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Keyed IPv6 Tunnel

Abstract

This document describes a tunnel encapsulation for Ethernet over IPv6 with a mandatory 64-bit cookie for connecting Layer 2 (L2) Ethernet attachment circuits identified by IPv6 addresses. The encapsulation is based on the Layer 2 Tunneling Protocol Version 3 (L2TPv3) over IP and does not use the L2TPv3 control plane.

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1. Introduction

L2TPv3, as defined in [RFC3931], provides a 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 [RFC2460] 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.

There are various advantages to this approach when compared to the "traditional" L2TPv3 approach of using a loopback address to terminate the tunnel and then carrying multiple sessions over the tunnel. These include better ECMP load balancing (since each tunnel has a unique source/destination IPv6 address pair) and finer-grained control when advertising tunnel endpoints using a routing protocol.

1.1. Requirements Language

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 RFC 2119 [RFC2119].

2. Static 1:1 Mapping without a Control Plane

The L2TPv3 control plane defined in [RFC3931] is not used for this encapsulation. The management plane is used to create and maintain matching configurations at either end of each tunnel. Local configuration by the management plane 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 IPv6 L2TPv3 tunnel encapsulating device uniquely identifies each Ethernet L2 attachment connection by a port ID or a combination of a port ID and VLAN ID(s) on the access side and by a local IPv6 address on the network side. The local IPv6 address also identifies the tunnel endpoint. The local IPv6 addresses identifying L2TPv3 tunnels SHOULD NOT be assigned from connected IPv6 subnets facing towards remote tunnel endpoints, since that approach would result in an IPv6 Neighbor Discovery cache entry per tunnel on the next-hop router towards the remote tunnel endpoint. It is RECOMMENDED that local IPv6 addresses identifying L2TPv3 tunnels are assigned from dedicated subnets used only for such tunnel endpoints.

Certain deployment scenarios may require using a single IPv6 address (such as a unicast or anycast address assigned to a specific service instance, for example, a virtual switch) to identify a tunnel endpoint for multiple IPv6 L2TPv3 tunnels. For such cases, the tunnel decapsulating device uses the local IPv6 address to identify the service instance and the remote IPv6 address to identify the individual tunnel within that service instance.

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] implementations, the packets need to be sent with the Session ID. Routers implementing L2TPv3 according to [RFC3931] can be configured with multiple L2TPv3 tunnels, with one session per tunnel, to interoperate with routers implementing the keyed IPv6 tunnel as specified by this document. Note that as Session ID processing is not enabled for keyed IPv6 tunnels, there can only be a single keyed IPv6 tunnel between two IPv6 addresses.

3. 64-Bit Cookie

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

In the absence of the L2TPv3 control plane, the L2TPv3 encapsulating router MUST be provided with a 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 and, in fact, SHOULD do so. 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 configurable to accept two discrete cookies for a single tunnel simultaneously. This enables the receiver to hold both the 'old' and 'new' cookie values during a change of cookie value. Cookie values SHOULD be changed periodically by the management plane.

Note that mandating a 64-bit cookie is a change from the optional variable-length cookie of [RFC3931] and that this requirement constrains interoperability with existing [RFC3931] implementations to those supporting a 64-bit cookie. The management plane MUST NOT configure a keyed IP tunnel unless both endpoints support the 64-bit cookie.

4. Encapsulation

The ingress router encapsulates the entire Ethernet frame, without the preamble and Frame Check Sequence (FCS) in L2TPv3 as per [RFC4719]. The L2-specific sublayer MAY be carried if Virtual Circuit Connectivity Verification (VCCV) [RFC5085] and/or frame sequencing is required, but it SHOULD NOT be carried otherwise. The L2TPv3 packet is encapsulated directly over IPv6 (i.e., no UDP header is carried).

The ingress router MAY retain the FCS as per [RFC4720]. Support for retaining the FCS and for receiving packets with a retained FCS is OPTIONAL and, if present, MUST be configurable. In the absence of the L2TPv3 control plane, such configuration MUST be consistent for the two endpoints of any given tunnel, i.e., if one router is configured to retain the FCS, then the other router MUST be configured to receive packets with the retained FCS. Any router configured to retain FCS for a tunnel MUST retain FCS for all frames sent over that tunnel. All routers implementing this specification MUST support the ability to send frames without retaining the FCS and to receive such frames.

Any service-delimiting IEEE 802.1Q [IEEE802.1Q] or IEEE 802.1ad [IEEE802.1ad] VLAN IDs -- S-tag, C-tag, or the tuple (S-tag, C-tag) -- are treated with local significance within the Ethernet L2 port and MUST NOT be forwarded over the IPv6 L2TPv3 tunnel.

Note that the same approach may be used to transport protocols other than Ethernet, though this is outside the scope of this specification.

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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+                    IPv6 Header (320 bits)                     +
~                                                               ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Session ID (32 bits)                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Cookie (0:31)                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Cookie (32:63)                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|          (Optional) L2-Specific Sublayer (32 bits)            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
|                                                               |
|                       Payload (variable)                      |
|                                                               |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The combined IPv6 and keyed IP tunnel header contains the following fields:

- IPv6 Header. Note that:

  * The traffic class may be set by the ingress router to ensure correct Per-Hop Behavior (PHB) treatment by transit routers between the ingress and egress and to correct QoS disposition at the egress router.

* The flow label, as defined in [RFC6437], 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 rather than per-circuit load balancing).

* The next header will be set to 0x73 to indicate that the next header is L2TPv3.

* In the "Static 1:1 Mapping" case described in Section 2, the IPv6 source address may correspond to a port or port/VLAN being transported as an L2 circuit, or it may correspond to a virtual interface terminating inside the router (e.g., if L2 circuits are being used within a multipoint VPN or if an anycast address is being terminated on a set of data-center virtual machines.)

* As with the source address, the IPv6 destination address may correspond to a port or port/VLAN being transported as an L2 circuit or to a virtual interface.

o Session ID. In the "Static 1:1 Mapping" case described in Section 2, the IPv6 address identifies an L2TPv3 session directly; thus, at endpoints supporting one-stage resolution (IPv6 Address Only), the Session ID SHOULD be ignored upon receipt. It is RECOMMENDED that the remote endpoint is configured to set the Session ID to all ones (0xFFFFFFFF) for easy identification in case of troubleshooting. For compatibility with other tunnel termination platforms supporting only two-stage resolution (IPv6 Address + Session ID), this specification recommends supporting explicit configuration of Session ID to any value other than zero (including all ones). The Session ID of zero MUST NOT be used, as it is reserved for use by L2TP control messages as specified in [RFC3931]. Note that the Session ID is unidirectional; the sent and received Session IDs at an endpoint may be different.

o Cookie. The 64-bit cookie, configured and described as in Section 3. All packets for a destined L2 circuit (or L2TPv3 Session) MUST match one of the cookie values configured for that circuit. Any packets that do not contain a valid cookie value MUST be discarded (see [RFC3931] for more details).

o L2-Specific Sublayer (Optional). As noted above, this will be present if VCCV and/or frame sequencing is required. If VCCV is required, then any frames with bit 0 (the "V-bit") set are VCCV messages. If frame sequencing is required, then any frames with bit 1 (the "S-bit") set have a valid frame sequence number in bits 8-31.

- o Payload (variable). As noted above, the preamble and any service-delimiting tags MUST be stripped before encapsulation, and the FCS MUST be stripped unless FCS retention is configured at both ingress and egress routers. Since a new FCS is added at each hop when the encapsulating IP packet is transmitted, the payload is protected against bit errors.

5. Fragmentation and Reassembly

Using tunnel encapsulation of Ethernet L2 datagrams in IPv6 will reduce the effective MTU allowed for the encapsulated traffic.

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 requiring fragmentation of the IPv6 packet.

It is RECOMMENDED that routers implementing this specification implement IPv6 Path MTU (PMTU) discovery as defined in [RFC1981] to confirm that the path over which packets are sent has sufficient MTU to transport a maximum-length Ethernet frame plus encapsulation overhead.

Routers implementing this specification MAY implement L2TPv3 fragmentation (as defined in Section 5 of [RFC4623]). In the absence of the L2TPv3 control plane, it is RECOMMENDED that fragmentation (if implemented) is locally configured on a per-tunnel basis. Fragmentation configuration MUST be consistent between the two ends of a tunnel.

It is NOT RECOMMENDED for routers implementing this specification to enable IPv6 fragmentation (as defined in Section 4.5 of [RFC2460]) for keyed IP tunnels.

6. OAM Considerations

Operations, Administration, and Maintenance (OAM) is an important consideration when providing circuit-oriented services such as those described in this document; it is all the more important 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, including the use of single-hop

Bidirectional Forwarding Detection (BFD) [RFC5881] to rapidly detect link failures. Multihop BFD MAY also be enabled between tunnel endpoints as per [RFC5883].

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, it is RECOMMENDED that Ethernet OAM as defined in [IEEE802.1ag] and/or [Y.1731] be enabled for keyed IP tunnels. As defined in those specifications, the following Connectivity 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 Maintenance End Point (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 verification: Use a Maintenance Intermediate Point (MIP) located at the tunnel endpoint to relay CFM PDUs.

In addition, Pseudowire VCCV [RFC5085] MAY be used. Furthermore, BFD MAY be enabled over the VCCV channel [RFC5885].

Note that since there is no control plane, it is RECOMMENDED that the management plane take action when attachment circuit failure is detected, for example, by dropping the remote attachment circuit.

7. IANA Considerations

This document does not require any IANA actions.

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 the use of separate 128-bit IPv6 addresses to identify the endpoints. The mandatory use of the 64-bit L2TPv3 cookie 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 64-bit L2TPv3 cookie provides security against inadvertent leaking of frames into a customer VPN, as documented in Section 8.2 of [RFC3931].

For protection against brute-force blind insertion attacks, the 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.

9. References

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