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Common Requirements for Carrier-Grade NATs (CGNs)

Abstract

This document defines common requirements for Carrier-Grade NATs (CGNs). It updates RFC 4787.

Status of This Memo

This memo documents an Internet Best Current Practice.

This document is a product of the Internet Engineering Task Force (IETF). It represents the consensus of the IETF community. It has received public review and has been approved for publication by the Internet Engineering Steering Group (IESG). Further information on BCPs is available in Section 2 of RFC 5741.

Information about the current status of this document, any errata, and how to provide feedback on it may be obtained at http://www.rfc-editor.org/info/rfc6888.

Table of Contents

1. Introduction

With the shortage of IPv4 addresses, it is expected that more Internet Service Providers (ISPs) may want to provide a service where a public IPv4 address would be shared by many subscribers. Each subscriber is assigned a private address, and a Network Address Translator (NAT) [RFC2663] situated in the ISP's network translates the traffic between private and public addresses. When a second IPv4 NAT is located at the customer edge, this results in two layers of NAT.

This service can conceivably be offered alongside others, such as IPv6 services or regular IPv4 service assigning public addresses to subscribers. Some ISPs started offering such a service long before there was a shortage of IPv4 addresses, showing that there are driving forces other than the shortage of IPv4 addresses. One approach to CGN deployment is described in [RFC6264].

This document describes behavior that is required of those multi-subscriber NATs for interoperability. It is not an IETF endorsement of CGNs or a real specification for CGNs; rather, it is just a minimal set of requirements that will increase the likelihood of applications working across CGNs.

Because subscribers do not receive unique IPv4 addresses, Carrier-Grade NATs introduce substantial limitations in communications between subscribers and with the rest of the Internet. In particular, it is considerably more involved to establish proxy functionality at the border between internal and external realms. Some applications may require substantial enhancements, while some others may not function at all in such an environment. Please see "Issues with IP Address Sharing" [RFC6269] for details.

This document builds upon previous works describing requirements for generic NATs [RFC4787][RFC5382][RFC5508]. These documents, and their updates if any, still apply in this context. What follows are additional requirements, to be satisfied on top of previous ones.

2. Terminology

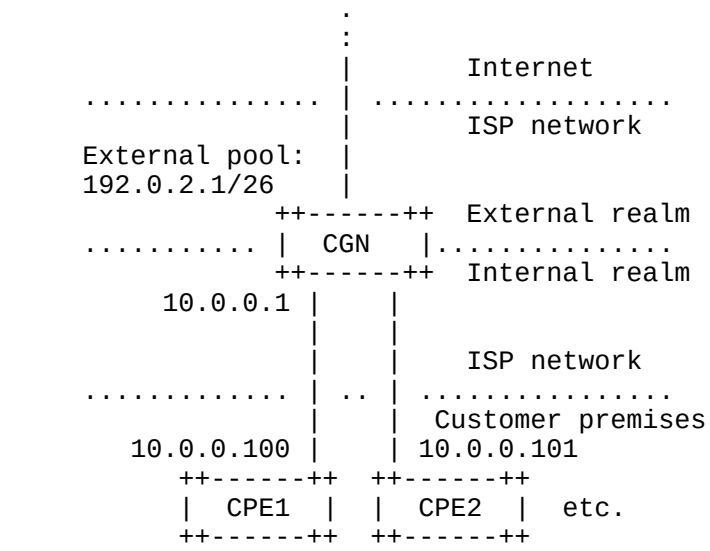
The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

Readers are expected to be familiar with "Network Address Translation (NAT) Behavioral Requirements for Unicast UDP" [RFC4787] and the terms defined there. The following additional term is used in this document:

Carrier-Grade NAT (CGN): A NAT-based [RFC2663] logical function used to share the same IPv4 address among several subscribers. A CGN is not managed by the subscribers.

> Note that the term "carrier-grade" has nothing to do with the quality of the NAT; that is left to discretion of implementers. Rather, it is to be understood as a topological qualifier: the NAT is placed in an ISP’s network and translates the traffic of potentially many subscribers. Subscribers have limited or no control over the CGN, whereas they typically have full control over a NAT placed on their premises.
>
> Note also that the CGN described in this document is IPv4-only. IPv6 address translation is not considered.
>
> However, the scenario in which the IPv4-only CGN logical function is used may include IPv6 elements. For example, Dual-Stack Lite (DS-Lite) [RFC6333] uses an IPv4-only CGN logical function in a scenario making use of IPv6 encapsulation. Therefore, this document would also apply to the CGN part of DS-Lite.

Figure 1 summarizes a common network topology in which a CGN operates.



(IP addresses are only for example purposes)

Figure 1: CGN Network Topology

Another possible topology is one for hotspots, where there is no customer premise or customer premises equipment (CPE), but where a CGN serves a bunch of customers who don't trust each other; hence, fairness is an issue. One important difference with the previous topology is the absence of a second layer of NAT. This, however, has no impact on CGN requirements since they are driven by fairness and robustness in the service provided to customers, which applies in both cases.

3. Requirements for CGNs

What follows is a list of requirements for CGNs. They are in addition to those found in other documents such as [RFC4787], [RFC5382], and [RFC5508].

REQ-1: If a CGN forwards packets containing a given transport protocol, then it MUST fulfill that transport protocol's behavioral requirements. Current applicable documents are as follows:

a. "NAT Behavioral Requirements for Unicast UDP" [RFC4787]

b. "Network Address Translation (NAT) Behavioral Requirements for TCP" [RFC5382]

c. "NAT Behavioral Requirements for ICMP" [RFC5508]

d. "Network Address Translation (NAT) Behavioral Requirements for the Datagram Congestion Control Protocol (DCCP)" [RFC5597]

Any future NAT behavioral requirements documents for IPv4 transport protocols will impose additional requirements for CGNs on top of those stated here.

Justification: It is crucial for CGNs to maximize the set of applications that can function properly across them. The IETF has documented the best current practices for UDP, TCP, ICMP, and DCCP.

REQ-2: A CGN MUST have a default "IP address pooling" behavior of "Paired" (as defined in Section 4.1 of [RFC4787]). A CGN MAY provide a mechanism for administrators to change this behavior on an application protocol basis.

* When multiple overlapping internal IP address ranges share the same external IP address pool (e.g., DS-Lite [RFC6333]), the "IP address pooling" behavior applies to mappings between external IP addresses and internal subscribers rather than between external and internal IP addresses.

Justification: This stronger form of REQ-2 from [RFC4787] is justified by the stronger need for not breaking applications that depend on the external address remaining constant.

Note that this requirement applies regardless of the transport protocol. In other words, a CGN must use the same external IP address mapping for all sessions associated with the same internal IP address, be they TCP, UDP, ICMP, something else, or a mix of different protocols.

The justification for allowing other behaviors is to allow the administrator to save external addresses and ports for application protocols that are known to work fine with other behaviors in practice. However, the default behavior MUST be "Paired".

REQ-3: The CGN function SHOULD NOT have any limitations on the size or the contiguity of the external address pool. In particular, the CGN function MUST be configurable with contiguous or non-contiguous external IPv4 address ranges.

Justification: Given the increasing rarity of IPv4 addresses, it is becoming harder for an operator to provide large contiguous address pools to CGNs. Additionally, operational flexibility may require non-contiguous address pools for reasons such as differentiated services, routing management, etc.

The reason for having SHOULD instead of MUST is to account for limitations imposed by available resources as well as constraints imposed for security reasons.

REQ-4: A CGN MUST support limiting the number of external ports (or, equivalently, "identifiers" for ICMP) that are assigned per subscriber.

a. Per-subscriber limits MUST be configurable by the CGN administrator.

b. Per-subscriber limits MAY be configurable independently per transport protocol.

c. Additionally, it is RECOMMENDED that the CGN include administrator-adjustable thresholds to prevent a single subscriber from consuming excessive CPU resources from the CGN (e.g., rate-limit the subscriber’s creation of new mappings).

Justification: A CGN can be considered a network resource that is shared by competing subscribers. Limiting the number of external ports assigned to each subscriber mitigates the denial-of-service (DoS) attack that a subscriber could launch against other subscribers through the CGN in order to get a larger share of the resource. It ensures fairness among subscribers. Limiting the rate of allocation mitigates a similar attack where the CPU is the resource being targeted instead of port numbers. However, this requirement is not a MUST because it is very hard to explicitly call out all CPU-consuming events.

REQ-5: A CGN SHOULD support limiting the amount of state memory allocated per mapping and per subscriber. This may include limiting the number of sessions, the number of filters, etc., depending on the NAT implementation.

a. Limits SHOULD be configurable by the CGN administrator.

b. Additionally, it SHOULD be possible to limit the rate at which memory-consuming state elements are allocated.

Justification: A NAT needs to keep track of TCP sessions associated with each mapping. This state consumes resources for which, in the case of a CGN, subscribers may compete. It is necessary to ensure that each subscriber has access to a fair share of the CGN's resources. Limiting the rate of allocation is intended to prevent CPU resource exhaustion. Item "B" is at the SHOULD level to account for the fact that means other than rate limiting may be used to attain the same goal.

REQ-6: It MUST be possible to administratively turn off translation for specific destination addresses and/or ports.

Justification: It is common for a CGN administrator to provide access for subscribers to servers installed in the ISP's network in the external realm. When such a server is able to reach the internal realm via normal routing (which is entirely controlled by the ISP), translation is unneeded. In that case, the CGN may forward packets without modification, thus acting like a plain router. This may represent an important efficiency gain.

Figure 2 illustrates this use-case.

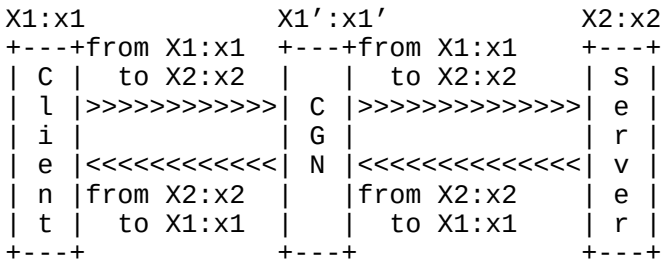


Figure 2: CGN Pass-Through

REQ-7: It is RECOMMENDED that a CGN use an "endpoint-independent filtering" behavior (as defined in Section 5 of [RFC4787]). If it is known that "Address-Dependent Filtering" does not cause the application-layer protocol to break (how to determine this is out of scope for this document), then it MAY be used instead.

Justification: This is a stronger form of REQ-8 from [RFC4787]. This is based on the observation that some games and peer-to-peer applications require EIF for the NAT traversal to work. In the context of a CGN, it is important to minimize application breakage.

REQ-8: Once an external port is deallocated, it SHOULD NOT be reallocated to a new mapping until at least 120 seconds have passed, with the exceptions being:

a. If the CGN tracks TCP sessions (e.g., with a state machine, as in Section 3.5.2.2 of [RFC6146]), TCP ports MAY be reused immediately.

b. If external ports are statically assigned to internal addresses (e.g., address X with port range 1000-1999 is assigned to subscriber A, 2000-2999 to subscriber B, etc.), and the assignment remains constant across state loss, then ports MAY be reused immediately.

c. If the allocated external ports used address-dependent or address-and-port-dependent filtering before state loss, they MAY be reused immediately.

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

Justification: 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.

The exceptions are for cases where reusing a port immediately does not create a possibility that packets would be redirected to the wrong peer. One can imagine other exceptions where mapping collisions are avoided, thus justifying the SHOULD level for this requirement.

The 120 seconds value corresponds to the Maximum Segment Lifetime (MSL) from [RFC0793].

Note that this requirement also applies to the case when a CGN loses state (due to a crash, reboot, failover to a cold standby, etc.). In that case, ports that were in use at the time of state loss SHOULD NOT be reallocated until at least 120 seconds have passed.

REQ-9: A CGN MUST implement a protocol giving subscribers explicit control over NAT mappings. That protocol SHOULD be the Port Control Protocol [RFC6887].

Justification: Allowing subscribers to manipulate the NAT state table with PCP greatly increases the likelihood that applications will function properly.

A study of PCP-less CGN impacts can be found in [NAT444]. Another study considering the effects of PCP on a peer-to-peer file sharing protocol can be found in [BITTORRENT].

REQ-10: CGN implementers SHOULD make their equipment manageable. Standards-based management using standards such as "Definitions of Managed Objects for NAT" [RFC4008] is RECOMMENDED.

Justification: It is anticipated that CGNs will be primarily deployed in ISP networks where the need for management is critical. This requirement is at the SHOULD level to account for the fact that some CGN operators may not need management functionality.

Note also that there are efforts within the IETF toward creating a MIB tailored for CGNs (e.g., [NAT-MIB]).

REQ-11: When a CGN is unable to create a dynamic mapping due to resource constraints or administrative restrictions (i.e., quotas):

a. it MUST drop the original packet;

b. it SHOULD send an ICMP Destination Unreachable message with code 1 (Host Unreachable) to the sender;

c. it SHOULD send a notification (e.g., SNMP trap) towards a management system (if configured to do so); and

d. it MUST NOT delete existing mappings in order to "make room" for the new one. (This only applies to normal CGN behavior, not to manual operator intervention.)

Justification: This is a slightly different form of REQ-8 from [RFC5508]. Code 1 is preferred to code 13 because it is listed as a "soft error" in [RFC1122], which is important because we don’t want TCP stacks to abort the connection attempt in this case. See [RFC5461] for details on TCP’s reaction to soft errors.

Sending ICMP errors and SNMP traps may be rate-limited for security reasons, which is why requirements B and C are SHOULDs, not MUSTs.

Applications generally handle connection establishment failure better than established connection failure. This is why dropping the packet initiating the new connection is preferred over deleting existing mappings. See also the rationale in Section 6 of [RFC5508].

4. Logging

It may be necessary for CGN administrators to be able to identify a subscriber based on external IPv4 address, port, and timestamp in order to deal with abuse. When multiple subscribers share a single external address, the source address and port that are visible at the destination host have been translated from the ones originated by the subscriber.

In order to be able to do this, the CGN would need to log the following information for each mapping created (this list is for informational purposes only and does not constitute a requirement):

- transport protocol
- subscriber identifier (e.g., internal source address or tunnel endpoint identifier)
- external source address
- external source port
- timestamp

By "subscriber identifier" we mean information that uniquely identifies a subscriber. For example, in a traditional NAT scenario, the internal source address would be sufficient. In the case of DS-Lite, many subscribers share the same internal address and the subscriber identifier is the tunnel endpoint identifier (i.e., the B4's IPv6 address).

A disadvantage of logging mappings is that CGNs under heavy usage may produce large amounts of logs, which may require large storage volume.

REQ-12: A CGN SHOULD NOT log destination addresses or ports unless required to do so for administrative reasons.

Justification: Destination logging at the CGN creates privacy issues. Furthermore, readers should be aware of logging recommendations for Internet-facing servers [RFC6302]. With compliant servers, the destination address and port do not need to be logged by the CGN. This can help reduce the amount of logging.

This requirement is at the SHOULD level to account for the fact that there may be other reasons for logging destination addresses or ports. One such reason might be that the remote server is not following [RFC6302].

5. Port Allocation Scheme

A CGN's port allocation scheme is subject to three competing requirements:

REQ-13: A CGN's port allocation scheme SHOULD maximize port utilization.

Justification: External ports are one of the resources being shared by a CGN. Efficient management of that resource directly impacts the quality of a subscriber's Internet connection.

Some schemes are very efficient in their port utilization. In that sense, they have good scaling properties (nothing is wasted). Others will systematically waste ports.

REQ-14: A CGN's port allocation scheme SHOULD minimize log volume.

Justification: Huge log volumes can be problematic to CGN operators.

Some schemes create one log entry per mapping. Others allow multiple mappings to generate a single log entry, which sometimes can be expressed very compactly. With some schemes, the logging frequency can approach that of DHCP servers.

REQ-15: A CGN's port allocation scheme SHOULD make it hard for attackers to guess port numbers.

Justification: Easily guessed port numbers put subscribers at risk of the attacks described in [RFC6056].

Some schemes provide very good security in that ports numbers are not easily guessed. Others provide poor security to subscribers.

A CGN implementation's choice of port allocation scheme optimizes to satisfy one requirement at the expense of another. Therefore, these are soft requirements (SHOULD as opposed to MUST).

6. Deployment Considerations

Several issues are encountered when CGNs are used [RFC6269]. There is current work in the IETF toward alleviating some of these issues. For example, see [NAT-REVEAL].

7. Security Considerations

If a malicious subscriber can spoof another subscriber's CPE, it may cause a DoS to that subscriber by creating mappings up to the allowed limit. An ISP can prevent this with ingress filtering, as described in [RFC2827].

This document recommends endpoint-independent filtering (EIF) as the default filtering behavior for CGNs. EIF has security considerations that are discussed in [RFC4787].

NATs sometimes perform fragment reassembly. CGNs would do so at presumably high data rates. Therefore, the reader should be familiar with the potential security issues described in [RFC4963].

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