           Unified IPv4-in-IPv6 Softwire Customer Premises Equipment (CPE):
                    A DHCPv6-Based Prioritization Mechanism

Abstract

   In IPv6-only provider networks, transporting IPv4 packets
   encapsulated in IPv6 is a common solution to the problem of IPv4
   service continuity. A number of differing functional approaches have
   been developed for this, each having their own specific
   characteristics. As these approaches share a similar functional
   architecture and use the same data plane mechanisms, this memo
   specifies a DHCPv6 option, whereby a single instance of Customer
   Premises Equipment (CPE) can interwork with all of the standardized
   and proposed approaches to providing encapsulated IPv4-in-IPv6
   services by providing a prioritization mechanism.

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   This is an Internet Standards Track document.

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1. Introduction

   IPv4 service continuity is one of the major technical challenges that
   must be considered during IPv6 migration. Over the past few years, a
   number of different approaches have been developed to assist with
   this problem (e.g., as described in [RFC6333], [RFC7596], and
   [RFC7597]). These approaches, referred to as "S46 mechanisms" in
   this document, exist in order to meet the particular deployment,
   scaling, addressing, and other requirements of different service
   providers' networks.

   A common feature shared among all of the differing modes is the
   integration of softwire tunnel endpoint functionality into the
   Customer Premises Equipment (CPE) router. Due to this inherent data
   plane similarity, a single CPE may be capable of supporting several
   different approaches. Users may also wish to configure a specific
   mode of operation.

   A service provider's network may also have more than one S46
   mechanism enabled in order to support a diverse CPE population with
   differing client functionality, such as during a migration between
   mechanisms or where services require specific supporting softwire
   architectures.

   For softwire-based services to be successfully established, it is
   essential that the customer's end node and the service provider's end
   node and provisioning systems are able to indicate their capabilities
   and preferred mode of operation.

   A number of DHCPv6 options for the provisioning of softwires have
   been standardized:

   RFC 6334 Defines DHCPv6 option 64 for configuring Basic Bridging
             BroadBand (B4) [RFC6333] elements with the IPv6 address of
             the Address Family Transition Router (AFTR) [RFC6333].

   RFC 7341 Defines DHCPv6 option 88 for configuring the address of a
             DHCPv4-over-DHCPv6 server, which can then be used by a
             softwire client for obtaining further configuration.

   RFC 7598 Defines DHCPv6 options 94, 95, and 96 for provisioning
             Mapping of Address and Port with Encapsulation (MAP-E)
             [RFC7597], Mapping of Address and Port using Translation
             (MAP-T) [RFC7599], and Lightweight 4over6 [RFC7596]
             respectively.

This document describes a DHCPv6-based prioritization method, whereby a CPE that supports several S46 mechanisms and receives configuration for more than one can prioritize which mechanism to use. The method requires no server-side logic to be implemented and only uses a simple S46 mechanism prioritization to be implemented in the CPE.

The prioritization method as described here does not provide redundancy between S46 mechanisms for the client. That is, if the highest priority S46 mechanism that has been provisioned to the client is not available for any reason, the means for identifying this and falling back to the S46 mechanism with the next highest priority is not in the scope of this document.

1.1. Terminology

This document makes use of the following terms:

o Address Family Transition Router (AFTR): The IPv4-in-IPv6 tunnel termination point and the Network Address Translator IPv4/IPv4 (NAT44) function deployed in the operator's network [RFC6333].

o Border Relay (BR): A MAP-enabled router managed by the service provider at the edge of a MAP domain. A BR has at least an IPv6-enabled interface and an IPv4 interface connected to the native IPv4 network [RFC7597].

o Customer Premises Equipment (CPE): Denotes the equipment at the customer edge that terminates the customer end of an IPv6 transitional tunnel. In some documents (e.g., [RFC7597]), this functional entity is called the Customer Edge (CE).

1.1.1. 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].

1.2. Rationale

The following rationale has been adopted for this document:

(1) Simplified solution migration paths: Define unified CPE behavior, allowing for smooth migration between the different S46 mechanisms.

(2) Deterministic CPE coexistence behavior: Specify the behavior when several S46 mechanisms coexist in the CPE.

   (3) Deterministic service provider coexistence behavior: Specify the
        behavior when several modes coexist in the service providers
        network.

   (4) Reusability: Maximize the reuse of existing functional blocks
        including tunnel endpoints, the port-restricted Network Address
        Port Translator IPv4/IPv4 (NAPT44), forwarding behavior, etc.

   (5) Solution agnostic: Adopt neutral terminology and avoid (as far
        as possible) overloading the document with solution-specific
        terms.

   (6) Flexibility: Allow operators to compile CPE software only for
        the mode(s) necessary for their chosen deployment context(s).

   (7) Simplicity: Provide a model that allows operators to only
        implement the specific mode(s) that they require without the
        additional complexity of unneeded modes.

1.3. DHCPv6 S46 Priority Option

   The S46 Priority Option is used to convey a priority order of IPv4
   service continuity mechanisms. Figure 1 shows the format of the S46
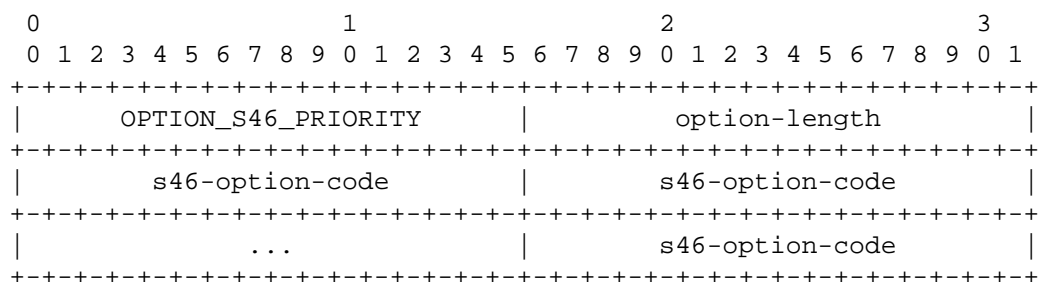   Priority Option.

```
    0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      OPTION_S46_PRIORITY       |          option-length        |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |        s46-option-code         |        s46-option-code        |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |             ...               |        s46-option-code         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

                      Figure 1: S46 Priority Option

   o option-code: OPTION_S46_PRIORITY (111)

   o option-length: >=2 and a multiple of 2, in octets.

   o s46-option-code: 16-bit IANA-registered option code of the DHCPv6
      option that is used to identify the softwire mechanism. S46
      mechanisms are prioritized in the appearance order in the S46
      Priority Option.

Codes in OPTION_S46_PRIORITY are processed in order; if a client
receives more than one s46-option-code with a particular value, it
should consider this case to be invalid. DHCP servers MAY validate
the list of s46-option-code values to detect invalid values and
duplicates. The option MUST contain at least one s46-option-code.

1.4. DHCPv6 Client Behavior

Clients MAY request the OPTION_S46_PRIORITY option, as defined in
[RFC3315], Sections 17.1.1, 18.1.1, 18.1.3, 18.1.4, 18.1.5, and 22.7.
As a convenience to the reader, we mention here that the client
includes requested option codes in the Option Request Option.

Upon receipt of a DHCPv6 Advertise message from the server containing
OPTION_S46_PRIORITY, the client performs the following steps:

1. Check the contents of the DHCPv6 message for options containing
    valid S46 mechanism configuration. A candidate list of possible
    S46 mechanisms is created from these option codes.

2. Check the contents of OPTION_S46_PRIORITY for the DHCPv6 option
    codes contained in the included s46-option-code fields. From
    this, an S46 mechanism priority list is created, ordered from
    highest to lowest following the appearance order.

3. Sequentially check the priority list against the candidate list
    until a match is found.

4. When a match is found, the client MUST configure the resulting
    S46 mechanism.

In the event that no match is found between the priority list and the
candidate list, the client MAY proceed with configuring one or more
of the provisioned S46 softwire mechanism(s). In this case, which
mechanism(s) are chosen by the client is implementation specific and
not defined here.

If an invalid OPTION_S46_PRIORITY option is received, the client MAY
proceed with configuring the provisioned S46 mechanisms as if
OPTION_S46_PRIORITY had not been received.

If an unknown option code is received in the OPTION_S46_PRIORITY
option, the client MUST skip it and continue processing other listed
option codes if they exist. The initial option codes that are
allowed to be included in an OPTION_S46_PRIORITY option are listed in
Section 4.1.

1.5. DHCPv6 Server Behavior

   Sections 17.2.2 and 18.2 of [RFC3315] govern server operation in
   regard to option assignment. As a convenience to the reader, we
   mention here that the server will send a particular option code only
   if configured with specific values for that option code and if the
   client requested it.

   Option OPTION_S46_PRIORITY is a singleton. Servers MUST NOT send
   more than one instance of the OPTION_S46_PRIORITY option.

2. Operator Deployment Considerations for Deploying Multiple Softwire
    Mechanisms

   The following subsections describe some considerations for operators
   who are planning on implementing multiple softwire mechanisms in
   their network (e.g., during a migration between mechanisms).

2.1. Client Address Planning

   As an operator's available IPv4 resources are likely to be limited,
   it may be desirable to use a common range of IPv4 addresses across
   all of the active softwire mechanisms. However, this is likely to
   result in difficulties in routing ingress IPv4 traffic to the correct
   Border Relay (BR) / AFTR instance, which is actively serving a given
   CE. For example, a client that is configured to use MAP-E may send
   its traffic to the MAP-E BR; however, on the return path, the ingress
   IP traffic gets routed to a MAP-T BR. The resulting translated
   packet that gets forwarded to the MAP-E client will be dropped.

   Therefore, operators are advised to use separate IPv4 pools for each
   of the different mechanisms to simplify planning and IPv4 routing.

   For IPv6 planning, there is less of a constraint as the BR/AFTR
   elements for the different mechanisms can contain configuration for
   overlapping the client's IPv6 addresses, provided that one mechanism
   is actively serving a given client at a time. However, the IPv6
   address that is used as the tunnel concentrator's endpoint (BR/AFTR
   address) needs to be different for each mechanism to ensure correct
   operation.

2.2. Backwards Compatability with Existing Softwire Clients

   Deployed clients that can support multiple softwire mechanisms, but
   do not implement the prioritization mechanism described here may
   require additional planning. In this scenario, the CPE would request
   configuration for all of the supported softwire mechanisms in its
   DHCPv6 Option Request Option (ORO), but would not request

   OPTION_S46_PRIORITY. By default, the DHCPv6 server will respond with
   configuration for all of the requested mechanisms, which could result
   in unpredictable and unwanted client configuration.

   In this scenario, it may be necessary for the operator to implement
   logic within the DHCPv6 server to identify such clients and only
   provision them with configuration for a single softwire mechanism.
   It should be noted that this can lead to complexity and reduced
   scalability in the DHCPv6 server implementation due to the additional
   DHCPv6 message processing overhead.

3. Security Considerations

   Security considerations discussed in [RFC6334] and [RFC7598] apply
   for this document.

   Misbehaving intermediate nodes may alter the content of the S46
   Priority Option. This may lead to setting a different IPv4 service
   continuity mechanism than the one initially preferred by the network
   side. Also, a misbehaving node may alter the content of the S46
   Priority Option and other DHCPv6 options (e.g., DHCPv6 Option 64 or
   90) so that the traffic is intercepted by an illegitimate node.
   Those attacks are not unique to the S46 Priority Option but are
   applicable to any DHCPv6 option that can be altered by a misbehaving
   intermediate node.

4. IANA Considerations

   IANA has allocated the following DHCPv6 option code:

      111 OPTION_S46_PRIORITY

   All values should be added to the DHCPv6 option code space defined in
   Section 24.3 of [RFC3315].

4.1. S46 Mechanisms and Their Identifying Option Codes

   IANA has created a new registry titled "Option Codes permitted in the
   S46 Priority Option". This registry enumerates the set of DHCPv6
   option codes that can be included in the OPTION_S46_PRIORITY option.
   Options may be added to this list using the IETF Review process
   described in Section 4.1 of [RFC5226].

   The following table shows the option codes that are currently defined
   and the S46 mechanisms that they represent. The contents of this
   table shows the format and the initial values for the new registry.
   Option codes that have not been requested to be added according to
   the stated procedure should not be mentioned at all in the table, and

they should not be listed as "reserved" or "unassigned". The valid
range of values for the registry is the range of DHCPv6 option codes
(1-65535).

```
+-------------+-------------------+----------+
| Option Code |   S46 Mechanism   | Reference |
+-------------+-------------------+----------+
|      64     |      DS-Lite      | [RFC6334] |
|      88     | DHCPv4 over DHCPv6 | [RFC7341] |
|      94     |       MAP-E       | [RFC7598] |
|      95     |       MAP-T       | [RFC7598] |
|      96     | Lightweight 4over6 | [RFC7598] |
+-------------+-------------------+----------+
```

Table 1: DHCPv6 Option to S46 Mechanism Mappings

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5.1. Normative References

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