

Network Working Group  
Internet-Draft  
Intended status: Informational  
Expires: June 22, 2018

F. Templin, Ed.  
Boeing Research & Technology  
December 19, 2017

**IPv6 Prefix Delegation Models**  
**draft-templin-v6ops-pdhost-18.txt**

Abstract

IPv6 prefixes are typically delegated to requesting routers which assign them to their downstream-attached links and networks. This document considers prefix delegation models according to whether the requesting router acts as a router on behalf of any downstream networks, as a host on behalf of its local applications or as both.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of [BCP 78](#) and [BCP 79](#).

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at <https://datatracker.ietf.org/drafts/current/>.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on June 22, 2018.

Copyright Notice

Copyright (c) 2017 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to [BCP 78](#) and the IETF Trust's Legal Provisions Relating to IETF Documents (<https://trustee.ietf.org/license-info>) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Simplified BSD License text as described in Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Simplified BSD License.

## Table of Contents

<a href="#">1.</a>	Introduction . . . . .	<a href="#">2</a>
<a href="#">2.</a>	Terminology . . . . .	<a href="#">5</a>
<a href="#">3.</a>	Multi-Addressing Considerations . . . . .	<a href="#">6</a>
<a href="#">4.</a>	Multi-Addressing Alternatives for Delegated Prefixes . . . . .	<a href="#">6</a>
<a href="#">5.</a>	Address Autoconfiguration Considerations . . . . .	<a href="#">7</a>
<a href="#">6.</a>	MLD/DAD Implications . . . . .	<a href="#">7</a>
<a href="#">7.</a>	Dynamic Routing Protocol Implications . . . . .	<a href="#">8</a>
<a href="#">8.</a>	IPv6 Neighbor Discovery Implications . . . . .	<a href="#">8</a>
<a href="#">9.</a>	ICMPv6 Implications . . . . .	<a href="#">9</a>
<a href="#">10.</a>	IANA Considerations . . . . .	<a href="#">9</a>
<a href="#">11.</a>	Security Considerations . . . . .	<a href="#">9</a>
<a href="#">12.</a>	Acknowledgements . . . . .	<a href="#">10</a>
<a href="#">13.</a>	References . . . . .	<a href="#">10</a>
<a href="#">13.1.</a>	Normative References . . . . .	<a href="#">10</a>
<a href="#">13.2.</a>	Informative References . . . . .	<a href="#">11</a>
<a href="#">Appendix A.</a>	Change Log . . . . .	<a href="#">12</a>
	Author's Address . . . . .	<a href="#">13</a>

## [1.](#) Introduction

IPv6 Prefix Delegation (PD) entails 1) the communication of a prefix from a server to a requesting router, 2) a representation of the prefix in the network's Routing Information Base (RIB) and the first-hop router's forwarding information base (FIB), and 3) a control messaging service to maintain prefix lifetimes. Following delegation, the prefix is available for the requesting router's exclusive use and is not shared with any other nodes. This document considers prefix delegation models where the requesting router acts as a router on behalf of any downstream networks, as a host on behalf of its local applications or as both.

For nodes that connect downstream-attached networks (e.g., a cellphone that connects a "tethered" Internet of Things, a host with a complex internal network of virtual machines, etc.), the prefix delegation model is shown in Figure 1:



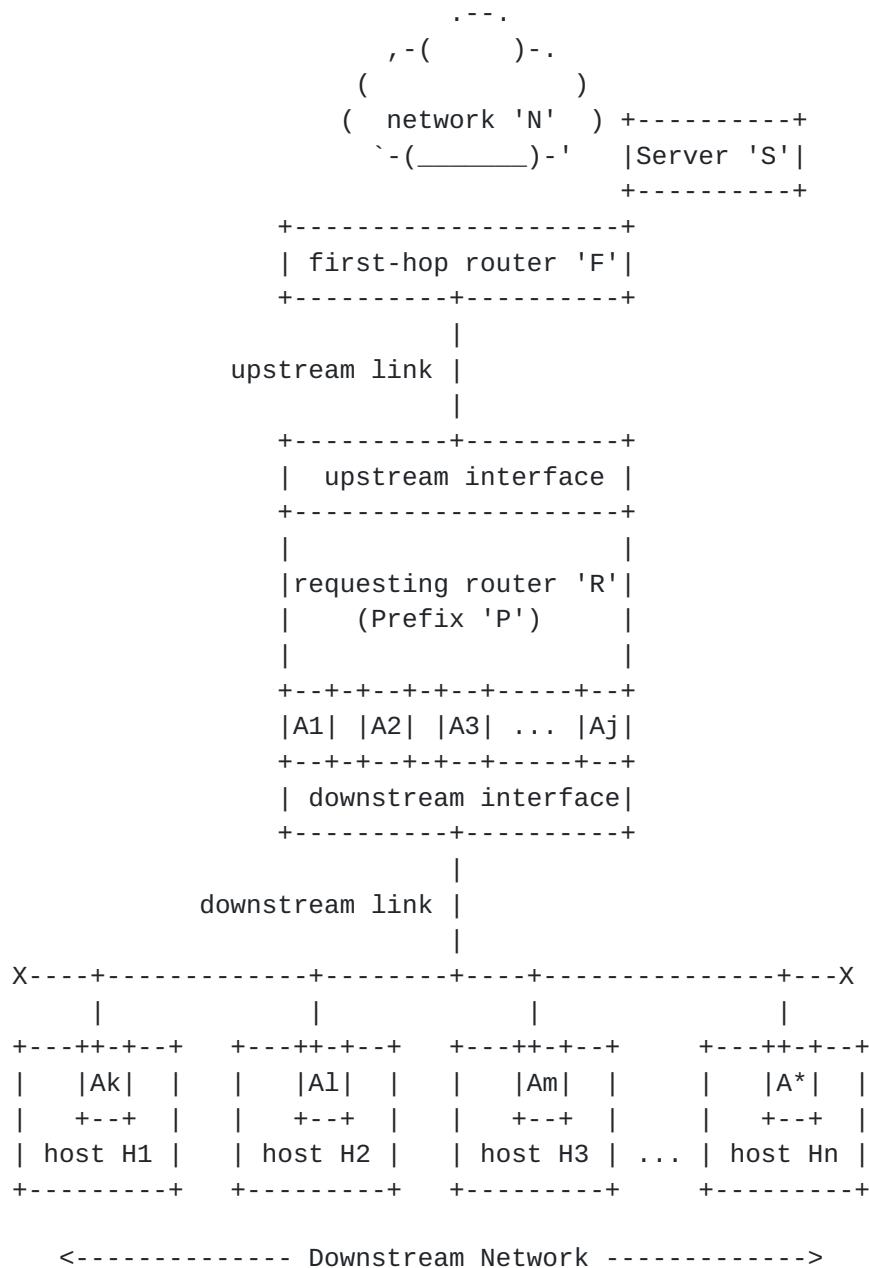


Figure 1: Classic Routing Model

In this model, when server 'S' delegates prefix 'P', first-hop router 'F' configures a FIB entry with requesting router 'R' as the next hop, and the prefix is injected into network 'N's RIB. Meanwhile, 'R' distributes 'P' to its downstream external (physical) and/or internal (virtual) networks. 'R' assigns addresses 'A(\*)' taken from 'P' to downstream interfaces, and hosts 'H(i)' on downstream networks assign addresses 'A(\*)' taken from 'P' to their interface attachments to the downstream link. 'R' then acts as a router for hosts 'H(i)'

Templin

Expires June 22, 2018

[Page 3]

on downstream networks and as a host on behalf of its local applications, i.e., the same as for any router.

This document also considers the case when 'R' does not have any downstream interfaces, and can use 'P' solely for its own internal addressing purposes. In that case, requesting node 'R' assigns 'P' to a virtual interface (e.g., a loopback) that serves as a downstream interface.

'R' can then function under the weak end system (aka "weak host") model [[RFC1122](#)][RFC8028] by assigning addresses taken from 'P' to a virtual interface as shown in Figure 2:

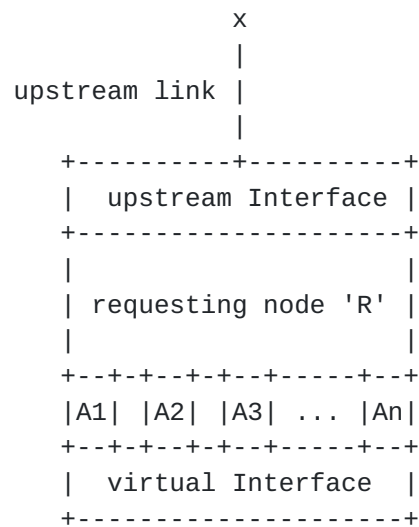


Figure 2: Weak End System Model

'R' could instead function under the strong end system (aka "strong host") model [[RFC1122](#)][RFC8028] by assigning IPv6 addresses taken from 'P' to an upstream interface as shown in Figure 3:



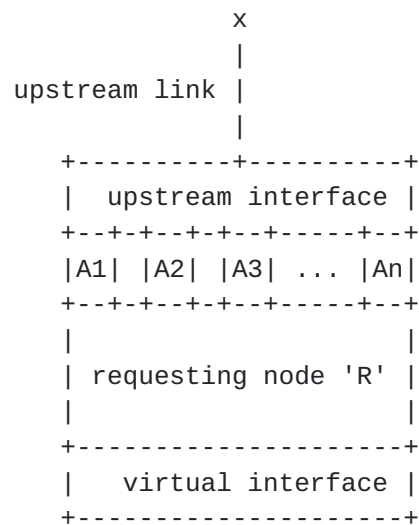


Figure 3: Strong End System Model

The major benefit for a node managing a delegated prefix in either the weak or strong end system models is multi-addressing. With IPv6 PD-based multi-addressing, the node can configure an unlimited supply of addresses to make them available for local applications without requiring coordination with other nodes on upstream interfaces.

The following sections present considerations for nodes that employ IPv6 PD mechanisms.

## 2. Terminology

The terminology of the normative references apply, and the terms "node", "host" and "router" are the same as defined in [[RFC8200](#)].

The following terms are defined for the purposes of this document:

### shared prefix

an IPv6 prefix that may be advertised to more than one node on the link, e.g., in a Router Advertisement (RA) message Prefix Information Option (PIO) [[RFC4861](#)]. The router that advertises the prefix must consider the prefix as on-link so that the IPv6 Neighbor Discovery (ND) address resolution function will identify the correct neighbor for each packet.

### individual prefix

an IPv6 prefix that is advertised to exactly one node on the link, where the node may be unaware that the prefix is individual and may not participate in prefix maintenance procedures. The router that advertises the prefix can consider the prefix as on-link or not on-link. In the former case, the router performs address





resolution and only forwards those packets that match one of the node's configured addresses so that the node will not receive unwanted packets. In the latter case, the router can simply forward all packets matching the prefix to the node which must then drop any packets that do not match one of its configured addresses. An example individual prefix service is documented in [[RFC8273](#)].

#### delegated prefix

an IPv6 prefix that is explicitly conveyed to a node for its own exclusive use, where the node is an active participant in prefix delegation and maintenance procedures. The first-hop router simply forwards all packets matching the prefix to the requesting node. The requesting node associates the prefix with downstream and/or internal virtual interfaces (i.e., and not the upstream interface). An example PD service is the Dynamic Host Configuration Protocol for IPv6 (DHCPv6) [[RFC3315](#)][[RFC3633](#)].

### **3. Multi-Addressing Considerations**

IPv6 allows nodes to assign multiple addresses to a single interface. [[RFC7934](#)] discusses options for multi-addressing as well as use cases where multi-addressing may be desirable. Address configuration options for multi-addressing include Stateless Address AutoConfiguration (SLAAC) [[RFC4862](#)], DHCPv6 address configuration [[RFC3315](#)], manual configuration, etc.

Nodes configure addresses from a shared or individual prefix and assign them to the upstream interface over which the prefix was received. When the node assigns the addresses, it is required to use Multicast Listener Discovery (MLD) [[RFC3810](#)] to join the appropriate solicited-node multicast group(s) and to use the Duplicate Address Detection (DAD) algorithm [[RFC4862](#)] to ensure that no other node configures a duplicate address.

In contrast, a node that configures addresses from a delegated prefix can assign them without invoking MLD/DAD on an upstream interface, since the prefix has been delegated to the node for its own exclusive use and is not shared with any other nodes.

### **4. Multi-Addressing Alternatives for Delegated Prefixes**

When a node receives a delegated prefix, it has many alternatives for provisioning the prefix to its local interfaces and/or downstream networks. [[RFC7278](#)] discusses alternatives for provisioning a prefix obtained by a User Equipment (UE) device under the 3rd Generation Partnership Program (3GPP) service model. This document considers



the more general case when the node receives a delegated prefix explicitly provided for its own exclusive use.

When the node receives the prefix, it can distribute the prefix to downstream networks and configure zero or more addresses for itself on downstream interfaces. The node then acts as a router on behalf of its downstream networks and configures a default route via a neighbor on an upstream interface.

The node could instead (or in addition) use portions of the delegated prefix for its own multi-addressing purposes. In a first alternative, the node can assign as many addresses as it wants from the prefix to virtual interfaces. In that case, applications running on the node can use the addresses according to the weak end system model.

In a second alternative, the node can assign as many addresses as it wants from the prefix to the upstream interface over which the prefix was received. In that case, applications running on the node can use the addresses according to the strong end system model.

In both of these latter two cases, the node assigns the prefix itself to a virtual interface so that unused portions of the prefix are correctly identified as unreachable. The node then acts as a host on behalf of its local applications even though neighbors on the upstream link see it as a router.

## **5. Address Autoconfiguration Considerations**

Nodes that act according to the weak/strong host models as discussed in the previous section autoconfigure addresses from delegated prefixes according to [Section 6](#) of IPv6 Node Requirements [[I-D.ietf-6man-rfc6434-bis](#)].

As a recipient of a delegated prefix, the node is also required to recognize the Subnet Router Anycast address [[RFC4291](#)]. Therefore, the node's use of the Subnet Router Anycast address must be indistinguishable from the behavior of an ordinary router when viewed from the outside world.

## **6. MLD/DAD Implications**

When a node configures addresses for itself from a shared or individual prefix, it performs MLD/DAD by sending multicast messages over upstream interfaces to test whether there is another node on the link that configures a duplicate address. When there are many such addresses and/or many such nodes, this could result in substantial multicast traffic that affects all nodes on the link.



When a node configures addresses for itself from a delegated prefix, it can configure as many addresses as it wants but does not perform MLD/DAD for any of the addresses over upstream interfaces. This means that the node can configure arbitrarily many addresses without causing any multicast messaging over the upstream interface that could disturb other nodes.

## **7. Dynamic Routing Protocol Implications**

Nodes that receive delegated prefixes can be configured to either participate or not participate in a dynamic routing protocol over the upstream interface, according to the deployment model. When there are many nodes on the upstream link, dynamic routing protocol participation might be impractical due to scaling limitations, and may also be exacerbated by factors such as node mobility.

Unless it participates in a dynamic routing protocol, the node initially has only a default route pointing to a neighbor via an upstream interface. This means that packets sent by the node over an upstream interface will initially go through a default router even if there is a better first-hop node on the link.

## **8. IPv6 Neighbor Discovery Implications**

When a node receives a shared or individual prefix with "L=1" and has a packet to send to an IPv6 destination within the prefix, it is required to use the IPv6 ND address resolution function over the upstream interface to resolve the link-layer address of a neighbor that configures the address. When a node receives a shared or individual prefix with "L=0" and has a packet to send to an IPv6 destination within the prefix, if the address is not one of the node's own addresses it sends the packet to a default router since "L=0" makes no statement about on-link or off-link properties of the prefix [[RFC4861](#)].

When a node receives a delegated prefix, it acts as a simple host to send Router Solicitation (RS) messages over upstream interfaces (i.e., the same as described in [Section 4.2 of \[RFC7084\]](#)) but also sets the "Router" flag to TRUE in its Neighbor Advertisement messages. The node considers the upstream interfaces as non-advertising interfaces [[RFC4861](#)], i.e., it does not send RA messages over the upstream interfaces. The node further does not perform the IPv6 ND address resolution function over upstream interfaces, since the delegated prefix is by definition not to be associated with an upstream interface.

In all cases, the current first-hop router may send a Redirect message that updates the node's neighbor cache so that future packets



can use a better first-hop node on the link. The Redirect can apply either to a singleton destination address, or to an entire destination prefix as described in [[I-D.templin-6man-rto-redirect](#)].

## **9. ICMPv6 Implications**

The Internet Control Message Protocol for IPv6 (ICMPv6) includes a set of control message types [[RFC4443](#)] including Destination Unreachable (DU).

According to [[RFC4443](#)], routers should return DU messages (subject to rate limiting) with code 0 ("No route to destination") when a packet arrives for which there is no matching entry in the routing table, and with code 3 ("Address unreachable") when the IPv6 destination address cannot be resolved.

According to [[RFC4443](#)], hosts should return DU messages (subject to rate limiting) with code 3 to internal applications when the IPv6 destination address cannot be resolved, and with code 4 ("Port unreachable") if the IPv6 destination address is one of its own addresses but the transport protocol has no listener.

Nodes that obtain and manage delegated prefixes per this document observe the same procedures as described for both routers and hosts above.

## **10. IANA Considerations**

This document introduces no IANA considerations.

## **11. Security Considerations**

Security considerations for IPv6 Neighbor Discovery [[RFC4861](#)] and any applicable PD mechanisms apply to this document. Nodes that receive delegated prefixes do not perform MLD/DAD procedures on their upstream interfaces, meaning that they cannot contribute to multicast messaging congestion on the upstream link. Also, routers that delegate prefixes keep only a single neighbor cache entry for each prefix delegation recipient, meaning that the router's neighbor cache cannot be subject to resource exhaustion attacks.

For shared and individual prefixes, if the router that advertises the prefix considers the prefix as on-link the IPv6 ND address resolution function will prevent unwanted IPv6 packets from reaching the node. For delegated prefixes and individual prefixes that are not considered on-link, the router delivers all packets that match the prefix to the unicast link-layer address of the node (i.e., as determined by resolution of the node's link-local address) even if





they do not match one of the node's configured addresses. In the latter case, the node may receive unwanted IPv6 packets via an upstream interface that do not match either a configured IPv6 address or a transport listener. The node then drops the packets and observes the "Destination Unreachable - Address/Port unreachable" procedures discussed in [Section 9](#).

The node may also receive IPv6 packets via an upstream interface that do not match any of the node's delegated prefixes. In that case, the node drops the packets and observes the "Destination Unreachable - No route to destination" procedures discussed in [Section 9](#). Dropping the packets is necessary to avoid a reflection attack that would cause the node to forward packets received from an upstream interface via the same or a different upstream interface.

In all cases, the node must decide whether or not to send DUs according to the specific operational scenario. In trusted networks, the node should send DU messages to provide useful information to potential correspondents. In untrusted networks, the node can refrain from sending DU messages to avoid providing sensitive information to potential attackers.

## **[12.](#) Acknowledgements**

This work was motivated by discussions on the v6ops list. Mark Smith, Ricardo Pelaez-Negro, Edwin Cordeiro, Fred Baker, Naveen Lakshman, Ole Troan, Bob Hinden, Brian Carpenter, Joel Halpern, Albert Manfredi, Dusan Mudric and Paul Marks provided useful comments that have greatly improved the document.

This work is aligned with the NASA Safe Autonomous Systems Operation (SASO) program under NASA contract number NNA16BD84C.

This work is aligned with the FAA as per the SE2025 contract number DTFWA-15-D-00030.

This work is aligned with the Boeing Information Technology (BIT) MobileNet program and the Boeing Research & Technology (BR&T) enterprise autonomy program.

## **[13.](#) References**

### **[13.1.](#) Normative References**

[RFC0791] Postel, J., "Internet Protocol", STD 5, [RFC 791](#), DOI 10.17487/RFC0791, September 1981, <<https://www.rfc-editor.org/info/rfc791>>.



- [RFC3315] Droms, R., Ed., Bound, J., Volz, B., Lemon, T., Perkins, C., and M. Carney, "Dynamic Host Configuration Protocol for IPv6 (DHCPv6)", [RFC 3315](#), DOI 10.17487/RFC3315, July 2003, <<https://www.rfc-editor.org/info/rfc3315>>.
- [RFC3633] Troan, O. and R. Droms, "IPv6 Prefix Options for Dynamic Host Configuration Protocol (DHCP) version 6", [RFC 3633](#), DOI 10.17487/RFC3633, December 2003, <<https://www.rfc-editor.org/info/rfc3633>>.
- [RFC3810] Vida, R., Ed. and L. Costa, Ed., "Multicast Listener Discovery Version 2 (MLDv2) for IPv6", [RFC 3810](#), DOI 10.17487/RFC3810, June 2004, <<https://www.rfc-editor.org/info/rfc3810>>.
- [RFC4443] Conta, A., Deering, S., and M. Gupta, Ed., "Internet Control Message Protocol (ICMPv6) for the Internet Protocol Version 6 (IPv6) Specification", STD 89, [RFC 4443](#), DOI 10.17487/RFC4443, March 2006, <<https://www.rfc-editor.org/info/rfc4443>>.
- [RFC4861] Narten, T., Nordmark, E., Simpson, W., and H. Soliman, "Neighbor Discovery for IP version 6 (IPv6)", [RFC 4861](#), DOI 10.17487/RFC4861, September 2007, <<https://www.rfc-editor.org/info/rfc4861>>.
- [RFC4862] Thomson, S., Narten, T., and T. Jinmei, "IPv6 Stateless Address Autoconfiguration", [RFC 4862](#), DOI 10.17487/RFC4862, September 2007, <<https://www.rfc-editor.org/info/rfc4862>>.
- [RFC8200] Deering, S. and R. Hinden, "Internet Protocol, Version 6 (IPv6) Specification", STD 86, [RFC 8200](#), DOI 10.17487/RFC8200, July 2017, <<https://www.rfc-editor.org/info/rfc8200>>.

### **13.2. Informative References**

- [I-D.ietf-6man-rfc6434-bis]  
Chown, T., Loughney, J., and T. Winters, "IPv6 Node Requirements", [draft-ietf-6man-rfc6434-bis-02](#) (work in progress), October 2017.
- [I-D.pioxfolks-6man-pio-exclusive-bit]  
Kline, E. and M. Abrahamsson, "IPv6 Router Advertisement Prefix Information Option eXclusive Flag", [draft-pioxfolks-6man-pio-exclusive-bit-02](#) (work in progress), March 2017.



[I-D.templin-6man-rio-redirect]

Templin, F. and j. woodyatt, "Route Information Options in IPv6 Neighbor Discovery", [draft-templin-6man-rio-redirect-05](#) (work in progress), October 2017.

[RFC1122] Braden, R., Ed., "Requirements for Internet Hosts - Communication Layers", STD 3, [RFC 1122](#), DOI 10.17487/RFC1122, October 1989, <<https://www.rfc-editor.org/info/rfc1122>>.

[RFC4291] Hinden, R. and S. Deering, "IP Version 6 Addressing Architecture", [RFC 4291](#), DOI 10.17487/RFC4291, February 2006, <<https://www.rfc-editor.org/info/rfc4291>>.

[RFC7084] Singh, H., Beebee, W., Donley, C., and B. Stark, "Basic Requirements for IPv6 Customer Edge Routers", [RFC 7084](#), DOI 10.17487/RFC7084, November 2013, <<https://www.rfc-editor.org/info/rfc7084>>.

[RFC7278] Byrne, C., Drown, D., and A. Vizdal, "Extending an IPv6 /64 Prefix from a Third Generation Partnership Project (3GPP) Mobile Interface to a LAN Link", [RFC 7278](#), DOI 10.17487/RFC7278, June 2014, <<https://www.rfc-editor.org/info/rfc7278>>.

[RFC7934] Colitti, L., Cerf, V., Cheshire, S., and D. Schinazi, "Host Address Availability Recommendations", [BCP 204](#), [RFC 7934](#), DOI 10.17487/RFC7934, July 2016, <<https://www.rfc-editor.org/info/rfc7934>>.

[RFC8028] Baker, F. and B. Carpenter, "First-Hop Router Selection by Hosts in a Multi-Prefix Network", [RFC 8028](#), DOI 10.17487/RFC8028, November 2016, <<https://www.rfc-editor.org/info/rfc8028>>.

[RFC8273] Brzozowski, J. and G. Van de Velde, "Unique IPv6 Prefix per Host", [RFC 8273](#), DOI 10.17487/RFC8273, December 2017, <<https://www.rfc-editor.org/info/rfc8273>>.

## [Appendix A](#). Change Log

Changes from -17 to -18:

- o re-worked discussion on the prefix delegation service in [Section 1](#)
- o updated figures in [Section 1](#)

Changes from -16 to -17:



- o added supporting text in the introduction to discuss the Delegating Router's relationship with the Requesting Router and with supporting infrastructure in the operator's network
- o updated figures in introduction to include representation of operator's network
- o added new section on Address Autoconfiguration Considerations

#### Author's Address

Fred L. Templin (editor)  
Boeing Research & Technology  
P.O. Box 3707  
Seattle, WA 98124  
USA

Email: [fltemplin@acm.org](mailto:fltemplin@acm.org)



