IP Security Protocol Working Group (IPSEC)
INTERNET-DRAFT
Category: Standards track
Expires: June 2003

A. Huttunen
F-Secure Corporation
B. Swander
Microsoft
M. Stenberg
SSH Communications Security Corp
V. Volpe
Cisco Systems
L. DiBurro
Nortel Networks

December 2002

**UDP Encapsulation of IPsec Packets**
**draft-ietf-ipsec-udp-encaps-05.txt**

Status of this Memo

This document is an Internet-Draft and is in full conformance with all provisions of Section 10 of RFC2026.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF), its areas, and its working groups. Note that other groups may also distribute working documents as Internet-Drafts.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

The list of current Internet-Drafts can be accessed at http://www.ietf.org/ietf/1id-abstracts.txt.

The list of Internet-Draft Shadow Directories can be accessed at http://www.ietf.org/shadow.html.

This Internet-Draft will expire on June, 2003.

Copyright Notice



Abstract

This draft 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).

Change Log

Version -01
- removed everything related to the AH-protocol
- added instructions on how to use the encapsulation with
  some other key management protocol than IKE
Version -02
- changed to using 4-byte non-ESP marker, removed all references
  to using this with other key management protocols
- TCP checksum handling for transport mode related discussion
  modified
- copied tunnel mode security considerations from the
  earlier draft-huttunen-ipsec-esp-in-udp-00.txt draft,
  added transport mode considerations
Version -03
- Clarifications to security considerations
Version -04
- Clarified checksum handling
- Added an IANA considerations section
- Added an implementation options appendix
- Reworded 'Abstract'
- References grouped
Version -05
- Changed incremental checksum fixup for transport mode

## 1. Introduction

This draft defines methods to encapsulate and decapsulate ESP packets inside UDP packets for the purpose of traversing NATs. The UDP port numbers are the same as used by IKE traffic, as defined in [Kiv05].

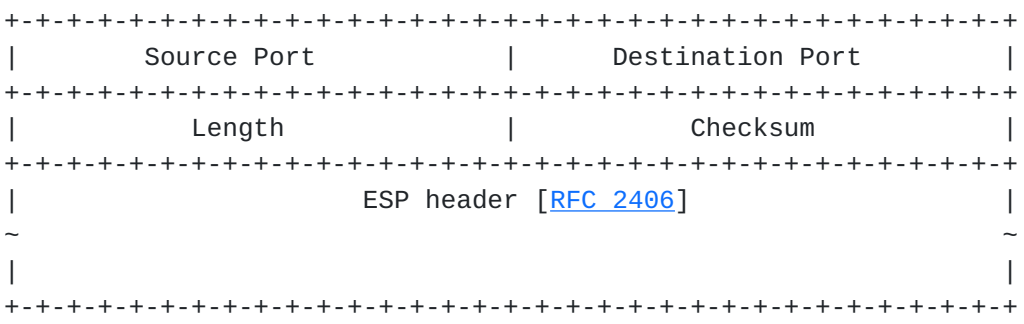
It is up to the need of the clients whether transport mode or tunnel mode is to be supported. L2TP/IPsec clients MUST support transport mode since [RFC 3193] defines that L2TP/IPsec MUST use transport mode], and IPsec tunnel mode clients MUST support tunnel mode.

An IKE implementation supporting this draft 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.

## 2. Packet Formats

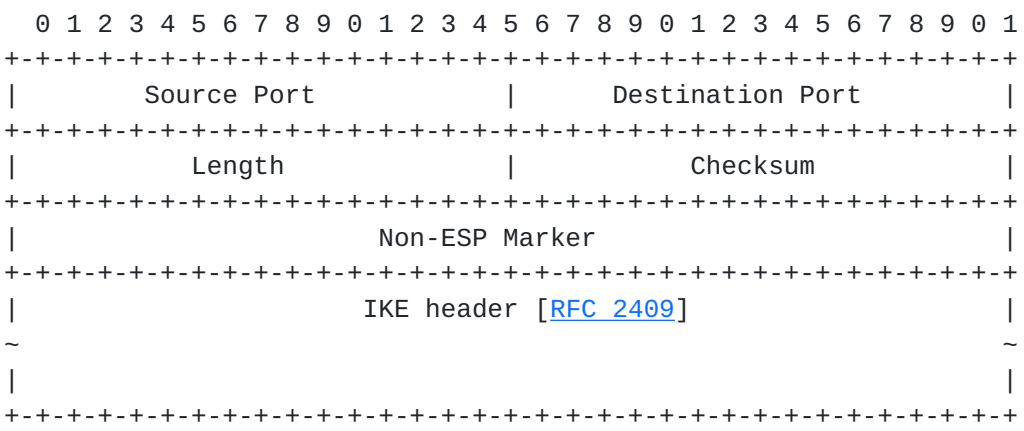
### 2.1 UDP-encapsulated ESP Header Format




The UDP header is a standard [RFC 768] header, where
- Source Port and Destination Port MUST be the same as used by
  floated IKE traffic.
- 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.

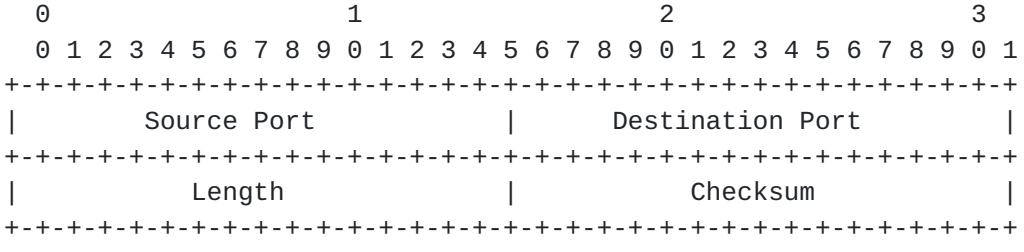
## 2.2 Floated IKE Header Format




The UDP header is a standard [RFC 768] header, and is used
as defined in [Kiv05]. 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



```
|    0xFF       |
+-+-+-+-+-+-+-+-+
```

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
- Checksum SHOULD be transmitted as a zero value.
- Receivers MUST NOT depend upon the UDP checksum being
  a zero value.

The sender SHOULD 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, 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:
a) 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.
b) 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.
c) 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.

Depending on local policy, one of the following MUST be done:
a) 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 [Kiv05], 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)

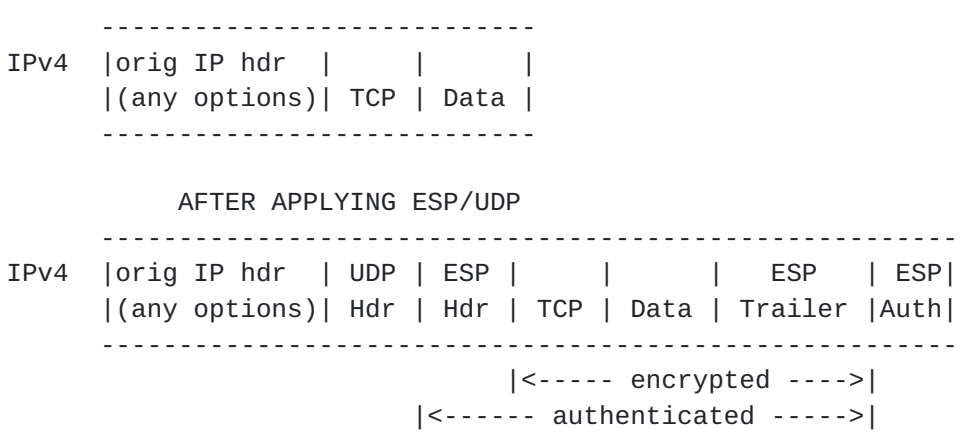
Note: if received and real address are the same for a given address, say the source address, the operations cancel and don't need to be performed.

b) If the protocol header after the ESP header is a TCP/UDP header, recompute the checksum field in the TCP/UDP header.

c) 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.

## 3.2 Transport Mode ESP Encapsulation

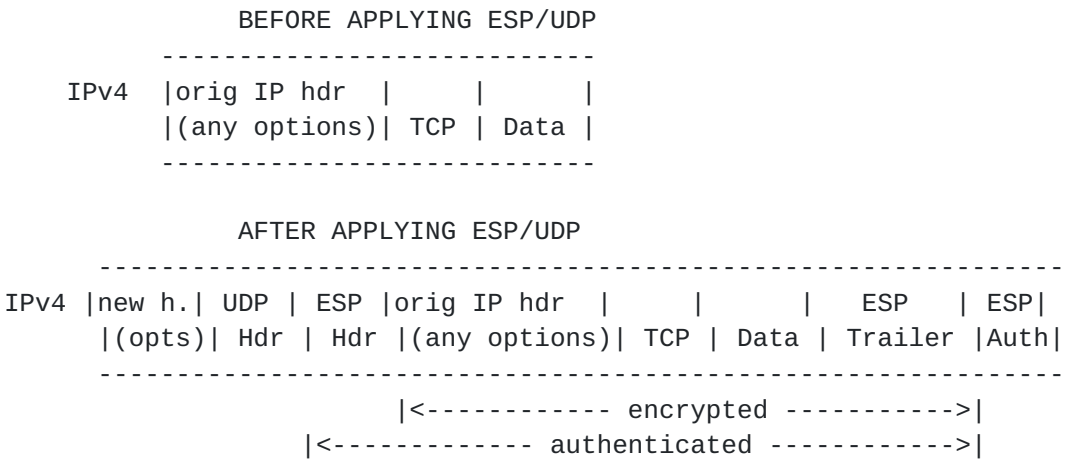



1) Ordinary ESP encapsulation procedure is used.
2) A properly formatted UDP header is inserted where shown.
3) The Total Length, Protocol and Header Checksum fields in the IP header are edited to match the resulting IP packet.

## 3.3 Transport Mode ESP Decapsulation

1) The UDP header is removed from the packet.
2) The Total Length, Protocol and Header Checksum 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 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 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. 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 [Kiv05] 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.

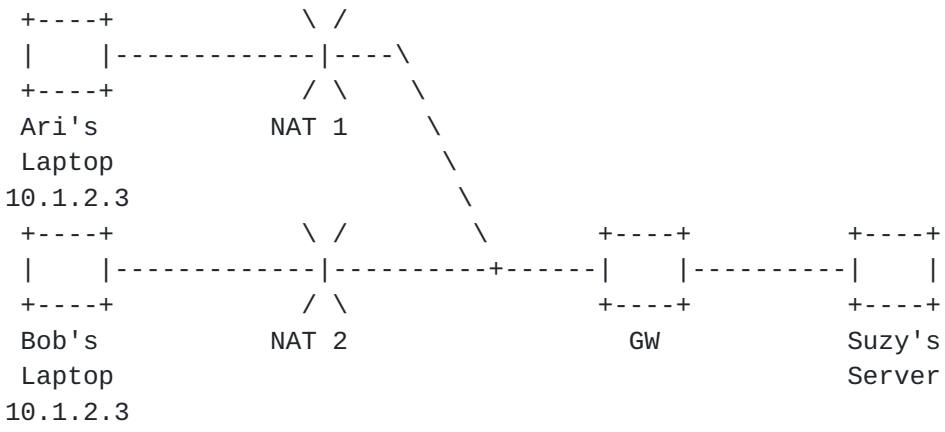
## 5. Security Considerations

### 5.1 DoS

On some systems ESPUDP may have DoS attack consequences, especially if ordinary operating system UDP-functionality is being used. It may be recommended not to open an ordinary UDP-port for this.

## 5.2 Tunnel Mode Conflict

Implementors are warned that it is possible for remote peers to negotiate entries that overlap in a GW, an issue affecting tunnel mode.



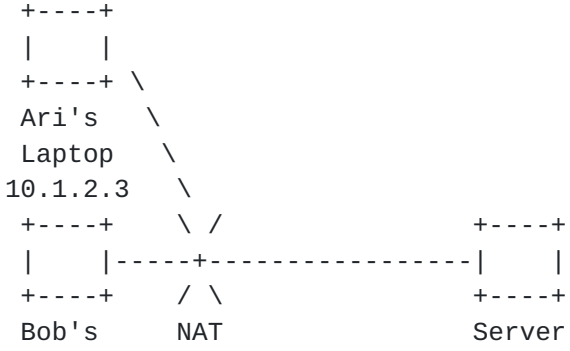

Because GW will now see two possible SAs that lead to 10.1.2.3, it can become confused where to send packets coming from Suzy's server. Implementators MUST devise ways of preventing such a thing from occurring.

It is recommended that GW either assign locally unique IP addresses to A and B using a protocol such as DHCP over IPsec, or uses NAT to change A's and B's source IP addresses to such locally unique addresses before sending packets forward to S.

## 5.3 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.

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




Now, transport SAs on the server will look like:
To Ari: S to NAT, <traffic desc1>, UDP encap <4500, Y>
To Bob: S 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 S in the
clear. This is going to be difficult to configure since
the server already has a policy from S 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: S to NAT, All UDP, secure
To Bob: S to NAT, All TCP, secure
To Cliff: S 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:

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

S 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.

## 6. IANA Considerations

This document depends on the reserved SPI value of zero (0) not being sent over the wire as a part of an ESP-packet [RFC 2406].

This document defines a "Non-ESP Marker" as 4 bytes of zero aligning with the SPI field of an ESP packet, and generally being followed by something that is not an ESP packet.

With regard to NAT-traversal in IKEv1 case, the Non-ESP Marker is being followed by an IKEv1 packet as specified in section 2.2.

## 7. Intellectual Property Rights

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.

## 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 previous drafts about NAT traversal.

## 9. References

Normative references:

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

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

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

[Kiv05] Kivinen, T. et. al., draft-ietf-ipsec-nat-t-ike-05.txt, "Negotiation of NAT-Traversal in the IKE", December 2002

Non-normative references:

[RFC 1122] R. Braden (Editor), "Requirements for Internet Hosts -- Communication Layers", October 1989

[RFC-2119] Bradner, S., "Key words for use in RFCs to indicate Requirement Levels", March 1997

[RFC 3193] Patel, B. et. al, "Securing L2TP using IPsec", November 2001

## 10. Authors' Addresses

Ari Huttunen
F-Secure Corporation
Tammasaarenkatu 7
FIN-00181 HELSINKI
Finland
E-mail: Ari.Huttunen@F-Secure.com

Brian Swander
Microsoft
One Microsoft Way
Redmond WA 98052
E-mail: briansw@microsoft.com

Markus Stenberg
SSH Communications Security Corp
Fredrikinkatu 42
FIN-00100 HELSINKI
Finland
E-mail: mstenber@ssh.com

Victor Volpe
Cisco Systems
124 Grove Street
Suite 205
Franklin, MA 02038
E-mail: vvolpe@cisco.com

Larry DiBurro
Nortel Networks
80 Central Street
Boxborough, MA 01719
ldiburro@nortelnetworks.com

## Appendix A: Clarification of potential NAT multiple client solutions

There have been requests to clarify potential solutions to the problem of multiple clients behind the same NAT simultaneously connecting to the same destination IP address.
Sections 5.2 and 5.3 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 draft 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. SSH may have intellectual property rights relating to this implementation technique. See their IPR notice on the IETF web site for the details.

Tr2) Implement a built-in NAPT (network address port translation) above IPsec decapsulation. Microsoft may have intellectual property rights relating to this implementation technique. See the Microsoft IPR notice on the IETF web site for the details.

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. Vendors should specify what applications or protocols should work using their NAT-T solution if these options are selected. Note that neither Tr4 nor Tn4 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. Microsoft may have intellectual property rights relating to this implementation technique.  See the Microsoft IPR notice on the IETF web site for the details.

Limited interoperability choices for ESP tunnel mode:

Tn4) Same as Tr4.