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Softwire Hub and Spoke Deployment Framework with Layer Two Tunneling Protocol Version 2 (L2TPv2)

Status of This Memo

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Abstract

This document describes the framework of the Softwire "Hub and Spoke" solution with the Layer Two Tunneling Protocol version 2 (L2TPv2). The implementation details specified in this document should be followed to achieve interoperability among different vendor implementations.

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1. Introduction

The Softwires Working Group has selected Layer Two Tunneling Protocol version 2 (L2TPv2) as the phase 1 protocol to be deployed in the Softwire "Hub and Spoke" solution space. This document describes the framework for the L2TPv2 "Hub and Spoke" solution, and the implementation details specified in this document should be followed to achieve interoperability among different vendor implementations.

In the "Hub and Spoke" solution space, a Softwire is established to provide the home network with IPv4 connectivity across an IPv6-only access network, or IPv6 connectivity across an IPv4-only access network. When L2TPv2 is used in the Softwire context, the voluntary tunneling model applies. The Softwire Initiator (SI) at the home network takes the role of the L2TP Access Concentrator (LAC) client (initiating both the L2TP tunnel/session and the PPP link) while the Softwire Concentrator (SC) at the ISP takes the role of the L2TP Network Server (LNS). The terms voluntary tunneling and compulsory tunneling are defined in Section 1.1 of [RFC3193]. Since the L2TPv2 compulsory tunneling model does not apply to Softwires, it SHOULD NOT be requested or honored. This document identifies all the voluntary tunneling related L2TPv2 attributes that apply to Softwires and specifies the handling mechanism for such attributes in order to avoid ambiguities in implementations. This document also identifies the set of L2TPv2 attributes specific to the compulsory tunneling model that does not apply to Softwires and specifies the mechanism to ignore or nullify their effect within the Softwire context.

The SI and SC MUST follow the L2TPv2 operations described in [RFC2661] when performing Softwire establishment, teardown, and Operations, Administration, and Management (OAM). With L2TPv2, a Softwire consists of an L2TPv2 Control Connection (also referred to as Control Channel), a single L2TPv2 Session, and the PPP link negotiated over the Session. To establish the Softwire, the SI first initiates an L2TPv2 Control Channel to the SC, which accepts the request and terminates the Control Channel. L2TPv2 supports an optional mutual Control Channel authentication that allows both SI and SC to validate each other's identity at the initial phase of hand-shaking before proceeding with Control Channel establishment. After the L2TPv2 Control Channel is established between the SI and SC, the SI initiates an L2TPv2 Session to the SC. Then the PPP/IP link is negotiated over the L2TPv2 Session between the SI and SC. After the PPP/IP link is established, it acts as the Softwire between the SI and SC for tunneling IP traffic of one Address Family (AF) across the access network of another Address Family.

During the life of the Softwire, both SI and SC send L2TPv2 keepalive HELLO messages to monitor the health of the Softwire and the peer L2TP Control Connection Endpoint (LCCE), and to potentially refresh the NAT/NAPT (Network Address Translation / Network Address Port Translation) entry at the CPE or at the other end of the access link. Optionally, Link Control Protocol (LCP) ECHO messages can be used as keepalives for the same purposes. In the event of keepalive timeout or administrative shutdown of the Softwire, either the SI or the SC MAY tear down the Softwire by tearing down the L2TPv2 Control Channel and Session as specified in [RFC2661].

1.1. Abbreviations

AF Address Family, IPv4 or IPv6.

CPE Customer Premises Equipment.

LCCE L2TP Control Connection Endpoint, an L2TP node that exists at either end of an L2TP Control Connection. (See [RFC3931].)

LNS L2TP Network Server, a node that acts as one side of an L2TP tunnel (Control Connection) endpoint. The LNS is the logical termination point of a PPP session that is being tunneled from the remote system by the peer LCCE. (See [RFC2661].)

SC Softwire Concentrator, the node terminating the Softwire in the service provider network. (See [RFC4925].)

SI Softwire Initiator, the node initiating the Softwire within the customer network. (See [RFC4925].)

SPH Softwire Payload Header, the IP headers being carried within a Softwire. (See [RFC4925].)

STH Softwire Transport Header, the outermost IP header of a Softwire. (See [RFC4925].)

SW Softwire, a shared-state "tunnel" created between the SC and SI. (See [RFC4925].)

1.2. 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].

1.3. Considerations

Some sections of this document contain considerations that are not required for interoperability and correct operation of Softwire implementations. These sections' titles are marked beginning with "Considerations".

2. Applicability of L2TPv2 for Softwire Requirements

A list of Softwire "Hub and Spoke" requirements has been identified by the Softwire Problem Statement [RFC4925]. The following sub-sections describe how L2TPv2 fulfills each of them.

2.1. Traditional Network Address Translation (NAT and NAPT)

A "Hub and Spoke" Softwire must be able to traverse Network Address Translation (NAT) and Network Address Port Translation (NAPT, also referred to as Port Address Translation or PAT) devices [RFC3022] in case the scenario in question involves a non-upgradable, preexisting IPv4 home gateway performing NAT/NAPT or some carrier equipment at the other end of the access link performing NAT/NAPT. The L2TPv2 Softwire (i.e., Control Channel and Session) is capable of NAT/NAPT traversal since L2TPv2 can run over UDP.

Since L2TPv2 does not detect NAT/NAPT along the path, L2TPv2 does not offer the option of disabling UDP. The UDP encapsulation is present regardless of NAT/NAPT presence. Both NAT/NAPT "autodetect" and UDP "bypass" are optional requirements in Section 2.3 of [RFC4925].

As mentioned in Section 8.1 of [RFC2661] and Section 4 of [RFC3193], an L2TP Start-Control-Connection-Reply (SCCRP) responder (SC) can chose a different IP address and/or UDP port than those from the initiator's Start-Control-Connection-Request (SCCRQ) (SI). This may or may not traverse a NAT/NAPT depending on the NAT/NAPT's Filtering Behavior (see Section 5 of [RFC4787]). Specifically, any IP address and port combination will work with Endpoint-Independent Filtering, but changing the IP address and port will not work through Address-Dependent or Address-and-Port-Dependent Filtering. Given this, responding from a different IP address and/or UDP port is NOT RECOMMENDED.

2.2. Scalability

In the "Hub and Spoke" model, a carrier must be able to scale the solution to millions of Softwire Initiators by adding more hubs (i.e., Softwire Concentrators). L2TPv2 is a widely deployed protocol in broadband services, and its scalability has been proven in multiple large-scale IPv4 Virtual Private Network deployments, which scale up to millions of subscribers each.

2.3. Routing

There are no dynamic routing protocols between the SC and SI. A default route from the SI to the SC is used.

2.4. Multicast

Multicast protocols simply run transparently over L2TPv2 Softwires together with other regular IP traffic.

2.5. Authentication, Authorization, and Accounting (AAA)

L2TPv2 supports optional mutual Control Channel authentication and leverages the optional mutual PPP per-session authentication. L2TPv2 is well integrated with AAA solutions (such as RADIUS) for both authentication and authorization. Most L2TPv2 implementations available in the market support the logging of authentication and authorization events.

L2TPv2 integration with RADIUS accounting (RADIUS Accounting extension for tunnel [RFC2867]) allows the collection and reporting of L2TPv2 Softwire usage statistics.

2.6. Privacy, Integrity, and Replay Protection

Since L2TPv2 runs over IP/UDP in the Softwire context, IPsec Encapsulating Security Payload (ESP) can be used in conjunction to provide per-packet authentication, integrity, replay protection, and confidentiality for both L2TPv2 control and data traffic [RFC3193] and [RFC3948].

For Softwire deployments in which full payload security is not required, the L2TPv2 built-in Control Channel authentication and the inherited PPP authentication and PPP Encryption Control Protocol can be considered.

2.7. Operations and Management

L2TPv2 supports an optional in-band keepalive mechanism that injects HELLO control messages after a specified period of time has elapsed since the last data or control message was received on a tunnel (see Section 5.5 of [RFC2661]). If the HELLO control message is not reliably delivered, then the Control Channel and its Session will be torn down. In the Softwire context, the L2TPv2 keepalive is used to monitor the connectivity status between the SI and SC and/or as a refresh mechanism for any NAT/NAPT translation entry along the access link.

LCP ECHO offers a similar mechanism to monitor the connectivity status, as described in [RFC1661]. Softwire implementations SHOULD use L2TPv2 Hello keepalives, and in addition MAY use PPP LCP Echo messages to ensure Dead End Detection and/or to refresh NAT/NAPT translation entries. The combination of these two mechanisms can be used as an optimization.

The L2TPv2 MIB [RFC3371] supports the complete suite of management operations such as configuration of Control Channel and Session, polling of Control Channel and Session status and their traffic statistics and notifications of Control Channel and Session UP/DOWN events.

2.8. Encapsulations

L2TPv2 supports the following encapsulations:

- IPv6/PPP/L2TPv2/UDP/IPv4

- IPv4/PPP/L2TPv2/UDP/IPv6

- IPv4/PPP/L2TPv2/UDP/IPv4

- IPv6/PPP/L2TPv2/UDP/IPv6

Note that UDP bypass is not supported by L2TPv2 since L2TPv2 does not support "autodetect" of NAT/NAPT.

3. Deployment Scenarios

For the "Hub and Spoke" problem space, four scenarios have been identified. In each of these four scenarios, different home equipment plays the role of the Softwire Initiator. This section elaborates each scenario with L2TPv2 as the Softwire protocol and other possible protocols involved to complete the solution. This section examines the four scenarios for both IPv6-over-IPv4 (Section 3.1) and IPv4-over-IPv6 (Section 3.2) encapsulations.

3.1. IPv6-over-IPv4 Softwires with L2TPv2

The following sub-sections cover IPv6 connectivity (SPH) across an IPv4-only access network (STH) using a Softwire.

3.1.1. Host CPE as Softwire Initiator

The Softwire Initiator (SI) is the host CPE (directly connected to a modem), which is dual-stack. There is no other gateway device. The IPv4 traffic SHOULD NOT traverse the Softwire. See Figure 1.

```
             IPv6 or dual-stack      IPv4-only      dual-stack
            |------------------||-----------------||----------|

      I                    SC                         SI
      N                  +-----+                  +----------+
      T                  |     |                  |  v4/v6   |
      E  <==[ IPv6  ]....|v4/v6|....[IPv4-only]....| host CPE |
      R     [network]    |     |    [ network ]   |          |
      N                  | LNS |                  |LAC Client|
      E                  +-----+                  +----------+
      T                           _ _ _ _ _ _ _ _ _
                               ()_ _ _ _ _ _ _ _ _() <-- IPv6 traffic
                             PPP o L2TPv2 o UDP o IPv4          (SPH)
                                      Softwire

                               <------------------->
                    IPV6CP: capable of /64 Intf-Id assignment or
                                 uniqueness check

                               |------------------>/64 prefix
                                        RA
                               |------------------>DNS, etc.
                                      DHCPv6
```

Figure 1: Host CPE as Softwire Initiator

In this scenario, after the L2TPv2 Control Channel and Session establishment and PPP LCP negotiation (and optionally PPP Authentication) are successful, the IPv6 Control Protocol (IPV6CP) negotiates IPv6-over-PPP, which also provides the capability for the ISP to assign the 64-bit Interface-Identifier to the host CPE or perform uniqueness validation for the two interface identifiers at the two PPP ends [RFC5072]. After IPv6-over-PPP is up, IPv6

Stateless Address Autoconfiguration / Neighbor Discovery runs over the IPv6-over-PPP link, and the LNS can inform the host CPE of a prefix to use for stateless address autoconfiguration through a Router Advertisement (RA) while other non-address configuration options (such as DNS [RFC3646] or other servers' addresses that might be available) can be conveyed to the host CPE via DHCPv6.

3.1.2. Router CPE as Softwire Initiator

The Softwire Initiator (SI) is the router CPE, which is a dual-stack device. The IPv4 traffic SHOULD NOT traverse the Softwire. See Figure 2.

```
          IPv6 or dual-stack      IPv4-only         dual-stack
         |------------------||-----------------||---------------------|

   I                    SC                          SI
   N                  +-----+                   +----------+
   T                  |     |                   |  v4/v6   |    +-----+
   E  <==[ IPv6  ]....|v4/v6|....[IPv4-only]....|   CPE    |----|v4/v6|
   R     [network]    |     |    [ network ]    |          |    | host|
   N                  | LNS |                   |LAC Client|    +-----+
   E                  +-----+                   +----------+
   T                          _ _ _ _ _ _ _ _ _
                            ()_ _ _ _ _ _ _ _ _() <-------- IPv6 traffic
                          PPP o L2TPv2 o UDP o IPv4               (SPH)
                                   Softwire

                            <------------------->
                    IPV6CP: capable of /64 Intf-Id assignment or
                                uniqueness check

                            |------------------>/64 prefix
                                     RA
                            |------------------>/48 prefix,
                                   DHCPv6       DNS, etc.

                                                     |------->/64 prefix
                                                         RA
                                                     |-------> DNS, etc.
                                                     DHCPv4/v6
```

Figure 2: Router CPE as Softwire Initiator

In this scenario, after the L2TPv2 Control Channel and Session establishment and PPP LCP negotiation (and optionally PPP Authentication) are successful, IPV6CP negotiates IPv6-over-PPP, which also provides the capability for the ISP to assign the 64-bit

Interface-Identifier to the router CPE or perform uniqueness validation for the two interface identifiers at the two PPP ends [RFC5072]. After IPv6-over-PPP is up, IPv6 Stateless Address Autoconfiguration / Neighbor Discovery runs over the IPv6-over-PPP link, and the LNS can inform the router CPE of a prefix to use for stateless address autoconfiguration through a Router Advertisement (RA). DHCPv6 can be used to perform IPv6 Prefix Delegation (e.g., delegating a prefix to be used within the home network [RFC3633]) and convey other non-address configuration options (such as DNS [RFC3646]) to the router CPE.

3.1.3. Host behind CPE as Softwire Initiator

The CPE is IPv4-only. The Softwire Initiator (SI) is a dual-stack host (behind the IPv4-only CPE), which acts as an IPv6 host CPE. The IPv4 traffic SHOULD NOT traverse the Softwire. See Figure 3.

```
          IPv6 or dual-stack            IPv4-only           dual-stack
         |------------------||----------------------------||----------|

    I                   SC                                    SI
    N                 +-----+                              +----------+
    T                 |     |                   +-------+  |   v4/v6  |
    E <==[ IPv6  ]....|v4/v6|....[IPv4-only]....|v4-only|--|   host   |
    R    [network]    |     |    [ network ]    |  CPE  |  |          |
    N                 | LNS |                   +-------+  |LAC Client|
    E                 +-----+                              +----------+
    T                         _ _ _ _ _ _ _ _ _ _ _ _ _ _
                            ()_ _ _ _ _ _ _ _ _ _ _ _ _ _() <--  IPv6
                               PPP o L2TPv2 o UDP o IPv4        traffic
                                        Softwire                 (SPH)

                            <------------------------------->
                     IPV6CP: capable of /64 Intf-Id assignment or
                                   uniqueness check

                            |------------------------------>/64 prefix
                                           RA
                            |------------------------------->DNS, etc.
                                         DHCPv6
```

Figure 3: Host behind CPE as Softwire Initiator

In this scenario, after the L2TPv2 Control Channel and Session establishment and PPP LCP negotiation (and optionally PPP Authentication) are successful, IPV6CP negotiates IPv6-over-PPP, which also provides the capability for the ISP to assign the 64-bit

Interface-Identifier to the host or perform uniqueness validation for the two interface identifiers at the two PPP ends [RFC5072]. After IPv6-over-PPP is up, IPv6 Stateless Address Autoconfiguration / Neighbor Discovery runs over the IPv6-over-PPP link, and the LNS can inform the host of a prefix to use for stateless address autoconfiguration through a Router Advertisement (RA) while other non-address configuration options (such as DNS [RFC3646]) can be conveyed to the host via DHCPv6.

3.1.4. Router behind CPE as Softwire Initiator

The CPE is IPv4-only. The Softwire Initiator (SI) is a dual-stack device (behind the IPv4-only CPE) acting as an IPv6 CPE router inside the home network. The IPv4 traffic SHOULD NOT traverse the Softwire. See Figure 4.

```
         IPv6 or dual-stack           IPv4-only           dual-stack
        |------------------||-------------------------||-------------|

   I                   SC                                 SI
   N                 +-----+                           +----------+
   T                 |     |               +-------+   |  v4/v6   |
   E <==[ IPv6  ]....|v4/v6|..[IPv4-only]..|v4-only|---|  router  |
   R    [network]    |     |  [ network ]  |  CPE  | | |          |
   N                 | LNS |               +-------+ | |LAC Client|
   E                 +-----+                         | +----------+
   T                                                 |
                                                     ---------+-----+
                                                              |v4/v6|
                                                              | host|
                             _ _ _ _ _ _ _ _ _ _ _ _ _        +-----+
                           ()_ _ _ _ _ _ _ _ _ _ _ _ _() <--  IPv6
                              PPP o L2TPv2 o UDP o IPv4      traffic
                                       Softwire               (SPH)

                           <--------------------------->
                  IPV6CP: capable of /64 Intf-Id assignment or
                                 uniqueness check

                           |--------------------------->/64 prefix
                                         RA
                           |--------------------------->/48 prefix,
                                       DHCPv6           DNS, etc.

                                                           |----> /64
                                                             RA   prefix
                                                           |----> DNS,
                                                           DHCPv6 etc.
```

Figure 4: Router behind CPE as Softwire Initiator

In this scenario, after the L2TPv2 Control Channel and Session establishment and PPP LCP negotiation (and optionally PPP Authentication) are successful, IPV6CP negotiates IPv6-over-PPP, which also provides the capability for the ISP to assign the 64-bit Interface-Identifier to the v4/v6 router or perform uniqueness validation for the two interface identifiers at the two PPP ends [RFC5072]. After IPv6-over-PPP is up, IPv6 Stateless Address Autoconfiguration / Neighbor Discovery runs over the IPv6-over-PPP link, and the LNS can inform the v4/v6 router of a prefix to use for stateless address autoconfiguration through a Router Advertisement

(RA). DHCPv6 can be used to perform IPv6 Prefix Delegation (e.g., delegating a prefix to be used within the home network [RFC3633]) and convey other non-address configuration options (such as DNS [RFC3646]) to the v4/v6 router.

3.2. IPv4-over-IPv6 Softwires with L2TPv2

The following sub-sections cover IPv4 connectivity (SPH) across an IPv6-only access network (STH) using a Softwire.

3.2.1. Host CPE as Softwire Initiator

The Softwire Initiator (SI) is the host CPE (directly connected to a modem), which is dual-stack. There is no other gateway device. The IPv6 traffic SHOULD NOT traverse the Softwire. See Figure 5.

```
             IPv4 or dual-stack      IPv6-only      dual-stack
            |------------------||-----------------||----------|

       I                   SC                          SI
       N                 +-----+                   +----------+
       T                 |     |                   |  v4/v6   |
       E <==[ IPv4  ]....|v4/v6|....[IPv6-only]....| host CPE |
       R    [network]    |     |    [ network ]    |          |
       N                 | LNS |                   |LAC Client|
       E                 +-----+                   +----------+
       T                         _ _ _ _ _ _ _ _ _
                               ()_ _ _ _ _ _ _ _ _() <-- IPv4 traffic
                             PPP o L2TPv2 o UDP o IPv6          (SPH)
                                      Softwire

                               <------------------->
                       IPCP: capable of global IP assignment
                                    and DNS, etc.
```

Figure 5: Host CPE as Softwire Initiator

In this scenario, after the L2TPv2 Control Channel and Session establishment and PPP LCP negotiation (and optionally PPP Authentication) are successful, the IP Control Protocol (IPCP) negotiates IPv4-over-PPP, which also provides the capability for the ISP to assign a global IPv4 address to the host CPE. A global IPv4 address can also be assigned via DHCP. Other configuration options (such as DNS) can be conveyed to the host CPE via IPCP [RFC1877] or DHCP [RFC2132].

3.2.2. Router CPE as Softwire Initiator

The Softwire Initiator (SI) is the router CPE, which is a dual-stack device. The IPv6 traffic SHOULD NOT traverse the Softwire. See Figure 6.

```
         IPv4 or dual-stack      IPv6-only        dual-stack Home
        |------------------||-----------------||-------------------|

   I                   SC                          SI
   N                 +-----+                   +----------+
   T                 |     |                   |  v4/v6   |  +-----+
   E <==[ IPv4  ]....|v4/v6|....[IPv6-only]....|   CPE    |--|v4/v6|
   R    [network]    |     |    [ network ]    |          |  | host|
   N                 | LNS |                   |LAC Client|  +-----+
   E                 +-----+                   +----------+
   T                         _ _ _ _ _ _ _ _ _
                           ()_ _ _ _ _ _ _ _ _() <--------- IPv4 traffic
                         PPP o L2TPv2 o UDP o IPv6                 (SPH)
                                  Softwire

                           <------------------>
                   IPCP: capable of global IP assignment
                               and DNS, etc.

                           |------------------>
                         DHCPv4: prefix, mask, PD

                                                             private/
                                                    |------> global
                                                      DHCP   IP, DNS,
                                                             etc.
```

Figure 6: Router CPE as Softwire Initiator

In this scenario, after the L2TPv2 Control Channel and Session establishment and PPP LCP negotiation (and optionally PPP Authentication) are successful, IPCP negotiates IPv4-over-PPP, which also provides the capability for the ISP to assign a global IPv4 address to the router CPE. A global IPv4 address can also be assigned via DHCP. Other configuration options (such as DNS) can be conveyed to the router CPE via IPCP [RFC1877] or DHCP [RFC2132]. For IPv4 Prefix Delegation for the home network, DHCP [SUBNET-ALL] can be used.

3.2.3. Host behind CPE as Softwire Initiator

The CPE is IPv6-only. The Softwire Initiator (SI) is a dual-stack host (behind the IPv6 CPE), which acts as an IPv4 host CPE. The IPv6 traffic SHOULD NOT traverse the Softwire. See Figure 7.

```
          IPv4 or dual-stack            IPv6-only           dual-stack
         |------------------||----------------------------||----------|

    I                   SC                                      SI
    N                 +-----+                              +----------+
    T                 |     |                   +-------+  |   v4/v6  |
    E <==[ IPv4  ]....|v4/v6|....[IPv6-only]....|v6-only|--|   host   |
    R    [network]    |     |    [ network ]    |  CPE  |  |          |
    N                 | LNS |                   +-------+  |LAC Client|
    E                 +-----+                              +----------+
    T                         _ _ _ _ _ _ _ _ _ _ _ _ _ _
                            ()_ _ _ _ _ _ _ _ _ _ _ _ _ _() <--  IPv4
                               PPP o L2TPv2 o UDP o IPv6        traffic
                                        Softwire                 (SPH)

                            <------------------------------>
                        IPCP: capable of global IP assignment
                                    and DNS, etc.
```

Figure 7: Host behind CPE as Softwire Initiator

In this scenario, after the L2TPv2 Control Channel and Session establishment and PPP LCP negotiation (and optionally PPP Authentication) are successful, IPCP negotiates IPv4-over-PPP, which also provides the capability for the ISP to assign a global IPv4 address to the host. A global IPv4 address can also be assigned via DHCP. Other configuration options (such as DNS) can be conveyed to the host CPE via IPCP [RFC1877] or DHCP [RFC2132].

3.2.4. Router behind CPE as Softwire Initiator

The CPE is IPv6-only. The Softwire Initiator (SI) is a dual-stack device (behind the IPv6-only CPE) acting as an IPv4 CPE router inside the home network. The IPv6 traffic SHOULD NOT traverse the Softwire. See Figure 8.

```
         IPv4 or dual-stack          IPv6-only           dual-stack
        |------------------||-------------------------||------------|

   I                   SC                                  SI
   N                 +-----+                            +----------+
   T                 |     |               +-------+    |  v4/v6   |
   E <==[ IPv4  ]....|v4/v6|..[IPv6-only]..|v6-only|---|  router  |
   R    [network]    |     |  [ network ]  |  CPE  | |  |          |
   N                 | LNS |               +-------+ |  |LAC Client|
   E                 +-----+                         |  +----------+
   T                                                 |
                                                     --------+-----+
                                                             |v4/v6|
                                                             | host|
                             _ _ _ _ _ _ _ _ _ _ _ _ _       +-----+
                           ()_ _ _ _ _ _ _ _ _ _ _ _ _() <---  IPv4
                             PPP o L2TPv2 o UDP o IPv4        traffic
                                      Softwire                 (SPH)

                           <--------------------------->
                   IPCP: assigns global IP address and DNS, etc.

                           |--------------------------->
                              DHCPv4: prefix, mask, PD

                                                                private/
                                                         |----> global
                                                          DHCP  IP, DNS,
                                                                etc.
```

Figure 8: Router behind CPE as Softwire Initiator

In this scenario, after the L2TPv2 Control Channel and Session establishment and PPP LCP negotiation (and optionally PPP Authentication) are successful, IPCP negotiates IPv4-over-PPP, which also provides the capability for the ISP to assign a global IPv4 address to the v4/v6 router. A global IPv4 address can also be assigned via DHCP. Other configuration options (such as DNS) can be conveyed to the v4/v6 router via IPCP [RFC1877] or DHCP [RFC2132]. For IPv4 Prefix Delegation for the home network, DHCP [SUBNET-ALL] can be used.

4. References to Standardization Documents

This section lists and groups documents from the Internet standardization describing technologies used to design the framework of the Softwire "Hub and Spoke" solution. This emphasizes the motivation of Softwire to reuse as many existing standards as possible. This list contains both Standards Track (Proposed Standard, Draft Standard, and Standard) and Informational documents. The list of documents and their status should only be only used for description purposes.

4.1. L2TPv2

RFC 2661 "Layer Two Tunneling Protocol 'L2TP'" [RFC2661].

- For both IPv4 and IPv6 payloads (SPH), support is complete.

- For both IPv4 and IPv6 transports (STH), support is complete.

4.2. Securing the Softwire Transport

RFC 3193 "Securing L2TP using IPsec" [RFC3193].

RFC 3948 "UDP Encapsulation of IPsec ESP Packets" [RFC3948].

- IPsec supports both IPv4 and IPv6 transports.

4.3. Authentication, Authorization, and Accounting

RFC 2865 "Remote Authentication Dial In User Service (RADIUS)" [RFC2865].

- Updated by [RFC2868], [RFC3575], and [RFC5080].

RFC 2867 "RADIUS Accounting Modifications for Tunnel Protocol Support" [RFC2867].

RFC 2868 "RADIUS Attributes for Tunnel Protocol Support" [RFC2868].

RFC 3162 "RADIUS and IPv6" [RFC3162].

4.4. MIB

RFC 1471 "The Definitions of Managed Objects for the Link Control Protocol of the Point-to-Point Protocol" [RFC1471].

RFC 1473 "The Definitions of Managed Objects for the IP Network Control Protocol of the Point-to-Point Protocol" [RFC1473].

```
   RFC 3371   "Layer Two Tunneling Protocol "L2TP" Management
              Information Base" [RFC3371].

   RFC 4087   "IP Tunnel MIB" [RFC4087].

              *  Both IPv4 and IPv6 transports are supported.
```

4.5. Softwire Payload Related

4.5.1. For IPv6 Payloads

```
   RFC 4861   "Neighbor Discovery for IP version 6 (IPv6)" [RFC4861].

   RFC 4862   "IPv6 Stateless Address Autoconfiguration" [RFC4862].

   RFC 5072   "IP Version 6 over PPP" [RFC5072].

   RFC 3315   "Dynamic Host Configuration Protocol for IPv6 (DHCPv6)"
              [RFC3315].

   RFC 3633   "IPv6 Prefix Options for Dynamic Host Configuration
              Protocol (DHCP) version 6" [RFC3633].

   RFC 3646   "DNS Configuration options for Dynamic Host Configuration
              Protocol for IPv6 (DHCPv6)" [RFC3646].

   RFC 3736   "Stateless Dynamic Host Configuration Protocol (DHCP)
              Service for IPv6" [RFC3736].
```

4.5.2. For IPv4 Payloads

```
   RFC 1332   "The PPP Internet Protocol Control Protocol (IPCP)"
              [RFC1332].

   RFC 1661   "The Point-to-Point Protocol (PPP)" [RFC1661].

   RFC 1877   "PPP Internet Protocol Control Protocol Extensions for
              Name Server Addresses" [RFC1877].

   RFC 2131   "Dynamic Host Configuration Protocol" [RFC2131].

   RFC 2132   "DHCP Options and BOOTP Vendor Extensions" [RFC2132].

   DHCP Subnet Allocation  "Subnet Allocation Option".

              *  Work in progress, see [SUBNET-ALL].
```

5. Softwire Establishment

A Softwire is established in three distinct steps, potentially preceded by an optional IPsec-related step 0 (see Figure 9). First, an L2TPv2 tunnel with a single session is established from the SI to the SC. Second, a PPP session is established over the L2TPv2 session and the SI obtains an address. Third, the SI optionally gets other information through DHCP such as a delegated prefix and DNS servers.

```
      SC                                 SI
       |                                  |
       |<-------------IKEv1------------->| Step 0
       |                                  | IPsec SA establishment
       |                                  | (optional)
       |                                  |
       |<-------------L2TPv2------------>| Step 1
       |                                  | L2TPv2 Tunnel establishment
       |                                  |
       |<--------------PPP-------------->| Step 2
       |<-----Endpoint Configuration---->| PPP and Endpoint
       |                                  | configuration
       |                                  |
       |<------Router Configuration----->| Step 3
       |                                  | Additional configuration
       |                                  | (optional)
```

Figure 9: Steps for the Establishment of a Softwire

Figure 10 depicts details of each of these steps required to establish a Softwire.

```
         SC                                 SI
          |                                 |
          |                                 | Step 0
          |<------------IKEv1-------------->| = IKEv1 (Optional)
          |                                 |
          |                                 | Step 1
          |<------------SCCRQ---------------| -
          |-------------SCCRP-------------->| |
          |<------------SCCCN---------------| |
          |<------------ICRQ----------------| | L2TPv2
          |-------------ICRP--------------->| |
          |<------------ICCN----------------| -
          |                                 |
          |                                 | Step 2
          |<-----Configuration-Request------| -
          |------Configuration-Request----->| | PPP
          |--------Configuration-Ack------->| | LCP
          |<-------Configuration-Ack--------| -
          |                                 |
          |-----------Challenge------------>| - PPP Authentication
          |<----------Response--------------| | (Optional - CHAP)
          |------------Success------------->| -
          |                                 |
          |<-----Configuration-Request------| -
          |------Configuration-Request----->| | PPP NCP
          |--------Configuration-Ack------->| | (IPV6CP or IPCP)
          |<-------Configuration-Ack--------| -
          |                                 |
          |<------Router-Solicitation-------| - Neighbor Discovery
          |-------Router-Advertisement----->| | (IPv6 only)
          |                                 | -
          |                                 |
          |                                 | Step3
          |                                 | DHCP (Optional)
          |<-----------SOLICIT--------------| -
          |-----------ADVERTISE------------>| | DHCPv6
          |<---------- REQUEST--------------| | (IPv6 SW, Optional)
          |-------------REPLY-------------->| -
          |                                 | or
          |<---------DHCPDISCOVER-----------| -
          |-----------DHCPOFFER------------>| | DHCPv4
          |<---------DHCPREQUEST------------| | (IPv4 SW, Optional)
          |------------DHCPACK------------->| -
```

Figure 10: Detailed Steps in the Establishment of a Softwire

The IPsec-related negotiations in step 0 are optional. The L2TPv2 negotiations in step 1 are described in Section 5.1. The PPP Network Control Protocol (NCP) negotiations in step 2 use IPV6CP for IPv6-over-IPv4 Softwires, and IPCP for IPv4-over-IPv6 Softwires (see Section 5.2.4). The optional DHCP negotiations in step 3 use DHCPv6 for IPv6-over-IPv4 Softwires, and DHCPv4 for IPv4-over-IPv6 Softwires (see Section 5.4). Additionally, for IPv6-over-IPv4 Softwires, the DHCPv6 exchange for non-address configuration (such as DNS) can use Stateless DHCPv6, the two-message exchange with Information-Request and Reply messages (see Section 1.2 of [RFC3315] and [RFC3736]).

5.1. L2TPv2 Tunnel Setup

L2TPv2 [RFC2661] was originally designed to provide private network access to end users connected to a public network. In the L2TPv2 incoming call model, the end user makes a connection to an L2TP Access Concentrator (LAC). The LAC then initiates an L2TPv2 tunnel to an L2TP Network Server (LNS). The LNS then transfers end-user traffic between the L2TPv2 tunnel and the private network.

In the Softwire "Hub and Spoke" model, the Softwire Initiator (SI) assumes the role of the LAC Client and the Softwire Concentrator (SC) assumes the role of the LNS.

In the Softwire model, an L2TPv2 packet MUST be carried over UDP. The underlying version of the IP protocol may be IPv4 or IPv6, depending on the Softwire scenario.

In the following sections, the term "Tunnel" follows the definition from Section 1.2 of [RFC2661], namely: "The Tunnel consists of a Control Connection and zero or more L2TP Sessions".

5.1.1. Tunnel Establishment

Figure 11 describes the messages exchanged and Attribute Value Pairs (AVPs) used to establish a tunnel between an SI (LAC) and an SC (LNS). The messages and AVPs described here are only a subset of those defined in [RFC2661]. This is because Softwires use only a subset of the L2TPv2 functionality. The subset of L2TP Control Connection Management AVPs that is applicable to Softwires is grouped into Required AVPs and Optional AVPs on a per-control-message basis (see Figure 11). For each control message, Required AVPs include all the "MUST be present" AVPs from [RFC2661] for that control message, and Optional AVPs include the "MAY be present" AVPs from [RFC2661] that are used in the Softwire context on that control message. Note that in the Softwire environment, the SI always initiates the tunnel. L2TPv2 AVPs SHOULD NOT be hidden.

```
                        SC                        SI
                         |<--------SCCRQ---------|
                          Required AVPs:
                             Message Type
                             Protocol Version
                             Host Name
                             Framing Capabilities
                             Assigned Tunnel ID
                          Optional AVPs:
                             Receive Window Size
                             Challenge
                             Firmware Revision
                             Vendor Name

                         |---------SCCRP-------->|
                          Required AVPs:
                             Message Type
                             Protocol Version
                             Framing Capabilities
                             Host Name
                             Assigned Tunnel ID
                          Optional AVPs:
                             Firmware Revision
                             Vendor Name
                             Receive Window Size
                             Challenge
                             Challenge Response

                         |<--------SCCCN---------|
                          Required AVPs:
                             Message Type
                          Optional AVPs:
                             Challenge Response
```

Figure 11: Control Connection Establishment

In L2TPv2, generally, the tunnel between an LAC and LNS may carry the data of multiple users. Each of these users is represented by an L2TPv2 session within the tunnel. In the Softwire environment, the tunnel carries the information of a single user. Consequently, there is only one L2TPv2 session per tunnel. Figure 12 describes the messages exchanged and the AVPs used to establish a session between an SI (LAC) and an SC (LNS). The messages and AVPs described here are only a subset of those defined in [RFC2661]. This is because Softwires use only a subset of the L2TPv2 functionality. The subset of L2TP Call Management (i.e., Session Management) AVPs that is applicable to Softwires is grouped into Required AVPs and Optional AVPs on a per-control-message basis (see Figure 12). For each control message, Required AVPs include all the "MUST be present" AVPs from [RFC2661] for that control message, and Optional AVPs include the "MAY be present" AVPs from [RFC2661] that are used in the Softwire context on that control message. Note that in the Softwire environment, the SI always initiates the session. An L2TPv2 session setup for a Softwire uses only the incoming call model. No outgoing or analog calls (sessions) are permitted. L2TPv2 AVPs SHOULD NOT be hidden.

```
                      SC                      SI
                       |<--------ICRQ---------|
                        Required AVPs:
                           Message Type
                           Assigned Session ID
                           Call Serial Number

                       |---------ICRP-------->|
                        Required AVPs:
                           Message Type
                           Assigned Session ID

                       |<--------ICCN---------|
                        Required AVPs:
                           Message Type
                           (Tx) Connect Speed
                           Framing Type
```

Figure 12: Session Establishment

The following sub-sections (5.1.1.1 through 5.1.1.3) describe in more detail the Control Connection and Session establishment AVPs (see message flows in Figures 11 and 12, respectively) that are required, optional and not relevant for the L2TPv2 Tunnel establishment of a Softwire. Specific L2TPv2 protocol messages and flows that are not explicitly described in these sections are handled as defined in [RFC2661].

The mechanism for hiding AVP Attribute values is used, as described in Section 4.3 of [RFC2661], to hide sensitive control message data such as usernames, user passwords, or IDs, instead of sending the AVP contents in the clear. Since AVPs used in L2TP messages for the Softwire establishment do not transport such sensitive data, L2TPv2 AVPs SHOULD NOT be hidden.

5.1.1.1. AVPs Required for Softwires

This section prescribes specific values for AVPs that are required (by [RFC2661]) to be present in one or more of the messages used for the Softwire establishment, as they are used in the Softwire context. It combines all the Required AVPs from all the control messages in Section 5.1.1, and provides Softwire-specific use guidance.

Host Name AVP

This AVP is required in SCCRQ and SCCRP messages. This AVP MAY be used to authenticate users, in which case it would contain a user identification. If this AVP is not used to authenticate users, it may be used for logging purposes.

Framing Capabilities AVP

Both the synchronous (S) and asynchronous (A) bits SHOULD be set to 1. This AVP SHOULD be ignored by the receiver.

Framing Type AVP

The synchronous bit SHOULD be set to 1 and the asynchronous bit to 0. This AVP SHOULD be ignored by the receiver.

(Tx) Connect Speed AVP

(Tx) Connect Speed is a required AVP but is not meaningful in the Softwire context. Its value SHOULD be set to 0 and ignored by the receiver.

Message Type AVP, Protocol Version AVP, Assigned Tunnel ID AVP, Call Serial Number AVP, and Assigned Session ID AVP

As defined in [RFC2661].

5.1.1.2. AVPs Optional for Softwires

This section prescribes specific values for AVPs that are Optional (not required by [RFC2661]) but used in the Softwire context. It combines all the Optional AVPs from all the control messages in Section 5.1.1, and provides Softwire-specific use guidance.

Challenge AVP and Challenge Response AVP

These AVPs are not required, but are necessary to implement tunnel authentication. Since tunnel authentication happens at the beginning of L2TPv2 tunnel creation, it can be helpful in preventing denial-of-service (DoS) attacks. See Section 5.1.1 of [RFC2661].

The usage of these AVPs in L2TP messages is OPTIONAL, but SHOULD be implemented in the SC.

Receive Window Size AVP, Firmware Revision AVP, and Vendor Name AVP

As defined in [RFC2661].

5.1.1.3. AVPs Not Relevant for Softwires

L2TPv2 specifies numerous AVPs that, while allowed for a given message, are irrelevant to Softwires. They can be irrelevant to Softwires because they do not apply to the Softwire establishment flow (e.g., they are only used in the Outgoing Call establishment message exchange, while Softwires only use the Incoming Call message flow), or because they are Optional AVPs that are not used. L2TPv2 AVPs that are relevant to Softwires were covered in Sections 5.1.1, 5.1.1.1, and 5.1.1.2. Softwire implementations SHOULD NOT send AVPs that are not relevant to Softwires. However, they SHOULD ignore them when they are received. This will simplify the creation of Softwire applications that build upon existing L2TPv2 implementations.

5.1.2. Tunnel Maintenance

Periodically, the SI/SC MUST transmit a message to the peer to detect tunnel or peer failure and maintain NAT/NAPT contexts. The L2TPv2 HELLO message provides a simple, low-overhead method of doing this.

The default values specified in [RFC2661] for L2TPv2 HELLO messages could result in a dead-end detection time of 83 seconds. Although these retransmission timers and counters SHOULD be configurable (see Section 5.8 of [RFC2661]), these values may not be adapted for all situations, where a quicker dead-end detection is required, or where NAT/NAPT context needs to be refreshed more frequently. In such cases, the SI/SC MAY use, in combination with L2TPv2 HELLO, LCP ECHO messages (Echo-Request and Echo-Reply codes) described in [RFC1661]. When used, LCP ECHO messages SHOULD have a re-emission timer lower than the value for L2TPv2 HELLO messages. The default value recommended in Section 6.5 of [RFC2661] for the HELLO message retransmission interval is 60 seconds. When used, a set of suggested values (included here only for guidance) for the LCP ECHO message request interval is a default of 30 seconds, a minimum of 10 seconds, and a maximum of the lesser of the configured L2TPv2 HELLO retransmission interval and 60 seconds.

5.1.3. Tunnel Teardown

Either the SI or SC can tear down the session and tunnel. This is done as specified in Section 5.7 of [RFC2661], by sending a StopCCN control message. There is no action specific to Softwires in this case.

5.1.4. Additional L2TPv2 Considerations

In the Softwire "Hub and Spoke" framework, L2TPv2 is layered on top of UDP, as part of an IP-in-IP tunnel; Section 8.1 of [RFC2661] describes L2TP over UDP/IP. Therefore, the UDP guidelines specified in [RFC5405] apply, as they pertain to the UDP tunneling scenarios carrying IP-based traffic. Section 3.1.3 of [RFC5405] specifies that for this case, specific congestion control mechanisms for the tunnel are not necessary. Additionally, Section 3.2 of [RFC5405] provides message size guidelines for the encapsulating (outer) datagrams, including the recommendation to implement Path MTU Discovery (PMTUD).

5.2. PPP Connection

This section describes the PPP negotiations between the SI and SC in the Softwire context.

5.2.1. MTU

The MTU of the PPP link presented to the SPH SHOULD be the link MTU minus the size of the IP, UDP, L2TPv2, and PPP headers together. On an IPv4 link with an MTU equal to 1500 bytes, this could typically mean a PPP MTU of 1460 bytes. When the link is managed by IPsec, this MTU SHOULD be lowered to take into account the ESP encapsulation (see [SW-SEC]). The value for the MTU may also vary according to the size of the L2TP header, as defined by the leading bits of the L2TP message header (see [RFC2661]). Additionally, see [RFC4623] for a detailed discussion of fragmentation issues.

5.2.2. LCP

Once the L2TPv2 session is established, the SI and SC initiate the PPP connection by negotiating LCP as described in [RFC1661]. The Address-and-Control-Field-Compression configuration option (ACFC) [RFC1661] MAY be rejected.

5.2.3. Authentication

After completing LCP negotiation, the SI and SC MAY optionally perform authentication. If authentication is chosen, Challenge Handshake Authentication Protocol (CHAP) [RFC1994] authentication MUST be supported by both the Softwire Initiator and Softwire Concentrator. Other authentication methods such as Microsoft CHAP version 1 (MS-CHAPv1) [RFC2433] and Extensible Authentication Protocol (EAP) [RFC3748] MAY be supported.

A detailed discussion of Softwire security is contained in [SW-SEC].

5.2.4. IPCP

The only Network Control Protocol (NCP) negotiated in the Softwire context is IPV6CP (see Section 5.2.4.1) for IPv6 as SPH, and IPCP (see Section 5.2.4.2) for IPv4 as SPH.

5.2.4.1. IPV6CP

In the IPv6-over-IPv4 scenarios (see Section 3.1), after the optional authentication phase, the Softwire Initiator MUST negotiate IPV6CP as defined in [RFC5072]. IPV6CP provides a way to negotiate a unique 64-bit Interface-Identifier to be used for the address autoconfiguration at the local end of the link.

5.2.4.2. IPv4CP

In the IPv4-over-IPv6 scenarios (see Section 3.2), a Softwire Initiator MUST negotiate IPCP [RFC1332]. The SI uses IPCP to obtain an IPv4 address from the SC. IPCP MAY also be used to obtain DNS information as described in [RFC1877].

5.3. Global IPv6 Address Assignment to Endpoints

In several scenarios defined in Section 3.1, global IPv6 addresses are expected to be allocated to Softwire endpoints (in addition to the Link-Local addresses autoconfigured using the IPV6CP negotiated interface identifier). The Softwire Initiator assigns global IPv6 addresses using the IPV6CP negotiated interface identifier and using Stateless Address Autoconfiguration [RFC4862], and/or using Privacy Extensions for Stateless Address Autoconfiguration [RFC4941], (as described in Section 5 of [RFC5072]), and/or using DHCPv6 [RFC3315].

The Softwire Initiator of an IPv6 Softwire MUST send a Router Solicitation message to the Softwire Concentrator after IPV6CP is completed. The Softwire Concentrator MUST answer with a Router Advertisement. This message MUST contain the global IPv6 prefix of the PPP link if Neighbor Discovery is used to configure addresses of Softwire endpoints.

If DHCPv6 is available for address delegation, the M bits of the Router Advertisement SHOULD be set. The Softwire Initiator MUST then send a DHCPv6 Request to configure the address of the Softwire endpoint.

Duplicate Address Detection ([RFC4861]) MUST be performed on the Softwire in both cases.

5.4. DHCP

The Softwire Initiator MAY use DHCP to get additional information such as delegated prefix and DNS servers.

5.4.1. DHCPv6

In the scenarios in Section 3.1, if the SI supports DHCPv6, it SHOULD send a Solicit message to verify if more information is available.

If an SI establishing an IPv6 Softwire acts as a router (i.e., in the scenarios in Sections 3.1.2 and 3.1.4) it MUST include the Identity Association for Prefix Delegation (IA_PD) option [RFC3633] in the DHCPv6 Solicit message [RFC3315] in order to request an IPv6 prefix.

When delegating an IPv6 prefix to the SI by returning a DHCPv6 Advertise message with the IA_PD and IP_PD Prefix options [RFC3633], the SC SHOULD inject a route for this prefix in the IPv6 routing table in order to forward the traffic to the relevant Softwire.

Configuration of DNS MUST be done as specified in [RFC3646] and transmitted according to [RFC3315] and [RFC3736]. In general, all DHCPv6 options MUST be transmitted according to [RFC3315] and [RFC3736].

5.4.2. DHCPv4

An SI establishing an IPv4 Softwire MAY send a DHCP request containing the Subnet Allocation option [SUBNET-ALL]. This practice is not common, but it may be used to connect IPv4 subnets using Softwires, as defined in Sections 3.2.2 and 3.2.4.

One Subnet-Request suboption MUST be configured with the 'h' bit set to '1', as the SI is expected to perform the DHCP server function. The 'i' bit of the Subnet-Request suboption SHOULD be set to '0' the first time a prefix is requested and to '1' on subsequent requests, if a prefix has been allocated. The Prefix length suboption SHOULD be 0 by default. If the SI is configured to support only specific prefix lengths, it SHOULD specify the longest (smallest) prefix length it supports.

If the SI was previously assigned a prefix from that same SC, it SHOULD include the Subnet-Information suboption with the prefix it was previously assigned. The 'c' and 's' bits of the suboption SHOULD be set to '0'.

In the scenarios in Section 3.2, when delegating an IPv4 prefix to the SI, the SC SHOULD inject a route for this prefix in the IPv4 routing table in order to forward the traffic to the relevant Softwire.

6. Considerations about the Address Provisioning Model

This section describes how a Softwire Concentrator may manage delegated addresses for Softwire endpoints and for subnets behind the Softwire Initiator. One common practice is to aggregate endpoints' addresses and delegated prefixes into one prefix routed to the SC. The main benefit is to ease the routing scheme by isolating on the SC succeeding route injections (when delegating new prefixes for SI).

6.1. Softwire Endpoints' Addresses

6.1.1. IPv6

A Softwire Concentrator should provide globally routable addresses to Softwire endpoints. Other types of addresses such as Unique Local Addresses (ULAs) [RFC4193] may be used to address Softwire endpoints in a private network with no global connectivity. A single /64 should be assigned to the Softwire to address both Softwire endpoints.

Global addresses or ULAs must be assigned to endpoints when the scenario "Host CPE as Softwire Initiator" (described in Section 3.1.1) is considered to be deployed. For other scenarios, link-local addresses may also be used.

6.1.2. IPv4

A Softwire Concentrator may provide either globally routable or private IPv4 addresses. When using IPv4 private addresses [RFC1918] on the endpoints, it is not recommended to delegate an IPv4 private prefix to the SI, as it can lead to a nested-NAT situation.

The endpoints of the PPP link use host addresses (i.e., /32), negotiated using IPCP.

6.2. Delegated Prefixes

6.2.1. IPv6 Prefixes

Delegated IPv6 prefixes should be of global scope if the IPv6 addresses assigned to endpoints are global. Using ULAs is not recommended when the subnet is connected to the global IPv6 Internet. When using IPv6 ULAs on the endpoints, the delegated IPv6 prefix may be either of global or ULA scope.

Delegated IPv6 prefixes are between /48 and /64 in length. When an SI receives a prefix shorter than 64, it can assign different /64 prefixes to each of its interfaces. An SI receiving a single /64 is expected to perform bridging if more than one interface is available (e.g., wired and wireless).

6.2.2. IPv4 Prefixes

Delegated IPv4 prefixes should be routable within the address space used by assigned IPv4 addresses. Delegate non-routable IPv4 prefixes (i.e., private IPv4 prefix over public IPv4 addresses or another class of private IPv4 addresses) is not recommended as a practice for provisioning and address translation should be considered in these cases. The prefix length is between /8 and /30.

6.3. Possible Address Provisioning Scenarios

This section summarizes the different scenarios for address provisioning with the considerations given in the previous sections.

6.3.1. Scenarios for IPv6

This table describes the possible combination of IPv6 address scope for endpoints and delegated prefixes.

Endpoint IPv6 Address	Delegated Global IPv6 Prefix	Delegated ULA IPv6 Prefix
Link Local	Possible	Possible
ULA	Possible	Possible
Global	Possible	Possible, but Not Recommended

Table 1: Scenarios for IPv6

6.3.2. Scenarios for IPv4

This table describes the possible combination of IPv4 address scope for endpoints and delegated prefixes.

Endpoint IPv4 Address	Delegated Public IPv4 Prefix	Delegated Private IPv4 Prefix
Private IPv4	Possible	Possible, but Not Recommended when using NAT (cf. Section 6.1.2)
Public IPv4	Possible	Possible, but NAT usage is recommended (cf. Section 6.2.2)

Table 2: Scenarios for IPv4

7. Considerations about Address Stability

A Softwire can provide stable addresses even if the underlying addressing scheme changes, by opposition to automatic tunneling. A Softwire Concentrator should always provide the same address and prefix to a reconnecting user. However, if the goal of the Softwire service is to provide a temporary address for a roaming user, it may be provisioned to provide only a temporary address.

The address and prefix are expected to change when reconnecting to a different Softwire Concentrator. However, an organization providing a Softwire service may provide the same address and prefix across different Softwire Concentrators at the cost of a more fragmented routing table. The routing fragmentation issue may be limited if the prefixes are aggregated in a location topologically close to the SC. This would be the case, for example, if several SCs are put in parallel for load-balancing purpose.

8. Considerations about RADIUS Integration

The Softwire Concentrator is expected to act as a client to a AAA server, for example, a RADIUS server. During the PPP authentication phase, the RADIUS server may return additional information in the form of attributes in the Access-Accept message.

The Softwire Concentrator may include the Tunnel-Type and Tunnel-Medium-Type attributes [RFC2868] in the Access-Request messages to provide a hint of the type of Softwire being configured.

8.1. Softwire Endpoints

8.1.1. IPv6 Softwires

If the RADIUS server includes a Framed-Interface-Id attribute [RFC3162], the Softwire Concentrator must send it to the Softwire Initiator in the Interface-Identifier field of its IPV6CP Configuration Request message.

If the Framed-IPv6-Prefix attribute [RFC3162] is included, that prefix must be used in the router advertisements sent to the SI. If Framed-IPv6-Prefix is not present but Framed-IPv6-Pool is, the SC must choose a prefix from that pool to send RAs.

8.1.2. IPv4 Softwires

If the Framed-IP-Address attribute [RFC2865] is present, the Softwire Concentrator must provide that address to the Softwire Initiator during IPCP address negotiation. That is, when the Softwire Initiator requests an IP address from the Softwire Concentrator, the address provided should be the Framed-IP-Address.

8.2. Delegated Prefixes

8.2.1. IPv6 Prefixes

If the attribute Delegated-IPv6-Prefix [RFC4818] is present in the RADIUS Access-Accept message, it must be used by the Softwire Concentrator for the delegation of the IPv6 prefix. Since the prefix delegation is performed by DHCPv6 and the attribute is linked to a username, the SC must associate the DHCP Unique Identifier (DUID) of a DHCPv6 request to the tunnel it came from and its user.

Interaction between RADIUS, PPP, and DHCPv6 server may follow the mechanism proposed in [RELAY-RAD]. In this case, during the Softwire authentication phase, PPP collects the RADIUS attributes for the user such as Delegated-IPv6-Prefix. A specific DHCPv6 relay is assigned to the Softwire. The DHCPv6 relay fills in these attributes in the Relay agent RADIUS Attribute Option (RRAO) DHCPv6 option, before forwarding the DHCPv6 requests to the DHCPv6 server.

8.2.2. IPv4 Prefixes

RADIUS does not define an attribute for the delegated IPv4 Prefix. Attributes indicating an IPv4 prefix and its length (for instance the combination of the Framed-IP-Address and Framed-IP-Netmask attributes [RFC2865]) may be used by the Softwire Concentrator to delegate an IPv4 prefix to the Softwire Initiator. The Softwire Concentrator must add a corresponding route with the Softwire Initiator as next-hop.

As this practice had been used, the inclusion of the Framed-IP-Netmask attribute along with the Framed-IP-Address attribute tells the Softwire Concentrator to delegate an IPv4 prefix to the Softwire Initiator (e.g., in the IPv4-over-IPv6 scenarios where the Softwire Initiator is a router, see Sections 3.2.2 and 3.2.4), as the SC should forward packets destined to any IPv4 address in the prefix to the SI.

9. Considerations for Maintenance and Statistics

Existing protocol mechanics for conveying adjunct or accessory information for logging purposes, including L2TPv2 and RADIUS methods, can include informational text that the behavior is according to the Softwire "Hub and Spoke" framework (following the implementation details specified in this document).

9.1. RADIUS Accounting

RADIUS Accounting for L2TP and PPP are documented (see Section 4.3).

When deploying Softwire solutions, operators may experience difficulties to differentiate the address family of the traffic reported in accounting information from RADIUS. This problem and some potential solutions are described in [SW-ACCT].

9.2. MIBs

MIB support for L2TPv2 and PPP are documented (see Section 4.4). Also, see [RFC4293].

10. Security Considerations

One design goal of the "Hub and Spoke" problem is to very strongly consider the reuse of already deployed protocols (see [RFC4925]). Another design goal is a solution with very high scaling properties. L2TPv2 [RFC2661] is the phase 1 protocol used in the Softwire "Hub and Spoke" solution space, and the L2TPv2 security considerations apply to this document (see Section 9 of [RFC2661]).

The L2TPv2 Softwire solution adds the following considerations:

o L2TP Tunnel Authentication (see Sections 5.1.1 and 9.1 of [RFC2661]) provides authentication at tunnel setup. It may be used to limit DoS attacks by authenticating the tunnel before L2TP and PPP resources are allocated.

o In a Softwire environment, L2TPv2 AVPs do not transport sensitive data, and thus the L2TPv2 AVP hiding mechanism is not used (see Section 5.1.1).

o PPP CHAP [RFC1994] provides basic user authentication. Other authentication protocols may additionally be supported (see Section 5.2.3).

L2TPv2 can also be secured with IPsec to provide privacy, integrity, and replay protection. Currently, there are two different solutions for security L2TPv2 with IPsec:

o Securing L2TPv2 using IPsec "version 2" (IKEv1) is specified in [RFC3193], [RFC3947], and [RFC3948]. When L2TPv2 is used in the Softwire context, the voluntary tunneling model applies. [RFC3193] describes the interaction between IPsec and L2TPv2, and is deployed. [RFC3193] MUST be supported, given that deployed technology must be very strongly considered [RFC4925] for this 'time-to-market' solution.

- [SW-SEC] also specifies a new (incompatible) solution for securing L2TPv2 with IPsec "version 3" (IKEv2). Section 3.5 of [SW-SEC] describes the advantages of using IKEv2, and this solution needs to be considered for future phases.

Additional discussion of Softwire security is contained in [SW-SEC].

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