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Improving the Robustness of Stateless Address Autoconfiguration (SLAAC)
to Flash Renumbering Events
[draft-ietf-6man-slaac-renum-02](#)

Abstract

In renumbering scenarios where an IPv6 prefix suddenly becomes invalid, hosts on the local network will continue using stale prefixes for an unacceptably long period of time, thus resulting in connectivity problems. This document improves the reaction of IPv6 Stateless Address Autoconfiguration to such renumbering scenarios.

Status of This Memo

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1. Introduction

IPv6 network renumbering is expected to take place in a planned manner, with old/stale prefixes being phased-out via reduced prefix lifetimes while new prefixes (with normal lifetimes) are introduced. However, there are a number of scenarios that may lead to the so-called "flash-renumbering" events, where the prefix being employed on a network suddenly becomes invalid and replaced by a new prefix [[I-D.ietf-v6ops-slaac-renum](#)]. In such scenarios, hosts on the local network will continue using stale prefixes for an unacceptably long period of time, thus resulting in connectivity problems. [[I-D.ietf-v6ops-slaac-renum](#)] discusses this problem in detail.

In some scenarios, the local router producing the network renumbering event may try to deprecate the currently-employed prefixes (thus explicitly signaling the network about the renumbering event), whereas in other scenarios it may be unaware about the renumbering event and thus unable signal hosts about it.

From the perspective of a Stateless Address Autoconfiguration (SLAAC) host, there are two different (but related) problems to be solved:

- o Avoiding the use of stale addresses for new communication instances
- o Performing "garbage collection" for the stale prefixes (and related network configuration information)

Clearly, if a host has both working and stale addresses, it is paramount that it employs working addresses for new communication instances. Additionally, a host should also perform garbage collection for the stale prefixes/addresses, since they not only tie system resources, but also prevent communication with the new "owners" of the stale prefixes.

2. Terminology

The term "globally reachable" is used in this document as defined in [[RFC8190](#)].

The term "Global Unicast Address" (or its acronym "GUA") is used throughout this document to refer to "globally reachable" [[RFC8190](#)] addresses. That is, when used throughout this document, GUAs do NOT include Unique Local Addresses (ULAs) [[RFC4193](#)]. Similarly, the term "Global Unicast prefix" (or "GUA prefix") is employed throughout this document to refer to network prefixes that specify GUAs, and does NOT include the ULA prefix (FC00::/7) [[RFC4193](#)].

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.

3. SLAAC reaction to Flash-renumbering Events

As noted in [Section 1](#), in some scenarios the router triggering the renumbering event may be able to explicitly signal the network about this event, while in other scenarios the renumbered hosts may need to infer a renumbering event is taking place. The following subsections analyze specific considerations for each of these scenarios.

3.1. Renumbering without Explicit Signaling

In the absence of explicit signalling from SLAAC routers (such as sending Prefix Information Options (PIOs) with small lifetimes to deprecate the stale prefixes), stale prefixes will remain preferred and valid according to the Preferred Lifetime and Valid Lifetime values (respectively) of the last received PIO. IPv6 SLAAC employs the following default values for PIOs:

- o Preferred Lifetime (AdvPreferredLifetime): 604800 seconds (7 days)
- o Valid Lifetime (AdvValidLifetime): 2592000 seconds (30 days)

This means that, in the absence of explicit signaling by a SLAAC router to deprecate a prefix, it will take a host 7 days (one week) to deprecate the corresponding addresses, and 30 days (one month) to eventually remove any addresses configured for the stale prefix. Clearly, for any practical purposes, employing such long default values is the equivalent of not using any timers at all, since taking 7 days or 30 days (respectively) to recover from a network problem is simply unacceptable.

Use of more appropriate timers in Router Advertisement messages can help limit the amount of time that hosts will maintain stale configuration information. Additionally, hosts are normally in a position to infer that a prefix has become stale -- for example, if a given router ceases to advertise an existing prefix and at the same time starts to advertise a new prefix.

[Section 4.1.1](#) recommends the use of more appropriate default lifetimes for PIOs, while [Section 4.5](#) specifies a local policy that SLAAC hosts can implement to heuristically infer that network configuration information has changed, such that stale configuration information can be phased out.

3.2. Renumbering with Explicit Signaling

In scenarios where a local router is aware about the renumbering event, it may try to phase out the stale network configuration information. In these scenarios, there are two aspects to be considered:

- o The amount of time during which the router should continue trying to deprecate the stale network configuration information
- o The ability of SLAAC hosts to phase out stale configuration in a timelier manner.

In the absence of Router Advertisements (RAs) that include PIOs that would reduce the Valid Lifetime and Preferred Lifetime of a prefix, hosts would normally employ the lifetime values from PIO options of the last received RA messages. Since the network could be partitioned for an arbitrarily long period of time, a router would need to try to deprecate a prefix for the amount of time employed for the "Preferred Lifetime", and try to invalidate the prefix for the amount of time employed for the "Valid Lifetime" (see [Section 12 of \[RFC4861\]](#)).

NOTE:

Once the number of seconds in the original "Preferred Lifetime" have elapsed, all hosts would have deprecated the corresponding addresses anyway, while once the number of seconds in the "Valid Lifetime" have elapsed, the corresponding addresses would be invalidated and removed.

Thus, use of more appropriate default lifetimes for PIOs, as proposed in [Section 4.1.1](#), would reduce the amount of time a stale prefix would need to be announced as such by a router in order to make sure that it is deprecated/invalidated.

In scenarios where a router has positive knowledge that a prefix has become invalid and thus could signal this condition to local hosts, the current specifications will prevent SLAAC hosts from fully recovering from such stale information. Item "e)" of [Section 5.5.3 of \[RFC4862\]](#) specifies that an RA may never reduce the "RemainingLifetime" to less than two hours. Additionally, if the RemainingLifetime of an address is smaller than 2 hours, then a Valid Lifetime smaller than 2 hours will be ignored. The inability to invalidate a stale prefix would prevent communication with the new "owners" of the stale prefix, and thus is highly undesirable. On the other hand, the Preferred Lifetime of an address *can* be reduced to any value to avoid the use of a stale prefix for new communications.

[Section 4.2](#) updates [\[RFC4862\]](#) such that this restriction is removed, and hosts react to the advertised "Valid Lifetime" (even if it is smaller than 2 hours).

Finally, [Section 4.3](#) recommends that routers disseminate network configuration information when a network interface is initialized, such that possibly new configuration information propagates in a timelier manner.

4. Improvements to Stateless Address Autoconfiguration (SLAAC)

The following subsections update [\[RFC4861\]](#) and [\[RFC4862\]](#), such that the problem discussed in this document is mitigated. The aforementioned updates are mostly orthogonal, and mitigate different aspects of SLAAC that prevent a timely reaction to flash renumbering events.

- o Reduce the default Valid Lifetime and Preferred Lifetime of PIOs ([Section 4.1.1](#)):
This helps limit the amount of time a host will employ stale information, and also limits the amount of time a router needs to try to obsolete stale information.
- o Honor PIOs with small Valid Lifetimes ([Section 4.2](#)):
This allows routers to invalidate stale prefixes, since otherwise [\[RFC4861\]](#) prevents hosts from honoring PIOs with a Valid Lifetime smaller than two hours.
- o Recommend routers to retransmit configuration information upon interface initialization/reinitialization ([Section 4.3](#)):
This helps spread the new information in a timelier manner, and also deprecate stale information via host-side heuristics (see [Section 4.5](#)).
- o Recommend routers to always send all options (i.e. the complete configuration information) in RA messages, and in the smallest possible number of packets ([Section 4.4](#)):
This helps propagate the same information to all hosts, and also allows hosts to better infer that information missing in RA messages has become stale (see [Section 4.5](#)).
- o Infer stale network configuration information from received RAs ([Section 4.5](#)):
This allows hosts to deprecate stale network configuration information, even in the absence of explicit signaling.

4.1. More Appropriate Lifetime Values

4.1.1. Router Configuration Variables

The default values of the Preferred Lifetime and the Valid Lifetime of PIOs are updated as follows:

```
AdvPreferredLifetime: max(AdvDefaultLifetime, 3 *  
MaxRtrAdvInterval)
```

```
AdvValidLifetime: 2 * AdvPreferredLifetime
```

where:

AdvPreferredLifetime:

Value to be placed in the "Preferred Lifetime" field of the PIO.

AdvValidLifetime:

Value to be placed in the "Valid Lifetime" field of the PIO.

AdvDefaultLifetime:

Value to be placed in the "Router Lifetime" field of the Router Advertisement message that will carry the PIO.

max():

A function that computes the maximum of its arguments.

NOTE:

[[RFC4861](#)] specifies the default value of MaxRtrAdvInterval as 600 seconds, and the default value of AdvDefaultLifetime as 3 * MaxRtrAdvInterval. Therefore, when employing default values for MaxRtrAdvInterval and AdvDefaultLifetime, the default values of AdvPreferredLifetime and AdvValidLifetime become 1800 seconds (30 minutes) and 3600 seconds (1 one hour), respectively. We note that when implementing [BCP202](#) [[RFC7772](#)], AdvDefaultLifetime will typically be in the range of 45-90 minutes, and therefore the default value of AdvPreferredLifetime will be in the range 45-90 minutes, while the default value of AdvValidLifetime will be in the range of 90-180 minutes.

RATIONALE:

- * The default values of the PIO lifetimes should be such that, under normal circumstances (including some packet loss), the associated timers are refreshed/reset, but in the presence of network failures (such as network configuration information becoming stale), some fault recovering action (such as

deprecating the corresponding addresses and subsequently removing them) is triggered.

- * In the context of [\[RFC8028\]](#), where it is clear that the use of addresses configured for a given prefix is tied to the next-hop router that advertised the prefix, the "Preferred Lifetime" of a PIO should not be larger than the "Router Lifetime" of Router Advertisement messages. Some leeway should be provided for the "Valid Lifetime" of PIOs, to cope with transient network problems. As a result, this document updates [\[RFC4861\]](#) such that the default Valid Lifetime (AdvValidLifetime) and the default Preferred Lifetime (AdvPreferredLifetime) of PIOs are specified as a function of the "Router Lifetime" (AdvDefaultLifetime) of Router Advertisement messages. In the absence of RAs that refresh information, addresses configured for previously-advertised prefixes become deprecated in a timelier manner, and thus Rule 3 of [\[RFC6724\]](#) will cause other configured addresses (if available) to be preferred.
- * The expression above computes the maximum between AdvDefaultLifetime and "3 * MaxRtrAdvInterval" (the default value of AdvDefaultLifetime, as per [\[RFC4861\]](#)) to cope with the case where an operator might simply want to disable one local router for maintenance, without disabling the use of the corresponding prefixes on the local network (e.g., on a multi-router network). [\[RFC4862\]](#) implementations would otherwise deprecate the corresponding prefixes. Similarly, [\[RFC8028\]](#) implementations would likely behave in the same way.

[4.2.](#) Honor Small PIO Valid Lifetimes

The entire item "e)" (pp. 19-20) from [Section 5.5.3 of \[RFC4862\]](#) is replaced with the following text:

e) If the advertised prefix is equal to the prefix of an address configured by stateless autoconfiguration in the list, the valid lifetime and the preferred lifetime of the address should be updated by processing the Valid Lifetime and the Preferred Lifetime (respectively) in the received advertisement.

RATIONALE:

- * This change allows hosts to react to the information provided by a router that has positive knowledge that a prefix has become invalid.
- * The behavior described in [RFC4862](#) had been incorporated during the revision of the original IPv6 Stateless Address

Autoconfiguration specification ([[RFC1971](#)]). At the time, the IPNG working group decided to mitigate the attack vector represented by Prefix Information Options with very short lifetimes, on the premise these packets represented a bigger risk than other ND-based attack vectors [[IPNG-minutes](#)].

While reconsidering the trade-offs represented by such decision, we conclude that the drawbacks of mitigating the aforementioned attack vector outweigh the possible benefits.

In scenarios where RA-based attacks are of concern, proper mitigations such as RA-Guard [[RFC6105](#)] [[RFC7113](#)] or SEND [[RFC3971](#)] should be implemented.

4.3. Interface Initialization

When an interface is initialized, it is paramount that network configuration information is spread on the corresponding network (particularly in scenarios where an interface has been re-initialized, and the conveyed information has changed). Thus, this document replaces the following text from [Section 6.2.4 of \[RFC4861\]](#):

In such cases, the router MAY transmit up to MAX_INITIAL_RTR_ADVERTISEMENTS unsolicited advertisements, using the same rules as when an interface becomes an advertising interface.

with:

In such cases, the router SHOULD transmit MAX_INITIAL_RTR_ADVERTISEMENTS unsolicited advertisements, using the same rules as when an interface becomes an advertising interface.

RATIONALE:

- * Use of stale information can lead to interoperability problems. Therefore, it is important that new configuration information propagates in a timelier manner to all hosts.

NOTE:

[[I-D.ietf-v6ops-cpe-slaac-renum](#)] specifies recommendations for CPE routers to deprecate any stale network configuration information.

4.4. Conveying Information in Router Advertisement (RA) Messages

[TBD]

4.5. Recovery from Stale Configuration Information without Explicit Signaling

[TBD]

5. IANA Considerations

This document has no actions for IANA.

6. Implementation Status

[NOTE: This section is to be removed by the RFC-Editor before this document is published as an RFC.]

This section summarizes the implementation status of the updates proposed in this document. In some cases, they correspond to variants of the mitigations proposed in this document (e.g., use of reduced default lifetimes for PIOs, albeit using different values than those recommended in this document). In such cases, we believe these implementations signal the intent to deal with the problems described in [[I-D.ietf-v6ops-slaac-renum](#)] while lacking any guidance on the best possible approach to do it.

6.1. More Appropriate Lifetime Values

6.1.1. Router Configuration Variables

6.1.1.1. rad(8)

We have produced a patch for OpenBSD's rad(8) [[rad](#)] that employs the default lifetimes recommended in this document, albeit it has not yet been committed to the tree. The patch is available at:
<<https://www.gont.com.ar/code/fgont-patch-rad-pio-lifetimes.txt>>.

6.1.1.2. radvd(8)

The radvd(8) daemon [[radvd](#)], normally employed by Linux-based router implementations, currently employs different default lifetimes than those recommended in [[RFC4861](#)]. radvd(8) employs the following default values [[radvd.conf](#)]:

- o Preferred Lifetime: 14400 seconds (4 hours)
- o Valid Lifetime: 86400 seconds (1 day)

This is not following the specific recommendation in this document, but is already a deviation from the current standards.

[6.2.](#) Honor Small PIO Valid Lifetimes

[6.2.1.](#) Linux Kernel

A Linux kernel implementation of this document has been committed to the net-next tree. The implementation was produced in April 2020 by Fernando Gont <fgont@si6networks.com>. The corresponding patch can be found at: <<https://patchwork.ozlabs.org/project/netdev/patch/20200419122457.GA971@archlinux-current.localdomain/>>

[6.2.2.](#) NetworkManager

NetworkManager [[NetworkManager](#)] processes RA messages with a Valid Lifetime smaller than two hours as recommended in this document.

[6.3.](#) Conveying Information in Router Advertisement (RA) Messages

We know of no implementation that splits network configuration information into multiple RA messages.

[6.4.](#) Recovery from Stale Configuration Information without Explicit Signaling

[6.4.1.](#) dhcpcd(8)

The dhcpcd(8) daemon [[dhcpcd](#)], a user-space SLAAC implementation employed by some Linux-based and BSD-derived operating systems, will set the Preferred Lifetime of addresses corresponding to a given prefix to 0 when a single RA from the router that previously advertised the prefix fails to advertise the corresponding prefix. However, it does not affect the corresponding Valid Lifetime. Therefore, it can be considered a partial implementation of this feature.

[6.5.](#) Other mitigations implemented in products

[FRITZ] is a Customer Edge Router that tries to deprecate stale prefixes by advertising stale prefixes with a Preferred Lifetime of 0, and a Valid Lifetime of 2 hours (or less). There are two things to note with respect to this implementation:

- o Rather than recording prefixes on stable storage (as recommended in [[I-D.ietf-v6ops-cpe-slaac-renum](#)]), this implementation checks the source address of IPv6 packets, and assumes that usage of any address that does not correspond to a prefix currently-advertised

by the Customer Edge Router is the result of stale network configuration information. Hence, upon receipt of a packet that employs a source address that does not correspond to a currently-advertised prefix, this implementation will start advertising the corresponding prefix with small lifetimes, with the intent of deprecating it.

- o Possibly as a result of item "e)" (pp. 19-20) from [Section 5.5.3 of \[RFC4862\]](#) (discussed in [Section 4.2](#) of this document), upon first occurrence of a stale prefix, this implementation will employ a decreasing Valid Lifetime, starting from 2 hours (7200 seconds), as opposed to a Valid Lifetime of 0.

7. Security Considerations

The protocol update in [Section 4.2](#) could allow an on-link attacker to perform a Denial of Service attack against local hosts, by sending a forged RA with a PIO with a Valid Lifetime of 0. Upon receipt of that packet, local hosts would invalidate the corresponding prefix, and therefore remove any addresses configured for that prefix, possibly terminating e.g. TCP connections employing such addresses. However, an attacker may achieve similar effects via a number of ND-based attack vectors, such as directing traffic to a non-existing node until ongoing TCP connections time out, or performing a ND-based man-in-the-middle (MITM) attack and subsequently forging TCP RST segments to cause on-going TCP connections to be aborted. Thus, for all practical purposes, this attack vector does not really represent a greater risk than other ND attack vectors. As noted in [Section 4.2](#), in scenarios where RA-based attacks are of concern, proper mitigations such as RA-Guard [[RFC6105](#)] [[RFC7113](#)] or SEND [[RFC3971](#)] should be implemented.

8. Acknowledgments

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The algorithm specified in [Section 4.5](#) is the result of mailing-list discussions over previous versions of this document with Philip Homburg.

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Fernando would also like to thank Brian Carpenter who, over the years, has answered many questions and provided valuable comments that has benefited his protocol-related work.

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Appendix A. Analysis of Some Suggested Workarounds

[This section is to be removed before publication of this document as an RFC].

During the discussion of this document, some alternative workarounds were suggested on the 6man mailing-list. The following subsections analyze these suggested workarounds, in the hopes of avoiding rehashing the same discussions.

A.1. On a Possible Reaction to ICMPv6 Error Messages

It has been suggested that if configured addresses become stale, a CPE enforcing ingress/egress filtering ([BCP38](#)) ([\[RFC2827\]](#)) could send ICMPv6 Type 1 (Destination Unreachable) Code 5 (Source address failed ingress/egress policy) error messages to the sending node, and that, upon receipt of such error messages, the sending node could perform heuristics that might help to mitigate the problem discussed in this document.

The aforementioned proposal has a number of drawbacks and limitations:

- o It assumes that the CPE routers enforce ingress/egress filtering [\[RFC2827\]](#). While this is desirable behaviour, it cannot be relied upon.
- o It assumes that if the CPE enforces ingress/egress filtering, the CPE will signal the packet drops to the sending node with ICMPv6 Type 1 (Destination Unreachable) Code 5 (Source address failed ingress/egress policy) error messages. While this may be desirable, [\[RFC2827\]](#) does not suggest signaling the packet drops with ICMPv6 error messages, let alone the use of specific error messages (such as Type 1 Code 5) as suggested.
- o ICMPv6 Type 1 Code 5 could be interpreted as the employed address being stale, but also as a selected route being inappropriate/suboptimal. If the later, deprecating addresses or invalidating addresses upon receipt of these error messages would be inappropriate.
- o Reacting to these error messages would create a new attack vector that could be exploited from remote networks. This is of particular concern since ICMP-based attacks do not even require that the Source Address of the attack packets be spoofed [\[RFC5927\]](#).

A.2. On a Possible Improvement to Source Address Selection

[RFC6724] specifies source address selection (SAS) for IPv6. Conceptually, it sorts the candidate set of source addresses for a given destination, based on a number of pair-wise comparison rules that must be successively applied until there is a "winning" address.

An implementation might improve source address selection, and prefer the most-recently advertised information. In order to incorporate the "freshness" of information in source address selection, an implementation would be updated as follows:

- o The node is assumed to maintain a timer/counter that is updated at least once per second. For example, the `time(2)` function from unix-like systems could be employed for this purpose.
- o The local information associated with each prefix advertised via RAs on the local network is augmented with a "LastAdvertised" timestamp value. Whenever an RA with a PIO with the "A" bit set for such prefix is received, the "LastAdvertised" timestamp is updated with the current value of the timer/counter.
- o [RFC6724] is updated such that this rule is incorporated:

Rule 7.5: Prefer fresh information If one of the two source addresses corresponds to a prefix that has been more recently advertised, say `LastAdvertised(SA) > LastAdvertised(SA)`, then prefer that address (SA in our case).

A clear benefit of this approach is that a host will normally prefer "fresh" addresses over possibly stale addresses.

However, there are a number of drawbacks associated with this approach:

- o In scenarios where multiple prefixes are being advertised on the same LAN segment, the new SAS rule is **guaranteed** to result in non-deterministic behaviour, with hosts frequently changing the default source address. This is certainly not desirable from a troubleshooting perspective.
- o Since the rule must be incorporated before "Rule 8: Use longest matching prefix" from [RFC6724], it may lead to suboptimal paths.
- o This new rule may help to improve the selection of a source address, but it does not help with the housekeeping (garbage collection) of configured information:

- * If the stale prefix is re-used in another network, nodes employing stale addresses and routes for this prefix will be unable to communicate with the new "owner" of the prefix, since the stale prefix will most likely be considered "on-link".
- * Given that the currently recommended default value for the "Valid Lifetime" of PIOs is 2592000 seconds (30 days), it would take too long for hosts to remove the configured addresses and routes for the stale prefix. While the proposed update in [Section 4.1](#) of this document would mitigate this problem, the lifetimes advertised by the local SLAAC router are not under the control of hosts.

As a result, updating IPv6 source address selection does not relieve nodes from improving their SLAAC implementations as specified in [Section 4](#), if at all desirable. On the other hand, the algorithm specified in [Section 4.5](#) would result in Rule 3 of [[RFC6724](#)] employing fresh addresses, without leading to non-deterministic behaviour.

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