Internet Engineering Task Force M. Mawatari
Internet-Draft Japan Internet Exchange Co.,Ltd.
Intended status: BCP M. Kawashima
Expires: October 19, 2012 NEC AccessTechnica, Ltd.
C. Byrne
T-Mobile USA
April 17, 2012

464XLAT: Combination of Stateful and Stateless Translation
draft-ietf-v6ops-464xlat-02

Abstract

This document describes an architecture (464XLAT) for providing limited IPv4 connectivity across an IPv6-only network by combining existing and well-known stateful protocol translation RFC 6146 in the core and stateless protocol translation RFC 6145 at the edge. 464XLAT is a simple and scalable technique to quickly deploy limited IPv4 access service to mobile and wireline IPv6-only edge networks without encapsulation.

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1. Introduction

The IANA unallocated IPv4 address pool was exhausted on February 3, 2011. Each RIR's unallocated IPv4 address pool will exhaust in the near future. It will be difficult for many networks to assign IPv4 addresses to end users, despite substantial IP connectivity growth required for mobile devices, smart-grid, and cloud nodes.

This document describes an IPv4 over IPv6 solution as one of the techniques for IPv4 service extension and encouragement of IPv6 deployment. 464XLAT is not a one for one replacement of full IPv4 functionality. The 464XLAT IPv4 service is limited to application that function in a client server model and is not fit for IPv4 peer-to-peer communication or inbound IPv4 connections.

The 464XLAT architecture described in this document uses IPv4/IPv6 translation standardized in [RFC6145] and [RFC6146]. It does not require DNS64 [RFC6147] since a host may simply send IPv4 packets, including packets to an IPv4 DNS server, which will be translated on the CLAT to IPv6 and back to IPv4 on the PLAT. 464XLAT networks may use DNS64 to enable single stateful translation [RFC6146] instead of 464XLAT double translation where possible. It is also possible to provide single IPv4/IPv6 translation service, which will be needed in the future case of IPv6-only servers and peers to be reached from legacy IPv4-only hosts. The 464XLAT architecture encourages IPv6 transition by making IPv4 services reachable across IPv6-only networks and providing IPv6 and IPv4 connectivity to single-stack IPv4 or IPv6 servers and peers.

Running a single-stack IPv6-only network has several operational benefits in terms of increasing scalability and decreasing operational complexity. Unfortunately, there are important cases where IPv6-only networks fail to meet subscriber expectations, as described in [I-D.arkko-ipv6-only-experience]. The 464XLAT overcomes the issues described in [I-D.arkko-ipv6-only-experience] to provide subscribers the full IPv6 and limited IPv4 functionality while providing the network operator the benefits of a simple yet highly scalable single-stack IPv6 network.

2. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

3. Terminology

PLAT: PLAT is Provider side translator(XLAT) that complies with [RFC6146]. It translates N:1 global IPv6 packets to global IPv4 packets, and vice versa.

CLAT: CLAT is Customer side translator(XLAT) that complies with [RFC6145]. It algorithmically translates 1:1 private IPv4 packets to global IPv6 packets, and vice versa. The CLAT function is applicable to a router or an end-node such as a mobile phone. CLAT SHOULD perform router function to facilitate packets forwarding through the stateless translation even if it is an end-node. In addition to stateless translation, the CLAT as a common home router or 3G router is expected to perform gateway functions such as DHCP server and DNS proxy for local clients.

UE: The 3GPP term for user equipment. The most common type of UE is a mobile phone.

PDP: A Packet Data Protocol (PDP) Context is the equivalent of a virtual connection between the host and a gateway.

4. Motivation and Uniqueness of 464XLAT

1. Minimal IPv4 resource requirements, maximum IPv4 efficiency

   464XLAT has low barriers to entry since only a small amount of IPv4 addresses are needed to support the stateful translation [RFC6146] function in the PLAT. With port-overloading, one IPv4 address can support millions of simultaneous translations.

   Given that network operators are deploying IPv6-only access networks because IPv4 resources are scarce, solutions that require dual-stack (no IPv4 multiplexing) or stateless address sharing (bounded static address multiplexing) are simply not IPv4-efficient enough to solve the two-pronged challenge of increasing IPv4 address scarcity and continued exponential network edge growth for network operators.

2. No new protocols required, quick deployment

   464XLAT can be deployed today, it uses existing RFCs ([RFC6145] and [RFC6146]), and there exists implementations for both wireline networks (CLAT in the home router) and wireless 3GPP networks (CLAT in the UE). The ability to quickly deploy 464XLAT is a critical feature given the urgency of IPv4 exhaustion and

brisk pace of internet growth.

3. Cost-effective transition to IPv6

   When combined with DNS64 [RFC6147], the 464XLAT architecture only requires double translation in the case of IPv4-referrals or IPv4-only socket calls. Consequently, the network traffic in the ISP backbone network is predominately IPv6 end-to-end or single translation. This is especially cost-effective in wireless 3GPP GSM and UMTS networks that would otherwise require two separate PDP connections to support IPv4 and IPv6.

   While translation on the CLAT is not always used, the CLAT function is crucial for enabling the IPv4-only applications. All IPv6-native flows pass end-to-end without any translation. This is a beneficial solution for end-users, content providers, and network operators that scale best with end-to-end IPv6 communication.

In summary, the 464XLAT architecture works today for service providers that require large-scale strategic IPv6 deployments to overcome the challenges of IPv4 address scarcity. Since 464XLAT is stateful, there is no tight coupling or IPv4 address coordination between the PLAT and the CLAT. Unlike other transition architectures associated with tunneling or [I-D.mdt-softwire-mapping-address-and-port], 464XLAT assumes that IPv4 is scarce and IPv6 must work with today's existing systems as much as possible. In the case of tunneling, the tunneling solutions like Dual-Stack Lite [RFC6333] are known to break existing network based deep packet inspection solutions like 3GPP standardized Policy and Charging Control (PCC). 464XLAT does not require much IPv4 address space to enable the stateful translation [RFC6146] function in the PLAT while providing global IPv4 and IPv6 reachability to IPv6-only wireline and wireless subscribers.

5. Network Architecture

464XLAT architecture is shown in the following figure.

5.1. Wireline Network Architecture

```
                                  ----
                                 | v6 |
                                  ----
                                    |
    ----      |                 .---+---.                    .------.
   | v6 |-----+                /         \                  /        \
    ----      |    ------     /   IPv6    \     ------     /   IPv4   \
              +---| CLAT |---+  Internet   +---| PLAT |---+  Internet  |
    -------   |    ------     \           /     ------     \           /
   |v4p/v6 |--+                `---------'                  `----+----'
    -------   |                                                  |
    -----     |                                                -----
   | v4p |----+                                               | v4g |
    -----     |                                                -----

          <- v4p -> XLAT <--------- v6 --------> XLAT <- v4g ->


     v6  : Global IPv6
     v4p : Private IPv4
     v4g : Global IPv4
```

                    Figure 1: Wireline Network Topology

5.2. Wireless 3GPP Network Architecture

```
                                   ----
                                  | v6 |
                                   ----
                                     |
                                 .---+---.
                                /         \
                               /   IPv6    \
                              |   Internet  |
                               \           /
    UE / Mobile Phone           `---------'
   +----------------------+          |
   |  ----     |          |      .---+---.                   .------.
   | | v6 |----+          |     /         \                 /        \
   |  ----     |    ------|    / IPv6 PDP  \     ------    /   IPv4   \
   |           +---| CLAT |---+ Mobile Core +---| PLAT |--+  Internet  |
   |           |    ------|    \    GGSN   /     ------    \          /
   |           |          |     \         '                 `----+---'
   |  ------   |          |      `-------'                       |
   | | v4p |---+          |                                    -----
   |  ------   |          |                                   | v4g |
   +----------------------+                                    -----

           <- v4p -> XLAT <--------- v6 --------> XLAT <- v4g ->


     v6  : Global IPv6
     v4p : Private IPv4
     v4g : Global IPv4
```

Figure 2: Wireless 3GPP Network Topology

6. Applicability

6.1. Wireline Network Applicability

When an ISP has IPv6 access network infrastructure and 464XLAT, the ISP can provide IPv4 service to end users across an IPv6 access network. The result is that edge network growth is no longer tightly coupled to the availability of scarce IPv4 addresses.

If the IXP or another provider operates the PLAT, the ISP is only required to deploy an IPv6 access network. All ISPs do not need IPv4 access networks. They can migrate their access network to a simple and highly scalable IPv6-only environment. Incidentally, Japan

Internet Exchange(JPIX) is providing 464XLAT trial service since July 2010. In addition to this, the effectiveness of 464XLAT was confirmed in the WIDE camp Spring 2012. The result is described in [I-D.hazeyama-widecamp-ipv6-only-experience].

6.2. Wireless 3GPP Network Applicability

The vast majority of mobile wireless networks are compliant to Pre-Release 9 3GPP standards. In Pre-Release 9 3GPP networks, GSM and UMTS networks must signal and support both IPv4 and IPv6 PDP attachments to access IPv4 and IPv6 network destinations. Since there are 2 PDPs required to support 2 address families, this is double the number of PDPs required to support the status quo of 1 address family, which is IPv4. Doubling the PDP count to support IPv4 and IPv6 is generally not operationally viable since a large portion of the network cost is derived from the number of PDP attachments, both in terms of licenses from the network hardware vendors and in terms of actual hardware resources required to support and maintain the PDP signaling and mobility events. Doubling the number of PDP attachments has been one of the major barriers to introducing IPv6 in mobile networks. Dual-stack IPv4 and IPv6 simply costs more from the network provider perspective and does not result in any new revenues. In 3GPP Release 9 and forward, 2 PDPs are no longer required but the scarcity of IPv4 addresses remain.

Now that both global and private IPv4 addresses are scarce to the extent that it is a substantial business risk and limiting growth in many areas, the mobile network providers must support IPv6 to solve the IP address scarcity issue. It is not feasible to simply turn on additional IPv6 PDP network attachments since that does not solve the near-term IPv4 scarcity issues and it increases cost in most cases. The most logical path forward is to replace IPv4 with IPv6 and replace the common NAT44 with stateful translation [RFC6146] and DNS64 [RFC6147]. Extensive live network testing with hundreds of friendly-users has shown that IPv6-only network attachments for mobile devices supports over 85% of the common applications on the Android mobile operating systems. The remaining 15% of applications do not work because the application requires an IPv4 socket or the application does an IPv4-referral. These findings are consistent with the mobile IPv6-only user experience in [I-D.arkko-ipv6-only-experience].

464XLAT in combination with stateful translation [RFC6146] and DNS64 [RFC6147] allows 85% of the Android applications to continue to work with single translation or native IPv6 access. For the remaining 15% of applications that require IPv4 connectivity, the CLAT function on the UE provides a private IPv4 address and IPv4 default-route on the host for the applications to reference and bind to. Connections

sourced from the IPv4 interface are immediately routed to the CLAT function and passed to the IPv6-only mobile network, destine to the PLAT. In summary, the UE has the CLAT function that does a stateless translation [RFC6145], but only when required. The mobile network has a PLAT that does stateful translation [RFC6146].

7. Implementation Considerations

7.1. IPv6 Address Format

IPv6 address format in 464XLAT is defined in Section 2.2 of [RFC6052].

7.2. IPv4/IPv6 Address Translation Chart

IPv4/IPv6 address translation chart is shown in the following figure.

```
                                      Source IPv4 address
                                     +--------------------------+
                                     | Global IPv4 address      |
                                     | assigned to IPv4 pool@PLAT |
                          +--------+ +--------------------------+
                          |  IPv4  |  Destination IPv4 address
                          | server | +--------------------------+
                          +--------+ | Global IPv4 address      |
                              ^      | assigned to IPv4 server  |
                              |      +--------------------------+
                          +--------+
                          |  PLAT  | Stateful XLATE(IPv4:IPv6=1:n)
                          +--------+
                              ^
                              |
        Source IPv6 address   (IPv6 cloud)
        +---------------------------------------------------------------+
        | IPv4-Embedded IPv6 address                                    |
        | defined in Section 2.2 of RFC6052                             |
        +---------------------------------------------------------------+
         Destination IPv6 address
        +---------------------------------------------------------------+
        | IPv4-Embedded IPv6 address                                    |
        | defined in Section 2.2 of RFC6052                             |
        +---------------------------------------------------------------+
                              (IPv6 cloud)
                              ^
                              |
                              |
```

```
              |
          +--------+
          |        | Case 1: CLAT will have a
          |        | dedicated IPv6 prefix
          |        |   -> Stateless XLATE
          |        |      (IPv4:IPv6=1:1)
          |  CLAT  |
          |        | Case 2: CLAT will not have a
          |        | dedicated IPv6 prefix
          |        |   -> NAT44 -> Stateless XLATE
          |        |               (IPv4:IPv6=1:1)
          +--------+
              ^       Source IPv4 address
              |      +-----------------------------+
          +--------+ | Private IPv4 address        |
          |  IPv4  | | assigned to IPv4 client     |
          | client | +-----------------------------+
          +--------+  Destination IPv4 address
                     +-----------------------------+
                     | Global IPv4 address         |
                     | assigned to IPv4 server     |
                     +-----------------------------+
```

IPv4/IPv6 Address Translation Chart

7.3. Traffic Treatment Scenarios

Server	Application and Host	Traffic Treatment	Location of Translation
IPv6	IPv6	End-to-end IPv6	None
IPv4	IPv6	Stateful Translation	PLAT
IPv4	IPv4	464XLAT	PLAT/CLAT
IPv6	IPv4	Stateless Translation	CLAT

Traffic Treatment Scenarios

The above chart shows most common traffic types and traffic treatment.

7.4. DNS Proxy Implementation

The CLAT SHOULD implement a DNS proxy as defined in [RFC5625]. The case of an IPv4-only node behind CLAT querying an IPv4 DNS server is undesirable since it requires both stateful and stateless translation for each DNS lookup. The CLAT SHOULD set itself as the DNS server via DHCP or other means and proxy DNS queries for IPv4 and IPv6 clients. Using the CLAT enabled home router or UE as a DNS proxy is a normal consume gateway function and simplifies the traffic flow so that only IPv6 native queries are made across the access network. The CLAT SHOULD allow for a client to query any DNS server of its choice and bypass the proxy.

7.5. IPv6 Prefix Handling

There are two approaches. In one of the cases, the CLAT will have a dedicated /64 via DHCPv6 prefix delegation [RFC3633] or other means to source and receive IPv6 packets associated with the [RFC6145] stateless translation of IPv4 packets to the local clients. If the CLAT choose one /64 prefix for translation from delegated prefix, then it SHOULD NOT be used for anything else.

In another cases where the access network does not allow for a dedicated translation prefix, the CLAT will do NAT44 such that all private IPv4 sourced LAN packets appears from one private IPv4 address which is statelessly translated to one IPv6 address.

The CLAT MAY discover the Pref64::/n of the PLAT via some method such as DHCPv6 option, TR-069, DNS APL RR [RFC3123] or [I-D.ietf-behave-nat64-discovery-heuristic].

7.6. CLAT in a Gateway

The CLAT is a stateless translation feature which can be implemented in a common home router or mobile phone that has a mobile router feature. The router with CLAT function SHOULD provide common router services such as DHCP of [RFC1918] addresses, DHCPv6, and DNS service. The router SHOULD set itself as the DNS server advertised via DHCP or other means to the clients so that it may implement the DNS proxy function to avoid double translation of DNS request.

7.7. CLAT to CLAT communications

While CLAT to CLAT IPv4 communication may work when the client IPv4 subnets do not overlap, this traffic flow is out of scope. 464XLAT is a hub and spoke architecture focused on enabling IPv4-only services over IPv6-only access networks.

8. Deployment Considerations

Even if the Internet access provider for consumers is different from the PLAT provider (another Internet access provider or Internet exchange provider, etc.), it can implement traffic engineering independently from the PLAT provider. Detailed reasons are below:

1. The Internet access provider for consumers can figure out IPv4 source address and IPv4 destination address from translated IPv6 packet header, so it can implement traffic engineering based on IPv4 source address and IPv4 destination address (e.g. traffic monitoring for each IPv4 destination address, packet filtering for each IPv4 destination address, etc.). The tunneling methods do not have such a advantage, without any deep packet inspection for processing the inner IPv4 packet of the tunnel packet.

2. If the Internet access provider for consumers can assign IPv6 prefix greater than /64 for each subscriber, this 464XLAT architecture can separate IPv6 prefix for native IPv6 packets and XLAT prefix for IPv4/IPv6 translation packets. Accordingly, it can identify the type of packets ("native IPv6 packets" and "IPv4/IPv6 translation packets"), and implement traffic engineering based on IPv6 prefix.

This 464XLAT architecture has two capabilities. One is a IPv4 -> IPv6 -> IPv4 translation for sharing global IPv4 addresses, another is a IPv4 -> IPv6 translation for reaching IPv6-only servers from IPv4-only clients that can not support IPv6. IPv4-only clients must be support through the long period of global transition to IPv6.

9. Security Considerations

To implement a PLAT, see security considerations presented in Section 5 of [RFC6146].

To implement a CLAT, see security considerations presented in Section 7 of [RFC6145]. The CLAT MAY comply with [RFC6092].

10. IANA Considerations

This document has no actions for IANA.

11. Acknowledgements

The authors would like to thank JPIX NOC members, JPIX 464XLAT trial

service members, Seiichi Kawamura, Dan Drown, Brian Carpenter, Rajiv Asati, Washam Fan, Behcet Sarikaya, Jan Zorz, Remi Despres, Tatsuya Oishi, Lorenzo Colitti, Erik Kline, and Ole Troan for their helpful comments. We also would like to thank Fred Baker and Joel Jaeggli for their support.

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Authors' Addresses

Masataka Mawatari
Japan Internet Exchange Co.,Ltd.
KDDI Otemachi Building 19F, 1-8-1 Otemachi,
Chiyoda-ku, Tokyo 100-0004
JAPAN

Phone: +81 3 3243 9579
Email: mawatari@jpix.ad.jp

Masanobu Kawashima
NEC AccessTechnica, Ltd.
800, Shimomata
Kakegawa-shi, Shizuoka 436-8501
JAPAN

Phone: +81 537 23 9655
Email: kawashimam@vx.jp.nec.com

Cameron Byrne
T-Mobile USA
Bellevue, Washington 98006
USA

Email: cameron.byrne@t-mobile.com