Internet Engineering Task Force   R. Despres
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IPv4-IPv6 Coexistence Scenarios based on Stateless Address Mapping
draft-despres-sam-scenarios-00

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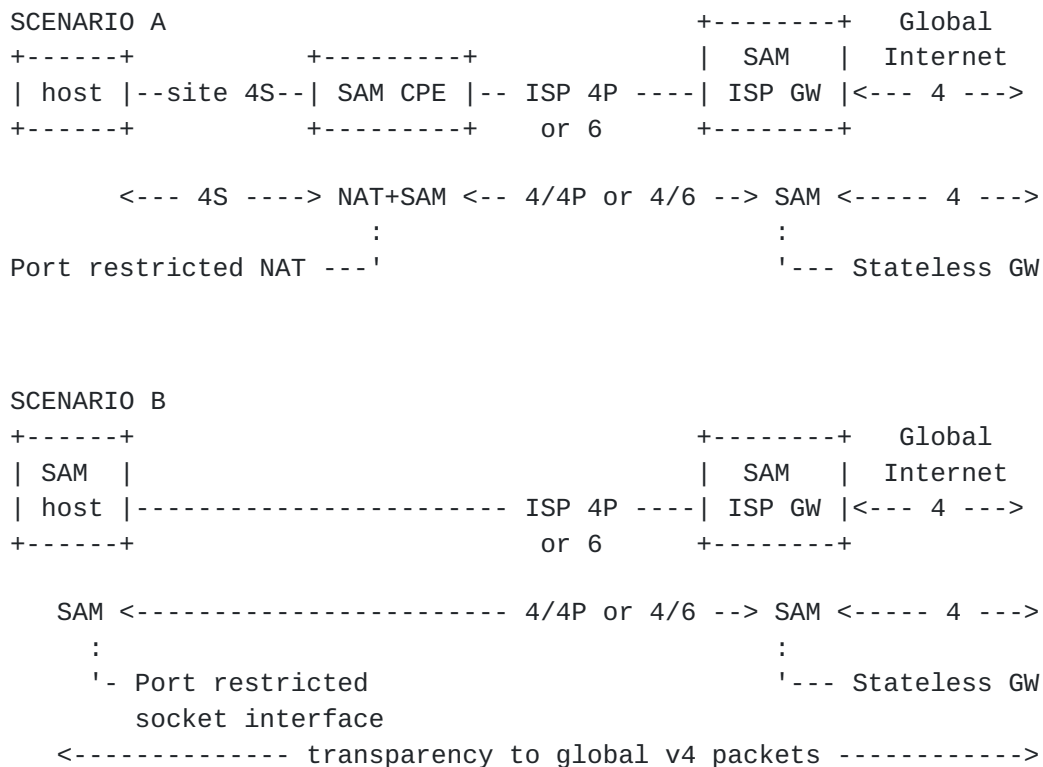
```
    SCENARIO A                                  +--------+   Global
    +------+             +---------+            |  SAM   |  Internet
    | host |--site 4S--| SAM CPE |-- ISP 4P ----| ISP GW |<--- 4 --->
    +------+             +---------+    or 6      +--------+

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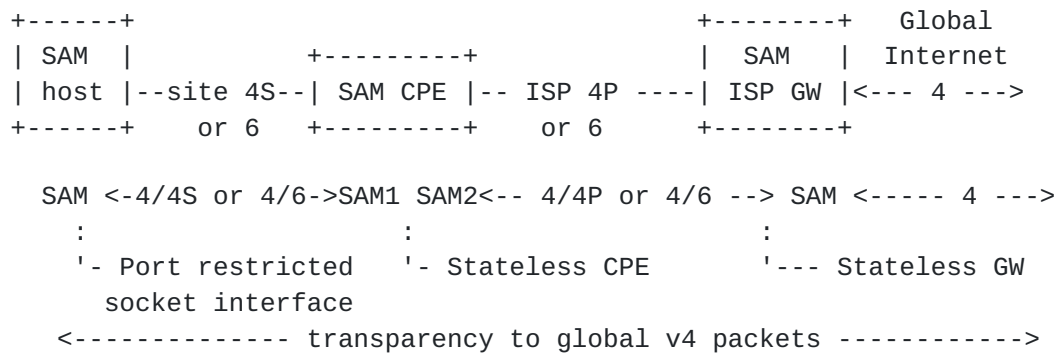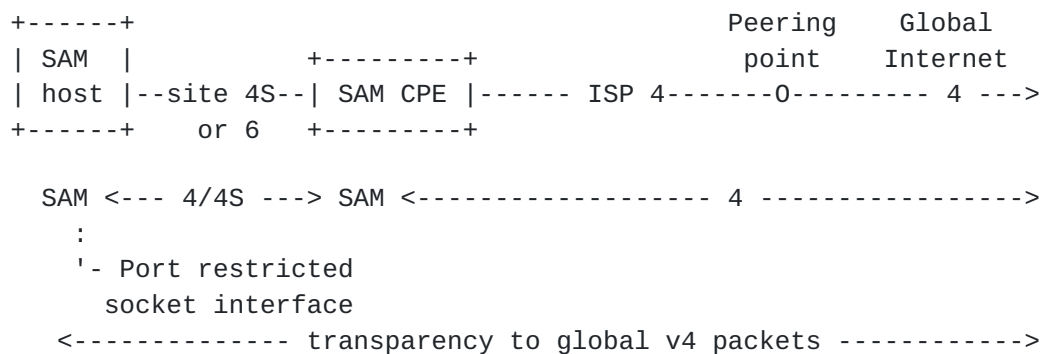
```
   SCENARIO C
   +------+                                    +--------+   Global
   | SAM  |             +---------+            |  SAM   |  Internet
   | host |--site 4S--| SAM CPE |-- ISP 4P ----| ISP GW |<--- 4 --->
   +------+    or 6   +---------+     or 6     +--------+

     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).
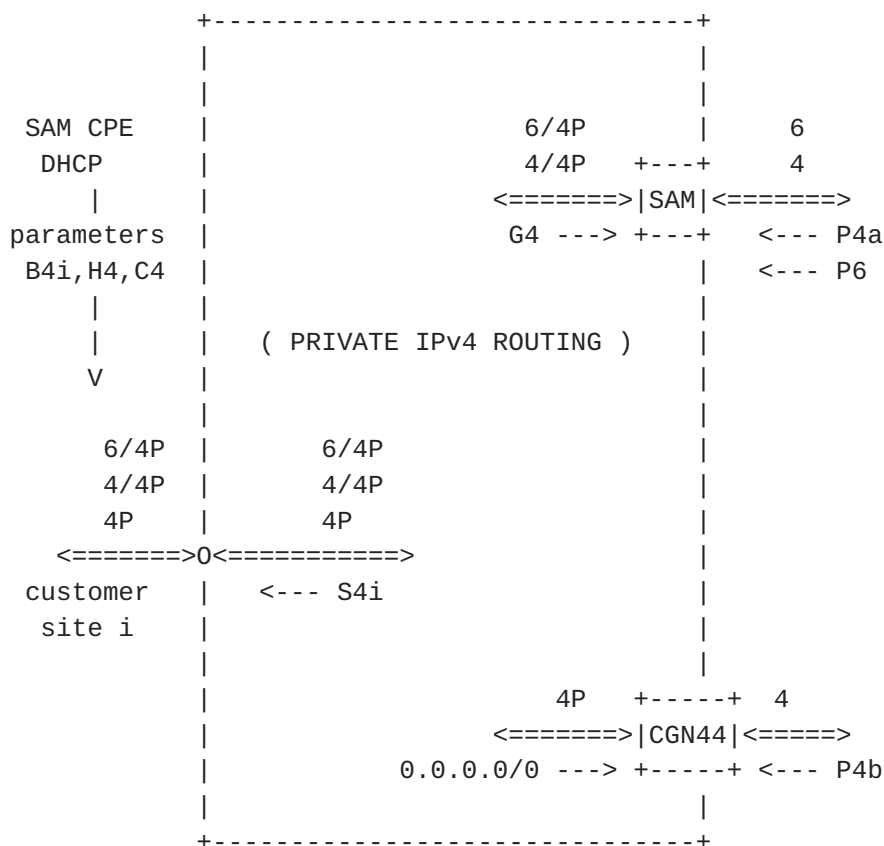
```
                  +-------------------------------+
                  |                               |
                  |                               |
     SAM CPE      |                    6/4P       |        6
       DHCP       |                    4/4P    +---+        4
        |         |               <=======>|SAM|<=======>
     parameters   |                    G4 ---> +---+   <--- P4a
     B4i,H4,C4    |                               |     <--- P6
        |         |                               |
        |         |    ( PRIVATE IPv4 ROUTING )   |
        V         |                               |
                  |                               |
      6/4P |          6/4P                        |
      4/4P |          4/4P                        |
       4P  |           4P                         |
     <=======>0<===========>                      |
     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

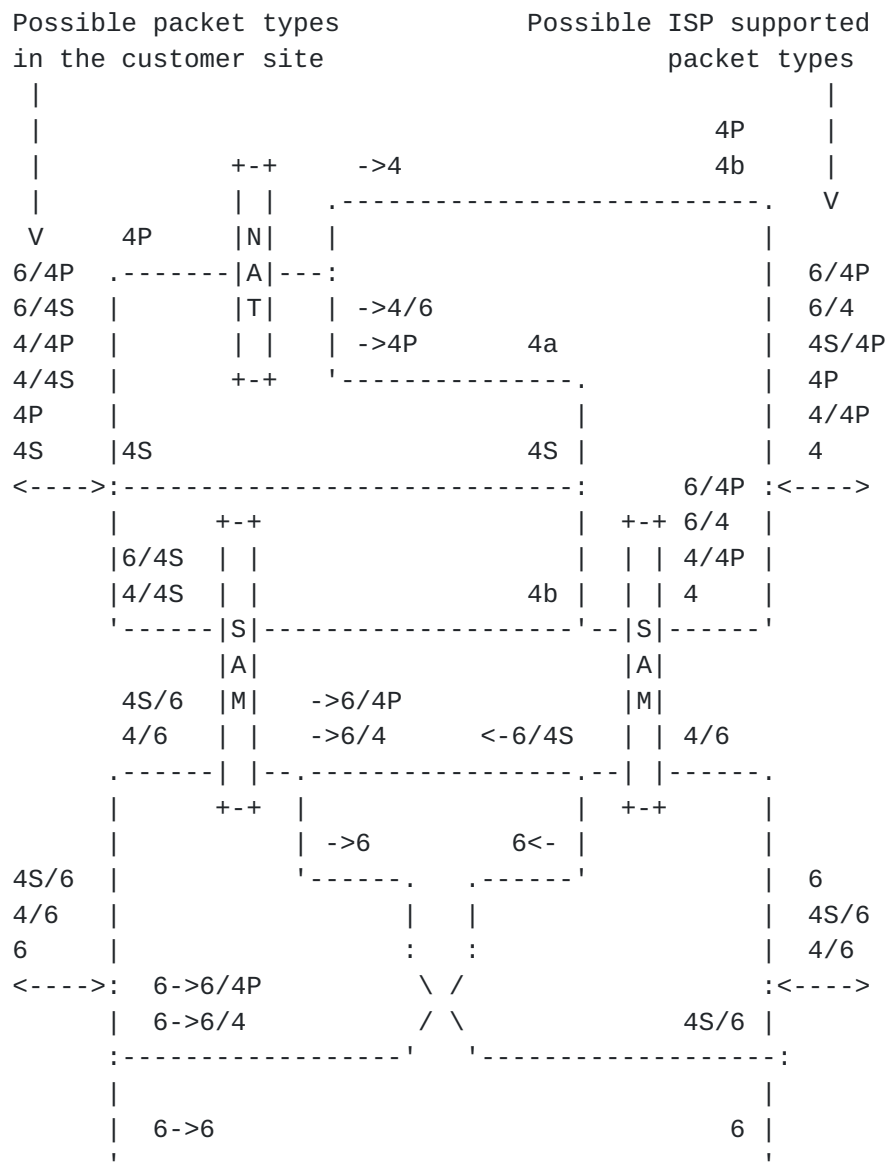5. **SAM CPE internal architecture**

   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
```
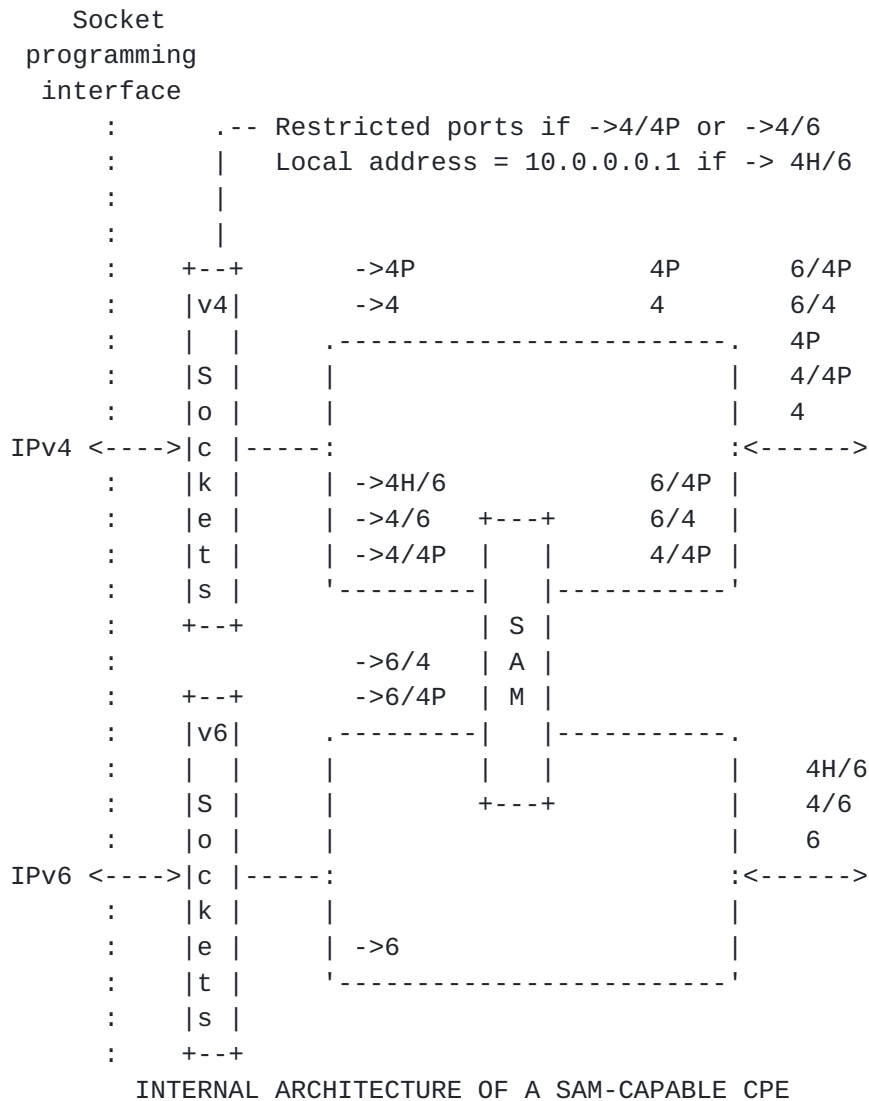
                             Figure 7

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

So far, the SAM approach has essentially been worked out by the
author, with various intermediate stages like the so called Address
Borrowing Protocol and the Global Address Protocol, respectively
presented in IETF 71 and IETF 72, without any sponsoring or company
contract and without seeking intellectual property protection. He
therefore wishes to expresses its first acknowledgment to his wife:
she accepted that traveling and other expenses be supported by the
uni-personal enterprise of the author, the money of which cannot be
distinguished from family money.

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.

Author's Address

    Remi Despres
    3 rue du President Wilson
    Levallois,
    France

    Email: remi.despres@free.fr