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Softwire Problem Statement
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Abstract

This document captures the problem statement for the Softwires Working Group, which is developing standards for the discovery, control, and encapsulation methods for connecting IPv4 networks across IPv6-only networks as well as IPv6 networks across IPv4-only networks. The standards will encourage multiple, inter-operable vendor implementations by identifying, and extending where necessary, existing standard protocols to resolve a selected set of "IPv4/IPv6" and "IPv6/IPv4" transition problems. This document describes the specific problems ("Hubs and Spokes" and "Mesh") that will be solved by the standards developed by the Softwires Working Group. Some requirements (and non-requirements) are also identified to better describe the specific problem scope.

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1. Introduction

The Softwires Working Group is specifying the standardization of discovery, control and encapsulation methods for connecting IPv4 networks across IPv6-only networks and IPv6 networks across IPv4-only networks in a way that will encourage multiple, inter-operable vendor implementations. This document describes the specific problems ("Hubs and Spokes" and "Mesh") that will be solved by the standards developed by the Softwires Working Group. Some requirements (and non-requirements) are also identified to better describe the specific problem scope. A few generic assumptions are listed up front:

- Local Area Networks will often support both protocol families in order to accommodate both IPv4-only and IPv6-only applications, in addition to dual-stack applications. Global reachability requires the establishment of softwire connectivity to transit across portions of the network that do not support both address families. Wide area networks that support one or both address families may be separated by transit networks that do not support all address families. Softwire connectivity is necessary to establish global reachability of both address families.

- Softwires are to be used in IP-based networks to forward both unicast and multicast traffic.

- Softwires are assumed to be long-lived in nature.

- Although Softwires are long-lived, the setup time of a softwire is expected to be a very small fraction of the total time required

for startup of the Customer Premise Equipment (CPE)/Address Family Border Router (AFBR).

- The nodes that actually initiate softwires should support dual-stack (IPv4 and IPv6) functionality.

- The goal of this effort is to reuse or extending existing technology. The 'time-to-market' requirement for solutions to the stated problems is very strict and existing, deployed technology must be very strongly considered in our solution selection.

The solution to the stated problem should address the following points:

- Relation of the softwire protocols to other host mechanisms in the same layer of the network stack. Examples of mechanisms to consider are tunneling mechanisms, VPNs, mobility (SHIM6,...

- Operational brittelness introduced by softwire, e.g. potential single point of failure or difficulties to deploy redundant systems.

- Effects of softwires on the transport layer. Issue like packet losses, congestion control and handling of QoS reservation and usage of on-path protocols such as RSVP.

The history of IPv4 and IPv6 transition strategies at the IETF is a very long and complex. Here we list out some steps we have taken to further the effort and it has lead to the creation of this document and a few 'working rules' for us to accomplish our work:

- At the IETF 63 "LightWeight Reachability softWires" (LRW) BOF meeting, attendees from several operators requested a very tight timeframe for delivery of a solution, based on time-to-market considerations. This problem statement is narrowly scoped to accommodate near-term deployment.

- At the Paris Softwires interim meeting in October, 2005, participants divided the overall problem space into two separate "sub-problems" to solve based on network topology. These two

problems are referred to as "Hubs and Spokes" (described in section 3) and "Mesh" (described in Section 4).

As stated, there are two scenarios that emerged when discussing the traversal of networks composed of differing address families. The scenarios are quite common in today's network deployments. The primary difference between "Spokes and Hubs" and "Mesh" is how many connections and associated routes are managed by each IPv4 or IPv6 "island". "Hubs and Spokes" is characterized with one connection and associated static default route, and "Mesh" is characterized by multiple connections and routing prefixes. In general, the two can be categorized as host or LAN connectivity and network (or VPN) connectivity problems. Looking at the history of multi-address family networking, the clear delineation of the two scenarios was never clearly illustrated but they are now the network norm, and both must be solved. Later during the solution phase of the WG, these problems will be treated as related, but separate, problem spaces. Similar protocols and mechanisms will be used when possible, but different protocols and mechanisms may be selected when necessary to meet the requirements of each given problem space.

1.1. Terminology

Address Family (AF) - IPv4 or IPv6. Presently defined values for this field are specified in http://www.iana.org/assignments/address-family-numbers.

Address Family Border Router (AFBR) - The router that interconnects two networks that use different address families.

Customer Premise Equipment (CPE) - Under the scope of this document, this refers to terminal and associated equipment and inside wiring located at a subscriber's premises and connected with a carrier's communication channel(s) at the demarcation point (" demarc "). The demarc is a point established in a building or complex to separate customer equipment from telephone, cable or other service provider equipment. CPE can be a host or router, depending on the specific characteristics of the access network. The demarc point for IPv4 may or may not be the same as the demarc point for IPv6, thus there can be one CPE box acting for IPv4 and IPv6 or two separate ones, one for IPv4 and one for IPv6.

Home gateway - Existing piece of equipment that connects the home network to the provider network. Usually act as CPE for one or both address family.

Softwire (SW) - A "tunnel" that is created on the basis of a control protocol setup between softwire endpoints with shared point-to-point or multipoint-to-point state. Softwires are generally dynamic in nature (they may be initiated and terminated on demand), but may be very long-lived.

Softwire Concentrator (SC) - The node terminating the softwire in the service provider network.

Softwire Initiator (SI) - The node initiating the softwire within the customer network.

Softwire Transport Header AF (STH AF) - the address family of the outermost IP header of a softwire.

Softwire Payload Header AF (SPH AF) - the address family of the IP headers being carried within a softwire. Note that additional "levels" of IP headers may be present if (for example) a tunnel is carried over a softwire - the key attribute of SPH AF is that it is directly encapsulated within the softwire and the softwire endpoint will base forwarding decisions on the SPH AF when a packet is exiting the softwire.

Subsequent Address Family (SAF) - Additional information about the type of the additional information about the type of the Network Layer Reachability Information (e.g. unicast or multicast).

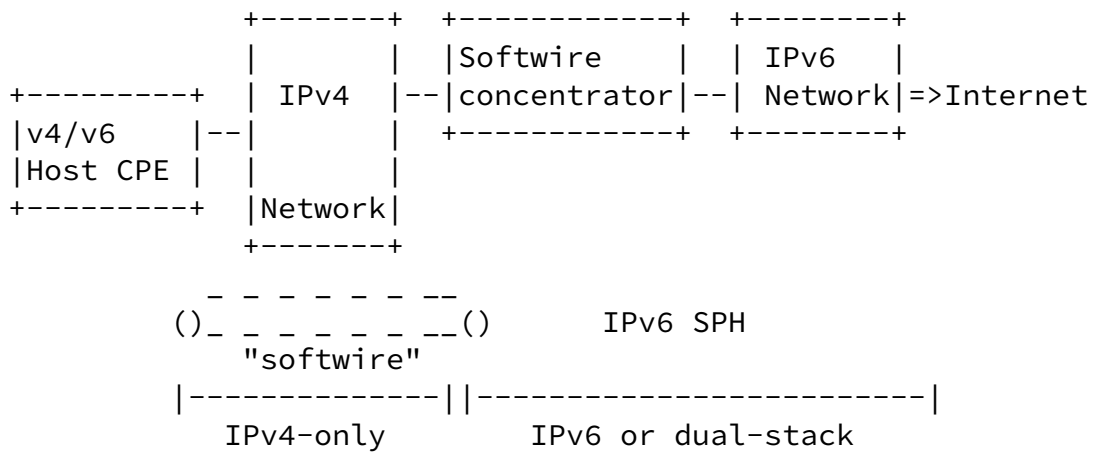
2. Hubs and Spokes Problem

The "Hubs and Spokes" problem is named in reference to the airline industry where major companies have estabilised a relatively small number of well connected hubs and then serve smaller airports from those hubs.

Manually configured tunnels (as described in [RFC4213]) can be

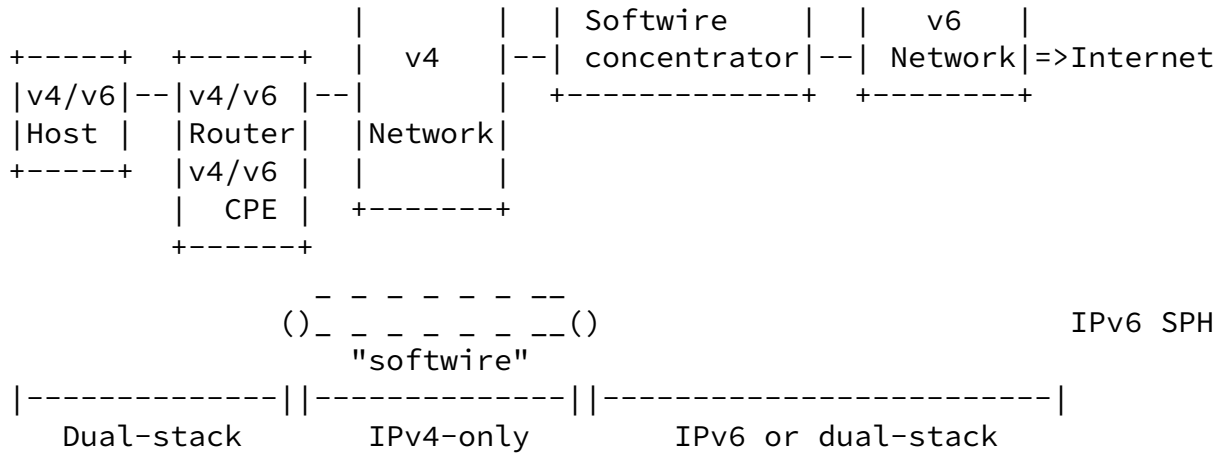
sufficient transition mechanism in some situations. However, cases where NAT traversal is a concern (see section 2.3), or dynamic IP address configuration is required, another solution is necessary.

There are four variant cases of the Hubs and Spokes problem which are shown in the following figures.



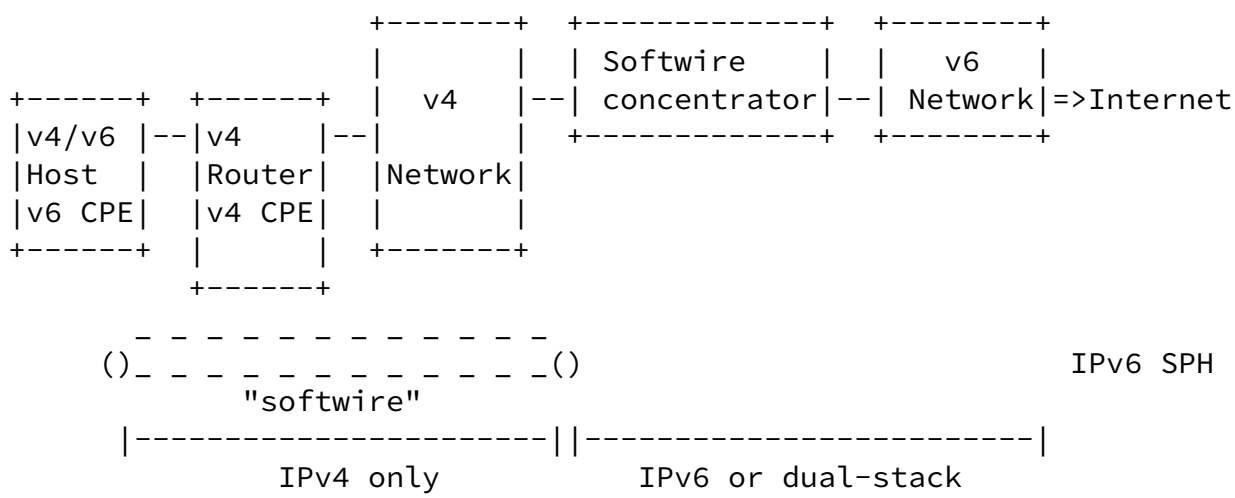
Case 1: IPv6 connectivity across an IPv4-only access network (STH). Softwire initiator is the host CPE (directly connected to a modem), which is dual-stack. There is no other gateway device. The IPv4 traffic should not traverse the softwire.

Figure 1: Case 1



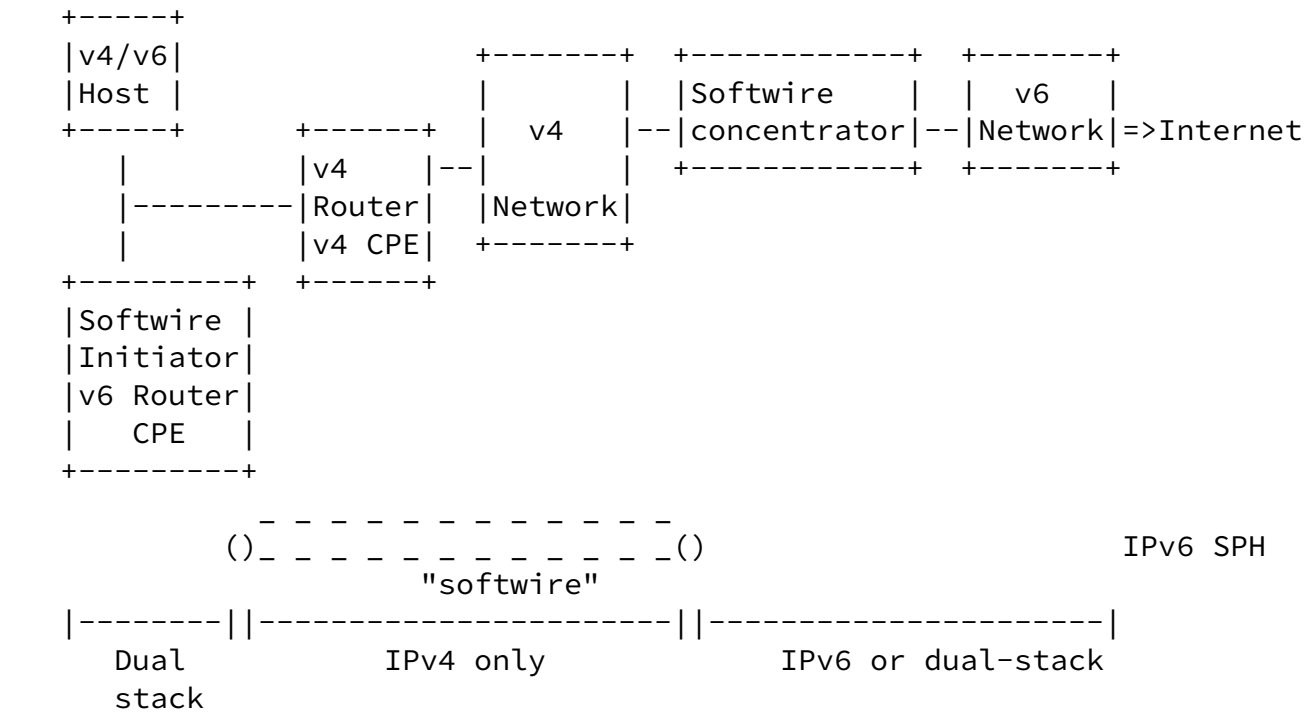
Case 2: IPv6 connectivity across an IPv4-only access network (STH). Softwire initiator is the router CPE, which is a dual-stack device. The IPv4 traffic should not traverse the softwire.

Figure 2: Case 2



Case 3: IPv6 connectivity across an IPv4-only access network (STH). The CPE is IPv4-only. Softwire initiator is a host, which act as an IPv6 host CPE. The IPv4 traffic should not traverse the softwire.

Figure 3: Case 3



Case 4: IPv6 connectivity across an IPv4-only access network (STH). The routing CPE is IPv4-only. Software initiator is a device acting as an IPv6 CPE router inside the home network. The IPv4 traffic should not traverse the softwire.

Figure 4: Case 4

The converse cases exist, replacing IPv4 by IPv6 and vice versa in the above figures.

2.1. Description

In this scenario, carriers (or large enterprise networks acting as carriers for their internal networks) have an infrastructure which in at least one device on any given path supports only one address family, with customers who wish to support applications bound to an address family that cannot be routed end-to-end. The address family that must be "crossed" is called the Softwire Transport Header, or STH AF (which could be either IPv4 or IPv6).

In order to support applications bound to another address family (the Softwire Payload Header Address Family, or SPH AF), it is necessary to establish a virtual dual-stack infrastructure (end-to-end), typically by means of automatically-established tunnels (Softwires). The traffic that can traverse the network via its native AF must not be forced to take the softwire path. Only the traffic that otherwise

would not be able to be forwarded due to the AF mismatch should be forwarded within the softwire. The goal is to avoid overwhelming the

softwire concentrator (SC).

A network operator may choose to enable a single address family in one or several parts of this infrastructure for policy reasons (i.e., traffic on the network is dominant in one of the address families, a single address family is used to lower OAM cost, etc.) or for technical reasons (i.e., because one or more devices are not able to support both address families).

There are several obstacles that may preclude support for both address families:

a) One or more devices (routers or some other media-specific aggregation point device) being used across the infrastructure (core, access) that supports only one address family. Typically the reasons for this situation include a lack of vendor support for one of the address families, the (perceived) cost of upgrading them, the (perceived) complexity of running both address families natively, operation/management reasons to avoid upgrades (perhaps temporarily), or economic reasons (such as a commercially insignificant amount of traffic with the non-supported address family).

b) The home gateway (CPE router or other equipment at the demarc point), cannot be easily upgraded to support both address families. Typically the reason for this is the lack of vendor support for one of the address families, commercial or operational reasons for not carrying out the upgrade (i.e., operational changes and/or cost may need to be supported by the carrier for all the customers, which can turn into millions of units), or customer reluctance to change/ upgrade CPE router (cost, "not broken, so don't change it"). Note that the un-practicality of systematic upgrades of the CPE routers is also hindering the deployment of 6to4 based solutions [RFC3056] in IPv4 networks.

2.2. Non-upgradable CPE router

Residential and small-office CPE equipment may be limited to support only one address family. Often, they are owned by a customer or carrier who is unwilling or unable to upgrade them to run in dual

stack mode (as shown in Figure 3 and Figure 4).

When the CPE router cannot run in dual-stack mode a softwire will have to be established by a node located behind that CPE router. This can be accomplished either by a regular host in the home running softwire software (Figure 1 or Figure 3) or by a dedicated piece of hardware acting as the "IPv6 router" (Figure 4). Such a device is fairly simple in design and only requires one physical network interface. Again, only the traffic of the mismatched AF will be

forwarded via the softwire. Traffic that can otherwise be forwarded without a softwire should not be encapsulated.

2.3. Network Address Translation (NAT) and Port Address Translation (PAT)

A typical case of non-upgradable CPE router is a pre-existing IPv4/NAT home gateway, so the softwires solution must support NAT traversal.

Establishing a Softwire through NAT or PAT must be supported without an explicit requirement to "autodetect" NAT or PAT presence during softwire setup. Simply enabling NAT traversal could be sufficient to meet this requirement.

Although the tunneling protocol must be able to traverse NATs, tunneling protocols may have an optional capability to bypass UDP encapsulation if not traversing a NAT.

2.4. Static Prefix Delegation

An important characteristic of this problem in IPv4 networks is that the carrier-facing CPE IP address is typically dynamically assigned (The IP address of the node establishing the softwire behind the CPE router can also be dynamically assigned.)

Solutions like external dynamic DNS and dynamic NAT port forwarding have been deployed to deal with ever changing addresses, but it would be simpler if, in IPv6 networks, a static prefix was delegated to customers. Such a prefix would allow for the registration of stable addresses in the DNS and enable the use of solutions like RFC3041 privacy extension or cryptographically generated addresses (CGA)

[RFC3972].

The softwire protocol does not need to define a new method for prefix delegation however DHCPv6 prefix delegation must be able to run over a softwire.

Link local addresses allocated at both ends of the tunnel are enough for packet forwarding, but for management purpose like traceroute, global addresses can be allocated using existing protocols such as stateless address auto-configuration or DHCPv6.

The IP addresses of the softwire link itself do not need to be stable, the desire for stability only applies to the delegated prefix. Even if there is a single node attached behind a softwire link, nothing prevents a softwire concentrator to delegate it a /64 prefix.

Similarly, in the case of an IPv4 softwire, the address could be provided by means of DHCP. In the case of an IPv4 softwire, a mechanism should be available in order to delegate an IPv4 prefix.

Note about 6to4: This is one of the main difference between Softwires and 6to4. 6to4 addresses will change every time the CPE router will get a new external address, where a DHCPv6 delegated prefix through a Softwire link could be stable.

2.5. Softwire Initiator

In the Hubs and Spokes problem, softwires are always initiated by the customer side. Thus, the node hosting the end of the softwire within the customer network is called the softwire initiator. It can run on any dual-stack node. As noted earlier, this can be the CPE access device, another dedicated CPE router behind the original CPE access device or actually any kind of node (host, appliance, sensor, etc.).

The softwire initiator node can change over time and may or may not be delegated the same IP address for the softwire endpoint. In particular, softwires should work in the nomadic case (e.g. a user opening up his laptop in various Wi-Fi hot-spots), where the softwire initiator could potentially obtain an IP address of one address family outside its original carrier network and still want to obtain the other address family addresses from its carrier.

If and when the IPv4 provider periodically changes the IPv4 address allocated to the gateway, the softwire initiator has to discover in a reasonable amount of time that the tunnel is down and restart it. This re-establishment should not change the IPv6 prefix and other parameters allocated to the site.

2.6. Softwire Concentrator

On the carrier side, softwires are terminated on a softwire concentrator. A softwire concentrator is usually a dual-stack router connected to the dual-stack core of the carrier.

A carrier may deploy several softwire concentrators (for example one per POP) for scalability reasons.

Softwire concentrators are usually not nomadic and have stable IP addresses.

It may be the case that one of the address families is not natively supported on the interface facing the core of the carrier. Connectivity must then be provided by other tunnels, potentially using the softwire mesh model.

Softwire concentrator functionality will be based on existing standards for tunneling, prefixes and addresses allocation, management. The working group must define a Softwires Concentrator architecture and interaction between these protocols and recommend profiles. These recommendations must take into account the distributed nature of the Softwires Concentrator in the provider network and the impact on core IPv6 networks (for instance: prefix aggregation).

2.7. Softwire Concentrator Discovery

The softwire initiator must know the DNS name or IP address of the softwire concentrator. An automated discovery phase may be used to return the IP address(s), or name(s) of the concentrator. Alternatively, this information may be configured by the user, or or by the provider of the softwire initiator in advance. The details of this discovery problem are outside the scope of this document, however previous work could be taken in consideration. Examples

include: [I-D.durand-naptr-service-discovery], [I-D.ietf-v6ops-ipsec-tunnels], and [I-D.palet-v6ops-tun-auto-disc].

2.8. Scaling

In a hubs and spokes model, a carrier must be able to scale the solution to millions of softwire initiators by adding more hubs (i.e. softwire concentrators).

2.9. Routing

As customer networks are typically attached via a single link to their carrier, the minimum routing requirement is a default route for each of the address families.

2.10. Multicast

Softwires must support multicast.

2.11. Security

2.11.1. Authentication, Authorization and Accounting

The softwire protocol must support customer authentication in the control plane, in order to authorize access to the service, and provide adequate logging of activity (accounting). However, an carrier may decide to turn it off in some circumstances, for instance, when the customer is already authenticated by some other means, such as closed networks, cellular networks, etc., in order to avoid unnecessary overhead.

The protocol should offer mutual authentication in scenarios where the initiator requires identity proof from the concentrator.

The softwire solution, at least for "Hubs and Spokes", must be integrable with commonly deployed AAA solutions (although extensions to those AAA solutions may be needed).

2.11.2. Privacy, Integrity, and Replay protection

The softwire Control and/or Data plane must be able to provide full payload security (such as IPsec or SSL) when desired. This

additional protection must be separable from the tunneling aspect of the softwire mechanism itself. For IPsec, default profiles must be defined. [draft-ietf-v6ops-ipsec-tunnels] provides guidelines on this.

2.12. Operations and Management (O&M)

As it is assumed that the softwire may have to go across NAT or PAT, a keepalive mechanism must be defined. Such a mechanism is also useful for dead peer detection. However in some circumstances (i.e., narrowband access, billing per traffic, etc.) the keepalive mechanism may consume unnecessary bandwidth, so turning it on or off, and modifying the periodicity, must be supported administrative options.

Other needed O&M features include:

- Logging

- Usage accounting

- End-point failure detection (the detection mechanism must operate within the tunnel)

- Path failure detection (the detection mechanism must operate outside the tunnel)

2.13. Encapsulations

IPv6/IPv4, IPv6/UDP/IPv4 and IPv4/IPv6 are on the critical path for "Hubs and Spokes" softwires. There is no intention to place limits on additional encapsulations beyond those explicitly mentioned in this specification.

3. Mesh Problem

3.1. Description

We use the term "Mesh Problem" to describe the problem of supporting a general routed topology in which a backbone network that does not support a particular address family can be used as part of the path for packets that belong to that address family. For example, the path for an IPv4 packet might include a transit network which supports only IPv6. There might (or might not) be other paths that the IPv4 packet could take that do not use the IPv6 transit network; the actual path chosen will be determined by the IPv4 routing procedures.

By saying that the transit network supports only a single address family, we mean that the "core" routers of that network do not maintain routing information for other address families, and they may not even be able to understand the packet headers of other address families. We do suppose though that the core will have "edge routers" or "border routers" which maintain the routing information for both address families, and which can parse the headers of both address families. We refer to these as "Address Family Border Routers" (AFBRs).

The following figure shows an AF2-only network connected to AF1-only networks, AF2-only networks, and dual stack networks. Note that in addition to paths through the AF2-only core, other paths may also exist between AF1 networks. The AFBRs which support AF1 would use BGP to exchange AF1 routing information between themselves, but such information would not be distributed to other core routers. The AFBRs would also participate in the exchange of AF2 routing information with the core nodes.

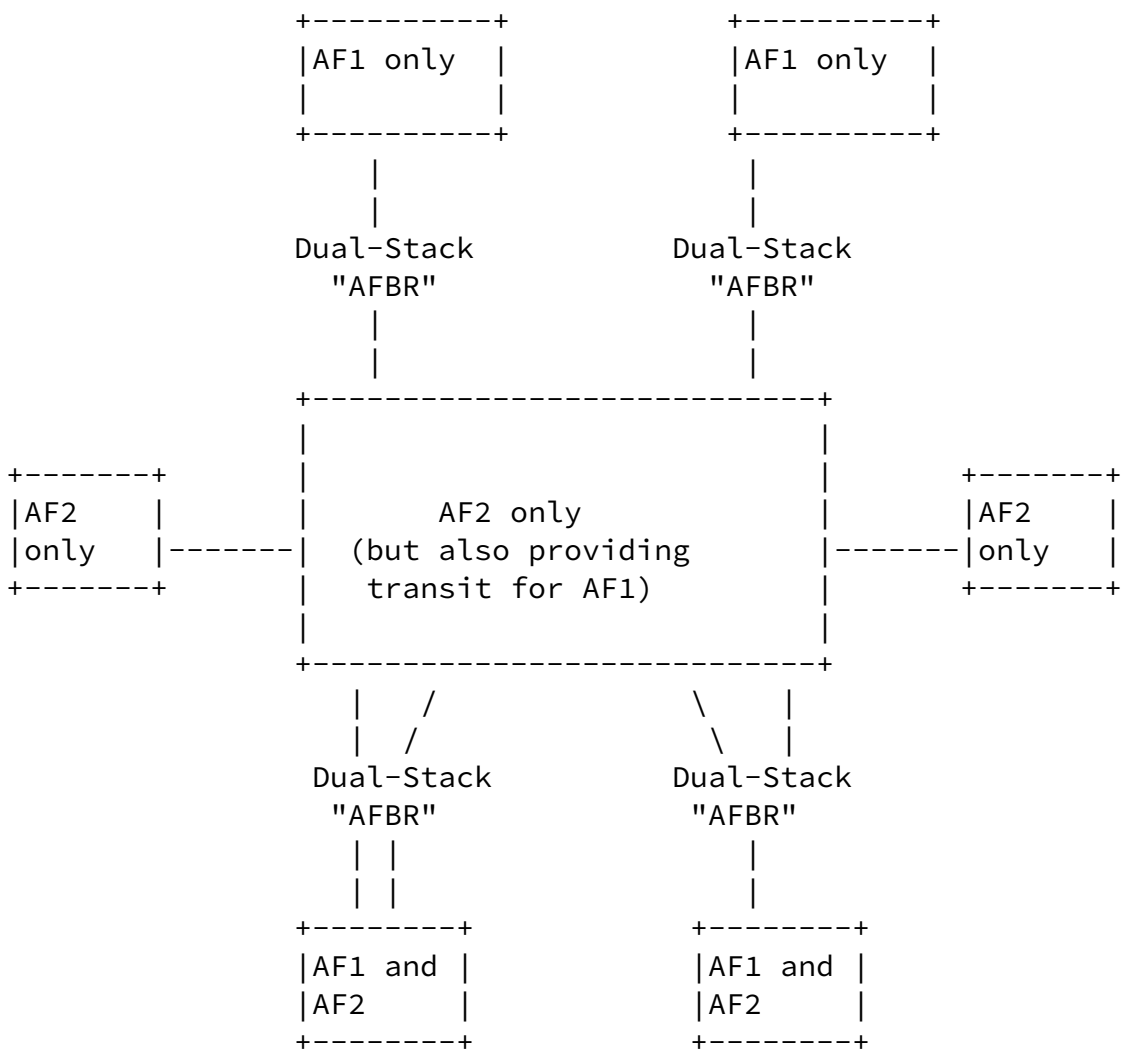


Figure 5: Mesh Topology

The situation in which a pair of border routers use BGP to exchange routing information that is not known to the core routers is sometimes known, somewhat misleadingly, as a "BGP-free core". In this sort of scenario, the problems to be solved are (a) to make sure that the BGP-distributed routing updates for AF1 allow a given AFBR, say AFBR1, to see that the path for a given AF1 address prefix is through a second AFBR, say AFBR2, and (b) to provide a way in which AFBR1 can send AF1 packets through the AF2-only core to AFBR2. Of course, sending AF1 packets through an AF2-only core requires the AF1 packets to be encapsulated and sent through "tunnels"; these tunnels are the entities known as "softwires".

One of the goals of the mesh problem is to provide a solution which does not require changes in any routers other than the AFBRs. This would allow a carrier (or large enterprise networks acting as carrier for their internal resources) with an AF2-only backbone to provide

AF1 transit services for its clients, without requiring any changes

whatsoever to the clients' routers, and without requiring any changes to the core routers. The AFBRs are the only devices that perform dual-stack operations, and the only devices that encapsulate and/or decapsulate the AF1 packets in order to send and/or receive them on softwires.

It may be recognized that this scenario is very similar to the scenario handled by the L3VPN solution described in RFC 4364. The AFBRs correspond to the "Provider Edge Routers" (PE) of RFC 4364. In those L3VPN scenarios, the PEs exchange routing information in an address family (e.g., the VPN-IPv4 address family), but they send VPN data packets through a core which does not have the VPN routing information. However, the Softwires problem is NOT focused on the situation in which the border routers maintain multiple private and/or overlapping address spaces. Techniques which are specifically needed to support multiple address spaces are in the domain of L3VPN, rather than in the domain of Softwires.

Note that the AFBRs may be multiply connected to the core network, and also may be multiply connected to the client networks. Further, the client networks may have "backdoor connections" to each other, through private networks or through the Internet.

3.2. Scaling

In the mesh problem, the number of AFBRs a backbone network supporting only AF2 will need is approximately on the order of the number of AF1 networks to which it connects. (This is really an upper limit, since a single AFBR can connect to many such networks.)

An AFBR may need to exchange a "full Internet's" worth of routing information with each network to which it connects. If these networks are not VPNs, the scaling issues associated with the amount of routing information are just the usual scaling issues faced by the border routers of any network which is providing Internet transit services. (If the AFBRs are also attached to VPNs, the usual L3VPN scaling issues apply, as discussed in RFC 4364 and RFC4365.) The number of BGP peering connections can be controlled through the usual methods, e.g., use of route reflectors.

3.3. Persistence, Discovery and Setup Time

AFBRs may discover each other, and may obtain any necessary information about each other, as a byproduct of the exchange of routing information (essentially in the same way that PE routers discovery each other in L3VPNs). This may require the addition of new protocol elements or attributes to existing protocols.

The softwires needed to allow packets to be sent from one AFBR to another should be "always available", i.e., should not require any extended setup time that would impart an appreciable delay to the data packets.

3.4. Multicast

If the AF2 core does not provide native multicast services, multicast between AF1 client networks should still be possible, even though it may require replication at the AFBRs and unicasting of the replicated packets through Softwires. If native multicast services are enabled, it should be possible to use these services to optimize the multicast flow.

3.5. Softwire Encapsulation

The solution to the mesh problem must not require the use of any one encapsulation. Rather, it must accommodate the use of a variety of different encapsulation mechanisms, and a means for choosing the one to be used in any particular circumstance based on policy.

In particular, the solution to the mesh problem must allow for at least the following encapsulations to be used: L2TPv3, IP-in-IP, MPLS (LDP-based and RSVP-TE based), GRE, and IPsec. The choice of encapsulation is to be based on policy, and the policies themselves may be based on various characteristics of the packets, of the routes, or of the softwire endpoints themselves.

3.6. Security

In the mesh problem, the routers are not advertising routes for individual users. So the mesh problem does not require the fine-grained authentication that is required by the hub and spoke problem.

There should however be a way to provide various levels of security for the data packets being transmitted on a softwire. The softwire solution must support IPsec and an IPsec profile must be defined. (see recommendations in [I-D.bellovin-useipsec]).

Security mechanisms for the control protocols are also required. It must be possible to protect control data from being modified in flight by an attacker, and to prevent an attacker from masquerading as a legitimate control protocol participant.

The verification of the reachability information exchanged and issues surrounding the security of routing protocols themselves is outside the scope of the specification.

4. Security Considerations

Security considerations specific to the "Hubs and Spokes" and "Mesh" models appear in those sections of the document.

As with any tunneling protocol, using this protocol may introduce a security issue by circumventing a site security policy implemented as ingress filtering, since these filters will only be applied to STH AF IP headers.

5. IANA Considerations

There are no IANA actions requested in this specification.

6. Changes from -01

1. Detailed mailing list comments from Jordi Palet Marinez (2006/03/07).

2. Detailed mailing list comments from Pekka Savola (2006/05/03).

7. Changes from -00

1. Individual-draft authors moved to Authors section, and added an acknowledgements section.

2. Detailed mailing list comments from Alain Baudot (2005/12/20).

3. Detailed mailing list comments from Pekka Savola (2005/12/22).

4. Detailed mailing list comments from Laurent Toutain (2005/12/26).

5. Detailed mailing list comments from Francis Dupont (editorial) (2005/12/29).

6. Detailed mailing list comments from Francis Dupont (non-editorial) (2005/12/29).

7. Detailed mailing list comments from Tom Pusateri (2005/12/29).

8. Detailed mailing list comments from Tom Alain Durant (2005/12/30).

9. Changed all occurances of "HGW" to "CPE" and added definitio

10. Removed all occurances of "TEP" (which seemed to be a synonym for concentrator anyway).

11. Changed all occurances of "ISP" to be "operator".

12. Removed all RFC 2119 language from the specification (since it's a problem statement).

13. Further linguistic clarificatons and edits (2006/01 and 02)

14. Remove Compare and Contrast section after discussion w/ authors (2006/02/19)

8. Acknowledgements

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Figure 12

8.2. Contributors

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Tunnel-based transition mechanisms have been under discussion in the IETF for more than a decade. Initial work related to softwire can be found in RFC3053. The earlier "V6 Tunnel Configuration" BOF problem statement [I-D.palet-v6tc-goals-tunneling] includes a reasonable pointer to prior work.

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