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Transition Requirements for IPv6 Customer Edge Routers to support IPv4 as a Service
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Abstract

This document specifies the transition requirements for an IPv6 Customer Edge (CE) router, either provided by the service provider or thru the retail market.

Specifically, this document extends the "Basic Requirements for IPv6 Customer Edge Routers" ([RFC7084]) in order to allow the provisioning of IPv6 transition services for the support of IPv4 as a Service (IPv4aaS) by means of new transition mechanisms, which where not available at the time [RFC7084] was published. The document only covers transition technologies for delivering IPv4 in IPv6-only access networks, commonly called IPv4 "as-a-service" (IPv4aaS), as required in a world where IPv4 addresses are no longer available, so hosts in the customer LANs with IPv4-only or IPv6-only applications or devices, requiring to communicate with IPv4-only services at the Internet, are still able to do so.

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1. Introduction

This document defines basic IPv6 transition features for a residential or small-office router, referred to as an "IPv6 Transition CE router with IPv4aaS support", in order to establish an industry baseline for transition features to be implemented on such a router.

These routers are based on "Basic Requirements for IPv6 Customer Edge Routers" ([RFC7084]), so the scope of this documents is to ensure the IPv4 "service continuity" support, in the LAN side and the access to IPv4-only Internet services from an IPv6-only access WAN even from IPv6-only applications or devices in the LAN side.

This document covers the IP transition technologies required when ISPs have already an IPv6-only access network, which is becoming a common situation in a world where IPv4 addresses are no longer available, so the service providers need to provision IPv6-only WAN access, while at the same time ensuring that both IPv4-only and IPv6-only devices or applications in the customer LANs, can still reach IPv4-only devices or applications in Internet, which still don't have IPv6 support.

This document specifies the transition mechanisms to be supported by an IPv6 transition CE router, and relevant provisioning or configuration information differences from [RFC7084].

This document is not a recommendation for service providers to use any specific transition mechanism.

Automatic provisioning of more complex topology than a single router with multiple LAN interfaces may be handled by means of HNCP ([RFC7788]), which is out of the scope of this document.

The CE vendors need to consider that the situation of lack of IPv4 addresses and the IPv6 deployment, is a global issue, so the CEs fulfilling the requirements of this document aren't only those provided by the service providers to the customers, but also the customers may need to replace existing ones by themselves thru the retail market.

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 IPv6 Transition CE router that interoperates successfully with a particular subset of currently deploying and planned common IPv6 access networks.

2. Terminology

This document uses the same terminology as in [RFC7084], with two minor clarifications.

The term "IPv6 transition Customer Edge Router with IPv4aaS" (shortened as "IPv6 transition CE") is defined as an "IPv6 Customer Edge Router" that provides transition support to allow IPv4-IPv6 coexistence either beyond the WAN, in the LAN or both.

The "WAN Interface" term used across this document, means that can also support link technologies based in Internet-layer (or higher-layers) "tunnels", such as IPv4-in-IPv6 tunnels.

3. Usage Scenarios

The situation before described, where there is ongoing IPv6 deployment and lack of IPv4 addresses, is not happening at the same pace at every country, and even within every country, every ISP. For different technical, financial, commercial/marketing and socio-economical reasons, each network is transitioning at their own pace, and nobody has a magic crystal ball, to make a guess.

Different studies also show that this is a changing situation, because in a single country, may be not all operators provide IPv6 support, and customer churn implies that the same customers at some point may have IPv6 service and may not have it, if changing ISP, and viceversa.

So it is clear that, to cover all those evolving situations, it is required an IPv6 transition CE which, at least from the perspective of the transition support, can keep accommodating to those changes, as it may be or not provided by the service provider. Even may be a point when, having one working seamlessly among different operators means lower cost for changing them, and so, increase and facilitate competition.

Moreover, because some services will remain as IPv4-only for an undetermined time and some service providers may also delay their IPv6 support, again for an undetermined period of time, there is an uncertainty about how much time there will be a percentage of IPv4 traffic between end-users and end-services, that definitively needs to be "serviced", so there will be a need to provide CEs with support "IPv4 as a Service" for some time.

This document is consequently, based on those premises, in order to ensure the continued transition from networks that today may provide access with dual-stack or IPv6-in-IPv4, as described in [RFC7084],

and as an "extension" to it, evolving to an IPv6-only access with IPv4-as-a-Service.

Considering that situation and different possible usage cases, the IPv6 Transition CE router described in this document is expected to be used typically, in any of the following scenarios:

1. Residential/household users. Common usage is any kind of Internet access (web, email, streaming, online gaming, etc.).

2. Residential with Small Office/Home Office (SOHO). Same usage as for the first scenario.

3. Small Office/Home Office (SOHO). Same usage as for the first scenario.

4. Small and Medium Enterprise (SME). Same usage as for the first scenario.

5. Residential/household with advanced requirements. Same basic usage as for the first scenario, however there may be requirements for exporting services to the WAN (IP cameras, web, DNS, email, VPN, etc.).

6. Small and Medium Enterprise (SME) with advanced requirements. Same basic usage as for the first scenario, however there may be requirements for exporting services to the WAN (IP cameras, web, DNS, email, VPN, etc.).

The above list is not intended to be comprehensive of all the possible usage scenarios, just the main ones. In fact, combinations of the above usages are also possible, for example a residential with SOHO and advanced requirements, as well as situations where the same CE is used at different times in different scenarios or even different services providers that may use a different transition mechanism.

The mechanisms for exporting IPv6 services are commonly "naturally" available in any IPv6 router, as when using GUA, unless they are blocked by firewall rules, which may require some manual configuration by means of a GUI and/or CLI.

However, in the case of IPv4, because the usage of private addresses and NAT, it typically requires some degree of manual configuration such as setting up a DMZ, virtual servers, or port/protocol forwarding. In general, CE routers already provide GUI and/or CLI to manually configure them, or the possibility to setup the CE in bridge mode, so another CE behind it, takes care of that. It is out of the

scope of this document the definition of any requirements for that.

The main difference for an IPv6 Transition CE router to support one or several of the above indicated scenarios, is related to the packet processing capabilities, performance, even other details such as the number of WAN/LAN interfaces, their maximum speed, memory for keeping tables or tracking connections, etc. So, it is out of the scope of this document to classify them.

For example, an SME may have just 10 employees (micro-SME), which commonly will be considered same as a SOHO, but a small SME can have up to 50 employees, or 250 for a medium one. Depending on the IPv6 Transition CE router capabilities or even how it is being configured (for instance, using SLAAC or DHCPv6), it may support even a higher number of employees if the traffic in the LANs is low, or switched by another device(s), or the WAN bandwidth requirements are low, etc. The actual bandwidth capabilities of access with technologies such as FTTH, cable and even 3GPP/LTE, allows the support of such usages, and indeed, is a very common situation that access networks and the IPv6 Transition CE provided by the service provider are the same for SMEs and residential users.

There is also no difference in terms of who actually provides the IPv6 Transition CE router. In most of the cases is the service provider, and in fact is responsible, typically, of provisioning/ managing at least the WAN side. However, commonly the user has access to configure the LAN interfaces, firewall, DMZ, and many other aspects. In fact, in many cases, the user must supply, or at least can replace the IPv6 Transition CE router, which makes even more relevant that all the IPv6 Transition CE routers, support the same requirements defined in this document, despite if they are provided directly by the service provider or acquired thru the retail market.

The IPv6 Transition CE router described in this document is not intended for usage in other scenarios such as bigger Enterprises, Data Centers, Content Providers, etc. So, even if the documented requirements meet their needs, may have additional requirements, which are out of the scope of this document.

4. End-User Network Architecture

According to the descriptions in the precedent sections, 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. 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.

From the perspective of an "IPv4 user" behind an IPv6 transition Customer Edge Router with IPv4aaS, this doesn't change.

However, while a typical IPv4 NAT deployment by default blocks all incoming connections and may allow opening of ports using a Universal Plug and Play Internet Gateway Device (UPnP IGD) [UPnP-IGD] or some other firewall control protocol, in the case of an IPv6-only access, the latest may not be feasible depending on specific transition mechanism details. PCP (Port Control Protocol, [RFC6887]) may be an alternative solution, as well.

Another consequence of using IPv4 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. In the case of an IPv6-only access, there is no change on that if the transition mechanism keeps running the NAT interface towards the LAN side.

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. Once again, this is true for both, IPv4 and IPv6.

In general, the end-user network architecture for IPv6 should provide equivalent or better capabilities and functionality than the current IPv4 architecture.

The end-user network is a stub network, in the sense that is not providing transit to other external networks. However HNCP ([RFC7788]) allows support for automatic provisioning of downstream routers. Figure 1 illustrates the model topology for the end-user network.

```
                     +---------------+                      \
                     |   Service     |                       \
                     |   Provider    |                        | Service
                     |    Router     |                        | Provider
                     +-------+-------+                        | Network
                             |                               /
                             | Customer                     /
                             | Internet Connection         /
                             |
                      +------+--------+                    \
                      |     IPv6       |                     \
                      | Customer Edge |                      \
                      |    Router     |                      /
                      +---+-------+---+                     /
          Network A       |       |   Network B            |
    ---+----------------+-+-    --+---+-------------+--    |
       |                |             |             |       \
   +---+------+         |        +----+-----+ +-----+----+   \
   |IPv6 Host |         |        | IPv4 Host| |IPv4/IPv6 |   /
   |          |         |        |          | | Host     |  /
   +----------+         |        +----------+ +----------+ /
                        |                                 |
                 +------+--------+                        | End-User
                 |     IPv6       |                        | Network(s)
                 |    Router     |                         \
                 +------+--------+                          \
          Network C     |                                    \
    ---+-------------+--+---                                  |
       |             |                                        |
   +---+------+ +----+-----+                                  |
   |IPv6 Host | |IPv6 Host |                                 /
   |          | |          |                                /
   +----------+ +----------+                               /
```

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

This architecture describes the:

o Basic capabilities of an IPv6 Transition CE router

o Provisioning of the WAN interface connecting to the service provider

o Provisioning of the LAN interfaces

The IPv6 Transition CE router may be manually configured in an arbitrary topology with a dynamic routing protocol or using HNCP ([RFC7788]). Automatic provisioning and configuration is described

for a single IPv6 Transition CE router only.

5. Requirements

The IPv6 Transition CE router must comply with all the requirements stated in [RFC7084].

5.1. General Requirements

A new general requirement is added:

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

5.2. LAN-Side Configuration

A new LAN requirement is:

L-15 The IPv6 CE router SHOULD implement a DNS proxy as described in [RFC5625].

5.3. Transition Technologies Support for IPv4 Service Continuity (IPv4 as a Service - IPv4aaS)

The main target of this document is the support of IPv6-only WAN access, and while needed, the support of IPv4-only devices and applications in the customers LANs, in one side of the picture. In the other side, some remote services may stay IPv4-only, so a solution is also required for both the IPv4-only and the IPv6-only devices inside the CE are able to reach the IPv4-only services. Consequently, transition technologies to resolve both sides of the picture are considered.

In order to seamlessly provide the IPv4 Service Continuity in Customer LANs, allowing an automated IPv6 transition mechanism provisioning, a new general transition requirement is added.

General transition requirement:

TRANS-1: The IPv6 Transition CE router MUST support the DHCPv6 S46 priority option described in [RFC8026] if more than one S46 mechanisms is supported.

The following sections describe the requirements for supporting additional transition mechanisms not included in [RFC7084].

5.3.1. 464XLAT

464XLAT [RFC6877] is a technique to provide IPv4 access service to IPv6-only edge networks without encapsulation.

The IPv6 Transition CE router SHOULD support CLAT functionality. If 464XLAT is supported, it MUST be implemented according to [RFC6877]. The following CE Requirements also apply:

464XLAT requirements:

464XLAT-1: The IPv6 Transition CE router MUST verify if the WAN link supports native IPv4, and if that's not available, MUST enable the CLAT (in order to automatically configure [RFC6877]), unless there is a match with a valid OPTION_S46_PRIORITY (following section 1.4 of [RFC8026]), which will allow configuring any of the other transition mechanisms.

464XLAT-2: The IPv6 Transition CE router MUST perform IPv4 Network Address Translation (NAT) on IPv4 traffic translated using the CLAT, unless a dedicated /64 prefix has been acquired using DHCPv6-PD [RFC3633].

464XLAT-3: The IPv6 Transition CE router MUST implement [RFC7050] in order to discover the PLAT-side translation IPv4 and IPv6 prefix(es)/suffix(es). In environments with PCP support, the IPv6 Transition CE SHOULD follow [RFC7225] to learn the PLAT-side translation IPv4 and IPv6 prefix(es)/suffix(es) used by an upstream PCP-controlled NAT64 device.

5.3.2. Lightweight 4over6 (lw4o6)

Lw4o6 [RFC7596] specifies an extension to DS-Lite, which moves the NAPT function from the DS-Lite tunnel concentrator to the tunnel client located in the IPv6 Transition CE router, removing the requirement for a CGN function in the tunnel concentrator and reducing the amount of centralized state.

The IPv6 Transition CE router SHOULD implement lw4o6 functionality. If DS-Lite is implemented, lw4o6 MUST be supported as well. If lw4o6 is supported, it MUST be implemented according to [RFC7596]. This document takes no position on simultaneous operation of lw4o6 and native IPv4. The following IPv6 Transition CE router Requirements also apply:

Lw4o6 requirements:

LW4O6-1: The IPv6 Transition CE router MUST support configuration of lw4o6 via the lw4o6 DHCPv6 options [RFC7598]. The IPv6 Transition CE router MAY use other mechanisms to configure lw4o6 parameters. Such mechanisms are outside the scope of this document.

LW4O6-2: The IPv6 Transition CE router MUST support the DHCPv4-over-DHCPv6 (DHCP 4o6) transport described in [RFC7341].

LW4O6-3: The IPv6 Transition CE router MAY support Dynamic Allocation of Shared IPv4 Addresses as described in [RFC7618].

5.3.3. MAP-E

MAP-E [RFC7597] is a mechanism for transporting IPv4 packets across an IPv6 network using IP encapsulation, including a generic mechanism for mapping between IPv6 addresses and IPv4 addresses as well as transport-layer ports.

The IPv6 Transition CE router SHOULD support MAP-E functionality. If MAP-E is supported, it MUST be implemented according to [RFC7597]. The following CE Requirements also apply:

MAP-E requirements:

MAPE-1: The IPv6 Transition CE router MUST support configuration of MAP-E via the MAP-E DHCPv6 options [RFC7598]. The IPv6 Transition CE router MAY use other mechanisms to configure MAP-E parameters. Such mechanisms are outside the scope of this document.

5.3.4. MAP-T

MAP-T [RFC7599] is a mechanism similar to MAP-E, differing from it in that MAP-T uses IPv4-IPv6 translation, rather than encapsulation, as the form of IPv6 domain transport.

The IPv6 Transition CE router SHOULD support MAP-T functionality. If MAP-T is supported, it MUST be implemented according to [RFC7599]. The following IPv6 Transition CE Requirements also apply:

MAP-T requirements:

MAPT-1: The CE router MUST support configuration of MAP-T via the MAP-T DHCPv6 options [RFC7598]. The IPv6 Transition CE router MAY use other mechanisms to configure MAP-T parameters. Such mechanisms are outside the scope of this

document.

6. IPv4 Multicast Support

Actual deployments support IPv4 multicast for services such as IPTV. In the transition phase it is expected that multicast services will still be provided using IPv4 to the customer LANs.

In order to support the delivery of IPv4 multicast services to IPv4 clients over an IPv6 multicast network, the IPv6 Transition CE router SHOULD support [RFC8114] and [RFC8115].

7. Code Considerations

One of the apparent main issues for vendors to include new functionalities, such as support for new transition mechanisms, is the lack of space in the flash (or equivalent) memory. However, it has been confirmed from existing open source implementations (OpenWRT/LEDE, Linux, others), that adding the support for the new transitions mechanisms, requires around 10-12 Kbytes (because most of the code base is shared among several transition mechanisms already supported by [RFC7084]), as a single data plane is common to all them, which typically means about 0,15% of the existing code size in popular CEs already in the market.

It is also clear that the new requirements don't have extra cost in terms of RAM memory, neither other hardware requirements such as more powerful CPUs.

The other issue seems to be the cost of developing the code for those new functionalities. However at the time of writing this document, it has been confirmed that there are several open source versions of the required code for supporting the new transition mechanisms, and even several vendors already have implementations and provide it to ISPs, so the development cost is negligent, and only integration and testing cost may become a minor issue.

8. Security Considerations

The IPv6 Transition CE router must comply with the Security Considerations as stated in [RFC7084].

9. Acknowledgements

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