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A YANG Module for
Network Address Translation (NAT) and Network Prefix Translation (NPT)

Abstract

This document defines a YANG module for the Network Address Translation (NAT) function.

Network Address Translation from IPv4 to IPv4 (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 (EAM) for SIIT, IPv6-to-IPv6 Network Prefix Translation (NPTv6), and Destination NAT are covered in this document.

Status of This Memo

This is an Internet Standards Track document.

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Table of Contents

1. Introduction	4
1.1. Terminology	4
2. Overview of the NAT YANG Data Model	6
2.1. Overview	6
2.2. Various Translation Flavors	7
2.3. TCP/UDP/ICMP NAT Behavioral Requirements	8
2.4. Other Transport Protocols	8
2.5. IP Addresses Used for Translation	9
2.6. Port-Set Assignment	9
2.7. Port-Restricted IP Addresses	9
2.8. NAT Mapping Entries	10
2.9. Resource Limits	13
2.10. Binding the NAT Function to an External Interface	16
2.11. Relationship to NATV2-MIB	16
2.12. Tree Structure	17
3. NAT YANG Module	24
4. Security Considerations	68
5. IANA Considerations	70
6. References	70
6.1. Normative References	70
6.2. Informative References	73
Appendix A. Some Examples	75
A.1. Traditional NAT44	75
A.2. Carrier Grade NAT (CGN)	76
A.3. CGN Pass-Through	80
A.4. NAT64	80
A.5. Stateless IP/ICMP Translation (SIIT)	81
A.6. Explicit Address Mappings (EAM) for Stateless IP/ICMP Translation (SIIT)	82
A.7. Static Mappings with Port Ranges	85
A.8. Static Mappings with IP Prefixes	86
A.9. Destination NAT	86
A.10. Customer-Side Translator (CLAT)	89
A.11. IPv6 Network Prefix Translation (NPTv6)	90
Acknowledgements	93
Authors' Addresses	94

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 (EAM) for SIIT [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.

Some 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 Network Address Translation from IPv4 to IPv4 (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 tuples, 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., a Port Control Protocol (PCP) message [RFC6887]. A validity lifetime is associated with this mapping.
- o **Static explicit mapping:** is created using, e.g., a command-line interface (CLI). 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.

This document follows the guidelines of [RFC8407], uses the common YANG types defined in [RFC6991], and adopts the Network Management Datastore Architecture (NMDA). The meaning of the symbols in tree diagrams is defined in [RFC8340].

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 [YANG-PCP]. Considerations about instructing by 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 maintain 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 does not provide any method to instruct a NAT function to enable the logging feature or to specify the information to be logged for administrative or regulatory reasons (Section 2.3 of [RFC6908] and REQ-12 of [RFC6888]). Those considerations 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

[RFC8513] specifies an extension to the NAT YANG module to support Dual-Stack Lite (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: NAT YANG Features

The following translation modes do not require that dedicated features be defined:

- 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 provides a method to retrieve the capabilities of a NAT instance (including a list of supported translation modes, a list of supported protocols, the supported NAT mapping types, the supported NAT filtering types, the behavior for handling fragments (all, out-of-order, in-order), and the support statuses for the following: port restriction, port range allocation, port parity preservation, and port preservation).

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 protocols other than UDP, TCP, and ICMP. Concretely, the module allows the operator to enable translation for other transport protocols when required (/nat/instances/instance/policy/transport-protocols). Moreover, the mapping table is designed so that it can indicate any transport protocol. For example, this module may be used to manage a NAT capable of the Datagram Congestion Control Protocol (DCCP) that adheres to [RFC5597].

Future extensions may be needed to cover NAT-related considerations that are specific to other transport protocols such as the Stream Control Transmission Protocol (SCTP) [NAT-SUPP]. Typically, the mapping entry can be extended to record two optional SCTP-specific parameters: the Internal Verification Tag (Int-VTag) and External Verification Tag (Ext-VTag).

This document only specifies transport-protocol-specific timers for UDP, TCP, and ICMP. While some timers could potentially be generalized for other connection-oriented protocols, this document does not follow such an approach because there is no standard document specifying such generic behavior. Future documents may be edited to clarify how to reuse TCP-specific timers when needed.

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), but this port allocation scheme may not be optimal for logging purposes (Section 12 of [RFC6269]). 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 restrict the source port numbers (e.g., Lightweight 4over6 [RFC7596] and Mapping of Address and Port with Encapsulation (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, and 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, the NAT mapping structure allows for the inclusion of 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 Endpoint-Dependent Mapping (EDM).

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

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 the 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 (DoS) 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 a NAT implementation 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 [RFC8343], 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 Customer Premises Equipment (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, which is not specified in [RFC7659]:

- o The set of address realms to which the device connects.

- o For the CGN case, per-subscriber information including the 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 numbers.
- 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 the configuration of 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-support?
|   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 protocol?     uint32
|   |   +--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 low-threshold?     percent
|   +--rw high-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 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
|       |           -> /nat/instances/instance/policy/
|               external-ip-address-pool/pool-id
+--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@2019-01-10.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;
    reference
      "Section 4 of RFC 6991";
  }
  import ietf-yang-types {
    prefix yang;
    reference
      "Section 3 of RFC 6991";
  }
  import ietf-interfaces {
    prefix if;
    reference
      "RFC 8343: A YANG Data Model for Interface Management";
  }

  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>

    Author:   Senthil Sivakumar
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    Author:   Christian Jacquenet
              <mailto:christian.jacquenet@orange.com>

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

    Author:   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 (EAM) for SIIT, IPv6 Network Prefix Translation (NPTv6), and Destination NAT are covered.

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This version of this YANG module is part of RFC 8512; see the RFC itself for full legal notices.";

```
revision 2019-01-10 {
  description
    "Initial revision.";
  reference
    "RFC 8512: 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, e.g., 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 RFC 6052, 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
      "An individual port number 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 port numbers.

      It may be a simple port range, or use the Port Set
      Identifier (PSID) algorithm to represent a range of
      transport-layer port numbers that will be used by a
      NAPT.";
    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
        "PSID value, which identifies a set
         of ports algorithmically.";
    reference
        "Section 5.1 of RFC 7597";
    }
}
reference
    "RFC 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,
        it means the corresponding field 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 a 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. For example,
  a mapping can be: static, implicit dynamic,
  or explicit dynamic.";
}
leaf transport-protocol {
  type uint8;
  description
    "The upper-layer protocol associated with this mapping.
    Values are taken from the IANA Protocol Numbers registry:
    <https://www.iana.org/assignments/protocol-numbers/>.

    For example, this field contains 6 for TCP,
    17 for UDP, 33 for DCCP, or 132 for SCTP.

    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 also used 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 also used 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 port numbers, 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 also used 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 also used 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
    "The upper-layer protocol associated with a mapping.

    Values are taken from the IANA Protocol Numbers
    registry.

    For example, this field contains 6 for TCP,
    17 for UDP, 33 for DCCP, or 132 for SCTP.";
}
leaf protocol-name {
  type string;
  description
    "The name of the upper-layer protocol associated
    with this mapping.

    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-suport {
  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 translation 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
        translation 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 is an 'internal' network
        link attached to a leaf network within a single
        administrative domain, and the other 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 is 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 a Network-Specific Prefix (NSP)
      or a Well-Known Prefix (WKP).

      Organizations deploying stateless IPv4/IPv6 translation
      should assign an NSP to their IPv4/IPv6 translation
      service.
```

For stateless NAT64, IPv4-translatable IPv6 addresses must use the selected NSP.

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
    "The upper-layer protocol associated with this
    mapping.

    Values are taken from the IANA Protocol Numbers
    registry.

    For example, this field contains 6 for TCP,
    17 for UDP, 33 for DCCP, or 132 for SCTP.";
}
leaf protocol-name {
  type string;
  description
    "The name of the upper-layer protocol associated
    with this mapping.

    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. For example, 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 the
         minimizing of the 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 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 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 the fragment-min-timeout interval.
        The default value is inspired from RFC 6146.";
}
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 protocol {
    type uint8;
    description
        "The upper-layer protocol associated with this port.

        Values are taken from the IANA Protocol Numbers
        registry.

        If no protocol is indicated, it means 'any
        protocol'.";
}
}
```

```
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 port pool.";
  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
```

```
    "Features related to the Application Layer
    Gateway (ALG).";
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 and 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
        "Disable/enable 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 low-threshold {
  type percent;
  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.

    0% indicates that low-threshold notification is
    disabled.";
}
leaf high-threshold {
  type percent;
  must '. >= ../low-threshold' {
    error-message
      "The high threshold must be greater than or equal
      to the low threshold.";
  }
  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.

    Setting the same value as low-threshold is equivalent
    to disabling high-threshold notification.";
}
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
      "The upper-layer protocol.

      Values are taken from the IANA Protocol Numbers
      registry.

      For example, this field contains 6 for TCP,
      17 for UDP, 33 for DCCP, or 132 for SCTP.";
  }
  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";
  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
      "The upper-layer protocol.

      Values are taken from the IANA Protocol Numbers
      registry.

      For example, this field contains 6 for TCP,
      17 for UDP, 33 for DCCP, or 132 for SCTP.";
  }
  leaf limit {
    type uint32;
    description
      "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.";
}
}
container mapping-table {
  if-feature "basic-nat44 or napt44 or nat64 "
    + "or clat or dst-nat";
  description
    "NAT mapping table. Applicable for functions that 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
      "The upper-layer protocol.
      For example, this field contains 6 for TCP,
      17 for UDP, 33 for DCCP, or 132 for SCTP.";
  }
  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;
  }
}
```



```
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 thresholds 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 specified in this document defines a schema for data that 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 [RFC8446].

The Network Configuration Access Control Model (NACM) [RFC8341] 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 that 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 provides a method to set parameters to prevent a user from aggressively using NAT resources

(port-quota), rate-limit connections as a guard against DoS, or to enable notifications so that appropriate measures are enforced to anticipate traffic drops. Nevertheless, an attacker who is able to access 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

IANA has registered the following URI in the "ns" subregistry within 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.
```

IANA has registered the following YANG module in the "YANG Module Names" subregistry [RFC7950] within the "YANG Parameters" registry.

```
name: ietf-nat
namespace: urn:ietf:params:xml:ns:yang:ietf-nat
prefix: nat
reference: RFC 8512
```

6. References

6.1. 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>>.
- [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>>.
- [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>>.
- [RFC6991] Schoenwaelder, J., Ed., "Common YANG Data Types", RFC 6991, DOI 10.17487/RFC6991, July 2013, <<https://www.rfc-editor.org/info/rfc6991>>.
- [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>>.
- [RFC8341] Bierman, A. and M. Bjorklund, "Network Configuration Access Control Model", STD 91, RFC 8341, DOI 10.17487/RFC8341, March 2018, <<https://www.rfc-editor.org/info/rfc8341>>.
- [RFC8343] Bjorklund, M., "A YANG Data Model for Interface Management", RFC 8343, DOI 10.17487/RFC8343, March 2018, <<https://www.rfc-editor.org/info/rfc8343>>.
- [RFC8446] Rescorla, E., "The Transport Layer Security (TLS) Protocol Version 1.3", RFC 8446, DOI 10.17487/RFC8446, August 2018, <<https://www.rfc-editor.org/info/rfc8446>>.

6.2. Informative References

- [NAT-SUPP] Stewart, R., Tuexen, M., and I. Ruengeler, "Stream Control Transmission Protocol (SCTP) Network Address Translation Support", Work in Progress, draft-ietf-tsvwg-natsupp-12, July 2018.
- [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>>.
- [RFC8340] Bjorklund, M. and L. Berger, Ed., "YANG Tree Diagrams", BCP 215, RFC 8340, DOI 10.17487/RFC8340, March 2018, <<https://www.rfc-editor.org/info/rfc8340>>.
- [RFC8407] Bierman, A., "Guidelines for Authors and Reviewers of Documents Containing YANG Data Models", BCP 216, RFC 8407, DOI 10.17487/RFC8407, October 2018, <<https://www.rfc-editor.org/info/rfc8407>>.
- [RFC8513] Boucadair, M., Jacquenet, C., and S. Sivakumar, "A YANG Data Model for Dual-Stack Lite (DS-Lite)", RFC 8513, DOI 10.17487/RFC8513, January 2019, <<https://www.rfc-editor.org/info/rfc8513>>.
- [YANG-PCP] Boucadair, M., Jacquenet, C., Sivakumar, S., and S. Vinapamula, "YANG Modules for the Port Control Protocol (PCP)", Work in Progress, draft-boucadair-pcp-yang-05, October 2017.

Appendix A. Some 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., a 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>
```


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 rules per RFC 6052 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 (see 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 (EAM) for Stateless IP/ICMP Translation (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 (RFC 7757)

The following XML excerpt illustrates how these EAMs can be configured using the NAT YANG 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 stateful 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-support>
    true
  </port-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>
  <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-src-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 example 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 a PLAT-side IPv6 prefix and 2001:db8:aaaa::/96 as a 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>
```


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).

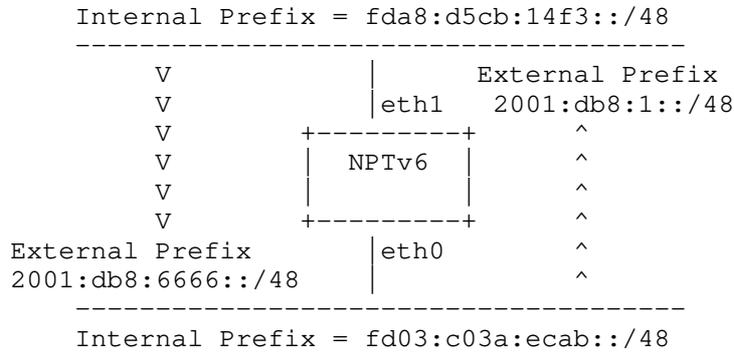


Figure 3: Connecting Two Peer Networks

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>
```

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