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Minimum Requirements for IPv6-only Customer Edge Routers
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Abstract

This document specifies minimum requirements for an IPv6-only Customer Edge (CE) router. Specifically, the current version of this document focuses on the basic provisioning of an IPv6-only CE router and the provisioning of IPv6 hosts attached to it. Neither the provisioning of IPv4 nor downstream routers are in the scope of this document. The document obsoletes RFC 7084.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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Table of Contents

1. Introduction

This document defines minimum IPv6 features for a very basic residential or small- office router, referred to as an "IPv6-only CE router", in order to establish an industry baseline for features to be implemented on such a router. This is, as well, the router to be used in remote locations where IPv6-only LANs/devices are used to connect sensors, displays, etc.

These routers don't support IPv4, neither functionalities for provisioning downstream routers.

This document specifies how an IPv6-only CE router automatically provisions its WAN interface, acquires address space for provisioning of its LAN interfaces, and fetches other configuration information from the service provider network. Automatic provisioning of more complex topology than a single router with multiple LAN interfaces is out of scope for this document.

This document doesn't cover the specific details of each possible access technology. For example, if the CE is supporting built-in or external 3GPP/LTE interfaces, [RFC7849] is a relevant reference. See [RFC4779] for a discussion of options available for deploying IPv6 in

wireline service provider access networks.

1.1. Requirements Language

Take careful note: Unlike other IETF documents, the key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are not used as described in RFC 2119 [RFC2119]. This document uses these keywords not strictly for the purpose of interoperability, but rather for the purpose of establishing industry-common baseline functionality. As such, the document points to several other specifications (preferable in RFC or stable form) to provide additional guidance to implementers regarding any protocol implementation required to produce a successful CE router that interoperates successfully with a particular subset of currently deploying and planned common IPv6 access networks.

2. Terminology

End-User Network — one or more links attached to the IPv6-only CE router that connect IPv6 hosts.

IPv6-only Customer Edge Router — a node intended for home or small-office use that forwards IPv6 packets not explicitly addressed to itself. The IPv6-only CE router connects the end-user network to a service provider network. In other documents, the CE is named as CPE (Customer Premises Equipment or Customer Provided Equipment). In the context of this document, both terminologies are synonymous.

IPv6 Host — any device implementing an IPv6 stack receiving IPv6 connectivity through the IPv6-only CE router.

LAN Interface — an IPv6-only CE router's attachment to a link in the end-user network. Examples are Ethernet (simple or bridged), 802.11 wireless, or other LAN technologies. An IPv6-only CE router may have one or more network-layer LAN interfaces.

Service Provider — an entity that provides access to the Internet. In this document, a service provider specifically offers Internet access using IPv6-only, and it may also

	offer IPv4 Internet access, but non intended to be supported by this IPv6-only CE router. The service provider can provide such access over a variety of different transport methods such as FTTH, DSL, cable, wireless, 3GPP/LTE, and others.
WAN Interface	an IPv6-only CE router's attachment to a link used to provide connectivity to the service provider network; example link technologies include Ethernet (simple or bridged), PPP links, Frame Relay, or ATM networks.

3. Architecture

3.1. Current IPv4 End-User Network Architecture

An end-user network will likely support both IPv4 and IPv6. It is not expected that an end user will change their existing network topology with the introduction of IPv6, however very simple networks may work perfectly with IPv6-only. There are some differences in how IPv6 works and is provisioned; these differences have implications for the network architecture. A typical IPv4 end-user network consists of a "plug and play" router with NAT functionality and a single link behind it, connected to the service provider network.

A typical IPv4 NAT deployment by default blocks all incoming connections. Opening of ports is typically allowed using a Universal Plug and Play Internet Gateway Device (UPnP IGD) [UPnP-IGD] or some other firewall control protocol.

Another consequence of using private address space in the end-user network is that it provides stable addressing; that is, it never changes even when you change service providers, and the addresses are always there even when the WAN interface is down or the customer edge router has not yet been provisioned.

Many existing routers support dynamic routing (which learns routes from other routers), and advanced end-users can build arbitrary, complex networks using manual configuration of address prefixes combined with a dynamic routing protocol.

3.2. IPv6 End-User Network Architecture

The end-user network architecture for a simple IPv6-only network should provide equivalent or better capabilities and functionality than the current IPv4 architecture.

The end-user network is a stub network. Figure 1 illustrates the model topology for the end-user network.

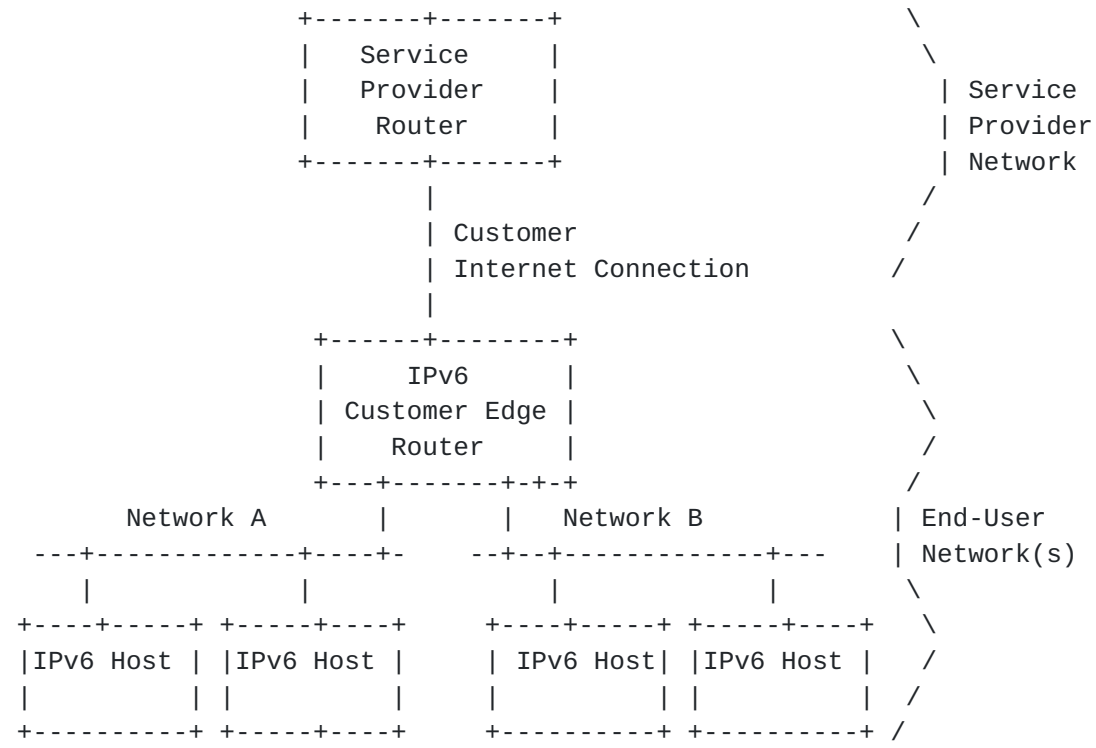

Figure 1: An Example of a Typical End-User Network

This architecture describes the:

- Basic capabilities of an IPv6-only CE router
- Provisioning of the WAN interface connecting to the service provider
- Provisioning of the LAN interfaces

For IPv6 multicast traffic, the IPv6-only CE router may act as a Multicast Listener Discovery (MLD) proxy [RFC4605] and may support a dynamic multicast routing protocol.

The IPv6-only CE router may be manually configured in an arbitrary topology with a dynamic routing protocol. Automatic provisioning and configuration is described for a single IPv6-only CE router only.

3.2.1. Local Communication

Link-local IPv6 addresses are used by hosts communicating on a single link. Unique Local IPv6 Unicast Addresses (ULAs) [RFC4193] are used by hosts communicating within the end-user network across multiple links, but without requiring the application to use a globally routable address. The IPv6-only CE router defaults to acting as the demarcation point between two networks by providing a ULA boundary, a multicast zone boundary, and ingress and egress traffic filters.

At the time of this writing, several host implementations do not handle the case where they have an IPv6 address configured and no IPv6 connectivity, either because the address itself has a limited topological reachability (e.g., ULA) or because the IPv6-only CE router is not connected to the IPv6 network on its WAN interface. To support host implementations that do not handle multihoming in a multi-prefix environment [RFC7157], the IPv6-only CE router should not, as detailed in the requirements below, advertise itself as a default router on the LAN interface(s) when it does not have IPv6 connectivity on the WAN interface or when it is not provisioned with IPv6 addresses. For local IPv6 communication, the mechanisms specified in [RFC4191] are used.

ULA addressing is useful where the IPv6-only CE router has multiple LAN interfaces with hosts that need to communicate with each other. If the IPv6 CE router has only a single LAN interface (IPv6 link), then link-local addressing can be used instead.

4. Requirements

4.1. General Requirements

The IPv6-only CE router is responsible for implementing IPv6 routing; that is, the IPv6-only CE router must look up the IPv6 destination address in its routing table to decide to which interface it should send the packet.

In this role, the IPv6-only CE router is responsible for ensuring that traffic using its ULA addressing does not go out the WAN interface and does not originate from the WAN interface.

G-1: An IPv6-only CE router is an IPv6 node according to the IPv6 Node Requirements specification [RFC6434].

G-2: The IPv6-only CE router MUST implement ICMPv6 according to [RFC4443]. In particular, point-to-point links MUST be handled as described in Section 3.1 of [RFC4443].

G-3: The IPv6-only CE router MUST NOT forward any IPv6 traffic between its LAN interface(s) and its WAN interface until the router has successfully completed the IPv6 address and the delegated prefix acquisition process.

G-4: By default, an IPv6-only CE router that has no default router(s) on its WAN interface MUST NOT advertise itself as an IPv6 default router on its LAN interfaces. That is, the "Router Lifetime" field is set to zero in all Router Advertisement messages it originates [RFC4861].

G-5: By default, if the IPv6-only CE router is an advertising router and loses its IPv6 default router(s) and/or detects loss of connectivity on the WAN interface, it MUST explicitly invalidate itself as an IPv6 default router on each of its advertising interfaces by immediately transmitting one or more Router Advertisement messages with the "Router Lifetime" field set to zero [RFC4861].

G-6: The IPv6-only CE router MUST comply with [RFC7608].

4.2. WAN-Side Configuration

The IPv6-only CE router will need to support connectivity to one or more access network architectures. This document describes an IPv6-only CE router that is not specific to any particular architecture or service provider and that supports all commonly used architectures.

IPv6 Neighbor Discovery and DHCPv6 protocols operate over any type of IPv6-supported link layer, and there is no need for a link-layer-specific configuration protocol for IPv6 network-layer configuration options as in, e.g., PPP IP Control Protocol (IPCP) for IPv4. This section makes the assumption that the same mechanism will work for any link layer, be it Ethernet, the Data Over Cable Service Interface Specification (DOCSIS), PPP, or others.

WAN-side requirements:

W-1: When the IPv6-only CE router is attached to the WAN interface link, it MUST act as an IPv6 host for the purposes of stateless [RFC4862] or stateful [RFC3315] interface address assignment.

W-2: The IPv6-only CE router MUST generate a link-local address and finish Duplicate Address Detection according to [RFC4862] prior to sending any Router Solicitations on the interface. The source address used in the subsequent Router Solicitation MUST be the link-local address on the WAN interface.

W-3: Absent other routing information, the IPv6-only CE router MUST use Router Discovery as specified in [RFC4861] to discover a default router(s) and install a default route(s) in its routing table with the discovered router's address as the next hop.

W-4: The IPv6-only CE router MUST act as a requesting router for the purposes of DHCPv6 prefix delegation ([RFC3633]).

W-5: The IPv6-only CE router MUST use a persistent DHCP Unique Identifier (DUID) for DHCPv6 messages. The DUID MUST NOT change between network-interface resets or IPv6 CE router reboots.

W-6: The WAN interface of the IPv6-only CE router SHOULD support a Port Control Protocol (PCP) client as specified in [RFC6887] for use by applications on the CE router. The PCP client SHOULD follow the procedure specified in Section 8.1 of [RFC6887] to discover its PCP server. This document takes no position on whether such functionality is enabled by default or mechanisms by which users would configure the functionality. Handling PCP requests from PCP clients in the LAN side of the CE router is out of scope.

Link-layer requirements:

WLL-1: If the WAN interface supports Ethernet encapsulation, then the IPv6-only CE router MUST support IPv6 over Ethernet [RFC2464].

WLL-2: If the WAN interface supports PPP encapsulation, the IPv6-only CE router MUST support IPv6 over PPP [RFC5072].

Address assignment requirements:

WAA-1: The IPv6-only CE router MUST support Stateless Address Autoconfiguration (SLAAC) [RFC4862].

WAA-2: The IPv6-only CE router MUST follow the recommendations in Section 4 of [RFC5942], and in particular the handling of the L flag in the Router Advertisement Prefix Information option.

WAA-3: The IPv6-only CE router MUST support DHCPv6 [RFC3315] client behavior.

WAA-4: The IPv6-only CE router MUST be able to support the following DHCPv6 options: Identity Association for Non-temporary Address (IA_NA), Reconfigure Accept [RFC3315], and

DNS_SERVERS [RFC3646]. The IPv6-only CE router SHOULD be able to support the DNS Search List (DNSSL) option as specified in [RFC3646].

WAA-5: The IPv6-only CE router SHOULD implement the Network Time Protocol (NTP) as specified in [RFC5905] to provide a time reference common to the service provider for other protocols, such as DHCPv6, to use. If the IPv6-only CE router implements NTP, it requests the NTP Server DHCPv6 option [RFC5908] and uses the received list of servers as primary time reference, unless explicitly configured otherwise. LAN side support of NTP is out of scope for this document.

WAA-6: If the IPv6-only CE router receives a Router Advertisement message (described in [RFC4861]) with the M flag set to 1, the IPv6 CE router MUST do DHCPv6 address assignment (request an IA_NA option).

WAA-7: If the IPv6-only CE router does not acquire a global IPv6 address(es) from either SLAAC or DHCPv6, then it MUST create a global IPv6 address(es) from its delegated prefix(es) and configure those on one of its internal virtual network interfaces, unless configured to require a global IPv6 address on the WAN interface.

WAA-8: The IPv6-only CE router MUST support the SOL_MAX_RT option [RFC7083] and request the SOL_MAX_RT option in an Option Request Option (ORO).

WAA-9: As a router, the IPv6-only CE router MUST follow the weak host (Weak End System) model [RFC1122]. When originating packets from an interface, it will use a source address from another one of its interfaces if the outgoing interface does not have an address of suitable scope.

WAA-10: The IPv6-only CE router SHOULD implement the Information Refresh Time option and associated client behavior as specified in [RFC4242].

Prefix delegation requirements:

WPD-1: The IPv6-only CE router MUST support DHCPv6 prefix delegation requesting router behavior as specified in [RFC3633] (Identity Association for Prefix Delegation (IA_PD) option).

WPD-2: The IPv6-only CE router MAY indicate as a hint to the delegating router the size of the prefix it requires. If so,

it MUST ask for a prefix large enough to assign one /64 for each of its interfaces, rounded up to the nearest nibble, and SHOULD be configurable to ask for more.

WPD-3: The IPv6-only CE router MUST be prepared to accept a delegated prefix size different from what is given in the hint. If the delegated prefix is too small to address all of its interfaces, the IPv6-only CE router SHOULD log a system management error. [RFC6177] covers the recommendations for service providers for prefix allocation sizes.

WPD-4: By default, the IPv6-only CE router MUST initiate DHCPv6 prefix delegation when either the M or O flags are set to 1 in a received Router Advertisement (RA) message. Behavior of the IPv6-only CE router to use DHCPv6 prefix delegation when the CE router has not received any RA or received an RA with the M and the O bits set to zero is out of scope for this document.

WPD-5: Any packet received by the IPv6-only CE router with a destination address in the prefix(es) delegated to the CE router but not in the set of prefixes assigned by the CE router to the LAN must be dropped. In other words, the next hop for the prefix(es) delegated to the CE router should be the null destination. This is necessary to prevent forwarding loops when some addresses covered by the aggregate are not reachable [RFC4632].

(a) The IPv6-only CE router SHOULD send an ICMPv6 Destination Unreachable message in accordance with Section 3.1 of [RFC4443] back to the source of the packet, if the packet is to be dropped due to this rule.

WPD-6: If the IPv6-only CE router requests both an IA_NA and an IA_PD option in DHCPv6, it MUST accept an IA_PD option in DHCPv6 Advertise/Reply messages, even if the message does not contain any addresses, unless configured to only obtain its WAN IPv6 address via DHCPv6; see [RFC7550].

WPD-7: By default, an IPv6-only CE router MUST NOT initiate any dynamic routing protocol on its WAN interface.

WPD-8: The IPv6-only CE router SHOULD support the [RFC6603] Prefix Exclude option.

4.3. LAN-Side Configuration

The IPv6-only CE router distributes configuration information obtained during WAN interface provisioning to IPv6 hosts and assists IPv6 hosts in obtaining IPv6 addresses. It also supports connectivity of these devices in the absence of any working WAN interface.

An IPv6-only CE router is expected to support an IPv6 end-user network and IPv6 hosts that exhibit the following characteristics:

1. Link-local addresses may be insufficient for allowing IPv6 applications to communicate with each other in the end-user network. The IPv6-only CE router will need to enable this communication by providing globally scoped unicast addresses or ULAs [RFC4193], whether or not WAN connectivity exists.

2. IPv6 hosts should be capable of using SLAAC and may be capable of using DHCPv6 for acquiring their addresses.

3. IPv6 hosts may use DHCPv6 for other configuration information, such as the DNS_SERVERS option for acquiring DNS information.

Unless otherwise specified, the following requirements apply to the IPv6-only CE router's LAN interfaces only.

ULA requirements:

ULA-1: The IPv6-only CE router SHOULD be capable of generating a ULA prefix [RFC4193].

ULA-2: An IPv6-only CE router with a ULA prefix MUST maintain this prefix consistently across reboots.

ULA-3: The value of the ULA prefix SHOULD be configurable.

ULA-4: By default, the IPv6-only CE router MUST act as a site border router according to Section 4.3 of [RFC4193] and filter packets with local IPv6 source or destination addresses accordingly.

ULA-5: An IPv6-only CE router MUST NOT advertise itself as a default router with a Router Lifetime greater than zero whenever all of its configured and delegated prefixes are ULA prefixes.

LAN requirements:

L-1: The IPv6-only CE router MUST support router behavior according

to Neighbor Discovery for IPv6 [RFC4861].

L-2: The IPv6-only CE router MUST assign a separate /64 from its delegated prefix(es) (and ULA prefix if configured to provide ULA addressing) for each of its LAN interfaces.

L-3: An IPv6-only CE router MUST advertise itself as a router for the delegated prefix(es) (and ULA prefix if configured to provide ULA addressing) using the "Route Information Option" specified in Section 2.3 of [RFC4191]. This advertisement is independent of having or not having IPv6 connectivity on the WAN interface.

L-4: An IPv6-only CE router MUST NOT advertise itself as a default router with a Router Lifetime [RFC4861] greater than zero if it has no prefixes configured or delegated to it.

L-5: The IPv6-only CE router MUST make each LAN interface an advertising interface according to [RFC4861].

L-6: In Router Advertisement messages ([RFC4861]), the Prefix Information option's A and L flags MUST be set to 1 by default.

L-7: The A and L flags' ([RFC4861]) settings SHOULD be user configurable.

L-8: The IPv6-only CE router MUST support a DHCPv6 server capable of IPv6 address assignment according to [RFC3315] OR a stateless DHCPv6 server according to [RFC3736] on its LAN interfaces.

L-9: Unless the IPv6-only CE router is configured to support the DHCPv6 IA_NA option, it SHOULD set the M flag to zero and the O flag to 1 in its Router Advertisement messages [RFC4861].

L-10: The IPv6-only CE router MUST support providing DNS information in the DHCPv6 DNS_SERVERS and DOMAIN_LIST options [RFC3646].

L-11: The IPv6-only CE router MUST support providing DNS information in the Router Advertisement Recursive DNS Server (RDNSS) and DNS Search List options. Both options are specified in [RFC6106].

L-12: The IPv6-only CE router SHOULD implement a DNS proxy as described in [RFC5625].

L-13: The IPv6-only CE router SHOULD make available a subset of

DHCPv6 options (as listed in Section 5.3 of [RFC3736]) received from the DHCPv6 client on its WAN interface to its LAN-side DHCPv6 server.

L-14: If the delegated prefix changes, i.e., the current prefix is replaced with a new prefix without any overlapping time period, then the IPv6-only CE router MUST immediately advertise the old prefix with a Preferred Lifetime of zero and a Valid Lifetime of either a) zero or b) the lower of the current Valid Lifetime and two hours (which must be decremented in real time) in a Router Advertisement message as described in Section 5.5.3, (e) of [RFC4862].

L-15: The IPv6-only CE router MUST send an ICMPv6 Destination Unreachable message, code 5 (Source address failed ingress/ egress policy) for packets forwarded to it that use an address from a prefix that has been invalidated.

4.4. Security Considerations

It is considered a best practice to filter obviously malicious traffic (e.g., spoofed packets, "Martian" addresses, etc.). Thus, the IPv6-only CE router ought to support basic stateless egress and ingress filters. The IPv6-only CE router is also expected to offer mechanisms to filter traffic entering the customer network; however, the method by which vendors implement configurable packet filtering is beyond the scope of this document.

Security requirements:

S-1: The IPv6-only CE router SHOULD support [RFC6092]. In particular, the IPv6-only CE router SHOULD support functionality sufficient for implementing the set of recommendations in [RFC6092], Section 4. This document takes no position on whether such functionality is enabled by default or mechanisms by which users would configure it.

S-2: The IPv6-only CE router SHOULD support ingress filtering in accordance with BCP 38 [RFC2827]. Note that this requirement was downgraded from a MUST from RFC 6204 due to the difficulty of implementation in the CE router and the feature's redundancy with upstream router ingress filtering.

S-3: If the IPv6-only CE router firewall is configured to filter incoming tunneled data, the firewall SHOULD provide the capability to filter decapsulated packets from a tunnel.

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6. Contributors

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7. ANNEX A: Changes from RFC7084

The -bis2 version of this document has some minor text edits here and there. Significant updates are:

1. Removed, in general requirements related to IPv4/dual-stack support.

2. References to IPv6 CE router changed to IPv6-only CE router.

3. Removed WLL-3, as it was referring to dual-stack support.

4. G-6 added in order to comply with [RFC7608].

5. L-12 added to support for DNS proxy [RFC5625] as general LAN requirement.

6. Removed transition support.

8. References

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