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     **A Mechanism to Measure the Quality of a Point-to-point Route in a Low
                         Power and Lossy Network**
                   draft-ietf-roll-p2p-measurement-00

Abstract

   This document specifies a mechanism that enables an RPL node to
   measure the quality of an existing route to/from another RPL node in
   a low power and lossy network, thereby allowing the node to decide if
   it wants to initiate the discovery of a more optimal route.

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1. Introduction

   Point to point (P2P) communication between arbitrary nodes in a Low
   power and Lossy Network (LLN) is a key requirement for many
   applications [RFC5826][RFC5867]. RPL [I-D.ietf-roll-rpl], the IPv6
   Routing Protocol for LLNs, constrains the LLN topology to a Directed
   Acyclic Graph (DAG) built to optimize routing costs to reach the
   DAG's root and requires the P2P routes to use the DAG links only.
   Such P2P routes may potentially be suboptimal and may lead to traffic
   congestion near the DAG root. Additionally, RPL is a proactive
   routing protocol and hence all P2P routes must be established ahead
   of the time they are used.

   To ameliorate situations, where RPL's P2P routing functionality does
   not meet the requirements, [I-D.ietf-roll-p2p-rpl] describes a
   reactive mechanism to discover P2P routes that meet the specified
   performance characteristics. This mechanism, henceforth referred to
   as the reactive P2P route discovery, requires the specification of
   "good enough criteria", in terms of constraints on aggregated values
   of the relevant routing metrics [I-D.ietf-roll-routing-metrics], that
   the discovered routes must satisfy. In some cases, the application
   requirements or the LLN's topological features allow a node to infer
   the good enough criteria intrinsically. For example, the application
   may require the end-to-end loss rate and/or latency on the route to
   be below certain thresholds or the LLN topology may be such that a
   router can safely assume its destination to be less than a certain
   number of hops away from itself.

   When the existing P2P routes are deemed unsatisfactory by the
   application layer but the node does not intrinsically know the good
   enough criteria, it may be necessary for the node to determine the
   aggregated values of relevant routing metrics along the existing
   routes. This knowledge will allow the node to frame a reasonable
   good enough criteria and initiate a reactive P2P route discovery to
   determine better routes. For example, if the router determines the
   aggregate ETX [I-D.ietf-roll-routing-metrics] along an existing route
   to be "x", it can use "ETX < x*y", where y is a certain fraction, as
   a constraint in the good enough criteria. Note that it is important
   that the good enough criteria is not overly strict; otherwise the
   route discovery may fail even though routes, much better than the
   ones being currently used, exist.

   This document specifies a mechanism that enables an RPL node to
   measure the aggregated values of the routing metrics along an
   existing route to/from another RPL node in an LLN, thereby allowing
   the node to decide if it wants to initiate the reactive discovery of
   a more optimal route and determine the good enough criteria to be
   used for this purpose.

1.1. 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].

Additionally, this document uses terminology from [I-D.ietf-roll-terminology], [I-D.ietf-roll-rpl] and [I-D.ietf-roll-p2p-rpl]. Specifically, the term node refers to an RPL router or an RPL host as defined in [I-D.ietf-roll-rpl]. The following terms, originally defined in [I-D.ietf-roll-p2p-rpl], are redefined in the following manner.

Origin Node: The origin node refers to the node that initiates the measurement process defined in this document and is one end point of the P2P route being measured.

Target Node: The target node refers to the other end of the P2P route being measured.

Intermediate Router: A router, other than the origin and the target node, on the P2P route being measured.

2. Functional Overview

The mechanism described in this document can be used by an origin node to measure the aggregated values of the routing metrics along a P2P route to/from a target node in the LLN. Such a route could be a source route or a hop-by-hop route established using RPL [I-D.ietf-roll-rpl] or the reactive P2P route discovery [I-D.ietf-roll-p2p-rpl].

When an origin node desires to measure the aggregated values of the routing metrics along a P2P route from itself to a target node, it sends a Measurement Request message along that route. The Measurement Request message accumulates the values of the relevant routing metrics as it travels towards the target node. Upon receiving the Measurement Request message, the target node unicasts a Measurement Reply message, carrying the accumulated values of the routing metrics, back to the origin node.

When an origin node desires to measure the aggregated values of the routing metrics along a P2P route from a target node to itself, it unicasts a Measurement Request message, specifying the routing metrics to be measured, to the target node. On receiving the Measurement Request message, the target node sends a Measurement

Reply message to the origin node along the P2P route to be measured.
The Measurement Reply message accumulates the values of the relevant
routing metrics as it travels towards the origin node.

3. The Measurement Object (MO)

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     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
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     | RPLInstanceID |      SequenceNo         |T|H|I|D| Resvd |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                                                               |
     |                     Origin Address                            |
     |                                                               |
     |                                                               |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                                                               |
     |                     Target Address                            |
     |                                                               |
     |                                                               |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                                                               |
     .                   Source Route Option(*)                      .
     .                                                               .
     |                                                               |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                                                               |
     .                   Metric Container Options                    .
     .                                                               .
     |                                                               |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
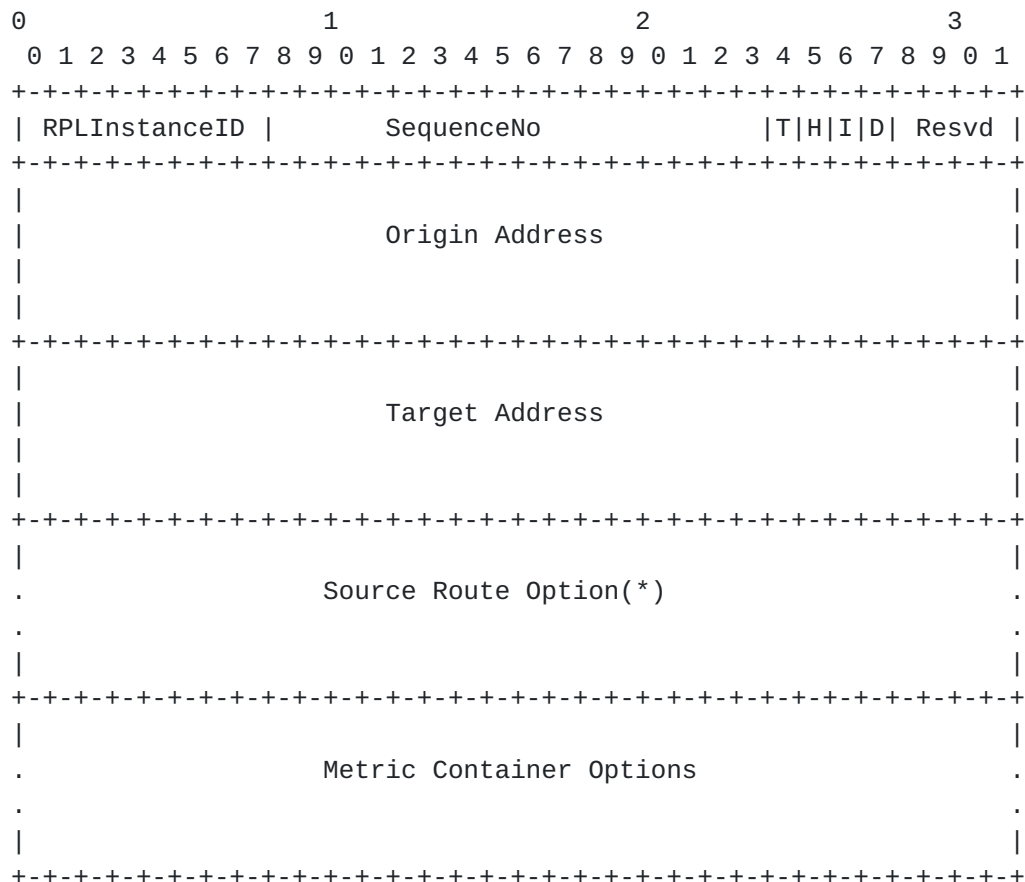
           Figure 1: Format of the Measurement Object (MO)

This document defines a new RPL Control Message type, the Measurement
Object (MO) with code 0x05 (to be confirmed by IANA) that serves as
both Measurement Request and Measurement Reply. The format of an MO
is shown in Figure 1. An MO consists of the following fields:

o RPLInstanceID: Relevant only if the MO travels along a hop-by-hop
   route. This field identifies the RPLInstanceID of the hop-by-hop
   route.

o SequenceNo: A 16-bit sequence number that uniquely identifies a
   Measurement Request and the corresponding Measurement Reply to the
   origin node.

o T: The type flag. This flag is set if the MO represents a
   Measurement Request. The flag is cleared if the MO is a
   Measurement Reply.

o H: This flag is set if the MO travels along a hop-by-hop route.
   In that case, the hop-by-hop route is identified by the
   RPLInstanceID and, if required, the Origin/Target Address serving
   as the DODAGID. This flag is cleared if the MO travels along a
   source route. In that case, the MO MUST contain a Source Route
   option [I-D.ietf-roll-p2p-rpl]. Note that, in case of a P2P route
   along a non-storing DAG, it is possible that an MO message travels
   along a hop-by-hop route till the DAG's root, which then sends it
   along a source route to its destination. In that case, the DAG
   root will reset the H flag and also insert a Source Route option
   in the MO.

o I: A flag that indicates which of the two - the Origin Address and
   the Target Address - indicates the DODAGID for the hop-by-hop
   route. This flag is relevant only if the MO travels along a hop-
   by-hop route (i.e., H flag is set) and a local RPLInstanceID has
   been specified to identify the hop-by-hop route. This flag is set
   if the Origin Address indicates the DODAGID; the flag is cleared
   if the Target Address indicates the DODAGID.

o D: A flag that indicates the direction of the P2P route. This
   flag is set when the route to be measured is from the origin node
   to the target node. Otherwise, the flag is cleared.

o Reserved: These bits are reserved for future use. These bits MUST
   be set to zero on transmission and MUST be ignored on reception.

o Origin Address: The IPv6 address of the origin node.

o Target Address: The IPv6 address of the target node.

o Source Route Option: An MO MUST contain one Source Route option if
   it travels along a source route.

o Metric Container Options: An MO MUST contain one or more Metric
   Container options to carry the routing metric objects
   [I-D.ietf-roll-routing-metrics].

4. Originating an MO To Measure a P2P Route

4.1. From the Origin Node to the Target Node

   If the origin node intends to measure the routing metric values along
   a P2P route towards a target node, it generates an MO message and
   sets its fields as follows:

   o RPLInstanceID: If the P2P route is a hop-by-hop route, the origin
      node specifies the RPLInstanceID to identify the route in this
      field. This field is not relevant if the P2P route is a source
      route specified in the Source Route option. This document
      RECOMMENDS a value 10000000 for this field if the P2P route is a
      source route.

   o SequenceNo: The origin node assigns a sequence number to the MO to
      uniquely identify the corresponding Measurement Reply.

   o T: The T flag is set to indicate that MO represents a Measurement
      Request.

   o H: The H flag is set if the MO travels along a hop-by-hop route.

   o I: This field in relevant only if the H flag is set and the
      RPLInstanceID is a local value. The origin node sets this flag if
      the Origin Address indicates the DODAGID. The origin node clears
      this flag if the Target Address indicates the DODAGID.

   o D: This flag is set.

   o Origin Address, Target Address: These fields are set to the IPv6
      addresses of the origin and target nodes respectively. If the H
      flag is set and the RPLInstanceID is a local value, the Origin
      Address or the Target Address MUST also indicate the DODAGID value
      required to identify the hop-by-hop route.

   o Source Route Option: If the P2P route is a source route (i.e., the
      H flag is cleared), the Source Route option MUST be present and
      MUST include a complete source route to the target node in forward
      direction (excluding the addresses of the origin and target
      nodes).

   o Metric Container Options: The origin node MUST also include one or
      more Metric Container options containing relevant routing metric
      objects to accumulate the costs for these metrics along the P2P
      route. The origin node also initiates the routing metric objects
      by including the local values of the routing metrics for the first
      hop on the P2P route.

   After setting the MO fields as described above, the origin node MUST

unicast the MO message to the next hop on the P2P route. The origin
node MAY include a Record Route IPv6 Extension Header, proposed in
[I-D.thubert-6man-reverse-routing-header], in the MO message to
accumulate a reverse route that the target node can use to send the
Measurement Reply back to the origin node.

4.2. From the Target Node to the Origin Node

If the origin node intends to measure the routing metric values along
a P2P route from a target node to itself, it generates an MO message
and sets its fields as follows:

o SequenceNo: The origin node assigns a sequence number to the MO to
   uniquely identify the corresponding Measurement Reply.

o T: The T flag is set to indicate that MO represents a Measurement
   Request.

o D: This flag is cleared.

o Origin Address, Target Address: These fields are set to the IPv6
   addresses of the origin and target nodes respectively.

o Source Route Option: In this case, the MO SHOULD NOT include any
   Source Route option.

o Metric Container Options: The origin node MUST include one or more
   Metric Container options containing relevant routing metric
   objects to accumulate the costs for these metrics along the P2P
   route. These routing metric objects MUST be empty.

The other fields in the MO are not relevant in this case and SHOULD
be set to zero. After setting the MO fields as described above, the
origin node MUST unicast the MO message to the target node.

5. Processing a Received MO at an Intermediate Router

When a node receives an MO, it examines if one of its IPv6 addresses
is listed as the Origin Address or the Target Address. If not, the
node checks if H bit is clear (i.e., the MO is traveling along a
source route). If yes, the node checks the Address[0] field inside
the Source Route Option contained in the MO. The node MUST drop the
MO with no further processing and send an ICMPv6 Destination
Unreachable error message to the source of the message (the Origin
Address if the MO is a Measurement Request; otherwise the Target
Address) if the received MO has a clear H bit but does not contain a
Source Route Option or if the Address[0] inside the Source Route

option does not match one of the node's IPv6 address.

The node then determines the next hop on the P2P route being
measured. In case the received MO has a clear H flag, the Address[1]
field (the second element in the Address vector) inside the Source
Route Option is taken as the next hop. If the Source Route Option
does not contain Address[1] element, the node checks the T flag
inside the MO. If T flag is set, i.e., MO is a Measurement Request,
the Target Address is taken as the next hop; otherwise the Origin
Address is the next hop. If the received MO has H flag set, the node
uses the RPLInstanceID, the ultimate destination of the MO (Target
Address if T flag is set; otherwise the Origin Address) and, if
RPLInstanceID is a local value, the DODAGID (the Origin Address if I
flag is set; otherwise the Target Address) to determine the next hop
for the MO. If the H flag in the MO is set and the node is the root
of a non-storing DAG, indicated by the RPLInstanceID, the node MAY
reset the H flag and insert a Source Route option in the MO to
indicate a source route along which the MO should travel on rest of
its way to its destination. The node MUST drop the MO with no
further processing and send an ICMPv6 Destination Unreachable error
message to the source of the message if it can not determine the next
hop for the message.

After determining the next hop, the node updates the routing metric
objects, contained in the Metric Container options inside the MO,
either by updating the aggregated value for the routing metric or by
attaching the local values for the metric inside the object. The
node MUST drop the MO with no further processing and send a suitable
ICMPv6 error message to the source of the message if the node does
not know the relevant routing metric values for the next hop.

After updating the routing metrics, the node MUST unicast the MO to
the next hop. If the MO to be forwarded has a clear H flag, the node
MUST ensure that the Address vector in the Source Route option
contains the next hop address as the first element.

6. Processing a Received MO at the Target Node

When a node receives an MO, it examines if one of its IPv6 addresses
is listed as the Target Address. If yes, the node checks the T flag.
The node MUST drop the MO with no further processing and optionally
log an error if the T flag is clear (i.e. the received MO is a
Measurement Reply).

The target node then checks the D flag to determine the direction of
the P2P route to be measured. If the D flag is set (i.e., the P2P
route to be measured is from the origin node to the target node), the

target node updates the routing metrics objects in the Metric
Container options if required, removes the Source Route Option if
present and clears the T bit thereby converting the MO into a
Measurement Reply. The target node then unicasts the updated MO back
to the origin node. For this purpose, the target node MAY use the
reverse route accumulated in the Record Route IPv6 Extension Header
[I-D.thubert-6man-reverse-routing-header] if present in the received
MO message.

If the D flag in the received MO message is clear (i.e., the P2P
route to be measured is from the target node to the origin node), the
target node selects the P2P route to be measured and modifies the
following MO fields:

o RPLInstanceID: If the P2P route is a hop-by-hop route, the target
   node specifies in this field the RPLInstanceID associated with the
   route. This field is not relevant if the P2P route is a source
   route. This document RECOMMENDS a value 10000000 for this field
   if the P2P route is a source route.

o T: The T flag is cleared to indicate that MO represents a
   Measurement Reply.

o H: The H flag is set if the P2P route is a hop-by-hop one.

o I: If the H flag is set and the RPLInstanceID is a local value,
   the target node sets this flag if the Origin Address indicates the
   DODAGID. The target node clears this flag if the Target Address
   indicates the DODAGID.

o D: This flag is cleared.

o Source Route Option: If the P2P route is a source route, the
   Source Route option MUST be present and MUST include a complete
   source route from the target node to the origin node (excluding
   the addresses of the target and origin nodes).

o Metric Container Options: The target node MUST initiate the
   routing metric objects inside the Metric Container options by
   including the local values of the routing metrics for the first
   hop on the P2P route.

The target node need not modify the other fields in the received MO.
After these modifications, the target node MUST unicast the MO
message to the next hop on the P2P route.

7. Processing a Received MO at the Origin Node

   When a node receives an MO, it examines if one of its IPv6 addresses
   is listed as the Origin Address. If yes, the node checks the T flag.
   The node MUST drop the MO with no further processing and optionally
   log an error if the T flag is set (i.e. the received MO is a
   Measurement Request) or if the node has no recollection of sending a
   Measurement Request with the sequence number listed in the received
   MO.

   If the D flag in the received MO is clear (i.e., the P2P route to be
   measured is from the target node to the origin node), the origin node
   MUST update the routing metrics objects in the Metric Container
   options if required.

   The origin node can now examine the routing metric objects inside the
   Metric Container options to evaluate the quality of the measured P2P
   route. If a routing metric object contains local metric values
   recorded by enroute nodes, the origin node MAY aggregate these local
   values into an end-to-end value as per the aggregation rules for the
   metric.

8. Security Considerations

   TBA

9. IANA Considerations

   TBA

10. Acknowledgement

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