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Keyed IPv6 Tunnel
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Abstract

   This document describes a simple L2 Ethernet over IPv6 tunnel
   encapsulation with mandatory 64-bit key for connecting L2 Ethernet
   attachment circuits identified by IPv6 addresses. The encapsulation
   is based on L2TPv3 over IP.

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 [RFC2119].

Status of This Memo

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Table of Contents

1. Introduction

   L2TPv3, as defined in RFC3931 [RFC3931], provides a dynamic mechanism
   for tunneling Layer 2 (L2) "circuits" across a packet-oriented data
   network (e.g., over IP), with multiple attachment circuits
   multiplexed over a single pair of IP address endpoints (i.e. a
   tunnel) using the L2TPv3 session ID as a circuit discriminator.

   Implementing L2TPv3 over IPv6 provides the opportunity to utilize
   unique IPv6 addresses to identify Ethernet attachment circuits
   directly, leveraging the key property that IPv6 offers, a vast number
   of unique IP addresses. In this case, processing of the L2TPv3
   Session ID may be bypassed upon receipt as each tunnel has one and
   only one associated session. This local optimization does not hinder
   the ability to continue supporting the multiplexing of circuits via
   the Session ID on the same router for other L2TPv3 tunnels.

2. Static 1:1 Mapping Without a Control Plane

Static local configuration creates a one-to-one mapping between the
access-side L2 attachment circuit and the IP address used in the
network-side IPv6 encapsulation. The L2TPv3 Control Plane defined in
RFC3931 [RFC3931] is not used.

The IPv6 L2TPv3 tunnel encapsulating device uniquely identifies each
Ethernet L2 attachment connection by a port ID or a combination of
port ID and VLAN ID(s) on the access side, and by an IPv6 address on
the network side.

Any VLAN identifiers, S-VID, C-VID or tuple (S-VID, C-VID) are
treated with local significance within the Ethernet L2 port and are
not forwarded over the IPv6 L2TPv3 tunnel. IPv6 address is treated
as the IPv6 L2TPv3 tunnel endpoint.

Certain deployment scenarios may require using a single IPv6 address
to identify a tunnel endpoint for many IPv6 L2TPv3 tunnels. For such
cases the tunnel encapsulating device identifies each tunnel by a
unique combination of tunnel source and destination IPv6 addresses.

As mentioned above Session ID processing is not required as each
keyed IPv6 tunnel has one and only one associated session. However
for compatibility with existing RFC3931 [RFC3931] implementations,
the packets need to be sent with Session ID. The router implementing
L2TPv3 according to RFC3931 [RFC3931] can be configured with multiple
L2TPv3 tunnels, with one session per tunnel, to interoperate with the
router implementing the keyed IPv6 tunnel as specified by this
document.

Note that a previous IETF draft [I.D.ietf-pppext-l2tphc] introduces
the concept of an L2TP tunnel carrying a single session and hence not
requiring session ID processing.

3. 64-bit Cookie

In line with RFC3931 [RFC3931], the key in the cookie field is used
for additional tunnel endpoint context check. All packets MUST carry
a 64-bit key in the L2TPv3 cookie field. The cookie MUST be 64-bits
long in order to provide sufficient protection against spoofing and
brute force blind insertion attacks.

In the absence of the L2TPv3 Control Plane, the L2TPv3 encapsulating
router must be provided with local configuration of the 64-bit cookie
for each local and remote IPv6 endpoint - note that cookies are
asymmetric, so local and remote endpoints may send different cookie
values. The value of the cookie must be able to be changed at any

time in a manner that does not drop any legitimate tunneled packets -
i.e. the receiver must be willing to accept both "old" and "new"
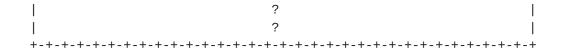cookie values during a change of cookie value.

4. Encapsulation

RFC4719 [RFC4719] describes encapsulation of Ethernet over L2TPv3.
Paraphrasing from this document, the Ethernet frame, without the
preamble or frame check sequence (FCS), is encapsulated in L2TPv3 and
is sent as a single packet by the ingress router.

The s-tag (or in the multi-stack access case the s-tag and c-tag)
SHOULD be removed before the packet is encapsulated.

The full encapsulation is as follows:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Ver   | Traffic Class |           Flow Label                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         Payload Length        |   Next Header |   Hop Limit   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                   Source address (0:31)                       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                   Source address (32:63)                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                   Source address (64:95)                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                   Source address (96:127)                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                 Destination address (0:31)                    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                 Destination address (32:63)                   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                 Destination address (64:95)                   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                 Destination address (96:127)                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                   Session ID (32 bits)                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      Cookie (0:31)                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      Cookie (32:63)                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Payload (variable)                        |
|                           ?                                   |
|                           ?                                   |
```

```
       |                              ?                              |
       |                              ?                              |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

   The combined IPv6 and L2TPv3 header contains the following fields:

   o Ver. Set to 0x6 to indicate IPv6.

   o Traffic Class. May be set by the ingress router to ensure correct
      PHB treatment by transit routers between the ingress and egress,
      and correct QoS disposition at the egress router.

   o Flow Label. May be set by the ingress router to indicate a flow
      of packets from the client which may not be reordered by the
      network (if there is a requirement for finer grained ECMP load
      balancing than per-circuit load balancing).

   o Payload Length. Set to the length of the packet, excluding the
      IPv6 header (i.e. the length from the Session ID to the end of the
      packet).

   o Next Header. Set to 0x73 to indicate that the next header is
      L2TPv3.

   o Hop Limit. Set to 0xFF, and decremented by one by each router in
      the path to the egress router.

   o Source Address. IPv6 source address for the tunnel. In the
      "Static 1:1" case the IPv6 source address may correspond to a port
      or VLAN being transported as an L2 circuit, or may be a loopback
      address terminating inside the router (e.g. if L2 circuits are
      being used within a multipoint VPN) or may be an anycast address
      terminating on a data center virtual machine.

   o Destination Address. IPv6 destination address for the tunnel. As
      with the source address this may correspond to a port or VLAN
      being transported as an L2 circuit or may be a loopback or anycast
      address.

   o Session ID. In the "Static 1:1 mapping" case described in
      Section 2, the IPv6 address resolves to an L2TPv3 session
      immediately, thus the Session ID may be ignored upon receipt. For
      compatibility with other tunnel termination platforms supporting
      only 2-stage resolution (IPv6 Address + Session ID), this
      specification recommends supporting explicit configuration of
      Session ID to any value other than zero. For cases where both

        tunnel endpoints support one-stage resolution (IPv6 Address only),
        this specification recommends setting the Session ID to all ones
        for easy identification in case of troubleshooting. The Session
        ID of zero MUST NOT be used, as it is reserved for use by L2TP
        control messages RFC3931 [RFC3931].

     o Cookie. 64 bits, configured and described as in Section 3. All
        packets for a destined L2 Circuit (or L2TPv3 Session) must match
        the configured Cookie value or be discarded (see RFC3931 [RFC3931]
        for more details).

     o Payload. The customer data, with s-tag or s-tag/c-tag removed.
        As noted above preamble and FCS are stripped before encapsulation.
        A new FCS will be added at each hop when the IP packet is
        transmitted.

5. Fragmentation and Reassembly

     Using tunnel encapsulation, Ethernet L2 datagrams in IPv6 in this
     case, will reduce the effective MTU of the Ethernet L2 datagram.

     The recommended solution to deal with this problem is for the network
     operator to increase the MTU size of all the links between the
     devices acting as IPv6 L2TPv3 tunnel endpoints to accommodate both
     the IPv6 L2TPv3 encapsulation header and the Ethernet L2 datagram
     without fragmenting the IPv6 packet.

     If it is impossible to increase the link MTU across the network, the
     IPv6 L2TPv3 encapsulating device MUST perform fragmentation and
     reassembly if the outgoing link MTU cannot accommodate the extra IPv6
     L2TPv3 header for specific Ethernet L2 payload. Fragmentation MUST
     happen after the encapsulation of the IPv6 L2TPv3 packet. Reassembly
     MUST happen before the decapsulation of the IPv6 L2TPv3 packet.

     The proposed approach is in line with the DS-Lite specification
     RFC6333 [RFC6333].

6. OAM Considerations

     OAM is an important consideration when providing circuit-oriented
     services such as those described in this document, and all the more
     so in the absence of a dedicated tunnel control plane, as OAM becomes
     the only way to detect failures in the tunnel overlay.

     Note that in the context of keyed IP tunnels, failures in the IPv6
     underlay network can be detected using the usual methods such as
     through the routing protocol.

Since keyed IP tunnels always carry an Ethernet payload, and since
OAM at the tunnel layer is unable to detect failures in the Ethernet
service processing at the ingress or egress router, or on the
Ethernet attachment circuit between the router and the Ethernet
client, this document recommends that Ethernet OAM as defined in IEEE
802.1ag [IEEE802.1ag] and/or ITU Y.1731 [Y.1731] is enabled for keyed
IP tunnels. More specifically the following Connecitivity Fault
Management (CFM) and/or Ethernet continuity check (ETH-CC)
configurations are to be used in conjunction with keyed IPv6 tunnels:

o Connectivity verification between the tunnel endpoints across the
   tunnel - use an Up MEP located at the tunnel endpoint for
   transmitting the CFM PDUs towards, and receiving them from the
   direction of the tunnel.

o Connectivity verification from the tunnel endpoint across the
   local attachment circuit - use a Down MEP located at the tunnel
   endpoint for transmitting the CFM PDUs towards, and receiving them
   from the direction of the local attachment circuit.

o Intermediate connectivity verifcation - use a MIP located at the
   tunnel endpoint to generate CFM PDUs in response to received CFM
   PDUs.

In addition the Pseudowire Virtual Circuit Connectivity Verfiication
(VCCV) RFC5085 [RFC5085] MAY be used.

7. IANA Considerations

None.

8. Security Considerations

Packet spoofing for any type of Virtual Private Network (VPN)
tunneling protocol is of particular concern as insertion of carefully
constructed rogue packets into the VPN transit network could result
in a violation of VPN traffic separation, leaking data into a
customer VPN. This is complicated by the fact that it may be
particularly difficult for the operator of the VPN to even be aware
that it has become a point of transit into or between customer VPNs.

Keyed IPv6 encapsulation provides traffic separation for its VPNs via
use of separate 128-bit IPv6 addresses to identify the endpoints.
The mandatory authentication key carried in the L2TPv3 cookie field,
provides an additional check to ensure that an arriving packet is
intended for the identified tunnel.

In the presence of a blind packet spoofing attack, the authentication
key provides security against inadvertent leaking of frames into a
customer VPN, like in case of L2TPv3 RFC3931 [RFC3931]. To
illustrate the type of security that it is provided in this case,
consider comparing the validation of a 64-bit Cookie in the L2TPv3
header to the admission of packets that match a given source and
destination IP address pair. Both the source and destination IP
address pair validation and Cookie validation consist of a fast check
on cleartext header information on all arriving packets. However,
since L2TPv3 uses its own value, it removes the requirement for one
to maintain a list of (potentially several) permitted or denied IP
addresses, and moreover, to guard knowledge of the permitted IP
addresses from hackers who may obtain and spoof them. Further, it is
far easier to change a compromised L2TPv3 Cookie than a compromised
IP address," and a cryptographically random RFC4086 [RFC4086] value
is far less likely to be discovered by brute-force attacks compared
to an IP address.

For protection against brute-force, blind, insertion attacks, a 64-
bit Cookie MUST be used with all tunnels.

Note that the Cookie provides no protection against a sophisticated
man-in-the-middle attacker who can sniff and correlate captured data
between nodes for use in a coordinated attack.

The L2TPv3 64-bit cookie must not be regarded as a substitute for
security such as that provided by IPsec when operating over an open
or untrusted network where packets may be sniffed, decoded, and
correlated for use in a coordinated attack.

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