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Common requirements for Carrier Grade NATs (CGNs)
draft-ietf-behave-lsn-requirements-08

Abstract

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

Status of this Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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This Internet-Draft will expire on January 12, 2013.

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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 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 CGN or a real specification for CGN, but rather 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 "NAT Behavioral Requirements for Unicast UDP" [RFC4787] and the terms defined there. The following additional term is used in this document:

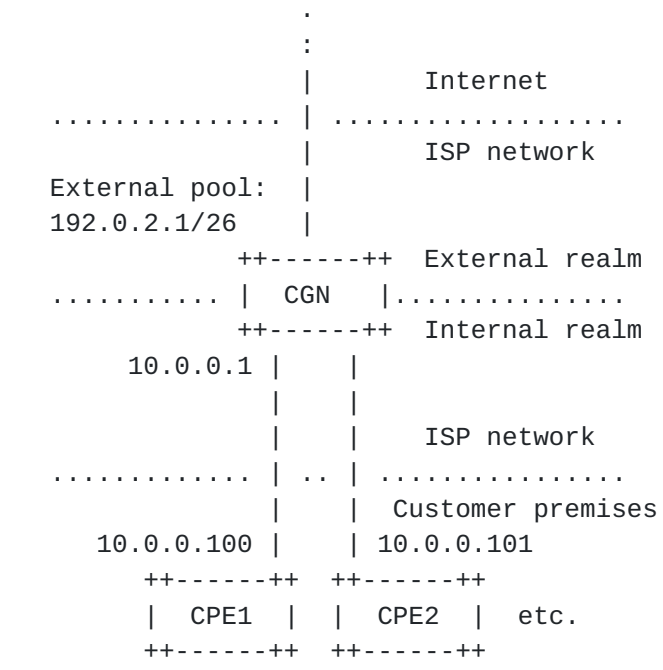
Carrier-Grade NAT (CGN): A NAT-based [RFC2663] logical function used to share the same IPv4 address among several subscribers. A CGN is not managed by the subscribers.

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, 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 and 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. "NAT Behavioral Requirements for TCP" [RFC5382]

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

D. "NAT Behavioral Requirements for DCCP" [RFC5597]

If NAT behavioral requirements documents are created for additional protocols, then these new documents MUST update this list by adding themselves to it.

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 [RFC4787] section 4.1). 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 nor 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. Limits MUST be configurable by the CGN administrator.

B. 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 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 to 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 against 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.

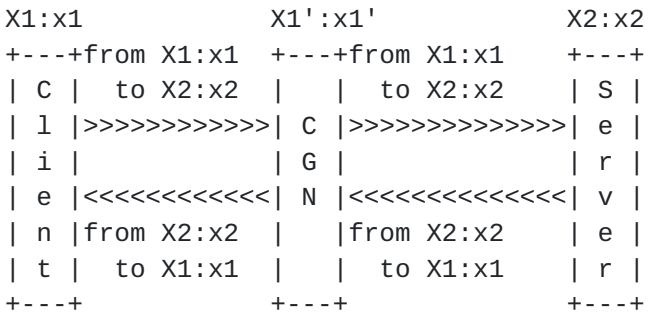


Figure 2: CGN pass-through

REQ-7: It is RECOMMENDED that a CGN have an "Endpoint-Independent Filtering" behavior (as defined in [RFC4787] section 5). 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 [RFC6146] section 3.5.2.2), 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 include a Port Control Protocol server [I-D.ietf-pcp-base] with the following constraints on its behavior:

A. It MUST NOT permit the lifetime of a mapping to be reduced beyond its current life or be set to zero (deleted).

B. It MUST NOT permit a NAT mapping to be created with a lifetime less than the lifetime used for implicit mappings.

C. The MAP opcode MAY be permitted if the recommendation of endpoint independent filtering behavior described in REQ-7 is adopted; the map opcode MUST NOT be permitted in other circumstances. These constraints MAY be relaxed if a security mechanism consistent with PCP's Advanced Threat Model (see Section 17.2 of [I-D.ietf-pcp-base]) is used; this is expected to be rare for CGN deployments.

D. Mappings created by PCP MUST follow the same deallocation behavior (REQ-8) as implicitly mapped traffic.

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 [I-D.donley-nat444-impacts]. Another study considering the effects of PCP on a peer-to-peer file sharing protocol can be found in [I-D.boucadair-pcp-bittorrent].

Items "A" to "D" are justified as follows: Most of the concern has to do with one customer device interacting negatively with the security of another; this is of particular concern when the devices belong to different customers, but devices belonging to the same customer are in scope for the PCP security analysis as well. Reducing a mapping lifetime or deleting a mapping create DoS opportunities and can create an opportunity for one device to intercept another device's traffic. If a device spoofs creation of a mapping with less than the default lifetime, then that can create DoS or packet capture opportunities. The behavior of REQ-8 is critical to avoiding packet capture attacks.

REQ-10: CGN implementrers 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., [I-D.ietf-behave-nat-mib]).

REQ-11: When a CGN is unable to create a 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);

D. and 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 a 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 [RFC5508] section 6.

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:

- 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.

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.

5. Bulk Port Allocation

So far we have assumed that a CGN allocates one external port for every outgoing connection. In this section, the impacts of allocating multiple external ports at a time are discussed.

There is a range of things a CGN can do:

Traditional: For every outgoing connection, allocate one external port.

Scattered port set: For an outgoing connection, create a set of several non-consecutive external ports. Subsequent outgoing connections will use ports from the set. When the set is exhausted, a new connection causes a new set to be created. A set is smaller or equal to the user's maximum port limit.

Consecutive port set: Same as the scattered port set, but the ports allocated to a set are consecutive.

Note that this list is not exhaustive. There is a continuum of behavior that a CGN may choose to implement. For example, a CGN could use scattered port sets of consecutive port sets.

The impacts of bulk port allocation are as follows.

Port Utilization: The mechanisms at the top of the list are very efficient in their port utilization. In that sense, they have good scaling properties (nothing is wasted). The mechanisms at the bottom of the list will waste ports. The number of wasted ports is proportional to size of the "bin".

Logging: Traditional allocation creates a lot of log entries as compared to allocation by port sets which creates much fewer entries. Scattered and consecutive port sets generate the same number of log entries. In the case of consecutive port sets, entries can be expressed very compactly by indicating a range (e.g., "12000-12009"). Some scattered port set allocation schemes can also generate small log entries containing the parameters and algorithm used for the port set generation (see, e.g., [RFC6431]).

With large set sizes, the logging frequency for scattered and consecutive port sets can approach that of DHCP servers.

Security: Traditional and scattered port sets provide very good security in that ports numbers are not easily guessed. Easily guessed port numbers put subscribers at risk of the attacks described in [RFC6056]. Consecutive port sets provides poor security to subscribers, especially if the set size is small.

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 [I-D.ietf-intarea-nat-reveal-analysis].

7. IANA Considerations

There are no IANA considerations.

8. 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 which 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].

9. Acknowledgements

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10. References

10.1. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

[RFC4008] Rohit, R., Srisuresh, P., Raghunarayan, R., Pai, N., and C. Wang, "Definitions of Managed Objects for Network Address Translators (NAT)", RFC 4008, March 2005.

[RFC4787] Audet, F. and C. Jennings, "Network Address Translation (NAT) Behavioral Requirements for Unicast UDP", BCP 127, RFC 4787, January 2007.

[RFC5382] Guha, S., Biswas, K., Ford, B., Sivakumar, S., and P. Srisuresh, "NAT Behavioral Requirements for TCP", BCP 142, RFC 5382, October 2008.

[RFC5508] Srisuresh, P., Ford, B., Sivakumar, S., and S. Guha, "NAT Behavioral Requirements for ICMP", BCP 148, RFC 5508, April 2009.

[RFC5597] Denis-Courmont, R., "Network Address Translation (NAT) Behavioral Requirements for the Datagram Congestion Control Protocol", BCP 150, RFC 5597, September 2009.

[I-D.ietf-pcp-base] Wing, D., Cheshire, S., Boucadair, M., Penno, R., and P. Selkirk, "Port Control Protocol (PCP)", draft-ietf-pcp-base-26 (work in progress), June 2012.

10.2. Informative Reference

[RFC0793] Postel, J., "Transmission Control Protocol", STD 7, RFC 793, September 1981.

[RFC1122] Braden, R., "Requirements for Internet Hosts - Communication Layers", STD 3, RFC 1122, October 1989.

[RFC2663] Srisuresh, P. and M. Holdrege, "IP Network Address Translator (NAT) Terminology and Considerations", RFC 2663, August 1999.

[RFC2827] Ferguson, P. and D. Senie, "Network Ingress Filtering: Defeating Denial of Service Attacks which employ IP Source Address Spoofing", BCP 38, RFC 2827, May 2000.

[RFC4963] Heffner, J., Mathis, M., and B. Chandler, "IPv4 Reassembly Errors at High Data Rates", RFC 4963, July 2007.

[RFC5461] Gont, F., "TCP's Reaction to Soft Errors", RFC 5461, February 2009.

[RFC6056] Larsen, M. and F. Gont, "Recommendations for Transport-Protocol Port Randomization", BCP 156, RFC 6056, January 2011.

[RFC6146] Bagnulo, M., Matthews, P., and I. van Beijnum, "Stateful NAT64: Network Address and Protocol Translation from IPv6 Clients to IPv4 Servers", RFC 6146, April 2011.

[RFC6264] Jiang, S., Guo, D., and B. Carpenter, "An Incremental Carrier-Grade NAT (CGN) for IPv6 Transition", RFC 6264, June 2011.

[RFC6269] Ford, M., Boucadair, M., Durand, A., Levis, P., and P. Roberts, "Issues with IP Address Sharing", RFC 6269, June 2011.

[RFC6302] Durand, A., Gashinsky, I., Lee, D., and S. Sheppard, "Logging Recommendations for Internet-Facing Servers", BCP 162, RFC 6302, June 2011.

[RFC6333] Durand, A., Droms, R., Woodyatt, J., and Y. Lee, "Dual-Stack Lite Broadband Deployments Following IPv4 Exhaustion", RFC 6333, August 2011.

[RFC6431] Boucadair, M., Levis, P., Bajko, G., Savolainen, T., and T. Tsou, "Huawei Port Range Configuration Options for PPP IP Control Protocol (IPCP)", RFC 6431, November 2011.

[I-D.ietf-behave-nat-mib] Perreault, S., Tsou, T., and S. Sivakumar, "Additional Managed Objects for Network Address Translators (NAT)",

draft-ietf-behave-nat-mib-01 (work in progress), June 2012.

[I-D.ietf-intarea-nat-reveal-analysis]
Boucadair, M., Touch, J., Levis, P., and R. Penno, "Analysis of Solution Candidates to Reveal a Host Identifier (HOST_ID) in Shared Address Deployments", draft-ietf-intarea-nat-reveal-analysis-02 (work in progress), April 2012.

[I-D.donley-nat444-impacts]
Donley, C., Howard, L., Kuarsingh, V., Berg, J., and U. Colorado, "Assessing the Impact of Carrier-Grade NAT on Network Applications", draft-donley-nat444-impacts-04 (work in progress), May 2012.

[I-D.boucadair-pcp-bittorrent]
Boucadair, M., Zheng, T., Deng, X., and J. Queiroz, "Behavior of BitTorrent service in PCP-enabled networks with Address Sharing", draft-boucadair-pcp-bittorrent-00 (work in progress), May 2012.

Appendix A. Change Log (to be removed by RFC Editor prior to publication)

A.1. Changed in -08

- Made it super explicit that we're talking about an IPv4-only CGN logical *function*, not an IPv4-only CGN *scenario*. This changes and simplifies the definition of CGN a bit.
- Did NOT change the intended status. Further guidance from IESG is necessary.
- Fixed a huge typo in REQ-7.
- Fixed bugs in REQ-5-B justification.
- Added REQ-9 items A to D which constrain PCP server behavior.

A.2. Changed in -07

- Fixed sub-requirement numbering in REQ-1.
- Reference update.

- Changed REQ-2 back to MUST (from SHOULD).
- Added reference to RFC6264 (incremental CGN).
- Be more clear that this is not an endorsement of CGN.
- Make it clear that this draft is only about IPv4.
- Added justification for a bunch of SHOULDs and turned the remaining ones into MUSTs.

A.3. Changed in -06

- Expanded some acronyms.
- Added example IP addresses to ASCII art.
- Reword transport protocol section.
- Stronger words of caution about CGNs.
- Refer to RFC for DCCP NAT behaviour.
- Note in headers and abstract that this updates RFC 4787.
- Remove sentence "This is not to be considered a solution to the shortage of IPv4 addresses."
- Remove text having marketing scent.
- Change some "MUST ... unless" requirements to "SHOULD ... unless".
- Merge REQ-8 and REQ-9.
- PCP is now a MUST.
- NAT-MIB is now an example rather than specificially required.
- When a quota is hit, send ICMP DU code 1 instead of code 3.
- Remove mention of "lawful intercept".
- Remove discussion on destination logging from section on bulk port allocation.
- Remove discussion on address sharing ratio.

A.4. Changed in -05

- Removed DSCP requirement since it applies to non-CG NATs as well.
- Removed instances of "NAT444".
- Filtering has no effect on the requirement for a hold down pool. Removed REQ-8-B.
- Statically assigned port ranges do not need to go in the hold down pool. Added a new REQ-8-B.
- Fixed various nits. More precise text in some places.

A.5. Changed in -04

- Fixed nits, spelling, updated references.
- CGNs SHOULD NOT log destinations.
- Allow address-dependent filtering when it does not cause the application protocol to break.
- Refer to RFC4787 security considerations on EIF.
- Clarify REQ-12 point D (it does not apply to operator intervention).
- Changed "CGNs SHOULD limit ..." to "SHOULD support limiting" to make it clear that the operator is in control.
- Added reference to RFC 4963.
- Added requirement for non-contiguous external address pools.

A.6. Changed in -03

- Added exceptions for which it is not necessary to wait 120 seconds before reusing a port.
- Renamed "random port set" to "scattered port set", which is more accurate.
- Log "subscriber identifier" instead of internal address+port to allow for overlapping internal address ranges (DS-Lite).
- Adjusted logging text and added reference to I-D.boucadair-pppext-portrange-option.

- Adjusted destination logging text for bulk port allocation schemes.
- Removed requirement for I-D.ietf-intarea-ipv4-id-update.
- Made PCP support a SHOULD-level requirement.
- Lowered the level of requirement for not dropping existing mappings in order to "make room" to SHOULD level, and added rationale.

A.7. Changed in -02

- CGNs MUST support at least TCP, UDP, and ICMP.
- Add requirement from I-D.ietf-intarea-ipv4-id-update.
- Add informative reference to [RFC6269].
- Add requirement (SHOULD level) for a port forwarding protocol.
- Allow any pooling behavior on a per-application protocol basis.
- Adjust wording for external port allocation rate limiting.
- Add requirement for RFC4008 support (SHOULD level).
- Adjust wording for swapping address pools when rebooting.
- Add DSCP requirement (stolen from draft-jennings-behave-nat6).
- Add informative reference to draft-boucadair-intarea-nat-reveal-analysis.
- Add requirement for hold-down pool.
- Change definition of CGN.
- Avoid usage of "device" loaded word throughout the document.
- Add requirement about resource exhaustion.
- Change title.
- Describe additional CGN topology where there is no NAT444.
- Better justification for "Paired" pool behavior.

- Make it clear that rate limiting allocation is for preserving CPU resources
- Generalize the requirement for limiting the number of TCP sessions per mapping so that it applies to all memory-consuming state elements.
- Change CPE to subscriber where it applies throughout the text.
- Better terminology for bulk port allocation mechanisms.
- Explain how external address pairing works with DS-Lite.

A.8. Changed in -01

- Terminology: LSN is now CGN.
- Imported all requirements from RFCs 4787, 5382, and 5508. This allowed us to eliminate some duplication.
- Added references to draft-ietf-intarea-server-logging-recommendations and draft-ford-shared-addressing-issues.
- Incorporated a requirement from draft-xu-behave-stateful-nat-standby-06.

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