                        A SAVI Solution for WLAN
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Abstract

    This document describes a source address validation solution for WLAN
    enabling 802.11i or other security mechanisms. This mechanism snoops
    NDP and DHCP packets to bind IP address to MAC address, and relies on
    the security of MAC address guaranteed by 802.11i or other mechanisms
    to filter IP spoofing packets. It can work in the special situations
    described in the charter of SAVI(Source Address Validation
    Improvements) workgroup, such as multiple MAC addresses on one
    interface. This document describes three different deployment
    scenarios, with solutions for migration of binding entries when hosts
    move from one access point to another.

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[1](#). Introduction

   This document describes a mechanism to perform per packet IP source

address validation in WLAN. This mechanism performs ND snooping or
DHCP snooping to bind allocated IP address with authenticated MAC
address. Static addresses are bound to the MAC addresses of
corresponding hosts manually. Then the mechanism can check validity

of source IP address in local packets according to the binding
association. The security of MAC address is assured by 802.11i or
other mechanisms, thus the binding association is secure.

The situation that one interfaces with multiple MAC addresses is a
special case mentioned in the charter of SAVI. And this situation is
the only special case that challenges MAC-IP binding. The mechanism
to handle this situation is specified in the document.

There are three deployment scenarios specified in this document. The
mechanism is deployed on different devices in different scenarios.
The deployment detail is described in the document.

When hosts move from one access point to another, the migration of
binding entries may be triggered according to the specific mobility
scenario. The mechanism to handle host mobility is specified in the
document according to different deployment scenarios.

2. Conventions used in this document

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. IP-MAC Binding

This section specifies the operations for creating and clearing of
bindings between IP addresses to MAC addresses.

3.1. Data Structures

3.1.1. IP-MAC Mapping Table

This table maps IP addresses to corresponding MAC addresses. IP
address is the index of the table. One IP address can only have one
corresponding MAC address, while different IP addresses can be mapped
to the same MAC address.

This table is used in control process. Before creating new IP-MAC
bindings, this table must first be consulted in case of conflict in
binding entries. Also, this table must be consulted before doing any
packet filtering. This table must be synchronized with the MAC-IP
table specified in Section 3.1.2.

Each entry in IP-MAC mapping table must also record the binding state
of the IP address. Addresses snooped in DHCP address assignment
procedure must record its state as "DHCPv6", and addresses snooped in

Duplicate Address Detection procedure must record its state as
"SLAAC".

Each entry in IP-MAC mapping table has its lifetime. According to
[RFC3315], the address allocated by DHCP has a limited lifetime, so
the related entry records its lifetime the same as that of the
address. According to [RFC4862], stateless address also has a limited
lifetime, and the host set this lifetime by itself. Thus the related
entry also records its lifetime the same as that of the address.

3.1.2. MAC-IP Mapping Table

This table maps MAC addresses to corresponding IP addresses. MAC
address is the index of the table. It is a one-to-many mapping table,
which means a MAC address can be mapped to multiple IP addresses.
Though multiple MAC addresses may exist on one interface, these MAC
addresses must be mapped to different IP addresses.

This table is used for filtering. Different from wired network, MAC-
IP mapping table and IP-MAC mapping table can be maintained
separately on different devices. Mechanisms for synchronization
between the two tables must be employed for the consistency of the
bindings. We will specify the details in Section 5 according to
different deployment scenarios.

3.2. Pre-conditions for binding

In the binding based mechanism, the security of IP address is based
on the security of the binding anchor. In WLAN, a number of security
mechanisms on link layer make MAC address a strong enough binding
anchor, for instance, 802.11i, WAPI, WEP.

If MAC address has no protection, attackers can spoof MAC address to

succeed in validation. However, in general cases, if MAC address is
not protected, more serious attack can be launched than IP spoofing
attack.

3.3. Binding IP addresses to MAC addresses

All the static IP-MAC address pairs are configured into the IP-MAC
Mapping Table with the mechanism enabled.

An individual procedure handles binding DHCP addresses to MAC
addresses. This procedure snoops the DHCP address assignment
procedure between attached hosts and DHCP server. DHCP snooping in
WLAN is the same as that in wired network specified in [RFC7513].

An individual procedure handles binding stateless addresses to MAC
addresses. This procedure snoops Duplicate Address Detection
procedure. ND snooping in WLAN is the same as that in wired network
specified in [RFC6620].

Data packets MAY also trigger the establishment of new IP-MAC binding
entries. Data packet with non-bound source IP address with a limited
rate is collected to handle DAD message loss in SLAAC procedure,
which can be quite frequent in wireless network. The detail of the
procedure is specified in Section 4. However, this mechanism will
bring potential security risks (e.g. attacks that aimed at exhausting
available IP addresses). Thus, it is optional whether to enable the
mechanism, and if it is enabled, additional security mechanisms MUST
also be employed to cope with the risks. Related security
considerations are discussed in Section 6.

In some deployment scenarios, the function of address snooping and
IP-MAC table maintaining may also be separated onto different devices.
Thus to prevent conflictions in binding entries, the device snoops
addresses must have interactions with the device maintains the IP-MAC
table. We will specify the details in Section 5.1.1.

3.4. Binding Migration

Different from wired network, SAVI for WLAN must handle migration of
binding entries when mobile hosts move from one access point to
another. After movement, hosts will not perform another address
allocation procedure to obtain new IP addresses, but continue to use

the existing IP address. Thus binding entries in the foreign device
that the mobile hosts access to cannot be established by snooping. A
new mechanism is needed to correctly migrate the binding entry
related to the IP address of the mobile host from the home device to
the foreign device. We will specify the details in [Section 5](#),
according to different deployment scenarios.

3.5. Binding Clearing

Three kinds of events will trigger binding clearing:

1. The lifetime of an IP address in one entry has expired. This IP
entry MUST be cleared.

2. A host leaves this access point. The entries for all the related
MAC addresses MUST be cleared.

3. A DHCP RELEASE message is received from the owner of corresponding
IP address. This IP entry MUST be cleared.

4. Source Address Validation

This section describes source address validation procedure on packet.
In this procedure, all the frames are assumed to have passed the
verifications of 802.11i or other security mechanisms.

This procedure has the following steps:

1. Extract the IP source and MAC source from the frame. Lookup the
MAC address in the MAC-IP Mapping Table and check if the MAC-IP pair
exists. If yes, forward the packet. Or else go to step 2.

2. Lookup the IP address in the IP-MAC Mapping Table and check if the
IP address exists. If no, go to step 3. If yes, check whether The MAC
address in the entry is the same as that in the frame. If yes,
forward the packet. Else drop the packet.

3. If the mechanism that allows data packets to trigger the
establishment of new IP-MAC binding entries is enabled, insert a new
entry into the IP-MAC Mapping Table and forward the packet. Otherwise
drop the packet.

In step 2, after the packet is judged valid and forwarded,

synchronization between the MAC-IP and IP-MAC mapping table should be
triggered. The MAC-IP binding of the packet should be synchronized
from IP-MAC mapping table to MAC-IP mapping table and thus the
following packets with the same MAC-IP pair will be forwarded without
going to step 2.

Also in step 3, if a new IP-MAC binding entry is established, it
should be synchronized to MAC-IP mapping table.

5. Deployment Scenarios

This section specifies three deployment scenarios including two under
centralized WLAN and one under autonomous WLAN. The deployment
details and solutions for host mobility between access points are
described respectively in each scenario.

5.1. Centralized WLAN

Centralized WLAN is comprised of FIT Access Points (AP) and Access
Controllers (AC). In this scenario, this document proposes the
following two deployment solutions.

5.1.1. AP Filtering

In this scenario, AC maintains IP-MAC Mapping Table while AP
maintains MAC-IP Mapping Table and perform address snooping.

5.1.1.1. Candidate Binding

AP executes the procedure specified in Section 3.3. Candidate binding
is generated after snooping procedure. Candidate binding must be
confirmed by AC to be valid.

After a candidate binding is generated, AC is notified and checks
whether the binding is valid or not. The validity of a candidate
binding is determined if the binding does not violate any existing
bindings in the IP-MAC Mapping Table. Otherwise if an address is not
suitable for a host to use, AC notifies the corresponding AP. If the
candidate binding is valid, AC adds an entry into the IP-MAC Mapping
Table and notifies AP. Afterwards AP also adds an entry into the

local MAC-IP Mapping Table.

5.1.1.2. Packet Filtering

As specified in Section 4, for incoming data packets, AP looks up the
MAC address in the local MAC-IP Mapping Table and check if the MAC-IP
pair exists. If yes, AP forwards the packet. Or else AP delivers the
packet to AC for further processing.

When receiving data packets from AP, AC Looks up the IP address in
the local IP-MAC Mapping Table and checks if the IP address exists.
If no, according to whether the AC is configured to allow data
packets to trigger binding entry creations, AC establishes a new IP-
MAC entry then forwards the packet, or drop the packet. If yes, AC
checks whether The MAC address in the entry is the same as that in
the frame. If yes, AC forwards the packet. Else AC drops the packet.

After AC forwards a valid packet, it synchronizes related MAC-IP
binding to the MAC-IP mapping table on the AP from which the packet
comes. Following packets with the same MAC-IP pair will be forwarded
directly by AP without going to AC.

5.1.1.3. CAPWAP Extension

CAPWAP protocol is used for communication between AP and AC. A new
CAPWAP protocol message element is introduced, which extends
[RFC5415]. The host IP message element is used by both AP and AC to
exchange the binding information of hosts.

The host IP message element can be used in the process of
confirmation of candidate binding. When AP generates a candidate
binding, it reports the MAC address and related IP addresses to AC
using this message, with suggestions of the state and lifetime of
each IP address as specified in Section 3.1.1. After AC checks the
validation of the candidate binding, it replies using a message of
the same format to inform AP the validation of each IP address with
suggestions of its state and lifetime.

The host IP message element also can be used in the process of
binding migration. In mobility scenario, foreign device the mobile
hosts accesses to need to request related bindings from home devices,
and host IP message element can be used for interactions between them.

Details will be specified in the following sections according to
different deployment scenarios.

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     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
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |    Radio ID    |                  Total Length               +
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |    Sender ID   |    Length     |            Description       +
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |    MAC flag    |    Length     |          MAC Address...      +
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                         MAC Address...                       +
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |    IPv4 flag   |    Length     |          IPv4 Address...     +
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                         IPv4 Address...                      +
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |    IPv6 flag   |    Length     |          IPv6 Address...     +
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                         IPv6 Address...                      +
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Radio ID: An 8-bit value representing the radio, whose value is
between 1 and 31.

Total Length: Total length of the following fields.

Sender ID: An 8-bit value representing the sender of the message. AP
is represented by value 1 and AC is represented by value 2.

Length: The length of the Value field.

Description: A 16-bit value for descriptions of the sender (AP or AC).

MAC flag: An 8-bit value representing that the sub-field's type is
MAC address, whose value is 1.

Length: The length of the MAC Address field. The formats and lengths
specified in [EUI-48] and [EUI-64] are supported.

MAC Address: A MAC address of the host.

IPv4 flag: An 8-bit value representing that the sub-field's type is
IPv4 address, whose value is 2.

Length: The length of the IPv4 Address field.

IPv4 Address: An IPv4 address of the host. There may exist many
entries, and each entry is comprised of an IPv4 address, an 8-bit
value for address state (only value 1 is used for now), and a 32-bit
value for lifetime.

IPv6 flag: An 8-bit value representing that the sub-field's type is
IPv6 address, whose value is 3.

Length: The length of the IPv6 Address field.

IPv6 Address: An IPv6 address of the host. There may exist many
entries, and each entry is comprised of an IPv6 address, an 8-bit
value of address state (also one value for now), and a 32-bit value
lifetime.

5.1.1.4. Mobility Solution

When a host moves from one AP to another, layer-2 association happens
before IP packet transfer. Home AP deletes the binding when mobile
host is disconnected, and foreign AP immediately requests the bound
addresses with the associated MAC from AC using host IP message
element specified in Section 5.1.1.2. AC returns the binding with
suggestions of its state and lifetime also using the new CAPWAP
protocol message. After AP get the addresses should be bound, the
binding migration is completed.

In WLAN, a host can move from an AC to another AC while keeping using
the same IP address. To be compatible with such scenario, ACs must
communicate to perform the binding migration. CAPWAP extensions

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specified in Section 5.1.1.2 can also be used for communications
between AC.

5.1.2. AC Filtering

In this scenario, AC maintains both MAC-IP and IP-MAC Mapping Table

and performs both address snooping and packet filtering. So all the
packets must be forwarded to AC firstly.

AC executes the procedure specified in Section 3.3 and check the
validity of IP-MAC pairs by consulting the local IP-MAC mapping table.
No extra procedure is needed to establish the IP-MAC bindings.

AC executes the procedure specified in Section 4 for packet filtering
and no extra procedure is involved.

Mobility within one AC does not trigger any binding migration.
Mobility between different ACs triggers binding migration. ACs must
communicate to perform the binding migration. CAPWAP extensions
specified in Section 5.1.1.2 can be used for communications between
ACs.

5.2. Autonomous WLAN

Autonomous WLAN is comprised of FAT Access Points. In this scenario,
FAT AP maintains both MAC-IP and IP-MAC Mapping Table and performs
both address snooping and packet filtering.

FAT AP executes the procedure specified in Section 3.3 and check the
validity of IP-MAC pairs by consulting the local IP-MAC mapping table.
No extra procedure is needed to establish the IP-MAC bindings.

FAT AP executes the procedure specified in Section 4 for packet
filtering and no extra procedure is involved.

Mobility between different FAT APs will trigger binding migration.
FAT APs must communicate to perform the binding migration. CAPWAP
extensions specified in Section 5.1.1.2 can be used for
communications between FAT AP.

6. Security Considerations

The security of address allocation methods matters the security of
this mechanism. Thus it is necessary to improve the security of
stateless auto-configuration and DHCP firstly.

In Section 3.3, a mechanism is described to allow data packets to

trigger the establishment of new binding entries. If the mechanism is
enabled, it can be used to launch attacks which may finally leads to
exhaustion of available IP addresses. If no restriction is taken, the
attacker can make as many IP-MAC bindings as possible with the same
MAC address. In this way, other hosts may fail to trigger any binding
entry establishment and thus cannot get their packets pass the SAVI
device. To cope with the potential security risks, additional
mechanism MUST be employed, e.g. to limit the maximum number of IP
addresses that one MAC address can bind to.

7. IANA Considerations

There is no IANA Consideration currently.

8. Acknowledgements

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