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Integrity Check Value and Timestamp TLV Definitions for Mobile Ad Hoc Networks (MANETs)

Abstract

This document describes general and flexible TLVs for representing cryptographic Integrity Check Values (ICVs) (i.e., digital signatures or Message Authentication Codes (MACs)) as well as timestamps, using the generalized Mobile Ad Hoc Network (MANET) packet/message format defined in RFC 5444. It defines two Packet TLVs, two Message TLVs, and two Address Block TLVs for affixing ICVs and timestamps to a packet, a message, and an address, respectively.

Status of This Memo

This is an Internet Standards Track document.

This document is a product of the Internet Engineering Task Force (IETF). It represents the consensus of the IETF community. It has received public review and has been approved for publication by the Internet Engineering Steering Group (IESG). Further information on Internet Standards is available in Section 2 of RFC 5741.

Information about the current status of this document, any errata, and how to provide feedback on it may be obtained at http://www.rfc-editor.org/info/rfc6622.

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1. Introduction

This document specifies

- Two TLVs for carrying Integrity Check Values (ICVs) and timestamps in packets, messages, and address blocks as defined by [RFC5444].

- A generic framework for ICVs, accounting (for Message TLVs) for mutable message header fields (<msg-hop-limit> and <msg-hop-count>), where these fields are present in messages.

This document sets up IANA registries for recording code points for hash-function and ICV calculation, respectively.

Moreover, in Section 12, this document defines the following:

- One common method for generating ICVs as a cryptographic function, calculated over the hash value of the content.

2. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

This document uses the terminology and notation defined in [RFC5444]. In particular, the following TLV fields from [RFC5444] are used in this specification:

<msg-hop-limit> is the hop limit of a message, as specified in Section 5.2 of [RFC5444].

<msg-hop-count> is the hop count of a message, as specified in Section 5.2 of [RFC5444].

<length> is the length of a TLV in octets, as specified in Section 5.4.1 of [RFC5444].

3. Applicability Statement

MANET routing protocols using the format defined in [RFC5444] are accorded the ability to carry additional information in control messages and packets, through the inclusion of TLVs. Information so included MAY be used by a MANET routing protocol, or by an extension of a MANET routing protocol, according to its specification.

This document specifies how to include an ICV for a packet, a message, and addresses in address blocks within a message, by way of such TLVs. This document also specifies a) how to treat "mutable" fields, specifically the <msg-hop-count> and <msg-hop-limit> fields, if present in the message header when calculating ICVs, such that the resulting ICV can be correctly verified by any recipient, and b) how to include this ICV.

This document describes a generic framework for creating ICVs, and how to include these ICVs in TLVs. In Section 12, an example method for calculating such ICVs is given, using a cryptographic function over the hash value of the content.

4. Security Architecture

Basic MANET routing protocol specifications are often "oblivious to security"; however, they have a clause allowing a control message to be rejected as "badly formed" or "insecure" prior to the message being processed or forwarded. MANET routing protocols such as the Neighborhood Discovery Protocol (NHDP) [RFC6130] and the Optimized Link State Routing Protocol version 2 [OLSRv2] recognize external reasons (such as failure to verify an ICV) for rejecting a message that would be considered "invalid for processing". This architecture is a result of the observation that with respect to security in MANETs, "one size rarely fits all" and that MANET routing protocol deployment domains have varying security requirements ranging from "unbreakable" to "virtually none". The virtue of this approach is that MANET routing protocol specifications (and implementations) can remain "generic", with extensions providing proper security mechanisms specific to a deployment domain.

The MANET routing protocol "security architecture", in which this specification situates itself, can therefore be summarized as follows:

- Security-oblivious MANET routing protocol specifications, with a clause allowing an extension to reject a message (prior to processing/forwarding) as "badly formed" or "insecure".

- MANET routing protocol security extensions, rejecting messages as "badly formed" or "insecure", as appropriate for a given security requirement specific to a deployment domain.

- Code points and an exchange format for information, necessary for specification of such MANET routing protocol security extensions.

This document addresses the last of the issues listed above by specifying a common exchange format for cryptographic ICVs, making reservations from within the Packet TLV, Message TLV, and Address Block TLV registries of [RFC5444], to be used (and shared) among MANET routing protocol security extensions.

For the specific decomposition of an ICV into a cryptographic function over a hash value (specified in Section 12), this document establishes two IANA registries for code points for hash functions and cryptographic functions adhering to [RFC5444].

With respect to [RFC5444], this document is

- Intended to be used in the non-normative, but intended, mode of use described in Appendix B of [RFC5444].

- A specific example of the Security Considerations section of [RFC5444] (the authentication part).

5. Overview and Functioning

This document specifies a syntactical representation of security-related information for use with [RFC5444] addresses, messages, and packets, and also establishes IANA registrations of TLV types and type extension registries for these TLV types.

Moreover, this document provides guidelines for how MANET routing protocols and MANET routing protocol extensions using this specification should treat ICV and Timestamp TLVs, and mutable fields in messages. This specification does not represent a stand-alone protocol; MANET routing protocols and MANET routing protocol extensions, using this specification, MUST provide instructions as to how to handle packets, messages, and addresses with security information, associated as specified in this document.

This document assigns TLV types from the registries defined for Packet, Message, and Address Block TLVs in [RFC5444]. When a TLV type is assigned from one of these registries, a registry for type extensions for that TLV type is created by IANA. This document utilizes these type extension registries so created, in order to specify internal structure (and accompanying processing) of the <value> field of a TLV.

For example, and as defined in this document, an ICV TLV with type extension = 0 specifies that the <value> field has no pre-defined internal structure but is simply a sequence of octets. An ICV TLV with type extension = 1 specifies that the <value> field has a pre-defined internal structure and defines its interpretation.

(Specifically, the <value> field consists of a cryptographic operation over a hash value, with fields indicating which hash function and cryptographic operation have been used; this is specified in Section 12.)

Other documents can request assignments for other type extensions; if they do so, they MUST specify their internal structure (if any) and interpretation.

6. General ICV TLV Structure

The value of the ICV TLV is

<value> := <ICV-value>

where

<ICV-value> is a field, of <length> octets, which contains the information to be interpreted by the ICV verification process, as specified by the type extension.

Note that this does not stipulate how to calculate the <ICV-value> nor the internal structure thereof, if any; such information MUST be specified by way of the type extension for the ICV TLV type. See Section 13. This document specifies two such type extensions -- one for ICVs without pre-defined structures, and one for ICVs constructed by way of a cryptographic operation over a hash value.

7. General Timestamp TLV Structure

The value of the Timestamp TLV is

<value> := <time-value>

where

<time-value> is an unsigned integer field, of length <length>, which contains the timestamp.

Note that this does not stipulate how to calculate the <time-value> nor the internal structure thereof, if any; such information MUST be specified by way of the type extension for the TIMESTAMP TLV type. See Section 13.

A timestamp is essentially "freshness information". As such, its setting and interpretation are to be determined by the MANET routing protocol, or MANET routing protocol extension, that uses the timestamp and can, for example, correspond to a UNIX timestamp, GPS timestamp, or a simple sequence number.

8. Packet TLVs

Two Packet TLVs are defined: one for including the cryptographic ICV of a packet and one for including the timestamp indicating the time at which the cryptographic ICV was calculated.

8.1. Packet ICV TLV

A Packet ICV TLV is an example of an ICV TLV as described in Section 6.

The following considerations apply:

- Because packets as defined in [RFC5444] are never forwarded by routers, no special considerations are required regarding mutable fields (e.g., <msg-hop-count> and <msg-hop-limit>), if present, when calculating the ICV.

- Any Packet ICV TLVs already present in the Packet TLV block MUST be removed before calculating the ICV, and the Packet TLV block size MUST be recalculated accordingly. Removed ICV TLVs MUST be restored after having calculated the ICV value.

The rationale for removing any Packet ICV TLV already present prior to calculating the ICV is that several ICVs may be added to the same packet, e.g., using different ICV functions.

8.2. Packet TIMESTAMP TLV

A Packet TIMESTAMP TLV is an example of a Timestamp TLV as described in Section 7. If a packet contains a TIMESTAMP TLV and an ICV TLV, the TIMESTAMP TLV SHOULD be added to the packet before any ICV TLV, in order that it be included in the calculation of the ICV.

9. Message TLVs

Two Message TLVs are defined: one for including the cryptographic ICV of a message and one for including the timestamp indicating the time at which the cryptographic ICV was calculated.

9.1. Message ICV TLV

A Message ICV TLV is an example of an ICV TLV as described in Section 6. When determining the <ICV-value> for a message, the following considerations MUST be applied:

- The fields <msg-hop-limit> and <msg-hop-count>, if present, MUST both be assumed to have the value 0 (zero) when calculating the ICV.

- Any Message ICV TLVs already present in the Message TLV block MUST be removed before calculating the ICV, and the message size as well as the Message TLV block size MUST be recalculated accordingly. Removed ICV TLVs MUST be restored after having calculated the ICV value.

The rationale for removing any Message ICV TLV already present prior to calculating the ICV is that several ICVs may be added to the same message, e.g., using different ICV functions.

9.2. Message TIMESTAMP TLV

A Message TIMESTAMP TLV is an example of a Timestamp TLV as described in Section 7. If a message contains a TIMESTAMP TLV and an ICV TLV, the TIMESTAMP TLV SHOULD be added to the message before the ICV TLV, in order that it be included in the calculation of the ICV.

10. Address Block TLVs

Two Address Block TLVs are defined: one for associating a cryptographic ICV to an address and one for including the timestamp indicating the time at which the cryptographic ICV was calculated.

10.1. Address Block ICV TLV

An Address Block ICV TLV is an example of an ICV TLV as described in Section 6. The ICV is calculated over the address, concatenated with any other values -- for example, any other Address Block TLV <value> fields -- associated with that address. A MANET routing protocol or MANET routing protocol extension using Address Block ICV TLVs MUST specify how to include any such concatenated attribute of the address

in the verification process of the ICV. When determining the <ICV-value> for an address, the following consideration MUST be applied:

- If other TLV values are concatenated with the address for calculating the ICV, these TLVs MUST NOT be Address Block ICV TLVs already associated with the address.

The rationale for not concatenating the address with any ICV TLV values already associated with the address when calculating the ICV is that several ICVs may be added to the same address, e.g., using different ICV functions.

10.2. Address Block TIMESTAMP TLV

An Address Block TIMESTAMP TLV is an example of a Timestamp TLV as described in Section 7. If both a TIMESTAMP TLV and an ICV TLV are associated with an address, the TIMESTAMP TLV <value> MUST be covered when calculating the value of the ICV to be contained in the ICV TLV value (i.e., concatenated with the associated address and any other values as described in Section 10.1).

11. ICV: Basic

The basic ICV, represented by way of an ICV TLV with type extension = 0, is a simple bit-field containing the cryptographic ICV. This assumes that the mechanism stipulating how ICVs are calculated and verified is established outside of this specification, e.g., by way of administrative configuration or external out-of-band signaling. Thus, the <ICV-value>, when using type extension = 0, is

```
<ICV-value> := <ICV-data>
```

where

<ICV-data> is an unsigned integer field, of length <length>, which contains the cryptographic ICV.

12. ICV: Cryptographic Function over a Hash Value

One common way of calculating an ICV is applying a cryptographic function over a hash value of the content. This decomposition is specified in this section, using a type extension = 1 in the ICV TLVs.

12.1. General ICV TLV Structure

The following data structure allows representation of a cryptographic ICV, including specification of the appropriate hash function and cryptographic function used for calculating the ICV:

```
<ICV-value> := <hash-function>
               <cryptographic-function>
               <key-id-length>
               <key-id>
               <ICV-data>
```

where

<hash-function> is an 8-bit unsigned integer field specifying the hash function.

<cryptographic-function> is an 8-bit unsigned integer field specifying the cryptographic function.

<key-id-length> is an 8-bit unsigned integer field specifying the length of the <key-id> field in number of octets. The value 0x00 is reserved for using a pre-installed, shared key.

<key-id> is a field specifying the key identifier of the key that was used to calculate the ICV of the message, which allows unique identification of different keys with the same originator. It is the responsibility of each key originator to make sure that actively used keys that it issues have distinct key identifiers. If <key-id-length> equals 0x00, the <key-id> field is not contained in the TLV, and a pre-installed, shared key is used.

<ICV-data> is an unsigned integer field, whose length is <length> - 3 - <key-id-length>, and which contains the cryptographic ICV.

The version of this TLV, specified in this section, assumes that calculating the ICV can be decomposed into

```
ICV-value = cryptographic-function(hash-function(content))
```

The hash function and the cryptographic function correspond to the entries in two IANA registries, which are set up by this specification and are described in Section 13.

12.1.1. Rationale

The rationale for separating the hash function and the cryptographic function into two octets instead of having all combinations in a single octet -- possibly as a TLV type extension -- is that adding further hash functions or cryptographic functions in the future may lead to a non-contiguous number space.

The rationale for not including a field that lists parameters of the cryptographic ICV in the TLV is that, before being able to validate a cryptographic ICV, routers have to exchange or acquire keys (e.g., public keys). Any additional parameters can be provided together with the keys in that bootstrap process. It is therefore not necessary, and would even entail an extra overhead, to transmit the parameters within every message. One implicitly available parameter is the length of the ICV, which is <length> - 3 - <key-id-length>, and which depends on the choice of the cryptographic function.

12.2. Considerations for Calculating the ICV

The considerations listed in the following subsections MUST be applied when calculating the ICV for Packet, Message, and Address ICV TLVs, respectively.

12.2.1. Packet ICV TLV

When determining the <ICV-value> for a packet, the ICV is calculated over the fields <hash-function>, <cryptographic-function>, <key-id-length>, and -- if present -- <key-id> (in that order), concatenated with the entire packet, including the packet header, all Packet TLVs (other than Packet ICV TLVs), and all included Messages and their message headers, in accordance with Section 8.1.

12.2.2. Message ICV TLV

When determining the <ICV-value> for a message, the ICV is calculated over the fields <hash-function>, <cryptographic-function>, <key-id-length>, and -- if present -- <key-id> (in that order), concatenated with the entire message. The considerations in Section 9.1 MUST be applied.

12.2.3. Address Block ICV TLV

When determining the <ICV-value> for an address, the ICV is calculated over the fields <hash-function>, <cryptographic-function>, <key-id-length>, and -- if present -- <key-id> (in that order), concatenated with the address, and concatenated with any other values -- for example, any other address block TLV <value> that is

associated with that address. A MANET routing protocol or MANET routing protocol extension using Address Block ICV TLVs MUST specify how to include any such concatenated attribute of the address in the verification process of the ICV. The considerations in Section 10.1 MUST be applied.

12.3. Example of a Message Including an ICV

The sample message depicted in Figure 1 is derived from Appendix D of [RFC5444]. The message contains an ICV Message TLV, with the value representing an ICV that is 16 octets long of the whole message, and a key identifier that is 4 octets long. The type extension of the Message TLV is 1, for the specific decomposition of an ICV into a cryptographic function over a hash value, as specified in Section 12.

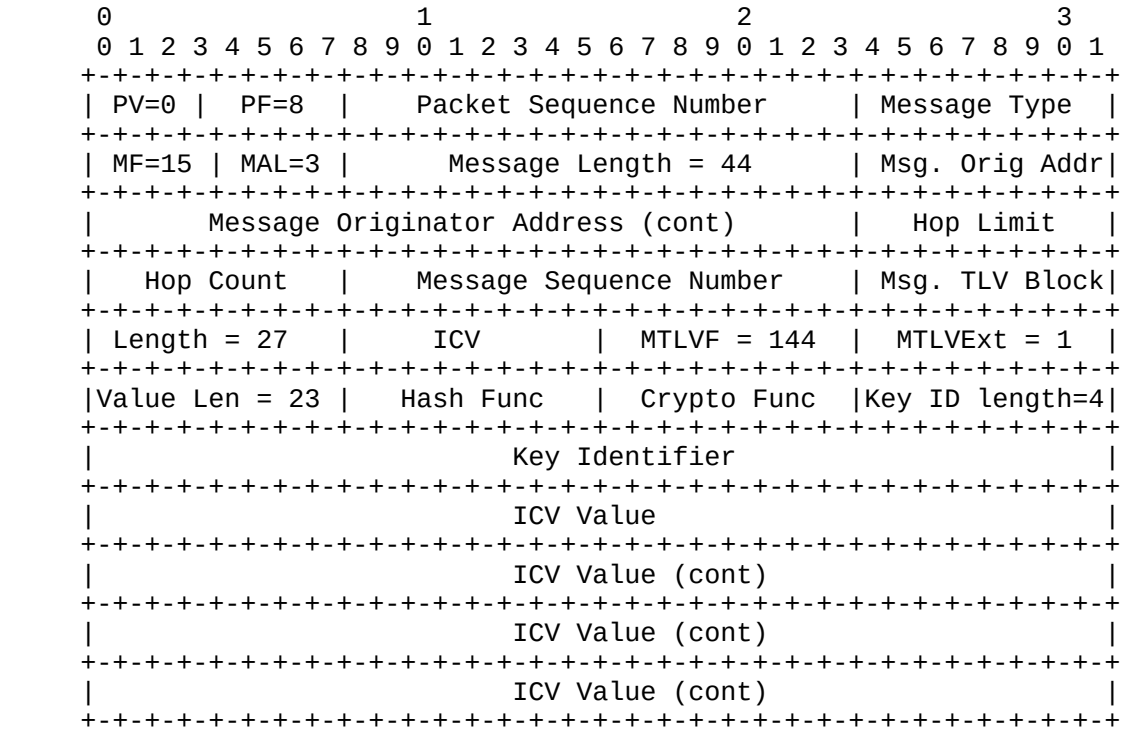

Figure 1: Example Message with ICV

13. IANA Considerations

This specification defines the following:

- Two Packet TLV types, which have been allocated from the 0-223 range of the "Packet TLV Types" repository of [RFC5444], as specified in Table 1.

- Two Message TLV types, which have been allocated from the 0-127 range of the "Message TLV Types" repository of [RFC5444], as specified in Table 2.

- Two Address Block TLV types, which have been allocated from the 0-127 range of the "Address Block TLV Types" repository of [RFC5444], as specified in Table 3.

This specification created the following:

- A type extension registry for each of these TLV types with initial values as listed in Tables 1, 2, and 3.

IANA has assigned the same numerical value to the Packet TLV, Message TLV, and Address Block TLV types with the same name.

The following terms are used as defined in [BCP26]: "Namespace", "Registration", and "Designated Expert".

The following policy is used as defined in [BCP26]: "Expert Review".

13.1. Expert Review: Evaluation Guidelines

For TLV type extensions registries where an Expert Review is required, the Designated Expert SHOULD take the same general recommendations into consideration as those specified by [RFC5444].

For the Timestamp TLV, the same type extensions for all Packet, Message, and Address Block TLVs SHOULD be numbered identically.

13.2. Packet TLV Type Registrations

IANA has made allocations from the "Packet TLV Types" namespace of [RFC5444] for the Packet TLVs specified in Table 1.

Name	Type	Type Extension	Description
ICV	5	0	ICV of a packet
		1	ICV, decomposed into cryptographic function over a hash value, as specified in Section 12 of this document
		2-251	Unassigned; Expert Review
		252-255	Experimental Use
TIMESTAMP	6	0	Unsigned timestamp of arbitrary length, given by the TLV Length field. The MANET routing protocol has to define how to interpret this timestamp
		1	Unsigned 32-bit timestamp, as specified in [IEEE 1003.1-2008 (POSIX)]
		2	NTP timestamp format, as defined in [RFC5905]
		3	Signed timestamp of arbitrary length with no constraints such as monotonicity. In particular, it may represent any random value
		4-251	Unassigned; Expert Review
		252-255	Experimental Use

Table 1: Packet TLV Types

13.3. Message TLV Type Registrations

IANA has made allocations from the "Message TLV Types" namespace of [RFC5444] for the Message TLVs specified in Table 2.

Name	Type	Type Extension	Description
ICV	5	0	ICV of a message
		1	ICV, decomposed into cryptographic function over a hash value, as specified in Section 12 of this document
		2-251	Unassigned; Expert Review
		252-255	Experimental Use
TIMESTAMP	6	0	Unsigned timestamp of arbitrary length, given by the TLV Length field
		1	Unsigned 32-bit timestamp, as specified in [IEEE 1003.1-2008 (POSIX)]
		2	NTP timestamp format, as defined in [RFC5905]
		3	Signed timestamp of arbitrary length with no constraints such as monotonicity. In particular, it may represent any random value
		4-251	Unassigned; Expert Review
		252-255	Experimental Use

Table 2: Message TLV Types

13.4. Address Block TLV Type Registrations

IANA has made allocations from the "Address Block TLV Types" namespace of [RFC5444] for the Packet TLVs specified in Table 3.

Name	Type	Type Extension	Description
ICV	5	0	ICV of an object (e.g., an address)
		1	ICV, decomposed into cryptographic function over a hash value, as specified in Section 12 of this document
		2-251	Unassigned; Expert Review
		252-255	Experimental Use
TIMESTAMP	6	0	Unsigned timestamp of arbitrary length, given by the TLV Length field
		1	Unsigned 32-bit timestamp, as specified in [IEEE 1003.1-2008 (POSIX)]
		2	NTP timestamp format, as defined in [RFC5905]
		3	Signed timestamp of arbitrary length with no constraints such as monotonicity. In particular, it may represent any random value
		4-251	Unassigned; Expert Review
		252-255	Experimental Use

Table 3: Address Block TLV Types

13.5. Hash Functions

IANA has created a new registry for hash functions that can be used when creating an ICV, as specified in Section 12 of this document. The initial assignments and allocation policies are specified in Table 4.

Hash Function Value	Algorithm	Description
0	none	The "identity function": The hash value of an object is the object itself
1	SHA1	[NIST-FIPS-180-2]
2	SHA224	[NIST-FIPS-180-2-change]
3	SHA256	[NIST-FIPS-180-2]
4	SHA384	[NIST-FIPS-180-2]
5	SHA512	[NIST-FIPS-180-2]
6-251		Unassigned; Expert Review
252-255		Experimental Use

Table 4: Hash-Function Registry

13.6. Cryptographic Functions

IANA has created a new registry for the cryptographic functions, as specified in Section 12 of this document. Initial assignments and allocation policies are specified in Table 5.

Cryptographic Function Value	Algorithm	Description
0	none	The "identity function": The value of an encrypted hash is the hash itself
1	RSA	[RFC3447]
2	DSA	[NIST-FIPS-186-3]
3	HMAC	[RFC2104]
4	3DES	[NIST-SP-800-67]
5	AES	[NIST-FIPS-197]
6	ECDSA	[ANSI-X9-62-2005]
7-251		Unassigned; Expert Review
252-255		Experimental Use

Table 5: Cryptographic Function Registry

14. Security Considerations

This document does not specify a protocol. It provides a syntactical component for cryptographic ICVs of messages and packets, as defined in [RFC5444]. It can be used to address security issues of a MANET routing protocol or MANET routing protocol extension. As such, it has the same security considerations as [RFC5444].

In addition, a MANET routing protocol or MANET routing protocol extension that uses this specification MUST specify how to use the framework, and the TLVs presented in this document. In addition, the protection that the MANET routing protocol or MANET routing protocol extensions attain by using this framework MUST be described.

As an example, a MANET routing protocol that uses this component to reject "badly formed" or "insecure" messages if a control message does not contain a valid ICV SHOULD indicate the security assumption that if the ICV is valid, the message is considered valid. It also SHOULD indicate the security issues that are counteracted by this measure (e.g., link or identity spoofing) as well as the issues that are not counteracted (e.g., compromised keys).

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16. References

16.1. Normative References

[ANSI-X9-62-2005]
American National Standards Institute, "Public Key Cryptography for the Financial Services Industry: The Elliptic Curve Digital Signature Algorithm (ECDSA)", ANSI X9.62-2005, November 2005.

[BCP26] Narten, T. and H. Alvestrand, "Guidelines for Writing an IANA Considerations Section in RFCs", BCP 26, RFC 5226, May 2008.

[IEEE 1003.1-2008 (POSIX)]
IEEE Computer Society, "1003.1-2008 Standard for Information Technology-Portable Operating System Interface (POSIX) Base Specifications, Issue 7", December 2008.

[NIST-FIPS-180-2]
National Institute of Standards and Technology, "Specifications for the Secure Hash Standard", FIPS 180-2, August 2002.

[NIST-FIPS-180-2-change]
National Institute of Standards and Technology, "Federal Information Processing Standards Publication 180-2 (+ Change Notice to include SHA-224)", FIPS 180-2, August 2002, <http:// csrc.nist.gov/publications/fips/ fips180-2/fips180-2withchangenotice.pdf>.

[NIST-FIPS-186-3]
National Institute of Standards and Technology, "Digital Signature Standard (DSS)", FIPS 186-3, June 2009.

[NIST-FIPS-197]
National Institute of Standards and Technology, "Specification for the Advanced Encryption Standard (AES)", FIPS 197, November 2001.

[NIST-SP-800-67]
National Institute of Standards and Technology, "Recommendation for the Triple Data Encryption Algorithm (TDEA) Block Cipher", Special Publication 800-67, May 2004.

[RFC2104] Krawczyk, H., Bellare, M., and R. Canetti, "HMAC: Keyed-Hashing for Message Authentication", RFC 2104, February 1997.

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

[RFC3447] Jonsson, J. and B. Kaliski, "Public-Key Cryptography Standards (PKCS) #1: RSA Cryptography Specifications Version 2.1", RFC 3447, February 2003.

[RFC5444] Clausen, T., Dearlove, C., Dean, J., and C. Adjih, "Generalized Mobile Ad Hoc Network (MANET) Packet/Message Format", RFC 5444, February 2009.

[RFC5905] Mills, D., Martin, J., Ed., Burbank, J., and W. Kasch, "Network Time Protocol Version 4: Protocol and Algorithms Specification", RFC 5905, June 2010.

16.2. Informative References

[OLSRv2] Clausen, T., Dearlove, C., Jacquet, P., and U. Herberg, "The Optimized Link State Routing Protocol version 2", Work in Progress, March 2012.

[RFC6130] Clausen, T., Dearlove, C., and J. Dean, "Mobile Ad Hoc Network (MANET) Neighborhood Discovery Protocol (NHDP)", RFC 6130, April 2011.

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