

This document includes text contributed by Nikos Mavrogiannopoulos, Simon Josefsson, Daiki Ueno, Carolin Latze, Alfredo Pironti, Ted Zlatanov and Andrew McDonald. Several corrections are due to Patrick Pelletier and Andreas Metzler.

ISBN 978-1-326-00266-4

Copyright © 2001-2015 Free Software Foundation, Inc.

Copyright © 2001-2015 Nikos Mavrogiannopoulos

Permission is granted to copy, distribute and/or modify this document under the terms of the GNU Free Documentation License, Version 1.3 or any later version published by the Free Software Foundation; with no Invariant Sections, no Front-Cover Texts, and no Back-Cover Texts. A copy of the license is included in the section entitled “GNU Free Documentation License”.



Contents

List of Tables

List of Figures

Preface

This document demonstrates and explains the GnuTLS library API. A brief introduction to the protocols and the technology involved is also included so that an application programmer can better understand the GnuTLS purpose and actual offerings. Even if GnuTLS is a typical library software, it operates over several security and cryptographic protocols which require the programmer to make careful and correct usage of them. Otherwise it is likely to only obtain a false sense of security. The term of security is very broad even if restricted to computer software, and cannot be confined to a single cryptographic library. For that reason, do not consider any program secure just because it uses GnuTLS; there are several ways to compromise a program or a communication line and GnuTLS only helps with some of them.

Although this document tries to be self contained, basic network programming and public key infrastructure (PKI) knowledge is assumed in most of it. A good introduction to networking can be found in [?], to public key infrastructure in [?] and to security engineering in [?].

Updated versions of the GnuTLS software and this document will be available from <http://www.gnutls.org/>.

1

Introduction to GnuTLS

In brief GnuTLS can be described as a library which offers an API to access secure communication protocols. These protocols provide privacy over insecure lines, and were designed to prevent eavesdropping, tampering, or message forgery.

Technically GnuTLS is a portable ANSI C based library which implements the protocols ranging from SSL 3.0 to TLS 1.2 (see ??, for a detailed description of the protocols), accompanied with the required framework for authentication and public key infrastructure. Important features of the GnuTLS library include:

- Support for TLS 1.2, TLS 1.1, TLS 1.0 and SSL 3.0 protocols.
- Support for Datagram TLS 1.0 and 1.2.
- Support for handling and verification of X.509 and OpenPGP certificates.
- Support for password authentication using TLS-SRP.
- Support for keyed authentication using TLS-PSK.
- Support for TPM, PKCS #11 tokens and smart-cards.

The GnuTLS library consists of three independent parts, namely the “TLS protocol part”, the “Certificate part”, and the “Cryptographic back-end” part. The “TLS protocol part” is the actual protocol implementation, and is entirely implemented within the GnuTLS library. The “Certificate part” consists of the certificate parsing, and verification functions and it uses functionality from the libtasn1 library. The “Cryptographic back-end” is provided by the nettle and gmp libraries.

1.1 Downloading and installing

GnuTLS is available for download at: <http://www.gnutls.org/download.html>

GnuTLS uses a development cycle where even minor version numbers indicate a stable release and an odd minor version number indicates a development release. For example, GnuTLS 1.6.3 denotes a stable release since 6 is even, and GnuTLS 1.7.11 denotes a development release since 7 is odd.

GnuTLS depends on `nettle` and `gmp`, and you will need to install it before installing GnuTLS. The `nettle` library is available from <http://www.lysator.liu.se/~nisse/nettle/>, while `gmp` is available from <http://www.gmp.org/>. Don't forget to verify the cryptographic signature after downloading source code packages.

The package is then extracted, configured and built like many other packages that use Autoconf. For detailed information on configuring and building it, refer to the "INSTALL" file that is part of the distribution archive. Typically you invoke `./configure` and then `make check install`. There are a number of compile-time parameters, as discussed below.

Several parts of GnuTLS require ASN.1 functionality, which is provided by a library called `libtasn1`. A copy of `libtasn1` is included in GnuTLS. If you want to install it separately (e.g., to make it possible to use `libtasn1` in other programs), you can get it from <http://www.gnu.org/software/libtasn1/>.

The compression library, `libz`, the PKCS #11 helper library `p11-kit`, the TPM library `trousers`, as well as the IDN library `libidn`¹ are optional dependencies. Check the README file in the distribution on how to obtain these libraries.

A few `configure` options may be relevant, summarized below. They disable or enable particular features, to create a smaller library with only the required features. Note however, that although a smaller library is generated, the included programs are not guaranteed to compile if some of these options are given.

```
--disable-srp-authentication
--disable-psk-authentication
--disable-anon-authentication
--disable-openpgp-authentication
--disable-dhe
--disable-ecdh
--disable-openssl-compatibility
--disable-dtls-srtp-support
--disable-alpn-support
--disable-heartbeat-support
--disable-libdane
--without-p11-kit
--without-tpm
--without-zlib
```

¹Needed to use RFC6125 name comparison in internationalized domains.

For the complete list, refer to the output from `configure --help`.

1.2 Installing for a software distribution

When installing for a software distribution, it is often desirable to preconfigure GnuTLS with the system-wide paths and files. There two important configuration options, one sets the trust store in system, which are the CA certificates to be used by programs by default (if they don't override it), and the other sets to DNSSEC root key file used by unbound for DNSSEC verification.

For the latter the following configuration option is available, and if not specified GnuTLS will try to auto-detect the location of that file.

`--with-unbound-root-key-file`

To set the trust store the following options are available.

`--with-default-trust-store-file`

`--with-default-trust-store-dir`

`--with-default-trust-store-pkcs11`

The first option is used to set a PEM file which contains a list of trusted certificates, while the second will read all certificates in the given path. The recommended option is the last, which allows to use a PKCS #11 trust policy module. That module not only provides the trusted certificates, but allows the categorization of them using purpose, e.g., CAs can be restricted for e-mail usage only, or administrative restrictions of CAs, for examples by restricting a CA to only issue certificates for a given DNS domain using NameConstraints. A publicly available PKCS #11 trust module is p11-kit's trust module².

1.3 Overview

In this document we present an overview of the supported security protocols in ??, and continue by providing more information on the certificate authentication in ??, and shared-key as well anonymous authentication in ?. We elaborate on certificate authentication by demonstrating advanced usage of the API in ?. The core of the TLS library is presented in ? and example applications are listed in ?. In ? the usage of few included programs that may assist debugging is presented. The last chapter is ? that provides a short introduction to GnuTLS' internal architecture.

²<http://p11-glue.freedesktop.org/doc/p11-kit/trust-module.html>

2

Introduction to TLS and DTLS

TLS stands for “Transport Layer Security” and is the successor of SSL, the Secure Sockets Layer protocol [?] designed by Netscape. TLS is an Internet protocol, defined by IETF¹, described in [?]. The protocol provides confidentiality, and authentication layers over any reliable transport layer. The description, above, refers to TLS 1.0 but applies to all other TLS versions as the differences between the protocols are not major.

The DTLS protocol, or “Datagram TLS” [?] is a protocol with identical goals as TLS, but can operate under unreliable transport layers such as UDP. The discussions below apply to this protocol as well, except when noted otherwise.

2.1 TLS layers

TLS is a layered protocol, and consists of the record protocol, the handshake protocol and the alert protocol. The record protocol is to serve all other protocols and is above the transport layer. The record protocol offers symmetric encryption, data authenticity, and optionally compression. The alert protocol offers some signaling to the other protocols. It can help informing the peer for the cause of failures and other error conditions. ??, for more information. The alert protocol is above the record protocol.

The handshake protocol is responsible for the security parameters’ negotiation, the initial key exchange and authentication. ??, for more information about the handshake protocol. The

¹IETF, or Internet Engineering Task Force, is a large open international community of network designers, operators, vendors, and researchers concerned with the evolution of the Internet architecture and the smooth operation of the Internet. It is open to any interested individual.

protocol layering in TLS is shown in ??.

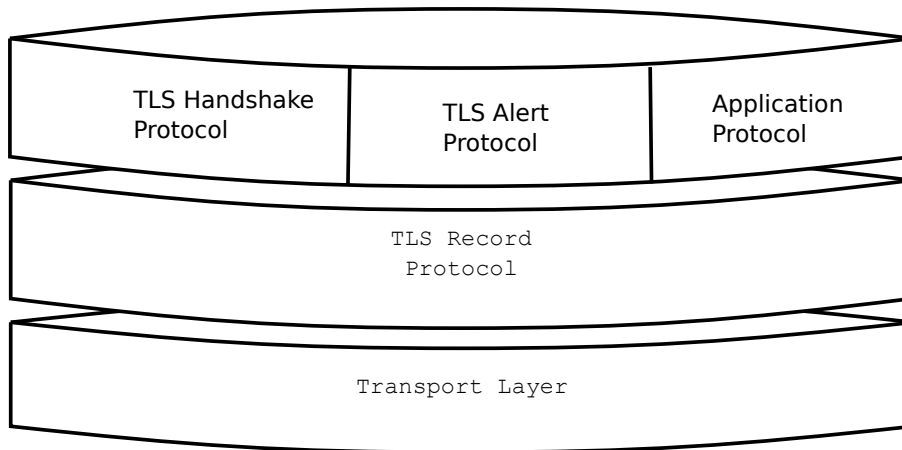


Figure 2.1: The TLS protocol layers.

2.2 The transport layer

TLS is not limited to any transport layer and can be used above any transport layer, as long as it is a reliable one. DTLS can be used over reliable and unreliable transport layers. GnuTLS supports TCP and UDP layers transparently using the Berkeley sockets API. However, any transport layer can be used by providing callbacks for GnuTLS to access the transport layer (for details see ??).

2.3 The TLS record protocol

The record protocol is the secure communications provider. Its purpose is to encrypt, authenticate and —optionally— compress packets. The record layer functions can be called at any time after the handshake process is finished, when there is need to receive or send data. In DTLS however, due to re-transmission timers used in the handshake out-of-order handshake data might be received for some time (maximum 60 seconds) after the handshake process is finished.

The functions to access the record protocol are limited to send and receive functions, which might, given the importance of this protocol in TLS, seem awkward. This is because the record protocol's parameters are all set by the handshake protocol. The record protocol initially starts with NULL parameters, which means no encryption, and no MAC is used. Encryption and authentication begin just after the handshake protocol has finished.

2.3.1 Encryption algorithms used in the record layer

Confidentiality in the record layer is achieved by using symmetric block encryption algorithms like 3DES, AES or stream algorithms like ARCFOUR_128. Ciphers are encryption algorithms that use a single, secret, key to encrypt and decrypt data. Block algorithms in CBC mode also provide protection against statistical analysis of the data. Thus, if you're using the TLS protocol, a random number of blocks will be appended to data, to prevent eavesdroppers from guessing the actual data size.

The supported in GnuTLS ciphers and MAC algorithms are shown in ?? and ??.

Algorithm	Description
AES_CBC	AES or RIJNDAEL is the block cipher algorithm that replaces the old DES algorithm. Has 128 bits block size and is used in CBC mode.
AES_GCM	This is the AES algorithm in the authenticated encryption GCM mode. This mode combines message authentication and encryption and can be extremely fast on CPUs that support hardware acceleration.
AES_CCM	This is the AES algorithm in the authenticated encryption CCM mode. This mode combines message authentication and encryption and is often used by systems without AES or GCM acceleration support.
AES_CCM_8	This is the AES algorithm in the authenticated encryption CCM mode with a truncated to 64-bit authentication tag. This mode is for communication with restricted systems.
CAMELLIA_CBC	This is an 128-bit block cipher developed by Mitsubishi and NTT. It is one of the approved ciphers of the European NESSIE and Japanese CRYPTREC projects.
CHACHA20_-POLY1305	CHACHA20-POLY1305 is an authenticated encryption algorithm based on CHACHA20 cipher and POLY1305 MAC. CHACHA20 is a refinement of SALSA20 algorithm, an approved cipher by the European ESTREAM project. POLY1305 is Wegman-Carter, one-time authenticator. The combination provides a fast stream cipher suitable for systems where a hardware AES accelerator is not available.
3DES_CBC	This is the DES block cipher algorithm used with triple encryption (EDE). Has 64 bits block size and is used in CBC mode.
ARCFOUR_128	ARCFOUR-128 is a compatible algorithm with RSA's RC4 algorithm, which is considered to be a trade secret. It is a fast cipher but considered weak today, and thus it is not enabled by default.

Table 2.1: Supported ciphers.

Algorithm	Description
MAC_MD5	This is an HMAC based on MD5 a cryptographic hash algorithm designed by Ron Rivest. Outputs 128 bits of data.
MAC_SHA1	An HMAC based on the SHA1 cryptographic hash algorithm designed by NSA. Outputs 160 bits of data.
MAC_SHA256	An HMAC based on SHA256. Outputs 256 bits of data.
MAC_AEAD	This indicates that an authenticated encryption algorithm, such as GCM, is in use.

Table 2.2: Supported MAC algorithms.

2.3.2 Compression algorithms used in the record layer

The TLS record layer also supports compression. The algorithms implemented in GnuTLS can be found in the table below. The included algorithms perform really good when text, or other compressible data are to be transferred, but offer nothing on already compressed data, such as compressed images, zipped archives etc. These compression algorithms, may be useful in high bandwidth TLS tunnels, and in cases where network usage has to be minimized. It should be noted however that compression increases latency.

The record layer compression in GnuTLS is implemented based on [?]. The supported algorithms are shown below.

```
enum gnutls_compression_method_t:
    GNUTLS_COMP_UNKNOWN           Unknown compression method.
    GNUTLS_COMP_NULL              The NULL compression method (no compression).
    GNUTLS_COMP_DEFLATE           The DEFLATE compression method from zlib.
    GNUTLS_COMP_ZLIB              Same as GNUTLS_COMP_DEFLATE.
```

Table 2.3: Supported compression algorithms

Note that compression enables attacks such as traffic analysis, or even plaintext recovery under certain circumstances. To avoid some of these attacks GnuTLS allows each record to be compressed independently (i.e., stateless compression), by using the "%STATELESS_COMPRESSION" priority string, in order to be used in cases where the attacker controlled data are pt in separate records.

2.3.3 Weaknesses and countermeasures

Some weaknesses that may affect the security of the record layer have been found in TLS 1.0 protocol. These weaknesses can be exploited by active attackers, and exploit the facts that

1. TLS has separate alerts for "decryption_failed" and "bad_record_mac"

2. The decryption failure reason can be detected by timing the response time.
3. The IV for CBC encrypted packets is the last block of the previous encrypted packet.

Those weaknesses were solved in TLS 1.1 [?] which is implemented in GnuTLS. For this reason we suggest to always negotiate the highest supported TLS version with the peer². For a detailed discussion of the issues see the archives of the TLS Working Group mailing list and [?].

2.3.4 On record padding

The TLS protocol allows for extra padding of records in CBC ciphers, to prevent statistical analysis based on the length of exchanged messages (see [?] section 6.2.3.2). GnuTLS appears to be one of few implementations that take advantage of this feature: the user can provide some plaintext data with a range of lengths she wishes to hide, and GnuTLS adds extra padding to make sure the attacker cannot tell the real plaintext length is in a range smaller than the user-provided one. Use `gnutls_record_send_range` to send length-hidden messages and `gnutls_record_can_use_length_hiding` to check whether the current session supports length hiding. Using the standard `gnutls_record_send` will only add minimal padding.

The TLS implementation in the Symbian operating system, frequently used by Nokia and Sony-Ericsson mobile phones, cannot handle non-minimal record padding. What happens when one of these clients handshake with a GnuTLS server is that the client will fail to compute the correct MAC for the record. The client sends a TLS alert (`bad_record_mac`) and disconnects. Typically this will result in error messages such as 'A TLS fatal alert has been received', 'Bad record MAC', or both, on the GnuTLS server side.

If compatibility with such devices is a concern, not sending length-hidden messages solves the problem by using minimal padding.

If you implement an application that has a configuration file, we recommend that you make it possible for users or administrators to specify a GnuTLS protocol priority string, which is used by your application via `gnutls_priority_set`. To allow the best flexibility, make it possible to have a different priority string for different incoming IP addresses.

2.4 The TLS alert protocol

The alert protocol is there to allow signals to be sent between peers. These signals are mostly used to inform the peer about the cause of a protocol failure. Some of these signals are used internally by the protocol and the application protocol does not have to cope with them (e.g. `GNUTLS_A_CLOSE_NOTIFY`), and others refer to the application protocol solely (e.g. `GNUTLS_A_USER_CANCELLED`). An alert signal includes a level indication which may be either fatal or warning. Fatal alerts always terminate the current connection, and prevent future re-negotiations using the current session ID. All alert messages are summarized in the table below.

²If this is not possible then please consult ??.

The alert messages are protected by the record protocol, thus the information that is included does not leak. You must take extreme care for the alert information not to leak to a possible attacker, via public log files etc.

Alert	ID	Description
GNUTLS_A_CLOSE_NOTIFY	0	Close notify
GNUTLS_A_UNEXPECTED_MESSAGE	10	Unexpected message
GNUTLS_A_BAD_RECORD_MAC	20	Bad record MAC
GNUTLS_A_DECRYPTION_FAILED	21	Decryption failed
GNUTLS_A_RECORD_OVERFLOW	22	Record overflow
GNUTLS_A_DECOMPRESSION_FAILURE	30	Decompression failed
GNUTLS_A_HANDSHAKE_FAILURE	40	Handshake failed
GNUTLS_A_SSL3_NO_CERTIFICATE	41	No certificate (SSL 3.0)
GNUTLS_A_BAD_CERTIFICATE	42	Certificate is bad
GNUTLS_A_UNSUPPORTED_CERTIFICATE	43	Certificate is not supported
GNUTLS_A_CERTIFICATE_REVOKED	44	Certificate was revoked
GNUTLS_A_CERTIFICATE_EXPIRED	45	Certificate is expired
GNUTLS_A_CERTIFICATE_UNKNOWN	46	Unknown certificate
GNUTLS_A_ILLEGAL_PARAMETER	47	Illegal parameter
GNUTLS_A_UNKNOWN_CA	48	CA is unknown
GNUTLS_A_ACCESS_DENIED	49	Access was denied
GNUTLS_A_DECODE_ERROR	50	Decode error
GNUTLS_A_DECRYPT_ERROR	51	Decrypt error
GNUTLS_A_EXPORT_RESTRICTION	60	Export restriction
GNUTLS_A_PROTOCOL_VERSION	70	Error in protocol version
GNUTLS_A_INSUFFICIENT_SECURITY	71	Insufficient security
GNUTLS_A_INTERNAL_ERROR	80	Internal error
GNUTLS_A_USER_CANCELED	90	User canceled
GNUTLS_A_NO_RENEGOTIATION	100	No renegotiation is allowed
GNUTLS_A_UNSUPPORTED_EXTENSION	110	An unsupported extension was sent
GNUTLS_A_CERTIFICATE_UNOBTAINABLE	111	Could not retrieve the specified certificate
GNUTLS_A_UNRECOGNIZED_NAME	112	The server name sent was not recognized
GNUTLS_A_UNKNOWN_PSK_IDENTITY	115	The SRP/PSK username is missing or not known
GNUTLS_A_NO_APPLICATION_PROTOCOL	120	No supported application protocol could be negotiated

Table 2.4: The TLS alert table

2.5 The TLS handshake protocol

The handshake protocol is responsible for the ciphersuite negotiation, the initial key exchange, and the authentication of the two peers. This is fully controlled by the application layer, thus your program has to set up the required parameters. The main handshake function is `gnutls_handshake`. In the next paragraphs we elaborate on the handshake protocol, i.e., the ciphersuite negotiation.

2.5.1 TLS ciphersuites

The handshake protocol of TLS negotiates cipher suites of a special form illustrated by the `TLS_DHE_RSA_WITH_3DES_CBC_SHA` cipher suite name. A typical cipher suite contains these parameters:

- The key exchange algorithm. `DHE_RSA` in the example.
- The Symmetric encryption algorithm and mode `3DES_CBC` in this example.
- The MAC³ algorithm used for authentication. `MAC_SHA` is used in the above example.

The cipher suite negotiated in the handshake protocol will affect the record protocol, by enabling encryption and data authentication. Note that you should not over rely on TLS to negotiate the strongest available cipher suite. Do not enable ciphers and algorithms that you consider weak.

All the supported ciphersuites are listed in ??.

2.5.2 Authentication

The key exchange algorithms of the TLS protocol offer authentication, which is a prerequisite for a secure connection. The available authentication methods in GnuTLS follow.

- Certificate authentication: Authenticated key exchange using public key infrastructure and certificates (X.509 or OpenPGP).
- SRP authentication: Authenticated key exchange using a password.
- PSK authentication: Authenticated key exchange using a pre-shared key.
- Anonymous authentication: Key exchange without peer authentication.

2.5.3 Client authentication

In the case of ciphersuites that use certificate authentication, the authentication of the client is optional in TLS. A server may request a certificate from the client using the `gnutls_certificate_server_set_request` function. We elaborate in ??.

³MAC stands for Message Authentication Code. It can be described as a keyed hash algorithm. See RFC2104.

2.5.4 Resuming sessions

The TLS handshake process performs expensive calculations and a busy server might easily be put under load. To reduce the load, session resumption may be used. This is a feature of the TLS protocol which allows a client to connect to a server after a successful handshake, without the expensive calculations. This is achieved by re-using the previously established keys, meaning the server needs to store the state of established connections (unless session tickets are used – ??).

Session resumption is an integral part of GnuTLS, and ??, ?? illustrate typical uses of it.

2.6 TLS extensions

A number of extensions to the TLS protocol have been proposed mainly in [?]. The extensions supported in GnuTLS are discussed in the subsections that follow.

2.6.1 Maximum fragment length negotiation

This extension allows a TLS implementation to negotiate a smaller value for record packet maximum length. This extension may be useful to clients with constrained capabilities. The functions shown below can be used to control this extension.

```
size_t gnutls_record_get_max_size (gnutls_session_t session)

ssize_t gnutls_record_set_max_size (gnutls_session_t session, size_t size)
```

2.6.2 Server name indication

A common problem in HTTPS servers is the fact that the TLS protocol is not aware of the hostname that a client connects to, when the handshake procedure begins. For that reason the TLS server has no way to know which certificate to send.

This extension solves that problem within the TLS protocol, and allows a client to send the HTTP hostname before the handshake begins within the first handshake packet. The functions `gnutls_server_name_set` and `gnutls_server_name_get` can be used to enable this extension, or to retrieve the name sent by a client.

```
int gnutls_server_name_set (gnutls_session_t session, gnutls_server_name_type_t
type, const void * name, size_t name_length)

int gnutls_server_name_get (gnutls_session_t session, void * data, size_t *
data_length, unsigned int * type, unsigned int indx)
```

2.6.3 Session tickets

To resume a TLS session, the server normally stores session parameters. This complicates deployment, and can be avoided by delegating the storage to the client. Because session parameters are sensitive they are encrypted and authenticated with a key only known to the server and then sent to the client. The Session Tickets extension is described in RFC 5077 [?].

A disadvantage of session tickets is that they eliminate the effects of forward secrecy when a server uses the same key for long time. That is, the secrecy of all sessions on a server using tickets depends on the ticket key being kept secret. For that reason server keys should be rotated and discarded regularly.

Since version 3.1.3 GnuTLS clients transparently support session tickets, unless forward secrecy is explicitly requested (with the PFS priority string).

2.6.4 HeartBeat

This is a TLS extension that allows to ping and receive confirmation from the peer, and is described in [?]. The extension is disabled by default and `gnutls_heartbeat_enable` can be used to enable it. A policy may be negotiated to only allow sending heartbeat messages or sending and receiving. The current session policy can be checked with `gnutls_heartbeat_allowed`. The requests coming from the peer result to `GNUTLS_E_HEARTBEAT_PING_RECEIVED` being returned from the receive function. Ping requests to peer can be send via `gnutls_heartbeat_ping`.

```
int gnutls_heartbeat_allowed (gnutls_session_t session, unsigned int type)

void gnutls_heartbeat_enable (gnutls_session_t session, unsigned int type)
```

```

int gnutls_heartbeat_ping (gnutls_session_t session, size_t data_size, unsigned int
max_tries, unsigned int flags)

int gnutls_heartbeat_pong (gnutls_session_t session, unsigned int flags)

void gnutls_heartbeat_set_timeouts (gnutls_session_t session, unsigned int re-
trans_timeout, unsigned int total_timeout)

unsigned int gnutls_heartbeat_get_timeout (gnutls_session_t session)

```

2.6.5 Safe renegotiation

TLS gives the option to two communicating parties to renegotiate and update their security parameters. One useful example of this feature was for a client to initially connect using anonymous negotiation to a server, and the renegotiate using some authenticated ciphersuite. This occurred to avoid having the client sending its credentials in the clear.

However this renegotiation, as initially designed would not ensure that the party one is renegotiating is the same as the one in the initial negotiation. For example one server could forward all renegotiation traffic to an other server who will see this traffic as an initial negotiation attempt.

This might be seen as a valid design decision, but it seems it was not widely known or understood, thus today some application protocols use the TLS renegotiation feature in a manner that enables a malicious server to insert content of his choice in the beginning of a TLS session.

The most prominent vulnerability was with HTTPS. There servers request a renegotiation to enforce an anonymous user to use a certificate in order to access certain parts of a web site. The attack works by having the attacker simulate a client and connect to a server, with server-only authentication, and send some data intended to cause harm. The server will then require renegotiation from him in order to perform the request. When the proper client attempts to contact the server, the attacker hijacks that connection and forwards traffic to the initial server that requested renegotiation. The attacker will not be able to read the data exchanged between the client and the server. However, the server will (incorrectly) assume that the initial request sent by the attacker was sent by the now authenticated client. The result is a prefix plain-text injection attack.

The above is just one example. Other vulnerabilities exists that do not rely on the TLS renegotiation to change the client's authenticated status (either TLS or application layer).

While fixing these application protocols and implementations would be one natural reaction, an extension to TLS has been designed that cryptographically binds together any renegotiated handshakes with the initial negotiation. When the extension is used, the attack is detected and the session can be terminated. The extension is specified in [?].

GnuTLS supports the safe renegotiation extension. The default behavior is as follows. Clients will attempt to negotiate the safe renegotiation extension when talking to servers. Servers will accept the extension when presented by clients. Clients and servers will permit an initial handshake to complete even when the other side does not support the safe renegotiation extension. Clients and servers will refuse renegotiation attempts when the extension has not been negotiated.

Note that permitting clients to connect to servers when the safe renegotiation extension is not enabled, is open up for attacks. Changing this default behavior would prevent interoperability against the majority of deployed servers out there. We will reconsider this default behavior in the future when more servers have been upgraded. Note that it is easy to configure clients to always require the safe renegotiation extension from servers.

To modify the default behavior, we have introduced some new priority strings (see ??). The `%UNSAFE_RENEGOTIATION` priority string permits (re-)handshakes even when the safe renegotiation extension was not negotiated. The default behavior is `%PARTIAL_RENEGOTIATION` that will prevent renegotiation with clients and servers not supporting the extension. This is secure for servers but leaves clients vulnerable to some attacks, but this is a trade-off between security and compatibility with old servers. The `%SAFE_RENEGOTIATION` priority string makes clients and servers require the extension for every handshake. The latter is the most secure option for clients, at the cost of not being able to connect to legacy servers. Servers will also deny clients that do not support the extension from connecting.

It is possible to disable use of the extension completely, in both clients and servers, by using the `%DISABLE_SAFE_RENEGOTIATION` priority string however we strongly recommend you to only do this for debugging and test purposes.

The default values if the flags above are not specified are:

- Server: `%PARTIAL_RENEGOTIATION`
- Client: `%PARTIAL_RENEGOTIATION`

For applications we have introduced a new API related to safe renegotiation. The `gnutls_safe_renegotiation_status` function is used to check if the extension has been negotiated on a session, and can be used both by clients and servers.

2.6.6 OCSP status request

The Online Certificate Status Protocol (OCSP) is a protocol that allows the client to verify the server certificate for revocation without messing with certificate revocation lists. Its drawback is that it requires the client to connect to the server's CA OCSP server and request the status of the certificate. This extension however, enables a TLS server to include its CA OCSP server response in the handshake. That is an HTTPS server may periodically run `ocsptool` (see ??) to obtain its certificate revocation status and serve it to the clients. That way a client avoids an additional connection to the OCSP server.

```

void gnutls_certificate_set_ocsp_status_request_function
(gnutls_certificate_credentials_t sc, gnutls_status_request_ocsp_func ocsp_func, void
* ptr)

int gnutls_certificate_set_ocsp_status_request_file (gnutls_certificate_credentials_t
sc, const char * response_file, unsigned int flags)

int gnutls_ocsp_status_request_enable_client (gnutls_session_t session,
gnutls_datum_t * responder_id, size_t responder_id_size, gnutls_datum_t * ex-
tensions)

int gnutls_ocsp_status_request_is_checked (gnutls_session_t session, unsigned int
flags)

```

A server is required to provide the OCSF server's response using the `gnutls_certificate_set_ocsp_status_request_file`. The response may be obtained periodically using the following command.

```

1 ocsptool --ask --load-cert server_cert.pem --load-issuer the_issuer.pem
2      --load-signer the_issuer.pem --outfile ocsf.response

```

Since version 3.1.3 GnuTLS clients transparently support the certificate status request.

2.6.7 SRTP

The TLS protocol was extended in [?] to provide keying material to the Secure RTP (SRTP) protocol. The SRTP protocol provides an encapsulation of encrypted data that is optimized for voice data. With the SRTP TLS extension two peers can negotiate keys using TLS or DTLS and obtain keying material for use with SRTP. The available SRTP profiles are listed below.

```

enum gnutls_srtp_profile_t:
  GNUTLS_SRTP_AES128_CM_HMAC_SHA1_80      128 bit AES with a 80 bit HMAC-SHA1
  GNUTLS_SRTP_AES128_CM_HMAC_SHA1_32      128 bit AES with a 32 bit HMAC-SHA1
  GNUTLS_SRTP_NULL_HMAC_SHA1_80            NULL cipher with a 80 bit HMAC-SHA1
  GNUTLS_SRTP_NULL_HMAC_SHA1_32            NULL cipher with a 32 bit HMAC-SHA1

```

Table 2.5: Supported SRTP profiles

To enable use the following functions.

```
int gnutls_srtp_set_profile (gnutls_session_t session, gnutls_srtp_profile_t profile)

int gnutls_srtp_set_profile_direct (gnutls_session_t session, const char * profiles,
const char ** err_pos)
```

To obtain the negotiated keys use the function below.

```
int gnutls_srtp_get_keys (gnutls_session_t session, void * key_material, unsigned
int key_material_size, gnutls_datum_t * client_key, gnutls_datum_t * client_salt,
gnutls_datum_t * server_key, gnutls_datum_t * server_salt)
```

Description: This is a helper function to generate the keying material for SRTP. It requires the space of the key material to be pre-allocated (should be at least 2x the maximum key size and salt size). The `client_key`, `client_salt`, `server_key` and `server_salt` are convenience datums that point inside the key material. They may be `NULL`.

Returns: On success the size of the key material is returned, otherwise, `GNUTLS_E_SHORT_MEMORY_BUFFER` if the buffer given is not sufficient, or a negative error code. Since 3.1.4

Other helper functions are listed below.

```
int gnutls_srtp_get_selected_profile (gnutls_session_t session, gnutls_srtp_profile_t *
profile)

const char * gnutls_srtp_get_profile_name (gnutls_srtp_profile_t profile)

int gnutls_srtp_get_profile_id (const char * name, gnutls_srtp_profile_t * profile)
```

2.6.8 Application Layer Protocol Negotiation (ALPN)

The TLS protocol was extended in `draft-ietf-tls-applayerprotoneg-00` to provide the application layer a method of negotiating the application protocol version. This allows for negotiation of the application protocol during the TLS handshake, thus reducing round-trips. The application protocol is described by an opaque string. To enable, use the following functions.

```
int gnutls_alpn_set_protocols (gnutls_session_t session, const gnutls_datum_t * protocols, unsigned protocols_size, unsigned int flags)
```

```
int gnutls_alpn_get_selected_protocol (gnutls_session_t session, gnutls_datum_t * protocol)
```

Note that these functions are intended to be used with protocols that are registered in the Application Layer Protocol Negotiation IANA registry. While you can use them for other protocols (at the risk of collisions), it is preferable to register them.

2.7 How to use TLS in application protocols

This chapter is intended to provide some hints on how to use TLS over simple custom made application protocols. The discussion below mainly refers to the TCP/IP transport layer but may be extended to other ones too.

2.7.1 Separate ports

Traditionally SSL was used in application protocols by assigning a new port number for the secure services. By doing this two separate ports were assigned, one for the non-secure sessions, and one for the secure sessions. This method ensures that if a user requests a secure session then the client will attempt to connect to the secure port and fail otherwise. The only possible attack with this method is to perform a denial of service attack. The most famous example of this method is “HTTP over TLS” or HTTPS protocol [?].

Despite its wide use, this method has several issues. This approach starts the TLS Handshake procedure just after the client connects on the —so called— secure port. That way the TLS protocol does not know anything about the client, and popular methods like the host advertising in HTTP do not work⁴. There is no way for the client to say “I connected to YYY server” before the Handshake starts, so the server cannot possibly know which certificate to use.

Other than that it requires two separate ports to run a single service, which is unnecessary complication. Due to the fact that there is a limitation on the available privileged ports, this approach was soon deprecated in favor of upward negotiation.

2.7.2 Upward negotiation

Other application protocols⁵ use a different approach to enable the secure layer. They use something often called as the “TLS upgrade” method. This method is quite tricky but it is

⁴See also the Server Name Indication extension on ??.

⁵See LDAP, IMAP etc.

more flexible. The idea is to extend the application protocol to have a “STARTTLS” request, whose purpose it to start the TLS protocols just after the client requests it. This approach does not require any extra port to be reserved. There is even an extension to HTTP protocol to support this method [?].

The tricky part, in this method, is that the “STARTTLS” request is sent in the clear, thus is vulnerable to modifications. A typical attack is to modify the messages in a way that the client is fooled and thinks that the server does not have the “STARTTLS” capability. See a typical conversation of a hypothetical protocol:

```
(client connects to the server)
CLIENT: HELLO I'M MR. XXX
SERVER: NICE TO MEET YOU XXX
CLIENT: PLEASE START TLS
SERVER: OK
*** TLS STARTS
CLIENT: HERE ARE SOME CONFIDENTIAL DATA
```

And an example of a conversation where someone is acting in between:

```
(client connects to the server)
CLIENT: HELLO I'M MR. XXX
SERVER: NICE TO MEET YOU XXX
CLIENT: PLEASE START TLS
(here someone inserts this message)
SERVER: SORRY I DON'T HAVE THIS CAPABILITY
CLIENT: HERE ARE SOME CONFIDENTIAL DATA
```

As you can see above the client was fooled, and was naïve enough to send the confidential data in the clear, despite the server telling the client that it does not support “STARTTLS”.

How do we avoid the above attack? As you may have already noticed this situation is easy to avoid. The client has to ask the user before it connects whether the user requests TLS or not. If the user answered that he certainly wants the secure layer the last conversation should be:

```
(client connects to the server)
CLIENT: HELLO I'M MR. XXX
SERVER: NICE TO MEET YOU XXX
CLIENT: PLEASE START TLS
(here someone inserts this message)
SERVER: SORRY I DON'T HAVE THIS CAPABILITY
```

CLIENT: BYE

(the client notifies the user that the secure connection was not possible)

This method, if implemented properly, is far better than the traditional method, and the security properties remain the same, since only denial of service is possible. The benefit is that the server may request additional data before the TLS Handshake protocol starts, in order to send the correct certificate, use the correct password file, or anything else!

2.8 On SSL 2 and older protocols

One of the initial decisions in the GnuTLS development was to implement the known security protocols for the transport layer. Initially TLS 1.0 was implemented since it was the latest at that time, and was considered to be the most advanced in security properties. Later the SSL 3.0 protocol was implemented since it is still the only protocol supported by several servers and there are no serious security vulnerabilities known.

One question that may arise is why we didn't implement SSL 2.0 in the library. There are several reasons, most important being that it has serious security flaws, unacceptable for a modern security library. Other than that, this protocol is barely used by anyone these days since it has been deprecated since 1996. The security problems in SSL 2.0 include:

- Message integrity compromised. The SSLv2 message authentication uses the MD5 function, and is insecure.
- Man-in-the-middle attack. There is no protection of the handshake in SSLv2, which permits a man-in-the-middle attack.
- Truncation attack. SSLv2 relies on TCP FIN to close the session, so the attacker can forge a TCP FIN, and the peer cannot tell if it was a legitimate end of data or not.
- Weak message integrity for export ciphers. The cryptographic keys in SSLv2 are used for both message authentication and encryption, so if weak encryption schemes are negotiated (say 40-bit keys) the message authentication code uses the same weak key, which isn't necessary.

Other protocols such as Microsoft's PCT 1 and PCT 2 were not implemented because they were also abandoned and deprecated by SSL 3.0 and later TLS 1.0.

3

Authentication methods

The initial key exchange of the TLS protocol performs authentication of the peers. In typical scenarios the server is authenticated to the client, and optionally the client to the server.

While many associate TLS with X.509 certificates and public key authentication, the protocol supports various authentication methods, including pre-shared keys, and passwords. In this chapter a description of the existing authentication methods is provided, as well as some guidance on which use-cases each method can be used at.

3.1 Certificate authentication

The most known authentication method of TLS are certificates. The PKIX [?] public key infrastructure is daily used by anyone using a browser today. GnuTLS supports both X.509 certificates [?] and OpenPGP certificates using a common API.

The key exchange algorithms supported by certificate authentication are shown in ??.

3.1.1 X.509 certificates

The X.509 protocols rely on a hierarchical trust model. In this trust model Certification Authorities (CAs) are used to certify entities. Usually more than one certification authorities exist, and certification authorities may certify other authorities to issue certificates as well, following a hierarchical model.

Key exchange	Description
RSA	The RSA algorithm is used to encrypt a key and send it to the peer. The certificate must allow the key to be used for encryption.
DHE_RSA	The RSA algorithm is used to sign ephemeral Diffie-Hellman parameters which are sent to the peer. The key in the certificate must allow the key to be used for signing. Note that key exchange algorithms which use ephemeral Diffie-Hellman parameters, offer perfect forward secrecy. That means that even if the private key used for signing is compromised, it cannot be used to reveal past session data.
ECDHE_RSA	The RSA algorithm is used to sign ephemeral elliptic curve Diffie-Hellman parameters which are sent to the peer. The key in the certificate must allow the key to be used for signing. It also offers perfect forward secrecy. That means that even if the private key used for signing is compromised, it cannot be used to reveal past session data.
DHE_DSS	The DSA algorithm is used to sign ephemeral Diffie-Hellman parameters which are sent to the peer. The certificate must contain DSA parameters to use this key exchange algorithm. DSA is the algorithm of the Digital Signature Standard (DSS).
ECDHE_ECDSA	The Elliptic curve DSA algorithm is used to sign ephemeral elliptic curve Diffie-Hellman parameters which are sent to the peer. The certificate must contain ECDSA parameters (i.e., EC and marked for signing) to use this key exchange algorithm.

Table 3.1: Supported key exchange algorithms.

One needs to trust one or more CAs for his secure communications. In that case only the certificates issued by the trusted authorities are acceptable. The framework is illustrated on ??.

X.509 certificate structure

An X.509 certificate usually contains information about the certificate holder, the signer, a unique serial number, expiration dates and some other fields [?] as shown in ??.

The certificate's *subject or issuer name* is not just a single string. It is a Distinguished name and in the ASN.1 notation is a sequence of several object identifiers with their corresponding values. Some of available OIDs to be used in an X.509 distinguished name are defined in "gnutls/x509.h".

The *Version* field in a certificate has values either 1 or 3 for version 3 certificates. Version 1 certificates do not support the extensions field so it is not possible to distinguish a CA from a person, thus their usage should be avoided.

The *validity* dates are there to indicate the date that the specific certificate was activated and

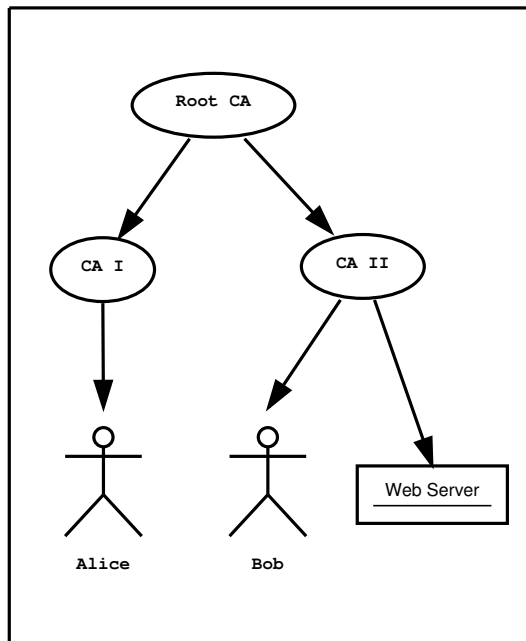


Figure 3.1: An example of the X.509 hierarchical trust model.

the date the certificate's key would be considered invalid.

In GnuTLS the X.509 certificate structures are handled using the `gnutls_x509_cert_t` type and the corresponding private keys with the `gnutls_x509_privkey_t` type. All the available functions for X.509 certificate handling have their prototypes in “`gnutls/x509.h`”. An example program to demonstrate the X.509 parsing capabilities can be found in ??.

Field	Description
version	The field that indicates the version of the certificate.
serialNumber	This field holds a unique serial number per certificate.
signature	The issuing authority's signature.
issuer	Holds the issuer's distinguished name.
validity	The activation and expiration dates.
subject	The subject's distinguished name of the certificate.
extensions	The extensions are fields only present in version 3 certificates.

Table 3.2: X.509 certificate fields.

Importing an X.509 certificate

The certificate structure should be initialized using `gnutls_x509_cert_init`, and a certificate structure can be imported using `gnutls_x509_cert_import`.

```
int gnutls_x509_cert_init (gnutls_x509_cert_t * cert)

int gnutls_x509_cert_import (gnutls_x509_cert_t cert, const gnutls_datum_t * data,
gnutls_x509_cert_fmt_t format)

void gnutls_x509_cert_deinit (gnutls_x509_cert_t cert)
```

In several functions an array of certificates is required. To assist in initialization and import the following two functions are provided.

```
int gnutls_x509_cert_list_import (gnutls_x509_cert_t * certs, unsigned int *
cert_max, const gnutls_datum_t * data, gnutls_x509_cert_fmt_t format, unsigned
int flags)

int gnutls_x509_cert_list_import2 (gnutls_x509_cert_t ** certs, unsigned int * size,
const gnutls_datum_t * data, gnutls_x509_cert_fmt_t format, unsigned int flags)
```

In all cases after use a certificate must be deinitialized using `gnutls_x509_cert_deinit`. Note that although the functions above apply to `gnutls_x509_cert_t` structure, similar functions exist for the CRL structure `gnutls_x509_crl_t`.

X.509 distinguished names

The “subject” of an X.509 certificate is not described by a single name, but rather with a distinguished name. This in X.509 terminology is a list of strings each associated an object identifier. To make things simple GnuTLS provides `gnutls_x509_cert_get_dn2` which follows the rules in [?] and returns a single string. Access to each string by individual object identifiers can be accessed using `gnutls_x509_cert_get_dn_by_oid`.

```
int gnutls_x509_cert_get_dn2 (gnutls_x509_cert_t cert, gnutls_datum_t * dn)
```

Description: This function will allocate buffer and copy the name of the Certificate. The name will be in the form "C=xxx,0=yyy,CN=zzz" as described in RFC4514. The output string will be ASCII or UTF-8 encoded, depending on the certificate data.

Returns: On success, GNUTLS_E_SUCCESS (0) is returned, otherwise a negative error value. and a negative error code on error.

```
int gnutls_x509_cert_get_dn (gnutls_x509_cert_t cert, char * buf, size_t * buf_size)
```

```
int gnutls_x509_cert_get_dn_by_oid (gnutls_x509_cert_t cert, const char * oid, int indx, unsigned int raw_flag, void * buf, size_t * buf_size)
```

```
int gnutls_x509_cert_get_dn_oid (gnutls_x509_cert_t cert, int indx, void * oid, size_t * oid_size)
```

Similar functions exist to access the distinguished name of the issuer of the certificate.

```
int gnutls_x509_cert_get_issuer_dn (gnutls_x509_cert_t cert, char * buf, size_t * buf_size)
```

```
int gnutls_x509_cert_get_issuer_dn2 (gnutls_x509_cert_t cert, gnutls_datum_t * dn)
```

```
int gnutls_x509_cert_get_issuer_dn_by_oid (gnutls_x509_cert_t cert, const char * oid, int indx, unsigned int raw_flag, void * buf, size_t * buf_size)
```

```
int gnutls_x509_cert_get_issuer_dn_oid (gnutls_x509_cert_t cert, int indx, void * oid, size_t * oid_size)
```

```
int gnutls_x509_cert_get_issuer (gnutls_x509_cert_t cert, gnutls_x509_dn_t * dn)
```

The more powerful `gnutls_x509_cert_get_subject` and `gnutls_x509_dn_get_rdn_ava` provide efficient but low-level access to the contents of the distinguished name structure.

```
int gnutls_x509_cert_get_subject (gnutls_x509_cert_t cert, gnutls_x509_dn_t * dn)
```

```
int gnutls_x509_cert_get_issuer (gnutls_x509_cert_t cert, gnutls_x509_dn_t * dn)
```

```
int gnutls_x509_dn_get_rdn_ava (gnutls_x509_dn_t dn, int irdn, int iava,
gnutls_x509_ava_st * ava)
```

Description: Get pointers to data within the DN. The format of the `ava` structure is shown below. `struct gnutls_x509_ava_st gnutls_datum_t oid; gnutls_datum_t value; unsigned long value_tag; ;` The X.509 distinguished name is a sequence of sequences of strings and this is what the `irdn` and `iava` indexes model. Note that `ava` will contain pointers into the `dn` structure which in turns points to the original certificate. Thus you should not modify any data or deallocate any of those. This is a low-level function that requires the caller to do the value conversions when necessary (e.g. from UCS-2).

Returns: Returns 0 on success, or an error code.

X.509 extensions

X.509 version 3 certificates include a list of extensions that can be used to obtain additional information on the subject or the issuer of the certificate. Those may be e-mail addresses, flags that indicate whether the belongs to a CA etc. All the supported X.509 version 3 extensions are shown in ??.

The certificate extensions access is split into two parts. The first requires to retrieve the extension, and the second is the parsing part.

To enumerate and retrieve the DER-encoded extension data available in a certificate the following two functions are available.

```
int gnutls_x509_cert_get_extension_info (gnutls_x509_cert_t cert, int indx, void *
oid, size_t * oid_size, unsigned int * critical)
```

```
int gnutls_x509_cert_get_extension_data2 (gnutls_x509_cert_t cert, unsigned int indx,
gnutls_datum_t * data)
```

```
int gnutls_x509_cert_get_extension_by_oid2 (gnutls_x509_cert_t cert, const char *
oid, int indx, gnutls_datum_t * output, unsigned int * critical)
```

After a supported DER-encoded extension is retrieved it can be parsed using the APIs in `x509-ext.h`. Complex extensions may require initializing an intermediate structure that holds the parsed extension data. Examples of simple parsing functions are shown below.

```
int gnutls_x509_ext_import_basic_constraints (const gnutls_datum_t * ext, unsigned int * ca, int * pathlen)

int gnutls_x509_ext_export_basic_constraints (unsigned int ca, int pathlen,
gnutls_datum_t * ext)

int gnutls_x509_ext_import_key_usage (const gnutls_datum_t * ext, unsigned int *
key_usage)

int gnutls_x509_ext_export_key_usage (unsigned int usage, gnutls_datum_t * ext)
```

More complex extensions, such as Name Constraints, require an intermediate structure, in that case `gnutls_x509_name_constraints_t` to be initialized in order to store the parsed extension data.

```
int gnutls_x509_ext_import_name_constraints (const gnutls_datum_t * ext,
gnutls_x509_name_constraints_t nc, unsigned int flags)

int gnutls_x509_ext_export_name_constraints (gnutls_x509_name_constraints_t nc,
gnutls_datum_t * ext)
```

After the name constraints are extracted in the structure, the following functions can be used to access them.

```
int gnutls_x509_name_constraints_get_permitted (gnutls_x509_name_constraints_t
nc, unsigned idx, unsigned * type, gnutls_datum_t * name)

int gnutls_x509_name_constraints_get_excluded (gnutls_x509_name_constraints_t
nc, unsigned idx, unsigned * type, gnutls_datum_t * name)

int gnutls_x509_name_constraints_add_permitted (gnutls_x509_name_constraints_t
nc, gnutls_x509_subject_alt_name_t type, const gnutls_datum_t * name)

int gnutls_x509_name_constraints_add_excluded (gnutls_x509_name_constraints_t
nc, gnutls_x509_subject_alt_name_t type, const gnutls_datum_t * name)
```

```
unsigned gnutls_x509_name_constraints_check (gnutls_x509_name_constraints_t nc,  
gnutls_x509_subject_alt_name_t type, const gnutls_datum_t * name)
```

```
unsigned gnutls_x509_name_constraints_check_cert (gnutls_x509_name_constraints_t  
nc, gnutls_x509_subject_alt_name_t type, gnutls_x509_cert_t cert)
```

Other utility functions are listed below.

```
int gnutls_x509_name_constraints_init (gnutls_x509_name_constraints_t * nc)
```

```
void gnutls_x509_name_constraints_deinit (gnutls_x509_name_constraints_t nc)
```

Similar functions exist for all of the other supported extensions, listed in ??.

Note, that there are also direct APIs to access extensions that may be simpler to use for non-complex extensions. They are available in `x509.h` and some examples are listed below.

```
int gnutls_x509_cert_get_basic_constraints (gnutls_x509_cert_t cert, unsigned int *  
critical, unsigned int * ca, int * pathlen)
```

```
int gnutls_x509_cert_set_basic_constraints (gnutls_x509_cert_t cert, unsigned int ca,  
int pathLenConstraint)
```

```
int gnutls_x509_cert_get_key_usage (gnutls_x509_cert_t cert, unsigned int *  
key_usage, unsigned int * critical)
```

```
int gnutls_x509_cert_set_key_usage (gnutls_x509_cert_t cert, unsigned int usage)
```

Accessing public and private keys

Each X.509 certificate contains a public key that corresponds to a private key. To get a unique identifier of the public key the `gnutls_x509_cert_get_key_id` function is provided. To export the public key or its parameters you may need to convert the X.509 structure to a `gnutls_pubkey_t`. See ?? for more information.

The private key parameters may be directly accessed by using one of the following functions.

Extension	OID	Description
Subject key id	2.5.29.14	An identifier of the key of the subject.
Key usage	2.5.29.15	Constraints the key's usage of the certificate.
Private key usage period	2.5.29.16	Constraints the validity time of the private key.
Subject alternative name	2.5.29.17	Alternative names to subject's distinguished name.
Issuer alternative name	2.5.29.18	Alternative names to the issuer's distinguished name.
Basic constraints	2.5.29.19	Indicates whether this is a CA certificate or not, and specify the maximum path lengths of certificate chains.
Name constraints	2.5.29.30	A field in CA certificates that restricts the scope of the name of issued certificates.
CRL distribution points	2.5.29.31	This extension is set by the CA, in order to inform about the issued CRLs.
Certificate policy	2.5.29.32	This extension is set to indicate the certificate policy as object identifier and may contain a descriptive string or URL.
Authority key identifier	2.5.29.35	An identifier of the key of the issuer of the certificate. That is used to distinguish between different keys of the same issuer.
Extended key usage	2.5.29.37	Constraints the purpose of the certificate.
Authority information access	1.3.6.1.5.5.7.1.1	Information on services by the issuer of the certificate.
Proxy Certification Information	1.3.6.1.5.5.7.1.14	Proxy Certificates includes this extension that contains the OID of the proxy policy language used, and can specify limits on the maximum lengths of proxy chains. Proxy Certificates are specified in [?].

Table 3.3: Supported X.509 certificate extensions.

```
int gnutls_x509_cert_get_key_id (gnutls_x509_cert_t crt, unsigned int flags, unsigned char * output_data, size_t * output_data_size)
```

Description: This function will return a unique ID that depends on the public key parameters. This ID can be used in checking whether a certificate corresponds to the given private key. If the buffer provided is not long enough to hold the output, then *output_data_size is updated and GNUTLS_E_SHORT_MEMORY_BUFFER will be returned. The output will normally be a SHA-1 hash output, which is 20 bytes.

Returns: In case of failure a negative error code will be returned, and 0 on success.

```
int gnutls_x509_privkey_get_pk_algorithm2 (gnutls_x509_privkey_t key, unsigned int * bits)

int gnutls_x509_privkey_export_rsa_raw2 (gnutls_x509_privkey_t key,
gnutls_datum_t * m, gnutls_datum_t * e, gnutls_datum_t * d, gnutls_datum_t *
p, gnutls_datum_t * q, gnutls_datum_t * u, gnutls_datum_t * e1, gnutls_datum_t *
e2)

int gnutls_x509_privkey_export_ecc_raw (gnutls_x509_privkey_t key,
gnutls_ecc_curve_t * curve, gnutls_datum_t * x, gnutls_datum_t * y, gnutls_datum_t *
k)

int gnutls_x509_privkey_export_dsa_raw (gnutls_x509_privkey_t key,
gnutls_datum_t * p, gnutls_datum_t * q, gnutls_datum_t * g, gnutls_datum_t * y,
gnutls_datum_t * x)

int gnutls_x509_privkey_get_key_id (gnutls_x509_privkey_t key, unsigned int flags,
unsigned char * output_data, size_t * output_data_size)
```

Verifying X.509 certificate paths

Verifying certificate paths is important in X.509 authentication. For this purpose the following functions are provided.

The verification function will verify a given certificate chain against a list of certificate authorities and certificate revocation lists, and output a bit-wise OR of elements of the `gnutls_certificate_status_t` enumeration shown in ???. The `GNUTLS_CERT_INVALID` flag is always set on a verification error and more detailed flags will also be set when appropriate.

An example of certificate verification is shown in ???. It is also possible to have a set of certificates that are trusted for a particular server but not to authorize other certificates. This purpose is served by the functions `gnutls_x509_trust_list_add_named_cert` and `gnutls_x509_trust_list_verify_named_cert`.


```
int gnutls_x509_trust_list_add_cas (gnutls_x509_trust_list_t list, const  
gnutls_x509_crt_t * clist, unsigned clist_size, unsigned int flags)
```

Description: This function will add the given certificate authorities to the trusted list. The list of CAs must not be deinitialized during this structure's lifetime. If the flag `GNUTLS_TLNO_DUPLICATES` is specified, then the provided `clist` entries that are duplicates will not be added to the list and will be deinitialized.

Returns: The number of added elements is returned.

```
int gnutls_x509_trust_list_add_named_crt (gnutls_x509_trust_list_t list,  
gnutls_x509_crt_t cert, const void * name, size_t name_size, unsigned int flags)
```

Description: This function will add the given certificate to the trusted list and associate it with a name. The certificate will not be used for verification with `gnutls_x509_trust_list_verify_crt()` but with `gnutls_x509_trust_list_verify_named_crt()` or `gnutls_x509_trust_list_verify_crt2()` - the latter only since GnuTLS 3.4.0 and if a hostname is provided. In principle this function can be used to set individual "server" certificates that are trusted by the user for that specific server but for no other purposes. The certificate must not be deinitialized during the lifetime of the trusted list.

Returns: On success, `GNUTLS_E_SUCCESS` (0) is returned, otherwise a negative error value.

```
int gnutls_x509_trust_list_add_crls (gnutls_x509_trust_list_t list, const  
gnutls_x509_crl_t * crl_list, int crl_size, unsigned int flags, unsigned int verifi-  
cation_flags)
```

Description: This function will add the given certificate revocation lists to the trusted list. The list of CRLs must not be deinitialized during this structure's lifetime. This function must be called after `gnutls_x509_trust_list_add_cas()` to allow verifying the CRLs for validity.

Returns: The number of added elements is returned.

```
int gnutls_x509_trust_list_verify_cert (gnutls_x509_trust_list_t list, gnutls_x509_cert_t  
* cert_list, unsigned int cert_list_size, unsigned int flags, unsigned int * voutput,  
gnutls_verify_output_function func)
```

Description: This function will try to verify the given certificate and return its status. The `voutput` parameter will hold an OR'ed sequence of `gnutls_certificate_status_t` flags. The details of the verification are the same as in `gnutls_x509_trust_list_verify_cert2()`.

Returns: On success, `GNUTLS_E_SUCCESS` (0) is returned, otherwise a negative error value.

```
int gnutls_x509_trust_list_verify_cert2 (gnutls_x509_trust_list_t list, gnutls_x509_cert_t  
* cert_list, unsigned int cert_list_size, gnutls_typed_vdata_st * data, unsigned int  
elements, unsigned int flags, unsigned int * voutput, gnutls_verify_output_function  
func)
```

Description: This function will attempt to verify the given certificate and return its status. The `voutput` parameter will hold an OR'ed sequence of `gnutls_certificate_status_t` flags. When a chain of `cert_list_size` with more than one certificates is provided, the verification status will apply to the first certificate in the chain that failed verification. The verification process starts from the end of the chain (from CA to end certificate). Additionally a certificate verification profile can be specified from the ones in `gnutls_certificate_verification_profiles_t` by ORing the result of `GNUTLS_PROFILE_TO_VFLAGS()` to the verification flags. The acceptable data types are `GNUTLS_DT_DNS_HOSTNAME` and `GNUTLS_DT_KEY_PURPOSE_OID`. The former accepts as data a null-terminated hostname, and the latter a null-terminated object identifier (e.g., `GNUTLS_KP_TLS_WWW_SERVER`). If a DNS hostname is provided then this function will compare the hostname in the certificate against the given. If names do not match the `GNUTLS_CERT_UNEXPECTED_OWNER` status flag will be set. In addition it will consider certificates provided with `gnutls_x509_trust_list_add_named_cert()`. If a key purpose OID is provided and the end-certificate contains the extended key usage PKIX extension, it will be required to match the provided OID or be marked for any purpose, otherwise verification will fail with `GNUTLS_CERT_PURPOSE_MISMATCH` status.

Returns: On success, `GNUTLS_E_SUCCESS` (0) is returned, otherwise a negative error value. Note that verification failure will not result to an error code, only `voutput` will be updated.

```
int gnutls_x509_trust_list_verify_named_cert (gnutls_x509_trust_list_t list,  
gnutls_x509_cert_t cert, const void * name, size_t name_size, unsigned int flags,  
unsigned int * voutput, gnutls_verify_output_function func)
```

Description: This function will try to find a certificate that is associated with the provided name --see `gnutls_x509_trust_list_add_named_cert()`. If a match is found the certificate is considered valid. In addition to that this function will also check CRLs. The `voutput` parameter will hold an OR'ed sequence of `gnutls_certificate_status_t` flags. Additionally a certificate verification profile can be specified from the ones in `gnutls_certificate_verification_profiles_t` by ORing the result of `GNUTLS_PROFILE_TO_VFLAGS()` to the verification flags.

Returns: On success, `GNUTLS_E_SUCCESS (0)` is returned, otherwise a negative error value.

```
int gnutls_x509_trust_list_add_trust_file (gnutls_x509_trust_list_t list, const char *  
ca_file, const char * crl_file, gnutls_x509_cert_fmt_t type, unsigned int tl_flags, un-  
signed int tl_vflags)
```

Description: This function will add the given certificate authorities to the trusted list. PKCS #11 URLs are also accepted, instead of files, by this function. A PKCS #11 URL implies a trust database (a specially marked module in `p11-kit`); the URL `"pkcs11:"` implies all trust databases in the system. Only a single URL specifying trust databases can be set; they cannot be stacked with multiple calls.

Returns: The number of added elements is returned.

```
int gnutls_x509_trust_list_add_trust_mem (gnutls_x509_trust_list_t list, const  
gnutls_datum_t * cas, const gnutls_datum_t * crls, gnutls_x509_cert_fmt_t type, un-  
signed int tl_flags, unsigned int tl_vflags)
```

Description: This function will add the given certificate authorities to the trusted list.

Returns: The number of added elements is returned.

```
int gnutls_x509_trust_list_add_system_trust (gnutls_x509_trust_list_t list, unsigned  
int tl_flags, unsigned int tl_vflags)
```

Description: This function adds the system's default trusted certificate authorities to the trusted list. Note that on unsupported systems this function returns `GNUTLS_E_UNIMPLEMENTED_FEATURE`. This function implies the flag `GNUTLS_TL_NO_DUPLICATES`.

Returns: The number of added elements or a negative error code on error.

Verifying a certificate in the context of TLS session

When operating in the context of a TLS session, the trusted certificate authority list may also be set using:

```
int gnutls_certificate_set_x509_trust_file (gnutls_certificate_credentials_t cred,  
const char * cafile, gnutls_x509_crt_fmt_t type)
```

```
int gnutls_certificate_set_x509_trust_dir (gnutls_certificate_credentials_t cred,  
const char * ca_dir, gnutls_x509_crt_fmt_t type)
```

```
int gnutls_certificate_set_x509_crl_file (gnutls_certificate_credentials_t res, const  
char * crlfile, gnutls_x509_crt_fmt_t type)
```

```
int gnutls_certificate_set_x509_system_trust (gnutls_certificate_credentials_t cred)
```

These functions allow the specification of the trusted certificate authorities, either via a file, a directory or use the system-specified certificate authorities. Unless the authorities are application specific, it is generally recommended to use the system trust storage (see `gnutls_certificate_set_x509_system_trust`).

Unlike the previous section it is not required to setup a trusted list, and the function `gnutls_certificate_verify_peers3` is used to verify the peer's certificate chain and identity. The reported verification status is identical to the verification functions described in the previous section. Note that in certain cases it is required to check the marked purpose of the end certificate (e.g. `GNUTLS_KP_TLS_WWW_SERVER`); in these cases the more advanced `gnutls_certificate_verify_peers` should be used instead.

There is also the possibility to pass some input to the verification functions in the form of flags. For `gnutls_x509_trust_list_verify_crt2` the flags are passed directly, but for `gnutls_certificate_verify_peers3`, the flags are set using `gnutls_certificate_set_verify_flags`. All the available flags are part of the enumeration `gnutls_certificate_verify_flags` shown

in ??.

Verifying a certificate using PKCS #11

Some systems provide a system wide trusted certificate storage accessible using the PKCS #11 API. That is, the trusted certificates are queried and accessed using the PKCS #11 API, and trusted certificate properties, such as purpose, are marked using attached extensions. One example is the p11-kit trust module¹.

These special PKCS #11 modules can be used for GnuTLS certificate verification if marked as trust policy modules, i.e., with `trust-policy: yes` in the p11-kit module file. The way to use them is by specifying to the file verification function (e.g., `gnutls_certificate_set_x509_trust_file`), a pkcs11 URL, or simply `pkcs11:` to use all the marked with trust policy modules.

The trust modules of p11-kit assign a purpose to trusted authorities using the extended key usage object identifiers. The common purposes are shown in ??. Note that typically according to [?] the extended key usage object identifiers apply to end certificates. Their application to CA certificates is an extension used by the trust modules.

With such modules, it is recommended to use the verification functions `gnutls_x509_trust_list_verify_cert2`, or `gnutls_certificate_verify_peers`, which allow to explicitly specify the key purpose. The other verification functions which do not allow setting a purpose, would operate as if `GNUTLS_KP_TLS_WWW_SERVER` was requested from the trusted authorities.

3.1.2 OpenPGP certificates

The OpenPGP key authentication relies on a distributed trust model, called the “web of trust”. The “web of trust” uses a decentralized system of trusted introducers, which are the same as a CA. OpenPGP allows anyone to sign anyone else’s public key. When Alice signs Bob’s key, she is introducing Bob’s key to anyone who trusts Alice. If someone trusts Alice to introduce keys, then Alice is a trusted introducer in the mind of that observer. For example in ??, David trusts Alice to be an introducer and Alice signed Bob’s key thus Dave trusts Bob’s key to be the real one.

There are some key points that are important in that model. In the example Alice has to sign Bob’s key, only if she is sure that the key belongs to Bob. Otherwise she may also make Dave falsely believe that this is Bob’s key. Dave has also the responsibility to know who to trust. This model is similar to real life relations.

Just see how Charlie behaves in the previous example. Although he has signed Bob’s key - because he knows, somehow, that it belongs to Bob - he does not trust Bob to be an introducer. Charlie decided to trust only Kevin, for some reason. A reason could be that Bob is lazy enough, and signs other people’s keys without being sure that they belong to the actual owner.

¹see <http://p11-glue.freedesktop.org/trust-module.html>.

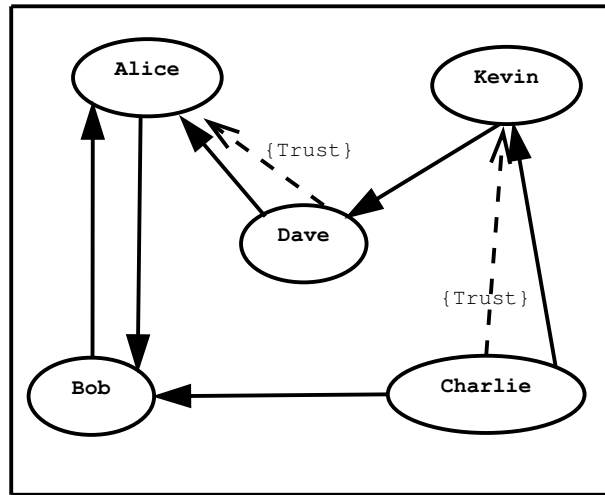


Figure 3.2: An example of the OpenPGP trust model.

OpenPGP certificate structure

In GnuTLS the OpenPGP certificate structures [?] are handled using the `gnutls_openpgp_cert_t` type. A typical certificate contains the user ID, which is an RFC 2822 mail and name address, a public key, possibly a number of additional public keys (called subkeys), and a number of signatures. The various fields are shown in ??.

The additional subkeys may provide key for various different purposes, e.g. one key to encrypt mail, and another to sign a TLS key exchange. Each subkey is identified by a unique key ID. The keys that are to be used in a TLS key exchange that requires signatures are called authentication keys in the OpenPGP jargon. The mapping of TLS key exchange methods to public keys is shown in ??.

The corresponding private keys are stored in the `gnutls_openpgp_privkey_t` type. All the prototypes for the key handling functions can be found in “`gnutls/openpgp.h`”.

Verifying an OpenPGP certificate

The verification functions of OpenPGP keys, included in GnuTLS, are simple ones, and do not use the features of the “web of trust”. For that reason, if the verification needs are complex, the assistance of external tools like GnuPG and GPGME² is recommended.

In GnuTLS there is a verification function for OpenPGP certificates, the `gnutls_openpgp_cert_verify_ring`. This checks an OpenPGP key against a given set of public keys (keyring) and returns the key status. The key verification status is the same as in X.509 certificates, although the meaning and interpretation are different. For example an OpenPGP key may be

²http://www.gnupg.org/related_software/gpgme/

valid, if the self signature is ok, even if no signers were found. The meaning of verification status flags is the same as in the X.509 certificates (see ??).

```
int gnutls_openpgp_cert_verify_ring (gnutls_openpgp_cert_t key,  
gnutls_openpgp_keyring_t keyring, unsigned int flags, unsigned int * verify)
```

Description: Verify all signatures in the key, using the given set of keys (keyring). The key verification output will be put in `verify` and will be one or more of the `gnutls_certificate_status_t` enumerated elements bitwise or'd. Note that this function does not verify using any "web of trust". You may use GnuPG for that purpose, or any other external PGP application.

Returns: `GNUTLS_E_SUCCESS` on success, or an error code.

```
int gnutls_openpgp_cert_verify_self (gnutls_openpgp_cert_t key, unsigned int flags,  
unsigned int * verify)
```

Description: Verifies the self signature in the key. The key verification output will be put in `verify` and will be one or more of the `gnutls_certificate_status_t` enumerated elements bitwise or'd.

Returns: `GNUTLS_E_SUCCESS` on success, or an error code.

Verifying a certificate in the context of a TLS session

Similarly with X.509 certificates, one needs to specify the OpenPGP keyring file in the credentials structure. The certificates in this file will be used by `gnutls_certificate_verify_peers3` to verify the signatures in the certificate sent by the peer.

```
int gnutls_certificate_set_openpgp_keyring_file (gnutls_certificate_credentials_t c,  
const char * file, gnutls_openpgp_cert_fmt_t format)
```

Description: The function is used to set keyrings that will be used internally by various OpenPGP functions. For example to find a key when it is needed for an operations. The keyring will also be used at the verification functions.

Returns: On success, `GNUTLS_E_SUCCESS` (0) is returned, otherwise a negative error value.

3.1.3 Advanced certificate verification

The verification of X.509 certificates in the HTTPS and other Internet protocols is typically done by loading a trusted list of commercial Certificate Authorities (see `gnutls_certificate_set_x509_system_trust`), and using them as trusted anchors. However, there are several examples (eg. the Diginotar incident) where one of these authorities was compromised. This risk can be mitigated by using in addition to CA certificate verification, other verification methods. In this section we list the available in GnuTLS methods.

Verifying a certificate using trust on first use authentication

It is possible to use a trust on first use (TOFU) authentication method in GnuTLS. That is the concept used by the SSH programs, where the public key of the peer is not verified, or verified in an out-of-bound way, but subsequent connections to the same peer require the public key to remain the same. Such a system in combination with the typical CA verification of a certificate, and OSCP revocation checks, can help to provide multiple factor verification, where a single point of failure is not enough to compromise the system. For example a server compromise may be detected using OSCP, and a CA compromise can be detected using the trust on first use method. Such a hybrid system with X.509 and trust on first use authentication is shown in ??.

See ?? on how to use the available functionality.

Verifying a certificate using DANE (DNSSEC)

The DANE protocol is a protocol that can be used to verify TLS certificates using the DNS (or better DNSSEC) protocols. The DNS security extensions (DNSSEC) provide an alternative public key infrastructure to the commercial CAs that are typically used to sign TLS certificates. The DANE protocol takes advantage of the DNSSEC infrastructure to verify TLS certificates. This can be in addition to the verification by CA infrastructure or may even replace it where DNSSEC is fully deployed. Note however, that DNSSEC deployment is fairly new and it would be better to use it as an additional verification method rather than the only one.

The DANE functionality is provided by the `libgnutls-dane` library that is shipped with GnuTLS and the function prototypes are in `gnutls/dane.h`. See ?? for information on how to use the library.

Note however, that the DANE RFC mandates the verification methods one should use in addition to the validation via DNSSEC TLSA entries. GnuTLS doesn't follow that RFC requirement, and the term DANE verification in this manual refers to the TLSA entry verification. In GnuTLS any other verification methods can be used (e.g., PKIX or TOFU) on top of DANE.

3.1.4 Digital signatures

In this section we will provide some information about digital signatures, how they work, and give the rationale for disabling some of the algorithms used.

Digital signatures work by using somebody's secret key to sign some arbitrary data. Then anybody else could use the public key of that person to verify the signature. Since the data may be arbitrary it is not suitable input to a cryptographic digital signature algorithm. For this reason and also for performance cryptographic hash algorithms are used to preprocess the input to the signature algorithm. This works as long as it is difficult enough to generate two different messages with the same hash algorithm output. In that case the same signature could be used as a proof for both messages. Nobody wants to sign an innocent message of donating 1 euro to Greenpeace and find out that they donated 1.000.000 euros to Bad Inc.

For a hash algorithm to be called cryptographic the following three requirements must hold:

1. Preimage resistance. That means the algorithm must be one way and given the output of the hash function $H(x)$, it is impossible to calculate x .
2. 2nd preimage resistance. That means that given a pair x, y with $y = H(x)$ it is impossible to calculate an x' such that $y = H(x')$.
3. Collision resistance. That means that it is impossible to calculate random x and x' such $H(x') = H(x)$.

The last two requirements in the list are the most important in digital signatures. These protect against somebody who would like to generate two messages with the same hash output. When an algorithm is considered broken usually it means that the Collision resistance of the algorithm is less than brute force. Using the birthday paradox the brute force attack takes $2^{\text{textasciicircum}(hash\ size)/2}$ operations. Today colliding certificates using the MD5 hash algorithm have been generated as shown in [?].

There has been cryptographic results for the SHA-1 hash algorithms as well, although they are not yet critical. Before 2004, MD5 had a presumed collision strength of $2^{\text{textasciicircum}64}$, but it has been showed to have a collision strength well under $2^{\text{textasciicircum}50}$. As of November 2005, it is believed that SHA-1's collision strength is around $2^{\text{textasciicircum}50}$.

$2^{\text{textasciicircum}63}$. We consider this sufficiently hard so that we still support SHA-1. We anticipate that SHA-256/386/512 will be used in publicly-distributed certificates in the future. When $2^{\text{textasciicircum}63}$

can be considered too weak compared to the computer power available sometime in the future, SHA-1 will be disabled as well. The collision attacks on SHA-1 may also get better, given the new interest in tools for creating them.

Trading security for interoperability

If you connect to a server and use GnuTLS' functions to verify the certificate chain, and get a `GNUTLS_CERT_INSECURE_ALGORITHM` validation error (see ??), it means that somewhere in the certificate chain there is a certificate signed using RSA-MD2 or RSA-MD5. These two digital

signature algorithms are considered broken, so GnuTLS fails verifying the certificate. In some situations, it may be useful to be able to verify the certificate chain anyway, assuming an attacker did not utilize the fact that these signatures algorithms are broken. This section will give help on how to achieve that.

It is important to know that you do not have to enable any of the flags discussed here to be able to use trusted root CA certificates self-signed using RSA-MD2 or RSA-MD5. The certificates in the trusted list are considered trusted irrespective of the signature.

If you are using `gnutls_certificate_verify_peers3` to verify the certificate chain, you can call `gnutls_certificate_set_verify_flags` with the flags:

- `GNUTLS_VERIFY_ALLOW_SIGN_RSA_MD2`
- `GNUTLS_VERIFY_ALLOW_SIGN_RSA_MD5`

as in the following example:

```
1 gnutls_certificate_set_verify_flags (x509cred,  
2                                   GNUTLS_VERIFY_ALLOW_SIGN_RSA_MD5);
```

This will signal the verifier algorithm to enable RSA-MD5 when verifying the certificates.

If you are using `gnutls_x509_cert_verify` or `gnutls_x509_cert_list_verify`, you can pass the `GNUTLS_VERIFY_ALLOW_SIGN_RSA_MD5` parameter directly in the `flags` parameter.

If you are using these flags, it may also be a good idea to warn the user when verification failure occur for this reason. The simplest is to not use the flags by default, and only fall back to using them after warning the user. If you wish to inspect the certificate chain yourself, you can use `gnutls_certificate_get_peers` to extract the raw server's certificate chain, `gnutls_x509_cert_list_import` to parse each of the certificates, and then `gnutls_x509_cert_get_signature_algorithm` to find out the signing algorithm used for each certificate. If any of the intermediary certificates are using `GNUTLS_SIGN_RSA_MD2` or `GNUTLS_SIGN_RSA_MD5`, you could present a warning.

3.2 More on certificate authentication

Certificates are not the only structures involved in a public key infrastructure. Several other structures that are used for certificate requests, encrypted private keys, revocation lists, GnuTLS abstract key structures, etc., are discussed in this chapter.

3.2.1 PKCS #10 certificate requests

A certificate request is a structure, which contain information about an applicant of a certificate service. It usually contains a private key, a distinguished name and secondary data such as a challenge password. GnuTLS supports the requests defined in PKCS #10 [?]. Other formats of certificate requests are not currently supported.

A certificate request can be generated by associating it with a private key, setting the subject's information and finally self signing it. The last step ensures that the requester is in possession of the private key.

```
int gnutls_x509_crq_set_version (gnutls_x509_crq_t crq, unsigned int version)

int gnutls_x509_crq_set_dn (gnutls_x509_crq_t crq, const char * dn, const char **
err)

int gnutls_x509_crq_set_dn_by_oid (gnutls_x509_crq_t crq, const char * oid, un-
signed int raw_flag, const void * data, unsigned int sizeof_data)

int gnutls_x509_crq_set_key_usage (gnutls_x509_crq_t crq, unsigned int usage)

int gnutls_x509_crq_set_key_purpose_oid (gnutls_x509_crq_t crq, const void * oid,
unsigned int critical)

int gnutls_x509_crq_set_basic_constraints (gnutls_x509_crq_t crq, unsigned int ca,
int pathLenConstraint)
```

The `gnutls_x509_crq_set_key` and `gnutls_x509_crq_sign2` functions associate the request with a private key and sign it. If a request is to be signed with a key residing in a PKCS #11 token it is recommended to use the signing functions shown in ??.

```
int gnutls_x509_crq_set_key (gnutls_x509_crq_t crq, gnutls_x509_privkey_t key)
```

Description: This function will set the public parameters from the given private key to the request.

Returns: On success, `GNUTLS_E_SUCCESS (0)` is returned, otherwise a negative error value.

The following example is about generating a certificate request, and a private key. A certificate request can be later be processed by a CA which should return a signed certificate.

```
1 /* This example code is placed in the public domain. */
2
3 #ifdef HAVE_CONFIG_H
4 #include <config.h>
5 #endif
6
7 #include <stdio.h>
8 #include <stdlib.h>
9 #include <string.h>
10 #include <gnutls/gnutls.h>
```

int gnutls_x509_crq_sign2 (gnutls_x509_crq_t crq, gnutls_x509_privkey_t key, gnutls_digest_algorithm_t dig, unsigned int flags)

Description: This function will sign the certificate request with a private key. This must be the same key as the one used in `gnutls_x509 crt.set_key()` since a certificate request is self signed. This must be the last step in a certificate request generation since all the previously set parameters are now signed.

Returns: `GNUTLS_E_SUCCESS` on success, otherwise a negative error code. `GNUTLS_E_ASN1_VALUE_NOT_FOUND` is returned if you didn't set all information in the certificate request (e.g., the version using `gnutls_x509_crq_set_version()`).

```

11 #include <gnutls/x509.h>
12 #include <gnutls/abstract.h>
13 #include <time.h>
14
15 /* This example will generate a private key and a certificate
16  * request.
17  */
18
19 int main(void)
20 {
21     gnutls_x509_crq_t crq;
22     gnutls_x509_privkey_t key;
23     unsigned char buffer[10 * 1024];
24     size_t buffer_size = sizeof(buffer);
25     unsigned int bits;
26
27     gnutls_global_init();
28
29     /* Initialize an empty certificate request, and
30      * an empty private key.
31      */
32     gnutls_x509_crq_init(&crq);
33
34     gnutls_x509_privkey_init(&key);
35
36     /* Generate an RSA key of moderate security.
37      */
38     bits =
39         gnutls_sec_param_to_pk_bits(GNUTLS_PK_RSA,
40                                     GNUTLS_SEC_PARAM_MEDIUM);
41     gnutls_x509_privkey_generate(key, GNUTLS_PK_RSA, bits, 0);
42
43     /* Add stuff to the distinguished name
44      */
45     gnutls_x509_crq_set_dn_by_oid(crq, GNUTLS_OID_X520_COUNTRY_NAME,
46                                   0, "GR", 2);
47
48     gnutls_x509_crq_set_dn_by_oid(crq, GNUTLS_OID_X520_COMMON_NAME,
49                                   0, "Nikos", strlen("Nikos"));
50

```

```
51     /* Set the request version.
52     */
53     gnutls_x509_crq_set_version(crq, 1);
54
55     /* Set a challenge password.
56     */
57     gnutls_x509_crq_set_challenge_password(crq,
58                                           "something to remember here");
59
60     /* Associate the request with the private key
61     */
62     gnutls_x509_crq_set_key(crq, key);
63
64     /* Self sign the certificate request.
65     */
66     gnutls_x509_crq_sign2(crq, key, GNUTLS_DIG_SHA1, 0);
67
68     /* Export the PEM encoded certificate request, and
69     * display it.
70     */
71     gnutls_x509_crq_export(crq, GNUTLS_X509_FMT_PEM, buffer,
72                           &buffer_size);
73
74     printf("Certificate Request: \n%s", buffer);
75
76
77     /* Export the PEM encoded private key, and
78     * display it.
79     */
80     buffer_size = sizeof(buffer);
81     gnutls_x509_privkey_export(key, GNUTLS_X509_FMT_PEM, buffer,
82                               &buffer_size);
83
84     printf("\n\nPrivate key: \n%s", buffer);
85
86     gnutls_x509_crq_deinit(crq);
87     gnutls_x509_privkey_deinit(key);
88
89     return 0;
90 }
91 }
```

3.2.2 PKIX certificate revocation lists

A certificate revocation list (CRL) is a structure issued by an authority periodically containing a list of revoked certificates serial numbers. The CRL structure is signed with the issuing authorities' keys. A typical CRL contains the fields as shown in ???. Certificate revocation lists are used to complement the expiration date of a certificate, in order to account for other reasons of revocation, such as compromised keys, etc.

Each CRL is valid for limited amount of time and is required to provide, except for the current issuing time, also the issuing time of the next update.

The basic CRL structure functions follow.

```
int gnutls_x509_crl_init (gnutls_x509_crl_t * crl)

int gnutls_x509_crl_import (gnutls_x509_crl_t crl, const gnutls_datum_t * data,
gnutls_x509_crt_fmt_t format)

int gnutls_x509_crl_export (gnutls_x509_crl_t crl, gnutls_x509_crt_fmt_t format,
void * output_data, size_t * output_data_size)

int gnutls_x509_crl_export (gnutls_x509_crl_t crl, gnutls_x509_crt_fmt_t format,
void * output_data, size_t * output_data_size)
```

Reading a CRL

The most important function that extracts the certificate revocation information from a CRL is `gnutls_x509_crl_get_cert_serial`. Other functions that return other fields of the CRL structure are also provided.

```
int gnutls_x509_crl_get_cert_serial (gnutls_x509_crl_t crl, int indx, unsigned char *
serial, size_t * serial_size, time_t * t)
```

Description: This function will retrieve the serial number of the specified, by the index, revoked certificate. Note that this function will have performance issues in large sequences of revoked certificates. In that case use `gnutls_x509_crl_iter_cert_serial()`.

Returns: On success, `GNUTLS_E_SUCCESS` (0) is returned, otherwise a negative error value.

```
int gnutls_x509_crl_get_version (gnutls_x509_crl_t crl)

int gnutls_x509_crl_get_issuer_dn (const gnutls_x509_crl_t crl, char * buf, size_t *
sizeof_buf)

int gnutls_x509_crl_get_issuer_dn2 (gnutls_x509_crl_t crl, gnutls_datum_t * dn)

time_t gnutls_x509_crl_get_this_update (gnutls_x509_crl_t crl)

time_t gnutls_x509_crl_get_next_update (gnutls_x509_crl_t crl)

int gnutls_x509_crl_get_crt_count (gnutls_x509_crl_t crl)
```

Generation of a CRL

The following functions can be used to generate a CRL.

```
int gnutls_x509_crl_set_version (gnutls_x509_crl_t crl, unsigned int version)

int gnutls_x509_crl_set_crt_serial (gnutls_x509_crl_t crl, const void * serial, size_t
serial_size, time_t revocation_time)
```

```
int gnutls_x509_crl_set_crt (gnutls_x509_crl_t crl, gnutls_x509_crt_t crt, time_t
revocation_time)

int gnutls_x509_crl_set_next_update (gnutls_x509_crl_t crl, time_t exp_time)

int gnutls_x509_crl_set_this_update (gnutls_x509_crl_t crl, time_t act_time)
```

The `gnutls_x509_crl_sign2` and `gnutls_x509_crl_privkey_sign` functions sign the revocation list with a private key. The latter function can be used to sign with a key residing in a PKCS #11 token.

Few extensions on the CRL structure are supported, including the CRL number extension and the authority key identifier.

```
int gnutls_x509_crl_sign2 (gnutls_x509_crl_t crl, gnutls_x509_crt_t issuer,
gnutls_x509_privkey_t issuer_key, gnutls_digest_algorithm_t dig, unsigned int flags)
```

Description: This function will sign the CRL with the issuer's private key, and will copy the issuer's information into the CRL. This must be the last step in a certificate CRL since all the previously set parameters are now signed.

Returns: On success, GNUTLS_E_SUCCESS (0) is returned, otherwise a negative error value.

```
int gnutls_x509_crl_privkey_sign (gnutls_x509_crl_t crl, gnutls_x509_crt_t issuer,
gnutls_privkey_t issuer_key, gnutls_digest_algorithm_t dig, unsigned int flags)
```

Description: This function will sign the CRL with the issuer's private key, and will copy the issuer's information into the CRL. This must be the last step in a certificate CRL since all the previously set parameters are now signed.

Returns: On success, GNUTLS_E_SUCCESS (0) is returned, otherwise a negative error value. Since 2.12.0

```
int gnutls_x509_crl_set_number (gnutls_x509_crl_t crl, const void * nr, size_t
nr_size)
```

```
int gnutls_x509_crl_set_authority_key_id (gnutls_x509_crl_t crl, const void * id,
size_t id_size)
```

3.2.3 OCSP certificate status checking

Certificates may be revoked before their expiration time has been reached. There are several reasons for revoking certificates, but a typical situation is when the private key associated with a certificate has been compromised. Traditionally, Certificate Revocation Lists (CRLs) have been used by application to implement revocation checking, however, several problems with CRLs have been identified [?].

The Online Certificate Status Protocol, or OCSP [?], is a widely implemented protocol which performs certificate revocation status checking. An application that wish to verify the identity of a peer will verify the certificate against a set of trusted certificates and then check whether the certificate is listed in a CRL and/or perform an OCSP check for the certificate.

Note that in the context of a TLS session the server may provide an OCSP response that will be used during the TLS certificate verification (see `gnutls_certificate_verify_peers2`).

You may obtain this response using `gnutls_ocsp_status_request_get`.

Before performing the OCSP query, the application will need to figure out the address of the OCSP server. The OCSP server address can be provided by the local user in manual configuration or may be stored in the certificate that is being checked. When stored in a certificate the OCSP server is in the extension field called the Authority Information Access (AIA). The following function extracts this information from a certificate.

```
int gnutls_x509_cert_get_authority_info_access (gnutls_x509_cert_t cert, unsigned int seq, int what, gnutls_datum_t * data, unsigned int * critical)
```

There are several functions in GnuTLS for creating and manipulating OCSP requests and responses. The general idea is that a client application creates an OCSP request object, stores some information about the certificate to check in the request, and then exports the request in DER format. The request will then need to be sent to the OCSP responder, which needs to be done by the application (GnuTLS does not send and receive OCSP packets). Normally an OCSP response is received that the application will need to import into an OCSP response object. The digital signature in the OCSP response needs to be verified against a set of trust anchors before the information in the response can be trusted.

The ASN.1 structure of OCSP requests are briefly as follows. It is useful to review the structures to get an understanding of which fields are modified by GnuTLS functions.

```
1 OCSPRequest ::= SEQUENCE {
2   tbsRequest      TBSRequest,
3   optionalSignature [0] EXPLICIT Signature OPTIONAL }
4
5 TBSRequest ::= SEQUENCE {
6   version          [0] EXPLICIT Version DEFAULT v1,
7   requestorName    [1] EXPLICIT GeneralName OPTIONAL,
8   requestList      SEQUENCE OF Request,
9   requestExtensions [2] EXPLICIT Extensions OPTIONAL }
10
11 Request ::= SEQUENCE {
12   reqCert          CertID,
13   singleRequestExtensions [0] EXPLICIT Extensions OPTIONAL }
14
15 CertID ::= SEQUENCE {
16   hashAlgorithm    AlgorithmIdentifier,
17   issuerNameHash    OCTET STRING, -- Hash of Issuer's DN
18   issuerKeyHash     OCTET STRING, -- Hash of Issuers public key
19   serialNumber      CertificateSerialNumber }
```

The basic functions to initialize, import, export and deallocate OCSP requests are the following.

```
int gnutls_ocsp_req_init (gnutls_ocsp_req_t * req)

void gnutls_ocsp_req_deinit (gnutls_ocsp_req_t req)

int gnutls_ocsp_req_import (gnutls_ocsp_req_t req, const gnutls_datum_t * data)

int gnutls_ocsp_req_export (gnutls_ocsp_req_t req, gnutls_datum_t * data)

int gnutls_ocsp_req_print (gnutls_ocsp_req_t req, gnutls_ocsp_print_formats_t format, gnutls_datum_t * out)
```

To generate an OCSF request the issuer name hash, issuer key hash, and the checked certificate's serial number are required. There are two interfaces available for setting those in an OCSF request. The first is a low-level function when you have the issuer name hash, issuer key hash, and certificate serial number in binary form. The second is more useful if you have the certificate (and its issuer) in a `gnutls_x509_crt_t` type. There is also a function to extract this information from existing an OCSF request.

```
int gnutls_ocsp_req_add_cert_id (gnutls_ocsp_req_t req, gnutls_digest_algorithm_t digest, const gnutls_datum_t * issuer_name_hash, const gnutls_datum_t * issuer_key_hash, const gnutls_datum_t * serial_number)

int gnutls_ocsp_req_add_cert (gnutls_ocsp_req_t req, gnutls_digest_algorithm_t digest, gnutls_x509_crt_t issuer, gnutls_x509_crt_t cert)

int gnutls_ocsp_req_get_cert_id (gnutls_ocsp_req_t req, unsigned int indx, gnutls_digest_algorithm_t * digest, gnutls_datum_t * issuer_name_hash, gnutls_datum_t * issuer_key_hash, gnutls_datum_t * serial_number)
```

Each OCSF request may contain a number of extensions. Extensions are identified by an Object Identifier (OID) and an opaque data buffer whose syntax and semantics is implied by the OID. You can extract or set those extensions using the following functions.

```
int gnutls_ocsp_req_get_extension (gnutls_ocsp_req_t req, unsigned int indx, gnutls_datum_t * oid, unsigned int * critical, gnutls_datum_t * data)

int gnutls_ocsp_req_set_extension (gnutls_ocsp_req_t req, const char * oid, unsigned int critical, const gnutls_datum_t * data)
```

A common OCSLP Request extension is the nonce extension (OID 1.3.6.1.5.5.7.48.1.2), which is used to avoid replay attacks of earlier recorded OCSLP responses. The nonce extension carries a value that is intended to be sufficiently random and unique so that an attacker will not be able to give a stale response for the same nonce.

```
int gnutls_ocsp_req_get_nonce (gnutls_ocsp_req_t req, unsigned int * critical,
gnutls_datum_t * nonce)

int gnutls_ocsp_req_set_nonce (gnutls_ocsp_req_t req, unsigned int critical, const
gnutls_datum_t * nonce)

int gnutls_ocsp_req_randomize_nonce (gnutls_ocsp_req_t req)
```

The OCSLP response structures is a complex structure. A simplified overview of it is in ?? . Note that a response may contain information on multiple certificates.

We provide basic functions for initialization, importing, exporting and deallocating OCSLP responses.

```
int gnutls_ocsp_resp_init (gnutls_ocsp_resp_t * resp)

void gnutls_ocsp_resp_deinit (gnutls_ocsp_resp_t resp)

int gnutls_ocsp_resp_import (gnutls_ocsp_resp_t resp, const gnutls_datum_t * data)

int gnutls_ocsp_resp_export (gnutls_ocsp_resp_t resp, gnutls_datum_t * data)

int gnutls_ocsp_resp_print (gnutls_ocsp_resp_t resp, gnutls_ocsp_print_formats_t
format, gnutls_datum_t * out)
```

The utility function that extracts the revocation as well as other information from a response is shown below.

The possible revocation reasons available in an OCSLP response are shown below.

Note, that the OCSLP response needs to be verified against some set of trust anchors before it can be relied upon. It is also important to check whether the received OCSLP response corresponds to the certificate being checked.

```
int gnutls_ocsp_resp_get_single (gnutls_ocsp_resp_t resp, unsigned indx,
gnutls_digest_algorithm_t * digest, gnutls_datum_t * issuer_name_hash,
gnutls_datum_t * issuer_key_hash, gnutls_datum_t * serial_number, unsigned
int * cert_status, time_t * this_update, time_t * next_update, time_t * revoca-
tion_time, unsigned int * revocation_reason)
```

Description: This function will return the certificate information of the `indx`'ed response in the Basic OCSP Response `resp`. The information returned corresponds to the OCSP SingleResponse structure except the final singleExtensions. Each of the pointers to output variables may be NULL to indicate that the caller is not interested in that value.

Returns: On success, `GNUTLS_E_SUCCESS` (0) is returned, otherwise a negative error code is returned. If you have reached the last CertID available `GNUTLS_E_REQUESTED_DATA_NOT_AVAILABLE` will be returned.

```
int gnutls_ocsp_resp_verify (gnutls_ocsp_resp_t resp, gnutls_x509_trust_list_t
trustlist, unsigned int * verify, unsigned int flags)

int gnutls_ocsp_resp_verify_direct (gnutls_ocsp_resp_t resp, gnutls_x509_crt_t is-
suer, unsigned int * verify, unsigned int flags)

int gnutls_ocsp_resp_check_crt (gnutls_ocsp_resp_t resp, unsigned int indx,
gnutls_x509_crt_t crt)
```

3.2.4 Managing encrypted keys

Transferring or storing private keys in plain may not be a good idea, since any compromise is irreparable. Storing the keys in hardware security modules (see ??) could solve the storage problem but it is not always practical or efficient enough. This section describes ways to store and transfer encrypted private keys.

There are methods for key encryption, namely the PKCS #8, PKCS #12 and OpenSSL's custom encrypted private key formats. The PKCS #8 and the OpenSSL's method allow encryption of the private key, while the PKCS #12 method allows, in addition, the bundling of accompanying data into the structure. That is typically the corresponding certificate, as well as a trusted CA certificate.

High level functionality

Generic and higher level private key import functions are available, that import plain or encrypted keys and will auto-detect the encrypted key format.

```
int gnutls_privkey_import_x509_raw (gnutls_privkey_t pkey, const gnutls_datum_t *  
data, gnutls_x509_crt_fmt_t format, const char * password, unsigned int flags)
```

Description: This function will import the given private key to the abstract *gnutls_privkey_t* type. The supported formats are basic unencrypted key, PKCS8, PKCS12, and the openssl format.

Returns: On success, `GNUTLS_E_SUCCESS` (0) is returned, otherwise a negative error value.

```
int gnutls_x509_privkey_import2 (gnutls_x509_privkey_t key, const gnutls_datum_t *  
data, gnutls_x509_crt_fmt_t format, const char * password, unsigned int flags)
```

Description: This function will import the given DER or PEM encoded key, to the native *gnutls_x509_privkey_t* format, irrespective of the input format. The input format is auto-detected. The supported formats are basic unencrypted key, PKCS8, PKCS12, and the openssl format. If the provided key is encrypted but no password was given, then `GNUTLS_E_DECRYPTION_FAILED` is returned. Since GnuTLS 3.4.0 this function will utilize the PIN callbacks if any.

Returns: On success, `GNUTLS_E_SUCCESS` (0) is returned, otherwise a negative error value.

Any keys imported using those functions can be imported to a certificate credentials structure using `gnutls_certificate_set_key`, or alternatively they can be directly imported using `gnutls_certificate_set_x509_key_file2`.

PKCS #8 structures

PKCS #8 keys can be imported and exported as normal private keys using the functions below. An addition to the normal import functions, are a password and a flags argument. The flags can be any element of the `gnutls_pkcs_encrypt_flags_t` enumeration. Note however, that GnuTLS only supports the PKCS #5 PBES2 encryption scheme. Keys encrypted with the obsolete PBES1 scheme cannot be decrypted.

```
int gnutls_x509_privkey_import_pkcs8 (gnutls_x509_privkey_t key, const
gnutls_datum_t * data, gnutls_x509_crt_fmt_t format, const char * password,
unsigned int flags)

int gnutls_x509_privkey_export_pkcs8 (gnutls_x509_privkey_t key,
gnutls_x509_crt_fmt_t format, const char * password, unsigned int flags, void
* output_data, size_t * output_data_size)

int gnutls_x509_privkey_export2_pkcs8 (gnutls_x509_privkey_t key,
gnutls_x509_crt_fmt_t format, const char * password, unsigned int flags,
gnutls_datum_t * out)
```

PKCS #12 structures

A PKCS #12 structure [?] usually contains a user's private keys and certificates. It is commonly used in browsers to export and import the user's identities. A file containing such a key can be directly imported to a certificate credentials structure by using `gnutls_certificate_set-x509_simple_pkcs12_file`.

In GnuTLS the PKCS #12 structures are handled using the `gnutls_pkcs12_t` type. This is an abstract type that may hold several `gnutls_pkcs12_bag_t` types. The bag types are the holders of the actual data, which may be certificates, private keys or encrypted data. A bag of type encrypted should be decrypted in order for its data to be accessed.

To reduce the complexity in parsing the structures the simple helper function `gnutls_pkcs12-simple_parse` is provided. For more advanced uses, manual parsing of the structure is required using the functions below.

```
int gnutls_pkcs12_get_bag (gnutls_pkcs12_t pkcs12, int indx, gnutls_pkcs12_bag_t
bag)

int gnutls_pkcs12_verify_mac (gnutls_pkcs12_t pkcs12, const char * pass)

int gnutls_pkcs12_bag_decrypt (gnutls_pkcs12_bag_t bag, const char * pass)

int gnutls_pkcs12_bag_get_count (gnutls_pkcs12_bag_t bag)
```

```
int gnutls_pkcs12_simple_parse (gnutls_pkcs12_t p12, const char * password,
gnutls_x509_privkey_t * key, gnutls_x509_crt_t ** chain, unsigned int * chain_len,
gnutls_x509_crt_t ** extra_certs, unsigned int * extra_certs_len, gnutls_x509_crl_t *
crl, unsigned int flags)
```

Description: This function parses a PKCS12 structure in `pkcs12` and extracts the private key, the corresponding certificate chain, any additional certificates and a CRL. The `extra_certs` and `extra_certs_len` parameters are optional and both may be set to `NULL`. If either is non-`NULL`, then both must be set. The value for `extra_certs` is allocated using `gnutls_malloc()`. Encrypted PKCS12 bags and PKCS8 private keys are supported, but only with password based security and the same password for all operations. Note that a PKCS12 structure may contain many keys and/or certificates, and there is no way to identify which key/certificate pair you want. For this reason this function is useful for PKCS12 files that contain only one key/certificate pair and/or one CRL. If the provided structure has encrypted fields but no password is provided then this function returns `GNUTLS_E_DECRYPTION_FAILED`. Note that normally the chain constructed does not include self signed certificates, to comply with TLS' requirements. If, however, the flag `GNUTLS_PKCS12_SP_INCLUDE_SELF_SIGNED` is specified then self signed certificates will be included in the chain. Prior to using this function the PKCS #12 structure integrity must be verified using `gnutls_pkcs12_verify_mac()`.

Returns: On success, `GNUTLS_E_SUCCESS` (0) is returned, otherwise a negative error value.

```
int gnutls_pkcs12_bag_get_data (gnutls_pkcs12_bag_t bag, int indx,
gnutls_datum_t * data)
```

```
int gnutls_pkcs12_bag_get_key_id (gnutls_pkcs12_bag_t bag, int indx,
gnutls_datum_t * id)
```

```
int gnutls_pkcs12_bag_get_friendly_name (gnutls_pkcs12_bag_t bag, int indx,
char ** name)
```

The functions below are used to generate a PKCS #12 structure. An example of their usage is shown at ??.

```
int gnutls_pkcs12_set_bag (gnutls_pkcs12_t pkcs12, gnutls_pkcs12_bag_t bag)

int gnutls_pkcs12_bag_encrypt (gnutls_pkcs12_bag_t bag, const char * pass, unsigned int flags)

int gnutls_pkcs12_generate_mac (gnutls_pkcs12_t pkcs12, const char * pass)
```

```
int gnutls_pkcs12_bag_set_data (gnutls_pkcs12_bag_t bag, gnutls_pkcs12_bag_type_t type, const gnutls_datum_t * data)

int gnutls_pkcs12_bag_set_crl (gnutls_pkcs12_bag_t bag, gnutls_x509_crl_t crl)

int gnutls_pkcs12_bag_set_cert (gnutls_pkcs12_bag_t bag, gnutls_x509_cert_t cert)

int gnutls_pkcs12_bag_set_key_id (gnutls_pkcs12_bag_t bag, int indx, const gnutls_datum_t * id)

int gnutls_pkcs12_bag_set_friendly_name (gnutls_pkcs12_bag_t bag, int indx, const char * name)
```

OpenSSL encrypted keys

Unfortunately the structures discussed in the previous sections are not the only structures that may hold an encrypted private key. For example the OpenSSL library offers a custom key encryption method. Those structures are also supported in GnuTLS with `gnutls_x509_privkey_import_openssl`.

3.2.5 Invoking certtool

Tool to parse and generate X.509 certificates, requests and private keys. It can be used interactively or non interactively by specifying the template command line option.

The tool accepts files or URLs supported by GnuTLS. In case PIN is required for the URL access you can provide it using the environment variables `GNUTLS_PIN` and `GNUTLS_SO_PIN`.

This section was generated by **AutoGen**, using the `agtexi-cmd` template and the option descriptions for the `certtool` program. This software is released under the GNU General Public License, version 3 or later.


```
int gnutls_x509_privkey_import_openssl (gnutls_x509_privkey_t key, const
gnutls_datum_t * data, const char * password)
```

Description: This function will convert the given PEM encrypted to the native gnutls_x509_privkey_t format. The output will be stored in key. The password should be in ASCII. If the password is not provided or wrong then **GNUTLS_E_DECRYPTION_FAILED** will be returned. If the Certificate is PEM encoded it should have a header of "PRIVATE KEY" and the "DEK-Info" header.

Returns: On success, **GNUTLS_E_SUCCESS** (0) is returned, otherwise a negative error value.

certtool help/usage (“--help”)

This is the automatically generated usage text for certtool.

The text printed is the same whether selected with the **help** option (“--help”) or the **more-help** option (“--more-help”). **more-help** will print the usage text by passing it through a pager program. **more-help** is disabled on platforms without a working **fork(2)** function. The **PAGER** environment variable is used to select the program, defaulting to “more”. Both will exit with a status code of 0.

```
1 certtool - GnuTLS certificate tool
2 Usage: certtool [ -<flag> [<val>] | --<name>[={| }<val>] ]...
3
4 -d, --debug=num          Enable debugging
5                          - it must be in the range:
6                          0 to 9999
7 -V, --verbose            More verbose output
8                          - may appear multiple times
9 --infile=file            Input file
10                        - file must pre-exist
11 --outfile=str            Output file
12 -s, --generate-self-signed Generate a self-signed certificate
13 -c, --generate-certificate Generate a signed certificate
14 --generate-proxy         Generates a proxy certificate
15 --generate-crl           Generate a CRL
16 -u, --update-certificate Update a signed certificate
17 -p, --generate-privkey   Generate a private key
18 -q, --generate-request   Generate a PKCS #10 certificate request
19                          - prohibits the option 'infile'
20 -e, --verify-chain       Verify a PEM encoded certificate chain
21 --verify                 Verify a PEM encoded certificate chain using a trusted list
22 --verify-crl             Verify a CRL using a trusted list
23                          - requires the option 'load-ca-certificate'
24 --generate-dh-params     Generate PKCS #3 encoded Diffie-Hellman parameters
25 --get-dh-params          Get the included PKCS #3 encoded Diffie-Hellman parameters
26 --dh-info                Print information PKCS #3 encoded Diffie-Hellman parameters
27 --load-privkey=str       Loads a private key file
28 --load-pubkey=str        Loads a public key file
```

3.2. MORE ON CERTIFICATE AUTHENTICATION

```
29      --load-request=str      Loads a certificate request file
30      --load-certificate=str  Loads a certificate file
31      --load-ca-privkey=str   Loads the certificate authority's private key file
32      --load-ca-certificate=str Loads the certificate authority's certificate file
33      --password=str          Password to use
34      --null-password         Enforce a NULL password
35      --empty-password        Enforce an empty password
36      --hex-numbers           Print big number in an easier format to parse
37      --cprint                 In certain operations it prints the information in C-friendly format
38      -i, --certificate-info   Print information on the given certificate
39      --certificate-pubkey     Print certificate's public key
40      --pgp-certificate-info   Print information on the given OpenPGP certificate
41      --pgp-ring-info         Print information on the given OpenPGP keyring structure
42      -l, --crl-info           Print information on the given CRL structure
43      --crq-info              Print information on the given certificate request
44      --no-crq-extensions      Do not use extensions in certificate requests
45      --p12-info              Print information on a PKCS #12 structure
46      --p12-name=str          The PKCS #12 friendly name to use
47      --p7-info               Print information on a PKCS #7 structure
48      --smime-to-p7           Convert S/MIME to PKCS #7 structure
49      -k, --key-info           Print information on a private key
50      --pgp-key-info           Print information on an OpenPGP private key
51      --pubkey-info           Print information on a public key
52      --v1                    Generate an X.509 version 1 certificate (with no extensions)
53      -!, --to-p12             Generate a PKCS #12 structure
54                              - requires the option 'load-certificate'
55      -, --to-p8               Generate a PKCS #8 structure
56      -8, --pkcs8              Use PKCS #8 format for private keys
57      -#, --rsa                Generate RSA key
58      -$, --dsa                Generate DSA key
59      -%, --ecc                Generate ECC (ECDSA) key
60      -&, --ecdsa              an alias for the 'ecc' option
61      -', --hash=str           Hash algorithm to use for signing
62      -(, --inder              Use DER format for input certificates, private keys, and DH parameters
63                              - disabled as '--no-inder'
64      -), --inraw              an alias for the 'inder' option
65      -*, --outder             Use DER format for output certificates, private keys, and DH parameters
66                              - disabled as '--no-outder'
67      +, --outraw              an alias for the 'outder' option
68      -, --bits=num            Specify the number of bits for key generate
69      --, --curve=str          Specify the curve used for EC key generation
70      -., --sec-param=str       Specify the security level [low, legacy, medium, high, ultra]
71      -/, --disable-quick-random No effect
72      -0, --template=str       Template file to use for non-interactive operation
73      -1, --stdout-info        Print information to stdout instead of stderr
74      -2, --ask-pass           Enable interaction for entering password when in batch mode.
75      -3, --pkcs-cipher=str     Cipher to use for PKCS #8 and #12 operations
76      -4, --provider=str       Specify the PKCS #11 provider library
77      -v, --version[=arg]      output version information and exit
78      -h, --help               display extended usage information and exit
79      -!, --more-help          extended usage information passed thru pager
80
81 Options are specified by doubled hyphens and their name or by a single
82 hyphen and the flag character.
83
84 Tool to parse and generate X.509 certificates, requests and private keys.
85 It can be used interactively or non interactively by specifying the
86 template command line option.
```

```
87 |  
88 | The tool accepts files or URLs supported by GnuTLS. In case PIN is  
89 | required for the URL access you can provide it using the environment  
90 | variables GNUTLS_PIN and GNUTLS_S0_PIN.  
91 |
```

debug option (-d)

This is the “enable debugging” option. This option takes a number argument. Specifies the debug level.

generate-request option (-q)

This is the “generate a pkcs #10 certificate request” option.

This option has some usage constraints. It:

- must not appear in combination with any of the following options: `infile`.

Will generate a PKCS #10 certificate request. To specify a private key use `-load-privkey`.

verify-chain option (-e)

This is the “verify a pem encoded certificate chain” option. The last certificate in the chain must be a self signed one. It can be combined with `-verify-purpose` or `-verify-hostname`.

verify option

This is the “verify a pem encoded certificate chain using a trusted list” option. The trusted certificate list can be loaded with `-load-ca-certificate`. If no certificate list is provided, then the system’s certificate list is used. Note that during verification multiple paths may be explored. On a successful verification the successful path will be the last one. It can be combined with `-verify-purpose` or `-verify-hostname`.

verify-crl option

This is the “verify a crl using a trusted list” option.

This option has some usage constraints. It:

- must appear in combination with the following options: `load-ca-certificate`.

The trusted certificate list must be loaded with `-load-ca-certificate`.

verify-hostname option

This is the “specify a hostname to be used for certificate chain verification” option. This option takes a string argument. This is to be combined with one of the verify certificate options.

verify-email option

This is the “specify a email to be used for certificate chain verification” option. This option takes a string argument.

This option has some usage constraints. It:

- must not appear in combination with any of the following options: verify-hostname.

This is to be combined with one of the verify certificate options.

verify-purpose option

This is the “specify a purpose oid to be used for certificate chain verification” option. This option takes a string argument. This object identifier restricts the purpose of the certificates to be verified. Example purposes are 1.3.6.1.5.5.7.3.1 (TLS WWW), 1.3.6.1.5.5.7.3.4 (EMAIL) etc. Note that a CA certificate without a purpose set (extended key usage) is valid for any purpose.

get-dh-params option

This is the “get the included pkcs #3 encoded diffie-hellman parameters” option. Returns stored DH parameters in GnuTLS. Those parameters are used in the SRP protocol. The parameters returned by fresh generation are more efficient since GnuTLS 3.0.9.

load-privkey option

This is the “loads a private key file” option. This option takes a string argument. This can be either a file or a PKCS #11 URL

load-pubkey option

This is the “loads a public key file” option. This option takes a string argument. This can be either a file or a PKCS #11 URL

load-certificate option

This is the “loads a certificate file” option. This option takes a string argument. This can be either a file or a PKCS #11 URL

load-ca-privkey option

This is the “loads the certificate authority’s private key file” option. This option takes a string argument. This can be either a file or a PKCS #11 URL

load-ca-certificate option

This is the “loads the certificate authority’s certificate file” option. This option takes a string argument. This can be either a file or a PKCS #11 URL

password option

This is the “password to use” option. This option takes a string argument. You can use this option to specify the password in the command line instead of reading it from the tty. Note, that the command line arguments are available for view in others in the system. Specifying password as ” is the same as specifying no password.

null-password option

This is the “enforce a null password” option. This option enforces a NULL password. This is different than the empty or no password in schemas like PKCS #8.

empty-password option

This is the “enforce an empty password” option. This option enforces an empty password. This is different than the NULL or no password in schemas like PKCS #8.

cprint option

This is the “in certain operations it prints the information in c-friendly format” option. In certain operations it prints the information in C-friendly format, suitable for including into C programs.

fingerprint option

This is the “print the fingerprint of the given certificate” option. This is a simple hash of the DER encoding of the certificate. It is always better to use the key-id.

key-id option

This is the “print the key id of the given certificate” option. This is a hash of the public key of the given certificate. It identifies the key uniquely, remains the same on a certificate renewal and depends only on signed fields of the certificate.

p12-info option

This is the “print information on a pkcs #12 structure” option. This option will dump the contents and print the metadata of the provided PKCS #12 structure.

p12-name option

This is the “the pkcs #12 friendly name to use” option. This option takes a string argument. The name to be used for the primary certificate and private key in a PKCS #12 file.

p8-info option

This is the “print information on a pkcs #8 structure” option. This option will print information about encrypted PKCS #8 structures. That option does not require the decryption of the structure.

pubkey-info option

This is the “print information on a public key” option. The option combined with `-load-request`, `-load-pubkey`, `-load-privkey` and `-load-certificate` will extract the public key of the object in question.

to-p12 option

This is the “generate a pkcs #12 structure” option.

This option has some usage constraints. It:

- must appear in combination with the following options: `load-certificate`.

It requires a certificate, a private key and possibly a CA certificate to be specified.

rsa option

This is the “generate rsa key” option. When combined with `-generate-privkey` generates an RSA private key.

dsa option

This is the “generate dsa key” option. When combined with `-generate-privkey` generates a DSA private key.

ecc option

This is the “generate ecc (ecdsa) key” option. When combined with `-generate-privkey` generates an elliptic curve private key to be used with ECDSA.

ecdsa option

This is an alias for the `ecc` option, ??.

hash option

This is the “hash algorithm to use for signing” option. This option takes a string argument. Available hash functions are SHA1, RMD160, SHA256, SHA384, SHA512.

inder option

This is the “use der format for input certificates, private keys, and dh parameters ” option.

This option has some usage constraints. It:

- can be disabled with `-no-inder`.

The input files will be assumed to be in DER or RAW format. Unlike options that in PEM input would allow multiple input data (e.g. multiple certificates), when reading in DER format a single data structure is read.

inraw option

This is an alias for the `inder` option, ??.

outder option

This is the “use der format for output certificates, private keys, and dh parameters” option.

This option has some usage constraints. It:

- can be disabled with `-no-outder`.

The output will be in DER or RAW format.

outraw option

This is an alias for the `outder` option, `??`.

curve option

This is the “specify the curve used for ec key generation” option. This option takes a string argument. Supported values are `secp192r1`, `secp224r1`, `secp256r1`, `secp384r1` and `secp521r1`.

sec-param option

This is the “specify the security level [low, legacy, medium, high, ultra]” option. This option takes a string argument “`Security parameter`”. This is alternative to the `bits` option.

ask-pass option

This is the “enable interaction for entering password when in batch mode.” option. This option will enable interaction to enter password when in batch mode. That is useful when the `template` option has been specified.

pkcs-cipher option

This is the “cipher to use for pkcs #8 and #12 operations” option. This option takes a string argument “`Cipher`”. Cipher may be one of `3des`, `3des-pkcs12`, `aes-128`, `aes-192`, `aes-256`, `rc2-40`, `arcfour`.

provider option

This is the “specify the pkcs #11 provider library” option. This option takes a string argument. This will override the default options in `/etc/gnutls/pkcs11.conf`

certtool exit status

One of the following exit values will be returned:

- 0 (`EXIT_SUCCESS`) Successful program execution.
- 1 (`EXIT_FAILURE`) The operation failed or the command syntax was not valid.

certtool See Also

`p11tool` (1)

certtool Examples

Generating private keys

To create an RSA private key, run:

```
1 $ certtool --generate-privkey --outfile key.pem --rsa
```

To create a DSA or elliptic curves (ECDSA) private key use the above command combined with 'dsa' or 'ecc' options.

Generating certificate requests

To create a certificate request (needed when the certificate is issued by another party), run:

```
1 certtool --generate-request --load-privkey key.pem \  
2 --outfile request.pem
```

If the private key is stored in a smart card you can generate a request by specifying the private key object URL.

```
1 $ ./certtool --generate-request --load-privkey "pkcs11:..." \  
2 --load-pubkey "pkcs11:..." --outfile request.pem
```

Generating a self-signed certificate

To create a self signed certificate, use the command:

```
1 $ certtool --generate-privkey --outfile ca-key.pem  
2 $ certtool --generate-self-signed --load-privkey ca-key.pem \  
3 --outfile ca-cert.pem
```

Note that a self-signed certificate usually belongs to a certificate authority, that signs other certificates.

Generating a certificate

To generate a certificate using the previous request, use the command:

```
1 $ certtool --generate-certificate --load-request request.pem \  
2 --outfile cert.pem --load-ca-certificate ca-cert.pem \  
3 --load-ca-privkey ca-key.pem
```

To generate a certificate using the private key only, use the command:

```
1 $ certtool --generate-certificate --load-privkey key.pem \  
2 --outfile cert.pem --load-ca-certificate ca-cert.pem \  
3 --load-ca-privkey ca-key.pem
```

Certificate information

To view the certificate information, use:

```
1 $ certtool --certificate-info --infile cert.pem
```

PKCS #12 structure generation

To generate a PKCS #12 structure using the previous key and certificate, use the command:

```
1 $ certtool --load-certificate cert.pem --load-privkey key.pem \  
2 --to-p12 --outder --outfile key.p12
```

Some tools (reportedly web browsers) have problems with that file because it does not contain the CA certificate for the certificate. To work around that problem in the tool, you can use the `--load-ca-certificate` parameter as follows:

```
1 $ certtool --load-ca-certificate ca.pem \  
2 --load-certificate cert.pem --load-privkey key.pem \  
3 --to-p12 --outder --outfile key.p12
```

Diffie-Hellman parameter generation

To generate parameters for Diffie-Hellman key exchange, use the command:

```
1 $ certtool --generate-dh-params --outfile dh.pem --sec-param medium
```

Proxy certificate generation

Proxy certificate can be used to delegate your credential to a temporary, typically short-lived, certificate. To create one from the previously created certificate, first create a temporary key and then generate a proxy certificate for it, using the commands:

```
1 $ certtool --generate-privkey > proxy-key.pem  
2 $ certtool --generate-proxy --load-ca-privkey key.pem \  
3 --load-privkey proxy-key.pem --load-certificate cert.pem \  
4 --outfile proxy-cert.pem
```

Certificate revocation list generation

To create an empty Certificate Revocation List (CRL) do:

```
1 $ certtool --generate-crl --load-ca-privkey x509-ca-key.pem \  
2   --load-ca-certificate x509-ca.pem
```

To create a CRL that contains some revoked certificates, place the certificates in a file and use `--load-certificate` as follows:

```
1 $ certtool --generate-crl --load-ca-privkey x509-ca-key.pem \  
2   --load-ca-certificate x509-ca.pem --load-certificate revoked-certs.pem
```

To verify a Certificate Revocation List (CRL) do:

```
1 $ certtool --verify-crl --load-ca-certificate x509-ca.pem < crl.pem
```

certtool Files

Certtool's template file format

A template file can be used to avoid the interactive questions of certtool. Initially create a file named 'cert.cfg' that contains the information about the certificate. The template can be used as below:

```
1 $ certtool --generate-certificate --load-privkey key.pem \  
2   --template cert.cfg --outfile cert.pem \  
3   --load-ca-certificate ca-cert.pem --load-ca-privkey ca-key.pem
```

An example certtool template file that can be used to generate a certificate request or a self signed certificate follows.

```
1 # X.509 Certificate options  
2 #  
3 # DN options  
4  
5 # The organization of the subject.  
6 organization = "Koko inc."  
7  
8 # The organizational unit of the subject.  
9 unit = "sleeping dept."  
10  
11 # The locality of the subject.  
12 # locality =  
13  
14 # The state of the certificate owner.  
15 state = "Attiki"  
16  
17 # The country of the subject. Two letter code.  
18 country = GR  
19  
20 # The common name of the certificate owner.
```

```

21 | cn = "Cindy Lauper"
22 |
23 | # A user id of the certificate owner.
24 | #uid = "clauper"
25 |
26 | # Set domain components
27 | #dc = "name"
28 | #dc = "domain"
29 |
30 | # If the supported DN OIDs are not adequate you can set
31 | # any OID here.
32 | # For example set the X.520 Title and the X.520 Pseudonym
33 | # by using OID and string pairs.
34 | #dn_oid = 2.5.4.12 Dr.
35 | #dn_oid = 2.5.4.65 jackal
36 |
37 | # This is deprecated and should not be used in new
38 | # certificates.
39 | # pkcs9_email = "none@none.org"
40 |
41 | # An alternative way to set the certificate's distinguished name directly
42 | # is with the "dn" option. The attribute names allowed are:
43 | # C (country), street, O (organization), OU (unit), title, CN (common name),
44 | # L (locality), ST (state), placeOfBirth, gender, countryOfCitizenship,
45 | # countryOfResidence, serialNumber, telephoneNumber, surName, initials,
46 | # generationQualifier, givenName, pseudonym, dnQualifier, postalCode, name,
47 | # businessCategory, DC, UID, jurisdictionOfIncorporationLocalityName,
48 | # jurisdictionOfIncorporationStateOrProvinceName,
49 | # jurisdictionOfIncorporationCountryName, XmppAddr, and numeric OIDs.
50 |
51 | #dn = "cn = Nikos,st = New\, Something,C=GR,surName=Mavrogiannopoulos,2.5.4.9=Arkadias"
52 |
53 | # The serial number of the certificate
54 | # Comment the field for a time-based serial number.
55 | serial = 007
56 |
57 | # In how many days, counting from today, this certificate will expire.
58 | # Use -1 if there is no expiration date.
59 | expiration_days = 700
60 |
61 | # Alternatively you may set concrete dates and time. The GNU date string
62 | # formats are accepted. See:
63 | # http://www.gnu.org/software/tar/manual/html\_node/Date-input-formats.html
64 |
65 | #activation_date = "2004-02-29 16:21:42"
66 | #expiration_date = "2025-02-29 16:24:41"
67 |
68 | # X.509 v3 extensions
69 |
70 | # A dnsname in case of a WWW server.
71 | #dns_name = "www.none.org"
72 | #dns_name = "www.morethanone.org"
73 |
74 | # A subject alternative name URI
75 | #uri = "http://www.example.com"
76 |
77 | # An IP address in case of a server.
78 | #ip_address = "192.168.1.1"

```

```
79 |
80 | # An email in case of a person
81 | email = "none@none.org"
82 |
83 | # Challenge password used in certificate requests
84 | challenge_password = 123456
85 |
86 | # Password when encrypting a private key
87 | #password = secret
88 |
89 | # An URL that has CRLs (certificate revocation lists)
90 | # available. Needed in CA certificates.
91 | #crl_dist_points = "http://www.getcrl.crl/getcrl/"
92 |
93 | # Whether this is a CA certificate or not
94 | #ca
95 |
96 | ##### Key usage
97 |
98 | # The following key usage flags are used by CAs and end certificates
99 |
100 | # Whether this certificate will be used to sign data (needed
101 | # in TLS DHE ciphersuites). This is the digitalSignature flag
102 | # in RFC5280 terminology.
103 | signing_key
104 |
105 | # Whether this certificate will be used to encrypt data (needed
106 | # in TLS RSA ciphersuites). Note that it is preferred to use different
107 | # keys for encryption and signing. This is the keyEncipherment flag
108 | # in RFC5280 terminology.
109 | encryption_key
110 |
111 | # Whether this key will be used to sign other certificates. The
112 | # keyCertSign flag in RFC5280 terminology.
113 | #cert_signing_key
114 |
115 | # Whether this key will be used to sign CRLs. The
116 | # cRLSign flag in RFC5280 terminology.
117 | #crl_signing_key
118 |
119 | # The keyAgreement flag of RFC5280. It's purpose is loosely
120 | # defined. Not use it unless required by a protocol.
121 | #key_agreement
122 |
123 | # The dataEncipherment flag of RFC5280. It's purpose is loosely
124 | # defined. Not use it unless required by a protocol.
125 | #data_encipherment
126 |
127 | # The nonRepudiation flag of RFC5280. It's purpose is loosely
128 | # defined. Not use it unless required by a protocol.
129 | #non_repudiation
130 |
131 | ##### Extended key usage (key purposes)
132 |
133 | # The following extensions are used in an end certificate
134 | # to clarify its purpose. Some CAs also use it to indicate
135 | # the types of certificates they are purposed to sign.
136 |
```

```

137
138 # Whether this certificate will be used for a TLS client;
139 # this sets the id-kp-serverAuth (1.3.6.1.5.5.7.3.1) of
140 # extended key usage.
141 #tls_www_client
142
143 # Whether this certificate will be used for a TLS server;
144 # This sets the id-kp-clientAuth (1.3.6.1.5.5.7.3.2) of
145 # extended key usage.
146 #tls_www_server
147
148 # Whether this key will be used to sign code. This sets the
149 # id-kp-codeSigning (1.3.6.1.5.5.7.3.3) of extended key usage
150 # extension.
151 #code_signing_key
152
153 # Whether this key will be used to sign OCSP data. This sets the
154 # id-kp-OCSPSigning (1.3.6.1.5.5.7.3.9) of extended key usage extension.
155 #ocsp_signing_key
156
157 # Whether this key will be used for time stamping. This sets the
158 # id-kp-timeStamping (1.3.6.1.5.5.7.3.8) of extended key usage extension.
159 #time_stamping_key
160
161 # Whether this key will be used for email protection. This sets the
162 # id-kp-emailProtection (1.3.6.1.5.5.7.3.4) of extended key usage extension.
163 #email_protection_key
164
165 # Whether this key will be used for IPsec IKE operations (1.3.6.1.5.5.7.3.17).
166 #ipsec_ike_key
167
168 ## adding custom key purpose OIDs
169
170 # for microsoft smart card logon
171 # key_purpose_oid = 1.3.6.1.4.1.311.20.2.2
172
173 # for email protection
174 # key_purpose_oid = 1.3.6.1.5.5.7.3.4
175
176 # for any purpose (must not be used in intermediate CA certificates)
177 # key_purpose_oid = 2.5.29.37.0
178
179 ### end of key purpose OIDs
180
181 # When generating a certificate from a certificate
182 # request, then honor the extensions stored in the request
183 # and store them in the real certificate.
184 #honor_crq_extensions
185
186 # Path length constraint. Sets the maximum number of
187 # certificates that can be used to certify this certificate.
188 # (i.e. the certificate chain length)
189 #path_len = -1
190 #path_len = 2
191
192 # OCSP URI
193 # ocsp_uri = http://my.ocsp.server/ocsp
194

```

```
195 # CA issuers URI
196 # ca_issuers_uri = http://my.ca.issuer
197
198 # Certificate policies
199 #policy1 = 1.3.6.1.4.1.5484.1.10.99.1.0
200 #policy1_txt = "This is a long policy to summarize"
201 #policy1_url = http://www.example.com/a-policy-to-read
202
203 #policy2 = 1.3.6.1.4.1.5484.1.10.99.1.1
204 #policy2_txt = "This is a short policy"
205 #policy2_url = http://www.example.com/another-policy-to-read
206
207 # Name constraints
208
209 # DNS
210 #nc_permit_dns = example.com
211 #nc_exclude_dns = test.example.com
212
213 # EMAIL
214 #nc_permit_email = "nmav@ex.net"
215
216 # Exclude subdomains of example.com
217 #nc_exclude_email = .example.com
218
219 # Exclude all e-mail addresses of example.com
220 #nc_exclude_email = example.com
221
222
223 # Options for proxy certificates
224 #proxy_policy_language = 1.3.6.1.5.5.7.21.1
225
226
227 # Options for generating a CRL
228
229 # The number of days the next CRL update will be due.
230 # next CRL update will be in 43 days
231 #crl_next_update = 43
232
233 # this is the 5th CRL by this CA
234 # Comment the field for a time-based number.
235 #crl_number = 5
236
```

3.2.6 Invoking ocsptool

Ocsptool is a program that can parse and print information about OCSP requests/responses, generate requests and verify responses.

This section was generated by **AutoGen**, using the `agtexi-cmd` template and the option descriptions for the `ocsptool` program. This software is released under the GNU General Public License, version 3 or later.

ocsptool help/usage (“--help”)

This is the automatically generated usage text for ocsptool.

The text printed is the same whether selected with the **help** option (“--help”) or the **more-help** option (“--more-help”). **more-help** will print the usage text by passing it through a pager program. **more-help** is disabled on platforms without a working **fork(2)** function. The **PAGER** environment variable is used to select the program, defaulting to “more”. Both will exit with a status code of 0.

```

1 ocsptool - GnuTLS OCSP tool
2 Usage: ocsptool [ -<flag> [<val>] | --<name>[={| }<val>] ]...
3
4     -d, --debug=num           Enable debugging
5                               - it must be in the range:
6                               0 to 9999
7     -V, --verbose             More verbose output
8                               - may appear multiple times
9     --infile=file             Input file
10                              - file must pre-exist
11     --outfile=str             Output file
12     --ask[=arg]               Ask an OCSP/HTTP server on a certificate validity
13                              - requires these options:
14                                load-cert
15                                load-issuer
16     -e, --verify-response     Verify response
17     -i, --request-info         Print information on a OCSP request
18     -j, --response-info       Print information on a OCSP response
19     -Q, --generate-request     Generate an OCSP request
20     --nonce                    Use (or not) a nonce to OCSP request
21                              - disabled as '--no-nonce'
22     --load-issuer=file         Read issuer certificate from file
23                              - file must pre-exist
24     --load-cert=file           Read certificate to check from file
25                              - file must pre-exist
26     --load-trust=file          Read OCSP trust anchors from file
27                              - prohibits the option 'load-signer'
28                              - file must pre-exist
29     --load-signer=file         Read OCSP response signer from file
30                              - prohibits the option 'load-trust'
31                              - file must pre-exist
32     --inder                    Use DER format for input certificates and private keys
33                              - disabled as '--no-inder'
34     -Q, --load-request=file     Read DER encoded OCSP request from file
35                              - file must pre-exist
36     -S, --load-response=file    Read DER encoded OCSP response from file
37                              - file must pre-exist
38     -v, --version[=arg]        output version information and exit
39     -h, --help                 display extended usage information and exit
40     -!, --more-help            extended usage information passed thru pager
41
42 Options are specified by doubled hyphens and their name or by a single
43 hyphen and the flag character.
44
45 Ocsptool is a program that can parse and print information about OCSP
46 requests/responses, generate requests and verify responses.

```


debug option (-d)

This is the “enable debugging” option. This option takes a number argument. Specifies the debug level.

ask option

This is the “ask an ocsdp/http server on a certificate validity” option. This option takes an optional string argument @fileserver name—url.

This option has some usage constraints. It:

- must appear in combination with the following options: load-cert, load-issuer.

Connects to the specified HTTP OCSP server and queries on the validity of the loaded certificate.

ocsptool exit status

One of the following exit values will be returned:

- 0 (EXIT_SUCCESS) Successful program execution.
- 1 (EXIT_FAILURE) The operation failed or the command syntax was not valid.

ocsptool See Also

certtool (1)

ocsptool Examples**Print information about an OCSP request**

To parse an OCSP request and print information about the content, the `-i` or `--request-info` parameter may be used as follows. The `-Q` parameter specify the name of the file containing the OCSP request, and it should contain the OCSP request in binary DER format.

```
1 $ ocsptool -i -Q ocsdp-request.der
```

The input file may also be sent to standard input like this:

```
1 $ cat ocsdp-request.der | ocsptool --request-info
```

Print information about an OCSF response

Similar to parsing OCSF requests, OCSF responses can be parsed using the `-j` or `--response-info` as follows.

```
1 $ ocsptool -j -Q ocsf-response.der
2 $ cat ocsf-response.der | ocsptool --response-info
```

Generate an OCSF request

The `-q` or `--generate-request` parameters are used to generate an OCSF request. By default the OCSF request is written to standard output in binary DER format, but can be stored in a file using `--outfile`. To generate an OCSF request the issuer of the certificate to check needs to be specified with `--load-issuer` and the certificate to check with `--load-cert`. By default PEM format is used for these files, although `--inder` can be used to specify that the input files are in DER format.

```
1 $ ocsptool -q --load-issuer issuer.pem --load-cert client.pem \
2   --outfile ocsf-request.der
```

When generating OCSF requests, the tool will add an OCSF extension containing a nonce. This behaviour can be disabled by specifying `--no-nonce`.

Verify signature in OCSF response

To verify the signature in an OCSF response the `-e` or `--verify-response` parameter is used. The tool will read an OCSF response in DER format from standard input, or from the file specified by `--load-response`. The OCSF response is verified against a set of trust anchors, which are specified using `--load-trust`. The trust anchors are concatenated certificates in PEM format. The certificate that signed the OCSF response needs to be in the set of trust anchors, or the issuer of the signer certificate needs to be in the set of trust anchors and the OCSF Extended Key Usage bit has to be asserted in the signer certificate.

```
1 $ ocsptool -e --load-trust issuer.pem \
2   --load-response ocsf-response.der
```

The tool will print status of verification.

Verify signature in OCSF response against given certificate

It is possible to override the normal trust logic if you know that a certain certificate is supposed to have signed the OCSF response, and you want to use it to check the signature. This is achieved using `--load-signer` instead of `--load-trust`. This will load one certificate and it will be used to verify the signature in the OCSF response. It will not check the Extended Key Usage bit.

```
1 $ ocsptool -e --load-signer ocsf-signer.pem \  
2      --load-response ocsf-response.der
```

This approach is normally only relevant in two situations. The first is when the OCSF response does not contain a copy of the signer certificate, so the `--load-trust` code would fail. The second is if you want to avoid the indirect mode where the OCSF response signer certificate is signed by a trust anchor.

Real-world example

Here is an example of how to generate an OCSF request for a certificate and to verify the response. For illustration we'll use the `blog.josefsson.org` host, which (as of writing) uses a certificate from CACert. First we'll use `gnutls-cli` to get a copy of the server certificate chain. The server is not required to send this information, but this particular one is configured to do so.

```
1 $ echo | gnutls-cli -p 443 blog.josefsson.org --print-cert > chain.pem
```

Use a text editor on `chain.pem` to create three files for each separate certificates, called `cert.pem` for the first certificate for the domain itself, secondly `issuer.pem` for the intermediate certificate and `root.pem` for the final root certificate.

The domain certificate normally contains a pointer to where the OCSF responder is located, in the Authority Information Access Information extension. For example, from `certtool -i < cert.pem` there is this information:

```
1 Authority Information Access Information (not critical):  
2 Access Method: 1.3.6.1.5.5.7.48.1 (id-ad-ocsp)  
3 Access Location URI: http://ocsp.CAcert.org/
```

This means the CA support OCSF queries over HTTP. We are now ready to create a OCSF request for the certificate.

```
1 $ ocsptool --ask ocsp.CAcert.org --load-issuer issuer.pem \  
2      --load-cert cert.pem --outfile ocsp-response.der
```

The request is sent via HTTP to the OCSF server address specified. If the address is omitted ocsptool will use the address stored in the certificate.

3.2.7 Invoking danetool

Tool to generate and check DNS resource records for the DANE protocol.

This section was generated by **AutoGen**, using the `agtexi-cmd` template and the option descriptions for the `danetool` program. This software is released under the GNU General Public License, version 3 or later.

danetool help/usage (“--help”)

This is the automatically generated usage text for danetool.

The text printed is the same whether selected with the `help` option (“--help”) or the `more-help` option (“--more-help”). `more-help` will print the usage text by passing it through a pager program. `more-help` is disabled on platforms without a working `fork(2)` function. The `PAGER` environment variable is used to select the program, defaulting to “more”. Both will exit with a status code of 0.

```

1 danetool - GnuTLS DANE tool
2 Usage: danetool [ -<flag> [<val>] | --<name>[={| }<val>] ]...
3
4 -d, --debug=num          Enable debugging
5                          - it must be in the range:
6                          0 to 9999
7 -V, --verbose            More verbose output
8                          - may appear multiple times
9 --infile=file            Input file
10                         - file must pre-exist
11 --outfile=str            Output file
12 --load-pubkey=str        Loads a public key file
13 --load-certificate=str   Loads a certificate file
14 --dlv=str                Sets a DLV file
15 --hash=str               Hash algorithm to use for signing
16 --check=str              Check a host's DANE TLSA entry
17 --check-ee               Check only the end-entity's certificate
18 --check-ca               Check only the CA's certificate
19 --tlsa-rr                Print the DANE RR data on a certificate or public key
20                         - requires the option 'host'
21 --host=str               Specify the hostname to be used in the DANE RR
22 --proto=str              The protocol set for DANE data (tcp, udp etc.)
23 --port=num               Specify the port number for the DANE data
24 --app-proto=str          The application protocol to be used to obtain the server's certificate
25 (https, smtp, imap)
26 --ca                      Whether the provided certificate or public key is a Certificate
27 Authority
28 --x509                    Use the hash of the X.509 certificate, rather than the public key
29 --local                   an alias for the 'domain' option
30                         - enabled by default
31 --domain                  The provided certificate or public key is issued by the local domain
32                         - disabled as '--no-domain'
33                         - enabled by default
34 --local-dns               Use the local DNS server for DNSSEC resolving
35                         - disabled as '--no-local-dns'
36 --insecure                Do not verify any DNSSEC signature
37 --inder                   Use DER format for input certificates and private keys
38                         - disabled as '--no-inder'
39 --inraw                   an alias for the 'inder' option
40 --print-raw               Print the received DANE data in raw format
41                         - disabled as '--no-print-raw'
42 --quiet                   Suppress several informational messages
43 -v, --version[=arg]      output version information and exit
44 -h, --help                display extended usage information and exit
45 -!, --more-help           extended usage information passed thru pager
46
47 Options are specified by doubled hyphens and their name or by a single

```

```
48 | hyphen and the flag character.  
49 |  
50 | Tool to generate and check DNS resource records for the DANE protocol.  
51 |
```

debug option (-d)

This is the “enable debugging” option. This option takes a number argument. Specifies the debug level.

load-pubkey option

This is the “loads a public key file” option. This option takes a string argument. This can be either a file or a PKCS #11 URL

load-certificate option

This is the “loads a certificate file” option. This option takes a string argument. This can be either a file or a PKCS #11 URL

dlv option

This is the “sets a dlv file” option. This option takes a string argument. This sets a DLV file to be used for DNSSEC verification.

hash option

This is the “hash algorithm to use for signing” option. This option takes a string argument. Available hash functions are SHA1, RMD160, SHA256, SHA384, SHA512.

check option

This is the “check a host’s dane tlsa entry” option. This option takes a string argument. Obtains the DANE TLSA entry from the given hostname and prints information. Note that the actual certificate of the host can be provided using `-load-certificate`, otherwise `danetool` will connect to the server to obtain it. The exit code on verification success will be zero.

check-ee option

This is the “check only the end-entity’s certificate” option. Checks the end-entity’s certificate only. Trust anchors or CAs are not considered.

check-ca option

This is the “check only the ca’s certificate” option. Checks the trust anchor’s and CA’s certificate only. End-entities are not considered.

tlsa-rr option

This is the “print the dane rr data on a certificate or public key” option.

This option has some usage constraints. It:

- must appear in combination with the following options: host.

This command prints the DANE RR data needed to enable DANE on a DNS server.

host option

This is the “specify the hostname to be used in the dane rr” option. This option takes a string argument “**Hostname**”. This command sets the hostname for the DANE RR.

proto option

This is the “the protocol set for dane data (tcp, udp etc.)” option. This option takes a string argument “**Protocol**”. This command specifies the protocol for the service set in the DANE data.

app-proto option

This is the “the application protocol to be used to obtain the server’s certificate (https, ftp, smtp, imap)” option. This option takes a string argument. When the server’s certificate isn’t provided danetool will connect to the server to obtain the certificate. In that case it is required to know the protocol to talk with the server prior to initiating the TLS handshake.

ca option

This is the “whether the provided certificate or public key is a certificate authority” option. Marks the DANE RR as a CA certificate if specified.

x509 option

This is the “use the hash of the x.509 certificate, rather than the public key” option. This option forces the generated record to contain the hash of the full X.509 certificate. By default only the hash of the public key is used.

local option

This is an alias for the `domain` option, `??`.

domain option

This is the “the provided certificate or public key is issued by the local domain” option.

This option has some usage constraints. It:

- can be disabled with `-no-domain`.
- It is enabled by default.

DANE distinguishes certificates and public keys offered via the DNSSEC to trusted and local entities. This flag indicates that this is a domain-issued certificate, meaning that there could be no CA involved.

local-dns option

This is the “use the local dns server for dnssec resolving” option.

This option has some usage constraints. It:

- can be disabled with `-no-local-dns`.

This option will use the local DNS server for DNSSEC. This is disabled by default due to many servers not allowing DNSSEC.

insecure option

This is the “do not verify any dnssec signature” option. Ignores any DNSSEC signature verification results.

inder option

This is the “use der format for input certificates and private keys” option.

This option has some usage constraints. It:

- can be disabled with `-no-inder`.

The input files will be assumed to be in DER or RAW format. Unlike options that in PEM input would allow multiple input data (e.g. multiple certificates), when reading in DER format a single data structure is read.

inraw option

This is an alias for the `inder` option, `??`.

print-raw option

This is the “print the received dane data in raw format” option.

This option has some usage constraints. It:

- can be disabled with `--no-print-raw`.

This option will print the received DANE data.

quiet option

This is the “suppress several informational messages” option. In that case on the exit code can be used as an indication of verification success

danetool exit status

One of the following exit values will be returned:

- 0 (EXIT_SUCCESS) Successful program execution.
- 1 (EXIT_FAILURE) The operation failed or the command syntax was not valid.

danetool See Also

`certtool` (1)

danetool Examples

DANE TLSA RR generation

To create a DANE TLSA resource record for a certificate (or public key) that was issued locally and may or may not be signed by a CA use the following command.

```
1 $ danetool --tlsa-rr --host www.example.com --load-certificate cert.pem
```

To create a DANE TLSA resource record for a CA signed certificate, which will be marked as such use the following command.

```
1 $ danetool --tlsa-rr --host www.example.com --load-certificate cert.pem \  
2 --no-domain
```


The former is useful to add in your DNS entry even if your certificate is signed by a CA. That way even users who do not trust your CA will be able to verify your certificate using DANE.

In order to create a record for the CA signer of your certificate use the following.

```
1 $ danetool --tlsa-rr --host www.example.com --load-certificate cert.pem \  
2 --ca --no-domain
```

To read a server's DANE TLSA entry, use:

```
1 $ danetool --check www.example.com --proto tcp --port 443
```

To verify a server's DANE TLSA entry, use:

```
1 $ danetool --check www.example.com --proto tcp --port 443 --load-certificate chain.pem
```

3.3 Shared-key and anonymous authentication

In addition to certificate authentication, the TLS protocol may be used with password, shared-key and anonymous authentication methods. The rest of this chapter discusses details of these methods.

3.3.1 SRP authentication

Authentication using SRP

GnuTLS supports authentication via the Secure Remote Password or SRP protocol (see [?, ?] for a description). The SRP key exchange is an extension to the TLS protocol, and it provides an authenticated with a password key exchange. The peers can be identified using a single password, or there can be combinations where the client is authenticated using SRP and the server using a certificate.

The advantage of SRP authentication, over other proposed secure password authentication schemes, is that SRP is not susceptible to off-line dictionary attacks. Moreover, SRP does not require the server to hold the user's password. This kind of protection is similar to the one used traditionally in the UNIX “`/etc/passwd`” file, where the contents of this file did not cause harm to the system security if they were revealed. The SRP needs instead of the plain password something called a verifier, which is calculated using the user's password, and if stolen cannot be used to impersonate the user.

Typical conventions in SRP are a password file, called “`tpasswd`” that holds the SRP verifiers (encoded passwords) and another file, “`tpasswd.conf`”, which holds the allowed SRP parameters. The included in GnuTLS helper follow those conventions. The `srptool` program, discussed in the next section is a tool to manipulate the SRP parameters.

The implementation in GnuTLS is based on [?]. The supported key exchange methods are shown below.

- SRP: Authentication using the SRP protocol.
- SRP_DSS: Client authentication using the SRP protocol. Server is authenticated using a certificate with DSA parameters.
- SRP_RSA: Client authentication using the SRP protocol. Server is authenticated using a certificate with RSA parameters.

```
int gnutls_srp_verifier (const char * username, const char * password, const  
gnutls_datum_t * salt, const gnutls_datum_t * generator, const gnutls_datum_t *  
prime, gnutls_datum_t * res)
```

Description: This function will create an SRP verifier, as specified in RFC2945. The **prime** and **generator** should be one of the static parameters defined in `gnutls/gnutls.h` or may be generated. The verifier will be allocated with `gnutls_malloc()` and will be stored in `res` using binary format.

Returns: On success, `GNUTLS_E_SUCCESS` (0) is returned, or an error code.

```
int gnutls_srp_base64_encode2 (const gnutls_datum_t * data, gnutls_datum_t * re-  
sult)
```

```
int gnutls_srp_base64_decode2 (const gnutls_datum_t * b64_data, gnutls_datum_t *  
result)
```

Invoking srptool

Simple program that emulates the programs in the Stanford SRP (Secure Remote Password) libraries using GnuTLS. It is intended for use in places where you don't expect SRP authentication to be the used for system users.

In brief, to use SRP you need to create two files. These are the password file that holds the users and the verifiers associated with them and the configuration file to hold the group parameters (called `tpasswd.conf`).

This section was generated by **AutoGen**, using the `agtexi-cmd` template and the option descriptions for the `srptool` program. This software is released under the GNU General Public License, version 3 or later.

srptool help/usage (“--help”)

This is the automatically generated usage text for `srptool`.

The text printed is the same whether selected with the **help** option (“**--help**”) or the **more-help** option (“**--more-help**”). **more-help** will print the usage text by passing it through a pager program. **more-help** is disabled on platforms without a working **fork(2)** function. The **PAGER** environment variable is used to select the program, defaulting to “**more**”. Both will exit with a status code of 0.

```
1 srptool - GnuTLS SRP tool
2 Usage: srptool [ -<flag> [<val>] | --<name>[={| }<val>] ]...
3
4 -d, --debug=num          Enable debugging
5                          - it must be in the range:
6                          0 to 9999
7 -i, --index=num          specify the index of the group parameters in tpasswd.conf to use
8 -u, --username=str       specify a username
9 -p, --passwd=str         specify a password file
10 -s, --salt=num          specify salt size
11 --verify                just verify the password.
12 -v, --passwd-conf=str    specify a password conf file.
13 --create-conf=str       Generate a password configuration file.
14 -v, --version[=arg]     output version information and exit
15 -h, --help              display extended usage information and exit
16 -!, --more-help         extended usage information passed thru pager
17
18 Options are specified by doubled hyphens and their name or by a single
19 hyphen and the flag character.
20
21 Simple program that emulates the programs in the Stanford SRP (Secure
22 Remote Password) libraries using GnuTLS. It is intended for use in places
23 where you don't expect SRP authentication to be the used for system users.
24
25 In brief, to use SRP you need to create two files. These are the password
26 file that holds the users and the verifiers associated with them and the
27 configuration file to hold the group parameters (called tpasswd.conf).
28
```

debug option (-d)

This is the “enable debugging” option. This option takes a number argument. Specifies the debug level.

verify option

This is the “just verify the password.” option. Verifies the password provided against the password file.

passwd-conf option (-v)

This is the “specify a password conf file.” option. This option takes a string argument. Specify a filename or a PKCS #11 URL to read the CAs from.

create-conf option

This is the “generate a password configuration file.” option. This option takes a string argument. This generates a password configuration file (tpasswd.conf) containing the required for TLS parameters.

srptool exit status

One of the following exit values will be returned:

- 0 (EXIT_SUCCESS) Successful program execution.
- 1 (EXIT_FAILURE) The operation failed or the command syntax was not valid.

srptool See Also

gnutls-cli-debug (1), gnutls-serv (1), srptool (1), psktool (1), certtool (1)

srptool Examples

To create “tpasswd.conf” which holds the g and n values for SRP protocol (generator and a large prime), run:

```
1 $ srptool --create-conf /etc/tpasswd.conf
```

This command will create “/etc/tpasswd” and will add user ‘test’ (you will also be prompted for a password). Verifiers are stored by default in the way libsrp expects.

```
1 $ srptool --passwd /etc/tpasswd --passwd-conf /etc/tpasswd.conf -u test
```

This command will check against a password. If the password matches the one in “/etc/tpasswd” you will get an ok.

```
1 $ srptool --passwd /etc/tpasswd --passwd-conf /etc/tpasswd.conf --verify -u test
```

3.3.2 PSK authentication

Authentication using PSK

Authentication using Pre-shared keys is a method to authenticate using usernames and binary keys. This protocol avoids making use of public key infrastructure and expensive calculations, thus it is suitable for constraint clients.

The implementation in GnuTLS is based on [?]. The supported PSK key exchange methods are:

- PSK: Authentication using the PSK protocol.
- DHE-PSK: Authentication using the PSK protocol and Diffie-Hellman key exchange. This method offers perfect forward secrecy.
- ECDHE-PSK: Authentication using the PSK protocol and Elliptic curve Diffie-Hellman key exchange. This method offers perfect forward secrecy.
- RSA-PSK: Authentication using the PSK protocol for the client and an RSA certificate for the server.

Helper functions to generate and maintain PSK keys are also included in GnuTLS.

```
int gnutls_key_generate (gnutls_datum_t * key, unsigned int key_size)

int gnutls_hex_encode (const gnutls_datum_t * data, char * result, size_t * result_size)

int gnutls_hex_decode (const gnutls_datum_t * hex_data, void * result, size_t * result_size)
```

Invoking psktool

Program that generates random keys for use with TLS-PSK. The keys are stored in hexadecimal format in a key file.

This section was generated by **AutoGen**, using the **agtexi-cmd** template and the option descriptions for the **psktool** program. This software is released under the GNU General Public License, version 3 or later.

psktool help/usage (“--help”)

This is the automatically generated usage text for psktool.

The text printed is the same whether selected with the **help** option (“--help”) or the **more-help** option (“--more-help”). **more-help** will print the usage text by passing it through a pager program. **more-help** is disabled on platforms without a working **fork(2)** function. The **PAGER** environment variable is used to select the program, defaulting to “more”. Both will exit with a status code of 0.

```
1 psktool - GnuTLS PSK tool
2 Usage: psktool [ -<flag> [<val>] | --<name>[={| }<val>] ]...
3
4 -d, --debug=num          Enable debugging
5                          - it must be in the range:
6                          0 to 9999
7 -s, --keysize=num        specify the key size in bytes
8                          - it must be in the range:
```

```

9          0 to 512
10  -u, --username=str      specify a username
11  -p, --passwd=str        specify a password file
12  -v, --version[=arg]     output version information and exit
13  -h, --help              display extended usage information and exit
14  -!, --more-help         extended usage information passed thru pager
15
16  Options are specified by doubled hyphens and their name or by a single
17  hyphen and the flag character.
18
19  Program that generates random keys for use with TLS-PSK. The keys are
20  stored in hexadecimal format in a key file.
21

```

debug option (-d)

This is the “enable debugging” option. This option takes a number argument. Specifies the debug level.

psktool exit status

One of the following exit values will be returned:

- 0 (EXIT_SUCCESS) Successful program execution.
- 1 (EXIT_FAILURE) The operation failed or the command syntax was not valid.

psktool See Also

gnutls-cli-debug (1), gnutls-serv (1), srptool (1), certtool (1)

psktool Examples

To add a user 'psk_identity' in “passwd.psk” for use with GnuTLS run:

```

1 $ ./psktool -u psk_identity -p passwd.psk
2 Generating a random key for user 'psk_identity'
3 Key stored to passwd.psk
4 $ cat psks.txt
5 psk_identity:88f3824b3e5659f52d00e959bacab954b6540344
6 $

```

This command will create “passwd.psk” if it does not exist and will add user 'psk_identity' (you will also be prompted for a password).

3.3.3 Anonymous authentication

The anonymous key exchange offers encryption without any indication of the peer's identity. This kind of authentication is vulnerable to a man in the middle attack, but can be used even if there is no prior communication or shared trusted parties with the peer. It is useful to establish a session over which certificate authentication will occur in order to hide the identities of the participants from passive eavesdroppers.

Unless in the above case, it is not recommended to use anonymous authentication. In the cases where there is no prior communication with the peers, an alternative with better properties, such as key continuity, is trust on first use (see ??).

The available key exchange algorithms for anonymous authentication are shown below, but note that few public servers support them, and they have to be explicitly enabled.

- ANON_DH: This algorithm exchanges Diffie-Hellman parameters.
- ANON_ECDH: This algorithm exchanges elliptic curve Diffie-Hellman parameters. It is more efficient than ANON_DH on equivalent security levels.

3.4 Selecting an appropriate authentication method

This section provides some guidance on how to use the available authentication methods in GnuTLS in various scenarios.

3.4.1 Two peers with an out-of-band channel

Let's consider two peers who need to communicate over an untrusted channel (the Internet), but have an out-of-band channel available. The latter channel is considered safe from eavesdropping and message modification and thus can be used for an initial bootstrapping of the protocol. The options available are:

- Pre-shared keys (see ??). The server and a client communicate a shared randomly generated key over the trusted channel and use it to negotiate further sessions over the untrusted channel.
- Passwords (see ??). The client communicates to the server its username and password of choice and uses it to negotiate further sessions over the untrusted channel.
- Public keys (see ??). The client and the server exchange their public keys (or fingerprints of them) over the trusted channel. On future sessions over the untrusted channel they verify the key being the same (similar to ??).

Provided that the out-of-band channel is trusted all of the above provide a similar level of protection. An out-of-band channel may be the initial bootstrapping of a user's PC in a corporate environment, in-person communication, communication over an alternative network (e.g. the phone network), etc.

3.4.2 Two peers without an out-of-band channel

When an out-of-band channel is not available a peer cannot be reliably authenticated. What can be done, however, is to allow some form of registration of users connecting for the first time and ensure that their keys remain the same after that initial connection. This is termed key continuity or trust on first use (TOFU).

The available option is to use public key authentication (see ??). The client and the server store each other's public keys (or fingerprints of them) and associate them with their identity. On future sessions over the untrusted channel they verify the keys being the same (see ??).

To mitigate the uncertainty of the information exchanged in the first connection other channels over the Internet may be used, e.g., DNSSEC (see ??).

3.4.3 Two peers and a trusted third party

When a trusted third party is available (or a certificate authority) the most suitable option is to use certificate authentication (see ??). The client and the server obtain certificates that associate their identity and public keys using a digital signature by the trusted party and use them to on the subsequent communications with each other. Each party verifies the peer's certificate using the trusted third party's signature. The parameters of the third party's signature are present in its certificate which must be available to all communicating parties.

While the above is the typical authentication method for servers in the Internet by using the commercial CAs, the users that act as clients in the protocol rarely possess such certificates. In that case a hybrid method can be used where the server is authenticated by the client using the commercial CAs and the client is authenticated based on some information the client provided over the initial server-authenticated channel. The available options are:

- Passwords (see ??). The client communicates to the server its username and password of choice on the initial server-authenticated connection and uses it to negotiate further sessions. This is possible because the SRP protocol allows for the server to be authenticated using a certificate and the client using the password.
- Public keys (see ??). The client sends its public key to the server (or a fingerprint of it) over the initial server-authenticated connection. On future sessions the client verifies the server using the third party certificate and the server verifies that the client's public key remained the same (see ??).

enum gnutls_certificate_status_t:	
GNUTLS_CERT_INVALID	The certificate is not signed by one of the known authorities or the signature is invalid (deprecated by the flags GNUTLS_CERT_SIGNATURE_FAILURE and GNUTLS_CERT_SIGNER_NOT_FOUND).
GNUTLS_CERT_REVOKED	Certificate is revoked by its authority. In X.509 this will be set only if CRLs are checked.
GNUTLS_CERT_SIGNER_NOT_FOUND	The certificate's issuer is not known. This is the case if the issuer is not included in the trusted certificate list.
GNUTLS_CERT_SIGNER_NOT_CA	The certificate's signer was not a CA. This may happen if this was a version 1 certificate, which is common with some CAs, or a version 3 certificate without the basic constraints extension.
GNUTLS_CERT_INSECURE_ALGORITHM	The certificate was signed using an insecure algorithm such as MD2 or MD5. These algorithms have been broken and should not be trusted.
GNUTLS_CERT_NOT_ACTIVATED	The certificate is not yet activated.
GNUTLS_CERT_EXPIRED	The certificate has expired.
GNUTLS_CERT_SIGNATURE_FAILURE	The signature verification failed.
GNUTLS_CERT_REVOCATION_DATA_SUPERSEDED	The revocation data are old and have been superseded.
GNUTLS_CERT_UNEXPECTED_OWNER	The owner is not the expected one.
GNUTLS_CERT_REVOCATION_DATA_ISSUED_IN_FUTURE	The revocation data have a future issue date.
GNUTLS_CERT_SIGNER_CONSTRAINTS_FAILURE	The certificate's signer constraints were violated.
GNUTLS_CERT_MISMATCH	The certificate presented isn't the expected one (TOFU)
GNUTLS_CERT_PURPOSE_MISMATCH	The certificate or an intermediate does not match the intended purpose (extended key usage).

Table 3.4: The `gnutls_certificate_status_t` enumeration.

enum gnutls_certificate_verify_flags:	
GNUTLS_VERIFY_DISABLE_CA_SIGN	If set a signer does not have to be a certificate authority. This flag should normally be disabled, unless you know what this means.
GNUTLS_VERIFY_DO_NOT_ALLOW_SAME	If a certificate is not signed by anyone trusted but exists in the trusted CA list do not treat it as trusted.
GNUTLS_VERIFY_ALLOW_ANY_X509_V1_CA_CRT	Allow CA certificates that have version 1 (both root and intermediate). This might be dangerous since those haven't the basicConstraints extension.
GNUTLS_VERIFY_ALLOW_SIGN_RSA_MD2	Allow certificates to be signed using the broken MD2 algorithm.
GNUTLS_VERIFY_ALLOW_SIGN_RSA_MD5	Allow certificates to be signed using the broken MD5 algorithm.
GNUTLS_VERIFY_DISABLE_TIME_CHECKS	Disable checking of activation and expiration validity periods of certificate chains. Don't set this unless you understand the security implications.
GNUTLS_VERIFY_DISABLE_TRUSTED_TIME_CHECKS	If set a signer in the trusted list is never checked for expiration or activation.
GNUTLS_VERIFY_DO_NOT_ALLOW_X509_V1_CA_CRT	Do not allow trusted CA certificates that have version 1. This option is to be used to deprecate all certificates of version 1.
GNUTLS_VERIFY_DISABLE_CRL_CHECKS	Disable checking for validity using certificate revocation lists or the available OCSP data.
GNUTLS_VERIFY_ALLOW_UNSORTED_CHAIN	A certificate chain is tolerated if unsorted (the case with many TLS servers out there). This is the default since GnuTLS 3.1.4.
GNUTLS_VERIFY_DO_NOT_ALLOW_UNSORTED_CHAIN	Do not tolerate an unsorted certificate chain.
GNUTLS_VERIFY_DO_NOT_ALLOW_WILDCARDS	When including a hostname check in the verification, do not consider any wildcards.

Table 3.5: The gnutls_certificate_verify_flags enumeration.

Purpose	OID	Description
GNUTLS_KP_TLS_WWW_SERVER	2.5.29.15.1	The certificate is to be used for TLS WWW authentication. When in a CA certificate, it indicates that the CA is allowed to sign certificates for TLS WWW authentication.
GNUTLS_KP_TLS_WWW_CLIENT	2.5.29.15.2	The certificate is to be used for TLS WWW client authentication. When in a CA certificate, it indicates that the CA is allowed to sign certificates for TLS WWW client authentication.
GNUTLS_KP_CODE_SIGNING	2.5.29.16.3	The certificate is to be used for code signing. When in a CA certificate, it indicates that the CA is allowed to sign certificates for code signing.
GNUTLS_KP_EMAIL_PROTECTION	2.5.29.17.1	The certificate is to be used for email protection. When in a CA certificate, it indicates that the CA is allowed to sign certificates for email users.
GNUTLS_KP_OCSP_SIGNING	2.5.29.18.9	The certificate is to be used for signing OCSP responses. When in a CA certificate, it indicates that the CA is allowed to sign certificates which sign OCSP responses.
GNUTLS_KP_ANY	2.5.29.37.0	The certificate is to be used for any purpose. When in a CA certificate, it indicates that the CA is allowed to sign any kind of certificates.

Table 3.6: Key purpose object identifiers.

Field	Description
version	The field that indicates the version of the OpenPGP structure.
user ID	An RFC 2822 string that identifies the owner of the key. There may be multiple user identifiers in a key.
public key	The main public key of the certificate.
expiration	The expiration time of the main public key.
public subkey	An additional public key of the certificate. There may be multiple subkeys in a certificate.
public subkey expiration	The expiration time of the subkey.

Table 3.7: OpenPGP certificate fields.

Key exchange	Public key requirements
RSA	An RSA public key that allows encryption.
DHE_RSA	An RSA public key that is marked for authentication.
ECDHE_RSA	An RSA public key that is marked for authentication.
DHE_DSS	A DSA public key that is marked for authentication.

Table 3.8: The types of (sub)keys required for the various TLS key exchange methods.

Field	Description
version	The field that indicates the version of the CRL structure.
signature	A signature by the issuing authority.
issuer	Holds the issuer's distinguished name.
thisUpdate	The issuing time of the revocation list.
nextUpdate	The issuing time of the revocation list that will update that one.
revokedCertificates	List of revoked certificates serial numbers.
extensions	Optional CRL structure extensions.

Table 3.9: Certificate revocation list fields.

Field	Description
version	The OCSP response version number (typically 1).
responder ID	An identifier of the responder (DN name or a hash of its key).
issue time	The time the response was generated.
thisUpdate	The issuing time of the revocation information.
nextUpdate	The issuing time of the revocation information that will update that one.
	Revoked certificates
certificate status	The status of the certificate.
certificate serial	The certificate's serial number.
revocationTime	The time the certificate was revoked.
revocationReason	The reason the certificate was revoked.

Table 3.10: The most important OCSP response fields.

enum gnutls_x509_crl_reason_t:	
GNUTLS_X509_CRLREASON_-UNSPECIFIED	Unspecified reason.
GNUTLS_X509_CRLREASON_-KEYCOMPROMISE	Private key compromised.
GNUTLS_X509_CRLREASON_-CACOMPROMISE	CA compromised.
GNUTLS_X509_CRLREASON_-AFFILIATIONCHANGED	Affiliation has changed.
GNUTLS_X509_CRLREASON_-SUPERSEDED	Certificate superseded.
GNUTLS_X509_CRLREASON_-CESSATIONOFOPERATION	Operation has ceased.
GNUTLS_X509_CRLREASON_-CERTIFICATEHOLD	Certificate is on hold.
GNUTLS_X509_CRLREASON_-REMOVEFROMCRL	Will be removed from delta CRL.
GNUTLS_X509_CRLREASON_-PRIVILEGEWITHDRAWN	Privilege withdrawn.
GNUTLS_X509_CRLREASON_-AACOMPROMISE	AA compromised.

Table 3.11: The revocation reasons

enum gnutls_pkcs_encrypt_flags_t:	
GNUTLS_PKCS_PLAIN	Unencrypted private key.
GNUTLS_PKCS_PKCS12_3DES	PKCS-12 3DES.
GNUTLS_PKCS_PKCS12_ARCFOUR	PKCS-12 ARCFOUR.
GNUTLS_PKCS_PKCS12_RC2_40	PKCS-12 RC2-40.
GNUTLS_PKCS_PBES2_3DES	PBES2 3DES.
GNUTLS_PKCS_PBES2_AES_128	PBES2 AES-128.
GNUTLS_PKCS_PBES2_AES_192	PBES2 AES-192.
GNUTLS_PKCS_PBES2_AES_256	PBES2 AES-256.
GNUTLS_PKCS_NULL_PASSWORD	Some schemas distinguish between an empty and a NULL password.
GNUTLS_PKCS_PBES2_DES	PBES2 single DES.

Table 3.12: Encryption flags

4

Abstract keys types and Hardware security modules

In several cases storing the long term cryptographic keys in a hard disk or even in memory poses a significant risk. Once the system they are stored is compromised the keys must be replaced as the secrecy of future sessions is no longer guaranteed. Moreover, past sessions that were not protected by a perfect forward secrecy offering ciphersuite are also to be assumed compromised.

If such threats need to be addressed, then it may be wise storing the keys in a security module such as a smart card, an HSM or the TPM chip. Those modules ensure the protection of the cryptographic keys by only allowing operations on them and preventing their extraction. The purpose of the abstract key API is to provide an API that will allow the handle of keys in memory and files, as well as keys stored in such modules.

In GnuTLS the approach is to handle all keys transparently by the high level API, e.g., the API that loads a key or certificate from a file. The high-level API will accept URIs in addition to files that specify keys on an HSM or in TPM, and a callback function will be used to obtain any required keys. The URI format is defined in [?] and [?], and is in the process of being standardized across systems.

More information on the API is provided in the next sections. Examples of a URI of a certificate stored in an HSM, as well as a key stored in the TPM chip are shown below. To discover the URIs of the objects the `p11tool` (see ??), or `tpmtool` (see ??) may be used.

```
1 pkcs11:token=Nikos;serial=307521161601031;model=PKCS%2315; \  
2 manufacturer=EnterSafe;object=test1;objecttype=cert  
3  
4 tpmkey:uuid=42309df8-d101-11e1-a89a-97bb33c23ad1;storage=user
```

4.1 Abstract key types

Since there are many forms of a public or private keys supported by GnuTLS such as X.509, OpenPGP, PKCS #11 or TPM it is desirable to allow common operations on them. For these reasons the abstract `gnutls_privkey_t` and `gnutls_pubkey_t` were introduced in `gnutls/abstract.h` header. Those types are initialized using a specific type of key and then can be used to perform operations in an abstract way. For example in order to sign an X.509 certificate with a key that resides in a token the following steps can be used.

```

1 #include <gnutls/abstract.h>
2
3 void sign_cert( gnutls_x509_crt_t to_be_signed)
4 {
5     gnutls_x509_crt_t ca_cert;
6     gnutls_privkey_t abs_key;
7
8     /* initialize the abstract key */
9     gnutls_privkey_init(&abs_key);
10
11     /* keys stored in tokens are identified by URLs */
12     gnutls_privkey_import_url(abs_key, key_url);
13
14     gnutls_x509_crt_init(&ca_cert);
15     gnutls_x509_crt_import_url(&ca_cert, cert_url);
16
17     /* sign the certificate to be signed */
18     gnutls_x509_crt_privkey_sign(to_be_signed, ca_cert, abs_key,
19                                 GNUTLS_DIG_SHA256, 0);
20 }

```

4.1.1 Public keys

An abstract `gnutls_pubkey_t` can be initialized using the functions below. It can be imported through an existing structure like `gnutls_x509_crt_t`, or through an ASN.1 encoding of the X.509 SubjectPublicKeyInfo sequence.

```

int gnutls_pubkey_import_x509 (gnutls_pubkey_t key, gnutls_x509_crt_t crt, un-
signed int flags)

int gnutls_pubkey_import_openpgp (gnutls_pubkey_t key, gnutls_openpgp_crt_t
crt, unsigned int flags)

int gnutls_pubkey_import_pkcs11 (gnutls_pubkey_t key, gnutls_pkcs11_obj_t obj,
unsigned int flags)

```



```

int gnutls_pubkey_import_url (gnutls_pubkey_t key, const char * url, unsigned int
flags)

int gnutls_pubkey_import_privkey (gnutls_pubkey_t key, gnutls_privkey_t pkey,
unsigned int usage, unsigned int flags)

int gnutls_pubkey_import (gnutls_pubkey_t key, const gnutls_datum_t * data,
gnutls_x509_crt_fmt_t format)

int gnutls_pubkey_export (gnutls_pubkey_t key, gnutls_x509_crt_fmt_t format,
void * output_data, size_t * output_data_size)

```

```

int gnutls_pubkey_export2 (gnutls_pubkey_t key, gnutls_x509_crt_fmt_t format,
gnutls_datum_t * out)

```

Description: This function will export the public key to DER or PEM format. The contents of the exported data is the SubjectPublicKeyInfo X.509 structure. The output buffer will be allocated using `gnutls_malloc()`. If the structure is PEM encoded, it will have a header of "BEGIN CERTIFICATE".

Returns: In case of failure a negative error code will be returned, and 0 on success.

Other helper functions that allow directly importing from raw X.509 or OpenPGP structures are shown below.

```

int gnutls_pubkey_import_x509_raw (gnutls_pubkey_t pkey, const gnutls_datum_t *
data, gnutls_x509_crt_fmt_t format, unsigned int flags)

int gnutls_pubkey_import_openpgp_raw (gnutls_pubkey_t pkey, const
gnutls_datum_t * data, gnutls_openpgp_crt_fmt_t format, const gnutls_openpgp_keyid_t
keyid, unsigned int flags)

```

An important function is `gnutls_pubkey_import_url` which will import public keys from URLs that identify objects stored in tokens (see ?? and ??). A function to check for a supported by GnuTLS URL is `gnutls_url_is_supported`.

Additional functions are available that will return information over a public key, such as a unique key ID, as well as a function that given a public key fingerprint would provide a memorable sketch.

Note that `gnutls_pubkey_get_key_id` calculates a SHA1 digest of the public key as a DER-formatted, subjectPublicKeyInfo object. Other implementations use different approaches, e.g.,

```
int gnutls_url_is_supported (const char * url)
```

Description: Check whether *url* is supported. Depending on the system libraries GnuTLS may support pkcs11 or tpmkey URLs.

Returns: return non-zero if the given URL is supported, and zero if it is not known.

some use the “common method” described in section 4.2.1.2 of [?] which calculates a digest on a part of the `subjectPublicKeyInfo` object.

```
int gnutls_pubkey_get_pk_algorithm (gnutls_pubkey_t key, unsigned int * bits)
```

```
int gnutls_pubkey_get_preferred_hash_algorithm (gnutls_pubkey_t key,  
gnutls_digest_algorithm_t * hash, unsigned int * mand)
```

```
int gnutls_pubkey_get_key_id (gnutls_pubkey_t key, unsigned int flags, unsigned char * output_data,  
size_t * output_data_size)
```

```
int gnutls_random_art (gnutls_random_art_t type, const char * key_type, unsigned int key_size,  
void * fpr, size_t fpr_size, gnutls_datum_t * art)
```

To export the key-specific parameters, or obtain a unique key ID the following functions are provided.

```
int gnutls_pubkey_export_rsa_raw (gnutls_pubkey_t key, gnutls_datum_t * m,  
gnutls_datum_t * e)
```

```
int gnutls_pubkey_export_dsa_raw (gnutls_pubkey_t key, gnutls_datum_t * p,  
gnutls_datum_t * q, gnutls_datum_t * g, gnutls_datum_t * y)
```

```
int gnutls_pubkey_export_ecc_raw (gnutls_pubkey_t key, gnutls_ecc_curve_t *  
curve, gnutls_datum_t * x, gnutls_datum_t * y)
```

```
int gnutls_pubkey_export_ecc_x962 (gnutls_pubkey_t key, gnutls_datum_t * pa-  
rameters, gnutls_datum_t * ecpoint)
```

4.1.2 Private keys

An abstract `gnutls_privkey_t` can be initialized using the functions below. It can be imported through an existing structure like `gnutls_x509_privkey_t`, but unlike public keys it cannot be

exported. That is to allow abstraction over keys stored in hardware that makes available only operations.

```
int gnutls_privkey_import_x509 (gnutls_privkey_t pkey, gnutls_x509_privkey_t key,
unsigned int flags)

int gnutls_privkey_import_openpgp (gnutls_privkey_t pkey,
gnutls_openpgp_privkey_t key, unsigned int flags)

int gnutls_privkey_import_pkcs11 (gnutls_privkey_t pkey, gnutls_pkcs11_privkey_t
key, unsigned int flags)
```

Other helper functions that allow directly importing from raw X.509 or OpenPGP structures are shown below. Again, as with public keys, private keys can be imported from a hardware module using URLs.

```
int gnutls_privkey_import_x509_raw (gnutls_privkey_t pkey, const gnutls_datum_t *
data, gnutls_x509_crt_fmt_t format, const char * password, unsigned int flags)

int gnutls_privkey_import_openpgp_raw (gnutls_privkey_t pkey, const
gnutls_datum_t * data, gnutls_openpgp_crt_fmt_t format, const gnutls_openpgp_keyid_t
keyid, const char * password)
```

```
int gnutls_privkey_import_url (gnutls_privkey_t key, const char * url, unsigned int
flags)
```

Description: This function will import a PKCS11 or TPM URL as a private key. The supported URL types can be checked using `gnutls_url_is_supported()`.

Returns: On success, `GNUTLS_E_SUCCESS` (0) is returned, otherwise a negative error value.

```
int gnutls_privkey_get_pk_algorithm (gnutls_privkey_t key, unsigned int * bits)

gnutls_privkey_type_t gnutls_privkey_get_type (gnutls_privkey_t key)

int gnutls_privkey_status (gnutls_privkey_t key)
```

In order to support cryptographic operations using an external API, the following function is provided. This allows for a simple extensibility API without resorting to PKCS #11.

```
int gnutls_privkey_import_ext3 (gnutls_privkey_t pkey, void * userdata,
gnutls_privkey_sign_func sign_fn, gnutls_privkey_decrypt_func decrypt_fn,
gnutls_privkey_deinit_func deinit_fn, gnutls_privkey_info_func info_fn, unsigned int
flags)
```

Description: This function will associate the given callbacks with the *gnutls_privkey_t* type. At least one of the two callbacks must be non-null. If a deinitialization function is provided then flags is assumed to contain **GNUTLS_PRIVKEY_IMPORT_AUTO-RELEASE**. Note that the signing function is supposed to "raw" sign data, i.e., without any hashing or preprocessing. In case of RSA the *DigestInfo* will be provided, and the signing function is expected to do the PKCS #1 1.5 padding and the exponentiation. The *info_fn* must provide information on the algorithms supported by this private key, and should support the flags **GNUTLS_PRIVKEY_INFO_PK_ALGO** and **GNUTLS_PRIVKEY-INFO_SIGN_ALGO**. It must return -1 on unknown flags.

Returns: On success, **GNUTLS_E_SUCCESS** (0) is returned, otherwise a negative error value.

4.1.3 Operations

The abstract key types can be used to access signing and signature verification operations with the underlying keys.

```
int gnutls_pubkey_verify_data2 (gnutls_pubkey_t pubkey, gnutls_sign_algorithm_t
algo, unsigned int flags, const gnutls_datum_t * data, const gnutls_datum_t *
signature)
```

Description: This function will verify the given signed data, using the parameters from the certificate.

Returns: In case of a verification failure **GNUTLS_E_PK_SIG_VERIFY_FAILED** is returned, and zero or positive code on success.

Signing existing structures, such as certificates, CRLs, or certificate requests, as well as associating public keys with structures is also possible using the key abstractions.

```
int gnutls_pubkey_verify_hash2 (gnutls_pubkey_t key, gnutls_sign_algorithm_t
algo, unsigned int flags, const gnutls_datum_t * hash, const gnutls_datum_t *
signature)
```

Description: This function will verify the given signed digest, using the parameters from the public key. Note that unlike `gnutls_privkey_sign_hash()`, this function accepts a signature algorithm instead of a digest algorithm. You can use `gnutls_pk_to_sign()` to get the appropriate value.

Returns: In case of a verification failure `GNUTLS_E_PK_SIG_VERIFY_FAILED` is returned, and zero or positive code on success.

```
int gnutls_pubkey_encrypt_data (gnutls_pubkey_t key, unsigned int flags, const
gnutls_datum_t * plaintext, gnutls_datum_t * ciphertext)
```

Description: This function will encrypt the given data, using the public key.

Returns: On success, `GNUTLS_E_SUCCESS` (0) is returned, otherwise a negative error value.

```
int gnutls_x509_crt_privkey_sign (gnutls_x509_crt_t crt, gnutls_x509_crt_t issuer,
gnutls_privkey_t issuer_key, gnutls_digest_algorithm_t dig, unsigned int flags)
```

```
int gnutls_x509_crl_privkey_sign (gnutls_x509_crl_t crl, gnutls_x509_crt_t issuer,
gnutls_privkey_t issuer_key, gnutls_digest_algorithm_t dig, unsigned int flags)
```

```
int gnutls_x509_crq_privkey_sign (gnutls_x509_crq_t crq, gnutls_privkey_t key,
gnutls_digest_algorithm_t dig, unsigned int flags)
```

```
int gnutls_privkey_sign_data (gnutls_privkey_t signer, gnutls_digest_algorithm_t
hash, unsigned int flags, const gnutls_datum_t * data, gnutls_datum_t * signature)
```

Description: This function will sign the given data using a signature algorithm supported by the private key. Signature algorithms are always used together with a hash functions. Different hash functions may be used for the RSA algorithm, but only the SHA family for the DSA keys. You may use `gnutls_pubkey_get_preferred_hash_algorithm()` to determine the hash algorithm.

Returns: On success, `GNUTLS_E_SUCCESS` (0) is returned, otherwise a negative error value.

```
int gnutls_privkey_sign_hash (gnutls_privkey_t signer, gnutls_digest_algorithm_t
hash_algo, unsigned int flags, const gnutls_datum_t * hash_data, gnutls_datum_t *
signature)
```

Description: This function will sign the given hashed data using a signature algorithm supported by the private key. Signature algorithms are always used together with a hash functions. Different hash functions may be used for the RSA algorithm, but only SHA-XXX for the DSA keys. You may use `gnutls_pubkey_get_preferred_hash_algorithm()` to determine the hash algorithm. Note that if `GNUTLS_PRIVKEY_SIGN_FLAG_TLS1_RSA` flag is specified this function will ignore `hash_algo` and perform a raw PKCS1 signature.

Returns: On success, `GNUTLS_E_SUCCESS` (0) is returned, otherwise a negative error value.

```
int gnutls_privkey_decrypt_data (gnutls_privkey_t key, unsigned int flags, const
gnutls_datum_t * ciphertext, gnutls_datum_t * plaintext)
```

Description: This function will decrypt the given data using the algorithm supported by the private key.

Returns: On success, `GNUTLS_E_SUCCESS` (0) is returned, otherwise a negative error value.

```
int gnutls_x509_crq_set_pubkey (gnutls_x509_crq_t crq, gnutls_pubkey_t key)
```

Description: This function will set the public parameters from the given public key to the request.

Returns: On success, `GNUTLS_E_SUCCESS` (0) is returned, otherwise a negative error value.

```
int gnutls_x509_cert_set_pubkey (gnutls_x509_cert_t crt, gnutls_pubkey_t key)
```

Description: This function will set the public parameters from the given public key to the request.

Returns: On success, `GNUTLS_E_SUCCESS` (0) is returned, otherwise a negative error value.

4.2 System and application-specific keys

4.2.1 System-specific keys

In several systems there are keystores which allow to read, store and use certificates and private keys. For these systems GnuTLS provides the system-key API in `gnutls/system-keys.h`. That API provides the ability to iterate through all stored keys, add and delete keys as well as use these keys using a URL which starts with "system:". The format of the URLs is system-specific.

```
int gnutls_system_key_iter_get_info (gnutls_system_key_iter_t * iter, unsigned
cert_type, char ** cert_url, char ** key_url, char ** label, gnutls_datum_t *
der, unsigned int flags)
```

Description: This function will return on each call a certificate and key pair URLs, as well as a label associated with them, and the DER-encoded certificate. When the iteration is complete it will return `GNUTLS_E_REQUESTED_DATA_NOT_AVAILABLE`. Typically `cert_type` should be `GNUTLS_CERT_X509`. All values set are allocated and must be cleared using `gnutls_free()`,

Returns: On success, `GNUTLS_E_SUCCESS` (0) is returned, otherwise a negative error value.

4.2.2 Application-specific keys

For systems where GnuTLS doesn't provide a system specific store, it may often be desirable to define a custom class of keys that are identified via URLs and available to GnuTLS calls such as `gnutls_certificate_set_x509_key_file2`. Such keys can be registered using the API in `gnutls/urls.h`. The function which registers such keys is `gnutls_register_custom_url`.

The input to this function are three callback functions as well as the prefix of the URL, (e.g., "mypkcs11:") and the length of the prefix. The types of the callbacks are shown below, and are expected to use the exported gnutls functions to import the keys and certificates. E.g., a typical `import_key` callback should use `gnutls_privkey_import_ext3`.

```
1 typedef int (*gnutls_privkey_import_url_func)(gnutls_privkey_t pkey,
2                                              const char *url,
3                                              unsigned flags);
4
5 typedef int (*gnutls_x509_cert_import_url_func)(gnutls_x509_cert_t pkey,
6                                              const char *url,
7                                              unsigned flags);
8
9 /* The following callbacks are optional */
```

```
int gnutls_register_custom_url (const gnutls_custom_url_st * st)
```

Description: Register a custom URL. This will affect the following functions: `gnutls_url_is_supported()`, `gnutls_privkey_import_url()`, `gnutls_pubkey_import_url`, `gnutls_x509_cert_import_url()` and all functions that depend on them, e.g., `gnutls_certificate_set_x509_key_file2()`. The provided structure and callback functions must be valid throughout the lifetime of the process. The registration of an existing URL type will fail with `GNUTLS_E_INVALID_REQUEST`. This function is not thread safe.

Returns: returns zero if the given structure was imported or a negative value otherwise.

```
10
11 /* This is to enable gnutls_pubkey_import_url() */
12 typedef int (*gnutls_pubkey_import_url_func)(gnutls_pubkey_t pkey,
13                                             const char *url, unsigned flags);
14
15 /* This is to allow constructing a certificate chain. It will be provided
16  * the initial certificate URL and the certificate to find its issuer, and must
17  * return zero and the DER encoding of the issuer's certificate. If not available,
18  * it should return GNUTLS_E_REQUESTED_DATA_NOT_AVAILABLE. */
19 typedef int (*gnutls_get_raw_issuer_func)(const char *url, gnutls_x509_cert_t crt,
20                                         gnutls_datum_t *issuer_der, unsigned flags);
21
22 typedef struct custom_url_st {
23     const char *name;
24     unsigned name_size;
25     gnutls_privkey_import_url_func import_key;
26     gnutls_x509_cert_import_url_func import_cert;
27     gnutls_pubkey_import_url_func import_pubkey;
28     gnutls_get_raw_issuer_func get_issuer;
29 } gnutls_custom_url_st;
```

4.3 Smart cards and HSMs

In this section we present the smart-card and hardware security module (HSM) support in GnuTLS using PKCS #11 [?]. Hardware security modules and smart cards provide a way to store private keys and perform operations on them without exposing them. This decouples cryptographic keys from the applications that use them and provide an additional security layer against cryptographic key extraction. Since this can also be achieved in software components such as in Gnome keyring, we will use the term security module to describe any cryptographic key separation subsystem.

PKCS #11 is plugin API allowing applications to access cryptographic operations on a security module, as well as to objects residing on it. PKCS #11 modules exist for hardware tokens such

as smart cards¹, cryptographic tokens, as well as for software modules like Gnome Keyring. The objects residing on a security module may be certificates, public keys, private keys or secret keys. Of those certificates and public/private key pairs can be used with GnuTLS. PKCS #11's main advantage is that it allows operations on private key objects such as decryption and signing without exposing the key. In GnuTLS the PKCS #11 functionality is available in `gnutls/pkcs11.h`.

Moreover PKCS #11 can be (ab)used to allow all applications in the same operating system to access shared cryptographic keys and certificates in a uniform way, as in ???. That way applications could load their trusted certificate list, as well as user certificates from a common PKCS #11 module. Such a provider is the p11-kit trust storage module².

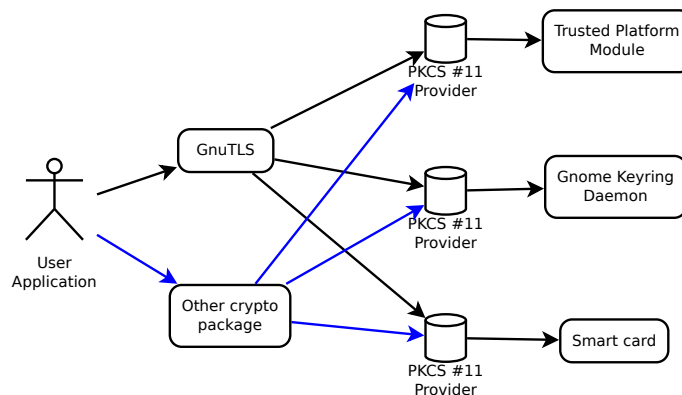


Figure 4.1: PKCS #11 module usage.

4.3.1 Initialization

To allow all GnuTLS applications to transparently access smart cards and tokens, PKCS #11 is automatically initialized during the global initialization (see `gnutls_global_init`). The initialization function, to select which modules to load reads certain module configuration files. Those are stored in `/etc/pkcs11/modules/` and are the configuration files of p11-kit³. For example a file that will load the OpenSC module, could be named `/etc/pkcs11/modules/opensc.module` and contain the following:

```
1 module: /usr/lib/opensc-pkcs11.so
```

If you use these configuration files, then there is no need for other initialization in GnuTLS, except for the PIN and token functions (see next section). In several cases, however, it is desirable to limit badly behaving modules (e.g., modules that add an unacceptable delay on initialization) to single applications. That can be done using the “enable-in:” option followed by the base name of applications that this module should be used.

¹<http://www.opensc-project.org>

²<http://p11-glue.freedesktop.org/trust-module.html>

³<http://p11-glue.freedesktop.org/>

In all cases, you can also manually initialize the PKCS #11 subsystem if the default settings are not desirable. To completely disable PKCS #11 support you need to call `gnutls_pkcs11_init` with the flag `GNUTLS_PKCS11_FLAG_MANUAL` prior to `gnutls_global_init`.

```
int gnutls_pkcs11_init (unsigned int flags, const char * deprecated_config_file)
```

Description: This function will initialize the PKCS 11 subsystem in gnutls. It will read configuration files if `GNUTLS_PKCS11_FLAG_AUTO` is used or allow you to independently load PKCS 11 modules using `gnutls_pkcs11_add_provider()` if `GNUTLS_PKCS11_FLAG_MANUAL` is specified. Normally you don't need to call this function since it is being called when the first PKCS 11 operation is requested using the `GNUTLS_PKCS11_FLAG_AUTO` flag. If another flags are required then it must be called independently prior to any PKCS 11 operation.

Returns: On success, `GNUTLS_E_SUCCESS` (0) is returned, otherwise a negative error value.

Note that PKCS #11 modules must be reinitialized on the child processes after a `fork`. In older versions of GnuTLS it was required to call `gnutls_pkcs11_reinit`; since 3.3.0 this is no longer required, as reinitialization occurs automatically.

4.3.2 Accessing objects that require a PIN

Objects stored in token such as a private keys are typically protected from access by a PIN or password. This PIN may be required to either read the object (if allowed) or to perform operations with it. To allow obtaining the PIN when accessing a protected object, as well as probe the user to insert the token the following functions allow to set a callback.

```
void gnutls_pkcs11_set_token_function (gnutls_pkcs11_token_callback_t fn, void * userdata)
```

```
void gnutls_pkcs11_set_pin_function (gnutls_pin_callback_t fn, void * userdata)
```

```
int gnutls_pkcs11_add_provider (const char * name, const char * params)
```

```
gnutls_pin_callback_t gnutls_pkcs11_get_pin_function (void ** userdata)
```

The callback is of type `gnutls_pin_callback_t` and will have as input the provided userdata, the PIN attempt number, a URL describing the token, a label describing the object and flags.

The PIN must be at most of `pin_max` size and must be copied to pin variable. The function must return 0 on success or a negative error code otherwise.

```
typedef int (*gnutls_pin_callback_t) (void *userdata, int attempt,  
                                     const char *token_url,  
                                     const char *token_label,  
                                     unsigned int flags,  
                                     char *pin, size_t pin_max);
```

The flags are of `gnutls_pin_flag_t` type and are explained below.

enum gnutls_pin_flag_t:	
GNUTLS_PIN_USER	The PIN for the user.
GNUTLS_PIN_SO	The PIN for the security officer (admin).
GNUTLS_PIN_FINAL_TRY	This is the final try before blocking.
GNUTLS_PIN_COUNT_LOW	Few tries remain before token blocks.
GNUTLS_PIN_CONTEXT_SPECIFIC	The PIN is for a specific action and key like signing.
GNUTLS_PIN_WRONG	Last given PIN was not correct.

Table 4.1: The `gnutls_pin_flag_t` enumeration.

Note that due to limitations of PKCS #11 there are issues when multiple libraries are sharing a module. To avoid this problem GnuTLS uses p11-kit that provides a middleware to control access to resources over the multiple users.

To avoid conflicts with multiple registered callbacks for PIN functions, `gnutls_pkcs11_get_pin_function` may be used to check for any previously set functions. In addition context specific PIN functions are allowed, e.g., by using functions below.

```
void gnutls_certificate_set_pin_function (gnutls_certificate_credentials_t cred,  
gnutls_pin_callback_t fn, void * userdata)  
  
void gnutls_pubkey_set_pin_function (gnutls_pubkey_t key, gnutls_pin_callback_t  
fn, void * userdata)  
  
void gnutls_privkey_set_pin_function (gnutls_privkey_t key, gnutls_pin_callback_t  
fn, void * userdata)  
  
void gnutls_pkcs11_obj_set_pin_function (gnutls_pkcs11_obj_t obj,  
gnutls_pin_callback_t fn, void * userdata)  
  
void gnutls_x509_crt_set_pin_function (gnutls_x509_crt_t crt, gnutls_pin_callback_t  
fn, void * userdata)
```

4.3.3 Reading objects

All PKCS #11 objects are referenced by GnuTLS functions by URLs as described in [?]. This allows for a consistent naming of objects across systems and applications in the same system. For example a public key on a smart card may be referenced as:

```
1 pkcs11:token=Nikos;serial=307521161601031;model=PKCS%2315; \
2 manufacturer=EnterSafe;object=test1;objecttype=public;\
3 id=32f153f3e37990b08624141077ca5dec2d15faed
```

while the smart card itself can be referenced as:

```
1 pkcs11:token=Nikos;serial=307521161601031;model=PKCS%2315;manufacturer=EnterSafe
```

Objects stored in a PKCS #11 token can be extracted if they are not marked as sensitive. Usually only private keys are marked as sensitive and cannot be extracted, while certificates and other data can be retrieved. The functions that can be used to access objects are shown below.

```
int gnutls_pkcs11_obj_import_url (gnutls_pkcs11_obj_t obj, const char * url, un-  
signed int flags)
```

```
int gnutls_pkcs11_obj_export_url (gnutls_pkcs11_obj_t obj, gnutls_pkcs11_url_type_t  
detailed, char ** url)
```

```
int gnutls_pkcs11_obj_get_info (gnutls_pkcs11_obj_t obj, gnutls_pkcs11_obj_info_t  
itype, void * output, size_t * output_size)
```

Description: This function will return information about the PKCS11 certificate such as the label, id as well as token information where the key is stored. When output is text it returns null terminated string although `output_size` contains the size of the actual data only.

Returns: `GNUTLS_E_SUCCESS` (0) on success or a negative error code on error.

```

int gnutls_x509_cert_import_pkcs11 (gnutls_x509_cert_t crt, gnutls_pkcs11_obj_t
pkcs11_cert)

int gnutls_x509_cert_import_url (gnutls_x509_cert_t crt, const char * url, unsigned
int flags)

int gnutls_x509_cert_list_import_pkcs11 (gnutls_x509_cert_t * certs, unsigned int
cert_max, gnutls_pkcs11_obj_t * const objs, unsigned int flags)

```

Properties of the physical token can also be accessed and altered with GnuTLS. For example data in a token can be erased (initialized), PIN can be altered, etc.

```

int gnutls_pkcs11_token_init (const char * token_url, const char * so_pin, const
char * label)

int gnutls_pkcs11_token_get_url (unsigned int seq, gnutls_pkcs11_url_type_t de-
tailed, char ** url)

int gnutls_pkcs11_token_get_info (const char * url, gnutls_pkcs11_token_info_t
ttype, void * output, size_t * output_size)

int gnutls_pkcs11_token_get_flags (const char * url, unsigned int * flags)

int gnutls_pkcs11_token_set_pin (const char * token_url, const char * oldpin,
const char * newpin, unsigned int flags)

```

The following examples demonstrate the usage of the API. The first example will list all available PKCS #11 tokens in a system and the latter will list all certificates in a token that have a corresponding private key.

```

1 int i;
2 char* url;
3
4 gnutls_global_init();
5
6 for (i=0;;i++)
7 {
8     ret = gnutls_pkcs11_token_get_url(i, &url);
9     if (ret == GNUTLS_E_REQUESTED_DATA_NOT_AVAILABLE)
10         break;
11
12     if (ret < 0)
13         exit(1);
14
15     fprintf(stdout, "Token[%d]: URL: %s\n", i, url);
16     gnutls_free(url);

```

```

17 }
18 gnutls_global_deinit();

1 /* This example code is placed in the public domain. */
2
3 #include <config.h>
4 #include <gnutls/gnutls.h>
5 #include <gnutls/pkcs11.h>
6 #include <stdio.h>
7 #include <stdlib.h>
8
9 #define URL "pkcs11:URL"
10
11 int main(int argc, char **argv)
12 {
13     gnutls_pkcs11_obj_t *obj_list;
14     gnutls_x509_crt_t xcrt;
15     unsigned int obj_list_size = 0;
16     gnutls_datum_t cinfo;
17     int ret;
18     unsigned int i;
19
20     ret = gnutls_pkcs11_obj_list_import_url4(&obj_list, &obj_list_size, URL,
21                                             GNUTLS_PKCS11_OBJ_FLAG_CERT|
22                                             GNUTLS_PKCS11_OBJ_FLAG_WITH_PRIVKEY);
23
24     if (ret < 0)
25         return -1;
26
27     /* now all certificates are in obj_list */
28     for (i = 0; i < obj_list_size; i++) {
29
30         gnutls_x509_crt_init(&xcrt);
31
32         gnutls_x509_crt_import_pkcs11(xcrt, obj_list[i]);
33
34         gnutls_x509_crt_print(xcrt, GNUTLS_CERT_PRINT_FULL, &cinfo);
35
36         fprintf(stdout, "cert[%d]:\n %s\n\n", i, cinfo.data);
37
38         gnutls_free(cinfo.data);
39         gnutls_x509_crt_deinit(xcrt);
40     }
41
42     for (i = 0; i < obj_list_size; i++)
43         gnutls_pkcs11_obj_deinit(obj_list[i]);
44     gnutls_free(obj_list);
45
46     return 0;
47 }

```

4.3.4 Writing objects

With GnuTLS you can copy existing private keys and certificates to a token. Note that when copying private keys it is recommended to mark them as sensitive using the `GNUTLS-`

PKCS11_OBJ_FLAG_MARK_SENSITIVE to prevent its extraction. An object can be marked as private using the flag GNUTLS_PKCS11_OBJ_FLAG_MARK_PRIVATE, to require PIN to be entered before accessing the object (for operations or otherwise).

```
int gnutls_pkcs11_copy_x509_privkey2 (const      char      * token_url,  
gnutls_x509_privkey_t key, const char * label, const gnutls_datum_t * cid, unsigned  
int key_usage, unsigned int flags)
```

Description: This function will copy a private key into a PKCS #11 token specified by a URL. It is highly recommended flags to contain GNUTLS_PKCS11_OBJ_FLAG_MARK_SENSITIVE unless there is a strong reason not to.

Returns: On success, GNUTLS_E_SUCCESS (0) is returned, otherwise a negative error value.

```
int gnutls_pkcs11_copy_x509_cert2 (const char * token_url, gnutls_x509_cert_t crt,  
const char * label, const gnutls_datum_t * cid, unsigned int flags)
```

Description: This function will copy a certificate into a PKCS #11 token specified by a URL. Valid flags to mark the certificate: GNUTLS_PKCS11_OBJ_FLAG_MARK_TRUSTED, GNUTLS_PKCS11_OBJ_FLAG_MARK_SENSITIVE, GNUTLS_PKCS11_OBJ_FLAG_MARK_PRIVATE, GNUTLS_PKCS11_OBJ_FLAG_MARK_CA, GNUTLS_PKCS11_OBJ_FLAG_MARK_ALWAYS_AUTH.

Returns: On success, GNUTLS_E_SUCCESS (0) is returned, otherwise a negative error value.

```
int gnutls_pkcs11_delete_url (const char * object_url, unsigned int flags)
```

Description: This function will delete objects matching the given URL. Note that not all tokens support the delete operation.

Returns: On success, the number of objects deleted is returned, otherwise a negative error value.

4.3.5 Using a PKCS #11 token with TLS

It is possible to use a PKCS #11 token to a TLS session, as shown in ???. In addition the following functions can be used to load PKCS #11 key and certificates by specifying a PKCS #11 URL instead of a filename.

```
int gnutls_certificate_set_x509_trust_file (gnutls_certificate_credentials_t cred,
const char * cafile, gnutls_x509_crt_fmt_t type)
```

```
int gnutls_certificate_set_x509_key_file2 (gnutls_certificate_credentials_t res, const
char * certfile, const char * keyfile, gnutls_x509_crt_fmt_t type, const char * pass,
unsigned int flags)
```

```
int gnutls_certificate_set_x509_system_trust (gnutls_certificate_credentials_t cred)
```

Description: This function adds the system's default trusted CAs in order to verify client or server certificates. In the case the system is currently unsupported GNUTLS-**E_UNIMPLEMENTED_FEATURE** is returned.

Returns: the number of certificates processed or a negative error code on error.

4.3.6 Invoking p11tool

Program that allows operations on PKCS #11 smart cards and security modules.

To use PKCS #11 tokens with GnuTLS the p11-kit configuration files need to be setup. That is create a .module file in /etc/pkcs11/modules with the contents 'module: /path/to/pkcs11.so'. Alternatively the configuration file /etc/gnutls/pkcs11.conf has to exist and contain a number of lines of the form 'load=/usr/lib/opensc-pkcs11.so'.

You can provide the PIN to be used for the PKCS #11 operations with the environment variables GNUTLS_PIN and GNUTLS_SO_PIN.

This section was generated by **AutoGen**, using the **agtexi-cmd** template and the option descriptions for the **p11tool** program. This software is released under the GNU General Public License, version 3 or later.

4.3.7 p11tool help/usage (“--help”)

This is the automatically generated usage text for p11tool.

The text printed is the same whether selected with the **help** option (“--help”) or the **more-help** option (“--more-help”). **more-help** will print the usage text by passing it through a pager program. **more-help** is disabled on platforms without a working **fork(2)** function. The **PAGER** environment variable is used to select the program, defaulting to “more”. Both will exit with a status code of 0.

```
1 p11tool - GnuTLS PKCS #11 tool
2 Usage: p11tool [ -<flag> [<val>] | --<name>[={| }<val>] ]... [url]
```



```

3
4 -d, --debug=num          Enable debugging
5                          - it must be in the range:
6                          0 to 9999
7
8 --outfile=str            Output file
9
10 --list-tokens            List all available tokens
11
12 --export                Export the object specified by the URL
13
14 --export-chain           Export the certificate specified by the URL and its chain of trust
15
16 --list-mechanisms        List all available mechanisms in a token
17
18 --info                  List information on an available object in a token
19
20 --list-all              List all available objects in a token
21
22 --list-all-certs        List all available certificates in a token
23
24 --list-certs             List all certificates that have an associated private key
25
26 --list-all-privkeys     List all available private keys in a token
27
28 --list-privkeys          an alias for the 'list-all-privkeys' option
29
30 --list-keys              an alias for the 'list-all-privkeys' option
31
32 --list-all-trusted      List all available certificates marked as trusted
33
34 --write                  Writes the loaded objects to a PKCS #11 token
35
36 --delete                 Deletes the objects matching the PKCS #11 URL
37
38 --generate-random=num    Generate random data
39
40 --generate-rsa           Generate an RSA private-public key pair
41
42 --generate-dsa           Generate an RSA private-public key pair
43
44 --generate-ecc           Generate an RSA private-public key pair
45
46 --export-pubkey          Export the public key for a private key
47
48 --label=str             Sets a label for the write operation
49
50 --mark-wrap              Marks the generated key to be a wrapping key
51                          - disabled as '--no-mark-wrap'
52
53 --mark-trusted           Marks the object to be written as trusted
54                          - disabled as '--no-mark-trusted'
55
56 --mark-ca                Marks the object to be written as a CA
57                          - disabled as '--no-mark-ca'
58
59 --mark-private           Marks the object to be written as private
60                          - disabled as '--no-mark-private'
61                          - enabled by default
62
63 --trusted                an alias for the 'mark-trusted' option
64
65 --ca                     an alias for the 'mark-ca' option
66
67 --private                an alias for the 'mark-private' option
68                          - enabled by default
69
70 --login                  Force (user) login to token
71                          - disabled as '--no-login'
72
73 --so-login               Force security officer login to token
74                          - disabled as '--no-so-login'
75
76 --admin-login            an alias for the 'so-login' option
77
78 --detailed-url           Print detailed URLs
79                          - disabled as '--no-detailed-url'
80
81 -!, --secret-key=str     Provide a hex encoded secret key
82
83 -, --load-privkey=file   Private key file to use
84                          - file must pre-exist
85
86 -#, --load-pubkey=file   Public key file to use
87                          - file must pre-exist
88
89 -$, --load-certificate=file Certificate file to use
90                          - file must pre-exist
91
92 -8, --pkcs8              Use PKCS #8 format for private keys
93
94 -%, --bits=num           Specify the number of bits for key generate
95
96 -&, --curve=str          Specify the curve used for EC key generation
97
98 -, --sec-param=str       Specify the security level
99
100 -(, --inder              Use DER/RAW format for input
101                          - disabled as '--no-inder'

```

```

61  -), --inraw          an alias for the 'inder' option
62  --*, --outder       Use DER format for output certificates, private keys, and DH parameters
63                      - disabled as '--no-outder'
64  --+, --outraw       an alias for the 'outder' option
65  --, --initialize    Initializes a PKCS #11 token
66  --, --set-pin=str   Specify the PIN to use on token initialization
67  --, --set-so-pin=str Specify the Security Officer's PIN to use on token initialization
68  --/, --provider=file Specify the PKCS #11 provider library
69                      - file must pre-exist
70  -0, --batch         Disable all interaction with the tool. All parameters need to be
71  specified on command line.
72  -v, --version[=arg] output version information and exit
73  -h, --help          display extended usage information and exit
74  -!, --more-help     extended usage information passed thru pager
75
76  Options are specified by doubled hyphens and their name or by a single
77  hyphen and the flag character.
78  Operands and options may be intermixed. They will be reordered.
79
80  Program that allows operations on PKCS #11 smart cards and security
81  modules.
82
83  To use PKCS #11 tokens with GnuTLS the p11-kit configuration files need to
84  be setup. That is create a .module file in /etc/pkcs11/modules with the
85  contents 'module: /path/to/pkcs11.so'. Alternatively the configuration
86  file /etc/gnutls/pkcs11.conf has to exist and contain a number of lines of
87  the form 'load=/usr/lib/opensc-pkcs11.so'.
88
89  You can provide the PIN to be used for the PKCS #11 operations with the
90  environment variables GNUTLS_PIN and GNUTLS_SO_PIN.
91

```

4.3.8 debug option (-d)

This is the “enable debugging” option. This option takes a number argument. Specifies the debug level.

4.3.9 export-chain option

This is the “export the certificate specified by the url and its chain of trust” option. Exports the certificate specified by the URL and generates its chain of trust based on the stored certificates in the module.

4.3.10 list-all-privkeys option

This is the “list all available private keys in a token” option. Lists all the private keys in a token that match the specified URL.

4.3.11 list-privkeys option

This is an alias for the `list-all-privkeys` option, ??.

4.3.12 list-keys option

This is an alias for the `list-all-privkeys` option, ??.

4.3.13 test-sign option

This is the “tests the signature operation of the provided object” option. It can be used to test the correct operation of the signature operation. If both a private and a public key are available this operation will sign and verify the signed data.

4.3.14 write option

This is the “writes the loaded objects to a pkcs #11 token” option. It can be used to write private keys, certificates or secret keys to a token.

4.3.15 generate-random option

This is the “generate random data” option. This option takes a number argument. Asks the token to generate a number of bytes of random bytes.

4.3.16 generate-rsa option

This is the “generate an rsa private-public key pair” option. Generates an RSA private-public key pair on the specified token.

4.3.17 generate-dsa option

This is the “generate an rsa private-public key pair” option. Generates an RSA private-public key pair on the specified token.

4.3.18 generate-ecc option

This is the “generate an rsa private-public key pair” option. Generates an RSA private-public key pair on the specified token.

4.3.19 export-pubkey option

This is the “export the public key for a private key” option. Exports the public key for the specified private key

4.3.20 set-id option

This is the “set the cka_id (in hex) for the specified by the url object” option. This option takes a string argument.

This option has some usage constraints. It:

- must not appear in combination with any of the following options: write.

Modifies or sets the CKA_ID in the specified by the URL object. The ID should be specified in hexadecimal format without a '0x' prefix.

4.3.21 set-label option

This is the “set the cka_label for the specified by the url object” option. This option takes a string argument.

This option has some usage constraints. It:

- must not appear in combination with any of the following options: write, set-id.

Modifies or sets the CKA_LABEL in the specified by the URL object

4.3.22 id option

This is the “sets an id for the write operation” option. This option takes a string argument. Sets the CKA_ID to be set by the write operation. The ID should be specified in hexadecimal format without a '0x' prefix.

4.3.23 mark-wrap option

This is the “marks the generated key to be a wrapping key” option.

This option has some usage constraints. It:

- can be disabled with `-no-mark-wrap`.

Marks the generated key with the CKA_WRAP flag.

4.3.24 mark-trusted option

This is the “marks the object to be written as trusted” option.

This option has some usage constraints. It:

- can be disabled with `-no-mark-trusted`.

Marks the object to be generated/copied with the `CKA_TRUST` flag.

4.3.25 mark-decrypt option

This is the “marks the object to be written for decryption” option.

This option has some usage constraints. It:

- can be disabled with `-no-mark-decrypt`.

Marks the object to be generated/copied with the `CKA_DECRYPT` flag set to true.

4.3.26 mark-sign option

This is the “marks the object to be written for signature generation” option.

This option has some usage constraints. It:

- can be disabled with `-no-mark-sign`.

Marks the object to be generated/copied with the `CKA_SIGN` flag set to true.

4.3.27 mark-ca option

This is the “marks the object to be written as a ca” option.

This option has some usage constraints. It:

- can be disabled with `-no-mark-ca`.

Marks the object to be generated/copied with the `CKA_CERTIFICATE_CATEGORY` as `CA`.

4.3.28 mark-private option

This is the “marks the object to be written as private” option.

This option has some usage constraints. It:

- can be disabled with `-no-mark-private`.
- It is enabled by default.

Marks the object to be generated/copied with the CKA_PRIVATE flag. The written object will require a PIN to be used.

4.3.29 trusted option

This is an alias for the `mark-trusted` option, `??`.

4.3.30 ca option

This is an alias for the `mark-ca` option, `??`.

4.3.31 private option

This is an alias for the `mark-private` option, `??`.

4.3.32 so-login option

This is the “force security officer login to token” option.

This option has some usage constraints. It:

- can be disabled with `-no-so-login`.

Forces login to the token as security officer (admin).

4.3.33 admin-login option

This is an alias for the `so-login` option, `??`.

4.3.34 curve option

This is the “specify the curve used for ec key generation” option. This option takes a string argument. Supported values are `secp192r1`, `secp224r1`, `secp256r1`, `secp384r1` and `secp521r1`.

4.3.35 sec-param option

This is the “specify the security level” option. This option takes a string argument “**Security parameter**”. This is alternative to the `bits` option. Available options are [low, legacy, medium, high, ultra].

4.3.36 **inder option**

This is the “use der/raw format for input” option.

This option has some usage constraints. It:

- can be disabled with `-no-inder`.

Use DER/RAW format for input certificates and private keys.

4.3.37 **inraw option**

This is an alias for the `inder` option, `??`.

4.3.38 **outder option**

This is the “use der format for output certificates, private keys, and dh parameters” option.

This option has some usage constraints. It:

- can be disabled with `-no-outder`.

The output will be in DER or RAW format.

4.3.39 **outraw option**

This is an alias for the `outder` option, `??`.

4.3.40 **set-pin option**

This is the “specify the pin to use on token initialization” option. This option takes a string argument. Alternatively the `GNUTLS_PIN` environment variable may be used.

4.3.41 **set-so-pin option**

This is the “specify the security officer’s pin to use on token initialization” option. This option takes a string argument. Alternatively the `GNUTLS_SO_PIN` environment variable may be used.

4.3.42 **provider option**

This is the “specify the pkcs #11 provider library” option. This option takes a file argument. This will override the default options in `/etc/gnutls/pkcs11.conf`

4.3.43 p11tool exit status

One of the following exit values will be returned:

- 0 (EXIT.SUCCESS) Successful program execution.
- 1 (EXIT.FAILURE) The operation failed or the command syntax was not valid.

4.3.44 p11tool See Also

certtool (1)

4.3.45 p11tool Examples

To view all tokens in your system use:

```
1 $ p11tool --list-tokens
```

To view all objects in a token use:

```
1 $ p11tool --login --list-all "pkcs11:TOKEN-URL"
```

To store a private key and a certificate in a token run:

```
1 $ p11tool --login --write "pkcs11:URL" --load-privkey key.pem \
2   --label "Mykey"
3 $ p11tool --login --write "pkcs11:URL" --load-certificate cert.pem \
4   --label "Mykey"
```

Note that some tokens require the same label to be used for the certificate and its corresponding private key.

To generate an RSA private key inside the token use:

```
1 $ p11tool --login --generate-rsa --bits 1024 --label "MyNewKey" \
2   --outfile MyNewKey.pub "pkcs11:TOKEN-URL"
```

The bits parameter in the above example is explicitly set because some tokens only support limited choices in the bit length. The output file is the corresponding public key. This key can be used to general a certificate request with certtool.

```
1 certtool --generate-request --load-privkey "pkcs11:KEY-URL" \
2   --load-pubkey MyNewKey.pub --outfile request.pem
```

4.4 Trusted Platform Module (TPM)

In this section we present the Trusted Platform Module (TPM) support in GnuTLS.

There was a big hype when the TPM chip was introduced into computers. Briefly it is a co-processor in your PC that allows it to perform calculations independently of the main processor. This has good and bad side-effects. In this section we focus on the good ones; these are the fact that you can use the TPM chip to perform cryptographic operations on keys stored in it, without accessing them. That is very similar to the operation of a PKCS #11 smart card. The chip allows for storage and usage of RSA keys, but has quite some operational differences from PKCS #11 module, and thus require different handling. The basic TPM operations supported and used by GnuTLS, are key generation and signing.

The next sections assume that the TPM chip in the system is already initialized and in a operational state.

In GnuTLS the TPM functionality is available in `gnutls/tpm.h`.

4.4.1 Keys in TPM

The RSA keys in the TPM module may either be stored in a flash memory within TPM or stored in a file in disk. In the former case the key can provide operations as with PKCS #11 and is identified by a URL. The URL is described in [?] and is of the following form.

```
tpmkey:uuid=42309df8-d101-11e1-a89a-97bb33c23ad1;storage=user
```

It consists from a unique identifier of the key as well as the part of the flash memory the key is stored at. The two options for the storage field are ‘user’ and ‘system’. The user keys are typically only available to the generating user and the system keys to all users. The stored in TPM keys are called registered keys.

The keys that are stored in the disk are exported from the TPM but in an encrypted form. To access them two passwords are required. The first is the TPM Storage Root Key (SRK), and the other is a key-specific password. Also those keys are identified by a URL of the form:

```
tpmkey:file=/path/to/file
```

When objects require a PIN to be accessed the same callbacks as with PKCS #11 objects are expected (see ??). Note that the PIN function may be called multiple times to unlock the SRK and the specific key in use. The label in the key function will then be set to ‘SRK’ when unlocking the SRK key, or to ‘TPM’ when unlocking any other key.

4.4.2 Key generation

All keys used by the TPM must be generated by the TPM. This can be done using `gnutls-tpm-privkey-generate`.

```
int gnutls_tpm_privkey_generate (gnutls_pk_algorithm_t pk, unsigned int bits,
const char *srk_password, const char *key_password, gnutls_tpmkey_fmt_t format,
gnutls_x509_cert_fmt_t pub_format, gnutls_datum_t *privkey, gnutls_datum_t *
pubkey, unsigned int flags)
```

Description: This function will generate a private key in the TPM chip. The private key will be generated within the chip and will be exported in a wrapped with TPM's master key form. Furthermore the wrapped key can be protected with the provided password. Note that bits in TPM is quantized value. If the input value is not one of the allowed values, then it will be quantized to one of 512, 1024, 2048, 4096, 8192 and 16384. Allowed flags are:

Returns: On success, GNUTLS_E_SUCCESS (0) is returned, otherwise a negative error value.

```
int gnutls_tpm_get_registered (gnutls_tpm_key_list_t *list)
```

```
void gnutls_tpm_key_list_deinit (gnutls_tpm_key_list_t list)
```

```
int gnutls_tpm_key_list_get_url (gnutls_tpm_key_list_t list, unsigned int idx, char **
url, unsigned int flags)
```

```
int gnutls_tpm_privkey_delete (const char *url, const char *srk_password)
```

Description: This function will unregister the private key from the TPM chip.

Returns: On success, GNUTLS_E_SUCCESS (0) is returned, otherwise a negative error value.

4.4.3 Using keys

Importing keys

The TPM keys can be used directly by the abstract key types and do not require any special structures. Moreover functions like `gnutls_certificate_set_x509_key_file2` can access TPM URLs.

```
int gnutls_privkey_import_tpm_raw (gnutls_privkey_t pkey, const gnutls_datum_t
* fdata, gnutls_tpmkey_fmt_t format, const char * srk_password, const char *
key_password, unsigned int flags)
```

```
int gnutls_pubkey_import_tpm_raw (gnutls_pubkey_t pkey, const gnutls_datum_t *
fdata, gnutls_tpmkey_fmt_t format, const char * srk_password, unsigned int flags)
```

```
int gnutls_privkey_import_tpm_url (gnutls_privkey_t pkey, const char * url,
const char * srk_password, const char * key_password, unsigned int flags)
```

Description: This function will import the given private key to the abstract *gnutls-privkey_t* type. Note that unless `GNUTLS_PRIVKEY_DISABLE_CALLBACKS` is specified, if incorrect (or NULL) passwords are given the PKCS11 callback functions will be used to obtain the correct passwords. Otherwise if the SRK password is wrong `GNUTLS_E_TPM_SRK_PASSWORD_ERROR` is returned and if the key password is wrong or not provided then `GNUTLS_E_TPM_KEY_PASSWORD_ERROR` is returned.

Returns: On success, `GNUTLS_E_SUCCESS` (0) is returned, otherwise a negative error value.

```
int gnutls_pubkey_import_tpm_url (gnutls_pubkey_t pkey, const char * url, const
char * srk_password, unsigned int flags)
```

Description: This function will import the given private key to the abstract *gnutls-privkey_t* type. Note that unless `GNUTLS_PUBKEY_DISABLE_CALLBACKS` is specified, if incorrect (or NULL) passwords are given the PKCS11 callback functions will be used to obtain the correct passwords. Otherwise if the SRK password is wrong `GNUTLS_E_TPM_SRK_PASSWORD_ERROR` is returned.

Returns: On success, `GNUTLS_E_SUCCESS` (0) is returned, otherwise a negative error value.

Listing and deleting keys

The registered keys (that are stored in the TPM) can be listed using one of the following functions. Those keys are unfortunately only identified by their UUID and have no label or other human friendly identifier. Keys can be deleted from permanent storage using `gnutls-tpm_privkey_delete`.

```

int gnutls_tpm_get_registered (gnutls_tpm_key_list_t * list)

void gnutls_tpm_key_list_deinit (gnutls_tpm_key_list_t list)

int gnutls_tpm_key_list_get_url (gnutls_tpm_key_list_t list, unsigned int idx, char
** url, unsigned int flags)

```

```

int gnutls_tpm_privkey_delete (const char * url, const char * srk_password)

```

Description: This function will unregister the private key from the TPM chip.

Returns: On success, GNUTLS_E_SUCCESS (0) is returned, otherwise a negative error value.

4.4.4 Invoking tpmtool

Program that allows handling cryptographic data from the TPM chip.

This section was generated by **AutoGen**, using the **agtexi-cmd** template and the option descriptions for the **tpmtool** program. This software is released under the GNU General Public License, version 3 or later.

4.4.5 tpmtool help/usage (“--help”)

This is the automatically generated usage text for tpmtool.

The text printed is the same whether selected with the **help** option (“--help”) or the **more-help** option (“--more-help”). **more-help** will print the usage text by passing it through a pager program. **more-help** is disabled on platforms without a working **fork(2)** function. The **PAGER** environment variable is used to select the program, defaulting to “more”. Both will exit with a status code of 0.

```

1 tpmtool is unavailable - no --help

```

4.4.6 debug option (-d)

This is the “enable debugging” option. This option takes a number argument. Specifies the debug level.

4.4.7 generate-rsa option

This is the “generate an rsa private-public key pair” option. Generates an RSA private-public key pair in the TPM chip. The key may be stored in filesystem and protected by a PIN, or stored (registered) in the TPM chip flash.

4.4.8 user option

This is the “any registered key will be a user key” option.

This option has some usage constraints. It:

- must appear in combination with the following options: register.
- must not appear in combination with any of the following options: system.

The generated key will be stored in a user specific persistent storage.

4.4.9 system option

This is the “any registered key will be a system key” option.

This option has some usage constraints. It:

- must appear in combination with the following options: register.
- must not appear in combination with any of the following options: user.

The generated key will be stored in system persistent storage.

4.4.10 sec-param option

This is the “specify the security level [low, legacy, medium, high, ultra].” option. This option takes a string argument “**Security parameter**”. This is alternative to the bits option. Note however that the values allowed by the TPM chip are quantized and given values may be rounded up.

4.4.11 inder option

This is the “use the der format for keys.” option.

This option has some usage constraints. It:

- can be disabled with `-no-inder`.

The input files will be assumed to be in the portable DER format of TPM. The default format is a custom format used by various TPM tools

4.4.12 outder option

This is the “use der format for output keys” option.

This option has some usage constraints. It:

- can be disabled with `--no-outder`.

The output will be in the TPM portable DER format.

4.4.13 tpmtool exit status

One of the following exit values will be returned:

- 0 (EXIT_SUCCESS) Successful program execution.
- 1 (EXIT_FAILURE) The operation failed or the command syntax was not valid.

4.4.14 tpmtool See Also

`pk11tool` (1), `certtool` (1)

4.4.15 tpmtool Examples

To generate a key that is to be stored in filesystem use:

```
1 $ tpmtool --generate-rsa --bits 2048 --outfile tpmkey.pem
```

To generate a key that is to be stored in TPM’s flash use:

```
1 $ tpmtool --generate-rsa --bits 2048 --register --user
```

To get the public key of a TPM key use:

```
1 $ tpmtool --pubkey tpmkey:uuid=58ad734b-bde6-45c7-89d8-756a55ad1891;storage=user \
2 --outfile pubkey.pem
```

or if the key is stored in the filesystem:

```
1 $ tpmtool --pubkey tpmkey:file=tpmkey.pem --outfile pubkey.pem
```

To list all keys stored in TPM use:

```
1 $ tpmtool --list
```

5

How to use GnuTLS in applications

5.1 Introduction

This chapter tries to explain the basic functionality of the current GnuTLS library. Note that there may be additional functionality not discussed here but included in the library. Checking the header files in “`/usr/include/gnutls/`” and the manpages is recommended.

5.1.1 General idea

A brief description of how GnuTLS sessions operate is shown at ???. This section will become more clear when it is completely read. As shown in the figure, there is a read-only global state that is initialized once by the global initialization function. This global structure, among others, contains the memory allocation functions used, structures needed for the ASN.1 parser and depending on the system’s CPU, pointers to hardware accelerated encryption functions. This structure is never modified by any GnuTLS function, except for the deinitialization function which frees all allocated memory and must be called after the program has permanently finished using GnuTLS.

The credentials structures are used by the authentication methods, such as certificate authentication. They store certificates, private keys, and other information that is needed to prove the identity to the peer, and/or verify the identity of the peer. The information stored in the credentials structures is initialized once and then can be shared by many TLS sessions.

A GnuTLS session contains all the required state and information to handle one secure connection. The session communicates with the peers using the provided functions of the transport

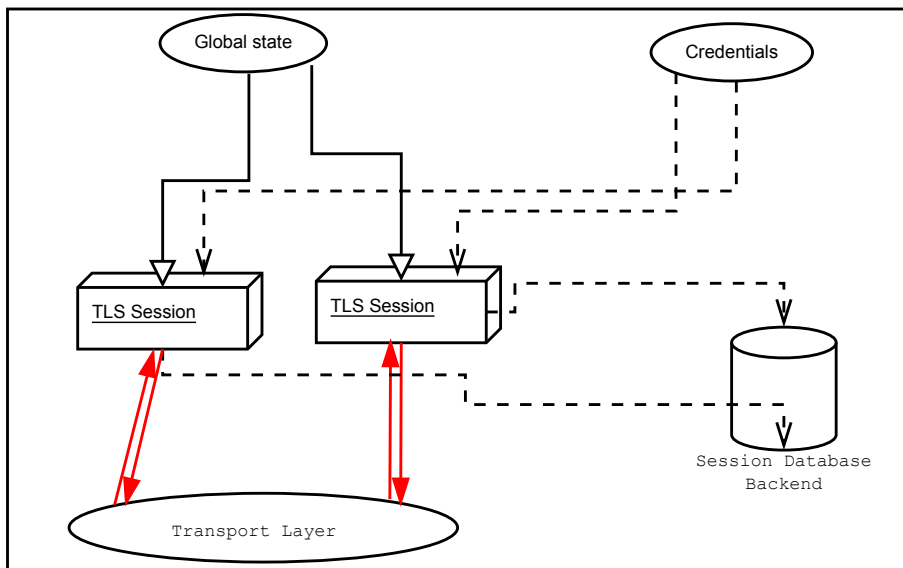


Figure 5.1: High level design of GnuTLS.

layer. Every session has a unique session ID shared with the peer.

Since TLS sessions can be resumed, servers need a database back-end to hold the session's parameters. Every GnuTLS session after a successful handshake calls the appropriate back-end function (see ??) to store the newly negotiated session. The session database is examined by the server just after having received the client hello¹, and if the session ID sent by the client, matches a stored session, the stored session will be retrieved, and the new session will be a resumed one, and will share the same session ID with the previous one.

5.1.2 Error handling

In GnuTLS most functions return an integer type as a result. In almost all cases a zero or a positive number means success, and a negative number indicates failure, or a situation that some action has to be taken. Thus negative error codes may be fatal or not.

Fatal errors terminate the connection immediately and further sends and receives will be disallowed. Such an example is `GNUTLS_E_DECRYPTION_FAILED`. Non-fatal errors may warn about something, i.e., a warning alert was received, or indicate the some action has to be taken. This is the case with the error code `GNUTLS_E_REHANDSHAKE` returned by `gnutls_record_recv`. This error code indicates that the server requests a re-handshake. The client may ignore this request, or may reply with an alert. You can test if an error code is a fatal one by using the `gnutls_error_is_fatal`. All errors can be converted to a descriptive string using `gnutls_strerror`.

¹The first message in a TLS handshake

If any non fatal errors, that require an action, are to be returned by a function, these error codes will be documented in the function's reference. For example the error codes `GNUTLS_E_WARNING_ALERT_RECEIVED` and `GNUTLS_E_FATAL_ALERT_RECEIVED` that may returned when receiving data, should be handled by notifying the user of the alert (as explained in ??). See ??, for a description of the available error codes.

5.1.3 Common types

All strings that are to provided as input to GnuTLS functions should be in UTF-8 unless otherwise specified. Output strings are also in UTF-8 format unless otherwise specified.

When data of a fixed size are provided to GnuTLS functions then the helper structure `gnutls_datum_t` is often used. Its definition is shown below.

```
typedef struct
{
    unsigned char *data;
    unsigned int size;
} gnutls_datum_t;
```

Other functions that require data for scattered read use a structure similar to `struct iovec` typically used by `readv`. It is shown below.

```
typedef struct
{
    void *iov_base;           /* Starting address */
    size_t iov_len;           /* Number of bytes to transfer */
} giovec_t;
```

5.1.4 Debugging and auditing

In many cases things may not go as expected and further information, to assist debugging, from GnuTLS is desired. Those are the cases where the `gnutls_global_set_log_level` and `gnutls_global_set_log_function` are to be used. Those will print verbose information on the GnuTLS functions internal flow.

```
void gnutls_global_set_log_level (int level)

void gnutls_global_set_log_function (gnutls_log_func log_func)
```

Alternatively the environment variable `GNUTLS_DEBUG_LEVEL` can be set to a logging level and GnuTLS will output debugging output to standard error. Other available environment variables are shown in ??.

Variable	Purpose
GNUTLS_DEBUG_LEVEL	When set to a numeric value, it sets the default debugging level for GnuTLS applications.
GNUTLS_CPUID_OVERRIDE	That environment variable can be used to explicitly enable/disable the use of certain CPU capabilities. Note that CPU detection cannot be overridden, i.e., VIA options cannot be enabled on an Intel CPU. The currently available options are: @itemize
0x1: Disable all run-time detected optimizations	
0x2: Enable AES-NI	
0x4: Enable SSSE3	
0x8: Enable PCLMUL	
0x100000: Enable VIA padlock	
0x200000: Enable VIA PHE	
0x400000: Enable VIA PHE SHA512 @end itemize	
GNUTLS_FORCE_FIPS_MODE	In setups where GnuTLS is compiled with support for FIPS140-2 (see <code>-enable-fips140-mode</code> in <code>configure</code>), that option if set to one enforces the FIPS140 mode.

Table 5.1: Environment variables used by the library.

When debugging is not required, important issues, such as detected attacks on the protocol still need to be logged. This is provided by the logging function set by `gnutls_global_set_audit_log_function`. The provided function will receive a message and the corresponding TLS session. The session information might be used to derive IP addresses or other information about the peer involved.

```
void gnutls_global_set_audit_log_function (gnutls_audit_log_func log_func)
```

Description: This is the function to set the audit logging function. This is a function to report important issues, such as possible attacks in the protocol. This is different from `gnutls_global_set_log_function()` because it will report also session-specific events. The session parameter will be null if there is no corresponding TLS session. `gnutls_audit_log_func` is of the form, `void (*gnutls_audit_log_func)(gnutls_session_t, const char*)`;

5.1.5 Thread safety

The GnuTLS library is thread safe by design, meaning that objects of the library such as TLS sessions, can be safely divided across threads as long as a single thread accesses a single object. This is sufficient to support a server which handles several sessions per thread. If, however,

an object needs to be shared across threads then access must be protected with a mutex. Read-only access to objects, for example the credentials holding structures, is also thread-safe.

A `gnutls_session_t` object can be shared by two threads, one sending, the other receiving. In that case rehandshakes, if required, must only be handled by a single thread being active. The termination of a session should be handled, either by a single thread being active, or by the sender thread using `gnutls_bye` with `GNUTLS_SHUT_WR` and the receiving thread waiting for a return value of zero.

The random generator of the cryptographic back-end, utilizes mutex locks (e.g., pthreads on GNU/Linux and CriticalSection on Windows) which are setup by GnuTLS on library initialization. Prior to version 3.3.0 they were setup by calling `gnutls_global_init`. On special systems you could manually specify the locking system using the function `gnutls_global_set_mutex` before calling any other GnuTLS function. Setting mutexes manually is not recommended. An example of non-native thread usage is shown below.

```
1 #include <gnutls/gnutls.h>
2
3 int main()
4 {
5     /* When the system mutexes are not to be used
6      * gnutls_global_set_mutex() must be called explicitly
7      */
8     gnutls_global_set_mutex (mutex_init, mutex_deinit,
9                             mutex_lock, mutex_unlock);
10 }
```

```
void gnutls_global_set_mutex (mutex_init_func init, mutex_deinit_func deinit,
mutex_lock_func lock, mutex_unlock_func unlock)
```

Description: With this function you are allowed to override the default mutex locks used in some parts of gnutls and dependent libraries. This function should be used if you have complete control of your program and libraries. Do not call this function from a library, or preferably from any application unless really needed to. GnuTLS will use the appropriate locks for the running system. This function must be called prior to any other gnutls function.

5.1.6 Sessions and fork

A `gnutls_session_t` object can be shared by two processes after a fork, one sending, the other receiving. In that case rehandshakes, cannot and must not be performed. As with threads, the termination of a session should be handled by the sender process using `gnutls_bye` with `GNUTLS_SHUT_WR` and the receiving process waiting for a return value of zero.

5.1.7 Callback functions

There are several cases where GnuTLS may need out of band input from your program. This is now implemented using some callback functions, which your program is expected to register.

An example of this type of functions are the push and pull callbacks which are used to specify the functions that will retrieve and send data to the transport layer.

```
void gnutls_transport_set_push_function (gnutls_session_t session,  
gnutls_push_func push_func)  
  
void gnutls_transport_set_pull_function (gnutls_session_t session, gnutls_pull_func  
pull_func)
```

Other callback functions may require more complicated input and data to be allocated. Such an example is `gnutls_srp_set_server_credentials_function`. All callbacks should allocate and free memory using `gnutls_malloc` and `gnutls_free`.

5.2 Preparation

To use GnuTLS, you have to perform some changes to your sources and your build system. The necessary changes are explained in the following subsections.

5.2.1 Headers

All the data types and functions of the GnuTLS library are defined in the header file “`gnutls/gnutls.h`”. This must be included in all programs that make use of the GnuTLS library.

5.2.2 Initialization

The GnuTLS library is initialized on load; prior to 3.3.0 was initialized by calling `gnutls_global_init`. The initialization typically enables CPU-specific acceleration, performs any required precalculations needed, opens any required system devices (e.g., `/dev/urandom` on Linux) and initializes subsystems that could be used later.

The resources allocated by the initialization process will be released on library deinitialization, or explicitly by calling `gnutls_global_deinit`.

Note that during initialization file descriptors may be kept open by GnuTLS (e.g. `/dev/urandom`) on library load. Applications closing all unknown file descriptors must immediately call `gnutls_global_init`, after that, to ensure they don't disrupt GnuTLS' operation.

5.2.3 Version check

It is often desirable to check that the version of ‘gnutls’ used is indeed one which fits all requirements. Even with binary compatibility new features may have been introduced but due to problem with the dynamic linker an old version is actually used. So you may want to check that the version is okay right after program start-up. See the function `gnutls_check_version`.

On the other hand, it is often desirable to support more than one versions of the library. In that case you could utilize compile-time feature checks using the the `GNUTLS_VERSION_NUMBER` macro. For example, to conditionally add code for GnuTLS 3.2.1 or later, you may use:

```
1 #if GNUTLS_VERSION_NUMBER >= 0x030201
2 ...
3 #endif
```

5.2.4 Building the source

If you want to compile a source file including the “`gnutls/gnutls.h`” header file, you must make sure that the compiler can find it in the directory hierarchy. This is accomplished by adding the path to the directory in which the header file is located to the compilers include file search path (via the “`-I`” option).

However, the path to the include file is determined at the time the source is configured. To solve this problem, the library uses the external package “`pkg-config`” that knows the path to the include file and other configuration options. The options that need to be added to the compiler invocation at compile time are output by the “`--cflags`” option to “`pkg-config gnutls`”. The following example shows how it can be used at the command line:

```
1 gcc -c foo.c 'pkg-config gnutls --cflags'
```

Adding the output of `pkg-config gnutls --cflags` to the compilers command line will ensure that the compiler can find the “`gnutls/gnutls.h`” header file.

A similar problem occurs when linking the program with the library. Again, the compiler has to find the library files. For this to work, the path to the library files has to be added to the library search path (via the “`-L`” option). For this, the option “`--libs`” to “`pkg-config gnutls`” can be used. For convenience, this option also outputs all other options that are required to link the program with the library (for instance, the `-ltasn1` option). The example shows how to link “`foo.o`” with the library to a program “`foo`”.

```
1 gcc -o foo foo.o 'pkg-config gnutls --libs'
```

Of course you can also combine both examples to a single command by specifying both options to “`pkg-config`”:

```
1 gcc -o foo foo.c 'pkg-config gnutls --cflags --libs'
```

When a program uses the GNU autoconf system, then the following line or similar can be used to detect the presence of GnuTLS.

```

1 PKG_CHECK_MODULES([LIBGNUTLS], [gnutls >= 3.3.0])
2
3 AC_SUBST([LIBGNUTLS_CFLAGS])
4 AC_SUBST([LIBGNUTLS_LIBS])

```

5.3 Session initialization

In the previous sections we have discussed the global initialization required for GnuTLS as well as the initialization required for each authentication method's credentials (see ??). In this section we elaborate on the TLS or DTLS session initiation. Each session is initialized using `gnutls_init` which among others is used to specify the type of the connection (server or client), and the underlying protocol type, i.e., datagram (UDP) or reliable (TCP).

```
int gnutls_init (gnutls_session_t * session, unsigned int flags)
```

Description: This function initializes the current session to null. Every session must be initialized before use, so internal structures can be allocated. This function allocates structures which can only be free'd by calling `gnutls_deinit()`. Returns `GNUTLS_E_SUCCESS` (0) on success. `flags` can be one of `GNUTLS_CLIENT` and `GNUTLS_SERVER`. For a DTLS entity, the flags `GNUTLS_DATAGRAM` and `GNUTLS_NONBLOCK` are also available. The latter flag will enable a non-blocking operation of the DTLS timers. The flag `GNUTLS_NO_REPLAY_PROTECTION` will disable any replay protection in DTLS mode. That must only used when replay protection is achieved using other means. Note that since version 3.1.2 this function enables some common TLS extensions such as session tickets and OCSP certificate status request in client side by default. To prevent that use the `GNUTLS_NO_EXTENSIONS` flag.

Returns: `GNUTLS_E_SUCCESS` on success, or an error code.

After the session initialization details on the allowed ciphersuites and protocol versions should be set using the priority functions such as `gnutls_priority_set_direct`. We elaborate on them in ??. The credentials used for the key exchange method, such as certificates or usernames and passwords should also be associated with the session current session using `gnutls_credentials_set`.

5.4 Associating the credentials

Each authentication method is associated with a key exchange method, and a credentials type. The contents of the credentials is method-dependent, e.g. certificates for certificate authenti-

```
int gnutls_credentials_set (gnutls_session_t session, gnutls_credentials_type_t type,
void * cred)
```

Description: Sets the needed credentials for the specified type. Eg username, password - or public and private keys etc. The cred parameter is a structure that depends on the specified type and on the current session (client or server). In order to minimize memory usage, and share credentials between several threads gnutls keeps a pointer to cred, and not the whole cred structure. Thus you will have to keep the structure allocated until you call gnutls_deinit(). For GNUTLS_CRD_ANON, cred should be *gnutls_anon_client_credentials_t* in case of a client. In case of a server it should be *gnutls_anon_server_credentials_t*. For GNUTLS_CRD_SRP, cred should be *gnutls_srp_client_credentials_t* in case of a client, and *gnutls_srp_server_credentials_t*, in case of a server. For GNUTLS_CRD_CERTIFICATE, cred should be *gnutls_certificate_credentials_t*.

Returns: On success, GNUTLS_E_SUCCESS (0) is returned, otherwise a negative error code is returned.

cation and should be initialized and associated with a session (see `gnutls_credentials_set`). A mapping of the key exchange methods with the credential types is shown in ??.

Authentication method	Key exchange	Client credentials	Server credentials
Certificate	KX_RSA, KX_DHE_RSA, KX_DHE_DSS, KX_ECDHE_RSA, KX_ECDHE_ECDSA, KX_RSA_EXPORT	CRD_CERTIFICATE	CRD_CERTIFICATE
Password and certificate	KX_SRP_RSA, KX_SRP_DSS	CRD_SRP	CRD_CERTIFICATE, CRD_SRP
Password	KX_SRP	CRD_SRP	CRD_SRP
Anonymous	KX_ANON_DH, KX_ANON_ECDH	CRD_ANON	CRD_ANON
Pre-shared key	KX_PSK, KX_DHE_PSK, KX_ECDHE_PSK	CRD_PSK	CRD_PSK

Table 5.2: Key exchange algorithms and the corresponding credential types.

5.4.1 Certificates

Server certificate authentication

When using certificates the server is required to have at least one certificate and private key pair. Clients may not hold such a pair, but a server could require it. In this section we discuss

general issues applying to both client and server certificates. The next section will elaborate on issues arising from client authentication only.

```
int gnutls_certificate_allocate_credentials (gnutls_certificate_credentials_t * res)

void gnutls_certificate_free_credentials (gnutls_certificate_credentials_t sc)
```

After the credentials structures are initialized, the certificate and key pair must be loaded. This occurs before any TLS session is initialized, and the same structures are reused for multiple sessions. Depending on the certificate type different loading functions are available, as shown below. For X.509 certificates, the functions will accept and use a certificate chain that leads to a trusted authority. The certificate chain must be ordered in such way that every certificate certifies the one before it. The trusted authority's certificate need not to be included since the peer should possess it already.

```
int gnutls_certificate_set_x509_key_file2 (gnutls_certificate_credentials_t res, const
char * certfile, const char * keyfile, gnutls_x509_crt_fmt_t type, const char * pass,
unsigned int flags)

int gnutls_certificate_set_x509_key_mem2 (gnutls_certificate_credentials_t res,
const gnutls_datum_t * cert, const gnutls_datum_t * key, gnutls_x509_crt_fmt_t type,
const char * pass, unsigned int flags)

int gnutls_certificate_set_x509_key (gnutls_certificate_credentials_t res,
gnutls_x509_crt_t * cert_list, int cert_list_size, gnutls_x509_privkey_t key)
```

```
int gnutls_certificate_set_openpgp_key_file (gnutls_certificate_credentials_t res,
const char * certfile, const char * keyfile, gnutls_openpgp_crt_fmt_t format)

int gnutls_certificate_set_openpgp_key_mem (gnutls_certificate_credentials_t res,
const gnutls_datum_t * cert, const gnutls_datum_t * key, gnutls_openpgp_crt_fmt_t
format)

int gnutls_certificate_set_openpgp_key (gnutls_certificate_credentials_t res,
gnutls_openpgp_crt_t crt, gnutls_openpgp_privkey_t pkey)
```

It is recommended to use the higher level functions such as `gnutls_certificate_set_x509_key_file2` which accept not only file names but URLs that specify objects stored in token, or system certificates and keys (see ??). For these cases, another important function is `gnutls_`

`certificate_set_pin_function`, that allows setting a callback function to retrieve a PIN if the input keys are protected by PIN.

```
void gnutls_certificate_set_pin_function (gnutls_certificate_credentials_t cred,  
gnutls_pin_callback_t fn, void * userdata)
```

Description: This function will set a callback function to be used when required to access a protected object. This function overrides any other global PIN functions. Note that this function must be called right after initialization to have effect.

If the imported keys and certificates need to be accessed before any TLS session is established, it is convenient to use `gnutls_certificate_set_key` in combination with `gnutls_pcert_import_x509_raw` and `gnutls_privkey_import_x509_raw`.

```
int gnutls_certificate_set_key (gnutls_certificate_credentials_t res, const char  
** names, int names_size, gnutls_pcert_st * pcert_list, int pcert_list_size,  
gnutls_privkey_t key)
```

Description: This function sets a certificate/private key pair in the `gnutls_certificate_credentials_t` type. This function may be called more than once, in case multiple keys/certificates exist for the server. For clients that wants to send more than its own end entity certificate (e.g., also an intermediate CA cert) then put the certificate chain in `pcert_list`. Note that the `pcert_list` and `key` will become part of the credentials structure and must not be deallocated. They will be automatically deallocated when the `res` type is deinitialized. If that function fails to load the `res` structure is at an undefined state, it must not be reused to load other keys or certificates.

Returns: `GNUTLS_E_SUCCESS` (0) on success, or a negative error code.

If multiple certificates are used with the functions above each client's request will be served with the certificate that matches the requested name (see ??).

As an alternative to loading from files or buffers, a callback may be used for the server or the client to specify the certificate and the key at the handshake time. In that case a certificate should be selected according the peer's signature algorithm preferences. To get those preferences use `gnutls_sign_algorithm_get_requested`. Both functions are shown below.

```

void gnutls_certificate_set_retrieve_function (gnutls_certificate_credentials_t cred,
gnutls_certificate_retrieve_function * func)

void gnutls_certificate_set_retrieve_function2 (gnutls_certificate_credentials_t cred,
gnutls_certificate_retrieve_function2 * func)

int gnutls_sign_algorithm_get_requested (gnutls_session_t session, size_t indx,
gnutls_sign_algorithm_t * algo)

```

c The functions above do not handle the requested server name automatically. A server would need to check the name requested by the client using `gnutls_server_name_get`, and serve the appropriate certificate. Note that some of these functions require the `gnutls_pcert_st` structure to be filled in. Helper functions to fill in the structure are listed below.

```

typedef struct gnutls_pcert_st
{
    gnutls_pubkey_t pubkey;
    gnutls_datum_t cert;
    gnutls_certificate_type_t type;
} gnutls_pcert_st;

```

```

int gnutls_pcert_import_x509 (gnutls_pcert_st * pcert, gnutls_x509_crt_t crt,
unsigned int flags)

int gnutls_pcert_import_openpgp (gnutls_pcert_st * pcert, gnutls_openpgp_crt_t
crt, unsigned int flags)

int gnutls_pcert_import_x509_raw (gnutls_pcert_st * pcert, const gnutls_datum_t *
cert, gnutls_x509_crt_fmt_t format, unsigned int flags)

int gnutls_pcert_import_openpgp_raw (gnutls_pcert_st * pcert, const
gnutls_datum_t * cert, gnutls_openpgp_crt_fmt_t format, gnutls_openpgp_keyid_t
keyid, unsigned int flags)

void gnutls_pcert_deinit (gnutls_pcert_st * pcert)

```

In a handshake, the negotiated cipher suite depends on the certificate's parameters, so some key exchange methods might not be available with all certificates. GnuTLS will disable ciphersuites that are not compatible with the key, or the enabled authentication methods. For example keys marked as sign-only, will not be able to access the plain RSA ciphersuites, that require decryption. It is not recommended to use RSA keys for both signing and encryption. If possible use a different key for the DHE-RSA which uses signing and RSA that requires decryption. All the key exchange methods shown in ?? are available in certificate authentication.

Client certificate authentication

If a certificate is to be requested from the client during the handshake, the server will send a certificate request message. This behavior is controlled `gnutls_certificate_server_set_request`. The request contains a list of the acceptable by the server certificate signers. This list is constructed using the trusted certificate authorities of the server. In cases where the server supports a large number of certificate authorities it makes sense not to advertise all of the names to save bandwidth. That can be controlled using the function `gnutls_certificate_send_x509_rdn_sequence`. This however will have the side-effect of not restricting the client to certificates signed by server's acceptable signers.

```
void gnutls_certificate_server_set_request (gnutls_session_t session,  
gnutls_certificate_request_t req)
```

Description: This function specifies if we (in case of a server) are going to send a certificate request message to the client. If req is GNUTLS_CERT_REQUIRE then the server will return an error if the peer does not provide a certificate. If you do not call this function then the client will not be asked to send a certificate.

```
void gnutls_certificate_send_x509_rdn_sequence (gnutls_session_t session, int  
status)
```

Description: If status is non zero, this function will order gnutls not to send the rdnSequence in the certificate request message. That is the server will not advertise its trusted CAs to the peer. If status is zero then the default behaviour will take effect, which is to advertise the server's trusted CAs. This function has no effect in clients, and in authentication methods other than certificate with X.509 certificates.

Client or server certificate verification

Certificate verification is possible by loading the trusted authorities into the credentials structure by using the following functions, applicable to X.509 and OpenPGP certificates.

```
int gnutls_certificate_set_x509_system_trust (gnutls_certificate_credentials_t cred)
```

```
int gnutls_certificate_set_x509_trust_file (gnutls_certificate_credentials_t cred,  
const char * cafile, gnutls_x509_crt_fmt_t type)
```

```
int gnutls_certificate_set_openpgp_keyring_file (gnutls_certificate_credentials_t c,  
const char * file, gnutls_openpgp_crt_fmt_t format)
```

The peer's certificate is not automatically verified and one must call `gnutls_certificate_verify_peers3` after a successful handshake to verify the certificate's signature and the owner of the certificate. The verification status returned can be printed using `gnutls_certificate_verification_status_print`.

Alternatively the verification can occur during the handshake by using `gnutls_certificate_set_verify_function`.

The functions above provide a brief verification output. If a detailed output is required one should call `gnutls_certificate_get_peers` to obtain the raw certificate of the peer and verify it using the functions discussed in ??.

```
int gnutls_certificate_verify_peers3 (gnutls_session_t session, const char * host-  
name, unsigned int * status)
```

Description: This function will verify the peer's certificate and store the status in the `status` variable as a bitwise or'd `gnutls_certificate_status_t` values or zero if the certificate is trusted. Note that value in `status` is set only when the return value of this function is success (i.e., failure to trust a certificate does not imply a negative return value). The default verification flags used by this function can be overridden using `gnutls_certificate_set_verify_flags()`. See the documentation of `gnutls_certificate_verify_peers2()` for details in the verification process. If the `hostname` provided is non-NULL then this function will compare the hostname in the certificate against the given. The comparison will be accurate for ascii names; non-ascii names are compared byte-by-byte. If names do not match the `GNUTLS_CERT_UNEXPECTED_OWNER` status flag will be set. In order to verify the purpose of the end-certificate (by checking the extended key usage), use `gnutls_certificate_verify_peers()`.

Returns: a negative error code on error and `GNUTLS_E_SUCCESS` (0) on success.

```
void gnutls_certificate_set_verify_function (gnutls_certificate_credentials_t cred,  
gnutls_certificate_verify_function * func)
```

Description: This function sets a callback to be called when peer's certificate has been received in order to verify it on receipt rather than doing after the handshake is completed. The callback's function prototype is: `int (*callback)(gnutls_session_t)`; If the callback function is provided then gnutls will call it, in the handshake, just after the certificate message has been received. To verify or obtain the certificate the `gnutls_certificate_verify_peers2()`, `gnutls_certificate_type_get()`, `gnutls_certificate_get_peers()` functions can be used. The callback function should return 0 for the handshake to continue or non-zero to terminate.

5.4.2 SRP

The initialization functions in SRP credentials differ between client and server. Clients supporting SRP should set the username and password prior to connection, to the credentials structure. Alternatively `gnutls_srp_set_client_credentials_function` may be used instead, to specify a callback function that should return the SRP username and password. The callback is called once during the TLS handshake.

```
int gnutls_srp_allocate_server_credentials (gnutls_srp_server_credentials_t * sc)

int gnutls_srp_allocate_client_credentials (gnutls_srp_client_credentials_t * sc)

void gnutls_srp_free_server_credentials (gnutls_srp_server_credentials_t sc)

void gnutls_srp_free_client_credentials (gnutls_srp_client_credentials_t sc)

int gnutls_srp_set_client_credentials (gnutls_srp_client_credentials_t res, const char
* username, const char * password)
```

```
void gnutls_srp_set_client_credentials_function (gnutls_srp_client_credentials_t
cred, gnutls_srp_client_credentials_function * func)
```

Description: This function can be used to set a callback to retrieve the username and password for client SRP authentication. The callback's function form is: `int (*callback)(gnutls_session_t, char** username, char**password);` The `username` and `password` must be allocated using `gnutls_malloc()`. `username` and `password` should be ASCII strings or UTF-8 strings prepared using the "SASLprep" profile of "stringprep". The callback function will be called once per handshake before the initial hello message is sent. The callback should not return a negative error code the second time called, since the handshake procedure will be aborted. The callback function should return 0 on success. -1 indicates an error.

In server side the default behavior of GnuTLS is to read the usernames and SRP verifiers from password files. These password file format is compatible with the *Stanford srp libraries* format. If a different password file format is to be used, then `gnutls_srp_set_server_credentials_function` should be called, to set an appropriate callback.

```
int gnutls_srp_set_server_credentials_file (gnutls_srp_server_credentials_t res, const
char * password_file, const char * password_conf_file)
```

Description: This function sets the password files, in a *gnutls_srp_server_credentials_t* type. Those password files hold usernames and verifiers and will be used for SRP authentication.

Returns: On success, GNUTLS_E_SUCCESS (0) is returned, or an error code.

```
void gnutls_srp_set_server_credentials_function (gnutls_srp_server_credentials_t
cred, gnutls_srp_server_credentials_function * func)
```

Description: This function can be used to set a callback to retrieve the user's SRP credentials. The callback's function form is: `int (*callback)(gnutls_session_t, const char* username, gnutls_datum_t *salt, gnutls_datum_t *verifier, gnutls_datum_t *generator, gnutls_datum_t *prime);` username contains the actual username. The salt, verifier, generator and prime must be filled in using the `gnutls_malloc()`. For convenience prime and generator may also be one of the static parameters defined in `gnutls.h`. Initially, the data field is NULL in every *gnutls_datum_t* structure that the callback has to fill in. When the callback is done GnuTLS deallocates all of those buffers which are non-NULL, regardless of the return value. In order to prevent attackers from guessing valid usernames, if a user does not exist, g and n values should be filled in using a random user's parameters. In that case the callback must return the special value (1). See *gnutls_srp_set_server_fake_salt_seed* too. If this is not required for your application, return a negative number from the callback to abort the handshake. The callback function will only be called once per handshake. The callback function should return 0 on success, while -1 indicates an error.

5.4.3 PSK

The initialization functions in PSK credentials differ between client and server.

```
int gnutls_psk_allocate_server_credentials (gnutls_psk_server_credentials_t * sc)
```

```
int gnutls_psk_allocate_client_credentials (gnutls_psk_client_credentials_t * sc)
```

```
void gnutls_psk_free_server_credentials (gnutls_psk_server_credentials_t sc)
```

```
void gnutls_psk_free_client_credentials (gnutls_psk_client_credentials_t sc)
```

Clients supporting PSK should supply the username and key before a TLS session is established. Alternatively `gnutls_psk_set_client_credentials_function` can be used to specify a callback function. This has the advantage that the callback will be called only if PSK has been negotiated.

```
int gnutls_psk_set_client_credentials (gnutls_psk_client_credentials_t res, const char
* username, const gnutls_datum_t * key, gnutls_psk_key_flags flags)
```

```
void gnutls_psk_set_client_credentials_function (gnutls_psk_client_credentials_t
cred, gnutls_psk_client_credentials_function * func)
```

Description: This function can be used to set a callback to retrieve the username and password for client PSK authentication. The callback's function form is: `int (*callback)(gnutls_session_t, char** username, gnutls_datum_t* key)`; The `username` and `key`→data must be allocated using `gnutls_malloc()`. `username` should be ASCII strings or UTF-8 strings prepared using the "SASLprep" profile of "stringprep". The callback function will be called once per handshake. The callback function should return 0 on success. -1 indicates an error.

In server side the default behavior of GnuTLS is to read the usernames and PSK keys from a password file. The password file should contain usernames and keys in hexadecimal format. The name of the password file can be stored to the credentials structure by calling `gnutls_psk_set_server_credentials_file`. If a different password file format is to be used, then a callback should be set instead by `gnutls_psk_set_server_credentials_function`.

The server can help the client chose a suitable username and password, by sending a hint. Note that there is no common profile for the PSK hint and applications are discouraged to use it. A server, may specify the hint by calling `gnutls_psk_set_server_credentials_hint`. The client can retrieve the hint, for example in the callback function, using `gnutls_psk_client_get_hint`.

```
int gnutls_psk_set_server_credentials_file (gnutls_psk_server_credentials_t res,
const char * password_file)
```

Description: This function sets the password file, in a `gnutls_psk_server_credentials_t` type. This password file holds usernames and keys and will be used for PSK authentication.

Returns: On success, `GNUTLS_E_SUCCESS` (0) is returned, otherwise an error code is returned.

```
void gnutls_psk_set_server_credentials_function (gnutls_psk_server_credentials_t
cred, gnutls_psk_server_credentials_function * func)

int gnutls_psk_set_server_credentials_hint (gnutls_psk_server_credentials_t res,
const char * hint)

const char * gnutls_psk_client_get_hint (gnutls_session_t session)
```

5.4.4 Anonymous

The key exchange methods for anonymous authentication might require Diffie-Hellman parameters to be generated by the server and associated with an anonymous credentials structure. Check ?? for more information. The initialization functions for the credentials are shown below.

```
int gnutls_anon_allocate_server_credentials (gnutls_anon_server_credentials_t * sc)

int gnutls_anon_allocate_client_credentials (gnutls_anon_client_credentials_t * sc)

void gnutls_anon_free_server_credentials (gnutls_anon_server_credentials_t sc)

void gnutls_anon_free_client_credentials (gnutls_anon_client_credentials_t sc)
```

5.5 Setting up the transport layer

The next step is to setup the underlying transport layer details. The Berkeley sockets are implicitly used by GnuTLS, thus a call to `gnutls_transport_set_int` would be sufficient to specify the socket descriptor.

```
void gnutls_transport_set_int (gnutls_session_t session, int i)

void gnutls_transport_set_int2 (gnutls_session_t session, int recv_int, int
send_int)
```

If however another transport layer than TCP is selected, then a pointer should be used instead

to express the parameter to be passed to custom functions. In that case the following functions should be used instead.

```
void gnutls_transport_set_ptr (gnutls_session_t session, gnutls_transport_ptr_t ptr)

void gnutls_transport_set_ptr2 (gnutls_session_t session, gnutls_transport_ptr_t
recv_ptr, gnutls_transport_ptr_t send_ptr)
```

Moreover all of the following push and pull callbacks should be set.

```
void gnutls_transport_set_push_function (gnutls_session_t session,
gnutls_push_func push_func)
```

Description: This is the function where you set a push function for gnutls to use in order to send data. If you are going to use berkeley style sockets, you do not need to use this function since the default send(2) will probably be ok. Otherwise you should specify this function for gnutls to be able to send data. The callback should return a positive number indicating the bytes sent, and -1 on error. `push_func` is of the form, `ssize_t (*gnutls_push_func)(gnutls_transport_ptr_t, const void*, size_t);`

```
void gnutls_transport_set_vec_push_function (gnutls_session_t session,
gnutls_vec_push_func vec_func)
```

Description: Using this function you can override the default writev(2) function for gnutls to send data. Setting this callback instead of `gnutls_transport_set_push_function()` is recommended since it introduces less overhead in the TLS handshake process. `vec_func` is of the form, `ssize_t (*gnutls_vec_push_func) (gnutls_transport_ptr_t, const gvec_t * iov, int iovcnt);`

The functions above accept a callback function which should return the number of bytes written, or -1 on error and should set `errno` appropriately. In some environments, setting `errno` is unreliable. For example Windows have several `errno` variables in different CRTs, or in other systems it may be a non thread-local variable. If this is a concern to you, call `gnutls-transport.set_errno` with the intended `errno` value instead of setting `errno` directly.

GnuTLS currently only interprets the `EINTR`, `EAGAIN` and `EMSGSIZE` `errno` values and returns the corresponding GnuTLS error codes:

- `GNUTLS_E_INTERRUPTED`
- `GNUTLS_E_AGAIN`

```
void gnutls_transport_set_pull_function (gnutls_session_t session, gnutls_pull_func  
pull_func)
```

Description: This is the function where you set a function for gnutls to receive data. Normally, if you use berkeley style sockets, do not need to use this function since the default `recv(2)` will probably be ok. The callback should return 0 on connection termination, a positive number indicating the number of bytes received, and -1 on error. `gnutls_pull_func` is of the form, `ssize_t (*gnutls_pull_func)(gnutls_transport_ptr_t, void*, size_t);`

```
void gnutls_transport_set_pull_timeout_function (gnutls_session_t session,  
gnutls_pull_timeout_func func)
```

Description: This is the function where you set a function for gnutls to know whether data are ready to be received. It should wait for data a given time frame in milliseconds. The callback should return 0 on timeout, a positive number if data can be received, and -1 on error. You'll need to override this function if `select()` is not suitable for the provided transport calls. As with `select()`, if the timeout value is zero the callback should return zero if no data are immediately available. `gnutls_pull_timeout_func` is of the form, `int (*gnutls_pull_timeout_func)(gnutls_transport_ptr_t, unsigned int ms);` The helper function `gnutls_system_recv_timeout()` is provided to simplify writing such callbacks.

- `GNUTLS_E_LARGE_PACKET`

The `EINTR` and `EAGAIN` values are returned by interrupted system calls, or when non blocking IO is used. All GnuTLS functions can be resumed (called again), if any of the above error codes is returned. The `EMSGSIZE` value is returned when attempting to send a large datagram.

In the case of DTLS it is also desirable to override the generic transport functions with functions

```
void gnutls_transport_set_errno (gnutls_session_t session, int err)
```

Description: Store `err` in the session-specific `errno` variable. Useful values for `err` are `EINTR`, `EAGAIN` and `EMSGSIZE`, other values are treated will be treated as real errors in the push/pull function. This function is useful in replacement push and pull functions set by `gnutls_transport_set_push_function()` and `gnutls_transport_set_pull_function()` under Windows, where the replacements may not have access to the same `errno` variable that is used by GnuTLS (e.g., the application is linked to `msvcrt71.dll` and gnutls is linked to `msvcrt.dll`).

that emulate the operation of `recvfrom` and `sendto`. In addition DTLS requires timers during the receive of a handshake message, set using the `gnutls_transport_set_pull_timeout_function` function. To check the retransmission timers the function `gnutls_dtls_get_timeout` is provided, which returns the time remaining until the next retransmission, or better the time until `gnutls_handshake` should be called again.

```
void gnutls_transport_set_pull_timeout_function (gnutls_session_t session,  
gnutls_pull_timeout_func func)
```

Description: This is the function where you set a function for gnutls to know whether data are ready to be received. It should wait for data a given time frame in milliseconds. The callback should return 0 on timeout, a positive number if data can be received, and -1 on error. You'll need to override this function if `select()` is not suitable for the provided transport calls. As with `select()`, if the timeout value is zero the callback should return zero if no data are immediately available. `gnutls_pull_timeout_func` is of the form, `int (*gnutls_pull_timeout_func)(gnutls_transport_ptr_t, unsigned int ms);` The helper function `gnutls_system_recv_timeout()` is provided to simplify writing such callbacks.

```
unsigned int gnutls_dtls_get_timeout (gnutls_session_t session)
```

Description: This function will return the milliseconds remaining for a retransmission of the previously sent handshake message. This function is useful when DTLS is used in non-blocking mode, to estimate when to call `gnutls_handshake()` if no packets have been received.

Returns: the remaining time in milliseconds.

5.5.1 Asynchronous operation

GnuTLS can be used with asynchronous socket or event-driven programming. The approach is similar to using Berkeley sockets under such an environment. The blocking, due to network interaction, calls such as `gnutls_handshake`, `gnutls_record_recv`, can be set to non-blocking by setting the underlying sockets to non-blocking. If other push and pull functions are setup, then they should behave the same way as `recv` and `send` when used in a non-blocking way, i.e., set `errno` to `EAGAIN`. Since, during a TLS protocol session GnuTLS does not block except for network interaction, the non blocking `EAGAIN` `errno` will be propagated and GnuTLS functions will return the `GNUTLS_E_AGAIN` error code. Such calls can be resumed the same way as a system call would. The only exception is `gnutls_record_send`, which if interrupted subsequent calls need not to include the data to be sent (can be called with `NULL` argument).

The `select` system call can also be used in combination with the GnuTLS functions. `select` allows monitoring of sockets and notifies on them being ready for reading or writing data. Note however that this system call cannot notify on data present in GnuTLS read buffers, it is only applicable to the kernel sockets API. Thus if you are using it for reading from a GnuTLS session, make sure that any cached data are read completely. That can be achieved by checking there are no data waiting to be read (using `gnutls_record_check_pending`), either before the `select` system call, or after a call to `gnutls_record_recv`. GnuTLS does not keep a write buffer, thus when writing no additional actions are required.

Although in the TLS protocol implementation each call to receive or send function implies to restoring the same function that was interrupted, in the DTLS protocol this requirement isn't true. There are cases where a retransmission is required, which are indicated by a received message and thus `gnutls_record_get_direction` must be called to decide which direction to check prior to restoring a function call.

```
int gnutls_record_get_direction (gnutls_session_t session)
```

Description: This function provides information about the internals of the record protocol and is only useful if a prior `gnutls` function call (e.g. `gnutls_handshake()`) was interrupted for some reason, that is, if a function returned `GNUTLS_E_INTERRUPTED` or `GNUTLS_E_AGAIN`. In such a case, you might want to call `select()` or `poll()` before calling the interrupted `gnutls` function again. To tell you whether a file descriptor should be selected for either reading or writing, `gnutls_record_get_direction()` returns 0 if the interrupted function was trying to read data, and 1 if it was trying to write data. This function's output is unreliable if you are using the session in different threads, for sending and receiving.

Returns: 0 if trying to read data, 1 if trying to write data.

Moreover, to prevent blocking from DTLS' retransmission timers to block a handshake, the `gnutls_init` function should be called with the `GNUTLS_NONBLOCK` flag set (see ??). In that case, in order to be able to use the DTLS handshake timers, the function `gnutls_dtls_get_timeout` should be used to estimate when to call `gnutls_handshake` if no packets have been received.

5.5.2 DTLS sessions

Because datagram TLS can operate over connections where the client cannot be reliably verified, functionality in the form of cookies, is available to prevent denial of service attacks to servers. GnuTLS requires a server to generate a secret key that is used to sign a cookie². That cookie is sent to the client using `gnutls_dtls_cookie_send`, and the client must reply using the correct cookie. The server side should verify the initial message sent by client using

²A key of 128 bits or 16 bytes should be sufficient for this purpose.

`gnutls_dtls_cookie_verify`. If successful the session should be initialized and associated with the cookie using `gnutls_dtls_prestate_set`, before proceeding to the handshake.

```
int gnutls_key_generate (gnutls_datum_t * key, unsigned int key_size)

int gnutls_dtls_cookie_send (gnutls_datum_t * key, void * client_data, size_t
client_data_size, gnutls_dtls_prestate_st * prestate, gnutls_transport_ptr_t ptr,
gnutls_push_func push_func)

int gnutls_dtls_cookie_verify (gnutls_datum_t * key, void * client_data, size_t
client_data_size, void * _msg, size_t msg_size, gnutls_dtls_prestate_st * prestate)

void gnutls_dtls_prestate_set (gnutls_session_t session, gnutls_dtls_prestate_st *
prestate)
```

Note that the above apply to server side only and they are not mandatory to be used. Not using them, however, allows denial of service attacks. The client side cookie handling is part of `gnutls_handshake`.

Datagrams are typically restricted by a maximum transfer unit (MTU). For that both client and server side should set the correct maximum transfer unit for the layer underneath GnuTLS. This will allow proper fragmentation of DTLS messages and prevent messages from being silently discarded by the transport layer. The “correct” maximum transfer unit can be obtained through a path MTU discovery mechanism [?].

```
void gnutls_dtls_set_mtu (gnutls_session_t session, unsigned int mtu)

unsigned int gnutls_dtls_get_mtu (gnutls_session_t session)

unsigned int gnutls_dtls_get_data_mtu (gnutls_session_t session)
```

5.6 TLS handshake

Once a session has been initialized and a network connection has been set up, TLS and DTLS protocols perform a handshake. The handshake is the actual key exchange.

The handshake process doesn’t ensure the verification of the peer’s identity. When certificates are in use, this can be done, either after the handshake is complete, or during the handshake if `gnutls_certificate_set_verify_function` has been used. In both cases the `gnutls-`

```
int gnutls_handshake (gnutls_session_t session)
```

Description: This function does the handshake of the TLS/SSL protocol, and initializes the TLS connection. This function will fail if any problem is encountered, and will return a negative error code. In case of a client, if the client has asked to resume a session, but the server couldn't, then a full handshake will be performed. The non-fatal errors expected by this function are: **GNUTLS_E_INTERRUPTED**, **GNUTLS_E_AGAIN**, **GNUTLS_E_WARNING_ALERT_RECEIVED**, and **GNUTLS_E_GOT_APPLICATION_DATA**, the latter only in a case of rehandshake. The former two interrupt the handshake procedure due to the lower layer being interrupted, and the latter because of an alert that may be sent by a server (it is always a good idea to check any received alerts). On these errors call this function again, until it returns 0; cf. `gnutls_record_get_direction()` and `gnutls_error_is_fatal()`. In DTLS sessions the non-fatal error **GNUTLS_E_LARGE_PACKET** is also possible, and indicates that the MTU should be adjusted. If this function is called by a server after a rehandshake request then **GNUTLS_E_GOT_APPLICATION_DATA** or **GNUTLS_E_WARNING_ALERT_RECEIVED** may be returned. Note that these are non fatal errors, only in the specific case of a rehandshake. Their meaning is that the client rejected the rehandshake request or in the case of **GNUTLS_E_GOT_APPLICATION_DATA** it could also mean that some data were pending. A client may receive that error code if it initiates the handshake and the server doesn't agreed.

Returns: **GNUTLS_E_SUCCESS** on success, otherwise a negative error code.

`certificate_verify_peers2` function can be used to verify the peer's certificate (see ?? for more information).

```
int gnutls_certificate_verify_peers2 (gnutls_session_t session, unsigned int * status)
```

```
void gnutls_handshake_set_timeout (gnutls_session_t session, unsigned int ms)
```

Description: This function sets the timeout for the TLS handshake process to the provided value. Use an `ms` value of zero to disable timeout, or **GNUTLS_DEFAULT_HANDSHAKE_TIMEOUT** for a reasonable default value. For the DTLS protocol, the more detailed `gnutls_dtls_set_timeouts()` is provided. The TLS handshake process always has the default timeout value since GnuTLS 3.4.0. To unset call this function with zero value.

5.7 Data transfer and termination

Once the handshake is complete and peer's identity has been verified data can be exchanged. The available functions resemble the POSIX `recv` and `send` functions. It is suggested to use `gnutls_error_is_fatal` to check whether the error codes returned by these functions are fatal for the protocol or can be ignored.

```
ssize_t gnutls_record_send (gnutls_session_t session, const void * data, size_t data_size)
```

Description: This function has the similar semantics with `send()`. The only difference is that it accepts a GnuTLS session, and uses different error codes. Note that if the send buffer is full, `send()` will block this function. See the `send()` documentation for more information. You can replace the default push function which is `send()`, by using `gnutls_transport_set_push_function()`. If the `EINTR` is returned by the internal push function then `GNUTLS_E_INTERRUPTED` will be returned. If `GNUTLS_E_INTERRUPTED` or `GNUTLS_E_AGAIN` is returned, you must call this function again, with the exact same parameters; alternatively you could provide a `NULL` pointer for data, and 0 for size. cf. `gnutls_record_get_direction()`. Note that in DTLS this function will return the `GNUTLS_E_LARGE_PACKET` error code if the send data exceed the data MTU value - as returned by `gnutls_dtls_get_data_mtu()`. The `errno` value `EMSGSIZE` also maps to `GNUTLS_E_LARGE_PACKET`. Note that since 3.2.13 this function can be called under cork in DTLS mode, and will refuse to send data over the MTU size by returning `GNUTLS_E_LARGE_PACKET`.

Returns: The number of bytes sent, or a negative error code. The number of bytes sent might be less than `data_size`. The maximum number of bytes this function can send in a single call depends on the negotiated maximum record size.

Although, in the TLS protocol the receive function can be called at any time, when DTLS is used the GnuTLS receive functions must be called once a message is available for reading, even if no data are expected. This is because in DTLS various (internal) actions may be required due to retransmission timers. Moreover, an extended receive function is shown below, which allows the extraction of the message's sequence number. Due to the unreliable nature of the protocol, this field allows distinguishing out-of-order messages.

The `gnutls_record_check_pending` helper function is available to allow checking whether data are available to be read in a GnuTLS session buffers. Note that this function complements but does not replace `select`, i.e., `gnutls_record_check_pending` reports no data to be read, `select` should be called to check for data in the network buffers.

```
int gnutls_record_get_direction (gnutls_session_t session)
```

```
ssize_t gnutls_record_recv (gnutls_session_t session, void * data, size_t data_size)
```

Description: This function has the similar semantics with `recv()`. The only difference is that it accepts a GnuTLS session, and uses different error codes. In the special case that a server requests a renegotiation, the client may receive an error code of `GNUTLS_E_REHANDSHAKE`. This message may be simply ignored, replied with an alert `GNUTLS_A_NO_RENEGOTIATION`, or replied with a new handshake, depending on the client's will. If `EINTR` is returned by the internal push function (the default is `recv()`) then `GNUTLS_E_INTERRUPTED` will be returned. If `GNUTLS_E_INTERRUPTED` or `GNUTLS_E_AGAIN` is returned, you must call this function again to get the data. See also `gnutls_record_get_direction()`. A server may also receive `GNUTLS_E_REHANDSHAKE` when a client has initiated a handshake. In that case the server can only initiate a handshake or terminate the connection.

Returns: The number of bytes received and zero on EOF (for stream connections). A negative error code is returned in case of an error. The number of bytes received might be less than the requested `data_size`.

```
int gnutls_error_is_fatal (int error)
```

Description: If a GnuTLS function returns a negative error code you may feed that value to this function to see if the error condition is fatal to a TLS session (i.e., must be terminated). Note that you may also want to check the error code manually, since some non-fatal errors to the protocol (such as a warning alert or a rehandshake request) may be fatal for your program. This function is only useful if you are dealing with errors from functions that relate to a TLS session (e.g., record layer or handshake layer handling functions).

Returns: Non-zero value on fatal errors or zero on non-fatal.

```
ssize_t gnutls_record_recv_seq (gnutls_session_t session, void * data, size_t data_size, unsigned char * seq)
```

Description: This function is the same as `gnutls_record_recv()`, except that it returns in addition to data, the sequence number of the data. This is useful in DTLS where record packets might be received out-of-order. The returned 8-byte sequence number is an integer in big-endian format and should be treated as a unique message identification.

Returns: The number of bytes received and zero on EOF. A negative error code is returned in case of an error. The number of bytes received might be less than `data_size`.

size_t **gnutls_record_check_pending** (*gnutls_session_t* session)

Description: This function checks if there are unread data in the gnutls buffers. If the return value is non-zero the next call to `gnutls_record_recv()` is guaranteed not to block.

Returns: Returns the size of the data or zero.

Once a TLS or DTLS session is no longer needed, it is recommended to use `gnutls_bye` to terminate the session. That way the peer is notified securely about the intention of termination, which allows distinguishing it from a malicious connection termination. A session can be deinitialized with the `gnutls_deinit` function.

int **gnutls_bye** (*gnutls_session_t* session, *gnutls_close_request_t* how)

Description: Terminates the current TLS/SSL connection. The connection should have been initiated using `gnutls_handshake()`. `how` should be one of `GNUTLS_SHUT_RDWR`, `GNUTLS_SHUT_WR`. In case of `GNUTLS_SHUT_RDWR` the TLS session gets terminated and further receives and sends will be disallowed. If the return value is zero you may continue using the underlying transport layer. `GNUTLS_SHUT_RDWR` sends an alert containing a close request and waits for the peer to reply with the same message. In case of `GNUTLS_SHUT_WR` the TLS session gets terminated and further sends will be disallowed. In order to reuse the connection you should wait for an EOF from the peer. `GNUTLS_SHUT_WR` sends an alert containing a close request. Note that not all implementations will properly terminate a TLS connection. Some of them, usually for performance reasons, will terminate only the underlying transport layer, and thus not distinguishing between a malicious party prematurely terminating the connection and normal termination. This function may also return `GNUTLS_E_AGAIN` or `GNUTLS_E_INTERRUPTED`; cf. `gnutls_record_get_direction()`.

Returns: `GNUTLS_E_SUCCESS` on success, or an error code, see function documentation for entire semantics.

void **gnutls_deinit** (*gnutls_session_t* session)

Description: This function clears all buffers associated with the session. This function will also remove session data from the session database if the session was terminated abnormally.

5.8 Buffered data transfer

Although `gnutls_record_send` is sufficient to transmit data to the peer, when many small chunks of data are to be transmitted it is inefficient and wastes bandwidth due to the TLS record overhead. In that case it is preferable to combine the small chunks before transmission. The following functions provide that functionality.

```
void gnutls_record_cork (gnutls_session_t session)
```

Description: If called, `gnutls_record_send()` will no longer send any records. Any sent records will be cached until `gnutls_record_uncork()` is called. This function is safe to use with DTLS after GnuTLS 3.3.0.

```
int gnutls_record_uncork (gnutls_session_t session, unsigned int flags)
```

Description: This resets the effect of `gnutls_record_cork()`, and flushes any pending data. If the `GNUTLS_RECORD_WAIT` flag is specified then this function will block until the data is sent or a fatal error occurs (i.e., the function will retry on `GNUTLS_E_AGAIN` and `GNUTLS_E_INTERRUPTED`). If the flag `GNUTLS_RECORD_WAIT` is not specified and the function is interrupted then the `GNUTLS_E_AGAIN` or `GNUTLS_E_INTERRUPTED` errors will be returned. To obtain the data left in the corked buffer use `gnutls_record_check_corked()`.

Returns: On success the number of transmitted data is returned, or otherwise a negative error code.

5.9 Handling alerts

During a TLS connection alert messages may be exchanged by the two peers. Those messages may be fatal, meaning the connection must be terminated afterwards, or warning when something needs to be reported to the peer, but without interrupting the session. The error codes `GNUTLS_E_WARNING_ALERT_RECEIVED` or `GNUTLS_E_FATAL_ALERT_RECEIVED` signal those alerts when received, and may be returned by all GnuTLS functions that receive data from the peer, being `gnutls_handshake` and `gnutls_record_recv`.

If those error codes are received the alert and its level should be logged or reported to the peer using the functions below.

The peer may also be warned or notified of a fatal issue by using one of the functions below. All the available alerts are listed in ??.

gnutls_alert_description_t **gnutls_alert_get** (*gnutls_session_t* session)

Description: This function will return the last alert number received. This function should be called when **GNUTLS_E_WARNING_ALERT_RECEIVED** or **GNUTLS_E_FATAL_ALERT_RECEIVED** errors are returned by a gnutls function. The peer may send alerts if he encounters an error. If no alert has been received the returned value is undefined.

Returns: the last alert received, a *gnutls_alert_description_t* value.

*const char ** **gnutls_alert_get_name** (*gnutls_alert_description_t* alert)

Description: This function will return a string that describes the given alert number, or **NULL**. See `gnutls_alert_get()`.

Returns: string corresponding to *gnutls_alert_description_t* value.

int **gnutls_alert_send** (*gnutls_session_t* session, *gnutls_alert_level_t* level, *gnutls_alert_description_t* desc)

Description: This function will send an alert to the peer in order to inform him of something important (eg. his Certificate could not be verified). If the alert level is Fatal then the peer is expected to close the connection, otherwise he may ignore the alert and continue. The error code of the underlying record send function will be returned, so you may also receive **GNUTLS_E_INTERRUPTED** or **GNUTLS_E_AGAIN** as well.

Returns: On success, **GNUTLS_E_SUCCESS** (0) is returned, otherwise an error code is returned.

int **gnutls_error_to_alert** (*int* err, *int ** level)

Description: Get an alert depending on the error code returned by a gnutls function. All alerts sent by this function should be considered fatal. The only exception is when err is **GNUTLS_E_REHANDSHAKE**, where a warning alert should be sent to the peer indicating that no renegotiation will be performed. If there is no mapping to a valid alert the alert to indicate internal error is returned.

Returns: the alert code to use for a particular error code.

5.10 Priority strings

The GnuTLS priority strings specify the TLS session's handshake algorithms and options in a compact, easy-to-use format. That string may contain a single initial keyword such as in ?? and may be followed by additional algorithm or special keywords. Note that their description is intentionally avoiding specific algorithm details, as the priority strings are not constant between gnutls versions (they are periodically updated to account for cryptographic advances while providing compatibility with old clients and servers).

```
int gnutls_priority_set_direct (gnutls_session_t session, const char * priorities,
const char ** err_pos)

int gnutls_priority_set (gnutls_session_t session, gnutls_priority_t priority)
```

Unless the initial keyword is "NONE" the defaults (in preference order) are for TLS protocols TLS 1.2, TLS1.1, TLS1.0; for compression NULL; for certificate types X.509. In key exchange algorithms when in NORMAL or SECURE levels the perfect forward secrecy algorithms take precedence of the other protocols. In all cases all the supported key exchange algorithms are enabled.

Note that the SECURE levels distinguish between overall security level and message authenticity security level. That is because the message authenticity security level requires the adversary to break the algorithms at real-time during the protocol run, whilst the overall security level refers to off-line adversaries (e.g. adversaries breaking the ciphertext years after it was captured).

The NONE keyword, if used, must followed by keywords specifying the algorithms and protocols to be enabled. The other initial keywords do not require, but may be followed by such keywords. All level keywords can be combined, and for example a level of "SECURE256:+SECURE128" is allowed.

The order with which every algorithm or protocol is specified is significant. Algorithms specified before others will take precedence. The supported algorithms and protocols are shown in ??. To avoid collisions in order to specify a compression algorithm in the priority string you have to prefix it with "COMP-", protocol versions with "VERS-", signature algorithms with "SIGN-" and certificate types with "CTYPE-". All other algorithms don't need a prefix. Each specified keyword can be prefixed with any of the following characters.

- '!' or '-' appended with an algorithm will remove this algorithm.
- "+" appended with an algorithm will add this algorithm.

Note that the DHE key exchange methods are generally slower⁴ than their elliptic curves

⁴It depends on the group used. Primes with lesser bits are always faster, but also easier to break. See ?? for the acceptable security levels.

Keyword	Description
@KEYWORD	Means that a compile-time specified system configuration file ³ will be used to expand the provided keyword. That is used to impose system-specific policies. It may be followed by additional options that will be appended to the system string (e.g., "@SYSTEM:+SRP"). The system file should have the format 'KEYWORD=VALUE', e.g., 'SYSTEM=NORMAL:+ARCFOUR-128'.
PERFORMANCE	All the known to be secure ciphersuites are enabled, limited to 128 bit ciphers and sorted by terms of speed performance. The message authenticity security level is of 64 bits or more, and the certificate verification profile is set to GNUTLS_PROFILE_LOW (80-bits).
NORMAL	Means all the known to be secure ciphersuites. The ciphers are sorted by security margin, although the 256-bit ciphers are included as a fallback only. The message authenticity security level is of 64 bits or more, and the certificate verification profile is set to GNUTLS_PROFILE_LOW (80-bits). This priority string implicitly enables ECDHE and DHE. The ECDHE ciphersuites are placed first in the priority order, but due to compatibility issues with the DHE ciphersuites they are placed last in the priority order, after the plain RSA ciphersuites.
LEGACY	This sets the NORMAL settings that were used for GnuTLS 3.2.x or earlier. There is no verification profile set, and the allowed DH primes are considered weak today (but are often used by misconfigured servers).
PFS	Means all the known to be secure ciphersuites that support perfect forward secrecy (ECDHE and DHE). The ciphers are sorted by security margin, although the 256-bit ciphers are included as a fallback only. The message authenticity security level is of 80 bits or more, and the certificate verification profile is set to GNUTLS_PROFILE_LOW (80-bits). This option is available since 3.2.4 or later.
SECURE128	Means all known to be secure ciphersuites that offer a security level 128-bit or more. The message authenticity security level is of 80 bits or more, and the certificate verification profile is set to GNUTLS_PROFILE_LOW (80-bits).
SECURE192	Means all the known to be secure ciphersuites that offer a security level 192-bit or more. The message authenticity security level is of 128 bits or more, and the certificate verification profile is set to GNUTLS_PROFILE_HIGH (128-bits).
SECURE256	Currently alias for SECURE192. This option, will enable ciphers which use a 256-bit key but, due to limitations of the TLS protocol, the overall security level will be 192-bits (the security level depends on more factors than cipher key size).
SUITEB128	Means all the NSA Suite B cryptography (RFC5430) ciphersuites with an 128 bit security level, as well as the enabling of the corresponding verification profile.
SUITEB192	Means all the NSA Suite B cryptography (RFC5430) ciphersuites with an 192 bit security level, as well as the enabling of the corresponding verification profile.
NONE	Means nothing is enabled. This disables even protocols and compression methods. It should be followed by the algorithms to be

Type	Keywords
Ciphers	AES-128-CBC, AES-256-CBC, AES-128-GCM, CAMELLIA-128-CBC, CAMELLIA-256-CBC, ARCFOUR-128, 3DES-CBC. Catch all name is CIPHER-ALL which will add all the algorithms from NORMAL priority.
Key exchange	RSA, DHE-RSA, DHE-DSS, SRP, SRP-RSA, SRP-DSS, PSK, DHE-PSK, ECDHE-RSA, ANON-ECDH, ANON-DH. The Catch all name is KX-ALL which will add all the algorithms from NORMAL priority. Add !DHE-RSA:!DHE-DSS to the priority string to disable DHE.
MAC	MD5, SHA1, SHA256, SHA384, AEAD (used with GCM ciphers only). All algorithms from NORMAL priority can be accessed with MAC-ALL.
Compression algorithms	COMP-NULL, COMP-DEFLATE. Catch all is COMP-ALL.
TLS versions	VERS-TLS1.0, VERS-TLS1.1, VERS-TLS1.2, VERS-DTLS1.0, VERS-DTLS1.2. Catch all are VERS-ALL, VERS-TLS-ALL and VERS-DTLS-ALL.
Signature algorithms	SIGN-RSA-SHA1, SIGN-RSA-SHA224, SIGN-RSA-SHA256, SIGN-RSA-SHA384, SIGN-RSA-SHA512, SIGN-DSA-SHA1, SIGN-DSA-SHA224, SIGN-DSA-SHA256, SIGN-RSA-MD5. Catch all is SIGN-ALL. This is only valid for TLS 1.2 and later.
Elliptic curves	CURVE-SECP192R1, CURVE-SECP224R1, CURVE-SECP256R1, CURVE-SECP384R1, CURVE-SECP521R1. Catch all is CURVE-ALL.

Table 5.4: The supported algorithm keywords in priority strings.

counterpart (ECDHE). Moreover the plain Diffie-Hellman key exchange requires parameters to be generated and associated with a credentials structure by the server (see ??).

The available special keywords are shown in ?? and ??.

Finally the ciphersuites enabled by any priority string can be listed using the `gnutls-cli` application (see ??), or by using the priority functions as in ??.

Example priority strings are:

```

1 The system imposed security level:
2   "SYSTEM"
3
4 The default priority without the HMAC-MD5:
5   "NORMAL:-MD5"
6
7 Specifying RSA with AES-128-CBC:
8   "NONE:+VERS-TLS-ALL:+MAC-ALL:+RSA:+AES-128-CBC:+SIGN-ALL:+COMP-NULL"
9
10 Specifying the defaults plus ARCFOUR-128:
11   "NORMAL:+ARCFOUR-128"
```

Keyword	Description
%COMPAT	will enable compatibility mode. It might mean that violations of the protocols are allowed as long as maximum compatibility with problematic clients and servers is achieved. More specifically this string would disable TLS record random padding, tolerate packets over the maximum allowed TLS record, and add a padding to TLS Client Hello packet to prevent it being in the 256-512 range which is known to be causing issues with a commonly used fire-wall.
%DUMBFW	will add a private extension with bogus data that make the client hello exceed 512 bytes. This avoids a black hole behavior in some firewalls. This is a non-standard TLS extension, use with care.
%NO_EXTENSIONS	will prevent the sending of any TLS extensions in client side. Note that TLS 1.2 requires extensions to be used, as well as safe renegotiation thus this option must be used with care.
%NO_TICKETS	will prevent the advertizing of the TLS session ticket extension. This is implied by the PFS keyword.
%NO_SESSION_HASH	will prevent the advertizing the TLS extended master secret (session hash) extension.
%SERVER_PRECEDENCE	The ciphersuite will be selected according to server priorities and not the client's.
%SSL3_RECORD_VERSION	will use SSL3.0 record version in client hello. This is the default.
%LATEST_RECORD_VERSION	will use the latest TLS version record version in client hello.

Table 5.5: Special priority string keywords.

Keyword	Description
%STATELESS_COMPRESSION	will disable keeping state across records when compressing. This may help to mitigate attacks when compression is used but an attacker is in control of input data. This has to be used only when the data that are possibly controlled by an attacker are placed in separate records.
%DISABLE_WILDCARDS	will disable matching wildcards when comparing hostnames in certificates.
%NO_ETM	will disable the encrypt-then-mac TLS extension (RFC7366). This is implied by the %COMPAT keyword.
%DISABLE_SAFE_RENEGOTIATION	will completely disable safe renegotiation completely. Do not use unless you know what you are doing.
%UNSAFE_RENEGOTIATION	will allow handshakes and re-handshakes without the safe renegotiation extension. Note that for clients this mode is insecure (you may be under attack), and for servers it will allow insecure clients to connect (which could be fooled by an attacker). Do not use unless you know what you are doing and want maximum compatibility.
%PARTIAL_RENEGOTIATION	will allow initial handshakes to proceed, but not re-handshakes. This leaves the client vulnerable to attack, and servers will be compatible with non-upgraded clients for initial handshakes. This is currently the default for clients and servers, for compatibility reasons.
%SAFE_RENEGOTIATION	will enforce safe renegotiation. Clients and servers will refuse to talk to an insecure peer. Currently this causes interoperability problems, but is required for full protection.
%VERIFY_ALLOW_SIGN_RSA_MD5	will allow RSA-MD5 signatures in certificate chains.
%VERIFY_DISABLE_CRL_CHECKS	will disable CRL or OCSP checks in the verification of the certificate chain.
%VERIFY_ALLOW_X509_V1_CA_CRT	will allow V1 CAs in chains.
%PROFILE_(LOW—LEGACY—MEDIUM—HIGH—ULTRA)	require a certificate verification profile the corresponds to the specified security level, see ?? for the mappings to values.
%PROFILE_(SUITEB128—SUITEB192)	require a certificate verification profile the corresponds to SUITEB. Note that an initial keyword that enables SUITEB automatically sets the profile.

158
Table 5.6: More priority string keywords.


```

12
13 Enabling the 128-bit secure ciphers, while disabling TLS 1.0 and enabling compression:
14     "SECURE128:-VERS-TLS1.0:+COMP-DEFLATE"
15
16 Enabling the 128-bit and 192-bit secure ciphers, while disabling all TLS versions
17 except TLS 1.2:
18     "SECURE128:+SECURE192:-VERS-TLS-ALL:+VERS-TLS1.2"

```

5.11 Selecting cryptographic key sizes

Because many algorithms are involved in TLS, it is not easy to set a consistent security level. For this reason in ?? we present some correspondence between key sizes of symmetric algorithms and public key algorithms based on [?]. Those can be used to generate certificates with appropriate key sizes as well as select parameters for Diffie-Hellman and SRP authentication.

Security bits	RSA, DH and SRP parameter size	ECC key size	Security parameter (profile)	Description
<64	<768	<128	INSECURE	Considered to be insecure
64	768	128	VERY WEAK	Short term protection against individuals
72	1008	160	WEAK	Short term protection against small organizations
80	1024	160	LOW	Very short term protection against agencies (corresponds to ENISA legacy level)
96	1776	192	LEGACY	Legacy standard level
112	2048	224	MEDIUM	Medium-term protection
128	3072	256	HIGH	Long term protection (corresponds to ENISA future level)
256	15424	512	ULTRA	Foreseeable future

Table 5.7: Key sizes and security parameters.

The first column provides a security parameter in a number of bits. This gives an indication of the number of combinations to be tried by an adversary to brute force a key. For example to test all possible keys in a 112 bit security parameter 2

*textasciicircum*112 combinations have to be tried. For today's technology this is infeasible. The next two columns correlate the security parameter with actual bit sizes of parameters for DH, RSA, SRP and ECC algorithms. A mapping to `gnutls_sec_param.t` value is given for each security parameter, on the next column, and finally a brief description of the level.

Note, however, that the values suggested here are nothing more than an educated guess that is valid today. There are no guarantees that an algorithm will remain unbreakable or that these

values will remain constant in time. There could be scientific breakthroughs that cannot be predicted or total failure of the current public key systems by quantum computers. On the other hand though the cryptosystems used in TLS are selected in a conservative way and such catastrophic breakthroughs or failures are believed to be unlikely. The NIST publication SP 800-57 [?] contains a similar table.

When using GnuTLS and a decision on bit sizes for a public key algorithm is required, use of the following functions is recommended:

```
unsigned          int gnutls_sec_param_to_pk_bits (gnutls_pk_algorithm_t algo,  
gnutls_sec_param_t param)
```

Description: When generating private and public key pairs a difficult question is which size of "bits" the modulus will be in RSA and the group size in DSA. The easy answer is 1024, which is also wrong. This function will convert a human understandable security parameter to an appropriate size for the specific algorithm.

Returns: The number of bits, or (0).

```
gnutls_sec_param_t gnutls_pk_bits_to_sec_param (gnutls_pk_algorithm_t algo, un-  
signed int bits)
```

Description: This is the inverse of `gnutls_sec_param_to_pk_bits()`. Given an algorithm and the number of bits, it will return the security parameter. This is a rough indication.

Returns: The security parameter.

Those functions will convert a human understandable security parameter of `gnutls_sec_param_t` type, to a number of bits suitable for a public key algorithm.

```
const char * gnutls_sec_param_get_name (gnutls_sec_param_t param)
```

The following functions will set the minimum acceptable group size for Diffie-Hellman and SRP authentication.

```
void gnutls_dh_set_prime_bits (gnutls_session_t session, unsigned int bits)

void gnutls_srp_set_prime_bits (gnutls_session_t session, unsigned int bits)
```

5.12 Advanced topics

5.12.1 Session resumption

Client side

To reduce time and roundtrips spent in a handshake the client can request session resumption from a server that previously shared a session with the client. For that the client has to retrieve and store the session parameters. Before establishing a new session to the same server the parameters must be re-associated with the GnuTLS session using `gnutls_session_set_data`.

```
int gnutls_session_get_data2 (gnutls_session_t session, gnutls_datum_t * data)

int gnutls_session_get_id2 (gnutls_session_t session, gnutls_datum_t * session_id)

int gnutls_session_set_data (gnutls_session_t session, const void * session_data,
size_t session_data_size)
```

Keep in mind that sessions will be expired after some time, depending on the server, and a server may choose not to resume a session even when requested to. The expiration is to prevent temporal session keys from becoming long-term keys. Also note that as a client you must enable, using the priority functions, at least the algorithms used in the last session.

```
int gnutls_session_is_resumed (gnutls_session_t session)
```

Description: Check whether session is resumed or not.

Returns: non zero if this session is resumed, or a zero if this is a new session.

Server side

In order to support resumption a server can store the session security parameters in a local database or by using session tickets (see ??) to delegate storage to the client. Because session tickets might not be supported by all clients, servers could combine the two methods.

A storing server needs to specify callback functions to store, retrieve and delete session data. These can be registered with the functions below. The stored sessions in the database can be checked using `gnutls_db_check_entry` for expiration.

```
void gnutls_db_set_retrieve_function (gnutls_session_t session, gnutls_db_retr_func
retr_func)

void gnutls_db_set_store_function (gnutls_session_t session, gnutls_db_store_func
store_func)

void gnutls_db_set_ptr (gnutls_session_t session, void * ptr)

void gnutls_db_set_remove_function (gnutls_session_t session,
gnutls_db_remove_func rem_func)
```

```
int gnutls_db_check_entry (gnutls_session_t session, gnutls_datum_t ses-
sion_entry)
```

A server utilizing tickets should generate ticket encryption and authentication keys using `gnutls_session_ticket_key_generate`. Those keys should be associated with the GnuTLS session using `gnutls_session_ticket_enable_server`, and should be rotated regularly (e.g., every few hours), to prevent them from becoming long-term keys which if revealed could be used to decrypt all previous sessions.

```
int gnutls_session_ticket_enable_server (gnutls_session_t session, const
gnutls_datum_t * key)
```

Description: Request that the server should attempt session resumption using SessionTicket. `key` must be initialized with `gnutls_session_ticket_key_generate()`, and should be overwritten using `gnutls_memset()` before being released.

Returns: On success, `GNUTLS_E_SUCCESS (0)` is returned, or an error code.

A server enabling both session tickets and a storage for session data would use session tickets when clients support it and the storage otherwise.

```
int gnutls_session_ticket_key_generate (gnutls_datum_t * key)
```

Description: Generate a random key to encrypt security parameters within SessionTicket.

Returns: On success, GNUTLS_E_SUCCESS (0) is returned, or an error code.

```
int gnutls_session_resumption_requested (gnutls_session_t session)
```

Description: Check whether the client has asked for session resumption. This function is valid only on server side.

Returns: non zero if session resumption was asked, or a zero if not.

5.12.2 Certificate verification

In this section the functionality for additional certificate verification methods is listed. These methods are intended to be used in addition to normal PKI verification, in order to reduce the risk of a compromised CA being undetected.

Trust on first use

The GnuTLS library includes functionality to use an SSH-like trust on first use authentication. The available functions to store and verify public keys are listed below.

In addition to the above the `gnutls_store_commitment` can be used to implement a key-pinning architecture as in [?]. This provides a way for web server to commit on a public key that is not yet active.

The storage and verification functions may be used with the default text file based back-end, or another back-end may be specified. That should contain storage and retrieval functions and specified as below.

```
int gnutls_verify_stored_pubkey (const char * db_name, gnutls_tdb_t tdb,
const char * host, const char * service, gnutls_certificate_type_t cert_type, const
gnutls_datum_t * cert, unsigned int flags)
```

Description: This function will try to verify the provided (raw or DER-encoded) certificate using a list of stored public keys. The **service** field if non-NULL should be a port number. The **retrieve** variable if non-null specifies a custom backend for the retrieval of entries. If it is NULL then the default file backend will be used. In POSIX-like systems the file backend uses the \$HOME/.gnutls/known_hosts file. Note that if the custom storage backend is provided the retrieval function should return **GNUTLS_E_CERTIFICATE_KEY_MISMATCH** if the host/service pair is found but key doesn't match, **GNUTLS_E_NO_CERTIFICATE_FOUND** if no such host/service with the given key is found, and 0 if it was found. The storage function should return 0 on success.

Returns: If no associated public key is found then **GNUTLS_E_NO_CERTIFICATE_FOUND** will be returned. If a key is found but does not match **GNUTLS_E_CERTIFICATE_KEY_MISMATCH** is returned. On success, **GNUTLS_E_SUCCESS** (0) is returned, or a negative error value on other errors.

```
int gnutls_tdb_init (gnutls_tdb_t * tdb)
```

```
void gnutls_tdb_deinit (gnutls_tdb_t tdb)
```

```
void gnutls_tdb_set_verify_func (gnutls_tdb_t tdb, gnutls_tdb_verify_func verify)
```

```
void gnutls_tdb_set_store_func (gnutls_tdb_t tdb, gnutls_tdb_store_func store)
```

```
void gnutls_tdb_set_store_commitment_func (gnutls_tdb_t tdb,
gnutls_tdb_store_commitment_func cstore)
```

```
int gnutls_store_pubkey (const char * db_name, gnutls_tdb_t tdb, const char *
host, const char * service, gnutls_certificate_type_t cert_type, const gnutls_datum_t *
cert, time_t expiration, unsigned int flags)
```

Description: This function will store the provided (raw or DER-encoded) certificate to the list of stored public keys. The key will be considered valid until the provided expiration time. The **store** variable if non-null specifies a custom backend for the storage of entries. If it is NULL then the default file backend will be used.

Returns: On success, **GNUTLS_E_SUCCESS** (0) is returned, otherwise a negative error value.

```
int gnutls_store_commitment (const char * db_name, gnutls_tdb_t tdb, const char * host, const char * service, gnutls_digest_algorithm_t hash_algo, const gnutls_datum_t * hash, time_t expiration, unsigned int flags)
```

Description: This function will store the provided hash commitment to the list of stored public keys. The key with the given hash will be considered valid until the provided expiration time. The store variable if non-null specifies a custom backend for the storage of entries. If it is NULL then the default file backend will be used. Note that this function is not thread safe with the default backend.

Returns: On success, GNUTLS_E_SUCCESS (0) is returned, otherwise a negative error value.

DANE verification

Since the DANE library is not included in GnuTLS it requires programs to be linked against it. This can be achieved with the following commands.

```
1 gcc -o foo foo.c `pkg-config gnutls-dane --cflags --libs`
```

When a program uses the GNU autoconf system, then the following line or similar can be used to detect the presence of the library.

```
1 PKG_CHECK_MODULES([LIBDANE], [gnutls-dane >= 3.0.0])
2
3 AC_SUBST([LIBDANE_CFLAGS])
4 AC_SUBST([LIBDANE_LIBS])
```

The high level functionality provided by the DANE library is shown below.

```
int dane_verify_session_cert (dane_state_t s, gnutls_session_t session, const char * hostname, const char * proto, unsigned int port, unsigned int sflags, unsigned int vflags, unsigned int * verify)

const char * dane_strerror (int error)
```

Note that the `dane_state_t` structure that is accepted by both verification functions is optional. It is required when many queries are performed to facilitate caching. The following flags are returned by the verify functions to indicate the status of the verification.

In order to generate a DANE TLSA entry to use in a DNS server you may use danetool (see ??).

```
int dane_verify_cert (dane_state_t s, const gnutls_datum_t * chain, unsigned
chain_size, gnutls_certificate_type_t chain_type, const char * hostname, const
char * proto, unsigned int port, unsigned int sflags, unsigned int vflags, unsigned
int * verify)
```

Description: This function will verify the given certificate chain against the CA constraints and/or the certificate available via DANE. If no information via DANE can be obtained the flag `DANE_VERIFY_NO_DANE_INFO` is set. If a DNSSEC signature is not available for the DANE record then the verify flag `DANE_VERIFY_NO_DNSSEC_DATA` is set. Due to the many possible options of DANE, there is no single threat model countered. When notifying the user about DANE verification results it may be better to mention: DANE verification did not reject the certificate, rather than mentioning a successful DANE verification. Note that this function is designed to be run in addition to PKIX - certificate chain - verification. To be run independently the `DANE_VFLAG_ONLY_CHECK_EE_USAGE` flag should be specified; then the function will check whether the key of the peer matches the key advertised in the DANE entry. If the `q` parameter is provided it will be used for caching entries.

Returns: On success, `DANE_E_SUCCESS` (0) is returned, otherwise a negative error value.

5.12.3 Parameter generation

Several TLS ciphersuites require additional parameters that need to be generated or provided by the application. The Diffie-Hellman based ciphersuites (ANON-DH or DHE), require the group parameters to be provided. Those can either be generated on the fly using `gnutls_dh_params_generate2` or imported from pregenerated data using `gnutls_dh_params_import_pkcs3`. The parameters can be used in a TLS session by calling `gnutls_certificate_set_dh_params` or `gnutls_anon_set_server_dh_params` for anonymous sessions.

```
int gnutls_dh_params_generate2 (gnutls_dh_params_t dparams, unsigned int bits)
```

```
int gnutls_dh_params_import_pkcs3 (gnutls_dh_params_t params, const
gnutls_datum_t * pkcs3_params, gnutls_x509_crt_fmt_t format)
```

```
void gnutls_certificate_set_dh_params (gnutls_certificate_credentials_t res,
gnutls_dh_params_t dh_params)
```

```
void gnutls_anon_set_server_dh_params (gnutls_anon_server_credentials_t res,
gnutls_dh_params_t dh_params)
```

Due to the time-consuming calculations required for the generation of Diffie-Hellman param-


```
enum dane_verify_status_t:
    DANE_VERIFY_CA_CONSTRAINTS_VIOLATED    The CA constraints were violated.
    DANE_VERIFY_CERT_DIFFERS                The certificate obtained via DNS differs.
    DANE_VERIFY_UNKNOWN_DANE_INFO           No known DANE data was found in the DNS record.
```

Table 5.8: The DANE verification status flags.

eters we suggest against performing generation of them within an application. The `certtool` tool can be used to generate or export known safe values that can be stored in code or in a configuration file to provide the ability to replace. We also recommend the usage of `gnutls-sec_param_to_pk_bits` (see ??) to determine the bit size of the generated parameters.

Note that the information stored in the generated PKCS #3 structure changed with GnuTLS 3.0.9. Since that version the `privateValueLength` member of the structure is set, allowing the server utilizing the parameters to use keys of the size of the security parameter. This provides better performance in key exchange.

To allow renewal of the parameters within an application without accessing the credentials, which are a shared structure, an alternative interface is available using a callback function.

```
void gnutls_certificate_set_params_function (gnutls_certificate_credentials_t res,
gnutls_params_function * func)
```

Description: This function will set a callback in order for the server to get the Diffie-Hellman or RSA parameters for certificate authentication. The callback should return `GNUTLS_E_SUCCESS` (0) on success.

5.12.4 Deriving keys for other applications/protocols

In several cases, after a TLS connection is established, it is desirable to derive keys to be used in another application or protocol (e.g., in an other TLS session using pre-shared keys). The following describe GnuTLS' implementation of RFC5705 to extract keys based on a session's master secret.

The API to use is `gnutls_prf`. The function needs to be provided with a label, and additional context data to mix in the `extra` parameter. Moreover, the API allows to switch the mix of the client and server random nonces, using the `server_random_first` parameter. In typical uses you don't need it, so a zero value should be provided in `server_random_first`.

For example, after establishing a TLS session using `gnutls_handshake`, you can obtain 32-bytes to be used as key, using this call:

```

1 #define MYLABEL "EXPORTER-My-protocol-name"
2 #define MYCONTEXT "my-protocol's-1st-session"
3
4 char out[32];
5 rc = gnutls_prf (session, sizeof(MYLABEL)-1, MYLABEL, 0,
6                 sizeof(MYCONTEXT)-1, MYCONTEXT, 32, out);

```

The output key depends on TLS' master secret, and is the same on both client and server.

If you don't want to use the RFC5705 interface and not mix in the client and server random nonces, there is a low-level TLS PRF interface called `gnutls_prf_raw`.

5.12.5 Channel bindings

In user authentication protocols (e.g., EAP or SASL mechanisms) it is useful to have a unique string that identifies the secure channel that is used, to bind together the user authentication with the secure channel. This can protect against man-in-the-middle attacks in some situations. That unique string is called a "channel binding". For background and discussion see [?].

In GnuTLS you can extract a channel binding using the `gnutls_session_channel_binding` function. Currently only the type `GNUTLS_CB_TLS_UNIQUE` is supported, which corresponds to the `tls-unique` channel binding for TLS defined in [?].

The following example describes how to print the channel binding data. Note that it must be run after a successful TLS handshake.

```

1 {
2     gnutls_datum_t cb;
3     int rc;
4
5     rc = gnutls_session_channel_binding (session,
6                                         GNUTLS_CB_TLS_UNIQUE,
7                                         &cb);
8
9     if (rc)
10         fprintf (stderr, "Channel binding error: %s\n",
11                 gnutls_strerror (rc));
12
13     else
14     {
15         size_t i;
16         printf ("- Channel binding 'tls-unique': ");
17         for (i = 0; i < cb.size; i++)
18             printf ("%02x", cb.data[i]);
19         printf ("\n");
20     }
21 }

```

5.12.6 Interoperability

The TLS protocols support many ciphersuites, extensions and version numbers. As a result, few implementations are not able to properly interoperate once faced with extensions or version protocols they do not support and understand. The TLS protocol allows for a graceful downgrade to the commonly supported options, but practice shows it is not always implemented correctly.

Because there is no way to achieve maximum interoperability with broken peers without sacrificing security, GnuTLS ignores such peers by default. This might not be acceptable in cases where maximum compatibility is required. Thus we allow enabling compatibility with broken peers using priority strings (see ??). A conservative priority string that would disable certain TLS protocol options that are known to cause compatibility problems, is shown below.

NORMAL:%COMPAT

For very old broken peers that do not tolerate TLS version numbers over TLS 1.0 another priority string is:

NORMAL:-VERS-TLS-ALL:+VERS-TLS1.0:+VERS-SSL3.0:%COMPAT

This priority string will in addition to above, only enable SSL 3.0 and TLS 1.0 as protocols.

5.12.7 Compatibility with the OpenSSL library

To ease GnuTLS' integration with existing applications, a compatibility layer with the OpenSSL library is included in the **gnutls-openssl** library. This compatibility layer is not complete and it is not intended to completely re-implement the OpenSSL API with GnuTLS. It only provides limited source-level compatibility.

The prototypes for the compatibility functions are in the “**gnutls/openssl.h**” header file. The limitations imposed by the compatibility layer include:

- Error handling is not thread safe.

6

GnuTLS application examples

In this chapter several examples of real-world use cases are listed. The examples are simplified to promote readability and contain little or no error checking.

6.1 Client examples

This section contains examples of TLS and SSL clients, using GnuTLS. Note that some of the examples require functions implemented by another example.

6.1.1 Simple client example with X.509 certificate support

Let's assume now that we want to create a TCP client which communicates with servers that use X.509 or OpenPGP certificate authentication. The following client is a very simple TLS client, which uses the high level verification functions for certificates, but does not support session resumption.

```
1  /* This example code is placed in the public domain. */
2
3  #ifdef HAVE_CONFIG_H
4  #include <config.h>
5  #endif
6
7  #include <stdio.h>
8  #include <stdlib.h>
9  #include <string.h>
10 #include <gnutls/gnutls.h>
```

```

11 #include <gnutls/x509.h>
12 #include "examples.h"
13
14 /* A very basic TLS client, with X.509 authentication and server certificate
15  * verification. Note that error checking for missing files etc. is omitted
16  * for simplicity.
17  */
18
19 #define MAX_BUF 1024
20 #define CAFILE "/etc/ssl/certs/ca-certificates.crt"
21 #define MSG "GET / HTTP/1.0\r\n\r\n"
22
23 extern int tcp_connect(void);
24 extern void tcp_close(int sd);
25 static int _verify_certificate_callback(gnutls_session_t session);
26
27 int main(void)
28 {
29     int ret, sd, ii;
30     gnutls_session_t session;
31     char buffer[MAX_BUF + 1];
32
33     #if 0
34     const char *err;
35     #endif
36
37     gnutls_certificate_credentials_t xcred;
38
39     if (gnutls_check_version("3.1.4") == NULL) {
40         fprintf(stderr, "GnuTLS 3.1.4 or later is required for this example\n");
41         exit(1);
42     }
43
44     /* for backwards compatibility with gnutls < 3.3.0 */
45     gnutls_global_init();
46
47     /* X509 stuff */
48     gnutls_certificate_allocate_credentials(&xcred);
49
50     /* sets the trusted cas file
51     */
52     gnutls_certificate_set_x509_trust_file(xcred, CAFILE,
53                                           GNUTLS_X509_FMT_PEM);
54     gnutls_certificate_set_verify_function(xcred,
55                                           _verify_certificate_callback);
56
57     /* If client holds a certificate it can be set using the following:
58     *
59     gnutls_certificate_set_x509_key_file (xcred,
60     "cert.pem", "key.pem",
61     GNUTLS_X509_FMT_PEM);
62     */
63
64     /* Initialize TLS session
65     */
66     gnutls_init(&session, GNUTLS_CLIENT);
67
68     gnutls_session_set_ptr(session, (void *) "my_host_name");
69
70     gnutls_server_name_set(session, GNUTLS_NAME_DNS, "my_host_name",

```

```
69         strlen("my_host_name"));
70
71     /* use default priorities */
72     gnutls_set_default_priority(session);
73 #if 0
74     /* if more fine-grained control is required */
75     ret = gnutls_priority_set_direct(session,
76                                     "NORMAL", &err);
77     if (ret < 0) {
78         if (ret == GNUTLS_E_INVALID_REQUEST) {
79             fprintf(stderr, "Syntax error at: %s\n", err);
80         }
81         exit(1);
82     }
83 #endif
84
85     /* put the x509 credentials to the current session
86     */
87     gnutls_credentials_set(session, GNUTLS_CRD_CERTIFICATE, xcred);
88
89     /* connect to the peer
90     */
91     sd = tcp_connect();
92
93     gnutls_transport_set_int(session, sd);
94     gnutls_handshake_set_timeout(session,
95                                 GNUTLS_DEFAULT_HANDSHAKE_TIMEOUT);
96
97     /* Perform the TLS handshake
98     */
99     do {
100         ret = gnutls_handshake(session);
101     }
102     while (ret < 0 && gnutls_error_is_fatal(ret) == 0);
103
104     if (ret < 0) {
105         fprintf(stderr, "*** Handshake failed\n");
106         gnutls_perror(ret);
107         goto end;
108     } else {
109         char *desc;
110
111         desc = gnutls_session_get_desc(session);
112         printf("- Session info: %s\n", desc);
113         gnutls_free(desc);
114     }
115
116     gnutls_record_send(session, MSG, strlen(MSG));
117
118     ret = gnutls_record_recv(session, buffer, MAX_BUF);
119     if (ret == 0) {
120         printf("- Peer has closed the TLS connection\n");
121         goto end;
122     } else if (ret < 0 && gnutls_error_is_fatal(ret) == 0) {
123         fprintf(stderr, "*** Warning: %s\n", gnutls_strerror(ret));
124     } else if (ret < 0) {
125         fprintf(stderr, "*** Error: %s\n", gnutls_strerror(ret));
126         goto end;
```

```

127     }
128
129     if (ret > 0) {
130         printf("- Received %d bytes: ", ret);
131         for (ii = 0; ii < ret; ii++) {
132             fputc(buffer[ii], stdout);
133         }
134         fputs("\n", stdout);
135     }
136
137     gnutls_bye(session, GNUTLS_SHUT_RDWR);
138
139 end:
140
141     tcp_close(sd);
142
143     gnutls_deinit(session);
144
145     gnutls_certificate_free_credentials(xcred);
146
147     gnutls_global_deinit();
148
149     return 0;
150 }
151
152 /* This function will verify the peer's certificate, and check
153  * if the hostname matches, as well as the activation, expiration dates.
154  */
155 static int _verify_certificate_callback(gnutls_session_t session)
156 {
157     unsigned int status;
158     int ret, type;
159     const char *hostname;
160     gnutls_datum_t out;
161
162     /* read hostname */
163     hostname = gnutls_session_get_ptr(session);
164
165     /* This verification function uses the trusted CAs in the credentials
166      * structure. So you must have installed one or more CA certificates.
167      */
168
169     /* The following demonstrate two different verification functions,
170      * the more flexible gnutls_certificate_verify_peers(), as well
171      * as the old gnutls_certificate_verify_peers3(). */
172 #if 1
173     {
174         gnutls_typed_vdata_st data[2];
175
176         memset(data, 0, sizeof(data));
177
178         data[0].type = GNUTLS_DT_DNS_HOSTNAME;
179         data[0].data = (void*)hostname;
180
181         data[1].type = GNUTLS_DT_KEY_PURPOSE_OID;
182         data[1].data = (void*)GNUTLS_KP_TLS_WWW_SERVER;
183
184         ret = gnutls_certificate_verify_peers(session, data, 2,

```



```
185                                     &status);
186     }
187 #else
188     ret = gnutls_certificate_verify_peers3(session, hostname,
189                                           &status);
190 #endif
191     if (ret < 0) {
192         printf("Error\n");
193         return GNUTLS_E_CERTIFICATE_ERROR;
194     }
195
196     type = gnutls_certificate_type_get(session);
197
198     ret =
199         gnutls_certificate_verification_status_print(status, type,
200                                                     &out, 0);
201     if (ret < 0) {
202         printf("Error\n");
203         return GNUTLS_E_CERTIFICATE_ERROR;
204     }
205
206     printf("%s", out.data);
207
208     gnutls_free(out.data);
209
210     if (status != 0) /* Certificate is not trusted */
211         return GNUTLS_E_CERTIFICATE_ERROR;
212
213     /* notify gnutls to continue handshake normally */
214     return 0;
215 }
```

6.1.2 Simple client example with SSH-style certificate verification

This is an alternative verification function that will use the X.509 certificate authorities for verification, but also assume an trust on first use (SSH-like) authentication system. That is the user is prompted on unknown public keys and known public keys are considered trusted.

```
1  /* This example code is placed in the public domain. */
2
3  #ifdef HAVE_CONFIG_H
4  #include <config.h>
5  #endif
6
7  #include <stdio.h>
8  #include <stdlib.h>
9  #include <string.h>
10 #include <gnutls/gnutls.h>
11 #include <gnutls/x509.h>
12 #include "examples.h"
13
14 /* This function will verify the peer's certificate, check
15  * if the hostname matches. In addition it will perform an
16  * SSH-style authentication, where ultimately trusted keys
17  * are only the keys that have been seen before.
```

```

18  */
19  int _ssh_verify_certificate_callback(gnutls_session_t session)
20  {
21      unsigned int status;
22      const gnutls_datum_t *cert_list;
23      unsigned int cert_list_size;
24      int ret, type;
25      gnutls_datum_t out;
26      const char *hostname;
27
28      /* read hostname */
29      hostname = gnutls_session_get_ptr(session);
30
31      /* This verification function uses the trusted CAs in the credentials
32       * structure. So you must have installed one or more CA certificates.
33       */
34      ret = gnutls_certificate_verify_peers3(session, hostname, &status);
35      if (ret < 0) {
36          printf("Error\n");
37          return GNUTLS_E_CERTIFICATE_ERROR;
38      }
39
40      type = gnutls_certificate_type_get(session);
41
42      ret =
43          gnutls_certificate_verification_status_print(status, type,
44                                                       &out, 0);
45      if (ret < 0) {
46          printf("Error\n");
47          return GNUTLS_E_CERTIFICATE_ERROR;
48      }
49
50      printf("%s", out.data);
51
52      gnutls_free(out.data);
53
54      if (status != 0) /* Certificate is not trusted */
55          return GNUTLS_E_CERTIFICATE_ERROR;
56
57      /* Do SSH verification */
58      cert_list = gnutls_certificate_get_peers(session, &cert_list_size);
59      if (cert_list == NULL) {
60          printf("No certificate was found!\n");
61          return GNUTLS_E_CERTIFICATE_ERROR;
62      }
63
64      /* service may be obtained alternatively using getservbyport() */
65      ret = gnutls_verify_stored_pubkey(NULL, NULL, hostname, "https",
66                                       type, &cert_list[0], 0);
67      if (ret == GNUTLS_E_NO_CERTIFICATE_FOUND) {
68          printf("Host %s is not known.", hostname);
69          if (status == 0)
70              printf("Its certificate is valid for %s.\n",
71                    hostname);
72
73          /* the certificate must be printed and user must be asked on
74           * whether it is trustworthy. --see gnutls_x509_crt_print() */
75

```

```

76         /* if not trusted */
77         return GNUTLS_E_CERTIFICATE_ERROR;
78     } else if (ret == GNUTLS_E_CERTIFICATE_KEY_MISMATCH) {
79         printf
80             ("Warning: host %s is known but has another key associated.",
81              hostname);
82         printf
83             ("It might be that the server has multiple keys, or you are under attack\n");
84         if (status == 0)
85             printf("Its certificate is valid for %s.\n",
86                  hostname);
87
88         /* the certificate must be printed and user must be asked on
89          * whether it is trustworthy. --see gnutls_x509_crt_print() */
90
91         /* if not trusted */
92         return GNUTLS_E_CERTIFICATE_ERROR;
93     } else if (ret < 0) {
94         printf("gnutls_verify_stored_pubkey: %s\n",
95              gnutls_strerror(ret));
96         return ret;
97     }
98
99     /* user trusts the key -> store it */
100    if (ret != 0) {
101        ret = gnutls_store_pubkey(NULL, NULL, hostname, "https",
102                                type, &cert_list[0], 0, 0);
103        if (ret < 0)
104            printf("gnutls_store_pubkey: %s\n",
105                 gnutls_strerror(ret));
106    }
107
108    /* notify gnutls to continue handshake normally */
109    return 0;
110 }

```

6.1.3 Simple client example with anonymous authentication

The simplest client using TLS is the one that doesn't do any authentication. This means no external certificates or passwords are needed to set up the connection. As could be expected, the connection is vulnerable to man-in-the-middle (active or redirection) attacks. However, the data are integrity protected and encrypted from passive eavesdroppers.

Note that due to the vulnerable nature of this method very few public servers support it.

```

1  /* This example code is placed in the public domain. */
2
3  #ifdef HAVE_CONFIG_H
4  #include <config.h>
5  #endif
6
7  #include <stdio.h>
8  #include <stdlib.h>
9  #include <string.h>

```

```

10 #include <sys/types.h>
11 #include <sys/socket.h>
12 #include <arpa/inet.h>
13 #include <unistd.h>
14 #include <gnutls/gnutls.h>
15
16 /* A very basic TLS client, with anonymous authentication.
17  */
18
19 #define MAX_BUF 1024
20 #define MSG "GET / HTTP/1.0\r\n\r\n"
21
22 extern int tcp_connect(void);
23 extern void tcp_close(int sd);
24
25 int main(void)
26 {
27     int ret, sd, ii;
28     gnutls_session_t session;
29     char buffer[MAX_BUF + 1];
30     gnutls_anon_client_credentials_t anoncred;
31     /* Need to enable anonymous KX specifically. */
32
33     gnutls_global_init();
34
35     gnutls_anon_allocate_client_credentials(&anoncred);
36
37     /* Initialize TLS session
38      */
39     gnutls_init(&session, GNUTLS_CLIENT);
40
41     /* Use default priorities */
42     gnutls_priority_set_direct(session,
43                               "PERFORMANCE:+ANON-ECDH:+ANON-DH",
44                               NULL);
45
46     /* put the anonymous credentials to the current session
47      */
48     gnutls_credentials_set(session, GNUTLS_CRD_ANON, anoncred);
49
50     /* connect to the peer
51      */
52     sd = tcp_connect();
53
54     gnutls_transport_set_int(session, sd);
55     gnutls_handshake_set_timeout(session,
56                                 GNUTLS_DEFAULT_HANDSHAKE_TIMEOUT);
57
58     /* Perform the TLS handshake
59      */
60     do {
61         ret = gnutls_handshake(session);
62     }
63     while (ret < 0 && gnutls_error_is_fatal(ret) == 0);
64
65     if (ret < 0) {
66         fprintf(stderr, "*** Handshake failed\n");
67         gnutls_perror(ret);

```

```

68         goto end;
69     } else {
70         char *desc;
71
72         desc = gnutls_session_get_desc(session);
73         printf("- Session info: %s\n", desc);
74         gnutls_free(desc);
75     }
76
77     gnutls_record_send(session, MSG, strlen(MSG));
78
79     ret = gnutls_record_recv(session, buffer, MAX_BUF);
80     if (ret == 0) {
81         printf("- Peer has closed the TLS connection\n");
82         goto end;
83     } else if (ret < 0 && gnutls_error_is_fatal(ret) == 0) {
84         fprintf(stderr, "*** Warning: %s\n", gnutls_strerror(ret));
85     } else if (ret < 0) {
86         fprintf(stderr, "*** Error: %s\n", gnutls_strerror(ret));
87         goto end;
88     }
89
90     if (ret > 0) {
91         printf("- Received %d bytes: ", ret);
92         for (ii = 0; ii < ret; ii++) {
93             fputc(buffer[ii], stdout);
94         }
95         fputs("\n", stdout);
96     }
97
98     gnutls_bye(session, GNUTLS_SHUT_RDWR);
99
100 end:
101
102     tcp_close(sd);
103
104     gnutls_deinit(session);
105
106     gnutls_anon_free_client_credentials(anoncred);
107
108     gnutls_global_deinit();
109
110     return 0;
111 }

```

6.1.4 Simple datagram TLS client example

This is a client that uses UDP to connect to a server. This is the DTLS equivalent to the TLS example with X.509 certificates.

```

1  /* This example code is placed in the public domain. */
2
3  #ifdef HAVE_CONFIG_H
4  #include <config.h>
5  #endif

```

```

6
7 #include <stdio.h>
8 #include <stdlib.h>
9 #include <string.h>
10 #include <sys/types.h>
11 #include <sys/socket.h>
12 #include <arpa/inet.h>
13 #include <unistd.h>
14 #include <gnutls/gnutls.h>
15 #include <gnutls/dtls.h>
16
17 /* A very basic Datagram TLS client, over UDP with X.509 authentication.
18  */
19
20 #define MAX_BUF 1024
21 #define CAFILE "/etc/ssl/certs/ca-certificates.crt"
22 #define MSG "GET / HTTP/1.0\r\n\r\n"
23
24 extern int udp_connect(void);
25 extern void udp_close(int sd);
26 extern int verify_certificate_callback(gnutls_session_t session);
27
28 int main(void)
29 {
30     int ret, sd, ii;
31     gnutls_session_t session;
32     char buffer[MAX_BUF + 1];
33     const char *err;
34     gnutls_certificate_credentials_t xcred;
35
36     if (gnutls_check_version("3.1.4") == NULL) {
37         fprintf(stderr, "GnuTLS 3.1.4 or later is required for this example\n");
38         exit(1);
39     }
40
41     /* for backwards compatibility with gnutls < 3.3.0 */
42     gnutls_global_init();
43
44     /* X509 stuff */
45     gnutls_certificate_allocate_credentials(&xcred);
46
47     /* sets the trusted cas file */
48     gnutls_certificate_set_x509_trust_file(xcred, CAFILE,
49                                           GNUTLS_X509_FMT_PEM);
50     gnutls_certificate_set_verify_function(xcred,
51                                           verify_certificate_callback);
52
53     /* Initialize TLS session */
54     gnutls_init(&session, GNUTLS_CLIENT | GNUTLS_DATAGRAM);
55
56     /* Use default priorities */
57     ret = gnutls_priority_set_direct(session,
58                                     "NORMAL", &err);
59     if (ret < 0) {
60         if (ret == GNUTLS_E_INVALID_REQUEST) {
61             fprintf(stderr, "Syntax error at: %s\n", err);
62         }
63         exit(1);

```

```
64     }
65
66     /* put the x509 credentials to the current session */
67     gnutls_credentials_set(session, GNUTLS_CRD_CERTIFICATE, xcred);
68     gnutls_server_name_set(session, GNUTLS_NAME_DNS, "my_host_name",
69                             strlen("my_host_name"));
70
71     /* connect to the peer */
72     sd = udp_connect();
73
74     gnutls_transport_set_int(session, sd);
75
76     /* set the connection MTU */
77     gnutls_dtls_set_mtu(session, 1000);
78     gnutls_handshake_set_timeout(session,
79                                  GNUTLS_DEFAULT_HANDSHAKE_TIMEOUT);
80
81     /* Perform the TLS handshake */
82     do {
83         ret = gnutls_handshake(session);
84     }
85     while (ret == GNUTLS_E_INTERRUPTED || ret == GNUTLS_E_AGAIN);
86     /* Note that DTLS may also receive GNUTLS_E_LARGE_PACKET */
87
88     if (ret < 0) {
89         fprintf(stderr, "*** Handshake failed\n");
90         gnutls_perror(ret);
91         goto end;
92     } else {
93         char *desc;
94
95         desc = gnutls_session_get_desc(session);
96         printf("- Session info: %s\n", desc);
97         gnutls_free(desc);
98     }
99
100    gnutls_record_send(session, MSG, strlen(MSG));
101
102    ret = gnutls_record_recv(session, buffer, MAX_BUF);
103    if (ret == 0) {
104        printf("- Peer has closed the TLS connection\n");
105        goto end;
106    } else if (ret < 0 && gnutls_error_is_fatal(ret) == 0) {
107        fprintf(stderr, "*** Warning: %s\n", gnutls_strerror(ret));
108    } else if (ret < 0) {
109        fprintf(stderr, "*** Error: %s\n", gnutls_strerror(ret));
110        goto end;
111    }
112
113    if (ret > 0) {
114        printf("- Received %d bytes: ", ret);
115        for (ii = 0; ii < ret; ii++) {
116            fputc(buffer[ii], stdout);
117        }
118        fputs("\n", stdout);
119    }
120
121    /* It is suggested not to use GNUTLS_SHUT_RDWR in DTLS
```

```

122     * connections because the peer's closure message might
123     * be lost */
124     gnutls_bye(session, GNUTLS_SHUT_WR);
125
126     end:
127
128     udp_close(sd);
129
130     gnutls_deinit(session);
131
132     gnutls_certificate_free_credentials(xcred);
133
134     gnutls_global_deinit();
135
136     return 0;
137 }

```

6.1.5 Obtaining session information

Most of the times it is desirable to know the security properties of the current established session. This includes the underlying ciphers and the protocols involved. That is the purpose of the following function. Note that this function will print meaningful values only if called after a successful `gnutls_handshake`.

```

1  /* This example code is placed in the public domain. */
2
3  #ifdef HAVE_CONFIG_H
4  #include <config.h>
5  #endif
6
7  #include <stdio.h>
8  #include <stdlib.h>
9  #include <gnutls/gnutls.h>
10 #include <gnutls/x509.h>
11
12 #include "examples.h"
13
14 /* This function will print some details of the
15  * given session.
16  */
17 int print_info(gnutls_session_t session)
18 {
19     const char *tmp;
20     gnutls_credentials_type_t cred;
21     gnutls_kx_algorithm_t kx;
22     int dhe, ecdh;
23
24     dhe = ecdh = 0;
25
26     /* print the key exchange's algorithm name
27     */
28     kx = gnutls_kx_get(session);
29     tmp = gnutls_kx_get_name(kx);
30     printf("- Key Exchange: %s\n", tmp);

```



```
31
32     /* Check the authentication type used and switch
33      * to the appropriate.
34      */
35     cred = gnutls_auth_get_type(session);
36     switch (cred) {
37     case GNUTLS_CRD_IA:
38         printf("- TLS/IA session\n");
39         break;
40
41
42 #ifdef ENABLE_SRP
43     case GNUTLS_CRD_SRP:
44         printf("- SRP session with username %s\n",
45              gnutls_srp_server_get_username(session));
46         break;
47 #endif
48
49     case GNUTLS_CRD_PSK:
50         /* This returns NULL in server side.
51          */
52         if (gnutls_psk_client_get_hint(session) != NULL)
53             printf("- PSK authentication. PSK hint '%s'\n",
54                  gnutls_psk_client_get_hint(session));
55         /* This returns NULL in client side.
56          */
57         if (gnutls_psk_server_get_username(session) != NULL)
58             printf("- PSK authentication. Connected as '%s'\n",
59                  gnutls_psk_server_get_username(session));
60
61         if (kx == GNUTLS_KX_ECDHE_PSK)
62             ecdh = 1;
63         else if (kx == GNUTLS_KX_DHE_PSK)
64             dhe = 1;
65         break;
66
67     case GNUTLS_CRD_ANON: /* anonymous authentication */
68
69         printf("- Anonymous authentication.\n");
70         if (kx == GNUTLS_KX_ANON_ECDH)
71             ecdh = 1;
72         else if (kx == GNUTLS_KX_ANON_DH)
73             dhe = 1;
74         break;
75
76     case GNUTLS_CRD_CERTIFICATE: /* certificate authentication */
77
78         /* Check if we have been using ephemeral Diffie-Hellman.
79          */
80         if (kx == GNUTLS_KX_DHE_RSA || kx == GNUTLS_KX_DHE_DSS)
81             dhe = 1;
82         else if (kx == GNUTLS_KX_ECDHE_RSA
83              || kx == GNUTLS_KX_ECDHE_ECDSA)
84             ecdh = 1;
85
86         /* if the certificate list is available, then
87          * print some information about it.
88          */
```

```

89         print_x509_certificate_info(session);
90
91     }          /* switch */
92
93     if (ecdh != 0)
94         printf("- Ephemeral ECDH using curve %s\n",
95             gnutls_ecc_curve_get_name(gnutls_ecc_curve_get
96                 (session)));
97     else if (dhe != 0)
98         printf("- Ephemeral DH using prime of %d bits\n",
99             gnutls_dh_get_prime_bits(session));
100
101     /* print the protocol's name (ie TLS 1.0)
102     */
103     tmp =
104         gnutls_protocol_get_name(gnutls_protocol_get_version(session));
105     printf("- Protocol: %s\n", tmp);
106
107     /* print the certificate type of the peer.
108     * ie X.509
109     */
110     tmp =
111         gnutls_certificate_type_get_name(gnutls_certificate_type_get
112             (session));
113
114     printf("- Certificate Type: %s\n", tmp);
115
116     /* print the compression algorithm (if any)
117     */
118     tmp = gnutls_compression_get_name(gnutls_compression_get(session));
119     printf("- Compression: %s\n", tmp);
120
121     /* print the name of the cipher used.
122     * ie 3DES.
123     */
124     tmp = gnutls_cipher_get_name(gnutls_cipher_get(session));
125     printf("- Cipher: %s\n", tmp);
126
127     /* Print the MAC algorithms name.
128     * ie SHA1
129     */
130     tmp = gnutls_mac_get_name(gnutls_mac_get(session));
131     printf("- MAC: %s\n", tmp);
132
133     return 0;
134 }

```

6.1.6 Using a callback to select the certificate to use

There are cases where a client holds several certificate and key pairs, and may not want to load all of them in the credentials structure. The following example demonstrates the use of the certificate selection callback.

```

1  /* This example code is placed in the public domain. */
2

```

```
3 #ifdef HAVE_CONFIG_H
4 #include <config.h>
5 #endif
6
7 #include <stdio.h>
8 #include <stdlib.h>
9 #include <string.h>
10 #include <sys/types.h>
11 #include <sys/socket.h>
12 #include <arpa/inet.h>
13 #include <unistd.h>
14 #include <gnutls/gnutls.h>
15 #include <gnutls/x509.h>
16 #include <gnutls/abstract.h>
17 #include <sys/types.h>
18 #include <sys/stat.h>
19 #include <fcntl.h>
20
21 /* A TLS client that loads the certificate and key.
22 */
23
24 #define MAX_BUF 1024
25 #define MSG "GET / HTTP/1.0\r\n\r\n"
26
27 #define CERT_FILE "cert.pem"
28 #define KEY_FILE "key.pem"
29 #define CAFILE "/etc/ssl/certs/ca-certificates.crt"
30
31 extern int tcp_connect(void);
32 extern void tcp_close(int sd);
33
34 static int
35 cert_callback(gnutls_session_t session,
36               const gnutls_datum_t * req_ca_rdn, int nreqs,
37               const gnutls_pk_algorithm_t * sign_algos,
38               int sign_algos_length, gnutls_pcert_st ** pcert,
39               unsigned int *pcert_length, gnutls_privkey_t * pkey);
40
41 gnutls_pcert_st pcrt;
42 gnutls_privkey_t key;
43
44 /* Load the certificate and the private key.
45 */
46 static void load_keys(void)
47 {
48     int ret;
49     gnutls_datum_t data;
50
51     ret = gnutls_load_file(CERT_FILE, &data);
52     if (ret < 0) {
53         fprintf(stderr, "*** Error loading certificate file.\n");
54         exit(1);
55     }
56
57     ret =
58         gnutls_pcert_import_x509_raw(&pcrt, &data, GNUTLS_X509_FMT_PEM,
59                                     0);
60     if (ret < 0) {
```

```

61         fprintf(stderr, "*** Error loading certificate file: %s\n",
62                 gnutls_strerror(ret));
63         exit(1);
64     }
65
66     gnutls_free(data.data);
67
68     ret = gnutls_load_file(KEY_FILE, &data);
69     if (ret < 0) {
70         fprintf(stderr, "*** Error loading key file.\n");
71         exit(1);
72     }
73
74     gnutls_privkey_init(&key);
75
76     ret =
77         gnutls_privkey_import_x509_raw(key, &data, GNUTLS_X509_FMT_PEM,
78                                     NULL, 0);
79     if (ret < 0) {
80         fprintf(stderr, "*** Error loading key file: %s\n",
81                 gnutls_strerror(ret));
82         exit(1);
83     }
84
85     gnutls_free(data.data);
86 }
87
88 int main(void)
89 {
90     int ret, sd, ii;
91     gnutls_session_t session;
92     gnutls_priority_t priorities_cache;
93     char buffer[MAX_BUF + 1];
94     gnutls_certificate_credentials_t xcred;
95
96     if (gnutls_check_version("3.1.4") == NULL) {
97         fprintf(stderr, "GnuTLS 3.1.4 or later is required for this example\n");
98         exit(1);
99     }
100
101     /* for backwards compatibility with gnutls < 3.3.0 */
102     gnutls_global_init();
103
104     load_keys();
105
106     /* X509 stuff */
107     gnutls_certificate_allocate_credentials(&xcred);
108
109     /* priorities */
110     gnutls_priority_init(&priorities_cache,
111                        "NORMAL", NULL);
112
113     /* sets the trusted cas file
114      */
115     gnutls_certificate_set_x509_trust_file(xcred, CAFILE,
116                                           GNUTLS_X509_FMT_PEM);
117
118     gnutls_certificate_set_retrieve_function2(xcred, cert_callback);

```

```
119
120     /* Initialize TLS session
121     */
122     gnutls_init(&session, GNUTLS_CLIENT);
123
124     /* Use default priorities */
125     gnutls_priority_set(session, priorities_cache);
126
127     /* put the x509 credentials to the current session
128     */
129     gnutls_credentials_set(session, GNUTLS_CRD_CERTIFICATE, xcred);
130
131     /* connect to the peer
132     */
133     sd = tcp_connect();
134
135     gnutls_transport_set_int(session, sd);
136
137     /* Perform the TLS handshake
138     */
139     ret = gnutls_handshake(session);
140
141     if (ret < 0) {
142         fprintf(stderr, "*** Handshake failed\n");
143         gnutls_perror(ret);
144         goto end;
145     } else {
146         char *desc;
147
148         desc = gnutls_session_get_desc(session);
149         printf("- Session info: %s\n", desc);
150         gnutls_free(desc);
151     }
152
153     gnutls_record_send(session, MSG, strlen(MSG));
154
155     ret = gnutls_record_recv(session, buffer, MAX_BUF);
156     if (ret == 0) {
157         printf("- Peer has closed the TLS connection\n");
158         goto end;
159     } else if (ret < 0) {
160         fprintf(stderr, "*** Error: %s\n", gnutls_strerror(ret));
161         goto end;
162     }
163
164     printf("- Received %d bytes: ", ret);
165     for (ii = 0; ii < ret; ii++) {
166         fputc(buffer[ii], stdout);
167     }
168     fputs("\n", stdout);
169
170     gnutls_bye(session, GNUTLS_SHUT_RDWR);
171
172 end:
173
174     tcp_close(sd);
175
176     gnutls_deinit(session);
```

```

177     gnutls_certificate_free_credentials(xcred);
178     gnutls_priority_deinit(priorities_cache);
179
180     gnutls_global_deinit();
181
182     return 0;
183 }
184
185
186
187
188 /* This callback should be associated with a session by calling
189  * gnutls_certificate_client_set_retrieve_function( session, cert_callback),
190  * before a handshake.
191  */
192
193 static int
194 cert_callback(gnutls_session_t session,
195              const gnutls_datum_t * req_ca_rdn, int nreqs,
196              const gnutls_pk_algorithm_t * sign_algos,
197              int sign_algos_length, gnutls_pcert_st ** pcert,
198              unsigned int *pcert_length, gnutls_privkey_t * pkey)
199 {
200     char issuer_dn[256];
201     int i, ret;
202     size_t len;
203     gnutls_certificate_type_t type;
204
205     /* Print the server's trusted CAs
206      */
207     if (nreqs > 0)
208         printf("- Server's trusted authorities:\n");
209     else
210         printf
211             ("- Server did not send us any trusted authorities names.\n");
212
213     /* print the names (if any) */
214     for (i = 0; i < nreqs; i++) {
215         len = sizeof(issuer_dn);
216         ret = gnutls_x509_rdn_get(&req_ca_rdn[i], issuer_dn, &len);
217         if (ret >= 0) {
218             printf("    [%d]: ", i);
219             printf("%s\n", issuer_dn);
220         }
221     }
222
223     /* Select a certificate and return it.
224      * The certificate must be of any of the "sign algorithms"
225      * supported by the server.
226      */
227     type = gnutls_certificate_type_get(session);
228     if (type == GNUTLS_CERT_X509) {
229         *pcert_length = 1;
230         *pcert = &pcrt;
231         *pkey = key;
232     } else {
233         return -1;
234     }

```

```
235 |
236 |     return 0;
237 |
238 | }
```

6.1.7 Verifying a certificate

An example is listed below which uses the high level verification functions to verify a given certificate list.

```
1  /* This example code is placed in the public domain. */
2
3  #ifdef HAVE_CONFIG_H
4  #include <config.h>
5  #endif
6
7  #include <stdio.h>
8  #include <stdlib.h>
9  #include <string.h>
10 #include <gnutls/gnutls.h>
11 #include <gnutls/x509.h>
12
13 #include "examples.h"
14
15 /* All the available CRLs
16  */
17 gnutls_x509_crl_t *crl_list;
18 int crl_list_size;
19
20 /* All the available trusted CAs
21  */
22 gnutls_x509_cert_t *ca_list;
23 int ca_list_size;
24
25 static int print_details_func(gnutls_x509_cert_t cert,
26                             gnutls_x509_cert_t issuer,
27                             gnutls_x509_crl_t crl,
28                             unsigned int verification_output);
29
30 /* This function will try to verify the peer's certificate chain, and
31  * also check if the hostname matches.
32  */
33 void
34 verify_certificate_chain(const char *hostname,
35                         const gnutls_datum_t * cert_chain,
36                         int cert_chain_length)
37 {
38     int i;
39     gnutls_x509_trust_list_t tlist;
40     gnutls_x509_cert_t *cert;
41
42     unsigned int output;
43
44     /* Initialize the trusted certificate list. This should be done
45      * once on initialization. gnutls_x509_cert_list_import2() and
```

```

46     * gnutls_x509_crl_list_import2() can be used to load them.
47     */
48     gnutls_x509_trust_list_init(&tlist, 0);
49
50     gnutls_x509_trust_list_add_cas(tlist, ca_list, ca_list_size, 0);
51     gnutls_x509_trust_list_add_crls(tlist, crl_list, crl_list_size,
52                                     GNUTLS_TL_VERIFY_CRL, 0);
53
54     cert = malloc(sizeof(*cert) * cert_chain_length);
55
56     /* Import all the certificates in the chain to
57      * native certificate format.
58      */
59     for (i = 0; i < cert_chain_length; i++) {
60         gnutls_x509_crt_init(&cert[i]);
61         gnutls_x509_crt_import(cert[i], &cert_chain[i],
62                                GNUTLS_X509_FMT_DER);
63     }
64
65     gnutls_x509_trust_list_verify_named_crt(tlist, cert[0], hostname,
66                                             strlen(hostname),
67                                             GNUTLS_VERIFY_DISABLE_CRL_CHECKS,
68                                             &output,
69                                             print_details_func);
70
71     /* if this certificate is not explicitly trusted verify against CAs
72      */
73     if (output != 0) {
74         gnutls_x509_trust_list_verify_crt(tlist, cert,
75                                           cert_chain_length, 0,
76                                           &output,
77                                           print_details_func);
78     }
79
80     if (output & GNUTLS_CERT_INVALID) {
81         fprintf(stderr, "Not trusted");
82
83         if (output & GNUTLS_CERT_SIGNER_NOT_FOUND)
84             fprintf(stderr, ": no issuer was found");
85         if (output & GNUTLS_CERT_SIGNER_NOT_CA)
86             fprintf(stderr, ": issuer is not a CA");
87         if (output & GNUTLS_CERT_NOT_ACTIVATED)
88             fprintf(stderr, ": not yet activated\n");
89         if (output & GNUTLS_CERT_EXPIRED)
90             fprintf(stderr, ": expired\n");
91
92         fprintf(stderr, "\n");
93     } else
94         fprintf(stderr, "Trusted\n");
95
96     /* Check if the name in the first certificate matches our destination!
97      */
98     if (!gnutls_x509_crt_check_hostname(cert[0], hostname)) {
99         printf
100             ("The certificate's owner does not match hostname '%s'\n",
101              hostname);
102     }
103

```



```
104     gnutls_x509_trust_list_deinit(tlist, 1);
105
106     return;
107 }
108
109 static int
110 print_details_func(gnutls_x509_cert_t cert,
111                   gnutls_x509_cert_t issuer, gnutls_x509_crl_t crl,
112                   unsigned int verification_output)
113 {
114     char name[512];
115     char issuer_name[512];
116     size_t name_size;
117     size_t issuer_name_size;
118
119     issuer_name_size = sizeof(issuer_name);
120     gnutls_x509_cert_get_issuer_dn(cert, issuer_name,
121                                     &issuer_name_size);
122
123     name_size = sizeof(name);
124     gnutls_x509_cert_get_dn(cert, name, &name_size);
125
126     fprintf(stdout, "\tSubject: %s\n", name);
127     fprintf(stdout, "\tIssuer: %s\n", issuer_name);
128
129     if (issuer != NULL) {
130         issuer_name_size = sizeof(issuer_name);
131         gnutls_x509_cert_get_dn(issuer, issuer_name,
132                                 &issuer_name_size);
133
134         fprintf(stdout, "\tVerified against: %s\n", issuer_name);
135     }
136
137     if (crl != NULL) {
138         issuer_name_size = sizeof(issuer_name);
139         gnutls_x509_crl_get_issuer_dn(crl, issuer_name,
140                                       &issuer_name_size);
141
142         fprintf(stdout, "\tVerified against CRL of: %s\n",
143                 issuer_name);
144     }
145
146     fprintf(stdout, "\tVerification output: %x\n\n",
147             verification_output);
148
149     return 0;
150 }
```

6.1.8 Using a smart card with TLS

This example will demonstrate how to load keys and certificates from a smart-card or any other PKCS #11 token, and use it in a TLS connection.

```
1  /* This example code is placed in the public domain. */
2
```

```

3  #ifdef HAVE_CONFIG_H
4  #include <config.h>
5  #endif
6
7  #include <stdio.h>
8  #include <stdlib.h>
9  #include <string.h>
10 #include <sys/types.h>
11 #include <sys/socket.h>
12 #include <arpa/inet.h>
13 #include <unistd.h>
14 #include <gnutls/gnutls.h>
15 #include <gnutls/x509.h>
16 #include <gnutls/pkcs11.h>
17 #include <sys/types.h>
18 #include <sys/stat.h>
19 #include <fcntl.h>
20 #include <getpass.h>          /* for getpass() */
21
22 /* A TLS client that loads the certificate and key.
23  */
24
25 #define MAX_BUF 1024
26 #define MSG "GET / HTTP/1.0\r\n\r\n"
27 #define MIN(x,y) (((x)<(y))?(x):(y))
28
29 #define CAFILE "/etc/ssl/certs/ca-certificates.crt"
30
31 /* The URLs of the objects can be obtained
32  * using p11tool --list-all --login
33  */
34 #define KEY_URL "pkcs11:manufacturer=SomeManufacturer;object=Private%20Key" \
35               ";objecttype=private;id=db%5b%3e%b5%72%33"
36 #define CERT_URL "pkcs11:manufacturer=SomeManufacturer;object=Certificate;" \
37               "objecttype=cert;id=db%5b%3e%b5%72%33"
38
39 extern int tcp_connect(void);
40 extern void tcp_close(int sd);
41
42 static int
43 pin_callback(void *user, int attempt, const char *token_url,
44             const char *token_label, unsigned int flags, char *pin,
45             size_t pin_max)
46 {
47     const char *password;
48     int len;
49
50     printf("PIN required for token '%s' with URL '%s'\n", token_label,
51           token_url);
52     if (flags & GNUTLS_PIN_FINAL_TRY)
53         printf("*** This is the final try before locking!\n");
54     if (flags & GNUTLS_PIN_COUNT_LOW)
55         printf("*** Only few tries left before locking!\n");
56     if (flags & GNUTLS_PIN_WRONG)
57         printf("*** Wrong PIN\n");
58
59     password = getpass("Enter pin: ");
60     if (password == NULL || password[0] == 0) {

```

```
61         fprintf(stderr, "No password given\n");
62         exit(1);
63     }
64
65     len = MIN(pin_max - 1, strlen(password));
66     memcpy(pin, password, len);
67     pin[len] = 0;
68
69     return 0;
70 }
71
72 int main(void)
73 {
74     int ret, sd, ii;
75     gnutls_session_t session;
76     gnutls_priority_t priorities_cache;
77     char buffer[MAX_BUF + 1];
78     gnutls_certificate_credentials_t xcred;
79     /* Allow connections to servers that have OpenPGP keys as well.
80      */
81
82     if (gnutls_check_version("3.1.4") == NULL) {
83         fprintf(stderr, "GnuTLS 3.1.4 or later is required for this example\n");
84         exit(1);
85     }
86
87     /* for backwards compatibility with gnutls < 3.3.0 */
88     gnutls_global_init();
89
90     /* The PKCS11 private key operations may require PIN.
91      * Register a callback. */
92     gnutls_pkcs11_set_pin_function(pin_callback, NULL);
93
94     /* X509 stuff */
95     gnutls_certificate_allocate_credentials(&xcred);
96
97     /* priorities */
98     gnutls_priority_init(&priorities_cache,
99                         "NORMAL", NULL);
100
101     /* sets the trusted cas file
102      */
103     gnutls_certificate_set_x509_trust_file(xcred, CAFILE,
104                                           GNUTLS_X509_FMT_PEM);
105
106     gnutls_certificate_set_x509_key_file(xcred, CERT_URL, KEY_URL,
107                                         GNUTLS_X509_FMT_DER);
108
109     /* Initialize TLS session
110      */
111     gnutls_init(&session, GNUTLS_CLIENT);
112
113     /* Use default priorities */
114     gnutls_priority_set(session, priorities_cache);
115
116     /* put the x509 credentials to the current session
117      */
118     gnutls_credentials_set(session, GNUTLS_CRD_CERTIFICATE, xcred);
```

```

119
120     /* connect to the peer
121     */
122     sd = tcp_connect();
123
124     gnutls_transport_set_int(session, sd);
125
126     /* Perform the TLS handshake
127     */
128     ret = gnutls_handshake(session);
129
130     if (ret < 0) {
131         fprintf(stderr, "*** Handshake failed\n");
132         gnutls_perror(ret);
133         goto end;
134     } else {
135         char *desc;
136
137         desc = gnutls_session_get_desc(session);
138         printf("- Session info: %s\n", desc);
139         gnutls_free(desc);
140     }
141
142     gnutls_record_send(session, MSG, strlen(MSG));
143
144     ret = gnutls_record_recv(session, buffer, MAX_BUF);
145     if (ret == 0) {
146         printf("- Peer has closed the TLS connection\n");
147         goto end;
148     } else if (ret < 0) {
149         fprintf(stderr, "*** Error: %s\n", gnutls_strerror(ret));
150         goto end;
151     }
152
153     printf("- Received %d bytes: ", ret);
154     for (ii = 0; ii < ret; ii++) {
155         fputc(buffer[ii], stdout);
156     }
157     fputs("\n", stdout);
158
159     gnutls_bye(session, GNUTLS_SHUT_RDWR);
160
161 end:
162
163     tcp_close(sd);
164
165     gnutls_deinit(session);
166
167     gnutls_certificate_free_credentials(xcred);
168     gnutls_priority_deinit(priorities_cache);
169
170     gnutls_global_deinit();
171
172     return 0;
173 }

```

6.1.9 Client with resume capability example

This is a modification of the simple client example. Here we demonstrate the use of session resumption. The client tries to connect once using TLS, close the connection and then try to establish a new connection using the previously negotiated data.

```
1  /* This example code is placed in the public domain. */
2
3  #ifdef HAVE_CONFIG_H
4  #include <config.h>
5  #endif
6
7  #include <string.h>
8  #include <stdio.h>
9  #include <stdlib.h>
10 #include <gnutls/gnutls.h>
11
12 /* Those functions are defined in other examples.
13  */
14 extern void check_alert(gnutls_session_t session, int ret);
15 extern int tcp_connect(void);
16 extern void tcp_close(int sd);
17
18 #define MAX_BUF 1024
19 #define CAFILE "/etc/ssl/certs/ca-certificates.crt"
20 #define MSG "GET / HTTP/1.0\r\n\r\n"
21
22 int main(void)
23 {
24     int ret;
25     int sd, ii;
26     gnutls_session_t session;
27     char buffer[MAX_BUF + 1];
28     gnutls_certificate_credentials_t xcred;
29
30     /* variables used in session resuming
31     */
32     int t;
33     char *session_data = NULL;
34     size_t session_data_size = 0;
35
36     gnutls_global_init();
37
38     /* X509 stuff */
39     gnutls_certificate_allocate_credentials(&xcred);
40
41     gnutls_certificate_set_x509_trust_file(xcred, CAFILE,
42                                           GNUTLS_X509_FMT_PEM);
43
44     for (t = 0; t < 2; t++) {      /* connect 2 times to the server */
45
46         sd = tcp_connect();
47
48         gnutls_init(&session, GNUTLS_CLIENT);
49
50         gnutls_priority_set_direct(session,
51                                    "PERFORMANCE:!ARCFOUR-128",
```

```

52         NULL);
53
54     gnutls_credentials_set(session, GNUTLS_CRD_CERTIFICATE,
55                             xcred);
56
57     if (t > 0) {
58         /* if this is not the first time we connect */
59         gnutls_session_set_data(session, session_data,
60                                 session_data_size);
61         free(session_data);
62     }
63
64     gnutls_transport_set_int(session, sd);
65     gnutls_handshake_set_timeout(session,
66                                   GNUTLS_DEFAULT_HANDSHAKE_TIMEOUT);
67
68     /* Perform the TLS handshake
69     */
70     do {
71         ret = gnutls_handshake(session);
72     }
73     while (ret < 0 && gnutls_error_is_fatal(ret) == 0);
74
75     if (ret < 0) {
76         fprintf(stderr, "*** Handshake failed\n");
77         gnutls_perror(ret);
78         goto end;
79     } else {
80         printf("- Handshake was completed\n");
81     }
82
83     if (t == 0) { /* the first time we connect */
84         /* get the session data size */
85         gnutls_session_get_data(session, NULL,
86                                 &session_data_size);
87         session_data = malloc(session_data_size);
88
89         /* put session data to the session variable */
90         gnutls_session_get_data(session, session_data,
91                                 &session_data_size);
92
93     } else { /* the second time we connect */
94
95         /* check if we actually resumed the previous session */
96         if (gnutls_session_is_resumed(session) != 0) {
97             printf("- Previous session was resumed\n");
98         } else {
99             fprintf(stderr,
100                    "*** Previous session was NOT resumed\n");
101         }
102     }
103
104     /* This function was defined in a previous example
105     */
106     /* print_info(session); */
107
108     gnutls_record_send(session, MSG, strlen(MSG));
109

```

```
110         ret = gnutls_record_recv(session, buffer, MAX_BUF);
111         if (ret == 0) {
112             printf("- Peer has closed the TLS connection\n");
113             goto end;
114         } else if (ret < 0 && gnutls_error_is_fatal(ret) == 0) {
115             fprintf(stderr, "*** Warning: %s\n",
116                     gnutls_strerror(ret));
117         } else if (ret < 0) {
118             fprintf(stderr, "*** Error: %s\n",
119                     gnutls_strerror(ret));
120             goto end;
121         }
122
123         if (ret > 0) {
124             printf("- Received %d bytes: ", ret);
125             for (ii = 0; ii < ret; ii++) {
126                 fputc(buffer[ii], stdout);
127             }
128             fputs("\n", stdout);
129         }
130
131         gnutls_bye(session, GNUTLS_SHUT_RDWR);
132
133     end:
134
135         tcp_close(sd);
136
137         gnutls_deinit(session);
138
139     }                /* for() */
140
141     gnutls_certificate_free_credentials(xcred);
142
143     gnutls_global_deinit();
144
145     return 0;
146 }
```

6.1.10 Simple client example with SRP authentication

The following client is a very simple SRP TLS client which connects to a server and authenticates using a *username* and a *password*. The server may authenticate itself using a certificate, and in that case it has to be verified.

```
1  /* This example code is placed in the public domain. */
2
3  #ifdef HAVE_CONFIG_H
4  #include <config.h>
5  #endif
6
7  #include <stdio.h>
8  #include <stdlib.h>
9  #include <string.h>
10 #include <gnutls/gnutls.h>
11
```

```

12  /* Those functions are defined in other examples.
13  */
14  extern void check_alert(gnutls_session_t session, int ret);
15  extern int tcp_connect(void);
16  extern void tcp_close(int sd);
17
18  #define MAX_BUF 1024
19  #define USERNAME "user"
20  #define PASSWORD "pass"
21  #define CAFILE "/etc/ssl/certs/ca-certificates.crt"
22  #define MSG "GET / HTTP/1.0\r\n\r\n"
23
24  int main(void)
25  {
26      int ret;
27      int sd, ii;
28      gnutls_session_t session;
29      char buffer[MAX_BUF + 1];
30      gnutls_srp_client_credentials_t srp_cred;
31      gnutls_certificate_credentials_t cert_cred;
32
33      if (gnutls_check_version("3.1.4") == NULL) {
34          fprintf(stderr, "GnuTLS 3.1.4 or later is required for this example\n");
35          exit(1);
36      }
37
38      /* for backwards compatibility with gnutls < 3.3.0 */
39      gnutls_global_init();
40
41      gnutls_srp_allocate_client_credentials(&srp_cred);
42      gnutls_certificate_allocate_credentials(&cert_cred);
43
44      gnutls_certificate_set_x509_trust_file(cert_cred, CAFILE,
45                                          GNUTLS_X509_FMT_PEM);
46      gnutls_srp_set_client_credentials(srp_cred, USERNAME, PASSWORD);
47
48      /* connects to server
49      */
50      sd = tcp_connect();
51
52      /* Initialize TLS session
53      */
54      gnutls_init(&session, GNUTLS_CLIENT);
55
56
57      /* Set the priorities.
58      */
59      gnutls_priority_set_direct(session,
60                               "NORMAL:+SRP:+SRP-RSA:+SRP-DSS",
61                               NULL);
62
63      /* put the SRP credentials to the current session
64      */
65      gnutls_credentials_set(session, GNUTLS_CRD_SRP, srp_cred);
66      gnutls_credentials_set(session, GNUTLS_CRD_CERTIFICATE, cert_cred);
67
68      gnutls_transport_set_int(session, sd);
69      gnutls_handshake_set_timeout(session,

```



```
70                                     GNUTLS_DEFAULT_HANDSHAKE_TIMEOUT);
71
72     /* Perform the TLS handshake
73     */
74     do {
75         ret = gnutls_handshake(session);
76     }
77     while (ret < 0 && gnutls_error_is_fatal(ret) == 0);
78
79     if (ret < 0) {
80         fprintf(stderr, "*** Handshake failed\n");
81         gnutls_perror(ret);
82         goto end;
83     } else {
84         char *desc;
85
86         desc = gnutls_session_get_desc(session);
87         printf("- Session info: %s\n", desc);
88         gnutls_free(desc);
89     }
90
91     gnutls_record_send(session, MSG, strlen(MSG));
92
93     ret = gnutls_record_recv(session, buffer, MAX_BUF);
94     if (gnutls_error_is_fatal(ret) != 0 || ret == 0) {
95         if (ret == 0) {
96             printf
97                 ("- Peer has closed the GnuTLS connection\n");
98             goto end;
99         } else {
100             fprintf(stderr, "*** Error: %s\n",
101                     gnutls_strerror(ret));
102             goto end;
103         }
104     } else
105         check_alert(session, ret);
106
107     if (ret > 0) {
108         printf("- Received %d bytes: ", ret);
109         for (ii = 0; ii < ret; ii++) {
110             fputc(buffer[ii], stdout);
111         }
112         fputs("\n", stdout);
113     }
114     gnutls_bye(session, GNUTLS_SHUT_RDWR);
115
116 end:
117
118     tcp_close(sd);
119
120     gnutls_deinit(session);
121
122     gnutls_srp_free_client_credentials(srp_cred);
123     gnutls_certificate_free_credentials(cert_cred);
124
125     gnutls_global_deinit();
126
127     return 0;
```

128 }

6.1.11 Simple client example using the C++ API

The following client is a simple example of a client client utilizing the GnuTLS C++ API.

```

1  #include <config.h>
2  #include <iostream>
3  #include <stdexcept>
4  #include <gnutls/gnutls.h>
5  #include <gnutls/gnutlsxx.h>
6  #include <cstring> /* for strlen */
7
8  /* A very basic TLS client, with anonymous authentication.
9   * written by Eduardo Villanueva Che.
10  */
11
12  #define MAX_BUF 1024
13  #define SA struct sockaddr
14
15  #define CAFILE "ca.pem"
16  #define MSG "GET / HTTP/1.0\r\n\r\n"
17
18  extern "C"
19  {
20      int tcp_connect(void);
21      void tcp_close(int sd);
22  }
23
24
25  int main(void)
26  {
27      int sd = -1;
28      gnutls_global_init();
29
30      try
31      {
32
33          /* Allow connections to servers that have OpenPGP keys as well.
34           */
35          gnutls::client_session session;
36
37          /* X509 stuff */
38          gnutls::certificate_credentials credentials;
39
40
41          /* sets the trusted cas file
42           */
43          credentials.set_x509_trust_file(CAFILE, GNUTLS_X509_FMT_PEM);
44          /* put the x509 credentials to the current session
45           */
46          session.set_credentials(credentials);
47
48          /* Use default priorities */
49          session.set_priority ("NORMAL", NULL);

```

```
50
51     /* connect to the peer
52     */
53     sd = tcp_connect();
54     session.set_transport_ptr((gnutls_transport_ptr_t) (ptrdiff_t)sd);
55
56     /* Perform the TLS handshake
57     */
58     int ret = session.handshake();
59     if (ret < 0)
60     {
61         throw std::runtime_error("Handshake failed");
62     }
63     else
64     {
65         std::cout << "- Handshake was completed" << std::endl;
66     }
67
68     session.send(MSG, strlen(MSG));
69     char buffer[MAX_BUF + 1];
70     ret = session.recv(buffer, MAX_BUF);
71     if (ret == 0)
72     {
73         throw std::runtime_error("Peer has closed the TLS connection");
74     }
75     else if (ret < 0)
76     {
77         throw std::runtime_error(gnutls_strerror(ret));
78     }
79
80     std::cout << "- Received " << ret << " bytes:" << std::endl;
81     std::cout.write(buffer, ret);
82     std::cout << std::endl;
83
84     session.bye(GNUTLS_SHUT_RDWR);
85 }
86 catch (std::exception &ex)
87 {
88     std::cerr << "Exception caught: " << ex.what() << std::endl;
89 }
90
91 if (sd != -1)
92     tcp_close(sd);
93
94 gnutls_global_deinit();
95
96 return 0;
97 }
```

6.1.12 Helper functions for TCP connections

Those helper function abstract away TCP connection handling from the other examples. It is required to build some examples.

```

1  /* This example code is placed in the public domain. */
2
3  #ifdef HAVE_CONFIG_H
4  #include <config.h>
5  #endif
6
7  #include <stdio.h>
8  #include <stdlib.h>
9  #include <string.h>
10 #include <sys/types.h>
11 #include <sys/socket.h>
12 #include <arpa/inet.h>
13 #include <netinet/in.h>
14 #include <unistd.h>
15
16 /* tcp.c */
17 int tcp_connect(void);
18 void tcp_close(int sd);
19
20 /* Connects to the peer and returns a socket
21  * descriptor.
22  */
23 extern int tcp_connect(void)
24 {
25     const char *PORT = "5556";
26     const char *SERVER = "127.0.0.1";
27     int err, sd;
28     struct sockaddr_in sa;
29
30     /* connects to server
31     */
32     sd = socket(AF_INET, SOCK_STREAM, 0);
33
34     memset(&sa, '\0', sizeof(sa));
35     sa.sin_family = AF_INET;
36     sa.sin_port = htons(atoi(PORT));
37     inet_pton(AF_INET, SERVER, &sa.sin_addr);
38
39     err = connect(sd, (struct sockaddr *) &sa, sizeof(sa));
40     if (err < 0) {
41         fprintf(stderr, "Connect error\n");
42         exit(1);
43     }
44
45     return sd;
46 }
47
48 /* closes the given socket descriptor.
49  */
50 extern void tcp_close(int sd)
51 {
52     shutdown(sd, SHUT_RDWR);      /* no more receptions */
53     close(sd);
54 }

```

6.1.13 Helper functions for UDP connections

The UDP helper functions abstract away UDP connection handling from the other examples. It is required to build the examples using UDP.

```
1  /* This example code is placed in the public domain. */
2
3  #ifdef HAVE_CONFIG_H
4  #include <config.h>
5  #endif
6
7  #include <stdio.h>
8  #include <stdlib.h>
9  #include <string.h>
10 #include <sys/types.h>
11 #include <sys/socket.h>
12 #include <arpa/inet.h>
13 #include <netinet/in.h>
14 #include <unistd.h>
15
16 /* udp.c */
17 int udp_connect(void);
18 void udp_close(int sd);
19
20 /* Connects to the peer and returns a socket
21  * descriptor.
22  */
23 extern int udp_connect(void)
24 {
25     const char *PORT = "5557";
26     const char *SERVER = "127.0.0.1";
27     int err, sd, optval;
28     struct sockaddr_in sa;
29
30     /* connects to server
31      */
32     sd = socket(AF_INET, SOCK_DGRAM, 0);
33
34     memset(&sa, '\0', sizeof(sa));
35     sa.sin_family = AF_INET;
36     sa.sin_port = htons(atoi(PORT));
37     inet_pton(AF_INET, SERVER, &sa.sin_addr);
38
39     #if defined(IP_DONTFRAG)
40         optval = 1;
41         setsockopt(sd, IPPROTO_IP, IP_DONTFRAG,
42                   (const void *) &optval, sizeof(optval));
43     #elif defined(IP_MTU_DISCOVER)
44         optval = IP_PMTUDISC_DO;
45         setsockopt(sd, IPPROTO_IP, IP_MTU_DISCOVER,
46                   (const void *) &optval, sizeof(optval));
47     #endif
48
49     err = connect(sd, (struct sockaddr *) &sa, sizeof(sa));
50     if (err < 0) {
51         fprintf(stderr, "Connect error\n");
52         exit(1);
53     }
```

```

53     }
54
55     return sd;
56 }
57
58 /* closes the given socket descriptor.
59 */
60 extern void udp_close(int sd)
61 {
62     close(sd);
63 }

```

6.2 Server examples

This section contains examples of TLS and SSL servers, using GnuTLS.

6.2.1 Echo server with X.509 authentication

This example is a very simple echo server which supports X.509 authentication.

```

1  /* This example code is placed in the public domain. */
2
3  #ifdef HAVE_CONFIG_H
4  #include <config.h>
5  #endif
6
7  #include <stdio.h>
8  #include <stdlib.h>
9  #include <errno.h>
10 #include <sys/types.h>
11 #include <sys/socket.h>
12 #include <arpa/inet.h>
13 #include <netinet/in.h>
14 #include <string.h>
15 #include <unistd.h>
16 #include <gnutls/gnutls.h>
17
18 #define KEYFILE "key.pem"
19 #define CERTFILE "cert.pem"
20 #define CAFILE "/etc/ssl/certs/ca-certificates.crt"
21 #define CRLFILE "crl.pem"
22
23 /* The OCSP status file contains up to date information about revocation
24  * of the server's certificate. That can be periodically be updated
25  * using:
26  * $ ocsptool --ask --load-cert your_cert.pem --load-issuer your_issuer.pem
27  *           --load-signer your_issuer.pem --outfile ocsp-status.der
28  */
29 #define OCSP_STATUS_FILE "ocsp-status.der"
30
31 /* This is a sample TLS 1.0 echo server, using X.509 authentication and
32  * OCSP stapling support.

```

```
33  */
34
35  #define MAX_BUF 1024
36  #define PORT 5556          /* listen to 5556 port */
37
38  /* These are global */
39  static gnutls_dh_params_t dh_params;
40
41  static int generate_dh_params(void)
42  {
43      unsigned int bits = gnutls_sec_param_to_pk_bits(GNUTLS_PK_DH,
44                                                       GNUTLS_SEC_PARAM_LEGACY);
45
46      /* Generate Diffie-Hellman parameters - for use with DHE
47       * kx algorithms. When short bit length is used, it might
48       * be wise to regenerate parameters often.
49       */
50      gnutls_dh_params_init(&dh_params);
51      gnutls_dh_params_generate2(dh_params, bits);
52
53      return 0;
54  }
55
56  int main(void)
57  {
58      int listen_sd;
59      int sd, ret;
60      gnutls_certificate_credentials_t x509_cred;
61      gnutls_priority_t priority_cache;
62      struct sockaddr_in sa_serv;
63      struct sockaddr_in sa_cli;
64      socklen_t client_len;
65      char topbuf[512];
66      gnutls_session_t session;
67      char buffer[MAX_BUF + 1];
68      int optval = 1;
69
70      /* for backwards compatibility with gnutls < 3.3.0 */
71      gnutls_global_init();
72
73      gnutls_certificate_allocate_credentials(&x509_cred);
74      /* gnutls_certificate_set_x509_system_trust(xcred); */
75      gnutls_certificate_set_x509_trust_file(x509_cred, CAFILE,
76                                             GNUTLS_X509_FMT_PEM);
77
78      gnutls_certificate_set_x509_crl_file(x509_cred, CRLFILE,
79                                           GNUTLS_X509_FMT_PEM);
80
81      ret =
82          gnutls_certificate_set_x509_key_file(x509_cred, CERTFILE,
83                                              KEYFILE,
84                                              GNUTLS_X509_FMT_PEM);
85      if (ret < 0) {
86          printf("No certificate or key were found\n");
87          exit(1);
88      }
89
90      /* loads an OCSP status request if available */
```

```

91     gnutls_certificate_set_ocsp_status_request_file(x509_cred,
92                                                    OCSP_STATUS_FILE,
93                                                    0);
94
95     generate_dh_params();
96
97     gnutls_priority_init(&priority_cache,
98                         "PERFORMANCE:%SERVER_PRECEDENCE", NULL);
99
100
101     gnutls_certificate_set_dh_params(x509_cred, dh_params);
102
103     /* Socket operations
104     */
105     listen_sd = socket(AF_INET, SOCK_STREAM, 0);
106
107     memset(&sa_serv, '\0', sizeof(sa_serv));
108     sa_serv.sin_family = AF_INET;
109     sa_serv.sin_addr.s_addr = INADDR_ANY;
110     sa_serv.sin_port = htons(PORT); /* Server Port number */
111
112     setsockopt(listen_sd, SOL_SOCKET, SO_REUSEADDR, (void *) &optval,
113               sizeof(int));
114
115     bind(listen_sd, (struct sockaddr *) &sa_serv, sizeof(sa_serv));
116
117     listen(listen_sd, 1024);
118
119     printf("Server ready. Listening to port '%d'.\n\n", PORT);
120
121     client_len = sizeof(sa_cli);
122     for (;;) {
123         gnutls_init(&session, GNUTLS_SERVER);
124         gnutls_priority_set(session, priority_cache);
125         gnutls_credentials_set(session, GNUTLS_CRD_CERTIFICATE,
126                               x509_cred);
127
128         /* We don't request any certificate from the client.
129          * If we did we would need to verify it. One way of
130          * doing that is shown in the "Verifying a certificate"
131          * example.
132          */
133         gnutls_certificate_server_set_request(session,
134                                              GNUTLS_CERT_IGNORE);
135
136         sd = accept(listen_sd, (struct sockaddr *) &sa_cli,
137                    &client_len);
138
139         printf("- connection from %s, port %d\n",
140               inet_ntop(AF_INET, &sa_cli.sin_addr, topbuf,
141                         sizeof(topbuf)), ntohs(sa_cli.sin_port));
142
143         gnutls_transport_set_int(session, sd);
144
145         do {
146             ret = gnutls_handshake(session);
147         }
148         while (ret < 0 && gnutls_error_is_fatal(ret) == 0);

```



```

149
150         if (ret < 0) {
151             close(sd);
152             gnutls_deinit(session);
153             fprintf(stderr,
154                 "*** Handshake has failed (%s)\n\n",
155                 gnutls_strerror(ret));
156             continue;
157         }
158         printf("- Handshake was completed\n");
159
160         /* see the Getting peer's information example */
161         /* print_info(session); */
162
163         for (;;) {
164             ret = gnutls_record_recv(session, buffer, MAX_BUF);
165
166             if (ret == 0) {
167                 printf
168                     ("\n- Peer has closed the GnuTLS connection\n");
169                 break;
170             } else if (ret < 0
171                 && gnutls_error_is_fatal(ret) == 0) {
172                 fprintf(stderr, "*** Warning: %s\n",
173                     gnutls_strerror(ret));
174             } else if (ret < 0) {
175                 fprintf(stderr, "\n*** Received corrupted "
176                     "data(%d). Closing the connection.\n\n",
177                     ret);
178                 break;
179             } else if (ret > 0) {
180                 /* echo data back to the client
181                  */
182                 gnutls_record_send(session, buffer, ret);
183             }
184         }
185         printf("\n");
186         /* do not wait for the peer to close the connection.
187          */
188         gnutls_bye(session, GNUTLS_SHUT_WR);
189
190         close(sd);
191         gnutls_deinit(session);
192
193     }
194     close(listen_sd);
195
196     gnutls_certificate_free_credentials(x509_cred);
197     gnutls_priority_deinit(priority_cache);
198
199     gnutls_global_deinit();
200
201     return 0;
202
203 }

```

6.2.2 Echo server with OpenPGP authentication

The following example is an echo server which supports OpenPGP key authentication. You can easily combine this functionality—that is have a server that supports both X.509 and OpenPGP certificates—but we separated them to keep these examples as simple as possible.

```

1  /* This example code is placed in the public domain. */
2
3  #ifdef HAVE_CONFIG_H
4  #include <config.h>
5  #endif
6
7  #include <stdio.h>
8  #include <stdlib.h>
9  #include <errno.h>
10 #include <sys/types.h>
11 #include <sys/socket.h>
12 #include <arpa/inet.h>
13 #include <netinet/in.h>
14 #include <string.h>
15 #include <unistd.h>
16 #include <gnutls/gnutls.h>
17 #include <gnutls/openpgp.h>
18
19 #define KEYFILE "secret.asc"
20 #define CERTFILE "public.asc"
21 #define RINGFILE "ring.gpg"
22
23 /* This is a sample TLS 1.0-OpenPGP echo server.
24  */
25
26
27 #define SOCKET_ERR(err,s) if(err==-1) {perror(s);return(1);}
28 #define MAX_BUF 1024
29 #define PORT 5556          /* listen to 5556 port */
30
31 /* These are global */
32 gnutls_dh_params_t dh_params;
33
34 static int generate_dh_params(void)
35 {
36     unsigned int bits = gnutls_sec_param_to_pk_bits(GNUTLS_PK_DH,
37                                                     GNUTLS_SEC_PARAM_LEGACY);
38
39     /* Generate Diffie-Hellman parameters - for use with DHE
40      * kx algorithms. These should be discarded and regenerated
41      * once a day, once a week or once a month. Depending on the
42      * security requirements.
43      */
44     gnutls_dh_params_init(&dh_params);
45     gnutls_dh_params_generate2(dh_params, bits);
46
47     return 0;
48 }
49
50 int main(void)
51 {

```

```
52     int err, listen_sd;
53     int sd, ret;
54     struct sockaddr_in sa_serv;
55     struct sockaddr_in sa_cli;
56     socklen_t client_len;
57     char topbuf[512];
58     gnutls_session_t session;
59     gnutls_certificate_credentials_t cred;
60     char buffer[MAX_BUF + 1];
61     int optval = 1;
62     char name[256];
63
64     strcpy(name, "Echo Server");
65
66     if (gnutls_check_version("3.1.4") == NULL) {
67         fprintf(stderr, "GnuTLS 3.1.4 or later is required for this example\n");
68         exit(1);
69     }
70
71     /* for backwards compatibility with gnutls < 3.3.0 */
72     gnutls_global_init();
73
74     gnutls_certificate_allocate_credentials(&cred);
75     gnutls_certificate_set_openpgp_keyring_file(cred, RINGFILE,
76                                                GNUTLS_OPENPGP_FMT_BASE64);
77
78     gnutls_certificate_set_openpgp_key_file(cred, CERTFILE, KEYFILE,
79                                             GNUTLS_OPENPGP_FMT_BASE64);
80
81     generate_dh_params();
82
83     gnutls_certificate_set_dh_params(cred, dh_params);
84
85     /* Socket operations
86     */
87     listen_sd = socket(AF_INET, SOCK_STREAM, 0);
88     SOCKET_ERR(listen_sd, "socket");
89
90     memset(&sa_serv, '\0', sizeof(sa_serv));
91     sa_serv.sin_family = AF_INET;
92     sa_serv.sin_addr.s_addr = INADDR_ANY;
93     sa_serv.sin_port = htons(PORT); /* Server Port number */
94
95     setsockopt(listen_sd, SOL_SOCKET, SO_REUSEADDR, (void *) &optval,
96               sizeof(int));
97
98     err =
99         bind(listen_sd, (struct sockaddr *) &sa_serv, sizeof(sa_serv));
100     SOCKET_ERR(err, "bind");
101     err = listen(listen_sd, 1024);
102     SOCKET_ERR(err, "listen");
103
104     printf("%s ready. Listening to port '%d'.\n\n", name, PORT);
105
106     client_len = sizeof(sa_cli);
107     for (;;) {
108         gnutls_init(&session, GNUTLS_SERVER);
109         gnutls_priority_set_direct(session,
```

```

110         "NORMAL:+CTYPE-OPENPGP", NULL);
111
112     /* request client certificate if any.
113     */
114     gnutls_certificate_server_set_request(session,
115                                         GNUTLS_CERT_REQUEST);
116
117     sd = accept(listen_sd, (struct sockaddr *) &sa_cli,
118                &client_len);
119
120     printf("- connection from %s, port %d\n",
121            inet_ntop(AF_INET, &sa_cli.sin_addr, topbuf,
122                      sizeof(topbuf)), ntohs(sa_cli.sin_port));
123
124     gnutls_transport_set_int(session, sd);
125     ret = gnutls_handshake(session);
126     if (ret < 0) {
127         close(sd);
128         gnutls_deinit(session);
129         fprintf(stderr,
130                "*** Handshake has failed (%s)\n\n",
131                gnutls_strerror(ret));
132         continue;
133     }
134     printf("- Handshake was completed\n");
135
136     /* see the Getting peer's information example */
137     /* print_info(session); */
138
139     for (;;) {
140         ret = gnutls_record_recv(session, buffer, MAX_BUF);
141
142         if (ret == 0) {
143             printf
144                 ("\n- Peer has closed the GnuTLS connection\n");
145             break;
146         } else if (ret < 0) {
147             && gnutls_error_is_fatal(ret) == 0) {
148                 fprintf(stderr, "*** Warning: %s\n",
149                         gnutls_strerror(ret));
150             } else if (ret < 0) {
151                 fprintf(stderr, "\n*** Received corrupted "
152                         "data(%d). Closing the connection.\n\n",
153                         ret);
154                 break;
155             } else if (ret > 0) {
156                 /* echo data back to the client
157                 */
158                 gnutls_record_send(session, buffer, ret);
159             }
160         }
161         printf("\n");
162         /* do not wait for the peer to close the connection.
163         */
164         gnutls_bye(session, GNUTLS_SHUT_WR);
165
166         close(sd);
167         gnutls_deinit(session);

```

```
168     }
169     close(listen_sd);
170
171     gnutls_certificate_free_credentials(cred);
172
173     gnutls_global_deinit();
174
175     return 0;
176 }
177
178 }
```

6.2.3 Echo server with SRP authentication

This is a server which supports SRP authentication. It is also possible to combine this functionality with a certificate server. Here it is separate for simplicity.

```
1  /* This example code is placed in the public domain. */
2
3  #ifdef HAVE_CONFIG_H
4  #include <config.h>
5  #endif
6
7  #include <stdio.h>
8  #include <stdlib.h>
9  #include <errno.h>
10 #include <sys/types.h>
11 #include <sys/socket.h>
12 #include <arpa/inet.h>
13 #include <netinet/in.h>
14 #include <string.h>
15 #include <unistd.h>
16 #include <gnutls/gnutls.h>
17
18 #define SRP_PASSWD "tpasswd"
19 #define SRP_PASSWD_CONF "tpasswd.conf"
20
21 #define KEYFILE "key.pem"
22 #define CERTFILE "cert.pem"
23 #define CAFILE "/etc/ssl/certs/ca-certificates.crt"
24
25 /* This is a sample TLS-SRP echo server.
26  */
27
28 #define SOCKET_ERR(err,s) if(err==-1) {perror(s);return(1);}
29 #define MAX_BUF 1024
30 #define PORT 5556          /* listen to 5556 port */
31
32 int main(void)
33 {
34     int err, listen_sd;
35     int sd, ret;
36     struct sockaddr_in sa_serv;
37     struct sockaddr_in sa_cli;
38     socklen_t client_len;
```

```

39     char topbuf[512];
40     gnutls_session_t session;
41     gnutls_srp_server_credentials_t srp_cred;
42     gnutls_certificate_credentials_t cert_cred;
43     char buffer[MAX_BUF + 1];
44     int optval = 1;
45     char name[256];
46
47     strcpy(name, "Echo Server");
48
49     if (gnutls_check_version("3.1.4") == NULL) {
50         fprintf(stderr, "GnuTLS 3.1.4 or later is required for this example\n");
51         exit(1);
52     }
53
54     /* for backwards compatibility with gnutls < 3.3.0 */
55     gnutls_global_init();
56
57     /* SRP_PASSWD a password file (created with the included srptool utility)
58     */
59     gnutls_srp_allocate_server_credentials(&srp_cred);
60     gnutls_srp_set_server_credentials_file(srp_cred, SRP_PASSWD,
61                                           SRP_PASSWD_CONF);
62
63     gnutls_certificate_allocate_credentials(&cert_cred);
64     gnutls_certificate_set_x509_trust_file(cert_cred, CAFILE,
65                                           GNUTLS_X509_FMT_PEM);
66     gnutls_certificate_set_x509_key_file(cert_cred, CERTFILE, KEYFILE,
67                                           GNUTLS_X509_FMT_PEM);
68
69     /* TCP socket operations
70     */
71     listen_sd = socket(AF_INET, SOCK_STREAM, 0);
72     SOCKET_ERR(listen_sd, "socket");
73
74     memset(&sa_serv, '\0', sizeof(sa_serv));
75     sa_serv.sin_family = AF_INET;
76     sa_serv.sin_addr.s_addr = INADDR_ANY;
77     sa_serv.sin_port = htons(PORT); /* Server Port number */
78
79     setsockopt(listen_sd, SOL_SOCKET, SO_REUSEADDR, (void *) &optval,
80               sizeof(int));
81
82     err =
83         bind(listen_sd, (struct sockaddr *) &sa_serv, sizeof(sa_serv));
84     SOCKET_ERR(err, "bind");
85     err = listen(listen_sd, 1024);
86     SOCKET_ERR(err, "listen");
87
88     printf("%s ready. Listening to port '%d'.\n\n", name, PORT);
89
90     client_len = sizeof(sa_cli);
91     for (;;) {
92         gnutls_init(&session, GNUTLS_SERVER);
93         gnutls_priority_set_direct(session,
94                                   "NORMAL"
95                                   ":-KX-ALL:+SRP:+SRP-DSS:+SRP-RSA",
96                                   NULL);

```

```
97     gnutls_credentials_set(session, GNUTLS_CRD_SRP, srp_cred);
98     /* for the certificate authenticated ciphersuites.
99     */
100     gnutls_credentials_set(session, GNUTLS_CRD_CERTIFICATE,
101                             cert_cred);
102
103     /* We don't request any certificate from the client.
104     * If we did we would need to verify it. One way of
105     * doing that is shown in the "Verifying a certificate"
106     * example.
107     */
108     gnutls_certificate_server_set_request(session,
109                                           GNUTLS_CERT_IGNORE);
110
111     sd = accept(listen_sd, (struct sockaddr *) &sa_cli,
112                &client_len);
113
114     printf("- connection from %s, port %d\n",
115            inet_ntop(AF_INET, &sa_cli.sin_addr, topbuf,
116                      sizeof(topbuf)), ntohs(sa_cli.sin_port));
117
118     gnutls_transport_set_int(session, sd);
119
120     do {
121         ret = gnutls_handshake(session);
122     }
123     while (ret < 0 && gnutls_error_is_fatal(ret) == 0);
124
125     if (ret < 0) {
126         close(sd);
127         gnutls_deinit(session);
128         fprintf(stderr,
129                "*** Handshake has failed (%s)\n\n",
130                gnutls_strerror(ret));
131         continue;
132     }
133     printf("- Handshake was completed\n");
134     printf("- User %s was connected\n",
135            gnutls_srp_server_get_username(session));
136
137     /* print_info(session); */
138
139     for (;;) {
140         ret = gnutls_record_recv(session, buffer, MAX_BUF);
141
142         if (ret == 0) {
143             printf
144                 ("\n- Peer has closed the GnuTLS connection\n");
145             break;
146         } else if (ret < 0
147                    && gnutls_error_is_fatal(ret) == 0) {
148             fprintf(stderr, "*** Warning: %s\n",
149                     gnutls_strerror(ret));
150         } else if (ret < 0) {
151             fprintf(stderr, "\n*** Received corrupted "
152                     "data(%d). Closing the connection.\n\n",
153                     ret);
154             break;
```

```

155         } else if (ret > 0) {
156             /* echo data back to the client
157             */
158             gnutls_record_send(session, buffer, ret);
159         }
160     }
161     printf("\n");
162     /* do not wait for the peer to close the connection. */
163     gnutls_bye(session, GNUTLS_SHUT_WR);
164
165     close(sd);
166     gnutls_deinit(session);
167
168 }
169 close(listen_sd);
170
171 gnutls_srp_free_server_credentials(srp_cred);
172 gnutls_certificate_free_credentials(cert_cred);
173
174 gnutls_global_deinit();
175
176 return 0;
177
178 }

```

6.2.4 Echo server with anonymous authentication

This example server supports anonymous authentication, and could be used to serve the example client for anonymous authentication.

```

1  /* This example code is placed in the public domain. */
2
3  #ifdef HAVE_CONFIG_H
4  #include <config.h>
5  #endif
6
7  #include <stdio.h>
8  #include <stdlib.h>
9  #include <errno.h>
10 #include <sys/types.h>
11 #include <sys/socket.h>
12 #include <arpa/inet.h>
13 #include <netinet/in.h>
14 #include <string.h>
15 #include <unistd.h>
16 #include <gnutls/gnutls.h>
17
18 /* This is a sample TLS 1.0 echo server, for anonymous authentication only.
19 */
20
21
22 #define SOCKET_ERR(err,s) if(err==-1) {perror(s);return(1);}
23 #define MAX_BUF 1024
24 #define PORT 5556          /* listen to 5556 port */
25

```



```
26 /* These are global */
27 static gnutls_dh_params_t dh_params;
28
29 static int generate_dh_params(void)
30 {
31     unsigned int bits = gnutls_sec_param_to_pk_bits(GNUTLS_PK_DH,
32                                                     GNUTLS_SEC_PARAM_LEGACY);
33     /* Generate Diffie-Hellman parameters - for use with DHE
34      * kx algorithms. These should be discarded and regenerated
35      * once a day, once a week or once a month. Depending on the
36      * security requirements.
37      */
38     gnutls_dh_params_init(&dh_params);
39     gnutls_dh_params_generate2(dh_params, bits);
40
41     return 0;
42 }
43
44 int main(void)
45 {
46     int err, listen_sd;
47     int sd, ret;
48     struct sockaddr_in sa_serv;
49     struct sockaddr_in sa_cli;
50     socklen_t client_len;
51     char topbuf[512];
52     gnutls_session_t session;
53     gnutls_anon_server_credentials_t anoncred;
54     char buffer[MAX_BUF + 1];
55     int optval = 1;
56
57     if (gnutls_check_version("3.1.4") == NULL) {
58         fprintf(stderr, "GnuTLS 3.1.4 or later is required for this example\n");
59         exit(1);
60     }
61
62     /* for backwards compatibility with gnutls < 3.3.0 */
63     gnutls_global_init();
64
65     gnutls_anon_allocate_server_credentials(&anoncred);
66
67     generate_dh_params();
68
69     gnutls_anon_set_server_dh_params(anoncred, dh_params);
70
71     /* Socket operations
72      */
73     listen_sd = socket(AF_INET, SOCK_STREAM, 0);
74     SOCKET_ERR(listen_sd, "socket");
75
76     memset(&sa_serv, '\0', sizeof(sa_serv));
77     sa_serv.sin_family = AF_INET;
78     sa_serv.sin_addr.s_addr = INADDR_ANY;
79     sa_serv.sin_port = htons(PORT); /* Server Port number */
80
81     setsockopt(listen_sd, SOL_SOCKET, SO_REUSEADDR, (void *) &optval,
82               sizeof(int));
83
```

```

84     err =
85         bind(listen_sd, (struct sockaddr *) &sa_serv, sizeof(sa_serv));
86     SOCKET_ERR(err, "bind");
87     err = listen(listen_sd, 1024);
88     SOCKET_ERR(err, "listen");
89
90     printf("Server ready. Listening to port '%d'.\n\n", PORT);
91
92     client_len = sizeof(sa_cli);
93     for (;;) {
94         gnutls_init(&session, GNUTLS_SERVER);
95         gnutls_priority_set_direct(session,
96             "NORMAL::+ANON-ECDH:+ANON-DH",
97             NULL);
98         gnutls_credentials_set(session, GNUTLS_CRD_ANON, anoncred);
99
100        sd = accept(listen_sd, (struct sockaddr *) &sa_cli,
101            &client_len);
102
103        printf("- connection from %s, port %d\n",
104            inet_ntop(AF_INET, &sa_cli.sin_addr, topbuf,
105                sizeof(topbuf)), ntohs(sa_cli.sin_port));
106
107        gnutls_transport_set_int(session, sd);
108
109        do {
110            ret = gnutls_handshake(session);
111        }
112        while (ret < 0 && gnutls_error_is_fatal(ret) == 0);
113
114        if (ret < 0) {
115            close(sd);
116            gnutls_deinit(session);
117            fprintf(stderr,
118                "*** Handshake has failed (%s)\n\n",
119                gnutls_strerror(ret));
120            continue;
121        }
122        printf("- Handshake was completed\n");
123
124        /* see the Getting peer's information example */
125        /* print_info(session); */
126
127        for (;;) {
128            ret = gnutls_record_recv(session, buffer, MAX_BUF);
129
130            if (ret == 0) {
131                printf
132                    ("\n- Peer has closed the GnuTLS connection\n");
133                break;
134            } else if (ret < 0)
135                && gnutls_error_is_fatal(ret) == 0) {
136                fprintf(stderr, "*** Warning: %s\n",
137                    gnutls_strerror(ret));
138            } else if (ret < 0) {
139                fprintf(stderr, "\n*** Received corrupted "
140                    "data(%d). Closing the connection.\n\n",
141                    ret);

```

```
142         break;
143     } else if (ret > 0) {
144         /* echo data back to the client
145         */
146         gnutls_record_send(session, buffer, ret);
147     }
148 }
149 printf("\n");
150 /* do not wait for the peer to close the connection.
151 */
152 gnutls_bye(session, GNUTLS_SHUT_WR);
153
154 close(sd);
155 gnutls_deinit(session);
156
157 }
158 close(listen_sd);
159
160 gnutls_anon_free_server_credentials(anoncred);
161
162 gnutls_global_deinit();
163
164 return 0;
165
166 }
```

6.2.5 DTLS echo server with X.509 authentication

This example is a very simple echo server using Datagram TLS and X.509 authentication.

```
1  /* This example code is placed in the public domain. */
2
3  #ifdef HAVE_CONFIG_H
4  #include <config.h>
5  #endif
6
7  #include <stdio.h>
8  #include <stdlib.h>
9  #include <errno.h>
10 #include <sys/types.h>
11 #include <sys/socket.h>
12 #include <arpa/inet.h>
13 #include <netinet/in.h>
14 #include <sys/select.h>
15 #include <netdb.h>
16 #include <string.h>
17 #include <unistd.h>
18 #include <gnutls/gnutls.h>
19 #include <gnutls/dtls.h>
20
21 #define KEYFILE "key.pem"
22 #define CERTFILE "cert.pem"
23 #define CAFILE "/etc/ssl/certs/ca-certificates.crt"
24 #define CRLFILE "crl.pem"
25
```

```

26 /* This is a sample DTLS echo server, using X.509 authentication.
27  * Note that error checking is minimal to simplify the example.
28  */
29
30 #define MAX_BUFFER 1024
31 #define PORT 5557
32
33 typedef struct {
34     gnutls_session_t session;
35     int fd;
36     struct sockaddr *cli_addr;
37     socklen_t cli_addr_size;
38 } priv_data_st;
39
40 static int pull_timeout_func(gnutls_transport_ptr_t ptr, unsigned int ms);
41 static ssize_t push_func(gnutls_transport_ptr_t p, const void *data,
42                         size_t size);
43 static ssize_t pull_func(gnutls_transport_ptr_t p, void *data,
44                         size_t size);
45 static const char *human_addr(const struct sockaddr *sa, socklen_t salen,
46                              char *buf, size_t buflen);
47 static int wait_for_connection(int fd);
48 static int generate_dh_params(void);
49
50 /* Use global credentials and parameters to simplify
51  * the example. */
52 static gnutls_certificate_credentials_t x509_cred;
53 static gnutls_priority_t priority_cache;
54 static gnutls_dh_params_t dh_params;
55
56 int main(void)
57 {
58     int listen_sd;
59     int sock, ret;
60     struct sockaddr_in sa_serv;
61     struct sockaddr_in cli_addr;
62     socklen_t cli_addr_size;
63     gnutls_session_t session;
64     char buffer[MAX_BUFFER];
65     priv_data_st priv;
66     gnutls_datum_t cookie_key;
67     gnutls_dtls_prestate_st prestate;
68     int mtu = 1400;
69     unsigned char sequence[8];
70
71     /* this must be called once in the program
72      */
73     gnutls_global_init();
74
75     gnutls_certificate_allocate_credentials(&x509_cred);
76     gnutls_certificate_set_x509_trust_file(x509_cred, CAFILE,
77                                           GNUTLS_X509_FMT_PEM);
78
79     gnutls_certificate_set_x509_crl_file(x509_cred, CRLFILE,
80                                         GNUTLS_X509_FMT_PEM);
81
82     ret =
83     gnutls_certificate_set_x509_key_file(x509_cred, CERTFILE,

```

```

84                                     KEYFILE,
85                                     GNUTLS_X509_FMT_PEM);
86     if (ret < 0) {
87         printf("No certificate or key were found\n");
88         exit(1);
89     }
90
91     generate_dh_params();
92
93     gnutls_certificate_set_dh_params(x509_cred, dh_params);
94
95     gnutls_priority_init(&priority_cache,
96                         "PERFORMANCE:-VERS-TLS-ALL:+VERS-DTLS1.0:%SERVER_PRECEDENCE",
97                         NULL);
98
99     gnutls_key_generate(&cookie_key, GNUTLS_COOKIE_KEY_SIZE);
100
101     /* Socket operations
102     */
103     listen_sd = socket(AF_INET, SOCK_DGRAM, 0);
104
105     memset(&sa_serv, '\0', sizeof(sa_serv));
106     sa_serv.sin_family = AF_INET;
107     sa_serv.sin_addr.s_addr = INADDR_ANY;
108     sa_serv.sin_port = htons(PORT);
109
110     {
111         /* DTLS requires the IP don't fragment (DF) bit to be set */
112         #if defined(IP_DONTFRAG)
113             int optval = 1;
114             setsockopt(listen_sd, IPPROTO_IP, IP_DONTFRAG,
115                       (const void *) &optval, sizeof(optval));
116         #elif defined(IP_MTU_DISCOVER)
117             int optval = IP_PMTUDISC_D0;
118             setsockopt(listen_sd, IPPROTO_IP, IP_MTU_DISCOVER,
119                       (const void *) &optval, sizeof(optval));
120         #endif
121     }
122
123     bind(listen_sd, (struct sockaddr *) &sa_serv, sizeof(sa_serv));
124
125     printf("UDP server ready. Listening to port '%d'.\n\n", PORT);
126
127     for (;;) {
128         printf("Waiting for connection...\n");
129         sock = wait_for_connection(listen_sd);
130         if (sock < 0)
131             continue;
132
133         cli_addr_size = sizeof(cli_addr);
134         ret = recvfrom(sock, buffer, sizeof(buffer), MSG_PEEK,
135                      (struct sockaddr *) &cli_addr,
136                      &cli_addr_size);
137         if (ret > 0) {
138             memset(&prestate, 0, sizeof(prestate));
139             ret =
140                 gnutls_dtls_cookie_verify(&cookie_key,
141                                           &cli_addr,
142                                           sizeof(cli_addr),

```

```

142         buffer, ret,
143         &prestate);
144     if (ret < 0) { /* cookie not valid */
145         priv_data_st s;
146
147         memset(&s, 0, sizeof(s));
148         s.fd = sock;
149         s.cli_addr = (void *) &cli_addr;
150         s.cli_addr_size = sizeof(cli_addr);
151
152         printf
153         ("Sending hello verify request to %s\n",
154          human_addr((struct sockaddr *)
155                    &cli_addr,
156                    sizeof(cli_addr), buffer,
157                    sizeof(buffer)));
158
159         gnutls_dtls_cookie_send(&cookie_key,
160                                &cli_addr,
161                                sizeof(cli_addr),
162                                &prestate,
163                                (gnutls_transport_ptr_t)
164                                &s, push_func);
165
166         /* discard peeked data */
167         recvfrom(sock, buffer, sizeof(buffer), 0,
168                  (struct sockaddr *) &cli_addr,
169                  &cli_addr_size);
170         usleep(100);
171         continue;
172     }
173     printf("Accepted connection from %s\n",
174            human_addr((struct sockaddr *)
175                      &cli_addr, sizeof(cli_addr),
176                      buffer, sizeof(buffer)));
177 } else
178     continue;
179
180 gnutls_init(&session, GNUTLS_SERVER | GNUTLS_DATAGRAM);
181 gnutls_priority_set(session, priority_cache);
182 gnutls_credentials_set(session, GNUTLS_CRD_CERTIFICATE,
183                        x509_cred);
184
185 gnutls_dtls_prestate_set(session, &prestate);
186 gnutls_dtls_set_mtu(session, mtu);
187
188 priv.session = session;
189 priv.fd = sock;
190 priv.cli_addr = (struct sockaddr *) &cli_addr;
191 priv.cli_addr_size = sizeof(cli_addr);
192
193 gnutls_transport_set_ptr(session, &priv);
194 gnutls_transport_set_push_function(session, push_func);
195 gnutls_transport_set_pull_function(session, pull_func);
196 gnutls_transport_set_pull_timeout_function(session,
197                                           pull_timeout_func);
198
199 do {

```

```

200         ret = gnutls_handshake(session);
201     }
202     while (ret == GNUTLS_E_INTERRUPTED
203           || ret == GNUTLS_E_AGAIN);
204     /* Note that DTLS may also receive GNUTLS_E_LARGE_PACKET.
205      * In that case the MTU should be adjusted.
206      */
207
208     if (ret < 0) {
209         fprintf(stderr, "Error in handshake(): %s\n",
210                gnutls_strerror(ret));
211         gnutls_deinit(session);
212         continue;
213     }
214
215     printf("- Handshake was completed\n");
216
217     for (;;) {
218         do {
219             ret =
220                 gnutls_record_recv_seq(session, buffer,
221                                       MAX_BUFFER,
222                                       sequence);
223         }
224         while (ret == GNUTLS_E_AGAIN
225               || ret == GNUTLS_E_INTERRUPTED);
226
227         if (ret < 0 && gnutls_error_is_fatal(ret) == 0) {
228             fprintf(stderr, "*** Warning: %s\n",
229                    gnutls_strerror(ret));
230             continue;
231         } else if (ret < 0) {
232             fprintf(stderr, "Error in recv(): %s\n",
233                    gnutls_strerror(ret));
234             break;
235         }
236
237         if (ret == 0) {
238             printf("EOF\n\n");
239             break;
240         }
241
242         buffer[ret] = 0;
243         printf
244             ("received[%.2x%.2x%.2x%.2x%.2x%.2x%.2x]: %s\n",
245              sequence[0], sequence[1], sequence[2],
246              sequence[3], sequence[4], sequence[5],
247              sequence[6], sequence[7], buffer);
248
249         /* reply back */
250         ret = gnutls_record_send(session, buffer, ret);
251         if (ret < 0) {
252             fprintf(stderr, "Error in send(): %s\n",
253                    gnutls_strerror(ret));
254             break;
255         }
256     }
257

```

```

258         gnutls_bye(session, GNUTLS_SHUT_WR);
259         gnutls_deinit(session);
260
261     }
262     close(listen_sd);
263
264     gnutls_certificate_free_credentials(x509_cred);
265     gnutls_priority_deinit(priority_cache);
266
267     gnutls_global_deinit();
268
269     return 0;
270 }
271
272 static int wait_for_connection(int fd)
273 {
274     fd_set rd, wr;
275     int n;
276
277     FD_ZERO(&rd);
278     FD_ZERO(&wr);
279
280     FD_SET(fd, &rd);
281
282     /* waiting part */
283     n = select(fd + 1, &rd, &wr, NULL, NULL);
284     if (n == -1 && errno == EINTR)
285         return -1;
286     if (n < 0) {
287         perror("select()");
288         exit(1);
289     }
290
291     return fd;
292 }
293
294 /* Wait for data to be received within a timeout period in milliseconds
295  */
296 static int pull_timeout_func(gnutls_transport_ptr_t ptr, unsigned int ms)
297 {
298     fd_set rfd;
299     struct timeval tv;
300     priv_data_st *priv = ptr;
301     struct sockaddr_in cli_addr;
302     socklen_t cli_addr_size;
303     int ret;
304     char c;
305
306     FD_ZERO(&rfd);
307     FD_SET(priv->fd, &rfd);
308
309     tv.tv_sec = 0;
310     tv.tv_usec = ms * 1000;
311
312     while (tv.tv_usec >= 1000000) {
313         tv.tv_usec -= 1000000;
314         tv.tv_sec++;
315     }

```



```
316     }
317
318     ret = select(priv->fd + 1, &rfd, NULL, NULL, &tv);
319
320     if (ret <= 0)
321         return ret;
322
323     /* only report ok if the next message is from the peer we expect
324      * from
325      */
326     cli_addr_size = sizeof(cli_addr);
327     ret =
328         recvfrom(priv->fd, &c, 1, MSG_PEEK,
329                 (struct sockaddr *) &cli_addr, &cli_addr_size);
330     if (ret > 0) {
331         if (cli_addr_size == priv->cli_addr_size
332             && memcmp(&cli_addr, priv->cli_addr,
333                     sizeof(cli_addr)) == 0)
334             return 1;
335     }
336
337     return 0;
338 }
339
340 static ssize_t
341 push_func(gnutls_transport_ptr_t p, const void *data, size_t size)
342 {
343     priv_data_st *priv = p;
344
345     return sendto(priv->fd, data, size, 0, priv->cli_addr,
346                  priv->cli_addr_size);
347 }
348
349 static ssize_t pull_func(gnutls_transport_ptr_t p, void *data, size_t size)
350 {
351     priv_data_st *priv = p;
352     struct sockaddr_in cli_addr;
353     socklen_t cli_addr_size;
354     char buffer[64];
355     int ret;
356
357     cli_addr_size = sizeof(cli_addr);
358     ret =
359         recvfrom(priv->fd, data, size, 0,
360                 (struct sockaddr *) &cli_addr, &cli_addr_size);
361     if (ret == -1)
362         return ret;
363
364     if (cli_addr_size == priv->cli_addr_size
365         && memcmp(&cli_addr, priv->cli_addr, sizeof(cli_addr)) == 0)
366         return ret;
367
368     printf("Denied connection from %s\n",
369           human_addr((struct sockaddr *)
370                     &cli_addr, sizeof(cli_addr), buffer,
371                     sizeof(buffer)));
372
373     gnutls_transport_set_errno(priv->session, EAGAIN);
```

```

374     return -1;
375 }
376
377 static const char *human_addr(const struct sockaddr *sa, socklen_t salen,
378                               char *buf, size_t buflen)
379 {
380     const char *save_buf = buf;
381     size_t l;
382
383     if (!buf || !buflen)
384         return NULL;
385
386     *buf = '\0';
387
388     switch (sa->sa_family) {
389 #if HAVE_IPV6
390     case AF_INET6:
391         snprintf(buf, buflen, "IPv6 ");
392         break;
393 #endif
394
395     case AF_INET:
396         snprintf(buf, buflen, "IPv4 ");
397         break;
398     }
399
400     l = strlen(buf);
401     buf += l;
402     buflen -= l;
403
404     if (getnameinfo(sa, salen, buf, buflen, NULL, 0, NI_NUMERICHOST) !=
405         0)
406         return NULL;
407
408     l = strlen(buf);
409     buf += l;
410     buflen -= l;
411
412     strncat(buf, " port ", buflen);
413
414     l = strlen(buf);
415     buf += l;
416     buflen -= l;
417
418     if (getnameinfo(sa, salen, NULL, 0, buf, buflen, NI_NUMERICSERV) !=
419         0)
420         return NULL;
421
422     return save_buf;
423 }
424
425 static int generate_dh_params(void)
426 {
427     int bits = gnutls_sec_param_to_pk_bits(GNUTLS_PK_DH,
428                                             GNUTLS_SEC_PARAM_LEGACY);
429
430     /* Generate Diffie-Hellman parameters - for use with DHE
431      * kx algorithms. When short bit length is used, it might

```

```
432     * be wise to regenerate parameters often.
433     */
434     gnutls_dh_params_init(&dh_params);
435     gnutls_dh_params_generate2(dh_params, bits);
436
437     return 0;
438 }
```

6.3 OCSP example

Generate OCSP request

A small tool to generate OCSP requests.

```
1  /* This example code is placed in the public domain. */
2
3  #ifdef HAVE_CONFIG_H
4  #include <config.h>
5  #endif
6
7  #include <stdio.h>
8  #include <stdlib.h>
9  #include <string.h>
10 #include <gnutls/gnutls.h>
11 #include <gnutls/crypto.h>
12 #include <gnutls/ocsp.h>
13 #ifndef NO_LIBCURL
14 #include <curl/curl.h>
15 #endif
16 #include "read-file.h"
17
18 size_t get_data(void *buffer, size_t size, size_t nmemb, void *userp);
19 static gnutls_x509_crt_t load_cert(const char *cert_file);
20 static void _response_info(const gnutls_datum_t * data);
21 static void
22 _generate_request(gnutls_datum_t * rdata, gnutls_x509_crt_t cert,
23                  gnutls_x509_crt_t issuer, gnutls_datum_t *nonce);
24 static int
25 _verify_response(gnutls_datum_t * data, gnutls_x509_crt_t cert,
26                  gnutls_x509_crt_t signer, gnutls_datum_t *nonce);
27
28 /* This program queries an OCSP server.
29  It expects three files. argv[1] containing the certificate to
30  be checked, argv[2] holding the issuer for this certificate,
31  and argv[3] holding a trusted certificate to verify OCSP's response.
32  argv[4] is optional and should hold the server host name.
33
34  For simplicity the libcurl library is used.
35  */
36
37 int main(int argc, char *argv[])
38 {
39     gnutls_datum_t ud, tmp;
```

```

40     int ret;
41     gnutls_datum_t req;
42     gnutls_x509_crt_t cert, issuer, signer;
43 #ifndef NO_LIBCURL
44     CURL *handle;
45     struct curl_slist *headers = NULL;
46 #endif
47     int v, seq;
48     const char *cert_file = argv[1];
49     const char *issuer_file = argv[2];
50     const char *signer_file = argv[3];
51     char *hostname = NULL;
52     unsigned char noncebuf[23];
53     gnutls_datum_t nonce = { noncebuf, sizeof(noncebuf) };
54
55     gnutls_global_init();
56
57     if (argc > 4)
58         hostname = argv[4];
59
60     ret = gnutls_rnd(GNUTLS_RND_NONCE, nonce.data, nonce.size);
61     if (ret < 0)
62         exit(1);
63
64     cert = load_cert(cert_file);
65     issuer = load_cert(issuer_file);
66     signer = load_cert(signer_file);
67
68     if (hostname == NULL) {
69
70         for (seq = 0;; seq++) {
71             ret =
72                 gnutls_x509_crt_get_authority_info_access(cert,
73                                                         seq,
74                                                         GNUTLS_IA_OCSP_URI,
75                                                         &tmp,
76                                                         NULL);
77
78             if (ret == GNUTLS_E_UNKNOWN_ALGORITHM)
79                 continue;
80             if (ret == GNUTLS_E_REQUESTED_DATA_NOT_AVAILABLE) {
81                 fprintf(stderr,
82                         "No URI was found in the certificate.\n");
83                 exit(1);
84             }
85             if (ret < 0) {
86                 fprintf(stderr, "error: %s\n",
87                         gnutls_strerror(ret));
88                 exit(1);
89             }
90
91             printf("CA issuers URI: %.*s\n", tmp.size,
92                   tmp.data);
93
94             hostname = malloc(tmp.size + 1);
95             memcpy(hostname, tmp.data, tmp.size);
96             hostname[tmp.size] = 0;
97
98             gnutls_free(tmp.data);

```

```
98         break;
99     }
100
101 }
102
103 /* Note that the OCSP servers hostname might be available
104  * using gnutls_x509_cert_get_authority_info_access() in the issuer's
105  * certificate */
106
107 memset(&ud, 0, sizeof(ud));
108 fprintf(stderr, "Connecting to %s\n", hostname);
109
110 _generate_request(&req, cert, issuer, &nonce);
111
112 #ifndef NO_LIBCURL
113     curl_global_init(CURL_GLOBAL_ALL);
114
115     handle = curl_easy_init();
116     if (handle == NULL)
117         exit(1);
118
119     headers =
120         curl_slist_append(headers,
121                             "Content-Type: application/ocsp-request");
122
123     curl_easy_setopt(handle, CURLOPT_HTTPHEADER, headers);
124     curl_easy_setopt(handle, CURLOPT_POSTFIELDS, (void *) req.data);
125     curl_easy_setopt(handle, CURLOPT_POSTFIELDSIZE, req.size);
126     curl_easy_setopt(handle, CURLOPT_URL, hostname);
127     curl_easy_setopt(handle, CURLOPT_WRITEFUNCTION, get_data);
128     curl_easy_setopt(handle, CURLOPT_WRITEDATA, &ud);
129
130     ret = curl_easy_perform(handle);
131     if (ret != 0) {
132         fprintf(stderr, "curl[%d] error %d\n", __LINE__, ret);
133         exit(1);
134     }
135
136     curl_easy_cleanup(handle);
137 #endif
138
139 _response_info(&ud);
140
141 v = _verify_response(&ud, cert, signer, &nonce);
142
143 gnutls_x509_cert_deinit(cert);
144 gnutls_x509_cert_deinit(issuer);
145 gnutls_x509_cert_deinit(signer);
146 gnutls_global_deinit();
147
148 return v;
149 }
150
151 static void _response_info(const gnutls_datum_t * data)
152 {
153     gnutls_ocsp_resp_t resp;
154     int ret;
155     gnutls_datum buf;
```

```

156     ret = gnutls_ocsp_resp_init(&resp);
157     if (ret < 0)
158         exit(1);
159
160     ret = gnutls_ocsp_resp_import(resp, data);
161     if (ret < 0)
162         exit(1);
163
164     ret = gnutls_ocsp_resp_print(resp, GNUTLS_OCSP_PRINT_FULL, &buf);
165     if (ret != 0)
166         exit(1);
167
168     printf("%.s", buf.size, buf.data);
169     gnutls_free(buf.data);
170
171     gnutls_ocsp_resp_deinit(resp);
172 }
173
174 static gnutls_x509_cert_t load_cert(const char *cert_file)
175 {
176     gnutls_x509_cert_t crt;
177     int ret;
178     gnutls_datum_t data;
179     size_t size;
180
181     ret = gnutls_x509_cert_init(&crt);
182     if (ret < 0)
183         exit(1);
184
185     data.data = (void *) read_binary_file(cert_file, &size);
186     data.size = size;
187
188     if (!data.data) {
189         fprintf(stderr, "Cannot open file: %s\n", cert_file);
190         exit(1);
191     }
192
193     ret = gnutls_x509_cert_import(crt, &data, GNUTLS_X509_FMT_PEM);
194     free(data.data);
195     if (ret < 0) {
196         fprintf(stderr, "Cannot import certificate in %s: %s\n",
197                 cert_file, gnutls_strerror(ret));
198         exit(1);
199     }
200 }
201
202     return crt;
203 }
204
205 static void
206 _generate_request(gnutls_datum_t * rdata, gnutls_x509_cert_t cert,
207                  gnutls_x509_cert_t issuer, gnutls_datum_t *nonce)
208 {
209     gnutls_ocsp_req_t req;
210     int ret;
211
212     ret = gnutls_ocsp_req_init(&req);
213     if (ret < 0)

```

```
214         exit(1);
215
216     ret = gnutls_ocsp_req_add_cert(req, GNUTLS_DIG_SHA1, issuer, cert);
217     if (ret < 0)
218         exit(1);
219
220
221     ret = gnutls_ocsp_req_set_nonce(req, 0, nonce);
222     if (ret < 0)
223         exit(1);
224
225     ret = gnutls_ocsp_req_export(req, rdata);
226     if (ret != 0)
227         exit(1);
228
229     gnutls_ocsp_req_deinit(req);
230
231     return;
232 }
233
234 static int
235 _verify_response(gnutls_datum_t * data, gnutls_x509_crt_t cert,
236                 gnutls_x509_crt_t signer, gnutls_datum_t *nonce)
237 {
238     gnutls_ocsp_resp_t resp;
239     int ret;
240     unsigned verify;
241     gnutls_datum_t rnonce;
242
243     ret = gnutls_ocsp_resp_init(&resp);
244     if (ret < 0)
245         exit(1);
246
247     ret = gnutls_ocsp_resp_import(resp, data);
248     if (ret < 0)
249         exit(1);
250
251     ret = gnutls_ocsp_resp_check_crt(resp, 0, cert);
252     if (ret < 0)
253         exit(1);
254
255     ret = gnutls_ocsp_resp_get_nonce(resp, NULL, &rnonce);
256     if (ret < 0)
257         exit(1);
258
259     if (rnonce.size != nonce->size || memcmp(nonce->data, rnonce.data,
260         nonce->size) != 0) {
261         exit(1);
262     }
263
264     ret = gnutls_ocsp_resp_verify_direct(resp, signer, &verify, 0);
265     if (ret < 0)
266         exit(1);
267
268     printf("Verifying OCSP Response: ");
269     if (verify == 0)
270         printf("Verification success!\n");
271     else
```

```

272         printf("Verification error!\n");
273
274     if (verify & GNUTLS_OCSP_VERIFY_SIGNER_NOT_FOUND)
275         printf("Signer cert not found\n");
276
277     if (verify & GNUTLS_OCSP_VERIFY_SIGNER_KEYUSAGE_ERROR)
278         printf("Signer cert keyusage error\n");
279
280     if (verify & GNUTLS_OCSP_VERIFY_UNTRUSTED_SIGNER)
281         printf("Signer cert is not trusted\n");
282
283     if (verify & GNUTLS_OCSP_VERIFY_INSECURE_ALGORITHM)
284         printf("Insecure algorithm\n");
285
286     if (verify & GNUTLS_OCSP_VERIFY_SIGNATURE_FAILURE)
287         printf("Signature failure\n");
288
289     if (verify & GNUTLS_OCSP_VERIFY_CERT_NOT_ACTIVATED)
290         printf("Signer cert not yet activated\n");
291
292     if (verify & GNUTLS_OCSP_VERIFY_CERT_EXPIRED)
293         printf("Signer cert expired\n");
294
295     gnutls_free(rnonce.data);
296     gnutls_ocsp_resp_deinit(resp);
297
298     return verify;
299 }
300
301 size_t get_data(void *buffer, size_t size, size_t nmemb, void *userp)
302 {
303     gnutls_datum_t *ud = userp;
304
305     size *= nmemb;
306
307     ud->data = realloc(ud->data, size + ud->size);
308     if (ud->data == NULL) {
309         fprintf(stderr, "Not enough memory for the request\n");
310         exit(1);
311     }
312
313     memcpy(&ud->data[ud->size], buffer, size);
314     ud->size += size;
315
316     return size;
317 }

```

6.4 Miscellaneous examples

6.4.1 Checking for an alert

This is a function that checks if an alert has been received in the current session.


```
1  /* This example code is placed in the public domain. */
2
3  #ifdef HAVE_CONFIG_H
4  #include <config.h>
5  #endif
6
7  #include <stdio.h>
8  #include <stdlib.h>
9  #include <gnutls/gnutls.h>
10
11 #include "examples.h"
12
13 /* This function will check whether the given return code from
14  * a gnutls function (recv/send), is an alert, and will print
15  * that alert.
16  */
17 void check_alert(gnutls_session_t session, int ret)
18 {
19     int last_alert;
20
21     if (ret == GNUTLS_E_WARNING_ALERT_RECEIVED
22         || ret == GNUTLS_E_FATAL_ALERT_RECEIVED) {
23         last_alert = gnutls_alert_get(session);
24
25         /* The check for renegotiation is only useful if we are
26          * a server, and we had requested a rehandshake.
27          */
28         if (last_alert == GNUTLS_A_NO_RENEGOTIATION &&
29             ret == GNUTLS_E_WARNING_ALERT_RECEIVED)
30             printf("* Received NO_RENEGOTIATION alert. "
31                   "Client Does not support renegotiation.\n");
32         else
33             printf("* Received alert '%d': %s.\n", last_alert,
34                   gnutls_alert_get_name(last_alert));
35     }
36 }
```

6.4.2 X.509 certificate parsing example

To demonstrate the X.509 parsing capabilities an example program is listed below. That program reads the peer's certificate, and prints information about it.

```
1  /* This example code is placed in the public domain. */
2
3  #ifdef HAVE_CONFIG_H
4  #include <config.h>
5  #endif
6
7  #include <stdio.h>
8  #include <stdlib.h>
9  #include <gnutls/gnutls.h>
10 #include <gnutls/x509.h>
11
12 #include "examples.h"
```

```

13 static const char *bin2hex(const void *bin, size_t bin_size)
14 {
15     static char printable[110];
16     const unsigned char *_bin = bin;
17     char *print;
18     size_t i;
19
20     if (bin_size > 50)
21         bin_size = 50;
22
23     print = printable;
24     for (i = 0; i < bin_size; i++) {
25         sprintf(print, "%.2x ", _bin[i]);
26         print += 2;
27     }
28
29     return printable;
30 }
31
32
33 /* This function will print information about this session's peer
34  * certificate.
35  */
36 void print_x509_certificate_info(gnutls_session_t session)
37 {
38     char serial[40];
39     char dn[256];
40     size_t size;
41     unsigned int algo, bits;
42     time_t expiration_time, activation_time;
43     const gnutls_datum_t *cert_list;
44     unsigned int cert_list_size = 0;
45     gnutls_x509_crt_t cert;
46     gnutls_datum_t cinfo;
47
48     /* This function only works for X.509 certificates.
49     */
50     if (gnutls_certificate_type_get(session) != GNUTLS_CERT_X509)
51         return;
52
53     cert_list = gnutls_certificate_get_peers(session, &cert_list_size);
54
55     printf("Peer provided %d certificates.\n", cert_list_size);
56
57     if (cert_list_size > 0) {
58         int ret;
59
60         /* we only print information about the first certificate.
61         */
62         gnutls_x509_crt_init(&cert);
63
64         gnutls_x509_crt_import(cert, &cert_list[0],
65                               GNUTLS_X509_FMT_DER);
66
67         printf("Certificate info:\n");
68
69         /* This is the preferred way of printing short information about
70          a certificate. */

```

```

71         ret =
72             gnutls_x509_crt_print(cert, GNUTLS_CERT_PRINT_ONELINE,
73                                   &cinfo);
74     if (ret == 0) {
75         printf("\t%s\n", cinfo.data);
76         gnutls_free(cinfo.data);
77     }
78
79     /* If you want to extract fields manually for some other reason,
80      below are popular example calls. */
81
82     expiration_time =
83         gnutls_x509_crt_get_expiration_time(cert);
84     activation_time =
85         gnutls_x509_crt_get_activation_time(cert);
86
87     printf("\tCertificate is valid since: %s",
88           ctime(&activation_time));
89     printf("\tCertificate expires: %s",
90           ctime(&expiration_time));
91
92     /* Print the serial number of the certificate.
93      */
94     size = sizeof(serial);
95     gnutls_x509_crt_get_serial(cert, serial, &size);
96
97     printf("\tCertificate serial number: %s\n",
98           bin2hex(serial, size));
99
100
101     /* Extract some of the public key algorithm's parameters
102      */
103     algo = gnutls_x509_crt_get_pk_algorithm(cert, &bits);
104
105     printf("Certificate public key: %s",
106           gnutls_pk_algorithm_get_name(algo));
107
108     /* Print the version of the X.509
109      * certificate.
110      */
111     printf("\tCertificate version: #%d\n",
112           gnutls_x509_crt_get_version(cert));
113
114     size = sizeof(dn);
115     gnutls_x509_crt_get_dn(cert, dn, &size);
116     printf("\tDN: %s\n", dn);
117
118     size = sizeof(dn);
119     gnutls_x509_crt_get_issuer_dn(cert, dn, &size);
120     printf("\tIssuer's DN: %s\n", dn);
121
122     gnutls_x509_crt_deinit(cert);
123
124     }
125 }

```

6.4.3 Listing the ciphersuites in a priority string

This is a small program to list the enabled ciphersuites by a priority string.

```

1  /* This example code is placed in the public domain. */
2
3  #include <config.h>
4  #include <stdio.h>
5  #include <stdlib.h>
6  #include <string.h>
7  #include <gnutls/gnutls.h>
8
9  static void print_cipher_suite_list(const char *priorities)
10 {
11     size_t i;
12     int ret;
13     unsigned int idx;
14     const char *name;
15     const char *err;
16     unsigned char id[2];
17     gnutls_protocol_t version;
18     gnutls_priority_t pcache;
19
20     if (priorities != NULL) {
21         printf("Cipher suites for %s\n", priorities);
22
23         ret = gnutls_priority_init(&pcache, priorities, &err);
24         if (ret < 0) {
25             fprintf(stderr, "Syntax error at: %s\n", err);
26             exit(1);
27         }
28
29         for (i = 0;; i++) {
30             ret =
31                 gnutls_priority_get_cipher_suite_index(pcache,
32                                                         i,
33                                                         &idx);
34             if (ret == GNUTLS_E_REQUESTED_DATA_NOT_AVAILABLE)
35                 break;
36             if (ret == GNUTLS_E_UNKNOWN_CIPHER_SUITE)
37                 continue;
38
39             name =
40                 gnutls_cipher_suite_info(idx, id, NULL, NULL,
41                                         NULL, &version);
42
43             if (name != NULL)
44                 printf("%-50s\t0x%02x, 0x%02x\t%s\n",
45                       name, (unsigned char) id[0],
46                           (unsigned char) id[1],
47                           gnutls_protocol_get_name(version));
48         }
49
50         return;
51     }
52 }
53

```

```
54 int main(int argc, char **argv)
55 {
56     if (argc > 1)
57         print_cipher_suite_list(argv[1]);
58     return 0;
59 }
```

6.4.4 PKCS #12 structure generation example

This small program demonstrates the usage of the PKCS #12 API, by generating such a structure.

```
1  /* This example code is placed in the public domain. */
2
3  #ifdef HAVE_CONFIG_H
4  #include <config.h>
5  #endif
6
7  #include <stdio.h>
8  #include <stdlib.h>
9  #include <gnutls/gnutls.h>
10 #include <gnutls/pkcs12.h>
11
12 #include "examples.h"
13
14 #define OUTFILE "out.p12"
15
16 /* This function will write a pkcs12 structure into a file.
17  * cert: is a DER encoded certificate
18  * pkcs8_key: is a PKCS #8 encrypted key (note that this must be
19  *   encrypted using a PKCS #12 cipher, or some browsers will crash)
20  * password: is the password used to encrypt the PKCS #12 packet.
21  */
22 int
23 write_pkcs12(const gnutls_datum_t * cert,
24             const gnutls_datum_t * pkcs8_key, const char *password)
25 {
26     gnutls_pkcs12_t pkcs12;
27     int ret, bag_index;
28     gnutls_pkcs12_bag_t bag, key_bag;
29     char pkcs12_struct[10 * 1024];
30     size_t pkcs12_struct_size;
31     FILE *fd;
32
33     /* A good idea might be to use gnutls_x509_privkey_get_key_id()
34      * to obtain a unique ID.
35      */
36     gnutls_datum_t key_id = { (void *) "\x00\x00\x07", 3 };
37
38     gnutls_global_init();
39
40     /* Firstly we create two helper bags, which hold the certificate,
41      * and the (encrypted) key.
42      */
43 }
```

```

44     gnutls_pkcs12_bag_init(&bag);
45     gnutls_pkcs12_bag_init(&key_bag);
46
47     ret =
48         gnutls_pkcs12_bag_set_data(bag, GNUTLS_BAG_CERTIFICATE, cert);
49     if (ret < 0) {
50         fprintf(stderr, "ret: %s\n", gnutls_strerror(ret));
51         return 1;
52     }
53
54     /* ret now holds the bag's index.
55      */
56     bag_index = ret;
57
58     /* Associate a friendly name with the given certificate. Used
59      * by browsers.
60      */
61     gnutls_pkcs12_bag_set_friendly_name(bag, bag_index, "My name");
62
63     /* Associate the certificate with the key using a unique key
64      * ID.
65      */
66     gnutls_pkcs12_bag_set_key_id(bag, bag_index, &key_id);
67
68     /* use weak encryption for the certificate.
69      */
70     gnutls_pkcs12_bag_encrypt(bag, password,
71                               GNUTLS_PKCS_USE_PKCS12_RC2_40);
72
73     /* Now the key.
74      */
75
76     ret = gnutls_pkcs12_bag_set_data(key_bag,
77                                     GNUTLS_BAG_PKCS8_ENCRYPTED_KEY,
78                                     pkcs8_key);
79     if (ret < 0) {
80         fprintf(stderr, "ret: %s\n", gnutls_strerror(ret));
81         return 1;
82     }
83
84     /* Note that since the PKCS #8 key is already encrypted we don't
85      * bother encrypting that bag.
86      */
87     bag_index = ret;
88
89     gnutls_pkcs12_bag_set_friendly_name(key_bag, bag_index, "My name");
90
91     gnutls_pkcs12_bag_set_key_id(key_bag, bag_index, &key_id);
92
93
94     /* The bags were filled. Now create the PKCS #12 structure.
95      */
96     gnutls_pkcs12_init(&pkcs12);
97
98     /* Insert the two bags in the PKCS #12 structure.
99      */
100
101     gnutls_pkcs12_set_bag(pkcs12, bag);

```

```
102     gnutls_pkcs12_set_bag(pkcs12, key_bag);
103
104
105     /* Generate a message authentication code for the PKCS #12
106      * structure.
107      */
108     gnutls_pkcs12_generate_mac(pkcs12, password);
109
110     pkcs12_struct_size = sizeof(pkcs12_struct);
111     ret =
112         gnutls_pkcs12_export(pkcs12, GNUTLS_X509_FMT_DER,
113                             pkcs12_struct, &pkcs12_struct_size);
114     if (ret < 0) {
115         fprintf(stderr, "ret: %s\n", gnutls_strerror(ret));
116         return 1;
117     }
118
119     fd = fopen(OUTFILE, "w");
120     if (fd == NULL) {
121         fprintf(stderr, "cannot open file\n");
122         return 1;
123     }
124     fwrite(pkcs12_struct, 1, pkcs12_struct_size, fd);
125     fclose(fd);
126
127     gnutls_pkcs12_bag_deinit(bag);
128     gnutls_pkcs12_bag_deinit(key_bag);
129     gnutls_pkcs12_deinit(pkcs12);
130
131     return 0;
132 }
```


7

Other included programs

Included with GnuTLS are also a few command line tools that let you use the library for common tasks without writing an application. The applications are discussed in this chapter.

7.1 Invoking `gnutls-cli`

Simple client program to set up a TLS connection to some other computer. It sets up a TLS connection and forwards data from the standard input to the secured socket and vice versa.

This section was generated by **AutoGen**, using the `agtexi-cmd` template and the option descriptions for the `gnutls-cli` program. This software is released under the GNU General Public License, version 3 or later.

`gnutls-cli help/usage (“--help”)`

This is the automatically generated usage text for `gnutls-cli`.

The text printed is the same whether selected with the `help` option (“--help”) or the `more-help` option (“--more-help”). `more-help` will print the usage text by passing it through a pager program. `more-help` is disabled on platforms without a working `fork(2)` function. The `PAGER` environment variable is used to select the program, defaulting to “more”. Both will exit with a status code of 0.

```
1 gnutls-cli - GnuTLS client
2 Usage: gnutls-cli [ -<flag> [<val>] | --<name>[={| }<val>] ]... [hostname]
```

```

3  -d, --debug=num          Enable debugging
4                          - it must be in the range:
5                          0 to 9999
6
7  -V, --verbose            More verbose output
8                          - may appear multiple times
9
10     --tofu               Enable trust on first use authentication
11                          - disabled as '--no-tofu'
12
13     --strict-tofu        Fail to connect if a known certificate has changed
14                          - disabled as '--no-strict-tofu'
15
16     --dane               Enable DANE certificate verification (DNSSEC)
17                          - disabled as '--no-dane'
18
19     --local-dns          Use the local DNS server for DNSSEC resolving
20                          - disabled as '--no-local-dns'
21
22     --ca-verification    Disable CA certificate verification
23                          - disabled as '--no-ca-verification'
24                          - enabled by default
25
26     --ocsp               Enable OCSP certificate verification
27                          - disabled as '--no-ocsp'
28
29 -r, --resume              Establish a session and resume
30
31 -e, --rehandshake         Establish a session and rehandshake
32
33 -s, --starttls            Connect, establish a plain session and start TLS
34
35 -u, --udp                 Use DTLS (datagram TLS) over UDP
36
37     --mtu=num             Set MTU for datagram TLS
38                          - it must be in the range:
39                          0 to 17000
40
41     --crlf               Send CR LF instead of LF
42
43     --x509fmtder          Use DER format for certificates to read from
44
45 -f, --fingerprint         Send the openpgp fingerprint, instead of the key
46
47     --print-cert          Print peer's certificate in PEM format
48
49     --dh-bits=num         The minimum number of bits allowed for DH
50
51     --priority=str        Priorities string
52
53     --x509cafile=str      Certificate file or PKCS #11 URL to use
54
55     --x509crlfile=file    CRL file to use
56                          - file must pre-exist
57
58     --pgpkeyfile=file     PGP Key file to use
59                          - file must pre-exist
60
61     --pgpkeyring=file     PGP Key ring file to use
62                          - file must pre-exist
63
64     --pgpcertfile=file    PGP Public Key (certificate) file to use
65                          - file must pre-exist
66
67     --x509keyfile=str      X.509 key file or PKCS #11 URL to use
68
69     --x509certfile=str     X.509 Certificate file or PKCS #11 URL to use
70
71     --pgpsubkey=str        PGP subkey to use (hex or auto)
72
73     --srpusername=str      SRP username to use
74
75     --srppasswd=str        SRP password to use
76
77     --pskusername=str      PSK username to use
78
79     --pskkey=str           PSK key (in hex) to use
80
81 -p, --port=str            The port or service to connect to
82
83     --insecure            Don't abort program if server certificate can't be validated
84
85     --ranges              Use length-hiding padding to prevent traffic analysis
86
87     --benchmark-ciphers   Benchmark individual ciphers
88
89     --benchmark-tls-kx    Benchmark TLS key exchange methods
90
91     --benchmark-tls-ciphers Benchmark TLS ciphers
92
93 -l, --list                Print a list of the supported algorithms and modes
94
95     --noticket            Don't allow session tickets
96
97     --srtp-profiles=str    Offer SRTP profiles
98
99     --alpn=str            Application layer protocol

```

```
61         - may appear multiple times
62 -b, --heartbeat      Activate heartbeat support
63 -!, --recordsize=num The maximum record size to advertize
64         - it must be in the range:
65         0 to 4096
66 -, --disable-sni     Do not send a Server Name Indication (SNI)
67 -#, --disable-extensions Disable all the TLS extensions
68 -$, --inline-commands Inline commands of the form ^<cmd>^
69 -%, --inline-commands-prefix=str Change the default (^) used as a delimiter for inline commands. The
70 value is a single US-ASCII character (octets 0 - 127).
71 -&, --provider=file  Specify the PKCS #11 provider library
72         - file must pre-exist
73 -, --fips140-mode     Reports the status of the FIPS140-2 mode in gnutls library
74 -v, --version[=arg]  output version information and exit
75 -h, --help           display extended usage information and exit
76 -!, --more-help      extended usage information passed thru pager
77
78 Options are specified by doubled hyphens and their name or by a single
79 hyphen and the flag character.
80 Operands and options may be intermixed. They will be reordered.
81
82 Simple client program to set up a TLS connection to some other computer. It
83 sets up a TLS connection and forwards data from the standard input to the
84 secured socket and vice versa.
85
```

debug option (-d)

This is the “enable debugging” option. This option takes a number argument. Specifies the debug level.

tofu option

This is the “enable trust on first use authentication” option.

This option has some usage constraints. It:

- can be disabled with `-no-tofu`.

This option will, in addition to certificate authentication, perform authentication based on previously seen public keys, a model similar to SSH authentication. Note that when `tofu` is specified (PKI) and DANE authentication will become advisory to assist the public key acceptance process.

strict-tofu option

This is the “fail to connect if a known certificate has changed” option.

This option has some usage constraints. It:

- can be disabled with `-no-strict-tofu`.

This option will perform authentication as with option `-tofu`; however, while `-tofu` asks whether to trust a changed public key, this option will fail in case of public key changes.

dane option

This is the “enable dane certificate verification (dnssec)” option.

This option has some usage constraints. It:

- can be disabled with `-no-dane`.

This option will, in addition to certificate authentication using the trusted CAs, verify the server certificates using on the DANE information available via DNSSEC.

local-dns option

This is the “use the local dns server for dnssec resolving” option.

This option has some usage constraints. It:

- can be disabled with `-no-local-dns`.

This option will use the local DNS server for DNSSEC. This is disabled by default due to many servers not allowing DNSSEC.

ca-verification option

This is the “disable ca certificate verification” option.

This option has some usage constraints. It:

- can be disabled with `-no-ca-verification`.
- It is enabled by default.

This option will disable CA certificate verification. It is to be used with the `-dane` or `-tofu` options.

ocsp option

This is the “enable ocsp certificate verification” option.

This option has some usage constraints. It:

- can be disabled with `-no-ocsp`.

This option will enable verification of the peer’s certificate using ocsp

resume option (-r)

This is the “establish a session and resume” option. Connect, establish a session, reconnect and resume.

rehandshake option (-e)

This is the “establish a session and rehandshake” option. Connect, establish a session and rehandshake immediately.

starttls option (-s)

This is the “connect, establish a plain session and start tls” option. The TLS session will be initiated when EOF or a SIGALRM is received.

app-proto option

This is an alias for the `starttls-proto` option, ??.

starttls-proto option

This is the “the application protocol to be used to obtain the server’s certificate (https, ftp, smtp, imap)” option. This option takes a string argument.

This option has some usage constraints. It:

- must not appear in combination with any of the following options: `starttls`.

Specify the application layer protocol for STARTTLS. If the protocol is supported, `gnutls-cli` will proceed to the TLS negotiation.

dh-bits option

This is the “the minimum number of bits allowed for dh” option. This option takes a number argument. This option sets the minimum number of bits allowed for a Diffie-Hellman key exchange. You may want to lower the default value if the peer sends a weak prime and you get an connection error with unacceptable prime.

priority option

This is the “priorities string” option. This option takes a string argument. TLS algorithms and protocols to enable. You can use predefined sets of ciphersuites such as PERFORMANCE, NORMAL, PFS, SECURE128, SECURE256. The default is NORMAL.

Check the GnuTLS manual on section “Priority strings” for more information on the allowed keywords

ranges option

This is the “use length-hiding padding to prevent traffic analysis” option. When possible (e.g., when using CBC ciphersuites), use length-hiding padding to prevent traffic analysis.

benchmark-ciphers option

This is the “benchmark individual ciphers” option. By default the benchmarked ciphers will utilize any capabilities of the local CPU to improve performance. To test against the raw software implementation set the environment variable GNUTLS_CPUID_OVERRIDE to 0x1.

benchmark-tls-ciphers option

This is the “benchmark tls ciphers” option. By default the benchmarked ciphers will utilize any capabilities of the local CPU to improve performance. To test against the raw software implementation set the environment variable GNUTLS_CPUID_OVERRIDE to 0x1.

list option (-l)

This is the “print a list of the supported algorithms and modes” option.

This option has some usage constraints. It:

- must not appear in combination with any of the following options: port.

Print a list of the supported algorithms and modes. If a priority string is given then only the enabled ciphersuites are shown.

priority-list option

This is the “print a list of the supported priority strings” option. Print a list of the supported priority strings. The ciphersuites corresponding to each priority string can be examined using -l -p.

alpn option

This is the “application layer protocol” option. This option takes a string argument.

This option has some usage constraints. It:

- may appear an unlimited number of times.

This option will set and enable the Application Layer Protocol Negotiation (ALPN) in the TLS protocol.

disable-extensions option

This is the “disable all the tls extensions” option. This option disables all TLS extensions. Deprecated option. Use the priority string.

inline-commands option

This is the “inline commands of the form

textasciicircum<cmd>

textasciicircum” option. Enable inline commands of the form

textasciicircum<cmd>

textasciicircum. The inline commands are expected to be in a line by themselves. The available commands are: resume and renegotiate.

inline-commands-prefix option

This is the “change the default delimiter for inline commands.” option. This option takes a string argument. Change the default delimiter (

textasciicircum) used for inline commands. The delimiter is expected to be a single US-ASCII character (octets 0 - 127). This option is only relevant if inline commands are enabled via the inline-commands option

provider option

This is the “specify the pkcs #11 provider library” option. This option takes a file argument. This will override the default options in /etc/gnutls/pkcs11.conf

gnutls-cli exit status

One of the following exit values will be returned:

- 0 (EXIT_SUCCESS) Successful program execution.

- 1 (EXIT FAILURE) The operation failed or the command syntax was not valid.

gnutls-cli See Also

gnutls-cli-debug(1), gnutls-serv(1)

gnutls-cli Examples

Connecting using PSK authentication

To connect to a server using PSK authentication, you need to enable the choice of PSK by using a cipher priority parameter such as in the example below.

```

1 $ ./gnutls-cli -p 5556 localhost --pskusername psk_identity \
2   --pskkey 88f3824b3e5659f52d00e959bacab954b6540344 \
3   --priority NORMAL:-KX-ALL:+ECDHE-PSK:+DHE-PSK:+PSK
4 Resolving 'localhost'...
5 Connecting to '127.0.0.1:5556'...
6 - PSK authentication.
7 - Version: TLS1.1
8 - Key Exchange: PSK
9 - Cipher: AES-128-CBC
10 - MAC: SHA1
11 - Compression: NULL
12 - Handshake was completed
13
14 - Simple Client Mode:
```

By keeping the `--pskusername` parameter and removing the `--pskkey` parameter, it will query only for the password during the handshake.

Listing ciphersuites in a priority string

To list the ciphersuites in a priority string:

```

1 $ ./gnutls-cli --priority SECURE192 -l
2 Cipher suites for SECURE192
3 TLS_ECDHE_ECDSA_AES_256_CBC_SHA384      0xc0, 0x24      TLS1.2
4 TLS_ECDHE_ECDSA_AES_256_GCM_SHA384      0xc0, 0x2e      TLS1.2
5 TLS_ECDHE_RSA_AES_256_GCM_SHA384        0xc0, 0x30      TLS1.2
6 TLS_DHE_RSA_AES_256_CBC_SHA256          0x00, 0x6b      TLS1.2
7 TLS_DHE_DSS_AES_256_CBC_SHA256          0x00, 0x6a      TLS1.2
8 TLS_RSA_AES_256_CBC_SHA256              0x00, 0x3d      TLS1.2
9
10 Certificate types: CTYPE-X.509
11 Protocols: VERS-TLS1.2, VERS-TLS1.1, VERS-TLS1.0, VERS-SSL3.0, VERS-DTLS1.0
12 Compression: COMP=NULL
13 Elliptic curves: CURVE-SECP384R1, CURVE-SECP521R1
14 PK-signatures: SIGN-RSA-SHA384, SIGN-ECDSA-SHA384, SIGN-RSA-SHA512, SIGN-ECDSA-SHA512
```


Connecting using a PKCS #11 token

To connect to a server using a certificate and a private key present in a PKCS #11 token you need to substitute the PKCS 11 URLs in the `x509certfile` and `x509keyfile` parameters.

Those can be found using `"p11tool --list-tokens"` and then listing all the objects in the needed token, and using the appropriate.

```
1 $ p11tool --list-tokens
2
3 Token 0:
4 URL: pkcs11:model=PKCS15;manufacturer=MyMan;serial=1234;token=Test
5 Label: Test
6 Manufacturer: EnterSafe
7 Model: PKCS15
8 Serial: 1234
9
10 $ p11tool --login --list-certs "pkcs11:model=PKCS15;manufacturer=MyMan;serial=1234;token=Test"
11
12 Object 0:
13 URL: pkcs11:model=PKCS15;manufacturer=MyMan;serial=1234;token=Test;object=client;object-type=cert
14 Type: X.509 Certificate
15 Label: client
16 ID: 2a:97:0d:58:d1:51:3c:23:07:ae:4e:0d:72:26:03:7d:99:06:02:6a
17
18 $ export MYCERT="pkcs11:model=PKCS15;manufacturer=MyMan;serial=1234;token=Test;object=client;object-type=cert"
19 $ export MYKEY="pkcs11:model=PKCS15;manufacturer=MyMan;serial=1234;token=Test;object=client;object-type=private"
20
21 $ gnutls-cli www.example.com --x509keyfile $MYKEY --x509certfile MYCERT
```

Notice that the private key only differs from the certificate in the object-type.

7.2 Invoking gnutls-serv

Server program that listens to incoming TLS connections.

This section was generated by **AutoGen**, using the `agtexi-cmd` template and the option descriptions for the `gnutls-serv` program. This software is released under the GNU General Public License, version 3 or later.

gnutls-serv help/usage (“--help”)

This is the automatically generated usage text for `gnutls-serv`.

The text printed is the same whether selected with the `help` option (“`--help`”) or the `more-help` option (“`--more-help`”). `more-help` will print the usage text by passing it through a pager program. `more-help` is disabled on platforms without a working `fork(2)` function. The `PAGER` environment variable is used to select the program, defaulting to “`more`”. Both will exit with a status code of 0.

```

1 gnutls-serv - GnuTLS server
2 Usage: gnutls-serv [ -<flag> [<val>] | --<name>[={| }<val>] ]...
3
4 -d, --debug=num          Enable debugging
5                          - it must be in the range:
6                          0 to 9999
7 --noticket              Don't accept session tickets
8 -g, --generate            Generate Diffie-Hellman and RSA-export parameters
9 -q, --quiet              Suppress some messages
10 --nodb                  Do not use a resumption database
11 --http                  Act as an HTTP server
12 --echo                  Act as an Echo server
13 -u, --udp                Use DTLS (datagram TLS) over UDP
14 --mtu=num                Set MTU for datagram TLS
15                          - it must be in the range:
16                          0 to 17000
17 --srtp-profiles=str      Offer SRTP profiles
18 -a, --disable-client-cert Do not request a client certificate
19 -r, --require-client-cert Require a client certificate
20 --verify-client-cert     If a client certificate is sent then verify it.
21 -b, --heartbeat          Activate heartbeat support
22 --x509fmtder             Use DER format for certificates to read from
23 --priority=str           Priorities string
24 --dhparams=file          DH params file to use
25                          - file must pre-exist
26 --x509cafile=str         Certificate file or PKCS #11 URL to use
27 --x509crlfile=file       CRL file to use
28                          - file must pre-exist
29 --pgpkeyfile=file        PGP Key file to use
30                          - file must pre-exist
31 --pgpkeyring=file        PGP Key ring file to use
32                          - file must pre-exist
33 --pgpcertfile=file       PGP Public Key (certificate) file to use
34                          - file must pre-exist
35 --x509keyfile=str        X.509 key file or PKCS #11 URL to use
36 --x509certfile=str       X.509 Certificate file or PKCS #11 URL to use
37 --x509dsakeyfile=str     Alternative X.509 key file or PKCS #11 URL to use
38 --x509dsacertfile=str    Alternative X.509 Certificate file or PKCS #11 URL to use
39 --x509ecckeyfile=str     Alternative X.509 key file or PKCS #11 URL to use
40 --x509ecccertfile=str    Alternative X.509 Certificate file or PKCS #11 URL to use
41 --pgpsubkey=str          PGP subkey to use (hex or auto)
42 --srppasswd=file         SRP password file to use
43                          - file must pre-exist
44 --srppasswdconf=file     SRP password configuration file to use
45                          - file must pre-exist
46 --pskpasswd=file         PSK password file to use
47                          - file must pre-exist
48 --pskhint=str            PSK identity hint to use
49 --ocsp-response=file     The OCSP response to send to client
50                          - file must pre-exist
51 -p, --port=num           The port to connect to
52 -l, --list                Print a list of the supported algorithms and modes
53 -v, --version[=arg]      output version information and exit
54 -h, --help                display extended usage information and exit
55 -!, --more-help           extended usage information passed thru pager
56
57 Options are specified by doubled hyphens and their name or by a single

```

```
58 | hyphen and the flag character.  
59 |  
60 | Server program that listens to incoming TLS connections.  
61 |
```

debug option (-d)

This is the “enable debugging” option. This option takes a number argument. Specifies the debug level.

verify-client-cert option

This is the “if a client certificate is sent then verify it.” option. Do not require, but if a client certificate is sent then verify it and close the connection if invalid.

heartbeat option (-b)

This is the “activate heartbeat support” option. Regularly ping client via heartbeat extension messages

priority option

This is the “priorities string” option. This option takes a string argument. TLS algorithms and protocols to enable. You can use predefined sets of ciphersuites such as PERFORMANCE, NORMAL, SECURE128, SECURE256. The default is NORMAL.

Check the GnuTLS manual on section “Priority strings” for more information on allowed keywords

ocsp-response option

This is the “the ocsp response to send to client” option. This option takes a file argument. If the client requested an OCSP response, return data from this file to the client.

list option (-l)

This is the “print a list of the supported algorithms and modes” option. Print a list of the supported algorithms and modes. If a priority string is given then only the enabled ciphersuites are shown.

provider option

This is the “specify the pkcs #11 provider library” option. This option takes a file argument. This will override the default options in `/etc/gnutls/pkcs11.conf`

gnutls-serv exit status

One of the following exit values will be returned:

- 0 (EXIT_SUCCESS) Successful program execution.
- 1 (EXIT_FAILURE) The operation failed or the command syntax was not valid.

gnutls-serv See Also

`gnutls-cli-debug(1)`, `gnutls-cli(1)`

gnutls-serv Examples

Running your own TLS server based on GnuTLS can be useful when debugging clients and/or GnuTLS itself. This section describes how to use `gnutls-serv` as a simple HTTPS server.

The most basic server can be started as:

```
1 gnutls-serv --http --priority "NORMAL:+ANON-ECDH:+ANON-DH"
```

It will only support anonymous ciphersuites, which many TLS clients refuse to use.

The next step is to add support for X.509. First we generate a CA:

```
1 $ certtool --generate-privkey > x509-ca-key.pem
2 $ echo 'cn = GnuTLS test CA' > ca.tmpl
3 $ echo 'ca' >> ca.tmpl
4 $ echo 'cert_signing_key' >> ca.tmpl
5 $ certtool --generate-self-signed --load-privkey x509-ca-key.pem \
6   --template ca.tmpl --outfile x509-ca.pem
7 ...
```

Then generate a server certificate. Remember to change the `dns_name` value to the name of your server host, or skip that command to avoid the field.

```
1 $ certtool --generate-privkey > x509-server-key.pem
2 $ echo 'organization = GnuTLS test server' > server.tmpl
3 $ echo 'cn = test.gnutls.org' >> server.tmpl
4 $ echo 'tls_www_server' >> server.tmpl
5 $ echo 'encryption_key' >> server.tmpl
6 $ echo 'signing_key' >> server.tmpl
7 $ echo 'dns_name = test.gnutls.org' >> server.tmpl
8 $ certtool --generate-certificate --load-privkey x509-server-key.pem \
9   --load-ca-certificate x509-ca.pem --load-ca-privkey x509-ca-key.pem \
```

```
10  --template server.tpl --outfile x509-server.pem
11  ...
```

For use in the client, you may want to generate a client certificate as well.

```
1  $ certtool --generate-privkey > x509-client-key.pem
2  $ echo 'cn = GnuTLS test client' > client.tpl
3  $ echo 'tls_www_client' >> client.tpl
4  $ echo 'encryption_key' >> client.tpl
5  $ echo 'signing_key' >> client.tpl
6  $ certtool --generate-certificate --load-privkey x509-client-key.pem \
7  --load-ca-certificate x509-ca.pem --load-ca-privkey x509-ca-key.pem \
8  --template client.tpl --outfile x509-client.pem
9  ...
```

To be able to import the client key/certificate into some applications, you will need to convert them into a PKCS#12 structure. This also encrypts the security sensitive key with a password.

```
1  $ certtool --to-p12 --load-ca-certificate x509-ca.pem \
2  --load-privkey x509-client-key.pem --load-certificate x509-client.pem \
3  --outder --outfile x509-client.p12
```

For icing, we'll create a proxy certificate for the client too.

```
1  $ certtool --generate-privkey > x509-proxy-key.pem
2  $ echo 'cn = GnuTLS test client proxy' > proxy.tpl
3  $ certtool --generate-proxy --load-privkey x509-proxy-key.pem \
4  --load-ca-certificate x509-client.pem --load-ca-privkey x509-client-key.pem \
5  --load-certificate x509-client.pem --template proxy.tpl \
6  --outfile x509-proxy.pem
7  ...
```

Then start the server again:

```
1  $ gnutls-serv --http \
2  --x509cafile x509-ca.pem \
3  --x509keyfile x509-server-key.pem \
4  --x509certfile x509-server.pem
```

Try connecting to the server using your web browser. Note that the server listens to port 5556 by default.

While you are at it, to allow connections using DSA, you can also create a DSA key and certificate for the server. These credentials will be used in the final example below.

```
1  $ certtool --generate-privkey --dsa > x509-server-key-dsa.pem
2  $ certtool --generate-certificate --load-privkey x509-server-key-dsa.pem \
3  --load-ca-certificate x509-ca.pem --load-ca-privkey x509-ca-key.pem \
4  --template server.tpl --outfile x509-server-dsa.pem
5  ...
```

The next step is to create OpenPGP credentials for the server.

```

1 gpg --gen-key
2 ...enter whatever details you want, use 'test.gnutls.org' as name...

```

Make a note of the OpenPGP key identifier of the newly generated key, here it was 5D1D14D8. You will need to export the key for GnuTLS to be able to use it.

```

1 gpg -a --export 5D1D14D8 > openpgp-server.txt
2 gpg --export 5D1D14D8 > openpgp-server.bin
3 gpg --export-secret-keys 5D1D14D8 > openpgp-server-key.bin
4 gpg -a --export-secret-keys 5D1D14D8 > openpgp-server-key.txt

```

Let's start the server with support for OpenPGP credentials:

```

1 gnutls-serv --http --priority NORMAL:+CTYPE-OPENPGP \
2             --pgpkeyfile openpgp-server-key.txt \
3             --pgpcertfile openpgp-server.txt

```

The next step is to add support for SRP authentication. This requires an SRP password file created with `srptool`. To start the server with SRP support:

```

1 gnutls-serv --http --priority NORMAL:+SRP-RSA:+SRP \
2             --srpasswdconf srp-tpasswd.conf \
3             --srpasswd srp-passwd.txt

```

Let's also start a server with support for PSK. This would require a password file created with `psktool`.

```

1 gnutls-serv --http --priority NORMAL:+ECDHE-PSK:+PSK \
2             --pskpasswd psk-passwd.txt

```

Finally, we start the server with all the earlier parameters and you get this command:

```

1 gnutls-serv --http --priority NORMAL:+PSK:+SRP:+CTYPE-OPENPGP \
2             --x509cafile x509-ca.pem \
3             --x509keyfile x509-server-key.pem \
4             --x509certfile x509-server.pem \
5             --x509dsafile x509-server-key-dsa.pem \
6             --x509dsacertfile x509-server-dsa.pem \
7             --pgpkeyfile openpgp-server-key.txt \
8             --pgpcertfile openpgp-server.txt \
9             --srpasswdconf srp-tpasswd.conf \
10            --srpasswd srp-passwd.txt \
11            --pskpasswd psk-passwd.txt

```

7.3 Invoking gnutls-cli-debug

TLS debug client. It sets up multiple TLS connections to a server and queries its capabilities. It was created to assist in debugging GnuTLS, but it might be useful to extract a TLS server's capabilities. It connects to a TLS server, performs tests and print the server's capabilities. If

called with the ‘-v’ parameter more checks will be performed. Can be used to check for servers with special needs or bugs.

This section was generated by **AutoGen**, using the `agtexi-cmd` template and the option descriptions for the `gnutls-cli-debug` program. This software is released under the GNU General Public License, version 3 or later.

gnutls-cli-debug help/usage (“--help”)

This is the automatically generated usage text for `gnutls-cli-debug`.

The text printed is the same whether selected with the `help` option (“--help”) or the `more-help` option (“--more-help”). `more-help` will print the usage text by passing it through a pager program. `more-help` is disabled on platforms without a working `fork(2)` function. The `PAGER` environment variable is used to select the program, defaulting to “more”. Both will exit with a status code of 0.

```
1 gnutls-cli-debug - GnuTLS debug client
2 Usage: gnutls-cli-debug [ -<flag> [<val>] | --<name>[={| }<val>] ]...
3
4 -d, --debug=num          Enable debugging
5                          - it must be in the range:
6                          0 to 9999
7 -V, --verbose            More verbose output
8                          - may appear multiple times
9 -p, --port=num           The port to connect to
10                          - it must be in the range:
11                          0 to 65536
12 --app-proto=str          The application protocol to be used to obtain the server's certificate
13 (https, smtp, imap)
14 -v, --version[=arg]      output version information and exit
15 -h, --help              display extended usage information and exit
16 -!, --more-help          extended usage information passed thru pager
17
18 Options are specified by doubled hyphens and their name or by a single
19 hyphen and the flag character.
20 Operands and options may be intermixed. They will be reordered.
21
22 TLS debug client. It sets up multiple TLS connections to a server and
23 queries its capabilities. It was created to assist in debugging GnuTLS,
24 but it might be useful to extract a TLS server's capabilities. It connects
25 to a TLS server, performs tests and print the server's capabilities. If
26 called with the ‘-v’ parameter more checks will be performed. Can be used
27 to check for servers with special needs or bugs.
28
```

debug option (-d)

This is the “enable debugging” option. This option takes a number argument. Specifies the debug level.

gnutls-cli-debug exit status

One of the following exit values will be returned:

- 0 (EXIT_SUCCESS) Successful program execution.
- 1 (EXIT_FAILURE) The operation failed or the command syntax was not valid.

gnutls-cli-debug See Also

gnutls-cli(1), gnutls-serv(1)

gnutls-cli-debug Examples

```

1 $ ../src/gnutls-cli-debug localhost
2 Resolving 'localhost'...
3 Connecting to '127.0.0.1:443'...
4 Checking for SSL 3.0 support... yes
5 Checking whether %COMPAT is required... no
6 Checking for TLS 1.0 support... yes
7 Checking for TLS 1.1 support... no
8 Checking fallback from TLS 1.1 to... TLS 1.0
9 Checking for TLS 1.2 support... no
10 Checking whether we need to disable TLS 1.0... N/A
11 Checking for Safe renegotiation support... yes
12 Checking for Safe renegotiation support (SCSV)... yes
13 Checking for HTTPS server name... not checked
14 Checking for version rollback bug in RSA PMS... no
15 Checking for version rollback bug in Client Hello... no
16 Checking whether the server ignores the RSA PMS version... no
17 Checking whether the server can accept Hello Extensions... yes
18 Checking whether the server can accept small records (512 bytes)... yes
19 Checking whether the server can accept cipher suites not in SSL 3.0 spec... yes
20 Checking whether the server can accept a bogus TLS record version in the client hello... yes
21 Checking for certificate information... N/A
22 Checking for trusted CAs... N/A
23 Checking whether the server understands TLS closure alerts... partially
24 Checking whether the server supports session resumption... yes
25 Checking for export-grade ciphersuite support... no
26 Checking RSA-export ciphersuite info... N/A
27 Checking for anonymous authentication support... no
28 Checking anonymous Diffie-Hellman group info... N/A
29 Checking for ephemeral Diffie-Hellman support... no
30 Checking ephemeral Diffie-Hellman group info... N/A
31 Checking for ephemeral EC Diffie-Hellman support... yes
32 Checking ephemeral EC Diffie-Hellman group info...
33   Curve SECP256R1
34 Checking for AES-GCM cipher support... no
35 Checking for AES-CBC cipher support... yes
36 Checking for CAMELLIA cipher support... no
37 Checking for 3DES-CBC cipher support... yes
38 Checking for ARCFOUR 128 cipher support... yes
39 Checking for ARCFOUR 40 cipher support... no

```



```
40 Checking for MD5 MAC support... yes
41 Checking for SHA1 MAC support... yes
42 Checking for SHA256 MAC support... no
43 Checking for ZLIB compression support... no
44 Checking for max record size... no
45 Checking for OpenPGP authentication support... no
```


8

Internal Architecture of GnuTLS

This chapter is to give a brief description of the way GnuTLS works. The focus is to give an idea to potential developers and those who want to know what happens inside the black box.

8.1 The TLS Protocol

The main use case for the TLS protocol is shown in ?? . A user of a library implementing the protocol expects no less than this functionality, i.e., to be able to set parameters such as the accepted security level, perform a negotiation with the peer and be able to exchange data.

8.2 TLS Handshake Protocol

The GnuTLS handshake protocol is implemented as a state machine that waits for input or returns immediately when the non-blocking transport layer functions are used. The main idea is shown in ?? .

Also the way the input is processed varies per ciphersuite. Several implementations of the internal handlers are available and `gnutls_handshake` only multiplexes the input to the appropriate handler. For example a PSK ciphersuite has a different implementation of the `process_client_key_exchange` than a certificate ciphersuite. We illustrate the idea in ?? .

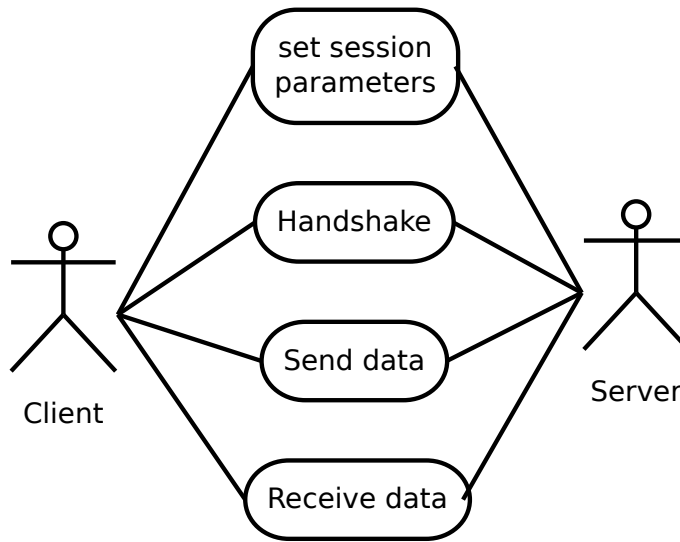


Figure 8.1: TLS protocol use case.

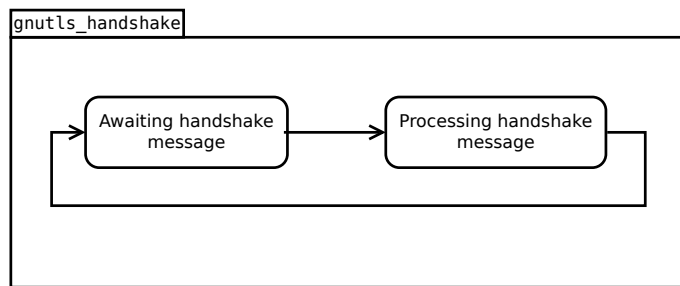


Figure 8.2: GnuTLS handshake state machine.

8.3 TLS Authentication Methods

In GnuTLS authentication methods can be implemented quite easily. Since the required changes to add a new authentication method affect only the handshake protocol, a simple interface is used. An authentication method needs to implement the functions shown below.

```

typedef struct
{
    const char *name;
    int (*gnutls_generate_server_certificate) (gnutls_session_t, gnutls_buffer_st*);
    int (*gnutls_generate_client_certificate) (gnutls_session_t, gnutls_buffer_st*);
    int (*gnutls_generate_server_kx) (gnutls_session_t, gnutls_buffer_st*);
    int (*gnutls_generate_client_kx) (gnutls_session_t, gnutls_buffer_st*);
    int (*gnutls_generate_client_cert_vrfy) (gnutls_session_t, gnutls_buffer_st *);
}
  
```

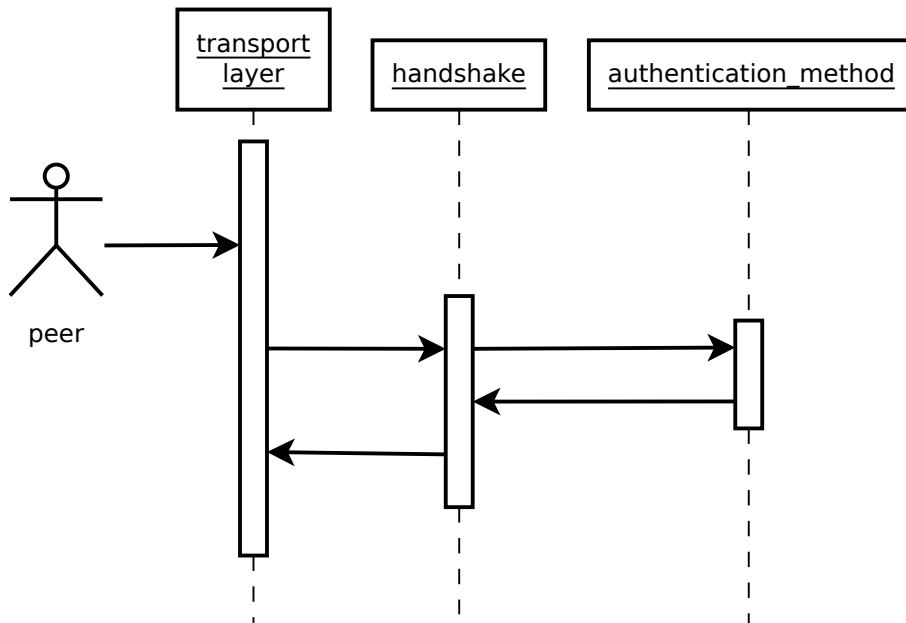


Figure 8.3: GnuTLS handshake process sequence.

```

int (*gnutls_generate_server_certificate_request) (gnutls_session_t,
                                                  gnutls_buffer_st *);

int (*gnutls_process_server_certificate) (gnutls_session_t, opaque *,
                                          size_t);
int (*gnutls_process_client_certificate) (gnutls_session_t, opaque *,
                                          size_t);
int (*gnutls_process_server_kx) (gnutls_session_t, opaque *, size_t);
int (*gnutls_process_client_kx) (gnutls_session_t, opaque *, size_t);
int (*gnutls_process_client_cert_vrfy) (gnutls_session_t, opaque *, size_t);
int (*gnutls_process_server_certificate_request) (gnutls_session_t,
                                                  opaque *, size_t);
} mod_auth_st;

```

Those functions are responsible for the interpretation of the handshake protocol messages. It is common for such functions to read data from one or more `credentials_t` structures¹ and write data, such as certificates, usernames etc. to `auth_info_t` structures.

Simple examples of existing authentication methods can be seen in `auth/psk.c` for PSK ciphersuites and `auth/srp.c` for SRP ciphersuites. After implementing these functions the structure holding its pointers has to be registered in `gnutls_algorithms.c` in the `_gnutls_kx_algorithms` structure.

¹such as the `gnutls_certificate_credentials_t` structures

8.4 TLS Extension Handling

As with authentication methods, the TLS extensions handlers can be implemented using the interface shown below.

```
typedef int (*gnutls_ext_recv_func) (gnutls_session_t session,
                                     const unsigned char *data, size_t len);
typedef int (*gnutls_ext_send_func) (gnutls_session_t session,
                                     gnutls_buffer_st *extdata);
```

Here there are two functions, one for receiving the extension data and one for sending. These functions have to check internally whether they operate in client or server side.

A simple example of an extension handler can be seen in `ext/srp.c` in GnuTLS' source code. After implementing these functions, together with the extension number they handle, they have to be registered using `_gnutls_ext_register` in `gnutls_extensions.c` typically within `_gnutls_ext_init`.

Adding a new TLS extension

Adding support for a new TLS extension is done from time to time, and the process to do so is not difficult. Here are the steps you need to follow if you wish to do this yourself. For sake of discussion, let's consider adding support for the hypothetical TLS extension `foobar`. The following section is about adding an extension to GnuTLS, for custom application extensions you should check the exported function `gnutls_ext_register`.

Add configure option like `--enable-foobar` or `--disable-foobar`.

This step is useful when the extension code is large and it might be desirable to disable the extension under some circumstances. Otherwise it can be safely skipped.

Whether to chose enable or disable depends on whether you intend to make the extension be enabled by default. Look at existing checks (i.e., SRP, authz) for how to model the code. For example:

```
1 AC_MSG_CHECKING([whether to disable foobar support])
2 AC_ARG_ENABLE(foobar,
3     AS_HELP_STRING([--disable-foobar],
4     [disable foobar support]),
5     ac_enable_foobar=no)
6 if test x$ac_enable_foobar != xno; then
7     AC_MSG_RESULT(no)
8     AC_DEFINE(ENABLE_FOOBAR, 1, [enable foobar])
9 else
10     ac_full=0
11     AC_MSG_RESULT(yes)
12 fi
13 AM_CONDITIONAL(ENABLE_FOOBAR, test "$ac_enable_foobar" != "no")
```

These lines should go in `m4/hooks.m4`.

Add IANA extension value to `extensions_t` in `gnutls_int.h`.

A good name for the value would be `GNUTLS_EXTENSION_FOOBAR`. Check with <http://www.iana.org/assignments/tls-extensiontype-values> for allocated values. For experiments, you could pick a number but remember that some consider it a bad idea to deploy such modified version since it will lead to interoperability problems in the future when the IANA allocates that number to someone else, or when the foobar protocol is allocated another number.

Add an entry to `_gnutls_extensions` in `gnutls_extensions.c`.

A typical entry would be:

```
1  int ret;
2
3  #if ENABLE_FOOBAR
4      ret = _gnutls_ext_register (&foobar_ext);
5      if (ret != GNUTLS_E_SUCCESS)
6          return ret;
7  #endif
```

Most likely you'll need to add an `#include "ext/foobar.h"`, that will contain something like:

```
1  extension_entry_st foobar_ext = {
2      .name = "FOOBAR",
3      .type = GNUTLS_EXTENSION_FOOBAR,
4      .parse_type = GNUTLS_EXT_TLS,
5      .recv_func = _foobar_recv_params,
6      .send_func = _foobar_send_params,
7      .pack_func = _foobar_pack,
8      .unpack_func = _foobar_unpack,
9      .deinit_func = NULL
10 }
```

The `GNUTLS_EXTENSION_FOOBAR` is the integer value you added to `gnutls_int.h` earlier. In this structure you specify the functions to read the extension from the hello message, the function to send the reply to, and two more functions to pack and unpack from stored session data (e.g. when resumming a session). The `deinit` function will be called to deinitialize the extension's private parameters, if any.

Note that the conditional `ENABLE_FOOBAR` definition should only be used if step 1 with the `configure` options has taken place.

Add new files that implement the extension.

The functions you are responsible to add are those mentioned in the previous step. They should be added in a file such as `ext/foobar.c` and headers should be placed in `ext/foobar.h`. As a starter, you could add this:

```

1  int
2  _foobar_recv_params (gnutls_session_t session, const opaque * data,
3                      size_t data_size)
4  {
5      return 0;
6  }
7
8  int
9  _foobar_send_params (gnutls_session_t session, gnutls_buffer_st* data)
10 {
11     return 0;
12 }
13
14 int
15 _foobar_pack (extension_priv_data_t epriv, gnutls_buffer_st * ps)
16 {
17     /* Append the extension's internal state to buffer */
18     return 0;
19 }
20
21 int
22 _foobar_unpack (gnutls_buffer_st * ps, extension_priv_data_t * epriv)
23 {
24     /* Read the internal state from buffer */
25     return 0;
26 }

```

The `_foobar_recv_params` function is responsible for parsing incoming extension data (both in the client and server).

The `_foobar_send_params` function is responsible for sending extension data (both in the client and server).

If you receive length fields that don't match, return `GNUTLS_E_UNEXPECTED_PACKET_LENGTH`. If you receive invalid data, return `GNUTLS_E_RECEIVED_ILLEGAL_PARAMETER`. You can use other error codes from the list in `??`. Return 0 on success.

An extension typically stores private information in the `session` data for later usage. That can be done using the functions `_gnutls_ext_set_session_data` and `_gnutls_ext_get_session_data`. You can check simple examples at `ext/max_record.c` and `ext/server_name.c` extensions. That private information can be saved and restored across session resumption if the following functions are set:

The `_foobar_pack` function is responsible for packing internal extension data to save them in the session resumption storage.

The `_foobar_unpack` function is responsible for restoring session data from the session resumption storage.

Recall that both the client and server, send and receive parameters, and your code most likely will need to do different things depending on which mode it is in. It may be useful to make this distinction explicit in the code. Thus, for example, a better template than above would be:

```
1 int
2 _gnutls_foobar_recv_params (gnutls_session_t session,
3                             const opaque * data,
4                             size_t data_size)
5 {
6     if (session->security_parameters.entity == GNUTLS_CLIENT)
7         return foobar_recv_client (session, data, data_size);
8     else
9         return foobar_recv_server (session, data, data_size);
10 }
11
12 int
13 _gnutls_foobar_send_params (gnutls_session_t session,
14                             gnutls_buffer_st * data)
15 {
16     if (session->security_parameters.entity == GNUTLS_CLIENT)
17         return foobar_send_client (session, data);
18     else
19         return foobar_send_server (session, data);
20 }
```

The functions used would be declared as `static` functions, of the appropriate prototype, in the same file. When adding the files, you'll need to add them to `ext/Makefile.am` as well, for example:

```
1 if ENABLE_FOOBAR
2 libgnutls_ext_la_SOURCES += ext/foobar.c ext/foobar.h
3 endif
```

Add API functions to enable/disable the extension.

It might be desirable to allow users of the extension to request use of the extension, or set extension specific data. This can be implemented by adding extension specific function calls that can be added to `includes/gnutls/gnutls.h`, as long as the LGPLv2.1+ applies. The implementation of the function should lie in the `ext/foobar.c` file.

To make the API available in the shared library you need to add the symbol in `lib/-libgnutls.map`, so that the symbol is exported properly.

When writing GTK-DOC style documentation for your new APIs, don't forget to add `Since:` tags to indicate the GnuTLS version the API was introduced in.

Heartbeat extension.

One such extension is HeartBeat protocol (RFC6520: <https://tools.ietf.org/html/rfc6520>) implementation. To enable it use option `-heartbeat` with example client and server supplied

with gnutls:

```
1 ./doc/credentials/gnutls-http-serv --priority "NORMAL:-CIPHER-ALL:+NULL" -d 100 \
2   --heartbeat --echo
3 ./src/gnutls-cli --priority "NORMAL:-CIPHER-ALL:+NULL" -d 100 localhost -p 5556 \
4   --insecure --heartbeat
```

After that pasting

```
1 **HEARTBEAT**
```

command into gnutls-cli will trigger corresponding command on the server and it will send HeartBeat Request with random length to client.

Another way is to run capabilities check with:

```
1 ./doc/credentials/gnutls-http-serv -d 100 --heartbeat
2 ./src/gnutls-cli-debug localhost -p 5556
```

Adding a new Supplemental Data Handshake Message

TLS handshake extensions allow to send so called supplemental data handshake messages [?]. This short section explains how to implement a supplemental data handshake message for a given TLS extension.

First of all, modify your extension `foobar` in the way, to instruct the handshake process to send and receive supplemental data, as shown below.

```
1 int
2 _gnutls_foobar_rcv_params (gnutls_session_t session, const opaque * data,
3                           size_t _data_size)
4 {
5     ...
6     gnutls_supplemental_rcv(session, 1);
7     ...
8 }
9
10 int
11 _gnutls_foobar_send_params (gnutls_session_t session, gnutls_buffer_st *extdata)
12 {
13     ...
14     gnutls_supplemental_send(session, 1);
15     ...
16 }
```

Furthermore you'll need two new functions `_foobar_supp_rcv_params` and `_foobar_supp_send_params`, which must conform to the following prototypes.

```
1 typedef int (*gnutls_supp_rcv_func)(gnutls_session_t session,
2                                     const unsigned char *data,
3                                     size_t data_size);
```

```
4 typedef int (*gnutls_supp_send_func)(gnutls_session_t session,  
5                                     gnutls_buffer_t buf);
```

The following example code shows how to send a “Hello World” string in the supplemental data handshake message.

```
1 int  
2 _foobar_supp_rcv_params(gnutls_session_t session, const opaque *data, size_t _data_size)  
3 {  
4     uint8_t len = _data_size;  
5     unsigned char *msg;  
6  
7     msg = gnutls_malloc(len);  
8     if (msg == NULL) return GNUTLS_E_MEMORY_ERROR;  
9  
10    memcpy(msg, data, len);  
11    msg[len]='\0';  
12  
13    /* do something with msg */  
14    gnutls_free(msg);  
15  
16    return len;  
17 }  
18  
19 int  
20 _foobar_supp_send_params(gnutls_session_t session, gnutls_buffer_t buf)  
21 {  
22     unsigned char *msg = "hello world";  
23     int len = strlen(msg);  
24  
25     gnutls_buffer_append_data(buf, msg, len);  
26  
27     return len;  
28 }
```

Afterwards, register the new supplemental data using `gnutls_supplemental_register`, at some point in your program.

8.5 Cryptographic Backend

Today most new processors, either for embedded or desktop systems include either instructions intended to speed up cryptographic operations, or a co-processor with cryptographic capabilities. Taking advantage of those is a challenging task for every cryptographic application or library. Unfortunately the cryptographic library that GnuTLS is based on takes no advantage of these capabilities. For this reason GnuTLS handles this internally by following a layered approach to accessing cryptographic operations as in ??.

The TLS layer uses a cryptographic provider layer, that will in turn either use the default crypto provider – a software crypto library, or use an external crypto provider, if available in the local system. The reason of handling the external cryptographic provider in GnuTLS and

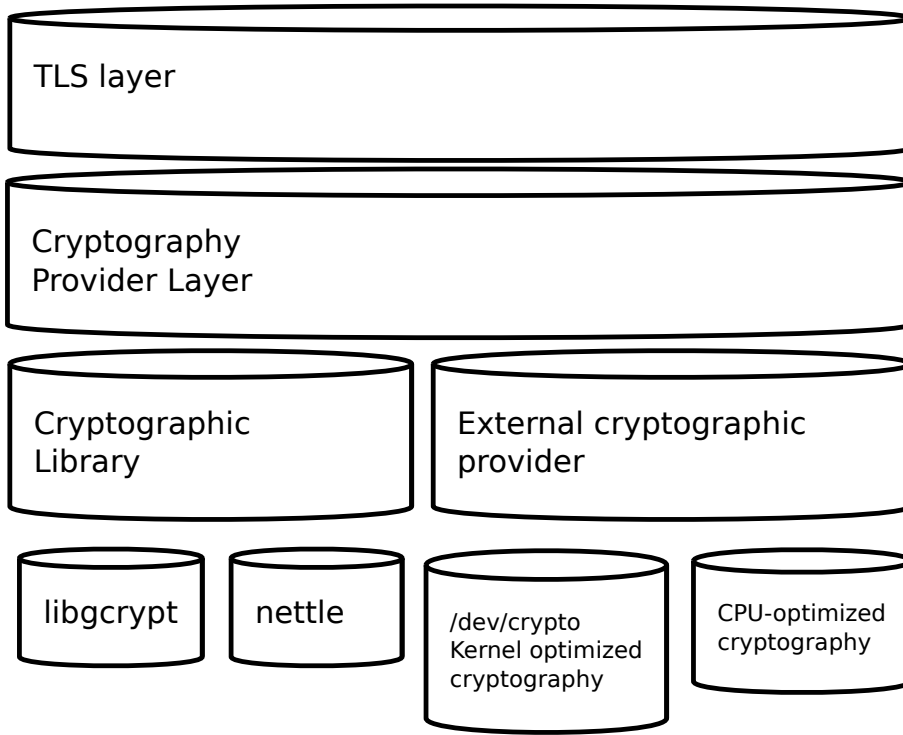


Figure 8.4: GnuTLS cryptographic back-end design.

not delegating it to the cryptographic libraries, is that none of the supported cryptographic libraries support `/dev/crypto` or CPU-optimized cryptography in an efficient way.

Cryptographic library layer

The Cryptographic library layer, currently supports only libnettle. Older versions of GnuTLS used to support libgcrypt, but it was switched with nettle mainly for performance reasons² and secondary because it is a simpler library to use. In the future other cryptographic libraries might be supported as well.

External cryptography provider

Systems that include a cryptographic co-processor, typically come with kernel drivers to utilize the operations from software. For this reason GnuTLS provides a layer where each individual algorithm used can be replaced by another implementation, i.e., the one provided by the driver.

²See <http://lists.gnu.org/archive/html/gnutls-devel/2011-02/msg00079.html>.

The FreeBSD, OpenBSD and Linux kernels³ include already a number of hardware assisted implementations, and also provide an interface to access them, called `/dev/crypto`. GnuTLS will take advantage of this interface if compiled with special options. That is because in most systems where hardware-assisted cryptographic operations are not available, using this interface might actually harm performance.

In systems that include cryptographic instructions with the CPU's instructions set, using the kernel interface will introduce an unneeded layer. For this reason GnuTLS includes such optimizations found in popular processors such as the AES-NI or VIA PADLOCK instruction sets. This is achieved using a mechanism that detects CPU capabilities and overrides parts of crypto back-end at runtime. The next section discusses the registration of a detected algorithm optimization. For more information please consult the GnuTLS source code in `lib/accelerated/`.

Overriding specific algorithms

When an optimized implementation of a single algorithm is available, say a hardware assisted version of AES-CBC then the following (internal) functions, from `crypto-backend.h`, can be used to register those algorithms.

- `gnutls_crypto_single_cipher_register`: To register a cipher algorithm.
- `gnutls_crypto_single_digest_register`: To register a hash (digest) or MAC algorithm.

Those registration functions will only replace the specified algorithm and leave the rest of subsystem intact.

Overriding the cryptographic library

In some systems, that might contain a broad acceleration engine, it might be desirable to override big parts of the cryptographic back-end, or even all of them. The following functions are provided for this reason.

- `gnutls_crypto_cipher_register`: To override the cryptographic algorithms back-end.
- `gnutls_crypto_digest_register`: To override the digest algorithms back-end.
- `gnutls_crypto_rnd_register`: To override the random number generator back-end.
- `gnutls_crypto_bigint_register`: To override the big number number operations back-end.
- `gnutls_crypto_pk_register`: To override the public key encryption back-end. This is tied to the big number operations so either none or both of them should be overridden.

³Check <http://home.gna.org/cryptodev-linux/> for the Linux kernel implementation of `/dev/crypto`.



Upgrading from previous versions

The GnuTLS library typically maintains binary and source code compatibility across versions. The releases that have the major version increased break binary compatibility but source compatibility is provided. This section lists exceptional cases where changes to existing code are required due to library changes.

Upgrading to 2.12.x from previous versions

GnuTLS 2.12.x is binary compatible with previous versions but changes the semantics of `gnutls_transport_set_lowat`, which might cause breakage in applications that relied on its default value be 1. Two fixes are proposed:

- Quick fix. Explicitly call `gnutls_transport_set_lowat (session, 1);` after `gnutls_init`.
- Long term fix. Because later versions of gnutls abolish the functionality of using the system call `select` to check for gnutls pending data, the function `gnutls_record_check_pending` has to be used to achieve the same functionality as described in ??.

Upgrading to 3.0.x from 2.12.x

GnuTLS 3.0.x is source compatible with previous versions except for the functions listed below.

Old function	Replacement
<code>gnutls_transport_set_lowat</code>	To replace its functionality the function <code>gnutls_record_check_pending</code> has to be used, as described in ??
<code>gnutls_session_get_server_random</code> , <code>gnutls_session_get_client_random</code>	They are replaced by the safer function <code>gnutls_session_get_random</code>
<code>gnutls_session_get_master_secret</code>	Replaced by the keying material exporters discussed in ??
<code>gnutls_transport_set_global_errno</code>	Replaced by using the system's <code>errno</code> facility or <code>gnutls_transport_set_errno</code> .
<code>gnutls_x509_privkey_verify_data</code>	Replaced by <code>gnutls_pubkey_verify_data2</code> .
<code>gnutls_certificate_verify_peers</code>	Replaced by <code>gnutls_certificate_verify_peers2</code> .
<code>gnutls_psk_netconf_derive_key</code>	Removed. The key derivation function was never standardized.
<code>gnutls_session_set_finished_function</code>	Removed.
<code>gnutls_ext_register</code>	Removed. Extension registration API is now internal to allow easier changes in the API.
<code>gnutls_certificate_get_x509_crls</code> , <code>gnutls_certificate_get_x509_cas</code>	Removed to allow updating the internal structures. Replaced by <code>gnutls_certificate_get_issuer</code> .
<code>gnutls_certificate_get_openpgp_keyring</code>	Removed.
<code>gnutls_ia_</code>	Removed. The inner application extensions were completely removed (they failed to be standardized).

Upgrading to 3.1.x from 3.0.x

GnuTLS 3.1.x is source and binary compatible with GnuTLS 3.0.x releases. Few functions have been deprecated and are listed below.

Old function	Replacement
<code>gnutls_pubkey_verify_hash</code>	The function <code>gnutls_pubkey_verify_hash2</code> is provided and is functionally equivalent and safer to use.
<code>gnutls_pubkey_verify_data</code>	The function <code>gnutls_pubkey_verify_data2</code> is provided and is functionally equivalent and safer to use.

Upgrading to 3.2.x from 3.1.x

GnuTLS 3.2.x is source and binary compatible with GnuTLS 3.1.x releases. Few functions have been deprecated and are listed below.

Old function	Replacement
<code>gnutls_privkey_sign_raw_data</code>	The function <code>gnutls_privkey_sign_hash</code> is equivalent when the flag <code>GNUTLS_PRIVKEY_SIGN_FLAG_TLS1_RSA</code> is specified.

Upgrading to 3.3.x from 3.2.x

GnuTLS 3.3.x is source and binary compatible with GnuTLS 3.2.x releases; however there few changes in semantics which are listed below.

Old function	Replacement
<code>gnutls_global_init</code>	No longer required. The library is initialized using a constructor.
<code>gnutls_global_deinit</code>	No longer required. The library is deinitialized using a destructor.

Upgrading to 3.4.x from 3.3.x

GnuTLS 3.4.x is source compatible with GnuTLS 3.3.x releases; however, several deprecated functions were removed, and are listed below.

Old function	Replacement
Priority string "NORMAL" has been modified	The following string emulates the 3.3.x behavior "NORMAL:+VERS-SSL3.0:+ARCFOUR-128:+DHE-DSS:+SIGN-DSA-SHA512:+SIGN-DSA-SHA256:+SIGN-DSA-SHA1"
gnutls_certificate_client_set_retrieve_function, gnutls_certificate_server_set_retrieve_function	gnutls_certificate_set_retrieve_function
gnutls_certificate_set_rsa_export_params, gnutls_rsa_export_get_modulus_bits, gnutls_rsa_export_get_pubkey, gnutls_rsa_params_cpy, gnutls_rsa_params_deinit, gnutls_rsa_params_export_pkcs1, gnutls_rsa_params_export_raw, gnutls_rsa_params_generate2, gnutls_rsa_params_import_pkcs1, gnutls_rsa_params_import_raw, gnutls_rsa_params_init	No replacement; the library does not support the RSA-EXPORT ciphersuites.
gnutls_pubkey_verify_hash,	gnutls_pubkey_verify_hash2.
gnutls_pubkey_verify_data,	gnutls_pubkey_verify_data2.
gnutls_x509_cert_get_verify_algorithm, No replacement; a similar function is	gnutls_x509_cert_get_signature_algorithm.
gnutls_pubkey_get_verify_algorithm,	No replacement; a similar function is gnutls_pubkey_get_preferred_hash_algorithm.
gnutls_certificate_type_set_priority, gnutls_cipher_set_priority, gnutls_compression_set_priority, gnutls_kx_set_priority, gnutls_mac_set_priority, gnutls_protocol_set_priority	gnutls_priority_set_direct.
gnutls_sign_callback_get, gnutls_sign_callback_set	gnutls_privkey_import_ext3
gnutls_x509_cert_verify_hash	gnutls_pubkey_verify_hash2
gnutls_x509_cert_verify_data	gnutls_pubkey_verify_data2

B

Support

B.1 Getting Help

A mailing list where users may help each other exists, and you can reach it by sending e-mail to gnutls-help@gnutls.org. Archives of the mailing list discussions, and an interface to manage subscriptions, is available through the World Wide Web at <http://lists.gnutls.org/pipermail/gnutls-help/>.

A mailing list for developers are also available, see <http://www.gnutls.org/lists.html>. Bug reports should be sent to bugs@gnutls.org, see ??.

B.2 Commercial Support

Commercial support is available for users of GnuTLS. The kind of support that can be purchased may include:

- Implement new features. Such as a new TLS extension.
- Port GnuTLS to new platforms. This could include porting to an embedded platforms that may need memory or size optimization.
- Integrating TLS as a security environment in your existing project.
- System design of components related to TLS.

If you are interested, please write to:

Simon Josefsson Datakonsult
Hagagatan 24
113 47 Stockholm
Sweden

E-mail: simon@josefsson.org

If your company provides support related to GnuTLS and would like to be mentioned here, contact the authors.

B.3 Bug Reports

If you think you have found a bug in GnuTLS, please investigate it and report it.

- Please make sure that the bug is really in GnuTLS, and preferably also check that it hasn't already been fixed in the latest version.
- You have to send us a test case that makes it possible for us to reproduce the bug.
- You also have to explain what is wrong; if you get a crash, or if the results printed are not good and in that case, in what way. Make sure that the bug report includes all information you would need to fix this kind of bug for someone else.

Please make an effort to produce a self-contained report, with something definite that can be tested or debugged. Vague queries or piecemeal messages are difficult to act on and don't help the development effort.

If your bug report is good, we will do our best to help you to get a corrected version of the software; if the bug report is poor, we won't do anything about it (apart from asking you to send better bug reports).

If you think something in this manual is unclear, or downright incorrect, or if the language needs to be improved, please also send a note.

Send your bug report to:

bugs@gnutls.org

B.4 Contributing

If you want to submit a patch for inclusion – from solving a typo you discovered, up to adding support for a new feature – you should submit it as a bug report, using the process in ???. There are some things that you can do to increase the chances for it to be included in the official package.

Unless your patch is very small (say, under 10 lines) we require that you assign the copyright of your work to the Free Software Foundation. This is to protect the freedom of the project.

If you have not already signed papers, we will send you the necessary information when you submit your contribution.

For contributions that doesn't consist of actual programming code, the only guidelines are common sense. For code contributions, a number of style guides will help you:

- **Coding Style.** Follow the GNU Standards document.
If you normally code using another coding standard, there is no problem, but you should use indent to reformat the code before submitting your work.
- **Use the unified diff format** `diff -u`.
- **Return errors.** No reason whatsoever should abort the execution of the library. Even memory allocation errors, e.g. when `malloc` return `NULL`, should work although result in an error code.
- **Design with thread safety in mind.** Don't use global variables. Don't even write to per-handle global variables unless the documented behaviour of the function you write is to write to the per-handle global variable.
- **Avoid using the C math library.** It causes problems for embedded implementations, and in most situations it is very easy to avoid using it.
- **Document your functions.** Use comments before each function headers, that, if properly formatted, are extracted into Texinfo manuals and GTK-DOC web pages.
- **Supply a ChangeLog and NEWS entries,** where appropriate.

B.5 Certification

Many cryptographic libraries claim certifications from national or international bodies. These certifications are tied on a specific (and often restricted) version of the library or a specific product using the library, and typically in the case of software they assure that the algorithms implemented are correct. The major certifications known are:

- **USA's FIPS 140-2 at Level 1** which certifies that approved algorithms are used (see http://en.wikipedia.org/wiki/FIPS_140-2);
- **Common Criteria for Information Technology Security Evaluation (CC)**, an international standard for verification of elaborate security claims (see http://en.wikipedia.org/wiki/Common_Criteria).

Obtaining such a certification is an expensive and elaborate job that has no immediate value for a continuously developed free software library (as the certification is tied to the particular version tested). While, as a free software project, we are not actively pursuing this kind of certification, GnuTLS has been FIPS-140-2 certified in several systems by third parties. If you are, interested, see ??.



Supported Ciphersuites

Ciphersuite name	TLS ID	Since
TLS_RSA_NULL_MD5	0x00 0x01	SSL3.0
TLS_RSA_NULL_SHA1	0x00 0x02	SSL3.0
TLS_RSA_NULL_SHA256	0x00 0x3B	TLS1.0
TLS_RSA_ARCFOUR_128_SHA1	0x00 0x05	SSL3.0
TLS_RSA_ARCFOUR_128_MD5	0x00 0x04	SSL3.0
TLS_RSA_3DES_EDE_CBC_SHA1	0x00 0x0A	SSL3.0
TLS_RSA_AES_128_CBC_SHA1	0x00 0x2F	SSL3.0
TLS_RSA_AES_256_CBC_SHA1	0x00 0x35	SSL3.0
TLS_RSA_CAMELLIA_128_CBC_SHA256	0x00 0xBA	TLS1.0
TLS_RSA_CAMELLIA_256_CBC_SHA256	0x00 0xC0	TLS1.0
TLS_RSA_CAMELLIA_128_CBC_SHA1	0x00 0x41	SSL3.0
TLS_RSA_CAMELLIA_256_CBC_SHA1	0x00 0x84	SSL3.0
TLS_RSA_AES_128_CBC_SHA256	0x00 0x3C	TLS1.0
TLS_RSA_AES_256_CBC_SHA256	0x00 0x3D	TLS1.0
TLS_RSA_AES_128_GCM_SHA256	0x00 0x9C	TLS1.2
TLS_RSA_AES_256_GCM_SHA384	0x00 0x9D	TLS1.2
TLS_RSA_CAMELLIA_128_GCM_SHA256	0xC0 0x7A	TLS1.2
TLS_RSA_CAMELLIA_256_GCM_SHA384	0xC0 0x7B	TLS1.2
TLS_RSA_CHACHA20_POLY1305	0xCC 0xA0	TLS1.2
TLS_RSA_AES_128_CCM	0xC0 0x9C	TLS1.2
TLS_RSA_AES_256_CCM	0xC0 0x9D	TLS1.2

TLS_RSA_AES.128.CCM.8	0xC0 0xA0	TLS1.2
TLS_RSA_AES.256.CCM.8	0xC0 0xA1	TLS1.2
TLS_DHE_DSS_ARCFOUR.128.SHA1	0x00 0x66	SSL3.0
TLS_DHE_DSS_3DES_EDE_CBC_SHA1	0x00 0x13	SSL3.0
TLS_DHE_DSS_AES.128_CBC_SHA1	0x00 0x32	SSL3.0
TLS_DHE_DSS_AES.256_CBC_SHA1	0x00 0x38	SSL3.0
TLS_DHE_DSS_CAMELLIA.128_CBC_SHA256	0x00 0xBD	TLS1.0
TLS_DHE_DSS_CAMELLIA.256_CBC_SHA256	0x00 0xC3	TLS1.0
TLS_DHE_DSS_CAMELLIA.128_CBC_SHA1	0x00 0x44	SSL3.0
TLS_DHE_DSS_CAMELLIA.256_CBC_SHA1	0x00 0x87	SSL3.0
TLS_DHE_DSS_AES.128_CBC_SHA256	0x00 0x40	TLS1.0
TLS_DHE_DSS_AES.256_CBC_SHA256	0x00 0x6A	TLS1.0
TLS_DHE_DSS_AES.128_GCM_SHA256	0x00 0xA2	TLS1.2
TLS_DHE_DSS_AES.256_GCM_SHA384	0x00 0xA3	TLS1.2
TLS_DHE_DSS_CAMELLIA.128_GCM_SHA256	0xC0 0x80	TLS1.2
TLS_DHE_DSS_CAMELLIA.256_GCM_SHA384	0xC0 0x81	TLS1.2
TLS_DHE_RSA_3DES_EDE_CBC_SHA1	0x00 0x16	SSL3.0
TLS_DHE_RSA_AES.128_CBC_SHA1	0x00 0x33	SSL3.0
TLS_DHE_RSA_AES.256_CBC_SHA1	0x00 0x39	SSL3.0
TLS_DHE_RSA_CAMELLIA.128_CBC_SHA256	0x00 0xBE	TLS1.0
TLS_DHE_RSA_CAMELLIA.256_CBC_SHA256	0x00 0xC4	TLS1.0
TLS_DHE_RSA_CAMELLIA.128_CBC_SHA1	0x00 0x45	SSL3.0
TLS_DHE_RSA_CAMELLIA.256_CBC_SHA1	0x00 0x88	SSL3.0
TLS_DHE_RSA_AES.128_CBC_SHA256	0x00 0x67	TLS1.0
TLS_DHE_RSA_AES.256_CBC_SHA256	0x00 0x6B	TLS1.0
TLS_DHE_RSA_AES.128_GCM_SHA256	0x00 0x9E	TLS1.2
TLS_DHE_RSA_AES.256_GCM_SHA384	0x00 0x9F	TLS1.2
TLS_DHE_RSA_CAMELLIA.128_GCM_SHA256	0xC0 0x7C	TLS1.2
TLS_DHE_RSA_CAMELLIA.256_GCM_SHA384	0xC0 0x7D	TLS1.2
TLS_DHE_RSA_CHACHA20_POLY1305	0xCC 0xA3	TLS1.2
TLS_DHE_RSA_AES.128_CCM	0xC0 0x9E	TLS1.2
TLS_DHE_RSA_AES.256_CCM	0xC0 0x9F	TLS1.2
TLS_DHE_RSA_AES.128_CCM.8	0xC0 0xA2	TLS1.2
TLS_DHE_RSA_AES.256_CCM.8	0xC0 0xA3	TLS1.2
TLS_ECDHE_RSA_NULL_SHA1	0xC0 0x10	SSL3.0
TLS_ECDHE_RSA_3DES_EDE_CBC_SHA1	0xC0 0x12	SSL3.0
TLS_ECDHE_RSA_AES.128_CBC_SHA1	0xC0 0x13	SSL3.0
TLS_ECDHE_RSA_AES.256_CBC_SHA1	0xC0 0x14	SSL3.0
TLS_ECDHE_RSA_AES.256_CBC_SHA384	0xC0 0x28	TLS1.0
TLS_ECDHE_RSA_ARCFOUR.128_SHA1	0xC0 0x11	SSL3.0
TLS_ECDHE_RSA_CAMELLIA.128_CBC_SHA256	0xC0 0x76	TLS1.0

TLS_ECDHE_RSA_CAMELLIA_256_CBC_SHA384	0xC0 0x77	TLS1.0
TLS_ECDHE_ECDSA_NULL_SHA1	0xC0 0x06	SSL3.0
TLS_ECDHE_ECDSA_3DES_EDE_CBC_SHA1	0xC0 0x08	SSL3.0
TLS_ECDHE_ECDSA_AES_128_CBC_SHA1	0xC0 0x09	SSL3.0
TLS_ECDHE_ECDSA_AES_256_CBC_SHA1	0xC0 0x0A	SSL3.0
TLS_ECDHE_ECDSA_ARCFOUR_128_SHA1	0xC0 0x07	SSL3.0
TLS_ECDHE_ECDSA_CAMELLIA_128_CBC_SHA256	0xC0 0x72	TLS1.0
TLS_ECDHE_ECDSA_CAMELLIA_256_CBC_SHA384	0xC0 0x73	TLS1.0
TLS_ECDHE_ECDSA_AES_128_CBC_SHA256	0xC0 0x23	TLS1.0
TLS_ECDHE_RSA_AES_128_CBC_SHA256	0xC0 0x27	TLS1.0
TLS_ECDHE_ECDSA_CAMELLIA_128_GCM_SHA256	0xC0 0x86	TLS1.2
TLS_ECDHE_ECDSA_CAMELLIA_256_GCM_SHA384	0xC0 0x87	TLS1.2
TLS_ECDHE_ECDSA_AES_128_GCM_SHA256	0xC0 0x2B	TLS1.2
TLS_ECDHE_ECDSA_AES_256_GCM_SHA384	0xC0 0x2C	TLS1.2
TLS_ECDHE_RSA_AES_128_GCM_SHA256	0xC0 0x2F	TLS1.2
TLS_ECDHE_RSA_AES_256_GCM_SHA384	0xC0 0x30	TLS1.2
TLS_ECDHE_ECDSA_AES_256_CBC_SHA384	0xC0 0x24	TLS1.0
TLS_ECDHE_RSA_CAMELLIA_128_GCM_SHA256	0xC0 0x8A	TLS1.2
TLS_ECDHE_RSA_CAMELLIA_256_GCM_SHA384	0xC0 0x8B	TLS1.2
TLS_ECDHE_RSA_CHACHA20_POLY1305	0xCC 0xA1	TLS1.2
TLS_ECDHE_ECDSA_CHACHA20_POLY1305	0xCC 0xA2	TLS1.2
TLS_ECDHE_ECDSA_AES_128_CCM	0xC0 0xAC	TLS1.2
TLS_ECDHE_ECDSA_AES_256_CCM	0xC0 0xAD	TLS1.2
TLS_ECDHE_ECDSA_AES_128_CCM_8	0xC0 0xAE	TLS1.2
TLS_ECDHE_ECDSA_AES_256_CCM_8	0xC0 0xAF	TLS1.2
TLS_ECDHE_PSK_3DES_EDE_CBC_SHA1	0xC0 0x34	SSL3.0
TLS_ECDHE_PSK_AES_128_CBC_SHA1	0xC0 0x35	SSL3.0
TLS_ECDHE_PSK_AES_256_CBC_SHA1	0xC0 0x36	SSL3.0
TLS_ECDHE_PSK_AES_128_CBC_SHA256	0xC0 0x37	TLS1.0
TLS_ECDHE_PSK_AES_256_CBC_SHA384	0xC0 0x38	TLS1.0
TLS_ECDHE_PSK_ARCFOUR_128_SHA1	0xC0 0x33	SSL3.0
TLS_ECDHE_PSK_NULL_SHA1	0xC0 0x39	SSL3.0
TLS_ECDHE_PSK_NULL_SHA256	0xC0 0x3A	TLS1.0
TLS_ECDHE_PSK_NULL_SHA384	0xC0 0x3B	TLS1.0
TLS_ECDHE_PSK_CAMELLIA_128_CBC_SHA256	0xC0 0x9A	TLS1.0
TLS_ECDHE_PSK_CAMELLIA_256_CBC_SHA384	0xC0 0x9B	TLS1.0
TLS_PSK_ARCFOUR_128_SHA1	0x00 0x8A	SSL3.0
TLS_PSK_3DES_EDE_CBC_SHA1	0x00 0x8B	SSL3.0
TLS_PSK_AES_128_CBC_SHA1	0x00 0x8C	SSL3.0
TLS_PSK_AES_256_CBC_SHA1	0x00 0x8D	SSL3.0
TLS_PSK_AES_128_CBC_SHA256	0x00 0xAE	TLS1.0

TLS_PSK_AES_256_GCM_SHA384	0x00 0xA9	TLS1.2
TLS_PSK_CAMELLIA_128_GCM_SHA256	0xC0 0x8E	TLS1.2
TLS_PSK_CAMELLIA_256_GCM_SHA384	0xC0 0x8F	TLS1.2
TLS_PSK_AES_128_GCM_SHA256	0x00 0xA8	TLS1.2
TLS_PSK_NULL_SHA1	0x00 0x2C	SSL3.0
TLS_PSK_NULL_SHA256	0x00 0xB0	TLS1.0
TLS_PSK_CAMELLIA_128_CBC_SHA256	0xC0 0x94	TLS1.0
TLS_PSK_CAMELLIA_256_CBC_SHA384	0xC0 0x95	TLS1.0
TLS_PSK_AES_256_CBC_SHA384	0x00 0xAF	TLS1.0
TLS_PSK_NULL_SHA384	0x00 0xB1	TLS1.0
TLS_RSA_PSK_ARCFOUR_128_SHA1	0x00 0x92	TLS1.0
TLS_RSA_PSK_3DES_EDE_CBC_SHA1	0x00 0x93	TLS1.0
TLS_RSA_PSK_AES_128_CBC_SHA1	0x00 0x94	TLS1.0
TLS_RSA_PSK_AES_256_CBC_SHA1	0x00 0x95	TLS1.0
TLS_RSA_PSK_CAMELLIA_128_GCM_SHA256	0xC0 0x92	TLS1.2
TLS_RSA_PSK_CAMELLIA_256_GCM_SHA384	0xC0 0x93	TLS1.2
TLS_RSA_PSK_AES_128_GCM_SHA256	0x00 0xAC	TLS1.2
TLS_RSA_PSK_AES_128_CBC_SHA256	0x00 0xB6	TLS1.0
TLS_RSA_PSK_NULL_SHA1	0x00 0x2E	TLS1.0
TLS_RSA_PSK_NULL_SHA256	0x00 0xB8	TLS1.0
TLS_RSA_PSK_AES_256_GCM_SHA384	0x00 0xAD	TLS1.2
TLS_RSA_PSK_AES_256_CBC_SHA384	0x00 0xB7	TLS1.0
TLS_RSA_PSK_NULL_SHA384	0x00 0xB9	TLS1.0
TLS_RSA_PSK_CAMELLIA_128_CBC_SHA256	0xC0 0x98	TLS1.0
TLS_RSA_PSK_CAMELLIA_256_CBC_SHA384	0xC0 0x99	TLS1.0
TLS_DHE_PSK_ARCFOUR_128_SHA1	0x00 0x8E	SSL3.0
TLS_DHE_PSK_3DES_EDE_CBC_SHA1	0x00 0x8F	SSL3.0
TLS_DHE_PSK_AES_128_CBC_SHA1	0x00 0x90	SSL3.0
TLS_DHE_PSK_AES_256_CBC_SHA1	0x00 0x91	SSL3.0
TLS_DHE_PSK_AES_128_CBC_SHA256	0x00 0xB2	TLS1.0
TLS_DHE_PSK_AES_128_GCM_SHA256	0x00 0xAA	TLS1.2
TLS_DHE_PSK_NULL_SHA1	0x00 0x2D	SSL3.0
TLS_DHE_PSK_NULL_SHA256	0x00 0xB4	TLS1.0
TLS_DHE_PSK_NULL_SHA384	0x00 0xB5	TLS1.0
TLS_DHE_PSK_AES_256_CBC_SHA384	0x00 0xB3	TLS1.0
TLS_DHE_PSK_AES_256_GCM_SHA384	0x00 0xAB	TLS1.2
TLS_DHE_PSK_CAMELLIA_128_CBC_SHA256	0xC0 0x96	TLS1.0
TLS_DHE_PSK_CAMELLIA_256_CBC_SHA384	0xC0 0x97	TLS1.0
TLS_DHE_PSK_CAMELLIA_128_GCM_SHA256	0xC0 0x90	TLS1.2
TLS_DHE_PSK_CAMELLIA_256_GCM_SHA384	0xC0 0x91	TLS1.2
TLS_PSK_AES_128_CCM	0xC0 0xA4	TLS1.2

TLS_PSK_AES_256_CCM	0xC0 0xA5	TLS1.2
TLS_DHE_PSK_AES_128_CCM	0xC0 0xA6	TLS1.2
TLS_DHE_PSK_AES_256_CCM	0xC0 0xA7	TLS1.2
TLS_PSK_AES_128_CCM_8	0xC0 0xA8	TLS1.2
TLS_PSK_AES_256_CCM_8	0xC0 0xA9	TLS1.2
TLS_DHE_PSK_AES_128_CCM_8	0xC0 0xAA	TLS1.2
TLS_DHE_PSK_AES_256_CCM_8	0xC0 0xAB	TLS1.2
TLS_DHE_PSK_CHACHA20_POLY1305	0xCC 0xA4	TLS1.2
TLS_ECDHE_PSK_CHACHA20_POLY1305	0xCC 0xA6	TLS1.2
TLS_RSA_PSK_CHACHA20_POLY1305	0xCC 0xA7	TLS1.2
TLS_PSK_CHACHA20_POLY1305	0xCC 0xA5	TLS1.2
TLS_DH_ANON_ARCFOUR_128_MD5	0x00 0x18	SSL3.0
TLS_DH_ANON_3DES_EDE_CBC_SHA1	0x00 0x1B	SSL3.0
TLS_DH_ANON_AES_128_CBC_SHA1	0x00 0x34	SSL3.0
TLS_DH_ANON_AES_256_CBC_SHA1	0x00 0x3A	SSL3.0
TLS_DH_ANON_CAMELLIA_128_CBC_SHA256	0x00 0xBF	TLS1.0
TLS_DH_ANON_CAMELLIA_256_CBC_SHA256	0x00 0xC5	TLS1.0
TLS_DH_ANON_CAMELLIA_128_CBC_SHA1	0x00 0x46	SSL3.0
TLS_DH_ANON_CAMELLIA_256_CBC_SHA1	0x00 0x89	SSL3.0
TLS_DH_ANON_AES_128_CBC_SHA256	0x00 0x6C	TLS1.0
TLS_DH_ANON_AES_256_CBC_SHA256	0x00 0x6D	TLS1.0
TLS_DH_ANON_AES_128_GCM_SHA256	0x00 0xA6	TLS1.2
TLS_DH_ANON_AES_256_GCM_SHA384	0x00 0xA7	TLS1.2
TLS_DH_ANON_CAMELLIA_128_GCM_SHA256	0xC0 0x84	TLS1.2
TLS_DH_ANON_CAMELLIA_256_GCM_SHA384	0xC0 0x85	TLS1.2
TLS_ECDH_ANON_NULL_SHA1	0xC0 0x15	SSL3.0
TLS_ECDH_ANON_3DES_EDE_CBC_SHA1	0xC0 0x17	SSL3.0
TLS_ECDH_ANON_AES_128_CBC_SHA1	0xC0 0x18	SSL3.0
TLS_ECDH_ANON_AES_256_CBC_SHA1	0xC0 0x19	SSL3.0
TLS_ECDH_ANON_ARCFOUR_128_SHA1	0xC0 0x16	SSL3.0
TLS_SRP_SHA_3DES_EDE_CBC_SHA1	0xC0 0x1A	SSL3.0
TLS_SRP_SHA_AES_128_CBC_SHA1	0xC0 0x1D	SSL3.0
TLS_SRP_SHA_AES_256_CBC_SHA1	0xC0 0x20	SSL3.0
TLS_SRP_SHA_DSS_3DES_EDE_CBC_SHA1	0xC0 0x1C	SSL3.0
TLS_SRP_SHA_RSA_3DES_EDE_CBC_SHA1	0xC0 0x1B	SSL3.0
TLS_SRP_SHA_DSS_AES_128_CBC_SHA1	0xC0 0x1F	SSL3.0
TLS_SRP_SHA_RSA_AES_128_CBC_SHA1	0xC0 0x1E	SSL3.0
TLS_SRP_SHA_DSS_AES_256_CBC_SHA1	0xC0 0x22	SSL3.0
TLS_SRP_SHA_RSA_AES_256_CBC_SHA1	0xC0 0x21	SSL3.0

Table C.1: The ciphersuites table



Error Codes and Descriptions

The error codes used throughout the library are described below. The return code `GNUTLS_E_SUCCESS` indicates a successful operation, and is guaranteed to have the value 0, so you can use it in logical expressions.

Code	Name	Description
0	<code>GNUTLS_E_SUCCESS</code>	Success.
-3	<code>GNUTLS_E_UNKNOWN_COMPRESSION_ALGORITHM</code>	Could not negotiate a supported compression method.
-6	<code>GNUTLS_E_UNKNOWN_CIPHER_TYPE</code>	The cipher type is unsupported.
-7	<code>GNUTLS_E_LARGE_PACKET</code>	The transmitted packet is too large (EMSGSIZE).
-8	<code>GNUTLS_E_UNSUPPORTED_VERSION_PACKET</code>	A packet with illegal or unsupported version was received.
-9	<code>GNUTLS_E_UNEXPECTED_PACKET_LENGTH</code>	A TLS packet with unexpected length was received.
-10	<code>GNUTLS_E_INVALID_SESSION</code>	The specified session has been invalidated for some reason.
-12	<code>GNUTLS_E_FATAL_ALERT_RECEIVED</code>	A TLS fatal alert has been received.
-15	<code>GNUTLS_E_UNEXPECTED_PACKET</code>	An unexpected TLS packet was received.
-16	<code>GNUTLS_E_WARNING_ALERT_RECEIVED</code>	A TLS warning alert has been received.
-18	<code>GNUTLS_E_ERROR_IN_FINISHED_PACKET</code>	An error was encountered at the TLS Finished packet calculation.

-19	GNUTLS_E.UNEXPECTED_HANDSHAKE_PACKET	An unexpected TLS handshake packet was received.
-21	GNUTLS_E.UNKNOWN_CIPHER_SUITE	Could not negotiate a supported cipher suite.
-22	GNUTLS_E.UNWANTED_ALGORITHM	An algorithm that is not enabled was negotiated.
-23	GNUTLS_E.MPI_SCAN_FAILED	The scanning of a large integer has failed.
-24	GNUTLS_E.DECRYPTION_FAILED	Decryption has failed.
-25	GNUTLS_E.MEMORY_ERROR	Internal error in memory allocation.
-26	GNUTLS_E.DECOMPRESSION_FAILED	Decompression of the TLS record packet has failed.
-27	GNUTLS_E.COMPRESSION_FAILED	Compression of the TLS record packet has failed.
-28	GNUTLS_E.AGAIN	Resource temporarily unavailable, try again.
-29	GNUTLS_E.EXPIRED	The requested session has expired.
-30	GNUTLS_E.DB_ERROR	Error in Database backend.
-31	GNUTLS_E.SRP_PWD_ERROR	Error in password file.
-32	GNUTLS_E.INSUFFICIENT_CREDENTIALS	Insufficient credentials for that request.
-33	GNUTLS_E.HASH_FAILED	Hashing has failed.
-34	GNUTLS_E.BASE64_DECODING_ERROR	Base64 decoding error.
-35	GNUTLS_E.MPI_PRINT_FAILED	Could not export a large integer.
-37	GNUTLS_E.REHANDSHAKE	Rehandshake was requested by the peer.
-38	GNUTLS_E.GOT_APPLICATION_DATA	TLS Application data were received, while expecting handshake data.
-39	GNUTLS_E.RECORD_LIMIT_REACHED	The upper limit of record packet sequence numbers has been reached. Wow!
-40	GNUTLS_E.ENCRYPTION_FAILED	Encryption has failed.
-43	GNUTLS_E.CERTIFICATE_ERROR	Error in the certificate.
-44	GNUTLS_E.PK_ENCRYPTION_FAILED	Public key encryption has failed.
-45	GNUTLS_E.PK_DECRYPTION_FAILED	Public key decryption has failed.
-46	GNUTLS_E.PK_SIGN_FAILED	Public key signing has failed.
-47	GNUTLS_E.X509_UNSUPPORTED_CRITICAL_EXTENSION	Unsupported critical extension in X.509 certificate.
-48	GNUTLS_E.KEY_USAGE_VIOLATION	Key usage violation in certificate has been detected.
-49	GNUTLS_E.NO_CERTIFICATE_FOUND	No certificate was found.
-50	GNUTLS_E.INVALID_REQUEST	The request is invalid.
-51	GNUTLS_E.SHORT_MEMORY_BUFFER	The given memory buffer is too short to hold parameters.

-52	GNUTLS_E_INTERRUPTED	Function was interrupted.
-53	GNUTLS_E_PUSH_ERROR	Error in the push function.
-54	GNUTLS_E_PULL_ERROR	Error in the pull function.
-55	GNUTLS_E_RECEIVED_ILLEGAL_PARAMETER	An illegal parameter has been received.
-56	GNUTLS_E_REQUESTED_DATA_NOT_AVAILABLE	The requested data were not available.
-57	GNUTLS_E_PKCS1_WRONG_PAD	Wrong padding in PKCS1 packet.
-58	GNUTLS_E_RECEIVED_ILLEGAL_EXTENSION	An illegal TLS extension was received.
-59	GNUTLS_E_INTERNAL_ERROR	GnuTLS internal error.
-60	GNUTLS_E_CERTIFICATE_KEY_MISMATCH	The certificate and the given key do not match.
-61	GNUTLS_E_UNSUPPORTED_CERTIFICATE_TYPE	The certificate type is not supported.
-62	GNUTLS_E_X509_UNKNOWN_SAN	Unknown Subject Alternative name in X.509 certificate.
-63	GNUTLS_E_DH_PRIME_UNACCEPTABLE	The Diffie-Hellman prime sent by the server is not acceptable (not long enough).
-64	GNUTLS_E_FILE_ERROR	Error while reading file.
-67	GNUTLS_E_ASN1_ELEMENT_NOT_FOUND	ASN1 parser: Element was not found.
-68	GNUTLS_E_ASN1_IDENTIFIER_NOT_FOUND	ASN1 parser: Identifier was not found
-69	GNUTLS_E_ASN1_DER_ERROR	ASN1 parser: Error in DER parsing.
-70	GNUTLS_E_ASN1_VALUE_NOT_FOUND	ASN1 parser: Value was not found.
-71	GNUTLS_E_ASN1_GENERIC_ERROR	ASN1 parser: Generic parsing error.
-72	GNUTLS_E_ASN1_VALUE_NOT_VALID	ASN1 parser: Value is not valid.
-73	GNUTLS_E_ASN1_TAG_ERROR	ASN1 parser: Error in TAG.
-74	GNUTLS_E_ASN1_TAG_IMPLICIT	ASN1 parser: error in implicit tag
-75	GNUTLS_E_ASN1_TYPE_ANY_ERROR	ASN1 parser: Error in type 'ANY'.
-76	GNUTLS_E_ASN1_SYNTAX_ERROR	ASN1 parser: Syntax error.
-77	GNUTLS_E_ASN1_DER_OVERFLOW	ASN1 parser: Overflow in DER parsing.
-78	GNUTLS_E_TOO_MANY_EMPTY_PACKETS	Too many empty record packets have been received.
-79	GNUTLS_E_OPENPGP_UID_REVOKED	The OpenPGP User ID is revoked.
-80	GNUTLS_E_UNKNOWN_PK_ALGORITHM	An unknown public key algorithm was encountered.
-81	GNUTLS_E_TOO_MANY_HANDSHAKE_PACKETS	Too many handshake packets have been received.
-84	GNUTLS_E_NO_TEMPORARY_RSA_PARAMS	No temporary RSA parameters were found.

-86	GNUTLS_E.NO_COMPRESSION_- ALGORITHMS	No supported compression algorithms have been found.
-87	GNUTLS_E.NO_CIPHER_SUITES	No supported cipher suites have been found.
-88	GNUTLS_E.OPENPGP_GETKEY_FAILED	Could not get OpenPGP key.
-89	GNUTLS_E.PK_SIG_VERIFY_FAILED	Public key signature verification has failed.
-90	GNUTLS_E.ILLEGAL_SRP_USERNAME	The SRP username supplied is illegal.
-91	GNUTLS_E.SRP_PWD_PARSING_ERROR	Parsing error in password file.
-93	GNUTLS_E.NO_TEMPORARY_DH_PARAMS	No temporary DH parameters were found.
-94	GNUTLS_E.OPENPGP_FINGERPRINT_- UNSUPPORTED	The OpenPGP fingerprint is not supported.
-95	GNUTLS_E.X509_UNSUPPORTED_- ATTRIBUTE	The certificate has unsupported attributes.
-96	GNUTLS_E.UNKNOWN_HASH_- ALGORITHM	The hash algorithm is unknown.
-97	GNUTLS_E.UNKNOWN_PKCS_CONTENT_- TYPE	The PKCS structure's content type is unknown.
-98	GNUTLS_E.UNKNOWN_PKCS_BAG_TYPE	The PKCS structure's bag type is unknown.
-99	GNUTLS_E.INVALID_PASSWORD	The given password contains invalid characters.
-100	GNUTLS_E.MAC_VERIFY_FAILED	The Message Authentication Code verification failed.
-101	GNUTLS_E.CONSTRAINT_ERROR	Some constraint limits were reached.
-104	GNUTLS_E.IA_VERIFY_FAILED	Verifying TLS/IA phase checksum failed
-105	GNUTLS_E.UNKNOWN_ALGORITHM	The specified algorithm or protocol is unknown.
-106	GNUTLS_E.UNSUPPORTED_SIGNATURE_- ALGORITHM	The signature algorithm is not supported.
-107	GNUTLS_E.SAFE_RENEGOTIATION_- FAILED	Safe renegotiation failed.
-108	GNUTLS_E.UNSAFE_RENEGOTIATION_- DENIED	Unsafe renegotiation denied.
-109	GNUTLS_E.UNKNOWN_SRP_USERNAME	The SRP username supplied is unknown.
-110	GNUTLS_E.PREMATURE_TERMINATION	The TLS connection was non-properly terminated.
-201	GNUTLS_E.BASE64_ENCODING_ERROR	Base64 encoding error.
-202	GNUTLS_E.INCOMPATIBLE_GCRYPT_- LIBRARY	The crypto library version is too old.
-203	GNUTLS_E.INCOMPATIBLE_LIBTASN1_- LIBRARY	The tasn1 library version is too old.
-204	GNUTLS_E.OPENPGP_KEYRING_ERROR	Error loading the keyring.

-205	GNUTLS_E_X509_UNSUPPORTED_OID	The OID is not supported.
-206	GNUTLS_E_RANDOM_FAILED	Failed to acquire random data.
-207	GNUTLS_E_BASE64_UNEXPECTED_HEADER_ERROR	Base64 unexpected header error.
-208	GNUTLS_E_OPENPGP_SUBKEY_ERROR	Could not find OpenPGP subkey.
-209	GNUTLS_E_CRYPTOP_ALREADY_REGISTERED	There is already a crypto algorithm with lower priority.
-210	GNUTLS_E_HANDSHAKE_TOO_LARGE	The handshake data size is too large.
-211	GNUTLS_E_CRYPTODEV_IOCTL_ERROR	Error interfacing with /dev/crypto
-212	GNUTLS_E_CRYPTODEV_DEVICE_ERROR	Error opening /dev/crypto
-213	GNUTLS_E_CHANNEL_BINDING_NOT_AVAILABLE	Channel binding data not available
-214	GNUTLS_E_BAD_COOKIE	The cookie was bad.
-215	GNUTLS_E_OPENPGP_PREFERRED_KEY_ERROR	The OpenPGP key has not a preferred key set.
-216	GNUTLS_E_INCOMPAT_DSA_KEY_WITH_TLS_PROTOCOL	The given DSA key is incompatible with the selected TLS protocol.
-292	GNUTLS_E_HEARTBEAT_PONG_RECEIVED	A heartbeat pong message was received.
-293	GNUTLS_E_HEARTBEAT_PING_RECEIVED	A heartbeat ping message was received.
-300	GNUTLS_E_PKCS11_ERROR	PKCS #11 error.
-301	GNUTLS_E_PKCS11_LOAD_ERROR	PKCS #11 initialization error.
-302	GNUTLS_E_PARSING_ERROR	Error in parsing.
-303	GNUTLS_E_PKCS11_PIN_ERROR	Error in provided PIN.
-305	GNUTLS_E_PKCS11_SLOT_ERROR	PKCS #11 error in slot
-306	GNUTLS_E_LOCKING_ERROR	Thread locking error
-307	GNUTLS_E_PKCS11_ATTRIBUTE_ERROR	PKCS #11 error in attribute
-308	GNUTLS_E_PKCS11_DEVICE_ERROR	PKCS #11 error in device
-309	GNUTLS_E_PKCS11_DATA_ERROR	PKCS #11 error in data
-310	GNUTLS_E_PKCS11_UNSUPPORTED_FEATURE_ERROR	PKCS #11 unsupported feature
-311	GNUTLS_E_PKCS11_KEY_ERROR	PKCS #11 error in key
-312	GNUTLS_E_PKCS11_PIN_EXPIRED	PKCS #11 PIN expired
-313	GNUTLS_E_PKCS11_PIN_LOCKED	PKCS #11 PIN locked
-314	GNUTLS_E_PKCS11_SESSION_ERROR	PKCS #11 error in session
-315	GNUTLS_E_PKCS11_SIGNATURE_ERROR	PKCS #11 error in signature
-316	GNUTLS_E_PKCS11_TOKEN_ERROR	PKCS #11 error in token
-317	GNUTLS_E_PKCS11_USER_ERROR	PKCS #11 user error
-318	GNUTLS_E_CRYPTOP_INIT_FAILED	The initialization of crypto backend has failed.
-319	GNUTLS_E_TIMEDOUT	The operation timed out
-320	GNUTLS_E_USER_ERROR	The operation was cancelled due to user error

-321	GNUTLS_E.ECC_NO_SUPPORTED_CURVES	No supported ECC curves were found
-322	GNUTLS_E.ECC_UNSUPPORTED_CURVE	The curve is unsupported
-323	GNUTLS_E.PKCS11_REQUESTED_- OBJECT_NOT_AVAILABLE	The requested PKCS #11 object is not available
-324	GNUTLS_E.CERTIFICATE_LIST_- UNSORTED	The provided X.509 certificate list is not sorted (in subject to issuer order)
-325	GNUTLS_E.ILLEGAL_PARAMETER	An illegal parameter was found.
-326	GNUTLS_E.NO_PRIORITIES.WERE_SET	No or insufficient priorities were set.
-327	GNUTLS_E.X509_UNSUPPORTED_- EXTENSION	Unsupported extension in X.509 certificate.
-328	GNUTLS_E.SESSION_EOF	Peer has terminated the connection
-329	GNUTLS_E.TPM_ERROR	TPM error.
-330	GNUTLS_E.TPM_KEY_PASSWORD_ERROR	Error in provided password for key to be loaded in TPM.
-331	GNUTLS_E.TPM_SRK_PASSWORD_ERROR	Error in provided SRK password for TPM.
-332	GNUTLS_E.TPM_SESSION_ERROR	Cannot initialize a session with the TPM.
-333	GNUTLS_E.TPM_KEY_NOT_FOUND	TPM key was not found in persistent storage.
-334	GNUTLS_E.TPM_UNINITIALIZED	TPM is not initialized.
-340	GNUTLS_E.NO_CERTIFICATE_STATUS	There is no certificate status (OCSP).
-341	GNUTLS_E.OCSP_RESPONSE_ERROR	The OCSP response is invalid
-342	GNUTLS_E.RANDOM_DEVICE_ERROR	Error in the system's randomness device.
-343	GNUTLS_E.AUTH_ERROR	Could not authenticate peer.
-344	GNUTLS_E.NO_APPLICATION_PROTOCOL	No common application protocol could be negotiated.
-345	GNUTLS_E.SOCKETS_INIT_ERROR	Error in sockets initialization.
-346	GNUTLS_E.KEY_IMPORT_FAILED	Failed to import the key into store.
-400	GNUTLS_E.SELF_TEST_ERROR	Error while performing self checks.
-401	GNUTLS_E.NO_SELF_TEST	There is no self test for this algorithm.
-402	GNUTLS_E.LIB_IN_ERROR_STATE	An error has been detected in the library and cannot continue operations.
-403	GNUTLS_E.PK_GENERATION_ERROR	Error in public key generation.

Table D.1: The error codes table

GNU Free Documentation License

Version 1.3, 3 November 2008

Copyright © 2000, 2001, 2002, 2007, 2008 Free Software Foundation, Inc.

<http://fsf.org/>

Everyone is permitted to copy and distribute verbatim copies of this license document, but changing it is not allowed.

Preamble

The purpose of this License is to make a manual, textbook, or other functional and useful document “free” in the sense of freedom: to assure everyone the effective freedom to copy and redistribute it, with or without modifying it, either commercially or noncommercially. Secondly, this License preserves for the author and publisher a way to get credit for their work, while not being considered responsible for modifications made by others.

This License is a kind of “copyleft”, which means that derivative works of the document must themselves be free in the same sense. It complements the GNU General Public License, which is a copyleft license designed for free software.

We have designed this License in order to use it for manuals for free software, because free software needs free documentation: a free program should come with manuals providing the same freedoms that the software does. But this License is not limited to software manuals; it can be used for any textual work, regardless of subject matter or whether it is published as a printed book. We recommend this License principally for works whose purpose is instruction or reference.

1. APPLICABILITY AND DEFINITIONS

This License applies to any manual or other work, in any medium, that contains a notice placed by the copyright holder saying it can be distributed under the terms of this License. Such a notice grants a world-wide, royalty-free license, unlimited in duration, to use that work under the conditions stated herein. The “**Document**”, below, refers to any such manual or work. Any member of the public is a licensee, and is addressed as “**you**”. You accept the license if you copy, modify or distribute the work in a way requiring permission under copyright law.

A “**Modified Version**” of the Document means any work containing the Document or a portion of it, either copied verbatim, or with modifications and/or translated into another language.

A “**Secondary Section**” is a named appendix or a front-matter section of the Document that deals exclusively with the relationship of the publishers or authors of the Document to the Document’s overall subject (or to related matters) and contains nothing that could fall directly within that overall subject. (Thus, if the Document is in part a textbook of mathematics, a Secondary Section may not explain any mathematics.) The relationship could be a matter of historical connection with the subject or with related matters, or of legal, commercial, philosophical, ethical or political position regarding them.

The “**Invariant Sections**” are certain Secondary Sections whose titles are designated, as being those of Invariant Sections, in the notice that says that the Document is released under this License. If a section does not fit the above definition of Secondary then it is not allowed to be designated as Invariant. The Document may contain zero Invariant Sections. If the Document does not identify any Invariant Sections then there are none.

The “**Cover Texts**” are certain short passages of text that are listed, as Front-Cover Texts or Back-Cover Texts, in the notice that says that the Document is released under this License. A Front-Cover Text may be at most 5 words, and a Back-Cover Text may be at most 25 words.

A “**Transparent**” copy of the Document means a machine-readable copy, represented in a format whose specification is available to the general public, that is suitable for revising the document straightforwardly with generic text editors or (for images composed of pixels) generic paint programs or (for drawings) some widely available drawing editor, and that is suitable for input to text formatters or for automatic translation to a variety of formats suitable for input to text formatters. A copy made in an otherwise Transparent file format whose markup, or absence of markup, has been arranged to thwart or discourage subsequent modification by readers is not Transparent. An image format is not Transparent if used for any substantial amount of text. A copy that is not “Transparent” is called “**Opaque**”.

Examples of suitable formats for Transparent copies include plain ASCII without markup, Texinfo input format, LaTeX input format, SGML or XML using a publicly available DTD, and standard-conforming simple HTML, PostScript or PDF designed for human modification. Examples of transparent image formats include PNG, XCF and JPG. Opaque formats include proprietary formats that can be read and edited only by proprietary word processors, SGML or XML for which the DTD and/or processing tools are not generally available, and the machine-generated HTML, PostScript or PDF produced by some word processors for output purposes only.

The “**Title Page**” means, for a printed book, the title page itself, plus such following pages as are needed to hold, legibly, the material this License requires to appear in the title page. For works in formats which do not have any title page as such, “Title Page” means the text near the most prominent appearance of the work’s title, preceding the beginning of the body of the text.

The “**publisher**” means any person or entity that distributes copies of the Document to the public.

A section “**Entitled XYZ**” means a named subunit of the Document whose title either is precisely XYZ or contains XYZ in parentheses following text that translates XYZ in another language. (Here XYZ stands for a specific section name mentioned below, such as “**Acknowledgements**”, “**Dedications**”, “**Endorsements**”, or “**History**”). To “**Preserve the Title**” of such a section when you modify the Document means that it remains a section “Entitled XYZ” according to this definition.

The Document may include Warranty Disclaimers next to the notice which states that this License applies to the Document. These Warranty Disclaimers are considered to be included by reference in this License, but only as regards disclaiming warranties: any other implication that these Warranty Disclaimers may have is void and has no effect on the meaning of this License.

2. VERBATIM COPYING

You may copy and distribute the Document in any medium, either commercially or noncommercially, provided that this License, the copyright notices, and the license notice saying this License applies to the Document are reproduced in all copies, and that you add no other conditions whatsoever to those of this License. You may not use technical measures to obstruct or control the reading or further copying of the copies you make or distribute. However, you may accept compensation in exchange for copies. If you distribute a large enough number of copies you must also follow the conditions in section 3.

You may also lend copies, under the same conditions stated above, and you may publicly display copies.

3. COPYING IN QUANTITY

If you publish printed copies (or copies in media that commonly have printed covers) of the Document, numbering more than 100, and the Document’s license notice requires Cover Texts, you must enclose the copies in covers that carry, clearly and legibly, all these Cover Texts: Front-Cover Texts on the front cover, and Back-Cover Texts on the back cover. Both covers must also clearly and legibly identify you as the publisher of these copies. The front cover must present the full title with all words of the title equally prominent and visible. You may add other material on the covers in addition. Copying with changes limited to the covers, as long as they preserve the title of the Document and satisfy these conditions, can be treated as verbatim copying in other respects.

If the required texts for either cover are too voluminous to fit legibly, you should put the first ones listed (as many as fit reasonably) on the actual cover, and continue the rest onto adjacent pages.

If you publish or distribute Opaque copies of the Document numbering more than 100, you must either include a machine-readable Transparent copy along with each Opaque copy, or state in or with each Opaque copy a computer-network location from which the general network-using public has access to download using public-standard network protocols a complete Transparent copy of the Document, free of added material. If you use the latter option, you must take reasonably prudent steps, when you begin distribution of Opaque copies in quantity, to ensure that this Transparent copy will remain thus accessible at the stated location until at least one year after the last time you distribute an Opaque copy (directly or through your agents or retailers) of that edition to the public.

It is requested, but not required, that you contact the authors of the Document well before redistributing any large number of copies, to give them a chance to provide you with an updated version of the Document.

4. MODIFICATIONS

You may copy and distribute a Modified Version of the Document under the conditions of sections 2 and 3 above, provided that you release the Modified Version under precisely this License, with the Modified Version filling the role of the Document, thus licensing distribution and modification of the Modified Version to whoever possesses a copy of it. In addition, you must do these things in the Modified Version:

- A. Use in the Title Page (and on the covers, if any) a title distinct from that of the Document, and from those of previous versions (which should, if there were any, be listed in the History section of the Document). You may use the same title as a previous version if the original publisher of that version gives permission.
- B. List on the Title Page, as authors, one or more persons or entities responsible for authorship of the modifications in the Modified Version, together with at least five of the principal authors of the Document (all of its principal authors, if it has fewer than five), unless they release you from this requirement.
- C. State on the Title page the name of the publisher of the Modified Version, as the publisher.
- D. Preserve all the copyright notices of the Document.
- E. Add an appropriate copyright notice for your modifications adjacent to the other copyright notices.
- F. Include, immediately after the copyright notices, a license notice giving the public permission to use the Modified Version under the terms of this License, in the form shown in the Addendum below.
- G. Preserve in that license notice the full lists of Invariant Sections and required Cover Texts given in the Document's license notice.
- H. Include an unaltered copy of this License.
- I. Preserve the section Entitled "History", Preserve its Title, and add to it an item stating at least the title, year, new authors, and publisher of the Modified Version as given on the Title Page. If there is no section Entitled "History" in the Document, create one stating the title, year, authors, and publisher of the Document as given on its Title Page, then add an item describing the Modified Version as stated in the previous sentence.
- J. Preserve the network location, if any, given in the Document for public access to a Transparent copy of the Document, and likewise the network locations given in the Document for previous versions it was based on. These may be placed in the "History" section. You may omit a network location for a work that was published at least four years before the Document itself, or if the original publisher of the version it refers to gives permission.
- K. For any section Entitled "Acknowledgements" or "Dedications", Preserve the Title of the section, and preserve in the section all the substance and tone of each of the contributor acknowledgements and/or dedications given therein.
- L. Preserve all the Invariant Sections of the Document, unaltered in their text and in their titles. Section numbers or the equivalent are not considered part of the section titles.
- M. Delete any section Entitled "Endorsements". Such a section may not be included in the Modified Version.
- N. Do not retitle any existing section to be Entitled "Endorsements" or to conflict in title with any Invariant Section.
- O. Preserve any Warranty Disclaimers.

If the Modified Version includes new front-matter sections or appendices that qualify as Secondary Sections and contain no material copied from the Document, you may at your option designate some or all of these sections as invariant. To do this, add their titles to the list of Invariant Sections in the Modified Version's license notice. These titles must be distinct from any other section titles.

You may add a section Entitled "Endorsements", provided it contains nothing but endorsements of your Modified Version by various parties—for example, statements of peer review or that the text has been approved by an organization as the authoritative definition of a standard.

You may add a passage of up to five words as a Front-Cover Text, and a passage of up to 25 words as a Back-Cover Text, to the end of the list of Cover Texts in the Modified Version. Only one passage of Front-Cover Text and one of Back-Cover Text may be added by (or through arrangements made by) any one entity. If the Document already includes a cover text for the same cover, previously added by you or by arrangement made by the same entity you are acting on behalf of, you may not add another; but you may replace the old one, on explicit permission from the previous publisher that added the old one.

The author(s) and publisher(s) of the Document do not by this License give permission to use their names for publicity for or to assert or imply endorsement of any Modified Version.

5. COMBINING DOCUMENTS

You may combine the Document with other documents released under this License, under the terms defined in section 4 above for modified versions, provided that you include in the combination all of the Invariant Sections of all of the original documents, unmodified, and list them all as Invariant Sections of your combined work in its license notice, and that you preserve all their Warranty Disclaimers.

The combined work need only contain one copy of this License, and multiple identical Invariant Sections may be replaced with a single copy. If there are multiple Invariant Sections with the same name but different contents, make the title of each such section unique by adding at the end of it, in parentheses, the name of the original author or publisher of that section if known, or else a unique number. Make the same adjustment to the section titles in the list of Invariant Sections in the license notice of the combined work.

In the combination, you must combine any sections Entitled “History” in the various original documents, forming one section Entitled “History”; likewise combine any sections Entitled “Acknowledgements”, and any sections Entitled “Dedications”. You must delete all sections Entitled “Endorsements”.

6. COLLECTIONS OF DOCUMENTS

You may make a collection consisting of the Document and other documents released under this License, and replace the individual copies of this License in the various documents with a single copy that is included in the collection, provided that you follow the rules of this License for verbatim copying of each of the documents in all other respects.

You may extract a single document from such a collection, and distribute it individually under this License, provided you insert a copy of this License into the extracted document, and follow this License in all other respects regarding verbatim copying of that document.

7. AGGREGATION WITH INDEPENDENT WORKS

A compilation of the Document or its derivatives with other separate and independent documents or works, in or on a volume of a storage or distribution medium, is called an “aggregate” if the copyright resulting from the compilation is not used to limit the legal rights of the compilation’s users beyond what the individual works permit. When the Document is included in an aggregate, this License does not apply to the other works in the aggregate which are not themselves derivative works of the Document.

If the Cover Text requirement of section 3 is applicable to these copies of the Document, then if the Document is less than one half of the entire aggregate, the Document’s Cover Texts may be placed on covers that bracket the Document within the aggregate, or the electronic equivalent of covers if the Document is in electronic form. Otherwise they must appear on printed covers that bracket the whole aggregate.

8. TRANSLATION

Translation is considered a kind of modification, so you may distribute translations of the Document under the terms of section 4. Replacing Invariant Sections with translations requires special permission from their copyright holders, but you may include translations of some or all Invariant Sections in addition to the original versions of these Invariant Sections. You may include a translation of this License, and all the license notices in the Document, and any Warranty Disclaimers, provided that you also include the original English version of this License and the original versions of those notices and disclaimers. In case of a disagreement between the translation and the original version of this License or a notice or disclaimer, the original version will prevail.

If a section in the Document is Entitled “Acknowledgements”, “Dedications”, or “History”, the requirement (section 4) to Preserve its Title (section 1) will typically require changing the actual title.

9. TERMINATION

You may not copy, modify, sublicense, or distribute the Document except as expressly provided under this License. Any attempt otherwise to copy, modify, sublicense, or distribute it is void, and will automatically terminate your rights under this License.

However, if you cease all violation of this License, then your license from a particular copyright holder is reinstated (a) provisionally, unless and until the copyright holder explicitly and finally terminates your license, and (b) permanently, if the copyright holder fails to notify you of the violation by some reasonable means prior to 60 days after the cessation.

Moreover, your license from a particular copyright holder is reinstated permanently if the copyright holder notifies you of the violation by some reasonable means, this is the first time you have received notice of violation of this License (for any work) from that copyright holder, and you cure the violation prior to 30 days after your receipt of the notice.

Termination of your rights under this section does not terminate the licenses of parties who have received copies or rights from you under this License. If your rights have been terminated and not permanently reinstated, receipt of a copy of some or all of the same material does not give you any rights to use it.

10. FUTURE REVISIONS OF THIS LICENSE

The Free Software Foundation may publish new, revised versions of the GNU Free Documentation License from time to time. Such new versions will be similar in spirit to the present version, but may differ in detail to address new problems or concerns. See <http://www.gnu.org/copyleft/>.

Each version of the License is given a distinguishing version number. If the Document specifies that a particular numbered version of this License “or any later version” applies to it, you have the option of following the terms and conditions either of that specified version or of any later version that has been published (not as a draft) by the Free Software Foundation. If the Document does not specify a version number of this License, you may choose any version ever published (not as a draft) by the Free Software Foundation. If the Document specifies that a proxy can decide which future versions of this License can be used, that proxy’s public statement of acceptance of a version permanently authorizes you to choose that version for the Document.

11. RELICENSING

“Massive Multiauthor Collaboration Site” (or “MMC Site”) means any World Wide Web server that publishes copyrightable works and also provides prominent facilities for anybody to edit those works. A public wiki that anybody can edit is an example of such a server. A “Massive Multiauthor Collaboration” (or “MMC”) contained in the site means any set of copyrightable works thus published on the MMC site.

“CC-BY-SA” means the Creative Commons Attribution-Share Alike 3.0 license published by Creative Commons Corporation, a not-for-profit corporation with a principal place of business in San Francisco, California, as well as future copyleft versions of that license published by that same organization.

“Incorporate” means to publish or republish a Document, in whole or in part, as part of another Document.

An MMC is “eligible for relicensing” if it is licensed under this License, and if all works that were first published under this License somewhere other than this MMC, and subsequently incorporated in whole or in part into the MMC, (1) had no cover texts or invariant sections, and (2) were thus incorporated prior to November 1, 2008.

The operator of an MMC Site may republish an MMC contained in the site under CC-BY-SA on the same site at any time before August 1, 2009, provided the MMC is eligible for relicensing.

ADDENDUM: How to use this License for your documents

To use this License in a document you have written, include a copy of the License in the document and put the following copyright and license notices just after the title page:

Copyright © YEAR YOUR NAME. Permission is granted to copy, distribute and/or modify this document under the terms of the GNU Free Documentation License, Version 1.3 or any later version published by the Free Software Foundation; with no Invariant Sections, no Front-Cover Texts, and no Back-Cover Texts. A copy of the license is included in the section entitled “GNU Free Documentation License”.

If you have Invariant Sections, Front-Cover Texts and Back-Cover Texts, replace the “with . . . Texts.” line with this:

with the Invariant Sections being LIST THEIR TITLES, with the Front-Cover Texts being LIST, and with the Back-Cover Texts being LIST.

If you have Invariant Sections without Cover Texts, or some other combination of the three, merge those two alternatives to suit the situation.

If your document contains nontrivial examples of program code, we recommend releasing these examples in parallel under your choice of free software license, such as the GNU General Public License, to permit their use in free software.

