crypto

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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 (eay@cryptsoft.com).

This product includes software written by Tim Hudson (tjh@cryptsoft.com).

For full OpenSSL and SSLeay license texts, see *Licenses*.

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

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 */
```

1.2 FIPS mode

This chapter describes FIPS mode support in the crypto application.

1.2.1 Background

OpenSSL can be built to provide FIPS 140-2 validated cryptographic services. It is not the OpenSSL application that is validated, but a special software component called the OpenSSL FIPS Object Module. However applications do not use this Object Module directly, but through the regular API of the OpenSSL library.

The crypto application supports using OpenSSL in FIPS mode. In this scenario only the validated algorithms provided by the Object Module are accessible, other algorithms usually available in OpenSSL (like md5) or implemented in the Erlang code (like SRP) are disabled.

1.2.2 Enabling FIPS mode

- Build or install the FIPS Object Module and a FIPS enabled OpenSSL library.

  You should read and precisely follow the instructions of the **Security Policy** and **User Guide**.

  > **Warning:**
  >
  > It is very easy to build a working OpenSSL FIPS Object Module and library from the source. However it **does not** qualify as FIPS 140-2 validated if the numerous restrictions in the Security Policy are not properly followed.

- Configure and build Erlang/OTP with FIPS support:

```
$ cd $ERL_TOP
$ ./otp_build configure --enable-fips
...
checking for FIPS_mode_set... yes
...
$ make
```

  If `FIPS_mode_set` returns `no` the OpenSSL library is not FIPS enabled and crypto won't support FIPS mode either.

- Set the `fips_mode` configuration setting of the crypto application to `true` **before loading the crypto module**.

  The best place is in the `sys.config` system configuration file of the release.

- Start and use the crypto application as usual. However take care to avoid the non-FIPS validated algorithms, they will all throw exception `not_supported`.

Entering and leaving FIPS mode on a node already running crypto is not supported. The reason is that OpenSSL is designed to prevent an application requesting FIPS mode to end up accidentally running in non-FIPS mode. If entering FIPS mode fails (e.g. the Object Module is not found or is compromised) any subsequent use of the OpenSSL API would terminate the emulator.

An on-the-fly FIPS mode change would thus have to be performed in a critical section protected from any concurrently running crypto operations. Furthermore in case of failure all crypto calls would have to be disabled from the Erlang or nif code. This would be too much effort put into this not too important feature.

1.2.3 Incompatibilities with regular builds

The Erlang API of the crypto application is identical regardless of building with or without FIPS support. However the nif code internally uses a different OpenSSL API.

This means that the context (an opaque type) returned from streaming crypto functions (`hash_(init|update|final)`, `hmac_(init|update|final)` and `stream_(init|encrypt|decrypt)`) is different and incompatible with regular builds when compiling crypto with FIPS support.

1.2.4 Common caveats

In FIPS mode non-validated algorithms are disabled. This may cause some unexpected problems in application relying on crypto.

Warning:

Do not try to work around these problems by using alternative implementations of the missing algorithms! An application can only claim to be using a FIPS 140-2 validated cryptographic module if it uses it exclusively for every cryptographic operation.

Restrictions on key sizes

Although public key algorithms are supported in FIPS mode they can only be used with secure key sizes. The Security Policy requires the following minimum values:

RSA
: 1024 bit

DSS
: 1024 bit

EC algorithms
: 160 bit

Restrictions on elliptic curves

The Erlang API allows using arbitrary curve parameters, but in FIPS mode only those allowed by the Security Policy shall be used.

Avoid md5 for hashing

Md5 is a popular choice as a hash function, but it is not secure enough to be validated. Try to use sha instead wherever possible.

For exceptional, non-cryptographic use cases one may consider switching to `erlang:md5/1` as well.

Certificates and encrypted keys

As md5 is not available in FIPS mode it is only possible to use certificates that were signed using sha hashing. When validating an entire certificate chain all certificates (including the root CA's) must comply with this rule.

For similar dependency on the md5 and des algorithms most encrypted private keys in PEM format do not work either. However, the PBES2 encryption scheme allows the use of stronger FIPS verified algorithms which is a viable alternative.

SNMP v3 limitations

It is only possible to use `usmHMACSHAAuthProtocol` and `usmAesCfb128Protocol` for authentication and privacy respectively in FIPS mode. The snmp application however won't restrict selecting disabled protocols in any way, and using them would result in run time crashes.

TLS 1.2 is required

All SSL and TLS versions prior to TLS 1.2 use a combination of md5 and sha1 hashes in the handshake for various purposes:

- Authenticating the integrity of the handshake messages.
- In the exchange of DH parameters in cipher suites providing non-anonymous PFS (perfect forward secrecy).
- In the PRF (pseud-random function) to generate keying materials in cipher suites not using PFS.

OpenSSL handles these corner cases in FIPS mode, however the Erlang crypto and ssl applications are not prepared for them and therefore you are limited to TLS 1.2 in FIPS mode.

On the other hand it worth mentioning that at least all cipher suites that would rely on non-validated algorithms are automatically disabled in FIPS mode.

Note:

Certificates using weak (md5) digests may also cause problems in TLS. Although TLS 1.2 has an extension for specifying which type of signatures are accepted, and in FIPS mode the ssl application will use it properly, most TLS implementations ignore this extension and simply send whatever certificates they were configured with.

1.3 Engine Load

This chapter describes the support for loading encryption engines in the crypto application.

1.3.1 Background

OpenSSL exposes an Engine API, which makes it possible to plug in alternative implementations for some or all of the cryptographic operations implemented by OpenSSL. When configured appropriately, OpenSSL calls the engine's implementation of these operations instead of its own.

Typically, OpenSSL engines provide a hardware implementation of specific cryptographic operations. The hardware implementation usually offers improved performance over its software-based counterpart, which is known as cryptographic acceleration.

Note:

The file name requirement on the engine dynamic library can differ between SSL versions.

1.3.2 Use Cases

Dynamically load an engine from default directory

If the engine is located in the OpenSSL/LibreSSL installation `engines` directory.

```
1> {ok, Engine} = crypto:engine_load(<<"otp_test_engine">>, [], []).
 {ok, #Ref}
```

Load an engine with the dynamic engine

Load an engine with the help of the dynamic engine by giving the path to the library.

```
 2> {ok, Engine} = crypto:engine_load(<<"dynamic">>,
                                      [{<<"SO_PATH">>,
                                        <<"/some/path/otp_test_engine.so">>},
                                       {<<"ID">>, <<"MD5">>},
                                       <<"LOAD">>],
                                      []).
 {ok, #Ref}
```

Load an engine and replace some methods

Load an engine with the help of the dynamic engine and just replace some engine methods.

```
 3> Methods = crypto:engine_get_all_methods() -- [engine_method_dh,engine_method_rand,
engine_method_ciphers,engine_method_digests, engine_method_store,
engine_method_pkey_meths, engine_method_pkey_asn1_meths].
[engine_method_rsa,engine_method_dsa,
 engine_method_ecdh,engine_method_ecdsa]
 4> {ok, Engine} = crypto:engine_load(<<"dynamic">>,
                                      [{<<"SO_PATH">>,
                                        <<"/some/path/otp_test_engine.so">>},
                                       {<<"ID">>, <<"MD5">>},
                                       <<"LOAD">>],
                                      [],
                         Methods).
 {ok, #Ref}
```

Load with the ensure loaded function

This function makes sure the engine is loaded just once and the ID is added to the internal engine list of OpenSSL. The following calls to the function will check if the ID is loaded and then just get a new reference to the engine.

```
 5> {ok, Engine} = crypto:ensure_engine_loaded(<<"MD5">>,
                                               <<"/some/path/otp_test_engine.so">>).
 {ok, #Ref}
```

To unload it use crypto:ensure_engine_unloaded/1 which removes the ID from the internal list before unloading the engine.

```
 6> crypto:ensure_engine_unloaded(<<"MD5">>).
 ok
```

List all engines currently loaded

```
 5> crypto:engine_list().
[<<"dynamic">>, <<"MD5">>]
```

1.4 Engine Stored Keys

This chapter describes the support in the crypto application for using public and private keys stored in encryption engines.

1.4.1 Background

OpenSSL exposes an Engine API, which makes it possible to plug in alternative implementations for some of the cryptographic operations implemented by OpenSSL. See the chapter *Engine Load* for details and how to load an Engine.

An engine could among other tasks provide a storage for private or public keys. Such a storage could be made safer than the normal file system. Those techniques are not described in this User's Guide. Here we concentrate on how to use private or public keys stored in such an engine.

The storage engine must call `ENGINE_set_load_privkey_function` and `ENGINE_set_load_pubkey_function`. See the OpenSSL cryptolib's **manpages**.

OTP/Crypto requires that the user provides two or three items of information about the key. The application used by the user is usually on a higher level, for example in *SSL*. If using the crypto application directly, it is required that:

- an Engine is loaded, see the chapter on *Engine Load* or the *Reference Manual*
- a reference to a key in the Engine is available. This should be an Erlang string or binary and depends on the Engine loaded

- an Erlang map is constructed with the Engine reference, the key reference and possibly a key passphrase if needed by the Engine. See the *Reference Manual* for details of the map.

1.4.2 Use Cases

Sign with an engine stored private key

This example shows how to construct a key reference that is used in a sign operation. The actual key is stored in the engine that is loaded at prompt 1.

```
1> {ok, EngineRef} = crypto:engine_load(....).
...
{ok,#Ref<0.2399045421.3028942852.173962>}
2> PrivKey = #{engine => EngineRef,
               key_id => "id of the private key in Engine"}.
...
3> Signature = crypto:sign(rsa, sha, <<"The message">>, PrivKey).
<<65,6,125,254,54,233,84,77,83,63,168,28,169,214,121,76,
  207,177,124,183,156,185,160,243,36,79,125,230,231,...>>
```

Verify with an engine stored public key

Here the signature and message in the last example is verifyed using the public key. The public key is stored in an engine, only to exemplify that it is possible. The public key could of course be handled openly as usual.

```
4> PublicKey = #{engine => EngineRef,
                 key_id => "id of the public key in Engine"}.
...
5> crypto:verify(rsa, sha, <<"The message">>, Signature, PublicKey).
true
6>
```

Using a password protected private key

The same example as the first sign example, except that a password protects the key down in the Engine.

```
6> PrivKeyPwd = #{engine => EngineRef,
                  key_id => "id of the pwd protected private key in Engine",
    password => "password"}.
...
7> crypto:sign(rsa, sha, <<"The message">>, PrivKeyPwd).
<<140,80,168,101,234,211,146,183,231,190,160,82,85,163,
  175,106,77,241,141,120,72,149,181,181,194,154,175,76,
  223,...>>
8>
```

1.5 Algorithm Details

This chapter describes details of algorithms in the crypto application.

The tables only documents the supported cryptos and key lengths. The user should not draw any conclusion on security from the supplied tables.

1.5.1 Ciphers

A *cipher* in the *new api* is categorized as either *cipher_no_iv()*, *cipher_iv()* or *cipher_aead()*. The letters IV are short for *Initialization Vector* and AEAD is an abreviation of *Authenticated Encryption with Associated Data*.

Due to irregular naming conventions, some cipher names in the old api are substitued by new names in the new api. For a list of retired names, see *Retired cipher names*.

To dynamically check availability, check that the name in the *Cipher and Mode* column is present in the list returned by *crypto:supports(ciphers)*.

Ciphers without an IV - cipher_no_iv()

To be used with:

- *crypto_one_time/4*
- *crypto_init/3*

The ciphers are:

Cipher and Mode	**Key length [bytes]**	**Block size [bytes]**
`aes_128_ecb`	16	16
`aes_192_ecb`	24	16
`aes_256_ecb`	32	16
`blowfish_ecb`	16	8
`des_ecb`	8	8
`rc4`	16	1

Table 5.1: Ciphers without IV

Ciphers with an IV - cipher_iv()

To be used with:

- *crypto_one_time/5*
- *crypto_init/4*
- *crypto_dyn_iv_init/3*

The ciphers are:

Cipher and Mode	**Key length [bytes]**	**IV length [bytes]**	**Block size [bytes]**	**Limited to OpenSSL versions**
`aes_128_cbc`	16	16	16	
`aes_192_cbc`	24	16	16	
`aes_256_cbc`	32	16	16	
`aes_128_cfb8`	16	16	1	
`aes_192_cfb8`	24	16	1	
`aes_256_cfb8`	32	16	1	

aes_128_cfb128	16	16	1	
aes_192_cfb128	24	16	1	
aes_256_cfb128	32	16	1	
aes_128_ctr	16	16	1	
aes_192_ctr	24	16	1	
aes_256_ctr	32	16	1	
aes_ige256	16	32	16	
blowfish_cbc	16	8	8	
blowfish_cfb64	16	8	1	
blowfish_ofb64	16	8	1	
chacha20	32	16	1	#1.1.0d
des_cbc	8	8	8	
des_ede3_cbc	24	8	8	
des_cfb	8	8	1	
des_ede3_cfb	24	8	1	
rc2_cbc	16	8	8	

Table 5.2: Ciphers with IV

Ciphers with AEAD - cipher_aead()

To be used with:

- *crypto_one_time_aead/6*
- *crypto_one_time_aead/7*

The ciphers are:

Cipher and Mode	**Key length [bytes]**	**IV length [bytes]**	**AAD length [bytes]**	**Tag length [bytes]**	**Block size [bytes]**	**Limited to OpenSSL versions**
aes_128_ccm	16	7-13	any	even 4-16 default: 12	any	#1.0.1
aes_192_ccm	24	7-13	any	even 4-16 default: 12	any	#1.0.1

aes_256_ccm	32	7-13	any	even 4-16 default: 12	any	#1.0.1
aes_128_gcm	16	#1	any	1-16 default: 16	any	#1.0.1
aes_192_gcm	24	#1	any	1-16 default: 16	any	#1.0.1
aes_256_gcm	32	#1	any	1-16 default: 16	any	#1.0.1
chacha20_poly1305	32	1-16	any	16	any	#1.1.0

Table 5.3: AEAD ciphers

1.5.2 Message Authentication Codes (MACs)

To be used in *mac/4* and *related functions*.

CMAC

CMAC with the following ciphers are available with OpenSSL 1.0.1 or later if not disabled by configuration.

To dynamically check availability, check that the name `cmac` is present in the list returned by *crypto:supports(macs)*. Also check that the name in the *Cipher and Mode* column is present in the list returned by *crypto:supports(ciphers)*.

Cipher and Mode	**Key length [bytes]**	**Max Mac Length (= default length) [bytes]**
aes_128_cbc	16	16
aes_192_cbc	24	16
aes_256_cbc	32	16
aes_128_ecb	16	16
aes_192_ecb	24	16
aes_256_ecb	32	16
blowfish_cbc	16	8
blowfish_ecb	16	8
des_cbc	8	8
des_ecb	8	8
des_ede3_cbc	24	8

rc2_cbc	16	8

Table 5.4: CMAC cipher key lengths

HMAC

Available in all OpenSSL compatible with Erlang CRYPTO if not disabled by configuration.

To dynamically check availability, check that the name `hmac` is present in the list returned by *crypto:supports(macs)* and that the hash name is present in the list returned by *crypto:supports(hashs)*.

Hash	**Max Mac Length (= default length) [bytes]**
sha	20
sha224	28
sha256	32
sha384	48
sha512	64
sha3_224	28
sha3_256	32
sha3_384	48
sha3_512	64
blake2b	64
blake2s	32
md4	16
md5	16
ripemd160	20

Table 5.5: HMAC output sizes

POLY1305

POLY1305 is available with OpenSSL 1.1.1 or later if not disabled by configuration.

To dynamically check availability, check that the name `poly1305` is present in the list returned by *crypto:supports(macs)*.

The poly1305 mac wants an 32 bytes key and produces a 16 byte MAC by default.

1.5.3 Hash

To dynamically check availability, check that the wanted name in the *Names* column is present in the list returned by *crypto:supports(hashs)*.

Type	**Names**	**Limitated to OpenSSL versions**
SHA1	sha	
SHA2	sha224, sha256, sha384, sha512	
SHA3	sha3_224, sha3_256, sha3_384, sha3_512	#1.1.1
MD4	md4	
MD5	md5	
RIPEMD	ripemd160	

Table 5.6:

1.5.4 Public Key Cryptography

RSA

RSA is available with all OpenSSL versions compatible with Erlang CRYPTO if not disabled by configuration. To dynamically check availability, check that the atom `rsa` is present in the list returned by *crypto:supports(public_keys)*.

Warning:

The RSA options are experimental.

The exact set of options and there syntax **may** be changed without prior notice.

Option	**sign/verify**	**public encrypt private decrypt**	**private encrypt public decrypt**
{rsa_padding,rsa_x931_padding}	x		x
{rsa_padding,rsa_pkcs1_padding}	x	x	x
{rsa_padding,rsa_pkcs1_pss_padding} {rsa_pss_saltlen, -2..} {rsa_mgf1_md, atom()}	x (2) x (2) x (2)		
{rsa_padding,rsa_pkcs1_oaep_padding} {rsa_mgf1_md, atom()} {rsa_oaep_label, binary()}} {rsa_oaep_md, atom()}		x (2) x (2) x (3) x (3)	

{rsa_padding,rsa_no_padding}	(1)		

Table 5.7:

Notes:

- (1) OpenSSL # 1.0.0
- (2) OpenSSL # 1.0.1
- (3) OpenSSL # 1.1.0

DSS

DSS is available with OpenSSL versions compatible with Erlang CRYPTO if not disabled by configuration. To dynamically check availability, check that the atom `dss` is present in the list returned by *crypto:supports(public_keys)*.

ECDSA

ECDSA is available with OpenSSL 0.9.8o or later if not disabled by configuration. To dynamically check availability, check that the atom `ecdsa` is present in the list returned by *crypto:supports(public_keys)*. If the atom `ec_gf2m` also is present, the characteristic two field curves are available.

The actual supported named curves could be checked by examining the list returned by *crypto:supports(curves)*.

EdDSA

EdDSA is available with OpenSSL 1.1.1 or later if not disabled by configuration. To dynamically check availability, check that the atom `eddsa` is present in the list returned by *crypto:supports(public_keys)*.

Support for the curves ed25519 and ed448 is implemented. The actual supported named curves could be checked by examining the list with the list returned by *crypto:supports(curves)*.

Diffie-Hellman

Diffie-Hellman computations are available with OpenSSL versions compatible with Erlang CRYPTO if not disabled by configuration. To dynamically check availability, check that the atom `dh` is present in the list returned by *crypto:supports(public_keys)*.

Elliptic Curve Diffie-Hellman

Elliptic Curve Diffie-Hellman is available with OpenSSL 0.9.8o or later if not disabled by configuration. To dynamically check availability, check that the atom `ecdh` is present in the list returned by *crypto:supports(public_keys)*.

The Edward curves `x25519` and `x448` are supported with OpenSSL 1.1.1 or later if not disabled by configuration.

The actual supported named curves could be checked by examining the list returned by *crypto:supports(curves)*.

1.6 New and Old API

This chapter describes the new api to encryption and decryption.

1.6.1 Background

The CRYPTO app has evolved during its lifetime. Since also the OpenSSL cryptolib has changed the API several times, there are parts of the CRYPTO app that uses a very old one internally and other parts that uses the latest one. The internal definitions of e.g cipher names was a bit hard to maintain.

It turned out that using the old api in the new way (more about that later), and still keep it backwards compatible, was not possible. Specially as more precision in the error messages is desired it could not be combined with the old standard.

Therefore the old api (see next section) is kept for now but internally implemented with new primitives.

1.6.2 The old API

The old functions - not recommended for new programs - are for chipers:

- *block_encrypt/3*
- *block_encrypt/4*
- *block_decrypt/3*
- *block_decrypt/4*
- *stream_init/2*
- *stream_init/3*
- *stream_encrypt/2*
- *stream_decrypt/2*

for lists of supported algorithms:

- *supports/0*

and for MACs (Message Authentication Codes):

- *cmac/3*
- *cmac/4*
- *hmac/3*
- *hmac/4*
- *hmac_init/2*
- *hmac_update/2*
- *hmac_final/1*
- *hmac_final_n/2*
- *poly1305/2*

They are not deprecated for now, but may be in a future release.

1.6.3 The new API

Encryption and decryption

The new functions for encrypting or decrypting one single binary are:

- *crypto_one_time/4*
- *crypto_one_time/5*
- *crypto_one_time_aead/6*
- *crypto_one_time_aead/7*

In those functions the internal crypto state is first created and initialized with the cipher type, the key and possibly other data. Then the single binary is encrypted or decrypted, the crypto state is de-allocated and the result of the crypto operation is returned.

The `crypto_one_time_aead` functions are for the ciphers of mode `ccm` or `gcm`, and for the cipher `chacha20-poly1305`.

For repeated encryption or decryption of a text divided in parts, where the internal crypto state is initialized once, and then many binaries are encrypted or decrypted with the same state, the functions are:

- *crypto_init/4*
- *crypto_init/3*
- *crypto_update/2*

The `crypto_init` initialies an internal cipher state, and one or more calls of `crypto_update` does the acual encryption or decryption. Note that AEAD ciphers can't be handled this way due to their nature.

For repeated encryption or decryption of a text divided in parts where the same cipher and same key is used, but a new initialization vector (nounce) should be applied for each part, the functions are:

- *crypto_dyn_iv_init/3*
- *crypto_dyn_iv_update/3*

An example of where those functions are needed, is when handling the TLS protocol.

For information about available algorithms, use:

- *supports/1*
- *hash_info/1*
- *cipher_info/1*

MACs (Message Authentication Codes)

The new functions for calculating a MAC of a single piece of text are:

- *mac/3*
- *mac/4*
- *macN/4*
- *macN/5*

For calculating a MAC of a text divided in parts use:

- *mac_init/2*
- *mac_init/3*
- *mac_update/2*
- *mac_final/1*
- *mac_finalN/2*

1.6.4 Examples of the new api

Examples of crypto_init/4 and crypto_update/2

The functions *crypto_init/4* and *crypto_update/2* are intended to be used for encrypting or decrypting a sequence of blocks. First one call of `crypto_init/4` initialises the crypto context. One or more calls `crypto_update/2` does the actual encryption or decryption for each block.

This example shows first the encryption of two blocks and then decryptions of the cipher text, but divided into three blocks just to show that it is possible to divide the plain text and cipher text differently for some ciphers:

```
1> crypto:start().
ok
2> Key = <<1:128>>.
<<0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1>>
3> IV = <<0:128>>.
<<0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0>>
4> StateEnc = crypto:crypto_init(aes_128_ctr, Key, IV, true). % encrypt -> true
#Ref<0.3768901617.1128660993.124047>
5> crypto:crypto_update(StateEnc, <<"First bytes">>).
<<67,44,216,166,25,130,203,5,66,6,162>>
6> crypto:crypto_update(StateEnc, <<"Second bytes">>).
<<16,79,94,115,234,197,94,253,16,144,151,41>>
7>
7> StateDec = crypto:crypto_init(aes_128_ctr, Key, IV, false). % decrypt -> false
#Ref<0.3768901617.1128660994.124255>
8> crypto:crypto_update(StateDec, <<67,44,216,166,25,130,203>>).
<<"First b">>
9> crypto:crypto_update(StateDec, <<5,66,6,162,16,79,94,115,234,197,
       94,253,16,144,151>>).
<<"ytesSecond byte">>
10> crypto:crypto_update(StateDec, <<41>>).
<<"s">>
11>
```

Note that the internal data that the `StateEnc` and `StateDec` references are destructivly updated by the calls to *crypto_update/2*. This is to gain time in the calls of the nifs interfacing the cryptolib. In a loop where the state is saved in the loop's state, it also saves one update of the loop state per crypto operation.

For example, a simple server receiving text parts to encrypt and send the result back to the one who sent them (the `Requester`):

```
encode(Crypto, Key, IV) ->
crypto_loop(crypto:crypto_init(Crypto, Key, IV, true)).

crypto_loop(State) ->
receive
       {Text, Requester} ->
       Requester ! crypto:crypto_update(State, Text),
loop(State)
end.
```

Example of crypto_one_time/5

The same example as in the *previous section*, but now with one call to *crypto_one_time/5*:

```
1> Key = <<1:128>>.
<<0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1>>
2> IV = <<0:128>>.
<<0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0>>
3> Txt = [<<"First bytes">>,<<"Second bytes">>].
[<<"First bytes">>,<<"Second bytes">>]
4> crypto:crypto_one_time(aes_128_ctr, Key, IV, Txt, true).
<<67,44,216,166,25,130,203,5,66,6,162,16,79,94,115,234,
197,94,253,16,144,151,41>>
5>
```

The `[<<"First bytes">>,<<"Second bytes">>]` could of course have been one single binary: `<<"First bytesSecond bytes">>`.

Example of crypto_one_time_aead/6

The same example as in the *previous section*, but now with one call to *crypto_one_time_aead/6*:

```
1> Key = <<1:128>>.
<<0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1>>
2> IV = <<0:128>>.
<<0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0>>
3> Txt = [<<"First bytes">>,<<"Second bytes">>].
[<<"First bytes">>,<<"Second bytes">>]
4> AAD = <<"Some bytes">>.
<<"Some bytes">>
5> crypto:crypto_one_time_aead(aes_128_gcm, Key, IV, Txt, AAD, true).
{<<240,130,38,96,130,241,189,52,3,190,179,213,132,1,72,
192,103,176,90,104,15,71,158>>,
<<131,47,45,91,142,85,9,244,21,141,214,71,31,135,2,155>>}
9>
```

The `[<<"First bytes">>,<<"Second bytes">>]` could of course have been one single binary: `<<"First bytesSecond bytes">>`.

Example of mac_init mac_update and mac_final

```
1> Key = <<1:128>>.
<<0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1>>
2> StateMac = crypto:mac_init(cmac, aes_128_cbc, Key).
#Ref<0.2424664121.2781478916.232610>
3> crypto:mac_update(StateMac, <<"First bytes">>).
#Ref<0.2424664121.2781478916.232610>
4> crypto:mac_update(StateMac, " ").
#Ref<0.2424664121.2781478916.232610>
5> crypto:mac_update(StateMac, <<"last bytes">>).
#Ref<0.2424664121.2781478916.232610>
6> crypto:mac_final(StateMac).
<<68,191,219,128,84,77,11,193,197,238,107,6,214,141,160,
249>>
7>
```

and compare the result with a single calculation just for this example:

```
7> crypto:mac(cmac, aes_128_cbc, Key, "First bytes last bytes").
<<68,191,219,128,84,77,11,193,197,238,107,6,214,141,160,
249>>
8> v(7) == v(6).
true
9>
```

1.6.5 Retired cipher names

This table lists the retired cipher names in the first column and suggests names to replace them with in the second column.

The new names follows the OpenSSL libcrypto names. The format is ALGORITM_KEYSIZE_MODE.

Examples of algorithms are aes, chacha20 and des. The keysize is the number of bits and examples of the mode are cbc, ctr and gcm. The mode may be followed by a number depending on the mode. An example is the ccm mode which has a variant called ccm8 where the so called tag has a length of eight bits.

The old names had by time lost any common naming convention which the new names now introduces. The new names include the key length which improves the error checking in the lower levels of the crypto application.

Instead of:	**Use:**
`aes_cbc128`	`aes_128_cbc`

aes_cbc256	aes_256_cbc
aes_cbc	aes_128_cbc, aes_192_cbc, aes_256_cbc
aes_ccm	aes_128_ccm, aes_192_ccm, aes_256_ccm
aes_cfb128	aes_128_cfb128, aes_192_cfb128, aes_256_cfb128
aes_cfb8	aes_128_cfb8, aes_192_cfb8, aes_256_cfb8
aes_ctr	aes_128_ctr, aes_192_ctr, aes_256_ctr
aes_gcm	aes_128_gcm, aes_192_gcm, aes_256_gcm
des3_cbc	des_ede3_cbc
des3_cbf	des_ede3_cfb
des3_cfb	des_ede3_cfb
des_ede3	des_ede3_cbc
des_ede3_cbf	des_ede3_cfb

Table 6.1:

2 Reference Manual

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

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 (eay@cryptsoft.com).

This product includes software written by Tim Hudson (tjh@cryptsoft.com).

For full OpenSSL and SSLeay license texts, see *Licenses*.

crypto

Application

The purpose of the Crypto application is to provide an Erlang API to cryptographic functions, see *crypto(3)*. Note that the API is on a fairly low level and there are some corresponding API functions available in *public_key(3)*, on a higher abstraction level, that uses the crypto application in its implementation.

DEPENDENCIES

The current crypto implementation uses nifs to interface OpenSSLs crypto library and may work with limited functionality with as old versions as **OpenSSL** 0.9.8c. FIPS mode support requires at least version 1.0.1 and a FIPS capable OpenSSL installation. We recommend using a version that is officially supported by the OpenSSL project. API compatible backends like LibreSSL should also work.

Source releases of OpenSSL can be downloaded from the **OpenSSL** project home page, or mirror sites listed there.

CONFIGURATION

The following configuration parameters are defined for the crypto application. See `app(3)` for more information about configuration parameters.

`fips_mode = boolean()`

Specifies whether to run crypto in FIPS mode. This setting will take effect when the nif module is loaded. If FIPS mode is requested but not available at run time the nif module and thus the crypto module will fail to load. This mechanism prevents the accidental use of non-validated algorithms.

`rand_cache_size = integer()`

Sets the cache size in bytes to use by `crypto:rand_seed_alg(crypto_cache)` and `crypto:rand_seed_alg_s(crypto_cache)` . This parameter is read when a seed function is called, and then kept in generators state object. It has a rather small default value that causes reads of strong random bytes about once per hundred calls for a random value. The set value is rounded up to an integral number of words of the size these seed functions use.

SEE ALSO

application(3)

crypto

Erlang module

This module provides a set of cryptographic functions.

Hash functions

- SHA1, SHA2
  Secure Hash Standard [FIPS PUB 180-4]
- SHA3
  SHA-3 Standard: Permutation-Based Hash and Extendable-Output Functions [FIPS PUB 202]
- BLAKE2
  BLAKE2 — fast secure hashing
- MD5
  The MD5 Message Digest Algorithm [RFC 1321]
- MD4
  The MD4 Message Digest Algorithm [RFC 1320]

MACs - Message Authentication Codes

- Hmac functions
  Keyed-Hashing for Message Authentication [RFC 2104]
- Cmac functions
  The AES-CMAC Algorithm [RFC 4493]
- POLY1305
  ChaCha20 and Poly1305 for IETF Protocols [RFC 7539]

Symmetric Ciphers

- DES, 3DES and AES
  Block Cipher Techniques [NIST]
- Blowfish
  Fast Software Encryption, Cambridge Security Workshop Proceedings (December 1993), Springer-Verlag, 1994, pp. 191-204.
- Chacha20
  ChaCha20 and Poly1305 for IETF Protocols [RFC 7539]
- Chacha20_poly1305
  ChaCha20 and Poly1305 for IETF Protocols [RFC 7539]

Modes

- ECB, CBC, CFB, OFB and CTR
  Recommendation for Block Cipher Modes of Operation: Methods and Techniques [NIST SP 800-38A]
- GCM
  Recommendation for Block Cipher Modes of Operation: Galois/Counter Mode (GCM) and GMAC [NIST SP 800-38D]
- CCM
  Recommendation for Block Cipher Modes of Operation: The CCM Mode for Authentication and Confidentiality [NIST SP 800-38C]

Asymetric Ciphers - Public Key Techniques

RSA
PKCS #1: RSA Cryptography Specifications [RFC 3447]
DSS
Digital Signature Standard (DSS) [FIPS 186-4]
ECDSA
Elliptic Curve Digital Signature Algorithm [ECDSA]
SRP
The SRP Authentication and Key Exchange System [RFC 2945]

Note:

The actual supported algorithms and features depends on their availability in the actual libcrypto used. See the *crypto (App)* about dependencies.

Enabling FIPS mode will also disable algorithms and features.

The *CRYPTO User's Guide* has more information on FIPS, Engines and Algorithm Details like key lengths.

Data Types

Ciphers, new API

```
cipher() = cipher_no_iv() | cipher_iv() | cipher_aead()
cipher_no_iv() =
    aes_128_ecb | aes_192_ecb | aes_256_ecb | blowfish_ecb |
    des_ecb | rc4
cipher_iv() =
    aes_128_cbc | aes_192_cbc | aes_256_cbc | aes_128_cfb128 |
    aes_192_cfb128 | aes_256_cfb128 | aes_128_cfb8 |
    aes_192_cfb8 | aes_256_cfb8 | aes_128_ctr | aes_192_ctr |
    aes_256_ctr | aes_ige256 | blowfish_cbc | blowfish_cfb64 |
    blowfish_ofb64 | chacha20 | des_ede3_cbc | des_ede3_cfb |
    des_cbc | des_cfb | rc2_cbc
cipher_aead() =
    aes_128_ccm | aes_192_ccm | aes_256_ccm | aes_128_gcm |
    aes_192_gcm | aes_256_gcm | chacha20_poly1305
```

Ciphers known by the CRYPTO application when using the *new API*.

Note that this list might be reduced if the underlying libcrypto does not support all of them.

Ciphers, old API

```
block_cipher_with_iv() =
    cbc_cipher() | cfb_cipher() | blowfish_ofb64 | aes_ige256
block_cipher_without_iv() = ecb_cipher()
stream_cipher() = ctr_cipher() | chacha20 | rc4
aead_cipher() = aes_gcm | aes_ccm | chacha20_poly1305
cbc_cipher() =
    aes_128_cbc | aes_192_cbc | aes_256_cbc | blowfish_cbc |
    des_cbc | des_ede3_cbc | rc2_cbc |
```

```
    retired_cbc_cipher_aliases()
cfb_cipher() =
    aes_128_cfb128 | aes_192_cfb128 | aes_256_cfb128 |
    aes_128_cfb8 | aes_192_cfb8 | aes_256_cfb8 | blowfish_cfb64 |
    des_cfb | des_ede3_cfb |
    retired_cfb_cipher_aliases()
ctr_cipher() =
    aes_128_ctr | aes_192_ctr | aes_256_ctr |
    retired_ctr_cipher_aliases()
ecb_cipher() =
    aes_128_ecb | aes_192_ecb | aes_256_ecb | blowfish_ecb |
    retired_ecb_cipher_aliases()
```

Ciphers known by the CRYPTO application when using the *old API*.

Note that this list might be reduced if the underlying libcrypto does not support all of them.

```
retired_cbc_cipher_aliases() =
    aes_cbc | aes_cbc128 | aes_cbc256 | des3_cbc | des_ede3
retired_cfb_cipher_aliases() =
    aes_cfb8 | aes_cfb128 | des3_cbf | des3_cfb | des_ede3_cbf
retired_ctr_cipher_aliases() = aes_ctr
retired_ecb_cipher_aliases() = aes_ecb
```

Alternative, old names of ciphers known by the CRYPTO application when using the *old API*. See *Retired cipher names* for names to use instead to be prepared for an easy convertion to the *new API*.

Note that this list might be reduced if the underlying libcrypto does not support all of them.

Digests and hash

```
hash_algorithm() =
    sha1() |
    sha2() |
    sha3() |
    blake2() |
    ripemd160 |
    compatibility_only_hash()
hmac_hash_algorithm() =
    sha1() | sha2() | sha3() | compatibility_only_hash()
cmac_cipher_algorithm() =
    aes_128_cbc | aes_192_cbc | aes_256_cbc | blowfish_cbc |
    des_cbc | des_ede3_cbc | rc2_cbc | aes_128_cfb128 |
    aes_192_cfb128 | aes_256_cfb128 | aes_128_cfb8 |
```

```
    aes_192_cfb8 | aes_256_cfb8
rsa_digest_type() = sha1() | sha2() | md5 | ripemd160
dss_digest_type() = sha1() | sha2()
ecdsa_digest_type() = sha1() | sha2()
sha1() = sha
sha2() = sha224 | sha256 | sha384 | sha512
sha3() = sha3_224 | sha3_256 | sha3_384 | sha3_512
blake2() = blake2b | blake2s
compatibility_only_hash() = md5 | md4
```

The `compatibility_only_hash()` algorithms are recommended only for compatibility with existing applications.

Elliptic Curves

```
ec_named_curve() =
    brainpoolP160r1 | brainpoolP160t1 | brainpoolP192r1 |
    brainpoolP192t1 | brainpoolP224r1 | brainpoolP224t1 |
    brainpoolP256r1 | brainpoolP256t1 | brainpoolP320r1 |
    brainpoolP320t1 | brainpoolP384r1 | brainpoolP384t1 |
    brainpoolP512r1 | brainpoolP512t1 | c2pnb163v1 | c2pnb163v2 |
    c2pnb163v3 | c2pnb176v1 | c2pnb208w1 | c2pnb272w1 |
    c2pnb304w1 | c2pnb368w1 | c2tnb191v1 | c2tnb191v2 |
    c2tnb191v3 | c2tnb239v1 | c2tnb239v2 | c2tnb239v3 |
    c2tnb359v1 | c2tnb431r1 | ipsec3 | ipsec4 | prime192v1 |
    prime192v2 | prime192v3 | prime239v1 | prime239v2 |
    prime239v3 | prime256v1 | secp112r1 | secp112r2 | secp128r1 |
    secp128r2 | secp160k1 | secp160r1 | secp160r2 | secp192k1 |
    secp192r1 | secp224k1 | secp224r1 | secp256k1 | secp256r1 |
    secp384r1 | secp521r1 | sect113r1 | sect113r2 | sect131r1 |
    sect131r2 | sect163k1 | sect163r1 | sect163r2 | sect193r1 |
    sect193r2 | sect233k1 | sect233r1 | sect239k1 | sect283k1 |
    sect283r1 | sect409k1 | sect409r1 | sect571k1 | sect571r1 |
    wtls1 | wtls10 | wtls11 | wtls12 | wtls3 | wtls4 | wtls5 |
    wtls6 | wtls7 | wtls8 | wtls9
edwards_curve_dh() = x25519 | x448
edwards_curve_ed() = ed25519 | ed448
```

Note that some curves are disabled if FIPS is enabled.

```
ec_explicit_curve() =
    {Field :: ec_field(),
     Curve :: ec_curve(),
     BasePoint :: binary(),
     Order :: binary(),
     CoFactor :: none | binary()}
ec_field() = ec_prime_field() | ec_characteristic_two_field()
ec_curve() =
    {A :: binary(), B :: binary(), Seed :: none | binary()}
```

Parametric curve definition.

```
ec_prime_field() = {prime_field, Prime :: integer()}
ec_characteristic_two_field() =
    {characteristic_two_field,
     M :: integer(),
     Basis :: ec_basis()}
ec_basis() =
    {tpbasis, K :: integer() >= 0} |
    {ppbasis,
     K1 :: integer() >= 0,
     K2 :: integer() >= 0,
     K3 :: integer() >= 0} |
    onbasis
```

Curve definition details.

Keys

```
key() = iodata()
des3_key() = [key()]
```

For keylengths, iv-sizes and blocksizes see the *User's Guide*.

A key for des3 is a list of three iolists

```
key_integer() = integer() | binary()
```

Always `binary()` when used as return value

Public/Private Keys

```
rsa_public() = [key_integer()]
rsa_private() = [key_integer()]
rsa_params() =
    {ModulusSizeInBits :: integer(),
     PublicExponent :: key_integer()}
```

```
rsa_public() = [E, N]
```

```
rsa_private() = [E, N, D] | [E, N, D, P1, P2, E1, E2, C]
```

Where E is the public exponent, N is public modulus and D is the private exponent. The longer key format contains redundant information that will make the calculation faster. P1,P2 are first and second prime factors. E1,E2 are first and second exponents. C is the CRT coefficient. Terminology is taken from **RFC 3447**.

```
dss_public() = [key_integer()]
dss_private() = [key_integer()]
```

```
dss_public() = [P, Q, G, Y]
```

Where P, Q and G are the dss parameters and Y is the public key.

```
dss_private() = [P, Q, G, X]
```

Where P, Q and G are the dss parameters and X is the private key.

```
ecdsa_public() = key_integer()
ecdsa_private() = key_integer()
ecdsa_params() = ec_named_curve() | ec_explicit_curve()
eddsa_public() = key_integer()
eddsa_private() = key_integer()
eddsa_params() = edwards_curve_ed()
srp_public() = key_integer()
srp_private() = key_integer()
```

```
srp_public() = key_integer()
```

Where is A or B from **SRP design**

```
srp_private() = key_integer()
```

Where is a or b from **SRP design**

```
srp_gen_params() =
    {user, srp_user_gen_params()} | {host, srp_host_gen_params()}
srp_comp_params() =
    {user, srp_user_comp_params()} |
    {host, srp_host_comp_params()}
```

```
srp_user_gen_params() = [DerivedKey::binary(), Prime::binary(), Generator::binary(), Version::atom()]
```

```
srp_host_gen_params() = [Verifier::binary(), Prime::binary(), Version::atom() ]
```

```
srp_user_comp_params() = [DerivedKey::binary(), Prime::binary(), Generator::binary(), Version::atom() | Scra
```

```
srp_host_comp_params() = [Verifier::binary(), Prime::binary(), Version::atom() | ScramblerArg::list()]
```

Where Verifier is v, Generator is g and Prime is N, DerivedKey is X, and Scrambler is u (optional will be generated if not provided) from **SRP design** Version = '3' | '6' | '6a'

Public Key Ciphers

```
pk_encrypt_decrypt_algs() = rsa
```

Algorithms for public key encrypt/decrypt. Only RSA is supported.

```
pk_encrypt_decrypt_opts() = [rsa_opt()] | rsa_compat_opts()
rsa_opt() =
    {rsa_padding, rsa_padding()} |
    {signature_md, atom()} |
    {rsa_mgf1_md, sha} |
    {rsa_oaep_label, binary()} |
    {rsa_oaep_md, sha}
rsa_padding() =
    rsa_pkcs1_padding | rsa_pkcs1_oaep_padding |
    rsa_sslv23_padding | rsa_x931_padding | rsa_no_padding
```

Options for public key encrypt/decrypt. Only RSA is supported.

> **Warning:**
>
> The RSA options are experimental.
>
> The exact set of options and there syntax **may** be changed without prior notice.

```
rsa_compat_opts() = [{rsa_pad, rsa_padding()}] | rsa_padding()
```

Those option forms are kept only for compatibility and should not be used in new code.

Public Key Sign and Verify

```
pk_sign_verify_algs() = rsa | dss | ecdsa | eddsa
```

Algorithms for sign and verify.

```
pk_sign_verify_opts() = [rsa_sign_verify_opt()]
rsa_sign_verify_opt() =
    {rsa_padding, rsa_sign_verify_padding()} |
    {rsa_pss_saltlen, integer()} |
    {rsa_mgf1_md, sha2()}
rsa_sign_verify_padding() =
    rsa_pkcs1_padding | rsa_pkcs1_pss_padding | rsa_x931_padding |
    rsa_no_padding
```

Options for sign and verify.

> **Warning:**
>
> The RSA options are experimental.
>
> The exact set of options and there syntax **may** be changed without prior notice.

Diffie-Hellman Keys and parameters

```
dh_public() = key_integer()
dh_private() = key_integer()
dh_params() = [key_integer()]
```

```
dh_params() = [P, G] | [P, G, PrivateKeyBitLength]
```

```
ecdh_public() = key_integer()
ecdh_private() = key_integer()
ecdh_params() =
    ec_named_curve() | edwards_curve_dh() | ec_explicit_curve()
```

Types for Engines

```
engine_key_ref() =
    #{engine := engine_ref(),
      key_id := key_id(),
      password => password(),
      term() => term()}
engine_ref() = term()
```

The result of a call to *engine_load/3*.

```
key_id() = string() | binary()
```

Identifies the key to be used. The format depends on the loaded engine. It is passed to the `ENGINE_load_(private|public)_key` functions in libcrypto.

```
password() = string() | binary()
```

The password of the key stored in an engine.

```
engine_method_type() =
    engine_method_rsa | engine_method_dsa | engine_method_dh |
    engine_method_rand | engine_method_ecdh |
    engine_method_ecdsa | engine_method_ciphers |
    engine_method_digests | engine_method_store |
    engine_method_pkey_meths | engine_method_pkey_asn1_meths |
    engine_method_ec
engine_cmnd() = {unicode:chardata(), unicode:chardata()}
```

Pre and Post commands for *engine_load/3 and /4*.

Internal data types

```
crypto_state()
hash_state()
hmac_state()
mac_state()
stream_state()
```

Contexts with an internal state that should not be manipulated but passed between function calls.

Error types

```
run_time_error() = no_return()
```

The exception `error:badarg` signifies that one or more arguments are of wrong data type, or are otherwise badly formed.

The exception `error:notsup` signifies that the algorithm is known but is not supported by current underlying libcrypto or explicitly disabled when building that.

For a list of supported algorithms, see *supports/0*.

```
descriptive_error() = no_return()
```

This is a more developed variant of the older *run_time_error()*.

The exception is:

```
{Tag, {C_FileName,LineNumber}, Description}

 Tag = badarg | notsup | error
 C_FileName = string()
 LineNumber = integer()
 Description = string()
```

It is like the older type an exception of the `error` class. In addition they contain a descriptive text in English. That text is targeted to a developer. Examples are "Bad key size" or "Cipher id is not an atom".

The exception tags are:

`badarg`

Signifies that one or more arguments are of wrong data type or are otherwise badly formed.

`notsup`

Signifies that the algorithm is known but is not supported by current underlying libcrypto or explicitly disabled when building that one.

`error`

An error condition that should not occur, for example a memory allocation failed or the underlying cryptolib returned an error code, for example "Can't initialize context, step 1". Thoose text usually needs searching the C-code to be understood.

To catch the exception, use for example:

```
try crypto:crypto_init(Ciph, Key, IV, true)
catch
    error:{Tag, {C_FileName,LineNumber}, Description} ->
            do_something(......)
    .....
end
```

New API

Exports

```
crypto_init(Cipher, Key, EncryptFlag) ->
               State | descriptive_error()
```

Types:

```
Cipher = cipher_no_iv()
Key = iodata()
EncryptFlag = boolean()
State = crypto_state()
```

As *crypto_init/4* but for ciphers without IVs.

```
crypto_init(Cipher, Key, IV, EncryptFlag) ->
               State | descriptive_error()
```

Types:

```
Cipher = cipher_iv()
Key = IV = iodata()
EncryptFlag = boolean()
State = crypto_state()
```

Part of the *new API*. Initializes a series of encryptions or decryptions and creates an internal state with a reference that is returned. The actual encryption or decryption is done by *crypto_update/2*.

For encryption, set the `EncryptFlag` to `true`. For decryption, set it to `false`.

See *examples in the User's Guide.*

```
crypto_update(State, Data) -> Result | descriptive_error()
```

Types:

```
State = crypto_state()
Data = iodata()
Result = binary()
```

Part of the *new API*. It does an actual crypto operation on a part of the full text. If the part is less than a number of full blocks, only the full blocks (possibly none) are encrypted or decrypted and the remaining bytes are saved to the next `crypto_update` operation. The `State` should be created with *crypto_init/3* or *crypto_init/4*.

See *examples in the User's Guide*.

```
crypto_dyn_iv_init(Cipher, Key, EncryptFlag) ->
                      State | descriptive_error()
```

Types:

```
Cipher = cipher_iv()
Key = iodata()
EncryptFlag = boolean()
State = crypto_state()
```

Part of the *new API*. Initializes a series of encryptions or decryptions where the IV is provided later. The actual encryption or decryption is done by *crypto_dyn_iv_update/3*.

For encryption, set the `EncryptFlag` to `true`. For decryption, set it to `false`.

```
crypto_dyn_iv_update(State, Data, IV) ->
                        Result | descriptive_error()
```

Types:

```
State = crypto_state()
Data = IV = iodata()
Result = binary()
```

Part of the *new API*. Do an actual crypto operation on a part of the full text and the IV is supplied for each part. The `State` should be created with *crypto_dyn_iv_init/3*.

```
crypto_one_time(Cipher, Key, Data, EncryptFlag) ->
                    Result | descriptive_error()
```

Types:

```
Cipher = cipher_no_iv()
Key = Data = iodata()
EncryptFlag = boolean()
Result = binary()
```

As *crypto_one_time/5* but for ciphers without IVs.

```
crypto_one_time(Cipher, Key, IV, Data, EncryptFlag) ->
                    Result | descriptive_error()
```

Types:

```
Cipher = cipher_iv()
Key = IV = Data = iodata()
EncryptFlag = boolean()
Result = binary()
```

Part of the *new API*. Do a complete encrypt or decrypt of the full text in the argument `Data`.

For encryption, set the `EncryptFlag` to `true`. For decryption, set it to `false`.

See *examples in the User's Guide.*

```
crypto_one_time_aead(Cipher, Key, IV, InText, AAD,
                     EncFlag :: true) ->
                        Result | descriptive_error()
crypto_one_time_aead(Cipher, Key, IV, InText, AAD, TagOrTagLength,
                     EncFlag) ->
                        Result | descriptive_error()
```

Types:

```
Cipher = cipher_aead()
Key = IV = InText = AAD = iodata()
TagOrTagLength = EncryptTagLength | DecryptTag
EncryptTagLength = integer() >= 0
DecryptTag = iodata()
EncFlag = boolean()
Result = EncryptResult | DecryptResult
EncryptResult = {OutCryptoText, OutTag}
DecryptResult = OutPlainText | error
OutCryptoText = OutTag = OutPlainText = binary()
```

Part of the *new API*. Do a complete encrypt or decrypt with an AEAD cipher of the full text.

For encryption, set the `EncryptFlag` to `true` and set the `TagOrTagLength` to the wanted size (in bytes) of the tag, that is, the tag length. If the default length is wanted, the `crypto_aead/6` form may be used.

For decryption, set the `EncryptFlag` to `false` and put the tag to be checked in the argument `TagOrTagLength`.

See *examples in the User's Guide.*

```
supports(Type) -> Support
```

Types:

```
Type = hashs | ciphers | public_keys | macs | curves | rsa_opts
Support = Hashs | Ciphers | PKs | Macs | Curves | RSAopts
Hashs =
    [sha1() |
     sha2() |
     sha3() |
     blake2() |
     ripemd160 |
     compatibility_only_hash()]
Ciphers = [cipher()]
PKs = [rsa | dss | ecdsa | dh | ecdh | ec_gf2m]
Macs = [hmac | cmac | poly1305]
Curves =
    [ec_named_curve() | edwards_curve_dh() | edwards_curve_ed()]
RSAopts = [rsa_sign_verify_opt() | rsa_opt()]
```

Can be used to determine which crypto algorithms that are supported by the underlying libcrypto library

See *hash_info/1* and *cipher_info/1* for information about the hash and cipher algorithms.

```
mac(Type :: poly1305, Key, Data) -> Mac | descriptive_error()
```

Types:

```
Key = Data = iodata()
Mac = binary()
```

Short for *mac(Type, undefined, Key, Data)*.

```
mac(Type, SubType, Key, Data) -> Mac | descriptive_error()
```

Types:

```
Type = hmac | cmac | poly1305
SubType =
    hmac_hash_algorithm() | cmac_cipher_algorithm() | undefined
Key = Data = iodata()
Mac = binary()
```

Computes a MAC (Message Authentication Code) of type `Type` from `Data`.

`SubType` depends on the MAC `Type`:

- For `hmac` it is a hash algorithm, see *Algorithm Details* in the User's Guide.
- For `cmac` it is a cipher suitable for cmac, see *Algorithm Details* in the User's Guide.
- For `poly1305` it should be set to `undefined` or the *mac/2* function could be used instead, see *Algorithm Details* in the User's Guide.

`Key` is the authentication key with a length according to the `Type` and `SubType`. The key length could be found with the *hash_info/1* (`hmac`) for and *cipher_info/1* (`cmac`) functions. For `poly1305` the key length is 32 bytes. Note that the cryptographic quality of the key is not checked.

The `Mac` result will have a default length depending on the `Type` and `SubType`. To set a shorter length, use *macN/4* or *macN/5* instead. The default length is documented in *Algorithm Details* in the User's Guide.

```
macN(Type :: poly1305, Key, Data, MacLength) ->
```

```
        Mac | descriptive_error()
```

Types:

```
   Key = Data = iodata()
   Mac = binary()
   MacLength = integer() >= 1
```

Short for *macN(Type, undefined, Key, Data, MacLength)*.

```
macN(Type, SubType, Key, Data, MacLength) ->
        Mac | descriptive_error()
```

Types:

```
   Type = hmac | cmac | poly1305
   SubType =
       hmac_hash_algorithm() | cmac_cipher_algorithm() | undefined
   Key = Data = iodata()
   Mac = binary()
   MacLength = integer() >= 1
```

Computes a MAC (Message Authentication Code) as *mac/3* and *mac/4* but `MacLength` will limit the size of the resultant `Mac` to at most `MacLength` bytes. Note that if `MacLength` is greater than the actual number of bytes returned from the underlying hash, the returned hash will have that shorter length instead.

The max `MacLength` is documented in *Algorithm Details* in the User's Guide.

```
mac_init(Type :: poly1305, Key) -> State | descriptive_error()
```

Types:

```
   Key = iodata()
   State = mac_state()
```

Short for *mac_init(Type, undefined, Key)*.

```
mac_init(Type, SubType, Key) -> State | descriptive_error()
```

Types:

```
   Type = hmac | cmac | poly1305
   SubType =
       hmac_hash_algorithm() | cmac_cipher_algorithm() | undefined
   Key = iodata()
   State = mac_state()
```

Initializes the context for streaming MAC operations.

`Type` determines which mac algorithm to use in the MAC operation.

`SubType` depends on the MAC `Type`:

- For `hmac` it is a hash algorithm, see *Algorithm Details* in the User's Guide.
- For `cmac` it is a cipher suitable for cmac, see *Algorithm Details* in the User's Guide.
- For `poly1305` it should be set to `undefined` or the *mac/2* function could be used instead, see *Algorithm Details* in the User's Guide.

Key is the authentication key with a length according to the Type and SubType. The key length could be found with the *hash_info/1* (hmac) for and *cipher_info/1* (cmac) functions. For poly1305 the key length is 32 bytes. Note that the cryptographic quality of the key is not checked.

The returned State should be used in one or more subsequent calls to *mac_update/2*. The MAC value is finally returned by calling *mac_final/1* or *mac_finalN/2*.

See *examples in the User's Guide.*

```
mac_update(State0, Data) -> State | descriptive_error()
```

Types:

```
Data = iodata()
State0 = State = mac_state()
```

Updates the MAC represented by State0 using the given Data which could be of any length.

The State0 is the State value originally from a MAC init function, that is *mac_init/2*, *mac_init/3* or a previous call of mac_update/2. The value State0 is returned unchanged by the function as State.

```
mac_final(State) -> Mac | descriptive_error()
```

Types:

```
State = mac_state()
Mac = binary()
```

Finalizes the MAC operation referenced by State. The Mac result will have a default length depending on the Type and SubType in the *mac_init/2,3* call. To set a shorter length, use *mac_finalN/2* instead. The default length is documented in *Algorithm Details* in the User's Guide.

```
mac_finalN(State, MacLength) -> Mac | descriptive_error()
```

Types:

```
State = mac_state()
MacLength = integer() >= 1
Mac = binary()
```

Finalizes the MAC operation referenced by State.

Mac will be a binary with at most MacLength bytes. Note that if MacLength is greater than the actual number of bytes returned from the underlying hash, the returned hash will have that shorter length instead.

The max MacLength is documented in *Algorithm Details* in the User's Guide.

API kept from previous versions

Exports

```
bytes_to_integer(Bin :: binary()) -> integer()
```

Convert binary representation, of an integer, to an Erlang integer.

```
compute_key(Type, OthersPublicKey, MyPrivateKey, Params) ->
               SharedSecret
```

Types:

```
Type = dh | ecdh | srp
SharedSecret = binary()
OthersPublicKey = dh_public() | ecdh_public() | srp_public()
MyPrivateKey =
    dh_private() | ecdh_private() | {srp_public(), srp_private()}
Params = dh_params() | ecdh_params() | srp_comp_params()
```

Computes the shared secret from the private key and the other party's public key. See also *public_key:compute_key/2*

```
exor(Bin1 :: iodata(), Bin2 :: iodata()) -> binary()
```

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

```
generate_key(Type, Params) -> {PublicKey, PrivKeyOut}
generate_key(Type, Params, PrivKeyIn) -> {PublicKey, PrivKeyOut}
```

Types:

```
Type = dh | ecdh | rsa | srp
PublicKey =
    dh_public() | ecdh_public() | rsa_public() | srp_public()
PrivKeyIn =
    undefined |
    dh_private() |
    ecdh_private() |
    rsa_private() |
    {srp_public(), srp_private()}
PrivKeyOut =
    dh_private() |
    ecdh_private() |
    rsa_private() |
    {srp_public(), srp_private()}
Params =
    dh_params() | ecdh_params() | rsa_params() | srp_comp_params()
```

Generates a public key of type `Type`. See also *public_key:generate_key/1*. May raise exception:

- `error:badarg`: an argument is of wrong type or has an illegal value,
- `error:low_entropy`: the random generator failed due to lack of secure "randomness",
- `error:computation_failed`: the computation fails of another reason than `low_entropy`.

Note:

RSA key generation is only available if the runtime was built with dirty scheduler support. Otherwise, attempting to generate an RSA key will raise exception `error:notsup`.

```
hash(Type, Data) -> Digest
```

Types:

```
Type = hash_algorithm()
Data = iodata()
Digest = binary()
```

Computes a message digest of type `Type` from `Data`.

May raise exception `error:notsup` in case the chosen `Type` is not supported by the underlying libcrypto implementation.

`hash_init(Type) -> State`

Types:

```
Type = hash_algorithm()
State = hash_state()
```

Initializes the context for streaming hash operations. `Type` determines which digest to use. The returned context should be used as argument to *hash_update*.

May raise exception `error:notsup` in case the chosen `Type` is not supported by the underlying libcrypto implementation.

`hash_update(State, Data) -> NewState`

Types:

```
State = NewState = hash_state()
Data = iodata()
```

Updates the digest represented by `Context` using the given `Data`. `Context` must have been generated using *hash_init* or a previous call to this function. `Data` can be any length. `NewContext` must be passed into the next call to `hash_update` or *hash_final*.

`hash_final(State) -> Digest`

Types:

```
State = hash_state()
Digest = binary()
```

Finalizes the hash operation referenced by `Context` returned from a previous call to *hash_update*. The size of `Digest` is determined by the type of hash function used to generate it.

`info_fips() -> not_supported | not_enabled | enabled`

Provides information about the FIPS operating status of crypto and the underlying libcrypto library. If crypto was built with FIPS support this can be either `enabled` (when running in FIPS mode) or `not_enabled`. For other builds this value is always `not_supported`.

See *enable_fips_mode/1* about how to enable FIPS mode.

Warning:

In FIPS mode all non-FIPS compliant algorithms are disabled and raise exception `error:notsup`. Check *supports* that in FIPS mode returns the restricted list of available algorithms.

`enable_fips_mode(Enable) -> Result`

Types:

```
Enable = Result = boolean()
```

Enables (`Enable = true`) or disables (`Enable = false`) FIPS mode. Returns `true` if the operation was successful or `false` otherwise.

Note that to enable FIPS mode succesfully, OTP must be built with the configure option `--enable-fips`, and the underlying libcrypto must also support FIPS.

See also *info_fips/0*.

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

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">>,269484095,<<"OpenSSL 1.1.0c  10 Nov 2016"">>}]
```

Note:

From OTP R16 the **numeric version** represents the version of the OpenSSL **header files** (`openssl/opensslv.h`) used when crypto was compiled. The text variant represents the libcrypto library used at runtime. In earlier OTP versions both numeric and text was taken from the library.

```
hash_info(Type) -> Result | run_time_error()
```

Types:

```
Type = hash_algorithm()
Result =
    #{size := integer(),
      block_size := integer(),
      type := integer()}
```

Provides a map with information about block_size, size and possibly other properties of the hash algorithm in question.

For a list of supported hash algorithms, see *supports/0*.

```
cipher_info(Type) -> Result | run_time_error()
```

Types:

```
Type = cipher()
Result =
    #{key_length := integer(),
      iv_length := integer(),
      block_size := integer(),
      mode := CipherModes,
      type := undefined | integer()}
CipherModes =
    undefined | cbc_mode | ccm_mode | cfb_mode | ctr_mode |
    ecb_mode | gcm_mode | ige_mode | ocb_mode | ofb_mode |
    wrap_mode | xts_mode
```

Provides a map with information about block_size, key_length, iv_length and possibly other properties of the cipher algorithm in question.

Note:

The ciphers `aes_cbc`, `aes_cfb8`, `aes_cfb128`, `aes_ctr`, `aes_ecb`, `aes_gcm` and `aes_ccm` has no keylength in the `Type` as opposed to for example `aes_128_ctr`. They adapt to the length of the key provided in the encrypt and decrypt function. Therefor it is impossible to return a valid keylength in the map.

Always use a `Type` with an explicit key length,

For a list of supported cipher algorithms, see *supports/0*.

```
mod_pow(N, P, M) -> Result
```

Types:

```
N = P = M = binary() | integer()
Result = binary() | error
```

Computes the function `N^P mod M`.

```
next_iv(Type :: cbc_cipher(), Data) -> NextIVec
next_iv(Type :: des_cfb, Data, IVec) -> NextIVec
```

Types:

```
Data = iodata()
IVec = NextIVec = binary()
```

Returns the initialization vector to be used in the next iteration of encrypt/decrypt of type `Type`. `Data` is the encrypted data from the previous iteration step. The `IVec` argument is only needed for `des_cfb` as the vector used in the previous iteration step.

```
private_decrypt(Algorithm, CipherText, PrivateKey, Options) ->
                  PlainText
```

Types:

```
   Algorithm = pk_encrypt_decrypt_algs()
   CipherText = binary()
   PrivateKey = rsa_private() | engine_key_ref()
   Options = pk_encrypt_decrypt_opts()
   PlainText = binary()
```

Decrypts the `CipherText`, encrypted with *public_encrypt/4* (or equivalent function) using the `PrivateKey`, and returns the plaintext (message digest). This is a low level signature verification operation used for instance by older versions of the SSL protocol. See also *public_key:decrypt_private/[2,3]*

```
private_encrypt(Algorithm, PlainText, PrivateKey, Options) ->
                   CipherText
```

Types:

```
   Algorithm = pk_encrypt_decrypt_algs()
   PlainText = binary()
   PrivateKey = rsa_private() | engine_key_ref()
   Options = pk_encrypt_decrypt_opts()
   CipherText = binary()
```

Encrypts the `PlainText` using the `PrivateKey` and returns the ciphertext. This is a low level signature operation used for instance by older versions of the SSL protocol. See also *public_key:encrypt_private/[2,3]*

```
public_decrypt(Algorithm, CipherText, PublicKey, Options) ->
                  PlainText
```

Types:

```
   Algorithm = pk_encrypt_decrypt_algs()
   CipherText = binary()
   PublicKey = rsa_public() | engine_key_ref()
   Options = pk_encrypt_decrypt_opts()
   PlainText = binary()
```

Decrypts the `CipherText`, encrypted with *private_encrypt/4*(or equivalent function) using the `PrivateKey`, and returns the plaintext (message digest). This is a low level signature verification operation used for instance by older versions of the SSL protocol. See also *public_key:decrypt_public/[2,3]*

```
public_encrypt(Algorithm, PlainText, PublicKey, Options) ->
                  CipherText
```

Types:

```
   Algorithm = pk_encrypt_decrypt_algs()
   PlainText = binary()
   PublicKey = rsa_public() | engine_key_ref()
   Options = pk_encrypt_decrypt_opts()
   CipherText = binary()
```

Encrypts the `PlainText` (message digest) using the `PublicKey` and returns the `CipherText`. This is a low level signature operation used for instance by older versions of the SSL protocol. See also *public_key:encrypt_public/[2,3]*

`rand_seed(Seed :: binary()) -> ok`

Set the seed for PRNG to the given binary. This calls the RAND_seed function from openssl. Only use this if the system you are running on does not have enough "randomness" built in. Normally this is when *strong_rand_bytes/1* raises `error:low_entropy`

`rand_uniform(Lo, Hi) -> N`

Types:

`Lo, Hi, N = integer()`

Generate a random number `N, Lo =< N < Hi.` Uses the `crypto` library pseudo-random number generator. `Hi` must be larger than `Lo`.

`start() -> ok | {error, Reason :: term()}`

Equivalent to application:start(crypto).

`stop() -> ok | {error, Reason :: term()}`

Equivalent to application:stop(crypto).

`strong_rand_bytes(N :: integer() >= 0) -> binary()`

Generates N bytes randomly uniform 0..255, and returns the result in a binary. Uses a cryptographically secure prng seeded and periodically mixed with operating system provided entropy. By default this is the `RAND_bytes` method from OpenSSL.

May raise exception `error:low_entropy` in case the random generator failed due to lack of secure "randomness".

`rand_seed() -> ***rand:state()***`

Creates state object for *random number generation*, in order to generate cryptographically strong random numbers (based on OpenSSL's `BN_rand_range`), and saves it in the process dictionary before returning it as well. See also *rand:seed/1* and *rand_seed_s/0*.

When using the state object from this function the *rand* functions using it may raise exception `error:low_entropy` in case the random generator failed due to lack of secure "randomness".

Example

```
_ = crypto:rand_seed(),
_IntegerValue = rand:uniform(42), % [1; 42]
_FloatValue = rand:uniform().     % [0.0; 1.0[
```

`rand_seed_s() -> ***rand:state()***`

Creates state object for *random number generation*, in order to generate cryptographically strongly random numbers (based on OpenSSL's `BN_rand_range`). See also *rand:seed_s/1*.

When using the state object from this function the *rand* functions using it may raise exception `error:low_entropy` in case the random generator failed due to lack of secure "randomness".

> **Note:**
>
> The state returned from this function cannot be used to get a reproducable random sequence as from the other *rand* functions, since reproducability does not match cryptographically safe.
>
> The only supported usage is to generate one distinct random sequence from this start state.

`rand_seed_alg(Alg) -> rand:state()`

Types:

`Alg = crypto | crypto_cache`

Creates state object for *random number generation*, in order to generate cryptographically strong random numbers, and saves it in the process dictionary before returning it as well. See also *rand:seed/1* and *rand_seed_alg_s/1*.

When using the state object from this function the *rand* functions using it may raise exception `error:low_entropy` in case the random generator failed due to lack of secure "randomness".

Example

```
_ = crypto:rand_seed_alg(crypto_cache),
_IntegerValue = rand:uniform(42), % [1; 42]
_FloatValue = rand:uniform().     % [0.0; 1.0[
```

`rand_seed_alg(Alg, Seed) -> rand:state()`

Types:

`Alg = crypto_aes`

Creates a state object for *random number generation*, in order to generate cryptographically unpredictable random numbers, and saves it in the process dictionary before returning it as well. See also *rand_seed_alg_s/2*.

Example

```
_ = crypto:rand_seed_alg(crypto_aes, "my seed"),
IntegerValue = rand:uniform(42), % [1; 42]
FloatValue = rand:uniform(),     % [0.0; 1.0[
_ = crypto:rand_seed_alg(crypto_aes, "my seed"),
IntegerValue = rand:uniform(42), % Same values
FloatValue = rand:uniform().     % again
```

`rand_seed_alg_s(Alg) -> rand:state()`

Types:

`Alg = crypto | crypto_cache`

Creates state object for *random number generation*, in order to generate cryptographically strongly random numbers. See also *rand:seed_s/1*.

If `Alg` is `crypto` this function behaves exactly like *rand_seed_s/0*.

If `Alg` is `crypto_cache` this function fetches random data with OpenSSL's `RAND_bytes` and caches it for speed using an internal word size of 56 bits that makes calculations fast on 64 bit machines.

When using the state object from this function the *rand* functions using it may raise exception `error:low_entropy` in case the random generator failed due to lack of secure "randomness".

The cache size can be changed from its default value using the *crypto app's* configuration parameter `rand_cache_size`.

When using the state object from this function the *rand* functions using it may throw exception `low_entropy` in case the random generator failed due to lack of secure "randomness".

Note:

The state returned from this function cannot be used to get a reproducable random sequence as from the other *rand* functions, since reproducability does not match cryptographically safe.

In fact since random data is cached some numbers may get reproduced if you try, but this is unpredictable.

The only supported usage is to generate one distinct random sequence from this start state.

```
rand_seed_alg_s(Alg, Seed) -> rand:state()
```

Types:

```
Alg = crypto_aes
```

Creates a state object for *random number generation*, in order to generate cryptographically unpredictable random numbers. See also *rand_seed_alg/1*.

To get a long period the Xoroshiro928 generator from the *rand* module is used as a counter (with period 2^928 - 1) and the generator states are scrambled through AES to create 58-bit pseudo random values.

The result should be statistically completely unpredictable random values, since the scrambling is cryptographically strong and the period is ridiculously long. But the generated numbers are not to be regarded as cryptographically strong since there is no re-keying schedule.

- If you need cryptographically strong random numbers use *rand_seed_alg_s/1* with `Alg =:= crypto` or `Alg =:= crypto_cache`.
- If you need to be able to repeat the sequence use this function.
- If you do not need the statistical quality of this function, there are faster algorithms in the *rand* module.

Thanks to the used generator the state object supports the `rand:jump/0,1` function with distance 2^512.

Numbers are generated in batches and cached for speed reasons. The cache size can be changed from its default value using the *crypto app's* configuration parameter `rand_cache_size`.

```
ec_curves() -> [EllipticCurve]
```

Types:

```
EllipticCurve =
    ec_named_curve() | edwards_curve_dh() | edwards_curve_ed()
```

Can be used to determine which named elliptic curves are supported.

```
ec_curve(CurveName) -> ExplicitCurve
```

Types:

```
CurveName = ec_named_curve()
ExplicitCurve = ec_explicit_curve()
```

Return the defining parameters of a elliptic curve.

```
sign(Algorithm, DigestType, Msg, Key) -> Signature
sign(Algorithm, DigestType, Msg, Key, Options) -> Signature
```

Types:

```
Algorithm = pk_sign_verify_algs()
DigestType =
    rsa_digest_type() |
    dss_digest_type() |
    ecdsa_digest_type() |
    none
Msg = iodata() | {digest, iodata()}
Key =
    rsa_private() |
    dss_private() |
    [ecdsa_private() | ecdsa_params()] |
    [eddsa_private() | eddsa_params()] |
    engine_key_ref()
Options = pk_sign_verify_opts()
Signature = binary()
```

Creates a digital signature.

The msg is either the binary "cleartext" data to be signed or it is the hashed value of "cleartext" i.e. the digest (plaintext).

Algorithm `dss` can only be used together with digest type `sha`.

See also *public_key:sign/3*.

```
verify(Algorithm, DigestType, Msg, Signature, Key) -> Result
verify(Algorithm, DigestType, Msg, Signature, Key, Options) ->
          Result
```

Types:

```
Algorithm = pk_sign_verify_algs()
DigestType =
    rsa_digest_type() | dss_digest_type() | ecdsa_digest_type()
Msg = iodata() | {digest, iodata()}
Signature = binary()
Key =
    rsa_public() |
    dss_public() |
    [ecdsa_public() | ecdsa_params()] |
    [eddsa_public() | eddsa_params()] |
    engine_key_ref()
Options = pk_sign_verify_opts()
Result = boolean()
```

Verifies a digital signature

The msg is either the binary "cleartext" data to be signed or it is the hashed value of "cleartext" i.e. the digest (plaintext).

Algorithm `dss` can only be used together with digest type `sha`.

See also *public_key:verify/4*.

Engine API

Exports

```
privkey_to_pubkey(Type, EnginePrivateKeyRef) -> PublicKey
```

Types:

```
Type = rsa | dss
EnginePrivateKeyRef = engine_key_ref()
PublicKey = rsa_public() | dss_public()
```

Fetches the corresponding public key from a private key stored in an Engine. The key must be of the type indicated by the Type parameter.

```
engine_get_all_methods() -> Result
```

Types:

```
Result = [engine_method_type()]
```

Returns a list of all possible engine methods.

May raise exception `error:notsup` in case there is no engine support in the underlying OpenSSL implementation.

See also the chapter *Engine Load* in the User's Guide.

```
engine_load(EngineId, PreCmds, PostCmds) -> Result
```

Types:

```
EngineId = unicode:chardata()
PreCmds = PostCmds = [engine_cmnd()]
Result =
    {ok, Engine :: engine_ref()} | {error, Reason :: term()}
```

Loads the OpenSSL engine given by `EngineId` if it is available and then returns ok and an engine handle. This function is the same as calling `engine_load/4` with `EngineMethods` set to a list of all the possible methods. An error tuple is returned if the engine can't be loaded.

The function raises a `error:badarg` if the parameters are in wrong format. It may also raise the exception `error:notsup` in case there is no engine support in the underlying OpenSSL implementation.

See also the chapter *Engine Load* in the User's Guide.

```
engine_load(EngineId, PreCmds, PostCmds, EngineMethods) -> Result
```

Types:

```
EngineId = unicode:chardata()
PreCmds = PostCmds = [engine_cmnd()]
EngineMethods = [engine_method_type()]
Result =
    {ok, Engine :: engine_ref()} | {error, Reason :: term()}
```

Loads the OpenSSL engine given by `EngineId` if it is available and then returns ok and an engine handle. An error tuple is returned if the engine can't be loaded.

The function raises a `error:badarg` if the parameters are in wrong format. It may also raise the exception `error:notsup` in case there is no engine support in the underlying OpenSSL implementation.

See also the chapter *Engine Load* in the User's Guide.

```
engine_unload(Engine) -> Result
```

Types:

```
Engine = engine_ref()
Result = ok | {error, Reason :: term()}
```

Unloads the OpenSSL engine given by `Engine`. An error tuple is returned if the engine can't be unloaded.

The function raises a `error:badarg` if the parameter is in wrong format. It may also raise the exception `error:notsup` in case there is no engine support in the underlying OpenSSL implementation.

See also the chapter *Engine Load* in the User's Guide.

```
engine_by_id(EngineId) -> Result
```

Types:

```
EngineId = unicode:chardata()
Result =
    {ok, Engine :: engine_ref()} | {error, Reason :: term()}
```

Get a reference to an already loaded engine with `EngineId`. An error tuple is returned if the engine can't be unloaded.

The function raises a `error:badarg` if the parameter is in wrong format. It may also raise the exception `error:notsup` in case there is no engine support in the underlying OpenSSL implementation.

See also the chapter *Engine Load* in the User's Guide.

```
engine_ctrl_cmd_string(Engine, CmdName, CmdArg) -> Result
```

Types:

```
Engine = term()
CmdName = CmdArg = unicode:chardata()
Result = ok | {error, Reason :: term()}
```

Sends ctrl commands to the OpenSSL engine given by `Engine`. This function is the same as calling `engine_ctrl_cmd_string/4` with `Optional` set to `false`.

The function raises a `error:badarg` if the parameters are in wrong format. It may also raise the exception `error:notsup` in case there is no engine support in the underlying OpenSSL implementation.

```
engine_ctrl_cmd_string(Engine, CmdName, CmdArg, Optional) ->
                          Result
```

Types:

```
Engine = term()
CmdName = CmdArg = unicode:chardata()
Optional = boolean()
Result = ok | {error, Reason :: term()}
```

Sends ctrl commands to the OpenSSL engine given by `Engine`. `Optional` is a boolean argument that can relax the semantics of the function. If set to `true` it will only return failure if the ENGINE supported the given command name but failed while executing it, if the ENGINE doesn't support the command name it will simply return success without doing anything. In this case we assume the user is only supplying commands specific to the given ENGINE so we set this to `false`.

The function raises a `error:badarg` if the parameters are in wrong format. It may also raise the exception `error:notsup` in case there is no engine support in the underlying OpenSSL implementation.

`engine_add(Engine) -> Result`

Types:

```
Engine = engine_ref()
Result = ok | {error, Reason :: term()}
```

Add the engine to OpenSSL's internal list.

The function raises a `error:badarg` if the parameters are in wrong format. It may also raise the exception `error:notsup` in case there is no engine support in the underlying OpenSSL implementation.

`engine_remove(Engine) -> Result`

Types:

```
Engine = engine_ref()
Result = ok | {error, Reason :: term()}
```

Remove the engine from OpenSSL's internal list.

The function raises a `error:badarg` if the parameters are in wrong format. It may also raise the exception `error:notsup` in case there is no engine support in the underlying OpenSSL implementation.

`engine_get_id(Engine) -> EngineId`

Types:

```
Engine = engine_ref()
EngineId = unicode:chardata()
```

Return the ID for the engine, or an empty binary if there is no id set.

The function raises a `error:badarg` if the parameters are in wrong format. It may also raise the exception `error:notsup` in case there is no engine support in the underlying OpenSSL implementation.

`engine_get_name(Engine) -> EngineName`

Types:

```
Engine = engine_ref()
EngineName = unicode:chardata()
```

Return the name (eg a description) for the engine, or an empty binary if there is no name set.

The function raises a `error:badarg` if the parameters are in wrong format. It may also raise the exception `error:notsup` in case there is no engine support in the underlying OpenSSL implementation.

`engine_list() -> Result`

Types:

```
Result = [EngineId :: unicode:chardata()]
```

List the id's of all engines in OpenSSL's internal list.

It may also raise the exception `error:notsup` in case there is no engine support in the underlying OpenSSL implementation.

See also the chapter *Engine Load* in the User's Guide.

May raise exception `error:notsup` in case engine functionality is not supported by the underlying OpenSSL implementation.

`ensure_engine_loaded(EngineId, LibPath) -> Result`

Types:

```
EngineId = LibPath = unicode:chardata()
Result =
    {ok, Engine :: engine_ref()} | {error, Reason :: term()}
```

Loads the OpenSSL engine given by `EngineId` and the path to the dynamic library implementing the engine. This function is the same as calling `ensure_engine_loaded/3` with `EngineMethods` set to a list of all the possible methods. An error tuple is returned if the engine can't be loaded.

The function raises a `error:badarg` if the parameters are in wrong format. It may also raise the exception `error:notsup` in case there is no engine support in the underlying OpenSSL implementation.

See also the chapter *Engine Load* in the User's Guide.

`ensure_engine_loaded(EngineId, LibPath, EngineMethods) -> Result`

Types:

```
EngineId = LibPath = unicode:chardata()
EngineMethods = [engine_method_type()]
Result =
    {ok, Engine :: engine_ref()} | {error, Reason :: term()}
```

Loads the OpenSSL engine given by `EngineId` and the path to the dynamic library implementing the engine. This function differs from the normal engine_load in that sense it also add the engine id to the internal list in OpenSSL. Then in the following calls to the function it just fetch the reference to the engine instead of loading it again. An error tuple is returned if the engine can't be loaded.

The function raises a `error:badarg` if the parameters are in wrong format. It may also raise the exception `error:notsup` in case there is no engine support in the underlying OpenSSL implementation.

See also the chapter *Engine Load* in the User's Guide.

`ensure_engine_unloaded(Engine) -> Result`

Types:

```
Engine = engine_ref()
Result = ok | {error, Reason :: term()}
```

Unloads an engine loaded with the `ensure_engine_loaded` function. It both removes the label from the OpenSSL internal engine list and unloads the engine. This function is the same as calling `ensure_engine_unloaded/2` with `EngineMethods` set to a list of all the possible methods. An error tuple is returned if the engine can't be unloaded.

The function raises a `error:badarg` if the parameters are in wrong format. It may also raise the exception `error:notsup` in case there is no engine support in the underlying OpenSSL implementation.

See also the chapter *Engine Load* in the User's Guide.

`ensure_engine_unloaded(Engine, EngineMethods) -> Result`

Types:

```
Engine = engine_ref()
EngineMethods = [engine_method_type()]
Result = ok | {error, Reason :: term()}
```

Unloads an engine loaded with the `ensure_engine_loaded` function. It both removes the label from the OpenSSL internal engine list and unloads the engine. An error tuple is returned if the engine can't be unloaded.

The function raises a `error:badarg` if the parameters are in wrong format. It may also raise the exception `error:notsup` in case there is no engine support in the underlying OpenSSL implementation.

See also the chapter *Engine Load* in the User's Guide.

Old API

Exports

```
block_encrypt(Type :: block_cipher_without_iv(),
              Key :: key(),
              PlainText :: iodata()) ->
                 binary() | run_time_error()
```

Don't:

Don't use this function for new programs! Use *the-new-api*.

Encrypt `PlainText` according to `Type` block cipher.

May raise exception `error:notsup` in case the chosen `Type` is not supported by the underlying libcrypto implementation.

For keylengths and blocksizes see the *User's Guide*.

```
block_decrypt(Type :: block_cipher_without_iv(),
              Key :: key(),
              Data :: iodata()) ->
                 binary() | run_time_error()
```

Don't:

Don't use this function for new programs! Use *the new api*.

Decrypt `CipherText` according to `Type` block cipher.

May raise exception `error:notsup` in case the chosen `Type` is not supported by the underlying libcrypto implementation.

For keylengths and blocksizes see the *User's Guide*.

```
block_encrypt(Type, Key, Ivec, PlainText) -> CipherText | Error
block_encrypt(AeadType, Key, Ivec, {AAD, PlainText}) -> {CipherText,
CipherTag} | Error
block_encrypt(aes_gcm | aes_ccm, Key, Ivec, {AAD, PlainText, TagLength}) ->
{CipherText, CipherTag} | Error
```

Types:

Type = *block_cipher_with_iv()*
AeadType = *aead_cipher()*
Key = *key()* | *des3_key()*
PlainText = iodata()
AAD = IVec = CipherText = CipherTag = binary()
TagLength = 1..16
Error = *run_time_error()*

Don't:

Don't use this function for new programs! Use *the new api*.

Encrypt `PlainText` according to `Type` block cipher. `IVec` is an arbitrary initializing vector.

In AEAD (Authenticated Encryption with Associated Data) mode, encrypt `PlainText`according to `Type` block cipher and calculate `CipherTag` that also authenticates the `AAD` (Associated Authenticated Data).

May raise exception `error:notsup` in case the chosen `Type` is not supported by the underlying libcrypto implementation.

For keylengths, iv-sizes and blocksizes see the *User's Guide*.

```
block_decrypt(Type, Key, Ivec, CipherText) -> PlainText | Error
block_decrypt(AeadType, Key, Ivec, {AAD, CipherText, CipherTag}) -> PlainText
| Error
```

Types:

Type = *block_cipher_with_iv()*
AeadType = *aead_cipher()*
Key = *key()* | *des3_key()*
PlainText = iodata()
AAD = IVec = CipherText = CipherTag = binary()
Error = BadTag | *run_time_error()*
BadTag = error

Don't:

Don't use this function for new programs! Use *the new api*.

Decrypt `CipherText` according to `Type` block cipher. `IVec` is an arbitrary initializing vector.

In AEAD (Authenticated Encryption with Associated Data) mode, decrypt `CipherText`according to `Type` block cipher and check the authenticity the `PlainText` and `AAD` (Associated Authenticated Data) using the `CipherTag`. May return `error` if the decryption or validation fail's

May raise exception `error:notsup` in case the chosen `Type` is not supported by the underlying libcrypto implementation.

For keylengths, iv-sizes and blocksizes see the *User's Guide*.

```
stream_init(Type, Key) -> State | run_time_error()
```

Types:

```
Type = rc4
Key = iodata()
State = stream_state()
```

Don't:

Don't use this function for new programs! Use *the new api*.

Initializes the state for use in RC4 stream encryption *stream_encrypt* and *stream_decrypt*

For keylengths see the *User's Guide*.

```
stream_init(Type, Key, IVec) -> State | run_time_error()
```

Types:

```
Type = stream_cipher()
Key = iodata()
IVec = binary()
State = stream_state()
```

Don't:

Don't use this function for new programs! Use *the new api*.

Initializes the state for use in streaming AES encryption using Counter mode (CTR). `Key` is the AES key and must be either 128, 192, or 256 bits long. `IVec` is an arbitrary initializing vector of 128 bits (16 bytes). This state is for use with *stream_encrypt* and *stream_decrypt*.

For keylengths and iv-sizes see the *User's Guide*.

```
stream_encrypt(State, PlainText) ->
                  {NewState, CipherText} | run_time_error()
```

Types:

```
State = stream_state()
PlainText = iodata()
NewState = stream_state()
CipherText = iodata()
```

Don't:

Don't use this function for new programs! Use *the new api*.

Encrypts `PlainText` according to the stream cipher `Type` specified in stream_init/3. `Text` can be any number of bytes. The initial `State` is created using *stream_init*. `NewState` must be passed into the next call to `stream_encrypt`.

```
stream_decrypt(State, CipherText) ->
                  {NewState, PlainText} | run_time_error()
```

Types:

```
State = stream_state()
CipherText = iodata()
NewState = stream_state()
PlainText = iodata()
```

Don't:

Don't use this function for new programs! Use *the new api*.

Decrypts `CipherText` according to the stream cipher `Type` specified in stream_init/3. `PlainText` can be any number of bytes. The initial `State` is created using *stream_init*. `NewState` must be passed into the next call to `stream_decrypt`.

```
supports() -> [Support]
```

Types:

```
Support =
    {hashs, Hashs} |
    {ciphers, Ciphers} |
    {public_keys, PKs} |
    {macs, Macs} |
    {curves, Curves} |
    {rsa_opts, RSAopts}
Hashs =
    [sha1() |
     sha2() |
     sha3() |
     blake2() |
     ripemd160 |
     compatibility_only_hash()]
Ciphers = [cipher()]
PKs = [rsa | dss | ecdsa | dh | ecdh | ec_gf2m]
Macs = [hmac | cmac | poly1305]
Curves =
    [ec_named_curve() | edwards_curve_dh() | edwards_curve_ed()]
RSAopts = [rsa_sign_verify_opt() | rsa_opt()]
```

Don't:

Don't use this function for new programs! Use *supports/1* in *the new api*.

Can be used to determine which crypto algorithms that are supported by the underlying libcrypto library

See *hash_info/1* and *cipher_info/1* for information about the hash and cipher algorithms.

```
hmac(Type, Key, Data) -> Mac
hmac(Type, Key, Data, MacLength) -> Mac
```

Types:

Type = ***hmac_hash_algorithm()***
Key = Data = iodata()
MacLength = integer()
Mac = binary()

Don't:

Don't use this function for new programs! Use *mac/4* or *macN/5* in *the new api*.

Computes a HMAC of type `Type` from `Data` using `Key` as the authentication key.

`MacLength` will limit the size of the resultant `Mac`.

`hmac_init(Type, Key) -> State`

Types:

Type = ***hmac_hash_algorithm()***
Key = iodata()
State = ***hmac_state()***

Don't:

Don't use this function for new programs! Use *mac_init/3* in *the new api*.

Initializes the context for streaming HMAC operations. `Type` determines which hash function to use in the HMAC operation. `Key` is the authentication key. The key can be any length.

`hmac_update(State, Data) -> NewState`

Types:

Data = iodata()
State = NewState = ***hmac_state()***

Don't:

Don't use this function for new programs! Use *mac_update/2* in *the new api*.

Updates the HMAC represented by `Context` using the given `Data`. `Context` must have been generated using an HMAC init function (such as *hmac_init*). `Data` can be any length. `NewContext` must be passed into the next call to `hmac_update` or to one of the functions *hmac_final* and *hmac_final_n*

Warning:

Do not use a `Context` as argument in more than one call to hmac_update or hmac_final. The semantics of reusing old contexts in any way is undefined and could even crash the VM in earlier releases. The reason for this limitation is a lack of support in the underlying libcrypto API.

`hmac_final(State) -> Mac`

Types:

```
State = hmac_state()
Mac = binary()
```

Don't:

Don't use this function for new programs! Use *mac_final/1* in *the new api*.

Finalizes the HMAC operation referenced by `Context`. The size of the resultant MAC is determined by the type of hash function used to generate it.

```
hmac_final_n(State, HashLen) -> Mac
```

Types:

```
State = hmac_state()
HashLen = integer()
Mac = binary()
```

Don't:

Don't use this function for new programs! Use *mac_finalN/2* in *the new api*.

Finalizes the HMAC operation referenced by `Context`. `HashLen` must be greater than zero. `Mac` will be a binary with at most `HashLen` bytes. Note that if HashLen is greater than the actual number of bytes returned from the underlying hash, the returned hash will have fewer than `HashLen` bytes.

```
cmac(Type, Key, Data) -> Mac
cmac(Type, Key, Data, MacLength) -> Mac
```

Types:

```
Type =
    cbc_cipher() |
    cfb_cipher() |
    blowfish_cbc | des_ede3 | rc2_cbc
Key = Data = iodata()
MacLength = integer()
Mac = binary()
```

Don't:

Don't use this function for new programs! Use *mac/4* or *macN/5* in *the new api*.

Computes a CMAC of type `Type` from `Data` using `Key` as the authentication key.

`MacLength` will limit the size of the resultant `Mac`.

```
poly1305(Key :: iodata(), Data :: iodata()) -> Mac
```

Types:

```
Mac = binary()
```

Don't:

Don't use this function for new programs! Use *mac/3* or *macN/4* in *the new api*.

Computes a POLY1305 message authentication code (`Mac`) from `Data` using `Key` as the authentication key.