

Network Working Group
Internet-Draft
Intended status: Standards Track
Expires: August 26, 2018

M. Boucadair, Ed.
Orange
S. Sivakumar
Cisco Systems
C. Jacquenet
Orange
S. Vinapamula
Juniper Networks
Q. Wu
Huawei
February 22, 2018

**A YANG Module for Network Address Translation (NAT) and Network Prefix
Translation (NPT)
draft-ietf-opsawg-nat-yang-13**

Abstract

For the sake of network automation and the need for programming Network Address Translation (NAT) function in particular, a data model for configuring and managing the NAT is essential. This document defines a YANG module for the NAT function.

NAT44, Network Address and Protocol Translation from IPv6 Clients to IPv4 Servers (NAT64), Customer-side transLAtor (CLAT), Stateless IP/ICMP Translation (SIIT), Explicit Address Mappings for Stateless IP/ICMP Translation (SIIT EAM), IPv6 Network Prefix Translation (NPTv6), and Destination NAT are covered in this document.

Editorial Note (To be removed by RFC Editor)

Please update these statements with the RFC number to be assigned to this document:

"This version of this YANG module is part of RFC XXXX;"

"RFC XXXX: A YANG Module for Network Address Translation (NAT) and Network Prefix Translation (NPT)"

"reference: RFC XXXX"

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of [BCP 78](#) and [BCP 79](#).

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at <https://datatracker.ietf.org/drafts/current/>.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on August 26, 2018.

Copyright Notice

Copyright (c) 2018 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to [BCP 78](#) and the IETF Trust's Legal Provisions Relating to IETF Documents (<https://trustee.ietf.org/license-info>) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Simplified BSD License text as described in Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Simplified BSD License.

Table of Contents

1.	Introduction	3
1.1.	Terminology	3
2.	Overview of the NAT YANG Data Model	5
2.1.	Overview	5
2.2.	Various Translation Flavors	6
2.3.	TCP/UDP/ICMP NAT Behavioral Requirements	7
2.4.	Other Transport Protocols	7
2.5.	IP Addresses Used for Translation	8
2.6.	Port Set Assignment	8
2.7.	Port-Restricted IP Addresses	8
2.8.	NAT Mapping Entries	8
2.9.	Resource Limits	12
2.10.	Binding the NAT Function to an External Interface	15
2.11.	Relationship to NATV2-MIB	15
2.12.	Tree Structure	16
3.	NAT YANG Module	22
4.	Security Considerations	72
5.	IANA Considerations	73
6.	Acknowledgements	74

7.	References	74
7.1.	Normative References	74
7.2.	Informative References	76
Appendix A.	Sample Examples	78
A.1.	Traditional NAT44	78
A.2.	Carrier Grade NAT (CGN)	80
A.3.	CGN Pass-Through	83
A.4.	NAT64	84
A.5.	Stateless IP/ICMP Translation (SIIT)	84
A.6.	Explicit Address Mappings for Stateless IP/ICMP Translation (EAM SIIT)	85
A.7.	Static Mappings with Port Ranges	88
A.8.	Static Mappings with IP Prefixes	89
A.9.	Destination NAT	90
A.10.	Customer-side Translator (CLAT)	93
A.11.	IPv6 Network Prefix Translation (NPTv6)	93
	Authors' Addresses	96

[1.](#) Introduction

This document defines a data model for Network Address Translation (NAT) and Network Prefix Translation (NPT) capabilities using the YANG data modeling language [[RFC7950](#)].

Traditional NAT is defined in [[RFC2663](#)], while Carrier Grade NAT (CGN) is defined in [[RFC6888](#)]. Unlike traditional NAT, the CGN is used to optimize the usage of global IP address space at the scale of a domain: a CGN is not managed by end users, but by service providers instead. This document covers both traditional NATs and CGNs.

This document also covers NAT64 [[RFC6146](#)], customer-side translator (CLAT) [[RFC6877](#)], Stateless IP/ICMP Translation (SIIT) [[RFC7915](#)], Explicit Address Mappings for Stateless IP/ICMP Translation (EAM) [[RFC7757](#)], IPv6 Network Prefix Translation (NPTv6) [[RFC6296](#)], and Destination NAT. The full set of translation schemes that are in scope is included in [Section 2.2](#).

Sample examples are provided in [Appendix A](#). These examples are not intended to be exhaustive.

[1.1.](#) Terminology

This document makes use of the following terms:

- o Basic NAT44: translation is limited to IP addresses alone ([Section 2.1 of \[RFC3022\]](#)).

- o Network Address/Port Translator (NAPT): translation in NAPT is extended to include IP addresses and transport identifiers (such as a TCP/UDP port or ICMP query ID); refer to [Section 2.2 of \[RFC3022\]](#). A NAPT may use an extra identifier, in addition to the five transport tuple, to disambiguate bindings [\[RFC6619\]](#).
- o Destination NAT: is a translation that acts on the destination IP address and/or destination port number. This flavor is usually deployed in load balancers or at devices in front of public servers.
- o Port-restricted IPv4 address: An IPv4 address with a restricted port set. Multiple hosts may share the same IPv4 address; however, their port sets must not overlap [\[RFC7596\]](#).
- o Restricted port set: A non-overlapping range of allowed external ports to use for NAT operation. Source ports of IPv4 packets translated by a NAT must belong to the assigned port set. The port set is used for all port-aware IP protocols [\[RFC7596\]](#).
- o Internal Host: A host that may need to use a translation capability to send to and receive traffic from the Internet.
- o Internal Address/prefix: The IP address/prefix of an internal host.
- o External Address: The IP address/prefix assigned by a translator to an internal host; this is the address that will be seen by a remote host on the Internet.
- o Mapping: denotes a state at the translator that is necessary for network address and/or port translation.
- o Dynamic implicit mapping: is created implicitly as a side effect of processing a packet (e.g., an initial TCP SYN packet) that requires a new mapping. A validity lifetime is associated with this mapping.
- o Dynamic explicit mapping: is created as a result of an explicit request, e.g., PCP message [\[RFC6887\]](#). A validity lifetime is associated with this mapping.
- o Static explicit mapping: is created using, e.g., a CLI interface. This mapping is likely to be maintained by the NAT function till an explicit action is executed to remove it.

The usage of the term NAT in this document refers to any translation flavor (NAT44, NAT64, etc.) indifferently.

This document uses the term "session" as defined in [[RFC2663](#)] and [[RFC6146](#)] for NAT64.

The meaning of the symbols in tree diagrams is defined in [[I-D.ietf-netmod-yang-tree-diagrams](#)].

2. Overview of the NAT YANG Data Model

2.1. Overview

The NAT YANG module is designed to cover dynamic implicit mappings and static explicit mappings. The required functionality to instruct dynamic explicit mappings is defined in separate documents such as [[I-D.boucadair-pcp-yang](#)]. Considerations about instructing explicit dynamic means (e.g., [[RFC6887](#)], [[RFC6736](#)], or [[RFC8045](#)]) are out of scope. As a reminder, REQ-9 of [[RFC6888](#)] requires that a CGN must implement a protocol giving subscribers explicit control over NAT mappings; that protocol should be the Port Control Protocol [[RFC6887](#)].

A single NAT device can have multiple NAT instances; each of these instances can be provided with its own policies (e.g., be responsible for serving a group of hosts). This document does not make any assumption about how internal hosts or flows are associated with a given NAT instance.

The NAT YANG module assumes that each NAT instance can be enabled/disabled, be provisioned with a specific set of configuration data, and maintains its own mapping tables.

The NAT YANG module allows for a NAT instance to be provided with multiple NAT policies (/nat/instances/instance/policy). The document does not make any assumption about how flows are associated with a given NAT policy of a given NAT instance. Classification filters are out of scope.

Defining multiple NAT instances or configuring multiple NAT policies within one single NAT instance is implementation- and deployment-specific.

This YANG module allows to instruct a NAT function to enable the logging feature ([Section 2.3 of \[\[RFC6908\]\(#\)\]](#) and REQ-12 of [[RFC6888](#)]). Nevertheless, configuration parameters specific to logging protocols are out of the scope of this document.

2.2. Various Translation Flavors

The following translation modes are supported:

- o Basic NAT44
- o NAPT
- o Destination NAT
- o Port-restricted NAT
- o Stateful NAT64 (including with destination-based Pref64::/n
[RFC7050])
- o SIIT
- o CLAT
- o EAM
- o NPTv6
- o Combination of Basic NAT/NAPT and Destination NAT
- o Combination of port-restricted and Destination NAT
- o Combination of NAT64 and EAM
- o Stateful and Stateless NAT64

[I-D.ietf-softwire-dslite-yang] specifies an extension to the NAT YANG module to support DS-Lite.

The YANG "feature" statement is used to indicate which of the different translation modes is relevant for a specific data node. Table 1 lists defined features:

Translation Mode		YANG Feature
Basic NAT44		basic-nat44
NAPT		napt44
Destination NAT		dst-nat
Stateful NAT64		nat64
Stateless IPv4/IPv6 translation		siit
CLAT		clat
EAM		eam
NPTv6		nptv6

Table 1: YANG NAT Features

The following translation modes do not require defining dedicated features:

- o Port-restricted NAT: This mode corresponds to supplying port restriction policies to a NAPT or NAT64 (port-set-restrict).
- o Combination of Basic NAT/NAPT and Destination NAT: This mode corresponds to setting 'dst-nat-enable' for Basic NAT44 or NAPT.

- o Combination of port-restricted and Destination NAT: This mode can be achieved by configuring a NAPT with port restriction policies (port-set-restrict) together with a destination IP address pool (dst-ip-address-pool).
- o Combination of NAT64 and EAM: This mode corresponds to configuring static mappings for NAT64.
- o Stateful and stateless NAT64: A NAT64 implementation can be instructed to behave in the stateless mode for a given prefix by setting the parameter (nat64-prefixes/stateless-enable). A NAT64 implementation may behave in both stateful and stateless modes if, in addition to appropriately setting the parameter (nat64-prefixes/stateless-enable), an external IPv4 address pool is configured.

The NAT YANG module allows to retrieve the capabilities of a NAT instance (including, list of supported translation modes, list of supported protocols, port restriction support status, supported NAT mapping types, supported NAT filtering types, port range allocation support status, port parity preservation support status, port preservation support status, the behavior for handling fragments (all, out-of-order, in-order)).

2.3. TCP/UDP/ICMP NAT Behavioral Requirements

This document assumes NAT behavioral recommendations for UDP [[RFC4787](#)], TCP [[RFC5382](#)], and ICMP [[RFC5508](#)] are enabled by default.

Furthermore, the NAT YANG module relies upon the recommendations detailed in [[RFC6888](#)] and [[RFC7857](#)].

2.4. Other Transport Protocols

The module is structured to support other protocols than UDP, TCP, and ICMP. The mapping table is designed so that it can indicate any transport protocol. For example, this module may be used to manage a DCCP-capable NAT that adheres to [[RFC5597](#)].

Future extensions can be defined to cover NAT-related considerations that are specific to other transport protocols such as SCTP [[I-D.ietf-tsvwg-natsupp](#)]. Typically, the mapping entry can be extended to record two optional SCTP-specific parameters: Internal Verification Tag (Int-VTag) and External Verification Tag (Ext-VTag).

Also, the module allows to enable translation for these protocols when required (/nat/instances/instance/policy/transport-protocols).

2.5. IP Addresses Used for Translation

The NAT YANG module assumes that blocks of IP external addresses (external-ip-address-pool) can be provisioned to the NAT function. These blocks may be contiguous or not.

This behavior is aligned with [\[RFC6888\]](#) which specifies that a NAT function should not have any limitations on the size or the contiguity of the external address pool. In particular, the NAT function must be configurable with contiguous or non-contiguous external IPv4 address ranges. To accommodate traditional NAT, the module allows for a single IP address to be configured for external-ip-address-pool.

Likewise, one or multiple IP address pools may be configured for Destination NAT (dst-ip-address-pool).

2.6. Port Set Assignment

Port numbers can be assigned by a NAT individually (that is, a single port is assigned on a per session basis). Nevertheless, this port allocation scheme may not be optimal for logging purposes ([Section 12 of \[RFC6269\]](#)). Therefore, a NAT function should be able to assign port sets (e.g., [\[RFC7753\]](#)) to optimize the volume of the logging data (REQ-14 of [\[RFC6888\]](#)). Both allocation schemes are supported in the NAT YANG module.

When port set assignment is activated (i.e., port-allocation-type==port-range-allocation), the NAT can be provided with the size of the port set to be assigned (port-set-size).

2.7. Port-Restricted IP Addresses

Some NATs require to restrict the source port numbers (e.g., Lightweight 4over6 [\[RFC7596\]](#), MAP-E [\[RFC7597\]](#)). Two schemes of port set assignments (port-set-restrict) are supported in this document:

- o Simple port range: is defined by two port values, the start and the end of the port range [\[RFC8045\]](#).
- o Algorithmic: an algorithm is defined in [\[RFC7597\]](#) to characterize the set of ports that can be used.

2.8. NAT Mapping Entries

A TCP/UDP mapping entry maintains an association between the following information:


```
(internal-src-address, internal-src-port) (internal-dst-address,  
internal-dst-port) <=> (external-src-address, external-src-port)  
(external-dst-address, external-dst-port)
```

An ICMP mapping entry maintains an association between the following information:

```
(internal-src-address, internal-dst-address, internal ICMP/ICMPv6  
identifier) <=> (external-src-address, external-dst-address,  
external ICMP/ICMPv6 identifier)
```

As a reminder, all the ICMP Query messages contain an 'Identifier' field, which is referred to in this document as the 'ICMP Identifier'.

To cover TCP, UDP, and ICMP, the NAT YANG module assumes the following structure of a mapping entry:

type: Indicates how the mapping was instantiated. For example, it may indicate whether a mapping is dynamically instantiated by a packet or statically configured.

transport-protocol: Indicates the transport protocol (e.g., UDP, TCP, ICMP) of a given mapping.

internal-src-address: Indicates the source IP address/prefix as used by an internal host.

internal-src-port: Indicates the source port number (or ICMP identifier) as used by an internal host.

external-src-address: Indicates the source IP address/prefix as assigned by the NAT.

external-src-port: Indicates the source port number (or ICMP identifier) as assigned by the NAT.

internal-dst-address: Indicates the destination IP address/prefix as used by an internal host when sending a packet to a remote host.

internal-dst-port: Indicates the destination port number as used by an internal host when sending a packet to a remote host.

external-dst-address: Indicates the destination IP address/prefix used by a NAT when processing a packet issued by an internal host towards a remote host.

external-dst-port: Indicates the destination port number used by a NAT when processing a packet issued by an internal host towards a remote host.

In order to cover both NAT64 and NAT44 flavors in particular, the NAT mapping structure allows to include an IPv4 or an IPv6 address as an internal IP address. Remaining fields are common to both NAT schemes.

For example, the mapping that will be created by a NAT64 upon receipt of a TCP SYN from source address 2001:db8:aaaa::1 and source port number 25636 to destination IP address 2001:db8:1234::198.51.100.1 and destination port number 8080 is shown in Table 2. This example assumes EDM (Endpoint-Dependent Mapping).

Mapping Entry Attribute	Value
type	dynamic implicit mapping
transport-protocol	6 (TCP)
internal-src-address	2001:db8:aaaa::1
internal-src-port	25636
external-src-address	T (an IPv4 address configured on the NAT64)
external-src-port	t (a port number that is chosen by the NAT64)
internal-dst-address	2001:db8:1234::198.51.100.1
internal-dst-port	8080
external-dst-address	198.51.100.1
external-dst-port	8080

Table 2: Example of an EDM NAT64 Mapping

The mappings that will be created by a NAT44 upon receipt of an ICMP request from source address 198.51.100.1 and ICMP identifier (ID1) to destination IP address 198.51.100.11 is depicted in Table 3. This example assumes EIM (Endpoint-Independent Mapping).

Mapping Entry Attribute	Value
type	dynamic implicit mapping
transport-protocol	1 (ICMP)
internal-src-address	198.51.100.1
internal-src-port	ID1
external-src-address	T (an IPv4 address configured on the NAT44)
external-src-port	ID2 (an ICMP identifier that is chosen by the NAT44)

Table 3: Example of an EIM NAT44 Mapping Entry

The mapping that will be created by a NAT64 (EIM mode) upon receipt of an ICMP request from source address 2001:db8:aaaa::1 and ICMP identifier (ID1) to destination IP address 2001:db8:1234::198.51.100.1 is shown in Table 4.

Mapping Entry Attribute	Value
type	dynamic implicit mapping
transport-protocol	58 (ICMPv6)
internal-src-address	2001:db8:aaaa::1
internal-src-port	ID1
external-src-address	T (an IPv4 address configured on the NAT64)
external-src-port	ID2 (an ICMP identifier that is chosen by the NAT64)

Table 4: Example of an EIM NAT64 Mapping Entry

Note that a mapping table is maintained only for stateful NAT functions. Particularly:

- o No mapping table is maintained for NPTv6 given that it is stateless and transport-agnostic.
- o The double translations are stateless in CLAT if a dedicated IPv6 prefix is provided for CLAT. If not, a stateful NAT44 will be required.
- o No per-flow mapping is maintained for EAM [[RFC7757](#)].

- o No mapping table is maintained for Stateless IPv4/IPv6 translation. As a reminder, in such deployments internal IPv6 nodes are addressed using IPv4-translatable IPv6 addresses, which enable them to be accessed by IPv4 nodes [[RFC6052](#)].

2.9. Resource Limits

In order to comply with CGN deployments in particular, the NAT YANG module allows limiting the number of external ports per subscriber (port-quota) and the amount of state memory allocated per mapping and per subscriber (mapping-limits and connection-limits). According to [[RFC6888](#)], the module is designed to allow for the following:

- o Per-subscriber limits are configurable by the NAT administrator.
- o Per-subscriber limits are configurable independently per transport protocol.
- o Administrator-adjustable thresholds to prevent a single subscriber from consuming excessive CPU resources from the NAT (e.g., rate-limit the subscriber's creation of new mappings) can be configured.

Table 5 lists the various limits that can be set using the NAT YANG module. Once a limit is reached, packets that would normally trigger new port mappings or be translated because they match existing mappings, are dropped by the translator.

Limit	Description
port-quota	Specifies a port quota to be assigned per subscriber. It corresponds to the maximum number of ports to be used by a subscriber. The port quota can be configured to apply to all protocols or to a specific protocol. Distinct port quota may be configured per protocol.
fragments-limit	In order to prevent denial of service attacks that can be caused by fragments, this parameter is used to limit the number of out-of-order fragments that can be handled by a translator.
mapping-limits	This parameter can be used to control the maximum number of subscribers that can be serviced by a NAT instance (limit-subscriber) and the maximum number of address and/or port mappings that can be maintained by a NAT instance (limit-address-mappings and limit-port-mappings). Also, limits specific to protocols (e.g., TCP, UDP, ICMP) can also be specified (limit-per-protocol).
connection-limits	In order to prevent exhausting the resources of a NAT implementation and to ensure fairness usage among subscribers, various rate-limits can be specified. Rate-limiting can be enforced per subscriber ((limit-subscriber), per NAT instance (limit-per-instance), and/or be specified for each supported protocol (limit-per-protocol).

Table 5: NAT Limits

Table 6 describes limits, that once exceeded, will trigger notifications to be generated:

Notification Threshold	Description
high-threshold	Used to notify high address utilization of a given pool. When exceeded, a nat-pool-event notification will be generated.
low-threshold	Used to notify low address utilization of a given pool. An administrator is supposed to configure low-threshold so that it can reflect an abnormal usage of NAT resources. When exceeded, a nat-pool-event notification will be generated.
notify-addresses-usage	Used to notify high address utilization of all pools configured to a NAT instance. When exceeded, a nat-instance-event will be generated.
notify-ports-usage	Used to notify high port allocation taking into account all pools configured to a NAT instance. When exceeded, a nat-instance-event notification will be generated.
notify-subscribers-limit	Used to notify a high number of active subscribers that are serviced by a NAT instance. When exceeded, a nat-instance-event notification will be generated.

Table 6: Notification Thresholds

In order to prevent from generating frequent notifications, the NAT YANG module supports the following limits (Table 7) used to control how frequent notifications can be generated. That is, notifications are subject to rate-limiting imposed by these intervals.

Interval	Description
notify-pool-usage/notify-interval	Indicates the minimum number of seconds between successive notifications for a given address pool.
notification-limits/notify-interval	Indicates the minimum number of seconds between successive notifications for a NAT instance.

Table 7: Notification Intervals

2.10. Binding the NAT Function to an External Interface

The module is designed to specify an external realm on which the NAT function must be applied (external-realm). The module supports indicating an interface as an external realm, but the module is extensible so that other choices can be indicated in the future (e.g., Virtual Routing and Forwarding (VRF) instance).

Distinct external realms can be provided as a function of the NAT policy (see for example, [Section 4 of \[RFC7289\]](#)).

If no external realm is provided, this assumes that the system is able to determine the external interface (VRF instance, etc.) on which the NAT will be applied. Typically, the WAN and LAN interfaces of a CPE are determined by the CPE.

2.11. Relationship to NATV2-MIB

Section of 5.1 of [\[RFC7659\]](#) indicates that the NATV2-MIB assumes that the following information is configured on the NAT by some means, not specified in [\[RFC7659\]](#):

- o The set of address realms to which the device connect.
- o For the CGN case, per-subscriber information including subscriber index, address realm, assigned prefix or address, and (possibly) policies regarding address pool selection in the various possible address realms to which the subscriber may connect.

- o The set of NAT instances running on the device, identified by NAT instance index and name.
- o The port mapping, filtering, pooling, and fragment behaviors for each NAT instance.
- o The set of protocols supported by each NAT instance.
- o Address pools for each NAT instance, including for each pool the pool index, address realm, and minimum and maximum port number.
- o Static address and port mapping entries.

All the above parameters can be configured by means of the NAT YANG module.

Unlike the NATV2-MIB, the NAT YANG module allows to configure multiple policies per NAT instance.

[2.12.](#) Tree Structure

The tree structure of the NAT YANG module is provided below:

```

module: ietf-nat
  +--rw nat
    +--rw instances
      +--rw instance* [id]
        +--rw id                               uint32
        +--rw name?                           string
        +--rw enable?                         boolean
        +--ro capabilities
          | +--ro nat-flavor*
          | | identityref
          | +--ro per-interface-binding*
          | | enumeration
          | +--ro transport-protocols* [protocol-id]
          | | +--ro protocol-id      uint8
          | | +--ro protocol-name?   string
          | +--ro restricted-port-support?
          | | boolean
          | +--ro static-mapping-support?
          | | boolean
          | +--ro port-randomization-support?
          | | boolean
          | +--ro port-range-allocation-support?
          | | boolean
          | +--ro port-preservation-suport?
          | | boolean

```



```

| +---ro port-parity-preservation-support?
| |         boolean
| +---ro address-roundrobin-support?
| |         boolean
| +---ro paired-address-pooling-support?
| |         boolean
| +---ro endpoint-independent-mapping-support?
| |         boolean
| +---ro address-dependent-mapping-support?
| |         boolean
| +---ro address-and-port-dependent-mapping-support?
| |         boolean
| +---ro endpoint-independent-filtering-support?
| |         boolean
| +---ro address-dependent-filtering?
| |         boolean
| +---ro address-and-port-dependent-filtering?
| |         boolean
| +---ro fragment-behavior?
|         enumeration
+---rw type?                identityref
+---rw per-interface-binding? enumeration
+---rw nat-pass-through* [id]
|     {basic-nat44 or napt44 or dst-nat}?
| +---rw id                uint32
| +---rw prefix            inet:ip-prefix
| +---rw port?            inet:port-number
+---rw policy* [id]
| +---rw id                uint32
| +---rw clat-parameters {clat}?
| | +---rw clat-ipv6-prefixes* [ipv6-prefix]
| | | +---rw ipv6-prefix    inet:ipv6-prefix
| | +---rw ipv4-prefixes* [ipv4-prefix]
| | | +---rw ipv4-prefix    inet:ipv4-prefix
| +---rw nptv6-prefixes* [internal-ipv6-prefix] {nptv6}?
| | +---rw internal-ipv6-prefix    inet:ipv6-prefix
| | +---rw external-ipv6-prefix    inet:ipv6-prefix
| +---rw eam* [ipv4-prefix] {eam}?
| | +---rw ipv4-prefix    inet:ipv4-prefix
| | +---rw ipv6-prefix    inet:ipv6-prefix
| +---rw nat64-prefixes* [nat64-prefix]
| |     {siit or nat64 or clat}?
| | +---rw nat64-prefix    inet:ipv6-prefix
| | +---rw destination-ipv4-prefix* [ipv4-prefix]
| | | +---rw ipv4-prefix    inet:ipv4-prefix
| | +---rw stateless-enable?    boolean
| +---rw external-ip-address-pool* [pool-id]
| |     {basic-nat44 or napt44 or nat64}?

```



```

| | +--rw pool-id                uint32
| | +--rw external-ip-pool      inet:ipv4-prefix
| +--rw port-set-restrict {napt44 or nat64}?
| | +--rw (port-type)?
| |   +--:(port-range)
| |     | +--rw start-port-number?  inet:port-number
| |     | +--rw end-port-number?    inet:port-number
| |     +--:(port-set-algo)
| |       +--rw psid-offset?        uint8
| |       +--rw psid-len            uint8
| |       +--rw psid                uint16
| +--rw dst-nat-enable?            boolean
| |   {basic-nat44 or napt44}?
| +--rw dst-ip-address-pool* [pool-id] {dst-nat}?
| |   +--rw pool-id                uint32
| |   +--rw dst-in-ip-pool?        inet:ip-prefix
| |   +--rw dst-out-ip-pool        inet:ip-prefix
| +--rw transport-protocols* [protocol-id]
| |   {napt44 or nat64 or dst-nat}?
| |   +--rw protocol-id            uint8
| |   +--rw protocol-name?         string
| +--rw subscriber-mask-v6?        uint8
| +--rw subscriber-match* [match-id]
| |   {basic-nat44 or napt44 or dst-nat}?
| |   +--rw match-id              uint32
| |   +--rw subnet                inet:ip-prefix
| +--rw address-allocation-type?   enumeration
| +--rw port-allocation-type?      enumeration
| |   {napt44 or nat64}?
| +--rw mapping-type?              enumeration
| |   {napt44 or nat64}?
| +--rw filtering-type?            enumeration
| |   {napt44 or nat64}?
| +--rw fragment-behavior?         enumeration
| |   {napt44 or nat64}?
| +--rw port-quota* [quota-type] {napt44 or nat64}?
| |   +--rw port-limit?            uint16
| |   +--rw quota-type             uint8
| +--rw port-set {napt44 or nat64}?
| |   +--rw port-set-size          uint16
| |   +--rw port-set-timeout?      uint32
| +--rw timers {napt44 or nat64}?
| |   +--rw udp-timeout?           uint32
| |   +--rw tcp-idle-timeout?      uint32
| |   +--rw tcp-trans-open-timeout? uint32
| |   +--rw tcp-trans-close-timeout? uint32
| |   +--rw tcp-in-syn-timeout?    uint32
| |   +--rw fragment-min-timeout?  uint32

```



```

| | +--rw icmp-timeout?          uint32
| | +--rw per-port-timeout* [port-number]
| | | +--rw port-number      inet:port-number
| | | +--rw timeout          uint32
| | +--rw hold-down-timeout?     uint32
| | +--rw hold-down-max?        uint32
| +--rw fragments-limit?        uint32
| +--rw algs* [name]
| | +--rw name                 string
| | +--rw transport-protocol?   uint32
| | +--rw dst-transport-port
| | | +--rw start-port-number?  inet:port-number
| | | +--rw end-port-number?    inet:port-number
| | +--rw src-transport-port
| | | +--rw start-port-number?  inet:port-number
| | | +--rw end-port-number?    inet:port-number
| | +--rw status?              boolean
| +--rw all-algs-enable?        boolean
| +--rw notify-pool-usage
| | {basic-nat44 or napt44 or nat64}?
| | +--rw pool-id?             uint32
| | +--rw high-threshold?      percent
| | +--rw low-threshold?       percent
| | +--rw notify-interval?     uint32
| +--rw external-realm
| | +--rw (realm-type)?
| | +--:(interface)
| | +--rw external-interface?  if:interface-ref
+--rw mapping-limits {napt44 or nat64}?
| +--rw limit-subscribers?      uint32
| +--rw limit-address-mappings? uint32
| +--rw limit-port-mappings?    uint32
| +--rw limit-per-protocol* [protocol-id]
| | {napt44 or nat64 or dst-nat}?
| | +--rw protocol-id          uint8
| | +--rw limit?               uint32
+--rw connection-limits
| | {basic-nat44 or napt44 or nat64}?
| | +--rw limit-per-subscriber? uint32
| | +--rw limit-per-instance    uint32
| | +--rw limit-per-protocol* [protocol-id]
| | | {napt44 or nat64}?
| | | +--rw protocol-id        uint8
| | | +--rw limit?             uint32
+--rw notification-limits
| +--rw notify-interval?        uint32
| | {basic-nat44 or napt44 or nat64}?
| +--rw notify-addresses-usage? percent

```



```

| | {basic-nat44 or napt44 or nat64}?
| +--rw notify-ports-usage?          percent
| | {napt44 or nat64}?
| +--rw notify-subscribers-limit?    uint32
| | {basic-nat44 or napt44 or nat64}?
+--rw logging-enable?                boolean
| {basic-nat44 or napt44 or nat64}?
+--rw mapping-table
| | {basic-nat44 or napt44 or nat64 or clat or dst-nat}?
| +--rw mapping-entry* [index]
| | +--rw index                      uint32
| | +--rw type?                     enumeration
| | +--rw transport-protocol?       uint8
| | +--rw internal-src-address?     inet:ip-prefix
| | +--rw internal-src-port
| | | +--rw start-port-number?     inet:port-number
| | | +--rw end-port-number?       inet:port-number
| | +--rw external-src-address?     inet:ip-prefix
| | +--rw external-src-port
| | | +--rw start-port-number?     inet:port-number
| | | +--rw end-port-number?       inet:port-number
| | +--rw internal-dst-address?     inet:ip-prefix
| | +--rw internal-dst-port
| | | +--rw start-port-number?     inet:port-number
| | | +--rw end-port-number?       inet:port-number
| | +--rw external-dst-address?     inet:ip-prefix
| | +--rw external-dst-port
| | | +--rw start-port-number?     inet:port-number
| | | +--rw end-port-number?       inet:port-number
| | +--rw lifetime?                uint32
+--ro statistics
| +--ro discontinuity-time          yang:date-and-time
+--ro traffic-statistics
| +--ro sent-packets?
| | yang:zero-based-counter64
| +--ro sent-bytes?
| | yang:zero-based-counter64
| +--ro rcvd-packets?
| | yang:zero-based-counter64
| +--ro rcvd-bytes?
| | yang:zero-based-counter64
| +--ro dropped-packets?
| | yang:zero-based-counter64
| +--ro dropped-bytes?
| | yang:zero-based-counter64
| +--ro dropped-fragments?
| | yang:zero-based-counter64
| | {napt44 or nat64}?

```



```

| +--ro dropped-address-limit-packets?
| |   yang:zero-based-counter64
| |   {basic-nat44 or napt44 or nat64}?
| +--ro dropped-address-limit-bytes?
| |   yang:zero-based-counter64
| |   {basic-nat44 or napt44 or nat64}?
| +--ro dropped-address-packets?
| |   yang:zero-based-counter64
| |   {basic-nat44 or napt44 or nat64}?
| +--ro dropped-address-bytes?
| |   yang:zero-based-counter64
| |   {basic-nat44 or napt44 or nat64}?
| +--ro dropped-port-limit-packets?
| |   yang:zero-based-counter64
| |   {napt44 or nat64}?
| +--ro dropped-port-limit-bytes?
| |   yang:zero-based-counter64
| |   {napt44 or nat64}?
| +--ro dropped-port-packets?
| |   yang:zero-based-counter64
| |   {napt44 or nat64}?
| +--ro dropped-port-bytes?
| |   yang:zero-based-counter64
| |   {napt44 or nat64}?
| +--ro dropped-subscriber-limit-packets?
| |   yang:zero-based-counter64
| |   {basic-nat44 or napt44 or nat64}?
| +--ro dropped-subscriber-limit-bytes?
| |   yang:zero-based-counter64
| |   {basic-nat44 or napt44 or nat64}?
+--ro mappings-statistics
| +--ro total-active-subscribers?  yang:gauge32
| |   {basic-nat44 or napt44 or nat64}?
| +--ro total-address-mappings?    yang:gauge32
| |   {basic-nat44 or napt44 or nat64 or clat or dst-nat}?
| +--ro total-port-mappings?       yang:gauge32
| |   {napt44 or nat64}?
| +--ro total-per-protocol* [protocol-id]
| |   {napt44 or nat64}?
| |   +--ro protocol-id    uint8
| |   +--ro total?         yang:gauge32
+--ro pools-stats {basic-nat44 or napt44 or nat64}?
  +--ro addresses-allocated?  yang:gauge32
  +--ro addresses-free?       yang:gauge32
  +--ro ports-stats {napt44 or nat64}?
    +--ro ports-allocated?    yang:gauge32
    +--ro ports-free?         yang:gauge32
  +--ro per-pool-stats* [pool-id]

```



```

        {basic-nat44 or napt44 or nat64}?
+--ro pool-id                uint32
+--ro discontinuity-time     yang:date-and-time
+--ro pool-stats
|   +--ro addresses-allocated? yang:gauge32
|   +--ro addresses-free?      yang:gauge32
+--ro port-stats {napt44 or nat64}?
    +--ro ports-allocated?     yang:gauge32
    +--ro ports-free?          yang:gauge32

```

notifications:

```

+---n nat-pool-event {basic-nat44 or napt44 or nat64}?
|   +--ro id                -> /nat/instances/instance/id
|   +--ro policy-id?
|   |   -> /nat/instances/instance/policy/id
|   +--ro pool-id           leafref
|   +--ro notify-pool-threshold percent
+---n nat-instance-event {basic-nat44 or napt44 or nat64}?
    +--ro id
    |   -> /nat/instances/instance/id
    +--ro notify-subscribers-threshold? uint32
    +--ro notify-addresses-threshold?   percent
    +--ro notify-ports-threshold?       percent

```

3. NAT YANG Module

<CODE BEGINS> file "ietf-nat@2018-02-23.yang"

```

module ietf-nat {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-nat";
  prefix "nat";

  import ietf-inet-types { prefix inet; }
  import ietf-yang-types { prefix yang; }
  import ietf-interfaces { prefix if; }

  organization
    "IETF OPSAWG (Operations and Management Area Working Group)";

  contact

    "WG Web:  <https://datatracker.ietf.org/wg/opsawg/>
    WG List:  <mailto:opsawg@ietf.org>

    Editor:   Mohamed Boucadair
              <mailto:mohamed.boucadair@orange.com>

```


Editor: Senthil Sivakumar
<mailto:ssenthil@cisco.com>

Editor: Christian Jacquenet
<mailto:christian.jacquenet@orange.com>

Editor: Suresh Vinapamula
<mailto:sureshk@juniper.net>

Editor: Qin Wu
<mailto:bill.wu@huawei.com>;

description

"This module is a YANG module for NAT implementations.

NAT44, Network Address and Protocol Translation from IPv6
Clients to IPv4 Servers (NAT64), Customer-side transLATor (CLAT),
Stateless IP/ICMP Translation (SIIT), Explicit Address Mappings
for Stateless IP/ICMP Translation (SIIT EAM), IPv6 Network
Prefix Translation (NPTv6), and Destination NAT are covered.

Copyright (c) 2018 IETF Trust and the persons identified as
authors of the code. All rights reserved.

Redistribution and use in source and binary forms, with or
without modification, is permitted pursuant to, and subject
to the license terms contained in, the Simplified BSD License
set forth in [Section 4.c](#) of the IETF Trust's Legal Provisions
Relating to IETF Documents
(<http://trustee.ietf.org/license-info>).

This version of this YANG module is part of RFC XXXX; see
the RFC itself for full legal notices.";

```
revision 2018-02-23 {
  description
    "Initial revision.";
  reference
    "RFC XXXX: A YANG Module for Network Address Translation
      (NAT) and Network Prefix Translation (NPT)";
}

/*
 * Definitions
 */

typedef percent {
  type uint8 {
```



```
    range "0 .. 100";
  }
  description
    "Percentage";
}

/*
 * Features
 */

feature basic-nat44{
  description
    "Basic NAT44 translation is limited to IP addresses alone.";
  reference
    "RFC 3022: Traditional IP Network Address Translator
      (Traditional NAT)";
}

feature napt44 {
  description
    "Network Address/Port Translator (NAPT): translation is
    extended to include IP addresses and transport identifiers
    (such as a TCP/UDP port or ICMP query ID).

    If the internal IP address is not sufficient to uniquely
    disambiguate NAPT44 mappings, an additional attribute is
    required. For example, that additional attribute may
    be an IPv6 address (a.k.a., DS-Lite) or
    a Layer 2 identifier (a.k.a., Per-Interface NAT)";
  reference
    "RFC 3022: Traditional IP Network Address Translator
      (Traditional NAT)";
}

feature dst-nat {
  description
    "Destination NAT is a translation that acts on the destination
    IP address and/or destination port number. This flavor is
    usually deployed in load balancers or at devices
    in front of public servers.";
}

feature nat64 {
  description
    "NAT64 translation allows IPv6-only clients to contact IPv4
    servers using unicast UDP, TCP, or ICMP. One or more
    public IPv4 addresses assigned to a NAT64 translator are
    shared among several IPv6-only clients.";
```



```
reference
  "RFC 6146: Stateful NAT64: Network Address and Protocol
    Translation from IPv6 Clients to IPv4 Servers";
}

feature siit {
  description
    "The Stateless IP/ICMP Translation Algorithm (SIIT), which
    translates between IPv4 and IPv6 packet headers (including
    ICMP headers).

    In the stateless mode, an IP/ICMP translator converts IPv4
    addresses to IPv6 and vice versa solely based on the
    configuration of the stateless IP/ICMP translator and
    information contained within the packet being translated.

    The translator must support the stateless address mapping
    algorithm defined in RFC6052, which is the default behavior.";
  reference
    "RFC 7915: IP/ICMP Translation Algorithm";
}

feature clat {
  description
    "CLAT is customer-side translator that algorithmically
    translates 1:1 private IPv4 addresses to global IPv6 addresses,
    and vice versa.

    When a dedicated /64 prefix is not available for translation
    from DHCPv6-PD, the CLAT may perform NAT44 for all IPv4 LAN
    packets so that all the LAN-originated IPv4 packets appear
    from a single IPv4 address and are then statelessly translated
    to one interface IPv6 address that is claimed by the CLAT via
    the Neighbor Discovery Protocol (NDP) and defended with
    Duplicate Address Detection.";
  reference
    "RFC 6877: 464XLAT: Combination of Stateful and Stateless
    Translation";
}

feature eam {
  description
    "Explicit Address Mapping (EAM) is a bidirectional coupling
    between an IPv4 Prefix and an IPv6 Prefix.";
  reference
    "RFC 7757: Explicit Address Mappings for Stateless IP/ICMP
    Translation";
}
```



```
feature nptv6 {
  description
    "NPTv6 is a stateless transport-agnostic IPv6-to-IPv6
    prefix translation.";
  reference
    "RFC 6296: IPv6-to-IPv6 Network Prefix Translation";
}

/*
 * Identities
 */

identity nat-type {
  description
    "Base identity for nat type.";
}

identity basic-nat44 {
  base nat:nat-type;
  description
    "Identity for Basic NAT support.";
  reference
    "RFC 3022: Traditional IP Network Address Translator
    (Traditional NAT)";
}

identity napt44 {
  base nat:nat-type;
  description
    "Identity for NAPT support.";
  reference
    "RFC 3022: Traditional IP Network Address Translator
    (Traditional NAT)";
}

identity dst-nat {
  base nat:nat-type;
  description
    "Identity for Destination NAT support.";
}

identity nat64 {
  base nat:nat-type;
  description
    "Identity for NAT64 support.";
  reference
    "RFC 6146: Stateful NAT64: Network Address and Protocol
    Translation from IPv6 Clients to IPv4 Servers";
}
```



```
}

identity siit {
  base nat:nat-type;
  description
    "Identity for SIIT support.";
  reference
    "RFC 7915: IP/ICMP Translation Algorithm";
}

identity clat {
  base nat:nat-type;
  description
    "Identity for CLAT support.";
  reference
    "RFC 6877: 464XLAT: Combination of Stateful and Stateless
      Translation";
}

identity eam {
  base nat:nat-type;
  description
    "Identity for EAM support.";
  reference
    "RFC 7757: Explicit Address Mappings for Stateless IP/ICMP
      Translation";
}

identity nptv6 {
  base nat:nat-type;
  description
    "Identity for NPTv6 support.";
  reference
    "RFC 6296: IPv6-to-IPv6 Network Prefix Translation";
}

/*
 * Grouping
 */

grouping port-number {
  description
    "Individual port or a range of ports.
     When only start-port-number is present,
     it represents a single port number.";

  leaf start-port-number {
    type inet:port-number;
```



```
    description
      "Beginning of the port range.";
    reference
      "Section 3.2.9 of RFC 8045.";
  }

  leaf end-port-number {
    type inet:port-number;

    must ". >= ../start-port-number"
    {
      error-message
        "The end-port-number must be greater than or
        equal to start-port-number.";
    }
    description
      "End of the port range.";
    reference
      "Section 3.2.10 of RFC 8045.";
  }
}

grouping port-set {
  description
    "Indicates a set of ports.

    It may be a simple port range, or use the Port Set ID (PSID)
    algorithm to represent a range of transport layer
    ports which will be used by a NAT.";

  choice port-type {
    default port-range;
    description
      "Port type: port-range or port-set-algo.";
    case port-range {
      uses port-number;
    }

    case port-set-algo {
      leaf psid-offset {
        type uint8 {
          range 0..15;
        }

        description
          "The number of offset bits (a.k.a., 'a' bits).

          Specifies the numeric value for the excluded port
```


range/offset bits.

Allowed values are between 0 and 15 ";

```
reference
  "Section 5.1 of RFC 7597";
}

leaf psid-len {
  type uint8 {
    range 0..15;
  }
  mandatory true;

  description
    "The length of PSID, representing the sharing
    ratio for an IPv4 address.

    (also known as 'k').

    The address-sharing ratio would be 2^k.";
  reference
    "Section 5.1 of RFC 7597";
}

leaf psid {
  type uint16;
  mandatory true;
  description
    "Port Set Identifier (PSID) value, which
    identifies a set of ports algorithmically.";
  reference
    "Section 5.1 of RFC 7597";
}
}
reference
  "Section 7597: Mapping of Address and Port with
  Encapsulation (MAP-E)";
}
}

grouping mapping-entry {
  description
    "NAT mapping entry.
```

If an attribute is not stored in the mapping/session table,
this means the corresponding fields of a packet that
matches this entry is not rewritten by the NAT or this


```
information is not required for NAT filtering purposes.";

leaf index {
  type uint32;
  description
    "A unique identifier of a mapping entry. This identifier can be
    automatically assigned by the NAT instance or be explicitly
    configured.";
}

leaf type {
  type enumeration {
    enum "static" {
      description
        "The mapping entry is explicitly configured
        (e.g., via command-line interface).";
    }

    enum "dynamic-implicit" {
      description
        "This mapping is created implicitly as a side effect
        of processing a packet that requires a new mapping.";
    }

    enum "dynamic-explicit" {
      description
        "This mapping is created as a result of an explicit
        request, e.g., a PCP message.";
    }
  }
  description
    "Indicates the type of a mapping entry. E.g.,
    a mapping can be: static, implicit dynamic
    or explicit dynamic.";
}

leaf transport-protocol {
  type uint8;
  description
    "Upper-layer protocol associated with this mapping.
    Values are taken from the IANA protocol registry.
    For example, this field contains 6 (TCP) for a TCP
    mapping or 17 (UDP) for a UDP mapping.

    If this leaf is not instantiated, then the mapping
    applies to any protocol.";
```



```
}

leaf internal-src-address {
  type inet:ip-prefix;
  description
    "Corresponds to the source IPv4/IPv6 address/prefix
    of the packet received on an internal
    interface.";
}

container internal-src-port {
  description
    "Corresponds to the source port of the packet received
    on an internal interface.

    It is used also to indicate the internal source ICMP
    identifier.

    As a reminder, all the ICMP Query messages contain
    an 'Identifier' field, which is referred to in this
    document as the 'ICMP Identifier'.";

  uses port-number;
}

leaf external-src-address {
  type inet:ip-prefix;
  description
    "Source IP address/prefix of the packet sent on an
    external interface of the NAT.";
}

container external-src-port {
  description
    "Source port of the packet sent on an external
    interface of the NAT.

    It is used also to indicate the external source ICMP
    identifier.";

  uses port-number;
}

leaf internal-dst-address {
  type inet:ip-prefix;
  description
    "Corresponds to the destination IP address/prefix
    of the packet received on an internal interface
```


of the NAT.

For example, some NAT implementations support the translation of both source and destination addresses and ports, sometimes referred to as 'Twice NAT'.
";

}

```
container internal-dst-port {  
  description  
    "Corresponds to the destination port of the  
    IP packet received on the internal interface.
```

```
    It is used also to include the internal  
    destination ICMP identifier.";
```

```
  uses port-number;
```

```
}
```

```
leaf external-dst-address {  
  type inet:ip-prefix;  
  description  
    "Corresponds to the destination IP address/prefix  
    of the packet sent on an external interface  
    of the NAT.";
```

```
}
```

```
container external-dst-port {  
  description  
    "Corresponds to the destination port number of  
    the packet sent on the external interface  
    of the NAT.
```

```
    It is used also to include the external  
    destination ICMP identifier.";
```

```
  uses port-number;
```

```
}
```

```
leaf lifetime {  
  type uint32;  
  units "seconds";  
  description  
    "When specified, it is used to track the connection that is  
    fully-formed (e.g., once the three-way handshake  
    TCP is completed) or the duration for maintaining  
    an explicit mapping alive. The mapping entry will be  
    removed by the NAT instance once this lifetime is expired.
```


When reported in a get operation, the lifetime indicates the remaining validity lifetime.

Static mappings may not be associated with a lifetime. If no lifetime is associated with a static mapping, an explicit action is required to remove that mapping.";

```
    }  
  }  
/*  
 * NAT Module  
 */  
  
container nat {  
  description  
    "NAT module";  
  
  container instances {  
    description  
      "NAT instances";  
  
    list instance {  
      key "id";  
  
      description  
        "A NAT instance. This identifier can be automatically assigned  
        or explicitly configured.";  
  
      leaf id {  
        type uint32;  
        must ". >= 1";  
        description  
          "NAT instance identifier.  
  
          The identifier must be greater than zero.";  
        reference  
          "RFC 7659: Definitions of Managed Objects for Network  
          Address Translators (NATs)";  
      }  
  
      leaf name {  
        type string;  
        description  
          "A name associated with the NAT instance.";  
        reference  
          "RFC 7659: Definitions of Managed Objects for Network  
          Address Translators (NATs)";  
      }  
    }  
  }  
}
```



```
}

leaf enable {
  type boolean;
  description
    "Status of the NAT instance.";
}

container capabilities {
  config false;

  description
    "NAT capabilities";

  leaf-list nat-flavor {
    type identityref {
      base nat-type;
    }
    description
      "Supported translation type(s).";
  }

  leaf-list per-interface-binding {
    type enumeration {
      enum "unsupported" {
        description
          "No capability to associate a NAT binding with
          an extra identifier.";
      }

      enum "layer-2" {
        description
          "The NAT instance is able to associate a mapping with
          a layer-2 identifier.";
      }

      enum "dslite" {
        description
          "The NAT instance is able to associate a mapping with
          an IPv6 address (a.k.a., DS-Lite).";
      }
    }
  }

  description
    "Indicates the capability of a NAT to associate a particular
    NAT session not only with the five tuples used for the
    transport connection on both sides of the NAT but also with
    the internal interface on which the user device is
    connected to the NAT.";
```



```
    reference
      "Section 4 of RFC 6619";
  }

  list transport-protocols {
    key protocol-id;

    description
      "List of supported protocols.";

    leaf protocol-id {
      type uint8;
      mandatory true;
      description
        "Upper-layer protocol associated with this mapping.

        Values are taken from the IANA protocol registry:
        https://www.iana.org/assignments/protocol-numbers/protocol-numbers.xhtml

        For example, this field contains 6 (TCP) for a TCP
        mapping or 17 (UDP) for a UDP mapping.";
    }

    leaf protocol-name {
      type string;
      description
        "The name of the Upper-layer protocol associated
        with this mapping.

        Values are taken from the IANA protocol registry:
        https://www.iana.org/assignments/protocol-numbers/protocol-numbers.xhtml

        For example, TCP, UDP, DCCP, and SCTP.";
    }
  }

  leaf restricted-port-support {
    type boolean;
    description
      "Indicates source port NAT restriction support.";
    reference
      "RFC 7596: Lightweight 4over6: An Extension to
      the Dual-Stack Lite Architecture.";
  }

  leaf static-mapping-support {
```



```
    type boolean;
    description
      "Indicates whether static mappings are supported.";
  }

  leaf port-randomization-support {
    type boolean;
    description
      "Indicates whether port randomization is supported.";
    reference
      "Section 4.2.1 of RFC 4787.";
  }

  leaf port-range-allocation-support {
    type boolean;
    description
      "Indicates whether port range allocation is supported.";
    reference
      "Section 1.1 of RFC 7753.";
  }

  leaf port-preservation-support {
    type boolean;
    description
      "Indicates whether port preservation is supported.";
    reference
      "Section 4.2.1 of RFC 4787.";
  }

  leaf port-parity-preservation-support {
    type boolean;
    description
      "Indicates whether port parity preservation is
        supported.";
    reference
      "Section 8 of RFC 7857.";
  }

  leaf address-roundrobin-support {
    type boolean;
    description
      "Indicates whether address allocation round robin is
        supported.";
  }

  leaf paired-address-pooling-support {
    type boolean;
    description
```



```
        "Indicates whether paired-address-pooling is
        supported";
    reference
        "REQ-2 of RFC 4787.";
}

leaf endpoint-independent-mapping-support {
    type boolean;
    description
        "Indicates whether endpoint-independent-
        mapping is supported.";
    reference
        "Section 4 of RFC 4787.";
}

leaf address-dependent-mapping-support {
    type boolean;
    description
        "Indicates whether address-dependent-mapping is
        supported.";
    reference
        "Section 4 of RFC 4787.";
}

leaf address-and-port-dependent-mapping-support {
    type boolean;
    description
        "Indicates whether address-and-port-dependent-mapping is
        supported.";
    reference
        "Section 4 of RFC 4787.";
}

leaf endpoint-independent-filtering-support {
    type boolean;
    description
        "Indicates whether endpoint-independent-filtering is
        supported.";
    reference
        "Section 5 of RFC 4787.";
}

leaf address-dependent-filtering {
    type boolean;
    description
        "Indicates whether address-dependent-filtering is
        supported.";
    reference
```



```
    "Section 5 of RFC 4787.";
}

leaf address-and-port-dependent-filtering {
    type boolean;
    description
        "Indicates whether address-and-port-dependent is
        supported.";
    reference
        "Section 5 of RFC 4787.";
}

leaf fragment-behavior {
    type enumeration {
        enum "unsupported" {
            description
                "No capability to translate incoming fragments.
                All received fragments are dropped.";
        }

        enum "in-order" {
            description
                "The NAT instance is able to translate fragments only if
                they are received in order. That is, in particular the
                header is in the first packet. Fragments received
                out of order are dropped. ";
        }

        enum "out-of-order" {
            description
                "The NAT instance is able to translate a fragment even
                if it is received out of order.

                This behavior is recommended.";
            reference
                "REQ-14 of RFC 4787";
        }
    }
    description
        "The fragment behavior is the NAT instance's capability to
        translate fragments received on the external interface of
        the NAT.";
}

leaf type {
    type identityref {
        base nat-type;
```



```
    }
    description
      "Specify the translation type. Particularly useful when
       multiple translation flavors are supported.

       If one type is supported by a NAT, this parameter is by
       default set to that type.";
  }

  leaf per-interface-binding {
    type enumeration {
      enum "disabled" {
        description
          "Disable the capability to associate an extra identifier
           with NAT mappings.";
      }

      enum "layer-2" {
        description
          "The NAT instance is able to associate a mapping with
           a layer-2 identifier.";
      }

      enum "dslite" {
        description
          "The NAT instance is able to associate a mapping with
           an IPv6 address (a.k.a., DS-Lite).";
      }
    }
  }
  description
    "A NAT that associates a particular NAT session not only with
     the five tuples used for the transport connection on both
     sides of the NAT but also with the internal interface on
     which the user device is connected to the NAT.

     If supported, this mode of operation should be configurable,
     and it should be disabled by default in general-purpose NAT
     devices.

     If one single per-interface binding behavior is supported by
     a NAT, this parameter is by default set to that behavior.";
  reference
    "Section 4 of RFC 6619";
}

list nat-pass-through {
  if-feature "basic-nat44 or napt44 or dst-nat";
  key id;
```



```
description
  "IP prefix NAT pass through.";

leaf id {
  type uint32;
  description
    "An identifier of the IP prefix pass through.";
}

leaf prefix {
  type inet:ip-prefix;
  mandatory true;
  description
    "The IP addresses that match should not be translated.

    It must be possible to administratively turn
    off translation for specific destination addresses
    and/or ports.";
  reference
    "REQ#6 of RFC 6888.";
}

leaf port {
  type inet:port-number;
  description
    "It must be possible to administratively turn off
    translation for specific destination addresses
    and/or ports.

    If no prefix is defined, the NAT pass through bound
    to a given port applies for any destination address.";
  reference
    "REQ#6 of RFC 6888.";
}
}

list policy {
  key id;
  description
    "NAT parameters for a given instance";

  leaf id {
    type uint32;
    description
      "An identifier of the NAT policy. It must be unique
      within the NAT instance.";
  }
}
```



```
container clat-parameters {
  if-feature clat;
  description
    "CLAT parameters.";

  list clat-ipv6-prefixes {
    key ipv6-prefix;
    description
      "464XLAT double translation treatment is stateless when a
       dedicated /64 is available for translation on the CLAT.
       Otherwise, the CLAT will have both stateful and stateless
       since it requires NAT44 from the LAN to a single IPv4
       address and then stateless translation to a single
       IPv6 address.";
    reference
      "RFC 6877: 464XLAT: Combination of Stateful and Stateless
       Translation";

    leaf ipv6-prefix {
      type inet:ipv6-prefix;
      description
        "An IPv6 prefix used for CLAT.";
    }
  }

  list ipv4-prefixes {
    key ipv4-prefix;
    description
      "Pool of IPv4 addresses used for CLAT.
       192.0.0.0/29 is the IPv4 service continuity prefix.";
    reference
      "RFC 7335: IPv4 Service Continuity Prefix";

    leaf ipv4-prefix {
      type inet:ipv4-prefix;
      description
        "464XLAT double translation treatment is
         stateless when a dedicated /64 is available
         for translation on the CLAT. Otherwise, the
         CLAT will have both stateful and stateless
         since it requires NAT44 from the LAN to
         a single IPv4 address and then stateless
         translation to a single IPv6 address.
         The CLAT performs NAT44 for all IPv4 LAN
         packets so that all the LAN-originated IPv4
         packets appear from a single IPv4 address
         and are then statelessly translated to one
         interface IPv6 address that is claimed by
```


the CLAT.

An IPv4 address from this pool is also provided to an application that makes use of literals.";

reference

"[RFC 6877](#): 464XLAT: Combination of Stateful and Stateless Translation";

```
}  
}  
}
```

```
list nptv6-prefixes {
```

```
  if-feature nptv6;
```

```
  key internal-ipv6-prefix ;
```

```
  description
```

```
    "Provides one or a list of (internal IPv6 prefix,  
    external IPv6 prefix) required for NPTv6.
```

```
    In its simplest form, NPTv6 interconnects two network  
    links, one of which is an 'internal' network link  
    attached to a leaf network within a single  
    administrative domain and the other of which is an  
    'external' network with connectivity to the global  
    Internet.";
```

```
  reference
```

```
    "RFC 6296: IPv6-to-IPv6 Network Prefix Translation";
```

```
  leaf internal-ipv6-prefix {
```

```
    type inet:ipv6-prefix;
```

```
    mandatory true;
```

```
    description
```

```
      "An IPv6 prefix used by an internal interface of NPTv6.";
```

```
    reference
```

```
      "RFC 6296: IPv6-to-IPv6 Network Prefix Translation";
```

```
  }
```

```
  leaf external-ipv6-prefix {
```

```
    type inet:ipv6-prefix;
```

```
    mandatory true;
```

```
    description
```

```
      "An IPv6 prefix used by the external interface of NPTv6.";
```

```
    reference
```

```
      "RFC 6296: IPv6-to-IPv6 Network Prefix Translation";
```

```
  }
```

```
}
```



```
list eam {
  if-feature eam;
  key ipv4-prefix;
  description
    "The Explicit Address Mapping Table, a conceptual
    table in which each row represents an EAM.

    Each EAM describes a mapping between IPv4 and IPv6
    prefixes/addresses.";
  reference
    "Section 3.1 of RFC 7757";

  leaf ipv4-prefix {
    type inet:ipv4-prefix;
    mandatory true;
    description
      "The IPv4 prefix of an EAM.";
    reference
      "Section 3.2 of RFC 7757";
  }

  leaf ipv6-prefix {
    type inet:ipv6-prefix;
    mandatory true;
    description
      "The IPv6 prefix of an EAM.";
    reference
      "Section 3.2 of RFC 7757";
  }
}

list nat64-prefixes {
  if-feature "siit or nat64 or clat";
  key nat64-prefix;
  description
    "Provides one or a list of NAT64 prefixes
    with or without a list of destination IPv4 prefixes.
    It allows mapping IPv4 address ranges to IPv6 prefixes.

    For example:
    192.0.2.0/24 is mapped to 2001:db8:122:300::/56.
    198.51.100.0/24 is mapped to 2001:db8:122::/48.";
  reference
    "Section 5.1 of RFC 7050";

  leaf nat64-prefix {
    type inet:ipv6-prefix;
    mandatory true;
  }
}
```



```
description
  "A NAT64 prefix. Can be Network-Specific Prefix (NSP) or
  Well-Known Prefix (WKP).

  Organizations deploying stateless IPv4/IPv6 translation
  should assign a Network-Specific Prefix to their
  IPv4/IPv6 translation service.

  For stateless NAT64, IPv4-translatable IPv6 addresses
  must use the selected Network-Specific Prefix.

  Both IPv4-translatable IPv6 addresses and IPv4-converted
  IPv6 addresses should use the same prefix.";
reference
  "Sections 3.3 and 3.4 of RFC 6052.";
}

list destination-ipv4-prefix {
  key ipv4-prefix;
  description
    "An IPv4 prefix/address.";

  leaf ipv4-prefix {
    type inet:ipv4-prefix;
    description
      "An IPv4 address/prefix.";
  }
}

leaf stateless-enable {
  type boolean;
  default false;
  description
    "Enable explicitly stateless NAT64.";
}

list external-ip-address-pool {
  if-feature "basic-nat44 or napt44 or nat64";
  key pool-id;

  description
    "Pool of external IP addresses used to service internal
    hosts.

    A pool is a set of IP prefixes.";

  leaf pool-id {
```



```
    type uint32;
    must ". >= 1";
    description
        "An identifier that uniquely identifies the address pool
        within a NAT instance.

        The identifier must be greater than zero.";
    reference
        "RFC 7659: Definitions of Managed Objects for
        Network Address Translators (NATs)";
}

leaf external-ip-pool {
    type inet:ipv4-prefix;
    mandatory true;
    description
        "An IPv4 prefix used for NAT purposes.";
}

container port-set-restrict {
    if-feature "napt44 or nat64";
    description
        "Configures contiguous and non-contiguous port ranges.

        The port set is used to restrict the external source
        port numbers used by the translator.";

    uses port-set;
}

leaf dst-nat-enable {
    if-feature "basic-nat44 or napt44";
    type boolean;
    default false;
    description
        "Enable/Disable destination NAT.

        A NAT44 may be configured to enable Destination
        NAT, too.";
}

list dst-ip-address-pool {
    if-feature dst-nat;
    key pool-id;
    description
        "Pool of IP addresses used for destination NAT.";
```



```
leaf pool-id {
  type uint32;
  description
    "An identifier of the address pool.";
}

leaf dst-in-ip-pool {
  type inet:ip-prefix;
  description
    "Is used to identify an internal destination
    IP prefix/address to be translated.";
}

leaf dst-out-ip-pool {
  type inet:ip-prefix;
  mandatory true;
  description
    "IP address/prefix used for destination NAT.";
}
}

list transport-protocols {
  if-feature "napt44 or nat64 or dst-nat";
  key protocol-id;

  description
    "Configure the transport protocols to be handled by
    the translator.

    TCP and UDP are supported by default.";

  leaf protocol-id {
    type uint8;
    mandatory true;
    description
      "Upper-layer protocol associated with this mapping.

      Values are taken from the IANA protocol registry:
      https://www.iana.org/assignments/protocol-numbers/
      protocol-numbers.xhtml

      For example, this field contains 6 (TCP) for a TCP
      mapping or 17 (UDP) for a UDP mapping.";
  }

  leaf protocol-name {
    type string;
    description
```


"The name of the Upper-layer protocol associated with this mapping.

Values are taken from the IANA protocol registry:
<https://www.iana.org/assignments/protocol-numbers/protocol-numbers.xhtml>

For example, TCP, UDP, DCCP, and SCTP.";

```
}  
}
```

```
leaf subscriber-mask-v6 {  
  type uint8 {  
    range "0 .. 128";  
  }  
}
```

description

"The subscriber mask is an integer that indicates the length of significant bits to be applied on the source IPv6 address (internal side) to unambiguously identify a user device (e.g., CPE).

Subscriber mask is a system-wide configuration parameter that is used to enforce generic per-subscriber policies (e.g., port-quota).

The enforcement of these generic policies does not require the configuration of every subscriber's prefix.

Example: suppose the 2001:db8:100:100::/56 prefix is assigned to a NAT64 serviced CPE. Suppose also that 2001:db8:100:100::1 is the IPv6 address used by the client that resides in that CPE. When the NAT64 receives a packet from this client, it applies the subscriber-mask-v6 (e.g., 56) on the source IPv6 address to compute the associated prefix for this client (2001:db8:100:100::/56). Then, the NAT64 enforces policies based on that prefix (2001:db8:100:100::/56), not on the exact source IPv6 address.";

```
}
```

```
list subscriber-match {  
  if-feature "basic-nat44 or napt44 or dst-nat";  
  key match-id;
```

description


```
    "IP prefix match.
    A subscriber is identified by a subnet.";

leaf match-id {
    type uint32;
    description
        "An identifier of the subscriber match.";
}

leaf subnet {
    type inet:ip-prefix;
    mandatory true;
    description
        "The IP address subnets that match
        should be translated. E.g., all addresses
        that belong to the 192.0.2.0/24 prefix must
        be processed by the NAT.";
}
}

leaf address-allocation-type {
    type enumeration {
        enum "arbitrary" {
            if-feature "basic-nat44 or napt44 or nat64";
            description
                "Arbitrary pooling behavior means that the NAT
                instance may create the new port mapping using any
                address in the pool that has a free port for the
                protocol concerned.";
        }

        enum "roundrobin" {
            if-feature "basic-nat44 or napt44 or nat64";
            description
                "Round robin allocation.";
        }

        enum "paired" {
            if-feature "napt44 or nat64";
            description
                "Paired address pooling informs the NAT
                that all the flows from an internal IP
                address must be assigned the same external
                address. This is the recommended behavior for
                NAPT/NAT64.";
            reference
                "RFC 4787: Network Address Translation (NAT)
                Behavioral Requirements for Unicast UDP";
        }
    }
}
```



```
    }
  }
  description
    "Specifies how external IP addresses are allocated.";
}

leaf port-allocation-type {
  if-feature "napt44 or nat64";
  type enumeration {
    enum "random" {
      description
        "Port randomization is enabled. A NAT port allocation
        scheme should make it hard for attackers to guess
        port numbers";
      reference
        "REQ-15 of RFC 6888";
    }

    enum "port-preservation" {
      description
        "Indicates whether the NAT should preserve the internal
        port number.";
    }

    enum "port-parity-preservation" {
      description
        "Indicates whether the NAT should preserve the port
        parity of the internal port number.";
    }

    enum "port-range-allocation" {
      description
        "Indicates whether the NAT assigns a range of ports
        for an internal host. This scheme allows to minimize
        log volume.";
      reference
        "REQ-14 of RFC 6888";
    }
  }
  description
    "Indicates the type of port allocation.";
}

leaf mapping-type {
  if-feature "napt44 or nat64";
  type enumeration {
    enum "eim" {
      description
```



```
        "endpoint-independent-mapping.";
    reference
        "Section 4 of RFC 4787.";
}

enum "adm" {
    description
        "address-dependent-mapping.";
    reference
        "Section 4 of RFC 4787.";
}

enum "edm" {
    description
        "address-and-port-dependent-mapping.";
    reference
        "Section 4 of RFC 4787.";
}
}
description
    "Indicates the type of a NAT mapping.";
}

leaf filtering-type {
    if-feature "napt44 or nat64";
    type enumeration {
        enum "eif" {
            description
                "endpoint-independent-filtering.";
            reference
                "Section 5 of RFC 4787.";
        }

        enum "adf" {
            description
                "address-dependent-filtering.";
            reference
                "Section 5 of RFC 4787.";
        }

        enum "edf" {
            description
                "address-and-port-dependent-filtering";
            reference
                "Section 5 of RFC 4787.";
        }
    }
}
description
```



```
        "Indicates the type of a NAT filtering.";
    }

    leaf fragment-behavior {
        if-feature "napt44 or nat64";
        type enumeration {
            enum "drop-all" {
                description
                    "All received fragments are dropped.";
            }

            enum "in-order" {
                description
                    "Translate fragments only if they are received
                     in order.";
            }

            enum "out-of-order" {
                description
                    "Translate a fragment even if it is received out
                     of order.

                     This behavior is recommended.";
                reference
                    "REQ-14 of RFC 4787";
            }
        }
        description
            "The fragment behavior instructs the NAT about the
             behavior to follow to translate fragments received
             on the external interface of the NAT.";
    }

    list port-quota {
        if-feature "napt44 or nat64";
        key quota-type;
        description
            "Configures a port quota to be assigned per subscriber.
             It corresponds to the maximum number of ports to be
             used by a subscriber.";

        leaf port-limit {
            type uint16;
            description
                "Configures a port quota to be assigned per subscriber.
                 It corresponds to the maximum number of ports to be
                 used by a subscriber.";
            reference
```



```
    "REQ-4 of RFC 6888.";
  }

  leaf quota-type {
    type uint8;
    description
      "Indicates whether the port quota applies to
       all protocols (0) or to a specific protocol.";
  }
}

container port-set {

  when "../port-allocation-type = 'port-range-allocation'";

  if-feature "napt44 or nat64";
  description
    "Manages port-set assignments.";

  leaf port-set-size {
    type uint16;
    mandatory true;
    description
      "Indicates the size of assigned port sets.";
  }

  leaf port-set-timeout {
    type uint32;
    units "seconds";
    description
      "inactivity timeout for port sets.";
  }
}

container timers {
  if-feature "napt44 or nat64";
  description
    "Configure values of various timeouts.";

  leaf udp-timeout {
    type uint32;
    units "seconds";
    default 300;
    description
      "UDP inactivity timeout. That is the time a mapping
       will stay active without packets traversing the NAT.";
    reference
      "RFC 4787: Network Address Translation (NAT)"
  }
}
```



```
        Behavioral Requirements for Unicast UDP";
    }

    leaf tcp-idle-timeout {
        type uint32;
        units "seconds";
        default 7440;
        description
            "TCP Idle timeout should be 2 hours and 4 minutes.";
        reference
            "RFC 5382: NAT Behavioral Requirements for TCP";
    }

    leaf tcp-trans-open-timeout {
        type uint32;
        units "seconds";
        default 240;
        description
            "The value of the transitory open connection
            idle-timeout.

            A NAT should provide different configurable
            parameters for configuring the open and
            closing idle timeouts.

            To accommodate deployments that consider
            a partially open timeout of 4 minutes as being
            excessive from a security standpoint, a NAT may
            allow the configured timeout to be less than
            4 minutes.

            However, a minimum default transitory connection
            idle-timeout of 4 minutes is recommended.";
        reference
            "Section 2.1 of RFC 7857.";
    }

    leaf tcp-trans-close-timeout {
        type uint32;
        units "seconds";
        default 240;
        description
            "The value of the transitory close connection
            idle-timeout.

            A NAT should provide different configurable
            parameters for configuring the open and
            closing idle timeouts.";
```



```
    reference
      "Section 2.1 of RFC 7857.";
  }

  leaf tcp-in-syn-timeout {
    type uint32;
    units "seconds";
    default 6;
    description
      "A NAT must not respond to an unsolicited
       inbound SYN packet for at least 6 seconds
       after the packet is received.  If during
       this interval the NAT receives and translates
       an outbound SYN for the connection the NAT
       must silently drop the original unsolicited
       inbound SYN packet.";
    reference
      "RFC 5382 NAT Behavioral Requirements for TCP";
  }

  leaf fragment-min-timeout {
    when "../fragment-behavior='out-of-order'";
    type uint32;
    units "seconds";
    default 2;
    description
      "As long as the NAT has available resources,
       the NAT allows the fragments to arrive
       over fragment-min-timeout interval.
       The default value is inspired from RFC6146.";
  }

  leaf icmp-timeout {
    type uint32;
    units "seconds";
    default 60;
    description
      "An ICMP Query session timer must not expire
       in less than 60 seconds.  It is recommended
       that the ICMP Query session timer be made
       configurable";
    reference
      "RFC 5508: NAT Behavioral Requirements for ICMP";
  }

  list per-port-timeout {
    key port-number;
    description
```


"Some NATs are configurable with short timeouts for some ports, e.g., as 10 seconds on port 53 (DNS) and 123 (NTP) and longer timeouts on other ports.";

```
leaf port-number {  
  type inet:port-number;  
  description  
    "A port number.";  
}
```

```
leaf timeout {  
  type uint32;  
  units "seconds";  
  mandatory true;  
  description  
    "Timeout for this port number";  
}  
}
```

```
leaf hold-down-timeout {  
  type uint32;  
  units "seconds";  
  default 120;  
  description  
    "Hold down timer.
```

Ports in the hold down pool are not reassigned until hold-down-timeout expires.

The length of time and the maximum number of ports in this state must be configurable by the administrator.

This is necessary in order to prevent collisions between old and new mappings and sessions. It ensures that all established sessions are broken instead of redirected to a different peer.";

```
reference  
  "REQ#8 of RFC 6888.";
```

```
leaf hold-down-max {  
  type uint32;  
  description  
    "Maximum ports in the Hold down timer pool.
```

Ports in the hold down pool are not reassigned until hold-down-timeout expires.


```

        The length of time and the maximum
        number of ports in this state must be
        configurable by the administrator.
        This is necessary in order
        to prevent collisions between old
        and new mappings and sessions. It ensures
        that all established sessions are broken
        instead of redirected to a different peer.";
    reference
        "REQ#8 of RFC 6888.";
}
}

leaf fragments-limit{
    when "../fragment-behavior='out-of-order'";
    type uint32;
    description
        "Limits the number of out of order fragments that can
        be handled.";
    reference
        "Section 11 of RFC 4787.";
}

list algs {
    key name;
    description
        "ALG-related features.";

    leaf name {
        type string;
        description
            "The name of the ALG.";
    }

    leaf transport-protocol {
        type uint32;
        description
            "The transport protocol used by the ALG
            (e.g., TCP, UDP).";
    }
}

container dst-transport-port {
    uses port-number;
    description
        "The destination port number(s) used by the ALG.
        For example,
        - 21 for the FTP ALG
        - 53 for the DNS ALG.";
}
```



```
    }

    container src-transport-port {
        uses port-number;
        description
            "The source port number(s) used by the ALG.";
    }

    leaf status {
        type boolean;
        description
            "Enable/disable the ALG.";
    }
}

leaf all-algs-enable {
    type boolean;
    description
        "Enable/disable all ALGs.

        When specified, this parameter overrides the one
        that may be indicated, eventually, by the 'status'
        of an individual ALG.";
}

container notify-pool-usage {
    if-feature "basic-nat44 or napt44 or nat64";
    description
        "Notification of pool usage when certain criteria
        are met.";

    leaf pool-id {
        type uint32;
        description
            "Pool-ID for which the notification criteria
            is defined";
    }

    leaf high-threshold {
        type percent;
        description
            "Notification must be generated when the defined high
            threshold is reached.

            For example, if a notification is required when the
            pool utilization reaches 90%, this configuration
            parameter must be set to 90.
```



```
        0% indicates that no high threshold is enabled.";
    }

    leaf low-threshold {
        type percent;
        must ". >= ../high-threshold" {
            error-message
                "The upper port number must be greater than or
                equal to lower port number.";
        }
        description
            "Notification must be generated when the defined low
            threshold is reached.

            For example, if a notification is required when the
            pool utilization reaches below 10%, this
            configuration parameter must be set to 10";
    }

    leaf notify-interval {
        type uint32 {
            range "1 .. 3600";
        }
        units "seconds";
        default '20';
        description
            "Minimum number of seconds between successive
            notifications for this pool.";

        reference
            "RFC 7659: Definitions of Managed Objects for
            Network Address Translators (NATs)";
    }
}

container external-realm {
    description
        "Identifies the external realm of the NAT instance.";

    choice realm-type {
        description
            "Can be an interface, VRF instance, etc.";

        case interface {
            description
                "External interface.";

            leaf external-interface {
```



```
        type if:interface-ref;
        description
            "Name of the external interface.";
    }
}
}
}
}

container mapping-limits {
    if-feature "napt44 or nat64";
    description
        "Information about the configuration parameters that
        limits the mappings based upon various criteria.";

    leaf limit-subscribers {
        type uint32;
        description
            "Maximum number of subscribers that can be serviced
            by a NAT instance.

            A subscriber is identified by a given prefix.";
        reference
            "RFC 7659: Definitions of Managed Objects for
            Network Address Translators (NATs)";
    }

    leaf limit-address-mappings {
        type uint32;
        description
            "Maximum number of address mappings that can be
            handled by a NAT instance.

            When this limit is reached, packets that would
            normally trigger translation, will be dropped.";
        reference
            "RFC 7659: Definitions of Managed Objects
            for Network Address Translators
            (NATs)";
    }

    leaf limit-port-mappings {
        type uint32;
        description
            "Maximum number of port mappings that can be handled
            by a NAT instance.

            When this limit is reached, packets that would
```



```
        normally trigger translation, will be dropped.";
    reference
        "RFC 7659: Definitions of Managed Objects for
        Network Address Translators (NATs)";
}

list limit-per-protocol {
    if-feature "napt44 or nat64 or dst-nat";
    key protocol-id;

    description
        "Configure limits per transport protocol";

    leaf protocol-id {
        type uint8;
        mandatory true;
        description
            "Upper-layer protocol associated with this mapping.

            Values are taken from the IANA protocol registry:
            https://www.iana.org/assignments/protocol-numbers/
            protocol-numbers.xhtml

            For example, this field contains 6 (TCP) for a TCP
            mapping or 17 (UDP) for a UDP mapping.";
    }

    leaf limit {
        type uint32;
        description
            "Maximum number of protocol-specific NAT mappings
            per instance.";
    }
}

}

container connection-limits {
    if-feature "basic-nat44 or napt44 or nat64";
    description
        "Information about the configuration parameters that
        rate limit the translation based upon various criteria.";

    leaf limit-per-subscriber {
        type uint32;
        units "bits/second";
        description
            "Rate-limit the number of new mappings and sessions
            per subscriber.";
    }
}
```



```
    }

    leaf limit-per-instance {
        type uint32;
        units "bits/second";
        mandatory true;
        description
            "Rate-limit the number of new mappings and sessions
             per instance.";
    }

    list limit-per-protocol {
        if-feature "napt44 or nat64";
        key protocol-id;
        description
            "Configure limits per transport protocol";

        leaf protocol-id {
            type uint8;
            mandatory true;
            description
                "Upper-layer protocol associated with this mapping.

                Values are taken from the IANA protocol registry:
                https://www.iana.org/assignments/protocol-numbers/
                protocol-numbers.xhtml

                For example, this field contains 6 (TCP) for a TCP
                mapping or 17 (UDP) for a UDP mapping.";
        }

        leaf limit {
            type uint32;
            description
                "Rate-limit the number of protocol-specific mappings
                 and sessions per instance.";
        }
    }
}

container notification-limits {
    description "Sets notification limits.";

    leaf notify-interval {
        if-feature "basic-nat44 or napt44 or nat64";
        type uint32 {
            range "1 .. 3600";
        }
    }
}
```



```
    units "seconds";
    default '10';
    description
        "Minimum number of seconds between successive
         notifications for this NAT instance.";
    reference
        "RFC 7659: Definitions of Managed Objects
         for Network Address Translators (NATs)";
}

leaf notify-addresses-usage {
    if-feature "basic-nat44 or napt44 or nat64";
    type percent;
    description
        "Notification of address mappings usage over
         the whole NAT instance.

         Notification must be generated when the defined
         threshold is reached.

         For example, if a notification is required when
         the address mappings utilization reaches 90%,
         this configuration parameter must be set
         to 90.";
}

leaf notify-ports-usage {
    if-feature "napt44 or nat64";
    type percent;
    description
        "Notification of port mappings usage over the
         whole NAT instance.

         Notification must be generated when the defined
         threshold is reached.

         For example, if a notification is required when
         the port mappings utilization reaches 90%, this
         configuration parameter must be set to 90.";
}

leaf notify-subscribers-limit {
    if-feature "basic-nat44 or napt44 or nat64";
    type uint32;
    description
        "Notification of active subscribers per NAT
         instance.
```



```
        Notification must be generated when the defined
        threshold is reached.";
    }
}

leaf logging-enable {
    if-feature "basic-nat44 or napt44 or nat64";
    type boolean;
    description
        "Enable logging features.";
    reference
        "Section 2.3 of RFC 6908 and REQ-12 of RFC 6888.";
}

container mapping-table {
    if-feature "basic-nat44 or napt44 " +
        "or nat64 or clat or dst-nat";
    description
        "NAT mapping table. Applicable for functions which maintain
        static and/or dynamic mappings, such as NAT44, Destination
        NAT, NAT64, or CLAT.";

    list mapping-entry {
        key "index";
        description "NAT mapping entry.";
        uses mapping-entry;
    }
}

container statistics {
    config false;

    description
        "Statistics related to the NAT instance.";

    leaf discontinuity-time {
        type yang:date-and-time;
        mandatory true;
        description
            "The time on the most recent occasion at which the NAT
            instance suffered a discontinuity. This must be
            initialized when the NAT instance is configured
            or rebooted.";
    }

    container traffic-statistics {
        description
            "Generic traffic statistics.";
    }
}
```



```
leaf sent-packets {
  type yang:zero-based-counter64;
  description
    "Number of packets sent.";
}

leaf sent-bytes {
  type yang:zero-based-counter64;
  units 'bytes';
  description
    "Counter for sent traffic in bytes.";
}

leaf rcvd-packets {
  type yang:zero-based-counter64;
  description
    "Number of received packets.";
}

leaf rcvd-bytes {
  type yang:zero-based-counter64;
  units 'bytes';
  description
    "Counter for received traffic in bytes.";
}

leaf dropped-packets {
  type yang:zero-based-counter64;
  description
    "Number of dropped packets.";
}

leaf dropped-bytes {
  type yang:zero-based-counter64;
  units 'bytes';
  description
    "Counter for dropped traffic in bytes.";
}

leaf dropped-fragments {
  if-feature "napt44 or nat64";
  type yang:zero-based-counter64;
  description
    "Number of dropped fragments on the external realm.";
}

leaf dropped-address-limit-packets {
  if-feature "basic-nat44 or napt44 or nat64";
```



```
    type yang:zero-based-counter64;
    description
      "Number of dropped packets because an address limit
        is reached.";
  }

  leaf dropped-address-limit-bytes {
    if-feature "basic-nat44 or napt44 or nat64";
    type yang:zero-based-counter64;
    units 'bytes';
    description
      "Counter of dropped packets because an address limit
        is reached, in bytes.";
  }

  leaf dropped-address-packets {
    if-feature "basic-nat44 or napt44 or nat64";
    type yang:zero-based-counter64;
    description
      "Number of dropped packets because no address is
        available for allocation.";
  }

  leaf dropped-address-bytes {
    if-feature "basic-nat44 or napt44 or nat64";
    type yang:zero-based-counter64;
    units 'bytes';
    description
      "Counter of dropped packets because no address is
        available for allocation, in bytes.";
  }

  leaf dropped-port-limit-packets {
    if-feature "napt44 or nat64";
    type yang:zero-based-counter64;
    description
      "Number of dropped packets because a port limit
        is reached.";
  }

  leaf dropped-port-limit-bytes {
    if-feature "napt44 or nat64";
    type yang:zero-based-counter64;
    units 'bytes';
    description
      "Counter of dropped packets because a port limit
        is reached, in bytes.";
  }
}
```



```
leaf dropped-port-packets {
  if-feature "napt44 or nat64";
  type yang:zero-based-counter64;
  description
    "Number of dropped packets because no port is
    available for allocation.";
}

leaf dropped-port-bytes {
  if-feature "napt44 or nat64";
  type yang:zero-based-counter64;
  units 'bytes';
  description
    "Counter of dropped packets because no port is
    available for allocation, in bytes.";
}

leaf dropped-subscriber-limit-packets {
  if-feature "basic-nat44 or napt44 or nat64";
  type yang:zero-based-counter64;
  description
    "Number of dropped packets because the subscriber
    limit per instance is reached.";
}

leaf dropped-subscriber-limit-bytes {
  if-feature "basic-nat44 or napt44 or nat64";
  type yang:zero-based-counter64;
  units 'bytes';
  description
    "Counter of dropped packets because the subscriber
    limit per instance is reached, in bytes.";
}
}

container mappings-statistics {
  description
    "Mappings statistics.";

  leaf total-active-subscribers {
    if-feature "basic-nat44 or napt44 or nat64";
    type yang:gauge32;
    description
      "Total number of active subscribers (that is,
      subscribers for which the NAT maintains active
      mappings.

      A subscriber is identified by a subnet,
```



```
        subscriber-mask, etc.";
    }

    leaf total-address-mappings {
        if-feature "basic-nat44 or napt44 " +
            "or nat64 or clat or dst-nat";
        type yang:gauge32;
        description
            "Total number of address mappings present at a given
            time. It includes both static and dynamic mappings.";
        reference
            "Section 3.3.8 of RFC 7659";
    }

    leaf total-port-mappings {
        if-feature "napt44 or nat64";
        type yang:gauge32;
        description
            "Total number of NAT port mappings present at
            a given time. It includes both static and dynamic
            mappings.";
        reference
            "Section 3.3.9 of RFC 7659";
    }

    list total-per-protocol {
        if-feature "napt44 or nat64";
        key protocol-id;
        description
            "Total mappings for each enabled/supported protocol.";

        leaf protocol-id {
            type uint8;
            mandatory true;
            description
                "Upper-layer protocol associated with this mapping.
                For example, this field contains 6 (TCP) for a TCP
                mapping or 17 (UDP) for a UDP mapping.";
        }

        leaf total {
            type yang:gauge32;
            description
                "Total number of a protocol-specific mappings present
                at a given time. The protocol is identified by
                protocol-id.";
        }
    }
}
```



```
}

container pools-stats {
  if-feature "basic-nat44 or napt44 or nat64";
  description
    "Statistics related to address/prefix pools
     usage";

  leaf addresses-allocated {
    type yang:gauge32;
    description
      "Number of all allocated addresses.";
  }

  leaf addresses-free {
    type yang:gauge32;
    description
      "Number of unallocated addresses of all pools at
       a given time. The sum of unallocated and allocated
       addresses is the total number of addresses of
       the pools.";
  }

  container ports-stats {
    if-feature "napt44 or nat64";

    description
      "Statistics related to port numbers usage.";

    leaf ports-allocated {
      type yang:gauge32;
      description
        "Number of allocated ports from all pools.";
    }

    leaf ports-free {
      type yang:gauge32;
      description
        "Number of unallocated addresses from all pools.";
    }
  }
}

list per-pool-stats {
  if-feature "basic-nat44 or napt44 or nat64";
  key "pool-id";
  description
    "Statistics related to address/prefix pool usage";
```



```
leaf pool-id {
  type uint32;
  description
    "Unique Identifier that represents a pool of
    addresses/prefixes.";
}

leaf discontinuity-time {
  type yang:date-and-time;
  mandatory true;
  description
    "The time on the most recent occasion at which this
    pool counters suffered a discontinuity. This must
    be initialized when the address pool is
    configured.";
}

container pool-stats {
  description
    "Statistics related to address/prefix pool usage";

  leaf addresses-allocated {
    type yang:gauge32;
    description
      "Number of allocated addresses from this pool.";
  }

  leaf addresses-free {
    type yang:gauge32;
    description
      "Number of unallocated addresses in this pool.";
  }
}

container port-stats {
  if-feature "napt44 or nat64";
  description
    "Statistics related to port numbers usage.";

  leaf ports-allocated {
    type yang:gauge32;
    description
      "Number of allocated ports from this pool.";
  }

  leaf ports-free {
    type yang:gauge32;
    description
```



```
        "Number of unallocated addresses from this pool.";
    }
}
}
}
}
}
}
}
}

/*
 * Notifications
 */

notification nat-pool-event {
    if-feature "basic-nat44 or napt44 or nat64";
    description
        "Notifications must be generated when the defined high/low
        threshold is reached. Related configuration parameters
        must be provided to trigger the notifications.";

    leaf id {
        type leafref {
            path "/nat/instances/instance/id";
        }
        mandatory true;
        description
            "NAT instance Identifier.";
    }

    leaf policy-id {
        type leafref {
            path "/nat/instances/instance/policy/id";
        }

        description
            "Policy Identifier.";
    }

    leaf pool-id {
        type leafref {
            path "/nat/instances/instance/policy/" +
                "external-ip-address-pool/pool-id";
        }
        mandatory true;
        description
            "Pool Identifier.";
    }
}
```



```
leaf notify-pool-threshold {
  type percent;
  mandatory true;
  description
    "A threshold (high-threshold or low-threshold) has
    been fired.";
}
}

notification nat-instance-event {
  if-feature "basic-nat44 or napt44 or nat64";
  description
    "Notifications must be generated when notify-addresses-usage
    and/or notify-ports-usage threshold are reached.";

  leaf id {
    type leafref {
      path "/nat/instances/instance/id";
    }
    mandatory true;
    description
      "NAT instance Identifier.";
  }

  leaf notify-subscribers-threshold {
    type uint32;
    description
      "The notify-subscribers-limit threshold has been fired.";
  }

  leaf notify-addresses-threshold {
    type percent;
    description
      "The notify-addresses-usage threshold has been fired.";
  }

  leaf notify-ports-threshold {
    type percent;
    description
      "The notify-ports-usage threshold has been fired.";
  }
}
}
<CODE ENDS>
```


4. Security Considerations

Security considerations related to address and prefix translation are discussed in [RFC6888], [RFC6146], [RFC6877], [RFC6296], and [RFC7757].

The YANG module defined in this document is designed to be accessed via network management protocols such as NETCONF [RFC6241] or RESTCONF [RFC8040]. The lowest NETCONF layer is the secure transport layer, and the mandatory-to-implement secure transport is Secure Shell (SSH) [RFC6242]. The lowest RESTCONF layer is HTTPS, and the mandatory-to-implement secure transport is TLS [RFC5246].

The NETCONF access control model [RFC6536] provides the means to restrict access for particular NETCONF or RESTCONF users to a preconfigured subset of all available NETCONF or RESTCONF protocol operations and content.

All data nodes defined in the YANG module which can be created, modified and deleted (i.e., config true, which is the default) are considered sensitive. Write operations (e.g., edit-config) applied to these data nodes without proper protection can negatively affect network operations. The NAT YANG module allows to set parameters to prevent a user from aggressively using NAT resources (port-quota), rate-limit connections as a guard against Denial-of-Service, or to enable notifications so that appropriate measures are enforced to anticipate traffic drops. Nevertheless, an attacker who is able to access to the NAT can undertake various attacks, such as:

- o Set a high or low resource limit to cause a DoS attack:
 - * /nat/instances/instance/policy/port-quota
 - * /nat/instances/instance/policy/fragments-limit
 - * /nat/instances/instance/mapping-limits
 - * /nat/instances/instance/connection-limits
- o Set a low notification threshold to cause useless notifications to be generated:
 - * /nat/instances/instance/policy/notify-pool-usage/high-threshold
 - * /nat/instances/instance/notification-limits/notify-addresses-usage
 - * /nat/instances/instance/notification-limits/notify-ports-usage

- * /nat/instances/instance/notification-limits/notify-subscribers-limit
- o Set an arbitrarily high threshold, which may lead to the deactivation of notifications:
 - * /nat/instances/instance/policy/notify-pool-usage/high-threshold
 - * /nat/instances/instance/notification-limits/notify-addresses-usage
 - * /nat/instances/instance/notification-limits/notify-ports-usage
 - * /nat/instances/instance/notification-limits/notify-subscribers-limit
- o Set a low notification interval and a low notification threshold to induce useless notifications to be generated:
 - * /nat/instances/instance/policy/notify-pool-usage/notify-interval
 - * /nat/instances/instance/notification-limits/notify-interval
- o Access to privacy data maintained in the mapping table. Such data can be misused to track the activity of a host:
 - * /nat/instances/instance/mapping-table

5. IANA Considerations

This document requests IANA to register the following URI in the "IETF XML Registry" [[RFC3688](#)]:

URI: urn:ietf:params:xml:ns:yang:ietf-nat
Registrant Contact: The IESG.
XML: N/A; the requested URI is an XML namespace.

This document requests IANA to register the following YANG module in the "YANG Module Names" registry [[RFC7950](#)].

name: ietf-nat
namespace: urn:ietf:params:xml:ns:yang:ietf-nat
prefix: nat
reference: RFC XXXX

6. Acknowledgements

Many thanks to Dan Wing, Tianran Zhou, and Tom Petch for the review.

Thanks to Juergen Schoenwaelder for the comments on the YANG structure and the suggestion to use NMDA. Mahesh Jethanandani provided useful comments.

Thanks to Lee Howard and Jordi Palet for the CLAT comments, Fred Baker for the NPTv6 comments, Tore Anderson for EAM SIIT review, and Kristian Posic for the CGN review.

Special thanks to Maros Marsalek and Marek Gradzki for sharing their comments based on the FD.io implementation of an earlier version of this module.

Rajiv Asati suggested to clarify how the module applies for both stateless and stateful NAT64.

Juergen Schoenwaelder provided an early yandgoctors review. Many thanks to him.

Thanks to Roni Even, Mach Chen, and Tim Chown for the directorates review. Igor Ryzhov identified a nit in one example.

7. References

7.1. Normative References

- [RFC3688] Mealling, M., "The IETF XML Registry", [BCP 81](#), [RFC 3688](#), DOI 10.17487/RFC3688, January 2004, <<https://www.rfc-editor.org/info/rfc3688>>.
- [RFC4787] Audet, F., Ed. and C. Jennings, "Network Address Translation (NAT) Behavioral Requirements for Unicast UDP", [BCP 127](#), [RFC 4787](#), DOI 10.17487/RFC4787, January 2007, <<https://www.rfc-editor.org/info/rfc4787>>.
- [RFC5246] Dierks, T. and E. Rescorla, "The Transport Layer Security (TLS) Protocol Version 1.2", [RFC 5246](#), DOI 10.17487/RFC5246, August 2008, <<https://www.rfc-editor.org/info/rfc5246>>.
- [RFC5382] Guha, S., Ed., Biswas, K., Ford, B., Sivakumar, S., and P. Srisuresh, "NAT Behavioral Requirements for TCP", [BCP 142](#), [RFC 5382](#), DOI 10.17487/RFC5382, October 2008, <<https://www.rfc-editor.org/info/rfc5382>>.

- [RFC5508] Srisuresh, P., Ford, B., Sivakumar, S., and S. Guha, "NAT Behavioral Requirements for ICMP", [BCP 148](#), [RFC 5508](#), DOI 10.17487/RFC5508, April 2009, <<https://www.rfc-editor.org/info/rfc5508>>.
- [RFC6052] Bao, C., Huitema, C., Bagnulo, M., Boucadair, M., and X. Li, "IPv6 Addressing of IPv4/IPv6 Translators", [RFC 6052](#), DOI 10.17487/RFC6052, October 2010, <<https://www.rfc-editor.org/info/rfc6052>>.
- [RFC6146] Bagnulo, M., Matthews, P., and I. van Beijnum, "Stateful NAT64: Network Address and Protocol Translation from IPv6 Clients to IPv4 Servers", [RFC 6146](#), DOI 10.17487/RFC6146, April 2011, <<https://www.rfc-editor.org/info/rfc6146>>.
- [RFC6241] Enns, R., Ed., Bjorklund, M., Ed., Schoenwaelder, J., Ed., and A. Bierman, Ed., "Network Configuration Protocol (NETCONF)", [RFC 6241](#), DOI 10.17487/RFC6241, June 2011, <<https://www.rfc-editor.org/info/rfc6241>>.
- [RFC6242] Wasserman, M., "Using the NETCONF Protocol over Secure Shell (SSH)", [RFC 6242](#), DOI 10.17487/RFC6242, June 2011, <<https://www.rfc-editor.org/info/rfc6242>>.
- [RFC6296] Wasserman, M. and F. Baker, "IPv6-to-IPv6 Network Prefix Translation", [RFC 6296](#), DOI 10.17487/RFC6296, June 2011, <<https://www.rfc-editor.org/info/rfc6296>>.
- [RFC6536] Bierman, A. and M. Bjorklund, "Network Configuration Protocol (NETCONF) Access Control Model", [RFC 6536](#), DOI 10.17487/RFC6536, March 2012, <<https://www.rfc-editor.org/info/rfc6536>>.
- [RFC6619] Arkko, J., Eggert, L., and M. Townsley, "Scalable Operation of Address Translators with Per-Interface Bindings", [RFC 6619](#), DOI 10.17487/RFC6619, June 2012, <<https://www.rfc-editor.org/info/rfc6619>>.
- [RFC6877] Mawatari, M., Kawashima, M., and C. Byrne, "464XLAT: Combination of Stateful and Stateless Translation", [RFC 6877](#), DOI 10.17487/RFC6877, April 2013, <<https://www.rfc-editor.org/info/rfc6877>>.
- [RFC6888] Perreault, S., Ed., Yamagata, I., Miyakawa, S., Nakagawa, A., and H. Ashida, "Common Requirements for Carrier-Grade NATs (CGNs)", [BCP 127](#), [RFC 6888](#), DOI 10.17487/RFC6888, April 2013, <<https://www.rfc-editor.org/info/rfc6888>>.

- [RFC7596] Cui, Y., Sun, Q., Boucadair, M., Tsou, T., Lee, Y., and I. Farrer, "Lightweight 4over6: An Extension to the Dual-Stack Lite Architecture", [RFC 7596](#), DOI 10.17487/RFC7596, July 2015, <<https://www.rfc-editor.org/info/rfc7596>>.
- [RFC7597] Troan, O., Ed., Dec, W., Li, X., Bao, C., Matsushima, S., Murakami, T., and T. Taylor, Ed., "Mapping of Address and Port with Encapsulation (MAP-E)", [RFC 7597](#), DOI 10.17487/RFC7597, July 2015, <<https://www.rfc-editor.org/info/rfc7597>>.
- [RFC7757] Anderson, T. and A. Leiva Popper, "Explicit Address Mappings for Stateless IP/ICMP Translation", [RFC 7757](#), DOI 10.17487/RFC7757, February 2016, <<https://www.rfc-editor.org/info/rfc7757>>.
- [RFC7857] Penno, R., Perreault, S., Boucadair, M., Ed., Sivakumar, S., and K. Naito, "Updates to Network Address Translation (NAT) Behavioral Requirements", [BCP 127](#), [RFC 7857](#), DOI 10.17487/RFC7857, April 2016, <<https://www.rfc-editor.org/info/rfc7857>>.
- [RFC7915] Bao, C., Li, X., Baker, F., Anderson, T., and F. Gont, "IP/ICMP Translation Algorithm", [RFC 7915](#), DOI 10.17487/RFC7915, June 2016, <<https://www.rfc-editor.org/info/rfc7915>>.
- [RFC7950] Bjorklund, M., Ed., "The YANG 1.1 Data Modeling Language", [RFC 7950](#), DOI 10.17487/RFC7950, August 2016, <<https://www.rfc-editor.org/info/rfc7950>>.
- [RFC8040] Bierman, A., Bjorklund, M., and K. Watsen, "RESTCONF Protocol", [RFC 8040](#), DOI 10.17487/RFC8040, January 2017, <<https://www.rfc-editor.org/info/rfc8040>>.

7.2. Informative References

- [I-D.boucadair-pcp-yang]
Boucadair, M., Jacquenet, C., Sivakumar, S., and S. Vinapamula, "YANG Modules for the Port Control Protocol (PCP)", [draft-boucadair-pcp-yang-05](#) (work in progress), October 2017.
- [I-D.ietf-netmod-yang-tree-diagrams]
Bjorklund, M. and L. Berger, "YANG Tree Diagrams", [draft-ietf-netmod-yang-tree-diagrams-06](#) (work in progress), February 2018.

[I-D.ietf-softwire-dslite-yang]

Boucadair, M., Jacquenet, C., and S. Sivakumar, "A YANG Data Module for Dual-Stack Lite (DS-Lite)", [draft-ietf-softwire-dslite-yang-14](#) (work in progress), January 2018.

[I-D.ietf-tsvwg-natsupp]

Stewart, R., Tuexen, M., and I. Ruengeler, "Stream Control Transmission Protocol (SCTP) Network Address Translation Support", [draft-ietf-tsvwg-natsupp-11](#) (work in progress), July 2017.

[RFC2663] Srisuresh, P. and M. Holdrege, "IP Network Address Translator (NAT) Terminology and Considerations", [RFC 2663](#), DOI 10.17487/RFC2663, August 1999, <<https://www.rfc-editor.org/info/rfc2663>>.

[RFC3022] Srisuresh, P. and K. Egevang, "Traditional IP Network Address Translator (Traditional NAT)", [RFC 3022](#), DOI 10.17487/RFC3022, January 2001, <<https://www.rfc-editor.org/info/rfc3022>>.

[RFC5597] Denis-Courmont, R., "Network Address Translation (NAT) Behavioral Requirements for the Datagram Congestion Control Protocol", [BCP 150](#), [RFC 5597](#), DOI 10.17487/RFC5597, September 2009, <<https://www.rfc-editor.org/info/rfc5597>>.

[RFC6269] Ford, M., Ed., Boucadair, M., Durand, A., Levis, P., and P. Roberts, "Issues with IP Address Sharing", [RFC 6269](#), DOI 10.17487/RFC6269, June 2011, <<https://www.rfc-editor.org/info/rfc6269>>.

[RFC6736] Brockners, F., Bhandari, S., Singh, V., and V. Fajardo, "Diameter Network Address and Port Translation Control Application", [RFC 6736](#), DOI 10.17487/RFC6736, October 2012, <<https://www.rfc-editor.org/info/rfc6736>>.

[RFC6887] Wing, D., Ed., Cheshire, S., Boucadair, M., Penno, R., and P. Selkirk, "Port Control Protocol (PCP)", [RFC 6887](#), DOI 10.17487/RFC6887, April 2013, <<https://www.rfc-editor.org/info/rfc6887>>.

[RFC6908] Lee, Y., Maglione, R., Williams, C., Jacquenet, C., and M. Boucadair, "Deployment Considerations for Dual-Stack Lite", [RFC 6908](#), DOI 10.17487/RFC6908, March 2013, <<https://www.rfc-editor.org/info/rfc6908>>.

- [RFC7050] Savolainen, T., Korhonen, J., and D. Wing, "Discovery of the IPv6 Prefix Used for IPv6 Address Synthesis", [RFC 7050](#), DOI 10.17487/RFC7050, November 2013, <<https://www.rfc-editor.org/info/rfc7050>>.
- [RFC7289] Kuarsingh, V., Ed. and J. Cianfarani, "Carrier-Grade NAT (CGN) Deployment with BGP/MPLS IP VPNs", [RFC 7289](#), DOI 10.17487/RFC7289, June 2014, <<https://www.rfc-editor.org/info/rfc7289>>.
- [RFC7335] Byrne, C., "IPv4 Service Continuity Prefix", [RFC 7335](#), DOI 10.17487/RFC7335, August 2014, <<https://www.rfc-editor.org/info/rfc7335>>.
- [RFC7659] Perreault, S., Tsou, T., Sivakumar, S., and T. Taylor, "Definitions of Managed Objects for Network Address Translators (NATs)", [RFC 7659](#), DOI 10.17487/RFC7659, October 2015, <<https://www.rfc-editor.org/info/rfc7659>>.
- [RFC7753] Sun, Q., Boucadair, M., Sivakumar, S., Zhou, C., Tsou, T., and S. Perreault, "Port Control Protocol (PCP) Extension for Port-Set Allocation", [RFC 7753](#), DOI 10.17487/RFC7753, February 2016, <<https://www.rfc-editor.org/info/rfc7753>>.
- [RFC8045] Cheng, D., Korhonen, J., Boucadair, M., and S. Sivakumar, "RADIUS Extensions for IP Port Configuration and Reporting", [RFC 8045](#), DOI 10.17487/RFC8045, January 2017, <<https://www.rfc-editor.org/info/rfc8045>>.

[Appendix A](#). Sample Examples

This section provides a non-exhaustive set of examples to illustrate the use of the NAT YANG module.

[A.1](#). Traditional NAT44

Traditional NAT44 is a Basic NAT44 or NAPT that is used to share the same IPv4 address among hosts that are owned by the same subscriber. This is typically the NAT that is embedded in CPE devices.

This NAT is usually provided with one single external IPv4 address; disambiguating connections is achieved by rewriting the source port number. The XML snippet to configure the external IPv4 address in such case together with a mapping entry is depicted below:


```
<instances>
  <instance>
    <id>1</id>
    <name>NAT_Subscriber_A</name>
    ....
    <external-ip-address-pool>
      <pool-id>1</pool-id>
      <external-ip-pool>
        198.51.100.1/32
      </external-ip-pool>
    </external-ip-address-pool>
    ....
    <mapping-table>
      ....
      <external-src-address>
        198.51.100.1/32
      </external-src-address>
      ....
    </mapping-table>
  </instance>
</instances>
```

The following shows the XML excerpt depicting a dynamic UDP mapping entry maintained by a traditional NAPT44. In reference to this example, the UDP packet received with a source IPv4 address (192.0.2.1) and source port number (1568) is translated into a UDP packet having a source IPv4 address (198.51.100.1) and source port (15000). The remaining lifetime of this mapping is 300 seconds.


```
<mapping-entry>
  <index>15</index>
  <type>
    dynamic-explicit
  </type>
  <transport-protocol>
    17
  </transport-protocol>
  <internal-src-address>
    192.0.2.1/32
  </internal-src-address>
  <internal-src-port>
    <start-port-number>
      1568
    </start-port-number>
  </internal-src-port>
  <external-src-address>
    198.51.100.1/32
  </external-src-address>
  <external-src-port>
    <start-port-number>
      15000
    </start-port-number>
  </external-src-port>
  <lifetime>
    300
  </lifetime>
</mapping-entry>
```

[A.2.](#) Carrier Grade NAT (CGN)

The following XML snippet shows the example of the capabilities supported by a CGN as retrieved using NETCONF.

```
<capabilities
  <nat-flavor>napt44</nat-flavor>
  <transport-protocols>
    <protocol-id>1</protocol-id>
  </transport-protocols>
  <transport-protocols>
    <protocol-id>6</protocol-id>
  </transport-protocols>
  <transport-protocols>
    <protocol-id>17</protocol-id>
  </transport-protocols>
  <restricted-port-support>
    false
  </restricted-port-support>
```



```
<static-mapping-support>
  true
</static-mapping-support>
<port-randomization-support>
  true
</port-randomization-support>
<port-range-allocation-support>
  true
</port-range-allocation-support>
<port-preservation-suport>
  true
</port-preservation-suport>
<port-parity-preservation-support>
  false
</port-parity-preservation-support>
<address-roundrobin-support>
  true
</address-roundrobin-support>
<paired-address-pooling-support>
  true
</paired-address-pooling-support>
<endpoint-independent-mapping-support>
  true
</endpoint-independent-mapping-support>
<address-dependent-mapping-support>
  true
</address-dependent-mapping-support>
<address-and-port-dependent-mapping-support>
  true
</address-and-port-dependent-mapping-support>
<endpoint-independent-filtering-support>
  true
</endpoint-independent-filtering-support>
<address-dependent-filtering>
  true
</address-dependent-filtering>
<address-and-port-dependent-filtering>
  true
</address-and-port-dependent-filtering>
</capabilities>
```

The following XML snippet shows the example of a CGN that is provisioned with one contiguous pool of external IPv4 addresses (198.51.100.0/24). Further, the CGN is instructed to limit the number of allocated ports per subscriber to 1024. Ports can be allocated by the CGN by assigning ranges of 256 ports (that is, a subscriber can be allocated up to four port ranges of 256 ports each).


```
<instances>
  <instance>
    <id>1</id>
    <name>myCGN</name>
    ....
    <external-ip-address-pool>
      <pool-id>1</pool-id>
      <external-ip-pool>
        198.51.100.0/24
      </external-ip-pool>
    </external-ip-address-pool>
    <port-quota>
      <port-limit>
        1024
      </port-limit>
      <quota-type >
        all
      </quota-type >
    </port-quota>
    <port-allocation-type>
      port-range-allocation
    </port-allocation-type>
    <port-set>
      <port-set-size>
        256
      </port-set-size>
    </port-set>
    ....
  </instance>
</instances>
```

An administrator may decide to allocate one single port range per subscriber (e.g., port range of 1024 ports) as shown below:


```
<instances>
  <instance>
    <id>1</id>
    <name>myCGN</name>
    ....
    <external-ip-address-pool>
      <pool-id>1</pool-id>
      <external-ip-pool>
        198.51.100.0/24
      </external-ip-pool>
    </external-ip-address-pool>
    <port-quota>
      <port-limit>
        1024
      </port-limit>
      <quota-type >
        all
      </quota-type >
    </port-quota>
    <port-allocation-type>
      port-range-allocation
    </port-allocation-type>
    <port-set>
      <port-set-size>
        1024
      </port-set-size>
    </port-set>
    ....
  </instance>
</instances>
```

A.3. CGN Pass-Through

Figure 1 illustrates an example of the CGN pass-through feature.

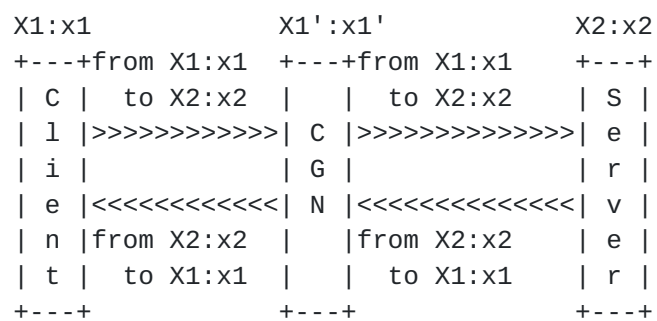


Figure 1: CGN Pass-Through

For example, in order to disable NAT for communications issued by the client (192.0.2.1), the following configuration parameter must be set:

```
<nat-pass-through>
  ...
  <prefix>192.0.2.1/32</prefix>
  ...
</nat-pass-through>
```

[A.4.](#) NAT64

Let's consider the example of a NAT64 that should use 2001:db8:122:300::/56 to perform IPv6 address synthesis [[RFC6052](#)]. The XML snippet to configure the NAT64 prefix in such case is depicted below:

```
<nat64-prefixes>
  <nat64-prefix>
    2001:db8:122:300::/56
  </nat64-prefix>
</nat64-prefixes>
```

Let's now consider the example of a NAT64 that should use 2001:db8:122::/48 to perform IPv6 address synthesis [[RFC6052](#)] only if the destination address matches 198.51.100.0/24. The XML snippet to configure the NAT64 prefix in such case is shown below:

```
<nat64-prefixes>
  <nat64-prefix>
    2001:db8:122::/48
  </nat64-prefix>
  <destination-ipv4-prefix>
    <ipv4-prefix>
      198.51.100.0/24
    </ipv4-prefix>
  </destination-ipv4-prefix>
</nat64-prefixes>
```

[A.5.](#) Stateless IP/ICMP Translation (SIIT)

Let's consider the example of a stateless translator that is configured with 2001:db8:100::/40 to perform IPv6 address synthesis [[RFC6052](#)]. Similar to the NAT64 case, the XML snippet to configure the NAT64 prefix in such case is depicted below:


```
<nat64-prefixes>
  <nat64-prefix>
    2001:db8:100::/40
  </nat64-prefix>
</nat64-prefixes>
```

When the translator receives an IPv6 packet, for example, with a source address (2001:db8:1c0:2:21::) and destination address (2001:db8:1c6:3364:2::), it extracts embedded IPv4 addresses following [RFC6052](#) rules with 2001:db8:100::/40 as the NSP:

- o 192.0.2.33 is extracted from 2001:db8:1c0:2:21::
- o 198.51.100.2 is extracted from 2001:db8:1c6:3364:2::

The translator transforms the IPv6 header into an IPv4 header using the IP/ICMP Translation Algorithm [[RFC7915](#)]. The IPv4 packets will include 192.0.2.33 as the source address and 198.51.100.2 as the destination address.

Also, a NAT64 can be instructed to behave in the stateless mode by providing the following configuration. The same NAT64 prefix is used for constructing both IPv4-translatable IPv6 addresses and IPv4-converted IPv6 addresses ([Section 3.3 of \[RFC6052\]](#)).

```
<nat64-prefixes>
  <nat64-prefix>
    2001:db8:122:300::/56
  </nat64-prefix>
  <stateless-enable>
    true
  </stateless-enable>
</nat64-prefixes>
```

[A.6.](#) Explicit Address Mappings for Stateless IP/ICMP Translation (EAM SIIT)

As specified in [[RFC7757](#)], an EAM consists of an IPv4 prefix and an IPv6 prefix. Let's consider the set of EAM examples in Table 8.

IPv4 Prefix	IPv6 Prefix
192.0.2.1	2001:db8:aaaa::
192.0.2.2/32	2001:db8:bbbb::b/128
192.0.2.16/28	2001:db8:cccc::/124
192.0.2.128/26	2001:db8:dddd::/64
192.0.2.192/29	2001:db8:eeee:8::/62
192.0.2.224/31	64:ff9b::/127

Table 8: EAM Examples ([RFC7757](#))

The following XML excerpt illustrates how these EAMs can be configured using the YANG NAT module:


```
<eam>
  <ipv4-prefix>
    192.0.2.1/32
  </ipv4-prefix>
  <ipv6-prefix>
    2001:db8:aaaa::/128
  </ipv6-prefix>
</eam>
<eam>
  <ipv4-prefix>
    192.0.2.2/32
  </ipv4-prefix>
  <ipv6-prefix>
    2001:db8:bbbb::b/128
  </ipv6-prefix>
</eam>
<eam>
  <ipv4-prefix>
    192.0.2.16/28
  </ipv4-prefix>
  <ipv6-prefix>
    2001:db8:cccc::/124
  </ipv6-prefix>
</eam>
<eam>
  <ipv4-prefix>
    192.0.2.128/26
  </ipv4-prefix>
  <ipv6-prefix>
    2001:db8:dddd::/64
  </ipv6-prefix>
</eam>
<eam>
  <ipv4-prefix>
    192.0.2.192/29
  </ipv4-prefix>
  <ipv6-prefix>
    2001:db8:eeee:8::/62
  </ipv6-prefix>
</eam>
<eam>
  <ipv4-prefix>
    192.0.2.224/31
  </ipv4-prefix>
  <ipv6-prefix>
    64:ff9b::/127
  </ipv6-prefix>
</eam>
```


EAMs may be enabled jointly with statefull NAT64. This example shows a NAT64 function that supports static mappings:

```
<capabilities
  <nat-flavor>
    nat64
  </nat-flavor>
  <static-mapping-support>
    true
  </static-mapping-support>
  <port-randomization-support>
    true
  </port-randomization-support>
  <port-range-allocation-support>
    true
  </port-range-allocation-support>
  <port-preservation-suport>
    true
  </port-preservation-suport>
  <address-roundrobin-support>
    true
  </address-roundrobin-support>
  <paired-address-pooling-support>
    true
  </paired-address-pooling-support>
  <endpoint-independent-mapping-support>
    true
  </endpoint-independent-mapping-support>
  <endpoint-independent-filtering-support>
    true
  </endpoint-independent-filtering-support>
</capabilities>
```

[A.7.](#) Static Mappings with Port Ranges

The following example shows a static mapping that instructs a NAT to translate packets issued from 192.0.2.1 and with source ports in the 100-500 range to 198.51.100.1:1100-1500.


```
<mapping-entry>
  <index>1</index>
  <type>
    static
  </type>
  <transport-protocol>
    6
  </transport-protocol>
  <internal-src-address>
    192.0.2.1/32
  </internal-src-address>
  <internal-src-port>
    <start-port-number>
      100
    </start-port-number>
    <end-port-number>
      500
    </end-port-number>
  </internal-dst-port>
  <external-src-address>
    198.51.100.1/32
  </external-src-address>
  <external-src-port>
    <start-port-number>
      1100
    </start-port-number>
    <end-port-number>
      1500
    </end-port-number>
  </external-src-port>
  ...
</mapping-entry>
```

[A.8.](#) Static Mappings with IP Prefixes

The following example shows a static mapping that instructs a NAT to translate TCP packets issued from 192.0.2.0/24 to 198.51.100.0/24.


```
<mapping-entry>
  <index>1</index>
  <type>
    static
  </type>
  <transport-protocol>
    6
  </transport-protocol>
  <internal-src-address>
    192.0.2.0/24
  </internal-src-address>
  <external-src-address>
    198.51.100.0/24
  </external-src-address>
  ...
</mapping-entry>
```

[A.9.](#) Destination NAT

The following XML snippet shows an example of a destination NAT that is instructed to translate all packets having 192.0.2.1 as a destination IP address to 198.51.100.1.

```
<dst-ip-address-pool>
  <pool-id>1</pool-id>
  <dst-in-ip-pool>
    192.0.2.1/32
  </dst-in-ip-pool>
  <dst-out-ip-pool>
    198.51.100.1/32
  </dst-out-ip-pool>
</dst-ip-address-pool>
```

In order to instruct a NAT to translate TCP packets destined to '192.0.2.1:80' to '198.51.100.1:8080', the following XML snippet shows the static mapping configured on the NAT:


```
<mapping-entry>
  <index>1568</index>
  <type>
    static
  </type>
  <transport-protocol>
    6
  </transport-protocol>
  <internal-dst-address>
    192.0.2.1/32
  </internal-dst-address>
  <internal-dst-port>
    <start-port-number>
      80
    </start-port-number>
  </internal-dst-port>
  <external-dst-address>
    198.51.100.1/32
  </external-dst-address>
  <external-dst-port>
    <start-port-number>
      8080
    </start-port-number>
  </external-dst-port>
</mapping-entry>
```

In order to instruct a NAT to translate TCP packets destined to '192.0.2.1:80' (http traffic) to 198.51.100.1 and '192.0.2.1:22' (ssh traffic) to 198.51.100.2, the following XML snippet shows the static mappings configured on the NAT:


```
<mapping-entry>
  <index>123</index>
  <type>
    static
  </type>
  <transport-protocol>
    6
  </transport-protocol>
  <internal-dst-address>
    192.0.2.1/32
  </internal-dst-address>
  <internal-dst-port>
    <start-port-number>
      80
    </start-port-number>
  </internal-dst-port>
  <external-dst-address>
    198.51.100.1/32
  </external-dst-address>
  ...
</mapping-entry>
<mapping-entry>
  <index>1236</index>
  <type>
    static
  </type>
  <transport-protocol>
    6
  </transport-protocol>
  <internal-dst-address>
    192.0.2.1/32
  </internal-dst-address>
  <internal-dst-port>
    <start-port-number>
      22
    </start-port-number>
  </internal-dst-port>
  <external-dst-address>
    198.51.100.2/32
  </external-dst-address>
  ...
</mapping-entry>
```

The NAT may also be instructed to proceed with both source and destination NAT. To do so, in addition to the above sample to configure destination NAT, the NAT may be provided, for example with a pool of external IP addresses (198.51.100.0/24) to use for source

address translation. An example of the corresponding XML snippet is provided hereafter:

```
<external-ip-address-pool>
  <pool-id>1</pool-id>
  <external-ip-pool>
    198.51.100.0/24
  </external-ip-pool>
</external-ip-address-pool>
```

Instead of providing an external IP address to share, the NAT may be configured with static mapping entries that modify the internal IP address and/or port number.

A.10. Customer-side Translator (CLAT)

The following XML snippet shows the example of a CLAT that is configured with 2001:db8:1234::/96 as PLAT-side IPv6 prefix and 2001:db8:aaaa::/96 as CLAT-side IPv6 prefix. The CLAT is also provided with 192.0.0.1/32 (which is selected from the IPv4 service continuity prefix defined in [[RFC7335](#)]).

```
<clat-ipv6-prefixes>
  <ipv6-prefix>
    2001:db8:aaaa::/96
  </ipv6-prefix>
</clat-ipv6-prefixes>
<clat-ipv4-prefixes>
  <ipv4-prefix>
    192.0.0.1/32
  </ipv4-prefix>
</clat-ipv4-prefixes>
<nat64-prefixes>
  <nat64-prefix>
    2001:db8:1234::/96
  </nat64-prefix>
</nat64-prefixes>
```

A.11. IPv6 Network Prefix Translation (NPTv6)

Let's consider the example of an NPTv6 translator that should rewrite packets with the source prefix (fd03:c03a:ecab::/48) with the external prefix (2001:db8:1::/48). The internal interface is "eth0" while the external interface is "eth1" (Figure 2).

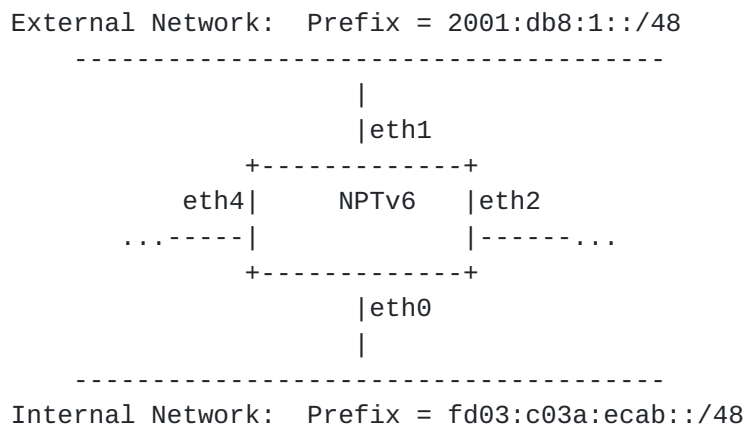


Figure 2: Example of NPTv6

The XML snippet to configure NPTv6 prefixes in such case is depicted below:

```

<nptv6-prefixes>
  <internal-ipv6-prefix>
    fd03:c03a:ecab::/48
  </internal-ipv6-prefix>
  <external-ipv6-prefix>
    2001:db8:1::/48
  </external-ipv6-prefix>
</nptv6-prefixes>
...
<external-realm>
  <external-interface>
    eth1
  </external-interface>
</external-realm>

```

Figure 3 shows an example of an NPTv6 translator that interconnects two internal networks (fd03:c03a:ecab::/48 and fda8:d5cb:14f3::/48); each is translated using a dedicated prefix (2001:db8:1::/48 and 2001:db8:6666::/48, respectively).

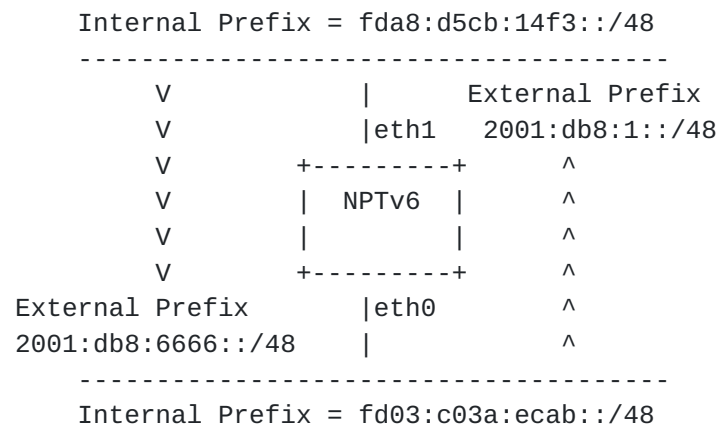


Figure 3: Connecting two Peer Networks

To that aim, the following configuration is provided to the NPTv6 translator:


```
<policy>
  <id>1</id>
  <nptv6-prefixes>
    <internal-ipv6-prefix>
      fd03:c03a:ecab::/48
    </internal-ipv6-prefix>
    <external-ipv6-prefix>
      2001:db8:1::/48
    </external-ipv6-prefix>
  </nptv6-prefixes>
  <external-realm>
    <external-interface>
      eth1
    </external-interface>
  </external-realm>
</policy>
<policy>
  <id>2</id>
  <nptv6-prefixes>
    <internal-ipv6-prefix>
      fda8:d5cb:14f3::/48
    </internal-ipv6-prefix>
    <external-ipv6-prefix>
      2001:db8:6666::/48
    </external-ipv6-prefix>
  </nptv6-prefixes>
  <external-realm>
    <external-interface>
      eth0
    </external-interface>
  </external-realm>
</policy>
```

Authors' Addresses

Mohamed Boucadair (editor)
Orange
Rennes 35000
France

Email: mohamed.boucadair@orange.com

Senthil Sivakumar
Cisco Systems
7100-8 Kit Creek Road
Research Triangle Park, North Carolina 27709
USA

Phone: +1 919 392 5158
Email: ssenthil@cisco.com

Christian Jacquenet
Orange
Rennes 35000
France

Email: christian.jacquenet@orange.com

Suresh Vinapamula
Juniper Networks
1133 Innovation Way
Sunnyvale 94089
USA

Email: sureshk@juniper.net

Qin Wu
Huawei
101 Software Avenue, Yuhua District
Nanjing, Jiangsu 210012
China

Email: bill.wu@huawei.com

