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Layer 2 Tunneling Protocol (L2TP) Active Discovery Relay for PPP over Ethernet (PPPoE)

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Abstract

The Point-to-Point Protocol (PPP) provides a standard method for transporting multi-protocol datagrams over point-to-point links. Layer Two Tunneling Protocol (L2TP), facilitates the tunneling of PPP packets across an intervening packet-switched network. And yet a third protocol, PPP over Ethernet (PPPoE) describes how to build PPP sessions and to encapsulate PPP packets over Ethernet.

L2TP Active Discovery Relay for PPPoE describes a method to relay Active Discovery and Service Selection functionality from PPPoE over the reliable control channel within L2TP. Two new L2TP control message types and associated PPPoE-specific Attribute Value Pairs (AVPs) for L2TP are defined. This relay mechanism provides enhanced integration of a specific feature in the PPPoE tunneling protocol with L2TP.

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1. Introduction

PPPoE [1] is often deployed in conjunction with L2TP [2] to carry PPP [3] frames over a network beyond the reach of the local Ethernet network to which a PPPoE Host is connected. For example, PPP frames tunneled within PPPoE may be received by an L2TP Access Concentrator (LAC) and then tunneled to any L2TP Network Server (LNS) reachable via an IP network.

In addition to tunneling PPP over Ethernet, PPPoE defines a simple method for discovering services offered by PPPoE Access Concentrators (PPPoE AC) reachable via Ethernet from the PPPoE Host. Since the packets used in this exchange are not carried over PPP, they are not tunneled with the PPP packets over L2TP, thus the discovery negotiation cannot extend past the LAC without adding functionality.

This document describes a simple method for relaying PPPoE Active Discovery (PAD) messages over L2TP by extracting the PAD messages and sending them over the L2TP control channel. After the completion of setup through the processing of PAD messages, PPP packets arriving via PPPoE are then tunneled over L2TP in the usual manner as defined in L2TP [2]. Thus, there are no data plane changes required at the LAC or LNS to support this feature. Also, by utilizing the L2TP control channel, the PPPoE discovery mechanism is transported to the LNS reliably, before creation of any L2TP sessions, and may take advantage of any special treatment applied to control messages in transit or upon receipt.

2. Protocol Operation

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 RFC 2119 [4].

When PPPoE PAD messages are received at a PPPoE Access Concentrator, the messages are passed over the L2TP control connection via a newly defined Service Relay Request Message (SRRQ) on an established tunnel (Section 3.1). When received, the PPPoE PAD message is processed at the L2TP node, or relayed to another L2TP node or PPPoE Access Concentrator. PPPoE PAD messages sent as replies are handled in a similar manner over a newly defined Service Relay Reply Message (SRRP) (Section 3.2).

2.1. PPPoE Active Discovery Stage

When a PPPoE Active Discovery Initiation packet (PADI) is received by an L2TP LAC that is providing PPPoE Service Relay, the PADI MUST be packaged in its entirety (including the Ethernet MAC header) within the PPPoE Relay AVP and transmitted over established L2TP Control Connection(s) associated with the interface on which the PADI arrived.

The PPPoE Relay AVP is sent via the Service Relay Request Message (SRRQ) defined in Section 3. The SRRQ message MUST NOT be sent to an L2TP node which did not include the PPPoE Service Relay Response Capability AVP during control connection establishment. If no acceptable control connection is available or cannot be created, PPPoE PAD operation MUST be handled locally by some means (including intentionally ignoring the PPPoE PAD message, though this must be a deliberate act).

It is a matter of local policy as to which control connections will be established for relay and associated with a given interface, and when the Control Connections will be established. For instance, an implementation may "nail up" a control connection to a particular L2TP destination and associate the connection with an interface over which PPPoE PADI packets will arrive. Alternatively, an implementation might dynamically establish a Control Connection to a predetermined destination upon receipt of a PADI, or upon receipt of a PADI from a particular source.

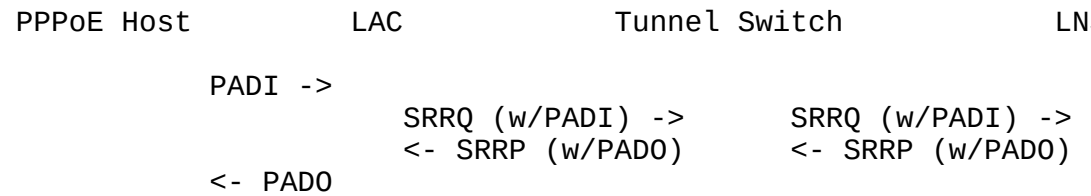
Upon receipt of the SRRQ, the included PPPoE PADI message MUST be processed as described in [3], be relayed to another L2TP control connection, or be relayed to another PPPoE AC.

After processing of a PADI, any resultant PPPoE Active Discovery Offer packet (PADO) MUST be encapsulated in a PPPoE Relay AVP and delivered via the Service Relay Reply Message (SRRP) to the sender of the SRRQ.

Upon receipt of an SRRP message with relayed PADO, a LAC MUST send the encapsulated PADO message to the corresponding PPPoE Host. The source MAC address of the PADO message MUST be one which the LAC will respond to, perhaps requiring substitution of its own MAC address.

In each exchange above, the PPPoE Host-Uniq TAG or AC-Cookie TAG MUST be used as described in Section 2.3.

Following is an example of the PAD exchange between a PPPoE Host, LAC and LNS up to this point, assuming the L2TP Control Connection has already been established. Examples that include AC-Cookie TAG and Host-Uniq TAG operation are included in the Appendix.



2.2. Session Establishment and Teardown

When a LAC that is providing the PPPoE Service Relay feature receives a valid PPPoE Active Discovery Request packet (PADR), the LAC MUST treat this as an action for creation of a Incoming Call Request (ICRQ) as defined in [2]. The resultant ICRQ message MUST contain the PPPoE Relay AVP containing the PADR in its entirety.

Upon receipt of an L2TP ICRQ message, the LNS parses the PADR message as described in [3]. If this is an acceptable PPPoE service connection (e.g., the Service-Name-Error TAG would not be included in a PPPoE Active Discovery Session-confirmation packet (PADS) response), the L2TP Incoming-Call-Reply (ICRP) message that is sent to the LAC includes the resultant PPPoE PADS encapsulated within the PPPoE Relay AVP. If the service is unacceptable, the PADS with a Service-Name-Error Tag is delivered via the Relay Session AVP within a Call-Disconnect-Notify (CDN) message, which also tears down the L2TP session. The PPPoE PADS SESSION_ID in the PPPoE Relay AVP MUST always be zero as it will be selected and filled in by the LAC.

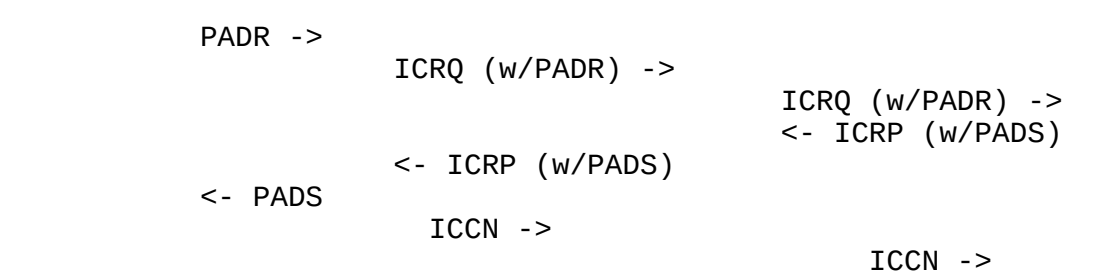
Upon receipt of an ICRP with the PPPoE Relay AVP, the LAC parses the PADS from the AVP, inserts a valid PPPoE SESSION_ID, and responds to the PPPoE Host with the PADS. The MAC address of the PADS MUST be the same one was utilized during the PADI/PADO exchange described above. The LAC also completes the L2TP session establishment by sending an Incoming-Call-Connected (ICCN) to the LNS and binds the

L2TP session with the PPPoE session. PPP data packets may now flow between the PPPoE session and the L2TP session in the traditional manner.

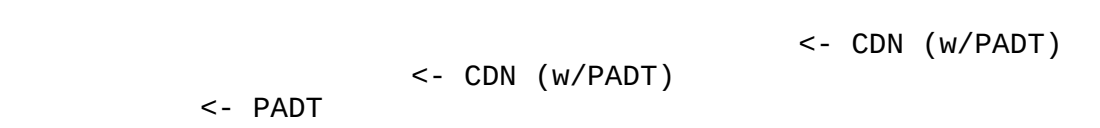
If the L2TP session is torn down for any reason, the LAC MUST send a PPPoE Active Discovery Terminate packet (PADT) to the host to indicate that the connection has been terminated. This PADT MAY be received from the LNS via the PPPoE Relay AVP within a CDN message if this was a graceful shutdown initiated by the PPPoE subsystem at the LNS. As with the PADS, the SESSION_ID in the PADT message is zero until filled in with the proper SESSION_ID at the LAC.

If the LAC receives a PADT from the PPPoE Host, the L2TP session MUST be shut down via the standard procedures defined in [2]. The PADT MUST be sent in the CDN message to the LNS via the PPPoE Relay AVP. If the PPPoE system at the LNS disconnects the session, a PADT SHOULD be sent in the CDN. In the event that the LAC receives a disconnect from L2TP and did not receive a PADT, it MUST generate a properly formatted PADT and send it to the PPPoE Host as described in [3].

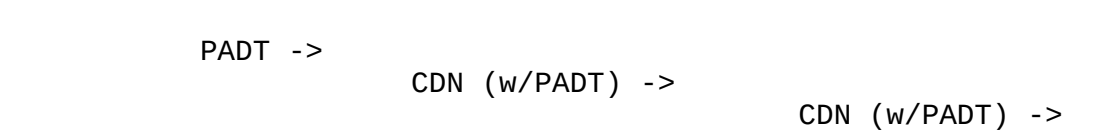
Session Establishment



Session Teardown (LNS Initiated)



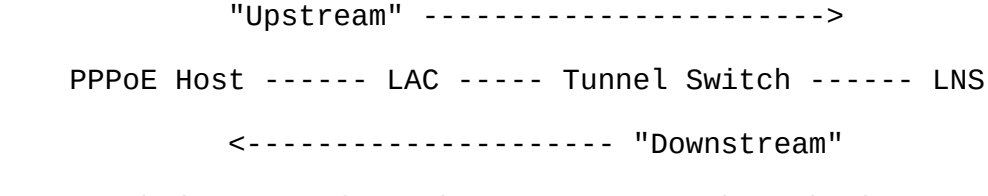
Session Teardown (Host Initiated)



2.3. PPPoE PAD Message Exchange Coherency

PPPoE PAD messages will arrive from multiple ethernet interfaces and be relayed across multiple L2TP control connections. In order to track which PAD messages must be sent where, we utilize the Host-Uniq TAG and AC-Cookie TAG. Each are used in the same manner, depending on which PAD message is being sent or replied to. Both take advantage of the fact that any PAD message sent as a reply to another PAD message MUST echo these TAGs in their entirety [3].

For purposes of this discussion, it is useful to define two "directions" which PAD messages will traverse during a relayed PPPoE PAD message exchange. Thus, for the following example,



PAD messages being sent from the PPPoE Host, through the LAC, Tunnel Switch, and LNS, are defined to be traversing "Upstream." PAD messages being sent in the opposite direction are defined to be traversing "Downstream."

Consider further, the following observation for this example:

PAD messages that are sent Upstream: PADI, PADR, PADT
PAD messages that are sent Downstream: PADO, PADS, PADT

Also, there is a request/response connection between the PADI and PADO which must be linked with some common value. Similarly, there is a request/response connection between PADO and PADR. The PADS is sent on its own with no response, but must be delivered to the sender of the PADR. The PADT must be sent with the same SESSION_ID as established in the PADS.

The goal for PAD message exchange coherency is to ensure that the connections between the PADI/PADO, PADO/PADR, and PADR/PADS and PADS/PADT all remain intact as the PAD messages are relayed from node to node.

The basic mechanism for ensuring this for PADI, PADO, and PADR messages is the AC-Cookie TAG and Host-Uniq TAG. Both of these TAGs are defined as arbitrary data which must be echoed in any message sent as a response to another message. This is the key to tying these PAD messages together at each hop. The following two rules makes this possible:

For PAD messages that are sent Upstream, a new Host-Uniq TAG MUST be inserted at each relaying node before the PAD message is forwarded. There SHOULD be at most one Host-Uniq TAG per PAD message.

For PAD messages being sent Downstream, a new AC-Cookie TAG MUST be inserted at each relaying node before the PAD message is forwarded. There SHOULD be at most one AC-Cookie TAG per PAD message. Additionally, for an LNS receiving multiple PAD messages from upstream, there SHOULD be at most one PAD message forwarded downstream per received SRRP Message. In other words, there SHOULD be exactly one PPPoE Relay AVP per L2TP SRRP Message.

The exception here is the PADS, which cannot carry an AC-Cookie TAG (and, thankfully, doesn't need to), and the PADT. We will discuss these later in this section. Using the above rules, PADI, PADO, and PADR messages may be relayed through an arbitrary number of nodes, each inserting its own value to link a message response that it might receive.

In order to implement this exchange without tying up resources at each L2TP node, it is desirable to not require ephemeral state at each node waiting for a message response from each forwarded PAD message. This is achievable if one is willing to be very intelligent about the values that will be sent in the PPPoE TAGs used for message coherency. Given that the TAGs are of arbitrary size and composition and are always echoed in their entirety, one may use the information here to map any next relay hop information. For example, the L2TP Tunnel ID (Control Connection ID) could be encoded in the TAG in order to identify where to relay the message when it arrives. If one chooses this method, the encoding MUST incorporate some method of encryption and authentication of the value. Note that this is a relatively simple proposition given that it is only the source of the encrypted and data that will ever need to decrypt and authenticate the value upon receipt (thus, no key exchanges are necessary, and any of a myriad of algorithms may be chosen). Note that individual TAGs MUST never exceed 255 octets in length, and the length of an entire PPPoE message MUST never exceed the maximum segment size of the underlying ethernet. In the event that a TAG exceeds 255 octets in length, a compression scheme which may include storage of state at an L2TP node may be necessary before constructing a new TAG.

The PADS and PADT messages do not rely on the AC-Cookie TAG or Host-Uniq TAG for directing to the proper node. As described in Section 2.2, the L2TP session is created upon receipt of a valid PADR at the L2TP LAC. Since the PADS is sent as an AVP on this message exchange,

its coherency may be secured via the L2TP session itself. Similarly for the PADT, as it is carried in the L2TP disconnect message (CDN) for the L2TP session.

Clients are supposed to treat an AC-Cookie TAG as an opaque object. They differentiate PADOs only by MAC address, Service-Name TAG(s) and by AC-Name TAG(s). If an LAC sends multiple PADOs, they should contain different AC-Name TAGs.

Furthermore, a node performing PPPoE L2TP Relay (such as an LAC) SHOULD attempt to distinguish or rate limit retransmitted PADx messages (perhaps via the source MAC address and/or arriving interface of the message) in order to limit the overloading of L2TP.

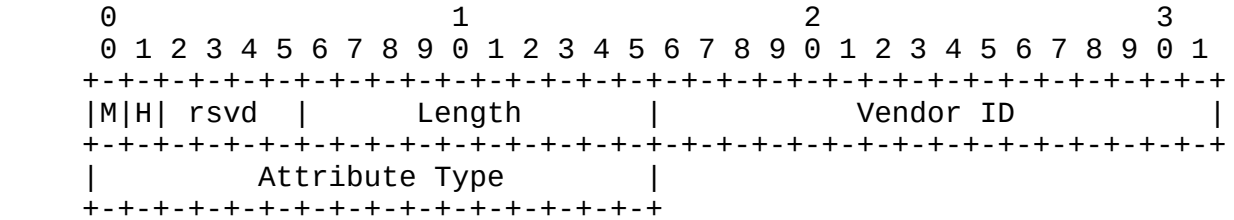
Examples of this operation for a number of scenarios and considerations for certain deployment situations may be found in the Appendix of this document.

2.4. PPPoE Service Relay Capabilities Negotiation

If the extensions defined in this document are present and configured for operation on a given Control Connection, the AVPs listed in this section MUST be present in the Start-Control-Connection-Request (SCCRQ) or Start-Control-Connection-Reply (SCCRP) messages during control connection setup.

2.4.1. PPPoE Service Relay Response Capability AVP

The PPPoE Service Relay Response Capability AVP, Attribute Type 56, indicates to an L2TP peer that the PPPoE Service Relay (SRRQ, SRRP) messages and the PPPoE Relay AVP will be processed and responded to when received.



The Vendor ID is the IETF Vendor ID of 0.

This AVP MAY be hidden (the H bit MAY be 0 or 1).

The M bit for this AVP may be set to 0 or 1. If the sender of this AVP does not wish to establish a connection to a peer which does not

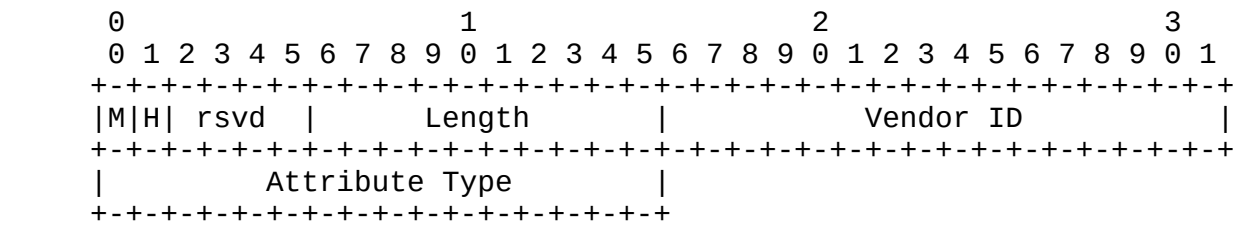
understand this L2TP extension, it SHOULD set the M bit to 1, otherwise it MUST be set to 0.

The Length of this AVP is 6.

The AVP may be present in the following messages: SCCRQ, SCCRP

2.4.2. PPPoE Service Relay Forward Capability AVP

The PPPoE Service Relay Forward Capability AVP, Attribute Type 57, indicates to an L2TP peer that PPPoE Service Relay (SRRQ, SRRP) messages and the PPPoE Relay AVP may be sent by this L2TP peer.



The Vendor ID is the IETF Vendor ID of 0.

This AVP MAY be hidden (the H bit MAY be 0 or 1).

The M bit for this AVP may be set to 0 or 1. If the sender of this AVP does not wish to establish a connection to a peer which does not understand this L2TP extension, it SHOULD set the M bit to 1, otherwise it MUST be set to 0.

The Length of this AVP is 6.

The AVP may be present in the following messages: SCCRQ, SCCRP

3. L2TP Service Relay Messages

This section identifies two new L2TP messages used to deliver PPPoE PADI and PADO messages.

3.1. Service Relay Request Message (SRRQ)

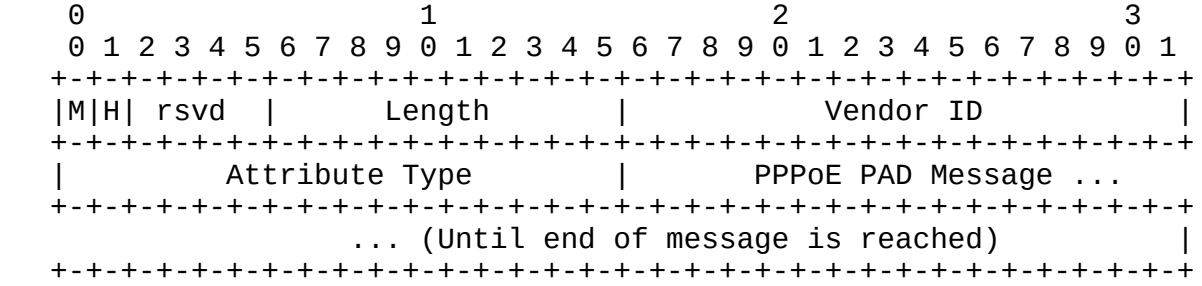
The Service Relay Request Message (SRRQ), Message Type 18, is sent by an LAC to relay requests for services. This document defines one new AVP that may be present to request service in section 2. Further service relay mechanisms may also use this message in a similar context. Discussion of other service relay mechanisms are outside the scope of this document.

3.2. Service Relay Reply Message (SRRP)

The Service Relay Reply Message (SRRP), Message Type 19, is sent by an LAC to relay responses of requests for services. This document defines one new AVP that may be present as a response to a request for service in section 2. Further service relay mechanisms may also use this message in a similar context. Discussion of other service relay mechanisms are outside the scope of this document.

4. PPPoE Relay AVP

The PPPoE Relay AVP, Attribute Type 55, carries the entire PADI, PADO, PADR, PADS and PADT messages within, including Ethernet MAC source and destination addresses. This is the only AVP necessary for relay of all PAD messages via L2TP.



The Vendor ID is the IETF Vendor ID of 0.

This AVP MAY be hidden (the H bit MAY be 0 or 1).

The M bit for this AVP may be set to 0 or 1. If the sender of this AVP does not wish to establish a connection to a peer which does not understand this L2TP extension, it SHOULD set the M bit to 1, otherwise it MUST be set to 0.

The Length of this AVP is 6 plus the length of the PPPoE PAD Message.

The AVP may be present in the following messages: SRRQ, SRRP, ICRQ, ICRP, ICCN, and CDN.

5. Security Considerations

PPPoE has a number of known security weaknesses that are not described here. For example, an intruder between a PPPoE Host and a PPPoE AC who can observe or modify PPPoE Active Discovery traffic has numerous opportunities for denial of service and other attacks. The use of the L2TP extensions described here makes it possible to tunnel PPPoE discovery packets between the LAC and LNS, extending the path

which the PPPoE Active Discovery packets are transported. There are two possible implications of this. First, the tunneled packets may now be observable by an intruder having access to traffic along the L2TP tunnel path. This MAY make information regarding service offerings or host identity easier to obtain to a rogue party given that it is being sent over a wider variety of media, and presumably over a longer distance and/or more hops or administrative domains. Whether this information could be used for malicious purposes depends on the information contained within, but it is conceivable that this could be sensitive information, and this mechanism increases the possibility that this information would be presented to an interloper. Second, it may also be possible for an intruder to modify PPPoE Active Discovery traffic while it is being carried within L2TP control messages.

There are at least two methods defined to help thwart this inspection or modification by an unauthorized individual. One of the two MUST be used if the service discovery information is considered to be sensitive and is traversing an untrusted network. The first suggested method is AVP hiding described in [2]. This may be used to hide the contents of the packets in transit, though offers no integrity protection against modification of data in the AVP. The second and more secure method is protecting L2TP with IPsec as defined in [6].

6. IANA Considerations

This document requires three new "AVP Attribute" (attribute type) numbers to be assigned through IETF Consensus [5] as indicated in Section 10.1 of [2].

1. PPPoE Relay AVP (section 4.0)
2. PPPoE Relay Response Capability AVP (section 2.4.1)
3. PPPoE Relay Forward Capability AVP (section 2.4.2)

This document requires two new "Message Type" numbers to be assigned through IETF Consensus [5] as indicated in Section 10.2 of [2].

1. Service Relay Request Message (SRRQ) (Section 3.1)
2. Service Relay Reply Message (SRRP) (Section 3.2)

There are no additional requirements on IANA to manage numbers in this document or assign any other numbers.

7. Acknowledgements

Thanks to Vinay Shankarkumar for valuable review, comment, and implementation.

Thanks to David Skoll and a number of others on pppoe@ipsec.org for providing very helpful discussion about their PPPoE implementations.

Thanks to Ross Wheeler, Louis Mamakos, and David Carrel for providing valuable clarifications of PPPoE [1] while designing this protocol.

8. References

8.1. Normative References

[1] Mamakos, L., Lidl, K., Evarts, J., Carrel, D., Simone, D. and R. Wheeler, "A Method for Transmitting PPP Over Ethernet (PPPoE)", RFC 2516, February 1999.

[2] Townsley, W., Valencia, A., Rubens, A., Pall, G., Zorn, G. and B. Palter, "Layer Two Tunneling Protocol 'L2TP'", RFC 2661, August 1999.

[3] Simpson, W., "The Point-to-Point Protocol (PPP)", STD 51, RFC 1661, July 1994.

[4] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

[5] Narten, T. and H. Alvestrand, "Guidelines for Writing an IANA Considerations Section in RFCs", BCP 26, RFC 2434, October 1998.

8.2. Informative References

[6] Patel, B., Aboba, B., Dixon, W., Zorn, G. and S. Booth, "Securing L2TP Using IPsec," RFC 3193, November 2001.

Appendix A: PPPoE Relay in Point to Multipoint Environments

The PPPoE PADI message in its native form, is sent as a broadcast message on an Ethernet link. Thus, more than one AC concentrator could conceivably receive and respond to this message. Similarly, a

PPPoE interface could be associated with more than one L2TP Control Connection, in order to query multiple LNSs with potentially varying service profiles, as well as to load balance requests.

As the PADI message is propagated, one may choose to replicate the message to multiple Control Connections in order to mimic the behavior of the PADI being sent on an ethernet link with multiple ACs attached. If the number of replicated nodes is large, and the number of hops deep, then an unmanageable "fan-out" of PADI propagation may occur. Thus, care should be taken here to only replicate messages to multiple Control Connections when it is absolutely necessary.

The only case where it is seems necessary to replicate messages to multiple destinations is in the case where each destination is known to have varying service policies that all need to be advertised to a PPPoE Host for its gathering and selection. At the time of this writing, the authors know of no PPPoE Host implementations that take advantage of this ability (instead, responding to only a single PPPoE PADO). This, of course, is subject to change if and when PPPoE implementations are advanced to this stage.

In cases where multiple Control Connections may exist to multiple LNSs for load balancing purposes, L2TP Service Relay should take measures to try one Control Connection at a time, rather than broadcasting to all Control Connections simultaneously.

Appendix B: PAD Message Exchange Coherency Examples

Example 1: "PPPoE Relay With Multiple LNSs"

This example assumes that there is good reason to send a copy of the PADI to both LNSs (e.g., each LNS may have a different service profile to offer).

1) a. Host sends PADI via broadcast MAC address to LAC

   b. LAC replicates the PADI message and forwards a copy to LNS1
      Host-Uniq = R1 (assigned)

   c. LAC replicates the PADI message and forwards a copy to LNS2
      Host-Uniq = R2 (assigned)

2) a. LNS1 responds with PADO to LAC
      Host-Uniq = R1 (echoed)
      AC-Cookie = C1 (assigned)

   b. LNS1 responds with PADO to LAC
      Host-Uniq = R2 (echoed)
      AC-Cookie = C2 (assigned)

   c. LAC forwards both PADO messages to Host with source MAC set to MAC address of LAC. PADO from (2a) is assigned new AC-Cookie C1' and PADO from (2b) is given AC-Cookie C2'

3) a. Host sends PADR to MAC address of LAC (choosing one)
      AC-Cookie = C1' (echoed)

   b. LAC knows to forward PADR to LNS1 based on C1'
      AC-Cookie = C1 (echoed)

4) Session Establishment at the LAC commences, with further PAD messages carried within the context of the L2TP session itself. No need to inspect the AC-Cookie TAG or Host-Uniq TAG from this point forward in order to direct messages properly.

Example 2: "PPPoE Relay With L2TP Tunnel-Switching"

```
        Host --- LAC ---- LNS1 ---- LNS2
```

1) a. Host sends PADI to LAC.

   b. LAC sends PADI to LNS1
      Host-Uniq = R1 (assigned)

   c. LNS1 sends PADI to LNS2
      Host-Uniq = R2 (assigned)

2) a. LNS2 responds to LNS1 with PADO
      Host-Uniq = R2 (echoed)
      AC-Cookie = C1 (assigned)

b. LNS1 relays PADO to LAC
   Host-Uniq = R1 (echoed)
   AC-Cookie = C1' (assigned)

c. LAC sends PADO to Host
   AC-Cookie = C1'' (assigned)

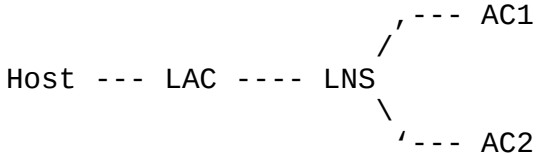
3) a. Host sends PADR to MAC address of LAC
   AC-Cookie = C1'' (echoed)

b. LAC sends PADR to LNS1
   AC-Cookie = C1' (echoed)

c. LNS1 sends PADR to LNS2
   AC-Cookie = C1 (echoed)

4) Session Establishment at the LAC, LNS1 and LNS2 commences, with further PAD messages carried within the context of the L2TP session itself. No need to inspect the AC-Cookie TAG or Host-Uniq TAG from this point forward in order to direct messages properly.

Example 3: "PPPoE Relay With Multiple PPPoE ACs"



In this example, AC1 and AC2 are PPPoE access concentrators on a broadcast domain. Sequence of operation is as follows.

1) a. Host sends PADI to LAC.

b. LAC sends PADI to LNS
   Host-Uniq = R1 (assigned)

c. LNS broadcasts PADI to AC1 and AC2
   Host-Uniq = R2 (assigned)

2) a. AC1 sends PADO to LNS
   Host-Uniq = R2 (echoed)
   AC-Cookie = C1 (assigned)

b. AC2 sends PADO to LNS
   Host-Uniq = R2 (echoed)
   AC-Cookie = C2 (assigned)

c. LNS sends two PADOs to LAC
   Host-Uniq = R1 (echoed)
   AC-Cookie (assigned) = C1′ and C2′, respectively

d. LAC sends two PADOs to Host
   Host-Uniq = R1
   AC-Cookie (assigned) = C1′′ and C2′′, respectively

3) a. Host sends PADR with to LAC to select service from AC2.
   AC-Cookie = C2′′ (echoed)

b. LAC sends PADR to LNS AC-Cookie = C2′ (echoed)

c. LAC sends PADR to AC2
   AC-Cookie = C1 (echoed)

4) Session Establishment at the LAC, LNS and AC2 commences, with further PAD messages carried within the context of the L2TP session or PPPoE session itself. No need to inspect the AC-Cookie TAG or Host-Uniq TAG from this point forward in order to direct messages properly.

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