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Stuart Cheshire
Marc Krochmal
Apple Inc.

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NAT Port Mapping Protocol (NAT-PMP)
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Abstract

This document describes a protocol for automating the process of creating Network Address Translation (NAT) port mappings. Included in the protocol is a method for retrieving the external IPv4 address of a NAT gateway, thus allowing a client to make this external IPv4 address and port known to peers that may wish to communicate with it. From 2005 onwards this protocol was implemented in Apple products including Mac OS X, Bonjour for Windows, and AirPort wireless base stations. In 2012 NAT-PMP was superseded by the IETF Standards-Track Port Control Protocol, which builds on NAT-PMP and uses a compatible packet format, but adds a number of significant enhancements [PCP].

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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1. Introduction

Network Address Translation (NAT) is a method of sharing one public internet address with a number of devices. This document is focused on devices that are formally classified as "NAPTs" (Network Address/Port Translators) [RFC 2663]. A full description of NAT is beyond the scope of this document. The following brief overview will cover the aspects relevant to this port mapping protocol. For more information on NAT, see "Traditional IP Network Address Translator" [RFC 3022].

NATs have one or more external IP addresses. A private network is set up behind the NAT. Devices behind the NAT are assigned private addresses and the private address of the NAT device is used as the gateway.

When a packet from any device behind the NAT is sent to an address on the public Internet, the packet first passes through the NAT box. The NAT box looks at the source port and address. In some cases, a NAT will also keep track of the destination port and address. The NAT then creates a mapping from the internal address and internal port to an external address and external port if a mapping does not already exist.

The NAT box replaces the internal address and port in the packet with the external entries from the mapping and sends the packet on to the next gateway.

When a packet from any address on the Internet is received on the NAT's external side, the NAT will look up the destination address and port (external address and port) in the list of mappings. If an entry is found, it will contain the internal address and port that the packet should be sent to. The NAT gateway will then rewrite the destination address and port with those from the mapping. The packet will then be forwarded to the new destination addresses. If the packet did not match any mapping, the packet will most likely be dropped. Various NATs implement different strategies to handle this. The important thing to note is that if there is no mapping, the NAT does not know to which internal address the packet should be sent.

Mappings are usually created automatically as a result of observing outbound packets. There are a few exceptions. Some NATs may allow manually-created permanent mappings that map an external port to a specific internal IP address and port. Such a mapping allows incoming connections to the device with that internal address. Some NATs also implement a default mapping where any inbound packet that does not match any other more specific mapping will be forwarded to a specified internal address. Both types of mappings are usually set up manually through some configuration tool.

Without these manually-created inbound port mappings, clients behind the NAT would be unable to receive inbound connections, which represents a loss of connectivity when compared to the original Internet architecture [ETEAISD]. For those who view this loss of connectivity as a bad thing, NAT-PMP allows clients to operate more like a host directly connected to the unrestricted public Internet, with an unrestricted public IPv4 address. NAT-PMP allows client hosts to communicate with the NAT gateway to request the creation of inbound mappings on demand. Having created a NAT mapping to allow inbound connections, the client can then record its external IPv4 address and external port in a public registry (e.g. the world-wide Domain Name System) or otherwise make it accessible to peers that wish to communicate with it.

2. Conventions and Terminology Used in this Document

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 "Key words for use in RFCs to Indicate Requirement Levels" [RFC 2119].

3. Protocol and Packet Format

NAT Port Mapping Protocol runs over UDP. Every packet starts with an 8 bit version followed by an 8 bit operation code.

All numeric quantities in NAT-PMP larger than a single byte are transmitted in the traditional IETF network byte order (i.e. most significant byte first).

This document specifies version 0 of the protocol. Any NAT-PMP gateway implementing this version of the protocol, receiving a request with a version number other than 0, MUST return result code 1 (Unsupported Version), indicating the highest version number it does support (i.e. 0) in the version field of the response.

Opcodes between 0 and 127 are client requests. Opcodes from 128 to 255 are server responses. Responses always contain a 16 bit result code in network byte order. A result code of zero indicates success. Responses also contain a 32 bit unsigned integer corresponding to the number of seconds since the NAT gateway was rebooted or since its port mapping state was reset.

This protocol SHOULD only be used when the client determines that its primary IPv4 address is in one of the private IPv4 address ranges defined in "Address Allocation for Private Internets" [RFC 1918]. This includes the address ranges 10/8, 172.16/12, and 192.168/16.

Clients always send their Port Mapping Protocol requests to their default gateway, as learned via DHCP [RFC 2131], or similar means. This protocol is designed for small home networks, with a single logical link (subnet) where the client's default gateway is also the NAT translator for that network. For more complicated networks where the NAT translator is some device other than the client's default gateway, this protocol is not appropriate.

3.1. Requests and Responses

NAT gateways are often low-cost devices, with limited memory and CPU speed. For this reason, to avoid making excessive demands on the NAT gateway, clients machines SHOULD NOT issue multiple requests simultaneously in parallel. If a client needs to perform multiple requests (e.g. on boot, wake from sleep, network connection, etc.) it SHOULD queue them and issue them serially one at a time. Once the NAT gateway responds to one request the client machine may issue the next. In the case of a fast NAT gateway, the client may be able to complete requests at a rate of hundreds per second. In the case of a slow NAT gateway that takes perhaps half a second to respond to a NAT-PMP request, the client SHOULD respect this and allow the

NAT gateway to operate at the pace it can manage, and not overload it by issuing requests faster than the rate it's answering them.

To determine the external IPv4 address or request a port mapping, a NAT-PMP client sends its request packet to port 5351 of its configured gateway address, and waits 250ms for a response. If no NAT-PMP response is received from the gateway after 250ms, the client retransmits its request and waits 500ms. The client SHOULD repeat this process with the interval between attempts doubling each time. If, after sending its 9th attempt (and then waiting for 64 seconds), the client has still received no response, then it SHOULD conclude that this gateway does not support NAT Port Mapping Protocol and MAY log an error message indicating this fact. In addition, if the NAT-PMP client receives an "ICMP Port Unreachable" message from the gateway for port 5351 then it can skip any remaining retransmissions and conclude immediately that the gateway does not support NAT-PMP.

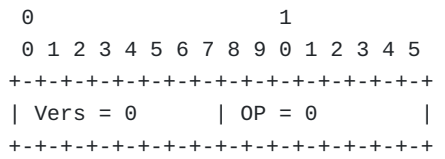
As a performance optimization the client MAY record this information and use it to suppress further attempts to use NAT-PMP, but the client should not retain this information for too long. In particular, any event that may indicate a potential change of gateway or a change in gateway configuration (hardware link change indication, change of gateway MAC address, acquisition of new DHCP lease, receipt of NAT-PMP announcement packet from gateway, etc.) should cause the client to discard its previous information regarding the gateway's lack of NAT-PMP support, and send its next NAT-PMP request packet normally.

When deleting a port mapping, the client uses the same initial 250ms timeout, doubling on each successive interval, except that clients may choose not to try the full nine times before giving up. This is because mapping deletion requests are in some sense advisory. They are useful for efficiency, but not required for correctness; it is always possible for client software to crash, or for power to fail, or for a client device to be physically unplugged from the network before it gets a chance to send its mapping deletion request(s), so NAT gateways already need to cope with this case. Because of this, it may be acceptable for a client to retry only once or twice before giving up on deleting its port mapping(s), but a client SHOULD always send at least one deletion request whenever possible, to reduce the amount of stale state that accumulates on NAT gateways.

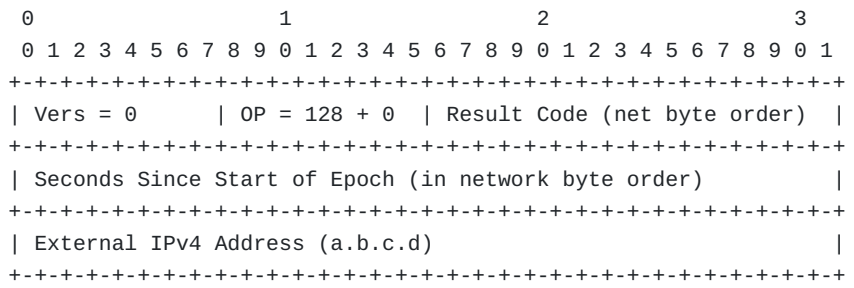
A client need not continue trying to delete a port mapping after the time when that mapping would naturally have expired anyway.

3.2. Determining the External Address

To determine the external address, the client behind the NAT sends the following UDP payload to port 5351 of the configured gateway address:



A compatible NAT gateway MUST generate a response with the following format:



This response indicates that the NAT gateway implements this version of the protocol and returns the external IPv4 address of the NAT gateway. If the result code is non-zero, the value of External IPv4 Address is undefined (MUST be set to zero on transmission, and MUST be ignored on reception).

The NAT gateway MUST fill in the "Seconds Since Start of Epoch" field with the time elapsed since its port mapping table was initialized on startup or reset for any other reason (see Section 3.6 "Seconds Since Start of Epoch").

Upon receiving a response packet, the client MUST check the source IP address, and silently discard the packet if the address is not the address of the gateway to which the request was sent.

3.2.1. Announcing Address Changes

Upon boot, acquisition of an external IPv4 address, subsequent change of the external IPv4 address, reboot, or any other event that may indicate possible loss or change of NAT mapping state, the NAT gateway MUST send a gratuitous response to the link-local multicast address 224.0.0.1, port 5350, with the packet format above, to notify clients of the external IPv4 address and Seconds Since Start of Epoch.

To accommodate packet loss, the NAT gateway SHOULD multicast 10 address notifications. The interval between the first two notifications SHOULD be 250ms, and the interval between each subsequent notification SHOULD double. The Seconds Since Start of Epoch field in each transmission MUST be updated appropriately to reflect the passage of time, so as not to trigger unnecessary additional mapping renewals (See Section 3.7 "Recreating Mappings On NAT Gateway Reboot".)

Upon receiving a gratuitous address announcement packet, the client MUST check the source IP address, and silently discard the packet if the address is not the address of the client's current configured gateway. This is to guard against inadvertent misconfigurations where there may be more than one NAT gateway active on the network.

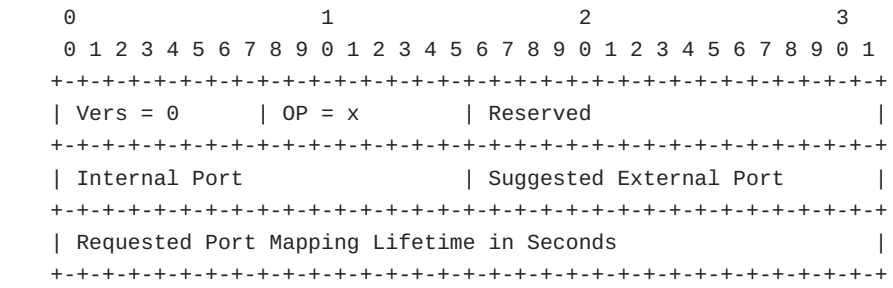
If the source IP address is correct, then the Seconds Since Start of Epoch field is checked as described in Section 3.6, and if the value is outside the expected plausible range, indicating that a NAT gateway state loss has occurred, then the NAT-PMP client promptly recreates all its active port mapping leases, as described in Section 3.7 "Recreating Mappings On NAT Gateway Reboot".

IMPLEMENTATION NOTE: Earlier implementations of NAT-PMP used UDP port 5351 as the destination both for client requests (address and port mapping) and for address announcements. NAT-PMP servers would listen on UDP 5351 for client requests, and NAT-PMP clients would listen on UDP 5351 for server announcements. However, implementers encountered difficulties when a single device is acting in both roles, for example a home computer with Internet Sharing enabled. This computer is acting in the role of NAT-PMP server to its DHCP clients, yet at the same time it has to act in the role of NAT-PMP client in order to determine whether it is, itself, behind another NAT gateway. While in principle it might be possible on some operating systems for two processes to coordinate sharing of a single UDP port, on many platforms this is difficult or even impossible, so for pragmatic engineering reasons it is convenient to have clients listen on UDP 5350 and servers listen on UDP 5351.

IMPLEMENTATION NOTE: A given host may have more than one independent NAT-PMP client running at the same time, and address announcements need to be available to all of them. Clients should therefore set the SO_REUSEPORT option or equivalent in order to allow other processes to also listen on port 5350. Additionally, implementers have encountered issues when one or more processes on the same device listen to port 5350 on *all* addresses. Clients should therefore bind specifically to 224.0.0.1:5350, not to 0.0.0.0:5350.

3.3. Requesting a Mapping

To create a mapping, the client sends a UDP packet to port 5351 of the gateway's internal IP address with the following format:



Opcodes supported:
1 - Map UDP
2 - Map TCP

The Reserved field MUST be set to zero on transmission and MUST be ignored on reception.

The Ports and Lifetime are transmitted in the traditional network byte order (i.e. most significant byte first).

The Internal Port is set to the local port on which the client is listening.

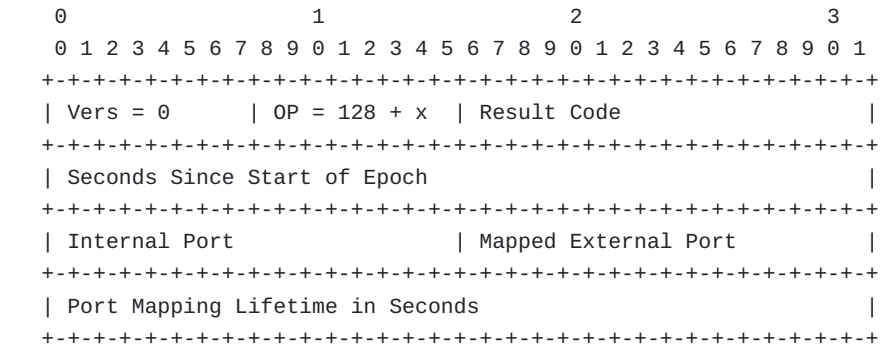
If the client would prefer to have a high-numbered "anonymous" external port assigned, then it should set the Suggested External Port to zero, which indicates to the gateway that it should allocate a high-numbered port of its choosing. If the client would prefer instead to have the mapped external port be the same as its local Internal Port if possible (e.g. a web server listening on port 80 that would ideally like to have external port 80) then it should set the Suggested External Port to the desired value. However, the gateway is not obliged to assign the port suggested, and may choose not to, either for policy reasons (e.g. port 80 is reserved and clients may not request it) or because that port has already been assigned to some other client. Because of this, some product developers have questioned the value of having the Suggested External Port field at all. The reason is for failure recovery. Most low-cost home NAT gateways do not record temporary port mappings in persistent storage, so if the gateway crashes or is rebooted, all the mappings are lost. A renewal packet is formatted identically to an initial mapping request packet, except that for renewals the client sets the Suggested External Port field to the port the gateway actually assigned, rather than the port the client originally wanted. When a freshly-rebooted NAT gateway receives a renewal packet from a client,

it appears to the gateway just like an ordinary initial request for a port mapping, except that in this case the Suggested External Port is likely to be one that the NAT gateway *is* willing to allocate (it allocated it to this client right before the reboot, so it should presumably be willing to allocate it again). This improves the stability of external ports across NAT gateway restarts.

The RECOMMENDED Port Mapping Lifetime is 7200 seconds (two hours).

After sending the port mapping request, the client then waits for the NAT gateway to respond. If after 250ms, the client hasn't received a response from the gateway, the client SHOULD re-issue its request as described above in Section 3.1 "Requests and Responses".

The NAT gateway responds with the following packet format:



The Epoch time, Ports and Lifetime are transmitted in the traditional network byte order (i.e. most significant byte first).

The 'x' in the OP field MUST match what the client requested. Some NAT gateways are incapable of creating a UDP port mapping without also creating a corresponding TCP port mapping, and vice versa, and these gateways MUST NOT implement NAT Port Mapping Protocol until this deficiency is fixed. A NAT gateway which implements this protocol MUST be able to create TCP-only and UDP-only port mappings. If a NAT gateway silently creates a pair of mappings for a client that only requested one mapping, then it may expose that client to receiving inbound UDP packets or inbound TCP connection requests that it did not ask for and does not want.

While a NAT gateway MUST NOT automatically create mappings for TCP when the client requests UDP, and vice versa, the NAT gateway MUST reserve the companion port so the same client can choose to map it in the future. For example, if a client requests to map TCP port 80, as long as the client maintains the lease for that TCP port mapping, another client with a different internal IP address MUST NOT be able to successfully acquire the mapping for UDP port 80.

The client normally requests the external port matching the internal port. If that external port is not available, the NAT gateway MUST return an available external port if possible, or return an error code if no external ports are available.

The source address of the packet MUST be used for the internal address in the mapping. This protocol is not intended to facilitate one device behind a NAT creating mappings for other devices. If there are legacy devices that require inbound mappings, permanent mappings can be created manually by the user through an administrative interface, just as they are today.

If a mapping already exists for a given internal address and port (whether that mapping was created explicitly using NAT-PMP, implicitly as a result of an outgoing TCP SYN packet, or manually by a human administrator) and that client requests another mapping for the same internal port (possibly requesting a different external port) then the mapping request should succeed, returning the already-assigned external port. This is necessary to handle the case where a client requests a mapping with suggested external port X, and is granted a mapping with actual external port Y, but the acknowledgment packet gets lost. When the client retransmits its mapping request, it should get back the same positive acknowledgment as was sent (and lost) the first time.

The NAT gateway MUST NOT accept mapping requests destined to the NAT gateway's external IP address or received on its external network interface. Only packets received on the internal interface(s) with a destination address matching the internal address(es) of the NAT gateway should be allowed.

The NAT gateway MUST fill in the "Seconds Since Start of Epoch" field with the time elapsed since its port mapping table was initialized on startup or reset for any other reason (see Section 3.6 "Seconds Since Start of Epoch").

The Port Mapping Lifetime is an unsigned integer in seconds. The NAT gateway MAY reduce the lifetime from what the client requested. The NAT gateway SHOULD NOT offer a lease lifetime greater than that requested by the client.

Upon receiving the response packet, the client MUST check the source IP address, and silently discard the packet if the address is not the address of the gateway to which the request was sent.

The client SHOULD begin trying to renew the mapping halfway to expiry time, like DHCP. The renewal packet should look exactly the same as a request packet, except that the client SHOULD set the Suggested External Port to what the NAT gateway previously mapped, not what the

client originally suggested. As described above, this enables the gateway to automatically recover its mapping state after a crash or reboot.

3.4. Destroying a Mapping

A mapping may be destroyed in a variety of ways. If a client fails to renew a mapping, then when its lifetime expires the mapping MUST be automatically deleted. In the common case where the gateway device is a combined DHCP server and NAT gateway, when a client's DHCP address lease expires, the gateway device MAY automatically delete any mappings belonging to that client. Otherwise a new client being assigned the same IP address could receive unexpected inbound UDP packets or inbound TCP connection requests that it did not ask for and does not want.

A client MAY also send an explicit packet to request deletion of a mapping that is no longer needed. A client requests explicit deletion of a mapping by sending a message to the NAT gateway requesting the mapping, with the Requested Lifetime in Seconds set to zero. The Suggested External Port MUST be set to zero by the client on sending, and MUST be ignored by the gateway on reception.

When a mapping is destroyed successfully as a result of the client explicitly requesting the deletion, the NAT gateway MUST send a response packet which is formatted as defined in Section 3.3 "Requesting a Mapping". The response MUST contain a result code of 0, the internal port as indicated in the deletion request, an external port of 0, and a lifetime of 0. The NAT gateway MUST respond to a request to destroy a mapping that does not exist as if the request were successful. This is because of the case where the acknowledgment is lost, and the client retransmits its request to delete the mapping. In this case the second request to delete the mapping MUST return the same response packet as the first request.

If the deletion request was unsuccessful, the response MUST contain a non-zero result code and the requested mapping; the lifetime is undefined (MUST be set to zero on transmission, and MUST be ignored on reception). If the client attempts to delete a port mapping which was manually assigned by some kind of configuration tool, the NAT gateway MUST respond with a 'Not Authorized' error, result code 2.

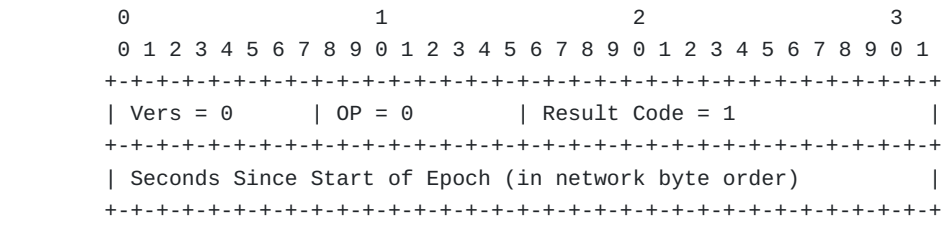
When a mapping is destroyed as a result of its lifetime expiring or for any other reason, if the NAT gateway's internal state indicates that there are still active TCP connections traversing that now-defunct mapping, then the NAT gateway SHOULD send appropriately-constructed TCP RST (reset) packets both to the local client and to the remote peer on the Internet to terminate that TCP connection.

A client can request the explicit deletion of all its UDP or TCP mappings by sending the same deletion request to the NAT gateway with external port, internal port, and lifetime set to zero. A client MAY choose to do this when it first acquires a new IP address in order to protect itself from port mappings that were performed by a previous owner of the IP address. After receiving such a deletion request, the gateway MUST delete all its UDP or TCP port mappings (depending on the opcode). The gateway responds to such a deletion request with a response as described above, with the internal port set to zero. If the gateway is unable to delete a port mapping, for example, because the mapping was manually configured by the administrator, the gateway MUST still delete as many port mappings as possible, but respond with a non-zero result code. The exact result code to return depends on the cause of the failure. If the gateway is able to successfully delete all port mappings as requested, it MUST respond with a result code of zero.

3.5. Result Codes

Currently defined result codes:
0 - Success
1 - Unsupported Version
2 - Not Authorized/Refused
(e.g. box supports mapping, but user has turned feature off)
3 - Network Failure
(e.g. NAT box itself has not obtained a DHCP lease)
4 - Out of resources
(NAT box cannot create any more mappings at this time)
5 - Unsupported opcode

If the version in the request is not zero, then the NAT-PMP server MUST return the following "Unsupported Version" error response to the client:



If the opcode in the request is 128 or greater, then this is not a request; it's a response, and the NAT-PMP server MUST silently ignore it. Otherwise, if the opcode in the request is less than 128, but is not a supported opcode (currently 0, 1 or 2), then the entire request MUST be returned to the sender, with the top bit of the opcode set

(to indicate that this is a response) and the result code set to 5 (Unsupported opcode).

For version 0 and a supported opcode (0, 1 or 2), if the operation fails for some reason (Not Authorized, Network Failure, or Out of resources) then a valid response MUST be sent to the client, with the top bit of the opcode set (to indicate that this is a response) and the result code set appropriately. Other fields in the response MUST be set appropriately. Specifically:

- Seconds Since Start of Epoch MUST be set correctly
- The External IPv4 Address should be set to the correct address, or to 0.0.0.0, as appropriate.
- The Internal Port MUST be set to the client's requested Internal Port. This is particularly important, because the client needs this information to identify which request suffered the failure.
- The Mapped External Port and Port Mapping Lifetime MUST be set appropriately -- i.e. zero if no successful port mapping was created.

Should future NAT-PMP opcodes be defined, their error responses MUST similarly be specified to include sufficient information to identify which request suffered the failure. By design, NAT-PMP messages do not contain any transaction identifier. All NAT-PMP messages are idempotent and self-describing; therefore the specifications of future NAT-PMP messages need to include enough information for their responses to be self-describing.

Clients MUST be able to properly handle result codes not defined in this document. Undefined results codes MUST be treated as fatal errors of the request.

3.6. Seconds Since Start of Epoch

Every packet sent by the NAT gateway includes a "Seconds since start of epoch" field (SSSOE). If the NAT gateway resets or loses the state of its port mapping table, due to reboot, power failure, or any other reason, it MUST reset its epoch time and begin counting SSSOE from zero again. Whenever a client receives any packet from the NAT gateway, either gratuitously or in response to a client request, the client computes its own conservative estimate of the expected SSSOE value by taking the SSSOE value in the last packet it received from the gateway and adding 7/8 (87.5%) of the time elapsed according to the client's local clock since that packet was received. If the SSSOE in the newly received packet is less than the client's conservative

estimate by more than two seconds, then the client concludes that the NAT gateway has undergone a reboot or other loss of port mapping state, and the client MUST immediately renew all its active port mapping leases as described in Section 3.7 "Recreating Mappings On NAT Gateway Reboot".

3.7. Recreating Mappings On NAT Gateway Reboot

The NAT gateway MAY store mappings in persistent storage so that when it is powered off or rebooted, it remembers the port mapping state of the network.

However, maintaining this state is not essential for correct operation. When the NAT gateway powers on or clears its port mapping state as the result of a configuration change, it MUST reset the epoch time and re-announce its IPv4 address as described in Section 3.2.1 "Announcing Address Changes". Reception of this packet where time has apparently gone backwards serves as a hint to clients on the network that they SHOULD immediately send renewal packets (to immediately recreate their mappings) instead of waiting until the originally scheduled time for those renewals. Clients who miss receiving those gateway announcement packets for any reason will still renew their mappings at the originally scheduled time and cause their mappings to be recreated; it will just take a little longer for these clients.

A mapping renewal packet is formatted identically to an original mapping request; from the point of view of the client it is a renewal of an existing mapping, but from the point of view of the freshly-rebooted NAT gateway it appears as a new mapping request.

This self-healing property of the protocol is very important.

The remarkable reliability of the Internet as a whole derives in large part from the fact that important state is held in the endpoints, not in the network itself [ETEAISD]. Power-cycling an Ethernet switch results only in a brief interruption in the flow of packets; established TCP connections through that switch are not broken, merely delayed for a few seconds. Indeed, a failing Ethernet switch can even be replaced with a new one, and as long as the cables are transferred over reasonably quickly, after the upgrade all the TCP connections that were previously going through the old switch will be unbroken and now going through the new one. The same is true of IP routers, wireless base stations, etc. The one exception is NAT gateways. Because the port mapping state is required for the NAT gateway to know where to forward inbound packets, loss of that state breaks connectivity through the NAT gateway. By allowing clients to detect when this loss of NAT gateway state has occurred, and recreate

it on demand, we turn hard state in the network into soft state, and allow it to be recovered automatically when needed.

Without this automatic recreation of soft state in the NAT gateway, reliable long-term networking would not be achieved. As mentioned above, the reliability of the Internet does not come from trying to build a perfect network in which errors never happen, but from accepting that in any sufficiently large system there will always be some component somewhere that's failing, and designing mechanisms that can handle those failures and recover. To illustrate this point with an example, consider the following scenario: Imagine a network security camera that has a web interface and accepts incoming connections from web browser clients. Imagine this network security camera uses NAT-PMP or a similar protocol to set up an inbound port mapping in the NAT gateway so that it can receive incoming connections from clients the other side of the NAT gateway. Now, this camera may well operate for weeks, months, or even years. During that time it's possible that the NAT gateway could experience a power failure or be rebooted. The user could upgrade the NAT gateway's firmware, or even replace the entire NAT gateway device with a newer model. The general point is that if the camera operates for a long enough period of time, some kind of disruption to the NAT gateway becomes inevitable. The question is not whether the NAT gateway will lose its port mappings, but when, and how often. If the network camera and devices like it on the network can detect when the NAT gateway has lost its port mappings, and recreate them automatically, then these disruptions are self-correcting and largely invisible to the end user. If, on the other hand, the disruptions are not self-correcting, and after a NAT gateway reboot the user has to manually reset or reboot all the other devices on the network too, then these disruptions are *very* visible to the end user. This aspect of the design is part of what makes the difference between a protocol that keeps on working indefinitely over a time scale of months or years, and a protocol that works in brief testing, but in the real world is continually failing and requiring manual intervention to get it going again.

When a client renews its port mappings as the result of receiving a packet where the "Seconds since start of epoch" field (SSSOE) indicates that a reboot or similar loss of state has occurred, the client MUST first delay by a random amount of time selected with uniform random distribution in the range 0 to 5 seconds, and then send its first port mapping request. After that request is acknowledged by the gateway, the client may then send its second request, and so on, as rapidly as the gateway allows. The requests SHOULD be issued serially, one at a time; the client SHOULD NOT issue multiple requests simultaneously in parallel.

The discussion in this section focusses on recreating inbound port mappings after loss of NAT gateway state, because that is the more serious problem. Losing port mappings for outgoing connections destroys those currently active connections, but does not prevent clients from establishing new outgoing connections. In contrast, losing inbound port mappings not only destroys all existing inbound connections, but also prevents the reception of any new inbound connections until the port mapping is recreated. Accordingly, we consider recovery of inbound port mappings the more important priority. However, clients that want outgoing connections to survive a NAT gateway reboot can also achieve that using NAT-PMP, in the common case of a residential NAT gateway with a single, relatively stable, external IP address. After initiating an outbound TCP connection (which will cause the NAT gateway to establish an implicit port mapping) the client should send the NAT gateway a port mapping request for the source port of its TCP connection, which will cause the NAT gateway to send a response giving the external port it allocated for that mapping. The client can then store this information, and use later to recreate the mapping if it determines that the NAT gateway has lost its mapping state.

3.8. NAT Gateways with NAT Function Disabled

Note that only devices that are *currently* acting in the role of NAT gateway should participate in NAT-PMP protocol exchanges with clients. A network device that is capable of NAT (and NAT-PMP), but is currently configured not to perform that function, (e.g. it is acting as a traditional IP router, forwarding packets without modifying them), MUST NOT respond to NAT-PMP requests from clients, nor send spontaneous NAT-PMP address-change announcements.

In particular, a network device not currently acting in the role of NAT gateway should not even respond to NAT-PMP requests by returning an error code such as "2 - Not Authorized/Refused", since to do so is misleading to clients -- it suggests that NAT port mapping is necessary on this network for the client to successfully receive inbound connections, but is not available because the administrator has chosen to disable that functionality.

Clients should also be careful to avoid making unfounded assumptions, such as the assumption that if the client has an IPv4 address in one of the RFC 1918 private IPv4 address ranges then that means NAT necessarily must be in use. Net 10/8 has enough addresses to build a private network with millions of hosts and thousands of interconnected subnets, all without any use of NAT. Many organizations have built such private networks that benefit from using standard TCP/IP technology, but by choice do not connect to the public Internet. The purpose of NAT-PMP is to mitigate some of the damage caused by NAT. It would be an ironic and unwanted

side-effect of this protocol if it were to lead well-meaning but misguided developers to create products that refuse to work on a private network *unless* they can find a NAT gateway to talk to. Consequently, a client finding that NAT-PMP is not available on its network should not give up, but should proceed on the assumption that the network may be a traditional routed IP network, with no address translation being used. This assumption may not always be true, but it is better than the alternative of falsely assuming the worst and not even trying to use normal (non-NAT) IP networking.

If a network device not currently acting in the role of NAT gateway receives UDP packets addressed to port 5351, it SHOULD respond immediately with an "ICMP Port Unreachable" message to tell the client that it needn't continue with timeouts and retransmissions, and it should assume that NAT-PMP is not available and not needed on this network. Typically this behaviour can be achieved merely by not having an open socket listening on UDP port 5351.

3.9 All Mappings are Bidirectional

All NAT mappings, whether created implicitly by an outbound packet, created explicitly using NAT-PMP, or statically configured, are bidirectional. This means that when an outbound packet from a particular internal address and port is translated to an external address and port, replies addressed to that external address and port need to be translated back to the corresponding internal address and port.

The converse is also true. When an inbound packet is received that is addressed to an external address and port that matches an existing mapping (implicit, explicit, or static), it is translated to the corresponding internal address and port and forwarded. Outbound replies from that internal address and port need to be translated to the correct external address and port so that they are correctly recognized by the remote peer.

In particular, if an outbound UDP reply, that matches an existing explicit or static mapping, is instead treated like a "new" outbound UDP packet, and a new dynamic mapping is created (with a different external address and port) then when that packet arrives at the remote peer it will not be recognized as a valid reply. For TCP this bug is quickly spotted because all TCP implementations will ignore replies with the wrong apparent source address and port. For UDP this bug can more easily go unnoticed, because some UDP clients neglect to check the source address and port of replies, and thus will appear to work some of the time with NAT gateways that put the wrong source address and port in outbound packets. All NAT gateways MUST ensure that mappings, however created, are bidirectional.

4. UNSAF Considerations

The document "IAB Considerations for UNilateral Self-Address Fixing Across NAT" [RFC 3424] covers a number of issues when working with NATs. It outlines some requirements for any document that attempts to work around problems associated with NATs. This section addresses those requirements.

4.1. Scope

This protocol addresses the needs of TCP and UDP transport peers that are separated from the public Internet by exactly one IPv4 NAT. Such peers must have access to some form of directory server for registering the public IPv4 address and port at which they can be reached.

4.2. Transition Plan

Any client making use of this protocol SHOULD implement IPv6 support. If a client supports IPv6 and is running on a device with a global IPv6 address, that IPv6 address SHOULD be preferred to the IPv4 external address learned via this NAT mapping protocol. In case other clients do not have IPv6 connectivity, both the IPv4 and IPv6 addresses SHOULD be registered with whatever form of directory server is used. Preference SHOULD be given to IPv6 addresses when available. By implementing support for IPv6 and using this protocol for IPv4, vendors can ship products today that will work under both scenarios. As IPv6 is more widely deployed, clients of this protocol following these recommendations will transparently make use of IPv6.

4.3. Failure Cases

Aside from NATs that do not implement this protocol, there are a number of situations where this protocol may not work.

4.3.1. NAT Behind NAT

Some people's primary IPv4 address, assigned by their ISP, may itself be a NAT address. In addition, some people may have an external IPv4 address, but may then double NAT themselves, perhaps by choice or perhaps by accident. Although it might be possible in principle for one NAT gateway to recursively request a mapping from the next one, this document does not advocate that and does not try to prescribe how it would be done.

It would be a lot of work to implement nested NAT port mapping correctly, and there are a number of reasons why the end result might not be as useful as we might hope. Consider the case of an ISP that offers each of its customers only a single NAT address. This ISP could instead have chosen to provide each customer with a single public IPv4 address, or, if the ISP insists on running NAT, it could have chosen to allow each customer a reasonable number of addresses, enough for each customer device to have its own NAT address directly from the ISP. If instead this ISP chooses to allow each customer just one and only one NAT address, forcing said customer to run nested NAT in order to use more than one device, it seems unlikely that such an ISP would be so obliging as to provide a NAT service that supports NAT Port Mapping Protocol. Supposing that such an ISP did wish to offer its customers NAT service with NAT-PMP so as to give them the ability to receive inbound connections, this ISP could easily choose to allow each client to request a reasonable number of DHCP addresses from that gateway. Remember that Net 10/8 [RFC 1918] allows for over 16 million addresses, so NAT addresses are not in any way in short supply. A single NAT gateway with 16 million available addresses is likely to run out of packet forwarding capacity before it runs out of internal addresses to hand out. In this way the ISP could offer single-level NAT with NAT-PMP, obviating the need to support nested NAT-PMP. In addition, an ISP that is motivated to provide their customers with unhindered access to the Internet by allowing incoming as well as outgoing connections has better ways to offer this service. Such an ISP could offer its customers real public IPv4 addresses instead of NAT addresses, or could choose to offer its customers full IPv6 connectivity, where no mapping or translation is required at all.

4.3.2. NATs with Multiple External IPv4 Addresses

If a NAT maps internal addresses to multiple external addresses, then it SHOULD pick one of those external addresses as the one it will support for inbound connections, and for the purposes of this protocol it SHOULD act as if that address were its only address.

4.3.3. NATs and Routed Private Networks

In some cases, a large network may be subnetted. Some sites may install a NAT gateway and subnet the private network. Such subnetting breaks this protocol because the router address is not necessarily the address of the device performing NAT.

Addressing this problem is not a high priority. Any site with the resources to set up such a configuration should have the resources to add manual mappings or attain a range of globally unique addresses.

Not all NATs will support this protocol. In the case where a client is run behind a NAT that does not support this protocol, the software relying on the functionality of this protocol may be unusable.

4.3.4. Communication Between Hosts Behind the Same NAT

NAT gateways supporting NAT-PMP should also implement "hairpin translation". Hairpin translation means supporting communication between two local clients being served by the same NAT gateway.

Suppose device A is listening on internal address and port 10.0.0.2:80 for incoming connections. Using NAT-PMP, device A has obtained a mapping to external address and port x.x.x.x:80, and has recorded this external address and port in a public directory of some kind. For example, it could have created a DNS SRV record containing this information, and recorded it, using DNS Dynamic Update [RFC 3007], in a publicly accessible DNS server. Suppose then that device B, behind the same NAT gateway as device A, but unknowing or uncaring of this fact, retrieves device A's DNS SRV record and attempts to open a TCP connection to x.x.x.x:80. The outgoing packets addressed to this public Internet address will be sent to the NAT gateway for translation and forwarding. Having translated the source address and port number on the outgoing packet, the NAT gateway needs to be smart enough to recognize that the destination address is in fact itself, and then feed this packet back into its packet reception engine, to perform the destination port mapping lookup to translate and forward this packet to device A at address and port 10.0.0.2:80.

4.3.5. Non UDP/TCP Transport Traffic

Any communication over transport protocols other than TCP and UDP will not be served by this protocol. Examples are Generic Routing Encapsulation (GRE), Authentication Header (AH) and Encapsulating Security Payload (ESP).

4.4. Long Term Solution

As IPv6 is deployed, clients of this protocol supporting IPv6 will be able to bypass this protocol and the NAT when communicating with other IPv6 devices. In order to ensure this transition, any client implementing this protocol SHOULD also implement IPv6 and use this solution only when IPv6 is not available to both peers.

4.5. Existing Deployed NATs

Existing deployed NATs will not support this protocol. This protocol will only work with NATs that are upgraded to support it.

5. Security Considerations

As discussed in Section 3.2 "Determining the External Address", only clients on the internal side of the NAT may create port mappings, and only on behalf of themselves. By using IP address spoofing, it's possible for one client to delete the port mappings of another client. It's also possible for one client to create port mappings on behalf of another client. In cases where this is a concern, it can be dealt with using IPSec [RFC 4301].

The multicast announcements described in Section 3.2.1 "Announcing Address Changes" could be spoofed, facilitating a denial-of-service attack. This makes NAT-PMP unsuitable for use on LANs with large numbers of hosts where one or more of the hosts may be untrustworthy.

Another concern is that rogue software running on a local host could create port mappings for unsuspecting hosts, thereby rendering them vulnerable to external attack. However, it's not clear how realistic this threat model is, since rogue software on a local host could attack such unsuspecting hosts directly itself, without resorting to such a convoluted indirect technique. This concern is also a little misguided because it is based on the assumption that a NAT gateway and a firewall are the same thing, which they are not.

Some people view the property that NATs block inbound connections as a security benefit which is undermined by this protocol. The authors of this document have a different point of view. In the days before NAT became prevalent, all hosts had unique public IP addresses, and had unhindered ability to communicate with any other host on the Internet (a configuration that is still surprisingly common). Using NAT breaks this unhindered connectivity, relegating hosts to second-class status, unable to receive inbound connections. This protocol goes some way to partially reverse that damage. The purpose of a NAT gateway should be to allow several hosts to share a single address, not to simultaneously impede those host's ability to communicate freely. Security is most properly provided by end-to-end cryptographic security, and/or by explicit firewall functionality, as appropriate. Blocking of certain connections should occur only as a result of explicit and intentional firewall policy, not as an accidental side-effect of some other technology.

However, since many users do have an expectation that their NAT gateways can function as a kind of firewall, any NAT gateway implementing this protocol SHOULD have an administrative mechanism to disable it, thereby restoring the pre-NAT-PMP behaviour.

6. IANA Considerations

UDP ports 5350 and 5351 have been assigned for use by NAT-PMP, and subsequently by its successor, Port Control Protocol [PCP].

No further IANA services are required by this document.

7. Acknowledgments

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Special credit goes to Mike Bell, the Apple Vice President who recognized the need for a clean, elegant, reliable Port Mapping Protocol, and made the decision early on that Apple's AirPort base stations would support NAT-PMP.

8. Deployment History

In August 2004 NAT-PMP client software first became available to the public through Apple's Darwin Open Source code. In April 2005 NAT-PMP implementations began shipping to end users with the launch of Mac OS X 10.4 Tiger and Bonjour for Windows 1.0, and in June 2005 the protocol was first publicly documented in Internet-Draft draft-cheshire-nat-pmp-00.txt.

The NAT-PMP client in Mac OS X 10.4 Tiger and Bonjour for Windows exists as part of the mDNSResponder/mdnsd system service. When a client advertises a service using Wide Area Bonjour [DNS-SD], and the machine is behind a NAT-PMP-capable NAT gateway, and the machine is so configured, the mDNSResponder system service automatically uses NAT-PMP to set up an inbound port mapping, and then records the external IPv4 address and port in the global DNS. Existing client software using the Bonjour programming APIs [Bonjour] got this new NAT traversal functionality automatically. The logic behind this decision was that if client software publishes its information into the global DNS via Wide Area Bonjour service advertising, then it's reasonable to infer an expectation that this information should actually be usable by the peers retrieving it. Generally speaking, recording a private IPv4 address like 10.0.0.2 in the public DNS is likely to be pointless because that address is not reachable from clients on the other side of the NAT gateway. In the case of a home user with a single computer directly connected to their Cable or DSL modem, with a single global IPv4 address and no NAT gateway (a common configuration at that time), publishing the machine's global IPv4

address into the global DNS is useful, because that IPv4 address is globally reachable. In contrast, a home user using a NAT gateway to share a single global IPv4 address between several computers loses this ability to receive inbound connections. This breaks many peer-to-peer collaborative applications, like the multi-user text editor SubEthaEdit [SEE]. For many users, moving from one computer with a global IPv4 address, to two computers using NAT to share a single global IPv4 address, loss of inbound reachability was an unwanted side-effect of using NAT for address sharing. Automatically creating the necessary inbound port mappings helped remedy this unwanted side-effect of NAT.

The server side of the NAT-PMP protocol is implemented in Apple's "AirPort Extreme", "AirPort Express", and "Time Capsule" wireless base stations, and in the "Internet Sharing" feature of Mac OS X 10.4 and later.

In Mac OS X 10.4 Tiger, the NAT-PMP client was invoked automatically as a side-effect of clients requesting Wide Area Bonjour service registrations. Using NAT-PMP without an associated Wide Area Bonjour service registration required use of a third-party client library.

In October 2007 Mac OS X 10.5 Leopard added the "DNSServiceNATPort-MappingCreate" API, which made NAT-PMP client functionality directly available, so software could use it with other directory and rendezvous mechanisms in addition to Wide Area Bonjour DNS Updates.

In 2012 NAT-PMP was superseded by the IETF Standards-Track Port Control Protocol [PCP]. PCP builds on NAT-PMP and uses a compatible packet format, and adds a number of significant enhancements, including IPv6 support, management of outbound mappings, management of firewall rules, full compatibility with large-scale NATs with a pool of external addresses, error lifetimes, and an extension mechanism to enable future enhancements.

9. Noteworthy Features of NAT Port Mapping Protocol and PCP

Some readers have asked how NAT-PMP and PCP compare to other similar solutions, particularly the UPnP Forum's Internet Gateway Device (IGD) Device Control Protocol [IGD].

The answer is that although UPnP IGD is often used as a way for client devices to create port mappings programmatically, it's not ideal for that task. Whereas NAT-PMP was explicitly designed to be used primarily by software entities managing their own port mappings, UPnP IGD is more tailored towards being used by humans configuring all the settings of their gateway using some GUI tool. This difference in emphasis leads to protocol differences. For example, while it is reasonable and sensible to require software entities to renew their mappings periodically to prove that they are still there (like a device renewing its DHCP address lease), it would be unreasonable to require the same thing of a human user. When a human user configures their gateway, they expect it to stay configured that way until they decide to change it. If they configure a port mapping, they expect it to stay configured until they decide to delete it.

Because of this focus on being a general administration protocol for all aspects of home gateway configuration, UPnP IGD is a large and complicated collection of protocols (360 pages of specification spread over 13 separate documents, not counting supporting protocol specifications like SSDP and XML). While it may be a fine way for human users to configure their home gateways, it is not especially suited to the task of programmatically creating dynamic port mappings.

The requirements for a good port mapping protocol, requirements which are met by NAT-PMP, are outlined below:

9.1. Simplicity

Many home gateways, and many of the devices that connect to them, are small, low-cost devices, with limited RAM, flash memory, and CPU resources. Protocols they use should be considerate of this, supporting a small number of simple operations that can be implemented easily with a small amount of code. A quick comparison, based on page count of the respective documents alone, suggests that NAT-PMP is at least ten times simpler than UPnP IGD.

9.2. Focussed Scope

The more things a protocol can do, the more chance there is that something it does could be exploited for malicious purposes. NAT-PMP is tightly focussed on the specific task of creating port mappings. Were the protocol to be misused in some way, this helps limit the scope of what mischief could be performed using the protocol.

Because UPnP IGD allows control over all home gateway configuration settings, the potential for mischief is far greater. For example, a UPnP IGD home gateway allows messages that tell it to change the DNS server addresses that it sends to clients in its DHCP packets. Using this mechanism, a single item of malicious web content (e.g. a rogue Flash banner advert on a web page) can make a persistent change to the home gateway's configuration without the user's knowledge, such that all future DNS requests by all local clients will be sent to a rogue DNS server. This allows criminals to perform a variety of mischief, such as hijacking connections to bank web sites and redirecting them to the criminals' web servers instead [VU347812].

9.3. Efficiency

In addition to low-cost home gateways, many of the clients will also be similarly constrained low-cost devices with limited RAM resources.

When implementing a NAT-PMP client on a constrained device, it's beneficial to have well-defined bounds on RAM requirements that are fixed and known in advance. For example, when requesting the gateway's external IPv4 address, a NAT-PMP client on Ethernet knows that to receive the reply it will require 14 bytes for the Ethernet header, 20 bytes for the IPv4 header, 8 bytes for the UDP header, and 12 bytes for the NAT-PMP payload, making a total of 54 bytes.

In contrast, UPnP IGD uses an XML reply of unbounded size. It is not uncommon for a UPnP IGD device to return an XML document 4000 to 8000 bytes in size to communicate its four-byte external IPv4 address, and the protocol specification places no upper bound on how large the XML response may be, so there's nothing to stop the reply being even larger. This means that developers of UPnP client devices can only guess at how much memory they may need to receive the XML reply. Operational experience suggests that 10,000 bytes is usually enough for most UPnP IGD home gateways today, but that's no guarantee that some future UPnP IGD home gateway might not return a perfectly legal XML reply much larger than that.

In addition, because the XML reply is too large to fit in a single UDP packet, UPnP IGD has to use a TCP connection, thereby adding the overhead of TCP connection setup and teardown.

The process of discovering a UPnP IGD home gateway's external IPv4 address consists of:

- SSDP transaction to discover the TCP port to use, and the "URL" of the XML document to fetch from the gateway. If following the SSDP specification, this is 3 multicast requests, eliciting 9 unicast responses.

- HTTP "GET" request to get the device description. Typically 16 packets: 3 for TCP connection setup, 9 packets of data exchange, and a 4-packet FIN-ACK-FIN-ACK sequence to close the connection.

- HTTP "POST" to request the external IPv4 address. Typically 14 packets: 3 for TCP connection setup, 7 packets of data exchange, and a 4-packet FIN-ACK-FIN-ACK sequence to close the connection.

To retrieve the external IPv4 address NAT-PMP takes a two-packet UDP exchange (44-byte request, 54-byte response); the same thing using UPnP IGD takes 42 packets and thousands of bytes.

Similarly, UPnP IGD's HTTP "POST" request for a port mapping is typically a 14-packet exchange, compared with NAT-PMP's two-packet UDP exchange.

9.4. Atomic Allocation Operations

Some of the useful properties of NAT-PMP were inspired by DHCP, a reliable and successful protocol. For example, DHCP allows a client to request a desired IP address, but if that address is already in use the DHCP server will instead assign some other available address.

Correspondingly, NAT-PMP allows a client to request a desired external port, and if that external port is already in use by some other client, the NAT-PMP server will instead assign some other available external port.

UPnP IGD does not do this. If a UPnP IGD client requests an external port that has already been allocated, then one of two things happens.

Some UPnP IGD home gateways just silently overwrite the old mapping with the new one, causing the previous client to lose connectivity. If the previous client renews its port mapping, then it in turn overwrites the new mapping, and the two clients fight over the same external port indefinitely, neither achieving reliable connectivity.

Other IGD home gateways return a "Conflict" error if the port is already in use, which does at least tell the client what happened, but doesn't tell the client what to do. Instead of the NAT gateway

(which does know which ports are available) assigning one to the client, the NAT gateway makes the client (which doesn't know) keep guessing until it gets lucky. This problem remains mild as long as not many clients are using UPnP IGD, but gets progressively worse as the number of clients on the network requesting port mappings goes up. In addition, UPnP IGD works particularly badly in conjunction with the emerging policy of allocating pre-assigned port ranges to each client. If a client is assigned TCP port range 63488-64511, and the UPnP IGD client requests TCP port 80, trying successive incrementing ports until it succeeds, then the UPnP IGD client will have to issue 63,409 requests before it succeeds.

9.5. Garbage Collection

In any system that operates for a long period of time (as a home gateway should) it is important that garbage data does not accumulate indefinitely until the system runs out of memory and fails.

Like DHCP address leases, NAT-PMP leases a port mapping to a client for a finite length of time. The NAT-PMP client must renew the port mapping before it expires or, like an unrenewed DHCP address, it will be reclaimed. If a laptop computer is abruptly disconnected from the network without the opportunity to delete its port mappings, the NAT gateway will reclaim those mappings when they are not renewed.

In principle UPnP IGD should allow clients to specify a lifetime on port mappings. However, a Google search for "UPnP NewLeaseDuration" shows that in practice pretty much every client uses "<NewLeaseDuration>0</NewLeaseDuration>" to request an infinite lease, and the protocol has no way for the NAT gateway to decline that infinite lease request and require the client to renew it at reasonable intervals. Furthermore, anecdotal evidence is that if the client requests a lease other than zero, there are IGD home gateways that will ignore the request, fail in other ways, or even crash completely. As a client implementer then, you would be well advised not to attempt to request a lease other than zero, unless you want to suffer the support costs and bad publicity of lots of people complaining that your device brought down their entire network.

Because none of the early UPnP IGD clients requested port mapping leases, many UPnP IGD home gateway vendors never tested that functionality, and got away with shipping home gateways where that functionality was buggy or nonexistent. Because there are so many buggy UPnP IGD home gateways already deployed, client writers wisely stick to the well-trodden path of only requesting infinite leases. Because there are now few (if any) clients attempting to request non-zero leases, home gateway vendors have little incentive to expend resources implementing a feature no one uses.

This unfortunate consequence of the way UPnP IGD was developed and deployed means that in practice it has no usable port mapping lease facility today, and therefore when run for a long period of time UPnP IGD home gateways have no good way to avoid accumulating an unbounded number of stale port mappings.

9.6. State Change Announcements

When using DHCP on the external interface, as is the norm for home gateways, there is no guarantee that a UPnP IGD home gateway's external IPv4 address will remain unchanged. Indeed, some ISPs change their customer's IPv4 address every 24 hours (possibly in an effort to make it harder for their customers to "run a server" at home). What this means is that if the home gateway's external IPv4 address changes, it needs to inform its clients, so that they can make any necessary updates to global directory information (e.g. performing a Dynamic DNS update to update their address record).

When a NAT-PMP gateway's external IPv4 address changes, it broadcasts announcement packets to inform clients of this. UPnP IGD does not.

9.7. Soft State Recovery

When run for a long enough period of time, any network will have devices that fail, get rebooted, suffer power outages, or lose state for other reasons. A home gateway that runs for long enough is likely to suffer some such incident eventually. After losing state, it has no record of the port mappings it created, and clients suffer a consequent loss of connectivity.

To handle this case, NAT-PMP has the "Seconds Since Start of Epoch" mechanism. After a reboot or other loss of state, a NAT-PMP gateway broadcasts announcement packets giving its external IPv4 address, with the "Seconds Since Start of Epoch" field reset to begin counting from zero again. When a NAT-PMP client observes packets from its NAT-PMP gateway where the gateway's notion of time has apparently gone backwards compared to the client's, the client knows the gateway has probably lost state, and immediately recreates its mappings to restore connectivity.

UPnP IGD has no equivalent mechanism.

9.8. On-Path NAT Discovery

For any given host, it is only useful to request NAT port mappings in the NAT gateway through which that host's packets are flowing. A NAT port mapping is a request for packets to be translated in a certain way; the NAT gateway can only perform that translation if it's actually forwarding inbound and outbound packets for that host.

This is why NAT-PMP sends its requests to the host's default router, since this is the device that is forwarding (and possibly translating) inbound and outbound packets for that host. (In a larger network with multiple hops between a host and its NAT gateway, some other mechanism would need to be used to discover the correct on-path NAT for a host; this is possible, but outside the scope of this document.)

In contrast, UPnP IGD does not limit itself to using only on-path NATs. UPnP IGD uses a multicast SSDP query, and uses any device it finds on the local network claiming UPnP IGD capability, regardless of whether any inbound or outbound traffic is actually flowing through that device. Over the past few years this led to many bug reports being sent to Apple with the general form: "Port Mapping doesn't work on my Mac and that's a bug because everything else on my network says UPnP IGD is working fine." Upon investigation it always turned out that: (i) these people had NAT gateways that either didn't support port mapping requests, or had that capability disabled, and (ii) for some reason they also had some other old NAT device still connected to their network, and those other NAT devices were advertising UPnP IGD capability, even though they were not the active NAT gateway for the network. This led to UPnP IGD clients falsely reporting that they were "working fine", and only the Mac correctly reporting that it was unable to make any useful port mappings. In many cases the people reporting this "bug" had devices like game consoles on their home network that for many years had been reporting that UPnP IGD was "working fine", yet during those years they had never once successfully received any inbound network packet or connection. The irony is that, for these people who were reporting bugs to Apple, UPnP IGD "working fine" had been indistinguishable from UPnP IGD doing nothing useful at all. It was only when Back To My Mac [RFC 6281] started reporting that it was unable to make any functional port mappings that these people discovered they'd never had any working port mappings on their NAT gateway.

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12. Authors' Addresses

Stuart Cheshire
Apple Inc.
1 Infinite Loop
Cupertino
California 95014
USA

Email: cheshire@apple.com

Marc Krochmal
Apple Inc.
1 Infinite Loop
Cupertino
California 95014
USA

Email: marc@apple.com