A Source Routing Header for RPL
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Abstract

In Low power and Lossy Networks (LLNs), memory constraints on routers may limit them to maintaining at most a few routes. In some configurations, it is necessary to use these memory constrained routers to deliver datagrams to nodes within the LLN. The Routing for Low Power and Lossy Networks (RPL) protocol can be used in some deployments to store most, if not all, routes on one (e.g. the Directed Acyclic Graph (DAG) root) or few routers and forward the IPv6 datagram using a source routing technique to avoid large routing tables on memory constrained routers. This document specifies a new IPv6 Routing header type for delivering datagrams within a RPL domain.

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1. Introduction

Routing for Low Power and Lossy Networks (RPL) is a distance vector IPv6 routing protocol designed for Low Power and Lossy networks (LLN) [I-D.ietf-roll-rpl]. Such networks are typically constrained in resources (limited communication data rate, processing power, energy capacity, memory). In particular, some LLN configurations may utilize LLN routers where memory constraints limit nodes to maintaining only a small number of default routes and no other destinations. However, it may be necessary to utilize such memory-constrained routers to forward datagrams and maintain reachability to destinations within the LLN.

To utilize paths that include memory-constrained routers, RPL relies on source routing from more capable RPL routers. RPL provides the necessary mechanisms to collect routing information at more capable RPL routers and form paths from those routers to arbitrary destinations within the RPL domain. However, a source routing mechanism supported by IPv6 is needed to deliver datagrams.

This document specifies the Type 4 Routing header (RH4) (to be confirmed by IANA) for use strictly within a RPL domain. The basic format of RH4 draws from that of the Type 0 Routing header (RH0) [RFC2460]. However, RH4 introduces mechanisms to compact the source route entries when all entries share the same prefix with the IPv6 Destination Address of the encapsulating header, a typical scenario in LLNs using source routing. The compaction mechanism reduces consumption of scarce resources such as bandwidth.

RH4 also differs from RH0 in the processing rules to alleviate security concerns that lead to the deprecation of RH0 [RFC5095]. Unlike RH0, routers processing RH4 must implement a strict source route policy where each and every IPv6 hop is specified within the datagram itself. Furthermore, a RH4 header must only be used within a RPL domain. RPL Border Routers, responsible for connecting RPL domains and IP domains that use other routing protocols, may insert a RH4 header into datagrams entering the RPL domain but must not allow datagrams already carrying a RH4 header to enter or exit the RPL domain.

1.1. Requirements Language

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].
2. Format of the RPL Routing Header

The Type 4 Routing header has the following format:

```
+---------------+---------------+---------------+---------------+
|   Next Header  |   Hdr Ext Len  |   Routing Type=4|   Segments Left |
+---------------+---------------+---------------+---------------+
|   Compr       |   Pad         |   Reserved    |
+---------------+---------------+---------------+---------------+
|               |               |               |
| Addresses[1..n]|               |               |
+---------------+---------------+---------------+---------------+
```

**Next Header**
- 8-bit selector. Identifies the type of header immediately following the Routing header. Uses the same values as the IPv4 Protocol field [RFC3232].

**Hdr Ext Len**
- 8-bit unsigned integer. Length of the Routing header in 8-octet units, not including the first 8 octets. Note that when Addresses[1..n] are compressed (i.e. value of Compr is not 0), Hdr Ext Len does not equal twice the number of Addresses.

**Routing Type**
- 8-bit selector. Set to 4 (to be confirmed by IANA).

**Segments Left**
- 8-bit unsigned integer. Number of route segments remaining, i.e., number of explicitly listed intermediate nodes still to be visited before reaching the final destination. Value MUST be between 0 and Segments, inclusive.

**Compr**
- 4-bit unsigned integer. Number of prefix octets from each segment that is elided. For example, a Type 4 Routing header carrying full IPv6 addresses sets Compr to 0.
Pad 4-bit unsigned integer. Number of octets that are used to for padding after Address[n] and the end of the Type 4 Routing header.

Address[1..n] Vector of addresses, numbered 1 to n. Each vector element has size (16 - Compr).

The Type 4 Routing header shares the same basic format as the Type 0 Routing header [RFC2460]. When carrying full IPv6 addresses, the Compr and Pad fields are set to 0 and the only difference between the Type 4 and Type 0 encodings is the value of the Routing Type field.

A common network configuration for a RPL domain is that all nodes within a LLN share a common prefix. Type 4 Routing header introduces the Compr and Pad fields to allow compaction of the Address[1..n] vector when all entries share the same prefix as the IPv6 Destination Address field of the encapsulating packet. The Compr field indicates the number of prefix octets that are shared with the IPv6 Destination Address of the encapsulating header. The shared prefix octets are not carried within the Routing header and each entry in Address[1..n] has size (16 - Compr) octets. When Compr is non-zero, there may exists unused octets between the last entry, Address[n], and the end of the Routing header. The Pad field indicates the number of unused octets that are used for padding. Note that when Compr is 0, Pad MUST be null and carry a value of 0.

IPv6 Addresses MUST NOT appear more than once in a Type 4 Routing header. The IPv6 Destination Address of the encapsulating packet MUST NOT appear in a Type 4 Routing header.

Multicast addresses MUST NOT appear in a Type 4 Routing header, or in the IPv6 Destination Address field of a packet carrying a Type 4 Routing header.
3. RPL Router Behavior

A RPL Router MAY insert a Type 4 Routing header if one does not already exist. The conditions for inserting a Type 4 Routing header are out of scope of this document.

As specified in [RFC2460], a routing header is not examined or processed until it reaches the node identified in the Destination Address field of the IPv6 header. In that node, dispatching on the Next Header field of the immediately preceding header causes the Routing header module to be invoked.

The function of Type 4 Routing header is intended to be very similar to IPv4’s Strict Source and Record Route option [RFC0791]. When processing the Type 4 Routing header, a router MUST drop the packet if the next entry is not a neighboring node and SHOULD send an ICMP Destination Unreachable (ICMPv6 Type 1) message with ICMPv6 Code set to 7 (to be confirmed by IANA) to the packet’s Source Address. An ICMPv6 Code of 7 indicates that the router does not have the next Address entry as a neighbor and cannot satisfy the strict source route. When generating ICMPv6 error messages, the rules in Section 2.4 of [RFC4443] must be observed.

The following describes the algorithm performed when processing a Type 4 Routing header:
if Segments Left = 0 {
    proceed to process the next header in the packet, whose type is
    identified by the Next Header field in the Routing header
} else {
    compute n, the number of addresses in the Routing header, by
    \[ n = \frac{((\text{Hdr Ext Len} \times 8) - \text{Pad})}{(16 - \text{Comp})} \]
    if Segments Left is greater than n {
        send an ICMP Parameter Problem, Code 0, message to the Source
        Address, pointing to the Segments Left field, and discard the
        packet
    } else {
        decrement Segments Left by 1;
        compute i, the index of the next address to be visited in
        the address vector, by subtracting Segments Left from n
        if Address[i] or the IPv6 Destination Address is multicast {  
            discard the packet
        } else if Address[i] is not a neighboring node {
            send an ICMP Destination Unreachable, Code 3, message to
            the Source Address and discard the packet
        } else {
            swap the IPv6 Destination Address and Address[i]
            if the IPv6 Hop Limit is less than or equal to 1 {  
                send an ICMP Time Exceeded -- Hop Limit Exceeded in
                Transit message to the Source Address and discard the
                packet
            } else {
                decrement the Hop Limit by 1
                resubmit the packet to the IPv6 module for transmission
                to the new destination
            }
        }
    }
}
4. RPL Border Router Behavior

RPL Border Routers (referred to as LBRs in [I-D.ietf-roll-terminology]) are responsible for ensuring that a Type 4 Routing header is only used within the RPL domain it was created. RPL Border Routers MUST drop datagrams entering or exiting the RPL domain that contain a Type 4 Routing header in the IPv6 Extension headers.
5. Security Considerations

5.1. Source Routing Attacks

[RFC5095] deprecates the Type 0 Routing header due to a number of significant attacks that are referenced in that document. Such attacks include network discovery, bypassing filtering devices, denial-of-service, and defeating anycast.

Because this document specifies that Type 4 Routing headers are only for use within a RPL domain, such attacks cannot be mounted from outside the RPL domain. As described in Section 4, RPL Border Routers MUST drop datagrams entering or exiting the RPL domain that contain a Type 4 Routing header in the IPv6 Extension headers.

5.2. ICMPv6 Attacks

The generation of ICMPv6 error messages may be used to attempt denial-of-service attacks by sending error-causing Type 4 Routing headers in back-to-back datagrams. An implementation that correctly follows Section 2.4 of [RFC4443] would be protected by the ICMPv6 rate limiting mechanism.
6. IANA Considerations

This document defines a new IPv6 Routing Type of 4 (to be confirmed).

This document defines a new ICMPv6 Destination Unreachable Code of 7 to indicate that the router does not have the next Address element as a neighbor and could not satisfy the strict source route.
7. Acknowledgements

TODO.
8. References

8.1. Normative References


8.2. Informative References


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