

Network Working Group
Internet-Draft
Intended status: Standards Track
Expires: January 17, 2013

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July 16, 2012

Stateless IPv4 Network Address Translation
draft-tsou-stateless-nat44-01

Abstract

This memo describes a protocol for decentralizing IPv4 NAT to the customer-premises equipment (CPE) such that no state information is kept on the central NAT device. The CPE uses a restricted source port set that is encoded in its provisioned IPv4 WAN address. The NAT device performs only strictly stateless address (not port) translation.

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1. Introduction

IPv4 address exhaustion has become world-wide reality. NAT is one of the solutions to deal with the problem. The drawbacks of traditional NAT include statefulness and the need to track transport-layer sessions. This makes NAT complex, hard to scale up, and fragile.

This document describes a method of deploying stateless NAT as a backwards-compatible evolution of an IPv4-only network.

The assumed topology is illustrated in Figure 1.

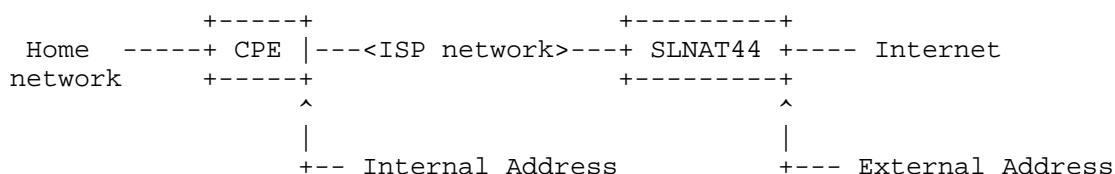


Figure 1: Stateless NAT44 topology

Note that SLNAT44 has no IPv6 component. Any deployment of IPv6 is unaffected by SLNAT44. Therefore, this document only describes IPv4 addresses and IPv4 packets. IPv6 is not discussed further.

2. Terminology

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].

The following terms are used throughout this document:

Port set: Set of transport-layer ports that each CPE is assigned, to be used as source ports by packets sent by the CPE.

Port Set ID: A value from which a unique port set is algorithmically derived.

SLNAT44: Depending on the context, either the stateless NAT44 protocol or the stateless NAT44 device that translates between internal and external addresses. NAT44 in turn stands for "IPv4-to-IPv4 NAT".

Internal Address: The IPv4 address assigned to a CPE. It is used in the ISP network between the CPE and the SLNAT44.

External Address: The IPv4 address used on the Internet and routed to the SLNAT44.

Mapping rule: A set of parameters configured on the SLNAT44 (not on the CPE) describing the relationship between internal and external addresses.

3. Address Formats

Internal addresses have the format illustrated in Figure 2. The addresses are simply made of three parts concatenated together: the Internal Prefix, the External Suffix, and the Port Set ID.

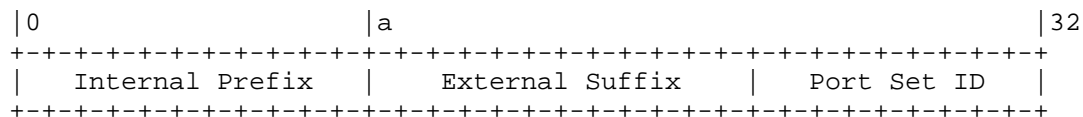


Figure 2: Internal Address format

External Addresses have the format illustrated in Figure 3. It is made of two parts: the External Prefix and the External Suffix.

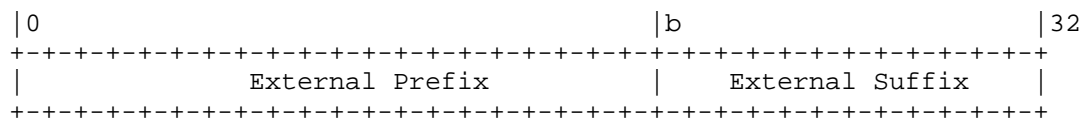


Figure 3: External Address format

The lengths of the Internal and External Prefixes, "a" and "b", are mandatory parameters of SLNAT44. They are determined by the ISP. They need not be communicated to the CPE. Other lengths can be computed from them as follows:

- o Length of External Suffix: 32 - b
- o Length of Port Set ID: b - a

4. CPE Provisioning

As part of its start up routine, the CPE is assigned an IPv4 address by the ISP using regular means (DHCP, PPP, etc.). This is the

Internal Address.

In addition, using new provisioning options, the CPE is assigned a Port Set ID.

Optionally, a Port Set Mask is also provisioned to the CPE. This mask is of the same length as the Port Set ID (i.e., b-a bits). Its purpose is to allow discontinuous port ranges. If no mask is provided, a mask of all ones is assumed by default, which implies a continuous port range. System ports (0-1023) should not to be assigned to any CPE.

In summary, the CPE is provisioned with the following elements:

- o IPv4 address (as usual)
- o Port Set ID
- o Port Set Mask (optional)

5. SLNAT44 Configuration

The SLNAT44 is configured with a set of mapping rules. Each rule contains:

- o Internal Prefix
- o External Prefix
- o Port Set Mask (optional)

Prefixes include their length. For simplicity, rule prefixes MUST NOT overlap with other rules.

If it is absent, the Port Set Mask is assumed to be all ones by default.

6. Port Set Computation

Given a Port Set ID and a Port Set Mask, both n bits in length, the set of allowed ports is defined as the set of port numbers for which the higher-order n bits of their binary expression whose corresponding mask bits are 1 are equal to corresponding bits from the Port Set ID.

```

|0           |5
+---+---+---+
|1 1 1 0 1|   Port Set ID = 29 (length n = 5 bits)
+---+---+---+
& & & & &
+---+---+---+
|1 1 1 1 1|   Port Set Mask
+---+---+---+
| | | | |
V V V V V
+---+---+---+
|1 1 1 0 1 x x x x x x x x x x x x|   Port Set = 59392-61439
+---+---+---+
|0                                     |16

```

Figure 4: Example Contiguous Port Set Computation

```

|0           |8
+---+---+---+
|0 0 1 0 1 1 1 1|   Port Set ID = 29 (length n = 8 bits)
+---+---+---+
& & & & & & &
+---+---+---+
|0 0 1 1 1 1 1 1|   Port Set Mask
+---+---+---+
| | | | | | | |
V V V V V V V V
+---+---+---+
|x x 1 0 1 1 1 1 x x x x x x x x x|   Port Set = 12032-12287, 28416-28671,
+---+---+---+                                     44800-45055, 61184-61439
|0                                     |16

```

Figure 5: Example Non-Contiguous Port Set Computation

It follows that the number of ports in the set is $2^{(16-x)}$, where x is the number of ones in the Port Set Mask.

This computation is performed by the CPE as part of its provisioning routine as well as by the SLNAT44 for dropping packets with ports outside the allowed range.

For the purposes of SLNAT44, a "source port" corresponds to either a TCP source port, a UDP source port, or an ICMPv4 identifier, while a "destination port" corresponds to either a TCP destination port, a UDP destination port, or an ICMPv4 identifier. Note that an ICMPv4 identifier plays the role of both source and destination port.

Transport protocols other than TCP and UDP, as well as ICMPv4 types without an identifier field are out of scope of this specification.

7. CPE Operation

Packets sent from the CPE MUST have the provisioned IPv4 address as source and MUST have a source port that is within the allowed set. This is usually accomplished by having the CPE run a NAT44 configured with the provisioned address and allowed port set and having it process all packets sent out the WAN interface.

Packets received by the CPE on its WAN interface with a destination port outside the allowed range MUST be dropped.

7.1. ALG Handling

If the CPE implements application level gateways (ALGs) such as FTP, RSTP or PPTP, it must ensure that ports present in the payload when translated fall within the allowed range.

8. SLNAT44 Operation

8.1. Internal to External

When it receives a packet on an internal interface, the SLNAT44 finds the rule whose Internal Prefix matches the packet's source address. It extracts the Port Set ID from the packet's source address. It then checks if the packet's source port is within the allowed set, using the rule's Port Set Mask. If it is not, the packet MUST be dropped.

If the packet's source port is within the allowed set, the SLNAT44 builds the External Address by concatenating the rule's External Prefix with the External Suffix extracted from the packet's source address. It then replaces the packet's source address with this External Address. The IPv4 and transport-layer checksums are updated as necessary. The packet is then forwarded as usual.

8.2. External to Internal

When it receives a packet on an external interface, the SLNAT44 finds the rule whose External Prefix matches the packet's destination address. It then builds the Internal Address by concatenating the rule's Internal Prefix, the External Suffix extracted from the packet's destination address, and the Port Set ID computed by applying the rule's Port Set Mask to the packet's destination port's

higher-order bits. It then replaces the packet's destination address with this Internal Address. The IPv4 and transport-layer checksums are updated as necessary. The packet is then forwarded as usual.

8.3. Fragment Handling

If the incoming IP packet contains a fragment, then more processing may be needed. This specification leaves open the exact details of how a SLNAT44 handles incoming IP packets containing fragments, and simply requires that the external behavior of the SLNAT44 be compliant with the following conditions.

The SLNAT44 MUST handle fragments. In particular, SLNAT44 MUST handle fragments arriving out of order, conditional on the following:

- o The SLNAT44 MUST limit the amount of resources devoted to the storage of fragmented packets in order to protect from DoS attacks.
- o As long as the SLNAT44 has available resources, the SLNAT44 MUST allow the fragments to arrive over a time interval. The time interval SHOULD be configurable and the default value MUST be of at least 2 seconds.
- o The SLNAT44 MAY require that the UDP, TCP, or ICMPv4 header be completely contained within the fragment that contains fragment offset equal to zero.

For incoming packets carrying TCP or UDP fragments with a non-zero checksum, SLNAT44 MAY elect to queue the fragments as they arrive and translate all fragments at the same time. In this case, the incoming tuple is determined as documented above to the un-fragmented packets. Alternatively, a SLNAT44 MAY translate the fragments as they arrive, by storing information that allows it to compute the necessary port number for fragments other than the first. In the latter case, subsequent fragments may arrive before the first, and the rules (in the bulleted list above) about how the SLNAT44 handles (out-of-order) fragments apply.

Implementers of SLNAT44 should be aware that there are a number of well-known attacks against IP fragmentation; see [RFC1858] and [RFC3128]. Implementers should also be aware of additional issues with reassembling packets at high rates, described in [RFC4963].

9. Address Mapping Example

An operator has two public ranges of size /18 and /19 called foo and

bar respectively. It plans to use 10/8 as its internal address prefix and PSID (port range) of length 5. Two prefixes of the internal network

The internal prefixes lengths are:

- o $32 - 18 - 5 = 13$ (derived from foo)
- o $32 - 19 - 5 = 14$ (derived from bar)

This will give the following possible mappings:

- o foo/18 <--> 10.0.0.0/13
- o bar/19 <--> 10.128.0.0/14

Author note: Discuss the where internal prefixes are overlapping

10. Security Considerations

The security considerations related to IP address sharing documented in RFC 6269 [RFC6269] and RFC 6056 [RFC6056] apply to SLNAT44.

11. Acknowledgements

Section 8.3 is adapted from [RFC6146].

12. References

12.1. Normative References

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