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MANET Neighborhood Discovery Protocol (NHDP)  
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## Abstract

This document describes a 1-hop and symmetric 2-hop neighborhood discovery protocol (NHDP) for mobile ad hoc networks (MANETs).

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## [1.](#) Introduction

This document describes a neighborhood discovery protocol (NHDP) for a mobile ad hoc network (MANET) [[RFC2501](#)]. This protocol uses an exchange of HELLO messages in order that each node can determine the presence and status of its 1-hop and symmetric 2-hop neighbors. Messages are defined as instances of the specification [[packetbb](#)].

This neighborhood information is recorded in the form of Information Bases. These may be used by other protocols, such as MANET routing protocols, for determining local connectivity and node configuration. This protocol is designed to maintain this information in the presence of a dynamic network topology.

This protocol makes no assumptions about the underlying link layer, other than support of link local broadcast or multicast. Link layer information may be used if available and applicable.

This protocol is based on the neighborhood discovery process contained in the Optimized Link State Routing Protocol (OLSR) [[RFC3626](#)].

### [1.1.](#) Motivation

MANETs differ from more traditional wired and infrastructure based wireless networks, due to their envisioned applicability also over more challenging network interfaces (e.g. wireless, lossy, broadcast interfaces with moderate and shared bandwidth, hidden and exposed terminals and interference from other network interfaces and the

environment) and in more challenging topological conditions (e.g. rapid and unpredictable mobility, dynamic and non-predetermined network membership). An approach, often taken by MANET routing protocols, is to collect local topological information up to 2 hops, in order to, for example, optimize their flooding performance within the MANET.

Due to the properties of wireless transmissions, communication between two network interfaces on neighboring nodes may not be bi-directional; even if node A is able to receive a packets from node B, the converse is not guaranteed to be true. Furthermore, because of the localized nature of wireless broadcasts communication, differing neighbor sets often exist for differing neighboring nodes within the same communications channel. If node A is able to exchange packets with node B and node B is able to exchange packets with node C on the same interface, this does not guarantee that node A and node C can exchange packets directly.

Nodes in a MANET may have multiple heterogeneous interfaces

participating in the same MANET routing protocol, each of which with the characteristics as described above. Between the same pair of nodes more than one distinct communications channel (links) may therefore exist, with different properties.

For MANET routing protocols to correctly identify candidate links for inclusion in a routing path, the existence and bi-directionality of such distinct links between a node and its neighbors must be established and monitored.

The set of neighbor nodes of a given MANET node may be continuously changing, often due to node mobility or due to a changing physical environment in which the MANET is located. There are typically no signals from lower layers which would enable an IP routing protocol to detect and, as appropriate, react to such changes. Yet as such changes are can often take place on the order of seconds, requiring MANET IP routing protocols to also act rapidly to ensure sufficient convergence properties.

MANET routing protocols often employ relay set reductions in order to conserve network capacity when maintaining network-wide topological information, with calculation of these reduced relay sets employing

up to 2-hop information. Such is the case e.g. for [[RFC3626](#)].

The neighborhood discovery protocol specified in this document provides continued tracking of neighborhood changes, continued bi-directionality tracking of links between neighbors and local topological information up to two hops. Combined, this allows a MANET routing protocol access to information describing link establishment/disappearance, and provides the necessary topological information for reduced relay set selection and other purposes.

## [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](#)].

The terms "packet", "message", "address", "address block", "TLV", and "TLV block" in this document are to be interpreted as described in [[packetbb](#)].

Additionally, this document uses the following terminology:

Node - A MANET router which implements this neighborhood discovery protocol.

Interface - A network device, configured and assigned one or more IP addresses.

Address - An address, as recorded in the Information Bases specified by this protocol, and included in HELLO messages generated by this protocol, may be either an address or an address prefix. The exception to this is addresses described as originator addresses; these must be simple addresses without a prefix length. Non-originator addresses can be represented as a single address object in a HELLO message, as defined by [[packetbb](#)]. An address so represented is considered to have a prefix length equal to its length (in bits) when considered as an address object, and a similar convention is used in the Information Bases specified by this protocol. Two addresses (address objects) are considered equal only if their prefix lengths are also equal.

MANET interface - An interface participating in a MANET and using this neighborhood discovery protocol. A node may have several MANET interfaces.

Heard - A MANET interface of node X is considered heard on a MANET interface of a node Y if the latter can receive traffic from the former.

Link - A pair of MANET interfaces from two different nodes, where at least one interface is heard by the other.

Symmetric link - A link where both MANET interfaces are heard by the other.

1-hop neighbor - A node X is a 1-hop neighbor of a node Y if a MANET interface of node X is heard by a MANET interface of node Y.

Symmetric 1-hop neighbor - A node X is a symmetric 1-hop neighbor of a node Y if a symmetric link exists between a MANET interface on node X and a MANET interface on node Y.

Symmetric 2-hop neighbor - A node X is a symmetric 2-hop neighbor of

a node Y if node X is a symmetric 1-hop neighbor of a symmetric 1-hop neighbor of node Y, but is not node Y itself.

1-hop neighborhood - The 1-hop neighborhood of a node X is the set of the 1-hop neighbors of node X.

Symmetric 1-hop neighborhood - The symmetric 1-hop neighborhood of a node X is the set of the symmetric 1-hop neighbors of node X.

Symmetric 2-hop neighborhood - The symmetric 2-hop neighborhood of a node X is the set of the symmetric 2-hop neighbors of node X. (This may include nodes in the 1-hop neighborhood, or even in the symmetric 1-hop neighborhood, of node X.)

Constant - A constant is a numerical value which MUST be the same for all MANET interfaces of all nodes in the MANET, at all times.

Interface parameter - An interface parameter is a boolean or numerical value, specified separately for each MANET interface of each node. A node MAY change interface parameter values at any time, subject to some constraints.

Node parameter - A node parameter is a boolean or numerical value, specified for each node. A node MAY change node parameter values at any time, subject to some constraints.



This protocol:

- o Is applicable to networks, especially wireless networks, in which unknown neighbors (i.e. other nodes with which direct communication can be established) can be reached by local broadcast or multicast packets.
- o Is designed to work in networks with a dynamic topology, and in which messages may be lost, such as due to collisions in wireless networks.
- o Supports nodes that each have one or more participating MANET interfaces. The set of a node's interfaces may change over time. Each interface may have one or more interface addresses, and these may also be dynamically changing.
- o Can use the link local multicast address "LL-MANET-Routers", and either the "manet" UDP port or the "manet" IP protocol number, all as specified in [[manet-iana](#)].
- o Uses the packet and message formats specified in [[packetbb](#)]. Such packets may contain messages specified by this protocol as well as other protocols.
- o Specifies signaling using HELLO messages. The necessary contents of these messages are defined in this specification, and may be extended using the TLV mechanisms described in [[packetbb](#)].
- o Can use relevant link layer information if it is available.
- o Provides each node with local topology information up to two hops away. This information is made available to other protocols, of which this protocol may be a part, in Information Bases defined in this specification.
- o Is designed to work in a completely distributed manner, and does not depend on any central entity.

#### 4. Protocol Overview and Functioning

The objective of this protocol is, for each node:

- o To identify other nodes with which bidirectional links can be established (symmetric 1-hop neighbors).
- o To agree on the status of such links with the corresponding symmetric 1-hop neighbor.
- o To find the node's symmetric 2-hop neighbors.
- o To record this information in Information Bases that can be used by other protocols, of which this neighborhood discovery protocol may be a part.

These objectives are achieved using local (one hop) signaling that:

- o Advertises the presence of a node and its interfaces.
- o Discovers links with adjacent nodes.
- o Performs bidirectionality checks on the discovered links.
- o Advertises discovered links, and whether each is symmetric, to its 1-hop neighbors, and hence discovers symmetric 2-hop neighbors.

This specification defines, in turn:

- o Parameters and constants used by the protocol. Parameters used by this protocol may be, where appropriate, specific to a MANET interface. This protocol allows all parameters to be changed dynamically.
- o The Information Bases describing local interfaces, discovered links and their status, current and former 1-hop neighbors, and symmetric 2-hop neighbors.
- o The format of the HELLO message that is used for local signaling.
- o The generation of HELLO messages from some of the information in the Information Bases.
- o The updating of the Information Bases according to received HELLO messages and other events.

#### [4.1.](#) Nodes and Interfaces

In order for a node to participate in a MANET, it MUST have at least one, and possibly more, MANET interfaces. Each MANET interface:

- o Is characterized by a set of interface parameters, defining the behavior of this MANET interface. Each MANET interface MAY be individually parameterized.
- o Has an Interface Information Base, recording information regarding links to this MANET interface and symmetric 2-hop neighbors which can be reached through such links.
- o Generates and processes HELLO messages, according to the interface parameters for that MANET interface.

In addition to a set of MANET interfaces as described above, each node has:

- o A Local Information Base, containing the addresses of the interfaces (MANET and non-MANET) of this node. The contents of this Information Base are not changed by signaling.
- o A Node Information Base, recording information regarding current and recently lost 1-hop neighbors of this node.

A node may have both MANET interfaces and non-MANET interfaces. Interfaces of both of these types are recorded in a node's Local Information Base, which is used, but not updated, by the signaling of this protocol.

#### [4.2.](#) Information Base Overview

Each node maintains the Information Bases described in the following sections. These are used for describing the protocol in this document. An implementation of this protocol MAY maintain this information in the indicated form, or in any other organization which offers access to this information. In particular note that it is not necessary to remove Tuples from Sets at the exact time indicated,

only to behave as if the Tuples were removed at that time.

#### [4.2.1.](#) Local Information Base

Each node maintains a Local Information Base, which contains:

- o The Local Interface Set, which consists of Local Interface Tuples, each of which records the addresses of an interface (MANET or non-MANET) of the node.

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- o The Removed Interface Address Set, which consists of Removed Interface Address Tuples, each of which records a recently used address of an interface (MANET or non-MANET) of the node.

#### [4.2.2.](#) Interface Information Bases

Each node maintains, for each of its MANET interfaces, an Interface Information Base, which contains:

- o A Link Set, which records information about current and recently lost links between this interface and MANET interfaces of 1-hop neighbors. The Link Set consists of Link Tuples, each of which contains information about a single link. Recently lost links are recorded so that they can be advertised in HELLO messages, accelerating their removal from relevant 1-hop neighbors' Link Sets. Link quality information, if used and available, is recorded in Link Tuples and may indicate that links are treated as lost.
- o A 2-Hop Set, which records the existence of bidirectional links between symmetric 1-hop neighbors of this MANET interface and other nodes (symmetric 2-hop neighbors). The 2-Hop Set consists of 2-Hop Tuples, each of which records an interface address of a symmetric 2-hop neighbor, and all interface addresses of the corresponding symmetric 1-hop neighbor. The 2-Hop Set is updated by the signaling of this protocol, but is not itself reported in that signaling.

#### [4.2.3.](#) Node Information Base

Each node maintains a Node Information Base, which contains:

- o The Neighbor Set, which records 1-hop neighbors, each of which must be currently heard, although this may be over a link with insufficient link quality. The Neighbor Set consists of Neighbor Tuples, each of which records all interface addresses (whether directly linked or not) of a single 1-hop neighbor. Neighbor Tuples are maintained as long as there are corresponding current Link Tuples.
- o The Lost Neighbor Set, which records recently lost symmetric 1-hop neighbors. The Lost Neighbor Set consists of Lost Neighbor Tuples, each of which records an interface address of such a neighbor. These are recorded so that they can be advertised in HELLO messages, accelerating their removal from other nodes' 2-Hop Sets.

### [4.3.](#) Signaling Overview

This protocol contains a signaling mechanism for maintaining the Interface Information Bases and the Node Information Base. If information from the link layer, or any other source, is available and appropriate, it may also be used to update these Information Bases. Such updates are subject to the constraints specified in [Appendix C](#).

Signaling consists of a single type of message, known as a HELLO message. Each node generates HELLO messages on each of its MANET interfaces. Each HELLO message identifies that MANET interface, and reports the other interfaces (MANET and non-MANET) of the node. Each HELLO message includes information from the Link Set of the Interface Information Base of the MANET interface, and from the Node Information Base.

#### [4.3.1.](#) HELLO Message Generation

HELLO messages are generated by a node for each of its MANET interfaces, and MAY be sent:

- o Proactively, at a regular interval, known as HELLO\_INTERVAL. HELLO\_INTERVAL may be fixed, or may be dynamic. For example HELLO\_INTERVAL may be backed off due to congestion or network

stability.

- o As a response to a change in the node itself, or its 1-hop neighborhood, for example on first becoming active or in response to a new, broken, or changed status link.
- o In a combination of these proactive and responsive mechanisms.

Jittering of HELLO message generation and transmission, as described in [Section 11.2](#), SHOULD be used if appropriate.

HELLO messages are generated independently on each MANET interface of a node. HELLO messages MAY be scheduled independently for each MANET interface, or, interface parameters permitting, using the same schedule for all MANET interfaces of a node.

#### [4.3.2](#). HELLO Message Content

Each HELLO message sent over a MANET interface need not contain all of the information appropriate to that MANET interface, however:

- o A HELLO message MUST contain all of the addresses in the Local Interface Set of the node to which the MANET interface belongs.

- o Within every time interval of length REFRESH\_INTERVAL, the HELLO messages sent on each MANET interface of a node MUST collectively include:
  - \* All of the relevant information in the Link Set of the Interface Information Base of that MANET interface.
  - \* All of the relevant information in the Node Information Base of that node.

This applies to otherwise purely responsive nodes as well as to proactive nodes. In either case it means that all information appropriate to that MANET interface will have always been transmitted, in one or more HELLO messages, since the time REFRESH\_INTERVAL ago.

- o A HELLO message MUST include a VALIDITY\_TIME message TLV that indicates the length of time for which the message content is to

be considered valid, and included in the receiving node's Interface Information Base.

- o A periodically generated HELLO message SHOULD include an INTERVAL\_TIME message TLV that indicates the current value of HELLO\_INTERVAL for that MANET interface, i.e. the period within which a further HELLO message is guaranteed to be sent on that MANET interface.
- o Additional information may be added by a protocol using this protocol using the TLV mechanisms described in [[packetbb](#)]. For example, if multipoint relays (MPRs) are to be calculated similarly to as in OLSR [[RFC3626](#)] and signaled to neighbors, then this information may be added to HELLO messages using an address block TLV.

#### [4.3.3](#). HELLO Message Processing

All HELLO messages received by a node are used to update:

- o The Interface Information Base for the MANET interface on which that HELLO message is received.
- o The Node Information Base.

Specifically:

- o The node ensures that there is a single Neighbor Tuple corresponding to the originator of that HELLO message.

- o If a Link Tuple corresponding to the link on which that HELLO message was received exists, then its duration is extended, otherwise such a Link Tuple is created. If the HELLO message indicates that the receiving MANET interface has been heard, then the link is considered symmetric, or its duration as symmetric is extended. If the HELLO message indicates that the receiving MANET interface is lost, then the link is no longer considered symmetric. In this case one or more Lost Neighbor Tuples may be created.
- o If the link on which the HELLO message is received is symmetric,

then any symmetrically advertised neighbors in the HELLO message are added to the 2-Hop Set for the receiving interface, or if already present, the durations of the corresponding 2-Hop Tuples are extended.

In all cases the processing takes account of unexpected and erroneous information in the HELLO message, maintaining the constraints specified in [Appendix C](#).

#### [4.4](#). Link Quality

Some links in a MANET may be marginal, e.g. due to adverse wireless propagation. In order to avoid using such marginal links, a link quality is associated with each link in the Link Set, and links with insufficient link quality are considered lost. Modifying the link quality of a link is OPTIONAL. If link quality is not to be modified it MUST be set to indicate an always usable quality link. Link quality information is only used locally, it is not used in signaling, and nodes may interoperate whether they are using the same, different, or no, link quality information.

## [5](#). Protocol Parameters and Constants

The parameters and constants used in this specification are described in this section.



## [5.1.](#) Interface Parameters

The interface parameters used by this specification may be classified into the following four categories:

- o Message intervals
- o Information validity times
- o Link quality
- o Jitter

These are detailed in the following sections.

Different MANET interfaces (on the same or on different nodes) MAY employ different interface parameter values, and may change their interface parameter values dynamically, subject to the constraints given in this section. A particular case is where all MANET interfaces on all MANET nodes within a given MANET employ the same set of interface parameter values.

### [5.1.1.](#) Message Intervals

The following interface parameters regulate HELLO message transmissions over a given MANET interface.

HELLO messages serve two principal functions:

- o To advertise this node's own addresses to its 1-hop neighbors. The frequency of these advertisements is regulated by the interface parameters HELLO\_INTERVAL and HELLO\_MIN\_INTERVAL.
- o To advertise this node's knowledge of each of its 1-hop neighbors. The frequency of the advertisement of each such neighbor is regulated by the interface parameter REFRESH\_INTERVAL.

Specifically, these parameters are as follows:

HELLO\_INTERVAL - is the maximum time between the transmission of two successive HELLO messages on this MANET interface. If using periodic transmission of HELLO messages, these SHOULD be at a separation of HELLO\_INTERVAL, possibly modified by jitter as

specified in [[RFC5148](#)].

HELLO\_MIN\_INTERVAL - is the minimum interval between transmission of two successive HELLO messages, on this MANET interface. (This minimum interval MAY be modified by jitter, as defined in [[RFC5148](#)].)

REFRESH\_INTERVAL - is the maximum interval between advertisements in a HELLO message of each 1-hop neighbor address and its status. In all intervals of length REFRESH\_INTERVAL, a node MUST include all 1-hop neighbor information which it is specified as sending in at least one HELLO message on this MANET interface.

The following constraints apply to these interface parameters:

- o HELLO\_INTERVAL > 0
- o HELLO\_MIN\_INTERVAL >= 0
- o HELLO\_INTERVAL >= HELLO\_MIN\_INTERVAL
- o REFRESH\_INTERVAL >= HELLO\_INTERVAL
- o If INTERVAL\_TIME message TLVs as defined in [[timetlv](#)] are included in HELLO messages, then HELLO\_INTERVAL MUST be representable as described in [[timetlv](#)].

If REFRESH\_INTERVAL > HELLO\_INTERVAL, then a node may distribute its neighbor advertisements between HELLO messages in any manner, subject to the constraints above.

For a node to employ this protocol in a purely responsive manner on a MANET interface, REFRESH\_INTERVAL and HELLO\_INTERVAL SHOULD both be set to a value such that a responsive HELLO message is always expected in a shorter period than this value.

#### [5.1.2](#). Information Validity Times

The following interface parameters manage the validity time of link information:

L\_HOLD\_TIME - is the period of advertisement, on this MANET interface, of former 1-hop neighbor addresses as lost in HELLO messages, allowing recipients of these HELLO messages to accelerate removal of information from their Link Sets. L\_HOLD\_TIME can be set to zero if accelerated information removal is not required.

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H\_HOLD\_TIME - is used as the value in the VALIDITY\_TIME message TLV included in all HELLO messages on this MANET interface.

The following constraints apply to these interface parameters:

- o L\_HOLD\_TIME >= 0
- o H\_HOLD\_TIME >= REFRESH\_INTERVAL
- o If HELLO messages can be lost then both SHOULD be significantly greater than REFRESH\_INTERVAL.
- o H\_HOLD\_TIME MUST be representable as described in [[timetlv](#)].

### [5.1.3](#). Link Quality

The following interface parameters manage the usage of link quality (see [Section 4.4](#)):

HYST\_ACCEPT - is the link quality threshold at or above which a link becomes usable, if it was not already so.

HYST\_REJECT - is the link quality threshold below which a link becomes unusable, if it was not already so.

INITIAL\_QUALITY - is the initial quality of a newly identified link.

INITIAL\_PENDING - if true, then a newly identified link is considered pending, and is not usable until the link quality has reached or exceeded the HYST\_ACCEPT threshold.

The following constraints apply to these interface parameters:

- o  $0 \leq \text{HYST\_REJECT} \leq \text{HYST\_ACCEPT} \leq 1$
- o  $0 \leq \text{INITIAL\_QUALITY} \leq 1$ .
- o If link quality is not updated, then INITIAL\_QUALITY >= HYST\_ACCEPT.

- o If INITIAL\_QUALITY >= HYST\_ACCEPT, then INITIAL\_PENDING == false.
- o If INITIAL\_QUALITY < HYST\_REJECT, then INITIAL\_PENDING == true.

#### [5.1.4.](#) Jitter

If jitter, as defined in [[RFC5148](#)], is used then these parameters are as follows:

HP\_MAXJITTER - represents the value of MAXJITTER used in [[RFC5148](#)] for periodically generated HELLO messages on this MANET interface.

HT\_MAXJITTER - represents the value of MAXJITTER used in [[RFC5148](#)] for externally triggered HELLO messages on this MANET interface.

For constraints on these interface parameters see [[RFC5148](#)].

#### [5.2.](#) Node Parameters

The two node parameters defined by this specification are in the category of information validity time.

##### [5.2.1.](#) Information Validity Time

The following node parameter manages the validity time of lost symmetric 1-hop neighbor information:

N\_HOLD\_TIME - is used as the period during which former 1-hop neighbor addresses are advertised as lost in HELLO messages, allowing recipients of these HELLO messages to accelerate removal of information from their 2-Hop Sets. N\_HOLD\_TIME can be set to zero if accelerated information removal is not required.

I\_HOLD\_TIME - is the period for which a recently used local interface address is recorded.

The following constraints applies to these node parameters:

- o N\_HOLD\_TIME >= 0
- o I\_HOLD\_TIME >= 0

### [5.3.](#) Parameter Change Constraints

This section presents guidelines, applicable if protocol parameters are changed dynamically.

#### HELLO\_INTERVAL

- \* If the HELLO\_INTERVAL for a MANET interface increases, then the next HELLO message on this MANET interface MUST be generated according to the previous, shorter, HELLO\_INTERVAL. Additional

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subsequent HELLO messages MAY be generated according to the previous, shorter, HELLO\_INTERVAL (but MUST include times according to current parameters).

- \* If the HELLO\_INTERVAL for a MANET interface decreases, then the following HELLO messages on this MANET interface MUST be generated according to this current, shorter, HELLO\_INTERVAL.

#### REFRESH\_INTERVAL

- \* If the REFRESH\_INTERVAL for a MANET interface increases, then the content of subsequent HELLO messages must be organized such that the specification of the old value of REFRESH\_INTERVAL is satisfied for a further period equal to the old value of REFRESH\_INTERVAL.
- \* If the REFRESH\_INTERVAL for a MANET interface decreases, then it MAY be necessary to reschedule HELLO message generation on that MANET interface, in order that the specification of REFRESH\_INTERVAL is satisfied from the time of change.

#### HYST\_ACCEPT and HYST\_REJECT

- \* If HYST\_ACCEPT or HYST\_REJECT changes, then the appropriate actions for link quality change, as specified in [Section 14.3](#) MUST be taken.

#### L\_HOLD\_TIME

- \* If L\_HOLD\_TIME changes, then L\_time for all relevant Link Tuples MUST be changed.

#### N\_HOLD\_TIME

- \* If N\_HOLD\_TIME changes, then NL\_time for all relevant Lost Neighbor Tuples MUST be changed.

#### HP\_MAXJITTER

- \* If HP\_MAXJITTER changes, then the periodic HELLO message schedule on this MANET interface MAY be changed.

#### HT\_MAXJITTER

- \* If HT\_MAXJITTER changes, then externally triggered HELLO messages on this MANET interface MAY be rescheduled.

#### [5.4.](#) Constants

The constant C (time granularity) is used as specified in [[timetlv](#)].

## [6.](#) Local Information Base

A node maintains a Local Information Base that records information about its interfaces (MANET and non-MANET). Each interface **MUST** have at least one address, and **MAY** have more than one address.

The Local Information Base is not modified by signaling. If a node's interface configuration changes, then the Local Information Base **MUST** reflect these changes. This **MAY** also result in signaling to advertise these changes.

### [6.1.](#) Local Interface Set

A node's Local Interface Set records its local interfaces. It consists of Local Interface Tuples, one per interface:

(I\_local\_iface\_addr\_list, I\_manet)

where:

I\_local\_iface\_addr\_list is an unordered list of the addresses of this interface.

I\_manet is a boolean flag, describing if this interface is a MANET interface.

## [6.2.](#) Removed Interface Address Set

A node's Removed Interface Address Set records addresses which were recently local interface addresses. If a node's interface addresses are immutable then this set is always empty and MAY be omitted. It consists of Removed Interface Address Tuples, one per address:

(IR\_local\_iface\_addr, IR\_time)

where:

IR\_local\_iface\_addr is a recently used address of an interface of this node.

IR\_time specifies when this Tuple expires and MUST be removed.

## [7.](#) Interface Information Base

A node maintains an Interface Information Base for each of its MANET interfaces. This records information about links to that MANET interface and symmetric 2-hop neighbors which can be reached in two



hops using those links as the first hop. The Interface Information Base includes the Link Set and the 2-Hop Set.

A MANET interface address can be present as of both a 1-hop neighbor and a symmetric 2-hop neighbor. This allows the node with this MANET interface address to be immediately considered as a symmetric 2-hop neighbor if it fails to be a symmetric 1-hop neighbor.

### [7.1.](#) Link Set

A node's Link Set records links from other nodes which are, or recently were, 1-hop neighbors. It consists of Link Tuples, each representing a single link:

```
(L_neighbor_iface_addr_list, L_HEARD_time, L_SYM_time,  
  L_quality, L_pending, L_lost, L_time)
```

where:

`L_neighbor_iface_addr_list` is an unordered list of the addresses of the MANET interface of the 1-hop neighbor;

`L_HEARD_time` is the time until which the MANET interface of the 1-hop neighbor would be considered heard if not considering link quality;

`L_SYM_time` is the time until which the link to the 1-hop neighbor would be considered symmetric if not considering link quality;

`L_quality` is a dimensionless number between 0 (inclusive) and 1 (inclusive) describing the quality of a link; a greater value of `L_quality` indicating a higher quality link;

`L_pending` is a boolean flag, describing if a link is considered pending (i.e. a candidate, but not yet established, link);

`L_lost` is a boolean flag, describing if a link is considered lost due to link quality;

`L_time` specifies when this Tuple expires and MUST be removed.

The status of the link, as obtained through HELLO message exchange, and also taking link quality into account is denoted `L_status`.

L\_status can take the values PENDING, HEARD, SYMMETRIC and LOST. The values LOST, SYMMETRIC and HEARD are defined in [Section 17.3](#). The value PENDING is never used in a message, it is only used locally by a node, and any value distinct from LOST, SYMMETRIC and HEARD may be used.

L\_status is defined by:

1. If L\_pending is true, then L\_status = PENDING;
2. otherwise, if L\_lost is true, then L\_status = LOST;
3. otherwise, if L\_SYM\_time is not expired, then L\_status = SYMMETRIC;
4. otherwise, if L\_HEARD\_time is not expired, then L\_status = HEARD;
5. otherwise, L\_status = LOST.

## [7.2](#). 2-Hop Set

A node's 2-Hop Set records symmetric 2-hop neighbors, and the symmetric links to symmetric 1-hop neighbors through which the symmetric 2-hop neighbors can be reached. It consists of 2-Hop Tuples, each representing a single interface address of a symmetric 2-hop neighbor, and a single MANET interface of a symmetric 1-hop neighbor.

(N2\_neighbor\_iface\_addr\_list, N2\_2hop\_iface\_addr, N2\_time)

where:

N2\_neighbor\_iface\_addr\_list is an unordered list of the addresses of the MANET interface of the symmetric 1-hop neighbor from which this information was received;

N2\_2hop\_iface\_addr is an address of an interface of a symmetric 2-hop neighbor which has a symmetric link (using any MANET interface) to the indicated symmetric 1-hop neighbor;

N2\_time specifies when this Tuple expires and MUST be removed.

## [8.](#) Node Information Base

Each node maintains a Node Information Base that records information about addresses of current and recently symmetric 1-hop neighbors.

### [8.1.](#) Neighbor Set

A node's Neighbor Set records all interface addresses of each 1-hop neighbor. It consists of Neighbor Tuples, each representing a single 1-hop neighbor:

(N\_neighbor\_iface\_addr\_list, N\_symmetric)

where:

N\_neighbor\_iface\_addr\_list is an unordered list of the interface addresses of a 1-hop neighbor;

N\_symmetric is a boolean flag, describing if this is a symmetric 1-hop neighbor.

### [8.2.](#) Lost Neighbor Set

A node's Lost Neighbor Set records addresses of all interfaces of nodes which recently were symmetric 1-hop neighbors, but are now advertised as lost. It consists of Lost Neighbor Tuples, each representing a single such address:

(NL\_neighbor\_iface\_addr, NL\_time)

where:

NL\_neighbor\_iface\_addr is an address of an interface of a node which recently was a symmetric 1-hop neighbor of this node;

NL\_time specifies when this Tuple expires and MUST be removed.

## [9.](#) Local Information Base Changes

The Local Information Base MUST change to respond to changes in the node's local interface configuration. The node MUST update its Interface and Node Information Bases in response to such changes. If any changes in the Interface and Node Information Bases satisfy any of the conditions described in [Section 13](#), then those changes must be applied immediately, unless noted otherwise.

A node MAY transmit HELLO messages in response to these changes.

### [9.1.](#) Adding an Interface

If an interface is added to the node then this is indicated by the addition of a Local Interface Tuple to the Local Interface Set. If the new interface is a MANET interface then an initially empty Interface Information Base MUST be created for this new MANET interface. The actions in [Section 9.3](#) MUST be taken for each address of this added interface. A HELLO message MAY be sent on all MANET interfaces, it SHOULD be sent on the new interface if it is a MANET interface. If using scheduled messages, then a message schedule MUST be established on a new MANET interface.

### [9.2.](#) Removing an Interface

If an interface is removed from the node, then this MUST result in changes to the Local Information Base and the Node Information Base as follows:

1. Identify the Local Interface Tuple that corresponds to the interface to be removed.
2. For each address (henceforth removed address) in the `I_local_iface_addr_list` of that Local Interface Tuple, create a Removed Interface Address Tuple with:

- \* IR\_local\_iface\_addr = removed address;
  - \* IR\_time = current time + I\_HOLD\_TIME.
3. Remove that Local Interface Tuple from the Local Interface Set.
  4. If the interface to be removed is a MANET interface (i.e. with I\_manet == true) then:
    1. Remove the Interface Information Base for that MANET interface;

2. All Neighbor Tuples for which none of the addresses in its N\_neighbor\_iface\_addr\_list are found in any L\_neighbor\_iface\_addr\_list in any remaining Link Set, are removed.

If a node removes the Local Interface Tuple that contains the interface address that is used to define the node's originator address, as defined in [[packetbb](#)], then the node MAY change originator address.

If the removed interface is the last MANET interface of the node, then there will be no remaining Interface Information Bases, and the node will longer participate in this protocol.

After removing the interface and making these changes, a HELLO message MAY be sent on all remaining MANET interfaces.

### [9.3](#). Adding an Address to an Interface

If an address is added to an interface then this is indicated by the addition of an address to the appropriate I\_local\_iface\_addr\_list. The following changes MUST be made to the Information Bases:

1. The Neighbor Tuples, if any, whose N\_neighbor\_iface\_addr\_list contains the added address, are removed.
2. Any Link Tuples, in any Link Set, whose L\_neighbor\_iface\_addr\_list contains:

- \* the added address; OR
- \* any address in the N\_neighbor\_iface\_addr\_list of the removed Neighbor Tuples, if any

are removed; apply [Section 13.1](#), but not [Section 13.3](#).

3. Any Lost Neighbor Tuples whose NL\_neighbor\_iface\_addr is the added address, are removed.
4. Any 2-Hop Tuples whose N2\_2hop\_iface\_addr is the added address, are removed.

After adding the address and making these changes, a HELLO message MAY be sent on all MANET interfaces.

#### [9.4](#). Removing an Address from an Interface

If an address (henceforth removed address) is removed from an interface then:

1. Identify the Local Interface Tuple that corresponds to the interface to be removed.
2. If this is the only address of that interface (the only address in the corresponding I\_local\_iface\_addr\_list) then remove that interface as specified in [Section 9.2](#).
3. Otherwise:
  1. Remove the removed address from this I\_local\_iface\_addr\_list.
  2. Create a Removed Interface Address Tuple with:
    - + IR\_local\_iface\_addr = removed address;
    - + IR\_time = current time + I\_HOLD\_TIME.

If a node removes the interface address that is used to define the node's originator address, as defined in [[packetbb](#)], then the node MAY change originator address.

After removing the address and making these changes, a HELLO message MAY be sent on all MANET interfaces.

## [10](#). Packets and Messages

The packet and message format used by this protocol is defined in [[packetbb](#)], which is used with the following considerations:

- o This protocol specifies one message type, the HELLO message.
- o HELLO message header options MAY be used as specified by a protocol which uses this neighborhood discovery protocol.
- o HELLO messages MUST NOT be forwarded.
- o HELLO messages MAY be included in multi-message packets as specified in [[packetbb](#)].

- o Packet header options MAY be used as specified by a protocol which uses this neighborhood discovery protocol.
- o Received HELLO messages MUST be parsed in accordance with [\[packetbb\]](#). A HELLO message which is not in conformance with [\[packetbb\]](#) MUST be discarded.
- o This protocol specifies three address block TLVs. It also uses two message TLVs defined in [\[timetlv\]](#). These five TLV types are all defined only with Type Extension == 0. TLVs of other types, and of these types but without Type Extension == 0, are ignored by this protocol. All references in this protocol to, for example, a TLV with Type == LINK\_STATUS, are to be considered as referring to a TLV with Type == LINK\_STATUS and Type Extension == 0.

### [10.1.](#) HELLO Messages

A HELLO message MUST contain:

- o A VALIDITY\_TIME message TLV as specified in [\[timetlv\]](#), representing H\_HOLD\_TIME for the transmitting MANET interface. The options included in [\[timetlv\]](#) for representing zero and infinite times MUST NOT be used.

A HELLO message which is transmitted periodically SHOULD contain, and otherwise MAY contain:

- o An INTERVAL\_TIME message TLV as specified in [\[timetlv\]](#), representing HELLO\_INTERVAL for the transmitting MANET interface. The options included in [\[timetlv\]](#) for representing zero and infinite times MUST NOT be used.

A HELLO message MAY contain:

- o One or more address blocks, each with an associated TLV block.
- o Other message TLVs.

#### [10.1.1.](#) Address Blocks

All addresses in a node's Local Interface Set (i.e. in any



I\_local\_iface\_addr\_list) MUST be included in the address blocks in all generated HELLO messages with the following exception. If the MANET interface on which the HELLO message is to be sent has a single interface address with maximum prefix length then that address MAY be omitted. All addresses of the node's interfaces included in an address block MUST be associated with a TLV with Type == LOCAL\_IF, as defined in Table 1.

Name	Value Length	Description
LOCAL_IF	1 octet	Specifies that the address is an address associated with the interface on which the message was sent (THIS_IF), another interface of the sending node (OTHER_IF), or an unspecified interface of the sending node (UNSPEC_IF).

Table 1

Note that the value UNSPEC\_IF is not used by this protocol. It is provided for an expected alternative use of this TLV.

Address blocks MAY contain current or recently lost 1-hop neighbors' interface addresses, each of which is associated with address block TLVs as described in Table 2.

Name	Value Length	Description
LINK_STATUS	1 octet	Specifies the status of the link from the indicated address (LOST, SYMMETRIC or HEARD).
OTHER_NEIGHB	1 octet	Specifies that the address is (SYMMETRIC) or was (LOST) of an interface of a symmetric 1-hop neighbor of the node transmitting the HELLO message.

Table 2

A TLV with Type == LINK\_STATUS and (Value == SYMMETRIC or Value == LOST) also performs the function of a TLV with Type == OTHER\_NEIGHB and the same value. The latter SHOULD NOT also be included. If a TLV with Type == LINK\_STATUS and Value == SYMMETRIC is combined with a TLV with Type == OTHER\_NEIGHB and Value == LOST then the latter MUST be ignored, and SHOULD NOT be included. See [Appendix A](#).

Other addresses MAY be included in address blocks, but MUST NOT be associated with any of the TLVs specified in this section.

## [11.](#) HELLO Message Generation

Each MANET interface **MUST** generate HELLO messages according to the specification in this section. HELLO message generation and scheduling **MUST** be according to the interface parameters for that MANET interface and **MAY** be independent for each MANET interface or, interface parameters permitting, MANET interfaces **MAY** use the same schedule.

If transmitting periodic HELLO messages then, following a HELLO message transmission on a MANET interface, another HELLO message **MUST** be transmitted on the same MANET interface after an interval not greater than HELLO\_INTERVAL. Two successive HELLO message transmissions on the same MANET interface **MUST** be separated by at least HELLO\_MIN\_INTERVAL, except as noted in [Section 11.2.1](#).

### [11.1.](#) HELLO Message Specification

HELLO messages are generated independently on each MANET interface.

All addresses in any I\_local\_iface\_addr\_list **MUST** be included, except that:

- o If the interface on which the HELLO message is to be sent has a single interface address with maximum prefix length then that interface address **MAY** be omitted.

All such included addresses **MUST** be associated with a TLV with Type == LOCAL\_IF and value according to the following:

- o If the address is of the sending interface, then Value == THIS\_IF.
- o Otherwise, Value == OTHER\_IF.

The following addresses of current or former 1-hop neighbors **MAY** be included in any HELLO message:

- o Addresses of MANET interfaces of 1-hop neighbors from the Link Set of the Interface Information Base for this MANET interface.
- o Other addresses of symmetric 1-hop neighbors from the Neighbor Set of this node's Node Information Base.

- o Addresses of MANET interfaces of previously symmetric or heard 1-hop neighbors connected on this MANET interface from the Link Set of the Interface Information Base for this MANET interface. (These are advertised for a period equal to this interface's L\_HOLD\_TIME after loss.)

- o Other addresses of previously symmetric 1-hop neighbors from the Lost Neighbor Set of this node's Node Information Base. (These are advertised for a period equal to N\_HOLD\_TIME after loss.)

Each such address MUST be associated with one or more appropriate TLVs, respecting the parameter REFRESH\_INTERVAL for each association for each MANET interface. Specifically:

1. For each address (henceforth linked address) which appears in a Link Tuple in the Link Set for this MANET interface, for which L\_status does not equal PENDING, include the linked address with an associated TLV with:
  - \* Type = LINK\_STATUS; AND
  - \* Value = L\_status.
2. For each address (henceforth neighbor address) which appears in an N\_neighbor\_iface\_addr\_list in a Neighbor Tuple with N\_symmetric == true, and which has not already been included with an associated TLV with (Type == LINK\_STATUS and Value == SYMMETRIC), include the neighbor address with an associated TLV with:
  - \* Type = OTHER\_NEIGHB; AND
  - \* Value = SYMMETRIC.
3. For each Lost Neighbor Tuple whose NL\_neighbor\_iface\_addr (henceforth lost address) has not already been included, include the lost address with an associated TLV with:
  - \* Type = OTHER\_NEIGHB; AND
  - \* Value = LOST.

If a 1-hop neighbor address is specified with more than one associated TLV, then these TLVs MAY be independently included or excluded from each HELLO message. Each such TLV MUST be included associated with that address in a HELLO message sent on that MANET interface in every interval of length equal to that MANET interface's parameter REFRESH\_INTERVAL. TLVs associated with the same address included in the same HELLO message MAY be applied to the same or different copies of that address.

## [11.2.](#) HELLO Message Transmission

HELLO messages are transmitted in the packet/message format specified by [[packetbb](#)] using the "LL-MANET-Routers" multicast address specified by [[manet-iana](#)] as destination IP address, using either the "manet" UDP port, or the "manet" IP protocol number specified in [[manet-iana](#)].

### [11.2.1.](#) HELLO Message Jitter

HELLO messages MAY be sent using periodic message generation or externally triggered message generation. If using data link and physical layers which are subject to packet loss due to collisions, HELLO messages SHOULD be jittered as described in [[RFC5148](#)].

Internally triggered message generation (such as due to a change in local interfaces) MAY be treated as if externally generated message generation, or MAY be not jittered.

HELLO messages MUST NOT be forwarded, and thus message forwarding jitter does not apply to HELLO messages.

Each form of jitter described in [[RFC5148](#)] requires a parameter MAXJITTER. These interface parameters may be dynamic, and are specified by:

- o For periodic message generation: HP\_MAXJITTER.
- o For externally triggered message generation: HT\_MAXJITTER.

When HELLO message generation is delayed in order that a HELLO message is not sent within HELLO\_MIN\_INTERVAL of the previous HELLO message on the same MANET interface, then HELLO\_MIN\_INTERVAL SHOULD be reduced by jitter, with maximum reduction HP\_MAXJITTER. In this case HP\_MAXJITTER MUST NOT be greater than HELLO\_MIN\_INTERVAL.

## [12.](#) HELLO Message Processing

On receiving a HELLO message, a node MUST first check if any address associated with a TLV with Type == LOCAL\_IF is one of the receiving node's current or recently used interface addresses (i.e. is in any I\_local\_iface\_addr\_list in the Local Interface Set or is equal to any IR\_local\_iface\_addr in the Removed Interface Address Set). If so then the HELLO message MUST be discarded.

Otherwise the receiving node MUST update its appropriate Interface Information Base and its Node Information Base according to this section. [Section 12.1](#) to [Section 12.4](#) MUST be performed in the order presented. If any changes satisfy any of the conditions described in [Section 13](#) then the indicated consequences MUST be applied immediately, unless noted otherwise.

For the purpose of this section, note the following definitions:

- o "validity time" is calculated from the VALIDITY\_TIME message TLV of the HELLO message as specified in [[timetlv](#)]. All information in the HELLO message has the same validity time.

- o "Receiving Address List" is the `I_local_iface_addr_list` corresponding to the MANET interface on which the HELLO message was received
- o "Sending Address List" is the list of the addresses contained in the HELLO message with an associated TLV with `Type == LOCAL_IF` and `Value == THIS_IF`. If the Sending Address List is otherwise empty, then the Sending Address List contains a single address (with maximum prefix length) equal to the sending address of the IP datagram in which the HELLO message was included.
- o "Neighbor Address List" is the Sending Address List, plus the addresses contained in the HELLO message with an associated TLV with `Type == LOCAL_IF` and `Value == OTHER_IF`.
- o EXPIRED indicates that a timer is set to a value clearly preceding the current time (e.g. current time - 1).
- o "Removed Address List" is a list of addresses created by this HELLO message processing which were formerly reported as local by the node originating the HELLO message, but which are not included in the Neighbor Address List. This list is initialized as empty.
- o "Lost Address List" is a subset of the Removed Address List containing addresses which were formerly considered as symmetric. This list is initialized as empty.

### [12.1.](#) Updating the Neighbor Set

On receiving a HELLO message, the node MUST update its Neighbor Set and populate the Removed Address List and Lost Address List:

1. Find all Neighbor Tuples (hereafter matching Neighbor Tuples) where:
  - \* `N_neighbor_iface_addr_list` contains at least one address in the Neighbor Address List.
2. If there are no matching Neighbor Tuples, then:
  1. Create a new Neighbor Tuple with:

- + N\_neighbor\_iface\_addr\_list = Neighbor Address List;
  - + N\_symmetric = false.
3. If there is one matching Neighbor Tuple, then:
    1. If the N\_neighbor\_iface\_addr\_list of the matching Neighbor Tuple is not equal to the Neighbor Address List, then:
      1. For each address (henceforth removed address) which is in the N\_neighbor\_iface\_addr\_list, but not in the Neighbor Address List:
        1. Add the removed address to the Removed Address List.
        2. If N\_symmetric == true, then add the removed address to the Lost Address List.
      2. Update the matching Neighbor Tuple by:
        - N\_neighbor\_iface\_addr\_list = Neighbor Address List.
  4. If there are two or more matching Neighbor Tuples, then:
    1. For each address (henceforth removed address) which is in the N\_neighbor\_iface\_addr\_list of any of the matching Neighbor Tuples:
      1. Add the removed address to the Removed Address List.
      2. If N\_symmetric == true, then add the removed address to the Lost Address List.

2. Replace the matching Neighbor Tuples by a single Neighbor Tuple with:
  - + N\_neighbor\_iface\_addr\_list = Neighbor Address List;
  - + N\_symmetric = false

## [12.2.](#) Updating the Lost Neighbor Set



On receiving a HELLO message, a node MUST update its Lost Neighbor Set:

1. For each address (henceforth lost address) in the Lost Address List, if no Lost Neighbor Tuple with NL\_neighbor\_iface\_addr == lost address exists, then add a Lost Neighbor Tuple with:
  - \* NL\_neighbor\_iface\_addr = lost address;
  - \* NL\_time = current time + N\_HOLD\_TIME.

### [12.3.](#) Updating the Link Set

On receiving a HELLO message, a node MUST update its Link Set for the MANET interface on which the HELLO message is received:

1. Remove all addresses in the Removed Address List from the L\_neighbor\_iface\_addr\_list of all Link Tuples.
2. Remove all Link Tuples whose L\_neighbor\_iface\_addr\_list is now empty; apply [Section 13.1](#), but not [Section 13.3](#).
3. Find all Link Tuples (hereafter matching Link Tuples) where:
  - \* L\_neighbor\_iface\_addr\_list contains one or more addresses in the Sending Address List.
4. If there is more than one matching Link Tuple, then remove them all; apply [Section 13.1](#), but not [Section 13.3](#).
5. If no matching Link Tuples remain, then create a new matching Link Tuple with:
  - \* L\_neighbor\_iface\_addr\_list = empty;
  - \* L\_HEARD\_time = EXPIRED;
  - \* L\_SYM\_time = EXPIRED;

- \* L\_pending = INITIAL\_PENDING;
  - \* L\_lost = false;
  - \* L\_time = current time + validity time.
6. The matching Link Tuple, existing or new, is then modified as follows:
1. If the node finds any address (henceforth receiving address) in the Receiving Address List in an address block in the HELLO message, then the Link Tuple is modified as follows:
    1. If any receiving address in the HELLO message is associated with a TLV with Type == LINK\_STATUS and (Value == HEARD or Value == SYMMETRIC) then:
      - L\_SYM\_time = current time + validity time.
    2. Otherwise if any receiving address in the HELLO message is associated with a TLV with Type == LINK\_STATUS and Value == LOST then:
      1. if L\_SYM\_time has not expired, then:
        1. L\_SYM\_time = EXPIRED.
        2. if L\_status == HEARD or SYMMETRIC, then:
          - \* L\_time = current time + L\_HOLD\_TIME.
  2. L\_neighbor\_iface\_addr\_list = Sending Address List.
  3. L\_HEARD\_time = max(current time + validity time, L\_SYM\_time).
  4. If L\_status == PENDING, then:
    - + L\_time = max(L\_time, L\_HEARD\_time).
  5. Otherwise if L\_status == HEARD or SYMMETRIC, then:
    - + L\_time = max(L\_time, L\_HEARD\_time + L\_HOLD\_TIME).

#### [12.4.](#) Updating the 2-Hop Set

On receiving a HELLO message a node MUST update its 2-Hop Set for the MANET interface on which the HELLO message was received:

1. Remove all addresses in the Removed Address List from the N2\_neighbor\_iface\_addr\_list of all 2-Hop Tuples.
2. If the Link Tuple with L\_neighbor\_iface\_addr\_list == Sending Address List has L\_status == SYMMETRIC then:
  1. For each address (henceforth 2-hop address) in an address block of the HELLO message, which is not in the Neighbor Address List, in any I\_local\_iface\_addr\_list, or equal to any IR\_local\_iface\_addr:
    1. If the 2-hop address has an associated TLV with:
      - Type == LINK\_STATUS and Value == SYMMETRIC; OR
      - Type == OTHER\_NEIGHB and Value == SYMMETRIC,then, if there is no 2-Hop Tuple such that:
      - N2\_neighbor\_iface\_addr\_list contains one or more addresses in the Sending Address List; AND
      - N2\_2hop\_iface\_addr == 2-hop address.then create a 2-Hop Neighbor Tuple with:
      - N2\_2hop\_iface\_addr = 2-hop address.This 2-Hop Tuple (existing or new) is then modified as follows:
      - N2\_neighbor\_iface\_addr\_list = Sending Address List;
      - N2\_time = current time + validity time.
    2. Otherwise if the 2-hop address has a TLV with:
      - Type == LINK\_STATUS and (Value == LOST or Value == HEARD); OR
      - Type == OTHER\_NEIGHB and Value == LOST;

then remove all 2-Hop Tuples with:

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- N2\_neighbor\_iface\_addr\_list contains one or more addresses in the Sending Address List; AND
- N2\_2hop\_iface\_addr == 2-hop address.

### [13.](#) Other Information Base Changes

The Interface and Node Information Bases MUST be changed when some events occur. These events may result from HELLO message processing, or may be otherwise generated (e.g. expiry of timers or link quality changes).

Events which cause changes in the Information Bases are:

- o A Link Tuple's state changes from symmetric, or the Link Tuple is removed.
- o A Link Tuple's state changes to symmetric.
- o A Link Tuple's L\_HEARD\_time expires, or the Link Tuple is removed.
- o Local interface address changes, as specified in [Section 9](#).
- o Link quality changes, as specified in [Section 14](#).

A node MAY report updated information in response to any of these changes in HELLO message(s), subject to the constraints in [Section 11](#).

A node which transmits HELLO messages in response to such changes SHOULD transmit a HELLO message:

- o On all MANET interfaces, if the Neighbor Set changes such as to indicate the change in symmetry of any 1-hop neighbors (including addition or removal of symmetric 1-hop neighbors).
- o Otherwise, on all those MANET interfaces whose Link Set changes

such as to indicate a change in status of any 1-hop neighbors (including the addition or removal of any 1-hop neighbors, other than those considered pending).

### 13.1. Link Tuple Not Symmetric

If for any Link Tuple with L\_status == SYMMETRIC:

- o L\_status changes to any other value; OR
- o the Link Tuple is removed;

then:

1. All 2-Hop Tuples for the same MANET interface with:

- \* N2\_neighbor\_iface\_addr\_list contains one or more addresses in L\_neighbor\_iface\_addr\_list;

are removed.

2. For the Neighbor Tuple whose N\_neighbor\_iface\_addr\_list contains L\_neighbor\_iface\_addr\_list:

1. If there are no remaining Link Tuples for any MANET interface with:

- + L\_neighbor\_iface\_addr\_list contained in N\_neighbor\_iface\_addr\_list; AND
- + L\_status == SYMMETRIC;

then modify the Neighbor Tuple by:

1. N\_symmetric = false.
2. For each address (henceforth neighbor address) in N\_neighbor\_iface\_addr\_list, add a Lost Neighbor Tuple with:
  - NL\_neighbor\_iface\_addr = neighbor address;

- NL\_time = current time + N\_HOLD\_TIME.

### [13.2.](#) Link Tuple Symmetric

If, for any Link Tuple which does not have L\_status == SYMMETRIC:

- o L\_status changes to SYMMETRIC;

(this includes a newly created Link Tuple which is immediately updated to have L\_status == SYMMETRIC) then:

1. For the Neighbor Tuple whose N\_neighbor\_iface\_addr\_list includes L\_neighbor\_iface\_addr\_list, set:
  - \* N\_symmetric = true.
2. Remove all Lost Neighbor Tuples whose NL\_neighbor\_iface\_addr is included in that N\_neighbor\_iface\_addr\_list.

### [13.3.](#) Link Tuple Heard Timeout

If, for any Link Tuple:

- o L\_HEARD\_time expires; OR
- o the Link Tuple is removed;

then:

1. For the Neighbor Tuple whose N\_neighbor\_iface\_addr\_list contains L\_neighbor\_iface\_addr\_list, if no Link Tuples for any MANET interface remain with:
  - \* L\_neighbor\_iface\_addr\_list contained in N\_neighbor\_iface\_addr\_list; AND
  - \* L\_HEARD\_time is not expired;

then remove the Neighbor Tuple.

## [14.](#) Link Quality

Link quality is a mechanism whereby a node MAY take considerations other than message exchange into account for determining when a link is and is not a candidate for being considered as HEARD or SYMMETRIC.

For deployments where no link quality is used, the considerations in [Section 14.1](#) apply. For deployments where link quality is used, the general principles of link quality usage are described in [Section 14.2](#). [Section 14.3](#) and [Section 14.4](#) detail link quality functioning.



Link quality is used only locally by a node, and nodes may fully interoperate whether they are using the same, different or no link quality methods.

#### [14.1.](#) Deployment Without Link Quality

In order for a node to not employ link quality, the node MUST define:

- o INITIAL\_PENDING = false;
- o INITIAL\_QUALITY >= HYST\_REJECT (there is no reason not to define INITIAL\_QUALITY = 1).

#### [14.2.](#) Basic Principles of Link Quality

To enable link quality usage, the L\_quality value of a Link Tuple is used in conjunction with two thresholds, HYST\_ACCEPT and HYST\_REJECT, to set the flags L\_pending and L\_lost of that Link Tuple. Based on these flags, the link status to advertise for that Link Tuple is determined as described in [Section 7.1](#).

The use of two thresholds implements link hysteresis, whereby a link which has  $\text{HYST\_REJECT} \leq \text{L\_quality} < \text{HYST\_ACCEPT}$  may be either accepted or rejected (depending on which threshold it has most recently crossed, or if neither the value of INITIAL\_QUALITY). With appropriate values of these parameters, this prevents over-rapid changes of link status.

The basic principles of link quality usage are as follows:

- o A node does not advertise a neighbor interface in any state until L\_quality is acceptable:
  - \* If INITIAL\_PENDING == true, then this is such that  $\text{L\_quality} \geq \text{HYST\_ACCEPT}$ .

- \* Otherwise this is such that  $\text{L\_quality} \geq \text{HYST\_REJECT}$ . To ensure this, a node MUST NOT define INITIAL\_PENDING == false and INITIAL\_QUALITY < HYST\_REJECT. (A node also MUST NOT define INITIAL\_PENDING == true and INITIAL\_QUALITY >=

HYST\_ACCEPT.)

- \* A link which is not yet advertised has `L_pending == true`.
- o Once `L_quality >= HYST_ACCEPT`, the `L_pending` flag is set false, indicating that the link can be advertised.
- o A link for which `L_pending == false` is advertised until its `L_quality` drops below `HYST_REJECT`.
- o If a link has `L_pending == false` and `L_quality < HYST_REJECT`, the link is LOST and is advertised as such. This link is not reconsidered as a candidate HEARD or SYMMETRIC link until `L_quality >= HYST_ACCEPT`.
- o A link which has an acceptable quality may be advertised as HEARD, SYMMETRIC or LOST according to the exchange of HELLO messages.

#### [14.3](#). When Link Quality Changes

If `L_quality` for a link changes, then the following actions MUST be taken:

1. If `L_quality >= HYST_ACCEPT` then the corresponding Link Tuple is modified by:
  1. `L_pending = false`.
  2. `L_lost = false`.
  3. If `L_status == HEARD` or `L_status == SYMMETRIC`, then:
    - + `L_time = max(L_time, L_HEARD_time + L_HOLD_TIME)`
2. If `L_status` is not equal to `PENDING`, and `L_quality < HYST_REJECT` then the corresponding Link Tuple is modified by:
  1. If `L_lost == false`, then:
    - + `L_lost = true`
    - + `L_time = min(L_time, current time + L_HOLD_TIME)`

Any appropriate action indicted in [Section 13](#) MUST also be taken.

If L\_quality for a link is updated based on HELLO message reception, or on reception of a packet including a HELLO message, then L\_quality MUST be updated prior to the HELLO message processing described in [Section 12](#). (If the receipt of the HELLO message, or the packet containing it, creates the Link Tuple then the Link Tuple MUST be created with the appropriately updated L\_quality value, rather than with L\_quality = INITIAL\_QUALITY.)

#### [14.4](#). Updating Link Quality

A node MAY update link quality based on any information available to it. Particular cases that MAY be used include:

- o Information from the link layer, such as signal to noise ratio or acknowledgement reception and loss information.
- o Receipt or loss of packets. If packets include a packet sequence number as defined in [\[packetbb\]](#), then packets on a link SHOULD have sequential packet sequence numbers, whether or not they include HELLO messages. Link quality can be updated when a packet is received based on, for example, whether the last N out of M packets on the link were received, or a "leaky integrator" tracking packets.
- o Receipt or loss of HELLO messages. If the maximum interval between HELLO messages is known (such as by inclusion of a message TLV with Type == INTERVAL\_TIME, as defined in [\[timetlv\]](#), in HELLO messages) then the loss of HELLO messages can be determined without the need to receive a HELLO message. Note that if this case is combined with the previous case then care must be taken to avoid "double counting" a lost HELLO message in a lost packet.

## [15.](#) Proposed Values for Parameters and Constants

This section lists the parameters and constants used in the specification of the protocol, and proposed values of each which may be used when a single value of each is used.

### [15.1.](#) Message Interval Interface Parameters

- o HELLO\_INTERVAL = 2 seconds
- o HELLO\_MIN\_INTERVAL = HELLO\_INTERVAL/4
- o REFRESH\_INTERVAL = HELLO\_INTERVAL

### [15.2.](#) Information Validity Time Interface Parameters

- o H\_HOLD\_TIME = 3 x REFRESH\_INTERVAL
- o L\_HOLD\_TIME = H\_HOLD\_TIME

### [15.3.](#) Information Validity Time Node Parameters

- o N\_HOLD\_TIME = L\_HOLD\_TIME
- o I\_HOLD\_TIME = N\_HOLD\_TIME

### [15.4.](#) Link Quality Interface Parameters

If link quality is changed, then parameter values will depend on the link quality process. If link quality is not changed, then:

- o HYST\_ACCEPT = 1
- o HYST\_REJECT = 0
- o INITIAL\_QUALITY = 1
- o INITIAL\_PENDING = false

### [15.5.](#) Jitter Interface Parameters

- o  $HP\_MAXJITTER = HELLO\_INTERVAL/4$
- o  $HT\_MAXJITTER = HP\_MAXJITTER$

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#### [15.6.](#) Constants

- o  $C = 1/1024$  second

## 16. Security Considerations

The objective of this protocol is to allow each node in the network to acquire information describing its 1-hop and symmetric 2-hop neighborhoods. This is acquired through message exchange between neighboring nodes. The information is made available through the Interface Information Bases and Node Information Base, describing the node's 1-hop neighborhood and symmetric 2-hop neighborhood.

Under normal circumstances, the information recorded in these Information Bases is correct - i.e. corresponds to the actual network topology, apart from any changes which have not (yet) been tracked by the HELLO message exchanges.

If some node for some reason, malice or malfunction, injects invalid HELLO messages, incorrect information may be recorded in the Information Bases. The protocol specification does, however, prevent inconsistent information from being injected in the protocol sets through the constraints in [Appendix C](#). The exact consequence of information inexactness depends on the use of these Information Bases, and should be reflected in the specification of protocols which use information provided by NHDP.

This section, therefore, only outlines the ways in which correctly formed, but still invalid, HELLO messages may appear.

### [16.1.](#) Invalid HELLO messages

A correctly formed, but still invalid, HELLO message may take any of the following forms. Note that a present or absent address in an address block, does not in and by itself cause a problem. It is the presence, absence, or incorrectness of associated LOCAL\_IF, LINK\_STATUS and OTHER\_NEIGHB TLVs that causes problems.

A node may provide false information about its own identity:

- \* The HELLO message may contain addresses with an associated LOCAL\_IF TLV which do not correspond to addresses of interfaces of the node transmitting the HELLO message.
- \* The HELLO message may omit addresses, or their associated LOCAL\_IF TLV, of interfaces of the local node transmitting the HELLO message (other than the allowed omission of the only local interface address of the MANET interface over which the HELLO message is transmitted, if that is the case).
- \* The HELLO message may incorrectly specify the LOCAL\_IF TLV value associated with one or more local interface addresses,

indicating incorrectly whether they are associated with the MANET interface over which the HELLO message is transmitted.

A node may provide false information about the identity of other nodes:

- \* A present LINK\_STATUS TLV may, incorrectly, identify an address as being of a MANET interface which is or was heard on the MANET interface over which the HELLO message is transmitted.
- \* A consistently absent LINK\_STATUS TLV may, incorrectly, fail to identify an address as being of a MANET interface which is or was heard on the MANET interface over which the HELLO message is transmitted.
- \* A present OTHER\_NEIGHB TLV may, incorrectly, identify an address as being of a node which is or was in the sending node's symmetric 1-hop neighborhood;

- \* A consistently absent OTHER\_NEIGHB TLV may, incorrectly, fail to identify an address as being of a node which is or was in the sending node's symmetric 1-hop neighborhood;
- \* The value of a LINK\_STATUS TLV may incorrectly indicate the status (LOST, SYMMETRIC or HEARD) of the link from a 1-hop neighbor.
- \* The value of an OTHER\_NEIGHB TLV may incorrectly indicate the status (LOST or SYMMETRIC) of a symmetric 1-hop neighbor.

## [17.](#) IANA Considerations

### [17.1.](#) Message Types

This specification defines one message type, to be allocated from the 0-223 range of the "Message Types" namespace defined in [[packetbb](#)], as specified in Table 3.

	Name		Type
			Description
	HELLO		TBD1
			Local signaling.



+-----+-----+-----+-----+

Table 3

## 17.2. Address Block TLV Types

This specification defines three address block TLV types, which must be allocated from the "Address Block TLV Types" namespace defined in [packetbb]. IANA are requested to make allocations in the 8-127 range for these types. This will create three new type extension registries with assignments as specified in Table 4, Table 5 and Table 6. Specifications of these TLVs are in [Section 10.1.1](#), with value constants defined in [Section 17.3](#).

Name	Type	Type extension	Description
LOCAL_IF	TBD2	0	Specifies that the address is associated with a local interface of the sending node.
		1-255	Expert Review

Table 4

Name	Type	Type extension	Description
LINK_STATUS	TBD3	0	Specifies the status of the link

			from the indicated address (LOST, SYMMETRIC or HEARD).
		1-255	Expert Review

Table 5

Name	Type	Type extension	Description
OTHER_NEIGHB	TBD4	0	Specifies that the address is (SYMMETRIC) or recently was (LOST) of an interface of a symmetric 1-hop neighbor of the node transmitting the message.
		1-255	Expert Review

Table 6

Type extensions indicated as Expert Review SHOULD be allocated as described in [[packetbb](#)], based on Expert Review as defined in [[RFC5226](#)].

### [17.3](#). LINK\_STATUS and OTHER\_NEIGHB Values

The values which the LOCAL\_IF TLV can use are the following:

- o UNSPEC\_IF = 0
- o THIS\_IF = 1
- o OTHER\_IF = 2

The values which the LINK\_STATUS TLV can use are the following:

- o LOST = 0
- o SYMMETRIC = 1

- o HEARD = 2

The values which the OTHER\_NEIGHB TLV can use are the following:

- o LOST = 0
- o SYMMETRIC = 1

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## [18.](#) References

### [18.1.](#) Normative References

- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", [RFC 2119](#), [BCP 14](#), March 1997.
- [RFC5148] Clausen, T., Dearlove, C., and B. Adamson, "Jitter considerations in MANETs", [RFC 5148](#), February 2008.
- [RFC5226] Narten, T. and H. Alvestrand, "Guidelines for Writing an IANA Considerations Section in RFCs", [RFC 5226](#), [BCP 26](#), May 2008.
- [packetbb] Clausen, T., Dearlove, C., Dean, J., and C. Adjih, "Generalized MANET Packet/Message Format", Work In Progress [draft-ietf-manet-packetbb-13.txt](#), June 2008.
- [timetlv] Clausen, T. and C. Dearlove, "Representing multi-value time in MANETs", Work In Progress [draft-ietf-manet-timetlv-04.txt](#), November 2007.
- [manet-iana] Chakeres, I., "IANA Allocations for MANET Protocols", Work In Progress [draft-ietf-manet-iana-07.txt](#), November 2007.

### [18.2.](#) Informative References

- [RFC2501] Macker, J. and S. Corson, "Mobile Ad hoc Networking (MANET): Routing Protocol Performance Issues and Evaluation Considerations", [RFC 2501](#), January 1999.
- [RFC3626] Clausen, T. and P. Jacquet, "The Optimized Link State Routing Protocol", [RFC 3626](#), October 2003.

[Appendix A](#). Address Block TLV Combinations

The algorithm for generating HELLO messages in [Section 11](#) specifies which 1-hop addresses may be included in the address blocks, and with which associated TLVs. These TLVs may have Type == LINK\_STATUS or Type == OTHER\_NEIGHB, or both. TLVs with Type == LINK\_STATUS may have three possible values (Value == HEARD, Value == SYMMETRIC or Value == LOST), and TLVs of TYPE == OTHER\_NEIGHB may have two possible values (Value == SYMMETRIC or Value == LOST). When both TLVs are associated with the same address only certain combinations of these TLV values are necessary, and are the only combinations generated by the algorithm in [Section 11](#). These combinations are indicated in Table 7.

Cells labeled with "Yes" indicate the possible combinations which are generated by the algorithm in [Section 11](#). Cells labeled with "No" indicate combinations not generated by the algorithm in [Section 11](#), but which are correctly parsed and interpreted by the algorithm in [Section 12](#).

	Type == OTHER_NEIGHB (absent)	Type == OTHER_NEIGHB, Value == SYMMETRIC	Type == OTHER_NEIGHB, Value == LOST
Type == LINK_STATUS (absent)	No	Yes	Yes
Type == LINK_STATUS, Value == HEARD	Yes	Yes	Yes
Type ==	Yes	No	No

LINK_STATUS, Value == SYMMETRIC			
Type == LINK_STATUS, Value == LOST	Yes	Yes	No

Table 7

## [Appendix B](#). HELLO Message Example

An example HELLO message, transmitted by an originator node with a single MANET interface, is as follows. The message uses IPv4 (four octet) addresses without specified prefix lengths. The message is transmitted with a full message header (flags octet value is 240) with a hop limit of 1 and a hop count of 0. The overall message length is 49 octets.

The message contains a message TLV block with content length 8 octets containing two message TLVs, of types VALIDITY\_TIME and INTERVAL\_TIME. Each uses a TLV with flags octet value 16, indicating that each has a value. Each has a value length of 1 octet; the values included (0x64 and 0x58) are time codes representing the default values of parameters H\_HOLD\_TIME and HELLO\_INTERVAL, respectively (6 seconds and 2 seconds) assuming the default value of constant C (1/1024 second).

The message has a single address block containing 5 addresses. The flags octet value 128 indicates an address head but no address tail. The head length of 3 octets indicates address mid sections of one octet each (Mid 0 to Mid 4).

The following TLV block (content length 14 octets) includes two TLVs. The first is a LOCAL\_IF TLV which (with flags octet value 80) indicates that a single address, with index 0 (i.e. Head:Mid 0) is the single local interface address of this node (the 1 octet value THIS\_IF indicates that this address is of this interface). The







```

+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
| 0 0 0 0 0 1 0 0 |      HEARD      |      HEARD      |      SYMMETRIC      |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|      LOST      |
+---+---+---+---+---+---+---+---+

```

[Appendix C](#). Constraints

Any process which updates the Local Information Base or the Node Information Base MUST ensure that all constraints specified in this appendix are maintained.

In each Local Interface Tuple:

- o I\_local\_iface\_addr\_list MUST NOT be empty.
- o I\_local\_iface\_addr\_list MUST NOT contain any duplicated addresses.
- o I\_local\_iface\_addr\_list MUST NOT contain any address which is in the I\_local\_iface\_addr\_list of any other Local Interface Tuple.

In each Removed Interface Address Tuple:

- o IR\_local\_iface\_addr MUST NOT contain any address which is in the I\_local\_iface\_addr\_list of any Local Interface Tuple.
- o IR\_local\_iface\_addr MUST NOT equal the IR\_local\_iface\_addr of any other Removed Interface Address Tuple.

In each Link Tuple:

- o L\_neighbor\_iface\_addr\_list MUST NOT be empty.
- o L\_neighbor\_iface\_addr\_list MUST NOT contain any address which is in the I\_local\_iface\_addr\_list of any Local Interface Tuple or the IR\_local\_iface\_addr of any Removed Interface Address Tuple.
- o L\_neighbor\_iface\_addr\_list MUST NOT contain any duplicated addresses.
- o L\_neighbor\_iface\_addr\_list MUST NOT contain any address which is in the L\_neighbor\_iface\_addr\_list of any other Link Tuple in the same Link Set.
- o If L\_HEARD\_time has not expired then there MUST be a Neighbor Tuple whose N\_neighbor\_iface\_addr\_list contains L\_neighbor\_iface\_addr\_list.
- o L\_HEARD\_time MUST NOT be greater than L\_time.
- o L\_SYM\_time MUST NOT be greater than L\_HEARD\_time (unless both are expired).

- o L\_quality MUST NOT be less than 0 or greater than 1.
- o If L\_quality >= HYST\_ACCEPT then L\_pending MUST be false.
- o If L\_quality < HYST\_REJECT then L\_status MUST be PENDING or LOST.
- o L\_pending MUST NOT be set to true if it is currently false.

In each Neighbor Tuple:

- o N\_neighbor\_iface\_addr\_list MUST NOT contain any address which is in the I\_local\_iface\_addr\_list of any Local Interface Tuple or the IR\_local\_iface\_addr of any Removed Interface Address Tuple.
- o N\_neighbor\_iface\_addr\_list MUST NOT contain any duplicated addresses.
- o N\_neighbor\_iface\_addr\_list MUST NOT contain any address which is in the N\_neighbor\_iface\_addr\_list of any other Neighbor Tuple.
- o If N\_symmetric == true, then there MUST be one or more Link Tuples with:
  - \* L\_neighbor\_iface\_addr\_list contained in N\_neighbor\_iface\_addr\_list; AND
  - \* L\_status == SYMMETRIC.
- o If N\_symmetric == false, then there MUST be one or more Link Tuples with:
  - \* L\_neighbor\_iface\_addr\_list contained in N\_neighbor\_iface\_addr\_list.

All such Link Tuples MUST NOT have L\_status == SYMMETRIC. At least one such Link Tuple MUST have L\_HEARD\_time not expired.

In each Lost Neighbor Tuple:

- o NL\_neighbor\_iface\_addr MUST NOT be in the I\_local\_iface\_addr\_list of any Local Interface Tuple or the IR\_local\_iface\_addr of any Removed Interface Address Tuple.
- o NL\_neighbor\_iface\_addr MUST NOT equal the NL\_neighbor\_iface\_addr of any other Lost Neighbor Tuple.
- o NL\_neighbor\_iface\_addr MUST NOT be in the N\_neighbor\_iface\_addr\_list of any Neighbor Tuple with N\_symmetric

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== true.

In each 2-Hop Tuple:

- o There MUST be a Link Tuple associated with the same MANET interface with:
  - \* L\_neighbor\_iface\_addr\_list == N2\_neighbor\_iface\_addr\_list; AND
  - \* L\_status == SYMMETRIC.
- o N2\_2hop\_iface\_addr MUST NOT be in the I\_local\_iface\_addr\_list of any Local Interface Tuple or the IR\_local\_iface\_addr of any Removed Interface Address Tuple.
- o N2\_2hop\_iface\_addr MUST NOT be the N2\_2hop\_iface\_addr of any other 2-Hop Tuple in the same 2-Hop Set and with the same N2\_neighbor\_iface\_addr\_list.
- o N2\_2hop\_iface\_addr MUST NOT be in the N2\_neighbor\_iface\_addr\_list of the same 2-Hop Tuple.

#### [Appendix D](#). Flow and Congestion Control

This protocol specifies one message type, the HELLO message. The maximum size of a HELLO message is proportional to the size of the originating node's 1-hop neighborhood. HELLO messages MUST NOT be forwarded.

A node MUST report its 1-hop neighborhood in HELLO messages on each of its MANET interfaces at least each REFRESH\_INTERVAL. This puts a lower bound on the control traffic generated by each node in the network employing this protocol.

A node MUST ensure that two successive HELLO messages sent on the same MANET interface are separated by at least HELLO\_MIN\_INTERVAL. (If using jitter then this may be reduced to a mean minimum value of  $\text{HELLO\_MIN\_INTERVAL} - \text{HP\_MAXJITTER}/2$ .) Thus, this puts an upper bound on the control traffic generated by each node in the network employing this protocol.

## [Appendix E](#). Contributors

This specification is the result of the joint efforts of the following contributors, listed alphabetically.

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## [Appendix F](#). Acknowledgements

The authors would like to acknowledge the team behind OLSRv1, specified in [RFC3626](#) for their contributions.

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