DHCWG
Internet-Draft
Updates: 7598 (if approved)
Intended status: Standards Track
Expires: May 16, 2019

I. Farrer
Deutsche Telekom AG
Q. Sun
Y. Cui
L. Sun
Tsinghua University

November 12, 2018

Softwire Provisioning using DHCPv4 Over DHCPv6
draft-ietf-dhc-dhcp4o6-saddr-opt-08

Abstract

DHCPv4 over DHCPv6 (RFC7341) is a mechanism for dynamically configuring IPv4 for use as an over-the-top service in a IPv6-only network. Softwires are an example of such a service. For DHCPv4 over DHCPv6 (DHCP 4o6) to function with some IPv4-over-IPv6 softwire mechanisms and deployment scenarios (e.g., RFC7596 or RFC7597), the operator needs to know the IPv6 address that the client will use as the source of IPv4-in-IPv6 softwire tunnel. This address, in conjunction with the client's IPv4 address, and (in some deployments) the Port Set ID are used to create a binding table entry in the operator's softwire tunnel concentrator. This memo defines a DHCPv6 option to convey IPv6 parameters for establishing the softwire tunnel and a DHCPv4 option (to be used only with DHCP 4o6) to communicate the source tunnel IPv6 address between the DHCP 4o6 client and server. It is designed to work in conjunction with the IPv4 address allocation process.

DHCPv6 Options for Configuration of Softwire Address and Port-Mapped Clients (RFC7598) describes a deterministic DHCPv6 based mechanism for provisioning softwires. This document updates "DHCPv6 Options for Configuration of Softwire Address and Port-Mapped Clients" (RFC7598), allowing OPTION_S46_BR (90) to be enumerated in the DHCPv6 client's Option Request Option (ORO) request and appear directly within subsequent messages sent by the DHCPv6 server.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at https://datatracker.ietf.org/drafts/current/.

Copyright Notice

Table of Contents

1. Introduction

Deterministic IPv4-over-IPv6 transition technologies require that elements are pre-configured with binding rules for routing traffic to clients. This places a constraint on the choice of address used as the client's softwire source address: it must use a pre-determined prefix which is usually configured on the home gateway device. [RFC7598] describes a DHCPv6 based mechanism for provisioning such deterministic softwires.

A dynamic provisioning model, such as using DHCPv4 over DHCPv6 [RFC7341] (DHCP 4o6) allows much more flexibility in the location of the IPv4-over-IPv6 softwire source address. In this model, the IPv6 address is dynamically communicated back to the service provider allowing the corresponding softwire configuration to be created in the border router (BR).

The DHCP 4o6 client and softwire client could be run on end devices attached to a network segment using any routable IPv6 prefix allocated to an end-user, located anywhere within an arbitrary home network topology. Dynamic allocation also helps to optimize IPv4 resource usage as only clients which are actively renewing their IPv4 lease hold on to the address.

This document describes a mechanism for dynamically provisioning softwires created using DHCP 4o6, including provisioning the client with the address of the softwire border router (BR) and informing the service provider of client's binding between the dynamically allocated IPv4 address and Port Set ID and the IPv6 address that the softwire Initiator will use for accessing IPv4-over-IPv6 services.

The mechanism operates alongside the DHCP 4o6 message flows to communicate the binding information over the IPv6-only network. The DHCP 4o6 server provides a single point in the network which holds the current client binding information. The service provider can then use this binding information to provision other functional elements, such as the BR(s).

2. Applicability

The mechanism described in this document is only suitable for use for provisioning softwire clients via DHCP 4o6. The options described here are only applicable within the DHCP 4o6 message exchange process. Current softwire technologies suitable for extending to incorporate DHCP 4o6 with dynamic IPv4 address leasing include [RFC7597] and [RFC7596].

3. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

4. Solution Overview

In order to provision a softwire, both IPv6 and IPv4 configuration needs to be passed to the client. To map this to the DHCP 4o6 configuration process, the IPv6 configuration is carried in DHCPv6 options [I-D.ietf-dhc-rfc3315bis], carried inside the DHCPv6 message DHCPV4-RESPONSE (21) sent by the server. OPTION_S46_BR (90) is used to provision the remote IPv6 address for the softwire border router (see Section 4.1 below). OPTION_S46_BIND_IPV6_PREFIX (TBD1), is optionally sent by the DHCP 4o6 server to indicate to the client a preferred IPv6 prefix for binding the received IPv4 configuration and sourcing tunnel traffic. This may be necessary if there are multiple IPv6 prefixes in use in the customer network (e.g., Unique Local Addresses (ULAs)), or if the specific IPv4-over-IPv6 transition mechanism requires the use of a particular prefix for any reason.

IPv4 configuration is carried in DHCPv4 messages [RFC2131], (inside the DHCP 4o6 option OPTION_DHCPV4_MSG (87)) using the mechanism described in [RFC7341].

In order for the client to communicate the softwire source address, a new DHCPv4 option OPTION_DHCP4O6_S46_SADDR (TBD2) is defined in this document. This is included in DHCPREQUEST messages sent by the client and is stored by the server for the lifetime of the IPv4 address lease.

4.1. Updating RFC7598 to Permit the Reuse of OPTION_S46_BR(90)

Section 4.2 of [RFC7598] defines option OPTION_S46_BR(90) for communicating remote softwire border relay (BR) IPv6 address(es) to a client, but mandates that the option can only be used when

encapsulated within one of the softwire container options: OPTION_S46_CONT_MAPE (94) or OPTION_S46_CONT_LW(96). From Section 3 of [RFC7598]:

> "Softwire46 DHCPv6 clients that receive provisioning options that are not encapsulated in container options MUST silently ignore these options."

This document updates [RFC7598], removing this restriction for OPTION_S46_BR (90), allowing it to be enumerated in the client's ORO request and appear directly within subsequent messages sent by the DHCPv6 server.

5. DHCP 4o6 IPv6/IPv4 Binding Message Flow

The following diagram shows the relevant extensions to the successful DHCP 4o6 IPv4 allocation client/server message flow for the softwire source address function. The full process, including error handling is described in Section 7.

In each step, the DHCPv6 portion of the message and any relevant option is shown above the arrow. The DHCP 4o6 content of the message and its relevant options are below the arrow. All the DHCPv4 messages are encapsulated in DHCPV4-QUERY (20) or DHCPV4-RESPONSE (21) messages. Where relevant, the necessary options and their contents are shown.

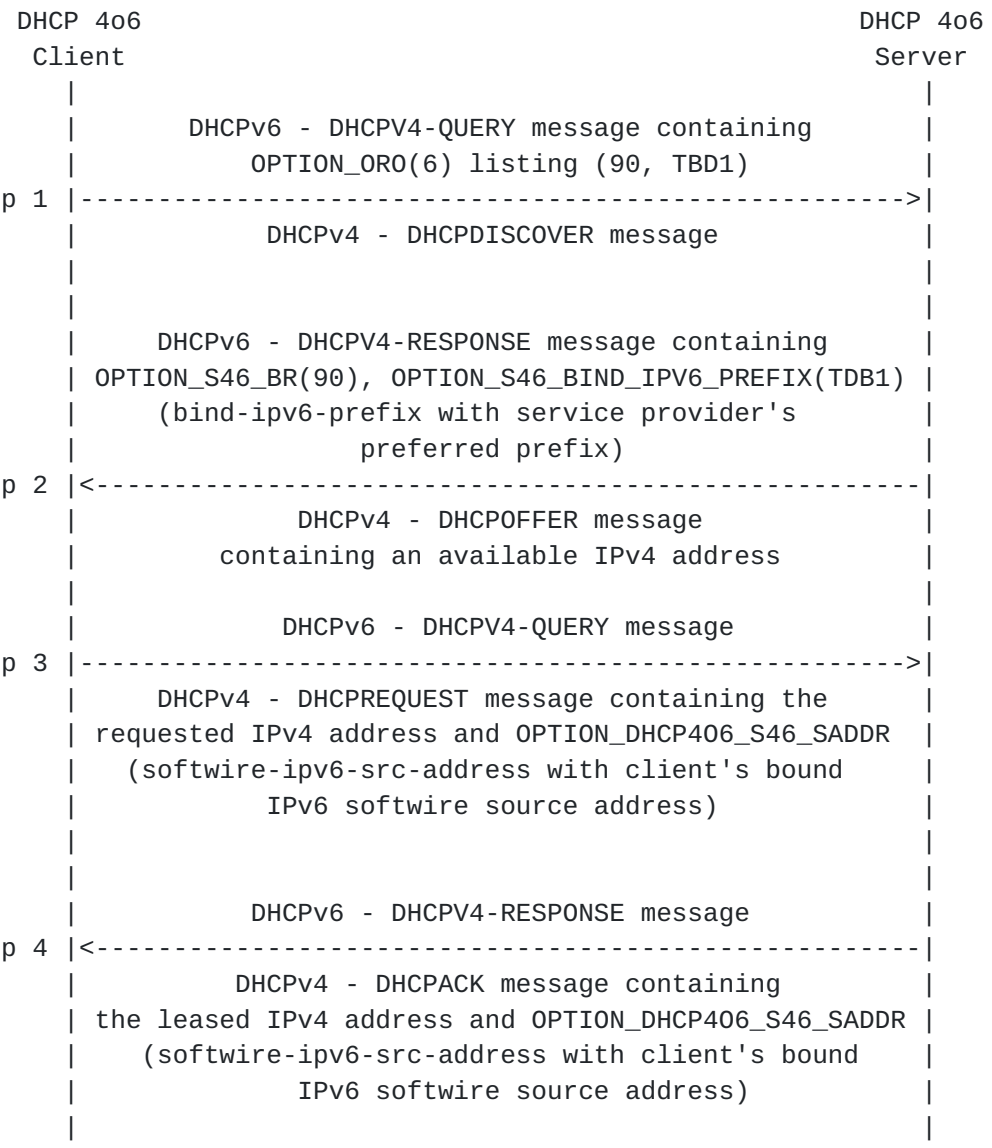


Figure 1: IPv6/IPv4 Binding Message Flow

Step 1 The client constructs a DHCPv6 'DHCPV4-QUERY(20)' message. This message contains two options: DHCPv6 OPTION_ORO (6) and OPTION_DHCPV4_MSG (87). OPTION_ORO lists '90' (OPTION_S46_BR) and 'TBD1' (OPTION_S46_BIND_IPV6_PREFIX). OPTION_DHCPV4_MSG contains a DHCPv4 DHCPDISCOVER message.

Step 2 The server responds with a DHCPv6 'DHCPV4-RESPONSE (21)' message. This message contains an OPTION_S46_BR (90) containing the IPv6 address of the BR for the client's softwire configuration. The message may also optionally contain OPTION_S46_BIND_IPV6_PREFIX (TBD1). OPTION_DHCPV4_MSG contains a DHCPv4 DHCPOFFER message. The DHCPv4 message contains an available IPv4 address.

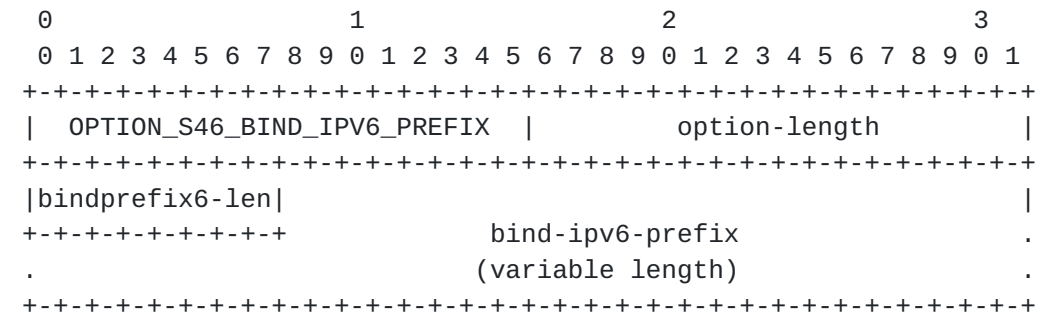
Step 3 The client sends with a DHCPv6 'DHCPV4-QUERY(20)' message containing a DHCPv4 DHCPREQUEST message with the requested IPv4 address and OPTION_DHCP4O6_S46_SADDR (TBD2) with the IPv6 address which the client will use as its softwire source address.

Step 4 The server sends a DHCPv6 'DHCPV4-RESPONSE (21)' message. OPTION_DHCPV4_MSG contains a DHCPv4 DHCPACK message with the allocated IPv4 address. OPTION_DHCP4O6_S46_SADDR with the client's bound softwire source address is included.

6. DHCP Options

6.1. DHCPv6 Softwire Source Binding Prefix Hint Option

The format of DHCPv6 Source Binding Prefix hint option is as follows:



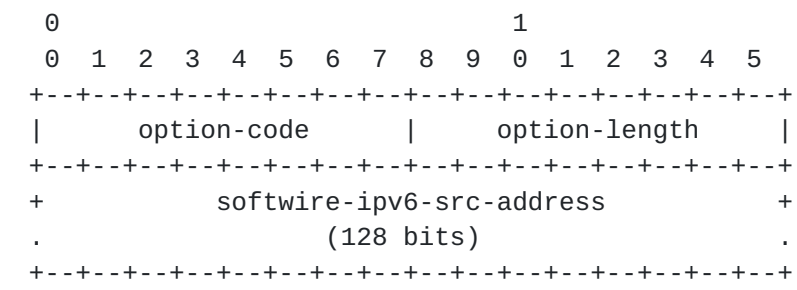
Format of OPTION_S46_BIND_IPV6_PREFIX

- option-code: OPTION_S46_BIND_IPV6_PREFIX (TBD1)
- option-length: 1 + length of bind-ipv6-prefix, specified in bytes.
- bindprefix6-len: 8-bit field expressing the bit mask length of the IPv6 prefix specified in bind-ipv6-prefix. Valid values are 0 to 128.
- bind-ipv6-prefix: The IPv6 prefix indicating the preferred prefix for the client to bind the received IPv4 configuration to. The length is (bindprefix6-len + 7) / 8. The field is padded on the right with zero bits up to the next octet boundary when bind-ipv6-prefix is not evenly divisible by 8. These padding bits are ignored by the receiver (see Section 7.4).

OPTION_S46_BIND_IPV6_PREFIX is a singleton. Servers MUST NOT send more than one instance of the OPTION_S46_BIND_IPV6_PREFIX option.

6.2. DHCPv4 over DHCPv6 Softwire Source Address Option

The format of DHCPv4 over DHCPv6 softwire source address option is as follows:



Format of OPTION_DHCP4O6_S46_SADDR

- option-code: OPTION_DHCP4O6_S46_SADDR (TBD2)
- option-length: 16.
- softwire-ipv6-src-address: 16 bytes long; The IPv6 address that is associated (either being requested for binding or currently bound) with the client's IPv4 configuration.

NB - The function of OPTION_DHCP4O6_S46_SADDR may seem similar to the DHCPv4 message's 'chaddr' field, or the Client Identifier (61) option in that it provides a lower-layer address which is unique that the server can use for identifying the client. However, as both of these are required to remain constant throughout the address lease lifetime, they cannot be used with the mechanism described in this document. This is because the client may only be able to construct the IPv6 address to use as the source address after it has received the first DHCPV4-RESPONSE message from the server containing OPTION_S46_BIND_IPV6_PREFIX.

7. Client Behavior

A client requiring dynamic softwire configuration first enables DHCP 4o6 configuration using the method described in Section 5 of [RFC7341]. If OPTION_DHCP4_O_DHCP6_SERVER is received in the corresponding REPLY message, the client MAY continue with the configuration process described below.

Before the dynamic softwire configuration process can commence, the client MUST be configured with a suitable IPv6 prefix to be used as the local softwire endpoint. This could be obtained using DHCPv6, RA/PIO or another mechanism.

7.1. Client Initialization

When constructing the initial DHCP 4o6 DHCPDISCOVER message, the client includes a DHCPv6 OPTION_ORO (6) within the options field of the DHCP-QUERY message. OPTION_ORO contains the option codes for OPTION_S46_BR (90) and OPTION_S46_BIND_IPV6_PREFIX (TBD1).

On receipt of the DHCP 4o6 server's reply (a DHCPV4-RESPONSE containing a DHCPOFFER message), the client checks the contents of the DHCPv4-RESPONSE for the presence of a valid OPTION_S46_BR option. If this option is not present, or does not contain at least one valid IPv6 address for a BR, then the client MUST discard the message, as without the address of the BR the client cannot configure the softwire and so has no interface to request IPv4 configuration for.

The DHCPV4-RESPONSE message may also include OPTION_S46_BIND_IPV6_PREFIX, which is used by the operator to indicate a preferred prefix that the client should use to bind IPv4 configuration to. If received, the client first checks the option according to Section 7.4. If valid, the client uses this prefix as the 'IPv6 binding prefix' and follows to the process described in Section 5.1 of [RFC7596] in order to select an active IPv6 prefix to construct the softwire. If no match is found, or the client doesn't receive OPTION_S46_BIND_IPV6_PREFIX the client MAY select any valid IPv6 prefix (of a suitable scope) to use as the tunnel source.

Once the client has selected a suitable prefix, it MAY use either an existing IPv6 address that is already configured on an interface, or create a new address specifically for use as the softwire source address (e.g., using an Interface Identifier constructed as per Section 6 of [RFC7597]). If a new address is being created, the client MUST complete configuration of the new address, performing duplicate address detection (if required) before proceeding.

The client then constructs a DHCPV4-QUERY message containing a DHCPv4 DHCPREQUEST message. OPTION_DHCP4O6_S46_SADDR is included in the options field of the DHCPREQUEST message with the IPv6 address of its softwire source address in the softwire-ipv6-src-address field.

When the client receives a DHCPv4 DHCPACK message from the server, it checks the IPv6 address in OPTION_DHCP4O6_S46_SADDR against its active softwire source address. If they match, the allocation process has concluded. If there is a discrepancy then the process described in Section 7.5 is followed.

If the client receives a DHCPv4 DHCPNAK message from the server, then the configuration process has been unsuccessful. The client then restarts the process from Step 1 of Figure 1.

7.2. Renewing or Rebinding the IPv4 Address Lease and Softwire Source Address

Whenever the client attempts to extend the lease time of the IPv4 address, OPTION_DHCP4O6_S46_SADDR with the IPv6 address of its softwire source address in the softwire-ipv6-src-address field MUST be included in the DHCPREQUEST message.

7.2.1. Changing the Bound IPv6 Softwire Source Address

Across the lifetime of the leased IPv4 address, it is possible that the client's IPv6 address will change, e.g., if there is an IPv6 re-numbering event.

In this situation, the client MUST inform the server of the new address. This is done by sending a DHCPREQUEST message containing OPTION_DHCP4O6_S46_SADDR with the new IPv6 source address.

When the client receives a DHCPv4 DHCPACK message from the server, it checks the IPv6 address in OPTION_DHCP4O6_S46_SADDR against its active softwire source address. If they match, the allocation process has concluded. If there is a discrepancy then the process described in Section 7.5 is followed.

If the client receives a DHCPv4 DHCPNAK message in response from the server, then the change of the bound IPv6 Softwire source address has been unsuccessful. In this case, the client MUST stop using the new IPv6 source address. The client then restarts the process from Step 1 of Figure 1.

7.3. Releasing the IPv4 Address Lease and Softwire Source Address

When the client no longer requires the IPv4 resource, it sends a DHCPv4 DHCPRELEASE message to the server. As the options field is unused in this message type, OPTION_DHCP4O6_S46_SADDR is not included.

7.4. OPTION_S46_BIND_IPV6_PREFIX Validation Behavior

On receipt of the OPTION_S46_BIND_IPV6_PREFIX option, the client makes the following validation checks:

- The received bindprefix6-len value is not larger than 128.
- The number of bytes received in the bind-ipv6-prefix field is consistent with the received bindprefix6-len value (calculated as described in Section 6.1).

If either check fails, the receiver discards the invalid option and proceeds to attempt configuration as if the option had not been received.

The receiver MUST only use bits from the bind-ipv6-prefix field up to the value specified in the bindprefix6-len when performing the longest prefix match. bind-ipv6-prefix bits beyond this value MUST be ignored.

7.5. Client and Server Softwire Source Address Mismatch

If the client receives a DHCPACK message with an OPTION_DHCP4O6_S46_SADDR containing an IPv6 address which differs from its active softwire source address, the client SHOULD wait for a randomized time interval and then resend the DHCPREQUEST message with the correct softwire source address. [RFC2131] Section 4.1 descibes the retransmission backoff interval process.

The default minimum time for the client to attempt retransmission is 60 seconds. If, after this time has expired, the client has not received a DHCPACK message with the correct bound IPv6 address, client MAY send a DHCPRELEASE message and re-start the process described in Section 7. The re-try interval should be configurable and aligned with any server policy defining the minimum time interval for client address updates as described in Section 8.1.

7.6. Use With Dynamic, Shared IPv4 Addresses

[RFC7618] describes a mechanism for using DHCPv4 to distribute dynamic, shared IPv4 addresses to clients. The mechanism described in this document is compatible with IPv4 address sharing, and can be enabled by following the process described in Section 6 of [RFC7618].

8. Server Behavior

Beyond the normal DHCP 4o6 functionality defined in [RFC7341], the server MUST also store the IPv6 softwire source address of the client in the leasing address database, alongside the IPv4 address and client identifier.

An OPTION_DHCP4O6_S46_SADDR containing the bound softwire source address MUST be sent in every DHCPACK message sent by the server.

The binding entry between the client's IPv6 softwire source address and the leased IPv4 address is valid as long as the IPv4 lease remains valid.

8.1. Changing the Bound IPv6 Source Address

In the event that the server receives a DHCPREQUEST message for an active IPv4 lease containing a OPTION_DHCP4O6_S46_SADDR with an IPv6 address which differs from the address which is currently stored, the server updates the stored softwire source address with the new address supplied by the client, and sends a DHCPACK message containing the updated softwire source address in OPTION_DHCP4O6_S46_SADDR.

The server MAY implement a policy enforcing a minimum time interval between a client updating its softwire source IPv6 address. If a client attempts to update the softwire source IPv6 address before the minimum time has expired, the server can either silently drop the client's message or send back a DHCPACK message containing the existing IPv6 address binding in OPTION_DHCP4O6_S46_SADDR. If implemented, the default minimum client source address update interval is 60 seconds.

8.2. Handling Conflicts Between Client's Bound IPv6 Source Addresses

In order for traffic to be forwarded correctly, each CE's softwire IPv6 source addresses must be unique. To ensure this, on receipt of every client DHCPREQUEST message containing OPTION_DHCP4O6_S46_SADDR, the DHCP 4o6 server MUST check the received IPv6 address against all existing CE source addresses stored for active client IPv4 leases. If there is a match for any active lease other than the lease belonging to the client sending the DHCPREQUEST, then the client's IPv6 source address MUST NOT be stored or updated.

Depending on where the client and server are in the address leasing lifecycle, the DHCP 4o6 server then takes the following action:

- If the DHCP 4o6 does not have a current, active IPv4 address lease for the client, then the DHCP address allocation process has not been succesful. The server returns a DHCPNAK message to the client.
- If the DHCP 4o6 does have a current, active IPv4 address lease, then the source address update process (see Section 8.1) has not been successful. The DHCP 4o6 server can either silently drop the client's message or return a DHCPACK message containing the existing IPv6 address binding in OPTION_DHCP4O6_S46_SADDR.

9. Security Considerations

Security considerations which are applicable to [RFC7341] are also applicable here.

A rogue client could attempt to use the mechanism described in Section 7.2.1 to redirect IPv4 traffic intended for another client to itself. This would be performed by sending a DHCPREQUEST message for another client's active IPv4 lease containing the attacker's softwire IPv6 address in OPTION_DHCP4O6_S46_SADDR.

For such an attack to be effective, the attacker would need to know both the client identifier and active IPv4 address lease currently in use by another client. This could be attempted in three ways:

1. One customer learning the active IPv4 address lease and client identifier of another customer via snooping the DHCP4o6 message flow between the client and server. The mechanism described in this document is intended for use in a typical ISP network topology with a dedicated layer-2 access network per-client, meaning that snooping of another client's traffic is not possible. If the access network is a shared medium then provisioning softwire clients using dynamic DHCP4o6 as described here is NOT RECOMMENDED.
2. Learning the active IPv4 address lease and client identifier via snooping the DHCP4o6 message flow between the client and server in the aggregation or core ISP network. In this case, the attacker requires a level of access to the ISP's infrastructure that means they can already intercept or interfere with traffic flows to the client.
3. An attacker could attempt to brute-force guessing the IPv4 lease address and client identifier tuple. The risk of this can be reduced by using a client identifier format which is not easily guessable, e.g., by using a random based client identifier (see [RFC7844] Section 3.5).

An attacker could attempt to redirect existing flows to a client unable to process the traffic. This type of attack can be prevented by implementing [BCP38] network ingress filtering in conjunction with the BR source address validation processes described in [RFC7596] Section 5.2 and [RFC7597] Section 8.1.

A client may attempt to overload the server by sending multiple source address update messages (see Section 7.2.1) in a short time frame. This risk can be reduced by implementing a server policy enforcing a minimum time interval between client address changes as described in Section 8.1.

9.1. Client Privacy Considerations

[RFC7844] describes anonymity profiles for DHCP clients. These considerations and recommendations are also applicable to clients implementing the mechanism described in this document. As DHCP4o6

only uses DHCPv6 as a stateless transport for DHCPv4 messages, the "Anonymity Profile for DHCPv4" described in Section 3 is most relevant here.

In addition to the considerations given in [RFC7844], the mechanism that the client uses for constructing the interface identifier for its IPv6 softwire source address (see Section 7.1), could result in the device being trackable across different networks and sessions, e.g., if the client's softwire Interface Identifier (IID) is immutable.

This can be mitigated by constructing the softwire source IPv6 address as per Section 6 of [RFC7597]. Here, the address' IID contains only the allocated IPv4 address (and port set identifier if [RFC7618] is being used). This means no additional client information is exposed to the DHCP4o6 server, and will also mean that the IID will change as the leased IPv4 address changes (e.g., between sessions when Section 3.5 of [RFC7844] is implemented).

10. IANA Considerations

IANA is requested to assign the OPTION_S46_BIND_IPV6_PREFIX (TBD1) option code from the DHCPv6 "Option Codes" registry maintained at http://www.iana.org/assignments/dhcpv6-parameters and use the following data when adding the option to the registry:

Value:	TDB1
Description:	OPTION_S46_BIND_IPV6_PREFIX
Client ORO:	Yes
Singleton Option:	Yes
Reference:	this document

IANA is requested to assign the OPTION_DHCP4O6_S46_SADDR (TBD2) option code from the "BOOTP Vendor Extensions and DHCP Options" registry maintained at http://www.iana.org/assignments/bootp-dhcp-parameters and use the following data when adding the option to the registry:

Value:	TDB2
Name:	OPTION_DHCP4O6_S46_SADDR
Data Length:	16
Meaning:	DHCPv4 over DHCPv6 Softwire Source Address Option
Reference:	this document

IANA is requested to update the entry for DHCPv6 Option S46_BR (90) in the Option Codes table maintained at https://www.iana.org/assignments/dhcpv6-parameters as follows:

Old Entry:

Value:	90
Description:	OPTION_S46_BR
Client ORO:	No
Singleton Option:	No
Reference:	[RFC7598]

New Entry:

Value:	90
Description:	OPTION_S46_BR
Client ORO:	Yes
Singleton Option:	No
Reference:	[RFC7598], this document

11. Acknowledgements

The authors would like to thank Ted Lemon, Lishan Li, Tatuya Jinmei, Jonas Gorski and Razvan Becheriu for their contributions and comments.

12. References

12.1. Normative References

[I-D.ietf-dhc-rfc3315bis]
Mrugalski, T., Siodelski, M., Volz, B., Yourtchenko, A., Richardson, M., Jiang, S., Lemon, T., and T. Winters, "Dynamic Host Configuration Protocol for IPv6 (DHCPv6) bis", draft-ietf-dhc-rfc3315bis-13 (work in progress), April 2018.

[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>.

[RFC2131] Droms, R., "Dynamic Host Configuration Protocol", RFC 2131, DOI 10.17487/RFC2131, March 1997, <https://www.rfc-editor.org/info/rfc2131>.

[RFC7341] Sun, Q., Cui, Y., Siodelski, M., Krishnan, S., and I. Farrer, "DHCPv4-over-DHCPv6 (DHCP 4o6) Transport", RFC 7341, DOI 10.17487/RFC7341, August 2014, <https://www.rfc-editor.org/info/rfc7341>.

[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>.

[RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, DOI 10.17487/RFC8174, May 2017, <https://www.rfc-editor.org/info/rfc8174>.

12.2. Informative References

[BCP38] IETF, "Network Ingress Filtering: Defeating Denial of Service Attacks which employ IP Source Address Spoofing https://tools.ietf.org/html/bcp38", RFC 2827, BCP 38.

[RFC2827] Ferguson, P. and D. Senie, "Network Ingress Filtering: Defeating Denial of Service Attacks which employ IP Source Address Spoofing", BCP 38, RFC 2827, DOI 10.17487/RFC2827, May 2000, <https://www.rfc-editor.org/info/rfc2827>.

[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>.

[RFC7618] Cui, Y., Sun, Q., Farrer, I., Lee, Y., Sun, Q., and M. Boucadair, "Dynamic Allocation of Shared IPv4 Addresses", RFC 7618, DOI 10.17487/RFC7618, August 2015, <https://www.rfc-editor.org/info/rfc7618>.

[RFC7844] Huitema, C., Mrugalski, T., and S. Krishnan, "Anonymity Profiles for DHCP Clients", RFC 7844, DOI 10.17487/RFC7844, May 2016, <https://www.rfc-editor.org/info/rfc7844>.

Authors' Addresses

Ian Farrer
Deutsche Telekom AG
CTO-ATI, Landgrabenweg 151
Bonn, NRW 53227
Germany

Email: ian.farrer@telekom.de

Qi Sun
Tsinghua University
Beijing 100084
P.R. China

Phone: +86-10-6278-5822
Email: sunqi.ietf@gmail.com

Yong Cui
Tsinghua University
Beijing 100084
P.R. China

Phone: +86-10-6260-3059
Email: yong@csnet1.cs.tsinghua.edu.cn

Linhui Sun
Tsinghua University
Beijing 100084
P.R. China

Phone: +86-10-6278-5822
Email: lh.sunlinh@gmail.com