Issues with Private IP Addressing in the Internet
draft-ietf-grow-private-ip-sp-cores-05

Abstract

   The purpose of this document is to provide a discussion of the
   potential problems of using private, RFC1918, or non-globally-
   routable addressing within the core of an SP network. The discussion
   focuses on link addresses and to a small extent loopback addresses.
   While many of the issues are well recognised within the ISP
   community, there appears to be no document that collectively
   describes the issues.

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1. Introduction

   In the mid to late 90's, some Internet Service Providers (ISPs)
   adopted the practice of utilising private (or non-globally unique)
   [RFC1918] IP addresses for the infrastructure links and in some cases
   the loopback interfaces within their networks. The reasons for this
   approach centered on conservation of address space (i.e. scarcity of
   public IPv4 address space), and security of the core network (also
   known as core hiding).

   However, a number of technical and operational issues occurred as a
   result of using private (or non-globally unique) IP addresses, and
   virtually all these ISPs moved away from the practice. Tier 1 ISPs
   are considered the benchmark of the industry and as of the time of
   writing, there is no known tier 1 ISP that utilises the practice of
   private addressing within their core network.

   The following sections will discuss the various issues associated
   with deploying private [RFC1918] IP addresses within ISP core
   networks.

   The intent of this document is not to suggest that private IP can not
   be used with the core of an SP network as some providers use this
   practice and operate successfully. The intent is to outline the
   potential issues or effects of such a practice.

   Note: The practice of ISPs using 'stolen' address space (also known
   as 'squat' space) has many of the same, plus some additional issues
   (or effects) as that of using private IP address space within core
   networks. The term "stolen IP address space" refers to the practice
   of an ISP using address space for its own infrastructure/core network
   addressing that has been officially allocated by an RIR to another
   provider, but that provider is not currently using or advertising
   within the Internet. Stolen addressing is not discussed further in
   this document. It is simply noted as an associated issue.

2. Conservation of Address Space

   One of the original intents for the use of private IP addressing
   within an ISP core was the conservation of IP address space. When an
   ISP is allocated a block of public IP addresses (from a RIR), this
   address block was traditionally split in order to dedicate some
   portion for infrastructure use (i.e. for the core network), and the
   other portion for customer (subscriber) or other address pool use.
   Typically, the number of infrastructure addresses needed is
   relatively small in comparison to the total address count. So unless
   the ISP was only granted a small public block, dedicating some

   portion to infrastructure links and loopback addresses (/32) is
   rarely a large enough issue to outweigh the problems that are
   potentially caused when private address space is used.

   Additionally, specifications and equipment capability improvements
   now allow for the use of /31 subnets [RFC3021] for link addresses in
   place of the original /30 subnets - further minimising the impact of
   dedicating public addresses to infrastructure links by only using two
   (2) IP addresses per point to point link versus four (4)
   respectively.

   The use of private addressing as a conservation technique within an
   Internet Service Provider (ISP) core can cause a number of technical
   and operational issues or effects. The main effects are described
   below.

3. Effects on Traceroute

   The single biggest effect caused by the use of private [RFC1918]
   addressing within an Internet core is the fact that it can disrupt
   the operation of traceroute in some situations. This section
   provides some examples of the issues that can occur.

   A first example illustrates the situation where the traceroute
   crosses an AS boundary and one of the networks has utilised private
   addressing. The following simple network is used to show the
   effects.


```
              AS64496                      EBGP                 AS64497
                 IBGP Mesh <--------------->  IBGP Mesh

R1 Pool -                                                    R6 Pool -
203.0.113.0/26                                              203.0.113.64/26

                         198.51.100.8/30
                                     198.51.100.4/30
   10.1.1.0/30  10.1.1.4/30                                 198.51.100.0/30
                            .9           .10
    .1       .2  .5       .6   ------------   .6      .5  .2       .1
  R1----------R2----------R3--|         |--R4---------R5---------R6


  R1 Loopback: 10.1.1.101              R4 Loopback: 198.51.100.103
  R2 Loopback: 10.1.1.102              R5 Loopback: 198.51.100.102
  R3 Loopback: 10.1.1.103              R6 Loopback: 198.51.100.101
```
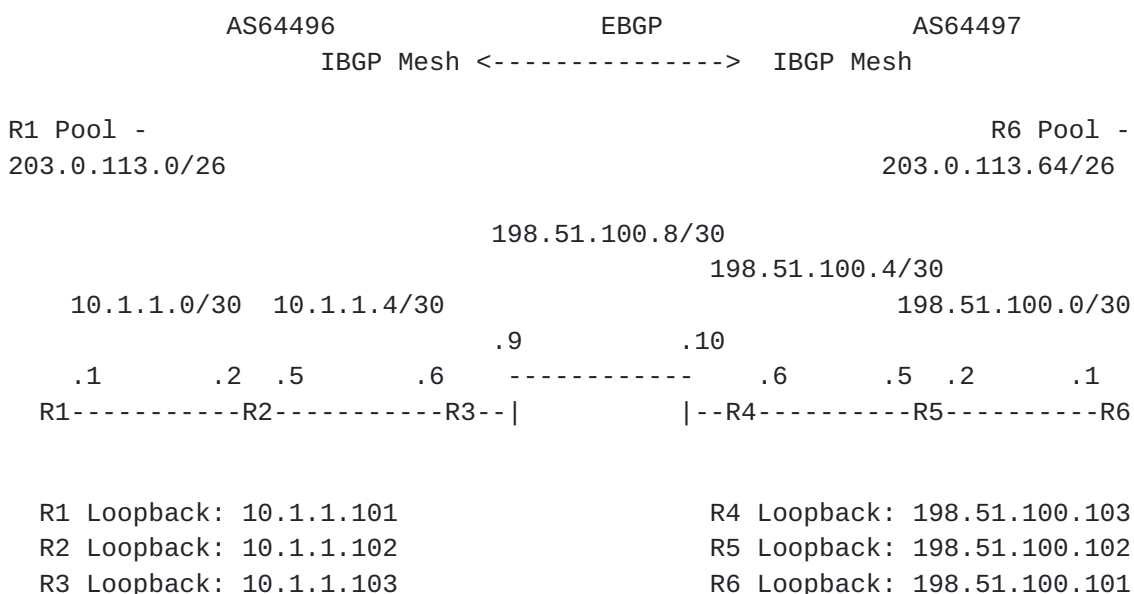
Using this example, performing the traceroute from AS64497 to
AS64496, we can see the private addresses of the infrastructure links
in AS64496 are returned.

```
R6#traceroute 203.0.113.1
Type escape sequence to abort.
Tracing the route to 203.0.113.1

  1 198.51.100.2 40 msec 20 msec 32 msec
  2 198.51.100.6 16 msec 20 msec 20 msec
  3 198.51.100.9 20 msec 20 msec 32 msec
  4 10.1.1.5 20 msec 20 msec 20 msec
  5 10.1.1.1 20 msec 20 msec 20 msec
R6#
```

This effect in itself is often not a problem. However, if anti-
spoofing controls are applied at network perimeters, then responses
returned from hops with private IP addresses will be dropped. Anti-
spoofing refers to a security control where traffic with an invalid
source address is discarded. Anti-spoofing is further described in
[BCP38]/[RFC2827]and[BCP84]/[RFC3704]. Additionally any RFC1918
filtering mechanism, such as those employed in most firewalls and
many other network devices can cause the same effect.

The effects are illustrated in a second example below. The same
network as example 1 is used, but with the addition of anti-spoofing
deployed at the ingress of R4 on the R3-R4 interface (IP Address
198.51.100.10).

```
R6#traceroute 203.0.113.1

Type escape sequence to abort.
Tracing the route to 203.0.113.1

  1 198.51.100.2 24 msec 20 msec 20 msec
  2 198.51.100.6 20 msec 52 msec 44 msec
  3 198.51.100.9 44 msec 20 msec 32 msec
  4  *   *   *
  5  *   *   *
  6  *   *   *
  7  *   *   *
  8  *   *   *
  9  *   *   *
 10  *   *   *
 11  *   *   *
 12  *   *   *
```

In a third example, a similar effect is caused. If a traceroute is
initiated from a router with a private (source) IP address, located
in AS64496 and the destination is outside of the ISPs AS (AS64497),
then in this situation the traceroute will fail completely beyond the
AS boundary.

```
R1# traceroute 203.0.113.65
Type escape sequence to abort.
Tracing the route to 203.0.113.65

  1 10.1.1.2 20 msec 20 msec 20 msec
  2 10.1.1.6 52 msec 24 msec 40 msec
  3  *   *   *
  4  *   *   *
  5  *   *   *
  6  *   *   *
R1#
```

While it is completely unreasonable to expect a packet with a private
source address to be successfully returned in a typical SP
environment, the case is included to show the effect as it can have
implications for troubleshooting. This case will be referenced in a
later section.

In a complex topology, with multiple paths and exit points, the
provider will lose their ability to trace paths originating within
their own AS, through their network, to destinations within other
ASs. Such a situation could be a severe troubleshooting impediment.

For completeness, a fourth example is included to show that a
successful traceroute can be achieved by specifying a public source
address as the source address of the traceroute. Such an approach
can be used in many operational situations if the router initiating
the traceroute has at least one public address configured. However,
the approach is more cumbersome.

```
R1#traceroute
Protocol [ip]:
Target IP address: 203.0.113.65
Source address: 203.0.113.1
Numeric display [n]:
Timeout in seconds [3]:
Probe count [3]:
Minimum Time to Live [1]:
Maximum Time to Live [30]: 10
Port Number [33434]:
Loose, Strict, Record, Timestamp, Verbose[none]:
Type escape sequence to abort.
Tracing the route to 203.0.113.65

  1 10.1.1.2 0 msec 4 msec 0 msec
  2 10.1.1.6 0 msec 4 msec 0 msec
  3 198.51.100.10 [AS 64497] 0 msec 4 msec 0 msec
  4 198.51.100.5 [AS 64497] 0 msec 0 msec 4 msec
  5 198.51.100.1 [AS 64497] 0 msec 0 msec 4 msec
R1#
```

It should be noted that some solutions to this problem have been
proposed in [RFC5837] which provides extensions to ICMP to allow the
identification of interfaces and their components by any combination
of the following: ifIndex, IPv4 address, IPv6 address, name, and
MTU. However at the time of writing, little or no deployment was
known to be in place.

4. Effects on Path MTU Discovery

The Path MTU Discovery (PMTUD) process was designed to allow hosts to
make an accurate assessment of the maximum packet size that can be
sent across a path without fragmentation. Path MTU Discovery is
supported by TCP over IPv4 [RFC1191], TCP over IPv6 [RFC1981] and
some tunneling protocols such as GRE and IPSEC.

The PMTUD mechanism requires that an intermediate router can reply to
the source address of an IP packet with an ICMP reply which uses the
router's interface address. If the router's interface address is a
private IP address, then this ICMP reply packet may be discarded due
to uRPF or ingress filtering, thereby causing the PMTUD mechanism to
fail. If the PMTUD mechanism fails, this will cause transmission of
data between the two hosts to fail silently due to the traffic being
black-holed. As a result, the potential for application level issues
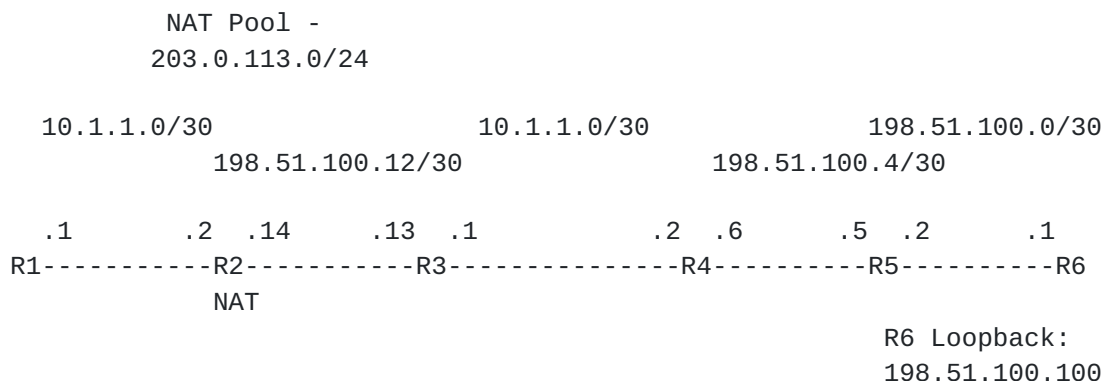may be created.

5. Unexpected interactions with some NAT implementations

   Private addressing is legitimately used within many enterprise,
   corporate or government networks for internal network addressing.
   When users on the inside of the network require Internet access, they
   will typically connect through a perimeter router, firewall, or
   network proxy, that provides Network Address Translation (NAT) or
   Network Address Port Translation (NAPT) services to a public
   interface.

   Scarcity of public IPv4 addresses, and the transition to IPv6, is
   forcing many service providers to make use of NAT. CGN (Carrier
   Grade NAT) will enable service providers to assign private [RFC1918]
   IPv4 addresses to their customers rather than public, globally unique
   IPv4 addresses. NAT444 will make use of a double NAT process.

   Unpredictable or confusing interactions could occur if traffic such
   as traceroute, PMTUD and possibly other applications were launched
   from the NAT IPv4 'inside address' and it passed over the same
   address range in the public IP core. While such a situation would be
   unlikely to occur if the NAT pools and the private infrastructure
   addressing were under the same administration, such a situation could
   occur in the more typical situation of a NAT'ed corporate network
   connecting to an ISP. For example, say if 10.1.1.0/24 is used to
   internally number the corporate network. A traceroute or PMTUD
   request is initiated inside the corporate network from say 10.1.1.1.
   The packet passes through a NAT (or NAPT) gateway, then over an ISP
   core numbered from the same range. When the responses are delivered
   back to the originator, the returned packets from the privately
   addressed part of the ISP core could have an identical source and
   destination address of 10.1.1.1.

            NAT Pool -
          203.0.113.0/24

    10.1.1.0/30   10.1.1.0/30   198.51.100.0/30
            198.51.100.12/30   198.51.100.4/30

     .1   .2 .14   .13 .1   .2 .6   .5 .2   .1
    R1-----------R2-----------R3---------------R4----------R5----------R6
              NAT

                                                    R6 Loopback:
                                                    198.51.100.100

```
   R1#traceroute 198.51.100.100

   Type escape sequence to abort.
   Tracing the route to 198.51.100.100

     1 10.1.1.2 0 msec 0 msec 0 msec
     2 198.51.100.13 0 msec 4 msec 0 msec
     3 10.1.1.2 0 msec 4 msec 0 msec        <<<<
     4 198.51.100.5 4 msec 0 msec 4 msec
     5 198.51.100.1 0 msec 0 msec 0 msec
   R1#
```

This duplicate address space scenario has the potential to cause
confusion among operational staff, thereby making it more difficult
to successfully debug networking problems.

Certainly a scenario where the same [RFC1918] address space becomes
utilised on both the inside and outside interfaces of a NAT/NAPT
device can be problematic. For example, the same private address
range is assigned by both the administrator of a corporate network
and their ISP. Some applications discover the outside address of
their local CPE to determine if that address is reserved for special
use. Application behavior may then be based on this determination.
"IANA-Reserved IPv4 Prefix for Shared Address Space" [RFC6598]
provides further analysis of this situation.

To address this scenario and others, "IANA-Reserved IPv4 Prefix for
Shared Address Space" [RFC6598] requests a dedicated /10 address
block for the purpose of Shared CGN (Carrier Grade NAT) Address
Space. The purpose of Shared CGN Address Space is to number CPE
(Customer Premise Equipment) interfaces that connect to CGN devices.
As explained in [RFC6598], [RFC1918] addressing has issues when used
in this deployment scenario.

6. Interactions with edge anti-spoofing techniques

Denial of Service Attacks (DOS) and Distributed Denial of Service
Attacks (DDoS) can make use of spoofed source IP addresses in an
attempt to obfuscate the source of an attack. Network Ingress
Filtering [RFC2827] strongly recommends that providers of Internet
connectivity implement filtering to prevent packets using source
addresses outside of their legitimately assigned and advertised
prefix ranges. Such filtering should also prevent packets with
private source addresses from egressing the AS.

Best security practices for ISPs also strongly recommend that packets
with illegitimate source addresses should be dropped at the AS

perimeter. Illegitimate source addresses includes private
[RFC1918]IP addresses, addresses within the provider's assigned
prefix ranges, and bogons (legitimate but unassigned IP addresses).
Additionally, packets with private IP destination addresses should
also be dropped at the AS perimeter.

If such filtering is properly deployed, then traffic either sourced
from, or destined for privately addressed portions of the network
should be dropped. Hence the negative consequences on traceroute,
PMTUD and regular ping type traffic.

7. Peering using loopbacks

Although not a common technique, some ISPs use the loopback addresses
of border routers (ASBRs) for peering, in particular where multiple
connections or exchange points exist between the two ISPs. Such a
technique is used by some ISPs as the foundation of fine grained
traffic engineering and load balancing through the combination of IGP
metrics and multi-hop BGP. When private or non-globally reachable
addresses are used as loopback addresses, this technique is either
not possible, or considerably more complex to implement.

8. DNS Interaction

Many ISPs utilise their DNS to perform both forward and reverse
resolution for the infrastructure devices and infrastructure
addresses. With a privately numbered core, the ISP itself will still
have the capability to perform name resolution of their own
infrastructure. However others outside of the autonomous system will
not have this capability. At best, they will get a number of
unidentified [RFC1918] IP addresses returned from a traceroute.

It is also worth noting that in some cases the reverse resolution
requests may leak outside of the AS. Such a situation can add load
to public DNS servers. Further information on this problem is
documented in "AS112 Nameserver Operations" [RFC6304].

9. Operational and Troubleshooting issues

Previous sections of the document have noted issues relating to
network operations and troubleshooting. In particular when private
IP addressing within an ISP core is used, the ability to easily
troubleshoot across the AS boundary may be limited. In some cases
this may be a serious troubleshooting impediment. In other cases, it
may be solved through the use of alternative troubleshooting

techniques.

The key point is that the flexibility of initiating an outbound ping
or traceroute from a privately numbered section of the network is
lost. In a complex topology, with multiple paths and exit points
from the AS, the provider may be restricted in their ability to trace
paths through the network to other ASs. Such a situation could be a
severe troubleshooting impediment.

For users outside of the AS, the loss of the ability to use a
traceroute for troubleshooting is very often a serious issue. As
soon as many of these people see a row of "* * *" in a traceroute
they often incorrectly assume that a large part of the network is
down or inaccessible (e.g. behind a firewall). Operational
experience in many large providers has shown that significant
confusion can result.

10. Security Considerations

One of the arguments often put forward for the use of private
addressing within an ISP is an improvement in the network security.
It has been argued that if private addressing is used within the
core, the network infrastructure becomes unreachable from outside the
providers autonomous system, hence protecting the infrastructure.
There is legitimacy to this argument. Certainly if the core is
privately numbered and unreachable, it potentially provides a level
of isolation in addition to what can be achieved with other
techniques, such as infrastructure ACLs, on their own. This is
especially true in the event of an ACL misconfiguration, something
that does commonly occur as the result of human error.

There are three key security gaps that exist in a privately addressed
IP core.

   The approach does not protect against reflection attacks if edge
   anti-spoofing is not deployed. For example, if a packet with
   spoofed source address corresponding to the networks
   infrastructure address range, is sent to a host (or other device)
   attached to the network, that host will send its response directly
   to the infrastructure address. If such an attack was performed
   across a large number of hosts, then a successful large scale
   denial of service attack on the infrastructure could be achieved.
   This is not to say that a publicly numbered core will protect from
   the same attack, it won't. The key point is that a reflection
   attack does get around the apparent security offered in a
   privately addressed core.

   Even if anti-spoofing is deployed at the AS boundary, the border
   routers will potentially carry routing information for the
   privately addressed network infrastructure. This can mean that
   packets with spoofed addresses, corresponding to the private
   infrastructure addressing, may be considered legitimate by edge
   anti-spoofing techniques such as Unicast Reverse Path Forwarding -
   Loose Mode, and forwarded. To avoid this situation, an edge anti-
   spoofing algorithm such as Unicast Reverse Path Forwarding -
   Strict Mode, would be required. Strict approaches can be
   problematic in some environments or where asymmetric traffic paths
   exist.

   The approach on its own does not protect the network
   infrastructure from directly connected customers (i.e. within the
   same AS). Unless other security controls, such as access control
   lists (ACLs), are deployed at the ingress point of the network,
   customer devices will normally be able to reach, and potentially
   attack, both core and edge infrastructure devices.

[11]. Alternate approaches to core network security

   Today, hardware-based ACLs, which have minimal to no performance
   impact, are now widespread. Applying an ACL at the AS perimeter to
   prevent access to the network core may be a far simpler approach and
   provide comparable protection to using private addressing; such a
   technique is known as an infrastructure ACL (iACL).

   In concept, iACLs provide filtering at the edge network which allows
   traffic to cross the network core, but not to terminate on
   infrastructure addresses within the core. Proper iACL deployment
   will normally allow required network management traffic to be passed,
   such that traceroutes and PMTUD can still operate successfully. For
   an iACL deployment to be practical, the core network needs to have
   been addressed with a relatively small number of contiguous address
   blocks. For this reason, the technique may or may not be practical.

   A second approach to preventing external access to the core is IS-IS
   core hiding. This technique makes use of a fundamental property of
   the IS-IS protocol which allows link addresses to be removed from the
   routing table while still allowing loopback addresses to be resolved
   as next hops for BGP. The technique prevents parties outside the AS
   from being able to route to infrastructure addresses, while still
   allowing traceroutes to operate successfully. IS-IS core hiding does
   not have the same practical requirement for the core to be addressed
   from a small number of contiguous address blocks as with iACLs. From
   an operational and troubleshooting perspective, care must be taken to
   ensure that pings and traceroutes are using source and destination

addresses that exist in the routing tables of all routers in the
path. i.e. Not hidden link addresses.

A third approach is the use of either an MPLS based IP VPN, or an
MPLS based IP Core where the 'P' routers (or Label Switch Routers) do
not carry global routing information. As the core 'P' routers (or
Label Switch Routers) are only switching labeled traffic, they are
effectively not reachable from outside of the MPLS domain. The 'P'
routers can optionally be hidden such they do not appear in a
traceroute. While this approach isolates the 'P' routers from
directed attacks, it does not protect the edge routers - being either
a 'PE' router or a Label Edge Router (LER). Obviously there are
numerous other engineering considerations in such an approach, we
simply note it as an option.

These techniques may not be suitable for every network, however,
there are many circumstances where they can be used successfully
without the associated effects of a privately addressing the core.

12. References

12.1. Normative References

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