

# **Crypto Application**

version 1.6



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# Chapter 1

## Crypto User's Guide

The *Crypto* application provides functions for computation of message digests, and functions for encryption and decryption.

This product includes software developed by the OpenSSL Project for use in the OpenSSL Toolkit (<http://www.openssl.org/>).

This product includes cryptographic software written by Eric Young ([ey@cryptsoft.com](mailto:ey@cryptsoft.com)).

This product includes software written by Tim Hudson ([tjh@cryptsoft.com](mailto:tjh@cryptsoft.com)).

For full OpenSSL and SSLeay license texts, see Licenses [page 1].

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This chapter contains in extenso versions of the OpenSSL and SSLeay licenses.

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```





# Crypto Reference Manual

## Short Summaries

- Application **crypto** [page 8] – The Crypto Application
- Erlang Module **crypto** [page 10] – Crypto Functions

### crypto

No functions are exported.

### crypto

The following functions are exported:

- `start()` -> `ok`  
[page 10] Start the crypto server.
- `stop()` -> `ok`  
[page 10] Stop the crypto server.
- `info()` -> `[atom()]`  
[page 10] Provide a list of available crypto functions.
- `info_lib()` -> `[{Name,VerNum,VerStr}]`  
[page 10] Provides information about the libraries used by crypto.
- `md5(Data)` -> `Digest`  
[page 11] Compute an MD5message digest from Data
- `md5_init()` -> `Context`  
[page 11] Creates an MD5 context
- `md5_update(Context, Data)` -> `NewContext`  
[page 11] Update an MD5 Contextwith Data, and return a `NewContext`
- `md5_final(Context)` -> `Digest`  
[page 11] Finish the update of an MD5 Contextand return the computed MD5message digest
- `sha(Data)` -> `Digest`  
[page 11] Compute an SHAmessage digest from Data
- `sha_init()` -> `Context`  
[page 11] Create an SHA context
- `sha_update(Context, Data)` -> `NewContext`  
[page 12] Update an SHA context

- `sha_final(Context)` -> Digest  
[page 12] Finish the update of an SHA context
- `md5_mac(Key, Data)` -> Mac  
[page 12] Compute an MD5 MACmessage authentication code
- `md5_mac_96(Key, Data)` -> Mac  
[page 12] Compute an MD5 MACmessage authentication code
- `sha_mac(Key, Data)` -> Mac  
[page 12] Compute an MD5 MACmessage authentication code
- `sha_mac_96(Key, Data)` -> Mac  
[page 12] Compute an MD5 MACmessage authentication code
- `des_cbc_encrypt(Key, IVec, Text)` -> Cipher  
[page 12] Encrypt Textaccording to DES in CBC mode
- `des_cbc_decrypt(Key, IVec, Cipher)` -> Text  
[page 13] Decrypt Cipheraccording to DES in CBC mode
- `des3_cbc_encrypt(Key1, Key2, Key3, IVec, Text)` -> Cipher  
[page 13] Encrypt Textaccording to DES3 in CBC mode
- `des3_cbc_decrypt(Key1, Key2, Key3, IVec, Cipher)` -> Text  
[page 13] Decrypt Cipheraccording to DES in CBC mode
- `aes_cfb_128_encrypt(Key, IVec, Text)` -> Cipher  
[page 13] Encrypt Textaccording to AES in Cipher Feedback mode or Cipher Block Chaining mode
- `aes_cbc_128_encrypt(Key, IVec, Text)` -> Cipher  
[page 13] Encrypt Textaccording to AES in Cipher Feedback mode or Cipher Block Chaining mode
- `aes_cfb_128_decrypt(Key, IVec, Cipher)` -> Text  
[page 13] Decrypt Cipheraccording to AES in Cipher Feedback mode or Cipher Block Chaining mode
- `aes_cbc_128_decrypt(Key, IVec, Cipher)` -> Text  
[page 13] Decrypt Cipheraccording to AES in Cipher Feedback mode or Cipher Block Chaining mode
- `erlint(Mpint)` -> N  
[page 14] Convert between binary multi-precision integer and erlang big integer
- `mpint(N)` -> Mpint  
[page 14] Convert between binary multi-precision integer and erlang big integer
- `rand_bytes(N)` -> binary()  
[page 14] Generate a binary of random bytes
- `rand_uniform(Lo, Hi)` -> N  
[page 14] Generate a random number
- `mod_exp(N, P, M)` -> Result  
[page 14] Perform  $N^P \text{ mod } M$
- `rsa_sign(Data, Key)` -> Signature  
[page 14] Sign the data using rsa with the given key.
- `rsa_sign(DigestType, Data, Key)` -> Signature  
[page 14] Sign the data using rsa with the given key.
- `rsa_verify(Data, Signature, Key)` -> Verified  
[page 15] Verify the digest and signature using rsa with given public key.

- `rsa_verify(DigestType, Data, Signature, Key) -> Verified`  
[page 15] Verify the digest and signature using rsa with given public key.
- `rsa_public_encrypt(PlainText, PublicKey, Padding) -> ChipherText`  
[page 15] Encrypts Msg using the public Key.
- `rsa_private_decrypt(ChipherText, PrivateKey, Padding) -> PlainText`  
[page 15] Decrypts ChipherText using the private Key.
- `rsa_private_encrypt(PlainText, PrivateKey, Padding) -> ChipherText`  
[page 16] Encrypts Msg using the private Key.
- `rsa_public_decrypt(ChipherText, PublicKey, Padding) -> PlainText`  
[page 16] Decrypts ChipherText using the public Key.
- `dss_sign(Data, Key) -> Signature`  
[page 16] Sign the data using dsa with given private key.
- `dss_verify(Data, Signature, Key) -> Verified`  
[page 16] Verify the data and signature using dsa with given public key.
- `rc4_encrypt(Key, Data) -> Result`  
[page 17] Encrypt data using RC4
- `dh_generate_key(DHParams) -> {PublicKey,PrivateKey}`  
[page 17] Generates a Diffie-Hellman public key
- `dh_generate_key(PrivateKey, DHParams) -> {PublicKey,PrivateKey}`  
[page 17] Generates a Diffie-Hellman public key
- `dh_compute_key(OthersPublicKey, MyPrivateKey, DHParams) -> SharedSecret`  
[page 17] Computes the shared secret
- `exor(Data1, Data2) -> Result`  
[page 17] XOR data

# crypto

## Application

The purpose of the Crypto application is to provide message digest and DES encryption for SMNPv3. It provides computation of message digests MD5 and SHA, and CBC-DES encryption and decryption.

## Configuration

The following environment configuration parameters are defined for the Crypto application. Refer to `application(3)` for more information about configuration parameters.

`debug = true | false <optional>` Causes debug information to be written to standard error or standard output. Default is `false`.

## OpenSSL libraries

The current implementation of the Erlang Crypto application is based on the *OpenSSL* package version 0.9.7 or higher. There are source and binary releases on the web.

Source releases of OpenSSL can be downloaded from the OpenSSL<sup>1</sup> project home page, or mirror sites listed there.

The same URL also contains links to some compiled binaries and libraries of OpenSSL (see the `Related/Binaries` menu) of which the Shining Light Productions Win32 and OpenSSL<sup>2</sup> pages are of interest for the Win32 user.

For some Unix flavours there are binary packages available on the net.

If you cannot find a suitable binary OpenSSL package, you have to fetch an OpenSSL source release and compile it.

You then have to compile and install the library `libcrypto.so` (Unix), or the library `libeay32.dll` (Win32).

For Unix The `crypto_drv` dynamic driver is delivered linked to OpenSSL libraries in `/usr/local/lib`, but the default dynamic linking will also accept libraries in `/lib` and `/usr/lib`.

If that is not applicable to the particular Unix operating system used, the example `Makefile` in the `Crypto priv/obj` directory, should be used as a basis for relinking the final version of the port program.

For Win32 it is only required that the library can be found from the `PATH` environment variable, or that they reside in the appropriate `SYSTEM32` directory; hence no particular relinking is need. Hence no example `Makefile` for Win32 is provided.

---

<sup>1</sup>URL: <http://www.openssl.org>

<sup>2</sup>URL: <http://www.shininglightpro.com/search.php?searchname=Win32+OpenSSL>

## SEE ALSO

application(3)

# crypto

Erlang Module

This module provides a set of cryptographic functions.

References:

- md5: The MD5 Message Digest Algorithm (RFC 1321)
- sha: Secure Hash Standard (FIPS 180-2)
- hmac: Keyed-Hashing for Message Authentication (RFC 2104)
- des: Data Encryption Standard (FIPS 46-3)
- aes: Advanced Encryption Standard (AES) (FIPS 197)
- ecb, cbc, cfb, ofb: Recommendation for Block Cipher Modes of Operation (NIST SP 800-38A).
- rsa: Recommendation for Block Cipher Modes of Operation (NIST 800-38A)
- dss: Digital Signature Standard (FIPS 186-2)

The above publications can be found at NIST publications<sup>3</sup>, at IETF<sup>4</sup>.

*Types*

```
byte() = 0 ... 255
ioelem() = byte() | binary() | iolist()
iolist() = [ioelem()]
Mpint() = <<ByteLen:32/integer-big, Bytes:ByteLen/binary>>
```

## Exports

`start()` -> ok

Starts the crypto server.

`stop()` -> ok

Stops the crypto server.

`info()` -> [atom()]

Provides the available crypto functions in terms of a list of atoms.

`info_lib()` -> [{Name, VerNum, VerStr}]

<sup>3</sup>URL: <http://csrc.nist.gov/publications>

<sup>4</sup>URL: <http://www.ietf.org>

Types:

- Name = binary()
- VerNum = integer()
- VerStr = binary()

Provides the name and version of the libraries used by crypto.

Name is the name of the library. VerNum is the numeric version according to the library's own versioning scheme. VerStr contains a text variant of the version.

> info\_lib().

```
[{<<"openssl">>,9469983,<<"openssl 0.9.8a 11 Oct 2005">>}]
```

md5(Data) -> Digest

Types:

- Data = iolist() | binary()
- Digest = binary()

Computes an MD5 message digest from Data, where the length of the digest is 128 bits (16 bytes).

md5\_init() -> Context

Types:

- Context = binary()

Creates an MD5 context, to be used in subsequent calls to md5\_update/2.

md5\_update(Context, Data) -> NewContext

Types:

- Data = iolist() | binary()
- Context = NewContext = binary()

Updates an MD5 Context with Data, and returns a NewContext.

md5\_final(Context) -> Digest

Types:

- Context = Digest = binary()

Finishes the update of an MD5 Context and returns the computed MD5 message digest.

sha(Data) -> Digest

Types:

- Data = iolist() | binary()
- Digest = binary()

Computes an SHA message digest from Data, where the length of the digest is 160 bits (20 bytes).

sha\_init() -> Context

Types:

- Context = binary()

Creates an SHA context, to be used in subsequent calls to sha\_update/2.

sha\_update(Context, Data) -> NewContext

Types:

- Data = iolist() | binary()
- Context = NewContext = binary()

Updates an SHA Context with Data, and returns a NewContext.

sha\_final(Context) -> Digest

Types:

- Context = Digest = binary()

Finishes the update of an SHA Context and returns the computed SHA message digest.

md5\_mac(Key, Data) -> Mac

Types:

- Key = Data = iolist() | binary()
- Mac = binary()

Computes an MD5 MAC message authentication code from Key and Data, where the length of the Mac is 128 bits (16 bytes).

md5\_mac\_96(Key, Data) -> Mac

Types:

- Key = Data = iolist() | binary()
- Mac = binary()

Computes an MD5 MAC message authentication code from Key and Data, where the length of the Mac is 96 bits (12 bytes).

sha\_mac(Key, Data) -> Mac

Types:

- Key = Data = iolist() | binary()
- Mac = binary()

Computes an SHA MAC message authentication code from Key and Data, where the length of the Mac is 160 bits (20 bytes).

sha\_mac\_96(Key, Data) -> Mac

Types:

- Key = Data = iolist() | binary()
- Mac = binary()

Computes an SHA MAC message authentication code from Key and Data, where the length of the Mac is 96 bits (12 bytes).

des\_cbc\_encrypt(Key, IVec, Text) -> Cipher



Types:

- Key = Text = iolist() | binary()
- IVec = Cipher = binary()

Encrypts *Text* according to DES in CBC mode. *Text* must be a multiple of 64 bits (8 bytes). *Key* is the DES key, and *IVec* is an arbitrary initializing vector. The lengths of *Key* and *IVec* must be 64 bits (8 bytes).

```
des_cbc_decrypt(Key, IVec, Cipher) -> Text
```

Types:

- Key = Cipher = iolist() | binary()
- IVec = Text = binary()

Decrypts *Cipher* according to DES in CBC mode. *Key* is the DES key, and *IVec* is an arbitrary initializing vector. *Key* and *IVec* must have the same values as those used when encrypting. *Cipher* must be a multiple of 64 bits (8 bytes). The lengths of *Key* and *IVec* must be 64 bits (8 bytes).

```
des3_cbc_encrypt(Key1, Key2, Key3, IVec, Text) -> Cipher
```

Types:

- Key1 = Key2 = Key3 Text = iolist() | binary()
- IVec = Cipher = binary()

Encrypts *Text* according to DES3 in CBC mode. *Text* must be a multiple of 64 bits (8 bytes). *Key1*, *Key2*, *Key3*, are the DES keys, and *IVec* is an arbitrary initializing vector. The lengths of each of *Key1*, *Key2*, *Key3* and *IVec* must be 64 bits (8 bytes).

```
des3_cbc_decrypt(Key1, Key2, Key3, IVec, Cipher) -> Text
```

Types:

- Key1 = Key2 = Key3 = Cipher = iolist() | binary()
- IVec = Text = binary()

Decrypts *Cipher* according to DES3 in CBC mode. *Key1*, *Key2*, *Key3* are the DES key, and *IVec* is an arbitrary initializing vector. *Key1*, *Key2*, *Key3* and *IVec* must and *IVec* must have the same values as those used when encrypting. *Cipher* must be a multiple of 64 bits (8 bytes). The lengths of *Key1*, *Key2*, *Key3*, and *IVec* must be 64 bits (8 bytes).

```
aes_cfb_128_encrypt(Key, IVec, Text) -> Cipher
```

```
aes_cbc_128_encrypt(Key, IVec, Text) -> Cipher
```

Types:

- Key = Text = iolist() | binary()
- IVec = Cipher = binary()

Encrypts *Text* according to AES in Cipher Feedback mode (CFB) or Cipher Block Chaining mode (CBC). *Text* must be a multiple of 128 bits (16 bytes). *Key* is the AES key, and *IVec* is an arbitrary initializing vector. The lengths of *Key* and *IVec* must be 128 bits (16 bytes).

```
aes_cfb_128_decrypt(Key, IVec, Cipher) -> Text
```

```
aes_cbc_128_decrypt(Key, IVec, Cipher) -> Text
```

Types:

- Key = Cipher = iolist() | binary()
- IVec = Text = binary()

Decrypts Cipher according to Cipher Feedback Mode (CFB) or Cipher Block Chaining mode (CBC). Key is the AES key, and IVec is an arbitrary initializing vector. Key and IVec must have the same values as those used when encrypting. Cipher must be a multiple of 128 bits (16 bytes). The lengths of Key and IVec must be 128 bits (16 bytes).

erlint(Mpint) -> N

mpint(N) -> Mpint

Types:

- Mpint = binary()
- N = integer()

Convert a binary multi-precision integer Mpint to and from an erlang big integer. A multi-precision integer is a binary with the following form: <<ByteLen:32/integer, Bytes:ByteLen/binary>> where both ByteLen and Bytes are big-endian. Mpints are used in some of the functions in crypto and are not translated in the API for performance reasons.

rand\_bytes(N) -> binary()

Types:

- N = integer()

Generates N bytes randomly uniform 0..255, and returns the result in a binary. Uses the crypto library pseudo-random number generator.

rand\_uniform(Lo, Hi) -> N

Types:

- Lo, Hi, N = Mpint | integer()
- Mpint = binary()

Generate a random number N,  $Lo \leq N < Hi$ . Uses the crypto library pseudo-random number generator. The arguments (and result) can be either erlang integers or binary multi-precision integers.

mod\_exp(N, P, M) -> Result

Types:

- N, P, M, Result = Mpint
- Mpint = binary()

This function performs the exponentiation  $N^P \bmod M$ , using the crypto library.

rsa\_sign(Data, Key) -> Signature

rsa\_sign(DigestType, Data, Key) -> Signature

Types:

- Data = Mpint

- Key = [E, N, D]
- E, N, D = Mpint  
Where E is the public exponent, N is public modulus and D is the private exponent.
- DigestType = md5 | sha  
The default DigestType is sha.
- Mpint = binary()
- Signature = binary()

Calculates a DigestType digest of the Data and creates a RSA signature with the private key Key of the digest.

```
rsa_verify(Data, Signature, Key) -> Verified
```

```
rsa_verify(DigestType, Data, Signature, Key) -> Verified
```

Types:

- Verified = boolean()
- Data, Signature = Mpint
- Key = [E, N]
- E, N = Mpint  
Where E is the public exponent and N is public modulus.
- DigestType = md5 | sha  
The default DigestType is sha.
- Mpint = binary()

Calculates a DigestType digest of the Data and verifies that the digest matches the RSA signature using the signer's public key Key.

```
rsa_public_encrypt(PlainText, PublicKey, Padding) -> ChipherText
```

Types:

- PlainText = binary()
- PublicKey = [E, N]
- E, N = Mpint  
Where E is the public exponent and N is public modulus.
- Padding = rsa\_pkcs1\_padding | rsa\_pkcs1\_oaep\_padding | rsa\_no\_padding
- ChipherText = binary()

Encrypts the PlainText (usually a session key) using the PublicKey and returns the chipher. The Padding decides what padding mode is used, `rsa_pkcs1_padding` is PKCS #1 v1.5 currently the most used mode and `rsa_pkcs1_oaep_padding` is EME-OAEP as defined in PKCS #1 v2.0 with SHA-1, MGF1 and an empty encoding parameter. This mode is recommended for all new applications. The size of the Msg must be less than `byte_size(N)-11` if `rsa_pkcs1_padding` is used, `byte_size(N)-41` if `rsa_pkcs1_oaep_padding` is used and `byte_size(N)` if `rsa_no_padding` is used. Where `byte_size(N)` is the size part of an Mpint-1.

```
rsa_private_decrypt(ChipherText, PrivateKey, Padding) -> PlainText
```

Types:

- ChipherText = binary()
- PrivateKey = [E, N, D]

- E, N, D = Mpint  
Where E is the public exponent, N is public modulus and D is the private exponent.
- Padding = rsa\_pkcs1\_padding | rsa\_pkcs1\_oaep\_padding | rsa\_no\_padding
- PlainText = binary()

Decrypts the ChipherText (usually a session key encrypted with rsa\_public\_encrypt/3 [page 15]) using the PrivateKey and returns the message. The Padding is the padding mode that was used to encrypt the data, see rsa\_public\_encrypt/3 [page 15].

rsa\_private\_encrypt(PlainText, PrivateKey, Padding) -> ChipherText

Types:

- PlainText = binary()
- PrivateKey = [E, N, D]
- E, N, D = Mpint  
Where E is the public exponent, N is public modulus and D is the private exponent.
- Padding = rsa\_pkcs1\_padding | rsa\_no\_padding
- ChipherText = binary()

Encrypts the PlainText using the PrivateKey and returns the chipher. The Padding decides what padding mode is used, rsa\_pkcs1\_padding is PKCS #1 v1.5 currently the most used mode. The size of the Msg must be less than byte\_size(N)-11 if rsa\_pkcs1\_padding is used, and byte\_size(N) if rsa\_no\_padding is used. Where byte\_size(N) is the size part of an Mpint-1.

rsa\_public\_decrypt(ChipherText, PublicKey, Padding) -> PlainText

Types:

- ChipherText = binary()
- PublicKey = [E, N]
- E, N = Mpint  
Where E is the public exponent and N is public modulus
- Padding = rsa\_pkcs1\_padding | rsa\_no\_padding
- PlainText = binary()

Decrypts the ChipherText (encrypted with rsa\_private\_encrypt/3 [page 16]) using the PrivateKey and returns the message. The Padding is the padding mode that was used to encrypt the data, see rsa\_private\_encrypt/3 [page 16].

dss\_sign(Data, Key) -> Signature

Types:

- Digest = Mpint
- Key = [P, Q, G, X]
- P, Q, G, X = Mpint  
Where P, Q and G are the dss parameters and X is the private key.
- Mpint = binary()
- Signature = binary()

Calculates the sha digest of the Data and creates a DSS signature with the private key Key of the digest.

dss\_verify(Data, Signature, Key) -> Verified

Types:

- Verified = boolean()
- Digest, Signature = Mpint
- Key = [P, Q, G, Y]
- P, Q, G, Y = Mpint  
Where P, Q and G are the dss parameters and Y is the public key.
- Mpint = binary()

Calculates the sha digest of the Data and verifies that the digest matches the DSS signature using the public key Key.

`rc4_encrypt(Key, Data) -> Result`

Types:

- Key, Data = iolist() | binary()
- Result = binary()

Encrypts the data with RC4 symmetric stream encryption. Since it is symmetric, the same function is used for decryption.

`dh_generate_key(DHParams) -> {PublicKey, PrivateKey}`

`dh_generate_key(PrivateKey, DHParams) -> {PublicKey, PrivateKey}`

Types:

- DHParameters = [P, G]
- P, G = Mpint  
Where P is the shared prime number and G is the shared generator.
- PublicKey, PrivateKey = Mpint()

Generates a Diffie-Hellman PublicKey and PrivateKey (if not given).

`dh_compute_key(OtherPublicKey, MyPrivateKey, DHParams) -> SharedSecret`

Types:

- DHParameters = [P, G]
- P, G = Mpint  
Where P is the shared prime number and G is the shared generator.
- OtherPublicKey, MyPrivateKey = Mpint()
- SharedSecret = binary()

Computes the shared secret from the private key and the other party's public key.

`exor(Data1, Data2) -> Result`

Types:

- Data1, Data2 = iolist() | binary()
- Result = binary()

Performs bit-wise XOR (exclusive or) on the data supplied.

## DES in CBC mode

The Data Encryption Standard (DES) defines an algorithm for encrypting and decrypting an 8 byte quantity using an 8 byte key (actually only 56 bits of the key is used).

When it comes to encrypting and decrypting blocks that are multiples of 8 bytes various modes are defined (NIST SP 800-38A). One of those modes is the Cipher Block Chaining (CBC) mode, where the encryption of an 8 byte segment depend not only of the contents of the segment itself, but also on the result of encrypting the previous segment: the encryption of the previous segment becomes the initializing vector of the encryption of the current segment.

Thus the encryption of every segment depends on the encryption key (which is secret) and the encryption of the previous segment, except the first segment which has to be provided with an initial initializing vector. That vector could be chosen at random, or be a counter of some kind. It does not have to be secret.

The following example is drawn from the old FIPS 81 standard (replaced by NIST SP 800-38A), where both the plain text and the resulting cipher text is settled. The following code fragment returns 'true'.

```

Key = <<16#01,16#23,16#45,16#67,16#89,16#ab,16#cd,16#ef>>,
IVec = <<16#12,16#34,16#56,16#78,16#90,16#ab,16#cd,16#ef>>,
P = "Now is the time for all ",
C = crypto:des_cbc_encrypt(Key, IVec, P),
  % Which is the same as
P1 = "Now is t", P2 = "he time ", P3 = "for all ",
C1 = crypto:des_cbc_encrypt(Key, IVec, P1),
C2 = crypto:des_cbc_encrypt(Key, C1, P2),
C3 = crypto:des_cbc_encrypt(Key, C2, P3),

C = <<C1/binary, C2/binary, C3/binary>>,
C = <<16#e5,16#c7,16#cd,16#de,16#87,16#2b,16#f2,16#7c,
      16#43,16#e9,16#34,16#00,16#8c,16#38,16#9c,16#0f,
      16#68,16#37,16#88,16#49,16#9a,16#7c,16#05,16#f6>>,
<<"Now is the time for all ">> ==
      crypto:des_cbc_decrypt(Key, IVec, C).

```

The following is true for the DES CBC mode. For all decompositions  $P1 ++ P2 = P$  of a plain text message  $P$  (where the length of all quantities are multiples of 8 bytes), the encryption  $C$  of  $P$  is equal to  $C1 ++ C2$ , where  $C1$  is obtained by encrypting  $P1$  with  $Key$  and the initializing vector  $IVec$ , and where  $C2$  is obtained by encrypting  $P2$  with  $Key$  and the initializing vector  $last8(C1)$ , where  $last(Binary)$  denotes the last 8 bytes of the binary  $Binary$ .

Similarly, for all decompositions  $C1 ++ C2 = C$  of a cipher text message  $C$  (where the length of all quantities are multiples of 8 bytes), the decryption  $P$  of  $C$  is equal to  $P1 ++ P2$ , where  $P1$  is obtained by decrypting  $C1$  with  $Key$  and the initializing vector  $IVec$ , and where  $P2$  is obtained by decrypting  $C2$  with  $Key$  and the initializing vector  $last8(C1)$ , where  $last8(Binary)$  is as above.

For DES3 (which uses three 64 bit keys) the situation is the same.

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