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R. Hinden
Check Point Software
B. Carpenter
Univ. of Auckland
B. Zeeb

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IPv6 Router Advertisement IPv6-Only Flag
draft-ietf-6man-ipv6only-flag-05

Abstract

This document specifies a Router Advertisement Flag to indicate to hosts that the administrator has configured the router to advertise that the link is IPv6-Only. This document updates RFC4861 and RFC5175.

Status of This Memo

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1. Introduction

This document specifies a Router Advertisement Flag to indicate to hosts that the administrator has configured the router to advertise that the link is IPv6-Only. The flag only applies to IPv6 default routers.

Hosts that support IPv4 and IPv6, usually called dual stack hosts, need to also work efficiently on IPv6-Only links, i.e, links where there are no IPv4 routers and/or IPv4 services. Dual stack is the default configuration for most current host operating systems such as Windows 10, iOS, Android, Linux, and BSD, as well as devices such as some printers. Monitoring of an IPv6-Only link, for example at the IETF 100 meeting in Singapore, shows that current dual stack hosts will create local auto-configured IPv4 addresses and attempt to reach IPv4 services, even though they cannot configure a normal address using DHCP. This may be a problem for several reasons, depending on the equipment in use and its configuration, especially on large wireless networks:

- It may result in an undesirable level of wasted Layer 2 broadcast traffic.

- Switches in multi-segment wireless networks may create IPv4 state for dual stack hosts (in particular, ARP cache entries to support ARP proxying).

- Such traffic may drain battery power on wireless hosts that have no interest in link-local IPv4, ARP, and DHCPv4 relay traffic, but receive unwanted IPv4 packets. [RFC7772] indicates how this risk might be quantified.

- Similarly, hosts may waste battery power on futile attempts to access services by sending IPv4 packets.

- On an IPv6-Only link, IPv4 might be used for malicious purposes and pass unnoticed by IPv6-Only monitoring mechanisms.

In networks with managed infrastructure whose equipment allows it, these problems could be mitigated by configuring the Layer 2 infrastructure to drop IPv4 and ARP traffic by filtering Ethertypes 0x0800 and 0x0806 [IANA-Ethertype]. IPv6 uses a different Ethertype, 0x86DD, so this filtering will not interfere with IPv6 traffic. Depending on the equipment details, this would limit the traffic to the link from an IPv4 sender to the switch, and would drop all IPv4 and ARP broadcast packets at the switch. This document recommends using such mechanisms when available.

However, hosts transmitting IPv4 packets would still do so, consuming their own battery power and some radio bandwidth. The intent of this specification is to provide a mechanism that prevents such traffic, and also works on networks without the ability to filter L2 traffic, or where there are portions of a network without the ability to filter L2 traffic. It may also be valuable on unmanaged networks using routers pre-configured for IPv6-Only operations and where Layer 2 filtering is unavailable.

An assumption of this document is that because it is an IPv6-Only link there is no IPv4 DHCP server or relay active on the link. This

further means that the DHCP option to disable IPv4 stateless auto-configuration [RFC2563] can not be used.

The remainder of this document therefore assumes that neither effective Layer 2 filtering nor the RFC 2563 DHCP option is applicable to the link concerned.

Because there is no IPv4 support on an IPv6-Only link, the only way to notify the dual stack hosts that this link is IPv6-Only is to use an IPv6 mechanism. An active notification will be much more precise than attempting to deduce this fact by the lack of IPv4 responses or traffic.

This document therefore defines a mechanism that a router administrator can use to inform hosts that this is an IPv6-Only link on their default routers such that they can disable IPv4 on this link, mitigating all of the above problems. The mechanism is based on the IPv6 Router Advertisement message because this is a type of message that is certain to be received by every dual stack host, regardless of what network management protocols may or may not be in use.

IPv4-only hosts, and dual-stack hosts that do not recognize the new flag, may continue to attempt IPv4 operations, in particular IPv4 discovery protocols typically sent as link-layer broadcasts. This legacy traffic cannot be prevented by any IPv6 mechanism. The value of the new flag is limited to hosts that recognize it.

A possible subsidiary use of the IPv6-Only flag is using it to trigger IPv6-Only testing and validation on a link.

This document specifies a new flag for Router Advertisement Flag [RFC5175]. It updates [RFC5175] to add this flag. It also updates [RFC4861] to add an additional item to check and report.

2. Requirements Language

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

3. Applicability Statements

This OPTIONAL mechanism is designed to allow administrators to notify hosts that the link is IPv6-Only. It SHOULD be only used in IPv6-Only links (see Section 4 for definition of IPv6-Only). For a VLAN, the IPv6-Only flag only applies to the specific VLAN on which it was received.

Dual stack hosts that have IPv4 active configuration obtained from the network (e.g., via DHCP), can ignore the flag and continue to use IPv4.

Administrators MUST only use this mechanism if they are certain that the link is IPv6-Only. For example, in cases where there is a need to continue to use IPv4, when there are intended to be IPv4-only hosts or IPv4 routers on the link, setting this flag to 1 is a configuration error.

This mechanism is intended to be compatible with link-layer solutions that filter out IPv4 traffic.

4. IPv6-Only Definition

IPv6-Only is defined to mean that no other versions of Internet Protocol than IPv6 are intentionally in use directly on the link. Today this effectively simply means that IPv4 is not intentionally in use on the link, and it includes:

* No IPv4 traffic on the link.
* No IPv4 routers on the link.
* No DHCPv4 servers on the link.
* No IPv4 accessible services on the link.
* All IPv4 and ARP traffic may be blocked at Layer 2 by the administrator.

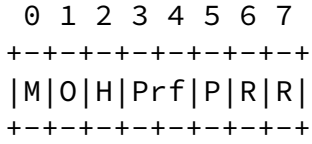
It is expected that on IPv6-Only networks it will be common to access to IPv4 external services by techniques such as NAT64 [RFC6146] and DNS64 [RFC6147] at the edge of the network. This is beyond the

scope of this document.

Note that IPv6-Only provides no information about other network protocols than IP (and ARP) in use directly over the link layer. It is out of scope of this specification whether any such protocol is in use on the link or whether any protocol is tunneled over IPv6.

5. IPv6-Only Flag

RFC5175 currently defines the flags in the NDP Router Advertisement message and these flags are registered in the IANA IPv6 ND Router Advertisement flags Registry [IANA-RF]. This currently contains the following one-bit flags defined in published RFCs:



M	Managed Address Configuration Flag [RFC4861]
O	Other Configuration Flag [RFC4861]
H	Mobile IPv6 Home Agent Flag [RFC3775]
Prf	Router Selection Preferences [RFC4191]
P	Neighbor Discovery Proxy Flag [RFC4389]

R	Reserved

This document defines bit 6 to be the IPv6-Only Flag:

S	IPv6-Only Flag

This flag has two values. These are:

0	This is not an IPv6-Only link
1	This is an IPv6-Only link

RFC 5175 requires that unused flag bits be set to zero. Therefore, a router that does not support the new flag will not appear to assert that this is an IPv6-Only link.

Hosts receiving the Router Advertisement SHOULD only process this flag if the advertising router is a Default Router. Specifically, if the Lifetime field in the Router Advertisement is not zero, otherwise it SHOULD be ignored. This is done to allow some IPv6 routers to advertise information without being a Default Router and providing IPv6 connectivity.

Note that although this mechanism uses one of only two reserved flag bits in the RA, an extension mechanism is defined in Section 4 of [RFC5175] in case additional flags are ever required for future extensions. It should be noted that since RFC5175 was published in 2008, no new RA flags have been assigned in the IANA registry.

6. Router and Operational Considerations

Default IPv6 routers that are on an IPv6-Only link SHOULD be configured by the administrator to set the IPv6-Only flag to 1 on interfaces on this link. In all other cases the flag SHOULD NOT be set to 1.

The intent is that the administrator of the router configures the router to set the IPv6-Only flag if and only if she/he wants to tell the hosts on the link that the link is IPv6-Only. This is a configuration flag, it is not something that the router decides on its own. Routers MAY log a configuration error if the flag is set and IPv4 is still active on the router's interface to the link.

Routers implementing this document SHOULD log to system or network management inconsistent setting of the IPv6-Only flag. This extends the behaviour specified in Section 6.2.7 of [RFC4861].

Operators of large IPv6-Only wireless links are advised to also use Layer 2 techniques to drop IPv4 and ARP packets (Ethertypes 0x0800 and 0x0806) at all switches, and to ensure that IPv4 and ARP features are disabled in all switches.

7. Host Behavior Considerations

Hosts that support the IPv6-Only RA flag MUST have a configuration option to ignore or process the flag. The motivation for this configuration option is for hosts that are capable of processing the IPv6-Only flag to only act on the flag if they are configured to do so.

If there are multiple IPv6 default routers on a link, they might send different values of the flag. If at least one IPv6 default router sends the flag with value 0, a dual stack host MUST NOT assume that the link is IPv6-Only. If all IPv6 default routers send the flag with value 1, a dual stack host SHOULD assume that this is an IPv6-Only link.

A host that receives only RAs with the flag set to 1 SHOULD NOT attempt any IPv4 operations, unless it subsequently receives at least one RA with the flag set to zero. As soon as such an RA is received, IPv4 operations MAY be started.

If the host has active IPv4 configuration information obtained from the network (e.g., via DHCP), the flag can be ignored and IPv4 operations can continue. The host MAY implement a policy overriding these default behaviors.

In the event that the host subsequently receives at least one RA with the flag set to zero IPv4 operations MAY be started.

A host MAY delay all IPv4 operations at start-up or reconnection until a reasonable time has elapsed for RA messages to arrive. If all RAs received have the flag set to 1, a host SHOULD NOT attempt IPv4 operations.

In all of the above, the flag's value is considered valid for the lifetime of the default router concerned, unless a subsequent RA delivers a different flag value. If a default router expires (i.e., no RA is received that refreshes its lifetime), the host must remove this router's flag value from consideration. If the result is that all surviving default routers have the flag set to 1, the host SHOULD

assume that the link is IPv6-Only. In other words, at any given

time, the state of the flag as seen by the host is the logical AND of the flags sent by all unexpired default IPv6 routers on the link.

This also means that if all default routers on the link have set the flag, the resulting host state for the link is IPv6-Only. If the lifetimes of all the routers on the link subsequently expire, then the host state for the link is not IPv6-Only.

8. IANA Considerations

IANA is requested to assign the new Router Advertisement flag defined in Section 5 of this document. Bit 6 is the next available bit in this registry, IANA is requested to use this bit unless there is a reason to use another bit in this registry.

IANA is also requested to register this new flag bit in the IANA IPv6 ND Router Advertisement flags Registry [IANA-RF].

9. Security Considerations

This document shares the security issues with other parts of IPv6 Neighbor Discovery. [RFC6104] discusses certain attacks and mitigations. General techniques to protect Router Advertisement traffic such as Router Guard [RFC6105] are useful in protecting against these vulnerabilities.

A bad actor could use this mechanism to attempt turn off IPv4 service on a link that is intentionally using IPv4, by sending Router Advertisements with the IPv6-Only flag set to 1. There are several protections to reduce this attack. These are:

- There is configuration setting that controls if the host should process the IPv6-Only flag. This gives local control over using the flag and reduces the ability of a bad actor to turn off IPv4 for hosts that support the flag.

- As long as there are one or more routers sending Router Advertisements with this flag set to 0, they would override this attack given the mechanism in Section 5. Specifically a host would only turn off IPv4 service if it wasn't hearing any Router Advertisement with the flag set to 0. If the advice in Section 6 is followed, this attack will fail.

- An attack would not succeed if the dual stack hosts had active IPv4 configuration. As specified in Section 7, a dual stack host will ignore the flag if it has active IPv4 configuration.

In a situation where the bad actor has control of all routers on the link and sends Router Advertisements with the IPv6-Only flag set to 1 from all of them and if the hosts don't have assigned IPv4 addresses, the attack will succeed, but so will many other forms of router-based attack.

Conversely, a bad actor could use this mechanism to turn on, or pretend to turn on, IPv4 service on an IPv6-Only link, by sending Router Advertisements with the flag set to 0. However, this is really no different than what such a bad actor can do anyway, if they have the ability to configure a bogus router in the first place. The advice in Section 6 will minimize such an attack by limiting it to a single link.

Note that manipulating the Router Preference [RFC4191] will not affect either of these attacks: any IPv6-Only flag of 0 will always override all flags set to 1.

The new flag is neutral from an IPv6 privacy viewpoint, since it does not affect IPv6 operations in any way. From an IPv4 privacy viewpoint, it has the potential benefit of suppressing unnecessary traffic that might reveal the existence of a host and the correlation between its hardware and IPv4 addresses. It should be noted that hosts that don't support this flag are not protected from IPv4-based attacks.

10. Acknowledgments

A closely related proposal was published earlier as [I-D.ietf-sunset4-noipv4].

Helpful comments were received from Lorenzo Colitti, David Farmer, Fernando Gont, Nick Hilliard, Lee Howard, Erik Kline, Jen Linkova, Veronika McKillop, George Michaelson, Alexandre Petrescu, Michael Richardson, Mark Smith, Barbara Stark, Tatuya Jinmei, Ole Troan, James Woodyatt, and other members of the 6MAN working group.

Bjoern Zeeb has also produced a variant of this proposal and proposed an IPv6 transition plan in [I-D.bz-v4goawayflag].

11. Change log [RFC Editor: Please remove]

draft-ietf-6man-ipv6only-flag-05, 2019-March-7:

* Added a host configuration option to Section 7 that controls if

the host should process the IPv6-Only flag. This provides local control over using the use of flag and reduces the

ability of a bad actor to turn off IPv4 for hosts that support the flag.

* Changed Section 7 to specify that the host can ignore flag set to 1 if it has active IPv4 configuration obtained from the network (e.g., via DHCP). Similar changes to Section 3 and Section 9
* Clarification in Section 6 to strengthen the text about the administrators intent.
* Added Bjoern Zeeb as an author.
* Updated information on FreeBSD implementation in Appendix A.1
* Editorial changes.

draft-ietf-6man-ipv6only-flag-04, 2018-November-4:

* Added text to Section 1 explaining why the mechanism is based on Router Advertisements.
* Added text to Section 3 that for a VLAN, the IPv6-Only flag only applies to the specific VLAN on which it was received.
* Changed Section 3 that administrators MUST only use this mechanism if they are certain that the link is IPv6-Only, instead of SHOULD.
* Added ARP to Section 4 protocols that the IPv6-Only flag applies to.
* Renamed the IPv6-Only flag label from "6" to "S".
* Added pointers to Section 7.2.7 of RFC4861 in Section 6.
* Added that RFC4861 is also updated by Section 6 for routers implementing this flag.
* Changed Section 7 from SHOULD NOT to MUST NOT.
* Added Appendix A on implementations and testing.
* Many small clarifications based on IPv6 list discussion and editorial changes.

draft-ietf-6man-ipv6only-flag-03, 2018-October-16:

* Reorganized text about problem statement and applicability
* Added note about shortage of flag bits
* Clarified text about logging configuration error in Section 6

* Editorial changes.

draft-ietf-6man-ipv6only-flag-02, 2018-August-14:

* Added text to Section 9 to clarify that hosts not supporting this flag are not protected from IPv4-based attacks.
* Editorial changes.

draft-ietf-6man-ipv6only-flag-01, 2018-June-29:

* Added text to section that defines what IPv6-Only includes to clarify that only other version of the Internet Protocol are in scope.
* Added clarification if the lifetime of all routers expire.
* Editorial changes.

draft-ietf-6man-ipv6only-flag-00, 2018-May-21:

* Changed the file name to draft-ietf-6man-ipv6only-flag to match the current tile and that it is a w.g. draft.
* Added new section that defines what IPv6-Only includes.
* Expanded description of using Layer 2 filter to block IPv4 and ARP traffic.
* Editorial changes.

draft-hinden-ipv4flag-04, 2018-April-16:

* Changed the name of the document and flag to be the IPv6-Only flag.
* Rewrote text to make it affirmative that this is used by an administrator to tell the hosts that the link is IPv6-Only.
* Added an Applicability Statements section to scope the intend use.
* Changed requirement language to upper case, added Requirements Language section with references to [RFC2119] and [RFC8174].
* Editorial changes.

draft-hinden-ipv4flag-03, 2018-Feb-15:

* Changed terminology to use "link" instead of "network".
* Improved text in Section 4. "Host Behavior Considerations" and added suggestion to only perform IPv4 if an application requests it.
* Added clarification that the bit is set because an administrator configured the router to send it.
* Editorial changes.

draft-hinden-ipv4flag-02, 2018-Feb-15:

* Improved text in introduction.
* Added reference to current IANA registry in Section 2.

* Editorial changes.

draft-hinden-ipv4flag-01, 2017-Dec-12

* Inverted name of flag from "Available" to "Unavailable".
* Added problem description and clarified scope.
* Added router and operational considerations.
* Added host behavior considerations.
* Extended security considerations.
* Added Acknowledgment section, including reference to prior sunset4 draft.

draft-hinden-ipv4flag-00, 2017-Nov-17:

* Original version.

12. References

12.1. Normative References

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12.2. Informative References

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Appendix A. Implementaton Status [RFC Editor: Please remove]

At the time this document was written there is one implementation and a few comparability tests.

A.1. FreeBSD Implementation

A FreeBSD implementation was written by Bjoern A. Zeeb.

Summary:

Changes for the IPv6-Only flag include updates of user space utilities to announce the "S" (IPv6-Only) flag to the network and to show it in management utilities.

The kernel logic includes a global flag to disable processing of the IPv6-Only flag even if the logic to act upon the IPv6-Only flag is compiled in. There are checks for IPv4 configuration on a receiving interface, which if found, will also force the IPv6-Only flag to be ignored.

Further there are input and output filters for IPv4, ARP, and REVARP in place for when the flag passes the aforementioned checks and is enabled.

In addition to the draft there is a manual option to enable the IPv6-Only filtering logic manually to observe the system behaviour on links without router(s) advertising the IPv6-Only flag.

The code was tested with 2 FreeBSD IPv6 routers, a FreeBSD laptop on ethernet as well as wifi, and with Win10 and OSX clients (which did not fall over with the "S" flag set but not understood).

More information and updates can be found at:

https://wiki.freebsd.org/IPv6/IPv6OnlyRAFlag

A.2. Test using Scapy

Independent tests have been done using [Scapy_RA] by Alexandre Petrescu and Brian Carpenter to verify that setting the IPv6-Only

Flag did not break legacy hosts. Both verified that setting this flag did not cause any adverse effects on Windows 10 and Android.

Authors' Addresses

Robert M. Hinden
Check Point Software
959 Skyway Road
San Carlos, CA 94070
USA

Email: bob.hinden@gmail.com

Brian Carpenter
Department of Computer Science
University of Auckland
PB 92019
Auckland 1142
New Zealand

Email: brian.e.carpenter@gmail.com

Bjoern A. Zeeb
Bruehlstr. 19
Bondorf 71149
Germany

Email: bzeeb+ietf@zabbadoz.net