

Mobile Ad hoc Networking (MANET)	U. Herberg	
Internet-Draft	T. Clausen	
Intended status: Standards Track	LIX, Ecole Polytechnique	
Expires: May 15, 2011	November 11, 2010	

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## **MANET Cryptographical Signature TLV Definition draft-ietf-manet-packetbb-sec-02**

### **Abstract**

This document describes general and flexible TLVs (type-length-value structure) for representing cryptographic signatures as well as timestamps, using the generalized MANET packet/message format [\[RFC5444\] \(Clausen, T., Dearlove, C., Dean, J., and C. Adjih, "Generalized MANET Packet/Message Format," February 2009.\)](#). It defines two Packet TLVs, two Message TLVs, and two Address Block TLVs, for affixing cryptographic signatures and timestamps to a packet, message and address, respectively.

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## 1. Introduction

This document specifies:

- \*two TLVs for carrying cryptographic signatures and timestamps in packets, messages and address blocks as defined by [\[RFC5444\]](#) (Clausen, T., Dearlove, C., Dean, J., and C. Adjih, "Generalized MANET Packet/Message Format," February 2009.),
- \*how cryptographic signatures are calculated, taking (for Message TLVs) into account the mutable message header fields (<msg-hop-limit> and <msg-hop-count>) where these fields are present in messages.

This document requests from IANA:

- \*allocations for these Packet, Message, and Address Block TLVs from the 0-223 Packet TLV range, the 0-127 Message TLV range and the 0-127 Address Block TLV range from [\[RFC5444\]](#) (Clausen, T., Dearlove, C., Dean, J., and C. Adjih, "Generalized MANET Packet/Message Format," February 2009.),
- \*creation of two IANA registries for recording code points for hash function and signature calculation, respectively.

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## 2. Terminology

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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 [\[RFC2119\]](#) (Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels," March 1997.).

This document uses the terminology and notation defined in [\[RFC5444\]](#) (Clausen, T., Dearlove, C., Dean, J., and C. Adjih, "Generalized MANET Packet/Message Format," February 2009.).

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## 3. Applicability Statement

[TOC](#)

MANET routing protocols using the format defined in [\[RFC5444\]](#) (Clausen, T., Dearlove, C., Dean, J., and C. Adjih, "Generalized MANET Packet/Message Format," February 2009.) are accorded the ability to carry additional information in control messages and packets, through inclusion of TLVs. Information so included MAY be used by a routing

protocol, or by an extension of a routing protocol, according to its specification.

This document specifies how to include a cryptographic signature for a packet, message or address by way of such TLVs. This document also specifies how to treat "mutable" fields (<msg-hop-count> and <msg-hop-limit>), if present, in the message header when calculating signatures, such that the resulting signature can be correctly verified by any recipient, and how to include this signature.

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## 4. Security Architecture

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Basic MANET routing protocol specifications are often "oblivious to security", however have a clause allowing a control message to be rejected as "badly formed" prior to it being processed or forwarded. Protocols such as [\[NHDP\] \(Clausen, T., Dean, J., and C. Dearlove, "MANET Neighborhood Discovery Protocol \(NHDP\)," July 2010.\)](#) and [\[OLSRv2\] \(Clausen, T., Dearlove, C., and P. Jacquet, "The Optimized Link State Routing Protocol version 2," April 2010.\)](#) recognize external reasons (such as failure to verify a signature) for rejecting a message as "badly formed", and therefore "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 deployment-domain specific security mechanisms.

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".
- \*MANET routing protocol security extensions, rejecting messages as "badly formed", as appropriate for a given deployment-domain specific security requirement.
- \*Code-points and an exchange format for information, necessary for specification of such MANET routing protocol security extensions.

This document addresses the last of these issues, by specifying a common exchange format for cryptographic signatures, making reservations from within the Packet TLV, Message TLV and Address Block TLV registries of [\[RFC5444\] \(Clausen, T., Dearlove, C., Dean, J., and C. Adjih, "Generalized MANET Packet/Message Format," February 2009.\)](#), to be used (and shared) among MANET routing protocol security

extensions, establishing two IANA registries for code-points for hash functions and cryptographic functions adhering to [\[RFC5444\] \(Clausen, T., Dearlove, C., Dean, J., and C. Adjih, "Generalized MANET Packet/Message Format," February 2009.\)](#).

With respect to [\[RFC5444\] \(Clausen, T., Dearlove, C., Dean, J., and C. Adjih, "Generalized MANET Packet/Message Format," February 2009.\)](#), this document:

- \*is intended to be used in the non-normative, but intended, mode of use of [\[RFC5444\] \(Clausen, T., Dearlove, C., Dean, J., and C. Adjih, "Generalized MANET Packet/Message Format," February 2009.\)](#) as described in its Appendix B.

- \*is a specific example of the Security Considerations section of [\[RFC5444\] \(Clausen, T., Dearlove, C., Dean, J., and C. Adjih, "Generalized MANET Packet/Message Format," February 2009.\)](#) (the authentication part).

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## 5. Protocol Overview and Functioning

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This specification does not describe a protocol, nor does it mandate specific router or protocol behavior. It represents a purely syntactical representation of security related information for use with [\[RFC5444\] \(Clausen, T., Dearlove, C., Dean, J., and C. Adjih, "Generalized MANET Packet/Message Format," February 2009.\)](#) addresses, messages and packets, as well as establishes IANA registrations and registries.

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## 6. Imported TLV Fields

[TOC](#)

In this specification, the following TLV fields from [\[RFC5444\] \(Clausen, T., Dearlove, C., Dean, J., and C. Adjih, "Generalized MANET Packet/Message Format," February 2009.\)](#) are used:

**<msg-hop-limit>** - hop limit of a message, as specified in Section 5.2 of [\[RFC5444\] \(Clausen, T., Dearlove, C., Dean, J., and C. Adjih, "Generalized MANET Packet/Message Format," February 2009.\)](#).

**<msg-hop-count>** - hop count of a message, as specified in Section 5.2 of [\[RFC5444\] \(Clausen, T., Dearlove, C., Dean, J., and C. Adjih, "Generalized MANET Packet/Message Format," February 2009.\)](#).

**<length>**

- length of a TLV in octets, as specified in Section 5.4.1 of [\[RFC5444\] \(Clausen, T., Dearlove, C., Dean, J., and C. Adjih, "Generalized MANET Packet/Message Format," February 2009.\)](#).

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**7. General Signature TLV Structure**[TOC](#)

The following data structure allows representation of a cryptographic signature, including specification of the appropriate hash function and cryptographic function used for calculating the signature. This <signature> data structure is specified, using the regular expression syntax of [\[RFC5444\] \(Clausen, T., Dearlove, C., Dean, J., and C. Adjih, "Generalized MANET Packet/Message Format," February 2009.\)](#), as:

```
<signature> := <hash-function>
               <cryptographic-function>
               <key-index>
               <signature-value>
```

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-index>** is an 8-bit unsigned integer field specifying the key index of the key which was used to sign 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 indices and that all key indices have a value unequal to 0x00. Value 0x00 is reserved for a pre-installed, shared key.

**<signature-value>** is an unsigned integer field, whose length is <length> - 3, and which contains the cryptographic signature.

The basic version of this TLV assumes that calculating the signature can be decomposed into:

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

The hash function and the cryptographic function correspond to the entries in two IANA registries, set up by this specification in [Section 12 \(IANA Considerations\)](#).

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## 7.1. Rationale

[TOC](#)

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 TLV type extension - is twofold: First, if further hash functions or cryptographic functions are added in the future, the number space might not remain continuous. More importantly, the number space of possible combinations would be rapidly exhausted. As new or improved cryptographic mechanism are continuously being developed and introduced, this format should be able to accommodate such for the foreseeable future.

The rationale for not including a field that lists parameters of the cryptographic signature in the TLV is, that before being able to validate a cryptographic signature, 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 inherently included parameter is the length of the signature, which is `<length> - 3` and which depends on the choice of the cryptographic function.

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## 8. General Timestamp TLV Structure

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The following data structure allows the representation of a timestamp. This `<timestamp>` data structure is specified as:

`<timestamp> := <time-value>`

where:

`<time-value>` is an unsigned integer field, whose length is `<length>`, and which contains the timestamp. The value of this variable is to be interpreted by the routing protocol as specified by the type extension of the Timestamp TLV, see [Section 12 \(IANA Considerations\)](#).

A timestamp is essentially "freshness information". As such, its setting and interpretation is to be determined by the routing protocol (or the extension to a routing protocol) that uses it, and may e.g. correspond to a UNIX-timestamp, GPS timestamp or a simple sequence number.

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## 9. Packet TLVs

[TOC](#)

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

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### 9.1. Packet SIGNATURE TLV

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A Packet SIGNATURE TLV is an example of a Signature TLV as described in [Section 7 \(General Signature TLV Structure\)](#). When calculating the <signature-value> for a Packet, the signature is calculated over the three fields <hash-function>, <cryptographic-function> and <key-index> (in that order), concatenated with the entire Packet, including the packet header, all Packet TLVs (other than Packet SIGNATURE TLVs) and all included Messages and their message headers.

The following considerations apply:

- \*As packets defined in [\[RFC5444\] \(Clausen, T., Dearlove, C., Dean, J., and C. Adjih, "Generalized MANET Packet/Message Format," February 2009.\)](#) are never forwarded by routers, it is unnecessary to consider mutable fields (e.g. <msg-hop-count> and <msg-hop-limit>), if present, when calculating the signature.

- \*any Packet SIGNATURE TLVs already present in the Packet TLV block MUST be removed before calculating the signature, and the Packet TLV block size MUST be recalculated accordingly. The TLVs can be restored after having calculated the signature value.

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

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### 9.2. Packet TIMESTAMP TLV

[TOC](#)

A Packet TIMESTAMP TLV is an example of a Timestamp TLV as described in [Section 8 \(General Timestamp TLV Structure\)](#). If a packet contains a TIMESTAMP TLV and a SIGNATURE TLV, the TIMESTAMP TLV SHOULD be added to the packet before any SIGNATURE TLV, in order that it be included in the calculation of the signature.

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## 10. Message TLVs

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

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### 10.1. Message SIGNATURE TLV

[TOC](#)

A Message SIGNATURE TLV is an example of a Signature TLV as described in [Section 7 \(General Signature TLV Structure\)](#). When determining the <signature-value> for a message, the signature is calculated over the three fields <hash-function>, <cryptographic-function>, and <key-index> (in that order), concatenated with the entire message with the following considerations:

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

- \*any Message SIGNATURE TLVs already present in the Message TLV block MUST be removed before calculating the signature, and the message size as well as the Message TLV block size MUST be recalculated accordingly. The TLVs can be restored after having calculated the signature value.

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

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### 10.2. Message TIMESTAMP TLV

[TOC](#)

A Message TIMESTAMP TLV is an example of a Timestamp TLV as described in [Section 8 \(General Timestamp TLV Structure\)](#). If a message contains a TIMESTAMP TLV and a SIGNATURE TLV, the TIMESTAMP TLV SHOULD be added to the message before the SIGNATURE TLV, in order that it be included in the calculation of the signature.

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## 11. Address Block TLVs

[TOC](#)

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

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### 11.1. Address Block SIGNATURE TLV

[TOC](#)

An Address Block SIGNATURE TLV is an example of a Signature TLV as described in [Section 7 \(General Signature TLV Structure\)](#). The signature is calculated over the three fields <hash-function>, <cryptographic-function>, and <key-index> (in that order), concatenated with the address, concatenated with any other values, for example, any other TLV value that is associated with that address. A routing protocol or routing protocol extension using Address Block SIGNATURE TLVs MUST specify how to include any such concatenated attribute of the address in the verification process of the signature.

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### 11.2. Address Block TIMESTAMP TLV

[TOC](#)

An Address Block TIMESTAMP TLV is an example of a Timestamp TLV as described in [Section 8 \(General Timestamp TLV Structure\)](#). If both a TIMESTAMP TLV and a SIGNATURE TLV are associated with an address, the timestamp value should be considered when calculating the value of the signature.

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## 12. IANA Considerations

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This section specifies requests to IANA.

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### 12.1. TLV Registrations

[TOC](#)

This specification defines:

- \*two Packet TLV types which must be allocated from the 0-223 range of the "Assigned Packet TLV Types" repository of [\[RFC5444\]](#) (Clausen, T., Dearlove, C., Dean, J., and C. Adjih, "Generalized MANET Packet/Message Format," February 2009.) as specified in [Table 1 \(Packet TLV types\)](#),

- \*two Message TLV types which must be allocated from the 0-127 range of the "Assigned Message TLV Types" repository of [\[RFC5444\]](#) (Clausen, T., Dearlove, C., Dean, J., and C. Adjih, "Generalized

[MANET Packet/Message Format," February 2009.](#)) as specified in [Table 2 \(Message TLV types\)](#),

\*and two Address Block TLV types which must be allocated from the 0-127 range of the "Assigned Address Block TLV Types" repository of [\[RFC5444\] \(Clausen, T., Dearlove, C., Dean, J., and C. Adjih, "Generalized MANET Packet/Message Format," February 2009.\)](#) as specified in [Table 3 \(Address Block TLV types\)](#).

This specification requests:

\*set up of type extension registries for these TLV types.

IANA is requested to assign the same numerical value to the Packet TLV, Message TLV and Address Block TLV types with the same name.

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#### 12.1.1. Expert Review: Evaluation Guidelines

[TOC](#)

For the registries for TLV type extensions where an Expert Review is required, the designated expert SHOULD take the same general recommendations into consideration as are specified by [\[RFC5444\] \(Clausen, T., Dearlove, C., Dean, J., and C. Adjih, "Generalized MANET Packet/Message Format," February 2009.\)](#).

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

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#### 12.1.2. Packet TLV Type Registrations

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The Packet TLVs as specified in [Table 1 \(Packet TLV types\)](#) must be allocated from the "Packet TLV Types" namespace of [\[RFC5444\] \(Clausen, T., Dearlove, C., Dean, J., and C. Adjih, "Generalized MANET Packet/Message Format," February 2009.\)](#).

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Name	Type	Type Extension	Description
SIGNATURE	TBD3	0	Signature of a packet
		1-223	Expert Review
		224-255	Experimental Use
TIMESTAMP	TBD4	0	Unsigned timestamp of arbitrary length, given by the TLV length field. The MANET routing

			protocol has to define how to interpret this timestamp
		1-223	Expert Review
		224-255	Experimental Use

**Table 1: Packet TLV types**

### 12.1.3. Message TLV Type Registrations

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The Message TLVs as specified in [Table 2 \(Message TLV types\)](#) must be allocated from the "Message TLV Types" namespace of [\[RFC5444\] \(Clausen, T., Dearlove, C., Dean, J., and C. Adjih, "Generalized MANET Packet/Message Format," February 2009.\)](#).

Name	Type	Type Extension	Description
SIGNATURE	TBD1	0	Signature of a message
		1-223	Expert Review
		224-255	Experimental Use
TIMESTAMP	TBD2	0	Unsigned timestamp of arbitrary length, given by the TLV length field.
		1-223	Expert Review
		224-255	Experimental Use

**Table 2: Message TLV types**

### 12.1.4. Address Block TLV Type Registrations

[TOC](#)

The Address Block TLVs as specified in [Table 3 \(Address Block TLV types\)](#) must be allocated from the "Address Block TLV Types" namespace of [\[RFC5444\] \(Clausen, T., Dearlove, C., Dean, J., and C. Adjih, "Generalized MANET Packet/Message Format," February 2009.\)](#).

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Name	Type	Type Extension	Description
SIGNATURE	TBD1	0	Signature of an object (e.g. an address)
		1-223	Expert Review
		224-255	Experimental Use
TIMESTAMP	TBD2	0	Unsigned timestamp of arbitrary length, given by the TLV length field.
		1-223	Expert Review
		224-255	Experimental Use

**Table 3: Address Block TLV types**

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## 12.2. New IANA Registries

[TOC](#)

This document introduces three namespaces that have been registered: Packet TLV Types, Message TLV Types, and Address Block TLV Types. This section specifies IANA registries for these namespaces and provides guidance to the Internet Assigned Numbers Authority regarding registrations in these namespaces.

The following terms are used with the meanings defined in [\[BCP26\]](#) (Narten, T. and H. Alvestrand, "Guidelines for Writing an IANA Considerations Section in RFCs," May 2008.): "Namespace", "Assigned Value", "Registration", "Unassigned", "Reserved", "Hierarchical Allocation", and "Designated Expert".

The following policies are used with the meanings defined in [\[BCP26\]](#) (Narten, T. and H. Alvestrand, "Guidelines for Writing an IANA Considerations Section in RFCs," May 2008.): "Private Use", "Expert Review", and "Standards Action".

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### 12.2.1. Expert Review: Evaluation Guidelines

[TOC](#)

For the registries for the following tables where an Expert Review is required, the designated expert SHOULD take the same general recommendations into consideration as are specified by [\[RFC5444\]](#) (Clausen, T., Dearlove, C., Dean, J., and C. Adjih, "Generalized MANET Packet/Message Format," February 2009.).

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### 12.2.2. Hash Function

[TOC](#)

IANA is requested to create a new registry for the hash functions that can be used when creating a signature. The initial assignments and allocation policies are specified in [Table 4 \(Hash-Function registry\)](#).

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Hash function value	Algorithm	Description
0	none	The "identity function": the hash value of an object is the object itself
1-223		Expert Review
224-255		Experimental Use

**Table 4: Hash-Function registry**

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### 12.2.3. Cryptographic Algorithm

[TOC](#)

IANA is requested to create a new registry for the cryptographic function. Initial assignments and allocation policies are specified in [Table 5 \(Cryptographic function registry\)](#).

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Cryptographic function value	Algorithm	Description
0	none	The "identity function": the value of an encrypted hash is the hash itself
1-223		Expert Review
224-255		Experimental Use

**Table 5: Cryptographic function registry**

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### 13. Security Considerations

[TOC](#)

This document does not specify a protocol itself. However, it provides a syntactical component for cryptographic signatures of messages and packets as defined in [\[RFC5444\] \(Clausen, T., Dearlove, C., Dean, J., and C. Adjih, "Generalized MANET Packet/Message Format," February 2009.\)](#). It can be used to address security issues of a protocol or extension that uses the component specified in this document. As such, it has the same security considerations as [\[RFC5444\] \(Clausen, T., Dearlove, C., Dean, J., and C. Adjih, "Generalized MANET Packet/Message Format," February 2009.\)](#).

In addition, a protocol that includes this component MUST specify the usage as well as the security that is attained by the cryptographic signatures of a message or a packet.

As an example, a routing protocol that uses this component to reject "badly formed" messages if a control message does not contain a valid signature, should indicate the security assumption that if the signature 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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### 14. Acknowledgements

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The authors would like to thank Jerome Milan (Ecole Polytechnique) for his advice as cryptographer. In addition, many thanks to Bo Berry (Cisco), Alan Cullen (BAE), Justin Dean (NRL), Christopher Dearlove (BAE), Paul Lambert (Marvell), and Henning Rogge (FGAN) for their constructive comments on the document.

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### 15. References

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#### 15.1. Normative References

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[BCP26]	Narten, T. and H. Alvestrand, " <a href="#">Guidelines for Writing an IANA Considerations Section in RFCs</a> ," RFC 5226, BCP 26, May 2008.
[RFC2119]	Bradner, S., " <a href="#">Key words for use in RFCs to Indicate Requirement Levels</a> ," RFC 2119, BCP 14, March 1997.
[RFC5444]	

Clausen, T., Dearlove, C., Dean, J., and C. Adjih, "Generalized MANET Packet/Message Format," RFC 5444, February 2009.
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## 15.2. Informative References

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[NHDP]	Clausen, T., Dean, J., and C. Dearlove, "MANET Neighborhood Discovery Protocol (NHDP)," work in progress draft-ietf-manet-nhdp-14.txt, July 2010.
[OLSRv2]	Clausen, T., Dearlove, C., and P. Jacquet, "The Optimized Link State Routing Protocol version 2," work in progress draft-ietf-manet-olsrv2-11.txt, April 2010.

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## Appendix A. Examples

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### A.1. Example of a Signed Message

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The sample message depicted in [Figure 1 \(Example message with signature\)](#) is derived from the appendix of [\[RFC5444\] \(Clausen, T., Dearlove, C., Dean, J., and C. Adjih, "Generalized MANET Packet/Message Format," February 2009.\)](#). A SIGNATURE Message TLV has been added, with the value representing a 15 octet long signature of the whole message.

---

```

0          1          2          3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|0 0 0 0 1 0 0 0|   Packet Sequence Number   | Message Type   |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|1 1 1 1 0 0 1 1|0 0 0 0 0 0 0 0 0 1 0 0 1 1 0 0|   Orig Addr   |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|               Originator Address (cont)       | Hop Limit   |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|   Hop Count   |   Message Sequence Number   |0 0 0 0 0 0 0 0|
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|0 0 0 1 1 1 1 0|   SIGNATURE   |0 0 0 1 0 0 0 0|0 0 0 1 0 0 1 0|
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|   Hash Func   | Crypto Func   |   Key Index   | Sign. Value   |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|               Signature Value (cont)           |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|               Signature Value (cont)           |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|               Signature Value (cont)           |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|   Signature Value (cont)   | TLV Type   |0 0 0 1 0 0 0 0|
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|0 0 0 0 0 1 1 0|               Value               |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|               Value (cont)               |0 0 0 0 0 0 1 0|
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|0 0 1 1 0 0 0 0|0 0 0 0 0 0 1 0|               Mid               |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|               Mid               | Prefix Length |0 0 0 0 0 0 0 0|
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|0 0 0 0 0 0 0 0|0 0 0 0 0 0 1 1|1 0 0 0 0 0 0 0|0 0 0 0 0 0 1 0|
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|               Head               |               Mid               |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|               Mid               |               Mid               |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 1|   TLV Type   |0 0 0 1 0 0 0 0|
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|0 0 0 0 0 0 1 0|               Value               |   TLV Type   |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|0 0 1 0 0 0 0 0|   Index Start   |   Index Stop   |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+

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**Figure 1: Example message with signature**

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## Authors' Addresses

[TOC](#)

	Ulrich Herberg
	LIX, Ecole Polytechnique
	91128 Palaiseau Cedex,
	France
Phone:	+33 1 6933 4126
Email:	<a href="mailto:ulrich@herberg.name">ulrich@herberg.name</a>
URI:	<a href="http://www.herberg.name/">http://www.herberg.name/</a>
	Thomas Heide Clausen
	LIX, Ecole Polytechnique
	91128 Palaiseau Cedex,
	France
Phone:	+33 6 6058 9349
Email:	<a href="mailto:T.Clausen@computer.org">T.Clausen@computer.org</a>
URI:	<a href="http://www.thomasclausen.org/">http://www.thomasclausen.org/</a>