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IP Encapsulating Security Payload (ESP)

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This particular Internet Draft is a product of the IETF's IPng and IPsec working groups. It is intended that a future version of this draft be submitted to the IPng Area Directors and the IESG for possible publication as a standards-track protocol.

0. ABSTRACT

This document describes the IP Encapsulating Security Payload (ESP). ESP is a mechanism for providing integrity and confidentiality to IP datagrams. In some circumstances it can also provide authentication to IP datagrams. The mechanism works with both IPv4 and IPv6. This document also describes the mandatory DES CBC encryption transform for use with ESP.

1. INTRODUCTION

ESP is a mechanism for providing integrity and confidentiality to IP datagrams. It may also provide authentication, depending on which algorithm and algorithm mode are used. Non-repudiation and protection from traffic analysis are not provided by ESP. The IP Authentication Header (AH) might provide non-repudiation if used with certain authentication algorithms. [Atk95b] The IP Authentication Header may be used in conjunction with ESP to provide authentication. Users desiring integrity and authentication without confidentiality should use the IP Authentication Header (AH) instead of ESP. This document

assumes that the reader is familiar with the related document "IP Security Architecture", which defines the overall Internet-layer security architecture for IPv4 and IPv6 and provides important background for this specification. [Atk95a]

1.1 Overview

The IP Encapsulating Security Payload (ESP) seeks to provide confidentiality and integrity by encrypting data to be protected and placing the encrypted data in the data portion of the IP Encapsulating Security Payload. Depending on the user's security requirements, this mechanism may be used to encrypt either a transport-layer segment (e.g. TCP, UDP, ICMP, IGMP) or an entire IP datagram. Encapsulating the protected data is necessary to provide confidentiality for the entire original datagram.

Use of this specification will increase the IP protocol processing costs in participating systems and will also increase the communications latency. The increased latency is primarily due to the encryption and decryption required for each IP datagram containing an Encapsulating Security Payload.

In order for ESP to work properly without changing the entire Internet infrastructure (e.g. non-participating systems), the original IP datagram is placed in the encrypted portion of the Encapsulating Security Payload and that entire ESP frame is placed within an datagram having unencrypted IP headers. The information in the unencrypted IP headers is used to route the secure datagram from origin to destination. An unencrypted IP Routing Header might be included between the IP Header and the Encapsulating Security Payload.

In the case of IP, an IP Authentication Header may be present both as an header of the unencrypted IP packet and also as a header within the encrypted IP packet. In such a case, the unencrypted IPv6 Authentication Header is primarily used to provide protection for the contents of the unencrypted IP headers and the encrypted Authentication Header is used to provide authentication for the encrypted IP packet. This is discussed in more detail later in this document.

The encapsulating security payload is structured a bit differently than other IP payloads. The first component of the ESP payload consist of the unencrypted field(s) of the payload. The second

component consists of encrypted data. The field(s) of the unencrypted ESP header inform the intended receiver how to properly decrypt and process the encrypted data. The encrypted data component includes protected fields for the security protocol and also the encrypted encapsulated IP datagram.

The concept of a "Security Association" is fundamental to ESP. It is described in detail in the compaion document "Security Architecture for the Internet Protocol" which is incorporated here by reference. [Atk95a] Implementers should read that document before reading this one.

1.2 Requirements Terminology

In this document, the words that are used to define the significance of each particular requirement are usually capitalised. These words are:

- MUST

This word or the adjective "REQUIRED" means that the item is an absolute requirement of the specification.

- SHOULD

This word or the adjective "RECOMMENDED" means that there might exist valid reasons in particular circumstances to ignore this item, but the full implications should be understood and the case carefully weighed before taking a different course.

- MAY

This word or the adjective "OPTIONAL" means that this item is truly optional. One vendor might choose to include the item because a particular marketplace requires it or because it enhances the product, for example; another vendor may omit the same item.

2. KEY MANAGEMENT

Key management is an important part of the IP security architecture. However, a specific key management protocol is not included in this specification because of a long history in the public

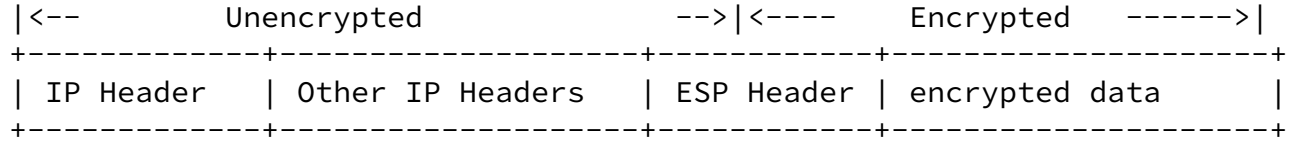
literature of subtle flaws in key management algorithms and protocols. IP tries to decouple the key management mechanisms from the security protocol mechanisms. The only coupling between the key management protocol and the security protocol is with the Security Association Identifier (SPI), which is described in more detail below. This decoupling permits several different key management mechanisms to be used. More importantly, it permits the key management protocol to be changed or corrected without unduly impacting the security protocol implementations. Thus, a key management protocol for IP is not specifed within this draft. The IP Security Architecture describes key management in more detail and specifies the key management requirements for IP. Those key management requirements are

incorporated here by reference. [Atk95a]

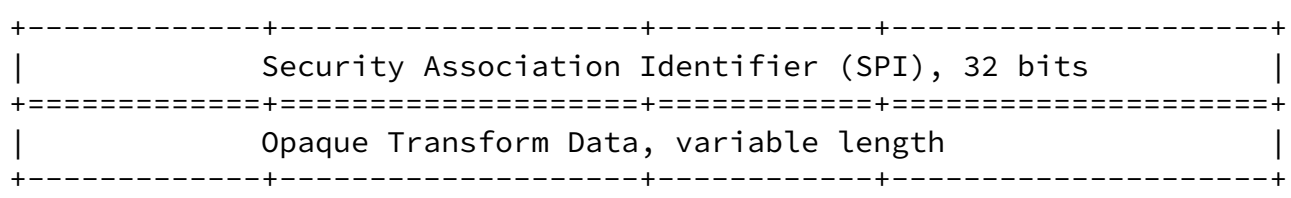
The key management mechanism is used to negotiate a number of parameters for each security association, including not only the keys but other information (e.g. the cryptographic algorithms and modes, security classification level if any) used by the communicating parties. The key management protocol implementation usually creates and maintains a logical table containing the several parameters for each current security association. An ESP implementation normally needs to read that security parameter table to determine how to process each datagram containing an ESP (e.g. which algorithm/mode and key to use).

3. ENCAPSULATING SECURITY PAYLOAD SYNTAX

The Encapsulating Security Payload (ESP) may appear anywhere after the IP header. The Internet Assigned Numbers Authority has assigned Protocol Number 50 to IP ESP. [STD-2] The header immediately preceding an ESP header will always contain the value 50 in its Next Header field. ESP consists of an unencrypted header followed by encrypted data. The encrypted data includes both the protected ESP header fields and the protected user data, which is either an entire IP datagram or an upper-layer protocol frame (e.g. TCP or UDP). A high-level diagram of a secure IP datagram follows.



A more detailed diagram of the ESP Header follows below.



Encryption and authentication algorithms, and the precise format of the Opaque Transform Data associated with them are known as "transforms". The ESP format is designed to support new transforms in the future to support new or additional cryptographic algorithms. The transforms are specified by themselves rather than in the main body of this specification. The mandatory transform for use with IP is defined in Appendix A of this specification. Other optional transforms exist in separate specifications and additional transforms might be defined in the future.

3.1 Fields of the Encapsulating Security Payload

This is a 32-bit pseudo-random value identifying the security association for this datagram. If no security association has been established, the value of this field shall be 0x00000000. An SPI is similar to the SAID used in other security protocols. The name has been changed because the semantics used here are not exactly the same as those used in other security protocols.

The set of SPI values in the range 0x00000001 though 0x000000FF are reserved to the Internet Assigned Numbers Authority (IANA) for future use. A reserved SPI value will not normally be assigned by IANA unless the use of that particular assigned SPI value is openly specified in an RFC.

The SPI is the only mandatory transform-independent field. Particular transforms may have other fields unique to the transform. Transforms are not specified in this document.

3.2 Security Labeling with ESP

The encrypted IP datagram need not and does not normally contain any

explicit Security Label because the SPI indicates the sensitivity label. This is an improvement over the current practices with IPv4 where an explicit Security Label is normally used with Compartmented Mode Workstations and other systems requiring Security Labels. [Ken91] [DIA] In some situations, users MAY choose to carry explicit labels (for example, IPSO labels as defined by RFC-1108 might be used with IPv4) in addition to using the implicit labels provided by ESP. Explicit label options could be defined for use with IPv6 (e.g. using the IPv6 End-to-End Options Header or the IPv6 Hop-by-Hop Options Header). Implementations MAY support explicit labels in addition to implicit labels, but implementations are not required to support explicit labels. Implementations of ESP in systems claiming to provide multi-level security MUST support implicit labels.

4. ENCAPSULATING SECURITY PROTOCOL PROCESSING

This section describes the steps taken when ESP is in use between two communicating parties. Multicast is different from unicast only in the area of key management (See the definition of the SPI, above, for more detail on this). There are two modes of use for ESP. The first mode, which is called "Tunnel-mode", encapsulates an entire IP datagram inside ESP. The second mode, which is called "Transport-Mode", encapsulates a transport-layer (e.g. UDP or TCP) frame inside ESP. The term "Transport-mode" must not be misconstrued as restricting its use to TCP and UDP. For example, an ICMP message MAY be sent either using the "Transport-mode" or the "IP-mode" depending upon circumstance. This section describes

protocol processing for each of these two modes.

4.1 ESP in Tunnel-mode

The sender takes the original IP datagram, encapsulates it into the ESP, locates the correct Security Association using the sending userid and the Destination Address, and then applies the appropriate encryption transform. If host-oriented keying is in use, then all sending userids on a given system will have the same Security Association for a given Destination Address. If no key has been established, then the key management mechanism is used to establish a encryption key for this communications session prior to the use of ESP. The (now encrypted) ESP is then encapsulated in a cleartext IP datagram as the last payload. If strict red/black separation is being enforced, then the addressing and other information in the cleartext

IP headers and optional payloads MAY be different from the values contained in the (now encrypted and encapsulated) original datagram.

The receiver strips off the cleartext IP header and cleartext optional IP payloads (if any) and discards them. It then uses the combination of Destination Address and SPI value to locate the correct decryption key to use for this packet. Then, it decrypts the ESP using the session key that has been established for this traffic.

If no valid Security Association exists for this session (for example, the receiver has no key), the receiver MUST discard the encrypted ESP and the failure MUST be recorded in the system log or audit log. This system log or audit log entry SHOULD include the SPI value, date/time, clear-text Sending Address, clear-text Destination Address, and the clear-text Flow ID. The log entry MAY also include other identifying data. The receiver might not wish to react by immediately informing the sender of this failure because of the strong potential for easy-to-exploit denial of service attacks.

If decryption succeeds, the original IP datagram is then removed from the (now decrypted) ESP. This original IP datagram is then processed as per the normal IP protocol specification. In the case of system claiming to provide multilevel security (for example, a B1 or Compartmented Mode Workstation) additional appropriate mandatory access controls MUST be applied based on the security level of the receiving process and the security level associated with this Security Association. If those mandatory access controls fail, then the packet SHOULD be discarded and the failure SHOULD be logged using implementation-specific procedures.

4.2 ESP in Transport-mode

The sender takes the original UDP or TCP or ICMP frame, encapsulates it into the ESP, locates the correct Security Association using the sending userid and Destination Address, and then applies the appropriate encryption transform. If host-oriented keying is in use, then all sending userids on a given system will have the same Security Association for a given Destination Address. If no key has been

established, then the key management mechanism is used to establish a encryption key for this communications session prior to the encryption. The (now encrypted) ESP is then encapsulated as the last payload of a cleartext IP datagram.

The receiver processes the cleartext IP header and cleartext optional IP headers (if any) and temporarily stores pertinent information (e.g. source and destination addresses, Flow ID, Routing Header). It then decrypts the ESP using the session key that has been established for this traffic, using the combination of the destination address and the packet's Security Association Identifier (SPI) to locate the correct key.

If no key exists for this session or the attempt to decrypt fails, the encrypted ESP MUST be discarded and the failure MUST be recorded in the system log or audit log. If such a failure occurs, the recorded log data SHOULD include the SPI value, date/time received, clear-text Sending Address, clear-text Destination Address, and the Flow ID. The log data MAY also include other information about the failed packet.

If decryption succeeds, the original UDP or TCP frame is removed from the (now decrypted) ESP. The information from the cleartext IP header and the now decrypted UDP or TCP header is jointly used to determine which application the data should be sent to. The data is then sent along to the appropriate application as normally per IP protocol specification. In the case of a system claiming to provide multilevel security (for example, a B1 or Compartmented Mode Workstation), additional Mandatory Access Controls MUST be applied based on the security level of the receiving process and the security level of the received packet's Security Association.

4.3. Authentication

Some transforms provide authentication as well as confidentiality and integrity. When such a transform is not used, then the Authentication Header might be used in conjunction with the Encapsulating Security Payload. There are two different approaches to using the Authentication Header with ESP, depending on which data is to be authenticated. The location of the Authentication Header makes

it clear which set of data is being authenticated.

In the first usage, the entire received datagram is authenticated, including both the encrypted and unencrypted portions, while only the data sent after the ESP Header is confidential. In this usage, the sender first applies ESP to the data being protected. Then the other plaintext IP headers are prepended to the ESP header and its now encrypted data. Finally, the IP Authentication Header is calculated over the resulting datagram according to the normal method. Upon receipt, the receiver first verifies the authenticity of the entire datagram using the normal IP Authentication Header process. Then if authentication succeeds, decryption using the normal IP ESP process occurs. If decryption is successful, then the resulting data is passed up to the upper layer.

If the authentication process were to be applied only to the data protected by IP ESP and the protected data were an entire IP datagram, then the IP Authentication Header would be placed normally within that protected datagram. However, if the protected data were less than an entire IP datagram, then the IP Authentication Header would be placed within the encrypted payload immediately after the ESP protected header and before any other header.

If the Authentication Header is encapsulated within the ESP header, and both headers have specific security classification levels associated with them, and the two security classification levels are not identical, then an error has occurred. That error SHOULD be recorded in the system log or audit log using the procedures described previously. It is not necessarily an error for an Authentication Header located outside of the ESP header to have a different security classification level than the ESP header's classification level. This might be valid because the cleartext IP headers might have a different classification level when the data has been encrypted using ESP.

5. CONFORMANCE REQUIREMENTS

Implementations that claim conformance or compliance with this specification MUST fully implement the header described here, MUST support manual key distribution with this header, MUST comply with all requirements of the "Security Architecture for the Internet Protocol" [Atk95a], and MUST support the use of DES CBC as specified in the companion document entitled "The ESP DES-CBC Transform" [MS95]. Implementers MAY also implement other ESP transforms. Implementers should consult the most recent version of the "IAB Official Standards" RFC for further guidance on the status of this document.

6. SECURITY CONSIDERATIONS

This entire draft discusses a security mechanism for use with IP. This mechanism is not a panacea, but it does provide an important component useful in creating a secure internetwork.

Users need to understand that the quality of the security provided by this specification depends completely on the strength of whichever encryption algorithm that has been implemented, the correctness of that algorithm's implementation, upon the security of the key management mechanism and its implementation, the strength of the key [CN94][Sch94, p233] and upon the correctness of the ESP and IP implementations in all of the participating systems.

If any of these assumptions do not hold, then little or no real security will be provided to the user. Use of high assurance development techniques is recommended for the IP Encapsulating Security Payload.

Users seeking protection from traffic analysis might consider the use of appropriate link encryption. Description and specification of link encryption is outside the scope of this note.

If user-oriented keying is not in use, then the algorithm in use should not be an algorithm vulnerable to any kind of Chosen Plaintext attack. Chosen Plaintext attacks on DES are described in [BS93] and [Mit94]. Use of user-oriented keying is recommended in order to preclude any sort of Chosen Plaintext attack and to generally make cryptanalysis more difficult. Implementations MUST support user-oriented keying as is described in the IP Security Architecture. [Atk95a]

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