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RADIUS Attribute for Softwire Address plus Port based Mechanisms
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Abstract

IPv4-over-IPv6 transition mechanisms provide both IPv4 and IPv6 connectivity services simultaneously during the IPv4/IPv6 co-existing period. The Dynamic Host Configuration Protocol for IPv6 (DHCPv6) options have been defined to configure Customer Edge (CE) in MAP-E, MAP-T, Lightweight 4over6 and PREFIX64 option for Multicast Basic Bridging BroadBand (mB4) in multicast scenarios. However, in many networks, the configuration information may be stored in an Authentication Authorization and Accounting (AAA) server, while user configuration information is mainly provided by the Broadband Network Gateway (BNG) through the DHCPv6 protocol. This document defines two new Remote Authentication Dial In User Service (RADIUS) attributes that carry CE or mB4 configuration information from an AAA server to BNG.

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Table of Contents

1. Introduction 3
2. Terminology 4
3. Configuration process with RADIUS 4
4. Attributes 7
  4.1. Softwire46-Configuration Attribute 7
  4.2. S46 Container Options 8
  4.3. Sub Options for S46 Container Option 9
    4.3.1. S46-Rule Sub Option 9
    4.3.2. S46-BR Sub Option 10
    4.3.3. S46-DMR Sub Option 11
    4.3.4. S46-V4V6Bind Sub Option 12
    4.3.5. S46-PORTPARAMS Sub Option 13
  4.4. Sub Options for S46-Rule Sub Option 13
    4.4.1. Rule-IPv6-Prefix Sub Option 13
    4.4.2. Rule-IPv4-Prefix Sub Option 14
    4.4.3. EA Length Sub Option 15
  4.5. Sub Options for S46-v4v6Bind Sub Option 15
    4.5.1. The IPv4-address Sub Option 15
    4.5.2. The Bind-IPv6-Prefix Sub Option 15
  4.6. Sub Options for S46-PORTPARAMS Sub Option 16
    4.6.1. The PSID-offset Sub Option 16
    4.6.2. The PSID-len Sub Option 17
    4.6.3. The PSID Sub Option 17
  4.7. Softwire46 Sub Options Encapsulation 17
  4.8. Softwire46-Priority Attribute 18
  4.9. Softwire46-Multicast Attribute 18

4.9.1. ASM-Prefix64 TLV 20
4.9.2. SSM-Prefix64 TLV 21
4.9.3. U-Prefix64 TLV 22
4.10. Table of attributes 23
5. Diameter Considerations 24
6. IANA Considerations 24
6.1. S46 Mechanisms and Their Identifying Option Codes 25
7. Security Considerations 25
8. Acknowledgements 26
9. References 26
9.1. Normative References 26
9.2. Informative References 27
Additional Authors 29
Authors' Addresses 30

1. Introduction

Recently providers have started to deploy IPv6 and consider how to transit to IPv6. Many IPv4 service continuity mechanisms based on the Address plus Port (A+P) [RFC6346] have been proposed for running IPv4 over IPv6-only infrastructure. Mapping of Address and Port with Encapsulation (MAP-E)[RFC7597] and Mapping of Address and Port using Translation (MAP-T)[RFC7599] are stateless mechanisms for running IPv4 over IPv6-only infrastructure. Lightweight 4over6 [RFC7596] is a hub-and-spoke IPv4-over-IPv6 tunneling mechanism, with complete independence of IPv4 and IPv6 addressing. MAP-E, MAP-T, and Lightweight 4over6 Customer Edge (CE) devices may be provisionned by mans of Dynamic Host Configuration Protocol for IPv6 (DHCPv6) [RFC3315]. In particualr, the CE uses DHCPv6 options to discover the Border Relay (BR) and retrieve Softwire46 (S46) configurations.

[RFC8114] specifies a generic solution for delivery of IPv4 multicast services to IPv4 clients over an IPv6 multicast network. The solution applies also for lw4o6 and MAP-E. [RFC8115] defines a DHCPv6 PREFIX64 option to convey the IPv6 prefixes to be used for constructing IPv4-embedded IPv6 addresses to inform the mB4 element of the PREFIX64. The following lists the multicast-related information that needs to be provisioned:

- o ASM Multicast Prefix64: the IPv6 multicast prefix to be used to synthesize the IPv4-embedded IPv6 addresses of the multicast groups in the Any-Source Multicast (ASM) mode.

- o SSM Multicast Prefix64: the IPv6 multicast prefix to be used to synthesize the IPv4-embedded IPv6 addresses of the multicast groups in the Source-Specific Multicast (SSM) [RFC4607] mode.

- o Unicast Prefix64: the IPv6 unicast prefix to be used in SSM mode for constructing the IPv4-embedded IPv6 addresses representing the IPv4 multicast sources in the IPv6 domain. Unicast Prefix64 may also be used to extract the IPv4 address from the received multicast data flows. The address mapping follows the guidelines documented in [RFC6052].

In many networks, user configuration information may be stored in an Authentication, Authorization, and Accounting (AAA) server. Currently, the AAA servers communicate using the Remote Authentication Dial In User Service (RADIUS) [RFC2865] protocol. In a fixed line broadband network, a Broadband Network Gateway (BNG) acts as the access gateway of users. The BNG is assumed to embed a DHCPv6 server function that allows it to locally handle any DHCPv6 requests initiated by hosts.

Since the S46 configuration information is stored in an AAA servers and user configuration information is mainly transmitted through DHCPv6 protocol between the BNGs and hosts/CEs, new RADIUS attributes are needed to propagate the information from the AAA servers to BNGs. The RADIUS attributes designed in this document are especially for the MAP-E[RFC7597], MAP-T[RFC7599] and Lightweight 4over6[RFC7596], providing enough information to form the correspondent DHCPv6 configuration options[RFC7598]. At the Section 4.9, a new RADIUS attribute is defined to be used for carrying the Multicast-Prefixes-64, based on the equivalent DHCPv6 option already specified in [RFC8115].

2. Terminology

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].

The terms DS-Lite multicast Basic Bridging BroadBand element (mB4) and the DS-Lite multicast Address Family Transition Router element (mAFTR) are defined in [RFC8114] .

3. Configuration process with RADIUS

The Figure 1 below illustrates how the RADIUS protocol and DHCPv6 co-operate to provide CE with MAP configuration information. The BNG acts as a RADIUS client and DHCPv6 server.

```
  CE                                BNG                          AAA Server
  |                                  |                                |
  |-------1.DHCPv6 Solicit-------> |                                |
  | (ORO w/container option code)  |                                |
  |                                  |-------2.Access-Request------->|
  |                                  | (S46-Configuration attribute  |
  |                                  |and/or S46-Multicast attribute)|
  |                                  |<------3.Access-Accept---------|
  |<---4.DHCPv6 Advertisement----- | (S46-Configuration attribute  |
  |      (container option)        |and/or S46-Multicast attribute)|
  |-------5.DHCPv6  Request------> |                                |
  |      (container Option)        |                                |
  |<------6.DHCPv6 Reply---------- |                                |
  |      (container option)        |                                |
  |                                  |                                |
                 DHCPv6                            RADIUS
```

Figure 1: the cooperation between DHCPv6 and RADIUS combining with RADIUS authentication

1. First, the CE may initiate a DHCPv6 Solicit message that includes an Option Request option(6) [RFC3315] with the S46 Container option codes as defined in[RFC7598]. As described in [RFC7598], OPTION_S46_CONT_MAPE should be included for MAP-E[RFC7597], OPTION_S46_CONT_MAPT for MAP-T [RFC7599], and OPTION_S46_CONT_LW for Lightweight 4over6 [RFC7596]. For the multicast case, OPTION_V6_PREFIX64 should be included for the delivery of multicast services in the context of transition to IPv6. Note however, that the ORO (Option Request option) with the S46 Container option code could be optional if the network was planned as being S46-enabled as default.

2. When the BNG receives the Solicit message, it should initiate a radius Access-Request message, in which an User-Name attribute (1) should be filled by a CE MAC address or interface-id or both, to the RADIUS server and a User-password attribute (2) should be filled by the shared password that has been preconfigured on the DHCPv6 server, requesting authentication as defined in [RFC2865] with the corresponding Softwire46-Configuration Attribute or Softwire46-Multicast Attribute , which will be defined in the next Section.

3. If the authentication request is approved by the AAA server, an Access-Accept message MUST be acknowledged with the corresponding Softwire46-Configuration Attribute or Softwire46-Multicast Attribute.

4. After receiving the Access-Accept message with the corresponding Attribute, the BNG SHOULD respond to the DHCPv6 Client (CE) with an Advertisement message.

5. After receiving the Advertise message, the CE MAY request for the corresponding S46 Container option, by including the S46 Container option in the Request message.

6. After receiving the client's Request message, containing the corresponding S46 Container option, the BNG SHOULD reply to the CE with the message containing the S46 Container option. The recommended format of the MAC address is defined as Calling-Station-Id (Section 3.20 in [RFC3580] without the SSID (Service Set Identifier) portion.

For Lightweight 4over6 [RFC7596], the subscriber's binding state should be synchronized between the AAA server and lwAFTR. If the bindings are pre-configured statically, in both the AAA server and lwAFTR, an AAA server does not need to configure the lwAFTR anymore. Otherwise, if the bindings are locally created on-demand in an AAA server, it should inform the lwAFTR with the subscriber's binding state, in order to synchronize the binding information of the lwB4 with the lwAFTR.

The authorization operation could also be done independently after the authentication process. In such a scenario, after the authentication operation, the client MAY initiate a DHCPv6 Request message that includes the corresponding S46 Container options. Similar to the above scenario, the ORO with the corresponding S46 Container option code in the initial DHCPv6 request could be optional if the network was planned as being S46-enabled by default. When the BNG receives the DHCPv6 Request, it SHOULD initiate the radius Access-Request message, which MUST contain a Service-Type attribute (6) with the value Authorize Only (17), the corresponding Softwire46-Configuration Attribute, and a State attribute obtained from the previous authentication process according to [RFC5080]. If the authorization request is approved by an AAA server, an Access-Accept message MUST be acknowledged with the corresponding Softwire46-Configuration Attribute. The BNG SHOULD then send the DHCPv6 Reply message containing the S46 Container option.

In both the above-mentioned scenarios, Message-authenticator (type 80) [RFC2869] SHOULD be used to protect both Access-Request and Access-Accept messages.

If the BNG does not receive the corresponding Softwire46-Configuration Attribute in the Access-Accept message it MAY fallback to a pre-configured default S46 configuration, if any.

If the BNG does not have any pre-configured default S46 configuration, or if the BNG receives an Access-Reject, then S46 connection cannot be established.

As specified in [RFC3315], section 18.1.4, "Creation and Transmission of Rebind Messages ", if the DHCPv6 server to which the DHCPv6 Renew message was sent at time T1 has not responded by time T2, the CE (DHCPv6 client) SHOULD enter the Rebind state and attempt to contact any available server. In this situation, the secondary BNG receiving the DHCPv6 message MUST initiate a new Access-Request message towards the AAA server. The secondary BNG MAY include the Softwire46-Configuration Attribute in its Access-Request message.

4. Attributes

This section defines the Softwire46-Configuration Attribute, Softwire46-Priority Attribute, and Softwire46-Multicast Attribute. The attribute design follows [RFC6158] and refers to [RFC6929].

The Softwire46-Configuration Attribute carries the configuration information for MAP-E, MAP-T, and Lightweight 4over6. The configuration information for each S46 mechanism is carried in the corresponding S46 Container option. Different sub options are required for each type of S46 Container option. The RADIUS attribute for Dual-Stack Lite [RFC6333] is defined in [RFC6519].

A client may be capable of supporting several different S46 mechanisms. Depending on the deployment scenario, a client might request for more than one S46 mechanism at a time. The Softwire46-Priority Attribute contains information allowing the client to prioritize which mechanism to use, corresponding to OPTION_S46_PRIORITY defined in [RFC8026].

The Softwire46-Multicast Attirbute conveys the IPv6 prefixes to be used in [RFC8114] to synthesize IPv4-embedded IPv6 addresses. The BNG SHALL use the IPv6 prefixes returned in the RADIUS Softwire46-Multicast Attirbute to populate the DHCPv6 PREFIX64 Option [RFC8115].

4.1. Softwire46-Configuration Attribute

The Softwire46-Configuration Attribute can only encapsulate S46 Container Option(s). The Softwire46-Configuration Attribute is structured as follows:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      Type     |    Length     |                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                               +
|                                                               |
+             S46 Container Option(s)                           +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Type
  TBD
Length
  2 + the length of the S46 Container option(s) specified in octets
S46 Container Option (s)
  A variable field that may contains one or more S46 Container option(s), defined in Section 4.2.

4.2. S46 Container Options

The S46 Container Option can only be encapsulated in the Softwire46-Configuration Attribute. Depending on the deployment scenario, a client might request for more than one transition mechanism at a time, there MUST be at least one S46 Container option encapsulated in one Softwire46-Configuration Attribute. There MUST be at most one instance of each type of S46 Container Option encapsulated in one Softwire46-Configuration Attribute.

```
                                                        /
                        /                      | 1.Rule-IPv6-Prefix
                       |                       |   Sub Option
                       | 1.S46-Rule Sub Option--+ 2.Rule-IPv4-Prefix
                       |                       |   Sub Option
                       | 2.S46-BR Sub Option   | 3.EA Length Sub
 S46 Container Option--+ 3.S46-DMR Sub Option   \  Option
                       |
                       |                            /1.IPv4-address
                       |                           |   Sub Option
                       | 4.S46-v4v6Bind Sub Option--| 2.Bind-IPv6-Prefix
                       |                            \  Sub Option
                       |                              /1.PSID-offset
                       |                             |   Sub Option
                       | 5.S46-PORTPARAMS Sub Option--| 2.PSID-len
                       |                             |   Sub Option
                        \                             \3.PSID Sub
                                                         Option
```

Figure 2: S46 Container Option Hierarchy

There are three types of S46 Container Options, namely MAP-E Container Option, MAP-T Container Option, Lightweight 4over6 Container Option. Each type of S46 Container Option contains a number of sub options, defined in Section 4.3. The hierarchy of the S46 Container Option is shown in Figure 2. Section 4.5 describes which Sub Options are mandatory, optional, or not permitted for each defined S46 Container Option.

There are three types of S46-Rule Sub Options, namely Basic Mapping Rule, Forwarding Mapping Rule, Basic and Forwarding Mapping Rule. Each type of S46-Rule Sub Option also contains a number of Sub Options. The Rule-IPv6-Prefix Sub Option is necessary for every type of S46-Rule Sub Option. It should appear for once and only once.

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      Type     |    Length     |                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                               +
|                                                               |
+                          Sub Options                          +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Type
TBD1 MAP-E Container Option
TBD2 MAP-T Container Option
TBD3 Lightweight 4over6 Container Option

Length
2 + the length of the Sub Options specified in octets

Sub Option
A variable field that contains necessary sub options defined in Section 4.3 and zero or several optional sub options, defined in Section 4.4.

NOTE: The Type values for each S46 Container Option are the same as the S46-option-code values of the corresponding S46 Mechanisms specified in Section 6.1.

4.3. Sub Options for S46 Container Option

4.3.1. S46-Rule Sub Option

The S46-Rule Sub Option can only be encapsulated in the MAP-E Container Option or the MAP-T Container Option. Depending on deployment scenario, one Basic Mapping Rule and zero or more Forwarding Mapping Rules MUST be included in one MAP-E Container Option or MAP-T Container Option.

Each type of S46-Rule Sub Option also contains a number of sub options, including Rule-IPv6-Prefix Sub Option, Rule-IPv4-Prefix Sub Option, and EA Length Sub Option. The structure of the sub options for S46-Rule Sub Option is defined in section 4.4.

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     SubType   |    SubLen     |                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                               +
|                                                               |
+                          Sub Options                          +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

SubType
  1 Basic Mapping Rule (Not Forwarding Mapping Rule)
  2 Forwarding Mapping Rule (Not Basic Mapping Rule)
  3 Basic & Forwarding Mapping Rule
SubLen
  2 + the length of the Sub Options specified in octets
Sub Option
  A variable field that contains sub options defined in Section 4.4.

4.3.2. S46-BR Sub Option

The S46-BR Sub Option an only be encapsulated in the MAP-E Container Option or the Lightweight 4over6 Container Option. There MUST be at least one S46-BR Sub Option included in each MAP-E Container Option or Lightweight 4over6 Container 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    SubType    |    SubLen     |                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                               +
|                                                               |
|                        BR-ipv6-address                        |
|                                                               |
+                               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

SubType
4 (SubType number, for the S46-BR sub option)
SubLen
18 (the length of the S46-BR sub option)
BR-ipv6-address
a fixed-length field of 16 octets that specifies the IPv6 address for the S46 BR.

4.3.3. S46-DMR Sub Option

The S46-DMR Sub Option can only appear in the MAP-T Container Option. There MUST be exactly one S46-DMR Sub Option included in one MAP-T Container 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    SubType    |    SubLen     |    Reserved   |dmr-prefix6-len|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        dmr-ipv6-prefix                        |
|                       (variable length)                       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

SubType
5 (SubType number, for the S46-DMR Sub Option)

SubLen
4 + length of dmr-ipv6-prefix specified in octets

Reserved
This field is reserved. It should be set to all zero.

dmr-prefix6-len
8 bits long; expresses the bitmask length of the IPv6 prefix specified in the dmr-ipv6-prefix field. Allowed values range from 0 to 96.

dmr-ipv6-prefix
a variable-length field specifying the IPv6 prefix or address for the BR. This field is right-padded with zeros to the nearest octet boundary when dmr-prefix6-len is not divisible by 8.

4.3.4. S46-V4V6Bind Sub Option

The S46-V4V6Bind Sub Option can only be encapsulated in the Lightweight 4over6 Container Option. There MUST be at most one S46-V4V6Bind Sub Option included in each Lightweight 4over6 Container 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     SubType   |    SubLen     |                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                               +
|                                                               |
+                         Sub Options                           +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

SubType
6 (SubType number, for the S46-V4V6Bind sub option)

SubLen
2 + the length of the Sub Options specified in octets

Sub Option
A variable field that contains sub options defined in Section 4.5.

4.3.5. S46-PORTPARAMS Sub Option

The S46-PORTPARAMS Sub Option specifies optional port set information that MAY be provided to CEs. The S46-PORTPARAMS sub option can be included optionally by each type of S46 Container 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     SubType   |    SubLen     |                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                               +
|                                                               |
+                         Sub Options                           +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

SubType
  7 (SubType number, for the S46-PORTPARAMS Sub Option)
SubLen
  2 + the length of the Sub Options specified in octets
Sub Option
  A variable field that contains sub options defined in Section 4.6.

4.4. Sub Options for S46-Rule Sub Option

4.4.1. Rule-IPv6-Prefix Sub Option

The Rule-IPv6-Prefix Sub Option is necessary for every S46-RULE sub option. There MUST be exactly one S46-IPv6-Prefix Sub Option encapsulated in each type of S46-Rule Sub Option.

The IPv6 Prefix sub option is followed the framed IPv6 prefix designed in [RFC3162].

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    SubType    |    SubLen     |   Reserved    |ruleprefix6-len|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
|                        rule-ipv6-prefix                       |
|                                                               |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

SubType
: 8 (SubType number, for the Rule-IPv6-Prefix Sub Option)

SubLen
: 20 (the length of the Rule-IPv6-Prefix Sub Option)

Reserved
: This field is reserved. It always set to zero. This field is one octet in length.

ruleprefix6-len
: the length of IPv6 prefix, specified in the rule-ipv6-prefix field, expressed in bits.

rule-ipv6-prefix
: a 128-bits field that specifies an IPv6 prefix that appears in a MAP rule.

4.4.2. Rule-IPv4-Prefix Sub 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    SubType    |    SubLen     |   Reserved    |  prefix4-len  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       rule-ipv4-prefix                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

SubType
: 9 (SubType number, for the Rule-IPv4-Prefix Sub Option)

SubLen
: 8 (the length of the Rule-IPv4-Prefix Sub Option)

Reserved
: This field is reserved. It always set to zero. This field is one octet in length.

Prefix4-len
: the length of IPv4 prefix, specified in the rule-ipv4-prefix field, expressed in bits.

rule-ipv4-prefix
: a 32-bits field that specifies an IPv4 prefix that appears in a MAP rule.

4.4.3. EA Length Sub 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    SubType    |    SubLen     |             EA-len            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

SubType
: 10 (SubType number, for the EA Length Sub Option)

SubLen
: 4 (the length of the EA Length Sub Option)

EA-len
: 16 bits long field that specifies the Embedded-Address (EA) bit length. Allowed values range from 0 to 48.

4.5. Sub Options for S46-v4v6Bind Sub Option

4.5.1. The IPv4-address Sub Option

The IPv4-address Sub Option MAY be used to specify the full or shared IPv4 address of the CE.

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    SubType    |    SubLen     |            ipv4-address       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           ipv4-address        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

SubType
: 11 (SubType number, for the IPv4-address Sub Option)

SubLen
: 6 (the length of the Rule-IPv4-Prefix Sub Option)

ipv4-address
: a 32-bits field that specifies an IPv4 address that appears in the V4V6Bind Option

4.5.2. The Bind-IPv6-Prefix Sub Option

The IPv6 prefix field specified in this field is used by the CE to identify the correct prefix to use for the tunnel source.

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    SubType    |    SubLen     |   Reserved    |bindprefix6-len|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
|                        bind-ipv6-prefix                       |
|                        (variable length)                      |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

SubType
: 12 (SubType number, for the Bind-IPv6-Prefix Sub Option)

SubLen
: 20 (the length of the Bind-IPv6-Prefix Sub Option)

Reserved
: This field is reserved. It always set to zero. This field is one octet in length.

bindprefix6-len
: 8 bits long; expresses the bitmask length of the IPv6 prefix specified in the bind-ipv6-prefix field. Allowed values range from 0 to 96.

bind-ipv6-prefix
: a variable-length field specifying the IPv6 prefix or address for the S46 CE. This field is right-padded with zeros to the nearest octet boundary when bindprefix6-len is not divisible by 8.

4.6. Sub Options for S46-PORTPARAMS Sub Option

4.6.1. The PSID-offset Sub Option

```
 0                   1                   2
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    SubType    |    SubLen     |   PSID-Offset |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

SubType
: 13 (SubType number, for the PSID-offset Sub Option)

SubLen
: 3 (the length of the PSID-offset Sub Option)

PSID Offset
: 8 bits long field that specifies the numeric value for the S46 algorithm's excluded port range/ offset bits (a bits), as per Section 5.1 of RFC7597. Allowed values are between 0 and 15. Default values for this field are specific to the Softwire mechanism being implemented and are defined in the relevant specification document.

4.6.2. The PSID-len Sub Option

```
 0                   1                   2
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    SubType    |    SubLen     |    PSID-len   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

SubType
: 14 (SubType number, for the PSID-len Sub Option)

SubLen
: 3 (the length of the PSID-len Sub Option)

PSID-len
: 8 bits long; specifies the number of significant bits in the PSID field. (also known as 'k'). When set to 0, the PSID field is to be ignored. After the first 'a' bits, there are k bits in the port number representing valid of PSID. Subsequently, the address sharing ratio would be 2 ^k.

4.6.3. The PSID Sub 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    SubType    |    SubLen     |             PSID              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

SubType
: 15 (SubType number, for the PSID Sub Option)

SubLen
: 4 (the length of the PSID Sub Option)

PSID (Port-set ID)
: Explicit 16-bit (unsigned word) PSID value. The PSID value algorithmically identifies a set of ports assigned to a CE. The first k-bits on the left of this 2-octets field is the PSID value. The remaining (16-k) bits on the right are padding zeros.

4.7. Softwire46 Sub Options Encapsulation

The table below shows which encapsulated Sub Options are mandatory, optional, or not permitted for each defined S46 Container Option.

Sub Option	MAP-E	MAP-T	Lightweight 4over6
S46-BR	M	N/P	M
S46-Rule	M	M	N/P
S46-DMR	N/P	M	N/P
S46-V4V6Bind	N/P	N/P	O
S46-PORTPARAMS	O	O	O

M - Mandatory, O - Optional, N/P - Not Permitted

4.8. Softwire46-Priority Attribute

The S46-Priority Attribute is structured as follows:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      Type     |    Length     |       S46-option-code         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             ...               |       S46-option-code         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Type
TBD
Length
2 + the length of the S46-option-code(s) specified in octets
S46-option-code
16-bit IANA-registered option code of the DHCPv6 option that is used to identify the softwire mechanisms. S46 mechanisms are prioritized in the appearance order of the S46-option-code(s) in the Softwire46-Priority Attribute. A Softwire46-Priority Attribute MUST contain at least one S46-option-code. The option codes of the corresponding S46 mechanisms are listed in Section 6.1.

4.9. Softwire46-Multicast Attribute

The Softwire46-Multicast attribute conveys the IPv6 prefixes to be used in [RFC8114] to synthesize IPv4-embedded IPv6 addresses. The BNG SHALL use the IPv6 prefixes returned in the RADIUS Softwire46-Multicast attribute to populate the DHCPv6 PREFIX64 Option [RFC8115].

This attribute MAY be used in Access-Request packets as a hint to the RADIUS server, for example, if the BNG is pre-configured with Softwire46-Multicast, these prefixes MAY be inserted in the attribute. The RADIUS server MAY ignore the hint sent by the BNG, and it MAY assign a different Softwire46-Multicast attribute.

The Softwire46-Multicast Attribute MAY appear in an Access-Accept packet. It MAY also appear in an Access-Request packet.

The Softwire46-Multicast Attribute MAY appear in a CoA-Request packet.

The Softwire46-Multicast Attribute MAY appear in an Accounting-Request packet.

The Softwire46-Multicast Attribute MUST NOT appear in any other RADIUS packet.

This attribute is of type "TLV" as defined in the RADIUS Protocol Extensions [RFC6929]. It contains some sub-attributes:

- o The Softwire46-Multicast Attribute MAY contain the ASM-Prefix64 TLV (see Section 4.9.1).

- o The Softwire46-Multicast Attribute MAY contain the SSM-Prefix64 TLV (see Section 4.9.2).

- o The Softwire46-Multicast Attribute MAY contain the U-Prefix64 TLV (see Section 4.9.3).

The Softwire46-Multicast Attribute MUST include the ASM-Prefix64 TLV or the SSM-Prefix64 TLV, and it MAY include both.

The U-Prefix64 TLV MUST be present when the SSM-Prefix64 TLV is present. The U-Prefix64 TLV MAY be present when the ASM-Prefix64 TLV is present.

The format of the Softwire46-Multicast Attribute is shown in Figure 3.

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      Type     |     Length    | Extended-Type |    Value ...
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 3

Type

241 (To be confirmed by IANA).

Length

This field indicates the total length in bytes of all fields of this attribute, including the Type, Length, Extended-Type, and the entire length of the embedded TLVs.

Extended-Type

TBD1.

Value

This field contains a set of TLVs as follows:

ASM-Prefix64 TLV

This TLV contains the ASM IPv6 prefix. Refer to Section 4.9.1.

SSM-Prefix64 TLV

This TLV contains the SSM IPv6 prefix. Refer to Section 4.9.2.

U-Prefix64 TLV

This TLV contains the IPv4 prefix used for address translation [RFC6052]. Refer to Section 4.9.3.

Softwire46-Multicast Attribute is associated with the following identifier: 241.Extended-Type(TBDx).

4.9.1. ASM-Prefix64 TLV

The format of ASM-Prefix64 TLV is shown in Figure 4.

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   TLV-Type    |   Reserved    | Prefix-Length |ASM Prefix64 ...
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     ... ASM Prefix64 ...
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     ... ASM Prefix64 ...
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     ... ASM Prefix64                                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 4

TLV-Type

1

Reserved

This field is reserved. It always set to zero. This field is one octet in length.

Length

The length of the prefix, in bits.

ASM Prefix64

IPv6 prefix. This field specifies the IPv6 multicast prefix to be used to synthesize the IPv4-embedded IPv6 addresses of the multicast groups in the ASM mode. The conveyed multicast IPv6 prefix MUST belong to the ASM range.

4.9.2. SSM-Prefix64 TLV

The format of SSM-Prefix64 TLV is shown in Figure 5.

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   TLV-Type    |    Reserved   |Prefix-Length | SSM Prefix64 ...
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     ... SSM Prefix64 ...
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     ... SSM Prefix64 ...
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     ... SSM Prefix64                                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 5

TLV-Type

2

Reserved

This fiel is reserved. It always set to zero. This field is one octet in length.

Length

The length of the prefix, in bits.

SSM Prefix64

IPv6 prefix. This field specifies the IPv6 multicast prefix to be used to synthesize the IPv4-embedded IPv6 addresses of the multicast groups in the SSM mode. The conveyed multicast IPv6 prefix MUST belong to the SSM range.

4.9.3. U-Prefix64 TLV

The format of U-Prefix64 TLV is shown in Figure 6.

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   TLV-Type    |  Reserved     | Prefix-Length |Unicast Prefix64
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     ... Unicast Prefix64 ...
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     ... Unicast Prefix64 ...
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     ... Unicast Prefix64                                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 6

TLV-Type

3

Reserved

This fiel is reserved. It always set to zero. This field is one octet in length.

Length

The length of the prefix, in bits.

Unicast Prefix64

IPv6 prefix. This field identifies the IPv6 unicast prefix to be used in SSM mode for constructing the IPv4-embedded IPv6 addresses representing the IPv4 multicast sources in the IPv6 domain. It may also be used to extract the IPv4 address from the received multicast data flows.

4.10. Table of attributes

The following table provides a guide to which attributes may be found in which kinds of packets, and in what quantity.

Request	Accept	Reject	Challenge	Accounting Request	#	Attribute
0-1	0-1	0	0	0-1	TBD1	Softwire46-Configuration
0-1	0-1	0	0	0-1	TBD2	Softwire46-Priority
0-1	0-1	0	0	0-1	TBD3	Softwire46-Multicast
0-1	0-1	0	0	0-1	1	User-Name
0-1	0	0	0	0	2	User-Password
0-1	0-1	0	0	0-1	6	Service-Type
0-1	0-1	0-1	0-1	0-1	80	Message-Authenticator

The following table defines the meaning of the above table entries.

0	This attribute MUST NOT be present in packet.
0+	Zero or more instances of this attribute MAY be present in packet.
0-1	Zero or one instance of this attribute MAY be present in packet.
1	Exactly one instance of this attribute MUST be present in packet.

5. Diameter Considerations

S46 Configuration using Diameter [RFC6733] is specified in [RFC7678].

6. IANA Considerations

This document requires the assignment of two new RADIUS Attribute Type in the "Radius Types" registry (currently located at http://www.iana.org/assignments/radius-types for the following attributes:

- Softwire46-Configuration Attribute TBD1

- Softwire46-Priority Attribute TBD2

- Softwire46-Multicast Attribute TBD3

IANA should allocate the numbers from the standard RADIUS Attributes space using the "IETF Review" policy [RFC5226].

6.1. S46 Mechanisms and Their Identifying Option Codes

The Softwire46-Priority Attribute defines a 16-bit S46-option-code field, for which IANA is to create and maintain a new registry entitled "Option Codes Permitted in the Softwire46-Priority Attribute". This document requires IANA to register four option codes of the Softwire46 mechanisms permitted to be included in the Softwire46-Priority Attribute. Additional options may be added to this list in the future using the IETF Review process described in Section 4.1 of [RFC5226].

The following table shows the option codes that are required and the S46 mechanisms that they represent. The option code for DS-Lite is derived from the IANA allocated RADIUS Attribute Type value for DS-Lite [RFC6519]. The option codes for MAP-E, MAP-T and Lightweight 4over6 need to be determined. The option codes for MAP-E, MAP-T, and Lightweight 4over6 should also be used as the option Type values for the MAP-E, MAP-T, and Lightweight 4over6 Container Options defined in Section 4.2.

Option Code	S46 Mechanism	Reference
TBD1	MAP-E	RFC7597
TBD2	MAP-T	RFC7599
TBD3	Lightweight 4over6	RFC7596
144	DS-Lite	RFC6519

Table 1: Option Codes to S46 Mechanisms

7. Security Considerations

Known security vulnerabilities of the RADIUS protocol are discussed in [RFC2607], [RFC2865], and[RFC2869]. Use of IPsec [RFC4301] for providing security when RADIUS is carried in IPv6 is discussed in [RFC3162].

A malicious user may use MAC address spoofing on the shared password that has been preconfigured on the DHCPv6 server to get unauthorized configuration information.

Security considerations for MAP specific between the MAP CE and the BNG are discussed in [RFC7597]. Security considerations for Lightweight 4over6 are discussed in [RFC7596]. Security

considerations for DHCPv6-Based S46 Prioritization Mechanism are discussed in [RFC8026]. Furthermore, generic DHCPv6 security mechanisms can be applied DHCPv6 intercommunication between the CE and the BNG.

Security considerations for the Diameter protocol are discussed in [RFC6733].

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This document was produced using the xml2rfc tool [RFC7991].

9. References

9.1. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <https://www.rfc-editor.org/info/rfc2119>.

[RFC2865] Rigney, C., Willens, S., Rubens, A., and W. Simpson, "Remote Authentication Dial In User Service (RADIUS)", RFC 2865, DOI 10.17487/RFC2865, June 2000, <https://www.rfc-editor.org/info/rfc2865>.

[RFC3162] Aboba, B., Zorn, G., and D. Mitton, "RADIUS and IPv6", RFC 3162, DOI 10.17487/RFC3162, August 2001, <https://www.rfc-editor.org/info/rfc3162>.

[RFC3315] Droms, R., Ed., Bound, J., Volz, B., Lemon, T., Perkins, C., and M. Carney, "Dynamic Host Configuration Protocol for IPv6 (DHCPv6)", RFC 3315, DOI 10.17487/RFC3315, July 2003, <https://www.rfc-editor.org/info/rfc3315>.

[RFC4607] Holbrook, H. and B. Cain, "Source-Specific Multicast for IP", RFC 4607, DOI 10.17487/RFC4607, August 2006, <https://www.rfc-editor.org/info/rfc4607>.

[RFC5080] Nelson, D. and A. DeKok, "Common Remote Authentication Dial In User Service (RADIUS) Implementation Issues and Suggested Fixes", RFC 5080, DOI 10.17487/RFC5080, December 2007, <https://www.rfc-editor.org/info/rfc5080>.

[RFC6052] Bao, C., Huitema, C., Bagnulo, M., Boucadair, M., and X. Li, "IPv6 Addressing of IPv4/IPv6 Translators", RFC 6052, DOI 10.17487/RFC6052, October 2010, <https://www.rfc-editor.org/info/rfc6052>.

[RFC6158] DeKok, A., Ed. and G. Weber, "RADIUS Design Guidelines", BCP 158, RFC 6158, DOI 10.17487/RFC6158, March 2011, <https://www.rfc-editor.org/info/rfc6158>.

[RFC6929] DeKok, A. and A. Lior, "Remote Authentication Dial In User Service (RADIUS) Protocol Extensions", RFC 6929, DOI 10.17487/RFC6929, April 2013, <https://www.rfc-editor.org/info/rfc6929>.

[RFC8026] Boucadair, M. and I. Farrer, "Unified IPv4-in-IPv6 Softwire Customer Premises Equipment (CPE): A DHCPv6-Based Prioritization Mechanism", RFC 8026, DOI 10.17487/RFC8026, November 2016, <https://www.rfc-editor.org/info/rfc8026>.

[RFC8114] Boucadair, M., Qin, C., Jacquenet, C., Lee, Y., and Q. Wang, "Delivery of IPv4 Multicast Services to IPv4 Clients over an IPv6 Multicast Network", RFC 8114, DOI 10.17487/RFC8114, March 2017, <https://www.rfc-editor.org/info/rfc8114>.

[RFC8115] Boucadair, M., Qin, J., Tsou, T., and X. Deng, "DHCPv6 Option for IPv4-Embedded Multicast and Unicast IPv6 Prefixes", RFC 8115, DOI 10.17487/RFC8115, March 2017, <https://www.rfc-editor.org/info/rfc8115>.

9.2. Informative References

[RFC2607] Aboba, B. and J. Vollbrecht, "Proxy Chaining and Policy Implementation in Roaming", RFC 2607, DOI 10.17487/RFC2607, June 1999, <https://www.rfc-editor.org/info/rfc2607>.

[RFC2869] Rigney, C., Willats, W., and P. Calhoun, "RADIUS Extensions", RFC 2869, DOI 10.17487/RFC2869, June 2000, <https://www.rfc-editor.org/info/rfc2869>.

[RFC3580] Congdon, P., Aboba, B., Smith, A., Zorn, G., and J. Roese, "IEEE 802.1X Remote Authentication Dial In User Service (RADIUS) Usage Guidelines", RFC 3580, DOI 10.17487/RFC3580, September 2003, <https://www.rfc-editor.org/info/rfc3580>.

[RFC4301] Kent, S. and K. Seo, "Security Architecture for the Internet Protocol", RFC 4301, DOI 10.17487/RFC4301, December 2005, <https://www.rfc-editor.org/info/rfc4301>.

[RFC5226] Narten, T. and H. Alvestrand, "Guidelines for Writing an IANA Considerations Section in RFCs", RFC 5226, DOI 10.17487/RFC5226, May 2008, <https://www.rfc-editor.org/info/rfc5226>.

[RFC6333] Durand, A., Droms, R., Woodyatt, J., and Y. Lee, "Dual-Stack Lite Broadband Deployments Following IPv4 Exhaustion", RFC 6333, DOI 10.17487/RFC6333, August 2011, <https://www.rfc-editor.org/info/rfc6333>.

[RFC6346] Bush, R., Ed., "The Address plus Port (A+P) Approach to the IPv4 Address Shortage", RFC 6346, DOI 10.17487/RFC6346, August 2011, <https://www.rfc-editor.org/info/rfc6346>.

[RFC6519] Maglione, R. and A. Durand, "RADIUS Extensions for Dual-Stack Lite", RFC 6519, DOI 10.17487/RFC6519, February 2012, <https://www.rfc-editor.org/info/rfc6519>.

[RFC6733] Fajardo, V., Ed., Arkko, J., Loughney, J., and G. Zorn, Ed., "Diameter Base Protocol", RFC 6733, DOI 10.17487/RFC6733, October 2012, <https://www.rfc-editor.org/info/rfc6733>.

[RFC7596] Cui, Y., Sun, Q., Boucadair, M., Tsou, T., Lee, Y., and I. Farrer, "Lightweight 4over6: An Extension to the Dual-Stack Lite Architecture", RFC 7596, DOI 10.17487/RFC7596, July 2015, <https://www.rfc-editor.org/info/rfc7596>.

[RFC7597] Troan, O., Ed., Dec, W., Li, X., Bao, C., Matsushima, S., Murakami, T., and T. Taylor, Ed., "Mapping of Address and Port with Encapsulation (MAP-E)", RFC 7597, DOI 10.17487/RFC7597, July 2015, <https://www.rfc-editor.org/info/rfc7597>.

[RFC7598] Mrugalski, T., Troan, O., Farrer, I., Perreault, S., Dec, W., Bao, C., Yeh, L., and X. Deng, "DHCPv6 Options for Configuration of Softwire Address and Port-Mapped Clients", RFC 7598, DOI 10.17487/RFC7598, July 2015, <https://www.rfc-editor.org/info/rfc7598>.

[RFC7599] Li, X., Bao, C., Dec, W., Ed., Troan, O., Matsushima, S., and T. Murakami, "Mapping of Address and Port using Translation (MAP-T)", RFC 7599, DOI 10.17487/RFC7599, July 2015, <https://www.rfc-editor.org/info/rfc7599>.

[RFC7678] Zhou, C., Taylor, T., Sun, Q., and M. Boucadair, "Attribute-Value Pairs for Provisioning Customer Equipment Supporting IPv4-Over-IPv6 Transitional Solutions", RFC 7678, DOI 10.17487/RFC7678, October 2015, <https://www.rfc-editor.org/info/rfc7678>.

[RFC7991] Hoffman, P., "The "xml2rfc" Version 3 Vocabulary", RFC 7991, DOI 10.17487/RFC7991, December 2016, <https://www.rfc-editor.org/info/rfc7991>.

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