEE 802.1X Supplicants and Authenticators exchange protocol information via the IEEE 802.1X Uncontrolled Port. The IEEE 802.1X Controlled Port is blocked from passing general data traffic between two STAs until an IEEE 802.1X authentication procedure completes successfully over the IEEE 802.1X Uncontrolled Port.

The Open System authentication algorithm is used in both basic service set (BSS) and IBSS RSNAs, although Open System authentication is optional in an RSNA IBSS. RSNA disallows the use of Shared Key authentication.

Management information base (MIB) functions are provided in Annex D to support the standardized authentication schemes.

A STA may be authenticated with many other STAs at any given instant.

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5.4.3.2 Deauthentication

Change the text of 5.4.3.2 as follows:

The deauthentication service is invoked when an existing Open System or Shared Key authentication is to be terminated. Deauthentication is an SS.

In an ESS, because authentication is a prerequisite for association, the act of deauthentication shall cause the station to be disassociated. The deauthentication service may be invoked by either authenticated party (non-AP STA or AP). Deauthentication is not a request; it is a notification. Deauthentication shall not be refused by either party. When an AP sends a deauthentication notice to an associated STA, the association shall also be terminated.

In an RSN ESS, Open System authentication is required. In an RSN ESS, deauthentication results in termination of any association for the deauthenticated station. It also results in the IEEE 802.1X Controlled Port for that STA being disabled and deletes the pairwise transient key security association (PTKSA). The deauthentication notification is provided to IEEE 802.1X via the MAC layer.

In an RSNA, deauthentication also destroys any related PTKSA, group temporal key security association (GTKSA), and STAKey security associations (STAKeySAs) that exist in the STA and closes the associated IEEE 802.1X Controlled Port. If pairwise master key (PMK) caching is not enabled, deauthentication also destroys the pairwise master key security association (PMKSA) from which the deleted PTKSA was derived.

In an RSN IBSS, Open System authentication is optional, but a STA is required to recognize Deauthentication frames. Deauthentication results in the IEEE 802.1X Controlled Port for that STA being disabled and deletes the PTKSA.

Change the title and text of 5.4.3.3 as follows:

5.4.3.3 ~~Privacy~~Confidentiality

In a wired LAN, only those stations physically connected to the wire ~~may hear~~ can send or receive LAN traffic. With a wireless shared medium, this is not the case. Any IEEE 802.11-compliant STA ~~may hear~~ can receive all like-PHY IEEE 802.11 traffic that is within range and can transmit to any other IEEE 802.11 STA within range. Thus the connection of a single wireless link (without ~~privacy~~confidentiality) to an existing wired LAN may seriously degrade the security level of the wired LAN.

To bring the ~~functionality~~ security of the wireless LAN up to the level implicit in wired LAN design, IEEE 802.11 provides the ability to ~~encrypt~~ protect the contents of messages. This functionality is provided by the ~~privacy~~confidentiality service. ~~Privacy~~Confidentiality is an SS.

~~IEEE 802.11 specifies an optional privacy algorithm, WEP, that is designed to satisfy the goal of wired LAN "equivalent" privacy. The algorithm is not designed for ultimate security but rather to be "at least as secure as a wire." See Clause 8 for more details.~~

~~IEEE 802.11 uses the WEP mechanism (see Clause 8) to perform the actual encryption of messages. MIB functions are provided to support WEP.~~

~~Note that privacy may only be invoked for data frames and some Authentication Management frames. All stations initially start "in the clear" in order to set up the authentication and privacy services.~~

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IEEE 802.11 provides three cryptographic algorithms to protect data traffic: WEP, TKIP, and CCMP. WEP and TKIP are based on the RC4[8] algorithm, and CCMP is based on the advanced encryption standard (AES). A means is provided for STAs to select the algorithm(s) to be used for a given association.

The default ~~privacy~~confidentiality state for all IEEE 802.11 STAs is "in the clear." If the ~~privacy~~confidentiality service is not invoked, all messages shall be sent ~~unencrypted~~unprotected. If this ~~default~~ policy is ~~not~~ unacceptable to ~~one party or the other, data frames shall not be successfully communicated between the LLC entities.~~ the sender, it shall not send data frames; and if the policy is unacceptable to the receiver, it shall discard any received data frames. ~~Unencrypted~~ Unprotected data frames received at a station configured for mandatory ~~privacy~~confidentiality, as well as protected~~encrypted~~ data frames using a key not available at the receiving station, are discarded without an indication to logical link control (LLC) (or without indication to distribution services in the case of "To DS" frames received at an AP). These frames are acknowledged on the WM [if received without frame check sequence (FCS) error] to avoid wasting WM bandwidth on retries.

After 5.4.3.3, insert 5.4.3.4 through 5.4.3.6:

5.4.3.4 Key management

The enhanced confidentiality, data authentication, and replay protection mechanisms require fresh cryptographic keys. The procedures defined in this amendment provide fresh keys by means of protocols called the 4-Way Handshake and Group Key Handshake.

5.4.3.5 Data origin authenticity

The data origin authenticity mechanism defines a means by which a STA that receives a data frame can determine which STA transmitted the MAC protocol data unit (MPDU). This feature is required in an RSNA to prevent one STA from masquerading as a different STA. This mechanism is provided for STAs that use CCMP or TKIP.

Data origin authenticity is only applicable to unicast data frames. The protocols do not guarantee data origin authenticity for broadcast/multicast data frames, as this cannot be accomplished using symmetric keys and public key methods are too computationally expensive.

5.4.3.6 Replay detection

The replay detection mechanism defines a means by which a STA that receives a data frame from another STA can detect whether the data frame is an unauthorized retransmission. This mechanism is provided for STAs that use CCMP or TKIP.

5.6 Differences between ESS and IBSS LANs

Insert the following paragraph at the end of 5.6:

In an IBSS, each STA must enforce its own security policy. In an ESS, an AP can enforce a uniform security policy across all STAs.

[8]Details of the RC4 algorithm are available from RSA Security, Inc. Contact RSA for algorithm details and the uniform RC4 license terms that RSA offers to anyone wishing to use RC4 for the purpose of implementing the IEEE 802.11 WEP option. If necessary, contact the IEEE Standards Department Intellectual Property Rights Administrator for details on how to communicate with RSA.

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5.7 Message information contents that support the services

Change the title and text of 5.7.5 as follows:

5.7.5 ~~Privacy~~Confidentiality

For a STA to invoke a ~~the WEP privacy~~ confidentiality algorithm (as controlled by MLME-SETKEYS, see Clause 10, or the related MIB attributes, see Clause 11), the ~~privacy~~ confidentiality service ~~causes MPDU encryption~~ selects the confidentiality algorithm and sets the ~~WEP frame header~~Protected Frame bit appropriately (see Clause 7).

5.7.6 Authentication

Change the first paragraph in 5.7.6 as follows:

For a STA to authenticate with another STA using either Open System or Shared Key authentication, the authentication service causes one or more authentication management frames to be exchanged. The exact sequence of frames and their content are dependent on the authentication scheme invoked. For ~~all~~both of these authentication schemes, the authentication algorithm is identified within the management frame body.

5.7.7 Deauthentication

Change the first paragraph in 5.7.7 as follows:

For a STA to invalidate an active authentication that was established using Open System or Shared Key authentication, the following message is sent:

5.8 Reference model

Replace Figure 11 with the following:

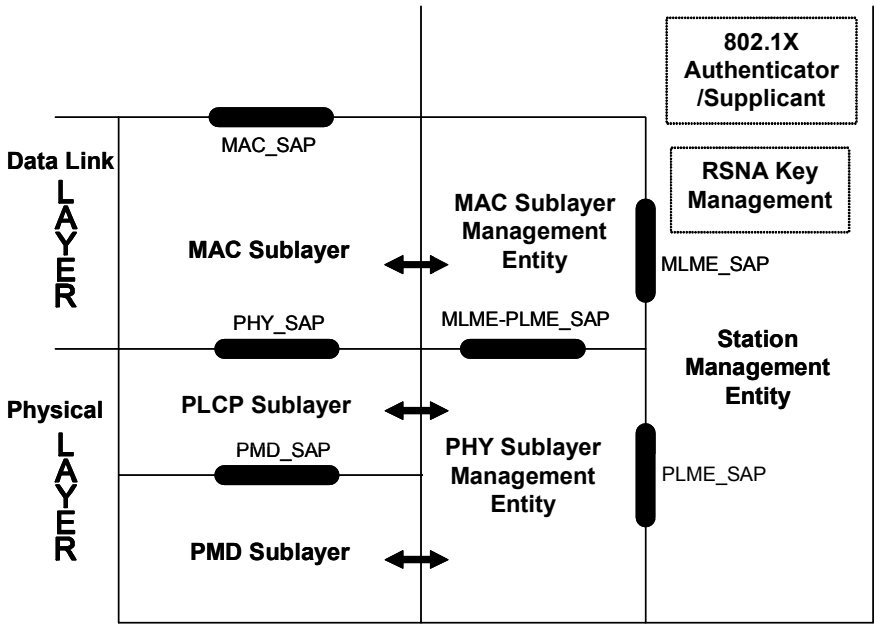

Figure 11—Portion of the ISO/IEC basic reference model covered in this standard

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Insert the following paragraph at the end of 5.8:

There is an interface between the IEEE 802.1X Supplicant/Authenticator and the SME shown in Figure 11. This interface is described in IEEE P802.1X-REV.

After 5.8, insert 5.9 through 5.9.5 and renumber the figures as necessary:

5.9 IEEE 802.11 and IEEE 802.1X

An RSNA relies on IEEE 802.1X to provide authentication services and uses the IEEE 802.11 key management scheme defined in 8.5. The IEEE 802.1X access control mechanisms apply to the association between a STA and an AP and to the relationship between the IBSS STA and STA peer. The AP's SME performs the Authenticator and, optionally, the Supplicant and AS roles. In an ESS, a non-AP STA's SME performs the Supplicant role. In an IBSS, a STA's SME takes on both the Supplicant and Authenticator roles and may take on the AS role.

5.9.1 IEEE 802.11 usage of IEEE 802.1X

IEEE 802.11 depends upon IEEE 802.1X to control the flow of MAC service data units (MSDUs) between the DS and STAs by use of the IEEE 802.1X Controlled/Uncontrolled Port model. IEEE 802.1X authentication frames are transmitted in IEEE 802.11 data frames and passed via the IEEE 802.1X Uncontrolled Port. The IEEE 802.1X Controlled Port is blocked from passing general data traffic between two STAs until an IEEE 802.1X authentication procedure completes successfully over the IEEE 802.1X Uncontrolled Port. It is the responsibility of both the Supplicant and the Authenticator to implement port blocking. Each association between a pair of STAs creates a unique pair of IEEE 802.1X Ports, and authentication takes place relative to those ports alone.

IEEE 802.11 depends upon IEEE 802.1X and the 4-Way Handshake and Group Key Handshake, described in Clause 8, to establish and change cryptographic keys. Keys are established after authentication has completed. Keys may change for a variety of reasons, including expiration of an IEEE 802.1X authentication timer, key compromise, danger of compromise, or policy.

5.9.2 Infrastructure functional model overview

This subclause summarizes the system setup and operation of an RSN, in two cases: when an IEEE 802.1X AS is used and when a PSK is used. For an ESS, the AP includes an Authenticator, and each associated STA includes a Supplicant.

5.9.2.1 AKM operations with AS

The following AKM operations are carried out when an IEEE 802.1X AS is used:

a) Prior to any use of IEEE 802.1X, IEEE 802.11 assumes that the Authenticator and AS have established a secure channel. The security of the channel between the Authenticator and the AS is outside the scope of this amendment.

   Authentication credentials must be distributed to the Supplicant and AS prior to association.

b) A STA discovers the AP's security policy through passively monitoring Beacon frames or through active probing (shown in Figure 11a). If IEEE 802.1X authentication is used, the EAP authentication process starts when the AP's Authenticator sends the EAP-Request (shown in Figure 11b) or the STA's Supplicant sends the EAPOL-Start message. EAP authentication frames pass between the Supplicant and AS via the Authenticator and Supplicant's Uncontrolled Ports. This is shown in Figure 11b.

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c) The Supplicant and AS authenticate each other and generate a PMK. The PMK is sent from the AS to the Authenticator over the secure channel. See Figure 11b.

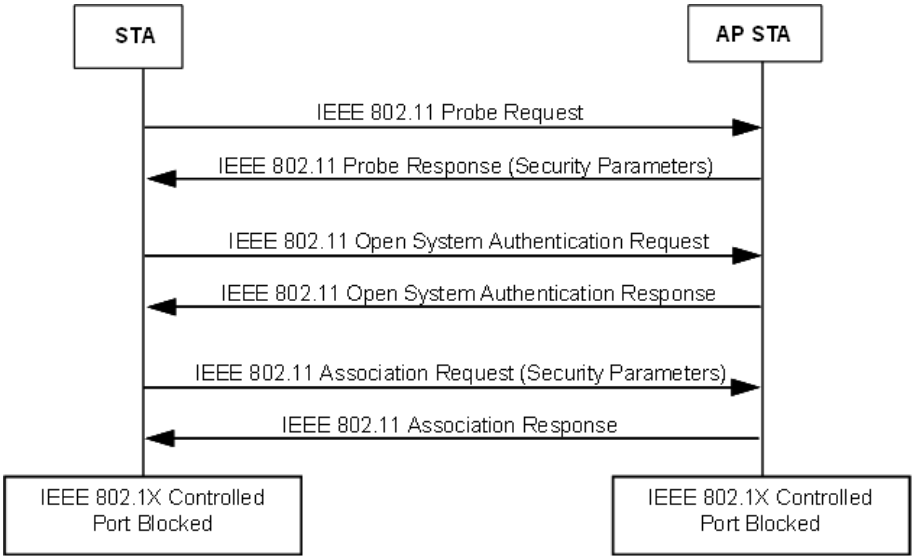

Figure 11a—Establishing the IEEE 802.11 association

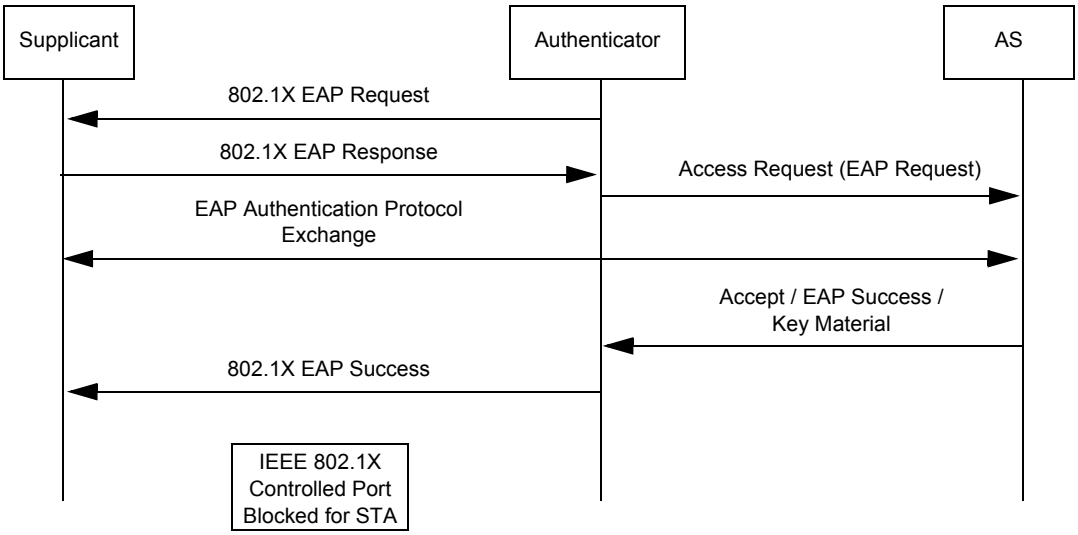

Figure 11b—IEEE 802.1X EAP authentication

A 4-Way Handshake utilizing EAPOL-Key frames is initiated by the Authenticator to do the following:

— Confirm that a live peer holds the PMK.

— Confirm that the PMK is current.

— Derive a fresh pairwise transient key (PTK) from the PMK.

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— Install the pairwise encryption and integrity keys into IEEE 802.11.
— Transport the group temporal key (GTK) and GTK sequence number from Authenticator to Supplicant and install the GTK and GTK sequence number in the STA and, if not already installed, in the AP.
— Confirm the cipher suite selection.

Upon successful completion of the 4-Way Handshake, the Authenticator and Supplicant have authenticated each other; and the IEEE 802.1X Controlled Ports are unblocked to permit general data traffic. See Figure 11c.

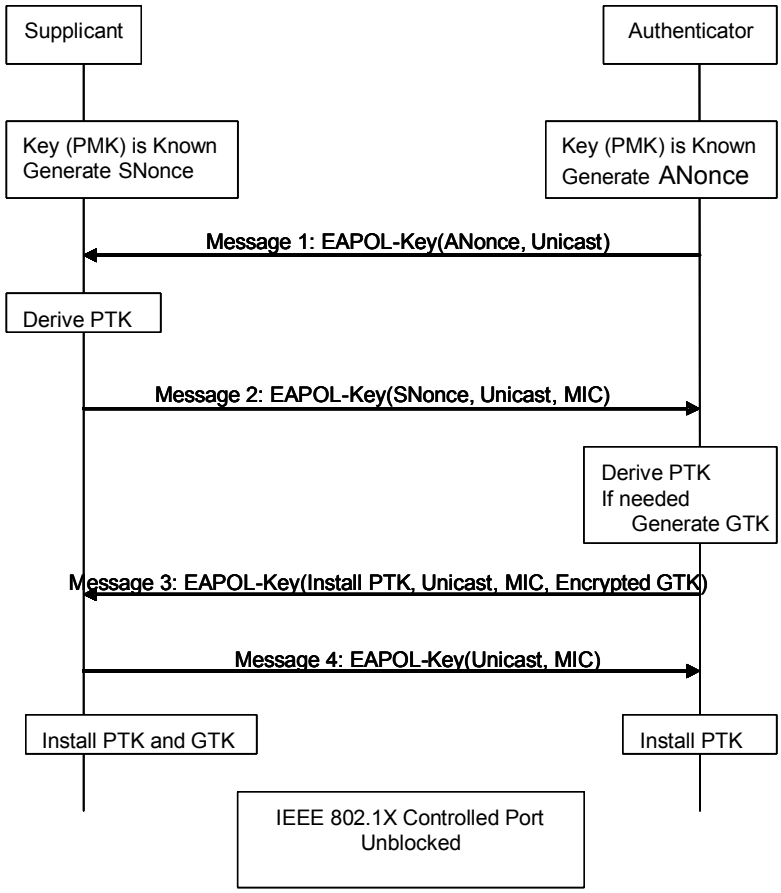

Figure 11c—Establishing pairwise and group keys

If the Authenticator later changes the GTK, it sends the new GTK and GTK sequence number to the Supplicant using the Group Key Handshake to allow the Supplicant to continue to receive broadcast/multicast messages and, optionally, to transmit and receive unicast frames. EAPOL-Key frames are used to carry out this exchange. See Figure 11d.

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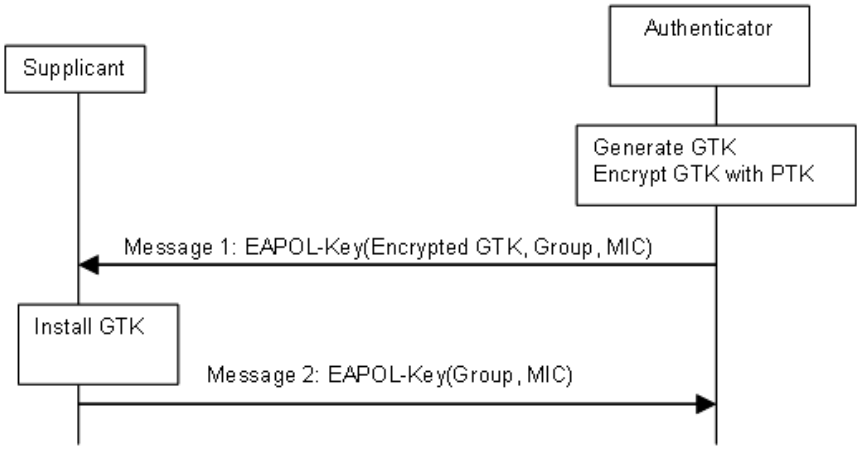

Figure 11d—Delivery of subsequent group keys

5.9.2.2 Operations with PSK

The following AKM operations are carried out when the PMK is a PSK:

— A STA discovers the AP's security policy through passively monitoring Beacon frames or through active probing (shown in Figure 11a). A STA associates with an AP and negotiates a security policy. The PMK is the PSK.

— The 4-Way Handshake using EAPOL-Key frames is used just as with IEEE 802.1X authentication, when an AS is present. See Figure 11c.

— The GTK and GTK sequence number are sent from the Authenticator to the Supplicant just as in the AS case. See Figure 11c and Figure 11d.

5.9.3 IBSS functional model description

This subclause summarizes the system setup and operation of an RSNA in an IBSS. An IBSS RSNA is specified in 8.4.7.

5.9.3.1 Key usage

In an IBSS, the unicast data frames between two STAs are protected with a pairwise key. The key is part of the PTK, which is derived during a 4-Way Handshake.

In an IBSS, the broadcast/multicast data frames are protected by a key, e.g., named B1, that is generated by the STA transmitting the broadcast/multicast frame. To allow other STAs to decrypt broadcast/multicast frames, B1 must be sent to all the other STAs in the IBSS. B1 is sent in an EAPOL-Key frame, encrypted under the EAPOL-Key encryption key (KEK) portion of the PTK, and protected from modification by the EAPOL-Key confirmation key (KCK) portion of the PTK.

In an IBSS, a STA's SME responds to Deauthentication frames from a STA by deleting the PTKSA associated with that STA.

5.9.3.2 Sample IBSS 4-Way Handshakes

In this example (see Figure 11e), there are three STAs: S1, S2, S3. The broadcast/multicast frames sent by S1 are protected by B1; similarly B2 for S2, and B3 for S3.

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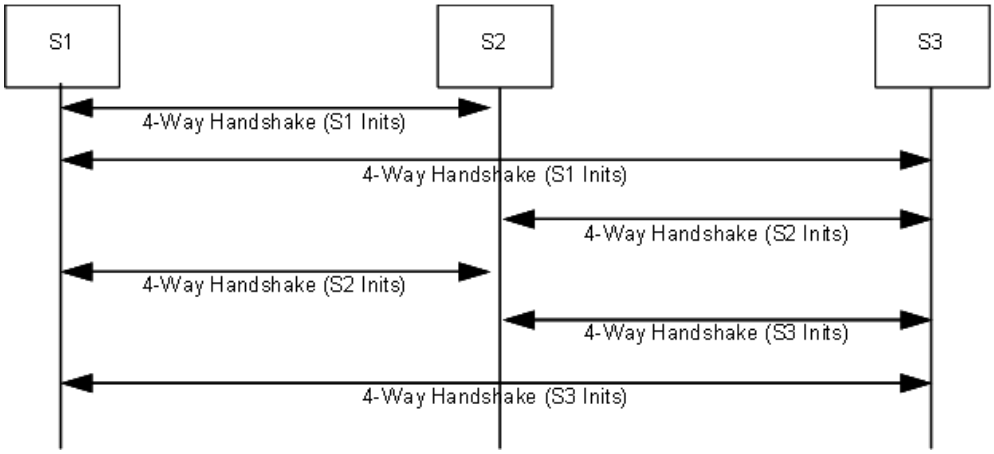

Figure 11e—Sample 4-Way Handshakes in an IBSS

For stations S2 and S3 to decrypt broadcast/multicast frames from S1, B1 must be sent to S2 and S3. This is done using the 4-Way Handshake initially and using the Group Key Handshake for GTK updates.

The 4-Way Handshake from S1 to S2 allows S1 to send broadcast/multicast frames to S2, but does not allow S2 to send broadcast/multicast frames to S1 because S2 has a different transmit GTK. Therefore, S2 needs to initiate a 4-Way Handshake to S1 to allow S1 to decrypt S2's broadcast/multicast frames. Similarly, S2 also needs to initiate a 4-Way Handshake to S3 to enable S3 to receive broadcast/multicast messages from S2.

In a similar manner S3 needs to complete the 4-Way Handshake with S1 and S2 to deliver B3 to S1 and S2.

In this example, there are six 4-Way Handshakes. In general, N STA Supplicants require $N(N-1)$ 4-Way Handshakes.

NOTE—In principle the KCK and KEK from a single 4-Way Handshake can be used for the Group Key Handshake in both directions, but using two 4-Way Handshakes means the Authenticator key state machine does not need to be different between IBSS and ESS.[9]

The Group Key Handshake can be used to send the GTKs to the correct STAs. The 4-Way Handshake is used to derive the pairwise key and to send the initial GTK. Because in an IBSS there are two 4-Way Handshakes between any two STA Supplicants and Authenticators, the pairwise key used between any two STAs is from the 4-Way Handshake initiated by the STA Authenticator with the higher MAC address (see 8.5.1 for the notion of address comparison). The KCK and KEK used for a Group Key Handshake are the KCK and KEK derived by the 4-Way Handshake initiated by the same Authenticator that is initiating the Group Key Handshake.

In an IBSS, a secure link exists between two stations when both 4-Way Handshakes have completed successfully. The Supplicant and Authenticator 4-Way Handshake state machines interact so the IEEE 802.1X variable portValid is not set until both 4-Way Handshakes complete.

If a fourth STA comes within range and its SME decides to initiate a security association with the three peers, its Authenticator initiates 4-Way Handshakes with each of the other three STA Supplicants. Similarly, the original three STA Authenticators in the IBSS need to initiate 4-Way Handshakes to the fourth STA

[9]Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement this amendment.

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Supplicant. A STA learns that a peer STA is RSNA-enabled and the peer's security policy (e.g., whether the Authentication and Key Management Protocol (AKMP) is PSK or IEEE 802.1X authentication) from the Beacon or Probe Response frame. The initiation may start for a number of reasons:

a) The fourth STA receives a Beacon or Probe Response frame from a MAC address with which it has not completed a 4-Way Handshake.

b) A STA's SME receives a MLME-PROTECTEDFRAMEDROPPED.indication primitive from a MAC address with which it has not completed a 4-Way Handshake. This could be a multicast/broadcast data frame transmitted by any of the STAs. If the SME wants to set up a security association to the peer STA, but does not know the security policy of the peer, it should send a Probe Request frame to the peer STA to find its security policy before setting up a security association to the peer STA.

c) A STA's SME receives Message 1 of the 4-Way Handshake sent to a STA because the initiator received a broadcast data frame, Beacon frame, or Probe Response frame from that STA. If a STA received a 4-Way Handshake, wants to set up a security association to the peer STA, but does not know the security policy of the peer, it should send a Probe Request frame to the peer STA to find its security policy before setting up a security association to the peer STA.

5.9.3.3 IBSS IEEE 802.1X Example

When IEEE 802.1X authentication is used, each STA will need to include an IEEE 802.1X Authenticator and AS. A STA learns that a peer STA is RSNA-enabled and the peer's security policy (e.g., whether the AKMP is PSK or IEEE 802.1X authentication) from the Beacon or Probe Response frame.

Each STA's Supplicant will send an EAPOL-Start message to every other station to which it wants to authenticate, and each STA's Authenticator will respond with the identity of the credential it wants to use.

The EAPOL-Start and EAP-Request/Identity messages are initiated when a protected data frame (indicated via a MLME-PROTECTEDFRAMEDROPPED.indication primitive), an IEEE 802.1X message, Beacon frame, or Probe Response frame is received from a MAC address with which the STA has not completed IEEE 802.1X authentication. If the SME wants to set up a security association to the peer STA, but does not know the security policy of the peer, it should send a Probe Request frame to the peer STA to find its security policy before setting up a security association to the peer STA.

Although Figure 11f shows the two IEEE 802.1X exchanges serialized, they may occur interleaved.

5.9.4 Authenticator-to-AS protocol

The Authenticator-to-AS authentication definition is out of the scope of this amendment, but, to provide security assurances, the protocol must support the following functions:

a) Mutual authentication between the Authenticator and AS

b) A channel for the Supplicant/AS authentication

c) The ability to pass the generated key from the AS to the Authenticator in a manner that provides authentication of the key source, ensures integrity of the key transfer, and preserves confidentiality of the key from all other parties

Suitable protocols include, but are not limited to, remote authentication dial-in user service (RADIUS) (IETF RFC 2865 [B14]) and Diameter (IETF RFC 3588 [B15]).

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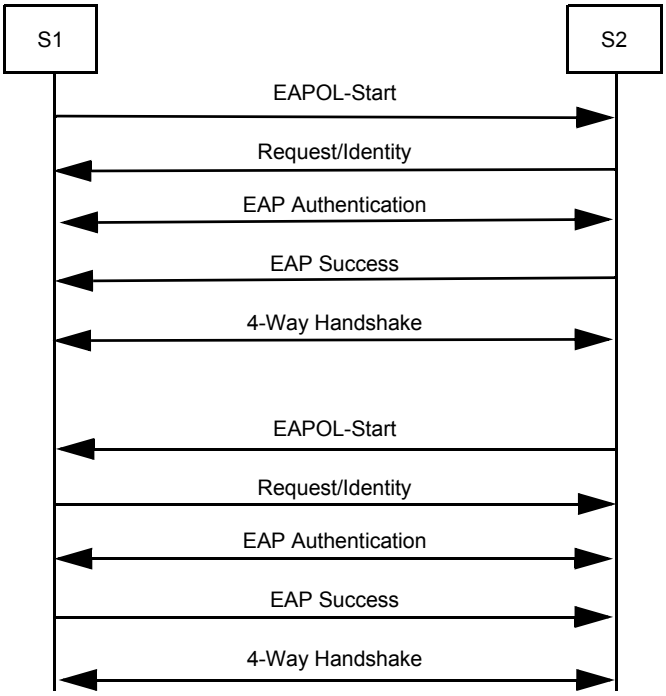

Figure 11f—Example using IEEE 802.1X authentication

5.9.5 PMKSA caching

The Authenticator and Supplicant may cache PMKSAs, which include the IEEE 802.1X state. A PMKSA can be deleted from the cache for any reason and at any time.

The STA may supply a list of PMK or PSK key identifiers in the (Re)Association Request frame. Each key identifier names a PMKSA; the PMKSA may contain a single PMK. The Authenticator specifies the selected PMK or PSK key identifier in Message 1 of the 4-Way Handshake. The selection of the key identifiers to be included within the (Re)Association Request frame and Message 1 of the 4-Way Handshake is out of the scope of this amendment.

End of changes to Clause 5.

6. MAC service definition

6.1 Overview of MAC services

6.1.2 Security services

Change the text of 6.1.2 as follows:

Security services in IEEE 802.11 are provided by the authentication service and the WEP, TKIP, and CCMP mechanisms. The scope of the security services provided is limited to station-to-station data exchange. The ~~privacy~~ confidentiality service offered by an IEEE 802.11 WEP, TKIP, and CCMP implementation is the encryption of the MSDU. For the purposes of this standard, WEP, TKIP, and CCMP are ~~is~~ viewed as ~~a~~

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logical services located within the MAC sublayer as shown in the reference model, Figure 11. Actual implementations of the WEP, TKIP, and CCMP services are transparent to the LLC and other layers above the MAC sublayer.

The security services provided by WEP, TKIP, and CCMP in IEEE 802.11 are as follows:

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

During the authentication exchange, both parties ~~A and B~~ exchange authentication information as described in Clause 8.

The MAC sublayer security services provided by WEP, TKIP, and CCMP rely on information from non-layer 2 management or system entities. Management entities communicate information to WEP through a set of MIB attributes. Management entities communicate information to TKIP and CCMP through a set of MAC sublayer management entity (MLME) interfaces and MIB attributes; in particular, the decision tree for TKIP and CCMP defined in 8.7 is driven by MIB attributes.

After 6.1.3, insert 6.1.4 and renumber the figures as necessary:

6.1.4 MAC data service architecture

The MAC data plane architecture (i.e., processes that involve transport of all or part of an MSDU) is shown in Figure 11g. During transmission, an MSDU goes through some or all of the following processes: frame delivery deferral during power save mode, sequence number assignment, fragmentation, encryption, integrity protection, and frame formatting. IEEE 802.1X may block the MSDU at the Controlled Port.

During reception, a received data frame goes through processes of MPDU header + cyclic redundancy code (CRC) validation, duplicate removal, decryption, defragmentation, integrity checking, and replay detection. The IEEE 802.1X Controlled/Uncontrolled Ports discard the MSDU if the Controlled Port is not enabled or if the MSDU does not represent an IEEE 802.1X frame. TKIP and CCMP MPDU frame order enforcement occurs after decryption, but prior to MSDU defragmentation; therefore, defragmentation will fail if MPDUs arrive out of order.

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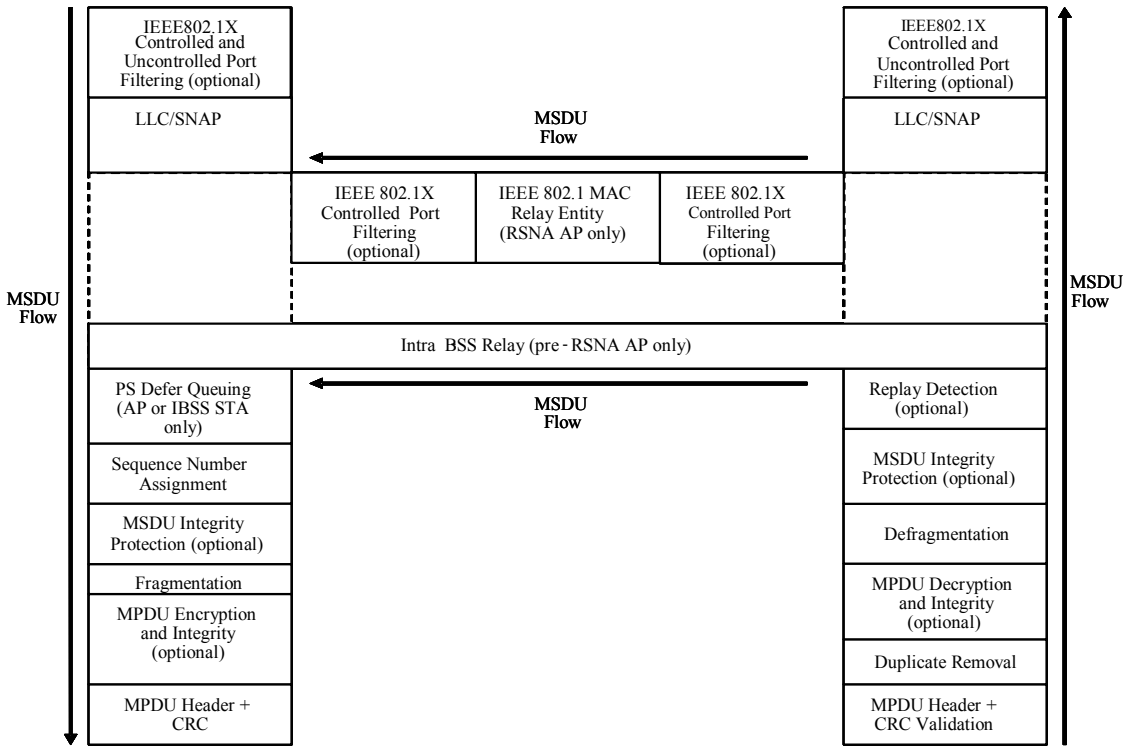

Figure 11g—MAC data plane architecture

End of changes to Clause 6.

7. Frame formats

7.1 MAC frame formats

7.1.3 Frame fields

7.1.3.1 Frame Control field

Change the text of 7.1.3.1 as follows:

The Frame Control field consists of the following subfields: Protocol Version, Type, Subtype, To DS, From DS, More Fragments, Retry, Power Management, More Data, ~~Wired Equivalent Privacy (WEP)~~ Protected Frame, and Order. The format of the Frame Control field is illustrated in Figure 13.

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Change Figure 13 as shown:

B0 B1	B2 B3	B4 B7	B8	B9	B10	B11	B11	B13	B14	B15
Protocol Version	Type	Subtype	To DS	From DS	More Frag	Retry	Pwr Mgt	More Data	~~WEP~~ Protected Frame	Order
Bits : 2	2	4	1	1	1	1	1	1	1	1

Figure 13—Frame Control field

Change the title and text of 7.1.3.1.9 as follows:

7.1.3.1.9 ~~WEP~~Protected Frame field

The ~~WEP~~ Protected Frame field is 1 bit in length. ~~It~~ The Protected Frame field is set to 1 if the Frame Body field contains information that has been processed by ~~the WEP~~ a cryptographic encapsulation algorithm. The ~~WEP~~ Protected Frame field is set to 1 only within data frames ~~of type Data~~ and within management frames of ~~type Management,~~ subtype Authentication. The ~~WEP~~ Protected Frame field is set to 0 in all other frames. When the ~~WEP bit~~ Protected Frame field is set to 1~~, the Frame Body field is expanded as defined in 8.2.5~~ in a data frame, the Frame Body field is protected utilizing the cryptographic encapsulation algorithm and expanded as defined in Clause 8. Only WEP is allowed as the cryptographic encapsulation algorithm for management frames of subtype Authentication.

7.2 Format of individual frame types

7.2.2 Data frames

Change the first paragraph after the lettered list in 7.2.2 as follows:

The frame body consists of the MSDU or a fragment thereof, and a ~~WEP IV and ICV~~ security header and trailer (if and only if the ~~WEP~~ Protected Frame subfield in the Frame Control field is set to 1). The frame body is null (0 octets in length) in data frames of subtypes Null Function (no data), CF-Ack (no data), CF-Poll (no data), and CF-Ack+CF-Poll (no data).

7.2.3 Management frames

7.2.3.1 Beacon frame format

Insert the order 21 information field in Table 5:

Table 5—Beacon frame body

21	RSN	The RSN information element is only present within Beacon frames generated by STAs that have `dot11RSNAEnabled` set to TRUE.

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7.2.3.4 Association Request frame format

Insert the order 8 information field in Table 7:

Table 7—Association Request frame body

8	RSN	The RSN information element is only present within Association Request frames generated by STAs that have `dot11RSNAEnabled` set to TRUE.

7.2.3.6 Reassociation Request frame format

Insert the order 9 information field to Table 9:

Table 9—Reassociation Request frame body

9	RSN	The RSN information element is only present within Reassociation Request frames generated by STAs that have `dot11RSNAEnabled` set to TRUE.

7.2.3.9 Probe Response frame format

Insert the order 21 and 22–n information fields in Table 12:

Table 12—Probe Response frame body

21	RSN	The RSN information element is only present within Probe Response frames generated by STAs that have `dot11RSNAEnabled` set to TRUE.
22–*n*	Requested information elements	Elements requested by the Request information element of the Probe Request frame.

7.2.3.10 Authentication frame format

Insert the following text after the first sentence of 7.2.3.10:

Only Authentication frames with the authentication algorithm set to Open System authentication may be used within an RSNA. RSNA STAs shall not associate if shared authentication was invoked prior to RSN association.

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7.3 Management frame body components

7.3.1 Fixed fields

7.3.1.4 Capability Information field

Change the sixth and seventh paragraphs in 7.3.1.4 as follows:

APs set the Privacy subfield to 1 within transmitted Beacon, Probe Response, Association Response, and Reassociation Response management frames if ~~WEP encryption~~ data confidentiality is required for all data type frames exchanged within the BSS. If ~~WEP encryption~~ data confidentiality is not required, ~~APs set~~ the Privacy subfield is set to 0 ~~within these management frames~~.

In an RSNA, non-AP STAs in an ESS set the Privacy subfield to 0 within transmitted Association and Reassociation Request management frames. APs ignore the Privacy subfield within received Association and Reassociation Request management frames.

STAs within an IBSS set the Privacy subfield to 1 in transmitted Beacon or Probe Response management frames if ~~WEP encryption~~ data confidentiality is required for all data type frames exchanged within the IBSS. If ~~WEP encryption~~ data confidentiality is not required, STAs in an IBSS set the Privacy subfield ~~is set~~ to 0 within these management frames.

STAs that include the RSN information element in Beacon and Probe Response frames shall set the Privacy subfield to 1 in any frame that includes the RSN information element.

7.3.1.7 Reason Code field

Insert reason codes 12 through 24 and change the final Reserved reason code row in Table 18 as follows:

Table 18—Reason codes

Reason code	Meaning
12	Reserved
13	Invalid information element
14	MIC failure
15	4-Way Handshake timeout
16	Group Key Handshake timeout
17	Information element in 4-Way Handshake different from (Re)Association Request/Probe Response/Beacon frame
18	Invalid group cipher
19	Invalid pairwise cipher
20	Invalid AKMP
21	Unsupported RSN information element version
22	Invalid RSN information element capabilities
23	IEEE 802.1X authentication failed

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Table 18—Reason codes *(continued)*

Reason code	Meaning
24	Cipher suite rejected per security policy
25–65 535	Reserved

7.3.1.9 Status Code field

Insert reason codes 27 through 46 and change the final Reserved reason code row in Table 19 as follows:

Table 19—Status codes

Status code	Meaning
27–39	Reserved
40	Invalid information element
41	Invalid group cipher
42	Invalid pairwise cipher
43	Invalid AKMP
44	Unsupported RSN information element version
45	Invalid RSN information element capabilities
46	Cipher suite rejected per security policy
47–65 535	Reserved

7.3.2 Information elements

Replace element identifiers (IDs) 43 through 49 in Table 20 as follows:

Table 20—Element IDs

Information element	Element ID
Reserved	43–47
RSN	48
Reserved	49

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After 7.3.2.24, insert 7.3.2.25 through 7.3.2.25.5 and renumber tables and figures as necessary:

7.3.2.25 RSN information element

The RSN information element contains authentication and pairwise cipher suite selectors, a single group cipher suite selector, an RSN Capabilities field, the PMK identifier (PMKID) count, and PMKID list. See Figure 46ta. All STAs implementing RSNA shall support this element. The size of the RSN information element is limited by the size of an information element, which is 255 octets. Therefore, the number of pairwise cipher suites, AKM suites, and PMKIDs is limited.

Element ID 1 octet	Length 1 octet	Version 2 octets	Group Cipher Suite 4 octets	Pairwise Cipher Suite 2 octets	Pairwise Cipher Suite List 4-*m* octets	AKM Suite Count 2 octets	AKM Suite List 4-*n* octets	RSN Capabilities 2 octets	PMKID Count 2 octets	PMKID List 16-*s* octets

Figure 46ta—RSN information element format

In Figure 46ta, *m* denotes the pairwise cipher suite count, *n* the AKM suite count, and *s* is the PMKID count.

All fields use the bit convention from 7.1.1. The RSN information element shall contain up to and including the Version field. All fields after the Version field are optional. If any optional field is absent, then none of the subsequent fields shall be included.

Element ID shall be 48 decimal (30 hex).

Length gives the number of octets in the information field (field(s) following the Element ID and Length fields) of the information element.

The Version field indicates the version number of the RSNA protocol. The range of Version field values a STA supports shall be contiguous. Values 0 and 2 or higher of the Version field are reserved. RSN Version 1 is defined in this amendment.

NOTE—The following represent sample information elements:

802.1X authentication, CCMP pairwise and group cipher suites (WEP-40, WEP-104, and TKIP not allowed).:

```
30, // information element id, 48 expressed as Hex value
14, // length in octets, 20 expressed as Hex value
01 00, // Version 1
00 0F AC 04, // CCMP as group cipher suite
01 00, // pairwise cipher suite count
00 0F AC 04, // CCMP as pairwise cipher suite
01 00, // authentication count
00 0F AC 01 // 802.1X authentication
00 00 // No capabilities
```

802.1X authentication, CCMP pairwise and group cipher suites (WEP-40, WEP-104 and TKIP not allowed), preauthentication supported:

```
30, // information element id, 48 expressed as Hex value
14, // length in octets, 20 expressed as Hex value
01 00, // Version 1
00 0F AC 04, // CCMP as group cipher suite
01 00, // pairwise cipher suite count
00 0F AC 04, // CCMP as pairwise cipher suite
01 00, // authentication count
00 0F AC 01 // 802.1X authentication
01 00 // Preauthentication capabilities
```

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802.1X authentication, Use GTK for pairwise cipher suite, WEP-40 group cipher suites, optional RSN Capabilities field omitted:

30, // information element id, 48 expressed as Hex value
12, // length in octets, 18 expressed as Hex value
01 00, // Version 1
00 0F AC 01, // WEP-40 as group cipher suite
01 00, // pairwise cipher suite count
00 0F AC 00, // Use group key as pairwise cipher suite
01 00, // authentication count
00 0F AC 01 // 802.1X authentication

802.1X authentication, Use CCMP for pairwise cipher suite, CCMP group cipher suites, preauthentication and a PMKID.

30, // information element id, 48 expressed as Hex value
26 // length in octets, 38 expressed as Hex value
01 00, // Version 1
00 0F AC 04, // CCMP as group cipher suite
01 00, // pairwise cipher suite count
00 0F AC 04, // CCMP as pairwise cipher suite
01 00, // authentication count
00 0F AC 01 // 802.1X authentication
01 00 // Preauthentication capabilities
01 00 // PMKID Count
01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F 10 // PMKID

7.3.2.25.1 Cipher suites

The Group Cipher Suite field contains the cipher suite selector used by the BSS to protect broadcast/multicast traffic.

The Pairwise Cipher Suite Count field indicates the number of pairwise cipher suite selectors that are contained in the Pairwise Cipher Suite List field.

The Pairwise Cipher Suite List field contains a series of cipher suite selectors that indicate the pairwise cipher suites contained in the RSN information element.

A suite selector has the format shown in Figure 46tb.

OUI 3 octets	Suite Type 1 octet

Figure 46tb—Suite selector format

The order of the organizationally unique indentifier (OUI) field shall follow the ordering convention for MAC addresses from 7.1.1.

Table 20da provides the cipher suite selectors defined by this amendment.

Table 20da—Cipher suite selectors

OUI	Suite type	Meaning
00-0F-AC	0	Use group cipher suite
00-0F-AC	1	WEP-40

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Table 20da—Cipher suite selectors *(continued)*

OUI	Suite type	Meaning
00-0F-AC	2	TKIP
00-0F-AC	3	Reserved
00-0F-AC	4	CCMP – default in an RSNA
00-0F-AC	5	WEP-104
00-0F-AC	6–255	Reserved
Vendor OUI	Other	Vendor specific
Other	Any	Reserved

The cipher suite selector 00-0F-AC:4 (CCMP) shall be the default cipher suite value.

The cipher suite selectors 00-0F-AC:1 (WEP-40) and 00-0F-AC:5 (WEP-104) are only valid as a group cipher suite in a transition security network (TSN) to allow pre-RSNA devices to join the BSS.

Use of CCMP as the group cipher suite with TKIP as the pairwise cipher suite shall not be supported.

NOTE—If the STAs can support CCMP, then there is no need for a weaker data confidentiality protocol.

The cipher suite selector 00-0F-AC:0 (Use group cipher suite) is only valid as the pairwise cipher suite. An AP may specify the selector 00-0F-AC:0 (Use group cipher suite) for a pairwise cipher suite if it does not support any pairwise cipher suites. If an AP specifies 00-0F-AC:0 (Use group cipher suite) as the pairwise cipher selection, this shall be the only pairwise cipher selection the AP advertises.

If CCMP is enabled, then the AP supports pairwise keys, and thus the suite selector 00-0F-AC:0 (Use group cipher suite) shall not be a valid option.

Table 20db indicates the circumstances under which each cipher suite shall be used.

Table 20db—Cipher suite usage

Cipher suite selector	GTK	PTK
Use group key	No	Yes
WEP-40	Yes	No
WEP-104	Yes	No
TKIP	Yes	Yes
CCMP	Yes	Yes

7.3.2.25.2 AKM suites

The AKM Suite Count field indicates the number of AKM suite selectors that are contained in the AKM Suite List field.

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The AKM Suite List field contains a series of AKM suite selectors contained in the RSN information element. In an IBSS, only a single AKM suite selector may be specified because STAs in an IBSS must use the same AKM suite and because there is no mechanism to negotiate the AKMP in an IBSS (see 8.4.4).

Each AKM suite selector specifies an AKMP. Table 20dc gives the AKM suite selectors defined by this amendment.

Table 20dc—AKM suite selectors

OUI	Suite type	Meaning	
		Authentication type	Key management type
00-0F-AC	0	Reserved	Reserved
00-0F-AC	1	Authentication negotiated over IEEE 802.1X or using PMKSA caching as defined in 8.4.6.2 – RSNA default	RSNA key management as defined in 8.5 or using PMKSA caching as defined in 8.4.6.2 – RSNA default
00-0F-AC	2	PSK	RSNA key management as defined in 8.5, using PSK
00-0F-AC	3–255	Reserved	Reserved
Vendor OUI	Any	Vendor specific	Vendor specific
Other	Any	Reserved	Reserved

The AKM suite selector value 00-0F-AC:1 (Authentication negotiated over IEEE 802.1X) with (RSNA key management as defined in 8.5 or using PMKSA caching as defined in 8.4.6.2) shall be the assumed default when the AKM suite selector field is not supplied.

NOTE—The selector value 00-0F-AC:1 specifies only that IEEE 802.1X is used as the authentication transport. IEEE 802.1X selects the authentication mechanism.

The AKM suite selector value 00-0F-AC:2 (PSK) is used when a PSK is used with RSNA key management.

NOTE—Selector values 00-0F-AC:1 and 00-0F-AC:2 can simultaneously be enabled by an Authenticator.

7.3.2.25.3 RSN capabilities

The RSN Capabilities field indicates requested or advertised capabilities. The value of each of the RSN Capabilities fields shall be taken to be 0 if the RSN Capabilities field is not available in the RSN information element.

The length of the RSN Capabilities field is 2 octets. The format of the RSN Capabilities field is as illustrated in Figure 46tc and described after the figure.

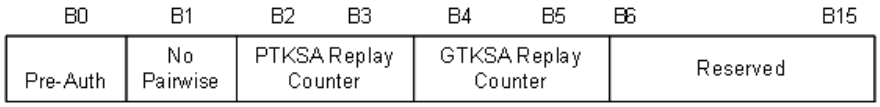

Figure 46tc—RSN Capabilities field format

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— Bit 0: Pre-Authentication. An AP sets the Pre-Authentication subfield of the RSN Capabilities field to 1 to signal it supports preauthentication (see 8.4.6.1) and sets the subfield to 0 when it does not support preauthentication. A non-AP STA sets the Pre-Authentication subfield to 0.

— Bit 1: No Pairwise. If a STA can support WEP default key 0 simultaneously with a pairwise key (see 8.5.1), then the STA sets the No Pairwise subfield of the RSN Capabilities field to 0.

If a STA cannot support WEP default key 0 simultaneously with a pairwise key (see 8.5.1), then the STA sets the No Pairwise subfield of the RSN Capabilities field to 1.

The No Pairwise subfield describes a capability of a non-AP STA. STAs in an IBSS and APs set the No Pairwise subfield to 0.

The No Pairwise subfield shall be set only in a TSN and when the pairwise cipher suite selected by the STA is TKIP.

— Bits 2–3: PTKSA Replay Counter. A STA sets the PTKSA Replay Counter subfield of the RSN Capabilities field to the value contained in `dot11RSNAConfigNumberofPTKSAReplay-Counters`. The least significant bit (LSB) of `dot11RSNAConfigNumberofPTKSA-ReplayCounters` is put in bit 2. See 8.3.2.6 and 8.3.3.4.3. The meaning of the value in the PTKSA/GTKSA/STAKeySA Replay Counter subfield is defined in Table 20dd. The number of replay counters per STAKeySA is the same as the number of replay counters per PTKSA or GTKSA.

Table 20dd—PTKSA/GTKSA/STAKeySA replay counters usage

Replay counter value	Meaning
0	1 replay counter per PTKSA/GTKSA/STAKeySA
1	2 replay counters per PTKSA/GTKSA/STAKeySA
2	4 replay counters per PTKSA/GTKSA/STAKeySA
3	16 replay counters per PTKSA/GTKSA/STAKeySA

— Bits 4–5: GTKSA Replay Counter. A STA sets the GTKSA Replay Counter subfield of the RSN Capabilities field to the value contained in `dot11RSNAConfigNumberofGTKSAReplay-Counters`. The LSB of `dot11RSNAConfigNumberofGTKSAReplayCounters` is put in bit 4. See 8.3.2.6 and 8.3.3.4.3. The meaning of the value in the GTKSA Replay Counter subfield is defined in Table 20dd.

— Bits 6–15: Reserved. The remaining subfields of the RSN Capabilities field are reserved and shall be set to 0 on transmission and ignored on reception.

7.3.2.25.4 PMKID

The PMKID Count and List fields shall be used only in the RSN information element in the (Re)Association Request frame to an AP. The PMKID Count specifies the number of PMKIDs in the PMKID List field. The PMKID list contains 0 or more PMKIDs that the STA believes to be valid for the destination AP. The PMKID can refer to

a) A cached PMKSA that has been obtained through preauthentication with the target AP

b) A cached PMKSA from an EAP authentication

c) A PMKSA derived from a PSK for the target AP

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