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Softwire Problem Statement
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Status of this Memo

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Abstract

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. At the highest level, the Softwires Working Group is tasked to identify, and extend where necessary, standard protocols to support 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 as part of a solution phase

following the completion of this document, within a relatively tight "time-to-market" as requested by operators at IETF 63. Some individual requirements (and non-requirements) are also identified in this document at times in order to better describe the specific scope for a given problem definition.

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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 is describing the scenarios that the Working Group is going to focus on leading toward defining solutions. 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 non-ephemeral 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 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).

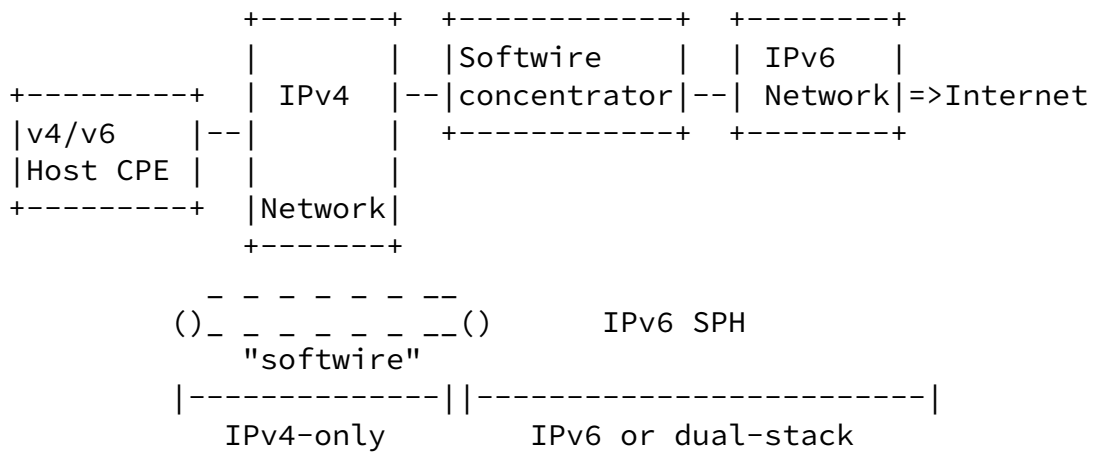
2. Hubs and Spokes Problem

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.

In some applications, manually configured tunnels (as described in

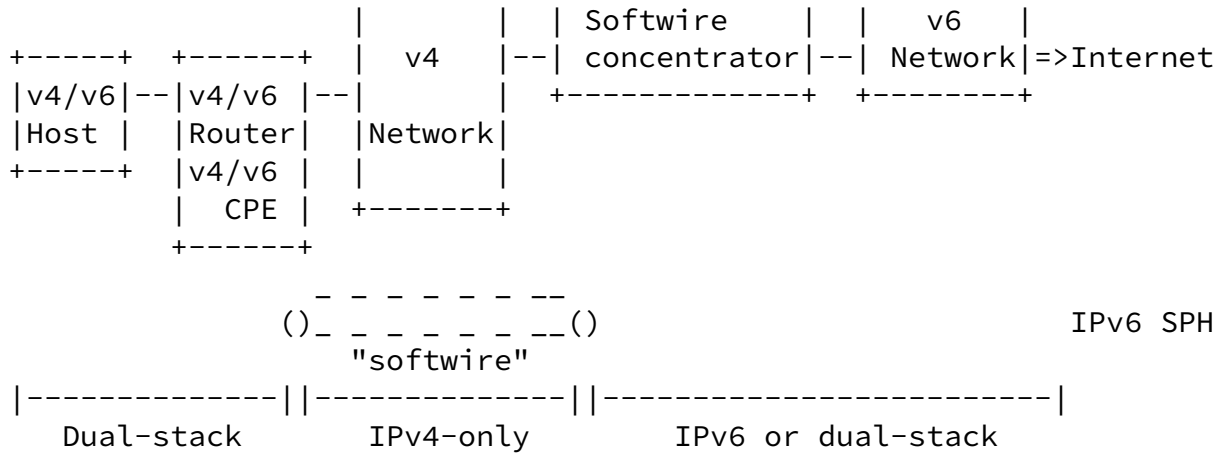
[RFC4213] are sufficient as a transition mechanism. For a variety of reasons (for example, use of dynamic IP addresses, and NAT traversal), other solutions are also necessary.

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



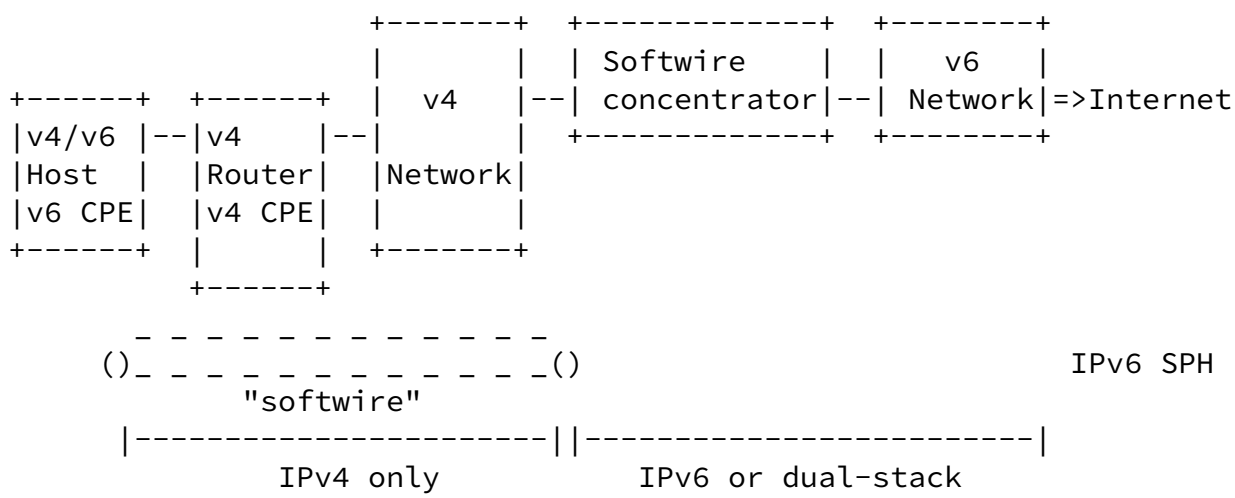
Case 1: IPv6 connectivity across an IPv4-only access network (STH). Softwire initiator is the host CPE (directly connected to a modem), which is dual-stack. There is no other gateway device. The IPv4 traffic should not traverse the softwire.

Figure 1: Case 1



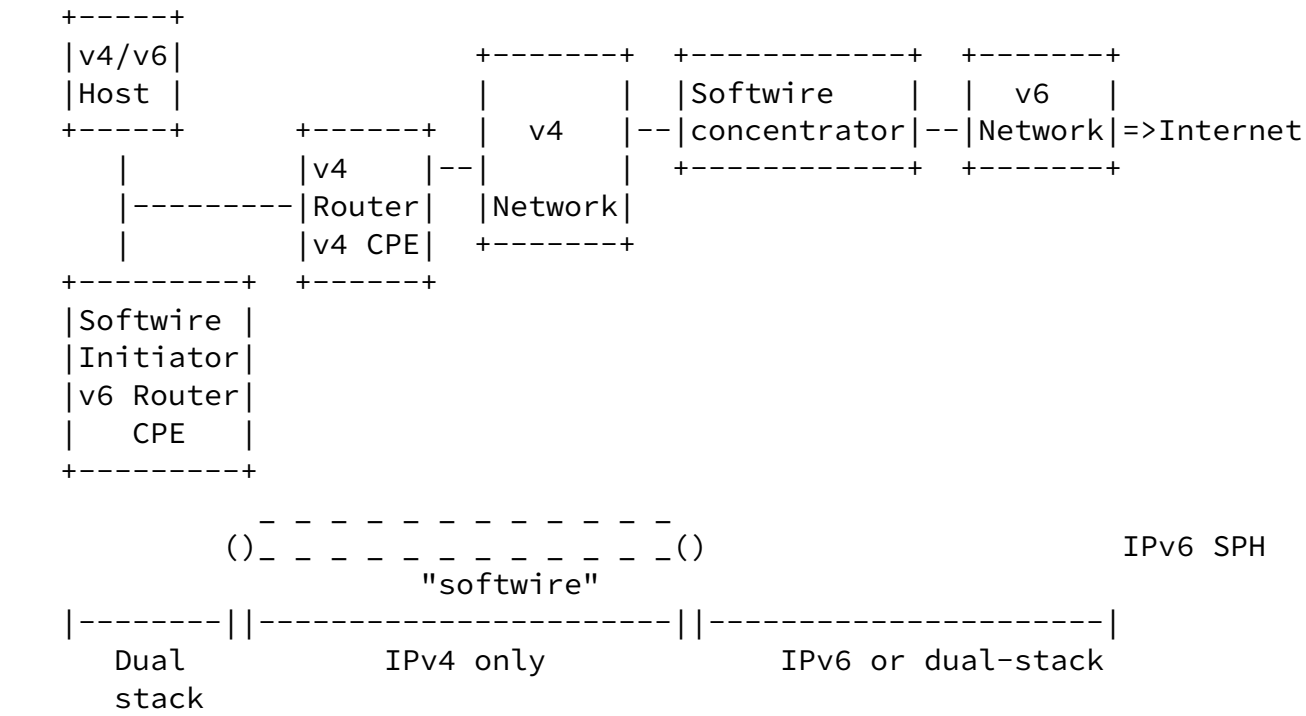
Case 2: IPv6 connectivity across an IPv4-only access network (STH). Softwire initiator is the router CPE, which is a dual-stack device. The IPv4 traffic should not traverse the softwire.

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").

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.

If the NAT is not in the home gateway, but in carrier equipment located at the other end of the access link (typically in an carrier POP), support for NAT traversal is still required.

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. Also, if the softwire has to be established from a node behind a CPE router, that node IP address can also be dynamically assigned. In cases where static IP addresses are unavailable, dynamic addresses are a problem for some Internet accessible services. Solutions like external dynamic DNS and dynamic NAT port forwarding have been deployed, but it would be simpler if, in IPv6 networks, a static prefix was delegated to the customer, even in the case of single node network. That prefix would allow for the registration of stable

addresses in the DNS and also enough room to use either 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. Note also that the IP addresses of the softwire link itself do not need to be stable, as, even if a single PC is attached behind it, a /64 prefix will be delegated.

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 Neighbor Discovery or DHCPv6.

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.

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 simply any kind of node (host, appliance, sensor, etc.).

The softwire initiator does not have to be always the same node and/or always have been delegated the same IP address. In particular, softwires should work in the nomadic case (e.g. a user opening up his laptop in various Wi-Fi hot-spots), since 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 original carrier.

IPv4 provider can also periodically change the IPv4 address allocated to the gateway. The softwire initiator has to discover in a reasonable period of time that the tunnel is down and restart tunnel establishment. 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. An carrier may deploy several softwire concentrators (for example one per POP) for scalability reasons. A softwire concentrator is in practice a dual-stack router connected to the dual-stack core of the carrier or directly to the upstream providers. Softwire concentrators are not nomadic and have stable IP addresses. It may be the case that one of the address families is not natively supported, even if this is not optimal, in the softwire concentrator, but instead by means of tunnels to the upstreams (or other networks).

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). DNS redirection and/or local anycast addresses among other choices, coupled with the (to-be-determined) softwire concentrator discovery solution will enable sharing the load among 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

Existing multicast solutions can be used over the softwire. Typically, such solution would be either Multicast Listener Discovery/Internet Group Membership Protocol proxy [I-D.ietf-magma-igmp-proxy] or Protocol-Independent 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. Other encapsulations, like IPv6/IPv6 or IPv4/IPv4, are nice to have but not on the critical path. There is no intention to place limits on additional encapsulations beyond those explicitly mentioned in this specification.

3. Mesh Problem

The "Mesh" problem is named in reference to typical routing problems in which there are more than one paths to a destination and a routing

protocol is needed to select the best path. It is also extremely similar to the problems that the L3VPN Working Group is tackling in which reduced, private and/or overlapping virtual routing and forwarding tables are announced. The key difference is that the reachability that must be announced across the transit core will include more than VPN address family routes.

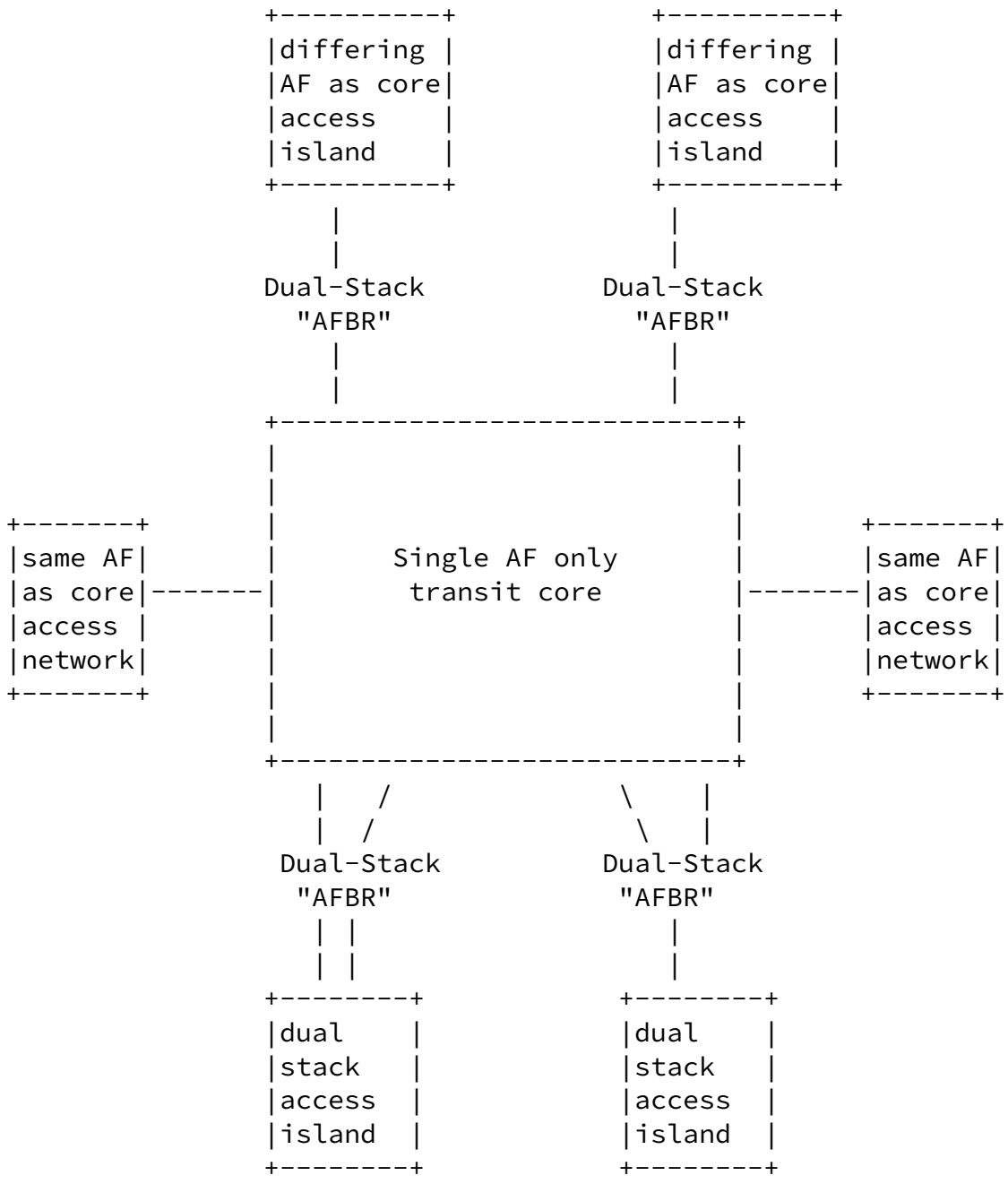


Figure 5: Mesh Topology

3.1. Mesh Description

In this problem, carriers (or large enterprise networks acting as carrier for their internal resources) may be required to establish connectivity to 'islands' of networks of one address family type across a transit core of a differing address family type. For an example, see Figure 5. To provide reachability across the transit core, dual-stack devices are installed that act as "Address Family Border Routers." These AFBRs can be performing peering across autonomous systems or, performing as Provider Edge routers (PE) in VPN parlance within an autonomous system. With respect to deployment considerations, the islands do not have to be upgraded at the time of deploying the transit core and interwork as if there was no awareness of the AFBR.

The AFBRs are the only devices in the carrier's network that must be able to perform dual-stack operations and setup and encapsulate softwires in a mesh to the other islands. They then pass reachability information as appropriate according to policy. They may be multiply connected to the transit network and thus, have to be able to exchange appropriate information and make a routing selection choice as to the best exit point. Note that this creates multipoint-to-point reachability using a point-to-point logical overlay of softwire connectivity.

It should also be noted that the mesh problem can be considered as a derivative of L3VPN, where the core provides transit in one address family and the islands are connected via L3VPN of another address family. This analogy only holds true if the islands can to be represented as VPNs. In general, the diagrams frequently used for L3VPNs is very similar. The key point is that the reachability information that is to be exchanged must not be limited to VPNs or any single AF or SAF or combination of AF/SAF. The solution must be generic enough to carry any AF or SAF.

In the future a tunnel concentrator may be a different device than the AFBR that is announcing reachability. In that future phase, the AFBR may need to announce a third party tunnel concentrator.

3.2. Scaling

In the mesh problem, the number of AFBRs is on the order of the number of islands though it should be clear that a single AFBR could handle many islands if the islands have distinct routing and forwarding tables. A primary issue in the Mesh problem is that the size of the routing tables exchanged between the islands is of the order of the 'full Internet' (with respect to the island's native

Address Family) plus any VPNs. These tables plus the routing tables

associated with the transit core (and VPNs of the same AF as the transit core) must be stored on the AFBRs. The number of peering points of an AFBR will be on the order of the number of Autonomous System Border Routers (ASBRs), which are assumed to be multiply peered to the transit core (multi-homed) for reliability. An island can also have multiple AFBRs for reliability as well. Both the island or the transit core may contain route reflectors or hierarchical routing with impunity.

An AFBR should be able to pass route filters of data or routing tables it does not wish to receive. Peering AFBRs must adhere to the route or route table filters and not send reachability information. Other attributes that can be sent from one AFBR to the other may include "no export" or similar mechanisms to prevent subsequent reannouncements of reachability information. The scaling of the information to be exchanged is on the order of similar data exchanged for L3VPNs.

3.3. Persistence, Discovery and Setup Time

Discovery of the AFBRs and softwire encapsulation could be accomplished by the routing protocol during capability advertisement. An alternative is that the endpoints could be passed in new data formats or attributes, within a routing protocol.

The duration of the softwire for inter-island reachability is considered to be as long as the duration of the peering session. Thus, dynamicity is very low. The setup time should be on the order of the same duration to setup L3VPNs.

3.4. Address Family/SAF Reachability

It has been reported that the softwires to connect the islands will need to be able to perform IPv4/IPv6, IPv6/IPv4 and be able to exchange multicast and VPN routing tables. The islands will need to be able to perform multicast routing and if the transit core does not provide native multicast services, the "classic" multicast solutions can be used over the softwires. If native multicast services are enabled, further work may need to be accomplished to optimize the multicast forwarding path, receiver transmission load or receiver

load.

3.5. Softwire Encapsulation

In the strictest sense, the softwire encapsulation has to be dual stack. There is no requirement that only one encapsulation technique must be used. It could be possible to have more than one available at each AFBR. The AFBR must be able to prioritize which

encapsulation technique it will use if there is more than one available.

The encapsulations used to traverse the transit core must be enabled to handle a choice of methods. Common choices that should create a minimal set would include: L2TPv3, IP in IP, MPLS, IPsec, GRE. The choice of encapsulation must not be subject to either an island or peer-wise limitation. Different AF/SAF combinations must be able to be encapsulated differently according to the requirements of the network deployment. For example, IPv4 unicast may be encapsulated in MPLS while IPv4 VPNs may be encapsulated in IPsec or L2TPv3. This flexibility should not cause multiple peering sessions although it is not precluded that this may be the desired network deployment. There must be a scheme in which preferencing the encapsulation to be used is exchanged between peers. Also, once the softwire encapsulation is established a minimal amount of information must be passed with reachability information to connect the AF/SAF reachability to softwire. The linking of reachability information should not be passed on a per route basis.

3.6. Security

In contrast with the hubs and spokes problem, routers are advertising route for relatively large network islands, not individual users, so fine-grained authentication is not necessary. However the solution should support security of the softwire mechanism itself or the softwire data plane or both.

In the softwire initialization mechanism, the softwire solution must support authentication, but an carrier may decide to turn it off in some circumstances. This means that if a routing protocol is used to advertise the softwire encapsulation, it must also support authentication.

In the data plane, the softwire solution must support IPsec and an IPsec profile must be defined. (see recommendations in [I-D.bellovin-useipsec]).

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

3.7. Operations and Management

There have been no reports of NATs between the AFBRs (in the transit core) so a NAT detection solution is not needed.

Other O&M needed features include:

- Usage accounting

- End-point failure detection (must be encapsulated within the tunnel in the transmitting direction)

- Path failure detection

Upon failure of a softwire, all reachability information must be withdrawn or a backup path used immediately.

3.8. Address Family Encapsulations

IPv6/IPv4, IPv4/IPv6 and overlapping address space as defined in the L3VPN working group (including overlapping RFC-1918 private address space) are on the critical path for "Mesh" softwires. Other encapsulations, like IPv6/IPv6, IPv4/IPv4 or IP-only LAN Service (IPLS) as defined in the L2VPN working group, are nice to have but not on the critical path.There is no intention to place limits on additional encapsulations beyond those explicitly mentioned in this 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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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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