Secure Socket Layer

version 3.1
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Chapter 1

SSL User’s Guide

Here we provide a short introduction to the SSL protocol. We only consider those part of the protocol that are important from a programming point of view.

For a very good general introduction to SSL and TLS see the book SSL and TLS [1].

Outline:

- Two types of connections - connection: handshake, data transfer, and shutdown - SSL/TLS protocol - server must have certificate - what the the server sends to the client - client may verify the server - server may ask client for certificate - what the client sends to the server - server may then verify the client - verification - certificate chains - root certificates - public keys - key agreement - purpose of certificate - references

1.1 SSL Connections

The SSL protocol is implemented on top of the TCP/IP protocol. From an endpoint view it also has the same type of connections as that protocol, almost always created by calls to socket interface functions listen, accept and connect. The endpoints are servers and clients.

A server listens for connections on a specific address and port. This is done once. The server then accepts each connections on that same address and port. This is typically done indefinitely many times.

A client connects to a server on a specific address and port. For each purpose this is done once.

For a plain TCP/IP connection the establishment of a connection (through an accept or a connect) is followed by data transfer between the client and server, finally ended by a connection close.

An SSL connection also consists of data transfer and connection close. However, the data transfer contains encrypted data, and in order to establish the encryption parameters, the data transfer is preceded by an SSL handshake. In this handshake the server plays a dominant role, and the main instrument used in achieving a valid SSL connection is the server’s certificate. We consider certificates in the next section, and the SSL handshake in a subsequent section.
1.2 Certificates

A certificate is similar to a driver's license, or a passport. The holder of the certificate is called the subject. First of all the certificate identifies the subject in terms of the name of the subject, its postal address, country name, company name (if applicable), etc.

Although a driver's license is always issued by a well-known and distinct authority, a certificate may have an issuer that is not so well-known. Therefore a certificate also always contains information on the issuer of the certificate. That information is of the same type as the information on the subject. The issuer of a certificate also signs the certificate with a digital signature (the signature is an inherent part of the certificate), which allow others to verify that the issuer really is the issuer of the certificate.

Now that a certificate can be checked by verifying the signature of the issuer, the question is how to trust the issuer. The answer to this question is to require that there is a certificate for the issuer as well. That issuer has in turn an issuer, which must also have a certificate, and so on. This certificate chain has to have an end, which then must be a certificate that is trusted by other means. We shall cover this problem of authentication in a subsequent section.

1.3 Encryption Algorithms

An encryption algorithm is a mathematical algorithm for encryption and decryption of messages (arrays of bytes, say). The algorithm as such is always required to be publicly known, otherwise its strength cannot be evaluated, and hence it cannot be used reliably. The secrecy of an encrypted message is not achieved by the secrecy of the algorithm used, but by the secrecy of the keys used as input to the encryption and decryption algorithms. For an account of cryptography in general see Applied Cryptography [2].

There are two classes of encryption algorithms: symmetric key algorithms and public key algorithms. Both types of algorithms are used in the SSL protocol.

In the sequel we assume holders of keys keep them secret (except public keys) and that they in that sense are trusted. How a holder of a secret key is proved to be the one it claims to be is a question of authentication, which, in the context of the SSL protocol, is described in a section further below.

1.3.1 Symmetric Key Algorithms

A symmetric key algorithm has one key only. The key is used for both encryption and decryption. Obviously the key of a symmetric key algorithm must always be kept secret by the users of the key. DES is an example of a symmetric key algorithm.

Symmetric key algorithms are fast compared to public key algorithms. They are therefore typically used for encrypting bulk data.

1.3.2 Public Key Algorithms

A public key algorithm has two keys. Any of the two keys can be used for encryption. A message encrypted with one of the keys, can only be decrypted with the other key. One of the keys is public (known to the world), while the other key is private (i.e. kept secret) by the owner of the two keys. RSA is an example of a public key algorithm.

Public key algorithms are slow compared to symmetric key algorithms, and they are therefore seldom used for bulk data encryption. They are therefore only used in cases where the fact that one key is public and the other is private, provides features that cannot be provided by symmetric algorithms.
1.3.3 Digital Signature Algorithms

An interesting feature of a public key algorithm is that its public and private keys can both be used for encryption. Anyone can use the public key to encrypt a message, and send that message to the owner of the private key, and be sure of that only the holder of the private key can decrypt the message.

On the other hand, the owner of the private key can encrypt a message with the private key, thus obtaining an encrypted message that can decrypted by anyone having the public key.

The last approach can be used as a digital signature algorithm. The holder of the private key signs an array of bytes by performing a specified well-known message digest algorithm to compute a hash of the array, encrypts the hash value with its private key, and then presents the original array, the name of the digest algorithm, and the encryption of the hash value as a signed array of bytes.

Now anyone having the public key, can decrypt the encrypted hash value with that key, compute the hash with the specified digest algorithm, and check that the hash values compare equal in order to verify that the original array was indeed signed by the holder of the private key.

What we have accounted for so far is by no means all that can be said about digital signatures (see Applied Cryptography [2] for further details).

1.3.4 Message Digests Algorithms

A message digest algorithm is a hash function that accepts an array bytes of arbitrary but finite length of input, and outputs an array of bytes of fixed length. Such an algorithm is also required to be very hard to invert.

MD5 (16 bytes output) and SHA1 (20 bytes output) are examples of message digest algorithms.

1.4 SSL Handshake

The main purpose of the handshake performed before an SSL connection is established is to negotiate the encryption algorithm and key to be used for the bulk data transfer between the client and the server. We are writing the key, since the algorithm to choose for bulk encryption one of the symmetric algorithms.

There is thus only one key to agree upon, and obviously that key has to be kept secret between the client and the server. To obtain that the handshake has to be encrypted as well.

The SSL protocol requires that the server always sends its certificate to the client in the beginning of the handshake. The client then retrieves the server's public key from the certificate, which means that the client can use the server's public key to encrypt messages to the server, and the server can decrypt those messages with its private key. Similarly, the server can encrypt messages to the client with its private key, and the client can decrypt messages with the server's public key. It is thus is with the server's public and private keys that messages in the handshake are encrypted and decrypted, and hence the key agreed upon for symmetric encryption of bulk data can be kept secret (there are more things to consider to really keep it secret, see SSL and TLS [1]).

The above indicates that the server does not care who is connecting, and that only the client has the possibility to properly identify the server based on the server's certificate. That is indeed true in the minimal use of the protocol, but it is possible to instruct the server to request the certificate of the client, in order to have a means to identify the client, but it is by no means required to establish an SSL connection.

If a server request the client certificate, it verifies, as a part of the protocol, that the client really holds the private key of the certificate by sending the client a string of bytes to encrypt with its private key, which the server then decrypts with the client's public key, the result of which is compared with the
original string of bytes (a similar procedure is always performed by the client when it has received the server’s certificate).

The way clients and servers authenticate each other, i.e. proves that their respective peers are what they claim to be, is the topic of the next section.

1.5 Authentication

As we have already seen the reception of a certificate from a peer is not enough to prove that the peer is authentic. More certificates are needed, and we have to consider how certificates are issued and on what grounds.

Certificates are issued by certification authorities (CAs) only. They issue certificates both for other CAs and ordinary users (which are not CAs).

Certain CAs are top CAs, i.e. they do not have a certificate issued by another CA. Instead they issue their own certificate, where the subject and issuer part of the certificate are identical (such a certificate is called a self-signed certificate). A top CA has to be well-known, and has to have a publicly available policy telling on what grounds it issues certificates.

There are a handful of top CAs in the world. You can examine the certificates of several of them by clicking through the menus of your web browser.

A top CA typically issues certificates for other CAs, called intermediate CAs, but possibly also to ordinary users. Thus the certificates derivable from a top CA constitute a tree, where the leaves of the tree are ordinary user certificates.

A certificate chain is an ordered sequence of certificates, \( C_1, C_2, \ldots, C_n \), say, where \( C_1 \) is a top CA certificate, and where \( C_n \) is an ordinary user certificate, and where the holder of \( C_1 \) is the issuer of \( C_2 \), the holder of \( C_2 \) is the issuer of \( C_3 \), ..., and the holder of \( C_{n-1} \) is the issuer of \( C_n \), the ordinary user certificate. The holders of \( C_2, C_3, \ldots, C_{n-1} \) are then intermediate CAs.

Now to verify that a certificate chain is unbroken we have to take the public key from each certificate \( C_k \), and apply that key to decrypt the signature of certificate \( C_{k-1} \), thus obtaining the message digest computed by the holder of the \( C_k \) certificate, compute the real message digest of the \( C_{k-1} \) certificate and compare the results. If they compare equal the link of the chain between \( C_k \) and \( C_{k-1} \) is considered to be unbroken. This is done for each link \( k = 1, 2, \ldots, n-1 \). If all links are found to be unbroken, the user certificate \( C_n \) is considered authenticated.

1.5.1 Trusted Certificates

Now that there is a way to authenticate a certificate by checking that all links of a certificate chain are unbroken, the question is how you can be sure to trust the certificates in the chain, and in particular the top CA certificate of the chain.

To provide an answer to that question consider the perspective of a client, which have just received the certificate of the server. In order to authenticate the server the client has to construct a certificate chain and to prove that the chain is unbroken. The client has to have a set of CA certificates (top CA or intermediate CA certificates) not obtained from the server, but obtained by other means. Those certificates are kept locally by the client, and are trusted by the client.

More specifically, the client does not really have to have top CA certificates in its local storage. In order to authenticate a server it is sufficient for the client to possess the trusted certificate of the issuer of the server certificate.

Now that is not the whole story. A server can send an (incomplete) certificate chain to its client, and then the task of the client is to construct a certificate chain that begins with a trusted certificate and
ends with the server’s certificate. (A client can also send a chain to its server, provided the server requested the client’s certificate.)

All this means that an unbroken certificate chain begins with a trusted certificate (top CA or not), and ends with the peer certificate. That is the end of the chain is obtained from the peer, but the beginning of the chain is obtained from local storage, which is considered trusted.
Chapter 2

Using the SSL application

Here we provide an introduction to using the Erlang/OTP SSL application, which is accessed through the ssl interface module. We also present example code in the Erlang module client_server, also provided in the directory ssl-X.Y.Z/examples, with source code in src and the compiled module in ebin of that directory.

2.1 The ssl Module

The ssl module provides the user interface to the Erlang/OTP SSL application. The interface functions provided are very similar to those provided by the gen_tcp and inet modules. Servers use the interface functions listen and accept. The listen function specifies a TCP port to listen to, and each call to the accept function establishes an incoming connection. Clients use the connect function which specifies the address and port of a server to connect to, and a successful call establishes such a connection.

The listen and connect functions have almost all the options that the corresponding functions in gen_tcp/ have, but there are also additional options specific to the SSL protocol. The most important SSL specific option is the cacertfile option which specifies a local file containing trusted CA certificates which are used for peer authentication. This option is used by clients and servers in case they want to authenticate their peers.

The certfile option specifies a local path to a file containing the certificate of the holder of the connection endpoint. In case of a server endpoint this option is mandatory since the contents of the sever certificate is needed in the the handshake preceeding the establishment of a connection. Similarly, the keyfile option points to a local file containing the private key of the holder of the endpoint. If the certfile option is present, this option has to be specified as well, unless the private key is provided in the same file as specified by the certfile option (a certificate and a private key can thus coexist in the same file).

The verify option specifies how the peer should be verified:

- **0**  Do not verify the peer,
- **1**  Verify peer,
- **2**  Verify peer, fail the verification if the peer has no certificate.
The `depth` option specifies the maximum length of the verification certificate chain. Depth = 0 means the peer certificate, depth = 1 the CA certificate, depth = 2 the next CA certificate etc. If the verification process does not find a trusted CA certificate within the maximum length, the verification fails.

The `ciphers` option specifies which ciphers to use (a string of colon separated cipher names). To obtain a list of available ciphers, evaluate the `ssl:ciphers/0` function (the SSL application has to be running).

### 2.2 A Client-Server Example

Here is a simple client server example.

```erlang
%% Purpose: Example of SSL client and server using example certificates.
-module(client_server).
-export([start/0, start/1, init_connect/1]).

start() ->
    start([ssl, subject]).

start(CertOpts) ->
    %% Start ssl application
    application:start(ssl),
    %% Always seed
    ssl:seed("ellynamefttidppohjeh"),
    %% Let the current process be the server that listens and accepts
    %% Listen
    {ok, LSock} = ssl:listen(0, mk_opts(listen)),
    {ok, LPort} = ssl:port(LSock),
    io:fwrite("Listen: port = ~w.\n", [LPort]),
    %% Spawn the client process that connects to the server
    spawn(?MODULE, init_connect, [{LPort, CertOpts}]),
    %% Accept
    {ok, ASock} = ssl:accept(LSock),
    io:fwrite("Accept: accepted.\n"),
    {ok, Cert} = ssl:peercert(ASock, CertOpts),
    io:fwrite("Accept: peer cert:~n"),
    io:fwrite("Accept: sending \"hello\"\n"),
    ssl:send(ASock, "hello"),
    {error, closed} = ssl:recv(ASock, 0),
    io:fwrite("Accept: detected closed.\n"),
    ssl:close(ASock),
    io:fwrite("Listen: closing and terminating.\n"),
    ssl:close(LSock),
    application:stop(ssl).
```

8 SSL Application
%% Client connect
init_connect({LPort, CertOpts}) ->
  {ok, Host} = inet:gethostname(),
  {ok, CSock} = ssl:connect(Host, LPort, mk_opts(connect)),
  io:fwrite("Connect: connected.\n"),
  {ok, Cert} = ssl:peercert(CSock, CertOpts),
  io:fwrite("Connect: peer cert:~n", [Cert]),
  {ok, Data} = ssl:recv(CSock, 0),
  io:fwrite("Connect: got data: ~p\n", [Data]),
  io:fwrite("Connect: closing and terminating.\n"),
  ssl:close(CSock).

mk_opts(listen) ->
  mk_opts("server");
mk_opts(connect) ->
  mk_opts("client");
mk_opts(Role) ->
  Dir = filename:join([code:lib_dir(ssl), "examples", "certs", "etc"],
  [{active, false},
   {verify, 2},
   {depth, 2},
   {cacertfile, filename:join([Dir, Role, "cacerts.pem"])),
   {certfile, filename:join([Dir, Role, "cert.pem"])),
   {keyfile, filename:join([Dir, Role, "key.pem"])}].
Chapter 3

PKIX Certificates

3.1 Introduction to Certificates

Certificates were originally defined by ITU (CCITT) and the latest definitions are described in ITU-T X.509 [3], but those definitions are (as always) not working.

Working certificate definitions for the Internet Community are found in the PKIX RFCs RFC 3279 [4] and RFC 3280 [5]. The parsing of certificates in the Erlang/OTP SSL application is based on those RFCs.

Certificates are defined in terms of ASN.1 (ITU-T X.680 [6]). For an introduction to ASN.1 see ASN.1 Information Site1.

3.2 PKIX Certificates

Here we base the PKIX certificate definitions in RFCs RFC 3279 [4] and RFC 3280 [5]. We however present the definitions according to SSL-PKIX.asn1 module, which is an amelioration of the PKIX1Explicit88.asn1, PKIX1Implicit88.asn1, and PKIX1Algorithms88.asn1 modules. You find all these modules in the pkix subdirectory of SSL.

The Erlang terms that are returned by the functions ssl:peercert/1/2, ssl:pkix:decode_cert/1/2, and ssl:pkix:decode_cert_file/1/2 when the option ssl is used in those functions, correspond the ASN.1 structures described in the sequel.

3.2.1 Certificate and TBSCertificate

Certificate ::= SEQUENCE {
  tbsCertificate   TBSCertificate,
  signatureAlgorithm   SignatureAlgorithm,
  signature BIT STRING }

TBSCertificate ::= SEQUENCE {
  version [0] Version DEFAULT v1,
  serialNumber CertificateSerialNumber,
  signature SignatureAlgorithm,
  issuer Name,

1URL: http://asn1.eilibel.tm.fr/
Chapter 3: PKIX Certificates

validity Validity, 
subject Name, 
subjectPublicKeyInfo SubjectPublicKeyInfo, 
issuerUniqueID [1] IMPLICIT UniqueIdentifier OPTIONAL, 
--- If present, version MUST be v2 or v3 
subjectUniqueID [2] IMPLICIT UniqueIdentifier OPTIONAL, 
--- If present, version MUST be v2 or v3 
extensions [3] Extensions OPTIONAL 
--- If present, version MUST be v3 -- }

Version ::= INTEGER { v1(0), v2(1), v3(2) }

CertificateSerialNumber ::= INTEGER

Validity ::= SEQUENCE {
  notBefore Time, 
  notAfter Time }

Time ::= CHOICE {
  utcTime UTCTime, 
  generalTime GeneralizedTime }

The meaning of the fields version, serialNumber, and validity are quite obvious given the type definitions above, so we do not go further into their details.

The signatureAlgorithm field of Certificate and the signature field of TBSCertificate contain the name and parameters of the algorithm used for signing the certificate. The values of these two fields must be equal.

The signature field of Certificate contains the value of the signature that the issuer computed by using the prescribed algorithm.

The issuer and subject fields can contain many different types of data, and is therefore considered in a separate section. The same holds for the extensions field. The issuerUniqueID and the subjectUniqueID fields are not considered further.

3.2.2 TBSCertificate issuer and subject

Name ::= CHOICE { -- only one possibility for now --
  rdnSequence RDNSequence }

RDNSequence ::= SEQUENCE OF RelativeDistinguishedName

DistinguishedName ::= RDNSequence

RelativeDistinguishedName ::= SET SIZE (1 .. MAX) OF AttributeTypeAndValue

AttributeTypeAndValue ::= SEQUENCE {
  type ATTRIBUTE-TYPE-AND-VALUE-CLASS.&id
    {{SupportedAttributeTypeAndValues}},
  value ATTRIBUTE-TYPE-AND-VALUE-CLASS.&Type
    {{SupportedAttributeTypeAndValues}{@type}} }

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SupportedAttributeTypeAndValues ATTRIBUTE-TYPE-AND-VALUE-CLASS ::= 
{ name | surname | givenName | initials | generationQualifier |
commonName | localityName | stateOrProvinceName | organizationName |
organizationalUnitName | title | dnQualifier | countryName |
serialNumber | pseudonym | domainComponent | emailAddress }

3.2.3 TBSCertificate extensions

The extensions field of a TBSCertificate is a sequence of type Extension, defined as follows,

Extension ::= SEQUENCE { 
  extnID OBJECT IDENTIFIER,
  critical BOOLEAN DEFAULT FALSE,
  extnValue ANY }

Each extension has a unique object identifier. An extension with a critical value set to TRUE must be
recognised by the reader of a certificate, or else the certificate must be rejected.

Extensions are divided into two groups: standard extensions and internet certificate extensions. All
extensions listed in the table that follows are standard extensions, except for authorityInfoAccess and
subjectInfoAccess, which are internet extensions.

Depending on the object identifier the extnValue is parsed into an appropriate well-defined structure.

The following table shows the purpose of each extension, but does not specify the structure. To see the
structure consult the PKIX1Implicit88.asn1 module.

<table>
<thead>
<tr>
<th>Extension</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>authorityKeyIdentifier</td>
<td>Used by to identify a certificate signed that has multiple signing keys.</td>
</tr>
<tr>
<td>subjectKeyIdentifier</td>
<td>Used to identify certificates that contain a public key. Must appear in CA certificates.</td>
</tr>
<tr>
<td>keyUsage</td>
<td>Defines the purpose of the certificate. Can be one or several of digitalSignature, nonRepudiation, keyEncipherment, dataEncipherment, keyAgreement, keyCertSign, cRLSign, encipherOnly, decipherOnly.</td>
</tr>
<tr>
<td>privateKeyUsagePeriod</td>
<td>Allows certificate issuer to provide a private key usage period to be short than the certificate usage period.</td>
</tr>
<tr>
<td>certificatePolicies</td>
<td>Contains one or more policy information terms indicating the policies under which the certificate has been issued.</td>
</tr>
<tr>
<td>policyMappings</td>
<td>Used in CA certificates.</td>
</tr>
<tr>
<td>subjectAltName</td>
<td>Allows additional identities to be bound the the subject.</td>
</tr>
<tr>
<td>issuerAltName</td>
<td>Allows additional identities to be bound the the issuer.</td>
</tr>
<tr>
<td>subjectDirectoryAttributes</td>
<td>Conveys identity attributes of the subject.</td>
</tr>
<tr>
<td>basicConstraints</td>
<td>Tells if the certificate holder is a CA or not.</td>
</tr>
<tr>
<td>nameConstraints</td>
<td>Used in CA certificates.</td>
</tr>
<tr>
<td>policyConstraints</td>
<td>Used in CA certificates.</td>
</tr>
<tr>
<td>extKeyUsage</td>
<td>Indicates for which purposed the public key may be used.</td>
</tr>
<tr>
<td>cRLDistributionPoints</td>
<td>Indicates how CRL (Certificate Revocation List) information is obtained.</td>
</tr>
<tr>
<td>inhibitAnyPolicy</td>
<td>Used in CA certificates.</td>
</tr>
</tbody>
</table>

continued ...
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... continued

<table>
<thead>
<tr>
<th>Extension</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>freshestCRL</td>
<td>For CRLs</td>
</tr>
<tr>
<td>authorityInfoAccess</td>
<td>How to access CA information of the issuer of the certificate.</td>
</tr>
<tr>
<td>subjectInfoAccess</td>
<td>How to access CA information of the subject of the certificate.</td>
</tr>
</tbody>
</table>

Table 3.1: PKIX Extensions
Chapter 4

Creating Certificates

Here we consider the creation of example certificates.

4.1 The openssl Command

The openssl command is a utility that comes with the OpenSSL distribution. It provides a variety of subcommands. Each subcommand is invoked as

    openssl subcmd <options and arguments>

where subcmd denotes the subcommand in question.

We shall use the following subcommands to create certificates for the purpose of testing Erlang/OTP SSL:

- req to create certificate requests and a self-signed certificates,
- ca to create certificates from certificate requests.

We create the following certificates:

- the erlangCA root certificate (a self-signed certificate),
- the otpCA certificate signed by the erlangCA,
- a client certificate signed by the otpCA, and
- a server certificate signed by the otpCA.
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4.1.1 The openssl configuration file

An openssl configuration file consist of a number of sections, where each section starts with one line containing \([\text{section\_name}]\), where \(\text{section\_name}\) is the name of the section. The first section of the file is either unnamed, or is named \([\text{default}]\). For further details see the OpenSSL config(5) manual page.

The required sections for the subcommands we are going to use are as follows:

<table>
<thead>
<tr>
<th>subcommand</th>
<th>required/default section</th>
<th>override command line option</th>
<th>configuration file option</th>
</tr>
</thead>
<tbody>
<tr>
<td>req</td>
<td>[req]</td>
<td>-</td>
<td>-config FILE</td>
</tr>
<tr>
<td>ca</td>
<td>[ca]</td>
<td>-name section</td>
<td>-config FILE</td>
</tr>
</tbody>
</table>

Table 4.1: openssl subcommands to use

4.1.2 Creating the Erlang root CA

The Erlang root CA is created with the command

```bash
openssl req -new -x509 -config /some/path/req.cnf
-keyout /some/path/key.pem -out /some/path/r
```

where the option \(-\text{new}\) indicates that we want to create a new certificate request and the option \(-\text{x509}\) implies that a self-signed certificate is created.

4.1.3 Creating the OTP CA

The OTP CA is created by first creating a certificate request with the command

```bash
openssl req -new -config /some/path/req.cnf
-keyout /some/path/key.pem -out /some/path/
```

and the ask the Erlang CA to sign it:

```bash
openssl ca -batch -notext -config /some/path/req.cnf
-extensions ca_cert -in /some/path/r
```

where the option \(-\text{extensions}\) refers to a section in the configuration file saying that it should create a CA certificate, and not a plain user certificate.

The client and server certificates are created similarly, except that the option \(-\text{extensions}\) then has the value user_cert.
4.2 An Example

The following module `create_certs` is used by the Erlang/OTP SSL application for generating certificates to be used in tests. The source code is also found in `ssl-X.Y.Z/examples/certs/src`.

The purpose of the `create_certs:all/1` function is to make it possible to provide from the `erl` command line, the full path name of the `openssl` command.

Note that the module creates temporary OpenSSL configuration files for the `req` and `ca` subcommands.

```erlang
%% The purpose of this module is to create example certificates for testing.
%% Run it as:
%%
%% erl -noinput -run make_certs all "/path/to/openssl" -s erlang halt
%%
-module(make_certs).
-export([all/0, all/1]).

-record(dn, {commonName, organizationalUnitName = "Erlang OTP", organizationName = "Ericsson AB", localityName = "Stockholm", countryName = "SE", emailAddress = "peter@erix.ericsson.se"}).

all() ->
    all(['openssl']).

all([OpenSSLCmd]) ->
    Root = filename:dirname(filename:dirname((code:which(?MODULE)))).
    file:make_dir(Root, "etc"), % For all requests
    create_rnd(Root, "etc"),
    rootCA(Root, OpenSSLCmd, "erlangCA"),
    intermediateCA(Root, OpenSSLCmd, "otpCA", "erlangCA"),
    endusers(Root, OpenSSLCmd, "otpCA", ["client", "server"], "otpCA", ["client", "server"],
    collect_certs(Root, ["erlangCA", "otpCA"], ["client", "server"]),
    remove_rnd(Root, "etc").

rootCA(Root, OpenSSLCmd, Name) ->
    create_ca_dir(Root, Name, ca_cnf(Name)),
    DN = #dn(commonName = Name),
    create_self_signed_cert(Root, OpenSSLCmd, Name, req_cnf(DN)),
    ok.

intermediateCA(Root, OpenSSLCmd, CA, ParentCA) ->
    CA = "otpCA",
    create_ca_dir(Root, CA, ca_cnf(CA)),
    CARoot = filename:join([Root, CA]),
    DN = #dn(commonName = CA),
    CnfFile = filename:join([CARoot, "req.cnf"]).
```

SSL Application 17
file:write_file(CnfFile, req_cnf(DN)),
KeyFile = filename:join([CARoot, "private", "key.pem"]),
ReqFile = filename:join([CARoot, "req.pem"]),
create_req(Root, OpenSSLCmd, CnfFile, KeyFile, ReqFile),
CertFile = filename:join([CARoot, "cert.pem"]),
sign_req(Root, OpenSSLCmd, ParentCA, "ca_cert", ReqFile, CertFile).

endusers(Root, OpenSSLCmd, CA, Users) ->
  lists:foreach(fun(User) -> enduser(Root, OpenSSLCmd, CA, User) end, Users).

enduser(Root, OpenSSLCmd, CA, User) ->
  UsrRoot = filename:join([Root, User]),
  file:make_dir(UsrRoot),
  CnfFile = filename:join([UsrRoot, "req.cnf"],
  DN = #dn{commonName = User},
  file:write_file(CnfFile, req_cnf(DN)),
  KeyFile = filename:join([UsrRoot, "key.pem"],
  ReqFile = filename:join([UsrRoot, "req.pem"],
  create_req(Root, OpenSSLCmd, CnfFile, KeyFile, ReqFile),
  CertFile = filename:join([UsrRoot, "cert.pem"],
  sign_req(Root, OpenSSLCmd, CA, "user_cert", ReqFile, CertFile).

collect_certs(Root, CAs, Users) ->
  Bins = lists:foldr(
    fun(CA, Acc) ->
      File = filename:join([Root, CA, "cert.pem"],
      {ok, Bin} = file:read_file(File),
      [Bin, "
    end, [], CAs),
  lists:foreach(
    fun(User) ->
      File = filename:join([Root, User, "cacerts.pem"],
      file:write_file(File, Bins)
    end, Users).

create_self_signed_cert(Root, OpenSSLCmd, CAName, Cnf) ->
  CARoot = filename:join([Root, CAName]),
  CnfFile = filename:join([CARoot, "req.cnf"],
  file:write_file(CnfFile, Cnf),
  KeyFile = filename:join([CARoot, "private", "key.pem"],
  CertFile = filename:join([CARoot, "cert.pem"],
  Cmd = [OpenSSLCmd, " req"
    " -new"
    " -x509"
    " -config ", CnfFile,
    " -keyout ", KeyFile,
    " -out ", CertFile],
  Env = [{"ROOTDIR", Root}],
  cmd(Cmd, Env).

create_ca_dir(Root, CAName, Cnf) ->
  CARoot = filename:join([Root, CAName]),
file:make_dir(CARoot),
create_dirs(CARoot, ["certs", "crl", "newcerts", "private"]),
create_rnd(Root, filename:join([CAName, "private"])),
create_files(CARoot, [{"serial", "01"},
  {"index.txt", ""},
  {"ca.cnf", Cnf}]).

create_req(Root, OpenSSLCmd, CnfFile, KeyFile, ReqFile) ->
  Cmd = [OpenSSLCmd, " req"
    " -new"
    " -config ", CnfFile,
    " -keyout ", KeyFile,
    " -out ", ReqFile],
  Env = [{"ROOTDIR", Root}],
  cmd(Cmd, Env).

sign_req(Root, OpenSSLCmd, CA, CertType, ReqFile, CertFile) ->
  CACnfFile = filename:join([Root, CA, "ca.cnf"]),
  Cmd = [OpenSSLCmd, " ca"
    " -batch"
    " -notext"
    " -config ", CACnfFile,
    " -extensions ", CertType,
    " -in ", ReqFile,
    " -out ", CertFile],
  Env = [{"ROOTDIR", Root}],
  cmd(Cmd, Env).

%%% Misc

create_dirs(Root, Dirs) ->
  lists:foreach(fun(Dir) ->
    file:make_dir(filename:join([Root, Dir])) end,
  Dirs).

create_files(Root, NameContents) ->
  lists:foreach(fun({Name, Contents}) ->
    file:write_file(filename:join([Root, Name]), Contents) end,
  NameContents).

create_rnd(Root, Dir) ->
  From = filename:join([Root, "rnd", "RAND"]),
  To = filename:join([Root, Dir, "RAND"]),
  file:copy(From, To).

remove_rnd(Root, Dir) ->
  File = filename:join([Root, Dir, "RAND"]),
  file:delete(File).
Chapter 4: Creating Certificates

cmd(Cmd, Env) ->
    FCmd = lists:flatten(Cmd),
    Port = open_port({spawn, FCmd}, [stream, eof, exit_status, {env, Env}]),
    eval_cmd(Port).

eval_cmd(Port) ->
    receive
        {Port, {data, _}} ->
        eval_cmd(Port);
        {Port, eof} ->
            ok
    end,
    receive
        {Port, {exit_status, Status}} when Status /= 0 ->
            %% io:fwrite("exit status: \"w\"n", [Status]),
            erlang:halt(Status)
        after 0 ->
            ok
    end.

%%
%% Contents of configuration files
%%

req_cnf(DN) ->
    [
        "# Purpose: Configuration for requests (end users and CAs)."
    , ""
    , "ROOTDIR = $ENV::ROOTDIR"
    , ""
    , "[req]
    , "input_password = secret"
    , "output_password = secret"
    , "default_bits = 1024"
    , "RANDFILE = $ROOTDIR/RAND"
    , "encrypt_key = no"
    , "default_md = sha1"
    , "#string_mask = pkix"
    , "x509_extensions = ca_ext"
    , "prompt = no"
    ]
4.2: An Example

```
distinguished_name= name

[name]

commonName = " , DN#dn.commonName , "
organizationalUnitName = " , DN#dn.organizationalUnitName , "
organizationName = " , DN#dn.organizationName , "
localityName = " , DN#dn.localityName , "
countryName = " , DN#dn.countryName , "
emailAddress = " , DN#dn.emailAddress , "

[ca_ext]

basicConstraints = critical, CA:true
keyUsage = cRLSign, keyCertSign
subjectKeyIdentifier = hash
subjectAltName = email:copy
```

cnf(CA) ->

```
"# Purpose: Configuration for CAs.

ROOTDIR = $ENV::ROOTDIR
default_ca = ca

[ca]
dir = $ROOTDIR/ , CA , "
certs = $dir/certs
```
Chapter 4: Creating Certificates

```
"crl_dir" = $dir/crl
"database" = $dir/index.txt
"new_certs_dir" = $dir/newcerts
"certificate" = $dir/cert.pem
"serial" = $dir/serial
"crl" = $dir/crl.pem
"private_key" = $dir/private/key.pem
"RANDFILE" = $dir/private/RAND

"x509_extensions" = user_cert
"default_days" = 3600
"default_md" = sha1
"preserve" = no
"policy" = policy_match

[policy_match]
"commonName" = supplied
"organizationalUnitName" = optional
"organizationName" = match
"countryName" = match
"localityName" = match
"emailAddress" = supplied

[user_cert]
"basicConstraints" = CA:false
"keyUsage" = nonRepudiation, digitalSignature, keyEncipherment
```
4.2: An Example

```
"subjectKeyIdentifier = hash
"authorityKeyIdentifier = keyid,issuer:always
"subjectAltName = email:copy
"issuerAltName = issuer:copy
"

"[ca_cert]
"basicConstraints = critical,CA:true
"keyUsage = cRLSign, keyCertSign
"subjectKeyIdentifier = hash
"authorityKeyIdentifier = keyid:always,issuer:always
"subjectAltName = email:copy
"issuerAltName = issuer:copy
"].
```
Chapter 5

Using SSL for Erlang Distribution

This chapter describes how the Erlang distribution can use SSL to get additional verification and security.

5.1 Introduction

The Erlang distribution can in theory use almost any connection based protocol as bearer. A module that implements the protocol specific parts of connection setup is however needed. The default distribution module is `inet_tcp_dist` which is included in the Kernel application. When starting an Erlang node distributed, `net_kernel` uses this module to setup listen ports and connections.

In the SSL application there is an additional distribution module, `inet_ssl_dist` which can be used as an alternative. All distribution connections will be using SSL and all participating Erlang nodes in a distributed system must use this distribution module.

The security depends on how the connections are set up, one can use key files or certificates to just get a encrypted connection. One can also make the SSL package verify the certificates of other nodes to get additional security. Cookies are however always used as they can be used to differentiate between two different Erlang networks.

Setting up Erlang distribution over SSL involves some simple but necessary steps:

- Building boot scripts including the SSL application
- Specifying the distribution module for `net_kernel`
- Specifying security options and other SSL options

The rest of this chapter describes the above mentioned steps in more detail.
5.2 Building boot scripts including the SSL application

Boot scripts are built using the systools utility in the SASL application. Refer to the SASL documentations for more information on systools. This is only an example of what can be done.

The simplest boot script possible includes only the Kernel and STDLIB applications. Such a script is located in the Erlang distributions bin directory. The source for the script can be found under the Erlang installation top directory under releases/OTP version/start_clean.rel. Copy that script to another location (and preferably another name) and add the SSL application with its current version number after the STDLIB application.

An example .rel file with SSL added may look like this:

```erlang
{release, {"OTP APN 181 01","P7A"}, {erts, "5.0"},
 [ {kernel,"2.5"},
   {stdlib,"1.8.1"},
   {ssl,"2.2.1"} ]}.
```

Note that the version numbers surely will differ in your system. Whenever one of the applications included in the script is upgraded, the script has to be changed.

Assuming the above .rel file is stored in a file start_ssl.rel in the current directory, a boot script can be built like this:

```erlang
1> systools:make_script("start_ssl",[]).
```

There will now be a file start_ssl.boot in the current directory. To test the boot script, start Erlang with the -boot command line parameter specifying this boot script (with its full path but without the .boot suffix), in Unix it could look like this:

```bash
$ erl -boot /home/me/ssl/start_ssl
```

Erlang (BEAM) emulator version 5.0

Eshell V5.0  (abort with "^G")
1> whereis(ssl_server).
<0.32.0>

The whereis function call verifies that the SSL application is really started.

As an alternative to building a bootscript, one can explicitly add the path to the ssl ebin directory on the command line. This is done with the command line option -pa. This works as the ssl application really need not be started for the distribution to come up, a primitive version of the ssl server is started by the distribution module itself, so as long as the primitive code server can reach the code, the distribution will start. The -pa method is only recommended for testing purposes.
5.3 Specifying distribution module for net_kernel

The distribution module for SSL is named \texttt{inet_ssl_dist} and is specified on the command line with the \texttt{-proto_dist} option. The argument to \texttt{-proto_dist} should be the module name without the \texttt{dist} suffix, so this distribution module is specified with \texttt{-proto_dist inet_ssl} on the command line.

Extending the command line from above gives us the following:

\begin{verbatim}
$ erl -boot /home/me/ssl/start_ssl -proto_dist inet_ssl
\end{verbatim}

For the distribution to actually be started, we need to give the emulator a name as well:

\begin{verbatim}
$ erl -boot /home/me/ssl/start_ssl -proto_dist inet_ssl -sname ssl_test
\end{verbatim}

Erlang (BEAM) emulator version 5.0 [source]

Eshell V5.0 (abort with \textasciitilde G)

Note however that a node started in this way will refuse to talk to other nodes, as no certificates or key files are supplied (see below).

When the SSL distribution starts, the OTP system is in its early boot stage, why neither application nor code are usable. As SSL needs to start a port program in this early stage, it tries to determine the path to that program from the primitive code loaders code path. If this fails, one need to specify the directory where the port program resides. This can be done either with an environment variable \texttt{ERL_SSL_PORTPROGRAM_DIR} or with the command line option \texttt{-ssl_portprogram_dir}. The value should be the directory where the \texttt{ssl_esock} port program is located. Note that this option is never needed in a normal Erlang installation.

5.4 Specifying security options and other SSL options

For SSL to work, you either need certificate files or a key file. Certificate files can be specified both when working as client and as server (connecting or accepting).

On the \texttt{erl} command line one can specify options that the ssl distribution will add when creation a socket. It is mandatory to specify at least a key file or client and server certificates. One can specify any SSL option on the command line, but must not specify any socket options (like packet size and such). The SSL options are listed in the Reference Manual. The only difference between the options in the reference manual and the ones that can be specified to the distribution on the command line is that \texttt{certfile} can (and usually needs to) be specified as \texttt{client_certfile} and \texttt{server_certfile}. The \texttt{client_certfile} is used when the distribution initiates a connection to another node and the \texttt{server_certfile} is used when accepting a connection from a remote node.

The command line argument for specifying the SSL options is named \texttt{-ssl_dist_opt} and should be followed by an even number of SSL options/option values. The \texttt{-ssl_dist_opt} argument can be repeated any number of times.

An example command line would now look something like this (line breaks in the command are for readability, they should not be there when typed):

\begin{verbatim}
$ erl -boot /home/me/ssl/start_ssl -ssl_dist_opt
\end{verbatim}
Chapter 5: Using SSL for Erlang Distribution

$ erl -boot /home/me/ssl/start_ssl -proto_dist inet_ssl
   -ssl_dist_opt client_certfile "/home/me/ssl/erlclient.pem"
   -ssl_dist_opt server_certfile "/home/me/ssl/erlserver.pem"
   -ssl_dist_opt verify 1 depth 1
   -sname ssl_test

Erlang (BEAM) emulator version 5.0 [source]

Eshell V5.0 (abort with ^G)
(ssl_test@myhost)1>

A node started in this way will be fully functional, using SSL as the distribution protocol.

5.5 Setting up environment to always use SSL

A convenient way to specify arguments to Erlang is to use the ERL_FLAGS environment variable. All the flags needed to use SSL distribution can be specified in that variable and will then be interpreted as command line arguments for all subsequent invocations of Erlang.

In a Unix (Bourne) shell it could look like this (line breaks for readability):

$ ERL_FLAGS="-boot "/home/me/ssl/start_ssl" -proto_dist inet_ssl
   -ssl_dist_opt client_certfile "/home/me/ssl/erlclient.pem"
   -ssl_dist_opt server_certfile "/home/me/ssl/erlserver.pem"
   -ssl_dist_opt verify 1 -ssl_dist_opt depth 1"
$ export ERL_FLAGS
$ erl -sname ssl_test

Erlang (BEAM) emulator version 5.0 [source]

Eshell V5.0 (abort with ^G)
(ssl_test@myhost)1> init:get_arguments().

[{root, ["/usr/local/erlang"]},
 {progname, ["erl "]},
 {sname, ["ssl_test"]},
 {boot, ["/home/me/ssl/start_ssl"]},
 {proto_dist, ["inet_ssl"]},
 {ssl_dist_opt, ["client_certfile", "/home/me/ssl/erlclient.pem"]},
 {ssl_dist_opt, ["server_certfile", "/home/me/ssl/erlserver.pem"]},
 {ssl_dist_opt, ["verify", "1"]},
 {ssl_dist_opt, ["depth", "1"]},
 {home, ["/home/me"]}]

The init:get_arguments() call verifies that the correct arguments are supplied to the emulator.
Chapter 6

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SSL Reference Manual

Short Summaries

- Application ssl [page 35] - The SSL Application
- Erlang Module ssl [page 37] - Interface Functions for Secure Socket Layer
- Erlang Module ssl_pki [page 46] - Decoding of PKIX certificates with representation in Erlang.

ssl

No functions are exported.

ssl

The following functions are exported:

- accept(ListenSocket) -> {ok, Socket} | {error, Reason} [page 39] Accept an incoming connection request.
- accept(ListenSocket, Timeout) -> {ok, Socket} | {error, Reason} [page 39] Accept an incoming connection request.
- ciphers() -> {ok, string()} | {error, enotstarted} [page 39] Get supported ciphers
- close(Socket) -> ok | {error, Reason} [page 39] Close a socket returned by accept/1/2, connect/3/4, or listen/2.
- connect(Address, Port, Options) -> {ok, Socket} | {error, Reason} [page 40] Connect to Port at Address.
- connect(Address, Port, Options, Timeout) -> {ok, Socket} | {error, Reason} [page 40] Connect to Port at Address.
- connection_info(Socket) -> {ok, {Protocol, Cipher}} | {error, Reason} [page 40] Get current protocol version and cipher.
- controlling_process(Socket, NewOwner) -> ok | {error, Reason} [page 40] Assign a new controlling process to the socket.
- format_error(ErrorCode) -> string() [page 40] Return an error string.
- getopts(Socket, OptionsTags) -> {ok, Options} | {error, Reason} [page 40] Get options set for socket
SSL Application

- `listen(Port, Options) -> {ok, ListenSocket} | {error, Reason}`
  Set up a socket to listen on a port on the local host.
- `peercert(Socket) -> {ok, Cert} | {error, Reason}`
  Return the peer certificate.
- `peercert(Socket, Opts) -> {ok, Cert} | {ok, Subject} | {error, Reason}`
  Return the peer certificate.
- `peername(Socket) -> {ok, {Address, Port}} | {error, Reason}`
  Return peer address and port.
- `pid(Socket) -> pid()`
  Return the pid of the socket process.
- `recv(Socket, Length) -> {ok, Data} | {error, Reason}`
  Receive data on socket.
- `recv(Socket, Length, Timeout) -> {ok, Data} | {error, Reason}`
  Receive data on socket.
- `seed(Data) -> ok | {error, Reason}`
  Seed the ssl random generator.
- `send(Socket, Data) -> ok | {error, Reason}`
  Write data to a socket.
- `setopts(Socket, Options) -> ok | {error, Reason}`
  Set socket options.
- `ssl_accept(Socket) -> ok | {error, Reason}`
  Perform server-side SSL handshake and key exchange.
- `ssl_accept(Socket, Timeout) -> ok | {error, Reason}`
  Perform server-side SSL handshake and key exchange.
- `sockname(Socket) -> {ok, {Address, Port}} | {error, Reason}`
  Return the local address and port.
- `transport_accept(Socket) -> {ok, NewSocket} | {error, Reason}`
  Accept an incoming connection and prepare for ssl_accept.
- `transport_accept(Socket, Timeout) -> {ok, NewSocket} | {error, Reason}`
  Accept an incoming connection and prepare for ssl_accept.
- `version() -> {ok, {SSLVsn, CompVsn, LibVsn}}`
  Return the version of SSL.

ssl_pkix

The following functions are exported:

- `decode_cert(Bin) -> {ok, Cert} | {error, Reason}`
  Decode a PKIX certificate.
- `decode_cert(Bin, Opts) -> {ok, Cert} | {error, Reason}`
  Decode a PKIX certificate.
- `decode_cert_file(File) -> {ok, Cert} | {error, Reason}`
  Decode a PKIX certificate file.
- `decode_cert_file(File, Opts) -> {ok, Cert} | {error, Reason}`
  Decode a PKIX certificate file.
The Secure Socket Layer (SSL) application provides secure socket communication over TCP/IP.

**Warning**

In previous versions of Erlang/OTP SSL it was advised, as a work-around, to set the operating system environment variable `SSL_CERT_FILE` to point at a file containing CA certificates. That variable is no longer needed, and is not recognised by Erlang/OTP SSL any more.

However, the OpenSSL package does interpret that environment variable. Hence a setting of that variable might have unpredictable effects on the Erlang/OTP SSL application. It is therefore advised to not used that environment variable at all.

**Environment**

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

Note that the environment parameters can be set on the command line, for instance,

```
erl ... -ssl protocol_version 'sslv2,sslv3' ...```

- `ephemeral_rsa = true | false <optional>` Enables all SSL servers (those that listen and accept) to use ephemeral RSA key generation when a client connects with weak handshake cipher specifications, that need equally weak ciphers from the server (i.e. obsolete restrictions on export ciphers). Default is `false`.
- `debug = true | false <optional>` Causes debug information to be written to standard output. Default is `false`.
- `debugdir = path() | false <optional>` Causes debug information output controlled by `debug` and `msgdebug` to be printed to a file named `ssl_esock.<pid>.log` in the directory specified by `debugdir`, where `<pid>` is the operating system specific textual representation of the process identifier of the external port program of the SSL application. Default is `false`, i.e. no log file is produced.
- `msgdebug = true | false <optional>` Sets `debug = true` and causes also the contents of low level messages to be printed to standard output. Default is `false`.
- `port_program = string() | false <optional>` Name of port program. The default is `ssl_esock`. 

SSL Application
protocol_version = [sslv2|sslv3|tlsv1] <optional>. Name of protocols to use. If this option is not set, all protocols are assumed, i.e. the default value is [sslv2, sslv3, tlsv1].

proxylsport = integer() | false <optional> Define the port number of the listen port of the SSL port program. Almost never is this option needed.

proxylsbacklog = integer() | false <optional> Set the listen queue size of the listen port of the SSL port program. The default is 128.

OpenSSL libraries

The current implementation of the Erlang SSL 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 OpenSSL1 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 OpenSSL2 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 libraries libcrypto.so and libssl.so (Unix), or the libraries libeay32.dll and ssleay32.dll (Win32).

For Unix The ssl_esock port program 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 SSL.priv/obj directory, should be used as a guide to relinking the final version of the port program.

For Win32 it is only required that the libraries 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.

Restrictions

Users must be aware of export restrictions and patent rights concerning cryptographic software.

SEE ALSO

application(3)

---

1URL: http://www.openssl.org
2URL: http://www.shininglightpro.com/search.php?searchname=Win32+OpenSSL
This module contains interface functions to the Secure Socket Layer.

**General**

The reader is advised to also read the `ssl(6)` manual page describing the SSL application.

**Warning:**
It is strongly advised to seed the random generator after the ssl application has been started (see `seed/1` below), and before any connections are established. Although the port program interfacing to the ssl libraries does a “random” seeding of its own in order to make everything work properly, that seeding is by no means random for the world since it has a constant value which is known to everyone reading the source code of the port program.

**Common data types**

The following datatypes are used in the functions below:

- `options() = [option()]`
- `option() = socketoption() | ssloption()`
- `socketoption() = {mode, list} | {mode, binary} | binary | {packet, packettype()} | {header, integer()} | {nodelay, boolean()} | {active, activetype()} | {backlog, integer()} | {ip, ipaddress()} | {port, integer()}
- `ssloption() = {verify, code()} | {depth, depth()} | {certfile, path()} | {keyfile, path()} | {password, string()} | {cacertfile, path()} | {ciphers, string()}
- `packettype()` (see `inet(3)``
- `activetype()` (see `inet(3)``
- `reason() = atom() | {atom(), string()``
- `bytes() = [byte()]`
- `string() = [byte()]`
- `byte() = 0 | 1 | 2 | ... | 255`
- `code() = 0 | 1 | 2`
- `depth() = byte()`
- `address() = hostname() | ipstring() | ipaddress()`
- `ipaddress() = ipstring() | iptuple()`
- `hostname() = string()`
- `ipstring() = string()`
- `iptuple() = {byte(), byte(), byte(), byte()}
- `sslsocket()`
- `protocol() = sslv2 | sslv3 | tlsv1`

The socket option `{backlog, integer()}` is for `listen/2` only, and the option `{port, integer()}` is for `connect/3/4` only.

The following socket options are set by default: `{mode, list},{packet, 0},{header, 0},{nodelay, false},{active, true},{backlog, 5},{ip, {0,0,0,0}},{port, 0}`.

Note that the options `{mode, binary}` and `{binary}` are equivalent. Similarly `{mode, list}` and the absence of option `{binary}` are equivalent.

The `ssl` options are for setting specific SSL parameters as follows:

- `{verify, code()}` Specifies type of verification: 0 = do not verify peer; 1 = verify peer, 2 = verify peer, fail if no peer certificate. The default value is 0.
- `{depth, depth()}` Specifies the maximum verification depth, i.e. how far in a chain of certificates the verification process can proceed before the verification is considered to fail. Peer certificate = 0, CA certificate = 1, higher level CA certificate = 2, etc. The value 2 thus means that a chain can at most contain peer cert, CA cert, next CA cert, and an additional CA cert. The default value is 1.
- `{certfile, path()}` Path to a file containing the user’s certificate. chain of PEM encoded certificates.
- `{keyfile, path()}` Path to file containing user’s private PEM encoded key.
- `{password, string()}` String containing the user’s password. Only used if the private keyfile is password protected.
- `{cacertfile, path()}` Path to file containing PEM encoded CA certificates (trusted certificates used for verifying a peer certificate).
- `{ciphers, string()}` String of ciphers as a colon separated list of ciphers. The function `ciphers/0` can be used to find all available ciphers.

The type `sslsocket()` is opaque to the user.

The owner of a socket is the one that created it by a call to `transport_accept` (or `accept/1`), `connect/3/4/`, or `listen/2`.

When a socket is in active mode (the default), data from the socket is delivered to the owner of the socket in the form of messages:

- `{ssl, Socket, Data}`
- `{ssl_closed, Socket}`
- {ssl_error, Socket, Reason}

A Timeout argument specifies a timeout in milliseconds. The default value for a Timeout argument is infinity.

Functions listed below may return the value {error, closed}, which only indicates that the SSL socket is considered closed for the operation in question. It is for instance possible to have {error, closed} returned from an call to `send/2`, and a subsequent call to `recv/3` returning {ok, Data}.

Hence a return value of {error, closed} must not be interpreted as if the socket was completely closed. On the contrary, in order to free all resources occupied by an SSL socket, `close/1` must be called, or else the process owning the socket has to terminate.

For each SSL socket there is an Erlang process representing the socket. When a socket is opened, that process links to the calling client process. Implementations that want to detect abnormal exits from the socket process by receiving `{EXIT', Pid, Reason}` messages, should use the function `pid/1` to retrieve the process identifier from the socket, in order to be able to match exit messages properly.

### Exports

```erlang
accept(ListenSocket) -> {ok, Socket} | {error, Reason}
accept(ListenSocket, Timeout) -> {ok, Socket} | {error, Reason}
```

Types:

- `ListenSocket = Socket = sslsocket()`
- `Timeout = integer()`

Accepts an incoming connection request on a listen socket. `ListenSocket` must be a socket returned from `listen/2`.

The accepted socket inherits the options set for `ListenSocket` in `listen/2`.

The default value for `Timeout` is infinity. If `Timeout` is specified, and no connection is accepted within the given time, `{error, timeout}` is returned.

**Warning:**

This call is obsolete and should be avoided. It calls both the unix system call `accept` and the SSL call `SSL_accept`. The latter can take time, and if a non-SSL client is connected to the socket, it can hang the server. A server using `ssl:accept` should use the two calls `transport:accept` and `ssl:accept` instead. For documentation of these, see below.

```erlang
ciphers() -> {ok, string()} | {error, enotstarted}
```

Returns a string consisting of colon separated cipher designations that are supported by the current SSL library implementation.

The SSL application has to be started to return the string of ciphers.

```erlang
close(Socket) -> ok | {error, Reason}
```
Types:
- **Socket** = sslsocket()

Closes a socket returned by `accept/1/2`, `connect/3/4`, or `listen/2`.

```erlang
connect(Address, Port, Options) -> {ok, Socket} | {error, Reason}
connect(Address, Port, Options, Timeout) -> {ok, Socket} | {error, Reason}
```

Types:
- **Address** = address()
- **Port** = integer()
- **Options** = [{connect_option()}]

**connect_option()** = 
- `mode`, list
- `mode`, binary
- `binary`
- `packet`, packettype()
- `header`, integer()
- `nodelay`, boolean()
- `active`, activetype()
- `ip`, ipaddress()
- `port`, integer()
- `verify`, code()
- `depth`, depth()
- `certfile`, path()
- `keyfile`, path()
- `password`, string()
- `cacertfile`, path()
- `ciphers`, string()
- `timeout`
- **Socket** = sslsocket()

Connects to `Port` at `Address`. If the optional `Timeout` argument is specified, and a connection could not be established within the given time, `{error, reason}` is returned. The default value for `Timeout` is infinity.

The `ip` and `port` options are for binding to a particular local address and port, respectively.

```erlang
connection_info(Socket) -> {ok, [Protocol, Cipher]} | {error, Reason}
```

Types:
- **Socket** = sslsocket()
- **Protocol** = protocol()
- **Cipher** = string()

Gets the chosen protocol version and cipher for an established connection (accepted or connected).

```erlang
controlling_process(Socket, NewOwner) -> ok | {error, Reason}
```

Types:
- **Socket** = sslsocket()
- **NewOwner** = pid()

Assigns a new controlling process to `Socket`. A controlling process is the owner of a socket, and receives all messages from the socket.

```erlang
format_error(ErrorCode) -> string()
```

Types:
- **ErrorCode** = term()

Returns a diagnostic string describing an error.

```erlang
getopts(Socket, OptionsTags) -> {ok, Options} | {error, Reason}
```

Types:
SSL Reference Manual

- Socket = sslsocket()
- OptionTags = [optiontag()]()

Returns the options the tags of which are OptionTags for the socket Socket.

listen(Port, Options) -> {ok, ListenSocket} | {error, Reason}

Types:
- Port = integer()
- Options = [listen_option()]
- listen_option() = {mode, list} | {mode, binary} | binary | {packet, packettype()} | {header, integer()} | {active, activetype()} | {backlog, integer()} | {ip, ipaddress()} | {verify, code()} | {depth, depth()} | {certfile, path()} | {keyfile, path()} | {password, string()} | {cacertfile, path()} | {ciphers, string()}
- ListenSocket = sslsocket()

Sets up a socket to listen on port Port at the local host. If Port is zero, listen/2 picks an available port number (use port/1 to retrieve it).

The listen queue size defaults to 5. If a different value is wanted, the option {backlog, Size} should be added to the list of options.

An empty Options list is considered an error, and {error, enooptions} is returned.

The returned ListenSocket can only be used in calls to accept/1/2.

peercert(Socket) ->
peercert(Socket, Opts) -> {ok, Cert} | {ok, Subject} | {error, Reason}

Types:
- Socket = sslsocket()
- Opts = [pkix | ssl | subject]()
- Cert = term()()
- Subject = term()()

peercert(Cert) is equivalent to peercert(Cert, []).

The form of the returned certificate depends on the options.

If the options list is empty the certificate is returned as a DER encoded binary.

The options pkix and ssl implies that the certificate is returned as a parsed ASN.1 structure in the form of an Erlang term.

The ssl option gives a more elaborate return structure, with more explicit information. In particular object identifiers are replaced by atoms.

The options pkix, and ssl are mutually exclusive.

The option subject implies that only the subject’s distinguished name part of the peer certificate is returned. It can only be used together with the option pkix or the option ssl.

peername(Socket) -> {ok, {Address, Port}} | {error, Reason}

Types:
- Socket = sslsocket()
- Address = ipaddress()
- Port = integer()
Returns the address and port number of the peer.

\[ \text{pid(Socket)} \rightarrow \text{pid()} \]

Types:
- \( \text{Socket} = \text{sslsocket()} \)
Returns the pid of the socket process. The returned pid should only be used for receiving exit messages.

\[ \text{recv(Socket, Length)} \rightarrow \{\text{ok, Data} \} | \{\text{error, Reason} \} \]
\[ \text{recv(Socket, Length, Timeout)} \rightarrow \{\text{ok, Data} \} | \{\text{error, Reason} \} \]

Types:
- \( \text{Socket} = \text{sslsocket()} \)
- \( \text{Length} = \text{integer()} \geq 0 \)
- \( \text{Timeout} = \text{integer()} \)
- \( \text{Data} = \text{bytes()} | \text{binary()} \)
Receives data on socket \( \text{Socket} \) when the socket is in passive mode, i.e. when the option \{\text{active, false} \} has been specified.
A notable return value is \{\text{error, closed} \} which indicates that the socket is closed.
A positive value of the \( \text{Length} \) argument is only valid when the socket is in raw mode (option \{\text{packet, 0} \} is set, and the option \text{binary} is not set); otherwise it should be set to 0, whence all available bytes are returned.
If the optional \( \text{Timeout} \) parameter is specified, and no data was available within the given time, \{\text{error, timeout} \} is returned. The default value for \( \text{Timeout} \) is \text{infinity}.

\[ \text{seed(Data)} \rightarrow \text{ok} | \{\text{error, Reason} \} \]

Types:
- \( \text{Data} = \text{iolist()} | \text{binary()} \)
Seeds the ssl random generator.
It is strongly advised to seed the random generator after the ssl application has been started, and before any connections are established. Although the port program interfacing to the OpenSSL libraries does a “random” seeding of its own in order to make everything work properly, that seeding is by no means random for the world since it has a constant value which is known to everyone reading the source code of the seeding.
A notable return value is \{\text{error, edata} \} indicating that \( \text{Data} \) was not a binary nor an iolist.

\[ \text{send(Socket, Data)} \rightarrow \text{ok} | \{\text{error, Reason} \} \]

Types:
- \( \text{Socket} = \text{sslsocket()} \)
- \( \text{Data} = \text{iolist()} | \text{binary()} \)
Writes \( \text{Data} \) to \( \text{Socket} \).
A notable return value is \{\text{error, closed} \} indicating that the socket is closed.
setopts(Socket, Options) -> ok | {error, Reason}

Types:
- Socket = sslsocket()
- Options = [socketoption]() Sets options according to Options for the socket Socket.

ssl_accept(Socket) -> ok | {error, Reason}
ssl_accept(Socket, Timeout) -> ok | {error, Reason}

Types:
- Socket = sslsocket()
- Timeout = integer()
- Reason = atom()

The ssl_accept function establish the SSL connection on the server side. It should be called directly after transport_accept, in the spawned server-loop.

Note that the ssl connection is not complete until ssl_accept has returned true, and if an error is returned, the socket is unavailable and for instance close/1 will crash.

sockname(Socket) -> {ok, {Address, Port}} | {error, Reason}

Types:
- Socket = sslsocket()
- Address = ipaddress()
- Port = integer()

Returns the local address and port number of the socket Socket.

transport_accept(Socket) -> {ok, NewSocket} | {error, Reason}
transport_accept(Socket, Timeout) -> {ok, NewSocket} | {error, Reason}

Types:
- Socket = NewSocket = sslsocket()
- Timeout = integer()
- Reason = atom()

Accepts an incoming connection request on a listen socket. ListenSocket must be a socket returned from listen/2. The socket returned should be passed to ssl_accept to complete ssl handshaking and establishing the connection.

**Warning:**
The socket returned can only be used with ssl_accept, no traffic can be sent or received before that call.

The accepted socket inherits the options set for ListenSocket in listen/2.

The default value for Timeout is infinity. If Timeout is specified, and no connection is accepted within the given time, {error, timeout} is returned.

version() -> {ok, {SSLVsn, CompVsn, LibVsn}}
Types:
- SSLVsn = CompVsn = LibVsn = string()

Returns the SSL application version (SSLVsn), the library version used when compiling the SSL application port program (CompVsn), and the actual library version used when dynamically linking in runtime (LibVsn).

If the SSL application has not been started, CompVsn and LibVsn are empty strings.

**ERRORS**

The possible error reasons and the corresponding diagnostic strings returned by format_error/1 are either the same as those defined in the inet(3) reference manual, or as follows:

- closed: Connection closed for the operation in question.
- ebadsocket: Connection not found (internal error).
- ebadstate: Connection not in connect state (internal error).
- ebrotkertype: Wrong broker type (internal error).
- ecacertfile: Own CA certificate file is invalid.
- ecertfile: Own certificate file is invalid.
- echaintoolong: The chain of certificates provided by peer is too long.
- ecipher: Own list of specified ciphers is invalid.
- ekeyfile: Own private key file is invalid.
- ekeymismatch: Own private key does not match own certificate.
- enoissuercert: Cannot find certificate of issuer of certificate provided by peer.
- enoservercert: Attempt to do accept without having set own certificate.
- enotlistener: Attempt to accept on a non-listening socket.
- enoproxysocket: No proxy socket found (internal error).
- enooptions: The list of options is empty.
- enotstarted: The SSL application has not been started.
- eoptions: Invalid list of options.
- epeercert: Certificate provided by peer is in error.
- epeercertexpired: Certificate provided by peer has expired.
- epeercertinvalid: Certificate provided by peer is invalid.
- eselfsignedcert: Certificate provided by peer is self signed.
- esslaccept: Server SSL handshake procedure between client and server failed.
- esslconnect: Client SSL handshake procedure between client and server failed.
- esslerrssl: SSL protocol failure. Typically because of a fatal alert from peer.
- ewantconnect: Protocol wants to connect, which is not supported in this version of the SSL application.
- ex509lookup: Protocol wants X.509 lookup, which is not supported in this version of the SSL application.

{badcall, Call}: Call not recognized for current mode (active or passive) and state of socket.
{badcast, Cast} Call not recognized for current mode (active or passive) and state of socket.
{badinfo, Info} Call not recognized for current mode (active or passive) and state of socket.

SEE ALSO

gen_tcp(3), inet(3)
This module provides decoding of PKIX certificates either provided as files or as binaries.

Exports

\[
\text{decode_cert(Bin)} \rightarrow \{\text{ok, Cert}\} \mid \{\text{error, Reason}\}
\]

\[
\text{decode_cert(Bin, Opts)} \rightarrow \{\text{ok, Cert}\} \mid \{\text{error, Reason}\}
\]

Types:
- \(\text{Bin} = \text{binary}()\)
- \(\text{Opts} = [\text{pkix} | \text{ssl} | \text{subject}]\)
- \(\text{Cert} = \text{term}()\)

\text{decode_cert(Bin)} \text{ is equivalent to } \text{decode_cert(Bin, [])}.

The form of the returned certificate depends on the options.

- If the options list is empty the certificate is returned as a DER encoded binary, i.e. \(\{\text{ok, Bin}\}\) is returned, where \(\text{Bin}\) is the provided input.
- The options \text{pkix} and \text{ssl} imply that the certificate is returned as a parsed ASN.1 structure in the form of an Erlang term.
- The \text{ssl} option gives a more elaborate return structure, with more explicit information.
  In particular object identifiers are replaced by atoms.
- The options \text{pkix}, and \text{ssl} are mutually exclusive.
- The option \text{subject} implies that only the subject’s distinguished name part of the certificate is returned. It can only be used together with the option \text{pkix} or the option \text{ssl}.

\[
\text{decode_cert_file(File)} \rightarrow \{\text{ok, Cert}\} \mid \{\text{error, Reason}\}
\]

\[
\text{decode_cert_file(File, Opts)} \rightarrow \{\text{ok, Cert}\} \mid \{\text{error, Reason}\}
\]

Types:
- \(\text{File} = \text{path}()\)
- \(\text{Opts} = [\text{pem} | \text{pkix} | \text{ssl} | \text{subject}]\)
- \(\text{Cert} = \text{term}()\)
decode_cert_file(File) is equivalent to decode_cert_file(File, []). The form of the returned certificate depends on the options. If the options list is empty the certificate is returned as a DER encoded binary, i.e. the contents of the input File is returned as a binary. The options pkix and ssl implies that the certificate is returned as a parsed ASN.1 structure in the form of an Erlang term. The ssl option gives a more elaborate return structure, with more explicit information. In particular object identifiers are replaced by atoms. The options pkix, and ssl are mutually exclusive. The option subject implies that only the subject’s distinguished name part of the peer certificate is returned. It can only be used together with the option pkix or the option ssl.
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