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SAVI Solution for DHCP
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Abstract

This document specifies the procedure for creating bindings between a DHCPv4/DHCPv6 assigned source IP address and a binding anchor on a SAVI (Source Address Validation Improvements) device. The bindings can be used to filter out packets with forged source IP address in DHCP scenario. This mechanism is proposed as a complement to ingress filtering to provide finer granularity source IP address validation.

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1. Introduction

This document describes the procedure for creating a binding between an address allocated to a network attachment point by DHCP and a suitable binding anchor on a SAVI device. Binding anchor is defined to be a link layer property of network attachment in [savi-framework]. A list of proper binding anchors can be found in the Section 3.2 of [savi-framework]. The bindings can be used to filter out or identify packets with forged source IP address. Section 9 suggests usage of these bindings to discard spoofing traffic in common practice.

The mechanism specified in this document is designed to provide a finer granularity source IP address validation, as a supplement to [BCP38]. This mechanism mainly performs DHCP snooping to set up bindings between IP addresses assigned by DHCP and corresponding binding anchors. The binding process is inspired by the work of [BA2007]. Besides the specifications about DHCPv4 in [BA2007], this mechanism covers DHCPv6 and binding recovery procedure. The latter is used to recover binding when DHCP snooping is no sufficient to set up all the bindings.

This solution is primarily designed for a pure DHCP scenario in which only addresses assigned through DHCP are legitimate global addresses. And it is designed for stateful DHCP scenario [rfc2131], [rfc3315]. In stateless DHCP scenarios [rfc3736], a node must have obtained its IPv6 addresses through some other mechanisms and so the address of the client SHOULD be bound based on other SAVI solutions, for example, SAVI FCFS[savi-fcfs]..

2. 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 RFC 2119 [rfc2119].

3. Terminology

DHCP address: IP address assigned to an interface via DHCP

SAVI-DHCP: The name of this SAVI mechanism for DHCP address

SAVI device: A network device which enables this SAVI mechanism

Non-SAVI device: A network device without this SAVI mechanism

DHCP client type message: Messages that can only originate from DHCP client. The list of such messages contains DHCPv4 Discover, DHCPv4 Request, DHCPv4 Decline, DHCPv4 Release, DHCPv4 Inform, DHCPv6 Request, DHCPv6 Confirm, DHCPv6 Solicitation, DHCPv6 Decline, DHCPv6 Release, DHCPv6 Rebind, DHCPv6 Renew

DHCP server/relay type message: Messages that can only originate from DHCP server or relay. The list of such messages contains DHCPv4 ACK, DHCPv4 NAK, DHCPv4 OFFER, DHCPv6 Reply, DHCPv6 Advertise, DHCPv6 Reconfiguration, DHCPv6 Relay-forward and DHCPv6 Relay-reply

Lease time: Lease time in IPv4 [rfc2131] and valid lifetime in IPv6 [rfc3315]

Binding entry limit: The upper limit of binding entries on an binding anchor. It is used to prevent a single node from overloading the binding resource of SAVI device.

4. SAVI-DHCP Scenario

Figure 1 shows the main elements in a network where this mechanism is deployed. One or more DHCP servers mediate the allocation and distribution of IP addresses to hosts requesting them using the DHCP protocol. A DHCP relay may be used to relay message between client and server. Multiple SAVI devices and non-SAVI devices can co-exist on link. A SAVI device can be connected to DHCP client, DHCP relay (even DHCP server), SAVI device and non-SAVI device. The attribute of a binding anchor is determined by the role to which it is connected, as specified in Section 5.

SAVI-DHCP provides perimetrical security as SAVI-FCFS for scalability (refer to Section 2.5 in [savi-fcfs]). SAVI devices can form a perimeter separating untrusted area and trusted area. Each SAVI device only need establish bindings for nodes partitioned by the edge it forms. In this way, binding entries are distributed on devices forming the perimeter. Then the SAVI devices can protect the inside of the perimeter collaboratively without setting up bindings for all the address on each device. For example, in Figure 1, protection perimeter is formed by SAVI Device A and SAVI Device B. In this case, SAVI device B wouldn't setup a binding for client A, and SAVI device wouldn't setup a binding for client B. But the SAVI device B is still protected from spoofing from client A and the SAVI device A is still protected from spoofing from client B. There is only one difference between the SAVI-DHCP protection perimeter and SAVI-FCFS protection perimeter: SAVI-DHCP follows the state announced in DHCP messages, thus there is no need to distribute state by NS/NA messages.

Other address assignment mechanisms may be also used in such a network. However, this solution is primarily designed for a pure DHCP scenario, in which only the DHCP servers can assign a valid global address.

Note that in an IPv6 environment, every interface has a link-local address, which is not assigned by DHCP. This solution will not validate the link-local address. It is RECOMMENDED to enable a SAVI solution for link-local addresses, e.g. [savi-fcfs].

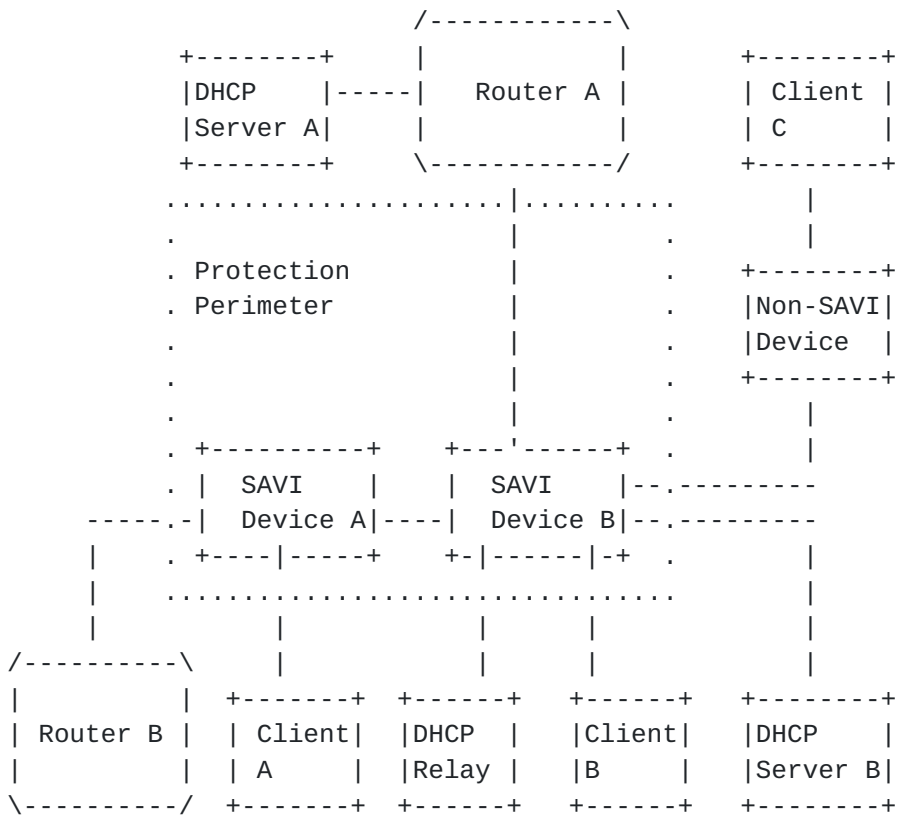


Figure 1: SAVI-DHCP Scenario

5. Binding Anchor Attributes

This section specifies the binding anchor attributes used by this mechanism. Attributes are used to distinguish different types of binding anchors. The procedure performed on each binding anchor is determined by the attributes set on the binding anchor.

By default, a binding anchor has no attribute. A binding anchor MAY be configured to have one or more compatible attributes. The attribute of each binding anchor should be manually configured before enabling this SAVI-DHCP function.

5.1. No Attribute

Before configuration, by default, a binding anchor has no attribute. Generally, each binding anchor is configured to have one or more attributes after configuration.

Data packet filtering will not be performed on binding anchor with no attribute. It is in consideration that turning on SAVI-DHCP function will not cause a break of the network even though binding anchors are not configured. However, if a binding anchor has no attribute, it means SAVI-DHCP-Trust is not configured on the binding anchor; thus, DHCP server/relay messages from the binding anchor with no attribute will be discarded. This is designed to prevent host attaching to unconfigured binding anchor plays as bogus DHCP server. It is SUGGESTED configure SAVI-DHCP-Trust on necessary binding anchors before turning on SAVI-DHCP function.

However, a binding anchor MAY have no attribute after configuration if data packet should be let through but server/relay type message should be discarded. For example, in Figure 1, on the binding anchor of SAVI Device A connected to Router B, it is unreasonable to filter out traffic from Router B, or allow forged DHCP message from Router B. Thus, no attribute should be configured on this binding anchor.

5.2. SAVI-Validation Attribute

SAVI-Validation attribute is used on a binding anchor on which the source address of data packet and control packet is to be validated. The filtering process on the binding anchor with such attribute is described in section 9. In Figure 1, the binding anchor between SAVI Device B and Client A, and the binding anchor between SAVI Device B and Non SAVI Device should be configured to have this attribute.

5.3. SAVI-DHCP-Trust Attribute

SAVI-DHCP-Trust Attribute is used on binding anchor on the path to a trustable DHCP server/relay. DHCP server/relay type message coming from binding anchor with this attribute will be forwarded. In Figure 1, the binding anchor between SAVI Device B and DHCP Relay, the binding anchor between SAVI Device B and DHCP Server B, and the binding anchor between SAVI Device B and Router A should be configured to have this attribute.

Note that if the binding anchor is not exclusive for the valid DHCP server, messages from a valid DHCP server and a bogus DHCP server may arrive with the same binding anchor with this attribute. Thus, only relying on configuring this attribute may not protect the network from bogus DHCP servers. In deployment, it is RECOMMENDED the binding anchor for any DHCP server should be exclusive to the DHCP server on the protection perimeter. The security problem related with the bogus DHCP server and deployment options are discussed in section 14.7.

5.4. SAVI-SAVI Attribute

This attribute is used on the binding anchor from which the data traffic is not to be checked. Binding will not be set up on binding anchor with this attribute. All data packets will be allowed directly. In Figure 1, the binding anchor between SAVI Device A and SAVI Device B should be configured with this attribute. DHCP server/ relay type messages from a binding anchor with this attribute but without SAVI-DHCP-Trust attribute will be filtered out.

Through configuring this attribute on binding anchor that joins two or more SAVI devices, SAVI-Validation and SAVI-SAVI attributes implement the security perimeter concept in [savi-framework]. Since no binding entry is needed on such binding anchors, the resource requirement can be reduced significantly.

Though there is no factual difference in packet process between a binding anchor with no attribute and a binding anchor only with SAVI-SAVI attribute, their connotations are different. SAVI-SAVI attribute is configured on binding anchor between SAVI devices on the same link inside the protection perimeter. A binding anchor can be configured with no attribute in more general case that data packet should be let through but server/relay type message should be discarded.

5.5. SAVI-BindRecovery Attribute

If SAVI-Validation attribute is configured on a binding anchor, the binding on this attribute is set up primarily based on DHCP message snooping described in Section 7. However, in some scenarios, a DHCP address may be used without previous DHCP exchange procedure performed on the binding anchor, as discussed in Section 8. In such scenarios, data-triggered binding procedure, which is described in Section 8, is required to be performed.

This attribute is used on the binding anchor that requires data-triggered binding recovery. It can be configured on any binding anchor with SAVI-Validation attribute, especially when the binding

anchor is not directly attached by client. In Figure 1, it is suggested to configure this attribute on binding anchor between SAVI Device B and Non SAVI Device.

5.6. Table of Mutual Exclusions

Mutually exclusive attributes MUST NOT be set on the same binding anchor. The compatibility of different attributes is listed in Figure 2.

	SAVI-Validation	SAVI-DHCP-Trust	SAVI-SAVI	SAVI-BindRecovery
SAVI-Validation	-	compatible	mutually exclusive	compatible
SAVI-DHCP-Trust	compatible	-	compatible	compatible
SAVI-SAVI	mutually exclusive	compatible	-	mutually exclusive
SAVI-Bind Recovery	compatible	compatible	mutually exclusive	-

Figure 2: Table of Mutual Exclusions

6. Data Structures

This section describes the data structures used in this mechanism. The main data structure, named Binding State Table, is used to record bindings and their states. A mapping table from the link layer address to the binding anchor may be required, as described in Section 13.7

6.1. Binding State Table (BST)

This table contains the state of a binding between a source address and a binding anchor. Entries are keyed on the binding anchor and source IP address. Each entry has a lifetime field recording the remaining lifetime of the entry, a state field recording the state of the binding and a TID field recording Transaction ID (TID) [rfc2131] [rfc3315] of DHCP message. The lifetime field counts down automatically. Entry with 0 lifetime will be removed. The state field changes over time to identify the current state of the binding. States of bindings are specified in Section 7.2 and Section 8.2. The TID field is used to keep the TID in DHCP request. The TID field can be cleared after the state is changed to BOUND. An instance of this table is shown in Figure 3.

Anchor	Address	State	Lifetime	TID
A	IP_1	BOUND	65535	TID_1
A	IP_2	BOUND	10000	TID_2
B	IP_3	INIT_BIND	1	TID_3

Figure 3: Instance of BST

6.2. Mapping Table from Link Layer Address to Binding Anchor

This table maps link layer address to binding anchor, so that the SAVI device can determine on which binding anchor to set up a binding only based on a DHCP Reply message. As described in Section 7.4.2.2, whenever binding anchors must be recovered from DCHP Reply, such a mapping table is required.

Such a table can already exist on SAVI devices. For example, if the binding anchor is a switch port, the mapping table from MAC address to switch port is required for switching frames. We don't require SAVI devices to set up a different mapping table from the existing ones.

The set up and update of this table is out of the scope of this document.

7. Procedure of Regular Binding Set Up

This section specifies the procedure of setting up bindings based on DHCP message snooping. The binding procedure makes use of a state machine. The binding procedure specified here is exclusively designed for binding anchor with SAVI-Validation attribute.

7.1. Rationale

The rationale of this mechanism is that if a node associated with a binding anchor is legitimate to use a DHCP address, the DHCP procedure which assigns the address to the node must have been performed on the same binding anchor. This basis stands when the SAVI device is an intermedia of the DHCP server(s) and the managed host, and the link layer routing is stable. However, arbitrary topologies, layer-2 mobility and unstable link layer routing may result in that data packet is received from a different binding anchor. Such scenarios, excluding frequent link layer routing change, can be handled (but not perfectly) by the mechanism described in Section 8. Section 13.3 discusses the situation that the link layer routing is naturally unstable. A solution for this issue is outside the scope of this document.

7.2. Binding States Description

This section describes the binding states of this mechanism.

NO_BIND: The state before a binding has been set up.

INIT_BIND: A DHCP request (or a DHCPv6 Confirm, or a DHCPv6 Solicitation with Rapid Commit option) has been received from client, and it may trigger a new binding.

BOUND: The address is authorized to the client.

7.3. Events

7.3.1. Timer Expiration Event

EVE_ENTRY_EXPIRE: The lifetime of an entry expires.

7.3.2. Control Message Arriving Events

Only if a DHCP message can pass the check in Section 9.2, the corresponding event is a valid event. For any message that may trigger a new binding, the binding entry limit (cf. Section 13.2, the limit is set to prevent attacks against the binding entry resource on SAVI device) on the corresponding binding anchor MUST NOT have not

been reached. On receiving a DHCP message without triggering a valid event, the state in the following section will not transit.

EVE_DHCP_REQUEST: A DHCP Request message is received from a binding anchor with SAVI-Validation attribute.

EVE_DHCP_CONFIRM: A DHCPv6 Confirm message is received from a binding anchor with SAVI-Validation attribute.

EVE_DHCP_REBIND: A DHCPv6 Rebind message is received from a binding anchor with SAVI-Validation attribute.

EVE_DHCP_OPTION_RC: A DHCPv6 Solicitation message with Rapid Commit option is received from a binding anchor with SAVI-Validation attribute.

EVE_DHCP_REPLY_LEASE: A DHCPv4 Acknowledgement or DHCPv6 Reply message is received, and there is an entry with matched TID in the BST, and lease time is contained in the message.

EVE_DHCP_REPLY_NOLEASE: A DHCPv4 Acknowledgement or DHCPv6 Reply message is received, and there is an entry with matched TID in the BST, and no lease time is contained in the message.

EVE_DHCP_REPLY_NULL: A DHCPv4 Acknowledgement or DHCPv6 Reply message is received, and there is no entry in the BST contains the same TID as the message.

EVE_DHCP_DECLINE: A DHCP Decline message is received from a binding anchor with SAVI-Validation attribute.

EVE_DHCP_RELEASE: A DHCP Release message is received from a binding anchor with SAVI-Validation attribute.

EVE_LEASEQUERY_REPLY: A successful DHCP LEASEQUERY_REPLY is received from a binding anchor with SAVI-DHCP-Trust attribute.

7.4. State Machine of DHCP Packet Snooping

7.4.1. From NO_BIND to Other States

7.4.1.1. Trigger Event

EVE_DHCP_REQUEST, EVE_DHCP_OPTION_RC, EVE_DHCP_CONFIRM, EVE_DHCP_REBIND, EVE_DHCP_REPLY_NULL.

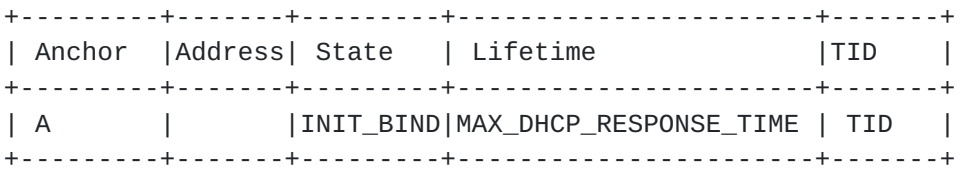
7.4.1.2. Following Actions

If the triggering event is EVE_DHCP_REQUEST/EVE_DHCP_OPTION_RC:

The SAVI device MUST forward the message.

As illustrated in Figure 4, the SAVI device MUST generate an entry for the binding anchor in the Binding State Table (BST) and set the state field to INIT_BIND. The lifetime of this entry is set to be MAX_DHCP_RESPONSE_TIME. The TID field of the triggering message MUST be recorded in the entry.

The TID is stored because it will be used to correctly associate message from the DHCP server with target binding anchor.

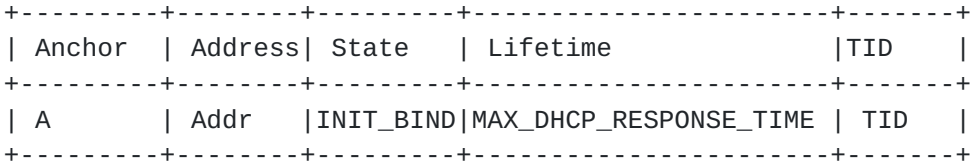


Anchor	Address	State	Lifetime	TID
A		INIT_BIND	MAX_DHCP_RESPONSE_TIME	TID

Figure 4: Binding entry in BST on Request/Rapid Commit triggered initialization

If the triggering event is EVE_DHCP_CONFIRM/EVE_DHCP_REBIND:

Besides forwarding the message and generating corresponding entry, the address to confirm/rebind MUST be recorded in the entry, as illustrated in Figure 5. The Lifetime field is set to MAX_DHCP_RESPONSE_TIME.



Anchor	Address	State	Lifetime	TID
A	Addr	INIT_BIND	MAX_DHCP_RESPONSE_TIME	TID

Figure 5: Binding entry in BST on Confirm/Rebind triggered initialization

If the triggering event is EVE_DHCP_REPLY_NULL:

If the binding anchor is not a link layer address and there is not a mapping table from the link layer address to the binding anchor, the message SHOULD be delivered, but no entry will be set up. This situation may happen when this mechanism is enabled after the client sends the DHCP Request. The binding can be recovered based on the binding recovery process described in Section 8.

Else:

The SAVI device MUST generate as many new entries in BST as the number of IADDR found in the message. If the binding anchor type inside the BST is not a link layer address, the binding anchor for an entry is recovered from the mapping table from the link layer address to the binding anchor (cf. Section 6.2) based on the destination link layer address inside the DHCP message.

As illustrated in Figure 6, the states of the corresponding entries are set to be BOUND. The lifetimes of the entries are set to be the lease time in the message.

The binding entry limit can be exceeded when setting up bindings for all addresses in a REPLY message. If there is enough binding entry resource left in the shared pool, corresponding new entries MUST be generated even when the binding number limit is exceeded. In case that there is not enough resources left in the shared pool, the message MUST be discarded.

If the binding anchor is a switch port, there can be a vulnerability in this process which is discussed in Section 13.1. Similar problems can happen with other binding anchors.

Anchor	Address	State	Lifetime	TID
A	Addr1	BOUND	Lease time 1	TID
A	Addr2	BOUND	Lease time 2	TID

Figure 6: Binding entry in BST on Reply triggered initialization

7.4.2. From INIT_BIND to Other States

7.4.2.1. Trigger Event

EVE_DHCP_REPLY_LEASE, EVE_LEASEQUERY_REPLY, EVE_ENTRY_EXPIRE.

7.4.2.2. Following Actions

If the trigger event is EVE_DHCP_REPLY_LEASE:

As illustrated in Figure 7, If the Address field is null, the lifetime field of the entry with matched TID is set to the sum of the lease time in Reply message and MAX_DHCP_RESPONSE_TIME. The state of the entry is changed to be BOUND. If more than one IADDR is found in the message and there is enough binding entry resources, corresponding new entries MUST be generated even when the binding number limit is exceeded. If there is not enough resources left, the message MUST be discarded.

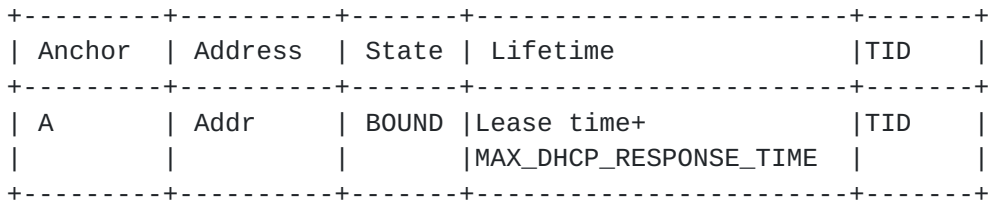


Figure 7: From INIT_BIND to BOUND with Lease Time

If the trigger event is EVE_DHCP_REPLY_NOLEASE:

The triggering message is in response to a Confirm message. If the message doesn't contain Status Code Success, discard the message. If the message is of Status Code Success, the state of the entry is changed to be BOUND. Because no lease time will be contained in the REPLY from DHCP server, the SAVI device MUST lookup in BST to determine whether there is an entry with the same address and TID. If there is such an entry and the corresponding binding anchor is off-link, it can be a local movement and the lifetime can be recovered from the entry. In this case, set the Lifetime to be the remaining value of Lifetime field of the existing entry, and remove the existing entry. If there is no such an entry, the SAVI device MUST send a LEASEQUERY [rfc5007] message querying by IP address to All_DHCP_Relay_Agents_and_Servers multicast address [rfc3315] or a configured server address. In this case, set the Lifetime of

corresponding entry to MAX_LEASEQUERY_DELAY, as illustrated in Figure 8.

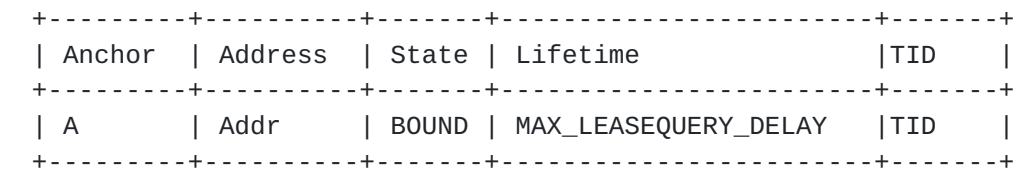


Figure 8: From INIT_BIND to BOUND without Lease Time

If the trigger event is EVE_ENTRY_EXPIRE:

The entry MUST be deleted from BST.

7.4.3. From BOUND to Other States

7.4.3.1. Trigger Event

EVE_ENTRY_EXPIRE, EVE_DHCP_RELEASE, EVE_DHCP_DECLINE, EVE_DHCP_REPLY_LEASE, EVE_LEASEQUERY_REPLY.

7.4.3.2. Following Actions

If the trigger event is EVE_ENTRY_EXPIRE:

Remove the corresponding entry in BST.

If the trigger event is EVE_DHCP_RELEASE/EVE_DHCP_DECLINE:

Remove the corresponding entry in BST. The Release or Decline message MUST be forwarded.

If the trigger event is EVE_DHCP_REPLY_LEASE:

Set the lifetime of the entry with the corresponding address and TID to be the sum of the new lease time and MAX_DHCP_RESPONSE_TIME.

If the trigger event is EVE_LEASEQUERY_REPLY:

The Lifetime field of entry with corresponding IP address MUST be set to the sum of the lease time in the LEASEQUERY_REPLY and MAX_DHCP_RESPONSE_TIME.

7.5. Table of State Machine

The main state transits are listed as follows.

State	Event	Action	Next State
NO_BIND	REQ/RC/RB/CFM	Generate entry	INIT_BIND
*NO_BIND	RPL_NULL	Generate entry with lease	BOUND
INIT_BIND	RPLL	Record lease time	BOUND
INIT_BIND	RPLN	Send Leasequery/set LQ_DLY	BOUND
INIT_BIND	Timeout	Remove entry	NO_BIND
BOUND	RLS/DCL	Remove entry	NO_BIND
BOUND	Timeout	Remove entry	NO_BIND
BOUND	RPLL	Set new lifetime	BOUND
BOUND	LQR	Record lease time	BOUND

Figure 9: Table of Transit

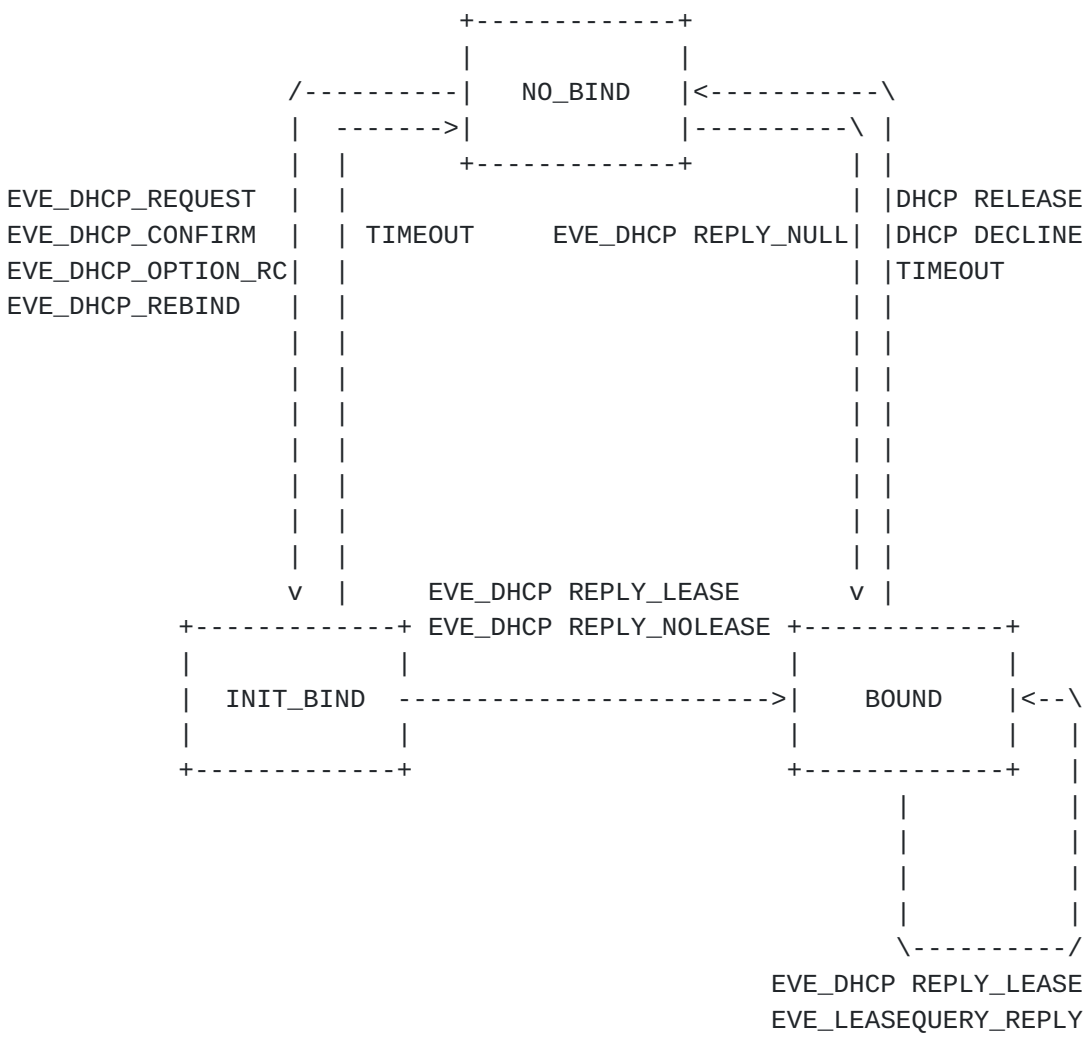


Figure 10: Diagram of Transit

*: optional but NOT RECOMMENDED.

REQ: EVE_DHCP_REQUEST

CFM: EVE_DHCP_CONFIRM

RC: EVE_DHCP_OPTION_RC

RB: EVE_DHCP_REBIND

RPLL: EVE_DHCP REPLY_LEASE

RPLN: EVE_DHCP REPLY_NOLEASE

RPL_NULL: EVE_DHCP REPLY_NULL

DCL: DHCP DECLINE

RLS: DHCP RELEASE

LQR: EVE_LEASEQUERY_REPLY

Timeout: EVE_ENTRY_EXPIRE

LQ_DLY: MAX_LEASEQUERY_DELAY

8. Supplemental Binding Process

Supplemental binding process is designed to cover scenarios where a packet is sent by a node but no previous DHCP exchanges have occurred to correctly update the SAVI device's BST. Several senarios that issues are listed:

(1) Arbitrary topologes: the SAVI device may not be able to snoop DHCP messages exchanged between nodes and DHCP servers in case of arbiraty topologies.

(2) Link topology change: when the link topology changes after the binding has been set up, and then the node will send packets through a different port rather than the bound port.

(3) Local link movement: a node moves on the local link without performing re-configuration process.

The binding recovery process is designed to avoid permanently blocking legitimate traffic. This process is performed on binding anchor with both SAVI-Validation and SAVI-BindRecovery attributes. It is not supposed to set up a binding whenever a data packet with an unbound source address is received. Generally, longer time and more packets are needed to trigger supplemental binding processes.

Considering the overhead of this procedure, the implementation of binding recovery process is a conditional SHOULD. This function SHOULD be implemented unless the implementation is known to be directly attached to the host. If an implementation is directly attached to host, change in link topology will not affect the bindings, and host will always start the re-configuration process after the interface is re-connected. Thus, there is no need to use additional processes to recovery bindings. If the mechanism is not implemented and managed hosts are not directly attached, legitimate traffic will be blocked until the node is reconfigured.

The security issues about this process is discussed is Section 13.5.

8.1. Rationale

If a DHCP address is allocated on the link, and the address is not used by another node in the network, the address can be bound with the binding anchor on which a message is received.

8.2. Additional Binding States Description

In addition to Section 7.2, new states used in this process are required here:

DETECTION The address is under local detection.

RECOVERY The address is in binding recovery process.

8.3. Events

Additional events in this process are described here. Also, if an event will trigger to set up a new binding entry, the binding entry limit on the binding anchor MUST NOT have not been reached.

EVE_BR_UNMATCH A data packet without matched binding of BOUND state in BST is received on a binding anchor with both SAVI-Validation and SAVI-BindRecovery attributes.

EVE_BR_CONFLICT Response against an address in DETECTION state is received.

EVE_BR_LEASEQUERY IPv4: a DHCPLEASEACTIVE message with IP Address Lease Time option is received from a binding anchor with SAVI-DHCP-Trust attribute; IPv6: a successful LEASEQUERY-REPLY is received.

8.4. State Machine of Binding Recovery Process

Through using additional states, the state machine of this process doesn't conflict the regular process described in Section 7. Thus, it can be implemented separately without changing the state machine in Section 7.

8.4.1. From NO_BIND to Other States

8.4.1.1. Trigger Event

EVE_BR_UNMATCH.

8.4.1.2. Following Action

Determine whether to process this event with a probability. The probability can be configured or calculated based on the state of the SAVI device. This probability should be low enough to mitigate the damage from DoS attack against this process. How to generate this probability is out of the scope of this document.

If there is a corresponding binding in BST on another binding anchor with the same source address, and the binding anchor is not off-link, the packet SHOULD be dropped, and no further actions will not be taken.

Check if the time since the last EVE_BR_UNMATCH on the same binding anchor is larger than BIND_RECOVERY_INTERVAL. No further actions will be taken if the last EVE_BR_UNMATCH on the same binding anchor in the last BIND_RECOVERY_INTERVAL.

Create a new entry in the BST. Set the Binding Anchor field to the corresponding binding anchor. Set the Address field to be source address of the packet. Set the state field to DETECTION. Set the lifetime of the created entry to 2*DAD_TIMEOUT.

Check if the address has a local conflict (it violates an address being used by another node) through:

(1) IPv4 address: sending a Address Resolution Protocol (ARP) Request [rfc826]or a ARP probe [rfc5227] on the address; if there is no response message after DAD_TIMEOUT, send another ARP Request or ARP probe;

(2) IPv6 address: performing Duplicate Address Detection (DAD) [rfc4862] on the address; if there is no response message after DAD_TIMEOUT, perform another DAD procedure.

Because the delivery of detection message is unreliable, the detection message is of a certain possibility of not reaching the targeting node. If the targeting node doesn't get the detection message, the address may be bound with a wrong binding anchor in the futher stages. This fault may introduce attack against this mechanism. Thus, the detection is performed again if there is no response after the first detection.

The messages MUST NOT be sent to the link with the binding anchor of the triggering packet.

The packet which triggers this event SHOULD be discarded.

8.4.2. From DETECTION to Other States

8.4.2.1. Trigger Event

EVE_ENTRY_EXPIRE, EVE_BR_CONFLICT.

8.4.2.2. Following Action

If the trigger event is EVE_ENTRY_EXPIRE:

(1) IPv4 address: Send a DHCPLEASEQUERY [rfc4388] message querying by IP address to all DHCPv4 servers with IP Address Lease Time option (option 51). The server addresses can be found through DHCPv4 Discovery or from configuration. Change the state of the corresponding entry to RECOVERY. Change the lifetime of the entry to be MAX_LEASEQUERY_DELAY.

(2) IPv6 address: Send a LEASEQUERY [rfc5007] message querying by IP address to All_DHCP_Relay_Agents_and_Servers multicast address or a configured server address.

Change the state of the corresponding entry to RECOVERY. Change the lifetime of the entry to be MAX_LEASEQUERY_DELAY.

If the trigger event is EVE_BR_CONFLICT:

Remove the entry.

8.4.3. From RECOVERY to Other States

8.4.3.1. Trigger Event

EVE_ENTRY_EXPIRE, EVE_BR_LEASEQUERY.

8.4.3.2. Following Action

If the trigger event is EVE_BR_LEASEQUERY:

(1) IPv4 address: Change the state of the corresponding binding to BOUND. Set life time to the sum of the value encoded in IP Address Lease Time option of the DHCPLEASEACTIVE message and MAX_DHCP_RESPONSE_TIME.

(2) IPv6 address: Change the state of the corresponding binding to BOUND. Set the lifetime to the sum of the valid lifetime extracted from OPTION_CLIENT_DATA option in the LEASEQUERY-REPLY message and MAX_DHCP_RESPONSE_TIME.

If multiple addresses are specified in the LEASEQUERY-REPLY message, new entries MUST also be created correspondingly on the same binding anchor.

If the trigger event is EVE_ENTRY_EXPIRE:

Remove the entry.

8.4.4. After BOUND

Note that the TID field contains no value after the binding state changes to BOUND. Because TID is used to associate entry with message from server, attaching node will be prevented from renewing the bound address. Thus, the TID field is recovered from snooping DHCP Renew message.

8.4.4.1. Trigger Event

EVE_DHCP_RENEW.

8.4.4.2. Following Action

Set the TID field of the corresponding entry to the TID in the trigger message.

9. Filtering Specification

This section specifies how to use bindings to filter out spoofing packets.

Filtering policies are different for data packet and control packet. DHCP and NDP (Neighbor Discovery Protocol) [rfc4861] messages that may cause state transit are classified into control packet. Neighbor Advertisement (NA) and ARP Response are also included in control packet, because the Target Address of NA and ARP Response should be checked to prevent spoofing. All other packets are considered to be data packets.

9.1. Data Packet Filtering

Data packets with a binding anchor which has attribute SAVI-Validation MUST be checked.

Packet whose source IP address is a link-local address SHOULD be forwarded.

If the source IP address of a packet is not a link-local address, but

the address is not bound with the corresponding binding anchor, this packet MUST be discarded.

The SAVI device MAY record any violation.

9.2. Control Packet Filtering

For binding anchors with SAVI-Validation attribute:

Discard DHCPv4 REQUEST message whose source IP address is neither all zeros nor a bound address in BST.

Discard DHCPv6 Request message whose source is neither a link-local address nor bound with the corresponding binding anchor in BST.

Discard NDP messages whose source address is neither a link-local address nor bound with the corresponding binding anchor. In addition, discard NA message whose target address is neither a link-local address nor bound with the corresponding binding anchor.

Discard ARP messages whose protocol is IP and sender protocol address is neither all zeros address nor bound with the corresponding binding anchor. In addition, discard ARP Reply messages whose target address is not bound with the corresponding binding anchor.

For other binding anchors:

Discard DHCP server/relay type message not from binding anchor with the SAVI-DHCP-Trust attribute or SAVI-SAVI attribute.

The SAVI device SHOULD record any violation of the previous rules.

10. State Restoration

If a SAVI device reboots accidentally or designedly, the information kept in volatile memory will be lost. This section specifies the restoration of binding anchor attribute and binding state.

10.1. Binding Anchor Attribute Restoration

The configuration of binding anchor attribute is critical to this mechanism. If this configuration is lost, DHCPv4 Acknowledgement/ DHCPv6 Reply will be discarded. Though legitimate packet will not be discarded, host will be prevented from getting new DHCP address or renewing existing address.

To avoid the loss of binding anchor attribute configuration, the

configuration MUST be able to be stored in non-volatile storage. After the reboot of SAVI device, if the configuration of binding anchor attribute can be found in non-volatile storage, the configuration MUST be used.

10.2. Binding State Restoration

The loss of binding state will cause legitimate traffic from host indirectly attached to the SAVI device to be blocked until binding recovery. Purely using the Binding Recovery Process to recover a large number of bindings is of heavy overhead and results considerable delay. Thus, recovery from non-volatile storage, as specified below, is RECOMMENDED.

If this function is supported by hardware, binding entries MAY be saved into non-volatile storage whenever a new binding entry changes to BOUND state. If a binding with BOUND state is removed, the saved entry MUST be removed correspondingly.

Immediately after reboot, the SAVI device SHOULD restore binding states from the non-volatile storage. The system time of save process MUST be stored. After rebooting, the SAVI device MUST check whether each entry has been obsolete through comparing the saved lifetime and the difference between the current system time and saved system time.

11. Constants

MAX_DHCP_RESPONSE_TIME 120s

BIND_RECOVERY_INTERVAL 60s and configurable

MAX_LEASEQUERY_DELAY 10s

OFFLINK_DELAY 30s

DAD_TIMEOUT 0.5s

12. MLD Consideration

To perform the binding recovery procedure in Section 8, the SAVI device MUST join the Solicited Node Multicast group of the source address of triggering IPv6 data packet whenever performing duplicate detection.

13. Security Considerations

13.1. Security Problem about Binding Triggered by EVE_DHCP_REPLY_NULL

When the binding anchor is a switch port, binding based on EVE_DHCP_REPLY_NULL can result in security threats. The assigned address could be bound to a wrong switch port if an attacker can maliciously pollute the table mapping a link layer address to switch port (cf. Section 6.2).

For example, host A requests address from port 1. When a SAVI switch receives a DHCP REPLY with assigned address IP_A and destination link layer address MAC_A, it will check its MAC/port table to find the right binding port. But MAC/port table might be polluted by an attacker host B attached to port 2. Then the SAVI switch will find the MAC_A is at port 2 from the polluted MAC/port table and it will result in a wrong binding which binds IP_A and port 2.

Protection from this attack can be ensured by making sure that one of the following conditions is satisfied:

(1) DHCP Option 82 is used to keep binding anchor in DHCP Request and Reply. DHCP Option 82 can be used to keep the circuit information of the client and returned by the DHCP server. Thus the binding anchor can be determined from the circuit information in the Option. It can be used whenever an implementation doesn't want to create an entry on the DHCP Request message.

(2) Unspoofable MAC is used as binding anchor (802.11i, 802.1ae/af).

(3) The mapping table from MAC to binding anchor is secure.

If the binding anchor is a link layer address, or there are mechanisms preventing the corruption of the table mapping the link layer to a switch port, mapping link layer address to binding anchor may be considered as secure.

It is NOT RECOMMENDED to initialize a binding based on DHCP Reply, unless a mechanism protecting the mapping table from corruption is also implemented. Similar problem may happen with binding anchors not based on link layer addresses.

13.2. Binding Number Limitation

In general case, a binding entry will cost a certain resource and a SAVI device can only afford a limited number of binding entries. In order to prevent a single node from overloading the binding table

entries on the SAVI device, binding entry limit is set. The binding entry limit is the upper bound of binding number for each binding anchor with SAVI-Validation. Besides, a SAVI device SHOULD reserve a shared pool of binding resources to handle the scenario that the number of adversed addresses exceeds the binding entry limit on the corresponding binding anchor as specified in Section 7.4.1.2.

13.3. Risk from Link Layer Routing Dynamic

An implicit assumption of this solution is that data packet must arrive at the same binding anchor with the binding anchor that the control packets have arrived at. If this assumption is not valid, this control packet based solution will fail or at least discard a number of legitimate packets. Unfortunately, the link layer routing between host and SAVI device can be inconsistent from time to time. Time consistency of the link layer routing is not assured by the link layer routing protocol. For example, TRILL, a recent link layer routing protocol, is flexible and multiple link layer paths are allowed.

To make the basic assumption stand, the best way is enforcing that there should be only one topology path from downstream host to the SAVI device. For example, SAVI device is directly attached by hosts.

If the assumption doesn't stand, a better solution is requiring inter-operation between SAVI protocol and the link layer routing protocol to make SAVI protocol sensitive to the link layer routing change. This solution is above the scope of this document.

13.4. Duplicate Bindings of Same Address

The same address may be bound with multiple binding anchors, only if the binding processes are finished on each binding anchor successfully. This mechanism is designed in consideration that a node may move on the local link, and a node may have multiple binding anchors. However, the traceability of address is reduced.

Note that the local link movement scenario is not handled perfectly. The former binding may not be removed, unless the node is directly attached to SAVI device. The nodes sharing the same former binding anchor of the moving node have the ability to use its address.

13.5. Security Problems about Binding Recovery Process

The Binding Recovery Process (cf. Section 8) MUST be rate limited to avoid Denial of Services attack against the SAVI device itself. A constant BIND_RECOVERY_INTERVAL is used to control the frequency. Two data-triggered recovery processes on one binding anchor MUST have

a minimum interval time BIND_RECOVERY_INTERVAL. This constant SHOULD be configured prudently to avoid Denial of Service attacks.

This process is not strictly secure. The node attached with a SAVI-BindRecovery binding anchor has the ability to use the address of an inactive node, which doesn't reply to the detection probes.

13.6. Compatibility with DNA (Detecting Network Attachment)

DNA [rfc4436] [rfc6059] is designed to decrease the handover latency after re-attachment to the same network. DNA mainly relies on performing reachability test through sending unicast Neighbor Solicitation/Router Solicitation/ARP Request message to determine whether a previously configured address is still valid. Though DNA provides optimization for host, it doesn't provide sufficient information for this mechanism to migrate or establish a binding. If a binding is set up only through snooping the reachability test message, the binding can be invalid. For example, an attacker can perform reachability test with address bound to another host. If binding is migrated to the attacker, the attacker can successful obtain the binding from the victim. Because this mechanism wouldn't set up a binding based on snooping the DNA procedure, it cannot achieve perfect compatibility with DNA. However, it only means the re-configuration of the interface is slowed but not prevented. Details are discussed as follows.

In Simple DNAv6 [rfc6059], the probe is sent with source address set to link-local address, and such messages will not be discarded by the policy specified in section Section 9.2. If an interface is re-attached to a previous network, the detection will be complete and the address will be regarded as valid by host. The candidate address is not contained in the probe. Thus, the binding cannot be recovered through snooping the probe. The binding can only be recovered from the DHCP snooping procedure. The DHCP REQUEST messages wouldn't be filtered out by this solution as their source address is link-local address. Before the DHCP procedure is completed, packets will be filtered out by SAVI device. In another word, in SAVI scenarios, Simple DNAv6 will not help reduce the handover latency. If SAVI-BindRecovery attribute is configured on the new binding anchor, data triggered procedure may reduce the latency.

In DNAv4 [rfc4436], the ARP probe will be discarded because unbound address is used as sender protocol address. As a result, the detection will not complete and false negative is caused. The DHCP REQUEST message sent by the node will not be discarded, because the source IP address field should be all zero as required by [rfc2131]. Thus, if the address is still valid, the binding will be recovered from the DHCP snooping procedure.

13.7. Bogus DHCP Server Threat

SAVI-DHCP-Trust attribute is designed to prevent attacks from bogus DHCP server. However, the security is not strict because messages from valid DHCP server and bogus DHCP server may arrive at the SAVI device with the same binding anchor. As a result, the SAVI device cannot recognize valid messages from bogus messages. Because the bindings are set up primarily based on DHCP message from DHCP server, the results can be quite serious. For example, invalid addresses are assigned to hosts and bindings of the addresses are set up. There can be a lot of other attacks in such a scenario.

Considering the restraint that no new protocol can be introduced, the countermeasure is quite limited. If placing the DHCP server inside the protection perimeter, or making the path from each valid DHCP servers to the SAVI perimeter exclusive for DHCP servers, or filtering out DHCP server/relay type messages that may get into the path from each DHCP server to the protection perimeter, messages from bogus DHCP server cannot share the same binding anchor with messages from valid DHCP server, and such attack can be prevented. If none of the above deployment requirements can be satisfied, the network administrator should be aware of the above limitation and deploy this mechanism prudently.

13.8. Handle Binding Anchor Off-link Event

Port DOWN event MUST be handled if the switch port is used as the binding anchor. In a more general case, if a binding anchor turns off-link, this event MUST be handled.

Whenever a binding anchor with attribute SAVI-Validation turns down, a timer of OFFLINK_DELAY is set. Until the timer becomes zero, the bindings with the binding anchor SHOULD be kept. As an exception to handle node movements, if receiving DAD Neighbor Solicitation/ Gratuitous ARP request targeting at the address during OFFLINK_DELAY, the entry MAY be removed.

If the binding anchor turns on-link during OFFLINK_DELAY, turn off the timer and keep corresponding bindings.

13.9. Authentication in DHCPv6 Leasequery

As required in section 5 of RFC5007, DHCPv6 Leasequery should use IPsec-based authentication specified in the section 21.1 of RFC3315.

13.10. TID Spoofing

A malicious node can make use of TID of another node through snooping or blind attack. With this mechanism, DHCP message from client with source address not bound on the corresponding binding anchor will be discarded;thus, if an attacker sends DHCP message with source address and TID not bound with its binding anchor, the message will be discarded. However, an attacker can make use of source address and TID bound with the same binding anchor.This mechanism cannot identify forged DHCP client message if the attacker and the victim share the same binding anchor. As a result, dedicated attacks can be introduced. For example, an attacker can send forged DHCP Release to remove binding of another node sharing the same binding anchor.

There is no easy way to avoid this weakness in this snooping based mechanism, though DHCP has authentication mechanisms designed. For DHCPv4, client doesn't expect a Reply from server after sending Decline/Release message. Thus, this mechanism cannot rely on authentication mechanism of the server to mitigate the TID spoofing threat. For DHCPv6, because the client expects a Reply after sending Decline/Release, an attacker has to compromise the authentication mechanism enforced by DHCP server to make the server return a valid message. However, it is hard to distinguish the Reply message is in response to a Decline or a Release or a Confirm. As a result, it is hard to design a state machine that can decide the correct state transition solely based on the Reply message.

Thus, it is SUGGESTED using exclusive binding anchor to avoid TID spoofing. But even the binding anchor is shared, the attacker can be located within a small scope.

If a bogus DHCP server shared the same binding anchor with the valid DHCP server, the TID in DHCP server message can be forged. Then this mechanism can suffer TID spoofing attack. The bogus DHCP server problem is discussed in Section 13.7.

13.11. Residual Threats

As described in [savi-framework], this solution cannot strictly prevent spoofing. There are two scenarios in which spoofing can still happen:

(1) The binding anchor is spoofable. If the binding anchor is spoofable, e.g., plain MAC address, an attacker can use forged binding anchor to send packet which will not be regarded as spoofing by SAVI device. Indeed, using binding anchor that can be easily spoofed is dangerous. An attacker can use the binding anchor of another host to perform a lot of DHCP procedures, and

the SAVI device will refuse to set up new binding for the host whenever the binding number limitation has been reached. Thus, it is RECOMMENDED to use strong enough binding anchor, e.g., switch port, secure association in 802.11ae/af and 802.11i.

(2) The binding anchor is shared by more than one host. If the binding anchor is shared by more than one host, they can spoof the addresses of each other. For example, a number of hosts can attach to the same switch port of a SAVI device through a hub. The SAVI device cannot distinguish packets from different hosts and thus the spoofing between them will not be detected. This problem can be solved by not sharing binding anchor between hosts.

14. IANA Considerations

This memo asks the IANA for no new parameters.

Note to RFC Editor: This section will have served its purpose if it correctly tells IANA that no new assignments or registries are required, or if those assignments or registries are created during the RFC publication process. From the authors' perspective, it may therefore be removed upon publication as an RFC at the RFC Editor's discretion.

15. Acknowledgment

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This document was generated using the xml2rfc tool.

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Appendix A. change log

Main changes from 02 to 03:

(1) Section 12, data trigger and counter trigger are combined to binding recovery process. The expression "one of MUST" is changed to "conditional MUST. Conditions related with the implementation are specified. Related constants are changed in section 26."

Main changes from 03 to 04:

(1) Section "Prefix configuration" is removed.

(2) Section "Supplemental binding process" is modified in requirement level.

(3) Sub-section 9.1 "Rationale" is added.

(4) Section "Filtering during Detection" is removed.

(5) Section "Handling layer 2 path change" is changed to "Consideration on Link layer routing complexity"

(6) Section "Background and related protocols" is removed.

Main changes from 04 to 05:

(1) Trigger events are listed explicitly in section 8.

(2) Detection and Live states are deleted, together with corresponding sections.

Main change from 05 to 06:

(1) Section 8.1: reference to section 20 is changed to section 15.

Main changes from 06 to 07:

(1) So many changes in this modification. We suggest to track http://www.ietf.org/mailarchive/web/savi/current/msg01543.ht ml. Changes are made according to the comments.

Main changes from 07 to 08,09:

(1) The modifications are made according to the comments from Jean-Michel Combes.

Main changes from 09 to 11:

(1) DNA issues raised by Jari Arkko

Main changes from 11 to 12:

(1) The modifications are made according to the comments from Eric, http://www.ietf.org/mail-archive/web/savi/current/msg01778.html.

Main changes from 12 to 13:

(1) Main modifications are made based on comments from Elwyn Davies. http://www.ietf.org/mail-archive/web/gen-art/current/msg07297.html.

(2) Other modifications are made based on comments from Barry Leiba.

Main changes from 13 to 14:

(1) A symbol error is corrected.

Main changes from 14 to 15:

(1) In corresponding to "1. Does section 8 describe the mechanism that a SAVI device must perform if it has been unable to snoop the DHCP traffic between a host and a DHCP server? It appears that way in the document, but it would be good to explicitly state that early in the document when the discussion of topologies is being carried out. This becomes important when arbitrary topologies do not provide a means for the SAVI device to eavesdrop on the DHCP traffic." We specified in s7.1 p1 that arbitrary topologies may result in the regular process cannot set up correct bindings. This is also specified in the beginning of s8.

(2) In corresponding to "2. Section 12 refers to the "tentative address multicast group". Do you really mean the Solicited Node Multicast address that is generated from the configured IPv6 unicast address?" Yes. We have changed s12 to "the SAVI device MUST join the Solicited Node Multicast group of the source address of triggering IPv6 data packet whenever performing duplicate detection."

(3) Other modifications are made according to the gen-art review. Refer to http://netarchlab.tsinghua.edu.cn/~yaog/review.txt.

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