IP Security Protocol Working Group
(IPSEC)
Internet-Draft
Expires: November 3, 2004

A. Huttunen
F-Secure Corporation
B. Swander
Microsoft
V. Volpe
Cisco Systems
L. DiBurro
Nortel Networks
M. Stenberg
May 5, 2004

UDP Encapsulation of IPsec ESP Packets
draft-ietf-ipsec-udp-encaps-09.txt

Status of this Memo

Copyright Notice

Abstract

This protocol specification defines methods to encapsulate and decapsulate IP Encapsulating Security Payload (ESP) packets inside UDP packets for the purpose of traversing Network Address Translators. ESP encapsulation as defined in this document is capable of being used in both IPv4 and IPv6 scenarios. The encapsulation is used whenever negotiated using Internet Key Exchange (IKE).

Table of Contents

1. Introduction

This protocol specification defines methods to encapsulate and decapsulate ESP packets inside UDP packets for the purpose of traversing NATs (see [RFC 3715] section 2.2, case i). The UDP port numbers are the same as used by IKE traffic, as defined in [NAT-T-IKE].

The sharing of the port numbers for both IKE and UDP encapsulated ESP traffic was selected because it offers better scaling (only one NAT mapping in the NAT, no need to send separate IKE keepalives), easier configuration (only one port to be configured in firewalls), and easier implementation.

It is up to the need of the clients whether transport mode or tunnel mode is to be supported (see [RFC 3715] Section 3 criteria "Telecommuter scenario"). L2TP/IPsec clients MUST support the modes as defined in [RFC 3193]. IPsec tunnel mode clients MUST support tunnel mode.

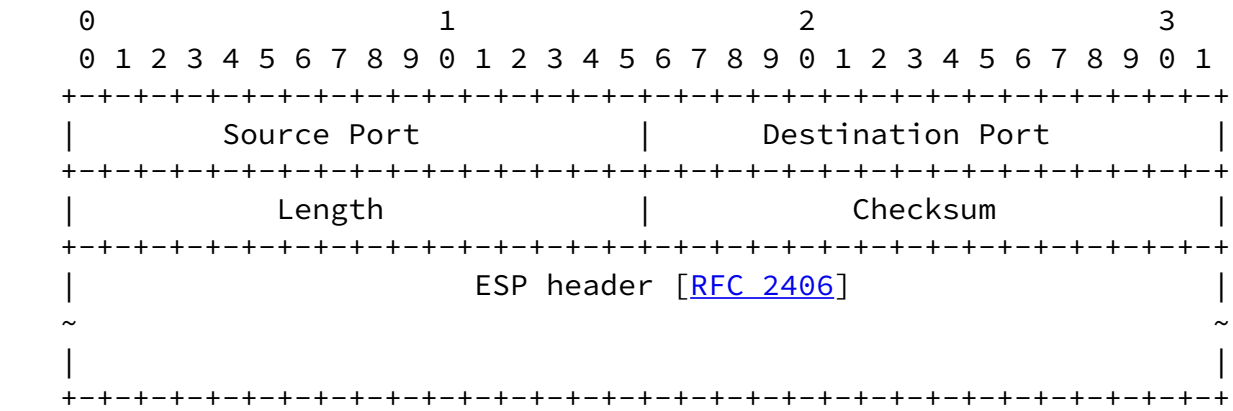
An IKE implementation supporting this protocol specification MUST NOT use the ESP SPI field zero for ESP packets. This ensures that IKE packets and ESP packets can be distinguished from each other.

UDP encapsulation of ESP packets as defined in this document is written in terms of IPv4 headers. There is no technical reason why an IPv6 header could not be used as the outer header and/or as the inner header.

Because the protection of the outer IP addresses in IPsec AH is inheritly incompatible with NAT, the IPsec AH was left out of the scope of this protocol specification. This protocol also assumes that IKE (IKEv1 [RFC2401] or IKEv2 [IKEv2]) is used to negotiate the IPsec SAs, manual keying is not supported.

2. Packet Formats

2.1 UDP-encapsulated ESP Header Format

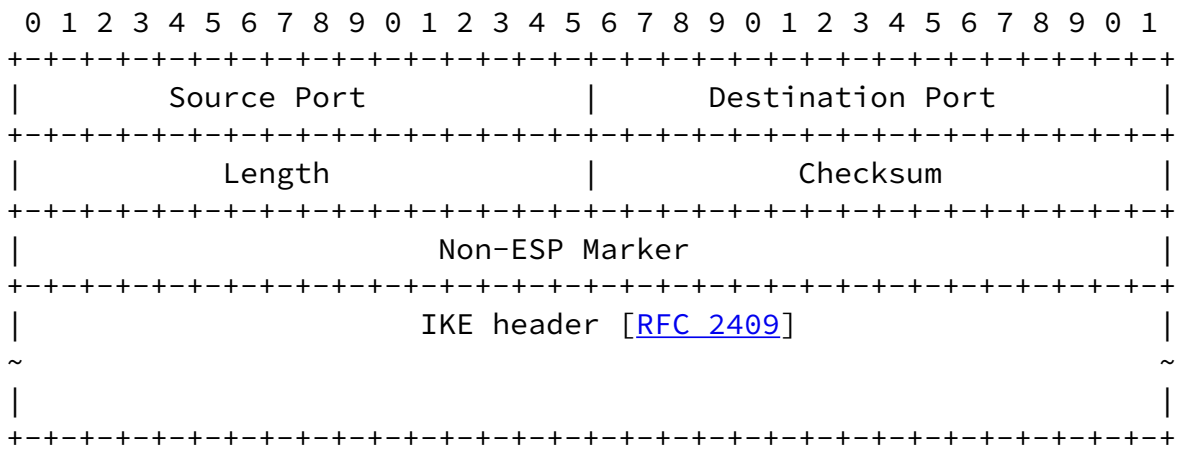


The UDP header is a standard [RFC 768] header, where

- Source Port and Destination Port MUST be the same as used by IKE traffic.
- IPv4 UDP Checksum SHOULD be transmitted as a zero value.
- Receivers MUST NOT depend upon the UDP checksum being a zero value.

The SPI field in the ESP header MUST NOT be zero.

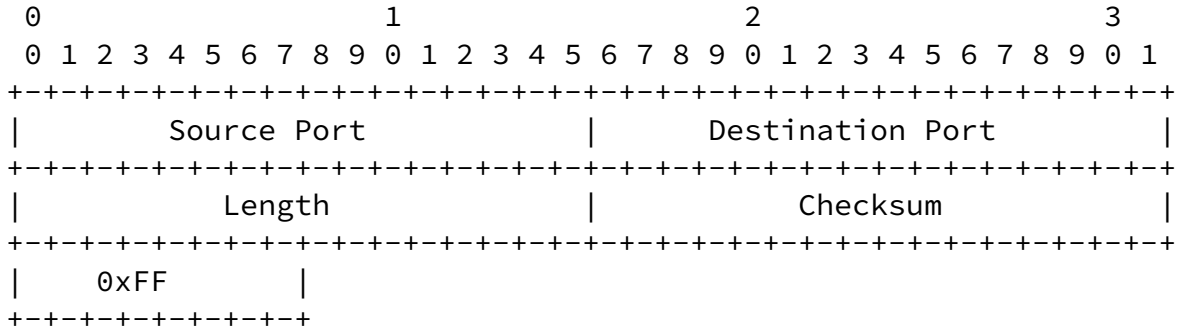
2.2 IKE Header Format for Port 4500



The UDP header is a standard [RFC 768] header, and is used as defined in [NAT-T-IKE]. This document does not set any new requirements for the checksum handling of an IKE packet.

Non-ESP Marker is 4 bytes of zero aligning with the SPI field of an ESP packet.

2.3 NAT-keepalive Packet Format



The UDP header is a standard [RFC 768] header, where

- Source Port and Destination Port MUST be the same as used by UDP-ESP encapsulation of Section 2.1
- IPv4 UDP Checksum SHOULD be transmitted as a zero value.
- Receivers MUST NOT depend upon the UDP checksum being a zero value.

The sender MUST use a one octet long payload with the value 0xFF. The receiver SHOULD ignore a received NAT-keepalive packet.

3. Encapsulation and Decapsulation Procedures

3.1 Auxiliary Procedures

3.1.1 Tunnel Mode Decapsulation NAT Procedure

When a tunnel mode has been used to transmit packets (see [RFC 3715] Section 3 criteria "Mode support" and "Telecommuter scenario"), the inner IP header can contain addresses that are not suitable for the current network. This procedure defines how these addresses are to be converted to suitable addresses for the current network.

Depending on local policy, one of the following MUST be done:

1. If a valid source IP address space has been defined in the policy

for the encapsulated packets from the peer, check that the source IP address of the inner packet is valid according to the policy.
2. If an address has been assigned for the remote peer, check that the source IP address used in the inner packet is the same as the IP address assigned.
3. NAT is performed for the packet, making it suitable for transport in the local network.

3.1.2 Transport Mode Decapsulation NAT Procedure

When a transport mode has been used to transmit packets, contained TCP or UDP headers will contain incorrect checksums due to the change of parts of the IP header during transit. This procedure defines how to fix these checksums (see [RFC 3715] Section 2.1, case b).

Depending on local policy, one of the following MUST be done:
1. If the protocol header after the ESP header is a TCP/UDP header and the peer's real source and destination IP address have been received according to [NAT-T-IKE], incrementally recompute the TCP/UDP checksum:
   * subtract the IP source address in the received packet from the checksum
   * add the real IP source address received via IKE to the checksum (obtained from the NAT-OA)
   * subtract the IP destination address in the received packet from the checksum
   * add the real IP destination address received via IKE to the checksum (obtained from the NAT-OA)

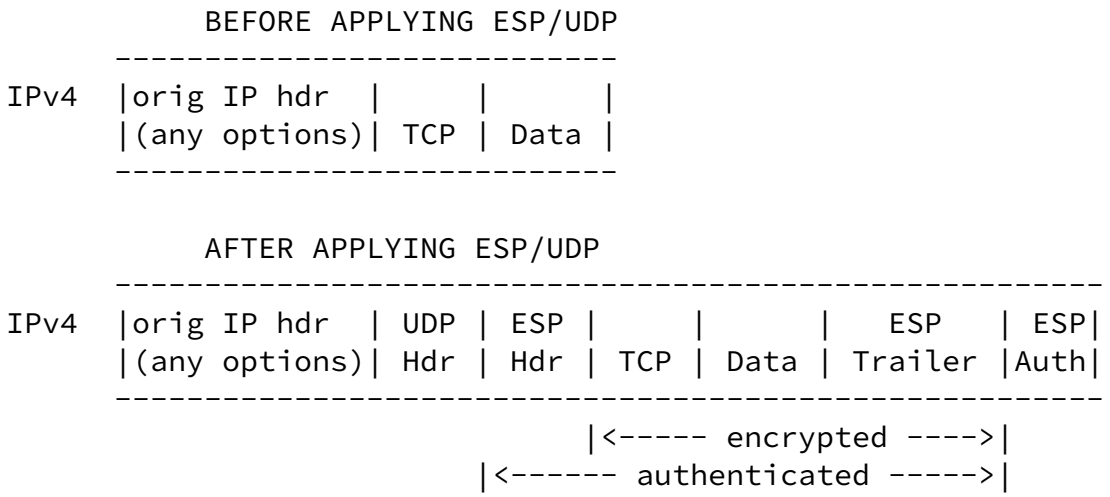
   Note: if received and real address are the same for a given address, say the source address, the operations cancel and don't need to be performed.
2. If the protocol header after the ESP header is a TCP/UDP header, recompute the checksum field in the TCP/UDP header.

3. If the protocol header after the ESP header is an UDP header, zero the checksum field in the UDP header. If the protocol header after the ESP header is a TCP header, and there is an option to flag to the stack that TCP checksum does not need to be computed, then that flag MAY be used. This SHOULD only be done for transport mode, and if the packet is integrity protected. Tunnel mode TCP checksums MUST be verified. [This is not a violation to

the spirit of section 4.2.2.7 in RFC 1122 because a checksum is being generated by the sender, and verified by the receiver. That checksum is the integrity over the packet performed by IPsec.]

In addition an implementation MAY fix any contained protocols that have been broken by NAT (see [RFC 3715] Section 2.1 case g).

3.2 Transport Mode ESP Encapsulation

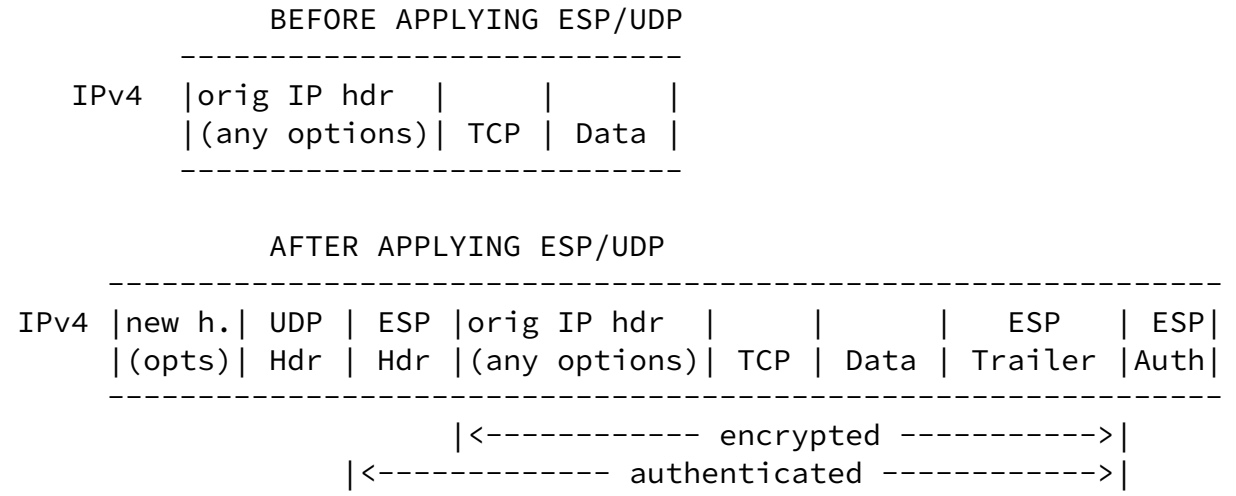


1. Ordinary ESP encapsulation procedure is used.
2. A properly formatted UDP header is inserted where shown.
3. The Total Length, Protocol and Header Checksum (for IPv4) fields in the IP header are edited to match the resulting IP packet.

3.3 Transport Mode ESP Decapsulation

1. The UDP header is removed from the packet.
2. The Total Length, Protocol and Header Checksum (for IPv4) fields in the new IP header are edited to match the resulting IP packet.
3. Ordinary ESP decapsulation procedure is used.
4. Transport mode decapsulation NAT procedure is used.

3.4 Tunnel Mode ESP Encapsulation



1. Ordinary ESP encapsulation procedure is used.
2. A properly formatted UDP header is inserted where shown.
3. The Total Length, Protocol and Header Checksum (for IPv4) fields in the new IP header are edited to match the resulting IP packet.

3.5 Tunnel Mode ESP Decapsulation

1. The UDP header is removed from the packet.
2. The Total Length, Protocol and Header Checksum (for IPv4) fields in the new IP header are edited to match the resulting IP packet.
3. Ordinary ESP decapsulation procedure is used.
4. Tunnel mode decapsulation NAT procedure is used.

4. NAT Keepalive Procedure

The sole purpose of sending NAT-keepalive packets is to keep NAT mappings alive for the duration of a connection between the peers (see [RFC 3715] Section 2.2 case j). Reception of NAT-keepalive packets MUST NOT be used to detect liveness of a connection.

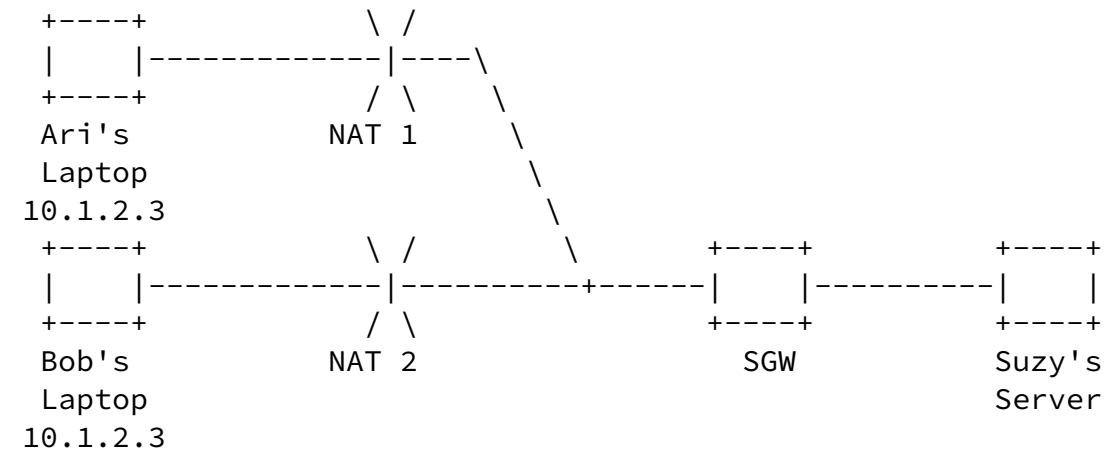
A peer MAY send a NAT-keepalive packet if there exists one or more phase I or phase II SAs between the peers, or such an SA has existed at most N minutes earlier. N is a locally configurable parameter with a default value of 5 minutes.

A peer SHOULD send a NAT-keepalive packet if a need to send such packets is detected according to [NAT-T-IKE] and if no other packet to the peer has been sent in M seconds. M is a locally configurable parameter with a default value of 20 seconds.

5. Security Considerations

5.1 Tunnel Mode Conflict

Implementors are warned that it is possible for remote peers to negotiate entries that overlap in a SGW (security gateway), an issue affecting tunnel mode (see [RFC 3715] Section 2.1 case e).



Because SGW will now see two possible SAs that lead to 10.1.2.3, it can become confused where to send packets coming from Suzy's server. Implementators MUST devise ways of preventing such a thing from occurring.

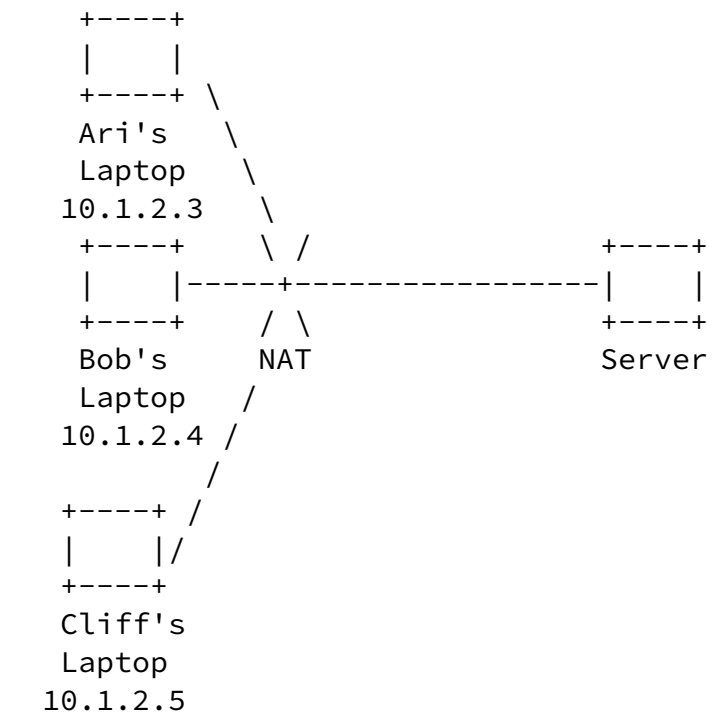
It is RECOMMENDED that SGW either assign locally unique IP addresses to Ari's and Bob's Laptop using a protocol such as DHCP over IPsec, or uses NAT to change Ari's and Bob's Laptop source IP addresses to such locally unique addresses before sending packets forward to Suzy's Server (this covers "Scaling" criteria of section 3 in [RFC 3715]).

Please see Appendix A

5.2 Transport Mode Conflict

Another similar issue may occur in transport mode, with 2 clients, Ari and Bob, behind the same NAT talking securely to the same server (see [RFC 3715] Section 2.1 case e).

Cliff wants to talk in the clear to the same server.



Now, transport SAs on the server will look like:

To Ari: Server to NAT, <traffic desc1>, UDP encap <4500, Y>

To Bob: Server to NAT, <traffic desc2>, UDP encap <4500, Z>

Cliff's traffic is in the clear, so there is no SA.

<traffic desc> is the protocol and port information. The UDP encap

ports are the ports used in UDP encapsulated ESP format of Section 2.1. Y,Z are the dynamic ports assigned by the NAT during the IKE negotiation. So IKE traffic from Ari's laptop goes out on UDP <4500,4500>. It reaches the server as UDP <Y,4500>, where Y is the dynamically assigned port.

If the <traffic desc1> overlaps <traffic desc2>, then simple filter lookups may not be sufficient to determine which SA needs to be used to send traffic. Implementations MUST handle this situation, either by disallowing conflicting connections, or by other means.

Assume now that Cliff wants to connect to the server in the clear. This is going to be difficult to configure since the server already has a policy from Server to the NAT's external address, for securing <traffic desc>. For totally non-overlapping traffic descriptions, this is possible.

Sample server policy could be:

To Ari: Server to NAT, All UDP, secure

To Bob: Server to NAT, All TCP, secure

To Cliff: Server to NAT, ALL ICMP, clear text

Note, this policy also lets Ari and Bob send cleartext ICMP to the server.

The server sees all clients behind the NAT as the same IP address, so setting up different policies for the same traffic descriptor is in principle impossible.

A problematic example configuration on the server is:

Server to NAT, TCP, secure (for Ari and Bob)

Server to NAT, TCP, clear (for Cliff)

The problem is that the server cannot enforce his policy, since it is possible that misbehaving Bob sends traffic in the clear. This is indistinguishable from Cliff sending traffic in the clear. So it is

impossible to guarantee security from some clients behind a NAT, and also allow clear text from different clients behind the SAME NAT. If the server's security policy allows, however, it can do best effort security: if the client from behind the NAT initiates security, his connection will be secured. If he sends in the clear, the server will still accept that clear text.

So, for security guarantees, the above problematic scenario MUST NOT be allowed on servers. For best effort security, this scenario MAY be used.

Please see Appendix A

6. IANA Considerations

No IANA assignments are needed.

7. IAB Considerations

The UNSAF [RFC 3424] questions are addressed by the IPsec-NAT compatibility requirements document [RFC 3715].

8. Acknowledgments

Thanks to Tero Kivinen and William Dixon who contributed actively to this document.

Thanks to Joern Sierwald, Tamir Zegman, Tatu Ylonen and Santeri Paavolainen who contributed to the early drafts about NAT traversal.

9. References

9.1 Normative references

[RFC0768] Postel, J., "User Datagram Protocol", STD 6, RFC 768, August 1980.

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

[RFC2406] Kent, S. and R. Atkinson, "IP Encapsulating Security Payload (ESP)", RFC 2406, November 1998.

[RFC2409] Harkins, D. and D. Carrel, "The Internet Key Exchange (IKE)", RFC 2409, November 1998.

[I-D.ietf-ipsec-nat-t-ike] Kivinen, T., "Negotiation of NAT-Traversal in the IKE", draft-ietf-ipsec-nat-t-ike-08 (work in progress), February 2004.

9.2 Non-normative references

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

[RFC3193] Patel, B., Aboba, B., Dixon, W., Zorn, G. and S. Booth, "Securing L2TP using IPsec", RFC 3193, November 2001.

[RFC3424] Daigle, L. and IAB, "IAB Considerations for UNilateral Self-Address Fixing (UNSAF) Across Network Address Translation", RFC 3424, November 2002.

[RFC3715] Aboba, B. and W. Dixon, "IPsec-Network Address Translation (NAT) Compatibility Requirements", RFC 3715, March 2004.

[I-D.ietf-ipsec-ikev2] Kaufman, C., "Internet Key Exchange (IKEv2) Protocol", draft-ietf-ipsec-ikev2-13 (work in progress), March 2004.

Authors' Addresses

Ari Huttunen
F-Secure Corporation
Tammasaarenkatu 7
HELSINKI FIN-00181
FI

EMail: Ari.Huttunen@F-Secure.com

Brian Swander
Microsoft
One Microsoft Way
Redmond, WA 98052
US

EMail: briansw@microsoft.com

Victor Volpe
Cisco Systems
124 Grove Street
Suite 205
Franklin, MA 02038
US

EMail: vvolpe@cisco.com

Larry DiBurro
Nortel Networks
80 Central Street
Boxborough, MA 01719
US

EMail: ldiburro@nortelnetworks.com

Markus Stenberg

FI

EMail: markus.stenberg@iki.fi

Appendix A. Clarification of potential NAT multiple client solutions

This appendix provides clarification about potential solutions to the problem of multiple clients behind the same NAT simultaneously connecting to the same destination IP address.

Section 5.1 and Section 5.2 say that you MUST avoid this problem. As this isn't a wire protocol matter, but a local implementation matter, specification of the mechanisms do not belong in the protocol specification itself. They are instead listed in this appendix.

Choosing an option will likely depend on the scenarios for which you use/support IPsec NAT-T. This list is not meant to be exhaustive, so other solutions may exist. We first describe the generic choices that solve the problem for all upper layer protocols.

Generic choices for ESP transport mode:

Tr1) Implement a built-in NAT (network address translation) above IPsec decapsulation.

Tr2) Implement a built-in NAPT (network address port translation) above IPsec decapsulation.

Tr3) An initiator may decide not to request transport mode once NAT is detected and instead request a tunnel mode SA. This may be a retry after transport mode is denied by the responder, or it may be the initiator's choice to propose a tunnel SA initially. This is no more difficult than knowing whether to propose transport mode or tunnel mode without NAT. If for some reason the responder prefers or requires tunnel mode for NAT traversal, it must reject the quick mode SA proposal for transport mode.

Generic choises for ESP tunnel mode:

Tn1) Same as Tr1.

Tn2) Same as Tr2.

Tn3) This option is possible if an initiator is capable of being assigned an address through it's tunnel SA with the responder using DHCP. The initiator may initially request an internal address via the DHCP-IPsec method, regardless of whether it knows it is behind a NAT. Or it may re-initiate an IKE quick mode negotiation for DHCP tunnel SA after the responder fails the quick mode SA transport mode proposal, either when NAT-OA payload is sent or because it discovers from NAT-D the initiator is behind a NAT and it's local configuration/policy will only accept connecting through NAT when

being assigned an address through DHCP-IPsec.

There are also implementation choices offereing limited interoperability. Implementors should specify what applications or protocols should work using their NAT-T solution if these options are selected. Note that neither Tr4 nor Tn4, as described below, are expected to work with TCP traffic.

Limited interoperability choices for ESP transport mode:

Tr4) Implement upper layer protocol awareness of the inbound & outbound IPsec SA so that it doesn't use the source IP and the source port as the session identifier. (E.g. L2TP session ID mapped to the IPsec SA pair which doesn't use the UDP source port or the source IP address for peer uniqueness.)

Tr5) Implement application integration with IKE initiation such that it can rebind to a different source port if the IKE quick mode SA proposal is rejected by the responder, then repropose the new QM selector.

Limited interoperability choices for ESP tunnel mode:

Tn4) Same as Tr4.

Intellectual Property Statement

The IETF takes no position regarding the validity or scope of any intellectual property or other rights that might be claimed to pertain to the implementation or use of the technology described in this document or the extent to which any license under such rights might or might not be available; neither does it represent that it has made any effort to identify any such rights. Information on the IETF's procedures with respect to rights in standards-track and standards-related documentation can be found in BCP-11. Copies of claims of rights made available for publication and any assurances of licenses to be made available, or the result of an attempt made to obtain a general license or permission for the use of such proprietary rights by implementors or users of this specification can be obtained from the IETF Secretariat.

The IETF invites any interested party to bring to its attention any copyrights, patents or patent applications, or other proprietary

rights which may cover technology that may be required to practice this standard. Please address the information to the IETF Executive Director.

The IETF has been notified of intellectual property rights claimed in regard to some or all of the specification contained in this document. For more information consult the online list of claimed rights.

Full Copyright Statement

Acknowledgment

Funding for the RFC Editor function is currently provided by the

Internet Society.

--