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Stream Control Transmission Protocol (SCTP) Network Address Translation Support

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Abstract

Stream Control Transmission Protocol [RFC4960] provides a reliable communications channel between two end-hosts in many ways similar to TCP [RFC0793]. With the widespread deployment of Network Address Translators (NAT), specialized code has been added to NAT for TCP that allows multiple hosts to reside behind a NAT and yet use only a single globally unique IPv4 address, even when two hosts (behind a NAT) choose the same port numbers for their connection. This additional code is sometimes classified as Network Address and Port Translation (NAPT). To date, specialized code for SCTP has not yet been added to most NATs so that only pure NAT is available. The end result of this is that only one SCTP capable host can be behind a NAT.

This document describes the protocol extensions required for the SCTP endpoints to help NATs provide similar features of NAPT in the single-point and multi-point traversal scenario.

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 August 29, 2015.

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1. Introduction

Stream Control Transmission Protocol [RFC4960] provides a reliable communications channel between two end-hosts in many ways similar to TCP [RFC0793]. With the widespread deployment of Network Address Translators (NAT), specialized code has been added to NAT for TCP that allows multiple hosts to reside behind a NAT using private addresses (see [RFC6890]) and yet use only a single globally unique IPv4 address, even when two hosts (behind a NAT) choose the same port numbers for their connection. This additional code is sometimes classified as Network Address and Port Translation (NAPT). To date, specialized code for SCTP has not yet been added to most NATs so that only true NAT is available. The end result of this is that only one SCTP capable host can be behind a NAT.

This document describes an SCTP specific variant NAT and specific packets and procedures to help NATs provide similar features of NAPT in the single-point and multi-point traversal scenario. An SCTP implementation supporting this extension will follow these procedures to assure that in both single-homed and multi-homed cases a NAT will maintain the proper state without needing to change port numbers.

The authors feel it is possible and desirable to make these changes for a number of reasons:

- It is desirable for SCTP internal end-hosts on multiple platforms to be able to share a NAT's public IP address, much as TCP does today.

- o If a NAT does not need to change any data within an SCTP packet it will reduce the processing burden of NAT'ing SCTP by NOT needing to execute the CRC32c checksum required by SCTP.

- o Not having to touch the IP payload makes the processing of ICMP messages in NATs easier.

An SCTP-aware NAT will need to follow these procedures for generating appropriate SCTP packet formats.

When considering this feature it is possible to have multiple levels of support. At each level, the Internal Host, External Host and NAT may or may not support the features described in this document. The following table illustrates the results of the various combinations of support and if communications can occur between two endpoints.

Internal Host	NAT	External Host	Communication
Support	Support	Support	Yes
Support	Support	No Support	Limited
Support	No Support	Support	None
Support	No Support	No Support	None
No Support	Support	Support	Limited
No Support	Support	No Support	Limited
No Support	No Support	Support	None
No Support	No Support	No Support	None

Table 1: Communication possibilities

From the table we can see that when a NAT does not support the extension no communication can occur. This is because for the most part of the current situation i. e. SCTP packets sent externally from behind a NAT are discarded by the NAT. In some cases, where the NAT supports the feature but one of the two external hosts does not support the feature, communication may occur but in a limited way. For example only one host may be able to have a connection when a collision case occurs.

2. Conventions

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].

3. Terminology

This document uses the following terms, which are depicted in Figure 1.

Private-Address (Priv-Addr): The private address that is known to the internal host.

Internal-Port (Int-Port): The port number that is in use by the host holding the Private-Address.

Internal-VTag (Int-VTag): The Verification Tag that the internal host has chosen for its communication. The VTag is a unique 32-bit tag that must accompany any incoming SCTP packet for this association to the Private-Address.

External-Address (Ext-Addr): The address that an internal host is attempting to contact.

External-Port (Ext-Port): The port number of the peer process at the External-Address.

External-VTag (Ext-VTag): The Verification Tag that the host holding the External-Address has chosen for its communication. The VTag is a unique 32-bit tag that must accompany any incoming SCTP packet for this association to the External-Address.

Public-Address (Pub-Addr): The public address assigned to the NAT box which it uses as a source address when sending packets towards the External-Address.

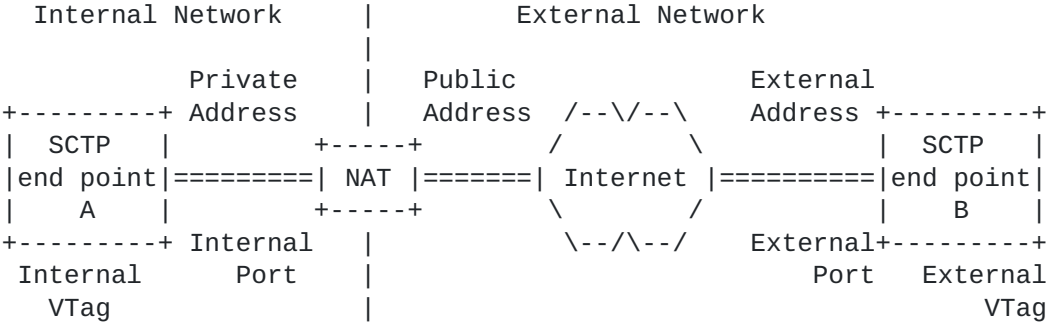


Figure 1: Basic network setup

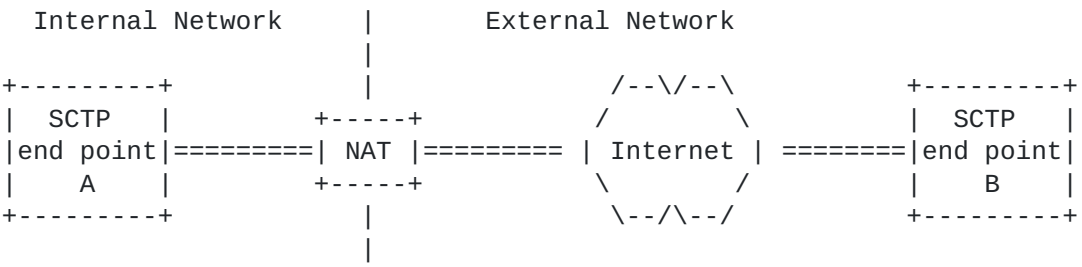
4. Motivation

4.1. SCTP NAT Traversal Scenarios

This section defines the notion of single and multi-point NAT traversal.

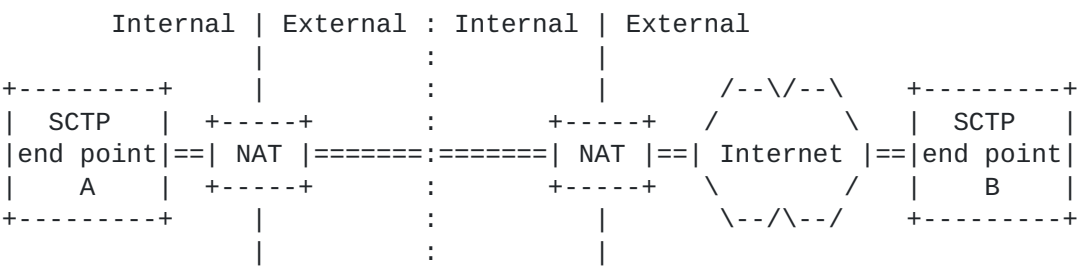
4.1.1. Single Point Traversal

In this case, all packets in the SCTP association go through a single NAT, as shown below:



Single NAT scenario

A variation of this case is shown below, i.e., multiple NATs in a single path:



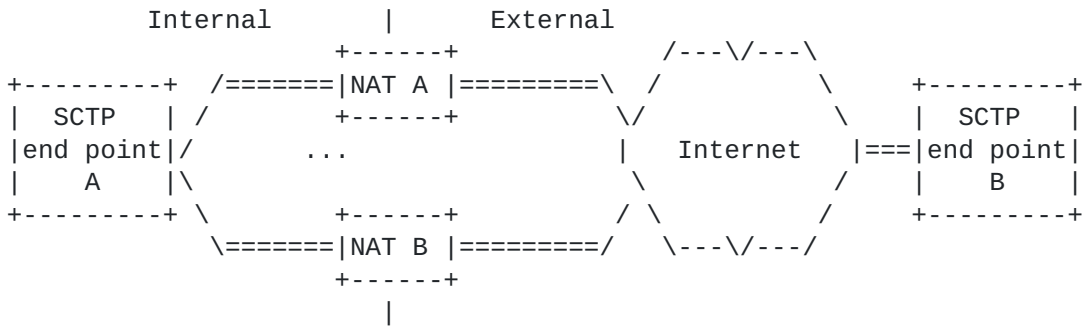
Serial NATs scenario

In this single point traversal scenario, we must acknowledge that while one of the main benefits of SCTP multi-homing is redundant paths, the NAT function represents a single point of failure in the path of the SCTP multi-home association. However, the rest of the path may still benefit from path diversity provided by SCTP multi-homing.

The two SCTP endpoints in this case can be either single-homed or multi-homed. However, the important thing is that the NAT (or NATs) in this case sees all the packets of the SCTP association.

4.1.2. Multi Point Traversal

This case involves multiple NATs and each NAT only sees some of the packets in the SCTP association. An example is shown below:



Parallel NATs scenario

This case does NOT apply to a single-homed SCTP association (i.e., BOTH endpoints in the association use only one IP address). The advantage here is that the existence of multiple NAT traversal points can preserve the path diversity of a multi-homed association for the entire path. This in turn can improve the robustness of the communication.

4.2. Limitations of Classical NAPT for SCTP

Using classical NAPT may result in changing one of the SCTP port numbers during the processing which requires the recomputation of the transport layer checksum. Whereas for UDP and TCP this can be done very efficiently, for SCTP the checksum (CRC32c) over the entire packet needs to be recomputed. This would add considerable to the NAT computational burden, however hardware support may mitigate this in some implementations.

An SCTP endpoint may have multiple addresses but only has a single port number. To make multipoint traversal work, all the NATs involved must recognize the packets they see as belonging to the same SCTP association and perform port number translation in a consistent way. One possible way of doing this is to use pre-defined table of ports and addresses configured within each NAT. Other mechanisms could make use of NAT to NAT communication. Such mechanisms are considered by the authors not to be deployable on a wide scale base and thus not a recommended solution. Therefore the SCTP variant of NAT has been developed.

4.3. The SCTP Specific Variant of NAT

In this section we assume that we have multiple SCTP capable hosts behind a NAT which has one Public-Address. Furthermore we are focusing in this section on the single point traversal scenario.

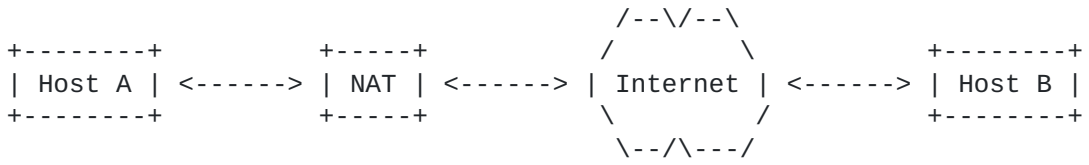
The modification of SCTP packets sent to the public Internet is easy. The source address of the packet has to be replaced with the Public-Address. It may also be necessary to establish some state in the NAT box to handle incoming packets, which is discussed later.

For SCTP packets coming from the public Internet the destination address of the packets has to be replaced with the Private-Address of the host the packet has to be delivered to. The lookup of the Private-Address is based on the External-VTag, External-Port, External-Address, Internal-VTag and the Internal-Port.

For the SCTP NAT processing the NAT box has to maintain a table of Internal-VTag, Internal-Port, Private-Address, External-VTag, External-Port and whether the restart procedure is disabled or not. An entry in that table is called a NAT state control block. The function Create() obtains the just mentioned parameters and returns a NAT-State control block.

The entries in this table fulfill some uniqueness conditions. There must not be more than one entry with the same pair of Internal-Port and External-Port. This rule can be relaxed, if all entries with the same Internal-Port and External-Port have the support for the restart procedure enabled. In this case there must be no more than one entry with the same Internal-Port, External-Port and Ext-VTag and no more than one entry with the same Internal-Port, External-Port and Int-VTag.

The processing of outgoing SCTP packets containing an INIT-chunk is described in the following figure. The scenario shown is valid for all message flows in this section.

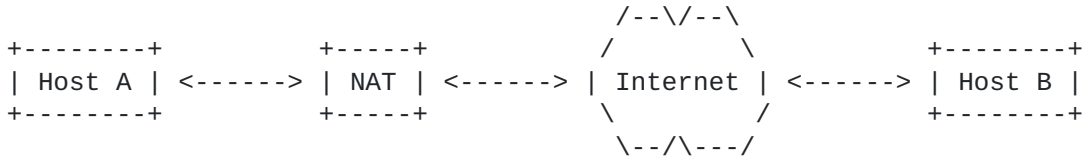



```
              INIT[Initiate-Tag]
Priv-Addr:Int-Port ------> Ext-Addr:Ext-Port
                  Ext-VTag=0

                   Create(Initiate-Tag, Int-Port, Priv-Addr, 0)
                   Returns(NAT-State control block)

            Translate To:

                        INIT[Initiate-Tag]
            Pub-Addr:Int-Port ------> Ext-Addr:Ext-Port
                            Ext-VTag=0
```

It should be noted that normally a NAT control block will be created. However, it is possible that there is already a NAT control block with the same External-Address, External-Port, Internal-Port, and Internal-VTag but different Private-Address. In this case the INIT SHOULD be dropped by the NAT and an ABORT SHOULD be sent back to the SCTP host with the M-Bit set and an appropriate error cause (see Section 5.1.1 for the format). The source address of the packet containing the ABORT chunk MUST be the destination address of the packet containing the INIT chunk.

It is also possible that a connection to External-Address and External-Port exists without an Internal-VTag conflict but the External-Address does not support the DISABLE_RESTART feature (noted in the NAT control block when the prior connection was established). In such a case the INIT SHOULD be dropped by the NAT and an ABORT SHOULD be sent back to the SCTP host with the M-Bit set and an appropriate error cause (see Section 5.1.1 for the format).

The processing of outgoing SCTP packets containing no INIT-chunk is described in the following figure.

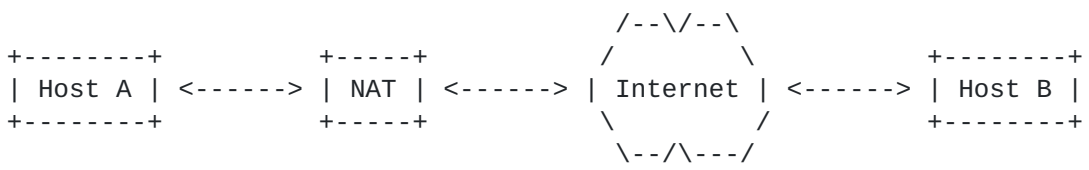


Priv-Addr:Int-Port ------> Ext-Addr:Ext-Port
Ext-VTag

Translate To:

Pub-Addr:Int-Port ------> Ext-Addr:Ext-Port
Ext-VTag

The processing of incoming SCTP packets containing INIT-ACK chunks is described in the following figure. The Lookup() function getting as input the Internal-VTag, Internal-Port, External-VTag (=0), External-Port, and External-Address, returns the corresponding entry of the NAT table and updates the External-VTag by substituting it with the value of the Initiate-Tag of the INIT-ACK chunk. The wildcard character signifies that the parameter's value is not considered in the Lookup() function or changed in the Update() function, respectively.



INIT-ACK[Initiate-Tag]
Pub-Addr:Int-Port <---- Ext-Addr:Ext-Port
Int-VTag

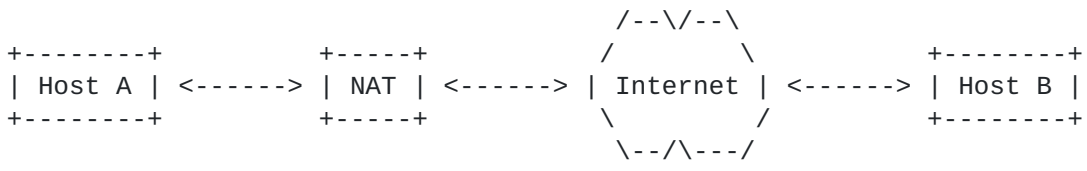
Lookup(Int-VTag, Int-Port, *, 0, Ext-Port)
Update(*, *, *, Initiate-Tag, *)

Returns(NAT-State control block containing Private-Address)

INIT-ACK[Initiate-Tag]
Priv-Addr:Int-Port <------ Ext-Addr:Ext-Port
Int-VTag

In the case Lookup fails, the SCTP packet is dropped. The Update routine inserts the External-VTag (the Initiate-Tag of the INIT-ACK chunk) in the NAT state control block.

The processing of incoming SCTP packets containing an ABORT or SHUTDOWN-COMPLETE chunk with the T-Bit set is described in the following figure.



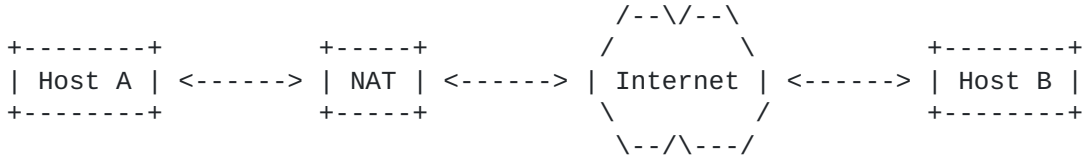
Pub-Addr:Int-Port <------ Ext-Addr:Ext-Port
Ext-VTag

Lookup(0, Int-Port, *, Ext-VTag, Ext-Port)

Returns(NAT-State control block containing Private-Address)

Priv-Addr:Int-Port <------ Ext-Addr:Ext-Port
Ext-VTag

The processing of other incoming SCTP packets is described in the following figure.



Pub-Addr:Int-Port <------ Ext-Addr:Ext-Port
Int-VTag

Lookup(Int-VTag, Int-Port, *, *, Ext-Port)

Returns(NAT-State control block containing Local-Address)

Priv-Addr:Int-Port <------ Ext-Addr:Ext-Port
Int-VTag

For an incoming packet containing an INIT-chunk a table lookup is made only based on the addresses and port numbers. If an entry with an External-VTag of zero is found, it is considered a match and the External-VTag is updated.

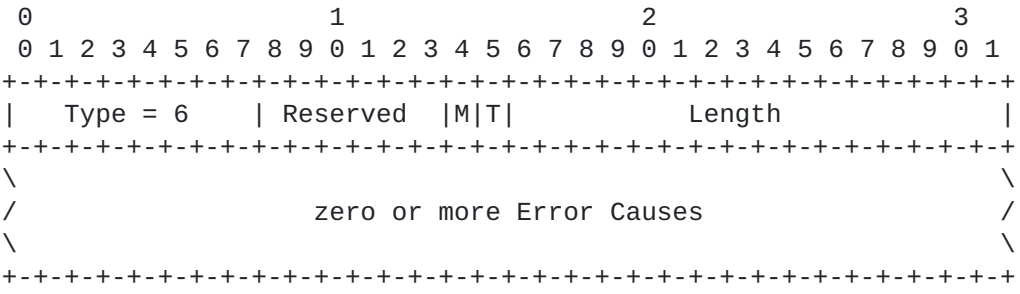
This allows the handling of INIT-collision through NAT.

5. Data Formats

5.1. Modified Chunks

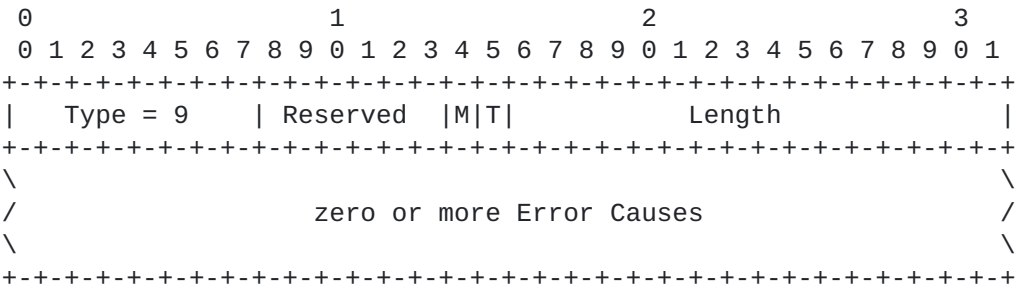
This section presents existing chunks defined in [RFC4960] that are modified by this document.

5.1.1. Extended ABORT Chunk



The ABORT chunk is extended to add the new 'M-bit'. The M-bit indicates to the receiver of the ABORT chunk that the chunk was not generated by the peer SCTP endpoint, but instead by a middle box.

5.1.2. Extended ERROR Chunk

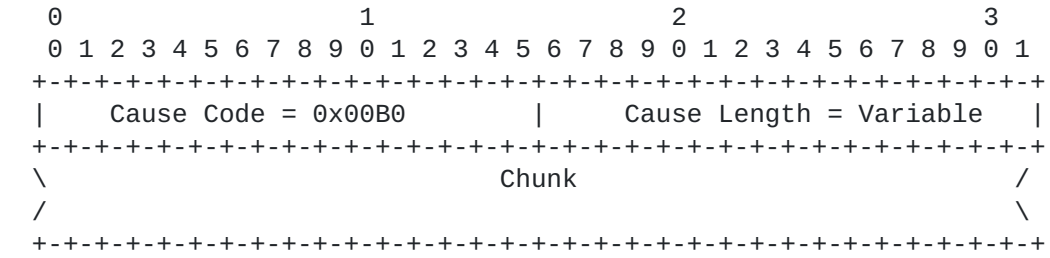


The ERROR chunk defined in [RFC4960] is extended to add the new 'M-bit'. The M-bit indicates to the receiver of the ERROR chunk that the chunk was not generated by the peer SCTP endpoint, but instead by a middle box.

5.2. New Error Causes

This section defines the new error causes added by this document.

5.2.1. VTag and Port Number Collision Error Cause

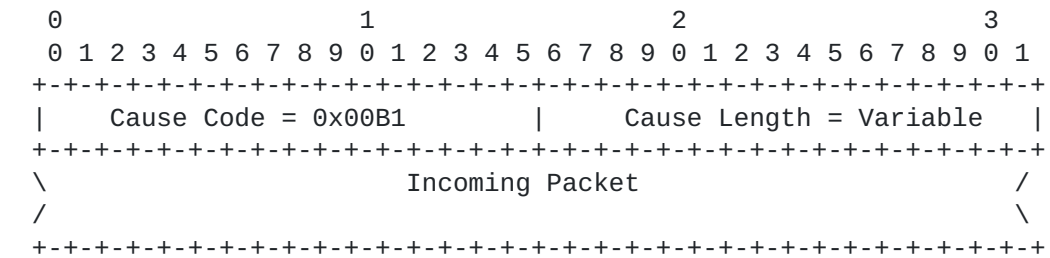


Cause Code: 2 bytes (unsigned integer)
This field holds the IANA defined cause code for the VTag and Port Number Collision Error Cause. The suggested value of this field for IANA is 0x00B0.

Cause Length: 2 bytes (unsigned integer)
This field holds the length in bytes of the error cause. The value MUST be the length of the Cause-Specific Information plus 4.

Chunk: variable length
The Cause-Specific Information is filled with the chunk that caused this error. This can be an INIT, INIT-ACK, or ASCONF chunk. Note that if the entire chunk will not fit in the ERROR chunk or ABORT chunk being sent then the bytes that do not fit are truncated.

5.2.2. Missing State Error Cause



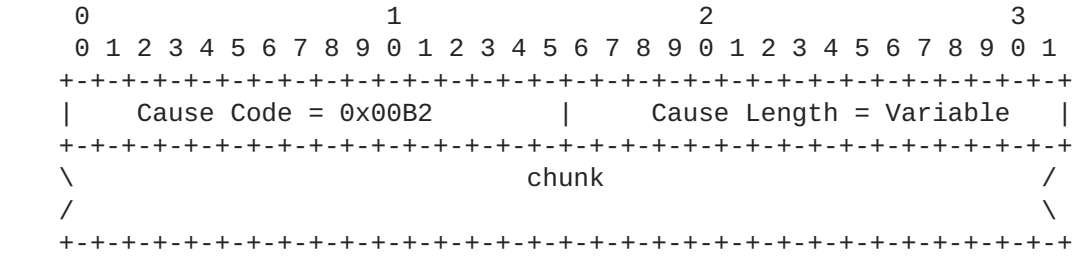
Cause Code: 2 bytes (unsigned integer)
This field holds the IANA defined cause code for the Missing State Error Cause. The suggested value of this field for IANA is 0x00B1.

Cause Length: 2 bytes (unsigned integer)

This field holds the length in bytes of the error cause. The value MUST be the length of the Cause-Specific Information plus 4.

Incoming Packet: variable length
The Cause-Specific Information is filled with the IPv4 or IPv6 packet that caused this error. The IPv4 or IPv6 header MUST be included. Note that if the packet will not fit in the ERROR chunk or ABORT chunk being sent then the bytes that do not fit are truncated.

5.2.3. Port Number Collision Error Cause



Cause Code: 2 bytes (unsigned integer)
This field holds the IANA defined cause code for the Port Number Collision Error Cause. The suggested value of this field for IANA is 0x00B2.

Cause Length: 2 bytes (unsigned integer)
This field holds the length in bytes of the error cause. The value MUST be the length of the Cause-Specific Information plus 4.

Chunk: variable length
The Cause-Specific Information is filled with the chunk that caused this error. This can be an INIT, INIT-ACK, or ASCONF chunk. Note that if the entire chunk will not fit in the ERROR chunk or ABORT chunk being sent then the bytes that do not fit are truncated.

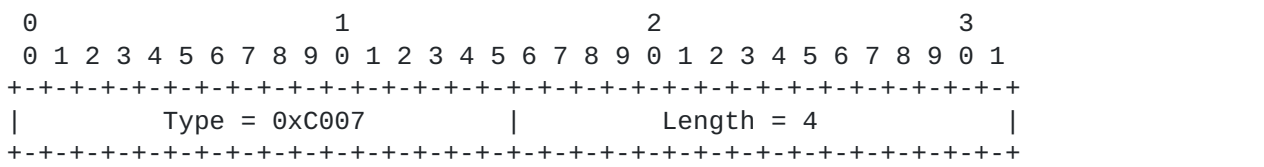
5.3. New Parameters

This section defines new parameters and their valid appearance defined by this document.

5.3.1. Disable Restart Parameter

This parameter is used to indicate that the RESTART procedure is requested to be disabled. Both endpoints of an association MUST include this parameter in the INIT chunk and INIT-ACK chunk when

establishing an association and MUST include it in the ASCONF chunk when adding an address to successfully disable the restart procedure.



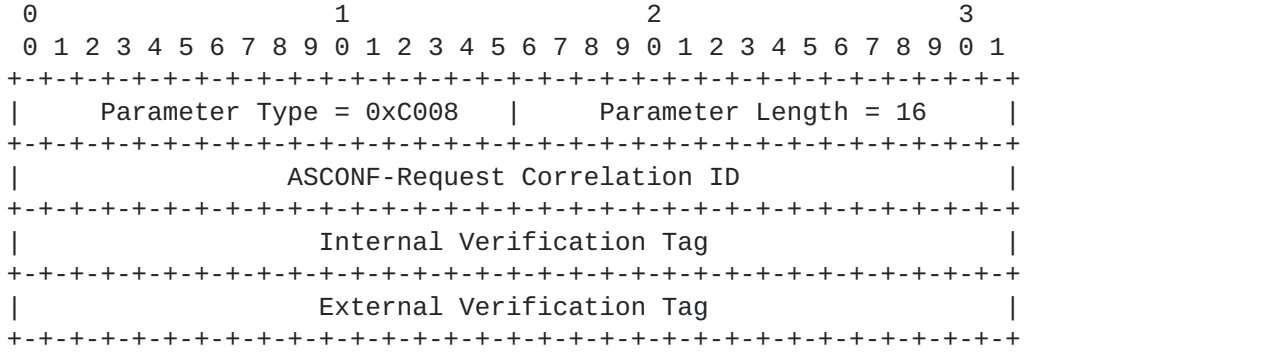
Parameter Type: 2 bytes (unsigned integer)
This field holds the IANA defined parameter type for the Disable Restart Parameter. The suggested value of this field for IANA is 0xC007.

Parameter Length: 2 bytes (unsigned integer)
This field holds the length in bytes of the parameter. The value MUST be 4.

This parameter MAY appear in INIT, INIT-ACK and ASCONF chunks and MUST NOT appear in any other chunk.

5.3.2. VTags Parameter

This parameter is used to help a NAT recover from state loss.



Parameter Type: 2 bytes (unsigned integer)
This field holds the IANA defined parameter type for the VTags Parameter. The suggested value of this field for IANA is 0xC008.

Parameter Length: 2 bytes (unsigned integer)
This field holds the length in bytes of the parameter. The value MUST be 16.

ASCONF-Request Correlation ID: 4 bytes (unsigned integer)
This is an opaque integer assigned by the sender to identify each request parameter. The receiver of the ASCONF Chunk will copy

this 32-bit value into the ASCONF Response Correlation ID field of the ASCONF-ACK response parameter. The sender of the ASCONF can use this same value in the ASCONF-ACK to find which request the response is for. Note that the receiver MUST NOT change this 32-bit value.

Internal Verification Tag: 4 bytes (unsigned integer)
The Verification Tag that the internal host has chosen for its communication. The Verification Tag is a unique 32-bit tag that must accompany any incoming SCTP packet for this association to the Private-Address.

External Verification Tag: 4 bytes (unsigned integer) The Verification Tag that the host holding the External-Address has chosen for its communication. The VTag is a unique 32-bit tag that must accompany any incoming SCTP packet for this association to the External-Address.

This parameter MAY appear in ASCONF chunks and MUST NOT appear in any other chunk.

6. Procedures

6.1. Overview

When an SCTP endpoint is behind an SCTP-aware NAT a number of problems may arise as it tries to communicate with its peer:

- More than one host behind a NAT may pick the same VTag and source port when talking to the same peer server. This creates a situation where the NAT will not be able to tell the two associations apart. This situation is discussed in Section 6.3.

- When an SCTP endpoint is a server communicating with multiple peers and the peers are behind the same NAT, then the two endpoints cannot be distinguished by the server. This case is discussed in Section 6.4.

- A restart of a NAT during a conversation could cause a loss of its state. This problem and its solution is discussed in Section 6.5.

- An SCTP endpoint may be behind two NATs providing redundancy. The method to set up this scenario is discussed in Section 6.7.

Each of these mechanisms requires additional chunks and parameters, defined in this document, and possibly modified handling procedures from those specified in [RFC4960] fdafdfafdafdafdafdafdasf.

6.2. Association Setup Considerations

Every association MUST initially be set up single-homed. There MUST NOT be any IPv4 Address parameter, IPv6 Address parameter, or Supported Address Types parameter in the INIT-chunk. The INIT-ACK chunk MUST NOT contain any IPv4 Address parameter or IPv6 Address parameter.

If the association should finally be multi-homed, the procedure in Section 6.7 MUST be used.

The INIT and INIT-ACK chunk SHOULD contain the Disable Restart parameter defined in Section 5.3.1.

6.3. Handling of Internal Port Number and Verification Tag Collisions

Consider the case where two hosts in the Private-Address space want to set up an SCTP association with the same server running on the same host in the Internet. This means that the External-Port and the External-Address are the same. If they both choose the same Internal-Port and Internal-VTag, the NAT box cannot distinguish between incoming packets anymore. But this is very unlikely. The Internal-VTags are chosen at random and if the Internal-Ports are also chosen from the ephemeral port range at random this gives a 46-bit random number which has to match. In the TCP like NAPT case the NAT box can control the 16-bit Natted Port and therefor avoid collisions deterministically.

The same can happen when an INIT-ACK chunk or an ASCONF chunk is processed by the NAT.

However, in this unlikely event the NAT box MUST send an ABORT chunk with the M-bit set if the collision is triggered by an INIT or INIT-ACK chunk or send an ERROR chunk with the M-bit set if the collision is triggered by an ASCONF chunk. The M-bit is a new bit defined by this document to express to SCTP that the source of this packet is a "middle" box, not the peer SCTP endpoint (see Section 5.1.1). If a packet containing an INIT-ACK chunk triggers the collision, the corresponding packet containing the ABORT chunk MUST contain the same source and destination address and port numbers as the packet containing the INIT-ACK chunk. In the other two cases, the source and destination address and port numbers MUST be swapped.

The sender of the packet containing the INIT chunk or the receiver of the INIT-ACK chunk, upon reception of an ABORT chunk with M-bit set, SHOULD reinitiate the association setup procedure after choosing a new initiate tag. These procedures SHOULD be followed only if the appropriate error cause code for colliding NAT table state is

included AND the association is in the COOKIE-WAIT state (i. e. it is awaiting an INIT-ACK). If the endpoint is in any other state an SCTP endpoint SHOULD NOT respond.

The sender of the ASCONF chunk, upon reception of an ERROR chunk with M-bit set, MUST stop adding the path to the association.

The sender of the ERROR or ABORT chunk MUST include the error cause with cause code 'VTag and Port Number Collision' (see Section 5.2.1).

6.4. Handling of Internal Port Number Collisions

When two SCTP hosts are behind an SCTP-aware NAT it is possible that two SCTP hosts in the Private-Address space will want to set up an SCTP association with the same server running on the same host in the Internet. For the NAT appropriate tracking may be performed by assuring that the VTags are unique between the two hosts. But for the external SCTP server on the internet this means that the External-Port and the External-Address are the same. If they both have chosen the same Internal-Port the server cannot distinguish between both associations based on the address and port numbers. For the server it looks like the association is being restarted. To overcome this limitation the client sends a Disable Restart parameter in the INIT-chunk.

When the server receives this parameter it MUST do the following:

- Include a Disable Restart parameter in the INIT-ACK to inform the client that it will support the feature.

- Disable the restart procedures defined in [RFC4960] for this association.

Servers that support this feature will need to be capable of maintaining multiple connections to what appears to be the same peer (behind the NAT) differentiated only by the VTags.

The NAT, when processing the INIT-ACK, should note in its internal table that the association supports the Disable Restart extension. This note is used when establishing future associations (i. e. when processing an INIT from an internal host) to decide if the connection should be allowed. The NAT MUST do the following when processing an INIT:

- If the INIT is destined to an external address and port for which the NAT has no outbound connection, allow the INIT creating an internal mapping table.

- If the INIT matches the external address and port of an already existing connection, validate that the external server supports the Disable Restart feature, if it does allow the INIT to be forwarded.

- If the external server does not support the Disable Restart extension the NAT MUST send an ABORT with the M-bit set.

The 'Port Number Collision' error cause (see Section 5.2.3) MUST be included in the ABORT chunk.

If the collision is triggered by an ASCONF chunk, a packet containing an ERROR chunk with the 'Port Number Collision' error cause MUST be sent back.

6.5. Handling of Missing State

If the NAT box receives a packet from the internal network for which the lookup procedure does not find an entry in the NAT table, a packet containing an ERROR chunk is sent back with the M-bit set. The source address of the packet containing the ERROR chunk MUST be the destination address of the incoming SCTP packet. The verification tag is reflected and the T-bit is set. Please note that such a packet containing an ERROR chunk SHOULD NOT be sent if the received packet contains an ABORT, SHUTDOWN-COMPLETE or INIT-ACK chunk. An ERROR chunk MUST NOT be sent if the received packet contains an ERROR chunk with the M-bit set.

When sending the ERROR chunk, the new error cause Missing state (see Section 5.2.2) MUST be included and the new M-bit of the ERROR chunk MUST be set (see Section 5.1.2).

Upon reception of this ERROR chunk by an SCTP endpoint the receiver SHOULD take the following actions:

- Validate that the verification tag is reflected by looking at the VTag that would have been included in the outgoing packet.

- Validate that the peer of the SCTP association supports the dynamic address extension, if it does not discard the incoming ERROR chunk.

- Generate a new ASCONF chunk containing the VTags parameter (see Section 5.3.2) and the Disable Restart parameter if the association is using the disabled restart feature. By processing this packet the NAT can recover the appropriate state. The procedures for generating an ASCONF chunk can be found in [RFC5061].

If the NAT box receives a packet for which it has no NAT table entry and the packet contains an ASCONF chunk with the VTags parameter, the NAT box MUST update its NAT table according to the verification tags in the VTags parameter and the optional Disable Restart parameter.

The peer SCTP endpoint receiving such an ASCONF chunk SHOULD either add the address and respond with an acknowledgment, if the address is new to the association (following all procedures defined in [RFC5061]). Or, if the address is already part of the association, the SCTP endpoint MUST NOT respond with an error, but instead should respond with an ASCONF-ACK chunk acknowledging the address but take no action (since the address is already in the association).

Note that it is possible that upon receiving an ASCONF chunk containing the VTags parameter the NAT will realize that it has an 'Internal Port Number and Verification Tag collision'. In such a case the NAT MUST send an ERROR chunk with the error cause code set to 'VTag and Port Number Collision' (see Section 5.2.1).

If an SCTP endpoint receives an ERROR with 'Internal Port Number and Verification Tag collision' as the error cause and the packet in the Error Chunk contains an ASCONF with the VTags parameter, careful examination of the association is required. The endpoint MUST do the following:

- Validate that the verification tag is reflected by looking at the VTag that would have been included in the outgoing packet.

- Validate that the peer of the SCTP association supports the dynamic address extension, if it does not discard the incoming ERROR chunk.

- If the association is attempting to add an address (i. e. following the procedures in Section 6.7) then the endpoint MUST-NOT consider the address part of the association and SHOULD make no further attempt to add the address (i. e. cancel any ASCONF timers and remove any record of the path), since the NAT has a VTag collision and the association cannot easily create a new VTag (as it would if the error occurred when sending an INIT).

- If the endpoint has no other path, i. e. the procedure was executed due to missing a state in the NAT, then the endpoint MUST abort the association. This would occur only if the local NAT restarted and accepted a new association before attempting to repair the missing state (Note that this is no different than what happens to all TCP connections when a NAT looses its state).

6.6. Handling of Fragmented SCTP Packets

A NAT box MUST support IP reassembly of received fragmented SCTP packets. The fragments may arrive in any order.

When an SCTP packet has to be fragmented by the NAT box and the IP header forbids fragmentation a corresponding ICMP packet SHOULD be sent.

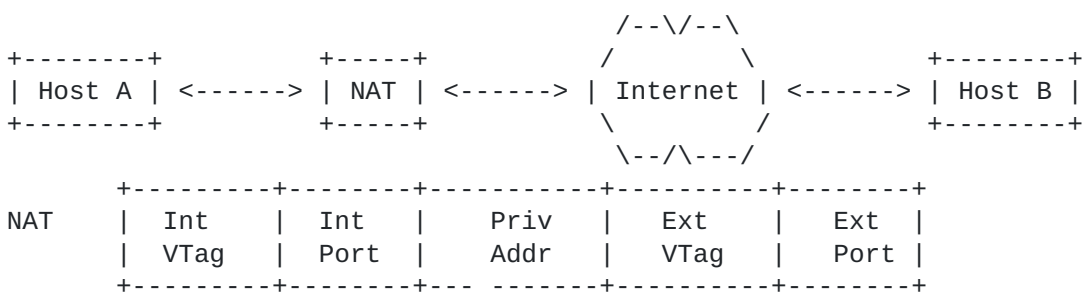
6.7. Multi-Point Traversal Considerations

If a multi-homed SCTP endpoint behind a NAT connects to a peer, it SHOULD first set up the association single-homed with only one address causing the first NAT to populate its state. Then it SHOULD add each IP address using ASCONF chunks sent via their respective NATs. The address to add is the wildcard address and the lookup address SHOULD also contain the VTags parameter and optionally the Disable Restart parameter as illustrated above.

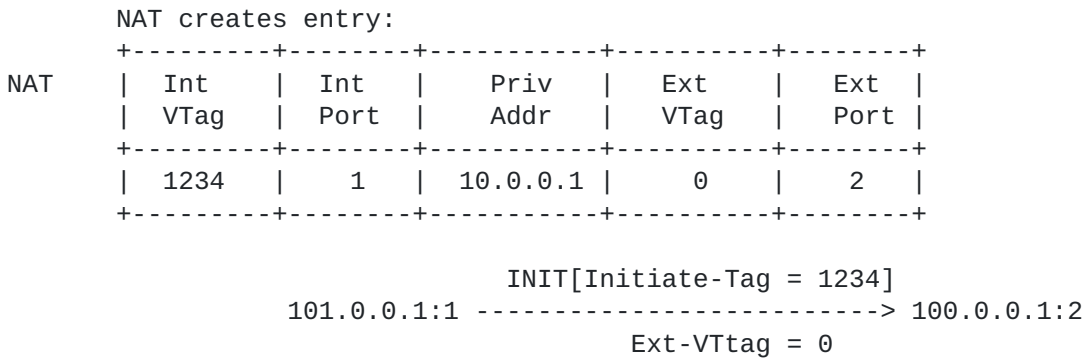
7. Various Examples of NAT Traversals

7.1. Single-homed Client to Single-homed Server

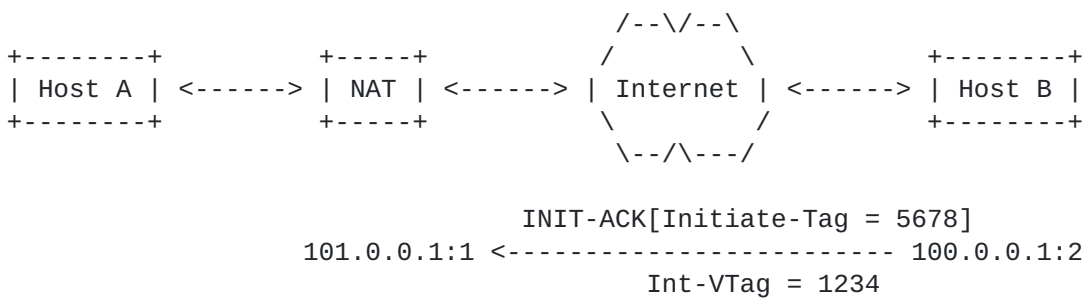
The internal client starts the association with the external server via a four-way-handshake. Host A starts by sending an INIT chunk.



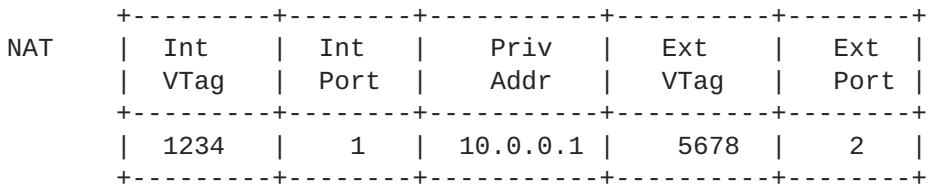
A NAT entry is created, the source address is substituted and the packet is sent on:

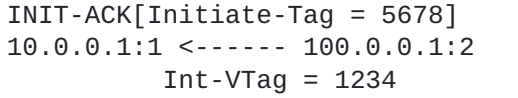


Host B receives the INIT and sends an INIT-ACK with the NAT's external address as destination address.

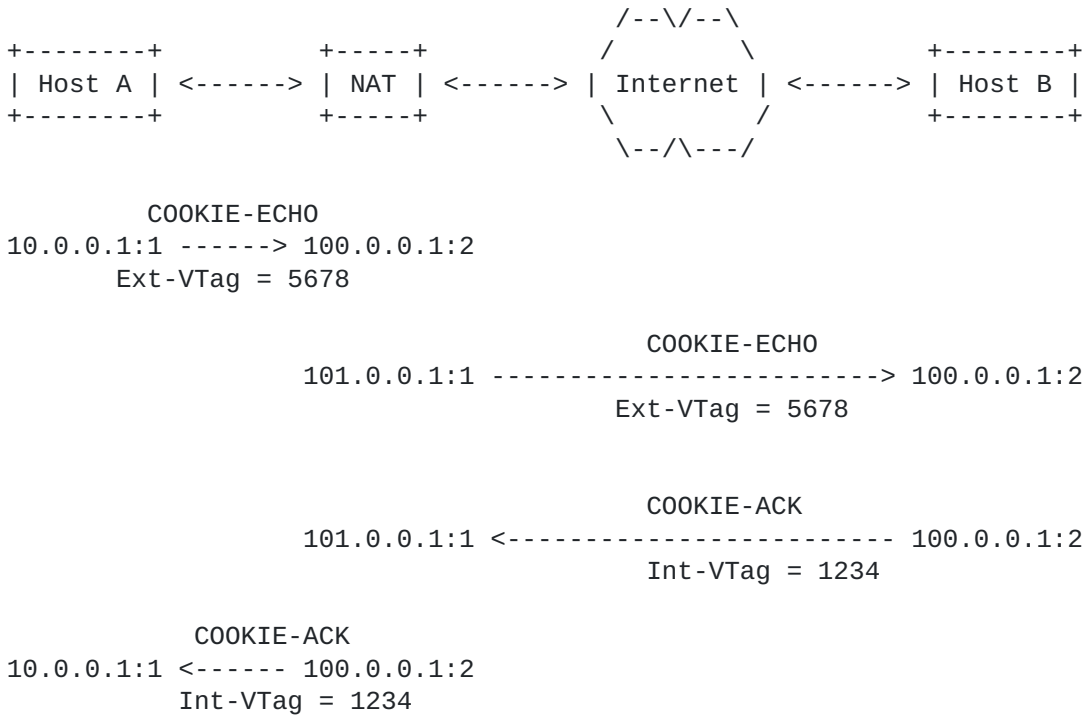


NAT updates entry:



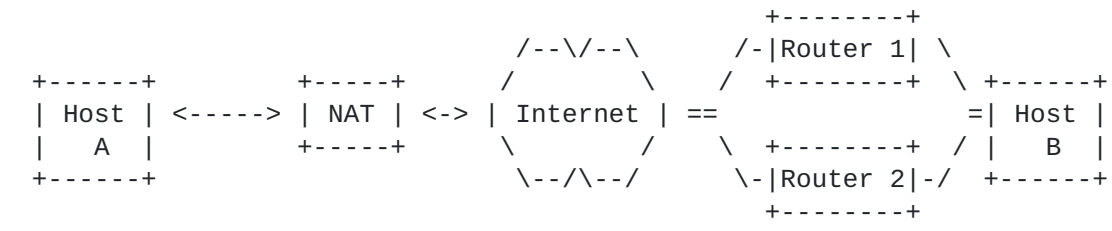


The handshake finishes with a COOKIE-ECHO acknowledged by a COOKIE-ACK.



7.2. Single-homed Client to Multi-homed Server

The internal client is single-homed whereas the external server is multi-homed. The client (Host A) sends an INIT like in the single-homed case.



NAT	Int VTag	Int Port	Priv Addr	Ext VTag	Ext Port

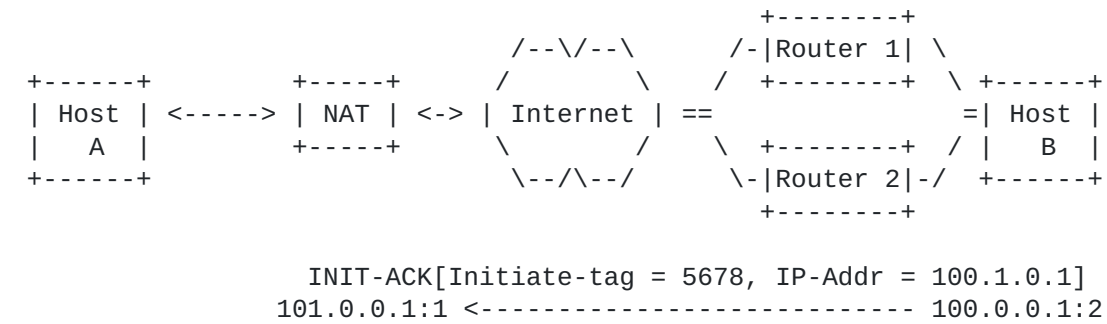
INIT[Initiate-Tag = 1234]
10.0.0.1:1 ---> 100.0.0.1:2
Ext-VTag = 0

NAT creates entry:

NAT	Int VTag	Int Port	Priv Addr	Ext VTag	Ext Port
	1234	1	10.0.0.1	0	2

INIT[Initiate-Tag = 1234]
101.0.0.1:1 ----------> 100.0.0.1:2
Ext-VTag = 0

The server (Host B) includes its two addresses in the INIT-ACK chunk, which results in two NAT entries.

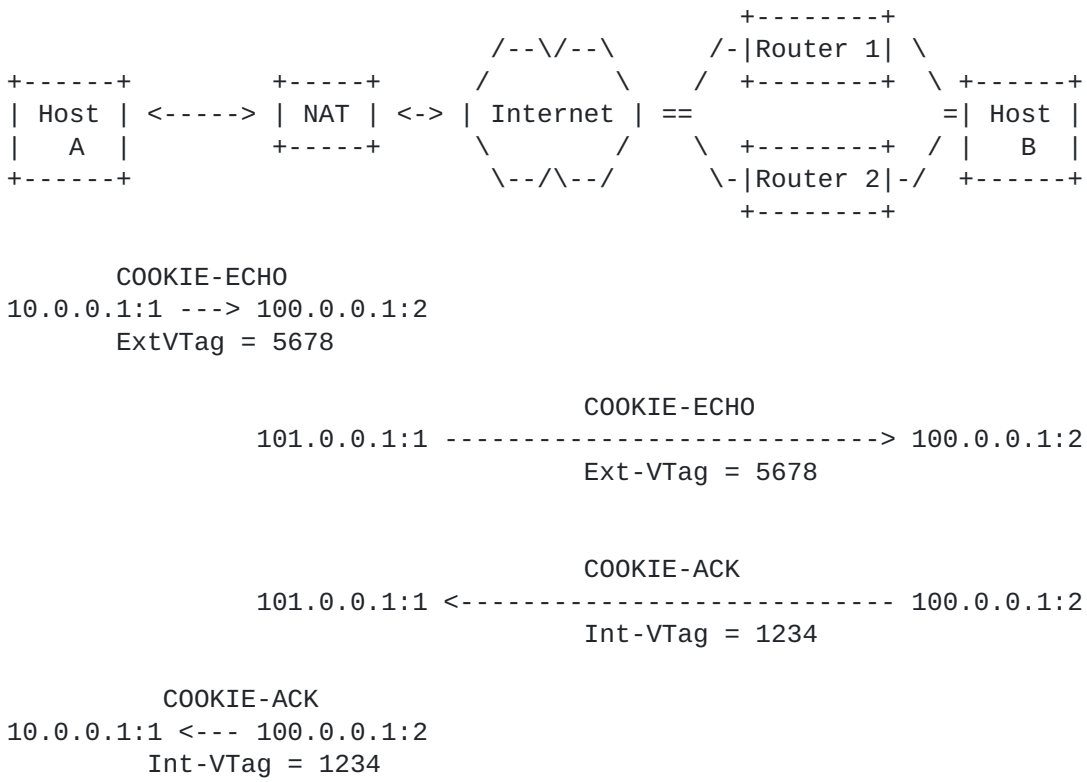


NAT does need to change the table for second address:

NAT	Int VTag	Int Port	Priv Addr	Ext VTag	Ext Port
	1234	1	10.0.0.1	5678	2

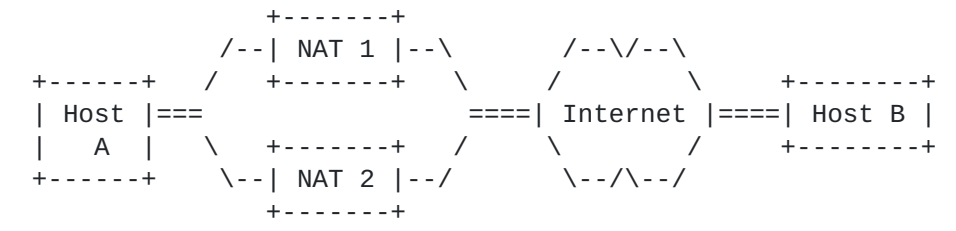
INIT-ACK[Initiate-Tag = 5678]
10.0.0.1:1 <--- 100.0.0.1:2
Int-VTag = 1234

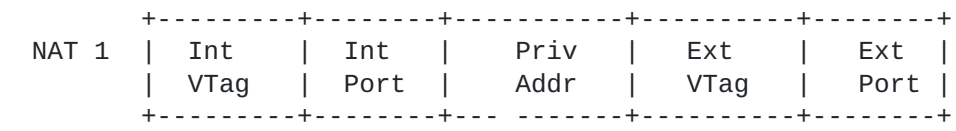
The handshake finishes with a COOKIE-ECHO acknowledged by a COOKIE-ACK.



7.3. Multihomed Client and Server

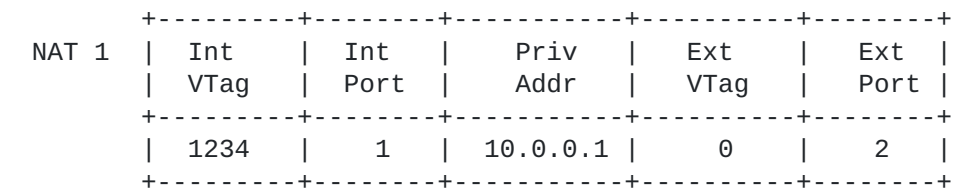
The client (Host A) sends an INIT to the server (Host B), but does not include the second address.





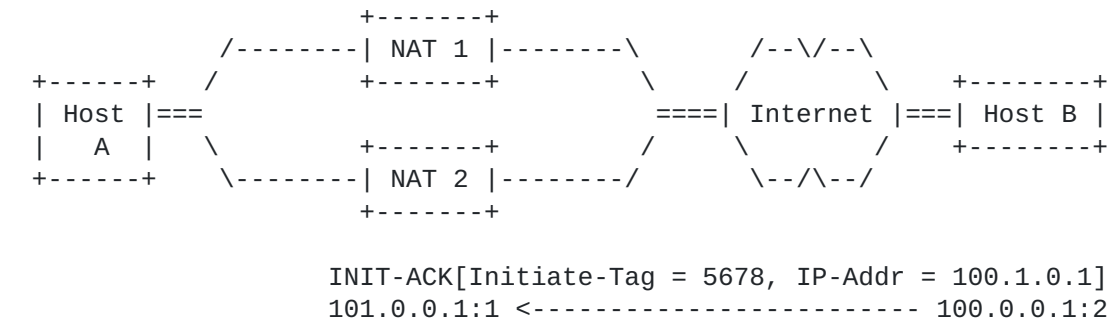
INIT[Initiate-Tag = 1234]
10.0.0.1:1 --------> 100.0.0.1:2
Ext-VTag = 0

NAT 1 creates entry:



INIT[Initiate-Tag = 1234]
101.0.0.1:1 ----------------------> 100.0.0.1:2
ExtVTag = 0

Host B includes its second address in the INIT-ACK, which results in two NAT entries in NAT 1.

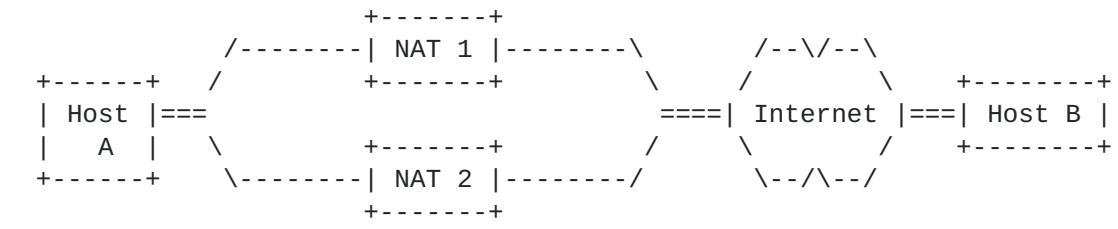


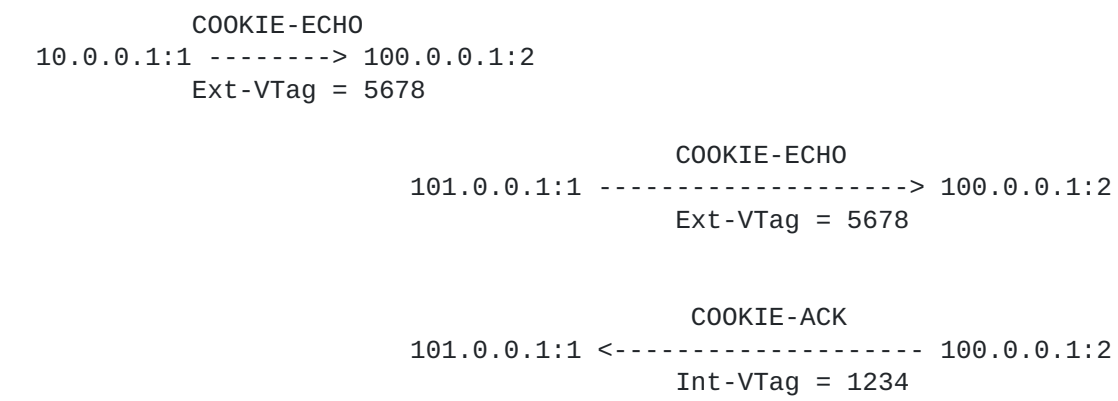
NAT 1 does not need to update the table for second address:

NAT 1	Int VTag	Int Port	Priv Addr	Ext VTag	Ext Port
	1234	1	10.0.0.1	5678	2

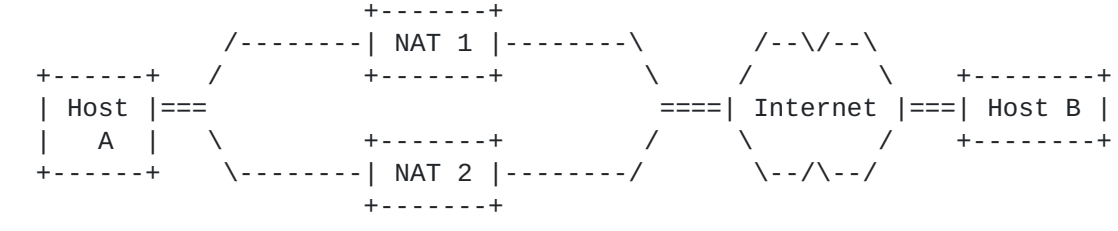
INIT-ACK[Initiate-Tag = 5678]
10.0.0.1:1 <---------100.0.0.1:2
Int-VTag = 1234

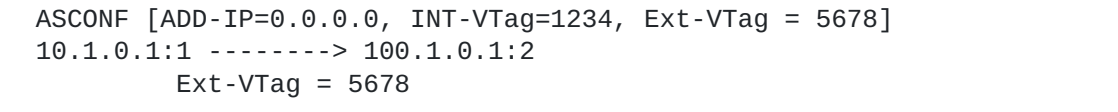
The handshake finishes with a COOKIE-ECHO acknowledged by a COOKIE-ACK.





Host A announces its second address in an ASCONF chunk. The address parameter contains an undefined address (0) to indicate that the source address should be added. The lookup address parameter within the ASCONF chunk will also contain the pair of VTags (external and internal) so that the NAT may populate its table completely with this single packet.





NAT 2 creates complete entry:

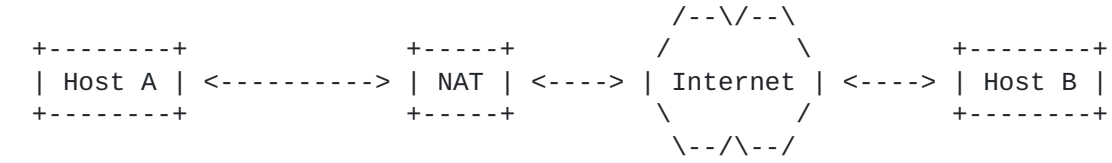
```
       +---------+--------+-----------+----------+--------+
NAT 2  |  Int    |  Int   |    Priv   |   Ext    |   Ext  |
       |  VTag   |  Port  |    Addr   |   VTag   |   Port |
       +---------+--------+-----------+----------+--------+
       |  1234   |    1   |  10.1.0.1 |    5678  |    2   |
       +---------+--------+-----------+----------+--------+


                ASCONF [ADD-IP,Int-VTag=1234, Ext-VTag = 5678]
                   101.1.0.1:1 ----------------------> 100.1.0.1:2
                                       Ext-VTag = 5678

                                          ASCONF-ACK
                   101.1.0.1:1 <---------------------- 100.1.0.1:2
                                        Int-VTag = 1234

          ASCONF-ACK
10.1.0.1:1 <----- 100.1.0.1:2
         Int-VTag = 1234
```

7.4. NAT Loses Its State

Association is already established between Host A and Host B, when the NAT loses its state and obtains a new public address. Host A sends a DATA chunk to Host B.

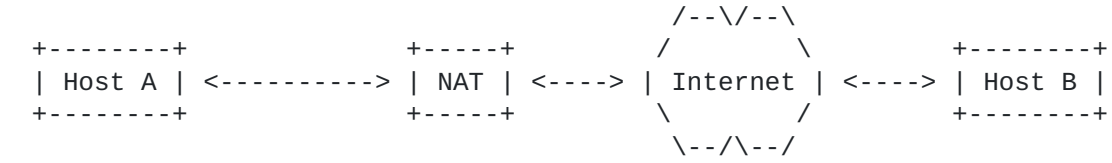
```
                                        /--\/--\
+--------+             +-----+         /        \         +--------+
| Host A | <---------> | NAT | <----> | Internet | <----> | Host B |
+--------+             +-----+         \        /         +--------+
                                        \--/\--/

       +---------+--------+-----------+----------+--------+
NAT    |  Int    |  Int   |    Priv   |   Ext    |   Ext  |
       |  VTag   |  Port  |    Addr   |   VTag   |   Port |
       +---------+--------+-----------+----------+--------+
       |  1234   |    1   |  10.0.0.1 |    5678  |    2   |
       +---------+--------+-----------+----------+--------+

              DATA
10.0.0.1:1 ----------> 100.0.0.1:2
           Ext-VTag = 5678
```

The NAT box cannot find entry for the association. It sends ERROR message with the M-Bit set and the cause "NAT state missing".



ERROR [M-Bit, NAT state missing]
10.0.0.1:1 <---------- 100.0.0.1:2
Ext-VTag = 5678

On reception of the ERROR message, Host A sends an ASCONF chunk indicating that the former information has to be deleted and the source address of the actual packet added.



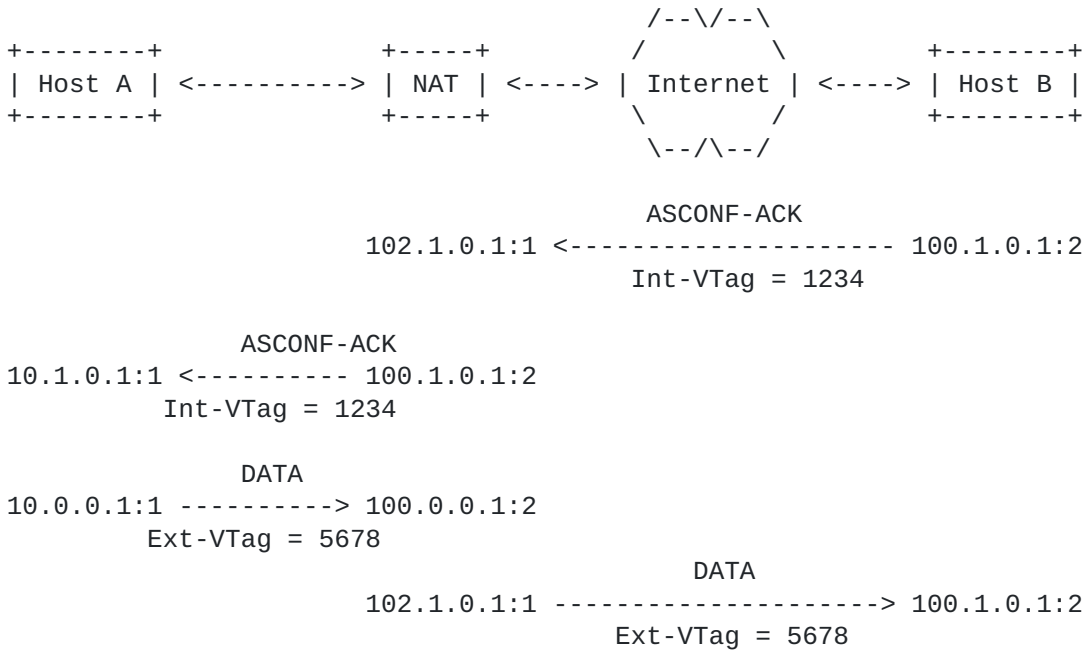
ASCONF [ADD-IP,DELETE-IP,Int-VTag=1234, Ext-VTag = 5678]
10.0.0.1:1 ----------> 100.1.0.1:2
Ext-VTag = 5678

NAT

Int VTag	Int Port	Priv Addr	Ext VTag	Ext Port
1234	1	10.0.0.1	5678	2

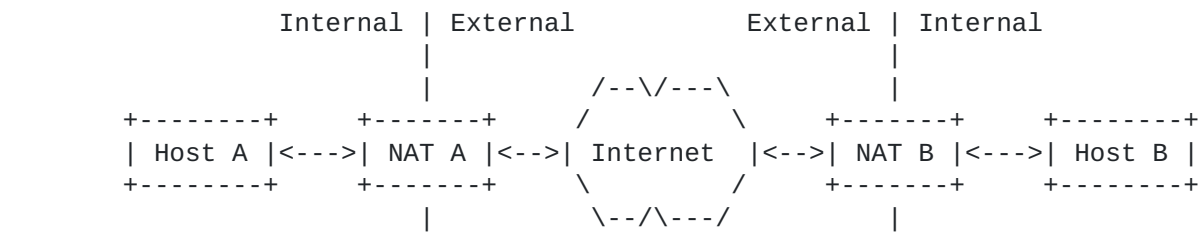
ASCONF [ADD-IP,DELETE-IP,Int-VTag=1234, Ext-VTag = 5678]
102.1.0.1:1 ----------> 100.1.0.1:2
Ext-VTag = 5678

Host B adds the new source address and deletes all former entries.



7.5. Peer-to-Peer Communication

If two hosts are behind NATs, they have to get knowledge of the peer's public address. This can be achieved with a so-called rendezvous server. Afterwards the destination addresses are public, and the association is set up with the help of the INIT collision. The NAT boxes create their entries according to their internal peer's point of view. Therefore, NAT A's Internal-VTag and Internal-Port are NAT B's External-VTag and External-Port, respectively. The naming of the verification tag in the packet flow is done from the sending peer's point of view.



NAT-Tables

NAT A	Int VTag	Int Port	Priv Addr	Ext VTag	Ext Port

NAT B	Int v-tag	int port	Priv addr	Ext v-tag	Ext port

INIT[Initiate-Tag = 1234]
10.0.0.1:1 --> 100.0.0.1:2
Ext-VTag = 0

NAT A creates entry:

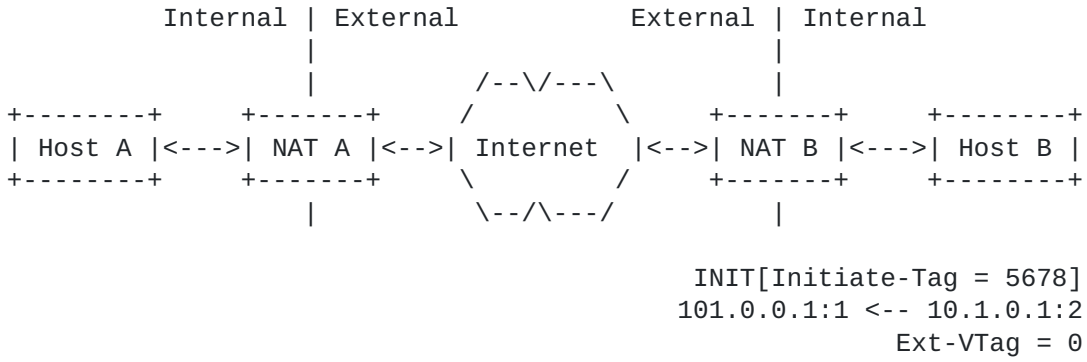
NAT A	Int VTag	Int Port	Priv Addr	Ext VTag	Ext Port
	1234	1	10.0.0.1	0	2

INIT[Initiate-Tag = 1234]
101.0.0.1:1 ----------------> 100.0.0.1:2
Ext-VTag = 0

NAT B processes INIT, but cannot find an entry. The SCTP packet is silently discarded and leaves the NAT table of NAT B unchanged.

NAT B	Int VTag	Int Port	Priv Addr	Ext VTag	Ext Port

Now Host B sends INIT, which is processed by NAT B. Its parameters are used to create an entry.



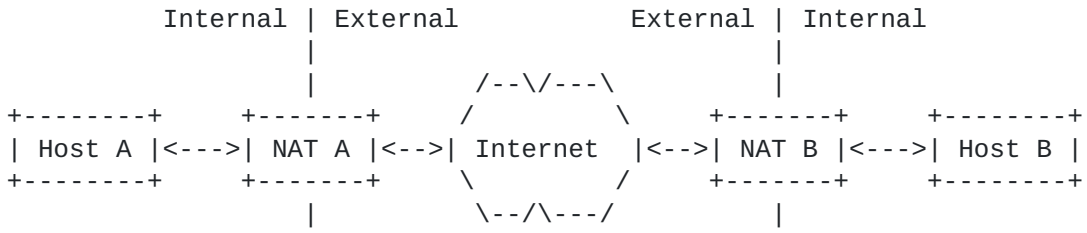
INIT[Initiate-Tag = 5678]
101.0.0.1:1 <-- 10.1.0.1:2
Ext-VTag = 0

NAT B

Int VTag	Int Port	Priv Addr	Ext VTag	Ext Port
5678	2	10.1.0.1	0	1

INIT[Initiate-Tag = 5678]
101.0.0.1:1 <---------- 100.0.0.1:2
Ext-VTag = 0

NAT A processes INIT. As the outgoing INIT of Host A has already created an entry, the entry is found and updated:

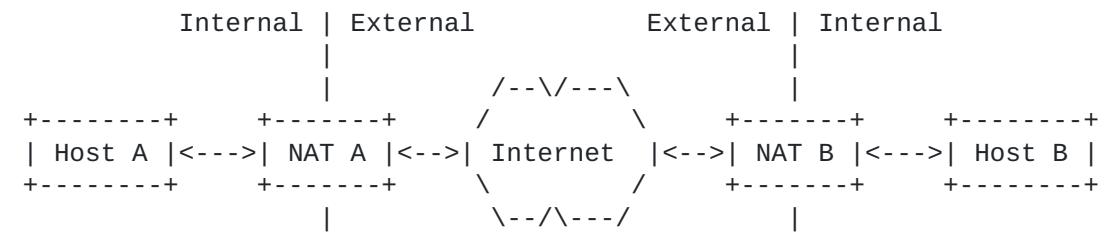


VTag != Int-VTag, but Ext-VTag == 0, find entry.

NAT A	Int VTag	Int Port	Priv Addr	Ext VTag	Ext Port
	1234	1	10.0.0.1	5678	2

INIT[Initiate-tag = 5678]
10.0.0.1:1 <-- 100.0.0.1:2
Ext-VTag = 0

Host A send INIT-ACK, which can pass through NAT B:



INIT-ACK[Initiate-Tag = 1234]
10.0.0.1:1 -->; 100.0.0.1:2
Ext-VTag = 5678

INIT-ACK[Initiate-Tag = 1234]
101.0.0.1:1 ----------> 100.0.0.1:2
Ext-VTag = 5678

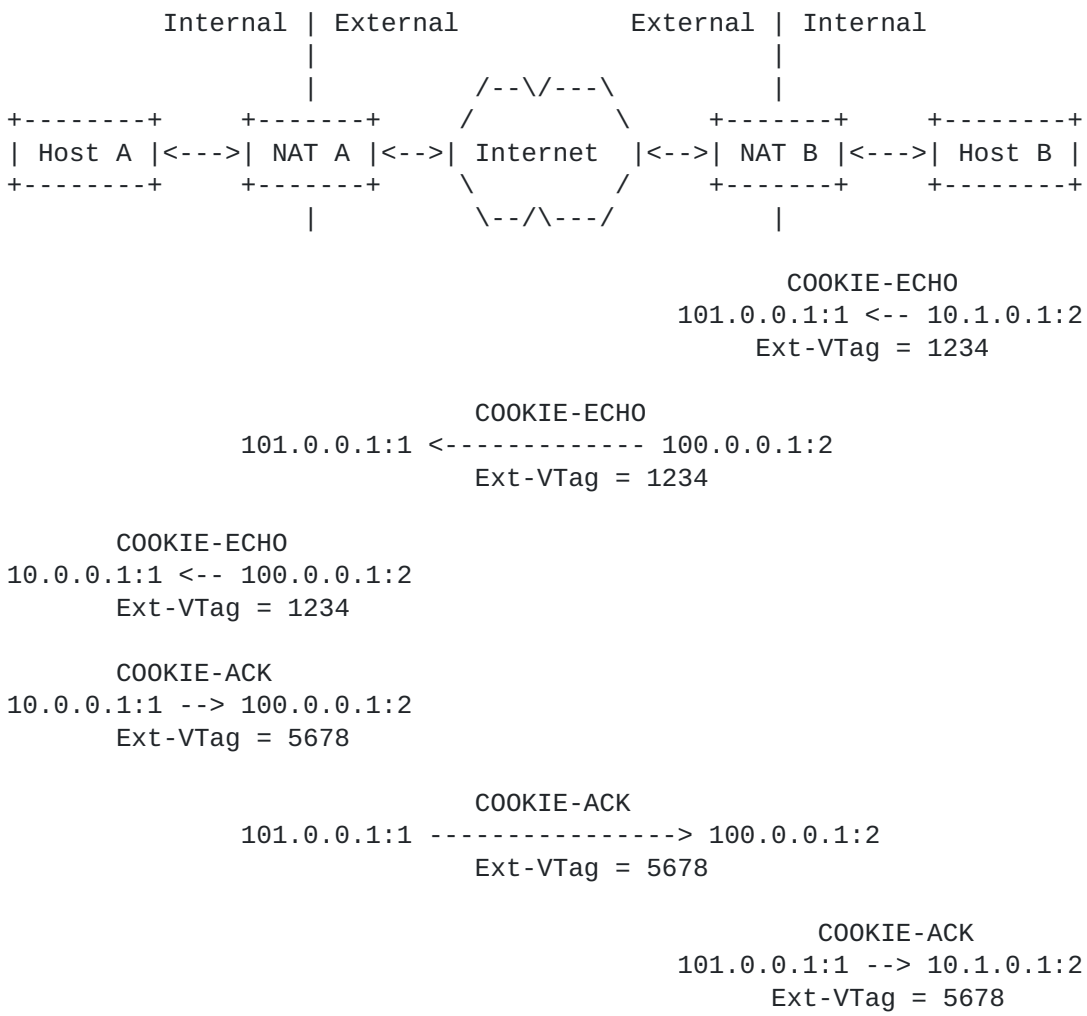
NAT B updates entry:

NAT B

Int VTag	Int Port	Priv Addr	Ext VTag	Ext Port
5678	2	10.1.0.1	1234	1

INIT-ACK[Initiate-Tag = 1234]
101.0.0.1:1 --> 10.1.0.1:2
Ext-VTag = 5678

The lookup for COOKIE-ECHO and COOKIE-ACK is successful.



8. Socket API Considerations

This section describes how the socket API defined in [RFC6458] is extended to provide a way for the application to control NAT friendliness.

Please note that this section is informational only.

A socket API implementation based on [RFC6458] is extended by supporting one new read/write socket option.

8.1. Get or Set the NAT Friendliness (SCTP_NAT_FRIENDLY)

This socket option uses the option_level IPPROTO_SCTP and the option_name SCTP_NAT_FRIENDLY. It can be used to enable/disable the NAT friendliness for future associations and retrieve the value for future and specific ones.

```
struct sctp_assoc_value {
  sctp_assoc_t assoc_id;
  uint32_t assoc_value;
};
```

assoc_id: This parameter is ignored for one-to-one style sockets. For one-to-many style sockets the application may fill in an association identifier or SCTP_FUTURE_ASSOC for this query. It is an error to use SCTP_{CURRENT|ALL}_ASSOC in assoc_id.

assoc_value: A non-zero value indicates a NAT-friendly mode.

9. IANA Considerations

[NOTE to RFC-Editor:

"RFCXXXX" is to be replaced by the RFC number you assign this document.

]

[NOTE to RFC-Editor:

The suggested values for the chunk type and the chunk parameter types are tentative and to be confirmed by IANA.

]

This document (RFCXXXX) is the reference for all registrations described in this section. The suggested changes are described below.

9.1. New Chunk Flags for Two Existing Chunk Types

As defined in [RFC6096] two chunk flags have to be assigned by IANA for the ERROR chunk. The suggested value for the T bit is 0x01 and for the M bit is 0x02.

This requires an update of the "ERROR Chunk Flags" registry for SCTP:

ERROR Chunk Flags

Chunk Flag Value	Chunk Flag Name	Reference
0x01	T bit	[RFCXXXX]
0x02	M bit	[RFCXXXX]
0x04	Unassigned	
0x08	Unassigned	
0x10	Unassigned	
0x20	Unassigned	
0x40	Unassigned	
0x80	Unassigned	

As defined in [RFC6096] one chunk flag has to be assigned by IANA for the ABORT chunk. The suggested value of the M bit is 0x02.

This requires an update of the "ABORT Chunk Flags" registry for SCTP:

ABORT Chunk Flags

Chunk Flag Value	Chunk Flag Name	Reference
0x01	T bit	[RFC4960]
0x02	M bit	[RFCXXXX]
0x04	Unassigned	
0x08	Unassigned	
0x10	Unassigned	
0x20	Unassigned	
0x40	Unassigned	
0x80	Unassigned	

9.2. Three New Error Causes

Three error causes have to be assigned by IANA. It is suggested to use the values given below.

This requires three additional lines in the "Error Cause Codes" registry for SCTP:

Error Cause Codes

Value	Cause Code	Reference
176	VTag and Port Number Collision	[RFCXXXX]
177	Missing State	[RFCXXXX]
178	Port Number Collision	[RFCXXXX]

9.3. Two New Chunk Parameter Types

Two chunk parameter types have to be assigned by IANA. It is suggested to use the values given below. IANA should assign these values from the pool of parameters with the upper two bits set to '11'.

This requires two additional lines in the "Chunk Parameter Types" registry for SCTP:

Chunk Parameter Types

ID Value	Chunk Parameter Type	Reference
49159	Disable Restart (0xC007)	[RFCXXXX]
49160	VTags (0xC008)	[RFCXXXX]

10. Security Considerations

State maintenance within a NAT is always a subject of possible Denial Of Service attacks. This document recommends that at a minimum a NAT runs a timer on any SCTP state so that old association state can be cleaned up.

For SCTP end-points, this document does not add any additional security considerations to the ones given in [RFC4960], [RFC4895], and [RFC5061].

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