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The PPP Triple-DES Encryption Protocol (3DESE)

Status of this Memo

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Abstract

The Point-to-Point Protocol (PPP) [1] provides a standard method for transporting multi-protocol datagrams over point-to-point links.

The PPP Encryption Control Protocol (ECP) [2] provides a method to negotiate and utilize encryption protocols over PPP encapsulated links.

This document provides specific details for the use of the Triple-DES standard (3DES) [6] for encrypting PPP encapsulated packets.

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1. Introduction

The purpose of encrypting packets exchanged between two PPP implementations is to attempt to insure the privacy of communication conducted via the two implementations. There exists a large variety of encryption algorithms, where one is the DES algorithm. The DES encryption algorithm is a well studied, understood and widely implemented encryption algorithm. Triple-DES means that this algorithm is applied three times on the data to be encrypted before it is sent over the line. The variant used is the DES-EDE3-CBC, which is described in more detail in the text. It was also chosen to be applied in the security section of IP [5].

This document shows how to send via the Triple-DES algorithm encrypted packets over a point-to-point-link. It lies in the context of the generic PPP Encryption Control Protocol [2].

Because of the use of the CBC-mode a sequence number is provided to

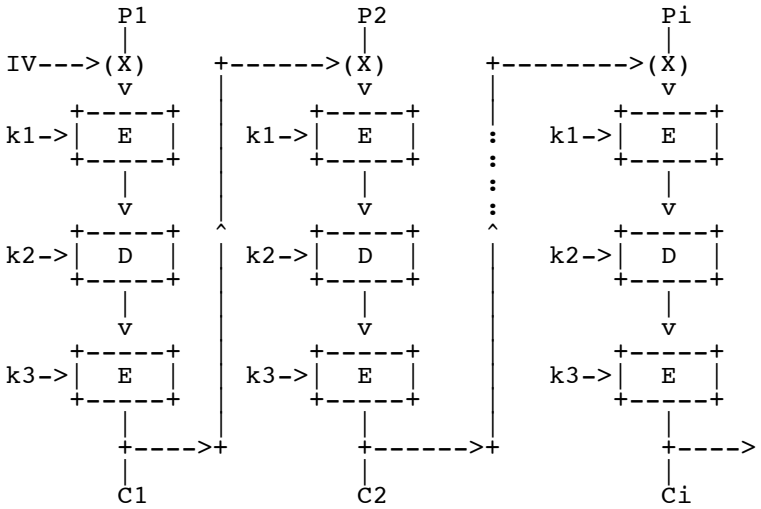
The padding section reflects the result of the discussion on this topic on the ppp mailing list.

In this document, the key words "MUST", "SHOULD", and "recommended" are to be interpreted as described in [3].

1.1 Algorithm

The DES-EDE3-CBC algorithm is a simple variant of the DES-CBC algorithm. In DES-EDE3-CBC, an Initialization Vector (IV) is XOR'd with the first 64-bit (8 octet) plaintext block (P1). The keyed DES function is iterated three times, an encryption (E) followed by a decryption (D) followed by an encryption (E), and generates the ciphertext (C1) for the block. Each iteration uses an independent key: k1, k2 and k3.

For successive blocks, the previous ciphertext block is XOR'd with the current 8-octet plaintext block (Pi). The keyed DES-EDE3 encryption function generates the ciphertext (Ci) for that block.



To decrypt, the order of the functions is reversed: decrypt with k3, encrypt with k2, decrypt with k1, and XOR with the previous cipher-text block.

When all three keys (k1, k2 and k3) are the same, DES-EDE3-CBC is equivalent to DES-CBC.

1.2 Keys

The secret DES-EDE3 key shared between the communicating parties is effectively 168-bits long. This key consists of three independent 56-bit quantities used by the DES algorithm. Each of the three 56-bit subkeys is stored as a 64-bit (8 octet) quantity, with the least significant bit of each octet used as a parity bit.

When configuring keys for 3DESE those with incorrect parity or so-called weak keys [6] SHOULD be rejected.

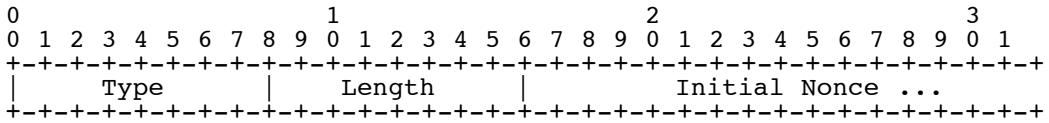
2. 3DESE Configuration Option for ECP

Description

implementation is offering to employ this specification for decrypting communications on the link, and may be thought of as a request for its peer to encrypt packets in this manner. The

ECP 3DESE Configuration Option has the following fields, which are transmitted from left to right:

Figure 1: ECP 3DESE Configuration Option



Type

2, to indicate the 3DESE protocol.

Length

10

Initial Nonce

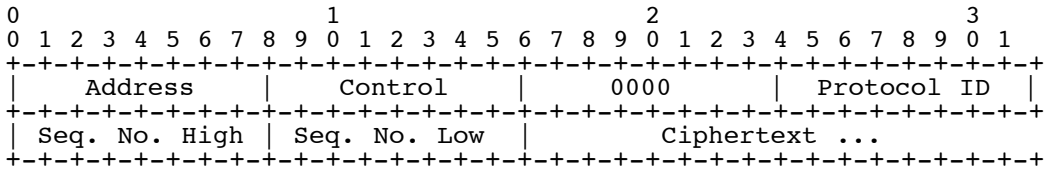
This field is an 8 byte quantity which is used by the peer implementation to encrypt the first packet transmitted after the sender reaches the opened state. To guard against replay attacks, the implementation SHOULD offer a different value during each ECP negotiation.

3. Packet format for 3DESE

Description

The 3DESE packets that contain the encrypted payload have the following fields:

Figure 2: 3DESE Encryption Protocol Packet Format



Address and Control

These fields MUST be present unless the PPP Address and Control Field Compression option (ACFC) has been

negotiated.

Protocol ID

The value of this field is 0x53 or 0x55; the latter indicates the use of the Individual Link Encryption Control Protocol and that the ciphertext contains a Multilink fragment. Protocol Field Compression MAY be applied to the leading zero if negotiated.

Sequence Number

transmitted once ECP has reached the opened state).

Ciphertext

The generation of this data is described in the next section.

4. Encryption

Once the ECP has reached the Opened state, the sender MUST NOT apply the encryption procedure to LCP packets nor ECP packets.

If the async control character map option has been negotiated on the link, the sender applies mapping after the encryption algorithm has been run.

The encryption algorithm is generally to pad the Protocol and Information fields of a PPP packet to some multiple of 8 bytes, and apply 3DES as described in section 1.1 with the three 56-bit keys k1, k2 and k3.

The encryption procedure is only applied to that portion of the packet excluding the address and control field.

When encrypting the first packet after ECP stepped into opened state the Initial Nonce is encrypted via 3DES-algorithm before its use.

4.1 Padding

Since the 3DES algorithm operates on blocks of 8 octets, plain text packets which are of length not a multiple of 8 octets must be padded prior to encrypting. If this padding is not removed after decryption this can be injurious to the interpretation of some protocols which do not contain an explicit length field in their protocol headers.

Therefore all packets not already a multiple of eight bytes in length MUST be padded prior to encrypting using the unambiguous technique of Self Describing Padding with a Maximum Pad Value (MPV) of 8. This means that the plain text is padded with the sequence of octets 1, 2, 3, .. 7 since its length is a multiple of 8 octets. Negotiation of SDP is not needed. Negotiation of the LCP Self Describing Option may be negotiated independently to solve an orthogonal problem.

Plain text which length is already a multiple of 8 octets may require padding with a further 8 octets (1, 2, 3 ... 8). These additional octets MUST only be appended, if the last octet of the plain text had a value of 8 or less.

When using Multilink and encrypting on individual links it is recommended that all non-terminating fragments have a length divisible by 8. So no additional padding is needed on those fragments.

After the peer has decrypted the ciphertext, it strips off the Self Describing Padding octets to recreate the original plain text. The peer SHOULD discard the frame if the octets forming the padding do not match the Self Describing Padding scheme just described.

Note that after decrypting, only the content of the last byte needs to be examined to determine the presence or absence of a Self Described Pad.

4.2 Recovery after packet loss

Packet loss is detected when there is a discontinuity in the sequence numbers of consecutive packets. Suppose packet number N - 1 has an unrecoverable error or is otherwise lost, but packets N and N + 1 are received correctly.

Since the previously described algorithm requires the last Ci of packet N - 1 to decrypt C1 of packet N, it will be impossible to decrypt packet N. However, all packets N + 1 and following can be

which WAS received).

5. Security Considerations

This proposal is concerned with providing confidentiality solely. It does not describe any mechanisms for integrity, authentication or nonrepudiation. It does not guarantee that any message received has not been modified in transit through replay, cut-and-paste or active tampering. It does not provide authentication of the source of any

packet received, or protect against the sender of any packet denying its authorship.

Security issues are the primary subject of this memo. This proposal relies on exterior and unspecified methods for retrieval of shared secrets. It proposes no new technology for privacy, but merely describes a convention for the application of the 3DES cipher to data transmission between PPP implementations. Any methodology for the protection and retrieval of shared secrets, and any limitations of the 3DES cipher are relevant to the use described here.

6. References

[1] Simpson, W., Editor, "The Point-to-Point Protocol (PPP)", STD 51, RFC 1661, July 1994.

[2] Meyer, G., "The PPP Encryption Control Protocol (ECP)", RFC 1968, June 1996.

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

[4] Sklower, K., and G. Meyer, "The PPP DES Encryption Protocol, Version 2 (DESE-bis)", RFC 2419, September 1998.

[5] Doraswamy, N., Metzger, P., Simpson, W., "The ESP Triple DES Transform", Work in Progress, June 1997.

[6] Schneier, B., "Applied Cryptography", Second Edition, John Wiley & Sons, New York, NY, 1995, ISBN 0-471-12845-7.

7. Acknowledgements

Many portions of this document were taken from [4] and [5]. Bill Simpson gave useful hints on the initial revision.

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