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IPv4-IPv6 Coexistence Scenarios based on Stateless Address Mapping
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Status of this Memo

Abstract

As each global IPv4 address will be shared among more and more customers, and as more and more NATs will be deployed in ISP infrastructures, the lack of end-to-end transparency and the limited scalability of some NATs are likely to cause increasing difficulties to customers and to ISPs. This document introduces IPv4-IPv6 coexistence scenarios where IPv4 addresses are shared with good scalability and, in favorable configurations, with full IPv4 end-to-end transparency. For this, the key tool is the Stateless Address Mapping (SAM) of draft-despres-SAM-00, with in particular its extended IPv4 addressing (IPv4E) in which port prefixes are used as IPv4 address extensions. For each considered scenario, Static Address Mappers (SAMs) are deployed at scenario specific places.

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1. Introduction

As each global IPv4 address will be shared among more and more customers, and as more and more NATs will be deployed in ISP infrastructures, the lack of end-to-end transparency and the limited scalability of such NATs are likely to cause increasing difficulties to customers and to ISPs.

This document introduces IPv4-IPv6 coexistence scenarios where IPv4 addresses are shared with good ISP infrastructure scalability and, in favorable configurations, with full IPv4 end-to-end transparency.

For this, the key tool is the Stateless Address Mapping (SAM) of draft-despres-SAM-00, with in particular its extended IPv4 addressing (IPv4E) in which port prefixes are used as IPv4 address extensions.

Section 3 describes four IPv4-IPv6 inter-working scenarios. For each one, it indicates which ISP functions are stateless, ensuring the good scalability, and where available port ranges are restricted.

Section 4 describes three ISP infrastructure configurations which are compatible with scenarios of Section 3, and which, for backward compatibility with non SAM solutions, are also compatible with many other scenarios. These configurations differ in that ISP routing is only private IPv4, is only IPv6, or is both private IPv4 and IPv6.

Section 5 describes a CPE internal architecture which is compatible with scenarios of Section 3 and, for backward compatible with non SAM solutions, which is is also compatible with many other scenarios.

Section 6 describes a host internal architecture which is compatible with all scenarios of Section 3, and which, for backward compatibility with non SAM solutions, is also compatible with many other scenarios.

2. Acronyms

PACKET TYPES

```
4     : global IPv4
4P    : ISP private IPv4
4S    : customer-site private IPv4
6     : global IPv6
a/b   : IPva encapsulated in IPvb
v     : address family 4 or 6
```

NEWORK COMPONENTS

```
CPE         : customer premise equipment
SAM CPE     : a router CPE which supports SAM at its site and/or ISP
              interfaces
SAM ISP GW : an ISP gateway to the global Internet which supports SAM
CGN44       : a NAT of an ISP, from 4P to 4, at its border to the global
              Internet
CGN4/64     : a NAT of an ISP, from 4S/6 to 4, at its border to the
              global Internet
PE            : ISP edge nodes, facing customer sites
```

PREFIXES AND ADDRESSES

```
Gv    : anycast address, in the ISP infrastructure, of gateways
        to the global Internet
```

```
Hv   : Header of all v addresses in the considered ISP infrastructure
Nv   : v unicast address of a CGN of the ISP
P6   : IPv6 prefix, in the global Internet, of SAMs of the ISP
P4a  : IPv4 prefix, in the global Internet, of SAMs of the ISP
P4b  : IPv4 prefix of ISP NAT  in the global Internet
Svi  : v prefix of customer site i in the ISP infrastructure
```


3. Examples of SAM based scenarios

Considered scenarios are presented in of Figure 1 and Figure 2. They all concern communication between host that cannot have global IPv4 address of their own, and remote hosts addresses of which are global IPv4, each end being able to initiate connections. None of the scenario involves a CGN. In scenarios A to C, sites themselves have no global IPv4 addresses. Scenarios B to D provide IPv4 packet transparency between considered hosts and the global Internet, so that this transparency is end-to-end if remote hosts have the same property.

```
     SCENARIO A                                  +--------+   Global
     +------+          +---------+               |  SAM    |  Internet
     | host |--site 4S--| SAM CPE |-- ISP 4P ----| ISP GW |<--- 4 --->
     +------+          +---------+    or 6       +--------+

            <--- 4S ----> NAT+SAM <-- 4/4P or 4/6 --> SAM <----- 4 --->
                            :                         :
```

```
     Port restricted NAT ---'                         '--- Stateless GW


     SCENARIO B
     +-------+                                    +---------+   Global
     | SAM   |                                    |  SAM    |  Internet
     | host  |------------------------ ISP 4P ----| ISP GW  |<--- 4 --->
     +-------+                          or 6      +---------+

        SAM <------------------------ 4/4P or 4/6 --> SAM <----- 4 --->
          :                                           :
          '- Port restricted                          '--- Stateless GW
             socket interface
        <--------------- transparency to global v4 packets ------------>

                             SCENARIOS A AND B

                                  Figure 1
```



```
    SCENARIO C
    +-------+                                    +---------+   Global
    | SAM   |            +----------+            |  SAM    |  Internet
    | host  |--site 4S--| SAM CPE |-- ISP 4P ----| ISP GW  |<--- 4 --->
    +-------+    or 6   +----------+    or 6      +---------+

      SAM <-4/4S or 4/6->SAM1 SAM2<-- 4/4P or 4/6 --> SAM <----- 4 --->
        :                    :                      :
        '- Port restricted   '- Stateless CPE       '--- Stateless GW
          socket interface
       <--------------- transparency to global v4 packets ------------>


    SCENARIO D
    +-------+                                          Peering    Global
```

```
| SAM   |              +----------+                    point    Internet
| host |--site 4S--| SAM CPE |------ ISP 4-------O--------- 4 --->
+-------+     or 6   +----------+

  SAM <--- 4/4S ---> SAM <------------------- 4 ----------------->
     :
     '- Port restricted
       socket interface
   <-------------- transparency to global v4 packets ------------>
```

SCENARIOS C AND D

Figure 2

4. Examples of SAM ISP configurations

In Figures of the following subsections, routing prefixes xx are shown with simple arrows xx --> style.

Types of packets that may arrive on these routes are shown above double arrows made of equal signs.

Packet types and parameters are as defined in Section 2.

Understanding which services are offered to customer sites in each of these configurations doesn't necessitate to know details of how SAMs make their address mappings and encapsulations-decapsulations. These details are available in [draft-despres-SAM-00].

4.1. ISP infrastructure with private IPv4 internal routing

If an ISP, to deploy customer sites without global IPv4 addresses, uses only a private IPv4 address space for its internal routing, it needs a CGN44 between its infrastructure and the global Internet.

It can, in addition, support SAMs at its border with IPv4 and IPv6 global Internets [Figure 3]. Doing it adds global IPv4E connectivity and IPv6 connectivity to customer sites where CPEs are SAM capable (router or hosts).

```
                     +-------------------------------+
                     |                               |
                     |                               |
          SAM CPE    |                    6/4P       |     6
           DHCP      |                    4/4P   +---+     4
              |      |                  <=======>|SAM|<=======>
         parameters  |                   G4 ---> +---+   <--- P4a
          B4i,H4,C4  |                               |   <--- P6
              |      |                               |
              |      |   ( PRIVATE IPv4 ROUTING )    |
              V      |                               |
                     |                               |
               6/4P  |       6/4P                    |
               4/4P  |       4/4P                    |
               4P    |       4P                      |
            <=======>O<===========>                  |
          customer   |   <--- S4i                    |
           site i    |                               |
                     |                               |
                     |                      4P   +-----+  4
                     |                  <=======>|CGN44|<=====>
                     |            0.0.0.0/0 ---> +-----+ <--- P4b
                     |                               |
                     +-------------------------------+

        Length of CPE port prefixes:  p = l(T4a) - l(H4)
                           Example: p = 12 - 8 = 4

        EXAMPLE OF ISP CONFIGURATION WITH ONLY PRIVATE IPV4 ROUTING
```

Figure 3

4.2. ISP infrastructure with private IPv4 and IPv6 internal routings

If an ISP, to deploy customer sites without global IPv4 addresses, uses both a private IPv4 and the IPv6 address spaces for its internal routing, it provides IPv6 connectivity to its customer sites, and can operate a CGN44 between its infrastructure and the global Internet for its IPv4 only CPEs.

It can, in addition, support SAMs at its border with IPv4 global Internet [Figure 4]. Doing it adds global IPv4E connectivity to CPEs that are SAM capable (router or hosts). .

```
                   +-------------------------------+
                   |                               |
                   |                    4/4P   +---+     4
                   |                  <=======>|SAM|<=======>
        SAM CPE    |                  G4 --->  +---+   <--- P4a
         DHCP      |                  G6 --->      |
       parameters  |                               |
        B4i,H4,C4  |                        6      |     6
        B6i,H6,C6  |                  <===========>O<=======>
            |      |                  0::/0 --->   |   <--- P6
            |      |                               |
            V      |     ( IPv6 & PRIVATE IPV4     |
                   |            ROUTINGS )         |
             6     |    6                          |
             4P    |    4P                         |
             4/4P  |    4/4P                       |
          <=======>O<===========>                  |
        customer   |  <--- S4i                     |
         site i    |  <--- S6i                     |
                   |                               |
                   |                     4P    +-----+   4
                   |                  <=======>|CGN44|<=====>
                   |           0.0.0.0/0 --->  +-----+ <--- P4b
                   |                               |
                   +-------------------------------+
```

4P : private IPv4 of the Provider

Length of CPE port prefixes: idem IPv4 Routing alone

EXAMPLE OF ISP CONFIGURATION WITH IPV6 AND PRIVATE IPV4 ROUTINGS

Figure 4

4.3. ISP infrastructure with only IPv6 internal routing

If an ISP, to deploy customer sites without global IPv4 addresses, uses only the IPv6 address space for its internal routing, it cannot support IPv4 only customers with a CGN44.

If it support SAMs and a CGN4/64 at its border with IPv4 global Internet, and if it also supports SAMs in its PEs, it adds global IPv4E connectivity to CPEs that are SAM capable (router or hosts), and adds IPv4 connectivity via a NAT to IPv4-only CPEs.

```
                    +--------------------------------+
                    |                                |
                    |                    4/6    +---+     4
                    |                  <=======>|SAM|<=======>
                    |                  G6 --->  +---+    <--- P4a
                    |                                |
         SAM CPE    |                    6           |     6
          DHCP      |                  <===========>o<=======>
        parameters  |                  0::/0 --->    |    <--- P6
       B6i,H6,C6,N6 |                                |
            |       |         ( IPv6 ROUTING )       |
            V       |                                |
                    |       6                        |
            6       |       4S/6                     |
            4P or 4S|       4P/6                     |
            4/6     +---+   4/6                      |
           <=======>|SAM|<=======>                   |
         customer   +---+ <--- S6i                   |
          site i    |                                |
                    |                     4S/6       |
                    |                     4P/6  +--------+     4
                    |                  <=======>|CGN4/64|<====>
                    |                  N6 --->  +--------+ <-- P4b
                    |                                |
                    +--------------------------------+
```

```
       4P   : private IPv4 of the Provider
       4S   : private IPv4 of the customer Site

       Length of CPE port prefixes:  p = l(B6i) - l(H6) - (32 - T4a)
                                Example: p = 60 - 36 - (32 - 12) = 4
```

EXAMPLE OF ISP CONFIGURATION WITH ONLY IPV6 ROUTING

Figure 5

5. SAM CPE internal architecture

Router CPEs can exist in many variants because of the variety of packet types that ISP can support at their customer site interfaces, because of the variety of routing families that customers may desire to support in their sites, and because some ISPs that supply CPEs to their customers may prefer to have NATs in their infrastructures rather than in CPEs (the DS lite approach).

The generic internal architecture which is proposed in Figure 6 is intended to cover all useful cases. Its operation in each particular case is governed by: (1) the presence or absence of a NAT in the CPE; (2) SAM parameters which determine which packet types are supported at ISP interfaces; (3) which packet types have to be routed in customer sites (4S, 6, or both 4S and 6).

Figure 6 details processing paths that each packet follows depending on: (1) which side it comes from; (2) what was its type when received; (3) what is the transmit type that is compatible with the receipt one, among those that are available at the forwarding interface (depending on configured SAM parameters).

CPE parameters should be configurable both manually, and automatically using IPv4 DHCP and/or DHCPv6.

SAM CPEs should also be able to provide in DHCP all SAM parameters that may be needed by SAM hosts.

```
         Possible packet types            Possible ISP supported
         in the customer site                      packet types
          |                                                  |
          |                                           4P     |
          |            +-+     ->4                    4b     |
          |            | |   .---------------------------.   V
          V     4P     |N|   |                           |
         6/4P  .-------|A|---:                           |  6/4P
         6/4S  |       |T|   | ->4/6                     |  6/4
         4/4P  |       | |   | ->4P       4a             |  4S/4P
         4/4S  |       +-+   '---------------.           |  4P
         4P    |                             |           |  4/4P
         4S    |4S                        4S |           |  4
         <---->:-----------------------------:      6/4P :<---->
               |      +-+                    |  +-+ 6/4  |
               |6/4S  | |                    |  | | 4/4P |
               |4/4S  | |                 4b |  | | 4    |
               '------|S|--------------------'--|S|------'
                      |A|                       |A|
                4S/6  |M|   ->6/4P              |M|
                4/6   | |   ->6/4      <-6/4S   | | 4/6
               .------| |--.-----------------.--| |------.
               |      +-+  |                 |  +-+      |
               |           | ->6         6<- |           |
         4S/6  |           '------.   .------'           |  6
         4/6   |                  |   |                  |  4S/6
         6     |                  :   :                  |  4/6
         <---->:  6->6/4P          \ /                   :<---->
               |  6->6/4           / \              4S/6 |
               :------------------'   '-------------------:
               |                                         |
               |  6->6                                 6 |
```

```
               '-----------------------------------------'

         ->x : processing path to be taken if SAM parameters show
               that type x is possible at the forwarding interface

                  A FLEXIBLE USE SAM CPE ARCHITECTURE

                                 Figure 6
```


6. SAM host internal architecture

Figure 7 presents a generic SAM host architecture. With it, a host can work in non SAM environments as well as in SAM environments, thus preserving the backward compatibility that is necessary for incremental deployment.

```
              Socket
           programming
            interface
                :      .-- Restricted ports if ->4/4P or ->4/6
                :      |   Local address = 10.0.0.0.1 if -> 4H/6
                :      |
                :      |
                :    +--+       ->4P                4P        6/4P
                :    |v4|       ->4                 4         6/4
                :    |  |     .-------------------------.   4P
                :    |S |     |                         |   4/4P
                :    |o |     |                         |   4
          IPv4 <---->|c |-----:                         :<------>
                :    |k |     | ->4H/6            6/4P |
                :    |e |     | ->4/6   +---+     6/4  |
                :    |t |     | ->4/4P  |   |     4/4P |
```

```
                :    |s |     '---------|   |-----------'
                :    +--+               | S |
                :          ->6/4        | A |
                :    +--+  ->6/4P       | M |
                :    |v6|     .---------|   |-----------.
                :    |  |     |         |   |           |    4H/6
                :    |S |     |        +---+            |    4/6
                :    |o |     |                         |    6
          IPv6 <---->|c |-----:                         :<------>
                :    |k |     |                         |
                :    |e |     | ->6                     |
                :    |t |     '-------------------------'
                :    |s |
                :    +--+
                  INTERNAL ARCHITECTURE OF A SAM-CAPABLE CPE
```

Figure 7

The logic is expected to be straightforward enough for operating systems of mobile phones and PCs to have it included it in not too distant a future, in any case well before the end of the coexistence period.

A host that has SAM compatibility has the benefit that it can support server applications that are reachable by IPv4-only hosts, even when this PC gets doesn't get a a global IPv4 address of its own. This remains true if it is behind a SAM CPE that has only a port restricted IPv4 address. Another expected benefit is that, with restoration of end-to-end transparency to IPv4 packets, protocols that need it or work better with it (e.g. SCTP) can work not only in IPv6 with unrestricted ports, but also in IPv4 with restricted ports.

Concerning the effect of restricted port ranges, it should be noted that reserving a local port for each outgoing connection, as apparently most socket modules do, leaves plenty of room for optimization: if a local socket used for a given connection identified by its 5-tuple [source and destination addresses & ports and protocol], it can be reused for different 5-tuples. Thus, the number of ports needed by each host can be drastically reduced. Whether this optimization has no risk to interfere with existing NAT traversal techniques like ICE has however to be checked.

7. Security considerations

8. IANA Considerations

9. Acknowledgements

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One important and recent progress of the approach has been the recognition that, with the flexibility of DHCP, no new protocol would be necessary to automate SAM parameter settings. Acknowledgment is due to Gabor Bajko and Teemu Savolainen for pointing it out at IETF 72.

10. Informative References

[draft-despres-SAM-00]

"Stateless Address Mapping (SAM) - Work in progress", September 2008.

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