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MPL Forwarder Select (MPLFS)
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Abstract

This document describes a Forwarder Selection (MPLFS) protocol for the Multicast Protocol for Low-Power and lossy Networks (MPL) to reduce the density of forwarders such that the number of forwarded messages is reduced. The protocol uses Trickle to distribute link-local information about the identity of the neighbours of the nodes that have MPL-enabled interfaces. In the end-state all nodes are connected to a minimum number, `N_DUPLICATE`, of forwarders, where `N_DUPLICATE` is application dependent, and there is a path between any two forwarders.

Note

Discussion and suggestions for improvement are requested, and should be sent to roll@ietf.org.

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1. Introduction

The Multicast Protocol for Low-Power and Lossy Networks (MPL) [RFC7731] is designed for small devices interconnected by a lossy wireless network such as IEEE 802.15.4. A seed sends a multicast message with a realm-local scope, admin-local scope or higher as specified in [RFC4291].

Forwarders forward these messages with an increasing interval size. When the density of forwarders is high, the message may be forwarded by a high number of forwarders that conflict on the link. With extreme forwarder densities and small Trickle intervals, just sending one multicast message may lead to an overload of the communication medium.

The number of forwarded messages can be reduced by selecting a minimal set of forwarders. However, for large networks, manually selecting the forwarders is much work, and changing network conditions and configurations make the manual selection an unwanted burden to the network management.

This document specifies a protocol that selects the forwarders such that each MPL-enabled device is connected to `N_DUPLICATE` forwarders, where `N_DUPLICATE > 0` can be set. The parameter `N_DUPLICATE` determines how much path redundancy there is for each MPL message. The value of `N_DUPLICATE` should be at least 1, because a value of 0 has as result that no forwarder exists in the network during the protocol execution. Moreover, the protocol is distributed and dynamic in nature to face a continuously changing topology.

The protocol is inspired by the work described for NeighbourHood Discovery (NHDP) [RFC6130] and Simple Multicast Forwarding (SMF) [RFC6621]. In contrast to the "HELLO" messages described in [RFC6130], this protocol uses the Trickle protocol [RFC6206] to multicast link-local messages, containing a CBOR payload [RFC7049].

1.1. Terminology

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

Readers of this specification should be familiar with all the terms and concepts discussed in [RFC7731]. The following terms are defined in this document:

synchronization time The moment that a node can change its state at messages reception.

The following list contains the abbreviations used in this document.

XXXX: TODO, and others to follow.

2. Protocol overview

Nodes participating in MPLFS exchange messages with a format that is described in Section 6. A participating node communicates to all its neighbours with link-local multicast messages as described in Section 4.

Failing links provide a lot of instability. Only messages sent over stable links are accepted. Section 4 describes a mechanism to refuse messages from unstable links.

Each node maintains a set of 1-hop neighbours where each neighbour contains information about its own 1-hop neighbours. On the basis of the contents of the set, the node can decide to become a Forwarder or not, as explained in Section 5.

The protocol never ends, with a minimum frequency of exchanging maintenance messages specified by an interval size of `I_MAX_SELECT`. When the set of links is stable, the protocol stabilizes such that there is a path between any two forwarders, and every MPL-enabled node is connected to at least `N_DUPLICATE` MPL forwarders (when existing), where `N_DUPLICATE > 0`. `N_DUPLICATE` can be set dependent on the application requirements. With `N_DUPLICATE = 2`, it is expected that a multicast message arrives at an intended recipient with very high probability.

Nodes have a state that determines whether they are forwarder or not. The state of a node can only be changed by the node itself. To avoid race conditions, (e.g. two nodes simultaneously decide to be no forwarder, while only one is intended) the node with the highest address of all 1-hop neighbours is the only one allowed to change state. Unlike [RFC5614], that considers 3-tuple (Router Priority, MDR Level and Router ID) to allow self state change, this approach only takes into account the node address. Consequently, only k-hop neighbours, with $k > 2$, can change state simultaneously, and the 1-hop and 2-hop neighbours of a given node can change state one by one.

3. Data sets

Each node, `n_0`, maintains a state with two values: Fixed Forwarder (FF) and No Forwarder (NF). Each node also maintains a set, `S1_0`, containing information about `n_0`'s 1-hop neighbours and `n_0` itself. Each entry, `n_i`, in `S1_0` has the following attributes:

`address of n_i`: the address can be the 64 bit IPv6 address or the short 16 bit address.

`average-rssi-in`: the average rssi of the messages received by `n_0` from `n_i`.

`average-rssi-out`: the average rssi of the messages received by `n_i` from `n_0`.

`nr_FF`: the number of neighbours, `n_ij`, of `n_i` (including `n_i`) with state = FF.

`nr_Under`: the number of neighbours, `n_ij`, of `n_i` with `nr_FF < N_DUPLICATE`.

nr_Above: the number of neighbours, n_{ij} , of n_i with $nr_FF > N_DUPLICATE$.

size: the size of $S1_i$, the set of 1-hop neighbours of n_i .

state: the state of n_i .

4. Neighbor distribution

A participating node multicasts link-local so-called "neighbour messages" with the Trickle protocol. It uses the multicast address `LINK_LOCAL_ALL_NODES` as destination. The message sent by n_0 contains the contents of $S1_0$. The contents of a "neighbour message" from n_i received by n_0 is called M_i . The `rss_i` value associated with the reception of the "neighbour message" is called `new_rssi`. The message M_i contains information about the set $S1_i$ with the following attributes for all nodes in $S1_i$:

- o address
- o average-rssi-in
- o nr_FF
- o nr_Under
- o nr_Above
- o size
- o state

On reception of M_i from n_i for the first time, the receiving node adds n_i to $S1_0$, and sets `average-rssi-in` of n_i in $S1_0$ to `new_rssi`. For all following messages from n_i , the `average-rssi-in` for n_i is calculated in the following way: `average-rssi-in := (average-rssi-in*WEIGHT_AVERAGE + new_rssi)/(WEIGHT_AVERAGE+1)`.

The neighbour nodes of M_i are called n_{ij} . For the n_{ij} with an address that is equal to the address of n_0 : the value of `average-rssi-out` of n_0 is set equal to the value of `average-rssi-in` of n_{ij} .

The contents of n_0 is updated with the contents of M_i . Updating includes the following actions:

- o Add n_i to $S1_0$, if n_i not present in $S1_0$.
- o Set size of n_i equal to the number of entries in M_i .

- o When `n_ij.address = n_j.address`, copy the values of `nr_Under`, `nr_Above`, `nr_FF`, and state of `n_ij` to `n_j`.

When the `average-rssi-in` and `average-rssi-out` values of `n_i` have been averaged over more than `WEIGHT_AVERAGE` messages, and the averaged RSSI values are smaller than `MAXIMUM_RSSI`, `n_i` is called "valid".

5. Selection Algorithm

The protocol aims at allocating forwarders in the densest part of the network. A dense network is characterized by a high number of neighbours. Therefore, the protocol attempts to assign status FF to the nodes with the highest number of neighbours that have less than `N_DUPLICATE` neighbours with state = FF (`nr_FF < N_DUPLICATE`).

It is required that a path exists between every two forwarders to prevent network partitioning. Therefore, a node can become forwarder iff one of its neighbours is a forwarder. The consequence of this rule is that one so-called "source-forwarder" must be selected by the network administrator. A likely choice for the "source-forwarder" is the border router.

At the start of the selection protocol the node, `n_0`, sets its state to No Forwarder (NF). It sets the Trickle timer to its minimum interval, `I_MIN_SELECT`, and starts multicasting `M_0` to its neighbours. Every time entries are added to, or removed from, `S1_0`, the Trickle interval timer is set to `I_MIN_SELECT`.

The executing node, `n_0`, calculates the following parameter values:

- o `max-under` is the maximum of the `nr_Under` attribute of all valid `n_i` in `S1_0`.
- o `max_address_u` is the maximum of the addresses of valid `n_i` with `nr_Under = max-under`.
- o `max_address_a` is the maximum of the addresses of all valid `n_i`.
- o `connected` is true iff `nr_FF` of all neighbouring forwarders is equal to `nr_FF` of `n_0`.

The information about the state and the `nr_Under` value of the neighbours comes in asynchronously. Time is needed before the state in a node correctly reflects the state changes of the network. A node can change its state when during the reception of messages of all neighbours, the value of `nr_Under` has not changed.

To calculate its new state, `n_0` does the following:

When the state is NF, a neighbour with state = FF exists, and address = max-address_u:
 set state to FF.

When the state is FF, nr_Above = size S1_0, connected is true, and address = max_address_a:
 set state to NF.

6. CBOR payload

The payload format is /application/cbor [RFC7049]. The contents of the message is a CBOR array (Major type 4) of CBOR arrays composed of neighbour address, rssi value, size of S1_i, forwarder state, nr_FF, nr_Under, and nr_Above. Assuming two neighbours, in diagnostic JSON the payload looks like:

```
[
[address_1, average-rssi-in_1, size_1, state_1,
nr_FF_1, nr_Under_1, nr_Above_1],
[address_2, average-rssi-in_2, size_2, state_2,
nr_FF_2, nr_Under_2, nr_Above_2]
]
```

Figure 1: CBOR payload

7. Default parameter values

The following text recommends default values for the MPLFS protocols.

I_MIN_SELECT = 0,2; minimum Trickle timer interval.

I_MAX_SELECT = 10; maximum Trickle timer interval.

WEIGHT_AVERAGE = 10; number of values to average rssi.

MAXIMUM_RSSI = 3; maximum acceptable average rssi value.

N_DUPLICATE = 2; requested number of MPL forwarder neighbours for every MPL enabled node.

8. Acknowledgements

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9. Changelog

Changes from version 00 to version 01

- o Definition of S1_0 improved
- o Algorithm changed and simulated
- o Moment of state change specified

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