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F. Gont
SI6 Networks / UTN-FRH
W. Liu
Huawei Technologies

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A Method for Generating Semantically Opaque Interface Identifiers with Dynamic Host Configuration Protocol for IPv6 (DHCPv6)
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Abstract

This document specifies a method for selecting IPv6 Interface Identifiers, to be employed by Dynamic Host Configuration Protocol for IPv6 (DHCPv6) servers when leasing non-temporary IPv6 addresses to DHCPv6 clients. This method is a DHCPv6 server side algorithm, that does not require any updates to the existing DHCPv6 specifications. The aforementioned method results in stable addresses within each subnet, even in the presence of multiple DHCPv6 servers or DHCPv6 server reinstallments. It is a DHCPv6-variant of the method specified in RFC 7217 for IPv6 Stateless Address Autoconfiguration.

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1. Introduction

Stable IPv6 addresses tend to simplify event logging, trouble-shooting, enforcement of access controls and quality of service, etc. However, there are a number of scenarios in which a host employing the DHCPv6 protocol [RFC3315] may be assigned different IPv6 addresses for the same interface within the same subnet over time. For example, this may happen when multiple servers operate on the same network to provide increased availability, but may also happen as a result of DHCPv6 server reinstallments and other scenarios.

This document specifies a method for selecting IPv6 Interface Identifiers, to be employed by Dynamic Host Configuration Protocol for IPv6 (DHCPv6) servers when leasing non-temporary IPv6 addresses to DHCPv6 clients (i.e., to be employed with IA_NA options). This method is a DHCPv6 server side algorithm, that does not require any updates to the existing DHCPv6 specifications. The aforementioned method has the following properties:

- The resulting IPv6 addresses remain stable within each subnet for the same network interface of the same client, even when different DHCPv6 servers (implementing this specification) are employed.

- Predicting the IPv6 addresses that will be generated by the method specified in this document, even with knowledge of the IPv6

addresses generated for other nodes within the same network, becomes very difficult.

The method specified in this document achieves the aforementioned properties by means of a calculated technique as opposed to e.g. state-sharing among DHCPv6 servers. This approach has been already suggested in [RFC7031]. We note that the method specified in this document is essentially a DHCPv6-version of the "Method for Generating Semantically Opaque Interface Identifiers with IPv6 Stateless Address Autoconfiguration (SLAAC)" specified in [RFC7217].

2. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

3. Applicability and Design Goals

This document does not update the DHCPv6 protocol [RFC3315]. DHCPv6 implementations are NOT required to implement/support the mechanism specified in this document. It is up to each DHCPv6 server implementation whether the scheme specified in this document is implemented and/or enabled.

This document simply specifies one possible approach for selecting IPv6 Interface Identifiers to be employed by Dynamic Host Configuration Protocol for IPv6 (DHCPv6) servers when leasing non-temporary IPv6 addresses to DHCPv6 clients, with the following properties:

- The resulting IPv6 addresses remain stable within each subnet for the same network interface of the same client.
- The resulting IPv6 addresses cannot be predicted by an attacker without knowledge of a secret key.
- The resulting IPv6 addresses remain stable across DHCPv6 server re-installations, or even a database of previous DHCPv6 address leases is not available.
- The resulting IPv6 addresses remain stable when different DHCPv6 servers (implementing this specification) are employed on the same network.

The benefits of stable IPv6 addresses are discussed in [I-D.ietf-6man-ipv6-address-generation-privacy]. Providing address stability across server re-installations or when a database of

previous DHCPv6 address leases is unavailable is of use not only when a DHCPv6 server must be re-installed or the address-lease database becomes corrupted, but is also of use when implementation constraints (e.g., a DHCPv6 server implementation on an embedded device) make it impossible for a DHCPv6 server implementation to maintain a database of previous DHCPv6 address leases. Finally, [RFC7031] describes scenarios where multiple DHCPv6 servers are required to run in such a way as to provide increased availability in case of server failure; the algorithm specified in this document employs a (lightweight) calculated technique to (as opposed to e.g. state-sharing among DHCPv6 servers) to achieve address stability in such scenarios, without the need of an additional protocol to synchronize the lease databases of DHCPv6 servers.

4. Method Specification

DHCPv6 server implementations conforming to this specification MUST generate non-temporary IPv6 addresses using the algorithm specified in this section.

Implementations conforming to this specification SHOULD provide the means for a system administrator to enable or disable the use of this algorithm for generating IPv6 addresses.

All of the parameters included in the expression below MUST be included when generating an IPv6 address.

A DHCPv6 server implementing this specification must select the IPv6 addresses to be leased with the following algorithm:

1. Compute a random (but stable) identifier with the expression:

    RID = F(Prefix | Client_DUID | IAID | Counter | secret_key)

    Where:

    RID:
       Random (but stable) Identifier

    F():
       A pseudorandom function (PRF) that MUST NOT be computable from the outside (without knowledge of the secret key). F() MUST also be difficult to reverse, such that it resists attempts to obtain the secret key, even when given samples of the output of F() and knowledge or control of the other input parameters. F() SHOULD produce an output of at least 64 bits. F() could be implemented as a cryptographic hash of the concatenation of each of the function parameters. The default algorithm to be

employed for F() SHOULD be SHA-1 [FIPS-SHS]. An implementation MAY provide the means for selecting other other algorithms (e.g., SHA-256) for F(). Note: MD5 [RFC1321] is considered unacceptable for F() [RFC6151].

Prefix:
The prefix employed for the local subnet. If multiple servers operate on the same network to provide increased availability, all such DHCPv6 servers MUST be configured with the same Prefix. It is the administrator's responsibility that the aforementioned requirement is met.

|:
An operator representing "concatenation".

Client_DUID:
The DUID value contained in the Client Identifier option received in the DHCPv6 client message. The DUID can be treated as an array of 8-bit unsigned integers.

IAID:
The IAID value contained in the IA_NA option received in the client message. It MUST be interpreted as a 32-bit unsigned integer in network byte order.

secret_key:
A secret key configured by the DHCPv6 server administrator, which MUST NOT be known by the attacker. It MUST be encoded as an array of 8-bit unsigned integers containing the ASCII codes corresponding to the secret key. An implementation of this specification MUST provide an interface for viewing and changing the secret key. All DHCPv6 servers leasing addresses from the same address range MUST employ the same secret key.

Counter:
A 32-bit unsigned integer in network byte order, that is employed to resolve address conflicts. It MUST be initialized to 0.

2. A candidate IPv6 address (IPV6_ADDR) to be leased is obtained by concatenating as many bits as necessary from the RID value computed in the previous step (starting from the least significant bit) to the Prefix employed in the equation above.

3. The candidate IPv6 address from the previous step should be adjusted (if necessary) to the IPv6 address range from which the DHCPv6 server is expected to lease IPv6 addresses, as follows:

```
   if(IPV6_ADDR < IPV6_ADDR_LOW || IPV6_ADDR > IPV6_ADDR_HI){
        IPV6_ADDR = IPV6_ADDR_LOW + IPV6_ADDR % \
                    (IPV6_ADDR_HI - IPV6_ADDR_LOW + 1);
   }
```

where:

IPV6_ADDR:
: The candidate IPv6 address generated in the previous step..

IPV6_ADDR_HI:
: An IPv6 address specifying the upper boundary of the IPv6 address pool from which the DHCPv6 server leases IPv6 addresses. If an address range is not explicitly selected, IPV6_ADDR_HI MUST be set to the IPv6 address from Prefix (see the expression above) that has all of the bits of the Interface Identifier set to 1.

IPV6_ADDR_LOW:
: An IPv6 address specifying the lower boundary of the IPv6 address pool from which the DHCPv6 server leases IPv6 addresses. If an address range is not explicitly selected, IPV6_ADDR_LOW MUST be set to the IPv6 address from Prefix (see the expression above) that has all of the bits of the Interface Identifier set to 0.

4. The Interface Identifier of the selected IPv6 address MUST be compared against the reserved IPv6 Interface Identifiers [RFC5453] [IANA-RESERVED-IID]. In the event that an unacceptable identifier has been generated, the Counter variable should be incremented by 1, and a new IPv6 address should be computed with the updated Counter value.

5. If the resulting address is not available (e.g., there is a conflicting binding), the server should increment the Counter variable, and a new Interface ID and IPv6 address should be computed with the updated Counter value.

This document requires that SHA-1 be the default function to be used for F(), such that, all other configuration parameters being the same, different implementations of this specification result in the same IPv6 addresses.

Including the Prefix in the PRF computation causes the Interface Identifier to be different for each address from a different prefix assigned to the same client. This mitigates the correlation of activities of multi-homed nodes (since each of the corresponding addresses will employ a different Interface ID), host-tracking (since

the network prefix will change as the node moves from one network to another), and any other attacks that benefit from predictable Interface Identifiers [I-D.ietf-6man-ipv6-address-generation-privacy].

As required by [RFC3315], an IAID is associated with each of the client's network interfaces, and is consistent across restarts of the DHCPv6 client.

The Counter parameter provides the means to intentionally cause this algorithm to produce different IPv6 addresses (all other parameters being the same). This can be of use to resolve address conflicts (e.g. the resulting address having a conflicting binding).

Note that the result of F() in the algorithm above is no more secure than the secret key. If an attacker is aware of the PRF that is being used by the DHCPv6 server (which we should expect), and the attacker can obtain enough material (i.e. addresses generated by the DHCPv6 server), the attacker may simply search the entire secret-key space to find matches. To protect against this, the secret key SHOULD be of at least 128 bits. Key lengths of at least 128 bits should be adequate.

Providing a mechanism to display and change the secret_key is crucial for having different DHCPv6 servers produce the same IPv6 addresses, and for causing a replacement system to generate the same IPv6 addresses as the system being replaced. We note that since the privacy of the scheme specified in this document relies on the secrecy of the secret_key parameter, implementations should constrain access to the secret_key parameter to the extent practicable (e.g., require superuser privileges to access it). Furthermore, in order to prevent leakages of the secret_key parameter, it should not be used for any other purposes than being a parameter to the scheme specified in this document.

We note that all of the bits in the resulting Interface IDs are treated as "opaque" bits [RFC7136]. For example, the universal/local bit of Modified EUI-64 format identifiers is treated as any other bit of such identifier.

5. IANA Considerations

There are no IANA registries within this document. The RFC-Editor can remove this section before publication of this document as an RFC.

6. Security Considerations

The method specified in this document results in IPv6 Interface Identifiers (and hence IPv6 addresses) that do not follow any specific pattern. Thus, attacks that rely on predictable Interface IDs (such as [I-D.ietf-opsec-ipv6-host-scanning]) are mitigated.

The method specified in this document neither mitigates nor exacerbates the security considerations for DHCPv6 discussed in [RFC3315].

7. Acknowledgements

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Authors' Addresses

Fernando Gont
SI6 Networks / UTN-FRH
Evaristo Carriego 2644
Haedo, Provincia de Buenos Aires 1706
Argentina

Phone: +54 11 4650 8472
Email: fgont@si6networks.com
URI: http://www.si6networks.com

Will(Shucheng) Liu
Huawei Technologies
Bantian, Longgang District
Shenzhen 518129
P.R. China

Email: liushucheng@huawei.com