

GNU TLS

Transport Layer Security Library for the GNU system
for version 2.2.0, 10 December 2007



Nikos Mavrogiannopoulos
Simon Josefsson (bug-gnutls@gnu.org)

This manual is last updated 10 December 2007 for version 2.2.0 of GNU TLS.

Copyright (C) 2001, 2002, 2003, 2004, 2005, 2006, 2007 Free Software Foundation, Inc.

Permission is granted to copy, distribute and/or modify this document under the terms of the GNU Free Documentation License, Version 1.2 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”.

Table of Contents

1	Preface	1
1.1	Getting Help	1
1.2	Commercial Support	1
1.3	Downloading and Installing	2
1.4	Bug Reports	3
1.5	Contributing	3
2	The Library	5
2.1	General Idea	6
2.2	Error Handling	7
2.3	Memory Handling	7
2.4	Callback Functions	7
3	Introduction to TLS	8
3.1	TLS Layers	8
3.2	The Transport Layer	9
3.3	The TLS Record Protocol	9
3.3.1	Encryption Algorithms Used in the Record Layer	10
3.3.2	Compression Algorithms Used in the Record Layer	10
3.3.3	Weaknesses and Countermeasures	11
3.4	The TLS Alert Protocol	11
3.5	The TLS Handshake Protocol	11
3.5.1	TLS Cipher Suites	12
3.5.2	Client Authentication	12
3.5.3	Resuming Sessions	13
3.5.4	Resuming Internals	13
3.6	TLS Extensions	13
3.6.1	Maximum Fragment Length Negotiation	13
3.6.2	Server Name Indication	14
3.7	Selecting Cryptographic Key Sizes	14
3.8	On SSL 2 and Older Protocols	14
4	Authentication Methods	16
4.1	Certificate Authentication	16
4.1.1	Authentication Using X.509 Certificates	16
4.1.2	Authentication Using OpenPGP Keys	16
4.1.3	Using Certificate Authentication	16
4.2	Anonymous Authentication	18
4.3	Authentication using SRP	18
4.4	Authentication using PSK	19
4.5	Authentication and Credentials	20
4.6	Parameters Stored in Credentials	20

5	More on Certificate Authentication.....	22
5.1	The X.509 Trust Model.....	22
5.1.1	X.509 Certificates.....	22
5.1.2	Verifying X.509 Certificate Paths.....	24
5.1.3	PKCS #10 Certificate Requests.....	25
5.1.4	PKCS #12 Structures	25
5.2	The OpenPGP Trust Model.....	25
5.2.1	OpenPGP Keys	26
5.2.2	Verifying an OpenPGP Key	26
5.3	Digital Signatures.....	27
5.3.1	Supported Algorithms.....	28
5.3.2	Trading Security for Interoperability.....	28
6	How To Use TLS in Application Protocols ..	30
6.1	Separate Ports	30
6.2	Upward Negotiation.....	30
7	How To Use GnuTLS in Applications	32
7.1	Preparation.....	32
7.1.1	Headers.....	32
7.1.2	Version Check.....	32
7.1.3	Debugging	32
7.1.4	Building the Source	32
7.2	Multi-Threaded Applications.....	33
7.3	Client Examples	34
7.3.1	Simple Client Example with Anonymous Authentication ..	34
7.3.2	Simple Client Example with X.509 Certificate Support	36
7.3.3	Obtaining Session Information.....	39
7.3.4	Verifying Peer's Certificate	42
7.3.5	Using a Callback to Select the Certificate to Use.....	49
7.3.6	Client with Resume Capability Example.....	55
7.3.7	Simple Client Example with SRP Authentication.....	58
7.3.8	Simple Client Example with TLS/IA Support	61
7.3.9	Helper Function for TCP Connections	65
7.4	Server Examples	66
7.4.1	Echo Server with X.509 Authentication	66
7.4.2	Echo Server with X.509 Authentication II	71
7.4.3	Echo Server with OpenPGP Authentication	79
7.4.4	Echo Server with SRP Authentication.....	83
7.4.5	Echo Server with Anonymous Authentication	87
7.5	Miscellaneous Examples	91
7.5.1	Checking for an Alert	91
7.5.2	X.509 Certificate Parsing Example	92
7.5.3	Certificate Request Generation	94
7.5.4	PKCS #12 Structure Generation.....	97
7.6	Compatibility with the OpenSSL Library	100
7.7	Opaque PRF Input TLS Extension.....	100

8	Included Programs	101
8.1	Invoking srptool	101
8.2	Invoking gnutls-cli	101
8.3	Invoking gnutls-cli-debug	102
8.4	Invoking gnutls-serv	103
8.4.1	Setting Up a Test HTTPS Server	104
8.5	Invoking certtool	106
9	Function Reference	111
9.1	Core Functions	111
9.2	X.509 Certificate Functions	165
9.3	GnuTLS-extra Functions	213
9.4	OpenPGP Functions	214
9.5	TLS Inner Application (TLS/IA) Functions	221
9.6	Error Codes and Descriptions	227
10	All the Supported Ciphersuites in GnuTLS	233
11	Guile Bindings	235
11.1	Guile Preparations	235
11.2	Guile API Conventions	236
11.2.1	Enumerates and Constants	236
11.2.2	Procedure Names	237
11.2.3	Representation of Binary Data	237
11.2.4	Input and Output	237
11.2.5	Exception Handling	238
11.3	Guile Examples	239
11.3.1	Anonymous Authentication Guile Example	239
11.3.2	OpenPGP Authentication Guile Example	240
11.3.3	Importing OpenPGP Keys Guile Example	242
11.4	Guile Reference	242
11.4.1	Core Interface	243
11.4.2	Extra Interface	251
12	Internal Architecture of GnuTLS	253
12.1	The TLS Protocol	253
12.2	TLS Handshake Protocol	254
12.3	TLS Authentication Methods	255
12.4	TLS Extension Handling	256
12.4.1	Adding a New TLS Extension	256
12.5	Certificate Handling	259

Appendix A	Copying Information	260
A.1	GNU Free Documentation License	260
A.2	GNU Lesser General Public License	266
A.3	GNU General Public License	274
Concept Index		286
Function and Data Index		288
Bibliography		294

1 Preface

This document tries to demonstrate and explain 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 he risks to offer just a false sense of security. Security and the network security terms are very general terms even for computer software thus cannot be easily restricted to a single cryptographic library. For that reason, do not consider a 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 PKI knowledge is assumed in most of it. A good introduction to networking can be found in [STEVENS] (see [Bibliography], page 294) and for Public Key Infrastructure in [GUTPKI] (see [Bibliography], page 294).

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

1.1 Getting Help

A mailing list where users may help each other exists, and you can reach it by sending e-mail to help-gnutls@gnu.org. Archives of the mailing list discussions, and an interface to manage subscriptions, is available through the World Wide Web at <http://lists.gnu.org/mailman/listinfo/help-gnutls>.

A mailing list for developers are also available, see <http://www.gnu.org/software/gnutls/lists.html>.

Bug reports should be sent to bug-gnutls@gnu.org, see See Section 1.4 [Bug Reports], page 3.

1.2 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 provide support related to GnuTLS and would like to be mentioned here, contact the author (see [Section 1.4 \[Bug Reports\]](#), page 3).

1.3 Downloading and Installing

GnuTLS is available for download from the following URL:

<http://www.gnutls.org/download.html>

The latest version is stored in a file, e.g., ‘`gnutls-2.2.0.tar.gz`’ where the ‘2.2.0’ value is the highest version number in the directory.

GnuTLS uses a Linux-like development cycle: even minor version numbers indicate a stable release and a odd minor version number indicates a development release. For example, GnuTLS 1.6.3 denote a stable release since 6 is even, and GnuTLS 1.7.11 denote a development release since 7 is odd.

GnuTLS depends on Libgcrypt, and you will need to install Libgcrypt before installing GnuTLS. Libgcrypt is available from <ftp://ftp.gnupg.org/gcrypt/libgcrypt>. Libgcrypt needs another library, libgpg-error, and you need to install libgpg-error before installing Libgcrypt. Libgpg-error is available from <ftp://ftp.gnupg.org/gcrypt/libgpg-error>.

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.

The compression libraries (libz and lzo) are optional dependencies. You can get libz from <http://www.zlib.net/>. You can get lzo from <http://www.oberhumer.com/opensource/lzo/>. If you do not have lzo installed, GnuTLS will enable an internal copy, called minilzo. Use parameter `--without-lzo` to disable LZO completely. Use parameter `--with-included-lzo` to unconditionally use the internal minilzo copy.

The X.509 part of GnuTLS needs ASN.1 functionality, from a library called libtasn1. A copy of libtasn1 is included in GnuTLS. If you want to install it separately (e.g., to make it possibly to use libtasn1 in other programs), you can get it from <http://www.gnu.org/software/gnutls/download.html>.

The OpenPGP part of GnuTLS-extra needs OpenCDK for parsing OpenPGP packets. A copy of OpenCDK is included in GnuTLS. If you want to install it separately (e.g., to make it possibly to use libtasn1 in other programs), you can get it from <http://www.gnu.org/software/gnutls/download.html>. Use parameter `--with-included-opencdk` to unconditionally use the internal copy of OpenCDK. Use parameter `--disable-openpgp-authentication` to disable the OpenPGP functionality in GnuTLS.

Regarding the Guile bindings, there are additional installation considerations, see [Section 11.1 \[Guile Preparations\]](#), page 235.

A few `configure` options may be relevant, summarized in the table.


```
--disable-srp-authentication
--disable-psk-authentication
--disable-anon-authentication
--disable-extra-pki
--disable-openpgp-authentication
--disable-openssl-compatibility
```

Disable or enable particular features. Generally not recommended.

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

1.4 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:

`'bug-gnutls@gnu.org'`

1.5 Contributing

If you want to submit a patch for inclusion – from solve a typo you discovered, up to adding support for a new feature – you should submit it as a bug report (see [Section 1.4 \[Bug Reports\]](#), [page 3](#)). 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. Use it.

For code contributions, a number of style guides will help you:

- Coding Style. Follow the GNU Standards document (see [\[top\]](#), [page \[undefined\]](#)).

If you normally code using another coding standard, there is no problem, but you should use `'indent'` to reformat the code (see [\[top\]](#), page [\[undefined\]](#)) 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.

2 The Library

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 TLS 1.1 and SSL 3.0 protocols (See [Chapter 3 \[Introduction to TLS\]](#), page 8, for a more detailed description of the protocols), accompanied with the required framework for authentication and public key infrastructure. The library is available under the GNU Lesser GPL license¹. Important features of the GnuTLS library include:

- Support for TLS 1.0, TLS 1.1, and SSL 3.0 protocols.
- Support for both X.509 and OpenPGP certificates.
- Support for handling and verification of certificates.
- Support for SRP for TLS authentication.
- Support for PSK for TLS authentication.
- Support for TLS Extension mechanism.
- Support for TLS Compression Methods.

Additionally GnuTLS provides a limited emulation API for the widely used OpenSSL² library, to ease integration with existing applications.

GnuTLS consists of three independent parts, namely the “TLS protocol part”, the “Certificate part”, and the “Crypto backend” 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 which is partially implemented in the GnuTLS library. The Libtasn1³, a library which offers ASN.1 parsing capabilities, is used for the X.509 certificate parsing functions, and Openssl⁴ is used for the OpenPGP key support in GnuTLS. The “Crypto backend” is provided by the Libgcrypt⁵ library.

In order to ease integration in embedded systems, parts of the GnuTLS library can be disabled at compile time. That way a small library, with the required features, can be generated.

¹ A copy of the license is included in the distribution

² <http://www.openssl.org/>

³ <ftp://ftp.gnupg.org/gcrypt/alpha/gnutls/libtasn1/>

⁴ <ftp://ftp.gnupg.org/gcrypt/alpha/gnutls/openssl/>

⁵ <ftp://ftp.gnupg.org/gcrypt/alpha/libgcrypt/>

2.1 General Idea

A brief description of how GnuTLS works internally is shown at the figure below. This section may be easier to understand after having seen the examples (see [\[examples\]](#), page 32).



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, and some structures needed for the ASN.1 parser. This structure is never modified by any GnuTLS function, except for the deinitialization function which frees all memory allocated in the global structure and is called after the program has permanently finished using GnuTLS.

The credentials structure is used by some authentication methods, such as certificate authentication (see [\[Certificate Authentication\]](#), page 22). A credentials structure may contain certificates, private keys, temporary parameters for diffie hellman or RSA key exchange, and other stuff that may be shared between several TLS sessions.

This structure should be initialized using the appropriate initialization functions. For example an application which uses certificate authentication would probably initialize the credentials, using the appropriate functions, and put its trusted certificates in this structure. The next step is to associate the credentials structure with each TLS session.

A GnuTLS session contains all the required stuff for a session to handle one secure connection. This session calls directly to the transport layer functions, in order to communicate with the peer. Every session has a unique session ID shared with the peer.

Since TLS sessions can be resumed, servers would probably need a database backend to hold the session's parameters. Every GnuTLS session after a successful handshake calls the appropriate backend function (See [\[resume\]](#), page 13, for information on initialization) to store the newly negotiated session. The session database is examined by the server just after having received the client hello⁶, and if the session ID sent by the client, matches a

⁶ The first message in a TLS handshake

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.

2.2 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. An example of a fatal error code 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 [\[gnutls_record_recv\]](#), page 150. 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 [\[gnutls_error_is_fatal\]](#), page 133.

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. See [\[Error Codes\]](#), page 227, for all the error codes.

2.3 Memory Handling

GnuTLS internally handles heap allocated objects differently, depending on the sensitivity of the data they contain. However for performance reasons, the default memory functions do not overwrite sensitive data from memory, nor protect such objects from being written to the swap. In order to change the default behavior the [\[gnutls_global_set_mem_functions\]](#), page 135 function is available which can be used to set other memory handlers than the defaults.

The Libcrypt library on which GnuTLS depends, has such secure memory allocation functions available. These should be used in cases where even the system's swap memory is not considered secure. See the documentation of Libcrypt for more information.

2.4 Callback Functions

There are several cases where GnuTLS may need some 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.

- [\[gnutls_transport_set_push_function\]](#), page 165
- [\[gnutls_transport_set_pull_function\]](#), page 164

Other callback functions such as the one set by [\[gnutls_srp_set_server_credentials_function\]](#), page 162, may require more complicated input, including data to be allocated. These callbacks should allocate and free memory using the functions shown below.

- [\[gnutls_malloc\]](#), page 140
- [\[gnutls_free\]](#), page 134

3 Introduction to TLS

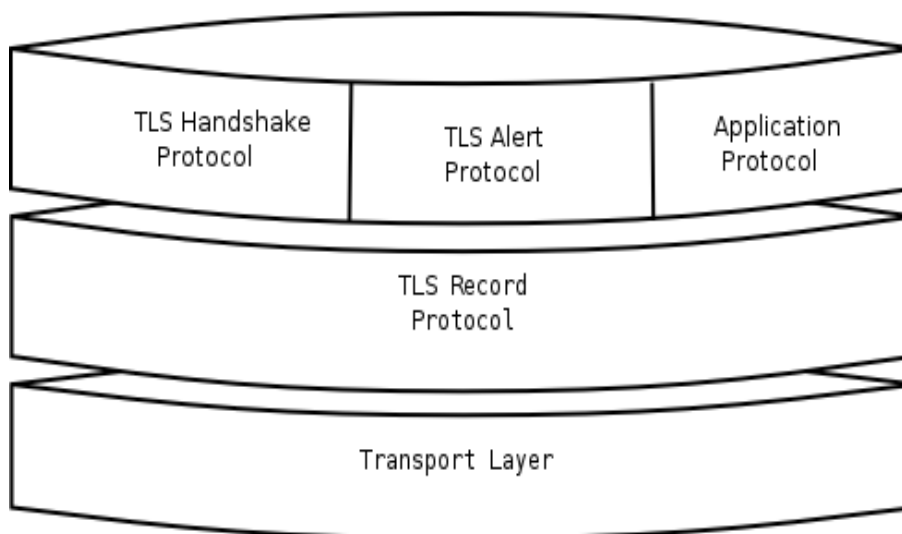
TLS stands for “Transport Layer Security” and is the successor of SSL, the Secure Sockets Layer protocol [SSL3] (see [Bibliography], page 294) designed by Netscape. TLS is an Internet protocol, defined by IETF¹, described in RFC 2246 and also in [RESCOLA] (see [Bibliography], page 294). The protocol provides confidentiality, and authentication layers over any reliable transport layer. The description, below, refers to TLS 1.0 but also applies to TLS 1.1 [RFC4346] (see [Bibliography], page 294) and SSL 3.0, since the differences of these protocols are minor. Older protocols such as SSL 2.0 are not discussed nor implemented in GnuTLS since they are not considered secure today.

3.1 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. See [The Alert Protocol], page 11, 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. See [The Handshake Protocol], page 11, for more information about the handshake protocol. The protocol layering in TLS is shown in the figure below.



¹ IETF, 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.

3.2 The Transport Layer

TLS is not limited to one transport layer, it can be used above any transport layer, as long as it is a reliable one. A set of functions is provided and their purpose is to load to GnuTLS the required callbacks to access the transport layer.

- [\[gnutls_transport_set_push_function\]](#), page 165
- [\[gnutls_transport_set_pull_function\]](#), page 164
- [\[gnutls_transport_set_ptr\]](#), page 164
- [\[gnutls_transport_set_lowat\]](#), page 164
- [\[gnutls_transport_set_errno\]](#), page 163

These functions accept a callback function as a parameter. The callback functions 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 it may be that `errno` is not a 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` and `EAGAIN` `errno` values and returns the corresponding GnuTLS error codes `GNUTLS_E_INTERRUPTED` and `GNUTLS_E_AGAIN`. These values are usually returned by interrupted system calls, or when non blocking IO is used. All GnuTLS functions can be resumed (called again), if any of these error codes is returned. The error codes above refer to the system call, not the GnuTLS function, since signals do not interrupt GnuTLS' functions.

For non blocking sockets or other custom made pull/push functions the [\[gnutls_transport_set_lowat\]](#), page 164 must be called, with a zero low water mark value.

By default, if the transport functions are not set, GnuTLS will use the Berkeley Sockets functions. In this case GnuTLS will use some hacks in order for `select` to work, thus making it easy to add TLS support to existing TCP/IP servers.

3.3 The TLS Record Protocol

The Record protocol is the secure communications provider. Its purpose is to encrypt, authenticate and —optionally— compress packets. The following functions are available:

[\[gnutls_record_send\]](#), page 150:

To send a record packet (with application data).

[\[gnutls_record_recv\]](#), page 150:

To receive a record packet (with application data).

[\[gnutls_record_get_direction\]](#), page 149:

To get the direction of the last interrupted function call.

As you may have already noticed, the functions which access the Record protocol, are quite limited, given the importance of this protocol in TLS. 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.

3.3.1 Encryption Algorithms Used in the Record Layer

Confidentiality in the record layer is achieved by using symmetric block encryption algorithms like 3DES, AES², or stream algorithms like ARCFOUR_128³. Ciphers are encryption algorithms that use a single, secret, key to encrypt and decrypt data. Block algorithms in TLS 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.

Supported cipher algorithms:

3DES_CBC 3DES_CBC 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 is a fast stream cipher.

ARCFOUR_40
This is the ARCFOUR cipher that is fed with a 40 bit key, which is considered weak.

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. This is not officially supported in TLS.

Supported MAC algorithms:

MAC_MD5 MD5 is a cryptographic hash algorithm designed by Ron Rivest. Outputs 128 bits of data.

MAC_SHA SHA is a cryptographic hash algorithm designed by NSA. Outputs 160 bits of data.

3.3.2 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. All the algorithms except for DEFLATE which is referenced in [RFC3749] (see [Bibliography], page 294), should be considered as GnuTLS' extensions⁴, and should be advertised only when the peer is known to have a compliant client, to avoid interoperability problems.

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. As a drawback, compression increases latency.

The record layer compression in GnuTLS is implemented based on the proposal [RFC3749] (see [Bibliography], page 294). The supported compression algorithms are:

DEFLATE Zlib compression, using the deflate algorithm.

² AES, or Advanced Encryption Standard, is actually the RIJNDAEL algorithm. This is the algorithm that replaced DES.

³ ARCFOUR_128 is a compatible algorithm with RSA's RC4 algorithm, which is considered to be a trade secret.

⁴ You should use [gnutls_handshake_set_private_extensions], page 137 to enable private extensions.

LZO LZO is a very fast compression algorithm. This algorithm is only available if the GnuTLS-extra library has been initialized and the private extensions are enabled.

3.3.3 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 [RFC4346] (see [Bibliography], page 294) which is implemented in GnuTLS. For a detailed discussion see the archives of the TLS Working Group mailing list and the paper [CBCATT] (see [Bibliography], page 294).

3.4 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 (see `GNUTLS_A_CLOSE_NOTIFY`), and others refer to the application protocol solely (see `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 renegotiations using the current session ID.

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.

[[gnutls_alert_send](#)], page 111:

To send an alert signal.

[[gnutls_error_to_alert](#)], page 133:

To map a gnutls error number to an alert signal.

[[gnutls_alert_get](#)], page 111:

Returns the last received alert.

[[gnutls_alert_get_name](#)], page 111:

Returns the name, in a character array, of the given alert.

3.5 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. Available functions to control the handshake protocol include:

[[gnutls_priority_init](#)], page 144:

To initialize a priority set of ciphers.

[\[gnutls_priority_deinit\]](#), page 144:

To deinitialize a priority set of ciphers.

[\[gnutls_priority_set\]](#), page 145:

To associate a priority set with a TLS session.

[\[gnutls_priority_set_direct\]](#), page 145:

To directly associate a session with a given priority string.

[\[gnutls_credentials_set\]](#), page 128:

To set the appropriate credentials structures.

[\[gnutls_certificate_server_set_request\]](#), page 117:

To set whether client certificate is required or not.

[\[gnutls_handshake\]](#), page 137:

To initiate the handshake.

3.5.1 TLS Cipher Suites

The Handshake Protocol of TLS negotiates cipher suites of the form `TLS_DHE_RSA_WITH_3DES_CBC_SHA`. The usual cipher suites contain these parameters:

- The key exchange algorithm. `DHE_RSA` in the example.
- The Symmetric encryption algorithm and mode `3DES_CBC` in this example.
- The MAC⁵ 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.

The priority functions, discussed above, allow the application layer to enable and set priorities on the individual ciphers. It may imply that all combinations of ciphersuites are allowed, but this is not true. For several reasons, not discussed here, some combinations were not defined in the TLS protocol. The supported ciphersuites are shown in [\[ciphersuites\]](#), page 233.

3.5.2 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 [\[gnutls_certificate_server_set_request\]](#), page 117 function. If a certificate is to be requested from the client during the handshake, the server will send a certificate request message that contains a list of acceptable certificate signers. In GnuTLS the certificate signers list is constructed using the trusted Certificate Authorities by the server. That is the ones set using

- [\[gnutls_certificate_set_x509_trust_file\]](#), page 122
- [\[gnutls_certificate_set_x509_trust_mem\]](#), page 122

Sending of the names of the CAs can be controlled using [\[gnutls_certificate_send_x509_rdn_sequence\]](#), page 117. The client, then, may send a certificate, signed by one of the server's acceptable signers.

⁵ MAC stands for Message Authentication Code. It can be described as a keyed hash algorithm. See RFC2104.

3.5.3 Resuming Sessions

The [\[gnutls_handshake\]](#), page 137 function, is expensive since a lot of calculations are performed. In order to support many fast connections to the same server a client may use session resuming. **Session resuming** 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 using the previously established keys. GnuTLS supports this feature, and the example (see [\[ex:resume-client\]](#), page 55) illustrates a typical use of it.

Keep in mind that sessions are expired after some time, for security reasons, thus it may be normal for a server not to resume a session even if you requested that. Also note that you must enable, using the priority functions, at least the algorithms used in the last session.

3.5.4 Resuming Internals

The resuming capability, mostly in the server side, is one of the problems of a thread-safe TLS implementations. The problem is that all threads must share information in order to be able to resume sessions. The gnutls approach is, in case of a client, to leave all the burden of resuming to the client. I.e., copy and keep the necessary parameters. See the functions:

- [\[gnutls_session_get_data\]](#), page 156
- [\[gnutls_session_get_id\]](#), page 156
- [\[gnutls_session_set_data\]](#), page 157

The server side is different. A server has to specify some callback functions which store, retrieve and delete session data. These can be registered with:

- [\[gnutls_db_set_remove_function\]](#), page 129
- [\[gnutls_db_set_store_function\]](#), page 129
- [\[gnutls_db_set_retrieve_function\]](#), page 129
- [\[gnutls_db_set_ptr\]](#), page 129

It might also be useful to be able to check for expired sessions in order to remove them, and save space. The function [\[gnutls_db_check_entry\]](#), page 128 is provided for that reason.

3.6 TLS Extensions

A number of extensions to the TLS protocol have been proposed mainly in [TLSEXT] (see [\[Bibliography\]](#), page 294). The extensions supported in GnuTLS are:

- Maximum fragment length negotiation
- Server name indication

and they will be discussed in the subsections that follow.

3.6.1 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. See the [\[gnutls_record_set_max_size\]](#), page 151 and the [\[gnutls_record_get_max_size\]](#), page 150 functions.

3.6.2 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]`, page 155 and `[gnutls_server_name_get]`, page 154 can be used to enable this extension, or to retrieve the name sent by a client.

3.7 Selecting Cryptographic Key Sizes

In TLS, since a lot of algorithms are involved, it is not easy to set a consistent security level. For this reason this section will present some correspondance between key sizes of symmetric algorithms and public key algorithms based on the most conservative values of [SELKEY] (see [Bibliography], page 294). Those can be used to generate certificates with appropriate key sizes as well as parameters for Diffie Hellman and SRP authentication.

Year	Symmetric key size	RSA key size, DH and SRP prime size	ECC key size
1982	56	417	105
1988	61	566	114
2002	72	1028	139
2015	82	1613	173
2028	92	2362	210
2040	101	3214	244
2050	109	4047	272

The first column provides an estimation of the year until these parameters are considered safe and the rest of the columns list the parameters for the various algorithms.

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.

3.8 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 use 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.

4 Authentication Methods

The TLS protocol provides confidentiality and encryption, but also offers authentication, which is a prerequisite for a secure connection. The available authentication methods in GnuTLS are:

- Certificate authentication
- Anonymous authentication
- SRP authentication
- PSK authentication

4.1 Certificate Authentication

4.1.1 Authentication Using X.509 Certificates

X.509 certificates contain the public parameters, of a public key algorithm, and an authority's signature, which proves the authenticity of the parameters. See [Section 5.1 \[The X.509 trust model\]](#), page 22, for more information on X.509 protocols.

4.1.2 Authentication Using OpenPGP Keys

OpenPGP keys also contain public parameters of a public key algorithm, and signatures from several other parties. Depending on whether a signer is trusted the key is considered trusted or not. GnuTLS's OpenPGP authentication implementation is based on the [TLSPGP] (see [\[Bibliography\]](#), page 294) proposal.

See [Section 5.2 \[The OpenPGP trust model\]](#), page 25, for more information about the OpenPGP trust model. For a more detailed introduction to OpenPGP and GnuPG see [\[GPGH\]](#) (see [\[Bibliography\]](#), page 294).

4.1.3 Using Certificate Authentication

In GnuTLS both the OpenPGP and X.509 certificates are part of the certificate authentication and thus are handled using a common API.

When using certificates the server is required to have at least one certificate and private key pair. A client may or may not have such a pair. The certificate and key pair should be loaded, before any TLS session is initialized, in a certificate credentials structure. This should be done by using [\[gnutls_certificate_set_x509_key_file\]](#), page 120 or [\[gnutls_certificate_set_openpgp_key_file\]](#), page 214 depending on the certificate type. In the X.509 case, the functions will also accept and use a certificate list that leads to a trusted authority. The certificate list 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.

As an alternative, a callback may be used so the server or the client specify the certificate and the key at the handshake time. That callback can be set using the functions:

- [\[gnutls_certificate_server_set_retrieve_function\]](#), page 118
- [\[gnutls_certificate_client_set_retrieve_function\]](#), page 115

Certificate verification is possible by loading the trusted authorities into the credentials structure by using [\[gnutls_certificate_set_x509_trust_file\]](#), page 122 or

[[gnutls_certificate_set_openpgp_keyring_file](#)], [page 214](#) for openpgp keys. Note however that the peer's certificate is not automatically verified, you should call [[gnutls_certificate_verify_peers2](#)], [page 124](#), after a successful handshake, to verify the signatures of the certificate. An alternative way, which reports a more detailed verification output, is to use [[gnutls_certificate_get_peers](#)], [page 117](#) to obtain the raw certificate of the peer and verify it using the functions discussed in [Section 5.1 \[The X.509 trust model\]](#), [page 22](#).

In a handshake, the negotiated cipher suite depends on the certificate's parameters, so not all key exchange methods will be available with some 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, but only the DHE_RSA ones. It is recommended not to use RSA keys for both signing and encryption. If possible use the same key for the DHE_RSA and RSA_EXPORT ciphersuites, which use signing, and a different key for the plain RSA ciphersuites, which use encryption. All the key exchange methods shown below are available in certificate authentication.

Note that the DHE key exchange methods are generally slower¹ than plain RSA and require Diffie Hellman parameters to be generated and associated with a credentials structure, by the server. The RSA-EXPORT method also requires 512 bit RSA parameters, that should also be generated and associated with the credentials structure. See the functions:

- [[gnutls_dh_params_generate2](#)], [page 132](#)
- [[gnutls_certificate_set_dh_params](#)], [page 118](#)
- [[gnutls_rsa_params_generate2](#)], [page 153](#)
- [[gnutls_certificate_set_rsa_export_params](#)], [page 118](#)

Sometimes in order to avoid bottlenecks in programs it is usefull to store and read parameters from formats that can be generated by external programs such as `certtool`. This is possible with GnuTLS by using the following functions:

- [[gnutls_dh_params_import_pkcs3](#)], [page 132](#)
- [[gnutls_rsa_params_import_pkcs1](#)], [page 153](#)
- [[gnutls_dh_params_export_pkcs3](#)], [page 131](#)
- [[gnutls_rsa_params_export_pkcs1](#)], [page 152](#)

Key exchange algorithms for OpenPGP and X.509 certificates:

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.

RSA_EXPORT:

The RSA algorithm is used to encrypt a key and send it to the peer. In the EXPORT algorithm, the server signs temporary RSA parameters of 512 bits — which are considered weak — and sends them to the client.

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

¹ It really depends on the group used. Primes with lesser bits are always faster, but also easier to break. Values less than 768 should not be used today

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.

DHE_DSS: The DSS 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. DSS stands for Digital Signature Standard.

4.2 Anonymous Authentication

The anonymous key exchange performs encryption but there is no indication of the identity of the peer. This kind of authentication is vulnerable to a man in the middle attack, but this protocol can be used even if there is no prior communication and trusted parties with the peer, or when full anonymity is required. Unless really required, do not use anonymous authentication. Available key exchange methods are shown below.

Note that the key exchange methods for anonymous authentication require Diffie Hellman parameters to be generated by the server and associated with an anonymous credentials structure.

Supported anonymous key exchange algorithms:

ANON_DH: This algorithm exchanges Diffie Hellman parameters.

4.3 Authentication using SRP

Authentication via the Secure Remote Password protocol, SRP², is supported. The SRP key exchange is an extension to the TLS protocol, and it is a password based authentication (unlike X.509 or OpenPGP that use certificates). The two 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 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. Check [TOMSRP] (see [Bibliography], page 294) for a detailed description of the SRP protocol and the Stanford SRP libraries, which includes a PAM module that synchronizes the system's users passwords with the SRP password files. That way SRP authentication could be used for all the system's users.

The implementation in GnuTLS is based on paper [TLSSRP] (see [Bibliography], page 294). The supported SRP key exchange methods are:

SRP: Authentication using the SRP protocol.

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

² SRP is described in [RFC2945] (see [Bibliography], page 294)

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

If clients supporting SRP know the username and password before the connection, should initialize the client credentials and call the function [\[gnutls_srp_set_client_credentials\]](#), page 161. Alternatively they could specify a callback function by using the function [\[gnutls_srp_set_client_credentials_function\]](#), page 161. This has the advantage that allows probing the server for SRP support. In that case the callback function will be called twice per handshake. The first time is before the ciphersuite is negotiated, and if the callback returns a negative error code, the callback will be called again if SRP has been negotiated. This uses a special TLS-SRP handshake idiom in order to avoid, in interactive applications, to ask the user for SRP password and username if the server does not negotiate an SRP ciphersuite.

In server side the default behaviour of GnuTLS is to read the usernames and SRP verifiers from password files. These password files are the ones used by the *Stanford srp libraries* and can be specified using the [\[gnutls_srp_set_server_credentials_file\]](#), page 161. If a different password file format is to be used, then the function [\[gnutls_srp_set_server_credentials_function\]](#), page 162, should be called, in order to set an appropriate callback.

Some helper functions such as

- [\[gnutls_srp_verifier\]](#), page 162
- [\[gnutls_srp_base64_encode\]](#), page 160
- [\[gnutls_srp_base64_decode\]](#), page 159

are included in GnuTLS, and can be used to generate and maintain SRP verifiers and password files. A program to manipulate the required parameters for SRP authentication is also included. See [\[srptool\]](#), page 101, for more information.

4.4 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 paper [TLSPSK] (see [\[Bibliography\]](#), page 294). 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.

Clients supporting PSK should supply the username and key before the connection to the client credentials by calling the function [\[gnutls_psk_set_client_credentials\]](#), page 148. Alternatively they could specify a callback function by using the function [\[gnutls_psk_set_client_credentials_function\]](#), page 147. This has the advantage that the callback will be called only if PSK has been negotiated.

In server side the default behaviour 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 [\[gnutls_psk_set_server_credentials_file\]](#), page 148. If a different password file format is to be used, then the function [\[gnutls_psk_set_server_credentials_function\]](#), page 148, should be used instead.

Some helper functions such as:

- [\[gnutls_hex_encode\]](#), page 138
- [\[gnutls_hex_decode\]](#), page 138

are included in GnuTLS, and may be used to generate and maintain PSK keys.

4.5 Authentication and Credentials

In GnuTLS every key exchange method is associated with a credentials type. So in order to enable to enable a specific method, the corresponding credentials type should be initialized and set using [\[gnutls_credentials_set\]](#), page 128. A mapping is shown below.

Key exchange algorithms and the corresponding credential types:

Key exchange	Client credentials	Server credentials
KX_RSA		
KX_DHE_RSA		
KX_DHE_DSS		
KX_RSA_EXPORT	CRD_CERTIFICATE	CRD_CERTIFICATE
KX_SRP_RSA	CRD_SRP	CRD_SRP
KX_SRP_DSS		CRD_CERTIFICATE
KX_SRP	CRD_SRP	CRD_SRP
KX_ANON_DH	CRD_ANON	CRD_ANON
KX_PSK	CRD_PSK	CRD_PSK

4.6 Parameters Stored in Credentials

Several parameters such as the ones used for Diffie-Hellman authentication are stored within the credentials structures, so all sessions can access them. Those parameters are stored in structures such as `gnutls_dh_params_t` and `gnutls_rsa_params_t`, and functions like [\[gnutls_certificate_set_dh_params\]](#), page 118 and [\[gnutls_certificate_set_rsa_export_params\]](#), page 118 can be used to associate those parameters with the given credentials structure.

Since those parameters need to be renewed from time to time and a global structure such as the credentials, may not be easy to modify since it is accessible by all sessions, an alternative interface is available using a callback function. This can be set using the [\[gnutls_certificate_set_params_function\]](#), page 118. An example is shown below.

```
#include <gnutls.h>
```

```
gnutls_rsa_params_t rsa_params;
gnutls_dh_params_t dh_params;

/* This function will be called once a session requests DH
 * or RSA parameters. The parameters returned (if any) will
 * be used for the first handshake only.
 */
static int get_params( gnutls_session_t session,
                      gnutls_params_type_t type,
                      gnutls_params_st *st)
{
    if (type == GNUTLS_PARAMS_RSA_EXPORT)
        st->params.rsa_export = rsa_params;
    else if (type == GNUTLS_PARAMS_DH)
        st->params.dh = dh_params;
    else return -1;

    st->type = type;
    /* do not deinitialize those parameters.
     */
    st->deinit = 0;

    return 0;
}

int main()
{
    gnutls_certificate_credentials_t cert_cred;

    initialize_params();

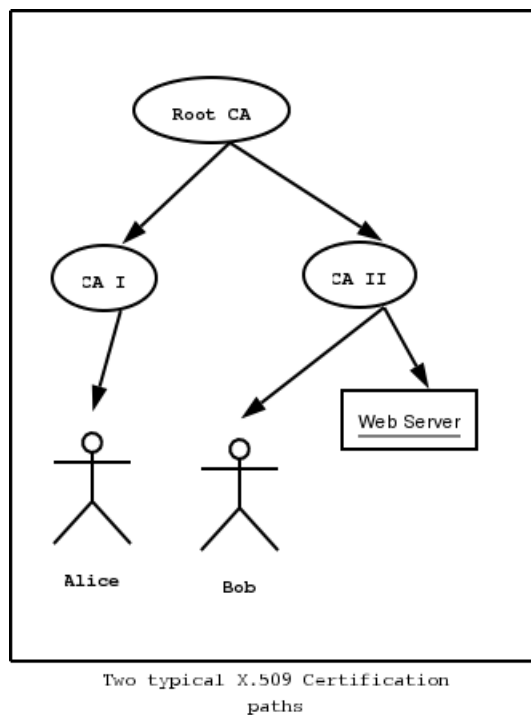
    /* ...
     */

    gnutls_certificate_set_params_function( cert_cred, get_params);
}
```

5 More on Certificate Authentication

5.1 The X.509 Trust Model

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.



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. See the figure above for a typical example. The API for handling X.509 certificates is described at section [\[sec:x509api\]](#), page 165. Some examples are listed below.

5.1.1 X.509 Certificates

An X.509 certificate usually contains information about the certificate holder, the signer, a unique serial number, expiration dates and some other fields [RFC3280] (see [\[Bibliography\]](#), page 294) as shown in the table below.

version: The field that indicates the version of the certificate.

serialNumber:

This field holds a unique serial number per certificate.

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.

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

Certificate *extensions* are there to include information about the certificate's subject that did not fit in the typical certificate fields. 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 table below.

subject key id (2.5.29.14):

An identifier of the key of the subject.

authority key id (2.5.29.35):

An identifier of the authority's key used to sign the certificate.

subject alternative name (2.5.29.17):

Alternative names to subject's distinguished name.

key usage (2.5.29.15):

Constraints the key's usage of the certificate.

extended key usage (2.5.29.37):

Constraints the purpose of the certificate.

basic constraints (2.5.29.19):

Indicates whether this is a CA certificate or not, and specify the maximum path lengths of certificate chains.

CRL distribution points (2.5.29.31):

This extension is set by the CA, in order to inform about the issued CRLs.

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 [RFC3820] (see [\[Bibliography\]](#), [page 294](#)).

In GnuTLS the X.509 certificate structures are handled using the `gnutls_x509_crt_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 at section [\[ex:x509-info\]](#), page 92.

5.1.2 Verifying X.509 Certificate Paths

Verifying certificate paths is important in X.509 authentication. For this purpose the function [\[gnutls_x509_cert_verify\]](#), page 206 is provided. The output of this function is the bitwise OR of the elements of the `gnutls_certificate_status_t` enumeration. A detailed description of these elements can be found in figure below. The function [\[gnutls_certificate_verify_peers2\]](#), page 124 is equivalent to the previous one, and will verify the peer's certificate in a TLS session.

CERT_INVALID:

The certificate is not signed by one of the known authorities, or the signature is invalid.

CERT_REVOKED:

The certificate has been revoked by its CA.

CERT_SIGNER_NOT_FOUND:

The certificate's issuer is not known. This is the case when the issuer is not in the trusted certificates 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.

There is also to possibility to pass some input to the verification functions in the form of flags. For [\[gnutls_x509_cert_verify\]](#), page 206 the flags are passed straightforward, but [\[gnutls_certificate_verify_peers2\]](#), page 124 depends on the flags set by calling [\[gnutls_certificate_set_verify_flags\]](#), page 119. All the available flags are part of the enumeration [\[gnutls_certificate_verify_flags\]](#), page 24 and are explained in the table below.

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_ALLOW_X509_V1_CA_CRT:

Allow only trusted CA certificates that have version 1. This is safer than `GNUTLS_VERIFY_ALLOW_ANY_X509_V1_CA_CRT`, and should be used instead. That way only signers in your trusted list will be allowed to have certificates of version 1.

GNUTLS_VERIFY_ALLOW_ANY_X509_V1_CA_CRT:

Allow CA certificates that have version 1 (both root and intermediate). This is dangerous since those haven't the basicConstraints extension. Must be used in combination with `GNUTLS_VERIFY_ALLOW_X509_V1_CA_CRT`.

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_SIGN_RSA_MD2:

Allow certificates to be signed using the old MD2 algorithm.

GNUTLS_VERIFY_ALLOW_SIGN_RSA_MD5:

Allow certificates to be signed using the broken MD5 algorithm.

Although the verification of a certificate path indicates that the certificate is signed by trusted authority, does not reveal anything about the peer's identity. It is required to verify if the certificate's owner is the one you expect. For more information consult [RFC2818] (see [Bibliography], page 294) and section [ex:verify], page 42 for an example.

5.1.3 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 [RFC2986] (see [Bibliography], page 294). Other certificate request's format such as PKIX's [RFC4211] (see [Bibliography], page 294) are not currently supported.

In GnuTLS the PKCS #10 structures are handled using the `gnutls_x509_crq_t` type. An example of a certificate request generation can be found at section [ex:crq], page 94.

5.1.4 PKCS #12 Structures

A PKCS #12 structure [PKCS12] (see [Bibliography], page 294) usually contains a user's private keys and certificates. It is commonly used in browsers to export and import the user's identities.

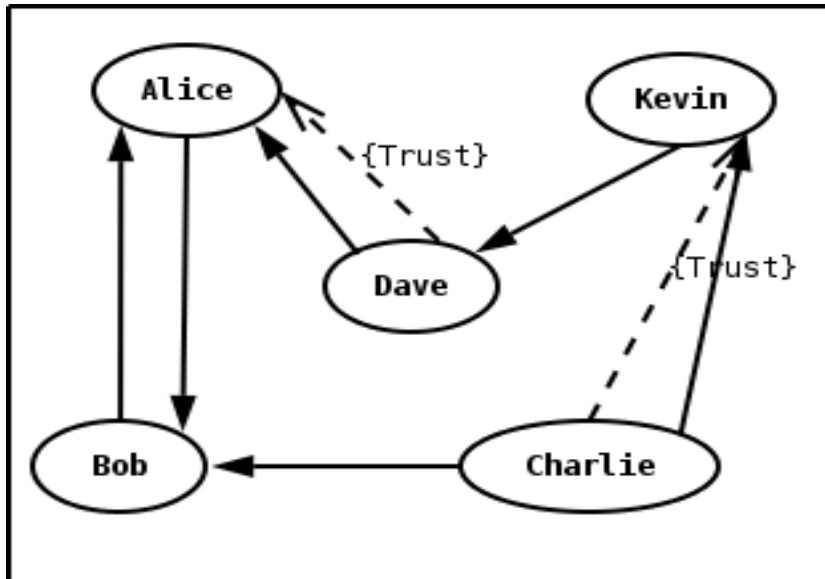
In GnuTLS the PKCS #12 structures are handled using the `gnutls_pkcs12_t` type. This is an abstract type that may hold several `gnutls_pkcs12_bag_t` types. The Bag types are the holders of the actual data, which may be certificates, private keys or encrypted data. An Bag of type encrypted should be decrypted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

An example of a PKCS #12 structure generation can be found at section [ex:pkcs12], page 97.

5.2 The OpenPGP Trust Model

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's else 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.



An example of the
web of trust model

For example: If David trusts Alice to be an introducer, and Alice signed Bob's key, Dave also 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.

5.2.1 OpenPGP Keys

In GnuTLS the OpenPGP key structures [RFC2440] (see [Bibliography], page 294) are handled using the `gnutls_openpgp_crt_t` type and the corresponding private keys with the `gnutls_openpgp_privkey_t` type. All the prototypes for the key handling functions can be found at 'gnutls/openpgp.h'.

5.2.2 Verifying an OpenPGP Key

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 GPGME (http://www.gnupg.org/related_software/gpgme/) is recommended.

There is one verification function in GnuTLS, the [\[gnutls_openpgp_cert_verify_ring\]](#), page 218. 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 valid, if the self signature is ok, even if no signers were found. The meaning of verification status is shown in the figure below.

CERT_INVALID:

A signature on the key is invalid. That means that the key was modified by somebody, or corrupted during transport.

CERT_REVOKED:

The key has been revoked by its owner.

CERT_SIGNER_NOT_FOUND:

The key was not signed by a known signer.

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.

5.3 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 € to Greenpeace and find out that he donated 1.000.000 € 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 $2^{(\text{hash size})/2}$ operations. Today colliding certificates using the MD5 hash algorithm have been generated as shown in [WEGER] (see [Bibliography], page 294).

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^{64} , but it

has been showed to have a collision strength well under 2^{50} . As of November 2005, it is believed that SHA-1's collision strength is around 2^{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^{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.

5.3.1 Supported Algorithms

The available digital signature algorithms in GnuTLS are listed below:

RSA	RSA is public key cryptosystem designed by Ronald Rivest, Adi Shamir and Leonard Adleman. It can be used with any hash functions.
DSA	DSA is the USA's Digital Signature Standard. It uses only the SHA-1 hash algorithm.

The supported cryptographic hash algorithms are:

MD2	MD2 is a cryptographic hash algorithm designed by Ron Rivest. It is optimized for 8-bit processors. Outputs 128 bits of data. There are no known weaknesses of this algorithm but since this algorithm is rarely used and not really studied it should not be used today.
MD5	MD5 is a cryptographic hash algorithm designed by Ron Rivest. Outputs 128 bits of data. It is considered to be broken.
SHA-1	SHA is a cryptographic hash algorithm designed by NSA. Outputs 160 bits of data. It is also considered to be broken, though no practical attacks have been found.
RMD160	RIPEMD is a cryptographic hash algorithm developed in the framework of the EU project RIPE. Outputs 160 bits of data.

5.3.2 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]`, [page 24](#) validation error (see [Section 5.1.2 \[Verifying X.509 certificate paths\]](#), [page 24](#)), 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 fail when attempting to verify 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.

First, 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 signed using RSA-MD2 or RSA-MD5. The only attack today is that it is possible to generate certificates with colliding signatures (collision resistance); you cannot generate a certificate that has the same signature as an already existing signature (2nd preimage resistance).

If you are using `[gnutls_certificate_verify_peers2]`, [page 124](#) to verify the certificate chain, you can call `[gnutls_certificate_set_verify_flags]`, [page 119](#) with the `GNUTLS_VERIFY_ALLOW_SIGN_RSA_MD2` or `GNUTLS_VERIFY_ALLOW_SIGN_RSA_MD5` flag, as in:

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

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

If you are using [\[gnutls_x509_cert_verify\]](#), page 206 or [\[gnutls_x509_cert_list_verify\]](#), page 198, 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 [\[gnutls_certificate_get_peers\]](#), page 117 to extract the raw server's certificate chain, then use [\[gnutls_x509_cert_import\]](#), page 197 to parse each of the certificates, and then use [\[gnutls_x509_cert_get_signature_algorithm\]](#), page 195 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.

6 How To Use TLS in Application Protocols

This chapter is intended to provide some hints on how to use the 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.

6.1 Separate Ports

Traditionally SSL was used in application protocols by assigning a new port number for the secure services. That way two separate ports were assigned, one for the non secure sessions, and one for the secured ones. This has the benefit that if a user requests a secure session then the client will try to connect to the secure port and fail otherwise. The only possible attack with this method is a denial of service one. The most famous example of this method is the famous “HTTP over TLS” or HTTPS protocol [RFC2818] (see [Bibliography], page 294).

Despite its wide use, this method is not as good as it seems. 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 work¹. 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 obsoleted.

6.2 Upward Negotiation

Other application protocols² use a different approach to enable the secure layer. They use something called the “TLS upgrade” method. This method is quite tricky but it is 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 is a really neat idea and does not require an extra port.

This method is used by almost all modern protocols and there is even the [RFC2817] (see [Bibliography], page 294) paper which proposes extensions to HTTP to support it.

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
```

¹ See also the Server Name Indication extension on [serverind], page 14.

² See LDAP, IMAP etc.

*** TLS STARTS

CLIENT: HERE ARE SOME CONFIDENTIAL DATA

And see 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 dummy enough to send the confidential data in the clear.

How to avoid the above attack? As you may have already thought this one 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 file³, or anything else!

³ in SRP authentication

7 How To Use GnuTLS in Applications

7.1 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.

7.1.1 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.

The extra functionality of the GnuTLS-extra library is available by including the header file ‘gnutls/extra.h’ in your programs.

7.1.2 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 startup. See the function [\[gnutls_check_version\]](#), [page 124](#).

7.1.3 Debugging

In many cases things may not go as expected and further information, to assist debugging, from GnuTLS is desired. Those are the case where the [\[gnutls_global_set_log_level\]](#), [page 135](#) and [\[gnutls_global_set_log_function\]](#), [page 135](#) are to be used. Those will print verbose information on the GnuTLS functions internal flow.

7.1.4 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, GnuTLS ships with two small helper programs `libgnutls-config` and `libgnutls-extra-config` that knows about 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 `libgnutls-config`. The following example shows how it can be used at the command line:

```
gcc -c foo.c 'libgnutls-config --cflags'
```

Adding the output of `libgnutls-config --cflags` to the compilers command line will ensure that the compiler can find the GnuTLS 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 `libgnutls-config` can be used. For convenience, this option also outputs all other options that are

required to link the program with the GnuTLS libraries. The example shows how to link ‘foo.o’ with the GnuTLS libraries to a program *foo*.

```
gcc -o foo foo.o 'libgnutls-config --libs'
```

Of course you can also combine both examples to a single command by specifying both options to ‘libgnutls-config’:

```
gcc -o foo foo.c 'libgnutls-config --cflags --libs'
```

7.2 Multi-Threaded Applications

Although the GnuTLS library is thread safe by design, some parts of the crypto backend, such as the random generator, are not. Since *libgcrypt 1.1.92* there was an automatic detection of the thread library used by the application, so most applications wouldn’t need to do any changes to ensure thread-safety. Due to the unportability of the automatic thread detection, this was removed from later releases of *libgcrypt*, so applications have now to register callback functions to ensure proper locking in sensitive parts of *libgcrypt*.

There are helper macros to help you properly initialize the libraries. Examples are shown below.

- POSIX threads

```
#include <gnutls.h>
#include <gcrypt.h>
#include <errno.h>
#include <pthread.h>
GCRY_THREAD_OPTION_PTHREAD_IMPL;

int main()
{
    /* The order matters.
     */
    gcry_control (GCRYCTL_SET_THREAD_CBS, &gcry_threads_pthread);
    gnutls_global_init();
}
```

- GNU PTH threads

```
#include <gnutls.h>
#include <gcrypt.h>
#include <errno.h>
#include <pth.h>
GCRY_THREAD_OPTION_PTH_IMPL;

int main()
{
    gcry_control (GCRYCTL_SET_THREAD_CBS, &gcry_threads_pth);
    gnutls_global_init();
}
```

- Other thread packages

```
/* The gcry_thread_cbs structure must have been
```

```

    * initialized.
    */
    static struct gcry_thread_cbs gcry_threads_other = { ... };

    int main()
    {
        gcry_control (GCRYCTL_SET_THREAD_CBS, &gcry_threads_other);
    }

```

7.3 Client Examples

This section contains examples of TLS and SSL clients, using GnuTLS. Note that these examples contain little or no error checking. Some of the examples require functions implemented by another example.

7.3.1 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 is integrity and privacy protected.

```

/* Copyright 2007 Free Software Foundation
 *
 * Copying and distribution of this file, with or without modification,
 * are permitted in any medium without royalty provided the copyright
 * notice and this notice are preserved.
 */

#ifdef HAVE_CONFIG_H
# include <config.h>
#endif

#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <sys/types.h>
#include <sys/socket.h>
#include <arpa/inet.h>
#include <unistd.h>
#include <gnutls/gnutls.h>

/* A very basic TLS client, with anonymous authentication.
 */

#define MAX_BUF 1024
#define SA struct sockaddr
#define MSG "GET / HTTP/1.0\r\n\r\n"

```



```
extern int tcp_connect (void);
extern void tcp_close (int sd);

int
main (void)
{
    int ret, sd, ii;
    gnutls_session_t session;
    char buffer[MAX_BUF + 1];
    gnutls_anon_client_credentials_t anoncred;
    /* Need to enable anonymous KX specifically. */

    gnutls_global_init ();

    gnutls_anon_allocate_client_credentials (&anoncred);

    /* Initialize TLS session
       */
    gnutls_init (&session, GNUTLS_CLIENT);

    /* Use default priorities */
    gnutls_priority_set_direct (session, "PERFORMANCE:+ANON-DH:!ARCFOUR-128", NULL);

    /* put the anonymous credentials to the current session
       */
    gnutls_credentials_set (session, GNUTLS_CRD_ANON, anoncred);

    /* connect to the peer
       */
    sd = tcp_connect ();

    gnutls_transport_set_ptr (session, (gnutls_transport_ptr_t) sd);

    /* Perform the TLS handshake
       */
    ret = gnutls_handshake (session);

    if (ret < 0)
    {
        fprintf (stderr, "*** Handshake failed\n");
        gnutls_perror (ret);
        goto end;
    }
    else
    {
        printf ("- Handshake was completed\n");
    }
}
```

```

gnutls_record_send (session, MSG, strlen (MSG));

ret = gnutls_record_recv (session, buffer, MAX_BUF);
if (ret == 0)
{
    printf ("- Peer has closed the TLS connection\n");
    goto end;
}
else if (ret < 0)
{
    fprintf (stderr, "*** Error: %s\n", gnutls_strerror (ret));
    goto end;
}

printf ("- Received %d bytes: ", ret);
for (ii = 0; ii < ret; ii++)
{
    fputc (buffer[ii], stdout);
}
fputs ("\n", stdout);

gnutls_bye (session, GNUTLS_SHUT_RDWR);

end:

tcp_close (sd);

gnutls_deinit (session);

gnutls_anon_free_client_credentials (anoncred);

gnutls_global_deinit ();

return 0;
}

```

7.3.2 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, it does not support session resuming, not even certificate verification. The TCP functions defined in this example are used in most of the other examples below, without redefining them.

```

/* Copyright 2007 Free Software Foundation
 *
 * Copying and distribution of this file, with or without modification,

```

```
* are permitted in any medium without royalty provided the copyright
* notice and this notice are preserved.
*/

#if HAVE_CONFIG_H
# include <config.h>
#endif

#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <sys/types.h>
#include <sys/socket.h>
#include <arpa/inet.h>
#include <unistd.h>
#include <gnutls/gnutls.h>

/* A very basic TLS client, with X.509 authentication.
*/

#define MAX_BUF 1024
#define CAFILE "ca.pem"
#define MSG "GET / HTTP/1.0\r\n\r\n"

extern int tcp_connect (void);
extern void tcp_close (int sd);

int
main (void)
{
    int ret, sd, ii;
    gnutls_session_t session;
    char buffer[MAX_BUF + 1];
    const char *err;
    gnutls_certificate_credentials_t xcred;

    gnutls_global_init ();

    /* X509 stuff */
    gnutls_certificate_allocate_credentials (&xcred);

    /* sets the trusted cas file
    */
    gnutls_certificate_set_x509_trust_file (xcred, CAFILE, GNUTLS_X509_FMT_PEM);

    /* Initialize TLS session
    */
```

```
gnutls_init (&session, GNUTLS_CLIENT);

/* Use default priorities */
ret = gnutls_priority_set_direct (session, "PERFORMANCE", &err);
if (ret < 0) {
    if (ret == GNUTLS_E_INVALID_REQUEST) {
        fprintf(stderr, "Syntax error at: %s\n", err);
    }
    exit(1);
}

/* put the x509 credentials to the current session
 */
gnutls_credentials_set (session, GNUTLS_CRD_CERTIFICATE, xcred);

/* connect to the peer
 */
sd = tcp_connect ();

gnutls_transport_set_ptr (session, (gnutls_transport_ptr_t) sd);

/* Perform the TLS handshake
 */
ret = gnutls_handshake (session);

if (ret < 0)
{
    fprintf (stderr, "*** Handshake failed\n");
    gnutls_perror (ret);
    goto end;
}
else
{
    printf ("- Handshake was completed\n");
}

gnutls_record_send (session, MSG, strlen (MSG));

ret = gnutls_record_recv (session, buffer, MAX_BUF);
if (ret == 0)
{
    printf ("- Peer has closed the TLS connection\n");
    goto end;
}
else if (ret < 0)
{
    fprintf (stderr, "*** Error: %s\n", gnutls_strerror (ret));
}
```

```

        goto end;
    }

    printf ("- Received %d bytes: ", ret);
    for (ii = 0; ii < ret; ii++)
    {
        fputc (buffer[ii], stdout);
    }
    fputs ("\n", stdout);

    gnutls_bye (session, GNUTLS_SHUT_RDWR);

end:

    tcp_close (sd);

    gnutls_deinit (session);

    gnutls_certificate_free_credentials (xcred);

    gnutls_global_deinit ();

    return 0;
}

```

7.3.3 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 [\[gnutls_handshake\]](#), [page 137](#).

```

/* Copyright 2007 Free Software Foundation
 *
 * Copying and distribution of this file, with or without modification,
 * are permitted in any medium without royalty provided the copyright
 * notice and this notice are preserved.
 */

#ifdef HAVE_CONFIG_H
# include <config.h>
#endif

#include <stdio.h>
#include <stdlib.h>
#include <gnutls/gnutls.h>
#include <gnutls/x509.h>

```

```

extern void print_x509_certificate_info (gnutls_session_t);

/* This function will print some details of the
 * given session.
 */
int
print_info (gnutls_session_t session)
{
    const char *tmp;
    gnutls_credentials_type_t cred;
    gnutls_kx_algorithm_t kx;

    /* print the key exchange's algorithm name
     */
    kx = gnutls_kx_get (session);
    tmp = gnutls_kx_get_name (kx);
    printf ("- Key Exchange: %s\n", tmp);

    /* Check the authentication type used and switch
     * to the appropriate.
     */
    cred = gnutls_auth_get_type (session);
    switch (cred)
    {
        case GNUTLS_CRD_IA:
            printf ("- TLS/IA session\n");
            break;

        case GNUTLS_CRD_SRP:
            printf ("- SRP session with username %s\n",
                    gnutls_srp_server_get_username (session));
            break;

        case GNUTLS_CRD_PSK:
            if (gnutls_psk_server_get_username (session) != NULL)
                printf ("- PSK authentication. Connected as '%s'\n",
                        gnutls_psk_server_get_username (session));
            break;

        case GNUTLS_CRD_ANON:          /* anonymous authentication */

            printf ("- Anonymous DH using prime of %d bits\n",
                    gnutls_dh_get_prime_bits (session));
            break;

        case GNUTLS_CRD_CERTIFICATE:    /* certificate authentication */

```

```

    /* Check if we have been using ephemeral Diffie Hellman.
    */
    if (kx == GNUTLS_KX_DHE_RSA || kx == GNUTLS_KX_DHE_DSS)
    {
        printf ("\n- Ephemeral DH using prime of %d bits\n",
                gnutls_dh_get_prime_bits (session));
    }

    /* if the certificate list is available, then
    * print some information about it.
    */
    print_x509_certificate_info (session);

}                                     /* switch */

/* print the protocol's name (ie TLS 1.0)
*/
tmp = gnutls_protocol_get_name (gnutls_protocol_get_version (session));
printf ("- Protocol: %s\n", tmp);

/* print the certificate type of the peer.
* ie X.509
*/
tmp =
    gnutls_certificate_type_get_name (gnutls_certificate_type_get (session));

printf ("- Certificate Type: %s\n", tmp);

/* print the compression algorithm (if any)
*/
tmp = gnutls_compression_get_name (gnutls_compression_get (session));
printf ("- Compression: %s\n", tmp);

/* print the name of the cipher used.
* ie 3DES.
*/
tmp = gnutls_cipher_get_name (gnutls_cipher_get (session));
printf ("- Cipher: %s\n", tmp);

/* Print the MAC algorithms name.
* ie SHA1
*/
tmp = gnutls_mac_get_name (gnutls_mac_get (session));
printf ("- MAC: %s\n", tmp);

return 0;

```

```
}
```

7.3.4 Verifying Peer's Certificate

A TLS session is not secure just after the handshake procedure has finished. It must be considered secure, only after the peer's certificate and identity have been verified. That is, you have to verify the signature in peer's certificate, the hostname in the certificate, and expiration dates. Just after this step you should treat the connection as being a secure one.

```
/* Copyright 2007 Free Software Foundation
 *
 * Copying and distribution of this file, with or without modification,
 * are permitted in any medium without royalty provided the copyright
 * notice and this notice are preserved.
 */

#if HAVE_CONFIG_H
# include <config.h>
#endif

#include <stdio.h>
#include <gnutls/gnutls.h>
#include <gnutls/x509.h>

/* This function will try to verify the peer's certificate, and
 * also check if the hostname matches, and the activation, expiration dates.
 */
void
verify_certificate (gnutls_session_t session, const char *hostname)
{
    unsigned int status;
    const gnutls_datum_t *cert_list;
    unsigned int cert_list_size;
    int ret;
    gnutls_x509_crt_t cert;

    /* This verification function uses the trusted CAs in the credentials
     * structure. So you must have installed one or more CA certificates.
     */
    ret = gnutls_certificate_verify_peers2 (session, &status);

    if (ret < 0)
    {
        printf ("Error\n");
        return;
    }
}
```



```
if (status & GNUTLS_CERT_INVALID)
    printf ("The certificate is not trusted.\n");

if (status & GNUTLS_CERT_SIGNER_NOT_FOUND)
    printf ("The certificate hasn't got a known issuer.\n");

if (status & GNUTLS_CERT_REVOKED)
    printf ("The certificate has been revoked.\n");

/* Up to here the process is the same for X.509 certificates and
 * OpenPGP keys. From now on X.509 certificates are assumed. This can
 * be easily extended to work with openpgp keys as well.
 */
if (gnutls_certificate_type_get (session) != GNUTLS_CERT_X509)
    return;

if (gnutls_x509_crt_init (&cert) < 0)
{
    printf ("error in initialization\n");
    return;
}

cert_list = gnutls_certificate_get_peers (session, &cert_list_size);
if (cert_list == NULL)
{
    printf ("No certificate was found!\n");
    return;
}

/* This is not a real world example, since we only check the first
 * certificate in the given chain.
 */
if (gnutls_x509_crt_import (cert, &cert_list[0], GNUTLS_X509_FMT_DER) < 0)
{
    printf ("error parsing certificate\n");
    return;
}

/* Beware here we do not check for errors.
 */
if (gnutls_x509_crt_get_expiration_time (cert) < time (0))
{
    printf ("The certificate has expired\n");
    return;
}
```

```

    if (gnutls_x509_cert_get_activation_time (cert) > time (0))
    {
        printf ("The certificate is not yet activated\n");
        return;
    }

    if (!gnutls_x509_cert_check_hostname (cert, hostname))
    {
        printf ("The certificate's owner does not match hostname '%s'\n",
                hostname);
        return;
    }

    gnutls_x509_cert_deinit (cert);

    return;
}

```

An other example is listed below which provides a more detailed verification output.

```

/* Copyright 2007 Free Software Foundation
 *
 * Copying and distribution of this file, with or without modification,
 * are permitted in any medium without royalty provided the copyright
 * notice and this notice are preserved.
 */

#ifdef HAVE_CONFIG_H
# include <config.h>
#endif

#include <stdio.h>
#include <stdlib.h>
#include <gnutls/gnutls.h>
#include <gnutls/x509.h>

/* All the available CRLs
 */
gnutls_x509_crl_t *crl_list;
int crl_list_size;

/* All the available trusted CAs
 */
gnutls_x509_cert_t *ca_list;
int ca_list_size;

static void verify_cert2 (gnutls_x509_cert_t crt,
                          gnutls_x509_cert_t issuer,

```

```

                                gnutls_x509_crl_t * crl_list, int crl_list_size);
static void verify_last_cert (gnutls_x509_crt_t crt,
                                gnutls_x509_crt_t * ca_list, int ca_list_size,
                                gnutls_x509_crl_t * crl_list,
                                int crl_list_size);

/* This function will try to verify the peer's certificate chain, and
 * also check if the hostname matches, and the activation, expiration dates.
 */
void
verify_certificate_chain (gnutls_session_t session,
                        const char *hostname,
                        const gnutls_datum_t * cert_chain,
                        int cert_chain_length)
{
    int i;
    gnutls_x509_crt_t *cert;

    cert = malloc (sizeof (*cert) * cert_chain_length);

    /* Import all the certificates in the chain to
     * native certificate format.
     */
    for (i = 0; i < cert_chain_length; i++)
    {
        gnutls_x509_crt_init (&cert[i]);
        gnutls_x509_crt_import (cert[i], &cert_chain[i], GNUTLS_X509_FMT_DER);
    }

    /* If the last certificate in the chain is self signed ignore it.
     * That is because we want to check against our trusted certificate
     * list.
     */
    if (gnutls_x509_crt_check_issuer (cert[cert_chain_length - 1],
                                      cert[cert_chain_length - 1]) > 0
        && cert_chain_length > 0)
    {
        cert_chain_length--;
    }

    /* Now verify the certificates against their issuers
     * in the chain.
     */
    for (i = 1; i < cert_chain_length; i++)
    {
        verify_cert2 (cert[i - 1], cert[i], crl_list, crl_list_size);
    }
}

```

```

    }

    /* Here we must verify the last certificate in the chain against
     * our trusted CA list.
     */
    verify_last_cert (cert[cert_chain_length - 1],
                     ca_list, ca_list_size, crl_list, crl_list_size);

    /* Check if the name in the first certificate matches our destination!
     */
    if (!gnutls_x509_cert_check_hostname (cert[0], hostname))
    {
        printf ("The certificate's owner does not match hostname '%s'\n",
                hostname);
    }

    for (i = 0; i < cert_chain_length; i++)
        gnutls_x509_cert_deinit (cert[i]);

    return;
}

/* Verifies a certificate against an other certificate
 * which is supposed to be it's issuer. Also checks the
 * crl_list if the certificate is revoked.
 */
static void
verify_cert2 (gnutls_x509_cert_t crt, gnutls_x509_cert_t issuer,
              gnutls_x509_crl_t * crl_list, int crl_list_size)
{
    unsigned int output;
    int ret;
    time_t now = time (0);
    size_t name_size;
    char name[64];

    /* Print information about the certificates to
     * be checked.
     */
    name_size = sizeof (name);
    gnutls_x509_cert_get_dn (crt, name, &name_size);

    fprintf (stderr, "\nCertificate: %s\n", name);

    name_size = sizeof (name);
    gnutls_x509_cert_get_issuer_dn (crt, name, &name_size);

```

```
fprintf (stderr, "Issued by: %s\n", name);

/* Get the DN of the issuer cert.
 */
name_size = sizeof (name);
gnutls_x509_cert_get_dn (issuer, name, &name_size);

fprintf (stderr, "Checking against: %s\n", name);

/* Do the actual verification.
 */
gnutls_x509_cert_verify (crt, &issuer, 1, 0, &output);

if (output & GNUTLS_CERT_INVALID)
{
    fprintf (stderr, "Not trusted");

    if (output & GNUTLS_CERT_SIGNER_NOT_FOUND)
        fprintf (stderr, ": no issuer was found");
    if (output & GNUTLS_CERT_SIGNER_NOT_CA)
        fprintf (stderr, ": issuer is not a CA");

    fprintf (stderr, "\n");
}
else
    fprintf (stderr, "Trusted\n");

/* Now check the expiration dates.
 */
if (gnutls_x509_cert_get_activation_time (crt) > now)
    fprintf (stderr, "Not yet activated\n");

if (gnutls_x509_cert_get_expiration_time (crt) < now)
    fprintf (stderr, "Expired\n");

/* Check if the certificate is revoked.
 */
ret = gnutls_x509_cert_check_revocation (crt, crl_list, crl_list_size);
if (ret == 1)
{
    /* revoked */
    fprintf (stderr, "Revoked\n");
}
}
```

```

/* Verifies a certificate against our trusted CA list.
 * Also checks the crl_list if the certificate is revoked.
 */
static void
verify_last_cert (gnutls_x509_cert_t crt,
                  gnutls_x509_cert_t * ca_list, int ca_list_size,
                  gnutls_x509_crl_t * crl_list, int crl_list_size)
{
    unsigned int output;
    int ret;
    time_t now = time (0);
    size_t name_size;
    char name[64];

    /* Print information about the certificates to
     * be checked.
     */
    name_size = sizeof (name);
    gnutls_x509_cert_get_dn (crt, name, &name_size);

    fprintf (stderr, "\nCertificate: %s\n", name);

    name_size = sizeof (name);
    gnutls_x509_cert_get_issuer_dn (crt, name, &name_size);

    fprintf (stderr, "Issued by: %s\n", name);

    /* Do the actual verification.
     */
    gnutls_x509_cert_verify (crt, ca_list, ca_list_size,
                             GNUTLS_VERIFY_ALLOW_X509_V1_CA_CRT, &output);

    if (output & GNUTLS_CERT_INVALID)
    {
        fprintf (stderr, "Not trusted");

        if (output & GNUTLS_CERT_SIGNER_NOT_CA)
            fprintf (stderr, ": Issuer is not a CA\n");
        else
            fprintf (stderr, "\n");
    }
    else
        fprintf (stderr, "Trusted\n");

    /* Now check the expiration dates.
     */

```

```

if (gnutls_x509_cert_get_activation_time (crt) > now)
    fprintf (stderr, "Not yet activated\n");

if (gnutls_x509_cert_get_expiration_time (crt) < now)
    fprintf (stderr, "Expired\n");

/* Check if the certificate is revoked.
   */
ret = gnutls_x509_cert_check_revocation (crt, crl_list, crl_list_size);
if (ret == 1)
    {
        /* revoked */
        fprintf (stderr, "Revoked\n");
    }
}

```

7.3.5 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.

```

/* Copyright 2007 Free Software Foundation
 *
 * Copying and distribution of this file, with or without modification,
 * are permitted in any medium without royalty provided the copyright
 * notice and this notice are preserved.
 */

#ifdef HAVE_CONFIG_H
# include <config.h>
#endif

#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <sys/types.h>
#include <sys/socket.h>
#include <arpa/inet.h>
#include <unistd.h>
#include <gnutls/gnutls.h>
#include <gnutls/x509.h>
#include <sys/types.h>
#include <sys/stat.h>
#include <fcntl.h>

/* A TLS client that loads the certificate and key.
 */

```

```

#define MAX_BUF 1024
#define MSG "GET / HTTP/1.0\r\n\r\n"

#define CERT_FILE "cert.pem"
#define KEY_FILE "key.pem"
#define CAFILE "ca.pem"

extern int tcp_connect (void);
extern void tcp_close (int sd);

static int cert_callback (gnutls_session_t session,
                          const gnutls_datum_t * req_ca_rdn, int nreqs,
                          const gnutls_pk_algorithm_t * sign_algos,
                          int sign_algos_length, gnutls_retr_st * st);

gnutls_x509_crt_t crt;
gnutls_x509_privkey_t key;

/* Helper functions to load a certificate and key
 * files into memory.
 */
static gnutls_datum_t
load_file (const char *file)
{
    FILE *f;
    gnutls_datum_t loaded_file = { NULL, 0 };
    long filelen;
    void *ptr;

    if (!(f = fopen(file, "r")))
        || fseek(f, 0, SEEK_END) != 0
        || (filelen = ftell(f)) < 0
        || fseek(f, 0, SEEK_SET) != 0
        || !(ptr = malloc((size_t)filelen))
        || fread(ptr, 1, (size_t)filelen, f) < (size_t)filelen)
    {
        return loaded_file;
    }

    loaded_file.data = ptr;
    loaded_file.size = (unsigned int)filelen;
    return loaded_file;
}

static void unload_file(gnutls_datum_t data)
{
    free(data.data);
}

```



```
}

/* Load the certificate and the private key.
 */
static void
load_keys (void)
{
    int ret;
    gnutls_datum_t data;

    data = load_file (CERT_FILE);
    if (data.data == NULL)
    {
        fprintf (stderr, "*** Error loading cert file.\n");
        exit (1);
    }
    gnutls_x509_crt_init (&crt);

    ret = gnutls_x509_crt_import (crt, &data, GNUTLS_X509_FMT_PEM);
    if (ret < 0)
    {
        fprintf (stderr, "*** Error loading key file: %s\n",
                 gnutls_strerror (ret));
        exit (1);
    }

    unload_file (data);

    data = load_file (KEY_FILE);
    if (data.data == NULL)
    {
        fprintf (stderr, "*** Error loading key file.\n");
        exit (1);
    }

    gnutls_x509_privkey_init (&key);

    ret = gnutls_x509_privkey_import (key, &data, GNUTLS_X509_FMT_PEM);
    if (ret < 0)
    {
        fprintf (stderr, "*** Error loading key file: %s\n",
                 gnutls_strerror (ret));
        exit (1);
    }

    unload_file (data);
```

```
}

int
main (void)
{
    int ret, sd, ii;
    gnutls_session_t session;
    gnutls_priority_t priorities_cache;
    char buffer[MAX_BUF + 1];
    gnutls_certificate_credentials_t xcred;
    /* Allow connections to servers that have OpenPGP keys as well.
       */

    gnutls_global_init ();

    load_keys ();

    /* X509 stuff */
    gnutls_certificate_allocate_credentials (&xcred);

    /* priorities */
    gnutls_priority_init( &priorities_cache, "NORMAL", NULL);

    /* sets the trusted cas file
       */
    gnutls_certificate_set_x509_trust_file (xcred, CAFILE, GNUTLS_X509_FMT_PEM);

    gnutls_certificate_client_set_retrieve_function (xcred, cert_callback);

    /* Initialize TLS session
       */
    gnutls_init (&session, GNUTLS_CLIENT);

    /* Use default priorities */
    gnutls_priority_set (session, priorities_cache);

    /* put the x509 credentials to the current session
       */
    gnutls_credentials_set (session, GNUTLS_CRD_CERTIFICATE, xcred);

    /* connect to the peer
       */
    sd = tcp_connect ();

    gnutls_transport_set_ptr (session, (gnutls_transport_ptr_t) sd);
```

```

/* Perform the TLS handshake
 */
ret = gnutls_handshake (session);

if (ret < 0)
{
    fprintf (stderr, "*** Handshake failed\n");
    gnutls_perror (ret);
    goto end;
}
else
{
    printf ("- Handshake was completed\n");
}

gnutls_record_send (session, MSG, strlen (MSG));

ret = gnutls_record_recv (session, buffer, MAX_BUF);
if (ret == 0)
{
    printf ("- Peer has closed the TLS connection\n");
    goto end;
}
else if (ret < 0)
{
    fprintf (stderr, "*** Error: %s\n", gnutls_strerror (ret));
    goto end;
}

printf ("- Received %d bytes: ", ret);
for (ii = 0; ii < ret; ii++)
{
    fputc (buffer[ii], stdout);
}
fputs ("\n", stdout);

gnutls_bye (session, GNUTLS_SHUT_RDWR);

end:

tcp_close (sd);

gnutls_deinit (session);

gnutls_certificate_free_credentials (xcred);
gnutls_priority_deinit (priorities_cache);

```

```

    gnutls_global_deinit ();

    return 0;
}

/* This callback should be associated with a session by calling
 * gnutls_certificate_client_set_retrieve_function( session, cert_callback),
 * before a handshake.
 */

static int
cert_callback (gnutls_session_t session,
               const gnutls_datum_t * req_ca_rdn, int nreqs,
               const gnutls_pk_algorithm_t * sign_algos,
               int sign_algos_length, gnutls_retr_st * st)
{
    char issuer_dn[256];
    int i, ret;
    size_t len;
    gnutls_certificate_type_t type;

    /* Print the server's trusted CAs
     */
    if (nreqs > 0)
        printf ("- Server's trusted authorities:\n");
    else
        printf ("- Server did not send us any trusted authorities names.\n");

    /* print the names (if any) */
    for (i = 0; i < nreqs; i++)
    {
        len = sizeof (issuer_dn);
        ret = gnutls_x509_rdn_get (&req_ca_rdn[i], issuer_dn, &len);
        if (ret >= 0)
        {
            printf ("    [%d]: ", i);
            printf ("%s\n", issuer_dn);
        }
    }

    /* Select a certificate and return it.
     * The certificate must be of any of the "sign algorithms"
     * supported by the server.
     */

```

```

type = gnutls_certificate_type_get (session);
if (type == GNUTLS_CERT_X509)
{
    st->type = type;
    st->ncerts = 1;

    st->cert.x509 = &crt;
    st->key.x509 = key;

    st->deinit_all = 0;
}
else
{
    return -1;
}

return 0;
}

```

7.3.6 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.

```

/* Copyright 2007 Free Software Foundation
 *
 * Copying and distribution of this file, with or without modification,
 * are permitted in any medium without royalty provided the copyright
 * notice and this notice are preserved.
 */

#if HAVE_CONFIG_H
# include <config.h>
#endif

#include <string.h>
#include <stdio.h>
#include <stdlib.h>
#include <gnutls/gnutls.h>

/* Those functions are defined in other examples.
 */
extern void check_alert (gnutls_session_t session, int ret);
extern int tcp_connect (void);
extern void tcp_close (int sd);

```

```

#define MAX_BUF 1024
#define CRLFILE "crl.pem"
#define CAFILE "ca.pem"
#define MSG "GET / HTTP/1.0\r\n\r\n"

int
main (void)
{
    int ret;
    int sd, ii;
    gnutls_session_t session;
    char buffer[MAX_BUF + 1];
    gnutls_certificate_credentials_t xcred;

    /* variables used in session resuming
       */
    int t;
    char *session_data;
    size_t session_data_size;

    gnutls_global_init ();

    /* X509 stuff */
    gnutls_certificate_allocate_credentials (&xcred);

    gnutls_certificate_set_x509_trust_file (xcred, CAFILE, GNUTLS_X509_FMT_PEM);

    for (t = 0; t < 2; t++)
    {
        /* connect 2 times to the server */

        sd = tcp_connect ();

        gnutls_init (&session, GNUTLS_CLIENT);

        gnutls_priority_set_direct (session, "PERFORMANCE:!ARCFOUR-128", NULL);

        gnutls_credentials_set (session, GNUTLS_CRD_CERTIFICATE, xcred);

        if (t > 0)
        {
            /* if this is not the first time we connect */
            gnutls_session_set_data (session, session_data, session_data_size);
            free (session_data);
        }

        gnutls_transport_set_ptr (session, (gnutls_transport_ptr_t) sd);
    }
}

```

```

/* Perform the TLS handshake
 */
ret = gnutls_handshake (session);

if (ret < 0)
{
    fprintf (stderr, "*** Handshake failed\n");
    gnutls_perror (ret);
    goto end;
}
else
{
    printf ("- Handshake was completed\n");
}

if (t == 0)
{
    /* the first time we connect */
    /* get the session data size */
    gnutls_session_get_data (session, NULL, &session_data_size);
    session_data = malloc (session_data_size);

    /* put session data to the session variable */
    gnutls_session_get_data (session, session_data, &session_data_size);
}
else
{
    /* the second time we connect */

    /* check if we actually resumed the previous session */
    if (gnutls_session_is_resumed (session) != 0)
    {
        printf ("- Previous session was resumed\n");
    }
    else
    {
        fprintf (stderr, "*** Previous session was NOT resumed\n");
    }
}

/* This function was defined in a previous example
 */
/* print_info(session); */

gnutls_record_send (session, MSG, strlen (MSG));

ret = gnutls_record_recv (session, buffer, MAX_BUF);
if (ret == 0)

```

```

    {
        printf ("- Peer has closed the TLS connection\n");
        goto end;
    }
else if (ret < 0)
    {
        fprintf (stderr, "*** Error: %s\n", gnutls_strerror (ret));
        goto end;
    }

printf ("- Received %d bytes: ", ret);
for (ii = 0; ii < ret; ii++)
    {
        fputc (buffer[ii], stdout);
    }
fputs ("\n", stdout);

gnutls_bye (session, GNUTLS_SHUT_RDWR);

end:

tcp_close (sd);

gnutls_deinit (session);

}                                /* for() */

gnutls_certificate_free_credentials (xcred);

gnutls_global_deinit ();

return 0;
}

```

7.3.7 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.

```

/* Copyright 2007 Free Software Foundation
 *
 * Copying and distribution of this file, with or without modification,
 * are permitted in any medium without royalty provided the copyright
 * notice and this notice are preserved.
 */

#if HAVE_CONFIG_H

```



```

# include <config.h>
#endif

#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <gnutls/gnutls.h>
#include <gnutls/extra.h>

/* Those functions are defined in other examples.
 */
extern void check_alert (gnutls_session_t session, int ret);
extern int tcp_connect (void);
extern void tcp_close (int sd);

#define MAX_BUF 1024
#define USERNAME "user"
#define PASSWORD "pass"
#define CAFILE "ca.pem"
#define SA struct sockaddr
#define MSG "GET / HTTP/1.0\r\n\r\n"

#define MAX_PRIORITIES 3

int
main (void)
{
    int ret;
    int sd, ii;
    gnutls_session_t session;
    char buffer[MAX_BUF + 1];
    gnutls_srp_client_credentials_t srp_cred;
    gnutls_certificate_credentials_t cert_cred;

    gnutls_global_init ();

    /* now enable the gnutls-extra library which contains the
     * SRP stuff.
     */
    gnutls_global_init_extra ();

    gnutls_srp_allocate_client_credentials (&srp_cred);
    gnutls_certificate_allocate_credentials (&cert_cred);

    gnutls_certificate_set_x509_trust_file (cert_cred, CAFILE,
                                           GNUTLS_X509_FMT_PEM);
    gnutls_srp_set_client_credentials (srp_cred, USERNAME, PASSWORD);

```

```
/* connects to server
 */
sd = tcp_connect ();

/* Initialize TLS session
 */
gnutls_init (&session, GNUTLS_CLIENT);

/* Set the priorities.
 */
gnutls_priority_set_direct (session, "NORMAL:+SRP:+SRP-RSA:+SRP-DSS", NULL);

/* put the SRP credentials to the current session
 */
gnutls_credentials_set (session, GNUTLS_CRD_SRP, srp_cred);
gnutls_credentials_set (session, GNUTLS_CRD_CERTIFICATE, cert_cred);

gnutls_transport_set_ptr (session, (gnutls_transport_ptr_t) sd);

/* Perform the TLS handshake
 */
ret = gnutls_handshake (session);

if (ret < 0)
{
    fprintf (stderr, "*** Handshake failed\n");
    gnutls_perror (ret);
    goto end;
}
else
{
    printf ("- Handshake was completed\n");
}

gnutls_record_send (session, MSG, strlen (MSG));

ret = gnutls_record_recv (session, buffer, MAX_BUF);
if (gnutls_error_is_fatal (ret) == 1 || ret == 0)
{
    if (ret == 0)
    {
        printf ("- Peer has closed the GNUTLS connection\n");
        goto end;
    }
}
else
```

```

        {
            fprintf (stderr, "*** Error: %s\n", gnutls_strerror (ret));
            goto end;
        }
    }
else
    check_alert (session, ret);

if (ret > 0)
{
    printf ("- Received %d bytes: ", ret);
    for (ii = 0; ii < ret; ii++)
    {
        fputc (buffer[ii], stdout);
    }
    fputs ("\n", stdout);
}
gnutls_bye (session, GNUTLS_SHUT_RDWR);

end:

    tcp_close (sd);

    gnutls_deinit (session);

    gnutls_srp_free_client_credentials (srp_cred);
    gnutls_certificate_free_credentials (cert_cred);

    gnutls_global_deinit ();

    return 0;
}

```

7.3.8 Simple Client Example with TLS/IA Support

The following client is a simple client which uses the TLS/IA extension to authenticate with the server.

```

/* Copyright 2007 Free Software Foundation
 *
 * Copying and distribution of this file, with or without modification,
 * are permitted in any medium without royalty provided the copyright
 * notice and this notice are preserved.
 */

#ifdef HAVE_CONFIG_H
# include <config.h>
#endif

```

```

#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <sys/types.h>
#include <sys/socket.h>
#include <arpa/inet.h>
#include <unistd.h>
#include <gnutls/gnutls.h>
#include <gnutls/extra.h>

/* A basic TLS client, with anonymous authentication and TLS/IA handshake.
 */

#define MAX_BUF 1024
#define SA struct sockaddr
#define MSG "GET / HTTP/1.0\r\n\r\n"

extern int tcp_connect (void);
extern void tcp_close (int sd);

int
client_avp (gnutls_session_t session, void *ptr,
            const char *last, size_t lastlen,
            char **new, size_t *newlen)
{
    if (last)
        printf ("- received %d bytes AVP: '%.*s'\n",
                lastlen, lastlen, last);
    else
        printf ("- new application phase\n");

    *new = gnutls_strdup ("client avp");
    if (!*new)
        return -1;
    *newlen = strlen (*new);

    printf ("- sending %d bytes AVP: '%s'\n", *newlen, *new);

    gnutls_ia_permute_inner_secret (session, 3, "foo");

    return 0;
}

int

```

```
main (void)
{
    int ret, sd, ii;
    gnutls_session_t session;
    char buffer[MAX_BUF + 1];
    gnutls_anon_client_credentials_t anoncred;
    gnutls_ia_client_credentials_t iacred;
    /* Need to enable anonymous KX specifically. */

    gnutls_global_init ();

    gnutls_anon_allocate_client_credentials (&anoncred);
    gnutls_ia_allocate_client_credentials (&iacred);

    /* Set TLS/IA stuff
     */
    gnutls_ia_set_client_avp_function (iacred, client_avp);

    /* Initialize TLS session
     */
    gnutls_init (&session, GNUTLS_CLIENT);

    /* Use default priorities */
    gnutls_priority_set_direct (session, "NORMAL:+ANON-DH", NULL);

    /* put the anonymous and TLS/IA credentials to the current session
     */
    gnutls_credentials_set (session, GNUTLS_CRD_ANON, anoncred);
    gnutls_credentials_set (session, GNUTLS_CRD_IA, iacred);

    /* connect to the peer
     */
    sd = tcp_connect ();

    gnutls_transport_set_ptr (session, (gnutls_transport_ptr_t) sd);

    /* Perform the TLS handshake
     */
    ret = gnutls_handshake (session);

    if (ret < 0)
    {
        fprintf (stderr, "*** Handshake failed\n");
        gnutls_perror (ret);
        goto end;
    }
    else
```

```
{
    printf ("- Handshake was completed\n");
}

if (!gnutls_ia_handshake_p (session))
{
    fprintf (stderr, "*** TLS/IA not negotiated...\n");
    goto end;
}
else
{
    printf ("- Starting TLS/IA handshake...\n");

    ret = gnutls_ia_handshake (session);

    if (ret < 0)
    {
        fprintf (stderr, "*** TLS/IA handshake failed\n");
        gnutls_perror (ret);
        goto end;
    }
    else
    {
        printf ("- TLS/IA Handshake was completed\n");
    }
}

gnutls_record_send (session, MSG, strlen (MSG));

ret = gnutls_record_recv (session, buffer, MAX_BUF);
if (ret == 0)
{
    printf ("- Peer has closed the TLS connection\n");
    goto end;
}
else if (ret < 0)
{
    fprintf (stderr, "*** Error: %s\n", gnutls_strerror (ret));
    goto end;
}

printf ("- Received %d bytes: ", ret);
for (ii = 0; ii < ret; ii++)
{
    fputc (buffer[ii], stdout);
}
```

```

    fputs ("\n", stdout);

    gnutls_bye (session, GNUTLS_SHUT_RDWR);

end:

    tcp_close (sd);

    gnutls_deinit (session);

    gnutls_ia_free_client_credentials (iacred);
    gnutls_anon_free_client_credentials (anoncred);

    gnutls_global_deinit ();

    return 0;
}

```

7.3.9 Helper Function for TCP Connections

This helper function abstracts away TCP connection handling from the other examples. It is required to build some examples.

```

/* Copyright 2007 Free Software Foundation
 *
 * Copying and distribution of this file, with or without modification,
 * are permitted in any medium without royalty provided the copyright
 * notice and this notice are preserved.
 */

#ifdef HAVE_CONFIG_H
# include <config.h>
#endif

#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <sys/types.h>
#include <sys/socket.h>
#include <arpa/inet.h>
#include <netinet/in.h>
#include <unistd.h>

#define SA struct sockaddr

/* Connects to the peer and returns a socket
 * descriptor.
 */

```

```

extern int
tcp_connect (void)
{
    const char *PORT = "5556";
    const char *SERVER = "127.0.0.1";
    int err, sd;
    struct sockaddr_in sa;

    /* connects to server
     */
    sd = socket (AF_INET, SOCK_STREAM, 0);

    memset (&sa, '\0', sizeof (sa));
    sa.sin_family = AF_INET;
    sa.sin_port = htons (atoi (PORT));
    inet_pton (AF_INET, SERVER, &sa.sin_addr);

    err = connect (sd, (SA *) & sa, sizeof (sa));
    if (err < 0)
    {
        fprintf (stderr, "Connect error\n");
        exit (1);
    }

    return sd;
}

/* closes the given socket descriptor.
 */
extern void
tcp_close (int sd)
{
    shutdown (sd, SHUT_RDWR);    /* no more receptions */
    close (sd);
}

```

7.4 Server Examples

This section contains examples of TLS and SSL servers, using GnuTLS.

7.4.1 Echo Server with X.509 Authentication

This example is a very simple echo server which supports X.509 authentication, using the RSA ciphersuites.

```

/* Copyright 2007 Free Software Foundation
 *
 * Copying and distribution of this file, with or without modification,
 * are permitted in any medium without royalty provided the copyright

```



```

    * notice and this notice are preserved.
    */

#if HAVE_CONFIG_H
# include <config.h>
#endif

#include <stdio.h>
#include <stdlib.h>
#include <errno.h>
#include <sys/types.h>
#include <sys/socket.h>
#include <arpa/inet.h>
#include <netinet/in.h>
#include <string.h>
#include <unistd.h>
#include <gnutls/gnutls.h>
#include <gcrypt.h> /* for gcry_control */

#define KEYFILE "key.pem"
#define CERTFILE "cert.pem"
#define CAFILE "ca.pem"
#define CRLFILE "crl.pem"

/* This is a sample TLS 1.0 echo server, using X.509 authentication.
   */

#define SA struct sockaddr
#define SOCKET_ERR(err,s) if(err== -1) {perror(s);return(1);}
#define MAX_BUF 1024
#define PORT 5556 /* listen to 5556 port */
#define DH_BITS 1024

/* These are global */
gnutls_certificate_credentials_t x509_cred;
gnutls_priority_t priority_cache;

gnutls_session_t
initialize_tls_session (void)
{
    gnutls_session_t session;

    gnutls_init (&session, GNUTLS_SERVER);

    gnutls_priority_set (session, priority_cache);

```

```

gnutls_credentials_set (session, GNUTLS_CRD_CERTIFICATE, x509_cred);

/* request client certificate if any.
 */
gnutls_certificate_server_set_request (session, GNUTLS_CERT_REQUEST);

/* Set maximum compatibility mode. This is only suggested on public web servers
 * that need to trade security for compatibility
 */
gnutls_session_enable_compatibility_mode( session);

return session;
}

static gnutls_dh_params_t dh_params;

static int
generate_dh_params (void)
{
    /* Generate Diffie Hellman parameters - for use with DHE
     * kx algorithms. When short bit length is used, it might
     * be wise to regenerate parameters.
     *
     * Check the ex-serv-export.c example for using static
     * parameters.
     */
    gnutls_dh_params_init (&dh_params);
    gnutls_dh_params_generate2 (dh_params, DH_BITS);

    return 0;
}

int
main (void)
{
    int err, listen_sd, i;
    int sd, ret;
    struct sockaddr_in sa_serv;
    struct sockaddr_in sa_cli;
    int client_len;
    char topbuf[512];
    gnutls_session_t session;
    char buffer[MAX_BUF + 1];
    int optval = 1;

    /* to disallow usage of the blocking /dev/random

```

```

    */
    gcry_control (GCRYCTL_ENABLE_QUICK_RANDOM, 0);

    /* this must be called once in the program
    */
    gnutls_global_init ();

    gnutls_certificate_allocate_credentials (&x509_cred);
    gnutls_certificate_set_x509_trust_file (x509_cred, CAFILE,
                                           GNUTLS_X509_FMT_PEM);

    gnutls_certificate_set_x509_crl_file (x509_cred, CRLFILE,
                                           GNUTLS_X509_FMT_PEM);

    gnutls_certificate_set_x509_key_file (x509_cred, CERTFILE, KEYFILE,
                                           GNUTLS_X509_FMT_PEM);

    generate_dh_params ();

    gnutls_priority_init( &priority_cache, "NORMAL", NULL);

    gnutls_certificate_set_dh_params (x509_cred, dh_params);

    /* Socket operations
    */
    listen_sd = socket (AF_INET, SOCK_STREAM, 0);
    SOCKET_ERR (listen_sd, "socket");

    memset (&sa_serv, '\0', sizeof (sa_serv));
    sa_serv.sin_family = AF_INET;
    sa_serv.sin_addr.s_addr = INADDR_ANY;
    sa_serv.sin_port = htons (PORT);      /* Server Port number */

    setsockopt (listen_sd, SOL_SOCKET, SO_REUSEADDR, &optval, sizeof (int));

    err = bind (listen_sd, (SA *) & sa_serv, sizeof (sa_serv));
    SOCKET_ERR (err, "bind");
    err = listen (listen_sd, 1024);
    SOCKET_ERR (err, "listen");

    printf ("Server ready. Listening to port '%d'.\n\n", PORT);

    client_len = sizeof (sa_cli);
    for (;;)
    {
        session = initialize_tls_session ();

```

```

sd = accept (listen_sd, (SA *) & sa_cli, &client_len);

printf ("- connection from %s, port %d\n",
        inet_ntop (AF_INET, &sa_cli.sin_addr, topbuf,
                  sizeof (topbuf)), ntohs (sa_cli.sin_port));

gnutls_transport_set_ptr (session, (gnutls_transport_ptr_t) sd);
ret = gnutls_handshake (session);
if (ret < 0)
{
    close (sd);
    gnutls_deinit (session);
    fprintf (stderr, "*** Handshake has failed (%s)\n\n",
            gnutls_strerror (ret));
    continue;
}
printf ("- Handshake was completed\n");

/* see the Getting peer's information example */
/* print_info(session); */

i = 0;
for (;;)
{
    memset (buffer, 0, MAX_BUF + 1);
    ret = gnutls_record_recv (session, buffer, MAX_BUF);

    if (ret == 0)
    {
        printf ("\n- Peer has closed the GNUTLS connection\n");
        break;
    }
    else if (ret < 0)
    {
        fprintf (stderr, "\n*** Received corrupted "
                "data(%d). Closing the connection.\n\n", ret);
        break;
    }
    else if (ret > 0)
    {
        /* echo data back to the client
         */
        gnutls_record_send (session, buffer, strlen (buffer));
    }
}
printf ("\n");

```

```

        /* do not wait for the peer to close the connection.
        */
        gnutls_bye (session, GNUTLS_SHUT_WR);

        close (sd);
        gnutls_deinit (session);

    }
    close (listen_sd);

    gnutls_certificate_free_credentials (x509_cred);
    gnutls_priority_deinit(priority_cache);

    gnutls_global_deinit ();

    return 0;
}

```

7.4.2 Echo Server with X.509 Authentication II

The following example is a server which supports X.509 authentication. This server supports the export-grade cipher suites, the DHE ciphersuites and session resuming.

```

/* Copyright 2007 Free Software Foundation
 *
 * Copying and distribution of this file, with or without modification,
 * are permitted in any medium without royalty provided the copyright
 * notice and this notice are preserved.
 */

#if HAVE_CONFIG_H
# include <config.h>
#endif

#include <stdio.h>
#include <stdlib.h>
#include <errno.h>
#include <sys/types.h>
#include <sys/socket.h>
#include <arpa/inet.h>
#include <netinet/in.h>
#include <string.h>
#include <unistd.h>
#include <gnutls/gnutls.h>
#include <gcrypt.h> /* for gcry_control */

#define KEYFILE "key.pem"

```

```

#define CERTFILE "cert.pem"
#define CAFILE "ca.pem"
#define CRLFILE "crl.pem"

/* This is a sample TLS 1.0 echo server.
 * Export-grade ciphersuites and session resuming are supported.
 */

#define SA struct sockaddr
#define SOCKET_ERR(err,s) if(err== -1) {perror(s);return(1);}
#define MAX_BUF 1024
#define PORT 5556 /* listen to 5556 port */
#define DH_BITS 1024

/* These are global */
gnutls_certificate_credentials_t cert_cred;

static void wrap_db_init (void);
static void wrap_db_deinit (void);
static int wrap_db_store (void *dbf, gnutls_datum_t key, gnutls_datum_t data);
static gnutls_datum_t wrap_db_fetch (void *dbf, gnutls_datum_t key);
static int wrap_db_delete (void *dbf, gnutls_datum_t key);

#define TLS_SESSION_CACHE 50

gnutls_session_t
initialize_tls_session (void)
{
    gnutls_session_t session;

    gnutls_init (&session, GNUTLS_SERVER);

    /* Use the default priorities, plus, export cipher suites.
     */
    gnutls_priority_set_direct( session, "EXPORT", NULL);

    gnutls_credentials_set (session, GNUTLS_CRD_CERTIFICATE, cert_cred);

    /* request client certificate if any.
     */
    gnutls_certificate_server_set_request (session, GNUTLS_CERT_REQUEST);

    gnutls_dh_set_prime_bits (session, DH_BITS);

    if (TLS_SESSION_CACHE != 0)
    {
        gnutls_db_set_retrieve_function (session, wrap_db_fetch);
    }
}

```

```

        gnutls_db_set_remove_function (session, wrap_db_delete);
        gnutls_db_set_store_function (session, wrap_db_store);
        gnutls_db_set_ptr (session, NULL);
    }

    return session;
}

gnutls_dh_params_t dh_params;
/* Export-grade cipher suites require temporary RSA
 * keys.
 */
gnutls_rsa_params_t rsa_params;

static char srp_dh_group2048[] =
    "-----BEGIN DH PARAMETERS-----\n"
    "MIIBBwKCAQCsa9tBMkqam/Fm3l4TiVgvr3K2ZRmH7gf8MZKUPbVgUKNzKcu0oJnt\n"
    "gZPgdxnoT3VixKrSwMxDc1/SKnaBP1Q6Ag5ae23Z7DPYJUXmhY6s2YaBfvV+qro\n"
    "KRipli8Lk7hV+XmT7Jde6qgNdArb9P90c1nQQdXDPqcdKB5EaxR308qXtDoj+4AW\n"
    "dr0gekNsZIHx0rkHhxdGGludMuaI+HdIVEUjtSSw1X1ep3onddLs+gMs+9v1L7N4\n"
    "YWAnkATleuavh05zA85TKZzMBBx7wwjYKlaY86jQw4JxrjX46dv7tpS1yAPYn3rk\n"
    "Nd4jbVJfVHwBZeNy/Na08g+nER+eSv9zAgEC\n"
    "-----END DH PARAMETERS-----\n";

int
generate_dh_params (void)
{
    gnutls_datum_t dparams = { srp_dh_group2048, sizeof( srp_dh_group2048) };
    /* Here instead of generating Diffie Hellman parameters (for use with DHE
     * kx algorithms) we import them.
     */
    gnutls_dh_params_init (&dh_params);
    gnutls_dh_params_import_pkcs3 (dh_params, &dparams, GNUTLS_X509_FMT_PEM);

    return 0;
}

static int
generate_rsa_params (void)
{
    gnutls_rsa_params_init (&rsa_params);

    /* Generate RSA parameters - for use with RSA-export
     * cipher suites. This is an RSA private key and should be
     * discarded and regenerated once a day, once every 500
     * transactions etc. Depends on the security requirements.
     */

```

```
    gnutls_rsa_params_generate2 (rsa_params, 512);

    return 0;
}

int
main (void)
{
    int err, listen_sd, i;
    int sd, ret;
    struct sockaddr_in sa_serv;
    struct sockaddr_in sa_cli;
    int client_len;
    char topbuf[512];
    gnutls_session_t session;
    char buffer[MAX_BUF + 1];
    int optval = 1;
    char name[256];

    strcpy (name, "Echo Server");

    /* to disallow usage of the blocking /dev/random
     */
    gcry_control (GCRYCTL_ENABLE_QUICK_RANDOM, 0);

    /* this must be called once in the program
     */
    gnutls_global_init ();

    gnutls_certificate_allocate_credentials (&cert_cred);

    gnutls_certificate_set_x509_trust_file (cert_cred, CAFILE,
                                           GNUTLS_X509_FMT_PEM);

    gnutls_certificate_set_x509_crl_file (cert_cred, CRLFILE,
                                           GNUTLS_X509_FMT_PEM);

    gnutls_certificate_set_x509_key_file (cert_cred, CERTFILE, KEYFILE,
                                           GNUTLS_X509_FMT_PEM);

    generate_dh_params ();
    generate_rsa_params ();

    if (TLS_SESSION_CACHE != 0)
    {
```



```

    wrap_db_init ();
}

gnutls_certificate_set_dh_params (cert_cred, dh_params);
gnutls_certificate_set_rsa_export_params (cert_cred, rsa_params);

/* Socket operations
*/
listen_sd = socket (AF_INET, SOCK_STREAM, 0);
SOCKET_ERR (listen_sd, "socket");

memset (&sa_serv, '\0', sizeof (sa_serv));
sa_serv.sin_family = AF_INET;
sa_serv.sin_addr.s_addr = INADDR_ANY;
sa_serv.sin_port = htons (PORT);      /* Server Port number */

setsockopt (listen_sd, SOL_SOCKET, SO_REUSEADDR, &optval, sizeof (int));

err = bind (listen_sd, (SA *) & sa_serv, sizeof (sa_serv));
SOCKET_ERR (err, "bind");
err = listen (listen_sd, 1024);
SOCKET_ERR (err, "listen");

printf ("%s ready. Listening to port '%d'.\n\n", name, PORT);

client_len = sizeof (sa_cli);
for (;;)
{
    session = initialize_tls_session ();

    sd = accept (listen_sd, (SA *) & sa_cli, &client_len);

    printf ("- connection from %s, port %d\n",
            inet_ntop (AF_INET, &sa_cli.sin_addr, topbuf,
                      sizeof (topbuf)), ntohs (sa_cli.sin_port));

    gnutls_transport_set_ptr (session, (gnutls_transport_ptr_t) sd);
    ret = gnutls_handshake (session);
    if (ret < 0)
    {
        close (sd);
        gnutls_deinit (session);
        fprintf (stderr, "*** Handshake has failed (%s)\n\n",
                gnutls_strerror (ret));
        continue;
    }
    printf ("- Handshake was completed\n");
}

```

```

    /* print_info(session); */

    i = 0;
    for (;;)
    {
        memset (buffer, 0, MAX_BUF + 1);
        ret = gnutls_record_recv (session, buffer, MAX_BUF);

        if (ret == 0)
        {
            printf ("\n- Peer has closed the TLS connection\n");
            break;
        }
        else if (ret < 0)
        {
            fprintf (stderr, "\n*** Received corrupted "
                    "data(%d). Closing the connection.\n\n", ret);
            break;
        }
        else if (ret > 0)
        {
            /* echo data back to the client
             */
            gnutls_record_send (session, buffer, strlen (buffer));
        }
    }
    printf ("\n");
    /* do not wait for the peer to close the connection.
     */
    gnutls_bye (session, GNUTLS_SHUT_WR);

    close (sd);
    gnutls_deinit (session);

}
close (listen_sd);

gnutls_certificate_free_credentials (cert_cred);

gnutls_global_deinit ();

return 0;
}

```

```
/* Functions and other stuff needed for session resuming.
 * This is done using a very simple list which holds session ids
 * and session data.
 */

#define MAX_SESSION_ID_SIZE 32
#define MAX_SESSION_DATA_SIZE 512

typedef struct
{
    char session_id[MAX_SESSION_ID_SIZE];
    int session_id_size;

    char session_data[MAX_SESSION_DATA_SIZE];
    int session_data_size;
} CACHE;

static CACHE *cache_db;
static int cache_db_ptr = 0;

static void
wrap_db_init (void)
{
    /* allocate cache_db */
    cache_db = calloc (1, TLS_SESSION_CACHE * sizeof (CACHE));
}

static void
wrap_db_deinit (void)
{
    return;
}

static int
wrap_db_store (void *dbuf, gnutls_datum_t key, gnutls_datum_t data)
{
    if (cache_db == NULL)
        return -1;

    if (key.size > MAX_SESSION_ID_SIZE)
        return -1;
    if (data.size > MAX_SESSION_DATA_SIZE)
        return -1;

    memcpy (cache_db[cache_db_ptr].session_id, key.data, key.size);
```

```

    cache_db[cache_db_ptr].session_id_size = key.size;

    memcpy (cache_db[cache_db_ptr].session_data, data.data, data.size);
    cache_db[cache_db_ptr].session_data_size = data.size;

    cache_db_ptr++;
    cache_db_ptr %= TLS_SESSION_CACHE;

    return 0;
}

static gnutls_datum_t
wrap_db_fetch (void *dbf, gnutls_datum_t key)
{
    gnutls_datum_t res = { NULL, 0 };
    int i;

    if (cache_db == NULL)
        return res;

    for (i = 0; i < TLS_SESSION_CACHE; i++)
    {
        if (key.size == cache_db[i].session_id_size &&
            memcmp (key.data, cache_db[i].session_id, key.size) == 0)
        {

            res.size = cache_db[i].session_data_size;

            res.data = gnutls_malloc (res.size);
            if (res.data == NULL)
                return res;

            memcpy (res.data, cache_db[i].session_data, res.size);

            return res;
        }
    }
    return res;
}

static int
wrap_db_delete (void *dbf, gnutls_datum_t key)
{
    int i;

    if (cache_db == NULL)

```

```

    return -1;

    for (i = 0; i < TLS_SESSION_CACHE; i++)
    {
        if (key.size == cache_db[i].session_id_size &&
            memcmp (key.data, cache_db[i].session_id, key.size) == 0)
        {

            cache_db[i].session_id_size = 0;
            cache_db[i].session_data_size = 0;

            return 0;
        }
    }

    return -1;
}

```

7.4.3 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.

```

/* Copyright 2007 Free Software Foundation
 *
 * Copying and distribution of this file, with or without modification,
 * are permitted in any medium without royalty provided the copyright
 * notice and this notice are preserved.
 */

#ifdef HAVE_CONFIG_H
# include <config.h>
#endif

#include <stdio.h>
#include <stdlib.h>
#include <errno.h>
#include <sys/types.h>
#include <sys/socket.h>
#include <arpa/inet.h>
#include <netinet/in.h>
#include <string.h>
#include <unistd.h>
#include <gnutls/gnutls.h>
/* Must be linked against gnutls-extra.
 */

```

```

#include <gnutls/extra.h>

#define KEYFILE "secret.asc"
#define CERTFILE "public.asc"
#define RINGFILE "ring.gpg"

/* This is a sample TLS 1.0-OpenPGP echo server.
   */

#define SA struct sockaddr
#define SOCKET_ERR(err,s) if(err==-1) {perror(s);return(1);}
#define MAX_BUF 1024
#define PORT 5556 /* listen to 5556 port */
#define DH_BITS 1024

/* These are global */
gnutls_certificate_credentials_t cred;
gnutls_dh_params_t dh_params;

static int
generate_dh_params (void)
{
    /* Generate Diffie Hellman parameters - for use with DHE
     * kx algorithms. These should be discarded and regenerated
     * once a day, once a week or once a month. Depending on the
     * security requirements.
     */
    gnutls_dh_params_init (&dh_params);
    gnutls_dh_params_generate2 (dh_params, DH_BITS);

    return 0;
}

gnutls_session_t
initialize_tls_session (void)
{
    gnutls_session_t session;

    gnutls_init (&session, GNUTLS_SERVER);

    gnutls_priority_set_direct(session, "NORMAL", NULL);

    /* request client certificate if any.
     */
    gnutls_certificate_server_set_request (session, GNUTLS_CERT_REQUEST);

```

```

    gnutls_dh_set_prime_bits (session, DH_BITS);

    return session;
}

int
main (void)
{
    int err, listen_sd, i;
    int sd, ret;
    struct sockaddr_in sa_serv;
    struct sockaddr_in sa_cli;
    int client_len;
    char topbuf[512];
    gnutls_session_t session;
    char buffer[MAX_BUF + 1];
    int optval = 1;
    char name[256];

    strcpy (name, "Echo Server");

    /* this must be called once in the program
       */
    gnutls_global_init ();

    gnutls_certificate_allocate_credentials (&cred);
    gnutls_certificate_set_openpgp_keyring_file (cred, RINGFILE, GNUTLS_OPENPGP_FMT_BASE64);

    gnutls_certificate_set_openpgp_key_file (cred, CERTFILE, KEYFILE, GNUTLS_OPENPGP_FMT_BASE64);

    generate_dh_params ();

    gnutls_certificate_set_dh_params (cred, dh_params);

    /* Socket operations
       */
    listen_sd = socket (AF_INET, SOCK_STREAM, 0);
    SOCKET_ERR (listen_sd, "socket");

    memset (&sa_serv, '\0', sizeof (sa_serv));
    sa_serv.sin_family = AF_INET;
    sa_serv.sin_addr.s_addr = INADDR_ANY;
    sa_serv.sin_port = htons (PORT);      /* Server Port number */

    setsockopt (listen_sd, SOL_SOCKET, SO_REUSEADDR, &optval, sizeof (int));

```

```

err = bind (listen_sd, (SA *) & sa_serv, sizeof (sa_serv));
SOCKET_ERR (err, "bind");
err = listen (listen_sd, 1024);
SOCKET_ERR (err, "listen");

printf ("%s ready. Listening to port '%d'.\n\n", name, PORT);

client_len = sizeof (sa_cli);
for (;;)
{
    session = initialize_tls_session ();

    sd = accept (listen_sd, (SA *) & sa_cli, &client_len);

    printf ("- connection from %s, port %d\n",
            inet_ntop (AF_INET, &sa_cli.sin_addr, topbuf,
                      sizeof (topbuf)), ntohs (sa_cli.sin_port));

    gnutls_transport_set_ptr (session, (gnutls_transport_ptr_t) sd);
    ret = gnutls_handshake (session);
    if (ret < 0)
    {
        close (sd);
        gnutls_deinit (session);
        fprintf (stderr, "*** Handshake has failed (%s)\n\n",
                gnutls_strerror (ret));
        continue;
    }
    printf ("- Handshake was completed\n");

    /* see the Getting peer's information example */
    /* print_info(session); */

    i = 0;
    for (;;)
    {
        memset (buffer, 0, MAX_BUF + 1);
        ret = gnutls_record_recv (session, buffer, MAX_BUF);

        if (ret == 0)
        {
            printf ("\n- Peer has closed the GNUTLS connection\n");
            break;
        }
        else if (ret < 0)
        {
            fprintf (stderr, "\n*** Received corrupted "

```



```

        "data(%d). Closing the connection.\n\n", ret);
        break;
    }
    else if (ret > 0)
    {
        /* echo data back to the client
        */
        gnutls_record_send (session, buffer, strlen (buffer));
    }
}
printf ("\n");
/* do not wait for the peer to close the connection.
*/
gnutls_bye (session, GNUTLS_SHUT_WR);

close (sd);
gnutls_deinit (session);

}
close (listen_sd);

gnutls_certificate_free_credentials (cred);

gnutls_global_deinit ();

return 0;
}

```

7.4.4 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.

```

/* Copyright 2007 Free Software Foundation
 *
 * Copying and distribution of this file, with or without modification,
 * are permitted in any medium without royalty provided the copyright
 * notice and this notice are preserved.
 */

#ifdef HAVE_CONFIG_H
# include <config.h>
#endif

#include <stdio.h>
#include <stdlib.h>
#include <errno.h>

```

```

#include <sys/types.h>
#include <sys/socket.h>
#include <arpa/inet.h>
#include <netinet/in.h>
#include <string.h>
#include <unistd.h>
#include <gnutls/gnutls.h>
#include <gnutls/extra.h>

#define SRP_PASSWD "tpasswd"
#define SRP_PASSWD_CONF "tpasswd.conf"

#define KEYFILE "key.pem"
#define CERTFILE "cert.pem"
#define CAFILE "ca.pem"

/* This is a sample TLS-SRP echo server.
 */

#define SA struct sockaddr
#define SOCKET_ERR(err,s) if(err== -1) {perror(s);return(1);}
#define MAX_BUF 1024
#define PORT 5556 /* listen to 5556 port */

/* These are global */
gnutls_srp_server_credentials_t srp_cred;
gnutls_certificate_credentials_t cert_cred;

gnutls_session_t
initialize_tls_session (void)
{
    gnutls_session_t session;

    gnutls_init (&session, GNUTLS_SERVER);

    gnutls_priority_set_direct (session, "NORMAL:+SRP:+SRP-DSS:+SRP-RSA", NULL);

    gnutls_credentials_set (session, GNUTLS_CRD_SRP, srp_cred);
    /* for the certificate authenticated ciphersuites.
     */
    gnutls_credentials_set (session, GNUTLS_CRD_CERTIFICATE, cert_cred);

    /* request client certificate if any.
     */
    gnutls_certificate_server_set_request (session, GNUTLS_CERT_IGNORE);

    return session;

```

```

}

int
main (void)
{
    int err, listen_sd, i;
    int sd, ret;
    struct sockaddr_in sa_serv;
    struct sockaddr_in sa_cli;
    int client_len;
    char topbuf[512];
    gnutls_session_t session;
    char buffer[MAX_BUF + 1];
    int optval = 1;
    char name[256];

    strcpy (name, "Echo Server");

    /* these must be called once in the program
       */
    gnutls_global_init ();
    gnutls_global_init_extra (); /* for SRP */

    /* SRP_PASSWD a password file (created with the included srptool utility)
       */
    gnutls_srp_allocate_server_credentials (&srp_cred);
    gnutls_srp_set_server_credentials_file (srp_cred, SRP_PASSWD,
                                           SRP_PASSWD_CONF);

    gnutls_certificate_allocate_credentials (&cert_cred);
    gnutls_certificate_set_x509_trust_file (cert_cred, CAFILE,
                                           GNUTLS_X509_FMT_PEM);
    gnutls_certificate_set_x509_key_file (cert_cred, CERTFILE, KEYFILE,
                                           GNUTLS_X509_FMT_PEM);

    /* TCP socket operations
       */
    listen_sd = socket (AF_INET, SOCK_STREAM, 0);
    SOCKET_ERR (listen_sd, "socket");

    memset (&sa_serv, '\0', sizeof (sa_serv));
    sa_serv.sin_family = AF_INET;
    sa_serv.sin_addr.s_addr = INADDR_ANY;
    sa_serv.sin_port = htons (PORT); /* Server Port number */

    setsockopt (listen_sd, SOL_SOCKET, SO_REUSEADDR, &optval, sizeof (int));

```

```

err = bind (listen_sd, (SA *) & sa_serv, sizeof (sa_serv));
SOCKET_ERR (err, "bind");
err = listen (listen_sd, 1024);
SOCKET_ERR (err, "listen");

printf ("%s ready. Listening to port '%d'.\n\n", name, PORT);

client_len = sizeof (sa_cli);
for (;;)
{
    session = initialize_tls_session ();

    sd = accept (listen_sd, (SA *) & sa_cli, &client_len);

    printf ("- connection from %s, port %d\n",
            inet_ntop (AF_INET, &sa_cli.sin_addr, topbuf,
                      sizeof (topbuf)), ntohs (sa_cli.sin_port));

    gnutls_transport_set_ptr (session, (gnutls_transport_ptr_t) sd);
    ret = gnutls_handshake (session);
    if (ret < 0)
    {
        close (sd);
        gnutls_deinit (session);
        fprintf (stderr, "*** Handshake has failed (%s)\n\n",
                gnutls_strerror (ret));
        continue;
    }
    printf ("- Handshake was completed\n");

    /* print_info(session); */

    i = 0;
    for (;;)
    {
        memset (buffer, 0, MAX_BUF + 1);
        ret = gnutls_record_recv (session, buffer, MAX_BUF);

        if (ret == 0)
        {
            printf ("\n- Peer has closed the GNUTLS connection\n");
            break;
        }
        else if (ret < 0)
        {
            fprintf (stderr, "\n*** Received corrupted "
                    "data(%d). Closing the connection.\n\n", ret);

```

```

        break;
    }
    else if (ret > 0)
    {
        /* echo data back to the client
        */
        gnutls_record_send (session, buffer, strlen (buffer));
    }
}
printf ("\n");
/* do not wait for the peer to close the connection. */
gnutls_bye (session, GNUTLS_SHUT_WR);

close (sd);
gnutls_deinit (session);

}
close (listen_sd);

gnutls_srp_free_server_credentials (srp_cred);
gnutls_certificate_free_credentials (cert_cred);

gnutls_global_deinit ();

return 0;
}

```

7.4.5 Echo Server with Anonymous Authentication

This example server support anonymous authentication, and could be used to serve the example client for anonymous authentication.

```

/* Copyright 2007 Free Software Foundation
 *
 * Copying and distribution of this file, with or without modification,
 * are permitted in any medium without royalty provided the copyright
 * notice and this notice are preserved.
 */

#ifdef HAVE_CONFIG_H
# include <config.h>
#endif

#include <stdio.h>
#include <stdlib.h>
#include <errno.h>
#include <sys/types.h>

```

```

#include <sys/socket.h>
#include <arpa/inet.h>
#include <netinet/in.h>
#include <string.h>
#include <unistd.h>
#include <gnutls/gnutls.h>

/* This is a sample TLS 1.0 echo server, for anonymous authentication only.
*/

#define SA struct sockaddr
#define SOCKET_ERR(err,s) if(err== -1) {perror(s);return(1);}
#define MAX_BUF 1024
#define PORT 5556 /* listen to 5556 port */
#define DH_BITS 1024

/* These are global */
gnutls_anon_server_credentials_t anoncred;

gnutls_session_t
initialize_tls_session (void)
{
    gnutls_session_t session;

    gnutls_init (&session, GNUTLS_SERVER);

    gnutls_priority_set_direct (session, "NORMAL:+ANON-DH", NULL);

    gnutls_credentials_set (session, GNUTLS_CRD_ANON, anoncred);

    gnutls_dh_set_prime_bits (session, DH_BITS);

    return session;
}

static gnutls_dh_params_t dh_params;

static int
generate_dh_params (void)
{
    /* Generate Diffie Hellman parameters - for use with DHE
     * kx algorithms. These should be discarded and regenerated
     * once a day, once a week or once a month. Depending on the
     * security requirements.
     */

```

```

    gnutls_dh_params_init (&dh_params);
    gnutls_dh_params_generate2 (dh_params, DH_BITS);

    return 0;
}

int
main (void)
{
    int err, listen_sd, i;
    int sd, ret;
    struct sockaddr_in sa_serv;
    struct sockaddr_in sa_cli;
    int client_len;
    char topbuf[512];
    gnutls_session_t session;
    char buffer[MAX_BUF + 1];
    int optval = 1;

    /* this must be called once in the program
       */
    gnutls_global_init ();

    gnutls_anon_allocate_server_credentials (&anoncred);

    generate_dh_params ();

    gnutls_anon_set_server_dh_params (anoncred, dh_params);

    /* Socket operations
       */
    listen_sd = socket (AF_INET, SOCK_STREAM, 0);
    SOCKET_ERR (listen_sd, "socket");

    memset (&sa_serv, '\0', sizeof (sa_serv));
    sa_serv.sin_family = AF_INET;
    sa_serv.sin_addr.s_addr = INADDR_ANY;
    sa_serv.sin_port = htons (PORT);      /* Server Port number */

    setsockopt (listen_sd, SOL_SOCKET, SO_REUSEADDR, &optval, sizeof (int));

    err = bind (listen_sd, (SA *) & sa_serv, sizeof (sa_serv));
    SOCKET_ERR (err, "bind");
    err = listen (listen_sd, 1024);
    SOCKET_ERR (err, "listen");

    printf ("Server ready. Listening to port '%d'.\n\n", PORT);

```

```

client_len = sizeof (sa_cli);
for (;;)
{
    session = initialize_tls_session ();

    sd = accept (listen_sd, (SA *) & sa_cli, &client_len);

    printf ("- connection from %s, port %d\n",
            inet_ntop (AF_INET, &sa_cli.sin_addr, topbuf,
                      sizeof (topbuf)), ntohs (sa_cli.sin_port));

    gnutls_transport_set_ptr (session, (gnutls_transport_ptr_t) sd);
    ret = gnutls_handshake (session);
    if (ret < 0)
    {
        close (sd);
        gnutls_deinit (session);
        fprintf (stderr, "*** Handshake has failed (%s)\n\n",
                gnutls_strerror (ret));
        continue;
    }
    printf ("- Handshake was completed\n");

    /* see the Getting peer's information example */
    /* print_info(session); */

    i = 0;
    for (;;)
    {
        memset (buffer, 0, MAX_BUF + 1);
        ret = gnutls_record_recv (session, buffer, MAX_BUF);

        if (ret == 0)
        {
            printf ("\n- Peer has closed the GNUTLS connection\n");
            break;
        }
        else if (ret < 0)
        {
            fprintf (stderr, "\n*** Received corrupted "
                    "data(%d). Closing the connection.\n\n", ret);
            break;
        }
        else if (ret > 0)
        {
            /* echo data back to the client

```



```

        */
        gnutls_record_send (session, buffer, strlen (buffer));
    }
}
printf ("\n");
/* do not wait for the peer to close the connection.
*/
gnutls_bye (session, GNUTLS_SHUT_WR);

close (sd);
gnutls_deinit (session);

}
close (listen_sd);

gnutls_anon_free_server_credentials (anoncred);

gnutls_global_deinit ();

return 0;

}

```

7.5 Miscellaneous Examples

7.5.1 Checking for an Alert

This is a function that checks if an alert has been received in the current session.

```

/* Copyright 2007 Free Software Foundation
 *
 * Copying and distribution of this file, with or without modification,
 * are permitted in any medium without royalty provided the copyright
 * notice and this notice are preserved.
 */

#if HAVE_CONFIG_H
# include <config.h>
#endif

#include <stdio.h>
#include <stdlib.h>
#include <gnutls/gnutls.h>

/* This function will check whether the given return code from
 * a gnutls function (recv/send), is an alert, and will print
 * that alert.
 */

```

```

void
check_alert (gnutls_session_t session, int ret)
{
    int last_alert;

    if (ret == GNUTLS_E_WARNING_ALERT_RECEIVED
        || ret == GNUTLS_E_FATAL_ALERT_RECEIVED)
    {
        last_alert = gnutls_alert_get (session);

        /* The check for renegotiation is only useful if we are
         * a server, and we had requested a rehandshake.
         */
        if (last_alert == GNUTLS_A_NO_RENEGOTIATION &&
            ret == GNUTLS_E_WARNING_ALERT_RECEIVED)
            printf ("* Received NO_RENEGOTIATION alert. "
                    "Client Does not support renegotiation.\n");
        else
            printf ("* Received alert '%d': %s.\n", last_alert,
                    gnutls_alert_get_name (last_alert));
    }
}

```

7.5.2 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.

```

/* Copyright 2007 Free Software Foundation
 *
 * Copying and distribution of this file, with or without modification,
 * are permitted in any medium without royalty provided the copyright
 * notice and this notice are preserved.
 */

#if HAVE_CONFIG_H
# include <config.h>
#endif

#include <stdio.h>
#include <stdlib.h>
#include <gnutls/gnutls.h>
#include <gnutls/x509.h>

static const char *
bin2hex (const void *bin, size_t bin_size)
{
    static char printable[110];

```

```

    const unsigned char *_bin = bin;
    char *print;
    size_t i;

    if (bin_size > 50)
        bin_size = 50;

    print = printable;
    for (i = 0; i < bin_size; i++)
    {
        sprintf (print, "%.2x ", _bin[i]);
        print += 2;
    }

    return printable;
}

/* This function will print information about this session's peer
 * certificate.
 */
void
print_x509_certificate_info (gnutls_session_t session)
{
    char serial[40];
    char dn[128];
    size_t size;
    unsigned int algo, bits;
    time_t expiration_time, activation_time;
    const gnutls_datum_t *cert_list;
    unsigned int cert_list_size = 0;
    gnutls_x509_crt_t cert;

    /* This function only works for X.509 certificates.
     */
    if (gnutls_certificate_type_get (session) != GNUTLS_CERT_X509)
        return;

    cert_list = gnutls_certificate_get_peers (session, &cert_list_size);

    printf ("Peer provided %d certificates.\n", cert_list_size);

    if (cert_list_size > 0)
    {
        /* we only print information about the first certificate.
         */
        gnutls_x509_crt_init (&cert);

```

```

gnutls_x509_cert_import (cert, &cert_list[0], GNUTLS_X509_FMT_DER);

printf ("Certificate info:\n");

expiration_time = gnutls_x509_cert_get_expiration_time (cert);
activation_time = gnutls_x509_cert_get_activation_time (cert);

printf ("\tCertificate is valid since: %s", ctime (&activation_time));
printf ("\tCertificate expires: %s", ctime (&expiration_time));

/* Print the serial number of the certificate.
 */
size = sizeof (serial);
gnutls_x509_cert_get_serial (cert, serial, &size);

size = sizeof (serial);
printf ("\tCertificate serial number: %s\n", bin2hex (serial, size));

/* Extract some of the public key algorithm's parameters
 */
algo = gnutls_x509_cert_get_pk_algorithm (cert, &bits);

printf ("Certificate public key: %s",
        gnutls_pk_algorithm_get_name (algo));

/* Print the version of the X.509
 * certificate.
 */
printf ("\tCertificate version: #%d\n",
        gnutls_x509_cert_get_version (cert));

size = sizeof (dn);
gnutls_x509_cert_get_dn (cert, dn, &size);
printf ("\tDN: %s\n", dn);

size = sizeof (dn);
gnutls_x509_cert_get_issuer_dn (cert, dn, &size);
printf ("\tIssuer's DN: %s\n", dn);

gnutls_x509_cert_deinit (cert);

}
}

```

7.5.3 Certificate Request Generation

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.

```
/* Copyright 2007 Free Software Foundation
 *
 * Copying and distribution of this file, with or without modification,
 * are permitted in any medium without royalty provided the copyright
 * notice and this notice are preserved.
 */

#if HAVE_CONFIG_H
# include <config.h>
#endif

#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <gnutls/gnutls.h>
#include <gnutls/x509.h>
#include <time.h>

/* This example will generate a private key and a certificate
 * request.
 */

int
main (void)
{
    gnutls_x509_crq_t crq;
    gnutls_x509_privkey_t key;
    unsigned char buffer[10 * 1024];
    size_t buffer_size = sizeof (buffer);

    gnutls_global_init ();

    /* Initialize an empty certificate request, and
     * an empty private key.
     */
    gnutls_x509_crq_init (&crq);

    gnutls_x509_privkey_init (&key);

    /* Generate a 1024 bit RSA private key.
     */
    gnutls_x509_privkey_generate (key, GNUTLS_PK_RSA, 1024, 0);

    /* Add stuff to the distinguished name
```

```
    /*
    gnutls_x509_crq_set_dn_by_oid (crq, GNUTLS_OID_X520_COUNTRY_NAME,
                                0, "GR", 2);

    gnutls_x509_crq_set_dn_by_oid (crq, GNUTLS_OID_X520_COMMON_NAME,
                                0, "Nikos", strlen ("Nikos"));

    /* Set the request version.
    */
    gnutls_x509_crq_set_version (crq, 1);

    /* Set a challenge password.
    */
    gnutls_x509_crq_set_challenge_password (crq, "something to remember here");

    /* Associate the request with the private key
    */
    gnutls_x509_crq_set_key (crq, key);

    /* Self sign the certificate request.
    */
    gnutls_x509_crq_sign (crq, key);

    /* Export the PEM encoded certificate request, and
    * display it.
    */
    gnutls_x509_crq_export (crq, GNUTLS_X509_FMT_PEM, buffer, &buffer_size);

    printf ("Certificate Request: \n%s", buffer);

    /* Export the PEM encoded private key, and
    * display it.
    */
    buffer_size = sizeof (buffer);
    gnutls_x509_privkey_export (key, GNUTLS_X509_FMT_PEM, buffer, &buffer_size);

    printf ("\n\nPrivate key: \n%s", buffer);

    gnutls_x509_crq_deinit (crq);
    gnutls_x509_privkey_deinit (key);

    return 0;
}
```

7.5.4 PKCS #12 Structure Generation

The following example is about generating a PKCS #12 structure.

```
/* Copyright 2007 Free Software Foundation
 *
 * Copying and distribution of this file, with or without modification,
 * are permitted in any medium without royalty provided the copyright
 * notice and this notice are preserved.
 */

#if HAVE_CONFIG_H
# include <config.h>
#endif

#include <stdio.h>
#include <stdlib.h>
#include <gnutls/gnutls.h>
#include <gnutls/pkcs12.h>

#define OUTFILE "out.p12"

/* This function will write a pkcs12 structure into a file.
 * cert: is a DER encoded certificate
 * pkcs8_key: is a PKCS #8 encrypted key (note that this must be
 * encrypted using a PKCS #12 cipher, or some browsers will crash)
 * password: is the password used to encrypt the PKCS #12 packet.
 */
int
write_pkcs12 (const gnutls_datum_t * cert,
              const gnutls_datum_t * pkcs8_key, const char *password)
{
    gnutls_pkcs12_t pkcs12;
    int ret, bag_index;
    gnutls_pkcs12_bag_t bag, key_bag;
    char pkcs12_struct[10 * 1024];
    size_t pkcs12_struct_size;
    FILE *fd;

    /* A good idea might be to use gnutls_x509_privkey_get_key_id()
     * to obtain a unique ID.
     */
    gnutls_datum_t key_id = { "\x00\x00\x07", 3 };

    gnutls_global_init ();

    /* Firstly we create two helper bags, which hold the certificate,
     * and the (encrypted) key.
     */
}
```

```
*/

gnutls_pkcs12_bag_init (&bag);
gnutls_pkcs12_bag_init (&key_bag);

ret = gnutls_pkcs12_bag_set_data (bag, GNUTLS_BAG_CERTIFICATE, cert);
if (ret < 0)
{
    fprintf (stderr, "ret: %s\n", gnutls_strerror (ret));
    return 1;
}

/* ret now holds the bag's index.
*/
bag_index = ret;

/* Associate a friendly name with the given certificate. Used
 * by browsers.
*/
gnutls_pkcs12_bag_set_friendly_name (bag, bag_index, "My name");

/* Associate the certificate with the key using a unique key
 * ID.
*/
gnutls_pkcs12_bag_set_key_id (bag, bag_index, &key_id);

/* use weak encryption for the certificate.
*/
gnutls_pkcs12_bag_encrypt (bag, password, GNUTLS_PKCS_USE_PKCS12_RC2_40);

/* Now the key.
*/

ret = gnutls_pkcs12_bag_set_data (key_bag,
                                GNUTLS_BAG_PKCS8_ENCRYPTED_KEY,
                                pkcs8_key);
if (ret < 0)
{
    fprintf (stderr, "ret: %s\n", gnutls_strerror (ret));
    return 1;
}

/* Note that since the PKCS #8 key is already encrypted we don't
 * bother encrypting that bag.
*/
bag_index = ret;
```



```
gnutls_pkcs12_bag_set_friendly_name (key_bag, bag_index, "My name");

gnutls_pkcs12_bag_set_key_id (key_bag, bag_index, &key_id);

/* The bags were filled. Now create the PKCS #12 structure.
 */
gnutls_pkcs12_init (&pkcs12);

/* Insert the two bags in the PKCS #12 structure.
 */

gnutls_pkcs12_set_bag (pkcs12, bag);
gnutls_pkcs12_set_bag (pkcs12, key_bag);

/* Generate a message authentication code for the PKCS #12
 * structure.
 */
gnutls_pkcs12_generate_mac (pkcs12, password);

pkcs12_struct_size = sizeof (pkcs12_struct);
ret =
    gnutls_pkcs12_export (pkcs12, GNUTLS_X509_FMT_DER, pkcs12_struct,
                          &pkcs12_struct_size);
if (ret < 0)
{
    fprintf (stderr, "ret: %s\n", gnutls_strerror (ret));
    return 1;
}

fd = fopen (OUTFILE, "w");
if (fd == NULL)
{
    fprintf (stderr, "cannot open file\n");
    return 1;
}
fwrite (pkcs12_struct, 1, pkcs12_struct_size, fd);
fclose (fd);

gnutls_pkcs12_bag_deinit (bag);
gnutls_pkcs12_bag_deinit (key_bag);
gnutls_pkcs12_deinit (pkcs12);

return 0;
}
```

7.6 Compatibility with the OpenSSL Library

To ease GnuTLS' integration with existing applications, a compatibility layer with the widely used OpenSSL library is included in the `gnutls-openssl` library. This compatibility layer is not complete and it is not intended to completely reimplement the OpenSSL API with GnuTLS. It only provides source-level compatibility. There is currently no attempt to make it binary-compatible with OpenSSL.

The prototypes for the compatibility functions are in the `'gnutls/openssl.h'` header file.

Current limitations imposed by the compatibility layer include:

- Error handling is not thread safe.

7.7 Opaque PRF Input TLS Extension

GnuTLS supports the Opaque PRF Input TLS extension (`draft-rescorla-tls-opaque-prf-input-00.txt`). The API consists of one API for use in the client, `[gnutls_oprfi_enable_client]`, [page 141](#), and one API for use in the server, `[gnutls_oprfi_enable_server]`, [page 141](#). You must invoke both functions before calling `[gnutls_handshake]`, [page 137](#). The server utilizes a callback function into the application. The callback can look at the random string provided by the client, and also set the server string. The string lengths must be equal according to the protocol.

8 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.

8.1 Invoking srptool

The ‘`srptool`’ is a very simple program that emulates the programs in the *Stanford SRP libraries*. It is intended for use in places where you don’t expect SRP authentication to be the used for system users. Traditionally *libsrp* used two files. One called ‘`tpasswd`’ which holds usernames and verifiers, and ‘`tpasswd.conf`’ which holds generators and primes.

How to use `srptool`:

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

```
$ 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.

```
$ 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.

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

8.2 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.

GNU TLS test client

Usage: `gnutls-cli` [options] hostname

<code>-d, --debug integer</code>	Enable debugging
<code>-r, --resume</code>	Connect, establish a session. Connect again and resume this session.
<code>-s, --starttls</code>	Connect, establish a plain session and start TLS when EOF or a SIGALRM is received.
<code>--crlf</code>	Send CR LF instead of LF.
<code>--x509fmtder</code>	Use DER format for certificates to read from.
<code>-f, --fingerprint</code>	Send the openpgp fingerprint, instead of the key.
<code>--disable-extensions</code>	Disable all the TLS extensions.
<code>--print-cert</code>	Print the certificate in PEM format.

```

-p, --port integer      The port to connect to.
--recordsize integer    The maximum record size to advertize.
-V, --verbose           More verbose output.
--ciphers cipher1 cipher2...
                        Ciphers to enable.
--protocols protocol1 protocol2...
                        Protocols to enable.
--comp comp1 comp2...   Compression methods to enable.
--macs mac1 mac2...     MACs to enable.
--kx kx1 kx2...         Key exchange methods to enable.
--ctypes certType1 certType2...
                        Certificate types to enable.
--x509cafile FILE       Certificate file to use.
--x509crlfile FILE      CRL file to use.
--pgpkeyfile FILE       PGP Key file to use.
--pgpkeyring FILE       PGP Key ring file to use.
--pgptrustdb FILE       PGP trustdb file to use.
--pgpcertfile FILE      PGP Public Key (certificate) file to
                        use.
--x509keyfile FILE      X.509 key file to use.
--x509certfile FILE     X.509 Certificate file to use.
--srpusername NAME      SRP username to use.
--srppasswd PASSWD      SRP password to use.
--insecure              Don't abort program if server
                        certificate can't be validated.
-l, --list              Print a list of the supported
                        algorithms and modes.
-h, --help              prints this help
-v, --version           prints the program's version number
--copyright             prints the program's license

```

8.3 Invoking gnutls-cli-debug

This program was created to assist in debugging GnuTLS, but it might be useful to extract a TLS server's capabilities. Its purpose is to connect onto a TLS server, perform some tests and print the server's capabilities. If called with the '-v' parameter a more checks will be performed. An example output is:

```

crystal:/cvs/gnutls/src$ ./gnutls-cli-debug localhost -p 5556
Resolving 'localhost'...
Connecting to '127.0.0.1:5556'...
Checking for TLS 1.1 support... yes
Checking fallback from TLS 1.1 to... N/A
Checking for TLS 1.0 support... yes
Checking for SSL 3.0 support... yes
Checking for version rollback bug in RSA PMS... no
Checking for version rollback bug in Client Hello... no
Checking whether we need to disable TLS 1.0... N/A
Checking whether the server ignores the RSA PMS version... no
Checking whether the server can accept Hello Extensions... yes
Checking whether the server can accept cipher suites not in SSL 3.0 spec... yes

```

```

Checking whether the server can accept a bogus TLS record version in the client hello... yes
Checking for certificate information... N/A
Checking for trusted CAs... N/A
Checking whether the server understands TLS closure alerts... yes
Checking whether the server supports session resumption... yes
Checking for export-grade ciphersuite support... no
Checking RSA-export ciphersuite info... N/A
Checking for anonymous authentication support... no
Checking anonymous Diffie Hellman group info... N/A
Checking for ephemeral Diffie Hellman support... no
Checking ephemeral Diffie Hellman group info... N/A
Checking for AES cipher support (TLS extension)... yes
Checking for 3DES cipher support... yes
Checking for ARCFOUR 128 cipher support... yes
Checking for ARCFOUR 40 cipher support... no
Checking for MD5 MAC support... yes
Checking for SHA1 MAC support... yes
Checking for ZLIB compression support (TLS extension)... yes
Checking for LZ0 compression support (GnuTLS extension)... yes
Checking for max record size (TLS extension)... yes
Checking for SRP authentication support (TLS extension)... yes
Checking for OpenPGP authentication support (TLS extension)... no

```

8.4 Invoking gnutls-serv

Simple server program that listens to incoming TLS connections.

GNU TLS test server

Usage: gnutls-serv [options]

<code>-d, --debug integer</code>	Enable debugging
<code>-g, --generate</code>	Generate Diffie Hellman Parameters.
<code>-p, --port integer</code>	The port to connect to.
<code>-q, --quiet</code>	Suppress some messages.
<code>--nodb</code>	Does not use the resume database.
<code>--http</code>	Act as an HTTP Server.
<code>--echo</code>	Act as an Echo Server.
<code>--dhparams FILE</code>	DH params file to use.
<code>--x509fmtder</code>	Use DER format for certificates
<code>--x509cafile FILE</code>	Certificate file to use.
<code>--x509crlfile FILE</code>	CRL file to use.
<code>--pgpkeyring FILE</code>	PGP Key ring file to use.
<code>--pgptrustdb FILE</code>	PGP trustdb file to use.
<code>--pgpkeyfile FILE</code>	PGP Key file to use.
<code>--pgpcertfile FILE</code>	PGP Public Key (certificate) file to use.
<code>--x509keyfile FILE</code>	X.509 key file to use.
<code>--x509certfile FILE</code>	X.509 Certificate file to use.
<code>--x509dsakeyfile FILE</code>	Alternative X.509 key file to use.
<code>--x509dsacertfile FILE</code>	Alternative X.509 certificate file to use.
<code>--srppasswd FILE</code>	SRP password file to use.

```

--srppasswdconf FILE      SRP password conf file to use.
--ciphers cipher1 cipher2...
                        Ciphers to enable.
--protocols protocol1 protocol2...
                        Protocols to enable.
--comp comp1 comp2...    Compression methods to enable.
--macs mac1 mac2...      MACs to enable.
--kx kx1 kx2...          Key exchange methods to enable.
--ctypes certType1 certType2...
                        Certificate types to enable.
-l, --list               Print a list of the supported
                        algorithms and modes.
-h, --help              prints this help
-v, --version            prints the program's version number
--copyright              prints the program's license

```

8.4.1 Setting Up a Test HTTPS Server

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:

```
gnutls-serv --http
```

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:

```

certtool --generate-privkey > x509-ca-key.pem
echo 'cn = GnuTLS test CA' > ca.tmpl
echo 'ca' >> ca.tmpl
echo 'cert_signing_key' >> ca.tmpl
certtool --generate-self-signed --load-privkey x509-ca-key.pem \
  --template ca.tmpl --outfile x509-ca.pem
...

```

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.

```

certtool --generate-privkey > x509-server-key.pem
echo 'organization = GnuTLS test server' > server.tmpl
echo 'cn = test.gnutls.org' >> server.tmpl
echo 'tls_www_server' >> server.tmpl
echo 'encryption_key' >> server.tmpl
echo 'signing_key' >> server.tmpl
echo 'dns_name = test.gnutls.org' >> server.tmpl
certtool --generate-certificate --load-privkey x509-server-key.pem \
  --load-ca-certificate x509-ca.pem --load-ca-privkey x509-ca-key.pem \
  --template server.tmpl --outfile x509-server.pem
...

```

For use in the client, you may want to generate a client certificate as well.

```
certtool --generate-privkey > x509-client-key.pem
echo 'cn = GnuTLS test client' > client.tmpl
echo 'tls_www_client' >> client.tmpl
echo 'encryption_key' >> client.tmpl
echo 'signing_key' >> client.tmpl
certtool --generate-certificate --load-privkey x509-client-key.pem \
  --load-ca-certificate x509-ca.pem --load-ca-privkey x509-ca-key.pem \
  --template client.tmpl --outfile x509-client.pem
...
```

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.

```
certtool --to-p12 --load-privkey x509-client-key.pem --load-certificate x509-client.pem
```

For icing, we'll create a proxy certificate for the client too.

```
certtool --generate-privkey > x509-proxy-key.pem
echo 'cn = GnuTLS test client proxy' > proxy.tmpl
certtool --generate-proxy --load-privkey x509-proxy-key.pem \
  --load-ca-certificate x509-client.pem --load-ca-privkey x509-client-key.pem \
  --load-certificate x509-client.pem --template proxy.tmpl \
  --outfile x509-proxy.pem
...
```

Then start the server again:

```
gnutls-serv --http \
  --x509cafile x509-ca.pem \
  --x509keyfile x509-server-key.pem \
  --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.

```
certtool --generate-privkey --dsa > x509-server-key-dsa.pem
certtool --generate-certificate --load-privkey x509-server-key-dsa.pem \
  --load-ca-certificate x509-ca.pem --load-ca-privkey x509-ca-key.pem \
  --template server.tmpl --outfile x509-server-dsa.pem
...
```

The next step is to create OpenPGP credentials for the server.

```
gpg --gen-key
...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.

```
gpg -a --export 5D1D14D8 > openpgp-server.txt
gpg --export 5D1D14D8 > openpgp-server.bin
gpg --export-secret-keys 5D1D14D8 > openpgp-server-key.bin
gpg -a --export-secret-keys 5D1D14D8 > openpgp-server-key.txt
```

Let's start the server with support for OpenPGP credentials:

```
gnutls-serv --http \
    --pgpkeyfile openpgp-server-key.txt \
    --pgpcertfile openpgp-server.txt
```

The next step is to add support for SRP authentication.

```
srptool --create-conf srp-tpasswd.conf
srptool --passwd-conf srp-tpasswd.conf --username jas --passwd srp-passwd.txt
Enter password: [TYPE "foo"]
```

Start the server with SRP support:

```
gnutls-serv --http \
    --srppasswdconf srp-tpasswd.conf \
    --srppasswd srp-passwd.txt
```

Let's also add support for PSK.

```
$ psktool --passwd psk-passwd.txt
```

Start the server with PSK support:

```
gnutls-serv --http \
    --pskpasswd psk-passwd.txt
```

Finally, we start the server with all the earlier parameters and you get this command:

```
gnutls-serv --http \
    --x509cafile x509-ca.pem \
    --x509keyfile x509-server-key.pem \
    --x509certfile x509-server.pem \
    --x509dsafile x509-server-key-dsa.pem \
    --x509dsacertfile x509-server-dsa.pem \
    --pgpkeyfile openpgp-server-key.txt \
    --pgpcertfile openpgp-server.txt \
    --srppasswdconf srp-tpasswd.conf \
    --srppasswd srp-passwd.txt \
    --pskpasswd psk-passwd.txt
```

8.5 Invoking certtool

This is a program to generate X.509 certificates, certificate requests, CRLs and private keys.

Certtool help

Usage: certtool [options]

```
-s, --generate-self-signed      Generate a self-signed certificate.
-c, --generate-certificate      Generate a signed certificate.
--generate-proxy               Generate a proxy certificate.
--generate-crl                 Generate a CRL.
-u, --update-certificate        Update a signed certificate.
-p, --generate-privkey          Generate a private key.
-q, --generate-request          Generate a PKCS #10 certificate
```


	request.
-e, --verify-chain	Verify a PEM encoded certificate chain. The last certificate in the chain must be a self signed one.
--verify-crl	Verify a CRL.
--generate-dh-params	Generate PKCS #3 encoded Diffie Hellman parameters.
--get-dh-params	Get the included PKCS #3 encoded Diffie Hellman parameters.
--load-privkey FILE	Private key file to use.
--load-request FILE	Certificate request file to use.
--load-certificate FILE	Certificate file to use.
--load-ca-privkey FILE	Certificate authority's private key file to use.
--load-ca-certificate FILE	Certificate authority's certificate file to use.
--password PASSWORD	Password to use.
-i, --certificate-info	Print information on a certificate.
-l, --crl-info	Print information on a CRL.
--p12-info	Print information on a PKCS #12 structure.
--p7-info	Print information on a PKCS #7 structure.
--smime-to-p7	Convert S/MIME to PKCS #7 structure.
-k, --key-info	Print information on a private key.
--fix-key	Regenerate the parameters in a private key.
--to-p12	Generate a PKCS #12 structure.
-8, --pkcs8	Use PKCS #8 format for private keys.
--dsa	Use DSA keys.
--hash STR	Hash algorithm to use for signing (MD5,SHA1,RMD160).
--export-ciphers	Use weak encryption algorithms.
--inder	Use DER format for input certificates and private keys.
--outder	Use DER format for output certificates and private keys.
--bits BITS	specify the number of bits for key generation.
--outfile FILE	Output file.
--infile FILE	Input file.
--template FILE	Template file to use for non interactive operation.
-d, --debug LEVEL	specify the debug level. Default is 1.
-h, --help	shows this help text

<code>-v, --version</code>	shows the program's version
<code>--copyright</code>	shows the program's license

The program can be used interactively or non interactively by specifying the `--template` command line option. See below for an example of a template file.

How to use certtool interactively:

- To generate parameters for Diffie Hellman key exchange, use the command:
`$ certtool --generate-dh-params --outfile dh.pem`
- To generate parameters for the RSA-EXPORT key exchange, use the command:
`$ certtool --generate-privkey --bits 512 --outfile rsa.pem`
- To create a self signed certificate, use the command:
`$ certtool --generate-privkey --outfile ca-key.pem`
`$ certtool --generate-self-signed --load-privkey ca-key.pem \`
`--outfile ca-cert.pem`

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

- To create a private key, run:
`$ certtool --generate-privkey --outfile key.pem`
- To create a certificate request, run:
`$ certtool --generate-request --load-privkey key.pem \`
`--outfile request.pem`
- To generate a certificate using the previous request, use the command:
`$ certtool --generate-certificate --load-request request.pem \`
`--outfile cert.pem \`
`--load-ca-certificate ca-cert.pem --load-ca-privkey ca-key.pem`
- To view the certificate information, use:
`$ certtool --certificate-info --infile cert.pem`
- To generate a PKCS #12 structure using the previous key and certificate, use the command:
`$ certtool --load-certificate cert.pem --load-privkey key.pem \`
`--to-p12 --outder --outfile key.p12`
- 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:
`$ certtool --generate-privkey > proxy-key.pem`
`$ certtool --generate-proxy --load-ca-privkey key.pem \`
`--load-privkey proxy-key.pem --load-certificate cert.pem \`
`--outfile proxy-cert.pem`

Certtool's template file format:

- Firstly create a file named 'cert.cfg' that contains the information about the certificate. An example file is listed below.
- Then execute:

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

An example certtool template file:

```
# X.509 Certificate options
#
# DN options

# The organization of the subject.
organization = "Koko inc."

# The organizational unit of the subject.
unit = "sleeping dept."

# The locality of the subject.
# locality =

# The state of the certificate owner.
state = "Attiki"

# The country of the subject. Two letter code.
country = GR

# The common name of the certificate owner.
cn = "Cindy Lauper"

# A user id of the certificate owner.
#uid = "clauper"

# If the supported DN OIDs are not adequate you can set
# any OID here.
# For example set the X.520 Title and the X.520 Pseudonym
# by using OID and string pairs.
#dn_oid = "2.5.4.12" "Dr." "2.5.4.65" "jackal"

# This is deprecated and should not be used in new
# certificates.
# pkcs9_email = "none@none.org"

# The serial number of the certificate
serial = 007

# In how many days, counting from today, this certificate will expire.
expiration_days = 700

# X.509 v3 extensions
```

```
# A dnsname in case of a WWW server.
#dns_name = "www.none.org"

# An IP address in case of a server.
#ip_address = "192.168.1.1"

# An email in case of a person
email = "none@none.org"

# An URL that has CRLs (certificate revocation lists)
# available. Needed in CA certificates.
#crl_dist_points = "http://www.getcrl.crl/getcrl/"

# Whether this is a CA certificate or not
#ca

# Whether this certificate will be used for a TLS client
#tls_www_client

# Whether this certificate will be used for a TLS server
#tls_www_server

# Whether this certificate will be used to sign data (needed
# in TLS DHE ciphersuites).
signing_key

# Whether this certificate will be used to encrypt data (needed
# in TLS RSA ciphersuites). Note that it is preferred to use different
# keys for encryption and signing.
#encryption_key

# Whether this key will be used to sign other certificates.
#cert_signing_key

# Whether this key will be used to sign CRLs.
#crl_signing_key

# Whether this key will be used to sign code.
#code_signing_key

# Whether this key will be used to sign OCSP data.
#ocsp_signing_key

# Whether this key will be used for time stamping.
#time_stamping_key
```

9 Function Reference

9.1 Core Functions

The prototypes for the following functions lie in ‘gnutls/gnutls.h’.

gnutls_alert_get_name

```
const char * gnutls_alert_get_name (gnutls_alert_description_t      [Function]
    alert)
```

alert: is an alert number `gnutls_session_t` structure.

This function will return a string that describes the given alert number or NULL. See `gnutls_alert_get()`.

gnutls_alert_get

```
gnutls_alert_description_t gnutls_alert_get (gnutls_session_t      [Function]
    session)
```

session: is a `gnutls_session_t` structure.

This function will return the last alert number received. This function should be called if `GNUTLS_E_WARNING_ALERT_RECEIVED` or `GNUTLS_E_FATAL_ALERT_RECEIVED` has been returned by a gnutls function. The peer may send alerts if he thinks some things were not right. Check `gnutls.h` for the available alert descriptions.

If no alert has been received the returned value is undefined.

gnutls_alert_send_appropriate

```
int gnutls_alert_send_appropriate (gnutls_session_t session, int    [Function]
    err)
```

session: is a `gnutls_session_t` structure.

err: is an integer

Sends an alert to the peer depending on the error code returned by a gnutls function. This function will call `gnutls_error_to_alert()` to determine the appropriate alert to send.

This function may also return `GNUTLS_E_AGAIN`, or `GNUTLS_E_INTERRUPTED`.

If the return value is `GNUTLS_E_INVALID_REQUEST`, then no alert has been sent to the peer.

Returns zero on success.

gnutls_alert_send

```
int gnutls_alert_send (gnutls_session_t session, gnutls_alert_level_t  [Function]
    level, gnutls_alert_description_t desc)
```

session: is a `gnutls_session_t` structure.

level: is the level of the alert

desc: is the alert 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 0 on success.

gnutls_anon_allocate_client_credentials

```
int gnutls_anon_allocate_client_credentials           [Function]
    (gnutls_anon_client_credentials_t * sc)
```

sc: is a pointer to an `gnutls_anon_client_credentials_t` structure.

This structure is complex enough to manipulate directly thus this helper function is provided in order to allocate it.

Returns: GNUTLS_E_SUCCESS on success, or an error code.

gnutls_anon_allocate_server_credentials

```
int gnutls_anon_allocate_server_credentials          [Function]
    (gnutls_anon_server_credentials_t * sc)
```

sc: is a pointer to an `gnutls_anon_server_credentials_t` structure.

This structure is complex enough to manipulate directly thus this helper function is provided in order to allocate it.

Returns: GNUTLS_E_SUCCESS on success, or an error code.

gnutls_anon_free_client_credentials

```
void gnutls_anon_free_client_credentials            [Function]
    (gnutls_anon_client_credentials_t sc)
```

sc: is an `gnutls_anon_client_credentials_t` structure.

This structure is complex enough to manipulate directly thus this helper function is provided in order to free (deallocate) it.

gnutls_anon_free_server_credentials

```
void gnutls_anon_free_server_credentials            [Function]
    (gnutls_anon_server_credentials_t sc)
```

sc: is an `gnutls_anon_server_credentials_t` structure.

This structure is complex enough to manipulate directly thus this helper function is provided in order to free (deallocate) it.

gnutls_anon_set_params_function

void gnutls_anon_set_params_function [Function]
 (*gnutls_anon_server_credentials_t* **res**, *gnutls_params_function* * **func**)

res: is a *gnutls_anon_server_credentials_t* structure

func: is the function to be called

This function will set a callback in order for the server to get the diffie hellman or RSA parameters for anonymous authentication. The callback should return zero on success.

gnutls_anon_set_server_dh_params

void gnutls_anon_set_server_dh_params [Function]
 (*gnutls_anon_server_credentials_t* **res**, *gnutls_dh_params_t* **dh_params**)

res: is a *gnutls_anon_server_credentials_t* structure

dh_params: is a structure that holds diffie hellman parameters.

This function will set the diffie hellman parameters for an anonymous server to use. These parameters will be used in Anonymous Diffie Hellman cipher suites.

gnutls_anon_set_server_params_function

void gnutls_anon_set_server_params_function [Function]
 (*gnutls_anon_server_credentials_t* **res**, *gnutls_params_function* * **func**)

res: is a *gnutls_certificate_credentials_t* structure

func: is the function to be called

This function will set a callback in order for the server to get the diffie hellman parameters for anonymous authentication. The callback should return zero on success.

gnutls_auth_client_get_type

gnutls_credentials_type_t gnutls_auth_client_get_type [Function]
 (*gnutls_session_t* **session**)

session: is a *gnutls_session_t* structure.

Returns the type of credentials that were used for client authentication. The returned information is to be used to distinguish the function used to access authentication data.

gnutls_auth_get_type

gnutls_credentials_type_t gnutls_auth_get_type [Function]
 (*gnutls_session_t* **session**)

session: is a *gnutls_session_t* structure.

Returns type of credentials for the current authentication schema. The returned information is to be used to distinguish the function used to access authentication data.

Eg. for CERTIFICATE ciphersuites (key exchange algorithms: KX_RSA, KX_DHE-RSA), the same function are to be used to access the authentication data.

gnutls_auth_server_get_type

`gnutls_credentials_type_t gnutls_auth_server_get_type` [Function]
(*gnutls_session_t session*)

session: is a `gnutls_session_t` structure.

Returns the type of credentials that were used for server authentication. The returned information is to be used to distinguish the function used to access authentication data.

gnutls_bye

`int gnutls_bye` (*gnutls_session_t session*, *gnutls_close_request_t how*) [Function]
session: is a `gnutls_session_t` structure.

how: is an integer

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` then the TLS connection gets terminated and further receives and sends will be disallowed. If the return value is zero you may continue using the connection. `GNUTLS_SHUT_RDWR` actually sends an alert containing a close request and waits for the peer to reply with the same message.

In case of `GNUTLS_SHUT_WR` then the TLS connection 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, thus causing a transmission error to the peer. This error cannot be distinguished from a malicious party prematurely terminating the session, thus this behavior is not recommended.

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.

gnutls_certificate_activation_time_peers

`time_t gnutls_certificate_activation_time_peers` [Function]
(*gnutls_session_t session*)

session: is a gnutls session

This function will return the peer's certificate activation time. This is the creation time for openpgp keys.

Returns: (time_t)-1 on error.

gnutls_certificate_allocate_credentials

int gnutls_certificate_allocate_credentials [Function]
 (gnutls_certificate_credentials_t * *res*)

res: is a pointer to an gnutls_certificate_credentials_t structure.

This structure is complex enough to manipulate directly thus this helper function is provided in order to allocate it.

Returns: GNUTLS_E_SUCCESS on success, or an error code.

gnutls_certificate_client_get_request_status

int gnutls_certificate_client_get_request_status [Function]
 (gnutls_session_t *session*)

session: is a gnutls session

This function will return 0 if the peer (server) did not request client authentication or 1 otherwise. Returns a negative value in case of an error.

gnutls_certificate_client_set_retrieve_function

void gnutls_certificate_client_set_retrieve_function [Function]
 (gnutls_certificate_credentials_t *cred*, gnutls_certificate_client_retrieve_function * *func*)

cred: is a gnutls_certificate_credentials_t structure.

func: is the callback function

This function sets a callback to be called in order to retrieve the certificate to be used in the handshake. The callback's function prototype is: int (*callback)(gnutls_session_t, const gnutls_datum_t* req_ca_dn, int nreqs, const gnutls_pk_algorithm_t* pk_algos, int pk_algos_length, gnutls_retr_st* st);

req_ca_cert is only used in X.509 certificates. Contains a list with the CA names that the server considers trusted. Normally we should send a certificate that is signed by one of these CAs. These names are DER encoded. To get a more meaningful value use the function `gnutls_x509_rdn_get()`.

pk_algos contains a list with server's acceptable signature algorithms. The certificate returned should support the server's given algorithms.

st should contain the certificates and private keys.

If the callback function is provided then gnutls will call it, in the handshake, after the certificate request message has been received.

The callback function should set the certificate list to be sent, and return 0 on success.

If no certificate was selected then the number of certificates should be set to zero.

The value (-1) indicates error and the handshake will be terminated.

gnutls_certificate_expiration_time_peers

time_t gnutls_certificate_expiration_time_peers [Function]
 (gnutls_session_t *session*)

session: is a gnutls session

This function will return the peer's certificate expiration time.

Returns: (time_t)-1 on error.

gnutls_certificate_free_ca_names

void gnutls_certificate_free_ca_names [Function]
 (*gnutls_certificate_credentials_t sc*)

sc: is an **gnutls_certificate_credentials_t** structure.

This function will delete all the CA name in the given credentials. Clients may call this to save some memory since in client side the CA names are not used.

CA names are used by servers to advertize the CAs they support to clients.

gnutls_certificate_free_cas

void gnutls_certificate_free_cas (*gnutls_certificate_credentials_t* [Function]
 sc)

sc: is an **gnutls_certificate_credentials_t** structure.

This function will delete all the CAs associated with the given credentials. Servers that do not use **gnutls_certificate_verify_peers2()** may call this to save some memory.

gnutls_certificate_free_credentials

void gnutls_certificate_free_credentials [Function]
 (*gnutls_certificate_credentials_t sc*)

sc: is an **gnutls_certificate_credentials_t** structure.

This structure is complex enough to manipulate directly thus this helper function is provided in order to free (deallocate) it.

This function does not free any temporary parameters associated with this structure (ie RSA and DH parameters are not freed by this function).

gnutls_certificate_free_crls

void gnutls_certificate_free_crls (*gnutls_certificate_credentials_t* [Function]
 sc)

sc: is an **gnutls_certificate_credentials_t** structure.

This function will delete all the CRLs associated with the given credentials.

gnutls_certificate_free_keys

void gnutls_certificate_free_keys (*gnutls_certificate_credentials_t* [Function]
 sc)

sc: is an **gnutls_certificate_credentials_t** structure.

This function will delete all the keys and the certificates associated with the given credentials. This function must not be called when a TLS negotiation that uses the credentials is in progress.

gnutls_certificate_get_ours

const gnutls_datum_t * gnutls_certificate_get_ours [Function]
 (*gnutls_session_t session*)

session: is a gnutls session

This function will return the certificate as sent to the peer, in the last handshake. These certificates are in raw format. In X.509 this is a certificate list. In OpenPGP this is a single certificate. Returns NULL in case of an error, or if no certificate was used.

gnutls_certificate_get_peers

const gnutls_datum_t * gnutls_certificate_get_peers [Function]
 (*gnutls_session_t session, unsigned int * list_size*)

session: is a gnutls session

list_size: is the length of the certificate list

This function will return the peer's raw certificate (chain) as sent by the peer. These certificates are in raw format (DER encoded for X.509). In case of a X.509 then a certificate list may be present. The first certificate in the list is the peer's certificate, following the issuer's certificate, then the issuer's issuer etc.

In case of OpenPGP keys a single key will be returned in raw format.

Returns NULL in case of an error, or if no certificate was sent.

gnutls_certificate_send_x509_rdn_sequence

void gnutls_certificate_send_x509_rdn_sequence [Function]
 (*gnutls_session_t session, int status*)

session: is a pointer to a gnutls_session_t structure.

status: is 0 or 1

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 advertize it's trusted CAs to the peer. If status is zero then the default behaviour will take effect, which is to advertize the server's trusted CAs.

This function has no effect in clients, and in authentication methods other than certificate with X.509 certificates.

gnutls_certificate_server_set_request

void gnutls_certificate_server_set_request (*gnutls_session_t session, gnutls_certificate_request_t req*) [Function]

session: is an gnutls_session_t structure.

req: is one of GNUTLS_CERT_REQUEST, GNUTLS_CERT_REQUIRE

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.

gnutls_certificate_server_set_retrieve_function

```
void gnutls_certificate_server_set_retrieve_function [Function]
      (gnutls_certificate_credentials_t cred, gnutls_certificate_server_retrieve_function
       * func)
```

cred: is a `gnutls_certificate_credentials_t` structure.

func: is the callback function

This function sets a callback to be called in order to retrieve the certificate to be used in the handshake. The callback's function prototype is: `int (*callback)(gnutls_session_t, gnutls_retr_st* st);`

st should contain the certificates and private keys.

If the callback function is provided then gnutls will call it, in the handshake, after the certificate request message has been received.

The callback function should set the certificate list to be sent, and return 0 on success. The value (-1) indicates error and the handshake will be terminated.

gnutls_certificate_set_dh_params

```
void gnutls_certificate_set_dh_params [Function]
      (gnutls_certificate_credentials_t res, gnutls_dh_params_t dh_params)
```

res: is a `gnutls_certificate_credentials_t` structure

dh_params: is a structure that holds diffie hellman parameters.

This function will set the diffie hellman parameters for a certificate server to use. These parameters will be used in Ephemeral Diffie Hellman cipher suites. Note that only a pointer to the parameters are stored in the certificate handle, so if you deallocate the parameters before the certificate is deallocated, you must change the parameters stored in the certificate first.

gnutls_certificate_set_params_function

```
void gnutls_certificate_set_params_function [Function]
      (gnutls_certificate_credentials_t res, gnutls_params_function * func)
```

res: is a `gnutls_certificate_credentials_t` structure

func: is the function to be called

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 zero on success.

gnutls_certificate_set_rsa_export_params

```
void gnutls_certificate_set_rsa_export_params [Function]
      (gnutls_certificate_credentials_t res, gnutls_rsa_params_t rsa_params)
```

res: is a `gnutls_certificate_credentials_t` structure

rsa_params: is a structure that holds temporary RSA parameters.

This function will set the temporary RSA parameters for a certificate server to use. These parameters will be used in RSA-EXPORT cipher suites.

gnutls_certificate_set_verify_flags

void gnutls_certificate_set_verify_flags [Function]

(*gnutls_certificate_credentials_t* *res*, *unsigned int flags*)

res: is a *gnutls_certificate_credentials_t* structure

flags: are the flags

This function will set the flags to be used at verification of the certificates. Flags must be OR of the *gnutls_certificate_verify_flags* enumerations.

gnutls_certificate_set_verify_limits

void gnutls_certificate_set_verify_limits [Function]

(*gnutls_certificate_credentials_t* *res*, *unsigned int max_bits*, *unsigned int max_depth*)

res: is a *gnutls_certificate_credentials_t* structure

max_bits: is the number of bits of an acceptable certificate (default 8200)

max_depth: is maximum depth of the verification of a certificate chain (default 5)

This function will set some upper limits for the default verification function, *gnutls_certificate_verify_peers2()*, to avoid denial of service attacks.

gnutls_certificate_set_x509_crl_file

int gnutls_certificate_set_x509_crl_file [Function]

(*gnutls_certificate_credentials_t* *res*, *const char *crlfile*,
gnutls_x509_crt_fmt_t type)

res: is an *gnutls_certificate_credentials_t* structure.

crlfile: is a file containing the list of verified CRLs (DER or PEM list)

type: is PEM or DER

This function adds the trusted CRLs in order to verify client or server certificates. In case of a client this is not required to be called if the certificates are not verified using *gnutls_certificate_verify_peers2()*. This function may be called multiple times.

Returns: number of CRLs processed or a negative value on error.

gnutls_certificate_set_x509_crl_mem

int gnutls_certificate_set_x509_crl_mem [Function]

(*gnutls_certificate_credentials_t* *res*, *const gnutls_datum_t *CRL*,
gnutls_x509_crt_fmt_t type)

res: is an *gnutls_certificate_credentials_t* structure.

CRL: is a list of trusted CRLs. They should have been verified before.

type: is DER or PEM

This function adds the trusted CRLs in order to verify client or server certificates. In case of a client this is not required to be called if the certificates are not verified using *gnutls_certificate_verify_peers2()*. This function may be called multiple times.

Returns: number of CRLs processed, or a negative value on error.

gnutls_certificate_set_x509_crl

```
int gnutls_certificate_set_x509_crl [Function]
    (gnutls_certificate_credentials_t res, gnutls_x509_crl_t * crl_list, int
     crl_list_size)
```

res: is an `gnutls_certificate_credentials_t` structure.

crl_list: is a list of trusted CRLs. They should have been verified before.

crl_list_size: holds the size of the *crl_list*

This function adds the trusted CRLs in order to verify client or server certificates. In case of a client this is not required to be called if the certificates are not verified using `gnutls_certificate_verify_peers2()`. This function may be called multiple times.

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

gnutls_certificate_set_x509_key_file

```
int gnutls_certificate_set_x509_key_file [Function]
    (gnutls_certificate_credentials_t res, const char * CERTFILE, const char *
     KEYFILE, gnutls_x509_crt_fmt_t type)
```

res: is an `gnutls_certificate_credentials_t` structure.

CERTFILE: is a file that containing the certificate list (path) for the specified private key, in PKCS7 format, or a list of certificates

KEYFILE: is a file that contains the private key

type: is PEM or DER

This function sets a certificate/private key pair in the `gnutls_certificate_credentials_t` structure. This function may be called more than once (in case multiple keys/certificates exist for the server).

Currently only PKCS-1 encoded RSA and DSA private keys are accepted by this function.

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

gnutls_certificate_set_x509_key_mem

```
int gnutls_certificate_set_x509_key_mem [Function]
    (gnutls_certificate_credentials_t res, const gnutls_datum_t * cert, const
     gnutls_datum_t * key, gnutls_x509_crt_fmt_t type)
```

res: is an `gnutls_certificate_credentials_t` structure.

cert: contains a certificate list (path) for the specified private key

key: is the private key, or NULL

type: is PEM or DER

This function sets a certificate/private key pair in the `gnutls_certificate_credentials_t` structure. This function may be called more than once (in case multiple keys/certificates exist for the server).

Currently are supported: RSA PKCS-1 encoded private keys, DSA private keys.

DSA private keys are encoded the OpenSSL way, which is an ASN.1 DER sequence of 6 INTEGERS - version, p, q, g, pub, priv.

Note that the keyUsage (2.5.29.15) PKIX extension in X.509 certificates is supported. This means that certificates intended for signing cannot be used for ciphersuites that require encryption.

If the certificate and the private key are given in PEM encoding then the strings that hold their values must be null terminated.

The key may be NULL if you are using a sign callback, see `gnutls_sign_callback_set()`.

Returns: GNUTLS_E_SUCCESS on success, or an error code.

`gnutls_certificate_set_x509_key`

```
int gnutls_certificate_set_x509_key [Function]
    (gnutls_certificate_credentials_t res, gnutls_x509_crt_t * cert_list, int
     cert_list_size, gnutls_x509_privkey_t key)
```

res: is an `gnutls_certificate_credentials_t` structure.

cert_list: contains a certificate list (path) for the specified private key

cert_list_size: holds the size of the certificate list

key: is a `gnutls_x509_privkey_t` key

This function sets a certificate/private key pair in the `gnutls_certificate_credentials_t` structure. This function may be called more than once (in case multiple keys/certificates exist for the server).

Returns: GNUTLS_E_SUCCESS on success, or an error code.

`gnutls_certificate_set_x509_simple_pkcs12_file`

```
int gnutls_certificate_set_x509_simple_pkcs12_file [Function]
    (gnutls_certificate_credentials_t res, const char * pkcs12file,
     gnutls_x509_crt_fmt_t type, const char * password)
```

res: is an `gnutls_certificate_credentials_t` structure.

pkcs12file: filename of file containing PKCS12 blob.

type: is PEM or DER of the *pkcs12file*.

password: optional password used to decrypt PKCS12 file, bags and keys.

This function sets a certificate/private key pair and/or a CRL in the `gnutls_certificate_credentials_t` structure. This function may be called more than once (in case multiple keys/certificates exist for the server).

MAC: ed PKCS12 files are supported. Encrypted PKCS12 bags are supported. Encrypted PKCS8 private keys are supported. However, only password based security, and the same password for all operations, are supported.

The private keys may be RSA PKCS1 or DSA private keys encoded in the OpenSSL way.

PKCS12 file may contain many keys and/or certificates, and there is no way to identify which key/certificate pair you want. You should make sure the PKCS12 file only contain one key/certificate pair and/or one CRL.

It is believed that the limitations of this function is acceptable for most usage, and that any more flexibility would introduce complexity that would make it harder to use this functionality at all.

Returns: GNUTLS_E_SUCCESS on success, or an error code.

gnutls_certificate_set_x509_trust_file

`int gnutls_certificate_set_x509_trust_file` [Function]
 (*gnutls_certificate_credentials_t* *res*, *const char * cafile*,
 gnutls_x509_crt_fmt_t type)

res: is an `gnutls_certificate_credentials_t` structure.

cafile: is a file containing the list of trusted CAs (DER or PEM list)

type: is PEM or DER

This function adds the trusted CAs in order to verify client or server certificates. In case of a client this is not required to be called if the certificates are not verified using `gnutls_certificate_verify_peers2()`. This function may be called multiple times.

In case of a server the names of the CAs set here will be sent to the client if a certificate request is sent. This can be disabled using `gnutls_certificate_send_x509_rdn_sequence()`.

Returns: number of certificates processed, or a negative value on error.

gnutls_certificate_set_x509_trust_mem

`int gnutls_certificate_set_x509_trust_mem` [Function]
 (*gnutls_certificate_credentials_t* *res*, *const gnutls_datum_t * ca*,
 gnutls_x509_crt_fmt_t type)

res: is an `gnutls_certificate_credentials_t` structure.

ca: is a list of trusted CAs or a DER certificate

type: is DER or PEM

This function adds the trusted CAs in order to verify client or server certificates. In case of a client this is not required to be called if the certificates are not verified using `gnutls_certificate_verify_peers2()`. This function may be called multiple times.

In case of a server the CAs set here will be sent to the client if a certificate request is sent. This can be disabled using `gnutls_certificate_send_x509_rdn_sequence()`.

Returns: the number of certificates processed or a negative value on error.

gnutls_certificate_set_x509_trust

`int gnutls_certificate_set_x509_trust` [Function]
 (*gnutls_certificate_credentials_t* *res*, *gnutls_x509_crt_t * ca_list*, *int*
 ca_list_size)

res: is an `gnutls_certificate_credentials_t` structure.

ca_list: is a list of trusted CAs

ca_list_size: holds the size of the CA list

This function adds the trusted CAs in order to verify client or server certificates. In case of a client this is not required to be called if the certificates are not verified using `gnutls_certificate_verify_peers2()`. This function may be called multiple times.

In case of a server the CAs set here will be sent to the client if a certificate request is sent. This can be disabled using `gnutls_certificate_send_x509_rdn_sequence()`.

Returns: GNUTLS_E_SUCCESS on success, or an error code.

gnutls_certificate_type_get_id

`gnutls_certificate_type_t gnutls_certificate_type_get_id` [Function]
(*const char* name*)

name: is a certificate type name

The names are compared in a case insensitive way.

Returns: an id of the specified in a string certificate type, or GNUTLS_CERT_UNKNOWN on error.

gnutls_certificate_type_get_name

`const char * gnutls_certificate_type_get_name` [Function]
(*gnutls_certificate_type_t type*)

type: is a certificate type

Returns: a string (or NULL) that contains the name of the specified certificate type.

gnutls_certificate_type_get

`gnutls_certificate_type_t gnutls_certificate_type_get` [Function]
(*gnutls_session_t session*)

session: is a `gnutls_session_t` structure.

The certificate type is by default X.509, unless it is negotiated as a TLS extension.

Returns: the currently used `gnutls_certificate_type_t` certificate type.

gnutls_certificate_type_list

`const gnutls_certificate_type_t *` [Function]
`gnutls_certificate_type_list (void)`

Get a list of certificate types. Note that to be able to use OpenPGP certificates, you must link to `libgnutls-extra` and call `gnutls_global_init_extra()`.

Returns: a zero-terminated list of `gnutls_certificate_type_t` integers indicating the available certificate types.

gnutls_certificate_type_set_priority

`int gnutls_certificate_type_set_priority` (*gnutls_session_t session, const int * list*) [Function]

session: is a `gnutls_session_t` structure.

list: is a 0 terminated list of `gnutls_certificate_type_t` elements.

Sets the priority on the certificate types supported by gnutls. Priority is higher for elements specified before others. After specifying the types you want, you must append a 0. Note that the certificate type priority is set on the client. The server does not use the cert type priority except for disabling types that were not specified.

Returns 0 on success.

gnutls_certificate_verify_peers2

```
int gnutls_certificate_verify_peers2 (gnutls_session_t session,    [Function]
                                     unsigned int * status)
```

session: is a gnutls session

status: is the output of the verification

This function will try to verify the peer's certificate and return its status (trusted, invalid etc.). The value of `status` should be one or more of the `gnutls_certificate_status_t` enumerated elements bitwise or'd. To avoid denial of service attacks some default upper limits regarding the certificate key size and chain size are set. To override them use `gnutls_certificate_set_verify_limits()`.

Note that you must also check the peer's name in order to check if the verified certificate belongs to the actual peer.

This is the same as `gnutls_x509 crt_list_verify()` and uses the loaded CAs in the credentials as trusted CAs.

Note that some commonly used X.509 Certificate Authorities are still using Version 1 certificates. If you want to accept them, you need to call `gnutls_certificate_set_verify_flags()` with, e.g., `GNUTLS_VERIFY_ALLOW_X509_V1_CA_CRT` parameter.

Returns: a negative error code on error and zero on success.

gnutls_certificate_verify_peers

```
int gnutls_certificate_verify_peers (gnutls_session_t session)    [Function]
```

session: is a gnutls session

This function will try to verify the peer's certificate and return its status (trusted, invalid etc.). However you must also check the peer's name in order to check if the verified certificate belongs to the actual peer.

The return value should be one or more of the `gnutls_certificate_status_t` enumerated elements bitwise or'd, or a negative value on error.

This is the same as `gnutls_x509 crt_list_verify()`.

Deprecated: Use `gnutls_certificate_verify_peers2()` instead.

gnutls_check_version

```
const char * gnutls_check_version (const char * req_version)    [Function]
```

req-version: the version to check

Check that the version of the library is at minimum the requested one and return the version string; return NULL if the condition is not satisfied. If a NULL is passed to this function, no check is done, but the version string is simply returned.

See `LIBGNETLS_VERSION` for a suitable `req_version` string.

Return value: Version string of run-time library, or `NULL` if the run-time library does not meet the required version number. If `NULL` is passed to this function no check is done and only the version string is returned.

`gnutls_cipher_get_id`

`gnutls_cipher_algorithm_t gnutls_cipher_get_id (const char* name)` [Function]

The names are compared in a case insensitive way.

Returns: an id of the specified cipher, or `GNUTLS_CIPHER_UNKNOWN` on error.

`gnutls_cipher_get_key_size`

`size_t gnutls_cipher_get_key_size (gnutls_cipher_algorithm_t algorithm)` [Function]

algorithm: is an encryption algorithm

Returns: length (in bytes) of the given cipher's key size, or 0 if the given cipher is invalid.

`gnutls_cipher_get_name`

`const char * gnutls_cipher_get_name (gnutls_cipher_algorithm_t algorithm)` [Function]

algorithm: is an encryption algorithm

Returns: a pointer to a string that contains the name of the specified cipher, or `NULL`.

`gnutls_cipher_get`

`gnutls_cipher_algorithm_t gnutls_cipher_get (gnutls_session_t session)` [Function]

session: is a `gnutls_session_t` structure.

Returns: the currently used cipher.

`gnutls_cipher_list`

`const gnutls_cipher_algorithm_t * gnutls_cipher_list (void)` [Function]

Get a list of supported cipher algorithms. Note that not necessarily all ciphers are supported as TLS cipher suites. For example, DES is not supported as a cipher suite, but is supported for other purposes (e.g., PKCS8 or similar).

Returns: a zero-terminated list of `gnutls_cipher_algorithm_t` integers indicating the available ciphers.

`gnutls_cipher_set_priority`

int `gnutls_cipher_set_priority` (*gnutls_session_t session*, *const int * list*) [Function]

session: is a `gnutls_session_t` structure.

list: is a 0 terminated list of `gnutls_cipher_algorithm_t` elements.

Sets the priority on the ciphers supported by gnutls. Priority is higher for elements specified before others. After specifying the ciphers you want, you must append a 0. Note that the priority is set on the client. The server does not use the algorithm's priority except for disabling algorithms that were not specified.

Returns 0 on success.

`gnutls_cipher_suite_get_name`

const char * `gnutls_cipher_suite_get_name` [Function]
 (*gnutls_kx_algorithm_t kx_algorithm*, *gnutls_cipher_algorithm_t cipher_algorithm*, *gnutls_mac_algorithm_t mac_algorithm*)

kx_algorithm: is a Key exchange algorithm

cipher_algorithm: is a cipher algorithm

mac_algorithm: is a MAC algorithm

Note that the full cipher suite name must be prepended by TLS or SSL depending of the protocol in use.

Returns: a string that contains the name of a TLS cipher suite, specified by the given algorithms, or NULL.

`gnutls_cipher_suite_info`

const char * `gnutls_cipher_suite_info` (*size_t idx*, *char * cs_id*, [Function]
*gnutls_kx_algorithm_t * kx*, *gnutls_cipher_algorithm_t * cipher*,
*gnutls_mac_algorithm_t * mac*, *gnutls_protocol_t * version*)

idx: index of cipher suite to get information about, starts on 0.

cs_id: output buffer with room for 2 bytes, indicating cipher suite value

kx: output variable indicating key exchange algorithm, or NULL.

cipher: output variable indicating cipher, or NULL.

mac: output variable indicating MAC algorithm, or NULL.

version: output variable indicating TLS protocol version, or NULL.

Get information about supported cipher suites. Use the function iteratively to get information about all supported cipher suites. Call with *idx*=0 to get information about first cipher suite, then *idx*=1 and so on until the function returns NULL.

Returns: the name of *idx* cipher suite, and set the information about the cipher suite in the output variables. If *idx* is out of bounds, NULL is returned.

`gnutls_compression_get_id`

gnutls_compression_method_t `gnutls_compression_get_id` [Function]
 (*const char * name*)

The names are compared in a case insensitive way.

Returns: an id of the specified in a string compression method, or GNUTLS_COMP_UNKNOWN on error.

gnutls_compression_get_name

`const char * gnutls_compression_get_name` [Function]
 (*gnutls_compression_method_t algorithm*)
algorithm: is a Compression algorithm

Returns: a pointer to a string that contains the name of the specified compression algorithm, or NULL.

gnutls_compression_get

`gnutls_compression_method_t gnutls_compression_get` [Function]
 (*gnutls_session_t session*)
session: is a `gnutls_session_t` structure.

Returns: the currently used compression method.

gnutls_compression_list

`const gnutls_compression_method_t *` [Function]
 `gnutls_compression_list (void)`

Get a list of compression methods. Note that to be able to use LZO compression, you must link to libgnutls-extra and call `gnutls_global_init_extra()`.

Returns: a zero-terminated list of `gnutls_compression_method_t` integers indicating the available compression methods.

gnutls_compression_set_priority

`int gnutls_compression_set_priority` (*gnutls_session_t session*, [Function]
 *const int * list*)

session: is a `gnutls_session_t` structure.

list: is a 0 terminated list of `gnutls_compression_method_t` elements.

Sets the priority on the compression algorithms supported by gnutls. Priority is higher for elements specified before others. After specifying the algorithms you want, you must append a 0. Note that the priority is set on the client. The server does not use the algorithm's priority except for disabling algorithms that were not specified.

TLS 1.0 does not define any compression algorithms except NULL. Other compression algorithms are to be considered as gnutls extensions.

Returns 0 on success.

gnutls_credentials_clear

`void gnutls_credentials_clear` (*gnutls_session_t session*) [Function]
session: is a `gnutls_session_t` structure.

Clears all the credentials previously set in this session.

gnutls_credentials_set

```
int gnutls_credentials_set (gnutls_session_t session,           [Function]
                           gnutls_credentials_type_t type, void * cred)
```

session: is a **gnutls_session_t** structure.

type: is the type of the credentials

cred: is a pointer to a structure.

Sets the needed credentials for the specified type. Eg username, password - or public and private keys etc. The (void* 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**.

gnutls_db_check_entry

```
int gnutls_db_check_entry (gnutls_session_t session,           [Function]
                           gnutls_datum_t session_entry)
```

session: is a **gnutls_session_t** structure.

session_entry: is the session data (not key)

This function returns GNUTLS_E_EXPIRED, if the database entry has expired or 0 otherwise. This function is to be used when you want to clear unnesessary session which occupy space in your backend.

gnutls_db_get_ptr

```
void * gnutls_db_get_ptr (gnutls_session_t session)           [Function]
```

session: is a **gnutls_session_t** structure.

Returns the pointer that will be sent to db store, retrieve and delete functions, as the first argument.

gnutls_db_remove_session

```
void gnutls_db_remove_session (gnutls_session_t session)      [Function]
```

session: is a **gnutls_session_t** structure.

This function will remove the current session data from the session database. This will prevent future handshakes reusing these session data. This function should be called if a session was terminated abnormally, and before **gnutls_deinit()** is called.

Normally **gnutls_deinit()** will remove abnormally terminated sessions.

gnutls_db_set_cache_expiration

void gnutls_db_set_cache_expiration (*gnutls_session_t session*, [Function]
int seconds)

session: is a **gnutls_session_t** structure.

seconds: is the number of seconds.

Sets the expiration time for resumed sessions. The default is 3600 (one hour) at the time writing this.

gnutls_db_set_ptr

void gnutls_db_set_ptr (*gnutls_session_t session*, *void *ptr*) [Function]

session: is a **gnutls_session_t** structure.

ptr: is the pointer

Sets the pointer that will be provided to db store, retrieve and delete functions, as the first argument.

gnutls_db_set_remove_function

void gnutls_db_set_remove_function (*gnutls_session_t session*, [Function]
gnutls_db_remove_func rem_func)

session: is a **gnutls_session_t** structure.

rem_func: is the function.

Sets the function that will be used to remove data from the resumed sessions database. This function must return 0 on success.

The first argument to **rem_func()** will be null unless **gnutls_db_set_ptr()** has been called.

gnutls_db_set_retrieve_function

void gnutls_db_set_retrieve_function (*gnutls_session_t session*, [Function]
gnutls_db_retr_func retr_func)

session: is a **gnutls_session_t** structure.

retr_func: is the function.

Sets the function that will be used to retrieve data from the resumed sessions database. This function must return a **gnutls_datum_t** containing the data on success, or a **gnutls_datum_t** containing null and 0 on failure.

The datum's data must be allocated using the function **gnutls_malloc()**.

The first argument to **retr_func()** will be null unless **gnutls_db_set_ptr()** has been called.

gnutls_db_set_store_function

void gnutls_db_set_store_function (*gnutls_session_t session*, [Function]
gnutls_db_store_func store_func)

session: is a **gnutls_session_t** structure.

store_func: is the function

Sets the function that will be used to store data from the resumed sessions database. This function must remove 0 on success.

The first argument to `store_func()` will be null unless `gnutls_db_set_ptr()` has been called.

gnutls_deinit

void gnutls_deinit (*gnutls_session_t session*) [Function]

session: is a `gnutls_session_t` structure.

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.

gnutls_dh_get_group

int gnutls_dh_get_group (*gnutls_session_t session*, *gnutls_datum_t * raw_gen*, *gnutls_datum_t * raw_prime*) [Function]

session: is a gnutls session

raw_gen: will hold the generator.

raw_prime: will hold the prime.

This function will return the group parameters used in the last Diffie Hellman authentication with the peer. These are the prime and the generator used. This function should be used for both anonymous and ephemeral diffie Hellman. The output parameters must be freed with `gnutls_free()`.

Returns a negative value in case of an error.

gnutls_dh_get_peers_public_bits

int gnutls_dh_get_peers_public_bits (*gnutls_session_t session*) [Function]

session: is a gnutls session

This function will return the bits used in the last Diffie Hellman authentication with the peer. Should be used for both anonymous and ephemeral diffie Hellman. Returns a negative value in case of an error.

gnutls_dh_get_prime_bits

int gnutls_dh_get_prime_bits (*gnutls_session_t session*) [Function]

session: is a gnutls session

This function will return the bits of the prime used in the last Diffie Hellman authentication with the peer. Should be used for both anonymous and ephemeral diffie Hellman. Returns a negative value in case of an error.

gnutls_dh_get_pubkey

int gnutls_dh_get_pubkey (*gnutls_session_t session*, *gnutls_datum_t* [Function]
**raw_key*)

session: is a gnutls session

raw_key: will hold the public key.

This function will return the peer's public key used in the last Diffie Hellman authentication. This function should be used for both anonymous and ephemeral diffie Hellman. The output parameters must be freed with **gnutls_free()**.

Returns a negative value in case of an error.

gnutls_dh_get_secret_bits

int gnutls_dh_get_secret_bits (*gnutls_session_t session*) [Function]

session: is a gnutls session

This function will return the bits used in the last Diffie Hellman authentication with the peer. Should be used for both anonymous and ephemeral diffie Hellman. Returns a negative value in case of an error.

gnutls_dh_params_cpy

int gnutls_dh_params_cpy (*gnutls_dh_params_t dst*, [Function]
gnutls_dh_params_t src)

dst: Is the destination structure, which should be initialized.

src: Is the source structure

This function will copy the DH parameters structure from source to destination.

gnutls_dh_params_deinit

void gnutls_dh_params_deinit (*gnutls_dh_params_t dh_params*) [Function]

dh_params: Is a structure that holds the prime numbers

This function will deinitialize the DH parameters structure.

gnutls_dh_params_export_pkcs3

int gnutls_dh_params_export_pkcs3 (*gnutls_dh_params_t params*, [Function]
gnutls_x509_cert_fmt_t format, *unsigned char *params_data*, *size_t **
params_data_size)

params: Holds the DH parameters

format: the format of output params. One of PEM or DER.

params_data: will contain a PKCS3 DHParams structure PEM or DER encoded

params_data_size: holds the size of *params_data* (and will be replaced by the actual size of parameters)

This function will export the given dh parameters to a PKCS3 DHParams structure. This is the format generated by "openssl dhparam" tool. If the buffer provided is not long enough to hold the output, then GNUTLS_E_SHORT_MEMORY_BUFFER will be returned.

If the structure is PEM encoded, it will have a header of "BEGIN DH PARAMETERS".

In case of failure a negative value will be returned, and 0 on success.

gnutls_dh_params_export_raw

```
int gnutls_dh_params_export_raw (gnutls_dh_params_t params,          [Function]
                                gnutls_datum_t *prime, gnutls_datum_t *generator, unsigned int *bits)
```

params: Holds the DH parameters

prime: will hold the new prime

generator: will hold the new generator

bits: if non null will hold is the prime's number of bits

This function will export the pair of prime and generator for use in the Diffie-Hellman key exchange. The new parameters will be allocated using `gnutls_malloc()` and will be stored in the appropriate datum.

gnutls_dh_params_generate2

```
int gnutls_dh_params_generate2 (gnutls_dh_params_t params,          [Function]
                                unsigned int bits)
```

params: Is the structure that the DH parameters will be stored

bits: is the prime's number of bits

This function will generate a new pair of prime and generator for use in the Diffie-Hellman key exchange. The new parameters will be allocated using `gnutls_malloc()` and will be stored in the appropriate datum. This function is normally slow.

Note that the bits value should be one of 768, 1024, 2048, 3072 or 4096. Also note that the DH parameters are only useful to servers. Since clients use the parameters sent by the server, it's of no use to call this in client side.

gnutls_dh_params_import_pkcs3

```
int gnutls_dh_params_import_pkcs3 (gnutls_dh_params_t params,      [Function]
                                    const gnutls_datum_t *pkcs3_params, gnutls_x509_crt_fmt_t format)
```

params: A structure where the parameters will be copied to

pkcs3_params: should contain a PKCS3 DHParams structure PEM or DER encoded

format: the format of params. PEM or DER.

This function will extract the DHParams found in a PKCS3 formatted structure. This is the format generated by "openssl dhparam" tool.

If the structure is PEM encoded, it should have a header of "BEGIN DH PARAMETERS".

In case of failure a negative value will be returned, and 0 on success.

gnutls_dh_params_import_raw

int gnutls_dh_params_import_raw (*gnutls_dh_params_t dh_params,* [Function]
*const gnutls_datum_t * prime, const gnutls_datum_t * generator*)

dh_params: Is a structure that will hold the prime numbers

prime: holds the new prime

generator: holds the new generator

This function will replace the pair of prime and generator for use in the Diffie-Hellman key exchange. The new parameters should be stored in the appropriate *gnutls_datum*.

gnutls_dh_params_init

int gnutls_dh_params_init (*gnutls_dh_params_t * dh_params*) [Function]

dh_params: Is a structure that will hold the prime numbers

This function will initialize the DH parameters structure.

gnutls_dh_set_prime_bits

void gnutls_dh_set_prime_bits (*gnutls_session_t session, unsigned* [Function]
int bits)

session: is a *gnutls_session_t* structure.

bits: is the number of bits

This function sets the number of bits, for use in an Diffie Hellman key exchange. This is used both in DH ephemeral and DH anonymous cipher suites. This will set the minimum size of the prime that will be used for the handshake.

In the client side it sets the minimum accepted number of bits. If a server sends a prime with less bits than that *GNUTLS_E_DH_PRIME_UNACCEPTABLE* will be returned by the handshake.

gnutls_error_is_fatal

int gnutls_error_is_fatal (*int error*) [Function]

error: is an error returned by a gnutls function. Error should be a negative value.

If a function returns a negative value you may feed that value to this function to see if it is fatal. Returns 1 for a fatal error 0 otherwise. However you may want to check the error code manually, since some non-fatal errors to the protocol may be fatal for you (your program).

This is only useful if you are dealing with errors from the record layer or the handshake layer.

For positive *error* values, 0 is returned.

gnutls_error_to_alert

int gnutls_error_to_alert (*int err, int * level*) [Function]

err: is a negative integer

level: the alert level will be stored there

Returns 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 == 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.

gnutls_fingerprint

int gnutls_fingerprint (*gnutls_digest_algorithm_t algo*, *const gnutls_datum_t * data*, *void * result*, *size_t * result_size*) [Function]

algo: is a digest algorithm

data: is the data

result: is the place where the result will be copied (may be null).

result_size: should hold the size of the result. The actual size of the returned result will also be copied there.

This function will calculate a fingerprint (actually a hash), of the given data. The result is not printable data. You should convert it to hex, or to something else printable.

This is the usual way to calculate a fingerprint of an X.509 DER encoded certificate. Note however that the fingerprint of an OpenPGP is not just a hash and cannot be calculated with this function.

Returns a negative value in case of an error.

gnutls_free

void gnutls_free (*void * ptr*) [Function]

This function will free data pointed by *ptr*.

The deallocation function used is the one set by `gnutls_global_set_mem_functions()`.

gnutls_global_deinit

void gnutls_global_deinit (*void*) [Function]

This function deinitializes the global data, that were initialized using `gnutls_global_init()`.

Note! This function is not thread safe. See the discussion for `gnutls_global_init()` for more information.

gnutls_global_init

int gnutls_global_init (*void*) [Function]

This function initializes the global data to defaults. Every gnutls application has a global data which holds common parameters shared by gnutls session structures. You must call `gnutls_global_deinit()` when gnutls usage is no longer needed Returns zero on success.

Note that this function will also initialize libgcrypt, if it has not been initialized before. Thus if you want to manually initialize libgcrypt you must do it before calling

this function. This is useful in cases you want to disable libgcrypt's internal lockings etc.

This function increment a global counter, so that `gnutls_global_deinit()` only releases resources when it has been called as many times as `gnutls_global_init()`. This is useful when GnuTLS is used by more than one library in an application. This function can be called many times, but will only do something the first time.

Note! This function is not thread safe. If two threads call this function simultaneously, they can cause a race between checking the global counter and incrementing it, causing both threads to execute the library initialization code. That would lead to a memory leak. To handle this, your application could invoke this function after acquiring a thread mutex. To ignore the potential memory leak is also an option.

gnutls_global_set_log_function

void gnutls_global_set_log_function (*gnutls_log_func log_func*) [Function]
log_func: it's a log function

This is the function where you set the logging function gnutls is going to use. This function only accepts a character array. Normally you may not use this function since it is only used for debugging purposes.

gnutls_log_func is of the form, void (**gnutls_log_func*)(int level, const char*);

gnutls_global_set_log_level

void gnutls_global_set_log_level (*int level*) [Function]
level: it's an integer from 0 to 9.

This is the function that allows you to set the log level. The level is an integer between 0 and 9. Higher values mean more verbosity. The default value is 0. Larger values should only be used with care, since they may reveal sensitive information.

Use a log level over 10 to enable all debugging options.

gnutls_global_set_mem_functions

void gnutls_global_set_mem_functions (*gnutls_alloc_function alloc_func, gnutls_alloc_function secure_alloc_func, gnutls_is_secure_function is_secure_func, gnutls_realloc_function realloc_func, gnutls_free_function free_func*) [Function]

alloc_func: it's the default memory allocation function. Like `malloc()`.

secure_alloc_func: This is the memory allocation function that will be used for sensitive data.

is_secure_func: a function that returns 0 if the memory given is not secure. May be NULL.

realloc_func: A realloc function

free_func: The function that frees allocated data. Must accept a NULL pointer.

This is the function where you set the memory allocation functions gnutls is going to use. By default the libc's allocation functions (`malloc()`, `free()`), are used by gnutls, to allocate both sensitive and not sensitive data. This function is provided

to set the memory allocation functions to something other than the defaults (ie the gcrypt allocation functions).

This function must be called before `gnutls_global_init()` is called.

gnutls_handshake_get_last_in

`gnutls_handshake_description_t` [Function]

`gnutls_handshake_get_last_in (gnutls_session_t session)`

session: is a `gnutls_session_t` structure.

This function is only useful to check where the last performed handshake failed. If the previous handshake succeed or was not performed at all then no meaningful value will be returned.

Check `gnutls_handshake_description_t` in `gnutls.h` for the available handshake descriptions.

Returns: the last handshake message type received, a `gnutls_handshake_description_t`.

gnutls_handshake_get_last_out

`gnutls_handshake_description_t` [Function]

`gnutls_handshake_get_last_out (gnutls_session_t session)`

session: is a `gnutls_session_t` structure.

This function is only useful to check where the last performed handshake failed. If the previous handshake succeed or was not performed at all then no meaningful value will be returned.

Check `gnutls_handshake_description_t` in `gnutls.h` for the available handshake descriptions.

Returns: the last handshake message type sent, a `gnutls_handshake_description_t`.

gnutls_handshake_set_max_packet_length

`void gnutls_handshake_set_max_packet_length (gnutls_session_t` [Function]

`session, size_t max)`

session: is a `gnutls_session_t` structure.

max: is the maximum number.

This function will set the maximum size of a handshake message. Handshake messages over this size are rejected. The default value is 16kb which is large enough. Set this to 0 if you do not want to set an upper limit.

gnutls_handshake_set_post_client_hello_function

`void gnutls_handshake_set_post_client_hello_function` [Function]

`(gnutls_session_t session, gnutls_handshake_post_client_hello_func func)`

func: is the function to be called

This function will set a callback to be called after the client hello has been received (callback valid in server side only). This allows the server to adjust settings based on received extensions.

Those settings could be ciphersuites, requesting certificate, or anything else except for version negotiation (this is done before the hello message is parsed).

This callback must return 0 on success or a gnutls error code to terminate the handshake.

NOTE: You should not use this function to terminate the handshake based on client input unless you know what you are doing. Before the handshake is finished there is no way to know if there is a man-in-the-middle attack being performed.

gnutls_handshake_set_private_extensions

```
void gnutls_handshake_set_private_extensions (gnutls_session_t session, int allow) [Function]
```

session: is a `gnutls_session_t` structure.

allow: is an integer (0 or 1)

This function will enable or disable the use of private cipher suites (the ones that start with 0xFF). By default or if `allow` is 0 then these cipher suites will not be advertized nor used.

Unless this function is called with the option to allow (1), then no compression algorithms, like LZO. That is because these algorithms are not yet defined in any RFC or even internet draft.

Enabling the private ciphersuites when talking to other than gnutls servers and clients may cause interoperability problems.

gnutls_handshake

```
int gnutls_handshake (gnutls_session_t session) [Function]
```

session: is a `gnutls_session_t` structure.

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 such as `GNUTLS_E_AGAIN` and `GNUTLS_E_INTERRUPTED` interrupt the handshake procedure, which should be later be resumed. Call this function again, until it returns 0; cf. `gnutls_record_get_direction()` and `gnutls_error_is_fatal()`.

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.

Returns: `GNUTLS_E_SUCCESS` on success, otherwise an error.

gnutls_hex_decode

```
int gnutls_hex_decode (const gnutls_datum_t * hex_data, char * result, size_t * result_size) [Function]
```

hex_data: contain the encoded data

result: the place where decoded data will be copied

result_size: holds the size of the result

This function will decode the given encoded data, using the hex encoding used by PSK password files.

Note that *hex_data* should be null terminated.

Returns: GNUTLS_E_SHORT_MEMORY_BUFFER if the buffer given is not long enough, or 0 on success.

gnutls_hex_encode

```
int gnutls_hex_encode (const gnutls_datum_t * data, char * result, size_t * result_size) [Function]
```

data: contain the raw data

result: the place where hex data will be copied

result_size: holds the size of the result

This function will convert the given data to printable data, using the hex encoding, as used in the PSK password files.

Returns: GNUTLS_E_SHORT_MEMORY_BUFFER if the buffer given is not long enough, or 0 on success.

gnutls_init

```
int gnutls_init (gnutls_session_t * session, gnutls_connection_end_t con_end) [Function]
```

session: is a pointer to a `gnutls_session_t` structure.

con_end: indicate if this session is to be used for server or client.

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 zero on success.

con_end can be one of GNUTLS_CLIENT and GNUTLS_SERVER.

Returns: GNUTLS_E_SUCCESS on success, or an error code.

gnutls_kx_get_id

```
gnutls_kx_algorithm_t gnutls_kx_get_id (const char* name) [Function]
```

The names are compared in a case insensitive way.

Returns: an id of the specified KX algorithm, or GNUTLS_KX_UNKNOWN on error.

gnutls_kx_get_name

`const char * gnutls_kx_get_name (gnutls_kx_algorithm_t algorithm)` [Function]

algorithm: is a key exchange algorithm

Returns: a pointer to a string that contains the name of the specified key exchange algorithm, or NULL.

gnutls_kx_get

`gnutls_kx_algorithm_t gnutls_kx_get (gnutls_session_t session)` [Function]

session: is a `gnutls_session_t` structure.

Returns: the key exchange algorithm used in the last handshake.

gnutls_kx_list

`const gnutls_kx_algorithm_t * gnutls_kx_list (void)` [Function]

Get a list of supported key exchange algorithms.

Returns: a zero-terminated list of `gnutls_kx_algorithm_t` integers indicating the available key exchange algorithms.

gnutls_kx_set_priority

`int gnutls_kx_set_priority (gnutls_session_t session, const int * list)` [Function]

session: is a `gnutls_session_t` structure.

list: is a 0 terminated list of `gnutls_kx_algorithm_t` elements.

Sets the priority on the key exchange algorithms supported by gnutls. Priority is higher for elements specified before others. After specifying the algorithms you want, you must append a 0. Note that the priority is set on the client. The server does not use the algorithm's priority except for disabling algorithms that were not specified.

Returns 0 on success.

gnutls_mac_get_id

`gnutls_mac_algorithm_t gnutls_mac_get_id (const char* name)` [Function]

Returns: an `gnutls_mac_algorithm_t` of the specified in a string MAC algorithm, or `GNUTLS_MAC_UNKNOWN` on failures. The names are compared in a case insensitive way.

gnutls_mac_get_key_size

`size_t gnutls_mac_get_key_size (gnutls_mac_algorithm_t algorithm)` [Function]

algorithm: is an encryption algorithm

Returns: length (in bytes) of the given MAC key size, or 0 if the given MAC algorithm is invalid.

gnutls_mac_get_name

`const char * gnutls_mac_get_name (gnutls_mac_algorithm_t algorithm)` [Function]

algorithm: is a MAC algorithm

Returns: a string that contains the name of the specified MAC algorithm, or NULL.

gnutls_mac_get

`gnutls_mac_algorithm_t gnutls_mac_get (gnutls_session_t session)` [Function]

session: is a `gnutls_session_t` structure.

Returns: the currently used mac algorithm.

gnutls_mac_list

`const gnutls_mac_algorithm_t * gnutls_mac_list (void)` [Function]

Get a list of hash algorithms for use as MACs. Note that not necessarily all MACs are supported in TLS cipher suites. For example, MD2 is not supported as a cipher suite, but is supported for other purposes (e.g., X.509 signature verification or similar).

Returns: Return a zero-terminated list of `gnutls_mac_algorithm_t` integers indicating the available MACs.

gnutls_mac_set_priority

`int gnutls_mac_set_priority (gnutls_session_t session, const int * list)` [Function]

session: is a `gnutls_session_t` structure.

list: is a 0 terminated list of `gnutls_mac_algorithm_t` elements.

Sets the priority on the mac algorithms supported by gnutls. Priority is higher for elements specified before others. After specifying the algorithms you want, you must append a 0. Note that the priority is set on the client. The server does not use the algorithm's priority except for disabling algorithms that were not specified.

Returns 0 on success.

gnutls_malloc

`void * gnutls_malloc (size_t s)` [Function]

This function will allocate 's' bytes data, and return a pointer to memory. This function is supposed to be used by callbacks.

The allocation function used is the one set by `gnutls_global_set_mem_functions()`.

gnutls_openpgp_send_cert

`void gnutls_openpgp_send_cert (gnutls_session_t session, gnutls_openpgp_cert_status_t status)` [Function]

session: is a pointer to a `gnutls_session_t` structure.

status: is one of GNUTLS_OPENPGP_CERT, or GNUTLS_OPENPGP_CERT_FINGERPRINT
 This function will order gnutls to send the key fingerprint instead of the key in the initial handshake procedure. This should be used with care and only when there is indication or knowledge that the server can obtain the client's key.

gnutls_oprfi_enable_client

void gnutls_oprfi_enable_client (*gnutls_session_t session*, *size_t len*, *unsigned char * data*) [Function]

session: is a **gnutls_session_t** structure.

len: length of Opaque PRF data to use in client.

data: Opaque PRF data to use in client.

Request that the client should attempt to negotiate the Opaque PRF Input TLS extension, using the given data as the client's Opaque PRF input.

The data is copied into the session context after this call, so you may de-allocate it immediately after calling this function.

gnutls_oprfi_enable_server

void gnutls_oprfi_enable_server (*gnutls_session_t session*, *gnutls_oprfi_callback_func cb*, *void * userdata*) [Function]

session: is a **gnutls_session_t** structure.

cb: function pointer to Opaque PRF extension server callback.

userdata: hook passed to callback function for passing application state.

Request that the server should attempt to accept the Opaque PRF Input TLS extension. If the client requests the extension, the provided callback *cb* will be invoked. The callback must have the following prototype:

```
int callback (gnutls_session_t session, void *userdata, size_t oprfi_len, const unsigned char *in_oprfi, unsigned char *out_oprfi);
```

The callback can inspect the client-provided data in the input parameters, and specify its own opaque prf input data in the output variable. The function must return 0 on success, otherwise the handshake will be aborted.

gnutls_pem_base64_decode_alloc

int gnutls_pem_base64_decode_alloc (*const char * header*, *const gnutls_datum_t * b64_data*, *gnutls_datum_t * result*) [Function]

header: The PEM header (eg. CERTIFICATE)

b64_data: contains the encoded data

result: the place where decoded data lie

This function will decode the given encoded data. The decoded data will be allocated, and stored into *result*. If the header given is non null this function will search for "—BEGIN header" and decode only this part. Otherwise it will decode the first PEM packet found.

You should use **gnutls_free()** to free the returned data.

gnutls_pem_base64_decode

int gnutls_pem_base64_decode (*const char *header, const* [Function]
*gnutls_datum_t *b64_data, unsigned char *result, size_t *result_size*)

header: A null terminated string with the PEM header (eg. CERTIFICATE)

b64_data: contain the encoded data

result: the place where decoded data will be copied

result_size: holds the size of the result

This function will decode the given encoded data. If the header given is non null this function will search for "—BEGIN header" and decode only this part. Otherwise it will decode the first PEM packet found.

Returns GNUTLS_E_SHORT_MEMORY_BUFFER if the buffer given is not long enough, or 0 on success.

gnutls_pem_base64_encode_alloc

int gnutls_pem_base64_encode_alloc (*const char *msg, const* [Function]
*gnutls_datum_t *data, gnutls_datum_t *result*)

msg: is a message to be put in the encoded header

data: contains the raw data

result: will hold the newly allocated encoded data

This function will convert the given data to printable data, using the base64 encoding. This is the encoding used in PEM messages. This function will allocate the required memory to hold the encoded data.

You should use `gnutls_free()` to free the returned data.

gnutls_pem_base64_encode

int gnutls_pem_base64_encode (*const char *msg, const* [Function]
*gnutls_datum_t *data, char *result, size_t *result_size*)

msg: is a message to be put in the header

data: contain the raw data

result: the place where base64 data will be copied

result_size: holds the size of the result

This function will convert the given data to printable data, using the base64 encoding. This is the encoding used in PEM messages. If the provided buffer is not long enough GNUTLS_E_SHORT_MEMORY_BUFFER is returned.

The output string will be null terminated, although the size will not include the terminating null.

gnutls_perror

void gnutls_perror (*int error*) [Function]

error: is an error returned by a gnutls function. Error is always a negative value.

This function is like `perror()`. The only difference is that it accepts an error number returned by a gnutls function.

gnutls_pk_algorithm_get_name

`const char * gnutls_pk_algorithm_get_name` [Function]
 (*gnutls_pk_algorithm_t algorithm*)

algorithm: is a pk algorithm

Returns: a string that contains the name of the specified public key algorithm, or NULL.

gnutls_prf_raw

`int gnutls_prf_raw` (*gnutls_session_t session, size_t label_size,* [Function]
 *const char * label, size_t seed_size, const char * seed, size_t outsize,*
 *char * out*)

session: is a `gnutls_session_t` structure.

label_size: length of the `label` variable.

label: label used in PRF computation, typically a short string.

seed_size: length of the `seed` variable.

seed: optional extra data to seed the PRF with.

outsize: size of pre-allocated output buffer to hold the output.

out: pre-allocate buffer to hold the generated data.

Apply the TLS Pseudo-Random-Function (PRF) using the master secret on some data.

The `label` variable usually contain a string denoting the purpose for the generated data. The `seed` usually contain data such as the client and server random, perhaps together with some additional data that is added to guarantee uniqueness of the output for a particular purpose.

Because the output is not guaranteed to be unique for a particular session unless `seed` include the client random and server random fields (the PRF would output the same data on another connection resumed from the first one), it is not recommended to use this function directly. The `gnutls_prf()` function seed the PRF with the client and server random fields directly, and is recommended if you want to generate pseudo random data unique for each session.

Returns: GNUTLS_E_SUCCESS on success, or an error code.

gnutls_prf

`int gnutls_prf` (*gnutls_session_t session, size_t label_size, const* [Function]
 *char * label, int server_random_first, size_t extra_size, const char **
 *extra, size_t outsize, char * out*)

session: is a `gnutls_session_t` structure.

label_size: length of the `label` variable.

label: label used in PRF computation, typically a short string.

server_random_first: non-0 if server random field should be first in seed

extra_size: length of the `extra` variable.

extra: optional extra data to seed the PRF with.

outsize: size of pre-allocated output buffer to hold the output.

out: pre-allocate buffer to hold the generated data.

Apply the TLS Pseudo-Random-Function (PRF) using the master secret on some data, seeded with the client and server random fields.

The `label` variable usually contain a string denoting the purpose for the generated data. The `server_random_first` indicate whether the client random field or the server random field should be first in the seed. Non-0 indicate that the server random field is first, 0 that the client random field is first.

The `extra` variable can be used to add more data to the seed, after the random variables. It can be used to tie make sure the generated output is strongly connected to some additional data (e.g., a string used in user authentication).

The output is placed in `*OUT`, which must be pre-allocated.

Returns: GNUTLS_E_SUCCESS on success, or an error code.

gnutls_priority_deinit

`void gnutls_priority_deinit (gnutls_priority_t priority_cache)` [Function]

priority_cache: is a `gnutls_priority_t` structure.

Deinitializes the priority cache.

gnutls_priority_init

`int gnutls_priority_init (gnutls_priority_t * priority_cache,` [Function]

`const char * priorities, const char ** err_pos)`

priority_cache: is a `gnutls_priority_t` structure.

priorities: is a string describing priorities

err_pos: In case of an error this will have the position in the string the error occurred

Sets priorities for the ciphers, key exchange methods, macs and compression methods.

This is to avoid using the `gnutls_*_priority()` functions.

The `priorities` option allows you to specify a semi-colon separated list of the cipher priorities to enable.

Unless the first keyword is "NONE" the defaults are:

Protocols: TLS1.1, TLS1.0, and SSL3.0.

Compression: NULL.

Certificate types: X.509, OpenPGP.

You can also use predefined sets of ciphersuites: "PERFORMANCE" all the "secure" ciphersuites are enabled, limited to 128 bit ciphers and sorted by terms of speed performance.

"NORMAL" option enables all "secure" ciphersuites. The 256-bit ciphers are included as a fallback only. The ciphers are sorted by security margin.

"SECURE128" flag enables all "secure" ciphersuites with ciphers up to 128 bits, sorted by security margin.

"SECURE256" flag enables all "secure" ciphersuites including the 256 bit ciphers, sorted by security margin.

"EXPORT" all the ciphersuites are enabled, including the low-security 40 bit ciphers.

"NONE" nothing is enabled. This disables even protocols and compression methods.

Special keywords: '!' or '-' appended with an algorithm will remove this algorithm. '+' appended with an algorithm will add this algorithm. 'COMPAT' will enable compatibility features for a server.

To avoid collisions in order to specify a compression algorithm in this string you have to prefix it with "COMP-", protocol versions with "VERS-" and certificate types with "CTYPE-". All other algorithms don't need a prefix.

For 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 (except for the RSA-EXPORT which is only enabled in EXPORT level).

Note that although one can select very long key sizes (such as 256 bits) for symmetric algorithms, to actually increase security the public key algorithms have to use longer key sizes as well.

Examples: "NORMAL:!AES-128-CBC", "EXPORT:!VERS-TLS1.0:+COMP-DEFLATE:+CTYPE-OPENPGP", "NONE:+VERS-TLS1.0:+AES-128-CBC:+RSA:+SHA1:+COMP-NUL", "NORMAL", "NORMAL:COMPAT".

Returns: On syntax error GNUTLS_E_INVALID_REQUEST is returned and 0 on success.

gnutls_priority_set_direct

`int gnutls_priority_set_direct (gnutls_session_t session, const char *priorities, const char **err_pos)` [Function]

session: is a `gnutls_session_t` structure.

priorities: is a string describing priorities

err_pos: In case of an error this will have the position in the string the error occurred

Sets the priorities to use on the ciphers, key exchange methods, macs and compression methods. This function avoids keeping a priority cache and is used to directly set string priorities to a TLS session. For documentation check the `gnutls_priority_init()`.

On syntax error GNUTLS_E_INVALID_REQUEST is returned and 0 on success.

gnutls_priority_set

`int gnutls_priority_set (gnutls_session_t session, gnutls_priority_t priority)` [Function]

session: is a `gnutls_session_t` structure.

priority: is a `gnutls_priority_t` structure.

Sets the priorities to use on the ciphers, key exchange methods, macs and compression methods.

On success 0 is returned.

gnutls_protocol_get_id

`gnutls_protocol_t gnutls_protocol_get_id (const char* name)` [Function]

The names are compared in a case insensitive way.

Returns: an id of the specified protocol, or GNUTLS_VERSION_UNKNOWN on error.

gnutls_protocol_get_name

`const char * gnutls_protocol_get_name (gnutls_protocol_t version)` [Function]

version: is a (gnutls) version number

Returns: a string that contains the name of the specified TLS version (e.g., "TLS 1.0"), or NULL.

gnutls_protocol_get_version

`gnutls_protocol_t gnutls_protocol_get_version (gnutls_session_t session)` [Function]

session: is a `gnutls_session_t` structure.

Returns: the version of the currently used protocol.

gnutls_protocol_list

`const gnutls_protocol_t * gnutls_protocol_list (void)` [Function]

Get a list of supported protocols, e.g. SSL 3.0, TLS 1.0 etc.

Returns: a zero-terminated list of `gnutls_protocol_t` integers indicating the available protocols.

gnutls_protocol_set_priority

`int gnutls_protocol_set_priority (gnutls_session_t session, const int * list)` [Function]

session: is a `gnutls_session_t` structure.

list: is a 0 terminated list of `gnutls_protocol_t` elements.

Sets the priority on the protocol versions supported by gnutls. This function actually enables or disables protocols. Newer protocol versions always have highest priority.

Returns 0 on success.

gnutls_psk_allocate_client_credentials

`int gnutls_psk_allocate_client_credentials (gnutls_psk_client_credentials_t * sc)` [Function]

sc: is a pointer to an `gnutls_psk_server_credentials_t` structure.

This structure is complex enough to manipulate directly thus this helper function is provided in order to allocate it.

Returns: GNUTLS_E_SUCCESS on success, or an error code.

gnutls_psk_allocate_server_credentials

int gnutls_psk_allocate_server_credentials [Function]
 (*gnutls_psk_server_credentials_t * sc*)

sc: is a pointer to an **gnutls_psk_server_credentials_t** structure.

This structure is complex enough to manipulate directly thus this helper function is provided in order to allocate it.

Returns: GNUTLS_E_SUCCESS on success, or an error code.

gnutls_psk_free_client_credentials

void gnutls_psk_free_client_credentials [Function]
 (*gnutls_psk_client_credentials_t sc*)

sc: is an **gnutls_psk_client_credentials_t** structure.

This structure is complex enough to manipulate directly thus this helper function is provided in order to free (deallocate) it.

gnutls_psk_free_server_credentials

void gnutls_psk_free_server_credentials [Function]
 (*gnutls_psk_server_credentials_t sc*)

sc: is an **gnutls_psk_server_credentials_t** structure.

This structure is complex enough to manipulate directly thus this helper function is provided in order to free (deallocate) it.

gnutls_psk_server_get_username

const char * gnutls_psk_server_get_username (*gnutls_session_t session*) [Function]

session: is a gnutls session

This should only be called in case of PSK authentication and in case of a server.

Returns: the username of the peer, or NULL in case of an error.

gnutls_psk_set_client_credentials_function

void gnutls_psk_set_client_credentials_function [Function]
 (*gnutls_psk_client_credentials_t cred, gnutls_psk_client_credentials_function * func*)

cred: is a **gnutls_psk_server_credentials_t** structure.

func: is the callback function

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** 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.

gnutls_psk_set_client_credentials

`int gnutls_psk_set_client_credentials` [Function]

(*gnutls_psk_client_credentials_t* *res*, *const char *username*, *const gnutls_datum_t *key*, *gnutls_psk_key_flags flags*)

res: is an `gnutls_psk_client_credentials_t` structure.

username: is the user's zero-terminated userid

key: is the user's key

This function sets the username and password, in a `gnutls_psk_client_credentials_t` structure. Those will be used in PSK authentication. **username** should be an ASCII string or UTF-8 strings prepared using the "SASLprep" profile of "stringprep". The key can be either in raw byte format or in Hex (not with the '0x' prefix).

Returns: GNUTLS_E_SUCCESS on success, or an error code.

gnutls_psk_set_params_function

`void gnutls_psk_set_params_function` [Function]

(*gnutls_psk_server_credentials_t res*, *gnutls_params_function *func*)

res: is a `gnutls_psk_server_credentials_t` structure

func: is the function to be called

This function will set a callback in order for the server to get the diffie hellman or RSA parameters for psk authentication. The callback should return zero on success.

gnutls_psk_set_server_credentials_file

`int gnutls_psk_set_server_credentials_file` [Function]

(*gnutls_psk_server_credentials_t res*, *const char *password_file*)

res: is an `gnutls_psk_server_credentials_t` structure.

password_file: is the PSK password file (passwd.psk)

This function sets the password file, in a `gnutls_psk_server_credentials_t` structure. This password file holds usernames and keys and will be used for PSK authentication.

Returns: GNUTLS_E_SUCCESS on success, or an error code.

gnutls_psk_set_server_credentials_function

`void gnutls_psk_set_server_credentials_function` [Function]

(*gnutls_psk_server_credentials_t cred*, *gnutls_psk_server_credentials_function *func*)

cred: is a `gnutls_psk_server_credentials_t` structure.

func: is the callback function

This function can be used to set a callback to retrieve the user's PSK credentials. The callback's function form is: `int (*callback)(gnutls_session_t, const char* username, gnutls_datum_t* key);`

username contains the actual username. The **key** must be filled in using the `gnutls_malloc()`.

In case the callback returned a negative number then gnutls will assume that the username does not exist.

The callback function will only be called once per handshake. The callback function should return 0 on success, while -1 indicates an error.

gnutls_psk_set_server_dh_params

void gnutls_psk_set_server_dh_params [Function]
 (*gnutls_psk_server_credentials_t* **res**, *gnutls_dh_params_t* **dh_params**)

res: is a *gnutls_psk_server_credentials_t* structure

dh_params: is a structure that holds diffie hellman parameters.

This function will set the diffie hellman parameters for an anonymous server to use. These parameters will be used in Diffie Hellman with PSK cipher suites.

gnutls_psk_set_server_params_function

void gnutls_psk_set_server_params_function [Function]
 (*gnutls_psk_server_credentials_t* **res**, *gnutls_params_function* * **func**)

res: is a *gnutls_certificate_credentials_t* structure

func: is the function to be called

This function will set a callback in order for the server to get the diffie hellman parameters for PSK authentication. The callback should return zero on success.

gnutls_record_check_pending

size_t gnutls_record_check_pending (*gnutls_session_t* **session**) [Function]
 session: is a *gnutls_session_t* structure.

This function checks if there are any data to receive in the gnutls buffers. Returns the size of that data or 0. Notice that you may also use `select()` to check for data in a TCP connection, instead of this function. (gnutls leaves some data in the tcp buffer in order for select to work).

gnutls_record_disable_padding

void gnutls_record_disable_padding (*gnutls_session_t* **session**) [Function]
 session: is a *gnutls_session_t* structure.

Used to disabled padding in TLS 1.0 and above. Normally you do not need to use this function, but there are buggy clients that complain if a server pads the encrypted data. This of course will disable protection against statistical attacks on the data.

Normally only servers that require maximum compatibility with everything out there, need to call this function.

gnutls_record_get_direction

int gnutls_record_get_direction (*gnutls_session_t* **session**) [Function]
 session: is a *gnutls_session_t* structure.

This function provides information about the internals of the record protocol and is only useful if a prior `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.

Returns: 0 if trying to read data, 1 if trying to write data.

`gnutls_record_get_max_size`

`size_t gnutls_record_get_max_size (gnutls_session_t session)` [Function]
session: is a `gnutls_session_t` structure.

This function returns the maximum record packet size in this connection. The maximum record size is negotiated by the client after the first handshake message.

`gnutls_record_recv`

`ssize_t gnutls_record_recv (gnutls_session_t session, void * data, size_t sizeofdata)` [Function]

session: is a `gnutls_session_t` structure.

data: the buffer that the data will be read into

sizeofdata: the number of requested bytes

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 containing `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. A negative error code is returned in case of an error. The number of bytes received might be less than `sizeofdata`.

`gnutls_record_send`

`ssize_t gnutls_record_send (gnutls_session_t session, const void * data, size_t sizeofdata)` [Function]

session: is a `gnutls_session_t` structure.

data: contains the data to send

sizeofdata: is the length of the data

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 full information. You can replace the default push function by using `gnutls_transport_set_ptr2()` with a call to `send()` with a `MSG_DONTWAIT` flag if blocking is a problem.

If the `EINTR` is returned by the internal push function (the default is `send()`) 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 same parameters; alternatively you could provide a `NULL` pointer for data, and 0 for size. cf. `gnutls_record_get_direction()`.

Returns: the number of bytes sent, or a negative error code. The number of bytes sent might be less than `sizeofdata`. The maximum number of bytes this function can send in a single call depends on the negotiated maximum record size.

`gnutls_record_set_max_size`

`ssize_t gnutls_record_set_max_size (gnutls_session_t session, [Function]
size_t size)`

session: is a `gnutls_session_t` structure.

size: is the new size

This function sets the maximum record packet size in this connection. This property can only be set to clients. The server may choose not to accept the requested size.

Acceptable values are 512(=2⁹), 1024(=2¹⁰), 2048(=2¹¹) and 4096(=2¹²). Returns 0 on success. The requested record size does get in effect immediately only while sending data. The receive part will take effect after a successful handshake.

This function uses a TLS extension called 'max record size'. Not all TLS implementations use or even understand this extension.

`gnutls_rehandshake`

`int gnutls_rehandshake (gnutls_session_t session) [Function]`

session: is a `gnutls_session_t` structure.

This function will renegotiate security parameters with the client. This should only be called in case of a server.

This message informs the peer that we want to renegotiate parameters (perform a handshake).

If this function succeeds (returns 0), you must call the `gnutls_handshake()` function in order to negotiate the new parameters.

If the client does not wish to renegotiate parameters he will should with an alert message, thus the return code will be `GNUTLS_E_WARNING_ALERT_RECEIVED` and the alert will be `GNUTLS_A_NO_RENEGOTIATION`. A client may also choose to ignore this message.

Returns: `GNUTLS_E_SUCCESS` on success, otherwise an error.

gnutls_rsa_export_get_modulus_bits

int gnutls_rsa_export_get_modulus_bits (*gnutls_session_t session*) [Function]

session: is a gnutls session

This function will return the bits used in the last RSA-EXPORT key exchange with the peer. Returns a negative value in case of an error.

gnutls_rsa_export_get_pubkey

int gnutls_rsa_export_get_pubkey (*gnutls_session_t session*, *gnutls_datum_t *exponent*, *gnutls_datum_t *modulus*) [Function]

session: is a gnutls session

exponent: will hold the exponent.

modulus: will hold the modulus.

This function will return the peer's public key exponent and modulus used in the last RSA-EXPORT authentication. The output parameters must be freed with **gnutls_free()**.

Returns a negative value in case of an error.

gnutls_rsa_params_cpy

int gnutls_rsa_params_cpy (*gnutls_rsa_params_t dst*, *gnutls_rsa_params_t src*) [Function]

dst: Is the destination structure, which should be initialized.

src: Is the source structure

This function will copy the RSA parameters structure from source to destination.

gnutls_rsa_params_deinit

void gnutls_rsa_params_deinit (*gnutls_rsa_params_t rsa_params*) [Function]

rsa_params: Is a structure that holds the parameters

This function will deinitialize the RSA parameters structure.

gnutls_rsa_params_export_pkcs1

int gnutls_rsa_params_export_pkcs1 (*gnutls_rsa_params_t params*, *gnutls_x509_crt_fmt_t format*, *unsigned char *params_data*, *size_t *params_data_size*) [Function]

params: Holds the RSA parameters

format: the format of output params. One of PEM or DER.

params_data: will contain a PKCS1 RSAPublicKey structure PEM or DER encoded

params_data_size: holds the size of *params_data* (and will be replaced by the actual size of parameters)

This function will export the given RSA parameters to a PKCS1 RSAPublicKey structure. If the buffer provided is not long enough to hold the output, then **GNUTLS_E_SHORT_MEMORY_BUFFER** will be returned.

If the structure is PEM encoded, it will have a header of "BEGIN RSA PRIVATE KEY".

In case of failure a negative value will be returned, and 0 on success.

gnutls_rsa_params_export_raw

int gnutls_rsa_params_export_raw (*gnutls_rsa_params_t params*, [Function]
*gnutls_datum_t * m*, *gnutls_datum_t * e*, *gnutls_datum_t * d*, *gnutls_datum_t * p*, *gnutls_datum_t * q*, *gnutls_datum_t * u*, *unsigned int * bits*)

params: a structure that holds the rsa parameters

m: will hold the modulus

e: will hold the public exponent

d: will hold the private exponent

p: will hold the first prime (p)

q: will hold the second prime (q)

u: will hold the coefficient

bits: if non null will hold the prime's number of bits

This function will export the RSA parameters found in the given structure. The new parameters will be allocated using `gnutls_malloc()` and will be stored in the appropriate datum.

gnutls_rsa_params_generate2

int gnutls_rsa_params_generate2 (*gnutls_rsa_params_t params*, [Function]
unsigned int bits)

params: The structure where the parameters will be stored

bits: is the prime's number of bits

This function will generate new temporary RSA parameters for use in RSA-EXPORT ciphersuites. This function is normally slow.

Note that if the parameters are to be used in export cipher suites the bits value should be 512 or less. Also note that the generation of new RSA parameters is only useful to servers. Clients use the parameters sent by the server, thus it's no use calling this in client side.

gnutls_rsa_params_import_pkcs1

int gnutls_rsa_params_import_pkcs1 (*gnutls_rsa_params_t params*, [Function]
*const gnutls_datum_t * pkcs1_params*, *gnutls_x509_crt_fmt_t format*)

params: A structure where the parameters will be copied to

pkcs1_params: should contain a PKCS1 RSAPublicKey structure PEM or DER encoded

format: the format of params. PEM or DER.

This function will extract the RSAPublicKey found in a PKCS1 formatted structure. If the structure is PEM encoded, it should have a header of "BEGIN RSA PRIVATE KEY".

In case of failure a negative value will be returned, and 0 on success.

gnutls_rsa_params_import_raw

```
int gnutls_rsa_params_import_raw (gnutls_rsa_params_t [Function]
                                rsa_params, const gnutls_datum_t * m, const gnutls_datum_t * e, const
                                gnutls_datum_t * d, const gnutls_datum_t * p, const gnutls_datum_t * q, const
                                gnutls_datum_t * u)
```

rsa_params: Is a structure will hold the parameters

m: holds the modulus

e: holds the public exponent

d: holds the private exponent

p: holds the first prime (*p*)

q: holds the second prime (*q*)

u: holds the coefficient

This function will replace the parameters in the given structure. The new parameters should be stored in the appropriate `gnutls_datum`.

gnutls_rsa_params_init

```
int gnutls_rsa_params_init (gnutls_rsa_params_t * rsa_params) [Function]
rsa_params: Is a structure that will hold the parameters
```

This function will initialize the temporary RSA parameters structure.

gnutls_server_name_get

```
int gnutls_server_name_get (gnutls_session_t session, void * data, [Function]
                           size_t * data_length, unsigned int * type, unsigned int indx)
session: is a gnutls_session_t structure.
```

data: will hold the data

data_length: will hold the data length. Must hold the maximum size of data.

type: will hold the server name indicator type

indx: is the index of the server_name

This function will allow you to get the name indication (if any), a client has sent. The name indication may be any of the enumeration `gnutls_server_name_type_t`.

If `type` is `GNUTLS_NAME_DNS`, then this function is to be used by servers that support virtual hosting, and the data will be a null terminated UTF-8 string.

If `data` has not enough size to hold the server name `GNUTLS_E_SHORT_MEMORY_BUFFER` is returned, and `data_length` will hold the required size.

`index` is used to retrieve more than one server names (if sent by the client). The first server name has an index of 0, the second 1 and so on. If no name with the given index exists `GNUTLS_E_REQUESTED_DATA_NOT_AVAILABLE` is returned.

gnutls_server_name_set

int gnutls_server_name_set (*gnutls_session_t session*, [Function]
gnutls_server_name_type_t type, *const void * name*, *size_t name_length*)

session: is a **gnutls_session_t** structure.

type: specifies the indicator type

name: is a string that contains the server name.

name_length: holds the length of name

This function is to be used by clients that want to inform (via a TLS extension mechanism) the server of the name they connected to. This should be used by clients that connect to servers that do virtual hosting.

The value of **name** depends on the **ind** type. In case of GNUTLS_NAME_DNS, an ASCII or UTF-8 null terminated string, without the trailing dot, is expected. IPv4 or IPv6 addresses are not permitted.

gnutls_session_enable_compatibility_mode

void gnutls_session_enable_compatibility_mode [Function]
(*gnutls_session_t session*)

session: is a **gnutls_session_t** structure.

This function can be used to disable certain (security) features in TLS in order to maintain maximum compatibility with buggy clients. It is equivalent to calling: **gnutls_record_disable_padding()**

Normally only servers that require maximum compatibility with everything out there, need to call this function.

gnutls_session_get_client_random

const void * gnutls_session_get_client_random [Function]
(*gnutls_session_t session*)

session: is a **gnutls_session_t** structure.

Return a pointer to the 32-byte client random field used in the session. The pointer must not be modified or deallocated.

If a client random value has not yet been established, the output will be garbage; in particular, a NULL return value should not be expected.

Returns: pointer to client random data.

gnutls_session_get_data2

int gnutls_session_get_data2 (*gnutls_session_t session*, [Function]
*gnutls_datum_t * data*)

session: is a **gnutls_session_t** structure.

Returns all session parameters, in order to support resuming. The client should call this, and keep the returned session, if he wants to resume that current version later by calling **gnutls_session_set_data()** This function must be called after a successful handshake. The returned datum must be freed with **gnutls_free()**.

Resuming sessions is really useful and speedups connections after a succesful one.

gnutls_session_get_data

```
int gnutls_session_get_data (gnutls_session_t session, void *
    session_data, size_t * session_data_size) [Function]
```

session: is a `gnutls_session_t` structure.

session_data: is a pointer to space to hold the session.

session_data_size: is the *session_data*'s size, or it will be set by the function.

Returns all session parameters, in order to support resuming. The client should call this, and keep the returned session, if he wants to resume that current version later by calling `gnutls_session_set_data()`. This function must be called after a successful handshake.

Resuming sessions is really useful and speeds up connections after a successful one.

gnutls_session_get_id

```
int gnutls_session_get_id (gnutls_session_t session, void *
    session_id, size_t * session_id_size) [Function]
```

session: is a `gnutls_session_t` structure.

session_id: is a pointer to space to hold the session id.

session_id_size: is the session id's size, or it will be set by the function.

Returns the current session id. This can be used if you want to check if the next session you tried to resume was actually resumed. This is because resumed sessions have the same sessionID with the original session.

Session id is some data set by the server, that identify the current session. In TLS 1.0 and SSL 3.0 session id is always less than 32 bytes.

Returns zero on success.

gnutls_session_get_master_secret

```
const void * gnutls_session_get_master_secret
    (gnutls_session_t session) [Function]
```

session: is a `gnutls_session_t` structure.

Return a pointer to the 48-byte master secret in the session. The pointer must not be modified or deallocated.

If a master secret value has not yet been established, the output will be garbage; in particular, a NULL return value should not be expected.

Consider using `gnutls_prf()` rather than extracting the master secret and use it to derive further data.

Returns: pointer to master secret data.

gnutls_session_get_ptr

```
void * gnutls_session_get_ptr (gnutls_session_t session) [Function]
```

session: is a `gnutls_session_t` structure.

Returns: the user given pointer from the session structure. This is the pointer set with `gnutls_session_set_ptr()`.

gnutls_session_get_server_random

`const void * gnutls_session_get_server_random` [Function]
 (*gnutls_session_t session*)

session: is a `gnutls_session_t` structure.

Return a pointer to the 32-byte server random field used in the session. The pointer must not be modified or deallocated.

If a server random value has not yet been established, the output will be garbage; in particular, a NULL return value should not be expected.

Returns: pointer to server random data.

gnutls_session_is_resumed

`int gnutls_session_is_resumed` (*gnutls_session_t session*) [Function]

session: is a `gnutls_session_t` structure.

Returns: non zero if this session is resumed, or a zero if this is a new session.

gnutls_session_set_data

`int gnutls_session_set_data` (*gnutls_session_t session*, *const void * session_data*, *size_t session_data_size*) [Function]

session: is a `gnutls_session_t` structure.

session_data: is a pointer to space to hold the session.

session_data_size: is the session's size

Sets all session parameters, in order to resume a previously established session. The session data given must be the one returned by `gnutls_session_get_data()`. This function should be called before `gnutls_handshake()`.

Keep in mind that session resuming is advisory. The server may choose not to resume the session, thus a full handshake will be performed.

Returns a negative value on error.

gnutls_session_set_ptr

`void gnutls_session_set_ptr` (*gnutls_session_t session*, *void * ptr*) [Function]

session: is a `gnutls_session_t` structure.

ptr: is the user pointer

This function will set (associate) the user given pointer to the session structure. This is pointer can be accessed with `gnutls_session_get_ptr()`.

gnutls_set_default_export_priority

`int gnutls_set_default_export_priority` (*gnutls_session_t session*) [Function]

session: is a `gnutls_session_t` structure.

Sets some default priority on the ciphers, key exchange methods, macs and compression methods. This function also includes weak algorithms.

This is the same as calling: `gnutls_priority_set_direct(session, "EXPORT", NULL);`

This function is kept around for backwards compatibility, but because of its wide use it is still fully supported. If you wish to allow users to provide a string that specify which ciphers to use (which is recommended), you should use `gnutls_priority_set_direct()` or `gnutls_priority_set()` instead.

Returns 0 on success.

gnutls_set_default_priority

int gnutls_set_default_priority (*gnutls_session_t session*) [Function]
session: is a `gnutls_session_t` structure.

Sets some default priority on the ciphers, key exchange methods, macs and compression methods.

This is the same as calling: `gnutls_priority_set_direct(session, "NORMAL", NULL);`

This function is kept around for backwards compatibility, but because of its wide use it is still fully supported. If you wish to allow users to provide a string that specify which ciphers to use (which is recommended), you should use `gnutls_priority_set_direct()` or `gnutls_priority_set()` instead.

Returns 0 on success.

gnutls_sign_algorithm_get_name

const char * `gnutls_sign_algorithm_get_name` [Function]
(*gnutls_sign_algorithm_t sign*)

Returns: a string that contains the name of the specified sign algorithm, or NULL.

gnutls_sign_callback_get

gnutls_sign_func gnutls_sign_callback_get (*gnutls_session_t session, void ** userdata*) [Function]

session: is a gnutls session

userdata: if non-NULL, will be set to abstract callback pointer.

Retrieve the callback function, and its userdata pointer.

Returns: The function pointer set by `gnutls_sign_callback_set()`, or if not set, NULL.

gnutls_sign_callback_set

void gnutls_sign_callback_set (*gnutls_session_t session, gnutls_sign_func sign_func, void * userdata*) [Function]

session: is a gnutls session

sign_func: function pointer to application's sign callback.

userdata: void pointer that will be passed to sign callback.

Set the callback function. The function must have this prototype:

```
typedef int (*gnutls_sign_func) (gnutls_session_t session, void *userdata,
gnutls_certificate_type_t cert_type, const gnutls_datum_t * cert, const
gnutls_datum_t * hash, gnutls_datum_t * signature);
```

The `userdata` parameter is passed to the `sign_func` verbatim, and can be used to store application-specific data needed in the callback function. See also `gnutls_sign_callback_get()`.

gnutls_srp_allocate_client_credentials

```
int gnutls_srp_allocate_client_credentials [Function]
    (gnutls_srp_client_credentials_t * sc)
```

`sc`: is a pointer to an `gnutls_srp_server_credentials_t` structure.

This structure is complex enough to manipulate directly thus this helper function is provided in order to allocate it.

Returns 0 on success.

gnutls_srp_allocate_server_credentials

```
int gnutls_srp_allocate_server_credentials [Function]
    (gnutls_srp_server_credentials_t * sc)
```

`sc`: is a pointer to an `gnutls_srp_server_credentials_t` structure.

This structure is complex enough to manipulate directly thus this helper function is provided in order to allocate it.

Returns 0 on success.

gnutls_srp_base64_decode_alloc

```
int gnutls_srp_base64_decode_alloc (const gnutls_datum_t * [Function]
    b64_data, gnutls_datum_t * result)
```

`b64_data`: contains the encoded data

`result`: the place where decoded data lie

This function will decode the given encoded data. The decoded data will be allocated, and stored into `result`. It will decode using the base64 algorithm found in `libsrp`.

You should use `gnutls_free()` to free the returned data.

gnutls_srp_base64_decode

```
int gnutls_srp_base64_decode (const gnutls_datum_t * b64_data, [Function]
    char * result, size_t * result_size)
```

`b64_data`: contain the encoded data

`result`: the place where decoded data will be copied

`result_size`: holds the size of the result

This function will decode the given encoded data, using the base64 encoding found in `libsrp`.

Note that `b64_data` should be null terminated.

Returns `GNUTLS_E_SHORT_MEMORY_BUFFER` if the buffer given is not long enough, or 0 on success.

gnutls_srp_base64_encode_alloc

```
int gnutls_srp_base64_encode_alloc (const gnutls_datum_t * data,      [Function]
                                   gnutls_datum_t * result)
```

data: contains the raw data

result: will hold the newly allocated encoded data

This function will convert the given data to printable data, using the base64 encoding. This is the encoding used in SRP password files. This function will allocate the required memory to hold the encoded data.

You should use `gnutls_free()` to free the returned data.

gnutls_srp_base64_encode

```
int gnutls_srp_base64_encode (const gnutls_datum_t * data, char *    [Function]
                             result, size_t * result_size)
```

data: contain the raw data

result: the place where base64 data will be copied

result_size: holds the size of the result

This function will convert the given data to printable data, using the base64 encoding, as used in the libsrp. This is the encoding used in SRP password files. If the provided buffer is not long enough GNUTLS_E_SHORT_MEMORY_BUFFER is returned.

gnutls_srp_free_client_credentials

```
void gnutls_srp_free_client_credentials (gnutls_srp_client_credentials_t sc)      [Function]
```

sc: is an `gnutls_srp_client_credentials_t` structure.

This structure is complex enough to manipulate directly thus this helper function is provided in order to free (deallocate) it.

gnutls_srp_free_server_credentials

```
void gnutls_srp_free_server_credentials (gnutls_srp_server_credentials_t sc)      [Function]
```

sc: is an `gnutls_srp_server_credentials_t` structure.

This structure is complex enough to manipulate directly thus this helper function is provided in order to free (deallocate) it.

gnutls_srp_server_get_username

```
const char * gnutls_srp_server_get_username (gnutls_session_t      [Function]
                                              session)
```

session: is a gnutls session

This function will return the username of the peer. This should only be called in case of SRP authentication and in case of a server. Returns NULL in case of an error.

gnutls_srp_set_client_credentials_function

```
void gnutls_srp_set_client_credentials_function [Function]
      (gnutls_srp_client_credentials_t cred, gnutls_srp_client_credentials_function *
       func)
```

cred: is a `gnutls_srp_server_credentials_t` structure.

func: is the callback function

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.

gnutls_srp_set_client_credentials

```
int gnutls_srp_set_client_credentials [Function]
      (gnutls_srp_client_credentials_t res, const char * username, const char *
       password)
```

res: is an `gnutls_srp_client_credentials_t` structure.

username: is the user's userid

password: is the user's password

This function sets the username and password, in a `gnutls_srp_client_credentials_t` structure. Those will be used in SRP authentication. `username` and `password` should be ASCII strings or UTF-8 strings prepared using the "SASLprep" profile of "stringprep".

Returns 0 on success.

gnutls_srp_set_server_credentials_file

```
int gnutls_srp_set_server_credentials_file [Function]
      (gnutls_srp_server_credentials_t res, const char * password_file, const char
       * password_conf_file)
```

res: is an `gnutls_srp_server_credentials_t` structure.

password_file: is the SRP password file (tpasswd)

password_conf_file: is the SRP password conf file (tpasswd.conf)

This function sets the password files, in a `gnutls_srp_server_credentials_t` structure. Those password files hold usernames and verifiers and will be used for SRP authentication.

Returns 0 on success.

gnutls_srp_set_server_credentials_function

```
void gnutls_srp_set_server_credentials_function [Function]
      (gnutls_srp_server_credentials_t cred, gnutls_srp_server_credentials_function *
       func)
```

cred: is a `gnutls_srp_server_credentials_t` structure.

func: is the callback function

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* g, gnutls_datum_t* n);`

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 `extra.h`.

In case the callback returned a negative number then gnutls will assume that the username does not exist.

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).

The callback function will only be called once per handshake. The callback function should return 0 on success, while -1 indicates an error.

gnutls_srp_verifier

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

username: is the user's name

password: is the user's password

salt: should be some randomly generated bytes

generator: is the generator of the group

prime: is the group's prime

res: where the verifier will be stored.

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/extra.h` or may be generated using the GCRYPT functions `gcry_prime_generate()` and `gcry_prime_group_generator()`. The verifier will be allocated with `malloc` and will be stored in *res* using binary format.

gnutls_strerror

```
const char * gnutls_strerror (int error) [Function]
```

error: is an error returned by a gnutls function. Error is always a negative value.

This function is similar to `strerror()`. Differences: it accepts an error number returned by a gnutls function; In case of an unknown error a descriptive string is sent instead of NULL.

gnutls_transport_get_ptr2

```
void gnutls_transport_get_ptr2 (gnutls_session_t session, [Function]
                               gnutls_transport_ptr_t *recv_ptr, gnutls_transport_ptr_t *send_ptr)
```

session: is a `gnutls_session_t` structure.

recv_ptr: will hold the value for the pull function

send_ptr: will hold the value for the push function

Used to get the arguments of the transport functions (like PUSH and PULL). These should have been set using `gnutls_transport_set_ptr2()`.

gnutls_transport_get_ptr

```
gnutls_transport_ptr_t gnutls_transport_get_ptr [Function]
(gnutls_session_t session)
```

session: is a `gnutls_session_t` structure.

Used to get the first argument of the transport function (like PUSH and PULL). This must have been set using `gnutls_transport_set_ptr()`.

Returns: first argument of the transport function.

gnutls_transport_set_errno

```
void gnutls_transport_set_errno (gnutls_session_t session, int [Function]
                                err)
```

session: is a `gnutls_session_t` structure.

err: error value to store in session-specific errno variable.

Store **err** in the session-specific errno variable. Useful values for **err** is EAGAIN and EINTR, other values are treated will be treated as real errors in the push/pull function.

This function is useful in replacement push/pull functions set by `gnutls_transport_set_push_function` and `gnutls_transport_set_pullpush_function` under Windows, where the replacement push/pull may not have access to the same **errno** variable that is used by GnuTLS (e.g., the application is linked to `msvcrt.dll` and `gnutls` is linked to `msvcrt.dll`).

If you don't have the **session** variable easily accessible from the push/pull function, and don't worry about thread conflicts, you can also use `gnutls_transport_set_global_errno()`.

gnutls_transport_set_global_errno

```
void gnutls_transport_set_global_errno (int err) [Function]
```

err: error value to store in global errno variable.

Store **err** in the global errno variable. Useful values for **err** is EAGAIN and EINTR, other values are treated will be treated as real errors in the push/pull function.

This function is useful in replacement push/pull functions set by `gnutls_transport_set_push_function` and `gnutls_transport_set_pullpush_function` under Windows, where the replacement push/pull 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).

Whether this function is thread safe or not depends on whether the global variable **errno** is thread safe, some system libraries make it a thread-local variable. When feasible, using the guaranteed thread-safe **gnutls_transport_set_errno()** may be better.

gnutls_transport_set_lowat

void gnutls_transport_set_lowat (*gnutls_session_t session*, *int num*) [Function]

session: is a **gnutls_session_t** structure.

num: is the low water value.

Used to set the lowat value in order for select to check if there are pending data to socket buffer. Used only if you have changed the default low water value (default is 1). Normally you will not need that function. This function is only useful if using berkeley style sockets. Otherwise it must be called and set lowat to zero.

gnutls_transport_set_ptr2

void gnutls_transport_set_ptr2 (*gnutls_session_t session*, *gnutls_transport_ptr_t recv_ptr*, *gnutls_transport_ptr_t send_ptr*) [Function]

session: is a **gnutls_session_t** structure.

recv_ptr: is the value for the pull function

send_ptr: is the value for the push function

Used to set the first argument of the transport function (like PUSH and PULL). In berkeley style sockets this function will set the connection handle. With this function you can use two different pointers for receiving and sending.

gnutls_transport_set_ptr

void gnutls_transport_set_ptr (*gnutls_session_t session*, *gnutls_transport_ptr_t ptr*) [Function]

session: is a **gnutls_session_t** structure.

ptr: is the value.

Used to set the first argument of the transport function (like PUSH and PULL). In berkeley style sockets this function will set the connection handle.

gnutls_transport_set_pull_function

void gnutls_transport_set_pull_function (*gnutls_session_t session*, *gnutls_pull_func pull_func*) [Function]

session: gnutls session

pull_func: a callback function similar to **read()**

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.

PULL_FUNC is of the form, `ssize_t (*gnutls_pull_func)(gnutls_transport_ptr_t, void*, size_t);`

gnutls_transport_set_push_function

`void gnutls_transport_set_push_function (gnutls_session_t session, gnutls_push_func push_func)` [Function]

session: gnutls session

push_func: a callback function similar to `write()`

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.

PUSH_FUNC is of the form, `ssize_t (*gnutls_push_func)(gnutls_transport_ptr_t, const void*, size_t);`

9.2 X.509 Certificate Functions

The following functions are to be used for X.509 certificate handling. Their prototypes lie in 'gnutls/x509.h'.

gnutls_pkcs12_bag_decrypt

`int gnutls_pkcs12_bag_decrypt (gnutls_pkcs12_bag_t bag, const char *pass)` [Function]

bag: The bag

pass: The password used for encryption. This can only be ASCII.

This function will decrypt the given encrypted bag and return 0 on success.

gnutls_pkcs12_bag_deinit

`void gnutls_pkcs12_bag_deinit (gnutls_pkcs12_bag_t bag)` [Function]

bag: The structure to be initialized

This function will deinitialize a PKCS12 Bag structure.

gnutls_pkcs12_bag_encrypt

`int gnutls_pkcs12_bag_encrypt (gnutls_pkcs12_bag_t bag, const char *pass, unsigned int flags)` [Function]

bag: The bag

pass: The password used for encryption. This can only be ASCII.

flags: should be one of `gnutls_pkcs_encrypt_flags_t` elements bitwise or'd

This function will encrypt the given bag and return 0 on success.

gnutls_pkcs12_bag_get_count

`int gnutls_pkcs12_bag_get_count (gnutls_pkcs12_bag_t bag)` [Function]

bag: The bag

This function will return the number of the elements within the bag.

gnutls_pkcs12_bag_get_data

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

bag: The bag

indx: The element of the bag to get the data from

data: where the bag's data will be. Should be treated as constant.

This function will return the bag's data. The data is a constant that is stored into the bag. Should not be accessed after the bag is deleted.

Returns 0 on success and a negative error code on error.

gnutls_pkcs12_bag_get_friendly_name

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

bag: The bag

indx: The bag's element to add the id

name: will hold a pointer to the name (to be treated as const)

This function will return the friendly name, of the specified bag element. The key ID is usually used to distinguish the local private key and the certificate pair.

Returns 0 on success, or a negative value on error.

gnutls_pkcs12_bag_get_key_id

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

bag: The bag

indx: The bag's element to add the id

id: where the ID will be copied (to be treated as const)

This function will return the key ID, of the specified bag element. The key ID is usually used to distinguish the local private key and the certificate pair.

Returns 0 on success, or a negative value on error.

gnutls_pkcs12_bag_get_type

```
gnutls_pkcs12_bag_type_t gnutls_pkcs12_bag_get_type      [Function]
                          (gnutls_pkcs12_bag_t bag, int indx)
```

bag: The bag

indx: The element of the bag to get the type

This function will return the bag's type. One of the `gnutls_pkcs12_bag_type_t` enumerations.

gnutls_pkcs12_bag_init

int gnutls_pkcs12_bag_init (*gnutls_pkcs12_bag_t * bag*) [Function]

bag: The structure to be initialized

This function will initialize a PKCS12 bag structure. PKCS12 Bags usually contain private keys, lists of X.509 Certificates and X.509 Certificate revocation lists.

Returns 0 on success.

gnutls_pkcs12_bag_set_crl

int gnutls_pkcs12_bag_set_crl (*gnutls_pkcs12_bag_t bag*, [Function]
gnutls_x509_crl_t crl)

bag: The bag

crl: the CRL to be copied.

This function will insert the given CRL into the bag. This is just a wrapper over `gnutls_pkcs12_bag_set_data()`.

Returns the index of the added bag on success, or a negative value on failure.

gnutls_pkcs12_bag_set_cert

int gnutls_pkcs12_bag_set_cert (*gnutls_pkcs12_bag_t bag*, [Function]
gnutls_x509_cert_t crt)

bag: The bag

crt: the certificate to be copied.

This function will insert the given certificate into the bag. This is just a wrapper over `gnutls_pkcs12_bag_set_data()`.

Returns the index of the added bag on success, or a negative value on failure.

gnutls_pkcs12_bag_set_data

int gnutls_pkcs12_bag_set_data (*gnutls_pkcs12_bag_t bag*, [Function]
gnutls_pkcs12_bag_type_t type, *const gnutls_datum_t * data*)

bag: The bag

type: The data's type

data: the data to be copied.

This function will insert the given data of the given type into the bag.

Returns the index of the added bag on success, or a negative value on error.

gnutls_pkcs12_bag_set_friendly_name

int gnutls_pkcs12_bag_set_friendly_name (*gnutls_pkcs12_bag_t* [Function]
bag, *int indx*, *const char * name*)

bag: The bag

indx: The bag's element to add the id

name: the name

This function will add the given key friendly name, to the specified, by the index, bag element. The name will be encoded as a 'Friendly name' bag attribute, which is usually used to set a user name to the local private key and the certificate pair.

Returns 0 on success, or a negative value on error.

gnutls_pkcs12_bag_set_key_id

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

bag: The bag

indx: The bag's element to add the id

id: the ID

This function will add the given key ID, to the specified, by the index, bag element. The key ID will be encoded as a 'Local key identifier' bag attribute, which is usually used to distinguish the local private key and the certificate pair.

Returns 0 on success, or a negative value on error.

gnutls_pkcs12_deinit

void gnutls_pkcs12_deinit (*gnutls_pkcs12_t pkcs12*) [Function]

pkcs12: The structure to be initialized

This function will deinitialize a PKCS12 structure.

gnutls_pkcs12_export

int gnutls_pkcs12_export (*gnutls_pkcs12_t pkcs12*, *gnutls_x509_cert_fmt_t format*, *void * output_data*, *size_t * output_data_size*) [Function]

pkcs12: Holds the pkcs12 structure

format: the format of output params. One of PEM or DER.

output_data: will contain a structure PEM or DER encoded

output_data_size: holds the size of output_data (and will be replaced by the actual size of parameters)

This function will export the pkcs12 structure to DER or PEM format.

If the buffer provided is not long enough to hold the output, then *output_data_size will be updated and GNUTLS_E_SHORT_MEMORY_BUFFER will be returned.

If the structure is PEM encoded, it will have a header of "BEGIN PKCS12".

Return value: In case of failure a negative value will be returned, and 0 on success.

gnutls_pkcs12_generate_mac

int gnutls_pkcs12_generate_mac (*gnutls_pkcs12_t pkcs12*, *const char * pass*) [Function]

pkcs12: should contain a gnutls_pkcs12_t structure

pass: The password for the MAC

This function will generate a MAC for the PKCS12 structure. Returns 0 on success.

gnutls_pkcs12_get_bag

int gnutls_pkcs12_get_bag (*gnutls_pkcs12_t pkcs12, int indx,* [Function]
gnutls_pkcs12_bag_t bag)
pkcs12: should contain a gnutls_pkcs12_t structure
indx: contains the index of the bag to extract
bag: An initialized bag, where the contents of the bag will be copied
 This function will return a Bag from the PKCS12 structure. Returns 0 on success.
 After the last Bag has been read GNUTLS_E_REQUESTED_DATA_NOT_AVAILABLE
 will be returned.

gnutls_pkcs12_import

int gnutls_pkcs12_import (*gnutls_pkcs12_t pkcs12, const* [Function]
*gnutls_datum_t * data, gnutls_x509_cert_fmt_t format, unsigned int flags*)
pkcs12: The structure to store the parsed PKCS12.
data: The DER or PEM encoded PKCS12.
format: One of DER or PEM
flags: an ORed sequence of gnutls_privkey_pkcs8_flags
 This function will convert the given DER or PEM encoded PKCS12 to the native
 gnutls_pkcs12_t format. The output will be stored in 'pkcs12'.
 If the PKCS12 is PEM encoded it should have a header of "PKCS12".
 Returns 0 on success.

gnutls_pkcs12_init

int gnutls_pkcs12_init (*gnutls_pkcs12_t * pkcs12*) [Function]
pkcs12: The structure to be initialized
 This function will initialize a PKCS12 structure. PKCS12 structures usually contain
 lists of X.509 Certificates and X.509 Certificate revocation lists.
 Returns 0 on success.

gnutls_pkcs12_set_bag

int gnutls_pkcs12_set_bag (*gnutls_pkcs12_t pkcs12,* [Function]
gnutls_pkcs12_bag_t bag)
pkcs12: should contain a gnutls_pkcs12_t structure
bag: An initialized bag
 This function will insert a Bag into the PKCS12 structure. Returns 0 on success.

gnutls_pkcs12_verify_mac

int gnutls_pkcs12_verify_mac (*gnutls_pkcs12_t pkcs12, const char ** [Function]
pass)
pkcs12: should contain a gnutls_pkcs12_t structure
pass: The password for the MAC
 This function will verify the MAC for the PKCS12 structure. Returns 0 on success.

gnutls_pkcs7_deinit

void gnutls_pkcs7_deinit (*gnutls_pkcs7_t pkcs7*) [Function]

pkcs7: The structure to be initialized

This function will deinitialize a PKCS7 structure.

gnutls_pkcs7_delete_crl

int gnutls_pkcs7_delete_crl (*gnutls_pkcs7_t pkcs7, int indx*) [Function]

indx: the index of the crl to delete

This function will delete a crl from a PKCS7 or RFC2630 crl set. Index starts from 0. Returns 0 on success.

gnutls_pkcs7_delete_cert

int gnutls_pkcs7_delete_cert (*gnutls_pkcs7_t pkcs7, int indx*) [Function]

indx: the index of the certificate to delete

This function will delete a certificate from a PKCS7 or RFC2630 certificate set. Index starts from 0. Returns 0 on success.

gnutls_pkcs7_export

int gnutls_pkcs7_export (*gnutls_pkcs7_t pkcs7,* [Function]

*gnutls_x509_crt_fmt_t format, void * output_data, size_t *
output_data_size*)

pkcs7: Holds the pkcs7 structure

format: the format of output params. One of PEM or DER.

output_data: will contain a structure PEM or DER encoded

output_data_size: holds the size of output_data (and will be replaced by the actual size of parameters)

This function will export the pkcs7 structure to DER or PEM format.

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.

If the structure is PEM encoded, it will have a header of "BEGIN PKCS7".

Return value: In case of failure a negative value will be returned, and 0 on success.

gnutls_pkcs7_get_crl_count

int gnutls_pkcs7_get_crl_count (*gnutls_pkcs7_t pkcs7*) [Function]

This function will return the number of certificates in the PKCS7 or RFC2630 crl set.

Returns a negative value on failure.

gnutls_pkcs7_get_crl_raw

int gnutls_pkcs7_get_crl_raw (*gnutls_pkcs7_t pkcs7, int indx, void* [Function]
**crl, size_t *crl_size*)

indx: contains the index of the crl to extract

crl: the contents of the crl will be copied there (may be null)

crl_size: should hold the size of the crl

This function will return a crl of the PKCS7 or RFC2630 crl set. Returns 0 on success. If the provided buffer is not long enough, then *crl_size* is updated and GNUTLS_E_SHORT_MEMORY_BUFFER is returned.

After the last crl has been read GNUTLS_E_REQUESTED_DATA_NOT_AVAILABLE will be returned.

gnutls_pkcs7_get_cert_count

int gnutls_pkcs7_get_cert_count (*gnutls_pkcs7_t pkcs7*) [Function]

This function will return the number of certificates in the PKCS7 or RFC2630 certificate set.

Returns a negative value on failure.

gnutls_pkcs7_get_cert_raw

int gnutls_pkcs7_get_cert_raw (*gnutls_pkcs7_t pkcs7, int indx, void* [Function]
**certificate, size_t *certificate_size*)

indx: contains the index of the certificate to extract

certificate: the contents of the certificate will be copied there (may be null)

certificate_size: should hold the size of the certificate

This function will return a certificate of the PKCS7 or RFC2630 certificate set. Returns 0 on success. If the provided buffer is not long enough, then *certificate_size* is updated and GNUTLS_E_SHORT_MEMORY_BUFFER is returned.

After the last certificate has been read GNUTLS_E_REQUESTED_DATA_NOT_AVAILABLE will be returned.

gnutls_pkcs7_import

int gnutls_pkcs7_import (*gnutls_pkcs7_t pkcs7, const* [Function]
*gnutls_datum_t *data, gnutls_x509_crt_fmt_t format*)

pkcs7: The structure to store the parsed PKCS7.

data: The DER or PEM encoded PKCS7.

format: One of DER or PEM

This function will convert the given DER or PEM encoded PKCS7 to the native gnutls_pkcs7_t format. The output will be stored in 'pkcs7'.

If the PKCS7 is PEM encoded it should have a header of "PKCS7".

Returns 0 on success.

gnutls_pkcs7_init

int gnutls_pkcs7_init (*gnutls_pkcs7_t *pkcs7*) [Function]

pkcs7: The structure to be initialized

This function will initialize a PKCS7 structure. PKCS7 structures usually contain lists of X.509 Certificates and X.509 Certificate revocation lists.

Returns 0 on success.

gnutls_pkcs7_set_crl_raw

int gnutls_pkcs7_set_crl_raw (*gnutls_pkcs7_t pkcs7, const gnutls_datum_t *crl*) [Function]

crl: the DER encoded crl to be added

This function will add a crl to the PKCS7 or RFC2630 crl set. Returns 0 on success.

gnutls_pkcs7_set_crl

int gnutls_pkcs7_set_crl (*gnutls_pkcs7_t pkcs7, gnutls_x509_crl_t crl*) [Function]

crl: the DER encoded crl to be added

This function will add a parsed crl to the PKCS7 or RFC2630 crl set. Returns 0 on success.

gnutls_pkcs7_set_cert_raw

int gnutls_pkcs7_set_cert_raw (*gnutls_pkcs7_t pkcs7, const gnutls_datum_t *crt*) [Function]

crt: the DER encoded certificate to be added

This function will add a certificate to the PKCS7 or RFC2630 certificate set. Returns 0 on success.

gnutls_pkcs7_set_cert

int gnutls_pkcs7_set_cert (*gnutls_pkcs7_t pkcs7, gnutls_x509_cert_t crt*) [Function]

crt: the certificate to be copied.

This function will add a parsed certificate to the PKCS7 or RFC2630 certificate set.

This is a wrapper function over `gnutls_pkcs7_set_cert_raw()`.

Returns 0 on success.

gnutls_x509_crl_check_issuer

int gnutls_x509_crl_check_issuer (*gnutls_x509_crl_t cert, gnutls_x509_cert_t issuer*) [Function]

issuer: is the certificate of a possible issuer

This function will check if the given CRL was issued by the given issuer certificate. It will return true (1) if the given CRL was issued by the given issuer, and false (0) if not.

A negative value is returned in case of an error.

gnutls_x509_crl_deinit

void gnutls_x509_crl_deinit (*gnutls_x509_crl_t crl*) [Function]

crl: The structure to be initialized

This function will deinitialize a CRL structure.

gnutls_x509_crl_export

int gnutls_x509_crl_export (*gnutls_x509_crl_t crl*, [Function]

gnutls_x509_crt_fmt_t format, *void * output_data*, *size_t * output_data_size*)

crl: Holds the revocation list

format: the format of output params. One of PEM or DER.

output_data: will contain a private key PEM or DER encoded

output_data_size: holds the size of *output_data* (and will be replaced by the actual size of parameters)

This function will export the revocation list to DER or PEM format.

If the buffer provided is not long enough to hold the output, then GNUTLS_E_SHORT_MEMORY_BUFFER will be returned.

If the structure is PEM encoded, it will have a header of "BEGIN X509 CRL".

Returns 0 on success, and a negative value on failure.

gnutls_x509_crl_get_crt_count

int gnutls_x509_crl_get_crt_count (*gnutls_x509_crl_t crl*) [Function]

crl: should contain a *gnutls_x509_crl_t* structure

This function will return the number of revoked certificates in the given CRL.

Returns a negative value on failure.

gnutls_x509_crl_get_crt_serial

int gnutls_x509_crl_get_crt_serial (*gnutls_x509_crl_t crl*, *int* [Function]

indx, *unsigned char * serial*, *size_t * serial_size*, *time_t * t*)

crl: should contain a *gnutls_x509_crl_t* structure

indx: the index of the certificate to extract (starting from 0)

serial: where the serial number will be copied

serial_size: initially holds the size of *serial*

t: if non null, will hold the time this certificate was revoked

This function will return the serial number of the specified, by the index, revoked certificate.

Returns a negative value on failure.

gnutls_x509_crl_get_dn_oid

```
int gnutls_x509_crl_get_dn_oid (gnutls_x509_crl_t crl, int indx,      [Function]
                               void * oid, size_t * sizeof_oid)
```

crl: should contain a gnutls_x509_crl_t structure

indx: Specifies which DN OID to send. Use zero to get the first one.

oid: a pointer to a structure to hold the name (may be null)

sizeof_oid: initially holds the size of 'oid'

This function will extract the requested OID of the name of the CRL issuer, specified by the given index.

If *oid* is null then only the size will be filled.

Returns GNUTLS_E_SHORT_MEMORY_BUFFER if the provided buffer is not long enough, and in that case the *sizeof_oid* will be updated with the required size. On success 0 is returned.

gnutls_x509_crl_get_issuer_dn_by_oid

```
int gnutls_x509_crl_get_issuer_dn_by_oid (gnutls_x509_crl_t      [Function]
                                           crl, const char * oid, int indx, unsigned int raw_flag, void * buf, size_t *
                                           sizeof_buf)
```

crl: should contain a gnutls_x509_crl_t structure

oid: holds an Object Identified in null terminated string

indx: In case multiple same OIDs exist in the RDN, this specifies which to send. Use zero to get the first one.

raw_flag: If non zero returns the raw DER data of the DN part.

buf: a pointer to a structure to hold the peer's name (may be null)

sizeof_buf: initially holds the size of *buf*

This function will extract the part of the name of the CRL issuer specified by the given OID. The output will be encoded as described in RFC2253. The output string will be ASCII or UTF-8 encoded, depending on the certificate data.

Some helper macros with popular OIDs can be found in gnutls/x509.h If *raw_flag* is zero, this function will only return known OIDs as text. Other OIDs will be DER encoded, as described in RFC2253 – in hex format with a '\#' prefix. You can check about known OIDs using `gnutls_x509_dn_oid_known()`.

If *buf* is null then only the size will be filled.

Returns GNUTLS_E_SHORT_MEMORY_BUFFER if the provided buffer is not long enough, and in that case the *sizeof_buf* will be updated with the required size, and 0 on success.

gnutls_x509_crl_get_issuer_dn

```
int gnutls_x509_crl_get_issuer_dn (const gnutls_x509_crl_t crl,      [Function]
                                   char * buf, size_t * sizeof_buf)
```

crl: should contain a gnutls_x509_crl_t structure

buf: a pointer to a structure to hold the peer's name (may be null)

sizeof_buf: initially holds the size of *buf*

This function will copy the name of the CRL issuer in the provided buffer. The name will be in the form "C=xxxx,O=yyyy,CN=zzzz" as described in RFC2253. The output string will be ASCII or UTF-8 encoded, depending on the certificate data.

If *buf* is null then only the size will be filled.

Returns GNUTLS_E_SHORT_MEMORY_BUFFER if the provided buffer is not long enough, and in that case the *sizeof_buf* will be updated with the required size, and 0 on success.

gnutls_x509_crl_get_next_update

time_t gnutls_x509_crl_get_next_update (*gnutls_x509_crl_t crl*) [Function]

crl: should contain a *gnutls_x509_crl_t* structure

This function will return the time the next CRL will be issued. This field is optional in a CRL so it might be normal to get an error instead.

Returns (time_t)-1 on error.

gnutls_x509_crl_get_signature_algorithm

int gnutls_x509_crl_get_signature_algorithm (*gnutls_x509_crl_t crl*) [Function]

crl: should contain a *gnutls_x509_crl_t* structure

This function will return a value of the *gnutls_sign_algorithm_t* enumeration that is the signature algorithm.

Returns a negative value on error.

gnutls_x509_crl_get_signature

int gnutls_x509_crl_get_signature (*gnutls_x509_crl_t crl*, *char * sig*, *size_t * sizeof_sig*) [Function]

crl: should contain a *gnutls_x509_crl_t* structure

sig: a pointer where the signature part will be copied (may be null).

sizeof_sig: initially holds the size of *sig*

This function will extract the signature field of a CRL.

Returns 0 on success, and a negative value on error.

gnutls_x509_crl_get_this_update

time_t gnutls_x509_crl_get_this_update (*gnutls_x509_crl_t crl*) [Function]

crl: should contain a *gnutls_x509_crl_t* structure

This function will return the time this CRL was issued.

Returns (time_t)-1 on error.

gnutls_x509_crl_get_version

int gnutls_x509_crl_get_version (*gnutls_x509_crl_t* *crl*) [Function]

crl: should contain a gnutls_x509_crl_t structure

This function will return the version of the specified CRL.

Returns a negative value on error.

gnutls_x509_crl_import

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

crl: The structure to store the parsed CRL.

data: The DER or PEM encoded CRL.

format: One of DER or PEM

This function will convert the given DER or PEM encoded CRL to the native gnutls_x509_crl_t format. The output will be stored in 'crl'.

If the CRL is PEM encoded it should have a header of "X509 CRL".

Returns 0 on success.

gnutls_x509_crl_init

int gnutls_x509_crl_init (*gnutls_x509_crl_t* * *crl*) [Function]

crl: The structure to be initialized

This function will initialize a CRL structure. CRL stands for Certificate Revocation List. A revocation list usually contains lists of certificate serial numbers that have been revoked by an Authority. The revocation lists are always signed with the authority's private key.

Returns 0 on success.

gnutls_x509_crl_print

int gnutls_x509_crl_print (*gnutls_x509_crl_t* *crl*, [Function]
gnutls_certificate_print_formats_t *format*, *gnutls_datum_t* * *out*)

crl: The structure to be printed

format: Indicate the format to use

out: Newly allocated datum with zero terminated string.

This function will pretty print a X.509 certificate revocation list, suitable for display to a human.

The output *out* needs to be deallocate using **gnutls_free()**.

Returns 0 on success.

gnutls_x509_crl_set_crt_serial

int gnutls_x509_crl_set_crt_serial (*gnutls_x509_crl_t* *crl*, *const void ***serial*, *size_t* *serial_size*, *time_t* *revocation_time*) [Function]

crl: should contain a *gnutls_x509_crl_t* structure

serial: The revoked certificate's serial number

serial_size: Holds the size of the serial field.

revocation_time: The time this certificate was revoked

This function will set a revoked certificate's serial number to the CRL.

Returns 0 on success, or a negative value in case of an error.

gnutls_x509_crl_set_crt

int gnutls_x509_crl_set_crt (*gnutls_x509_crl_t* *crl*, *gnutls_x509_crt_t* *crt*, *time_t* *revocation_time*) [Function]

crl: should contain a *gnutls_x509_crl_t* structure

crt: should contain a *gnutls_x509_crt_t* structure with the revoked certificate

revocation_time: The time this certificate was revoked

This function will set a revoked certificate's serial number to the CRL.

Returns 0 on success, or a negative value in case of an error.

gnutls_x509_crl_set_next_update

int gnutls_x509_crl_set_next_update (*gnutls_x509_crl_t* *crl*, *time_t* *exp_time*) [Function]

crl: should contain a *gnutls_x509_crl_t* structure

exp_time: The actual time

This function will set the time this CRL will be updated.

Returns 0 on success, or a negative value in case of an error.

gnutls_x509_crl_set_this_update

int gnutls_x509_crl_set_this_update (*gnutls_x509_crl_t* *crl*, *time_t* *act_time*) [Function]

crl: should contain a *gnutls_x509_crl_t* structure

act_time: The actual time

This function will set the time this CRL was issued.

Returns 0 on success, or a negative value in case of an error.

gnutls_x509_crl_set_version

int gnutls_x509_crl_set_version (*gnutls_x509_crl_t* *crl*, *unsigned int* *version*) [Function]

crl: should contain a *gnutls_x509_crl_t* structure

version: holds the version number. For CRLv1 crls must be 1.

This function will set the version of the CRL. This must be one for CRL version 1, and so on. The CRLs generated by gnutls should have a version number of 2.

Returns 0 on success.

gnutls_x509_crl_sign2

int gnutls_x509_crl_sign2 (*gnutls_x509_crl_t* *crl*, *gnutls_x509_crt_t* [Function]
issuer, *gnutls_x509_privkey_t* *issuer_key*, *gnutls_digest_algorithm_t* *dig*,
unsigned int *flags*)

crl: should contain a *gnutls_x509_crl_t* structure

issuer: is the certificate of the certificate issuer

issuer_key: holds the issuer's private key

dig: The message digest to use. GNUTLS_DIG_SHA1 is the safe choice unless you know what you're doing.

flags: must be 0

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 0 on success.

gnutls_x509_crl_sign

int gnutls_x509_crl_sign (*gnutls_x509_crl_t* *crl*, *gnutls_x509_crt_t* [Function]
issuer, *gnutls_x509_privkey_t* *issuer_key*)

crl: should contain a *gnutls_x509_crl_t* structure

issuer: is the certificate of the certificate issuer

issuer_key: holds the issuer's private key

This function is the same as *gnutls_x509_crl_sign2()* with no flags, and SHA1 as the hash algorithm.

Returns 0 on success.

gnutls_x509_crl_verify

int gnutls_x509_crl_verify (*gnutls_x509_crl_t* *crl*, *const* [Function]
gnutls_x509_crt_t * *CA_list*, *int* *CA_list_length*, *unsigned int* *flags*,
unsigned int * *verify*)

crl: is the crl to be verified

CA_list: is a certificate list that is considered to be trusted one

CA_list_length: holds the number of CA certificates in *CA_list*

flags: Flags that may be used to change the verification algorithm. Use OR of the *gnutls_certificate_verify_flags* enumerations.

verify: will hold the crl verification output.

This function will try to verify the given crl and return its status. See *gnutls_x509_crt_list_verify()* for a detailed description of return values.

Returns 0 on success and a negative value in case of an error.

gnutls_x509_crq_deinit

void gnutls_x509_crq_deinit (*gnutls_x509_crq_t crq*) [Function]

crq: The structure to be initialized

This function will deinitialize a CRL structure.

gnutls_x509_crq_export

int gnutls_x509_crq_export (*gnutls_x509_crq_t crq*, [Function]

gnutls_x509_crq_fmt_t format, *void * output_data*, *size_t * output_data_size*)

crq: Holds the request

format: the format of output params. One of PEM or DER.

output_data: will contain a certificate request PEM or DER encoded

output_data_size: holds the size of *output_data* (and will be replaced by the actual size of parameters)

This function will export the certificate request to a PKCS10

If the buffer provided is not long enough to hold the output, then GNUTLS_E_SHORT_MEMORY_BUFFER will be returned and **output_data_size* will be updated.

If the structure is PEM encoded, it will have a header of "BEGIN NEW CERTIFICATE REQUEST".

Return value: In case of failure a negative value will be returned, and 0 on success.

gnutls_x509_crq_get_attribute_by_oid

int gnutls_x509_crq_get_attribute_by_oid (*gnutls_x509_crq_t* [Function]

crq, *const char * oid*, *int indx*, *void * buf*, *size_t * sizeof_buf*)

crq: should contain a *gnutls_x509_crq_t* structure

oid: holds an Object Identified in null terminated string

indx: In case multiple same OIDs exist in the attribute list, this specifies which to send. Use zero to get the first one.

buf: a pointer to a structure to hold the attribute data (may be null)

sizeof_buf: initially holds the size of *buf*

This function will return the attribute in the certificate request specified by the given Object ID. The attribute will be DER encoded.

Returns 0 on success.

gnutls_x509_crq_get_challenge_password

int gnutls_x509_crq_get_challenge_password (*gnutls_x509_crq_t* [Function]

crq, *char * pass*, *size_t * sizeof_pass*)

crq: should contain a *gnutls_x509_crq_t* structure

pass: will hold a null terminated password

sizeof_pass: Initially holds the size of *pass*.

This function will return the challenge password in the request.

Returns 0 on success.

gnutls_x509_crq_get_dn_by_oid

```
int gnutls_x509_crq_get_dn_by_oid (gnutls_x509_crq_t crq, const [Function]  
    char * oid, int indx, unsigned int raw_flag, void * buf, size_t *  
    sizeof_buf)
```

crq: should contain a *gnutls_x509_crq_t* structure

oid: holds an Object Identified in null terminated string

indx: In case multiple same OIDs exist in the RDN, this specifies which to send. Use zero to get the first one.

raw_flag: If non zero returns the raw DER data of the DN part.

buf: a pointer to a structure to hold the name (may be null)

sizeof_buf: initially holds the size of *buf*

This function will extract the part of the name of the Certificate request subject, specified by the given OID. The output will be encoded as described in RFC2253. The output string will be ASCII or UTF-8 encoded, depending on the certificate data.

Some helper macros with popular OIDs can be found in *gnutls/x509.h*. If *raw_flag* is zero, this function will only return known OIDs as text. Other OIDs will be DER encoded, as described in RFC2253 – in hex format with a '\#' prefix. You can check about known OIDs using *gnutls_x509_dn_oid_known()*.

If *buf* is null then only the size will be filled.

Returns *GNUTLS_E_SHORT_MEMORY_BUFFER* if the provided buffer is not long enough, and in that case the **sizeof_buf* will be updated with the required size. On success 0 is returned.

gnutls_x509_crq_get_dn_oid

```
int gnutls_x509_crq_get_dn_oid (gnutls_x509_crq_t crq, int indx, [Function]  
    void * oid, size_t * sizeof_oid)
```

crq: should contain a *gnutls_x509_crq_t* structure

indx: Specifies which DN OID to send. Use zero to get the first one.

oid: a pointer to a structure to hold the name (may be null)

sizeof_oid: initially holds the size of *oid*

This function will extract the requested OID of the name of the Certificate request subject, specified by the given index.

If *oid* is null then only the size will be filled.

Returns *GNUTLS_E_SHORT_MEMORY_BUFFER* if the provided buffer is not long enough, and in that case the **sizeof_oid* will be updated with the required size. On success 0 is returned.

gnutls_x509_crq_get_dn

int gnutls_x509_crq_get_dn (*gnutls_x509_crq_t crq*, *char * buf*, [Function]
*size_t * sizeof_buf*)

crq: should contain a *gnutls_x509_crq_t* structure

buf: a pointer to a structure to hold the name (may be null)

sizeof_buf: initially holds the size of *buf*

This function will copy the name of the Certificate request subject in the provided buffer. The name will be in the form "C=xxxx,O=yyyy,CN=zzzz" as described in RFC2253. The output string will be ASCII or UTF-8 encoded, depending on the certificate data.

If *buf* is null then only the size will be filled.

Returns GNUTLS_E_SHORT_MEMORY_BUFFER if the provided buffer is not long enough, and in that case the **sizeof_buf* will be updated with the required size. On success 0 is returned.

gnutls_x509_crq_get_pk_algorithm

int gnutls_x509_crq_get_pk_algorithm (*gnutls_x509_crq_t crq*, [Function]
*unsigned int * bits*)

crq: should contain a *gnutls_x509_crq_t* structure

bits: if *bits* is non null it will hold the size of the parameters' in bits

This function will return the public key algorithm of a PKCS #10 certificate request.

If *bits* is non null, it should have enough size to hold the parameters size in bits. For RSA the bits returned is the modulus. For DSA the bits returned are of the public exponent.

Returns a member of the *gnutls_pk_algorithm_t* enumeration on success, or a negative value on error.

gnutls_x509_crq_get_version

int gnutls_x509_crq_get_version (*gnutls_x509_crq_t crq*) [Function]

crq: should contain a *gnutls_x509_crq_t* structure

This function will return the version of the specified Certificate request.

Returns a negative value on error.

gnutls_x509_crq_import

int gnutls_x509_crq_import (*gnutls_x509_crq_t crq*, *const gnutls_datum_t * data*, *gnutls_x509_crq_fmt_t format*) [Function]

crq: The structure to store the parsed certificate request.

data: The DER or PEM encoded certificate.

format: One of DER or PEM

This function will convert the given DER or PEM encoded Certificate to the native *gnutls_x509_crq_t* format. The output will be stored in *cert*.

If the Certificate is PEM encoded it should have a header of "NEW CERTIFICATE REQUEST".

Returns 0 on success.

gnutls_x509_crq_init

int gnutls_x509_crq_init (*gnutls_x509_crq_t * crq*) [Function]
crq: The structure to be initialized

This function will initialize a PKCS10 certificate request structure.

Returns 0 on success.

gnutls_x509_crq_set_attribute_by_oid

int gnutls_x509_crq_set_attribute_by_oid (*gnutls_x509_crq_t crq, const char * oid, void * buf, size_t sizeof_buf*) [Function]

crq: should contain a gnutls_x509_crq_t structure

oid: holds an Object Identified in null terminated string

buf: a pointer to a structure that holds the attribute data

sizeof_buf: holds the size of *buf*

This function will set the attribute in the certificate request specified by the given Object ID. The attribute must be DER encoded.

Returns 0 on success.

gnutls_x509_crq_set_challenge_password

int gnutls_x509_crq_set_challenge_password (*gnutls_x509_crq_t crq, const char * pass*) [Function]

crq: should contain a gnutls_x509_crq_t structure

pass: holds a null terminated password

This function will set a challenge password to be used when revoking the request.

Returns 0 on success.

gnutls_x509_crq_set_dn_by_oid

int gnutls_x509_crq_set_dn_by_oid (*gnutls_x509_crq_t crq, const char * oid, unsigned int raw_flag, const void * data, unsigned int sizeof_data*) [Function]

crq: should contain a gnutls_x509_crq_t structure

oid: holds an Object Identifier in a null terminated string

raw_flag: must be 0, or 1 if the data are DER encoded

data: a pointer to the input data

sizeof_data: holds the size of *data*

This function will set the part of the name of the Certificate request subject, specified by the given OID. The input string should be ASCII or UTF-8 encoded.

Some helper macros with popular OIDs can be found in `gnutls/x509.h`. With this function you can only set the known OIDs. You can test for known OIDs using `gnutls_x509_dn_oid_known()`. For OIDs that are not known (by gnutls) you should properly DER encode your data, and call this function with `raw_flag` set.

Returns 0 on success.

gnutls_x509_crq_set_key

int gnutls_x509_crq_set_key (*gnutls_x509_crq_t crq,* [Function]
gnutls_x509_privkey_t key)

crq: should contain a `gnutls_x509_crq_t` structure

key: holds a private key

This function will set the public parameters from the given private key to the request. Only RSA keys are currently supported.

Returns 0 on success.

gnutls_x509_crq_set_version

int gnutls_x509_crq_set_version (*gnutls_x509_crq_t crq, unsigned* [Function]
int version)

crq: should contain a `gnutls_x509_crq_t` structure

version: holds the version number. For v1 Requests must be 1.

This function will set the version of the certificate request. For version 1 requests this must be one.

Returns 0 on success.

gnutls_x509_crq_sign2

int gnutls_x509_crq_sign2 (*gnutls_x509_crq_t crq,* [Function]
gnutls_x509_privkey_t key, gnutls_digest_algorithm_t dig, unsigned int flags)

crq: should contain a `gnutls_x509_crq_t` structure

key: holds a private key

dig: The message digest to use. `GNUTLS_DIG_SHA1` is the safe choice unless you know what you're doing.

flags: must be 0

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 0 on success.

gnutls_x509_crq_sign

int gnutls_x509_crq_sign (*gnutls_x509_crq_t crq*, [Function]
gnutls_x509_privkey_t key)

crq: should contain a gnutls_x509_crq_t structure

key: holds a private key

This function is the same as **gnutls_x509_crq_sign2()** with no flags, and SHA1 as the hash algorithm.

Returns 0 on success.

gnutls_x509_cert_check_hostname

int gnutls_x509_cert_check_hostname (*gnutls_x509_cert_t cert*, *const char *hostname*) [Function]

cert: should contain an gnutls_x509_cert_t structure

hostname: A null terminated string that contains a DNS name

This function will check if the given certificate's subject matches the given hostname. This is a basic implementation of the matching described in RFC2818 (HTTPS), which takes into account wildcards, and the DNSName/IPAddress subject alternative name PKIX extension.

Returns non zero for a successful match, and zero on failure.

gnutls_x509_cert_check_issuer

int gnutls_x509_cert_check_issuer (*gnutls_x509_cert_t cert*, *gnutls_x509_cert_t issuer*) [Function]

cert: is the certificate to be checked

issuer: is the certificate of a possible issuer

This function will check if the given certificate was issued by the given issuer. It will return true (1) if the given certificate is issued by the given issuer, and false (0) if not.

A negative value is returned in case of an error.

gnutls_x509_cert_check_revocation

int gnutls_x509_cert_check_revocation (*gnutls_x509_cert_t cert*, *const gnutls_x509_crl_t *crl_list*, *int crl_list_length*) [Function]

cert: should contain a gnutls_x509_cert_t structure

crl_list: should contain a list of gnutls_x509_crl_t structures

crl_list_length: the length of the *crl_list*

This function will return check if the given certificate is revoked. It is assumed that the CRLs have been verified before.

Returns: 0 if the certificate is NOT revoked, and 1 if it is. A negative value is returned on error.

gnutls_x509_cert_cpy_crl_dist_points

int gnutls_x509_cert_cpy_crl_dist_points (*gnutls_x509_cert_t dst*, [Function]
gnutls_x509_cert_t src)

dst: should contain a gnutls_x509_cert_t structure

src: the certificate where the dist points will be copied from

This function will copy the CRL distribution points certificate extension, from the source to the destination certificate. This may be useful to copy from a CA certificate to issued ones.

Returns 0 on success.

gnutls_x509_cert_deinit

void gnutls_x509_cert_deinit (*gnutls_x509_cert_t cert*) [Function]

cert: The structure to be initialized

This function will deinitialize a CRL structure.

gnutls_x509_cert_export

int gnutls_x509_cert_export (*gnutls_x509_cert_t cert*, [Function]
gnutls_x509_cert_fmt_t format, void * *output_data*, size_t *
output_data_size)

cert: Holds the certificate

format: the format of output params. One of PEM or DER.

output_data: will contain a certificate PEM or DER encoded

output_data_size: holds the size of output_data (and will be replaced by the actual size of parameters)

This function will export the certificate to DER or PEM format.

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.

If the structure is PEM encoded, it will have a header of "BEGIN CERTIFICATE".

Return value: In case of failure a negative value will be returned, and 0 on success.

gnutls_x509_cert_get_activation_time

time_t gnutls_x509_cert_get_activation_time (*gnutls_x509_cert_t* [Function]
cert)

cert: should contain a gnutls_x509_cert_t structure

This function will return the time this Certificate was or will be activated.

Returns (time_t)-1 on error.

gnutls_x509_cert_get_authority_key_id

int gnutls_x509_cert_get_authority_key_id (*gnutls_x509_cert_t* [Function]
cert, void * *ret*, size_t * *ret_size*, unsigned int * *critical*)

cert: should contain a gnutls_x509_cert_t structure

critical: will be non zero if the extension is marked as critical (may be null)

This function will return the X.509v3 certificate authority's key identifier. This is obtained by the X.509 Authority Key identifier extension field (2.5.29.35). Note that this function only returns the keyIdentifier field of the extension.

Returns 0 on success and a negative value in case of an error.

gnutls_x509_cert_get_basic_constraints

int gnutls_x509_cert_get_basic_constraints (*gnutls_x509_cert_t* *cert*, *unsigned int * critical*, *int * ca*, *int * pathlen*) [Function]

cert: should contain a gnutls_x509_cert_t structure

critical: will be non zero if the extension is marked as critical

ca: pointer to output integer indicating CA status, may be NULL, value is 1 if the certificate CA flag is set, 0 otherwise.

pathlen: pointer to output integer indicating path length (may be NULL), non-negative values indicate a present pathLenConstraint field and the actual value, -1 indicate that the field is absent.

This function will read the certificate's basic constraints, and return the certificates CA status. It reads the basicConstraints X.509 extension (2.5.29.19).

Return value: If the certificate is a CA a positive value will be returned, or zero if the certificate does not have CA flag set. A negative value may be returned in case of errors. If the certificate does not contain the basicConstraints extension GNUTLS_E_REQUESTED_DATA_NOT_AVAILABLE will be returned.

gnutls_x509_cert_get_ca_status

int gnutls_x509_cert_get_ca_status (*gnutls_x509_cert_t cert*, *unsigned int * critical*) [Function]

cert: should contain a gnutls_x509_cert_t structure

critical: will be non zero if the extension is marked as critical

This function will return certificates CA status, by reading the basicConstraints X.509 extension (2.5.29.19). If the certificate is a CA a positive value will be returned, or zero if the certificate does not have CA flag set.

Use `gnutls_x509_cert_get_basic_constraints()` if you want to read the pathLenConstraint field too.

A negative value may be returned in case of parsing error. If the certificate does not contain the basicConstraints extension GNUTLS_E_REQUESTED_DATA_NOT_AVAILABLE will be returned.

gnutls_x509_cert_get_crl_dist_points

int gnutls_x509_cert_get_crl_dist_points (*gnutls_x509_cert_t* *cert*, *unsigned int seq*, *void * ret*, *size_t * ret_size*, *unsigned int * reason_flags*, *unsigned int * critical*) [Function]

cert: should contain a gnutls_x509_cert_t structure

seq: specifies the sequence number of the distribution point (0 for the first one, 1 for the second etc.)

ret: is the place where the distribution point will be copied to

ret_size: holds the size of *ret*.

reason_flags: Revocation reasons flags.

critical: will be non zero if the extension is marked as critical (may be null)

This function will return the CRL distribution points (2.5.29.31), contained in the given certificate.

reason_flags should be an ORed sequence of GNUTLS_CRL_REASON_UNUSED, GNUTLS_CRL_REASON_KEY_COMPROMISE, GNUTLS_CRL_REASON_CA_COMPROMISE, GNUTLS_CRL_REASON_AFFILIATION_CHANGED, GNUTLS_CRL_REASON_SUPERSEDED, GNUTLS_CRL_REASON_CESSATION_OF_OPERATION, GNUTLS_CRL_REASON_CERTIFICATE_REVOKED, GNUTLS_CRL_REASON_PRIVILEGE_WITHDRAWN, GNUTLS_CRL_REASON_AA_COMPROMISE or zero for all possible reasons.

This is specified in X509v3 Certificate Extensions. GNUTLS will return the distribution point type, or a negative error code on error.

Returns GNUTLS_E_SHORT_MEMORY_BUFFER and updates *&ret_size* if *&ret_size* is not enough to hold the distribution point, or the type of the distribution point if everything was ok. The type is one of the enumerated *gnutls_x509_subject_alt_name_t*. If the certificate does not have an Alternative name with the specified sequence number then GNUTLS_E_REQUESTED_DATA_NOT_AVAILABLE is returned.

gnutls_x509_crt_get_dn_by_oid

```
int gnutls_x509_crt_get_dn_by_oid (gnutls_x509_crt_t cert, const [Function]
    char * oid, int indx, unsigned int raw_flag, void * buf, size_t *
    sizeof_buf)
```

cert: should contain a *gnutls_x509_crt_t* structure

oid: holds an Object Identified in null terminated string

indx: In case multiple same OIDs exist in the RDN, this specifies which to send. Use zero to get the first one.

raw_flag: If non zero returns the raw DER data of the DN part.

buf: a pointer where the DN part will be copied (may be null).

sizeof_buf: initially holds the size of *buf*

This function will extract the part of the name of the Certificate subject specified by the given OID. The output, if the raw flag is not used, will be encoded as described in RFC2253. Thus a string that is ASCII or UTF-8 encoded, depending on the certificate data.

Some helper macros with popular OIDs can be found in *gnutls/x509.h*. If raw flag is zero, this function will only return known OIDs as text. Other OIDs will be DER encoded, as described in RFC2253 – in hex format with a '\#' prefix. You can check about known OIDs using *gnutls_x509_dn_oid_known()*.

If *buf* is null then only the size will be filled.

Returns GNUTLS_E_SHORT_MEMORY_BUFFER if the provided buffer is not long enough, and in that case the **sizeof_buf* will be updated with the required size. On success 0 is returned.

gnutls_x509_cert_get_dn_oid

int gnutls_x509_cert_get_dn_oid (*gnutls_x509_cert_t cert*, *int indx*, [Function]
*void * oid*, *size_t * sizeof_oid*)

cert: should contain a gnutls_x509_cert_t structure

indx: This specifies which OID to return. Use zero to get the first one.

oid: a pointer to a buffer to hold the OID (may be null)

sizeof_oid: initially holds the size of *oid*

This function will extract the OIDs of the name of the Certificate subject specified by the given index.

If *oid* is null then only the size will be filled.

Returns GNUTLS_E_SHORT_MEMORY_BUFFER if the provided buffer is not long enough, and in that case the **sizeof_oid* will be updated with the required size. On success 0 is returned.

gnutls_x509_cert_get_dn

int gnutls_x509_cert_get_dn (*gnutls_x509_cert_t cert*, *char * buf*, [Function]
*size_t * sizeof_buf*)

cert: should contain a gnutls_x509_cert_t structure

buf: a pointer to a structure to hold the name (may be null)

sizeof_buf: initially holds the size of *buf*

This function will copy the name of the Certificate in the provided buffer. The name will be in the form "C=xxxx,O=yyyy,CN=zzzz" as described in RFC2253. The output string will be ASCII or UTF-8 encoded, depending on the certificate data.

If *buf* is null then only the size will be filled.

Returns GNUTLS_E_SHORT_MEMORY_BUFFER if the provided buffer is not long enough, and in that case the **sizeof_buf* will be updated with the required size. On success 0 is returned.

gnutls_x509_cert_get_expiration_time

time_t gnutls_x509_cert_get_expiration_time (*gnutls_x509_cert_t* [Function]
cert)

cert: should contain a gnutls_x509_cert_t structure

This function will return the time this Certificate was or will be expired.

Returns (time_t)-1 on error.

gnutls_x509_cert_get_extension_by_oid

```
int gnutls_x509_cert_get_extension_by_oid (gnutls_x509_cert_t cert, [Function]
      const char * oid, int indx, void * buf, size_t * sizeof_buf, unsigned
      int * critical)
```

cert: should contain a gnutls_x509_cert_t structure

oid: holds an Object Identified in null terminated string

indx: In case multiple same OIDs exist in the extensions, this specifies which to send. Use zero to get the first one.

buf: a pointer to a structure to hold the name (may be null)

sizeof_buf: initially holds the size of *buf*

critical: will be non zero if the extension is marked as critical

This function will return the extension specified by the OID in the certificate. The extensions will be returned as binary data DER encoded, in the provided buffer.

A negative value may be returned in case of parsing error. If the certificate does not contain the specified extension GNUTLS_E_REQUESTED_DATA_NOT_AVAILABLE will be returned.

gnutls_x509_cert_get_extension_data

```
int gnutls_x509_cert_get_extension_data (gnutls_x509_cert_t cert, [Function]
      int indx, void * data, size_t * sizeof_data)
```

cert: should contain a gnutls_x509_cert_t structure

indx: Specifies which extension OID to send. Use zero to get the first one.

data: a pointer to a structure to hold the data (may be null)

sizeof_data: initially holds the size of *oid*

This function will return the requested extension data in the certificate. The extension data will be stored as a string in the provided buffer.

Use `gnutls_x509_cert_get_extension_info()` to extract the OID and critical flag. Use `gnutls_x509_cert_get_extension_by_oid()` instead, if you want to get data indexed by the extension OID rather than sequence.

Return 0 on success. A negative value may be returned in case of parsing error. If you have reached the last extension available GNUTLS_E_REQUESTED_DATA_NOT_AVAILABLE will be returned.

gnutls_x509_cert_get_extension_info

```
int gnutls_x509_cert_get_extension_info (gnutls_x509_cert_t cert, [Function]
      int indx, void * oid, size_t * sizeof_oid, int * critical)
```

cert: should contain a gnutls_x509_cert_t structure

indx: Specifies which extension OID to send. Use zero to get the first one.

oid: a pointer to a structure to hold the OID

sizeof_oid: initially holds the size of *oid*

critical: output variable with critical flag, may be NULL.

This function will return the requested extension OID in the certificate, and the critical flag for it. The extension OID will be stored as a string in the provided buffer. Use `gnutls_x509_cert_get_extension_data()` to extract the data.

Return 0 on success. A negative value may be returned in case of parsing error. If you have reached the last extension available GNUTLS_E_REQUESTED_DATA_NOT_AVAILABLE will be returned.

gnutls_x509_cert_get_extension_oid

int gnutls_x509_cert_get_extension_oid (*gnutls_x509_cert_t cert*, [Function]
*int indx, void * oid, size_t * sizeof_oid*)

cert: should contain a `gnutls_x509_cert_t` structure

indx: Specifies which extension OID to send. Use zero to get the first one.

oid: a pointer to a structure to hold the OID (may be null)

sizeof_oid: initially holds the size of *oid*

This function will return the requested extension OID in the certificate. The extension OID will be stored as a string in the provided buffer.

A negative value may be returned in case of parsing error. If your have reached the last extension available GNUTLS_E_REQUESTED_DATA_NOT_AVAILABLE will be returned.

gnutls_x509_cert_get_fingerprint

int gnutls_x509_cert_get_fingerprint (*gnutls_x509_cert_t cert*, [Function]
*gnutls_digest_algorithm_t algo, void * buf, size_t * sizeof_buf*)

cert: should contain a `gnutls_x509_cert_t` structure

algo: is a digest algorithm

buf: a pointer to a structure to hold the fingerprint (may be null)

sizeof_buf: initially holds the size of *buf*

This function will calculate and copy the certificate's fingerprint in the provided buffer.

If the buffer is null then only the size will be filled.

Returns: GNUTLS_E_SHORT_MEMORY_BUFFER if the provided buffer is not long enough, and in that case the **sizeof_buf* will be updated with the required size. On success 0 is returned.

gnutls_x509_cert_get_issuer_dn_by_oid

int gnutls_x509_cert_get_issuer_dn_by_oid (*gnutls_x509_cert_t* [Function]
*cert, const char * oid, int indx, unsigned int raw_flag, void * buf, size_t * sizeof_buf*)

cert: should contain a `gnutls_x509_cert_t` structure

oid: holds an Object Identified in null terminated string

indx: In case multiple same OIDs exist in the RDN, this specifies which to send. Use zero to get the first one.

raw_flag: If non zero returns the raw DER data of the DN part.

buf: a pointer to a structure to hold the name (may be null)

sizeof_buf: initially holds the size of *buf*

This function will extract the part of the name of the Certificate issuer specified by the given OID. The output, if the raw flag is not used, will be encoded as described in RFC2253. Thus a string that is ASCII or UTF-8 encoded, depending on the certificate data.

Some helper macros with popular OIDs can be found in `gnutls/x509.h`. If raw flag is zero, this function will only return known OIDs as text. Other OIDs will be DER encoded, as described in RFC2253 – in hex format with a '\#' prefix. You can check about known OIDs using `gnutls_x509_dn_oid_known()`.

If *buf* is null then only the size will be filled.

Returns `GNUTLS_E_SHORT_MEMORY_BUFFER` if the provided buffer is not long enough, and in that case the **sizeof_buf* will be updated with the required size. On success 0 is returned.

gnutls_x509_cert_get_issuer_dn_oid

int gnutls_x509_cert_get_issuer_dn_oid (*gnutls_x509_cert_t cert*, [Function]
int indx, *void *oid*, *size_t *sizeof_oid*)

cert: should contain a `gnutls_x509_cert_t` structure

indx: This specifies which OID to return. Use zero to get the first one.

oid: a pointer to a buffer to hold the OID (may be null)

sizeof_oid: initially holds the size of *oid*

This function will extract the OIDs of the name of the Certificate issuer specified by the given index.

If *oid* is null then only the size will be filled.

Returns `GNUTLS_E_SHORT_MEMORY_BUFFER` if the provided buffer is not long enough, and in that case the **sizeof_oid* will be updated with the required size. On success 0 is returned.

gnutls_x509_cert_get_issuer_dn

int gnutls_x509_cert_get_issuer_dn (*gnutls_x509_cert_t cert*, *char ** [Function]
buf, *size_t *sizeof_buf*)

cert: should contain a `gnutls_x509_cert_t` structure

buf: a pointer to a structure to hold the name (may be null)

sizeof_buf: initially holds the size of *buf*

This function will copy the name of the Certificate issuer in the provided buffer. The name will be in the form "C=xxxx,O=yyyy,CN=zzzz" as described in RFC2253. The output string will be ASCII or UTF-8 encoded, depending on the certificate data.

If *buf* is null then only the size will be filled.

Returns `GNUTLS_E_SHORT_MEMORY_BUFFER` if the provided buffer is not long enough, and in that case the **sizeof_buf* will be updated with the required size. On success 0 is returned.

gnutls_x509_cert_get_issuer

```
int gnutls_x509_cert_get_issuer (gnutls_x509_cert_t cert, [Function]
                                gnutls_x509_dn_t * dn)
```

cert: should contain a gnutls_x509_cert_t structure

dn: output variable with pointer to opaque DN

Return the Certificate's Issuer DN as an opaque data type. You may use `gnutls_x509_dn_get_rdn_ava()` to decode the DN.

Note that *dn* points into the *cert* object, and thus you may not deallocate *cert* and continue to access *dn*.

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

gnutls_x509_cert_get_key_id

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

crt: Holds the certificate

flags: should be 0 for now

output_data: will contain the key ID

output_data_size: holds the size of *output_data* (and will be replaced by the actual size of parameters)

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.

Return value: In case of failure a negative value will be returned, and 0 on success.

gnutls_x509_cert_get_key_purpose_oid

```
int gnutls_x509_cert_get_key_purpose_oid (gnutls_x509_cert_t [Function]
                                         cert, int indx, void * oid, size_t * sizeof_oid, unsigned int * critical)
```

cert: should contain a gnutls_x509_cert_t structure

indx: This specifies which OID to return. Use zero to get the first one.

oid: a pointer to a buffer to hold the OID (may be null)

sizeof_oid: initially holds the size of *oid*

This function will extract the key purpose OIDs of the Certificate specified by the given index. These are stored in the Extended Key Usage extension (2.5.29.37) See the `GNUTLS_KP_*` definitions for human readable names.

If *oid* is null then only the size will be filled.

Returns: `GNUTLS_E_SHORT_MEMORY_BUFFER` if the provided buffer is not long enough, and in that case the **sizeof_oid* will be updated with the required size. On success 0 is returned.

gnutls_x509_cert_get_key_usage

int gnutls_x509_cert_get_key_usage (*gnutls_x509_cert_t* *cert*, [Function]
*unsigned int *key_usage*, *unsigned int *critical*)

cert: should contain a gnutls_x509_cert_t structure

key_usage: where the key usage bits will be stored

critical: will be non zero if the extension is marked as critical

This function will return certificate's key usage, by reading the keyUsage X.509 extension (2.5.29.15). The key usage value will ORed values of the: GNUTLS_KEY_DIGITAL_SIGNATURE, GNUTLS_KEY_NON_REPUDIATION, GNUTLS_KEY_KEY_ENCIPHERMENT, GNUTLS_KEY_DATA_ENCIPHERMENT, GNUTLS_KEY_KEY_AGREEMENT, GNUTLS_KEY_KEY_CERT_SIGN, GNUTLS_KEY_CRL_SIGN, GNUTLS_KEY_ENCIPHER_ONLY, GNUTLS_KEY_DECIPHER_ONLY.

A negative value may be returned in case of parsing error. If the certificate does not contain the keyUsage extension GNUTLS_E_REQUESTED_DATA_NOT_AVAILABLE will be returned.

gnutls_x509_cert_get_pk_algorithm

int gnutls_x509_cert_get_pk_algorithm (*gnutls_x509_cert_t* *cert*, [Function]
*unsigned int *bits*)

cert: should contain a gnutls_x509_cert_t structure

bits: if bits is non null it will hold the size of the parameters' in bits

This function will return the public key algorithm of an X.509 certificate.

If bits is non null, it should have enough size to hold the parameters size in bits. For RSA the bits returned is the modulus. For DSA the bits returned are of the public exponent.

Returns a member of the gnutls_pk_algorithm_t enumeration on success, or a negative value on error.

gnutls_x509_cert_get_pk_dsa_raw

int gnutls_x509_cert_get_pk_dsa_raw (*gnutls_x509_cert_t* *crt*, [Function]
*gnutls_datum_t *p*, *gnutls_datum_t *q*, *gnutls_datum_t *g*, *gnutls_datum_t *y*)

crt: Holds the certificate

p: will hold the p

q: will hold the q

g: will hold the g

y: will hold the y

This function will export the DSA public key's parameters found in the given certificate. The new parameters will be allocated using **gnutls_malloc()** and will be stored in the appropriate datum.

Returns: GNUTLS_E_SUCCESS on success, otherwise an error.

gnutls_x509_cert_get_pk_rsa_raw

```
int gnutls_x509_cert_get_pk_rsa_raw (gnutls_x509_cert_t cert,           [Function]
                                     gnutls_datum_t * m, gnutls_datum_t * e)
```

cert: Holds the certificate

m: will hold the modulus

e: will hold the public exponent

This function will export the RSA public key's parameters found in the given structure. The new parameters will be allocated using `gnutls_malloc()` and will be stored in the appropriate datum.

Returns: GNUTLS_E_SUCCESS on success, otherwise an error.

gnutls_x509_cert_get_proxy

```
int gnutls_x509_cert_get_proxy (gnutls_x509_cert_t cert, unsigned      [Function]
                                int * critical, int * pathlen, char ** policyLanguage, char ** policy,
                                size_t * sizeof_policy)
```

cert: should contain a gnutls_x509_cert_t structure

critical: will be non zero if the extension is marked as critical

pathlen: pointer to output integer indicating path length (may be NULL), non-negative values indicate a present `pCPathLenConstraint` field and the actual value, -1 indicate that the field is absent.

This function will read the certificate's basic constraints, and return the certificates CA status. It reads the basicConstraints X.509 extension (2.5.29.19).

Return value: If the certificate is a CA a positive value will be returned, or zero if the certificate does not have CA flag set. A negative value may be returned in case of errors. If the certificate does not contain the basicConstraints extension GNUTLS_E_REQUESTED_DATA_NOT_AVAILABLE will be returned.

gnutls_x509_cert_get_raw_dn

```
int gnutls_x509_cert_get_raw_dn (gnutls_x509_cert_t cert,           [Function]
                                  gnutls_datum_t * start)
```

cert: should contain a gnutls_x509_cert_t structure

start: will hold the starting point of the DN

This function will return a pointer to the DER encoded DN structure and the length.

Returns 0 on success, or a negative value on error.

gnutls_x509_cert_get_raw_issuer_dn

```
int gnutls_x509_cert_get_raw_issuer_dn (gnutls_x509_cert_t cert,      [Function]
                                           gnutls_datum_t * start)
```

cert: should contain a gnutls_x509_cert_t structure

start: will hold the starting point of the DN

This function will return a pointer to the DER encoded DN structure and the length.

Returns 0 on success or a negative value on error.

gnutls_x509_cert_get_serial

```
int gnutls_x509_cert_get_serial (gnutls_x509_cert_t cert, void * result, size_t * result_size) [Function]
```

cert: should contain a gnutls_x509_cert_t structure

result: The place where the serial number will be copied

result_size: Holds the size of the result field.

This function will return the X.509 certificate's serial number. This is obtained by the X509 Certificate serialNumber field. Serial is not always a 32 or 64bit number. Some CAs use large serial numbers, thus it may be wise to handle it as something opaque.

Returns 0 on success and a negative value in case of an error.

gnutls_x509_cert_get_signature_algorithm

```
int gnutls_x509_cert_get_signature_algorithm (gnutls_x509_cert_t cert) [Function]
```

cert: should contain a gnutls_x509_cert_t structure

This function will return a value of the gnutls_sign_algorithm_t enumeration that is the signature algorithm.

Returns a negative value on error.

gnutls_x509_cert_get_signature

```
int gnutls_x509_cert_get_signature (gnutls_x509_cert_t cert, char * sig, size_t * sizeof_sig) [Function]
```

cert: should contain a gnutls_x509_cert_t structure

sig: a pointer where the signature part will be copied (may be null).

sizeof_sig: initially holds the size of *sig*

This function will extract the signature field of a certificate.

Returns 0 on success, and a negative value on error.

gnutls_x509_cert_get_subject_alt_name2

```
int gnutls_x509_cert_get_subject_alt_name2 (gnutls_x509_cert_t cert, unsigned int seq, void * ret, size_t * ret_size, unsigned int * ret_type, unsigned int * critical) [Function]
```

cert: should contain a gnutls_x509_cert_t structure

seq: specifies the sequence number of the alt name (0 for the first one, 1 for the second etc.)

ret: is the place where the alternative name will be copied to

ret_size: holds the size of *ret*.

ret_type: holds the type of the alternative name (one of gnutls_x509_subject_alt_name_t).

critical: will be non zero if the extension is marked as critical (may be null)

This function will return the alternative names, contained in the given certificate. It is the same as `gnutls_x509_cert_get_subject_alt_name()` except for the fact that it will return the type of the alternative name in `ret_type` even if the function fails for some reason (i.e. the buffer provided is not enough).

The return values are the same as with `gnutls_x509_cert_get_subject_alt_name()`.

gnutls_x509_cert_get_subject_alt_name

```
int gnutls_x509_cert_get_subject_alt_name (gnutls_x509_cert_t      [Function]
      cert, unsigned int seq, void *ret, size_t *ret_size, unsigned int *
      critical)
```

cert: should contain a `gnutls_x509_cert_t` structure

seq: specifies the sequence number of the alt name (0 for the first one, 1 for the second etc.)

ret: is the place where the alternative name will be copied to

ret_size: holds the size of *ret*.

critical: will be non zero if the extension is marked as critical (may be null)

This function will return the alternative names, contained in the given certificate.

This is specified in X509v3 Certificate Extensions. GNUTLS will return the Alternative name (2.5.29.17), or a negative error code.

When the SAN type is `otherName`, it will extract the data in the `otherName`'s value field, and `GNUTLS_SAN_OTHERNAME` is returned. You may use `gnutls_x509_cert_get_subject_alt_othername_oid()` to get the corresponding OID and the "virtual" SAN types (e.g., `GNUTLS_SAN_OTHERNAME_XMPP`).

If an `otherName` OID is known, the data will be decoded. Otherwise the returned data will be DER encoded, and you will have to decode it yourself. Currently, only the RFC 3920 `id-on-xmppAddr` SAN is recognized.

Returns the alternative subject name type on success. The type is one of the enumerated `gnutls_x509_subject_alt_name_t`. It will return `GNUTLS_E_SHORT_MEMORY_BUFFER` if *ret_size* is not large enough to hold the value. In that case *ret_size* will be updated with the required size. If the certificate does not have an Alternative name with the specified sequence number then `GNUTLS_E_REQUESTED_DATA_NOT_AVAILABLE` is returned.

gnutls_x509_cert_get_subject_alt_othername_oid

```
int gnutls_x509_cert_get_subject_alt_othername_oid      [Function]
      (gnutls_x509_cert_t cert, unsigned int seq, void *ret, size_t *ret_size)
```

cert: should contain a `gnutls_x509_cert_t` structure

seq: specifies the sequence number of the alt name (0 for the first one, 1 for the second etc.)

ret: is the place where the `otherName` OID will be copied to

ret_size: holds the size of *ret*.

This function will extract the type OID of an `otherName` Subject Alternative Name, contained in the given certificate, and return the type as an enumerated element.

This function is only useful if `gnutls_x509_cert_get_subject_alt_name()` returned `GNUTLS_SAN_OTHERNAME`.

Returns the alternative subject name type on success. The type is one of the enumerated `gnutls_x509_subject_alt_name_t`. For supported OIDs, it will return one of the virtual (`GNUTLS_SAN_OTHERNAME_*`) types, e.g. `GNUTLS_SAN_OTHERNAME_XMPP`, and `GNUTLS_SAN_OTHERNAME` for unknown OIDs. It will return `GNUTLS_E_SHORT_MEMORY_BUFFER` if `ret_size` is not large enough to hold the value. In that case `ret_size` will be updated with the required size. If the certificate does not have an Alternative name with the specified sequence number and with the `otherName` type then `GNUTLS_E_REQUESTED_DATA_NOT_AVAILABLE` is returned.

`gnutls_x509_cert_get_subject_key_id`

`int gnutls_x509_cert_get_subject_key_id (gnutls_x509_cert_t cert, [Function]
void *ret, size_t *ret_size, unsigned int *critical)`

cert: should contain a `gnutls_x509_cert_t` structure

ret: The place where the identifier will be copied

ret_size: Holds the size of the result field.

critical: will be non zero if the extension is marked as critical (may be null)

This function will return the X.509v3 certificate's subject key identifier. This is obtained by the X.509 Subject Key identifier extension field (2.5.29.14).

Returns 0 on success and a negative value in case of an error.

`gnutls_x509_cert_get_subject`

`int gnutls_x509_cert_get_subject (gnutls_x509_cert_t cert, [Function]
gnutls_x509_dn_t *dn)`

cert: should contain a `gnutls_x509_cert_t` structure

dn: output variable with pointer to opaque DN.

Return the Certificate's Subject DN as an opaque data type. You may use `gnutls_x509_dn_get_rdn_ava()` to decode the DN.

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

`gnutls_x509_cert_get_version`

`int gnutls_x509_cert_get_version (gnutls_x509_cert_t cert) [Function]`

cert: should contain a `gnutls_x509_cert_t` structure

This function will return the version of the specified Certificate.

Returns a negative value on error.

`gnutls_x509_cert_import`

`int gnutls_x509_cert_import (gnutls_x509_cert_t cert, const [Function]
gnutls_datum_t *data, gnutls_x509_cert_fmt_t format)`

cert: The structure to store the parsed certificate.

data: The DER or PEM encoded certificate.

format: One of DER or PEM

This function will convert the given DER or PEM encoded Certificate to the native `gnutls_x509_cert_t` format. The output will be stored in `cert`.

If the Certificate is PEM encoded it should have a header of "X509 CERTIFICATE", or "CERTIFICATE".

Returns 0 on success.

gnutls_x509_cert_init

int gnutls_x509_cert_init (*gnutls_x509_cert_t * cert*) [Function]

cert: The structure to be initialized

This function will initialize an X.509 certificate structure.

Returns 0 on success.

gnutls_x509_cert_list_import

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

certs: The structures to store the parsed certificate. Must not be initialized.

cert_max: Initially must hold the maximum number of certs. It will be updated with the number of certs available.

data: The PEM encoded certificate.

format: One of DER or PEM.

flags: must be zero or an OR'd sequence of `gnutls_certificate_import_flags`.

This function will convert the given PEM encoded certificate list to the native `gnutls_x509_cert_t` format. The output will be stored in `certs`. They will be automatically initialized.

If the Certificate is PEM encoded it should have a header of "X509 CERTIFICATE", or "CERTIFICATE".

Returns: the number of certificates read or a negative error value.

gnutls_x509_cert_list_verify

int gnutls_x509_cert_list_verify (*const gnutls_x509_cert_t * cert_list*, *int cert_list_length*, *const gnutls_x509_cert_t * CA_list*, *int CA_list_length*, *const gnutls_x509_crl_t * CRL_list*, *int CRL_list_length*, *unsigned int flags*, *unsigned int * verify*) [Function]

cert_list: is the certificate list to be verified

cert_list_length: holds the number of certificate in *cert_list*

CA_list: is the CA list which will be used in verification

CA_list_length: holds the number of CA certificate in *CA_list*

CRL_list: holds a list of CRLs.

CRL_list_length: the length of CRL list.

flags: Flags that may be used to change the verification algorithm. Use OR of the `gnutls_certificate_verify_flags` enumerations.

verify: will hold the certificate verification output.

This function will try to verify the given certificate list and return its status. Note that expiration and activation dates are not checked by this function, you should check them using the appropriate functions.

If no flags are specified (0), this function will use the basicConstraints (2.5.29.19) PKIX extension. This means that only a certificate authority is allowed to sign a certificate.

You must also check the peer's name in order to check if the verified certificate belongs to the actual peer.

The certificate verification output will be put in `verify` and will be one or more of the `gnutls_certificate_status_t` enumerated elements bitwise or'd. For a more detailed verification status use `gnutls_x509_cert_verify()` per list element.

GNUTLS_CERT_INVALID: the certificate chain is not valid.

GNUTLS_CERT_REVOKED: a certificate in the chain has been revoked.

Returns 0 on success and a negative value in case of an error.

gnutls_x509_cert_print

```
int gnutls_x509_cert_print (gnutls_x509_cert_t cert, [Function]
                           gnutls_certificate_print_formats_t format, gnutls_datum_t * out)
```

cert: The structure to be printed

format: Indicate the format to use

out: Newly allocated datum with zero terminated string.

This function will pretty print a X.509 certificate, suitable for display to a human.

If the format is `GNUTLS_X509_CERT_FULL` then all fields of the certificate will be output, on multiple lines. The `GNUTLS_X509_CERT_ONELINE` format will generate one line with some selected fields, which is useful for logging purposes.

The output `out` needs to be deallocate using `gnutls_free()`.

Returns 0 on success.

gnutls_x509_cert_set_activation_time

```
int gnutls_x509_cert_set_activation_time (gnutls_x509_cert_t [Function]
                                           cert, time_t act_time)
```

cert: should contain a `gnutls_x509_cert_t` structure

act_time: The actual time

This function will set the time this Certificate was or will be activated.

Returns 0 on success, or a negative value in case of an error.

gnutls_x509_cert_set_authority_key_id

int gnutls_x509_cert_set_authority_key_id (*gnutls_x509_cert_t* *cert*, *const void * id*, *size_t id_size*) [Function]

cert: should contain a gnutls_x509_cert_t structure

id: The key ID

id_size: Holds the size of the serial field.

This function will set the X.509 certificate's authority key ID extension. Only the keyIdentifier field can be set with this function.

Returns 0 on success, or a negative value in case of an error.

gnutls_x509_cert_set_basic_constraints

int gnutls_x509_cert_set_basic_constraints (*gnutls_x509_cert_t* *crt*, *unsigned int ca*, *int pathLenConstraint*) [Function]

crt: should contain a gnutls_x509_cert_t structure

ca: true(1) or false(0). Depending on the Certificate authority status.

pathLenConstraint: non-negative values indicate maximum length of path, and negative values indicate that the pathLenConstraints field should not be present.

This function will set the basicConstraints certificate extension.

Returns 0 on success.

gnutls_x509_cert_set_ca_status

int gnutls_x509_cert_set_ca_status (*gnutls_x509_cert_t crt*, *unsigned int ca*) [Function]

crt: should contain a gnutls_x509_cert_t structure

ca: true(1) or false(0). Depending on the Certificate authority status.

This function will set the basicConstraints certificate extension. Use `gnutls_x509_cert_set_basic_constraints()` if you want to control the pathLenConstraint field too.

Returns 0 on success.

gnutls_x509_cert_set_crl_dist_points

int gnutls_x509_cert_set_crl_dist_points (*gnutls_x509_cert_t crt*, *gnutls_x509_subject_alt_name_t type*, *const void * data_string*, *unsigned int reason_flags*) [Function]

crt: should contain a gnutls_x509_cert_t structure

type: is one of the gnutls_x509_subject_alt_name_t enumerations

data_string: The data to be set

reason_flags: revocation reasons

This function will set the CRL distribution points certificate extension.

Returns 0 on success.

gnutls_x509_cert_set_crq

int gnutls_x509_cert_set_crq (*gnutls_x509_cert_t crt*, [Function]
gnutls_x509_crq_t crq)

crt: should contain a gnutls_x509_cert_t structure

crq: holds a certificate request

This function will set the name and public parameters from the given certificate request to the certificate. Only RSA keys are currently supported.

Returns 0 on success.

gnutls_x509_cert_set_dn_by_oid

int gnutls_x509_cert_set_dn_by_oid (*gnutls_x509_cert_t crt*, *const* [Function]
*char * oid*, *unsigned int raw_flag*, *const void * name*, *unsigned int*
sizeof_name)

crt: should contain a gnutls_x509_cert_t structure

oid: holds an Object Identifier in a null terminated string

raw_flag: must be 0, or 1 if the data are DER encoded

name: a pointer to the name

sizeof_name: holds the size of *name*

This function will set the part of the name of the Certificate subject, specified by the given OID. The input string should be ASCII or UTF-8 encoded.

Some helper macros with popular OIDs can be found in gnutls/x509.h With this function you can only set the known OIDs. You can test for known OIDs using `gnutls_x509_dn_oid_known()`. For OIDs that are not known (by gnutls) you should properly DER encode your data, and call this function with *raw_flag* set.

Returns 0 on success.

gnutls_x509_cert_set_expiration_time

int gnutls_x509_cert_set_expiration_time (*gnutls_x509_cert_t* [Function]
cert, *time_t exp_time*)

cert: should contain a gnutls_x509_cert_t structure

exp_time: The actual time

This function will set the time this Certificate will expire.

Returns 0 on success, or a negative value in case of an error.

gnutls_x509_cert_set_extension_by_oid

int gnutls_x509_cert_set_extension_by_oid (*gnutls_x509_cert_t* [Function]
crt, *const char * oid*, *const void * buf*, *size_t sizeof_buf*, *unsigned int*
critical)

crt: should contain a gnutls_x509_cert_t structure

oid: holds an Object Identified in null terminated string

buf: a pointer to a DER encoded data

sizeof_buf: holds the size of *buf*

critical: should be non zero if the extension is to be marked as critical

This function will set an the extension, by the specified OID, in the certificate. The extension data should be binary data DER encoded.

Returns 0 on success and a negative value in case of an error.

gnutls_x509_cert_set_issuer_dn_by_oid

```
int gnutls_x509_cert_set_issuer_dn_by_oid (gnutls_x509_cert_t [Function]
    cert, const char * oid, unsigned int raw_flag, const void * name, unsigned int
    sizeof_name)
```

cert: should contain a gnutls_x509_cert_t structure

oid: holds an Object Identifier in a null terminated string

raw_flag: must be 0, or 1 if the data are DER encoded

name: a pointer to the name

sizeof_name: holds the size of *name*

This function will set the part of the name of the Certificate issuer, specified by the given OID. The input string should be ASCII or UTF-8 encoded.

Some helper macros with popular OIDs can be found in gnutls/x509.h With this function you can only set the known OIDs. You can test for known OIDs using `gnutls_x509_dn_oid_known()`. For OIDs that are not known (by gnutls) you should properly DER encode your data, and call this function with *raw_flag* set.

Normally you do not need to call this function, since the signing operation will copy the signer's name as the issuer of the certificate.

Returns 0 on success.

gnutls_x509_cert_set_key_purpose_oid

```
int gnutls_x509_cert_set_key_purpose_oid (gnutls_x509_cert_t [Function]
    cert, const void * oid, unsigned int critical)
```

cert: should contain a gnutls_x509_cert_t structure

oid: a pointer to a null terminated string that holds the OID

critical: Whether this extension will be critical or not

This function will set the key purpose OIDs of the Certificate. These are stored in the Extended Key Usage extension (2.5.29.37) See the GNUTLS_KP_* definitions for human readable names.

Subsequent calls to this function will append OIDs to the OID list.

On success 0 is returned.

gnutls_x509_cert_set_key_usage

```
int gnutls_x509_cert_set_key_usage (gnutls_x509_cert_t cert, [Function]
    unsigned int usage)
```

cert: should contain a gnutls_x509_cert_t structure

usage: an ORed sequence of the GNUTLS_KEY_* elements.

This function will set the keyUsage certificate extension.

Returns 0 on success.

gnutls_x509_cert_set_key

int gnutls_x509_cert_set_key (gnutls_x509_cert_t *crt*, [Function]
gnutls_x509_privkey_t *key*)

crt: should contain a gnutls_x509_cert_t structure

key: holds a private key

This function will set the public parameters from the given private key to the certificate. Only RSA keys are currently supported.

Returns 0 on success.

gnutls_x509_cert_set_proxy_dn

int gnutls_x509_cert_set_proxy_dn (gnutls_x509_cert_t *crt*, [Function]
gnutls_x509_cert_t *eecrt*, unsigned int *raw_flag*, const void * *name*, unsigned
int *sizeof_name*)

crt: a gnutls_x509_cert_t structure with the new proxy cert

eecrt: the end entity certificate that will be issuing the proxy

raw_flag: must be 0, or 1 if the CN is DER encoded

name: a pointer to the CN name, may be NULL (but MUST then be added later)

sizeof_name: holds the size of *name*

This function will set the subject in *crt* to the end entity's *eecrt* subject name, and add a single Common Name component *name* of size *sizeof_name*. This corresponds to the required proxy certificate naming style. Note that if *name* is NULL, you MUST set it later by using gnutls_x509_cert_set_dn_by_oid() or similar.

Returns 0 on success.

gnutls_x509_cert_set_proxy

int gnutls_x509_cert_set_proxy (gnutls_x509_cert_t *crt*, int [Function]
pathLenConstraint, const char * *policyLanguage*, const char * *policy*,
size_t *sizeof_policy*)

crt: should contain a gnutls_x509_cert_t structure

pathLenConstraint: non-negative values indicate maximum length of path, and negative values indicate that the pathLenConstraints field should not be present.

policyLanguage: OID describing the language of *policy*.

policy: opaque byte array with policy language, can be NULL

sizeof_policy: size of *policy*.

This function will set the proxyCertInfo extension.

Returns 0 on success.

gnutls_x509_cert_set_serial

```
int gnutls_x509_cert_set_serial (gnutls_x509_cert_t cert, const void [Function]
                                * serial, size_t serial_size)
```

cert: should contain a gnutls_x509_cert_t structure

serial: The serial number

serial_size: Holds the size of the serial field.

This function will set the X.509 certificate's serial number. Serial is not always a 32 or 64bit number. Some CAs use large serial numbers, thus it may be wise to handle it as something opaque.

Returns 0 on success, or a negative value in case of an error.

gnutls_x509_cert_set_subject_alternative_name

```
int gnutls_x509_cert_set_subject_alternative_name [Function]
(gnutls_x509_cert_t crt, gnutls_x509_subject_alt_name_t type, const char *
 data_string)
```

crt: should contain a gnutls_x509_cert_t structure

type: is one of the gnutls_x509_subject_alt_name_t enumerations

data_string: The data to be set

This function will set the subject alternative name certificate extension.

Returns 0 on success.

gnutls_x509_cert_set_subject_key_id

```
int gnutls_x509_cert_set_subject_key_id (gnutls_x509_cert_t cert, [Function]
                                          const void * id, size_t id_size)
```

cert: should contain a gnutls_x509_cert_t structure

id: The key ID

id_size: Holds the size of the serial field.

This function will set the X.509 certificate's subject key ID extension.

Returns 0 on success, or a negative value in case of an error.

gnutls_x509_cert_set_version

```
int gnutls_x509_cert_set_version (gnutls_x509_cert_t crt, unsigned [Function]
                                   int version)
```

crt: should contain a gnutls_x509_cert_t structure

version: holds the version number. For X.509v1 certificates must be 1.

This function will set the version of the certificate. This must be one for X.509 version 1, and so on. Plain certificates without extensions must have version set to one.

To create well-formed certificates, you must specify version 3 if you use any certificate extensions. Extensions are created by functions such as gnutls_x509_cert_set_subject_alternative_name or gnutls_x509_cert_set_key_usage.

Returns 0 on success.

gnutls_x509_cert_sign2

```
int gnutls_x509_cert_sign2 (gnutls_x509_cert_t crt, gnutls_x509_cert_t [Function]
                           issuer, gnutls_privkey_t issuer_key, gnutls_digest_algorithm_t dig,
                           unsigned int flags)
```

crt: should contain a gnutls_x509_cert_t structure

issuer: is the certificate of the certificate issuer

issuer_key: holds the issuer's private key

dig: The message digest to use. GNUTLS_DIG_SHA1 is the safe choice unless you know what you're doing.

flags: must be 0

This function will sign the certificate with the issuer's private key, and will copy the issuer's information into the certificate.

This must be the last step in a certificate generation since all the previously set parameters are now signed.

Returns 0 on success.

gnutls_x509_cert_sign

```
int gnutls_x509_cert_sign (gnutls_x509_cert_t crt, gnutls_x509_cert_t [Function]
                           issuer, gnutls_privkey_t issuer_key)
```

crt: should contain a gnutls_x509_cert_t structure

issuer: is the certificate of the certificate issuer

issuer_key: holds the issuer's private key

This function is the same as gnutls_x509_cert_sign2() with no flags, and SHA1 as the hash algorithm.

Returns 0 on success.

gnutls_x509_cert_verify_data

```
int gnutls_x509_cert_verify_data (gnutls_x509_cert_t crt, unsigned [Function]
                                  int flags, const gnutls_datum_t * data, const gnutls_datum_t * signature)
```

crt: Holds the certificate

flags: should be 0 for now

data: holds the data to be signed

signature: contains the signature

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

Returns: In case of a verification failure 0 is returned, and 1 on success.

gnutls_x509_cert_verify

```
int gnutls_x509_cert_verify (gnutls_x509_cert_t cert, const [Function]
                             gnutls_x509_cert_t * CA_list, int CA_list_length, unsigned int flags,
                             unsigned int * verify)
```

cert: is the certificate to be verified

CA_list: is one certificate that is considered to be trusted one

CA_list_length: holds the number of CA certificate in *CA_list*

flags: Flags that may be used to change the verification algorithm. Use OR of the `gnutls_certificate_verify_flags` enumerations.

verify: will hold the certificate verification output.

This function will try to verify the given certificate and return its status. The verification output in this functions cannot be `GNUTLS_CERT_NOT_VALID`.

Returns 0 on success and a negative value in case of an error.

gnutls_x509_dn_get_rdn_ava

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

dn: input variable with opaque DN pointer

irdn: index of RDN

iava: index of AVA.

ava: Pointer to structure which will hold output information.

Get pointers to data within the DN.

Note that *ava* will contain pointers into the *dn* structure, so you should not modify any data or deallocate it. Note also that the DN in turn points into the original certificate structure, and thus you may not deallocate the certificate and continue to access *dn*.

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

gnutls_x509_dn_oid_known

```
int gnutls_x509_dn_oid_known (const char * oid) [Function]
                                oid: holds an Object Identifier in a null terminated string
```

This function will inform about known DN OIDs. This is useful since functions like `gnutls_x509_cert_set_dn_by_oid()` use the information on known OIDs to properly encode their input. Object Identifiers that are not known are not encoded by these functions, and their input is stored directly into the ASN.1 structure. In that case of unknown OIDs, you have the responsibility of DER encoding your data.

Returns 1 on known OIDs and 0 otherwise.

gnutls_x509_privkey_cpy

int gnutls_x509_privkey_cpy (*gnutls_x509_privkey_t dst*, [Function]
gnutls_x509_privkey_t src)

dst: The destination key, which should be initialized.

src: The source key

This function will copy a private key from source to destination key.

gnutls_x509_privkey_deinit

void gnutls_x509_privkey_deinit (*gnutls_x509_privkey_t key*) [Function]

key: The structure to be initialized

This function will deinitialize a private key structure.

gnutls_x509_privkey_export_dsa_raw

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

p: will hold the p

q: will hold the q

g: will hold the g

y: will hold the y

x: will hold the x

This function will export the DSA private key's parameters found in the given structure. The new parameters will be allocated using `gnutls_malloc()` and will be stored in the appropriate datum.

gnutls_x509_privkey_export_pkcs8

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

key: Holds the key

format: the format of output params. One of PEM or DER.

password: the password that will be used to encrypt the key.

flags: an ORed sequence of `gnutls_pkcs_encrypt_flags_t`

output_data: will contain a private key PEM or DER encoded

output_data_size: holds the size of *output_data* (and will be replaced by the actual size of parameters)

This function will export the private key to a PKCS8 structure. Both RSA and DSA keys can be exported. For DSA keys we use PKCS 11 definitions. If the flags do not specify the encryption cipher, then the default 3DES (PBES2) will be used.

The `password` can be either ASCII or UTF-8 in the default PBES2 encryption schemas, or ASCII for the PKCS12 schemas.

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.

If the structure is PEM encoded, it will have a header of "BEGIN ENCRYPTED PRIVATE KEY" or "BEGIN PRIVATE KEY" if encryption is not used.

Return value: In case of failure a negative value will be returned, and 0 on success.

gnutls_x509_privkey_export_rsa_raw

```
int gnutls_x509_privkey_export_rsa_raw (gnutls_x509_privkey_t      [Function]
    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)
```

key: a structure that holds the rsa parameters

m: will hold the modulus

e: will hold the public exponent

d: will hold the private exponent

p: will hold the first prime (p)

q: will hold the second prime (q)

u: will hold the coefficient

This function will export the RSA private key's parameters found in the given structure. The new parameters will be allocated using `gnutls_malloc()` and will be stored in the appropriate datum.

gnutls_x509_privkey_export

```
int gnutls_x509_privkey_export (gnutls_x509_privkey_t key,          [Function]
    gnutls_x509_crt_fmt_t format, void * output_data, size_t *
    output_data_size)
```

key: Holds the key

format: the format of output params. One of PEM or DER.

output_data: will contain a private key PEM or DER encoded

output_data_size: holds the size of *output_data* (and will be replaced by the actual size of parameters)

This function will export the private key to a PKCS1 structure for RSA keys, or an integer sequence for DSA keys. The DSA keys are in the same format with the parameters used by openssl.

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.

If the structure is PEM encoded, it will have a header of "BEGIN RSA PRIVATE KEY".

Return value: In case of failure a negative value will be returned, and 0 on success.

gnutls_x509_privkey_fix

int gnutls_x509_privkey_fix (*gnutls_x509_privkey_t* *key*) [Function]

key: Holds the key

This function will recalculate the secondary parameters in a key. In RSA keys, this can be the coefficient and exponent^{1,2}.

Return value: In case of failure a negative value will be returned, and 0 on success.

gnutls_x509_privkey_generate

int gnutls_x509_privkey_generate (*gnutls_x509_privkey_t* *key*, [Function]
gnutls_pk_algorithm_t *algo*, *unsigned int* *bits*, *unsigned int* *flags*)

key: should contain a gnutls_x509_privkey_t structure

algo: is one of RSA or DSA.

bits: the size of the modulus

flags: unused for now. Must be 0.

This function will generate a random private key. Note that this function must be called on an empty private key.

Returns 0 on success or a negative value on error.

gnutls_x509_privkey_get_key_id

int gnutls_x509_privkey_get_key_id (*gnutls_x509_privkey_t* *key*, [Function]
unsigned int *flags*, *unsigned char ***output_data*, *size_t **
output_data_size)

key: Holds the key

flags: should be 0 for now

output_data: will contain the key ID

output_data_size: holds the size of *output_data* (and will be replaced by the actual size of parameters)

This function will return a unique ID the depends on the public key parameters. This ID can be used in checking whether a certificate corresponds to the given 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.

Return value: In case of failure a negative value will be returned, and 0 on success.

gnutls_x509_privkey_get_pk_algorithm

int gnutls_x509_privkey_get_pk_algorithm (*gnutls_x509_privkey_t* [Function]
key)

key: should contain a gnutls_x509_privkey_t structure

This function will return the public key algorithm of a private key.

Returns a member of the gnutls_pk_algorithm_t enumeration on success, or a negative value on error.

gnutls_x509_privkey_import_dsa_raw

```
int gnutls_x509_privkey_import_dsa_raw (gnutls_x509_privkey_t key, [Function]
    const gnutls_datum_t * p, const gnutls_datum_t * q, const gnutls_datum_t
    * g, const gnutls_datum_t * y, const gnutls_datum_t * x)
```

key: The structure to store the parsed key

p: holds the p

q: holds the q

g: holds the g

y: holds the y

x: holds the x

This function will convert the given DSA raw parameters to the native gnutls_x509_privkey_t format. The output will be stored in *key*.

gnutls_x509_privkey_import_pkcs8

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

key: The structure to store the parsed key

data: The DER or PEM encoded key.

format: One of DER or PEM

password: the password to decrypt the key (if it is encrypted).

flags: 0 if encrypted or GNUTLS_PKCS_PLAIN if not encrypted.

This function will convert the given DER or PEM encoded PKCS8 2.0 encrypted key to the native gnutls_x509_privkey_t format. The output will be stored in *key*. Both RSA and DSA keys can be imported, and flags can only be used to indicate an unencrypted key.

The *password* can be either ASCII or UTF-8 in the default PBES2 encryption schemas, or ASCII for the PKCS12 schemas.

If the Certificate is PEM encoded it should have a header of "ENCRYPTED PRIVATE KEY", or "PRIVATE KEY". You only need to specify the flags if the key is DER encoded, since in that case the encryption status cannot be auto-detected.

Returns 0 on success.

gnutls_x509_privkey_import_rsa_raw

```
int gnutls_x509_privkey_import_rsa_raw (gnutls_x509_privkey_t [Function]
    key, const gnutls_datum_t * m, const gnutls_datum_t * e, const gnutls_datum_t
    * d, const gnutls_datum_t * p, const gnutls_datum_t * q, const gnutls_datum_t
    * u)
```

key: The structure to store the parsed key

m: holds the modulus

e: holds the public exponent

d: holds the private exponent

p: holds the first prime (p)

q: holds the second prime (q)

u: holds the coefficient

This function will convert the given RSA raw parameters to the native `gnutls_x509_privkey_t` format. The output will be stored in `key`.

gnutls_x509_privkey_import

```
int gnutls_x509_privkey_import (gnutls_x509_privkey_t key, const [Function]
                                gnutls_datum_t * data, gnutls_x509_crt_fmt_t format)
```

key: The structure to store the parsed key

data: The DER or PEM encoded certificate.

format: One of DER or PEM

This function will convert the given DER or PEM encoded key to the native `gnutls_x509_privkey_t` format. The output will be stored in `key`.

If the key is PEM encoded it should have a header of "RSA PRIVATE KEY", or "DSA PRIVATE KEY".

Returns 0 on success.

gnutls_x509_privkey_init

```
int gnutls_x509_privkey_init (gnutls_x509_privkey_t * key) [Function]
```

key: The structure to be initialized

This function will initialize an private key structure.

Returns 0 on success.

gnutls_x509_privkey_sign_data

```
int gnutls_x509_privkey_sign_data (gnutls_x509_privkey_t key, [Function]
                                    gnutls_digest_algorithm_t digest, unsigned int flags, const gnutls_datum_t *
                                    data, void * signature, size_t * signature_size)
```

key: Holds the key

digest: should be MD5 or SHA1

flags: should be 0 for now

data: holds the data to be signed

signature: will contain the signature

signature_size: holds the size of signature (and will be replaced by the new size)

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 SHA-1 for the DSA keys.

If the buffer provided is not long enough to hold the output, then `*signature_size` is updated and `GNUTLS_E_SHORT_MEMORY_BUFFER` will be returned.

In case of failure a negative value will be returned, and 0 on success.

gnutls_x509_privkey_sign_hash

```
int gnutls_x509_privkey_sign_hash (gnutls_x509_privkey_t key,      [Function]
                                   const gnutls_datum_t * hash, gnutls_datum_t * signature)
```

key: Holds the key

hash: holds the data to be signed

signature: will contain newly allocated signature

This function will sign the given hash using the private key.

Return value: In case of failure a negative value will be returned, and 0 on success.

gnutls_x509_privkey_verify_data

```
int gnutls_x509_privkey_verify_data (gnutls_x509_privkey_t key,    [Function]
                                       unsigned int flags, const gnutls_datum_t * data, const gnutls_datum_t *
                                       signature)
```

key: Holds the key

flags: should be 0 for now

data: holds the data to be signed

signature: contains the signature

This function will verify the given signed data, using the parameters in the private key.

In case of a verification failure 0 is returned, and 1 on success.

gnutls_x509_rdn_get_by_oid

```
int gnutls_x509_rdn_get_by_oid (const gnutls_datum_t * idn, const  [Function]
                                 char * oid, int indx, unsigned int raw_flag, void * buf, size_t *
                                 sizeof_buf)
```

idn: should contain a DER encoded RDN sequence

oid: an Object Identifier

indx: In case multiple same OIDs exist in the RDN indicates which to send. Use 0 for the first one.

raw_flag: If non zero then the raw DER data are returned.

buf: a pointer to a structure to hold the peer's name

sizeof_buf: holds the size of *buf*

This function will return the name of the given Object identifier, of the RDN sequence. The name will be encoded using the rules from RFC2253.

Returns GNUTLS_E_SHORT_MEMORY_BUFFER and updates *sizeof_buf if the provided buffer is not long enough, and 0 on success.

gnutls_x509_rdn_get_oid

```
int gnutls_x509_rdn_get_oid (const gnutls_datum_t * idn, int indx,      [Function]
                             void * buf, size_t * sizeof_buf)
```

idn: should contain a DER encoded RDN sequence

indx: Indicates which OID to return. Use 0 for the first one.

This function will return the specified Object identifier, of the RDN sequence.

Returns GNUTLS_E_SHORT_MEMORY_BUFFER and updates *sizeof_buf if the provided buffer is not long enough, and 0 on success.

gnutls_x509_rdn_get

```
int gnutls_x509_rdn_get (const gnutls_datum_t * idn, char * buf,      [Function]
                         size_t * sizeof_buf)
```

idn: should contain a DER encoded RDN sequence

buf: a pointer to a structure to hold the peer's name

sizeof_buf: holds the size of *buf*

This function will return the name of the given RDN sequence. The name will be in the form "C=xxxx,O=yyyy,CN=zzzz" as described in RFC2253.

If the provided buffer is not long enough, returns GNUTLS_E_SHORT_MEMORY_BUFFER and *sizeof_buf will be updated. On success 0 is returned.

9.3 GnuTLS-extra Functions

These functions are only available in the GPL version of the library called **gnutls-extra**. The prototypes for this library lie in 'gnutls/extra.h'.

gnutls_extra_check_version

```
const char * gnutls_extra_check_version (const char *      [Function]
                                         req_version)
```

req_version: the version to check

Check that the version of the gnutls-extra library is at minimum the requested one and return the version string; return NULL if the condition is not satisfied. If a NULL is passed to this function, no check is done, but the version string is simply returned.

gnutls_global_init_extra

```
int gnutls_global_init_extra ( void)                                [Function]
```

This function initializes the global state of gnutls-extra library to defaults. Returns zero on success.

Note that **gnutls_global_init()** has to be called before this function. If this function is not called then the gnutls-extra library will not be usable.

9.4 OpenPGP Functions

The following functions are to be used for OpenPGP certificate handling. Their prototypes lie in ‘gnutls/openpgp.h’. You need to link with ‘libgnutls-extra’ to be able to use these functions (see [Section 9.3 \[GnuTLS-extra functions\]](#), page 213).

gnutls_certificate_set_openpgp_key_file

```
int gnutls_certificate_set_openpgp_key_file           [Function]
    (gnutls_certificate_credentials_t res, const char * certfile, const char *
    keyfile, gnutls_openpgp_cert_fmt_t format)
```

res: the destination context to save the data.

certfile: the file that contains the public key.

keyfile: the file that contains the secret key.

This function is used to load OpenPGP keys into the GnuTLS credentials structure. It doesn’t matter whether the keys are armored or not, but the files should only contain one key which should not be encrypted.

gnutls_certificate_set_openpgp_key_mem

```
int gnutls_certificate_set_openpgp_key_mem           [Function]
    (gnutls_certificate_credentials_t res, const gnutls_datum_t * icert, const
    gnutls_datum_t * key, gnutls_openpgp_cert_fmt_t format)
```

res: the destination context to save the data.

This function is used to load OpenPGP keys into the GnuTLS credential structure. It doesn’t matter whether the keys are armored or not, but the files should only contain one key which should not be encrypted.

gnutls_certificate_set_openpgp_keyring_file

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

c: A certificate credentials structure

file: filename of the keyring.

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.

gnutls_certificate_set_openpgp_keyring_mem

```
int gnutls_certificate_set_openpgp_keyring_mem      [Function]
    (gnutls_certificate_credentials_t c, const opaque * data, size_t dlen,
    gnutls_openpgp_cert_fmt_t format)
```

c: A certificate credentials structure

data: buffer with keyring data.

dlen: length of data buffer.

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.

gnutls_certificate_set_openpgp_key

int gnutls_certificate_set_openpgp_key [Function]

(*gnutls_certificate_credentials_t res*, *gnutls_openpgp_cert_t crt*,
gnutls_openpgp_privkey_t pkey)

res: is an *gnutls_certificate_credentials_t* structure.

pkey: is an openpgp private key

This function sets a certificate/private key pair in the *gnutls_certificate_credentials_t* structure. This function may be called more than once (in case multiple keys/certificates exist for the server).

gnutls_openpgp_cert_check_hostname

int gnutls_openpgp_cert_check_hostname (*gnutls_openpgp_cert_t* [Function]

key, *const char * hostname*)

key: should contain an *gnutls_openpgp_cert_t* structure

hostname: A null terminated string that contains a DNS name

This function will check if the given key's owner matches the given hostname. This is a basic implementation of the matching described in RFC2818 (HTTPS), which takes into account wildcards.

Returns non zero on success, and zero on failure.

gnutls_openpgp_cert_deinit

void gnutls_openpgp_cert_deinit (*gnutls_openpgp_cert_t key*) [Function]

key: The structure to be initialized

This function will deinitialize a key structure.

gnutls_openpgp_cert_export

int gnutls_openpgp_cert_export (*gnutls_openpgp_cert_t key*, [Function]

gnutls_openpgp_cert_fmt_t format, *void * output_data*, *size_t * output_data_size*)

key: Holds the key.

format: One of *gnutls_openpgp_cert_fmt_t* elements.

output_data: will contain the key base64 encoded or raw

output_data_size: holds the size of *output_data* (and will be replaced by the actual size of parameters)

This function will convert the given key to RAW or Base64 format. If the buffer provided is not long enough to hold the output, then GNUTLS_E_SHORT_MEMORY_BUFFER will be returned.

Returns 0 on success.

gnutls_openpgp_cert_get_creation_time

`time_t gnutls_openpgp_cert_get_creation_time` [Function]
 (*gnutls_openpgp_cert_t* *key*)

key: the structure that contains the OpenPGP public key.

Returns the timestamp when the OpenPGP key was created.

gnutls_openpgp_cert_get_expiration_time

`time_t gnutls_openpgp_cert_get_expiration_time` [Function]
 (*gnutls_openpgp_cert_t* *key*)

key: the structure that contains the OpenPGP public key.

Returns the time when the OpenPGP key expires. A value of '0' means that the key doesn't expire at all.

gnutls_openpgp_cert_get_fingerprint

`int gnutls_openpgp_cert_get_fingerprint` (*gnutls_openpgp_cert_t* [Function]
 key, *void *fpr*, *size_t *fprlen*)

key: the raw data that contains the OpenPGP public key.

fpr: the buffer to save the fingerprint, must hold at least 20 bytes.

fprlen: the integer to save the length of the fingerprint.

Returns the fingerprint of the OpenPGP key. Depends on the algorithm, the fingerprint can be 16 or 20 bytes.

gnutls_openpgp_cert_get_id

`int gnutls_openpgp_cert_get_id` (*gnutls_openpgp_cert_t* *key*, *unsigned* [Function]
 char keyid[8])

key: the structure that contains the OpenPGP public key.

Returns the 64-bit keyID of the OpenPGP key.

gnutls_openpgp_cert_get_key_usage

`int gnutls_openpgp_cert_get_key_usage` (*gnutls_openpgp_cert_t* *key*, [Function]
 *unsigned int *key_usage*)

key: should contain a *gnutls_openpgp_cert_t* structure

key_usage: where the key usage bits will be stored

This function will return certificate's key usage, by checking the key algorithm. The key usage value will ORed values of the: GNUTLS_KEY_DIGITAL_SIGNATURE, GNUTLS_KEY_KEY_ENCRYPTION.

A negative value may be returned in case of parsing error.

gnutls_openpgp_cert_get_name

int gnutls_openpgp_cert_get_name (*gnutls_openpgp_cert_t* **key**, *int* **idx**, *char ****buf**, *size_t ****sizeof_buf**) [Function]

key: the structure that contains the OpenPGP public key.

idx: the index of the ID to extract

buf: a pointer to a structure to hold the name

sizeof_buf: holds the maximum size of **buf**, on return hold the actual/required size of **buf**.

Extracts the userID from the parsed OpenPGP key.

Returns 0 on success, and GNUTLS_E_REQUESTED_DATA_NOT_AVAILABLE if the index of the ID does not exist.

gnutls_openpgp_cert_get_pk_algorithm

gnutls_pk_algorithm_t gnutls_openpgp_cert_get_pk_algorithm [Function]
(*gnutls_openpgp_cert_t* **key**, *unsigned int ****bits**)

key: is an OpenPGP key

bits: if bits is non null it will hold the size of the parameters' in bits

This function will return the public key algorithm of an OpenPGP certificate.

If bits is non null, it should have enough size to hold the parameters size in bits. For RSA the bits returned is the modulus. For DSA the bits returned are of the public exponent.

Returns a member of the GNUTLS_PKAlgorithm enumeration on success, or a negative value on error.

gnutls_openpgp_cert_get_version

int gnutls_openpgp_cert_get_version (*gnutls_openpgp_cert_t* **key**) [Function]

key: the structure that contains the OpenPGP public key.

Extract the version of the OpenPGP key.

gnutls_openpgp_cert_import

int gnutls_openpgp_cert_import (*gnutls_openpgp_cert_t* **key**, *const gnutls_datum_t ****data**, *gnutls_openpgp_cert_fmt_t* **format**) [Function]

key: The structure to store the parsed key.

data: The RAW or BASE64 encoded key.

format: One of gnutls_openpgp_cert_fmt_t elements.

This function will convert the given RAW or Base64 encoded key to the native gnutls_openpgp_cert_t format. The output will be stored in 'key'.

Returns 0 on success.

gnutls_openpgp_cert_init

int gnutls_openpgp_cert_init (*gnutls_openpgp_cert_t* * **key**) [Function]

key: The structure to be initialized

This function will initialize an OpenPGP key structure.

Returns 0 on success.

gnutls_openpgp_cert_verify_ring

int gnutls_openpgp_cert_verify_ring (*gnutls_openpgp_cert_t* **key**, [Function]
gnutls_openpgp_keyring_t **keyring**, unsigned int **flags**, unsigned int *
verify)

key: the structure that holds the key.

keyring: holds the keyring to check against

flags: unused (should be 0)

verify: will hold the certificate verification output.

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.

GNUTLS_CERT_INVALID: A signature on the key is invalid.

GNUTLS_CERT_REVOKED: The key has been revoked.

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 0 on success.

gnutls_openpgp_cert_verify_self

int gnutls_openpgp_cert_verify_self (*gnutls_openpgp_cert_t* **key**, [Function]
 unsigned int **flags**, unsigned int * **verify**)

key: the structure that holds the key.

flags: unused (should be 0)

verify: will hold the key verification output.

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.

GNUTLS_CERT_INVALID: The self signature on the key is invalid.

Returns 0 on success.

gnutls_openpgp_keyring_check_id

int gnutls_openpgp_keyring_check_id (*gnutls_openpgp_keyring_t* [Function]
ring, const unsigned char **keyid**[8], unsigned int **flags**)

ring: holds the keyring to check against

flags: unused (should be 0)

Check if a given key ID exists in the keyring.

Returns 0 on success (if *keyid* exists) and a negative error code on failure.

gnutls_openpgp_keyring_deinit

void gnutls_openpgp_keyring_deinit (*gnutls_openpgp_keyring_t* *keyring*) [Function]

keyring: The structure to be initialized

This function will deinitialize a keyring structure.

gnutls_openpgp_keyring_import

int gnutls_openpgp_keyring_import (*gnutls_openpgp_keyring_t* *keyring*, *const gnutls_datum_t * data*, *gnutls_openpgp_cert_fmt_t format*) [Function]

keyring: The structure to store the parsed key.

data: The RAW or BASE64 encoded keyring.

format: One of **gnutls_openpgp_keyring_fmt** elements.

This function will convert the given RAW or Base64 encoded keyring to the native **gnutls_openpgp_keyring_t** format. The output will be stored in 'keyring'.

Returns 0 on success.

gnutls_openpgp_keyring_init

int gnutls_openpgp_keyring_init (*gnutls_openpgp_keyring_t ** *keyring*) [Function]

keyring: The structure to be initialized

This function will initialize an OpenPGP keyring structure.

Returns 0 on success.

gnutls_openpgp_privkey_deinit

void gnutls_openpgp_privkey_deinit (*gnutls_openpgp_privkey_t* *key*) [Function]

key: The structure to be initialized

This function will deinitialize a key structure.

gnutls_openpgp_privkey_get_pk_algorithm

gnutls_pk_algorithm_t **gnutls_openpgp_privkey_get_pk_algorithm** (*gnutls_openpgp_privkey_t* *key*, *unsigned int * bits*) [Function]

key: is an OpenPGP key

bits: if bits is non null it will hold the size of the parameters' in bits

This function will return the public key algorithm of an OpenPGP certificate.

If bits is non null, it should have enough size to hold the parameters size in bits. For RSA the bits returned is the modulus. For DSA the bits returned are of the public exponent.

Returns a member of the **GNUTLS_PKAlgorithm** enumeration on success, or a negative value on error.

gnutls_openpgp_privkey_import

```
int gnutls_openpgp_privkey_import (gnutls_openpgp_privkey_t key, [Function]
    const gnutls_datum_t * data, gnutls_openpgp_cert_fmt_t format, const char *
    pass, unsigned int flags)
```

key: The structure to store the parsed key.

data: The RAW or BASE64 encoded key.

format: One of gnutls_openpgp_cert_fmt_t elements.

pass: Unused for now

flags: should be zero

This function will convert the given RAW or Base64 encoded key to the native gnutls_openpgp_privkey_t format. The output will be stored in 'key'.

Returns 0 on success.

gnutls_openpgp_privkey_init

```
int gnutls_openpgp_privkey_init (gnutls_openpgp_privkey_t * key) [Function]
    key: The structure to be initialized
```

This function will initialize an OpenPGP key structure.

Returns 0 on success.

gnutls_openpgp_privkey_sign_hash

```
int gnutls_openpgp_privkey_sign_hash (gnutls_openpgp_privkey_t [Function]
    key, const gnutls_datum_t * hash, gnutls_datum_t * signature)
```

key: Holds the key

hash: holds the data to be signed

signature: will contain newly allocated signature

This function will sign the given hash using the private key.

Return value: In case of failure a negative value will be returned, and 0 on success.

gnutls_openpgp_set_recv_key_function

```
void gnutls_openpgp_set_recv_key_function (gnutls_session_t [Function]
    session, gnutls_openpgp_recv_key_func func)
```

session: a TLS session

func: the callback

This function will set a key retrieval function for OpenPGP keys. This callback is only useful in server side, and will be used if the peer sent a key fingerprint instead of a full key.

9.5 TLS Inner Application (TLS/IA) Functions

The following functions are used for TLS Inner Application (TLS/IA). Their prototypes lie in ‘gnutls/extra.h’. You need to link with ‘libgnutls-extra’ to be able to use these functions (see [Section 9.3 \[GnuTLS-extra functions\]](#), page 213).

The typical control flow in an TLS/IA client (that would not require an Application Phase for resumed sessions) would be similar to the following:

```
int client_avp (gnutls_session_t *session, void *ptr,
               const char *last, size_t lastlen,
               char **new, size_t *newlen)
{
    ...
}

...
int main ()
{
    gnutls_ia_client_credentials_t iacred;
    ...
    gnutls_init (&session, GNUTLS_CLIENT);
    ...
    /* Enable TLS/IA. */
    gnutls_ia_allocate_client_credentials(&iacred);
    gnutls_ia_set_client_avp_function(iacred, client_avp);
    gnutls_credentials_set (session, GNUTLS_CRD_IA, iacred);
    ...
    ret = gnutls_handshake (session);
    // Error handling...
    ...
    if (gnutls_ia_handshake_p (session))
    {
        ret = gnutls_ia_handshake (session);
        // Error handling...
    }
    ...
}
```

See below for detailed descriptions of all the functions used above.

The function `client_avp` would have to be implemented by your application. The function is responsible for handling the AVP data. See `gnutls_ia_set_client_avp_function` below for more information on how that function should be implemented.

The control flow in a typical server is similar to the above, use `gnutls_ia_server_credentials_t` instead of `gnutls_ia_client_credentials_t`, and replace the call to the client functions with the corresponding server functions.

gnutls_ia_allocate_client_credentials

```
int gnutls_ia_allocate_client_credentials (gnutls_ia_client_credentials_t * sc) [Function]
```

`sc`: is a pointer to an `gnutls_ia_server_credentials_t` structure.

This structure is complex enough to manipulate directly thus this helper function is provided in order to allocate it.

Adding this credential to a session will enable TLS/IA, and will require an Application Phase after the TLS handshake (if the server support TLS/IA). Use `gnutls_ia_require_inner_phase()` to toggle the TLS/IA mode.

Returns 0 on success.

gnutls_ia_allocate_server_credentials

int gnutls_ia_allocate_server_credentials [Function]
 (*gnutls_ia_server_credentials_t* * *sc*)

sc: is a pointer to an `gnutls_ia_server_credentials_t` structure.

This structure is complex enough to manipulate directly thus this helper function is provided in order to allocate it.

Adding this credential to a session will enable TLS/IA, and will require an Application Phase after the TLS handshake (if the client support TLS/IA). Use `gnutls_ia_require_inner_phase()` to toggle the TLS/IA mode.

Returns 0 on success.

gnutls_ia_enable

void gnutls_ia_enable (*gnutls_session_t session*, *int* [Function]
 allow_skip_on_resume)

session: is a `gnutls_session_t` structure.

allow_skip_on_resume: non-zero if local party allows to skip the TLS/IA application phases for a resumed session.

Specify whether we must advertise support for the TLS/IA extension during the handshake.

At the client side, we always advertise TLS/IA if `gnutls_ia_enable` was called before the handshake; at the server side, we also require that the client has advertised that it wants to run TLS/IA before including the advertisement, as required by the protocol.

Similarly, at the client side we always advertise that we allow TLS/IA to be skipped for resumed sessions if `allow_skip_on_resume` is non-zero; at the server side, we also require that the session is indeed resumable and that the client has also advertised that it allows TLS/IA to be skipped for resumed sessions.

After the TLS handshake, call `gnutls_ia_handshake_p()` to find out whether both parties agreed to do a TLS/IA handshake, before calling `gnutls_ia_handshake()` or one of the lower level `gnutls_ia_*` functions.

gnutls_ia_endphase_send

int gnutls_ia_endphase_send (*gnutls_session_t session*, *int* [Function]
 final_p)

session: is a `gnutls_session_t` structure.

final_p: Set iff this should signal the final phase.

Send a TLS/IA end phase message.

In the client, this should only be used to acknowledge an end phase message sent by the server.

In the server, this can be called instead of `gnutls_ia_send()` if the server wishes to end an application phase.

Return value: Return 0 on success, or an error code.

gnutls_ia_extract_inner_secret

void gnutls_ia_extract_inner_secret (*gnutls_session_t session*, [Function]
*char * buffer*)

session: is a `gnutls_session_t` structure.

buffer: pre-allocated buffer to hold 48 bytes of inner secret.

Copy the 48 bytes large inner secret into the specified buffer

This function is typically used after the TLS/IA handshake has concluded. The TLS/IA inner secret can be used as input to a PRF to derive session keys. Do not use the inner secret directly as a session key, because for a resumed session that does not include an application phase, the inner secret will be identical to the inner secret in the original session. It is important to include, for example, the client and server randomness when deriving a session key from the inner secret.

gnutls_ia_free_client_credentials

void gnutls_ia_free_client_credentials [Function]
(*gnutls_ia_client_credentials_t sc*)

sc: is an `gnutls_ia_client_credentials_t` structure.

This structure is complex enough to manipulate directly thus this helper function is provided in order to free (deallocate) it.

gnutls_ia_free_server_credentials

void gnutls_ia_free_server_credentials [Function]
(*gnutls_ia_server_credentials_t sc*)

sc: is an `gnutls_ia_server_credentials_t` structure.

This structure is complex enough to manipulate directly thus this helper function is provided in order to free (deallocate) it.

gnutls_ia_generate_challenge

int gnutls_ia_generate_challenge (*gnutls_session_t session*, *size_t* [Function]
buffer_size, *char * buffer*)

session: is a `gnutls_session_t` structure.

buffer_size: size of output buffer.

buffer: pre-allocated buffer to contain `buffer_size` bytes of output.

Generate an application challenge that the client cannot control or predict, based on the TLS/IA inner secret.

Return value: Returns 0 on success, or an negative error code.

gnutls_ia_get_client_avp_ptr

void * gnutls_ia_get_client_avp_ptr [Function]

(*gnutls_ia_client_credentials_t cred*)

cred: is a *gnutls_ia_client_credentials_t* structure.

Returns the pointer that will be provided to the TLS/IA callback function as the first argument.

gnutls_ia_get_server_avp_ptr

void * gnutls_ia_get_server_avp_ptr [Function]

(*gnutls_ia_server_credentials_t cred*)

cred: is a *gnutls_ia_client_credentials_t* structure.

Returns the pointer that will be provided to the TLS/IA callback function as the first argument.

gnutls_ia_handshake_p

int gnutls_ia_handshake_p (*gnutls_session_t session*) [Function]

session: is a *gnutls_session_t* structure.

Predicate to be used after *gnutls_handshake()* to decide whether to invoke *gnutls_ia_handshake()*. Usable by both clients and servers.

Return value: non-zero if TLS/IA handshake is expected, zero otherwise.

gnutls_ia_handshake

int gnutls_ia_handshake (*gnutls_session_t session*) [Function]

session: is a *gnutls_session_t* structure.

Perform a TLS/IA handshake. This should be called after *gnutls_handshake()* iff *gnutls_ia_handshake_p()*.

Return 0 on success, or an error code.

gnutls_ia_permute_inner_secret

int gnutls_ia_permute_inner_secret (*gnutls_session_t session*, [Function]

size_t session_keys_size, *const char * session_keys*)

session: is a *gnutls_session_t* structure.

session_keys_size: Size of generated session keys (0 if none).

session_keys: Generated session keys, used to permute inner secret (NULL if none).

Permute the inner secret using the generated session keys.

This can be called in the TLS/IA AVP callback to mix any generated session keys with the TLS/IA inner secret.

Return value: Return zero on success, or a negative error code.

gnutls_ia_recv

`ssize_t gnutls_ia_recv (gnutls_session_t session, char * data, [Function]
size_t sizeofdata)`

session: is a `gnutls_session_t` structure.

data: the buffer that the data will be read into, must hold ≥ 12 bytes.

sizeofdata: the number of requested bytes, must be ≥ 12 .

Receive TLS/IA data. This function has the similar semantics with `recv()`. The only difference is that it accepts a GNUTLS session, and uses different error codes.

If the server attempt to finish an application phase, this function will return `GNUTLS_E_WARNING_IA_IPHF_RECEIVED` or `GNUTLS_E_WARNING_IA_FPHF_RECEIVED`. The caller should then invoke `gnutls_ia_verify_endphase()`, and if it runs the client side, also send an endphase message of its own using `gnutls_ia_endphase_send`.

If `EINTR` is returned by the internal push function (the default is `code{recv()}`) 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 same parameters; alternatively you could provide a NULL pointer for data, and 0 for size.

Returns the number of bytes received. A negative error code is returned in case of an error. The `GNUTLS_E_WARNING_IA_IPHF_RECEIVED` and `GNUTLS_E_WARNING_IA_FPHF_RECEIVED` errors are returned when an application phase finished message has been sent by the server.

gnutls_ia_send

`ssize_t gnutls_ia_send (gnutls_session_t session, const char * data, [Function]
size_t sizeofdata)`

session: is a `gnutls_session_t` structure.

data: contains the data to send

sizeofdata: is the length of the data

Send TLS/IA application payload data. This function has the similar semantics with `send()`. The only difference is that it accepts a GNUTLS session, and uses different error codes.

The TLS/IA protocol is synchronous, so you cannot send more than one packet at a time. The client always send the first packet.

To finish an application phase in the server, use `gnutls_ia_endphase_send()`. The client cannot end an application phase unilaterally; rather, a client is required to respond with an endphase of its own if `gnutls_ia_recv` indicates that the server has sent one.

If the `EINTR` is returned by the internal push function (the default is `send()`) 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 same parameters; alternatively you could provide a NULL pointer for data, and 0 for size.

Returns the number of bytes sent, or a negative error code.

gnutls_ia_set_client_avp_function

void gnutls_ia_set_client_avp_function [Function]

(*gnutls_ia_client_credentials_t cred*, *gnutls_ia_avp_func avp_func*)

cred: is a **gnutls_ia_client_credentials_t** structure.

avp_func: is the callback function

Set the TLS/IA AVP callback handler used for the session.

The AVP callback is called to process AVPs received from the server, and to get a new AVP to send to the server.

The callback's function form is: `int (*avp_func) (gnutls_session_t session, void *ptr, const char *last, size_t lastlen, char **next, size_t *nextlen);`

The **session** parameter is the **gnutls_session_t** structure corresponding to the current session. The **ptr** parameter is the application hook pointer, set through **gnutls_ia_set_client_avp_ptr()**. The AVP received from the server is present in **last** of **lastlen** size, which will be NULL on the first invocation. The newly allocated output AVP to send to the server should be placed in ***next** of ***nextlen** size.

The callback may invoke **gnutls_ia_permute_inner_secret()** to mix any generated session keys with the TLS/IA inner secret.

Return 0 (**GNUTLS_IA_APPLICATION_PAYLOAD**) on success, or a negative error code to abort the TLS/IA handshake.

Note that the callback must use allocate the **next** parameter using **gnutls_malloc()**, because it is released via **gnutls_free()** by the TLS/IA handshake function.

gnutls_ia_set_client_avp_ptr

void gnutls_ia_set_client_avp_ptr (*gnutls_ia_client_credentials_t* [Function]

cred, *void *ptr*)

cred: is a **gnutls_ia_client_credentials_t** structure.

ptr: is the pointer

Sets the pointer that will be provided to the TLS/IA callback function as the first argument.

gnutls_ia_set_server_avp_function

void gnutls_ia_set_server_avp_function [Function]

(*gnutls_ia_server_credentials_t cred*, *gnutls_ia_avp_func avp_func*)

cred: is a **gnutls_ia_server_credentials_t** structure.

Set the TLS/IA AVP callback handler used for the session.

The callback's function form is: `int (*avp_func) (gnutls_session_t session, void *ptr, const char *last, size_t lastlen, char **next, size_t *nextlen);`

The **session** parameter is the **gnutls_session_t** structure corresponding to the current session. The **ptr** parameter is the application hook pointer, set through **gnutls_ia_set_server_avp_ptr()**. The AVP received from the client is present in **last** of **lastlen** size. The newly allocated output AVP to send to the client should be placed in ***next** of ***nextlen** size.

The AVP callback is called to process incoming AVPs from the client, and to get a new AVP to send to the client. It can also be used to instruct the TLS/IA handshake to do go into the Intermediate or Final phases. It return a negative error code, or an `gnutls_ia_apptype_t` message type.

The callback may invoke `gnutls_ia_permute_inner_secret()` to mix any generated session keys with the TLS/IA inner secret.

Specifically, return `GNUTLS_IA_APPLICATION_PAYLOAD` (0) to send another AVP to the client, return `GNUTLS_IA_INTERMEDIATE_PHASE_FINISHED` (1) to indicate that an `IntermediatePhaseFinished` message should be sent, and return `GNUTLS_IA_FINAL_PHASE_FINISHED` (2) to indicate that an `FinalPhaseFinished` message should be sent. In the last two cases, the contents of the `next` and `nextlen` parameter is not used.

Note that the callback must use allocate the `next` parameter using `gnutls_malloc()`, because it is released via `gnutls_free()` by the TLS/IA handshake function.

`gnutls_ia_set_server_avp_ptr`

`void gnutls_ia_set_server_avp_ptr (gnutls_ia_server_credentials_t cred, void *ptr)` [Function]

`cred`: is a `gnutls_ia_client_credentials_t` structure.

`ptr`: is the pointer

Sets the pointer that will be provided to the TLS/IA callback function as the first argument.

`gnutls_ia_verify_endphase`

`int gnutls_ia_verify_endphase (gnutls_session_t session, const char *checksum)` [Function]

`session`: is a `gnutls_session_t` structure.

`checksum`: 12-byte checksum data, received from `gnutls_ia_recv()`.

Verify TLS/IA end phase checksum data. If verification fails, the `GNUTLS_A_INNER_APPLICATION_VERIFICATION` alert is sent to the other sie.

This function is called when `gnutls_ia_recv()` return `GNUTLS_E_WARNING_IA_IPHF_RECEIVED` or `GNUTLS_E_WARNING_IA_FPHF_RECEIVED`.

Return value: Return 0 on successful verification, or an error code. If the checksum verification of the end phase message fails, `GNUTLS_E_IA_VERIFY_FAILED` is returned.

9.6 Error Codes and Descriptions

The error codes used throughout the library are described below. The return code `GNUTLS_E_SUCCESS` indicate successful operation, and is guaranteed to have the value 0, so you can use it in logical expressions.

`GNUTLS_E_AGAIN:`

Function was interrupted.

`GNUTLS_E_ASN1_DER_ERROR:`

ASN1 parser: Error in DER parsing.

GNUTLS_E_ASN1_DER_OVERFLOW:
ASN1 parser: Overflow in DER parsing.

GNUTLS_E_ASN1_ELEMENT_NOT_FOUND:
ASN1 parser: Element was not found.

GNUTLS_E_ASN1_GENERIC_ERROR:
ASN1 parser: Generic parsing error.

GNUTLS_E_ASN1_IDENTIFIER_NOT_FOUND:
ASN1 parser: Identifier was not found

GNUTLS_E_ASN1_SYNTAX_ERROR:
ASN1 parser: Syntax error.

GNUTLS_E_ASN1_TAG_ERROR:
ASN1 parser: Error in TAG.

GNUTLS_E_ASN1_TAG_IMPLICIT:
ASN1 parser: error in implicit tag

GNUTLS_E_ASN1_TYPE_ANY_ERROR:
ASN1 parser: Error in type 'ANY'.

GNUTLS_E_ASN1_VALUE_NOT_FOUND:
ASN1 parser: Value was not found.

GNUTLS_E_ASN1_VALUE_NOT_VALID:
ASN1 parser: Value is not valid.

GNUTLS_E_BASE64_DECODING_ERROR:
Base64 decoding error.

GNUTLS_E_BASE64_ENCODING_ERROR:
Base64 encoding error.

GNUTLS_E_BASE64_UNEXPECTED_HEADER_ERROR:
Base64 unexpected header error.

GNUTLS_E_CERTIFICATE_ERROR:
Error in the certificate.

GNUTLS_E_CERTIFICATE_KEY_MISMATCH:
The certificate and the given key do not match.

GNUTLS_E_COMPRESSION_FAILED:
Compression of the TLS record packet has failed.

GNUTLS_E_CONSTRAINT_ERROR:
Some constraint limits were reached.

GNUTLS_E_DB_ERROR:
Error in Database backend.

GNUTLS_E_DECOMPRESSION_FAILED:
Decompression of the TLS record packet has failed.

- GNUTLS_E_DECRYPTION_FAILED:**
Decryption has failed.
- GNUTLS_E_DH_PRIME_UNACCEPTABLE:**
The Diffie Hellman prime sent by the server is not acceptable (not long enough).
- GNUTLS_E_ENCRYPTION_FAILED:**
Encryption has failed.
- GNUTLS_E_ERROR_IN_FINISHED_PACKET:**
An error was encountered at the TLS Finished packet calculation.
- GNUTLS_E_EXPIRED:**
The requested session has expired.
- GNUTLS_E_FATAL_ALERT_RECEIVED:**
A TLS fatal alert has been received.
- GNUTLS_E_FILE_ERROR:**
Error while reading file.
- GNUTLS_E_GOT_APPLICATION_DATA:**
TLS Application data were received, while expecting handshake data.
- GNUTLS_E_HASH_FAILED:**
Hashing has failed.
- GNUTLS_E_IA_VERIFY_FAILED:**
Verifying TLS/IA phase checksum failed
- GNUTLS_E_ILLEGAL_SRP_USERNAME:**
The SRP username supplied is illegal.
- GNUTLS_E_INCOMPATIBLE_GCRYPT_LIBRARY:**
The gcrypt library version is too old.
- GNUTLS_E_INCOMPATIBLE_LIBTASN1_LIBRARY:**
The tasn1 library version is too old.
- GNUTLS_E_INIT_LIBEXTRA:**
The initialization of GnuTLS-extra has failed.
- GNUTLS_E_INSUFFICIENT_CREDENTIALS:**
Insufficient credentials for that request.
- GNUTLS_E_INTERNAL_ERROR:**
GnuTLS internal error.
- GNUTLS_E_INTERRUPTED:**
Function was interrupted.
- GNUTLS_E_INVALID_PASSWORD:**
The given password contains invalid characters.
- GNUTLS_E_INVALID_REQUEST:**
The request is invalid.

GNUTLS_E_INVALID_SESSION:

The specified session has been invalidated for some reason.

GNUTLS_E_KEY_USAGE_VIOLATION:

Key usage violation in certificate has been detected.

GNUTLS_E_LARGE_PACKET:

A large TLS record packet was received.

GNUTLS_E_LIBRARY_VERSION_MISMATCH:

The GnuTLS library version does not match the GnuTLS-extra library version.

GNUTLS_E_LZO_INIT_FAILED:

The initialization of LZO has failed.

GNUTLS_E_MAC_VERIFY_FAILED:

The Message Authentication Code verification failed.

GNUTLS_E_MEMORY_ERROR:

Internal error in memory allocation.

GNUTLS_E_MPI_PRINT_FAILED:

Could not export a large integer.

GNUTLS_E_MPI_SCAN_FAILED:

The scanning of a large integer has failed.

GNUTLS_E_NO_CERTIFICATE_FOUND:

The peer did not send any certificate.

GNUTLS_E_NO_CIPHER_SUITES:

No supported cipher suites have been found.

GNUTLS_E_NO_COMPRESSION_ALGORITHMS:

No supported compression algorithms have been found.

GNUTLS_E_NO_TEMPORARY_DH_PARAMS:

No temporary DH parameters were found.

GNUTLS_E_NO_TEMPORARY_RSA_PARAMS:

No temporary RSA parameters were found.

GNUTLS_E_OPENPGP_FINGERPRINT_UNSUPPORTED:

The OpenPGP fingerprint is not supported.

GNUTLS_E_OPENPGP_GETKEY_FAILED:

Could not get OpenPGP key.

GNUTLS_E_OPENPGP_KEYRING_ERROR:

Error loading the keyring.

GNUTLS_E_PKCS1_WRONG_PAD:

Wrong padding in PKCS1 packet.

GNUTLS_E_PK_DECRYPTION_FAILED:

Public key decryption has failed.

GNUTLS_E_PK_ENCRYPTION_FAILED:
Public key encryption has failed.

GNUTLS_E_PK_SIGN_FAILED:
Public key signing has failed.

GNUTLS_E_PK_SIG_VERIFY_FAILED:
Public key signature verification has failed.

GNUTLS_E_PULL_ERROR:
Error in the pull function.

GNUTLS_E_PUSH_ERROR:
Error in the push function.

GNUTLS_E_RANDOM_FAILED:
Failed to acquire random data.

GNUTLS_E_RECEIVED_ILLEGAL_EXTENSION:
An illegal TLS extension was received.

GNUTLS_E_RECEIVED_ILLEGAL_PARAMETER:
An illegal parameter has been received.

GNUTLS_E_RECORD_LIMIT_REACHED:
The upper limit of record packet sequence numbers has been reached. Wow!

GNUTLS_E_REHANDSHAKE:
Rehandshake was requested by the peer.

GNUTLS_E_REQUESTED_DATA_NOT_AVAILABLE:
The requested data were not available.

GNUTLS_E_SHORT_MEMORY_BUFFER:
The given memory buffer is too short to hold parameters.

GNUTLS_E_SRP_PWD_ERROR:
Error in password file.

GNUTLS_E_SRP_PWD_PARSING_ERROR:
Parsing error in password file.

GNUTLS_E_SUCCESS:
Success.

GNUTLS_E_TOO_MANY_EMPTY_PACKETS:
Too many empty record packets have been received.

GNUTLS_E_UNEXPECTED_HANDSHAKE_PACKET:
An unexpected TLS handshake packet was received.

GNUTLS_E_UNEXPECTED_PACKET:
An unexpected TLS packet was received.

GNUTLS_E_UNEXPECTED_PACKET_LENGTH:
A TLS packet with unexpected length was received.

GNUTLS_E_UNKNOWN_ALGORITHM:
The specified algorithm or protocol is unknown.

GNUTLS_E_UNKNOWN_CIPHER_SUITE:
Could not negotiate a supported cipher suite.

GNUTLS_E_UNKNOWN_CIPHER_TYPE:
The cipher type is unsupported.

GNUTLS_E_UNKNOWN_COMPRESSION_ALGORITHM:
Could not negotiate a supported compression method.

GNUTLS_E_UNKNOWN_HASH_ALGORITHM:
The hash algorithm is unknown.

GNUTLS_E_UNKNOWN_PKCS_BAG_TYPE:
The PKCS structure's bag type is unknown.

GNUTLS_E_UNKNOWN_PKCS_CONTENT_TYPE:
The PKCS structure's content type is unknown.

GNUTLS_E_UNKNOWN_PK_ALGORITHM:
An unknown public key algorithm was encountered.

GNUTLS_E_UNSUPPORTED_CERTIFICATE_TYPE:
The certificate type is not supported.

GNUTLS_E_UNSUPPORTED_VERSION_PACKET:
A record packet with illegal version was received.

GNUTLS_E_UNWANTED_ALGORITHM:
An algorithm that is not enabled was negotiated.

GNUTLS_E_WARNING_ALERT_RECEIVED:
A TLS warning alert has been received.

GNUTLS_E_WARNING_IA_FPHF_RECEIVED:
Received a TLS/IA Final Phase Finished message

GNUTLS_E_WARNING_IA_IPHF_RECEIVED:
Received a TLS/IA Intermediate Phase Finished message

GNUTLS_E_X509_UNKNOWN_SAN:
Unknown Subject Alternative name in X.509 certificate.

GNUTLS_E_X509_UNSUPPORTED_ATTRIBUTE:
The certificate has unsupported attributes.

GNUTLS_E_X509_UNSUPPORTED_CRITICAL_EXTENSION:
Unsupported critical extension in X.509 certificate.

GNUTLS_E_X509_UNSUPPORTED_OID:
The OID is not supported.

10 All the Supported Ciphersuites in GnuTLS

TLS_RSA_NULL_MD5	0x00 0x01	RFC 2246
TLS_ANON_DH_3DES_EDE_CBC_SHA	0x00 0x1B	RFC 2246
TLS_ANON_DH_ARCFOUR_MD5	0x00 0x18	RFC 2246
TLS_ANON_DH_AES_128_CBC_SHA	0x00 0x34	RFC 2246
TLS_ANON_DH_AES_256_CBC_SHA	0x00 0x3A	RFC 2246
TLS_RSA_ARCFOUR_SHA	0x00 0x05	RFC 2246
TLS_RSA_ARCFOUR_MD5	0x00 0x04	RFC 2246
TLS_RSA_3DES_EDE_CBC_SHA	0x00 0x0A	RFC 2246
TLS_RSA_EXPORT_ARCFOUR_40_MD5	0x00 0x03	RFC 2246
TLS_DHE_DSS_3DES_EDE_CBC_SHA	0x00 0x13	RFC 2246
TLS_DHE_RSA_3DES_EDE_CBC_SHA	0x00 0x16	RFC 2246
TLS_RSA_AES_128_CBC_SHA	0x00 0x2F	RFC 3268
TLS_RSA_AES_256_CBC_SHA	0x00 0x35	RFC 3268
TLS_DHE_DSS_AES_256_CBC_SHA	0x00 0x38	RFC 3268
TLS_DHE_DSS_AES_128_CBC_SHA	0x00 0x32	RFC 3268
TLS_DHE_RSA_AES_256_CBC_SHA	0x00 0x39	RFC 3268
TLS_DHE_RSA_AES_128_CBC_SHA	0x00 0x33	RFC 3268
TLS_SRP_SHA_3DES_EDE_CBC_SHA	0x00 0x50	RFC 5054
TLS_SRP_SHA_AES_128_CBC_SHA	0x00 0x53	RFC 5054
TLS_SRP_SHA_AES_256_CBC_SHA	0x00 0x56	RFC 5054
TLS_SRP_SHA_RSA_3DES_EDE_CBC_SHA	0x00 0x51	RFC 5054
TLS_SRP_SHA_DSS_3DES_EDE_CBC_SHA	0x00 0x52	RFC 5054

TLS_SRP_SHA_RSA_AES_128_CBC_SHA	0x00 0x54	RFC 5054
TLS_SRP_SHA_DSS_AES_128_CBC_SHA	0x00 0x55	RFC 5054
TLS_SRP_SHA_RSA_AES_256_CBC_SHA	0x00 0x57	RFC 5054
TLS_SRP_SHA_DSS_AES_256_CBC_SHA	0x00 0x58	RFC 5054
TLS_DHE_DSS_ARCFOUR_SHA	0x00 0x66	draft-ietf-tls-56-bit-ciphersuites
TLS_PSK_ARCFOUR_SHA	0x00 0x8A	draft-ietf-tls-psk
TLS_PSK_3DES_EDE_CBC_SHA	0x00 0x8B	draft-ietf-tls-psk
TLS_PSK_AES_128_CBC_SHA	0x00 0x8C	draft-ietf-tls-psk
TLS_PSK_AES_256_CBC_SHA	0x00 0x8D	draft-ietf-tls-psk

11 Guile Bindings

This chapter describes the **GNU Guile** Scheme programming interface to GnuTLS. The reader is assumed to have basic knowledge of the protocol and library. Details missing from this chapter may be found in [Chapter 9 \[Function reference\]](#), page 111.

At this stage, not all the C functions are available from Scheme, but a large subset thereof is available.

11.1 Guile Preparations

The GnuTLS Guile bindings are by default installed under the GnuTLS installation directory (e.g., typically `/usr/local/share/guile/site/`). Normally Guile will not find the module there without help. You may experience something like this:

```
$ guile
guile> (use-modules (gnutls))
<unnamed port>: no code for module (gnutls)
guile>
```

There are two ways to solve this. The first is to make sure that when building GnuTLS, the Guile bindings will be installed in the same place where Guile looks. You may do this by using the `--with-guile-site-dir` parameter as follows:

```
$ ./configure --with-guile-site-dir=no
```

This will instruct GnuTLS to attempt to install the Guile bindings where Guile will look for them. It will use `guile-config info pkgdatadir` to learn the path to use.

If Guile was installed into `/usr`, you may also install GnuTLS using the same prefix:

```
$ ./configure --prefix=/usr
```

If you want to specify the path to install the Guile bindings you can also specify the path directly:

```
$ ./configure --with-guile-site-dir=/opt/guile/share/guile/site
```

The second solution requires some more work but may be easier to use if you do not have system administrator rights to your machine. You need to instruct Guile so that it finds the GnuTLS Guile bindings. Either use the `GUILE_LOAD_PATH` environment variable as follows:

```
$ GUILE_LOAD_PATH="/usr/local/share/guile/site:$GUILE_LOAD_PATH" guile
guile> (use-modules (gnutls))
guile>
```

Alternatively, you can modify Guile's `%load-path` variable (see [section "Build Config" in *The GNU Guile Reference Manual*](#)).

At this point, you might get an error regarding `'libguile-gnutls-v-0'` similar to:

```
gnutls.scm:361:1: In procedure dynamic-link in expression (load-extension "libguile-gn
gnutls.scm:361:1: file: "libguile-gnutls-v-0", message: "libguile-gnutls-v-0.so: cannot
```

In this case, you will need to modify the run-time linker path, for example as follows:

```
$ LD_LIBRARY_PATH=/usr/local/lib GUILE_LOAD_PATH=/usr/local/share/guile/site guile
guile> (use-modules (gnutls))
guile>
```

11.2 Guile API Conventions

This chapter details the conventions used by Guile API, as well as specificities of the mapping of the C API to Scheme.

11.2.1 Enumerates and Constants

Lots of enumerates and constants are used in the GnuTLS C API. For each C enumerate type, a disjoint Scheme type is used—thus, enumerate values and constants are not represented by Scheme symbols nor by integers. This makes it impossible to use an enumerate value of the wrong type on the Scheme side: such errors are automatically detected by type-checking.

The enumerate values are bound to variables exported by the `(gnutls)` and `(gnutls extra)` modules. These variables are named according to the following convention:

- All variable names are lower-case; the underscore `_` character used in the C API is replaced by hyphen `-`.
- All variable names are prepended by the name of the enumerate type and the slash `/` character.
- In some cases, the variable name is made more explicit than the one of the C API, e.g., by avoid abbreviations.

Consider for instance this C-side enumerate:

```
typedef enum
{
    GNUTLS_CRD_CERTIFICATE = 1,
    GNUTLS_CRD_ANON,
    GNUTLS_CRD_SRP,
    GNUTLS_CRD_PSK,
    GNUTLS_CRD_IA
} gnutls_credentials_type_t;
```

The corresponding Scheme values are bound to the following variables exported by the `(gnutls)` module:

```
credentials/certificate
credentials/anonymous
credentials/srp
credentials/psk
credentials/ia
```

Hopefully, most variable names can be deduced from this convention.

Scheme-side “enumerate” values can be compared using `eq?` (see [section “Equality” in *The GNU Guile Reference Manual*](#)). Consider the following example:

```
(let ((session (make-session connection-end/client)))

  ;;
  ;; ...
  ;;

  ;; Check the ciphering algorithm currently used by SESSION.
```

```
(if (eq? cipher/arcfour (session-cipher session))
    (format #t "We're using the ARCFOUR algorithm")))
```

In addition, all enumerate values can be converted to a human-readable string, in a type-specific way. For instance, `(cipher->string cipher/arcfour)` yields "ARCFOUR 128", while `(key-usage->string key-usage/digital-signature)` yields "digital-signature". Note that these strings may not be sufficient for use in a user interface since they are fairly concise and not internationalized.

11.2.2 Procedure Names

Unlike C functions in GnuTLS, the corresponding Scheme procedures are named in a way that is close to natural English. Abbreviations are also avoided. For instance, the Scheme procedure corresponding to `gnutls_certificate_set_dh_params` is named `set-certificate-credentials-dh-parameters!`. The `gnutls_` prefix is always omitted from variable names since a similar effect can be achieved using Guile's nifty binding renaming facilities, should it be needed (see [section "Using Guile Modules" in *The GNU Guile Reference Manual*](#)).

Often Scheme procedure names differ from C function names in a way that makes it clearer what objects they operate on. For example, the Scheme procedure named `set-session-transport-port!` corresponds to `gnutls_transport_set_ptr`, making it clear that this procedure applies to session.

11.2.3 Representation of Binary Data

Many procedures operate on binary data. For instance, `pkcs3-import-dh-parameters` expects binary data as input and, similarly, procedures like `pkcs1-export-rsa-parameters` return binary data.

Binary data is represented on the Scheme side using SRFI-4 homogeneous vectors (see [section "SRFI-4" in *The GNU Guile Reference Manual*](#)). Although any type of homogeneous vector may be used, `u8vectors` (i.e., vectors of bytes) are highly recommended.

As an example, generating and then exporting RSA parameters in the PEM format can be done as follows:

```
(let* ((rsa-params (make-rsa-parameters 1024))
      (raw-data
        (pkcs1-export-rsa-parameters rsa-params
                                      x509-certificate-format/pem)))
      (uniform-vector-write raw-data (open-output-file "some-file.pem")))
```

For an example of OpenPGP key import from a file, see [Section 11.3.3 \[Importing OpenPGP Keys Guile Example\]](#), page 242.

11.2.4 Input and Output

The underlying transport of a TLS session can be any Scheme input/output port (see [section "Ports and File Descriptors" in *The GNU Guile Reference Manual*](#)). This has to be specified using `set-session-transport-port!`.

However, for better performance, a raw file descriptor can be specified, using `set-session-transport-fd!`. For instance, if the transport layer is a socket port over an OS-provided socket, you can use the `port->fdes` or `fileno` procedure to obtain the underlying file

descriptor and pass it to `set-session-transport-fd!` (see [section “Ports and File Descriptors” in *The GNU Guile Reference Manual*](#)). This would work as follows:

```
(let ((socket (socket PF_INET SOCK_STREAM 0))
      (session (make-session connection-end/client)))

  ;;

  ;; Establish a TCP connection...
  ;;

  ;; Use the file descriptor that underlies SOCKET.
  (set-session-transport-fd! session (fileno socket)))
```

Once a TLS session is established, data can be communicated through it (i.e., *via* the TLS record layer) using the port returned by `session-record-port`:

```
(let ((session (make-session connection-end/client)))

  ;;

  ;; Initialize the various parameters of SESSION, set up
  ;; a network connection, etc...
  ;;

  (let ((i/o (session-record-port session)))
    (write "Hello peer!" i/o)
    (let ((greetings (read i/o)))

      ;; ...

      (bye session close-request/rdwr))))
```

A lower-level I/O API is provided by `record-send` and `record-receive!` which take an SRFI-4 vector to represent the data sent or received. While it might improve performance, it is much less convenient than the above and should rarely be needed.

11.2.5 Exception Handling

GnuTLS errors are implemented as Scheme exceptions (see [section “Exceptions” in *The GNU Guile Reference Manual*](#)). Each time a GnuTLS function returns an error, an exception with key `gnutls-error` is raised. The additional arguments that are thrown include an error code and the name of the GnuTLS procedure that raised the exception. The error code is pretty much like an enumerate value: it is one of the `error/` variables exported by the (`gnutls`) module (see [Section 11.2.1 \[Enumerates and Constants\], page 236](#)). Exceptions can be turned into error messages using the `error->string` procedure.

The following examples illustrates how GnuTLS exceptions can be handled:

```
(let ((session (make-session connection-end/server)))

  ;;

  ;; ...

  ;;
```

```
(catch 'gnutls-error
  (lambda ()
    (handshake session))
  (lambda (key err function . currently-unused)
    (format (current-error-port)
      "a GnuTLS error was raised by '~a': ~a~%"
      function (error->string err))))
```

Again, error values can be compared using `eq?`:

```
;; 'gnutls-error' handler.
(lambda (key err function . currently-unused)
  (if (eq? err error/fatal-alert-received)
      (format (current-error-port)
        "a fatal alert was caught!~%")
      (format (current-error-port)
        "something bad happened: ~a~%"
        (error->string err))))
```

Note that the `catch` handler is currently passed only 3 arguments but future versions might provide it with additional arguments. Thus, it must be prepared to handle more than 3 arguments, as in this example.

11.3 Guile Examples

This chapter provides examples that illustrate common use cases.

11.3.1 Anonymous Authentication Guile Example

Anonymous authentication is very easy to use. No certificates are needed by the communicating parties. Yet, it allows them to benefit from end-to-end encryption and integrity checks.

The client-side code would look like this (assuming *some-socket* is bound to an open socket port):

```
;; Client-side.

(let ((client (make-session connection-end/client)))
  ;; Use the default settings.
  (set-session-default-priority! client)

  ;; Don't use certificate-based authentication.
  (set-session-certificate-type-priority! client '())

  ;; Request the "anonymous Diffie-Hellman" key exchange method.
  (set-session-kx-priority! client (list kx/anon-dh))

  ;; Specify the underlying socket.
  (set-session-transport-fd! client (fileno some-socket)))
```

```
;; Create anonymous credentials.
(set-session-credentials! client
  (make-anonymous-client-credentials))

;; Perform the TLS handshake with the server.
(handshake client)

;; Send data over the TLS record layer.
(write "hello, world!" (session-record-port client))

;; Terminate the TLS session.
(bye client close-request/rdwr))
```

The corresponding server would look like this (again, assuming *some-socket* is bound to a socket port):

```
;; Server-side.

(let ((server (make-session connection-end/server)))
  (set-session-default-priority! server)
  (set-session-certificate-type-priority! server '())
  (set-session-kx-priority! server (list kx/anon-dh))

  ;; Specify the underlying transport socket.
  (set-session-transport-fd! server (fileno some-socket))

  ;; Create anonymous credentials.
  (let ((cred (make-anonymous-server-credentials))
        (dh-params (make-dh-parameters 1024)))
    ;; Note: DH parameter generation can take some time.
    (set-anonymous-server-dh-parameters! cred dh-params)
    (set-session-credentials! server cred))

  ;; Perform the TLS handshake with the client.
  (handshake server)

  ;; Receive data over the TLS record layer.
  (let ((message (read (session-record-port server))))
    (format #t "received the following message: ~a~%"
      message)

    (bye server close-request/rdwr)))
```

This is it!

11.3.2 OpenPGP Authentication Guile Example

GnuTLS allows users to authenticate using OpenPGP certificates. The relevant procedures are provided by the (`gnutls extra`) module. Using OpenPGP-based authentication is not more complicated than using anonymous authentication. It requires a bit of extra work,

though, to import the OpenPGP public and private key of the client/server. Key import is omitted here and is left as an exercise to the reader (see [Section 11.3.3 \[Importing OpenPGP Keys Guile Example\]](#), page 242).

Assuming *some-socket* is bound to an open socket port and *pub* and *sec* are bound to the client's OpenPGP public and secret key, respectively, client-side code would look like this:

```
;; Client-side.

(define %certs (list certificate-type/openpgp))

(let ((client (make-session connection-end/client))
      (cred (make-certificate-credentials)))
  (set-session-default-priority! client)

  ;; Choose OpenPGP certificates.
  (set-session-certificate-type-priority! client %certs)

  ;; Prepare appropriate client credentials.
  (set-certificate-credentials-openpgp-keys! cred pub sec)
  (set-session-credentials! client cred)

  ;; Specify the underlying transport socket.
  (set-session-transport-fd! client (fileno some-socket))

  (handshake client)
  (write "hello, world!" (session-record-port client))
  (bye client close-request/rdwr))
```

Similarly, server-side code would be along these lines:

```
;; Server-side.

(define %certs (list certificate-type/openpgp))

(let ((server (make-session connection-end/server))
      (rsa (make-rsa-parameters 1024))
      (dh (make-dh-parameters 1024)))
  (set-session-default-priority! server)

  ;; Choose OpenPGP certificates.
  (set-session-certificate-type-priority! server %certs)

  (let ((cred (make-certificate-credentials)))
    ;; Prepare credentials with RSA and Diffie-Hellman parameters.
    (set-certificate-credentials-dh-parameters! cred dh)
    (set-certificate-credentials-rsa-export-parameters! cred rsa)
    (set-certificate-credentials-openpgp-keys! cred pub sec)
    (set-session-credentials! server cred)))
```

```

(set-session-transport-fd! server (fileno some-socket))

(handshake server)
(let ((msg (read (session-record-port server))))
  (format #t "received: ~a~%" msg)

  (bye server close-request/rdwr)))

```

In practice, generating RSA parameters (and Diffie-Hellman parameters) can take a long time. Thus, you may want to generate them once and store them in a file for future re-use (see [Section 11.4.1 \[Core Interface\]](#), page 243).

11.3.3 Importing OpenPGP Keys Guile Example

The following example provides a simple way of importing “ASCII-armored” OpenPGP keys from files, using the `import-openpgp-certificate` and `import-openpgp-private-key` procedures provided by the (`gnutls extra`) module.

```

(use-modules (srfi srfi-4)
             (gnutls extra))

(define (import-key-from-file import-proc file)
  ;; Import OpenPGP key from FILE using IMPORT-PROC.

  ;; Prepare a u8vector large enough to hold the raw
  ;; key contents.
  (let* ((size (stat:size (stat path)))
         (raw (make-u8vector size)))

    ;; Fill in the u8vector with the contents of FILE.
    (uniform-vector-read! raw (open-input-file file))

    ;; Pass the u8vector to the import procedure.
    (import-proc raw openpgp-certificate-format/base64)))

(define (import-public-key-from-file file)
  (import-key-from-file import-openpgp-certificate file))

(define (import-private-key-from-file file)
  (import-key-from-file import-openpgp-private-key file))

```

The procedures `import-public-key-from-file` and `import-private-key-from-file` can be passed a file name. They return an OpenPGP public key and private key object, respectively (see [Section 11.4.2 \[Extra Interface\]](#), page 251).

11.4 Guile Reference

This chapter documents GnuTLS Scheme procedures available to Guile programmers.

11.4.1 Core Interface

This section lists the Scheme procedures exported by the (`gnutls`) module (see [section “The Guile module system”](#) in *The GNU Guile Reference Manual*). This module is licenced under the GNU Lesser General Public Licence, version 2.1 or later.

- set-log-level!** *level* [Scheme Procedure]
 Enable GnuTLS logging up to *level* (an integer).
- set-log-procedure!** *proc* [Scheme Procedure]
 Use *proc* (a two-argument procedure) as the global GnuTLS log procedure.
- x509-certificate-subject-alternative-name** *cert index* [Scheme Procedure]
 Return two values: the alternative name type for *cert* (i.e., one of the `x509-subject-alternative-name/` values) and the actual subject alternative name (a string) at *index*. Both values are `#f` if no alternative name is available at *index*.
- x509-certificate-subject-key-id** *cert* [Scheme Procedure]
 Return the subject key ID (a u8vector) for *cert*.
- x509-certificate-authority-key-id** *cert* [Scheme Procedure]
 Return the key ID (a u8vector) of the X.509 certificate authority of *cert*.
- x509-certificate-key-id** *cert* [Scheme Procedure]
 Return a statistically unique ID (a u8vector) for *cert* that depends on its public key parameters. This is normally a 20-byte SHA-1 hash.
- x509-certificate-version** *cert* [Scheme Procedure]
 Return the version of *cert*.
- x509-certificate-key-usage** *cert* [Scheme Procedure]
 Return the key usage of *cert* (i.e., a list of `key-usage/` values), or the empty list if *cert* does not contain such information.
- x509-certificate-public-key-algorithm** *cert* [Scheme Procedure]
 Return two values: the public key algorithm (i.e., one of the `pk-algorithm/` values) of *cert* and the number of bits used.
- x509-certificate-signature-algorithm** *cert* [Scheme Procedure]
 Return the signature algorithm used by *cert* (i.e., one of the `sign-algorithm/` values).
- x509-certificate-matches-hostname?** *cert hostname* [Scheme Procedure]
 Return true if *cert* matches *hostname*, a string denoting a DNS host name. This is the basic implementation of [RFC 2818](#) (aka. HTTPS).
- x509-certificate-issuer-dn-oid** *cert index* [Scheme Procedure]
 Return the OID (a string) at *index* from *cert*’s issuer DN. Return `#f` if no OID is available at *index*.
- x509-certificate-dn-oid** *cert index* [Scheme Procedure]
 Return OID (a string) at *index* from *cert*. Return `#f` if no OID is available at *index*.

- x509-certificate-issuer-dn** *cert* [Scheme Procedure]
Return the distinguished name (DN) of X.509 certificate *cert*.
- x509-certificate-dn** *cert* [Scheme Procedure]
Return the distinguished name (DN) of X.509 certificate *cert*. The form of the DN is as described in [RFC 2253](#).
- pkcs8-import-x509-private-key** *data format* [*pass* [encrypted]] [Scheme Procedure]
Return a new X.509 private key object resulting from the import of *data* (a uniform array) according to *format*. Optionally, if *pass* is not **#f**, it should be a string denoting a passphrase. *encrypted* tells whether the private key is encrypted (**#t** by default).
- import-x509-private-key** *data format* [Scheme Procedure]
Return a new X.509 private key object resulting from the import of *data* (a uniform array) according to *format*.
- import-x509-certificate** *data format* [Scheme Procedure]
Return a new X.509 certificate object resulting from the import of *data* (a uniform array) according to *format*.
- server-session-psk-username** *session* [Scheme Procedure]
Return the username associated with PSK server session *session*.
- set-psk-client-credentials!** *cred username key key-format* [Scheme Procedure]
Set the client credentials for *cred*, a PSK client credentials object.
- make-psk-client-credentials** [Scheme Procedure]
Return a new PSK client credentials object.
- set-psk-server-credentials-file!** *cred file* [Scheme Procedure]
Use *file* as the password file for PSK server credentials *cred*.
- make-psk-server-credentials** [Scheme Procedure]
Return new PSK server credentials.
- srp-base64-decode** *str* [Scheme Procedure]
Decode *str*, an SRP-base64 encoded string, and return the decoded string.
- srp-base64-encode** *str* [Scheme Procedure]
Encode *str* using SRP's base64 algorithm. Return the encoded string.
- server-session-srp-username** *session* [Scheme Procedure]
Return the SRP username used in *session* (a server-side session).
- set-srp-client-credentials!** *cred username password* [Scheme Procedure]
Use *username* and *password* as the credentials for *cred*, a client-side SRP credentials object.
- make-srp-client-credentials** [Scheme Procedure]
Return new SRP client credentials.

set-srp-server-credentials-files! *cred password-file* [Scheme Procedure]
password-conf-file

Set the credentials files for *cred*, an SRP server credentials object.

make-srp-server-credentials [Scheme Procedure]
 Return new SRP server credentials.

peer-certificate-status *session* [Scheme Procedure]
 Verify the peer certificate for *session* and return a list of **certificate-status** values (such as **certificate-status/revoked**), or the empty list if the certificate is valid.

set-certificate-credentials-verify-flags! *cred* [Scheme Procedure]
[flags...]
 Set the certificate verification flags to *flags*, a series of **certificate-verify** values.

set-certificate-credentials-verify-limits! *cred* [Scheme Procedure]
max-bits max-depth
 Set the verification limits of **peer-certificate-status** for certificate credentials *cred* to *max-bits* bits for an acceptable certificate and *max-depth* as the maximum depth of a certificate chain.

set-certificate-credentials-x509-keys! *cred certs* [Scheme Procedure]
privkey
 Have certificate credentials *cred* use the X.509 certificates listed in *certs* and X.509 private key *privkey*.

set-certificate-credentials-x509-key-data! *cred cert* [Scheme Procedure]
key format
 Use X.509 certificate *cert* and private key *key*, both uniform arrays containing the X.509 certificate and key in format *format*, for certificate credentials *cred*.

set-certificate-credentials-x509-crl-data! *cred data* [Scheme Procedure]
format
 Use *data* (a uniform array) as the X.509 CRL (certificate revocation list) database for *cred*. On success, return the number of CRLs processed.

set-certificate-credentials-x509-trust-data! *cred* [Scheme Procedure]
data format
 Use *data* (a uniform array) as the X.509 trust database for *cred*. On success, return the number of certificates processed.

set-certificate-credentials-x509-crl-file! *cred file* [Scheme Procedure]
format
 Use *file* as the X.509 CRL (certificate revocation list) file for certificate credentials *cred*. On success, return the number of CRLs processed.

set-certificate-credentials-x509-trust-file! *cred file* [Scheme Procedure]
format
 Use *file* as the X.509 trust file for certificate credentials *cred*. On success, return the number of certificates processed.

- set-certificate-credentials-x509-key-files!** *cred* [Scheme Procedure]
cert-file key-file format
 Use *file* as the password file for PSK server credentials *cred*.
- set-certificate-credentials-rsa-export-parameters!** [Scheme Procedure]
cred rsa-params
 Use RSA parameters *rsa_params* for certificate credentials *cred*.
- set-certificate-credentials-dh-parameters!** *cred* [Scheme Procedure]
dh-params
 Use Diffie-Hellman parameters *dh_params* for certificate credentials *cred*.
- make-certificate-credentials** [Scheme Procedure]
 Return new certificate credentials (i.e., for use with either X.509 or OpenPGP certificates).
- pkcs1-export-rsa-parameters** *rsa-params format* [Scheme Procedure]
 Export Diffie-Hellman parameters *rsa_params* in PKCS1 format according for *format* (an *x509-certificate-format* value). Return a *u8vector* containing the result.
- pkcs1-import-rsa-parameters** *array format* [Scheme Procedure]
 Import Diffie-Hellman parameters in PKCS1 format (further specified by *format*, an *x509-certificate-format* value) from *array* (a homogeneous array) and return a new *rsa-params* object.
- make-rsa-parameters** *bits* [Scheme Procedure]
 Return new RSA parameters.
- set-anonymous-server-dh-parameters!** *cred dh-params* [Scheme Procedure]
 Set the Diffie-Hellman parameters of anonymous server credentials *cred*.
- make-anonymous-client-credentials** [Scheme Procedure]
 Return anonymous client credentials.
- make-anonymous-server-credentials** [Scheme Procedure]
 Return anonymous server credentials.
- set-session-dh-prime-bits!** *session bits* [Scheme Procedure]
 Use *bits* DH prime bits for *session*.
- pkcs3-export-dh-parameters** *dh-params format* [Scheme Procedure]
 Export Diffie-Hellman parameters *dh_params* in PKCS3 format according for *format* (an *x509-certificate-format* value). Return a *u8vector* containing the result.
- pkcs3-import-dh-parameters** *array format* [Scheme Procedure]
 Import Diffie-Hellman parameters in PKCS3 format (further specified by *format*, an *x509-certificate-format* value) from *array* (a homogeneous array) and return a new *dh-params* object.
- make-dh-parameters** *bits* [Scheme Procedure]
 Return new Diffie-Hellman parameters.

- set-session-transport-port!** *session port* [Scheme Procedure]
 Use *port* as the input/output port for *session*.
- set-session-transport-fd!** *session fd* [Scheme Procedure]
 Use file descriptor *fd* as the underlying transport for *session*.
- session-record-port** *session* [Scheme Procedure]
 Return a read-write port that may be used to communicate over *session*. All invocations of **session-port** on a given session return the same object (in the sense of `eq?`).
- record-receive!** *session array* [Scheme Procedure]
 Receive data from *session* into *array*, a uniform homogeneous array. Return the number of bytes actually received.
- record-send** *session array* [Scheme Procedure]
 Send the record constituted by *array* through *session*.
- set-session-credentials!** *session cred* [Scheme Procedure]
 Use *cred* as *session*'s credentials.
- cipher-suite->string** *kx cipher mac* [Scheme Procedure]
 Return the name of the given cipher suite.
- set-session-default-export-priority!** *session* [Scheme Procedure]
 Have *session* use the default export priorities.
- set-session-default-priority!** *session* [Scheme Procedure]
 Have *session* use the default priorities.
- set-session-certificate-type-priority!** *session items* [Scheme Procedure]
 Use *items* (a list) as the list of preferred certificate-type for *session*.
- set-session-protocol-priority!** *session items* [Scheme Procedure]
 Use *items* (a list) as the list of preferred protocol for *session*.
- set-session-kx-priority!** *session items* [Scheme Procedure]
 Use *items* (a list) as the list of preferred kx for *session*.
- set-session-compression-method-priority!** *session items* [Scheme Procedure]
 Use *items* (a list) as the list of preferred compression-method for *session*.
- set-session-mac-priority!** *session items* [Scheme Procedure]
 Use *items* (a list) as the list of preferred mac for *session*.
- set-session-cipher-priority!** *session items* [Scheme Procedure]
 Use *items* (a list) as the list of preferred cipher for *session*.
- set-server-session-certificate-request!** *session request* [Scheme Procedure]
 Tell how *session*, a server-side session, should deal with certificate requests. *request* should be either `certificate-request/request` or `certificate-request/require`.

- session-our-certificate-chain** *session* [Scheme Procedure]
Return our certificate chain for *session* (as sent to the peer) in raw format (a u8vector). In the case of OpenPGP there is exactly one certificate. Return the empty list if no certificate was used.
- session-peer-certificate-chain** *session* [Scheme Procedure]
Return the a list of certificates in raw format (u8vectors) where the first one is the peer's certificate. In the case of OpenPGP, there is always exactly one certificate. In the case of X.509, subsequent certificates indicate form a certificate chain. Return the empty list if no certificate was sent.
- session-client-authentication-type** *session* [Scheme Procedure]
Return the client authentication type (a **credential-type** value) used in *session*.
- session-server-authentication-type** *session* [Scheme Procedure]
Return the server authentication type (a **credential-type** value) used in *session*.
- session-authentication-type** *session* [Scheme Procedure]
Return the authentication type (a **credential-type** value) used by *session*.
- session-protocol** *session* [Scheme Procedure]
Return the protocol used by *session*.
- session-certificate-type** *session* [Scheme Procedure]
Return *session*'s certificate type.
- session-compression-method** *session* [Scheme Procedure]
Return *session*'s compression method.
- session-mac** *session* [Scheme Procedure]
Return *session*'s MAC.
- session-kx** *session* [Scheme Procedure]
Return *session*'s kx.
- session-cipher** *session* [Scheme Procedure]
Return *session*'s cipher.
- alert-send** *session level alert* [Scheme Procedure]
Send *alert* via *session*.
- alert-get** *session* [Scheme Procedure]
Get an aleter from *session*.
- rehandshake** *session* [Scheme Procedure]
Perform a re-handshaking for *session*.
- handshake** *session* [Scheme Procedure]
Perform a handshake for *session*.
- bye** *session how* [Scheme Procedure]
Close *session* according to *how*.

<code>make-session</code>	<i>end</i>	[Scheme Procedure]
Return a new session for connection end <i>end</i> , either <code>connection-end/server</code> or <code>connection-end/client</code> .		
<code>gnutls-version</code>		[Scheme Procedure]
Return a string denoting the version number of the underlying GnuTLS library, e.g., "1.7.2".		
<code>x509-private-key?</code>	<i>obj</i>	[Scheme Procedure]
Return true if <i>obj</i> is of type <code>x509-private-key</code> .		
<code>x509-certificate?</code>	<i>obj</i>	[Scheme Procedure]
Return true if <i>obj</i> is of type <code>x509-certificate</code> .		
<code>psk-client-credentials?</code>	<i>obj</i>	[Scheme Procedure]
Return true if <i>obj</i> is of type <code>psk-client-credentials</code> .		
<code>psk-server-credentials?</code>	<i>obj</i>	[Scheme Procedure]
Return true if <i>obj</i> is of type <code>psk-server-credentials</code> .		
<code>srp-client-credentials?</code>	<i>obj</i>	[Scheme Procedure]
Return true if <i>obj</i> is of type <code>srp-client-credentials</code> .		
<code>srp-server-credentials?</code>	<i>obj</i>	[Scheme Procedure]
Return true if <i>obj</i> is of type <code>srp-server-credentials</code> .		
<code>certificate-credentials?</code>	<i>obj</i>	[Scheme Procedure]
Return true if <i>obj</i> is of type <code>certificate-credentials</code> .		
<code>rsa-parameters?</code>	<i>obj</i>	[Scheme Procedure]
Return true if <i>obj</i> is of type <code>rsa-parameters</code> .		
<code>dh-parameters?</code>	<i>obj</i>	[Scheme Procedure]
Return true if <i>obj</i> is of type <code>dh-parameters</code> .		
<code>anonymous-server-credentials?</code>	<i>obj</i>	[Scheme Procedure]
Return true if <i>obj</i> is of type <code>anonymous-server-credentials</code> .		
<code>anonymous-client-credentials?</code>	<i>obj</i>	[Scheme Procedure]
Return true if <i>obj</i> is of type <code>anonymous-client-credentials</code> .		
<code>session?</code>	<i>obj</i>	[Scheme Procedure]
Return true if <i>obj</i> is of type <code>session</code> .		
<code>error->string</code>	<i>enumval</i>	[Scheme Procedure]
Return a string describing <i>enumval</i> , a <code>error</code> value.		
<code>certificate-verify->string</code>	<i>enumval</i>	[Scheme Procedure]
Return a string describing <i>enumval</i> , a <code>certificate-verify</code> value.		
<code>key-usage->string</code>	<i>enumval</i>	[Scheme Procedure]
Return a string describing <i>enumval</i> , a <code>key-usage</code> value.		

<code>psk-key-format->string</code> <i>enumval</i>	[Scheme Procedure]
Return a string describing <i>enumval</i> , a <code>psk-key-format</code> value.	
<code>sign-algorithm->string</code> <i>enumval</i>	[Scheme Procedure]
Return a string describing <i>enumval</i> , a <code>sign-algorithm</code> value.	
<code>pk-algorithm->string</code> <i>enumval</i>	[Scheme Procedure]
Return a string describing <i>enumval</i> , a <code>pk-algorithm</code> value.	
<code>x509-subject-alternative-name->string</code> <i>enumval</i>	[Scheme Procedure]
Return a string describing <i>enumval</i> , a <code>x509-subject-alternative-name</code> value.	
<code>x509-certificate-format->string</code> <i>enumval</i>	[Scheme Procedure]
Return a string describing <i>enumval</i> , a <code>x509-certificate-format</code> value.	
<code>certificate-type->string</code> <i>enumval</i>	[Scheme Procedure]
Return a string describing <i>enumval</i> , a <code>certificate-type</code> value.	
<code>protocol->string</code> <i>enumval</i>	[Scheme Procedure]
Return a string describing <i>enumval</i> , a <code>protocol</code> value.	
<code>close-request->string</code> <i>enumval</i>	[Scheme Procedure]
Return a string describing <i>enumval</i> , a <code>close-request</code> value.	
<code>certificate-request->string</code> <i>enumval</i>	[Scheme Procedure]
Return a string describing <i>enumval</i> , a <code>certificate-request</code> value.	
<code>certificate-status->string</code> <i>enumval</i>	[Scheme Procedure]
Return a string describing <i>enumval</i> , a <code>certificate-status</code> value.	
<code>handshake-description->string</code> <i>enumval</i>	[Scheme Procedure]
Return a string describing <i>enumval</i> , a <code>handshake-description</code> value.	
<code>alert-description->string</code> <i>enumval</i>	[Scheme Procedure]
Return a string describing <i>enumval</i> , a <code>alert-description</code> value.	
<code>alert-level->string</code> <i>enumval</i>	[Scheme Procedure]
Return a string describing <i>enumval</i> , a <code>alert-level</code> value.	
<code>connection-end->string</code> <i>enumval</i>	[Scheme Procedure]
Return a string describing <i>enumval</i> , a <code>connection-end</code> value.	
<code>compression-method->string</code> <i>enumval</i>	[Scheme Procedure]
Return a string describing <i>enumval</i> , a <code>compression-method</code> value.	
<code>digest->string</code> <i>enumval</i>	[Scheme Procedure]
Return a string describing <i>enumval</i> , a <code>digest</code> value.	
<code>mac->string</code> <i>enumval</i>	[Scheme Procedure]
Return a string describing <i>enumval</i> , a <code>mac</code> value.	
<code>credentials->string</code> <i>enumval</i>	[Scheme Procedure]
Return a string describing <i>enumval</i> , a <code>credentials</code> value.	

`params->string enumval` [Scheme Procedure]
 Return a string describing *enumval*, a `params` value.

`kx->string enumval` [Scheme Procedure]
 Return a string describing *enumval*, a `kx` value.

`cipher->string enumval` [Scheme Procedure]
 Return a string describing *enumval*, a `cipher` value.

11.4.2 Extra Interface

This section lists the Scheme procedures exported by the `(gnutls extra)` module. This module is licenced under the GNU General Public Licence, version 3 or later.

`set-certificate-credentials-openpgp-keys! cred pub` [Scheme Procedure]
sec
 Use certificate *pub* and secret key *sec* in certificate credentials *cred*.

`openpgp-keyring-contains-key-id? keyring id` [Scheme Procedure]
 Return `#f` if key ID *id* is in *keyring*, `#f` otherwise.

`import-openpgp-keyring data format` [Scheme Procedure]
 Import *data* (a `u8vector`) according to *format* and return the imported keyring.

`openpgp-certificate-usage key` [Scheme Procedure]
 Return a list of values denoting the key usage of *key*.

`openpgp-certificate-version key` [Scheme Procedure]
 Return the version of the OpenPGP message format (RFC2440) honored by *key*.

`openpgp-certificate-algorithm key` [Scheme Procedure]
 Return two values: the certificate algorithm used by *key* and the number of bits used.

`openpgp-certificate-names key` [Scheme Procedure]
 Return the list of names for *key*.

`openpgp-certificate-name key index` [Scheme Procedure]
 Return the *index*th name of *key*.

`openpgp-certificate-fingerprint key` [Scheme Procedure]
 Return a new `u8vector` denoting the fingerprint of *key*.

`openpgp-certificate-fingerprint! key fpr` [Scheme Procedure]
 Store in *fpr* (a `u8vector`) the fingerprint of *key*. Return the number of bytes stored in *fpr*.

`openpgp-certificate-id! key id` [Scheme Procedure]
 Store the ID (an 8 byte sequence) of certificate *key* in *id* (a `u8vector`).

`openpgp-certificate-id key` [Scheme Procedure]
 Return the ID (an 8-element `u8vector`) of certificate *key*.

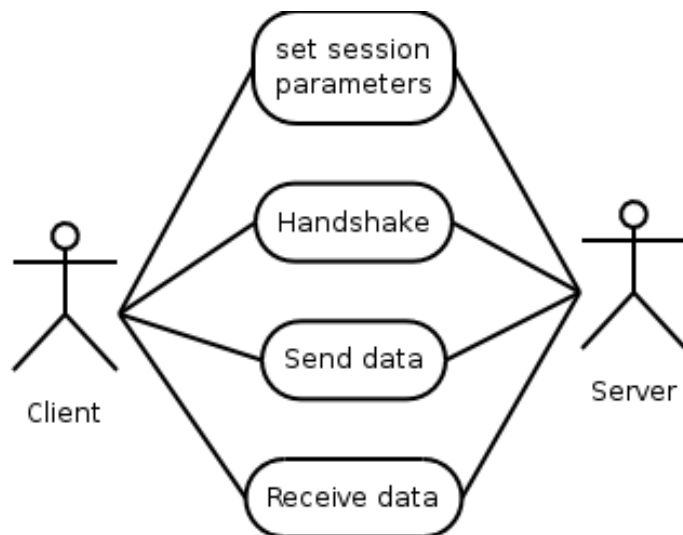
- `import-openpgp-private-key` *data format* [*pass*] [Scheme Procedure]
Return a new OpenPGP private key object resulting from the import of *data* (a uniform array) according to *format*. Optionally, a passphrase may be provided.
- `import-openpgp-certificate` *data format* [Scheme Procedure]
Return a new OpenPGP certificate object resulting from the import of *data* (a uniform array) according to *format*.
- `openpgp-certificate-format->string` *enumval* [Scheme Procedure]
Return a string describing *enumval*, a `openpgp-certificate-format` value.
- `openpgp-keyring?` *obj* [Scheme Procedure]
Return true if *obj* is of type `openpgp-keyring`.
- `openpgp-private-key?` *obj* [Scheme Procedure]
Return true if *obj* is of type `openpgp-private-key`.
- `openpgp-certificate?` *obj* [Scheme Procedure]
Return true if *obj* is of type `openpgp-certificate`.

12 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.

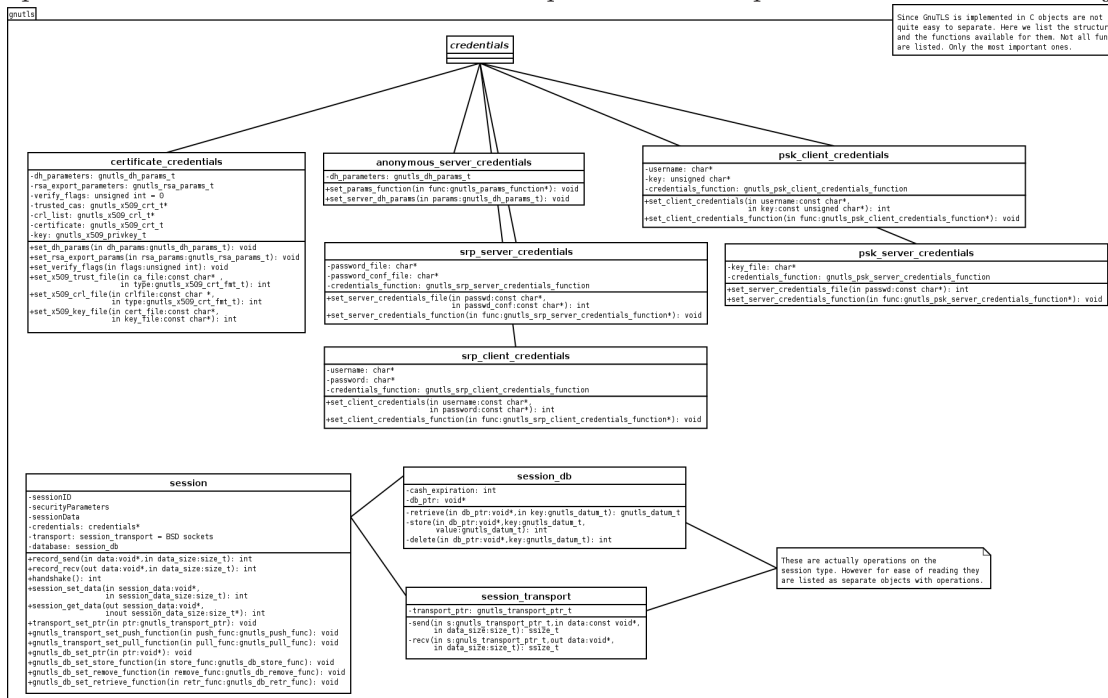
12.1 The TLS Protocol

The main needs for the TLS protocol to be used are shown in the image below.



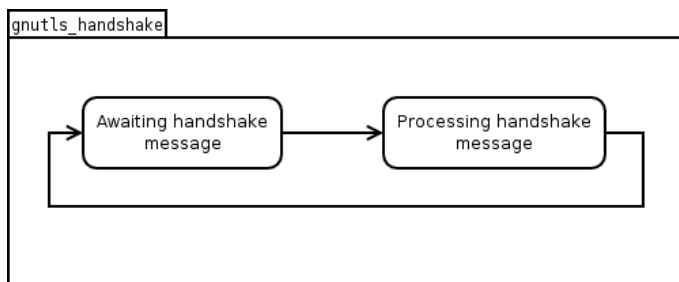
This is being accomplished by the following object diagram. Note that since GnuTLS is being developed in C object are just structures with attributes. The

operations listed are functions that require the first parameter to be that object.



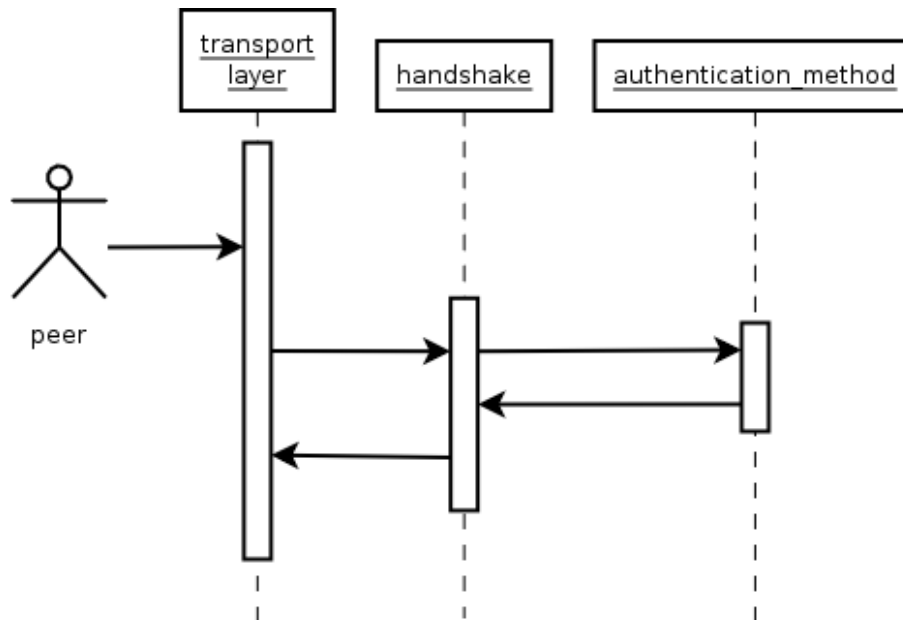
12.2 TLS Handshake Protocol

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 the following figure.



Also the way the input is processed varies per ciphersuite. Several implementations of the internal handlers are available and [\[gnutls_handshake\]](#), page 137 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.



12.3 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 only to implement the functions as seen in the figure below.

<i>mod_auth_st</i>
<pre> generate_server_certificate(in session:gnutls_session_t,out data:opaque**): int generate_client_certificate(in session:gnutls_session_t,out data:opaque**): int generate_server_kx(in session:gnutls_session_t,out data:opaque**): int generate_client_kx(in session:gnutls_session_t,out data:opaque**): int generate_client_cert_vrfy(in session:gnutls_session_t,out data:opaque**): int generate_server_certificate_request(in session:gnutls_session_t, out data:opaque**): int process_server_certificate(in session:gnutls_session_t,in data:opaque*, in data_size:size_t): int process_client_certificate(in session:gnutls_session_t,in data:opaque*, in data_size:size_t): int process_server_kx(in session:gnutls_session_t,in data:opaque*, in data_size:size_t): int process_client_kx(in session:gnutls_session_t,in data:opaque*, in data_size:size_t): int process_client_cert_vrfy(in session:gnutls_session_t,in data:opaque*, in data_size:size_t): int process_server_certificate_request(in session:gnutls_session_t, in data:opaque*,in data_size:size_t): int </pre>

The functions that need to be implemented are the ones responsible for interpreting 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.

12.4 TLS Extension Handling

As with authentication methods, the TLS extensions handlers can be implemented using the following interface.

<code>extensions_st</code>
<pre>ext_recv_func(in session:gnutls_session_t,in data:const opaque*, in data_size:size_t): int ext_send_func(in session:gnutls_session_t,out data:opaque*, in data_size:size_t): int</pre>

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`. After implementing these functions, together with the extension number they handle, they have to be registered in `gnutls_extensions.c` in the `_gnutls_extensions` structure.

12.4.1 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`.

1. Modify `configure.in` to add `--enable-foobar` or `--disable-foobar`.

Which to chose 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:

```
AC_MSG_CHECKING([whether to disable foobar support])
AC_ARG_ENABLE(foobar,
AS_HELP_STRING([--disable-foobar],
[disable foobar support]),
ac_enable_foobar=no)
if test x$ac_enable_foobar != xno; then
  AC_MSG_RESULT(no)
  AC_DEFINE(ENABLE_FOOBAR, 1, [enable foobar])
else
  ac_full=0
  AC_MSG_RESULT(yes)
```

¹ such as the `gnutls_certificate_credentials_t` structures

```

fi
AM_CONDITIONAL(ENABLE_FOOBAR, test "$ac_enable_foobar" != "no")

```

2. 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.

3. Add an entry to `_gnutls_extensions` in `gnutls_extensions.c`.

A typical entry would be:

```

#ifdef ENABLE_FOOBAR
    GNUTLS_EXTENSION_ENTRY (GNUTLS_EXTENSION_FOOBAR,
        _gnutls_foobar_recv_params,
        _gnutls_foobar_send_params),
#endif

```

The `GNUTLS_EXTENSION_FOOBAR` is the integer value you added to `gnutls_int.h` earlier. The two functions are new functions that you will need to implement, most likely you'll need to add an `#include "ext_foobar.h"` as well.

4. Add new files `ext_foobar.c` and `ext_foobar.h` that implements the extension.

The functions you are responsible to add are those mentioned in the previous step. As a starter, you could add this:

```

int
_gnutls_foobar_recv_params (gnutls_session_t session,
                           const opaque * data,
                           size_t data_size)
{
    return 0;
}

int
_gnutls_foobar_send_params (gnutls_session_t session,
                           opaque * data,
                           size_t _data_size)
{
    return 0;
}

```

The `_gnutls_foobar_recv_params` function is responsible for parsing incoming extension data (both in the client and server).

The `_gnutls_foobar_send_params` function is responsible for sending extension data (both in the client and server).

If you receive length fields that doesn'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 too. Return 0 on success.

The function typically store some information in the `session` variable for later usage. If you need to add new fields there, check `tls_ext_st` in `gnutls_int.h` and compare with existing TLS extension specific variables.

Recall that both the client and server both send and receives 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:

```
int
_gnutls_foobar_recv_params (gnutls_session_t session,
                           const opaque * data,
                           size_t data_size)
{
    if (session->security_parameters.entity == GNUTLS_CLIENT)
        return foobar_recv_client (session, data, data_size);
    else
        return foobar_recv_server (session, data, data_size);
}

int
_gnutls_foobar_send_params (gnutls_session_t session,
                           opaque * data,
                           size_t data_size)
{
    if (session->security_parameters.entity == GNUTLS_CLIENT)
        return foobar_send_client (session, data, data_size);
    else
        return foobar_send_server (session, data, data_size);
}
```

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 `Makefile.am` as well, for example:

```
if ENABLE_FOOBAR
OBJECTS += ext_foobar.c
HFILES += ext_foobar.h
endif
```

5. Add API functions to enable/disable the extension.

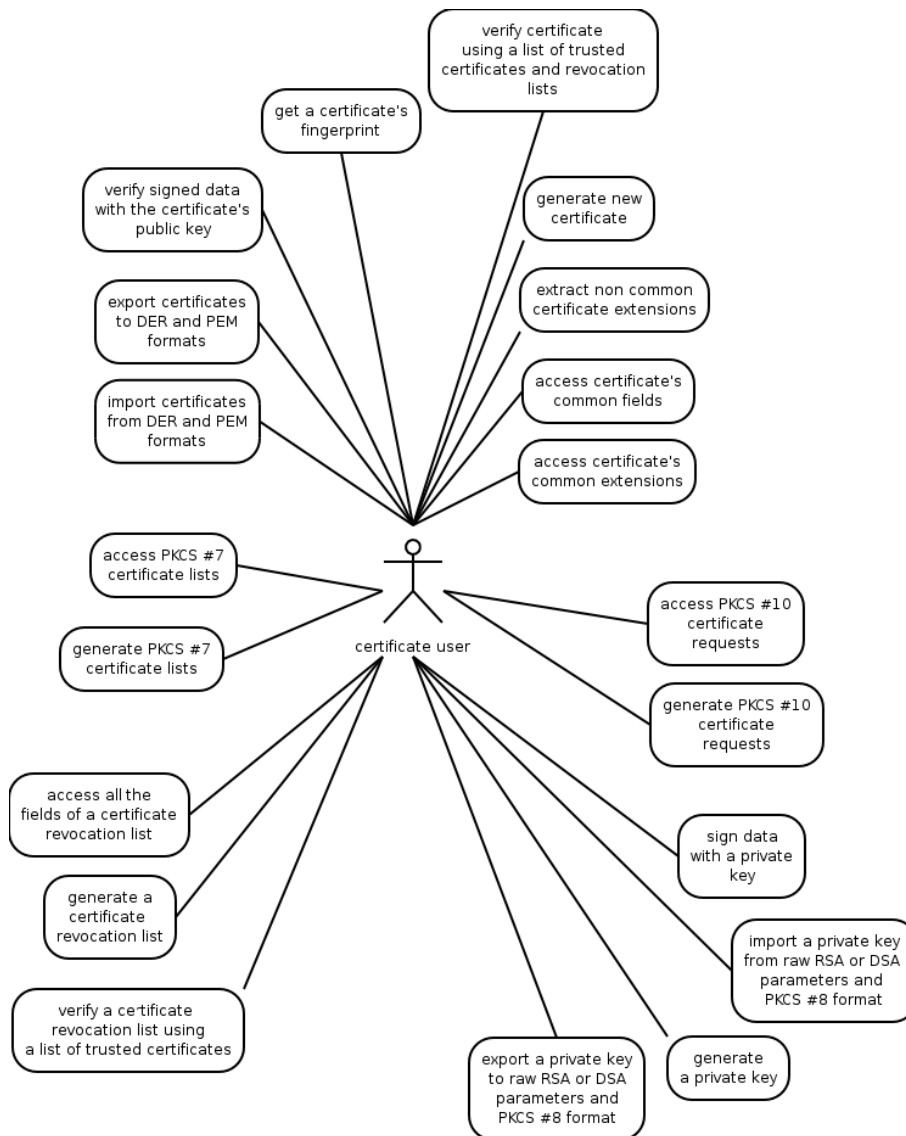
Normally the client will have one API to request use of the extension, and setting some extension specific data. The server will have one API to let the library know that it is willing to accept the extension, often this is implemented through a callback but it doesn't have to.

The APIs need to be added to `includes/gnutls/gnutls.h` or `includes/gnutls/extra.h` as appropriate. It is recommended that if you don't have a requirement to use the LGPL license for your extension, that you place your work under the GPL license and thus in the `libgnutls-extra` library.

You can implement the API function in the `ext_foobar.c` file, or if that file ends up becoming rather larger, add a `gnutls_foobar.c` file.

12.5 Certificate Handling

What is provided by the certificate handling functions is summarized in the following diagram.



Appendix A Copying Information

A.1 GNU Free Documentation License

Version 1.2, November 2002

Copyright © 2000,2001,2002 Free Software Foundation, Inc.
51 Franklin St, Fifth Floor, Boston, MA 02110-1301, USA

Everyone is permitted to copy and distribute verbatim copies
of this license document, but changing it is not allowed.

0. 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 non-commercially. 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.

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 for under this License. Any other attempt to copy, modify, sublicense or distribute the Document is void, and will automatically terminate your rights under this License. However, parties who have received copies, or rights, from you under this License will not have their licenses terminated so long as such parties remain in full compliance.

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.

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 (C)  year  your name.
Permission is granted to copy, distribute and/or modify this document
under the terms of the GNU Free Documentation License, Version 1.2
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.

A.2 GNU Lesser General Public License

Version 2.1, February 1999

Copyright © 1991, 1999 Free Software Foundation, Inc.
51 Franklin Street, Fifth Floor, Boston, MA 02110-1301, USA

Everyone is permitted to copy and distribute verbatim copies
of this license document, but changing it is not allowed.

[This is the first released version of the Lesser GPL. It also counts
as the successor of the GNU Library Public License, version 2, hence the
version number 2.1.]

Preamble

The licenses for most software are designed to take away your freedom to share and change it. By contrast, the GNU General Public Licenses are intended to guarantee your freedom to share and change free software—to make sure the software is free for all its users.

This license, the Lesser General Public License, applies to some specially designated software—typically libraries—of the Free Software Foundation and other authors who decide to use it. You can use it too, but we suggest you first think carefully about whether this license or the ordinary General Public License is the better strategy to use in any particular case, based on the explanations below.

When we speak of free software, we are referring to freedom of use, not price. Our General Public Licenses are designed to make sure that you have the freedom to distribute copies of free software (and charge for this service if you wish); that you receive source code or can get it if you want it; that you can change the software and use pieces of it in new free programs; and that you are informed that you can do these things.

To protect your rights, we need to make restrictions that forbid distributors to deny you these rights or to ask you to surrender these rights. These restrictions translate to certain responsibilities for you if you distribute copies of the library or if you modify it.

For example, if you distribute copies of the library, whether gratis or for a fee, you must give the recipients all the rights that we gave you. You must make sure that they, too, receive or can get the source code. If you link other code with the library, you must provide complete object files to the recipients, so that they can relink them with the library after making changes to the library and recompiling it. And you must show them these terms so they know their rights.

We protect your rights with a two-step method: (1) we copyright the library, and (2) we offer you this license, which gives you legal permission to copy, distribute and/or modify the library.

To protect each distributor, we want to make it very clear that there is no warranty for the free library. Also, if the library is modified by someone else and passed on, the recipients should know that what they have is not the original version, so that the original author's reputation will not be affected by problems that might be introduced by others.

Finally, software patents pose a constant threat to the existence of any free program. We wish to make sure that a company cannot effectively restrict the users of a free program by obtaining a restrictive license from a patent holder. Therefore, we insist that any patent license obtained for a version of the library must be consistent with the full freedom of use specified in this license.

Most GNU software, including some libraries, is covered by the ordinary GNU General Public License. This license, the GNU Lesser General Public License, applies to certain designated libraries, and is quite different from the ordinary General Public License. We use this license for certain libraries in order to permit linking those libraries into non-free programs.

When a program is linked with a library, whether statically or using a shared library, the combination of the two is legally speaking a combined work, a derivative of the original library. The ordinary General Public License therefore permits such linking only if the entire combination fits its criteria of freedom. The Lesser General Public License permits more lax criteria for linking other code with the library.

We call this license the *Lesser* General Public License because it does *Less* to protect the user's freedom than the ordinary General Public License. It also provides other free software developers *Less* of an advantage over competing non-free programs. These disadvantages are the reason we use the ordinary General Public License for many libraries. However, the Lesser license provides advantages in certain special circumstances.

For example, on rare occasions, there may be a special need to encourage the widest possible use of a certain library, so that it becomes a de-facto standard. To achieve this, non-free programs must be allowed to use the library. A more frequent case is that a free library does the same job as widely used non-free libraries. In this case, there is little to gain by limiting the free library to free software only, so we use the Lesser General Public License.

In other cases, permission to use a particular library in non-free programs enables a greater number of people to use a large body of free software. For example, permission to use the GNU C Library in non-free programs enables many more people to use the whole GNU operating system, as well as its variant, the GNU/Linux operating system.

Although the Lesser General Public License is Less protective of the users' freedom, it does ensure that the user of a program that is linked with the Library has the freedom and the wherewithal to run that program using a modified version of the Library.

The precise terms and conditions for copying, distribution and modification follow. Pay close attention to the difference between a "work based on the library" and a "work that uses the library". The former contains code derived from the library, whereas the latter must be combined with the library in order to run.

TERMS AND CONDITIONS FOR COPYING, DISTRIBUTION AND MODIFICATION

0. This License Agreement applies to any software library or other program which contains a notice placed by the copyright holder or other authorized party saying it may be distributed under the terms of this Lesser General Public License (also called "this License"). Each licensee is addressed as "you".

A "library" means a collection of software functions and/or data prepared so as to be conveniently linked with application programs (which use some of those functions and data) to form executables.

The "Library", below, refers to any such software library or work which has been distributed under these terms. A "work based on the Library" means either the Library or any derivative work under copyright law: that is to say, a work containing the Library or a portion of it, either verbatim or with modifications and/or translated straightforwardly into another language. (Hereinafter, translation is included without limitation in the term "modification".)

"Source code" for a work means the preferred form of the work for making modifications to it. For a library, complete source code means all the source code for all modules it contains, plus any associated interface definition files, plus the scripts used to control compilation and installation of the library.

Activities other than copying, distribution and modification are not covered by this License; they are outside its scope. The act of running a program using the Library is not restricted, and output from such a program is covered only if its contents constitute a work based on the Library (independent of the use of the Library in a tool for writing it). Whether that is true depends on what the Library does and what the program that uses the Library does.

1. You may copy and distribute verbatim copies of the Library's complete source code as you receive it, in any medium, provided that you conspicuously and appropriately publish on each copy an appropriate copyright notice and disclaimer of warranty; keep intact all the notices that refer to this License and to the absence of any warranty; and distribute a copy of this License along with the Library.

You may charge a fee for the physical act of transferring a copy, and you may at your option offer warranty protection in exchange for a fee.

2. You may modify your copy or copies of the Library or any portion of it, thus forming a work based on the Library, and copy and distribute such modifications or work under the terms of Section 1 above, provided that you also meet all of these conditions:
 - a. The modified work must itself be a software library.

- b. You must cause the files modified to carry prominent notices stating that you changed the files and the date of any change.
- c. You must cause the whole of the work to be licensed at no charge to all third parties under the terms of this License.
- d. If a facility in the modified Library refers to a function or a table of data to be supplied by an application program that uses the facility, other than as an argument passed when the facility is invoked, then you must make a good faith effort to ensure that, in the event an application does not supply such function or table, the facility still operates, and performs whatever part of its purpose remains meaningful.

(For example, a function in a library to compute square roots has a purpose that is entirely well-defined independent of the application. Therefore, Subsection 2d requires that any application-supplied function or table used by this function must be optional: if the application does not supply it, the square root function must still compute square roots.)

These requirements apply to the modified work as a whole. If identifiable sections of that work are not derived from the Library, and can be reasonably considered independent and separate works in themselves, then this License, and its terms, do not apply to those sections when you distribute them as separate works. But when you distribute the same sections as part of a whole which is a work based on the Library, the distribution of the whole must be on the terms of this License, whose permissions for other licensees extend to the entire whole, and thus to each and every part regardless of who wrote it.

Thus, it is not the intent of this section to claim rights or contest your rights to work written entirely by you; rather, the intent is to exercise the right to control the distribution of derivative or collective works based on the Library.

In addition, mere aggregation of another work not based on the Library with the Library (or with a work based on the Library) on a volume of a storage or distribution medium does not bring the other work under the scope of this License.

- 3. You may opt to apply the terms of the ordinary GNU General Public License instead of this License to a given copy of the Library. To do this, you must alter all the notices that refer to this License, so that they refer to the ordinary GNU General Public License, version 2, instead of to this License. (If a newer version than version 2 of the ordinary GNU General Public License has appeared, then you can specify that version instead if you wish.) Do not make any other change in these notices.

Once this change is made in a given copy, it is irreversible for that copy, so the ordinary GNU General Public License applies to all subsequent copies and derivative works made from that copy.

This option is useful when you wish to copy part of the code of the Library into a program that is not a library.

- 4. You may copy and distribute the Library (or a portion or derivative of it, under Section 2) in object code or executable form under the terms of Sections 1 and 2 above provided that you accompany it with the complete corresponding machine-readable source code, which must be distributed under the terms of Sections 1 and 2 above on a medium customarily used for software interchange.

If distribution of object code is made by offering access to copy from a designated place, then offering equivalent access to copy the source code from the same place satisfies the requirement to distribute the source code, even though third parties are not compelled to copy the source along with the object code.

5. A program that contains no derivative of any portion of the Library, but is designed to work with the Library by being compiled or linked with it, is called a “work that uses the Library”. Such a work, in isolation, is not a derivative work of the Library, and therefore falls outside the scope of this License.

However, linking a “work that uses the Library” with the Library creates an executable that is a derivative of the Library (because it contains portions of the Library), rather than a “work that uses the library”. The executable is therefore covered by this License. Section 6 states terms for distribution of such executables.

When a “work that uses the Library” uses material from a header file that is part of the Library, the object code for the work may be a derivative work of the Library even though the source code is not. Whether this is true is especially significant if the work can be linked without the Library, or if the work is itself a library. The threshold for this to be true is not precisely defined by law.

If such an object file uses only numerical parameters, data structure layouts and accessors, and small macros and small inline functions (ten lines or less in length), then the use of the object file is unrestricted, regardless of whether it is legally a derivative work. (Executables containing this object code plus portions of the Library will still fall under Section 6.)

Otherwise, if the work is a derivative of the Library, you may distribute the object code for the work under the terms of Section 6. Any executables containing that work also fall under Section 6, whether or not they are linked directly with the Library itself.

6. As an exception to the Sections above, you may also combine or link a “work that uses the Library” with the Library to produce a work containing portions of the Library, and distribute that work under terms of your choice, provided that the terms permit modification of the work for the customer’s own use and reverse engineering for debugging such modifications.

You must give prominent notice with each copy of the work that the Library is used in it and that the Library and its use are covered by this License. You must supply a copy of this License. If the work during execution displays copyright notices, you must include the copyright notice for the Library among them, as well as a reference directing the user to the copy of this License. Also, you must do one of these things:

- a. Accompany the work with the complete corresponding machine-readable source code for the Library including whatever changes were used in the work (which must be distributed under Sections 1 and 2 above); and, if the work is an executable linked with the Library, with the complete machine-readable “work that uses the Library”, as object code and/or source code, so that the user can modify the Library and then relink to produce a modified executable containing the modified Library. (It is understood that the user who changes the contents of definitions files in the Library will not necessarily be able to recompile the application to use the modified definitions.)

- b. Use a suitable shared library mechanism for linking with the Library. A suitable mechanism is one that (1) uses at run time a copy of the library already present on the user's computer system, rather than copying library functions into the executable, and (2) will operate properly with a modified version of the library, if the user installs one, as long as the modified version is interface-compatible with the version that the work was made with.
- c. Accompany the work with a written offer, valid for at least three years, to give the same user the materials specified in Subsection 6a, above, for a charge no more than the cost of performing this distribution.
- d. If distribution of the work is made by offering access to copy from a designated place, offer equivalent access to copy the above specified materials from the same place.
- e. Verify that the user has already received a copy of these materials or that you have already sent this user a copy.

For an executable, the required form of the “work that uses the Library” must include any data and utility programs needed for reproducing the executable from it. However, as a special exception, the materials to be distributed need not include anything that is normally distributed (in either source or binary form) with the major components (compiler, kernel, and so on) of the operating system on which the executable runs, unless that component itself accompanies the executable.

It may happen that this requirement contradicts the license restrictions of other proprietary libraries that do not normally accompany the operating system. Such a contradiction means you cannot use both them and the Library together in an executable that you distribute.

- 7. You may place library facilities that are a work based on the Library side-by-side in a single library together with other library facilities not covered by this License, and distribute such a combined library, provided that the separate distribution of the work based on the Library and of the other library facilities is otherwise permitted, and provided that you do these two things:
 - a. Accompany the combined library with a copy of the same work based on the Library, uncombined with any other library facilities. This must be distributed under the terms of the Sections above.
 - b. Give prominent notice with the combined library of the fact that part of it is a work based on the Library, and explaining where to find the accompanying uncombined form of the same work.
- 8. You may not copy, modify, sublicense, link with, or distribute the Library except as expressly provided under this License. Any attempt otherwise to copy, modify, sublicense, link with, or distribute the Library is void, and will automatically terminate your rights under this License. However, parties who have received copies, or rights, from you under this License will not have their licenses terminated so long as such parties remain in full compliance.
- 9. You are not required to accept this License, since you have not signed it. However, nothing else grants you permission to modify or distribute the Library or its derivative works. These actions are prohibited by law if you do not accept this License. Therefore, by modifying or distributing the Library (or any work based on the Library), you

indicate your acceptance of this License to do so, and all its terms and conditions for copying, distributing or modifying the Library or works based on it.

10. Each time you redistribute the Library (or any work based on the Library), the recipient automatically receives a license from the original licensor to copy, distribute, link with or modify the Library subject to these terms and conditions. You may not impose any further restrictions on the recipients' exercise of the rights granted herein. You are not responsible for enforcing compliance by third parties with this License.
11. If, as a consequence of a court judgment or allegation of patent infringement or for any other reason (not limited to patent issues), conditions are imposed on you (whether by court order, agreement or otherwise) that contradict the conditions of this License, they do not excuse you from the conditions of this License. If you cannot distribute so as to satisfy simultaneously your obligations under this License and any other pertinent obligations, then as a consequence you may not distribute the Library at all. For example, if a patent license would not permit royalty-free redistribution of the Library by all those who receive copies directly or indirectly through you, then the only way you could satisfy both it and this License would be to refrain entirely from distribution of the Library.

If any portion of this section is held invalid or unenforceable under any particular circumstance, the balance of the section is intended to apply, and the section as a whole is intended to apply in other circumstances.

It is not the purpose of this section to induce you to infringe any patents or other property right claims or to contest validity of any such claims; this section has the sole purpose of protecting the integrity of the free software distribution system which is implemented by public license practices. Many people have made generous contributions to the wide range of software distributed through that system in reliance on consistent application of that system; it is up to the author/donor to decide if he or she is willing to distribute software through any other system and a licensee cannot impose that choice.

This section is intended to make thoroughly clear what is believed to be a consequence of the rest of this License.

12. If the distribution and/or use of the Library is restricted in certain countries either by patents or by copyrighted interfaces, the original copyright holder who places the Library under this License may add an explicit geographical distribution limitation excluding those countries, so that distribution is permitted only in or among countries not thus excluded. In such case, this License incorporates the limitation as if written in the body of this License.
13. The Free Software Foundation may publish revised and/or new versions of the Lesser General Public 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.

Each version is given a distinguishing version number. If the Library specifies a version number of this License which applies to it and "any later version", you have the option of following the terms and conditions either of that version or of any later version published by the Free Software Foundation. If the Library does not specify a license version number, you may choose any version ever published by the Free Software Foundation.

14. If you wish to incorporate parts of the Library into other free programs whose distribution conditions are incompatible with these, write to the author to ask for permission. For software which is copyrighted by the Free Software Foundation, write to the Free Software Foundation; we sometimes make exceptions for this. Our decision will be guided by the two goals of preserving the free status of all derivatives of our free software and of promoting the sharing and reuse of software generally.

NO WARRANTY

15. BECAUSE THE LIBRARY IS LICENSED FREE OF CHARGE, THERE IS NO WARRANTY FOR THE LIBRARY, TO THE EXTENT PERMITTED BY APPLICABLE LAW. EXCEPT WHEN OTHERWISE STATED IN WRITING THE COPYRIGHT HOLDERS AND/OR OTHER PARTIES PROVIDE THE LIBRARY “AS IS” WITHOUT WARRANTY OF ANY KIND, EITHER EXPRESSED OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. THE ENTIRE RISK AS TO THE QUALITY AND PERFORMANCE OF THE LIBRARY IS WITH YOU. SHOULD THE LIBRARY PROVE DEFECTIVE, YOU ASSUME THE COST OF ALL NECESSARY SERVICING, REPAIR OR CORRECTION.
16. IN NO EVENT UNLESS REQUIRED BY APPLICABLE LAW OR AGREED TO IN WRITING WILL ANY COPYRIGHT HOLDER, OR ANY OTHER PARTY WHO MAY MODIFY AND/OR REDISTRIBUTE THE LIBRARY AS PERMITTED ABOVE, BE LIABLE TO YOU FOR DAMAGES, INCLUDING ANY GENERAL, SPECIAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES ARISING OUT OF THE USE OR INABILITY TO USE THE LIBRARY (INCLUDING BUT NOT LIMITED TO LOSS OF DATA OR DATA BEING RENDERED INACCURATE OR LOSSES SUSTAINED BY YOU OR THIRD PARTIES OR A FAILURE OF THE LIBRARY TO OPERATE WITH ANY OTHER SOFTWARE), EVEN IF SUCH HOLDER OR OTHER PARTY HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

END OF TERMS AND CONDITIONS

How to Apply These Terms to Your New Libraries

If you develop a new library, and you want it to be of the greatest possible use to the public, we recommend making it free software that everyone can redistribute and change. You can do so by permitting redistribution under these terms (or, alternatively, under the terms of the ordinary General Public License).

To apply these terms, attach the following notices to the library. It is safest to attach them to the start of each source file to most effectively convey the exclusion of warranty; and each file should have at least the “copyright” line and a pointer to where the full notice is found.

```
one line to give the library's name and an idea of what it does.
Copyright (C) year  name of author
```

```
This library is free software; you can redistribute it and/or modify it
under the terms of the GNU Lesser General Public License as published by
the Free Software Foundation; either version 2.1 of the License, or (at
your option) any later version.
```

```
This library is distributed in the hope that it will be useful, but
WITHOUT ANY WARRANTY; without even the implied warranty of
MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU
Lesser General Public License for more details.
```

```
You should have received a copy of the GNU Lesser General Public
License along with this library; if not, write to the Free Software
Foundation, Inc., 51 Franklin Street, Fifth Floor, Boston, MA 02110-1301,
USA.
```

Also add information on how to contact you by electronic and paper mail.

You should also get your employer (if you work as a programmer) or your school, if any, to sign a “copyright disclaimer” for the library, if necessary. Here is a sample; alter the names:

```
Yoyodyne, Inc., hereby disclaims all copyright interest in the library
‘Frob’ (a library for tweaking knobs) written by James Random Hacker.
```

```
signature of Ty Coon, 1 April 1990
Ty Coon, President of Vice
```

That’s all there is to it!

A.3 GNU General Public License

Version 3, 29 June 2007

Copyright © 2007 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 GNU General Public License is a free, copyleft license for software and other kinds of works.

The licenses for most software and other practical works are designed to take away your freedom to share and change the works. By contrast, the GNU General Public License is

intended to guarantee your freedom to share and change all versions of a program—to make sure it remains free software for all its users. We, the Free Software Foundation, use the GNU General Public License for most of our software; it applies also to any other work released this way by its authors. You can apply it to your programs, too.

When we speak of free software, we are referring to freedom, not price. Our General Public Licenses are designed to make sure that you have the freedom to distribute copies of free software (and charge for them if you wish), that you receive source code or can get it if you want it, that you can change the software or use pieces of it in new free programs, and that you know you can do these things.

To protect your rights, we need to prevent others from denying you these rights or asking you to surrender the rights. Therefore, you have certain responsibilities if you distribute copies of the software, or if you modify it: responsibilities to respect the freedom of others.

For example, if you distribute copies of such a program, whether gratis or for a fee, you must pass on to the recipients the same freedoms that you received. You must make sure that they, too, receive or can get the source code. And you must show them these terms so they know their rights.

Developers that use the GNU GPL protect your rights with two steps: (1) assert copyright on the software, and (2) offer you this License giving you legal permission to copy, distribute and/or modify it.

For the developers' and authors' protection, the GPL clearly explains that there is no warranty for this free software. For both users' and authors' sake, the GPL requires that modified versions be marked as changed, so that their problems will not be attributed erroneously to authors of previous versions.

Some devices are designed to deny users access to install or run modified versions of the software inside them, although the manufacturer can do so. This is fundamentally incompatible with the aim of protecting users' freedom to change the software. The systematic pattern of such abuse occurs in the area of products for individuals to use, which is precisely where it is most unacceptable. Therefore, we have designed this version of the GPL to prohibit the practice for those products. If such problems arise substantially in other domains, we stand ready to extend this provision to those domains in future versions of the GPL, as needed to protect the freedom of users.

Finally, every program is threatened constantly by software patents. States should not allow patents to restrict development and use of software on general-purpose computers, but in those that do, we wish to avoid the special danger that patents applied to a free program could make it effectively proprietary. To prevent this, the GPL assures that patents cannot be used to render the program non-free.

The precise terms and conditions for copying, distribution and modification follow.

TERMS AND CONDITIONS

0. Definitions.

“This License” refers to version 3 of the GNU General Public License.

“Copyright” also means copyright-like laws that apply to other kinds of works, such as semiconductor masks.

“The Program” refers to any copyrightable work licensed under this License. Each licensee is addressed as “you”. “Licensees” and “recipients” may be individuals or organizations.

To “modify” a work means to copy from or adapt all or part of the work in a fashion requiring copyright permission, other than the making of an exact copy. The resulting work is called a “modified version” of the earlier work or a work “based on” the earlier work.

A “covered work” means either the unmodified Program or a work based on the Program.

To “propagate” a work means to do anything with it that, without permission, would make you directly or secondarily liable for infringement under applicable copyright law, except executing it on a computer or modifying a private copy. Propagation includes copying, distribution (with or without modification), making available to the public, and in some countries other activities as well.

To “convey” a work means any kind of propagation that enables other parties to make or receive copies. Mere interaction with a user through a computer network, with no transfer of a copy, is not conveying.

An interactive user interface displays “Appropriate Legal Notices” to the extent that it includes a convenient and prominently visible feature that (1) displays an appropriate copyright notice, and (2) tells the user that there is no warranty for the work (except to the extent that warranties are provided), that licensees may convey the work under this License, and how to view a copy of this License. If the interface presents a list of user commands or options, such as a menu, a prominent item in the list meets this criterion.

1. Source Code.

The “source code” for a work means the preferred form of the work for making modifications to it. “Object code” means any non-source form of a work.

A “Standard Interface” means an interface that either is an official standard defined by a recognized standards body, or, in the case of interfaces specified for a particular programming language, one that is widely used among developers working in that language.

The “System Libraries” of an executable work include anything, other than the work as a whole, that (a) is included in the normal form of packaging a Major Component, but which is not part of that Major Component, and (b) serves only to enable use of the work with that Major Component, or to implement a Standard Interface for which an implementation is available to the public in source code form. A “Major Component”, in this context, means a major essential component (kernel, window system, and so on) of the specific operating system (if any) on which the executable work runs, or a compiler used to produce the work, or an object code interpreter used to run it.

The “Corresponding Source” for a work in object code form means all the source code needed to generate, install, and (for an executable work) run the object code and to modify the work, including scripts to control those activities. However, it does not include the work’s System Libraries, or general-purpose tools or generally available free programs which are used unmodified in performing those activities but which are not part of the work. For example, Corresponding Source includes interface definition

files associated with source files for the work, and the source code for shared libraries and dynamically linked subprograms that the work is specifically designed to require, such as by intimate data communication or control flow between those subprograms and other parts of the work.

The Corresponding Source need not include anything that users can regenerate automatically from other parts of the Corresponding Source.

The Corresponding Source for a work in source code form is that same work.

2. Basic Permissions.

All rights granted under this License are granted for the term of copyright on the Program, and are irrevocable provided the stated conditions are met. This License explicitly affirms your unlimited permission to run the unmodified Program. The output from running a covered work is covered by this License only if the output, given its content, constitutes a covered work. This License acknowledges your rights of fair use or other equivalent, as provided by copyright law.

You may make, run and propagate covered works that you do not convey, without conditions so long as your license otherwise remains in force. You may convey covered works to others for the sole purpose of having them make modifications exclusively for you, or provide you with facilities for running those works, provided that you comply with the terms of this License in conveying all material for which you do not control copyright. Those thus making or running the covered works for you must do so exclusively on your behalf, under your direction and control, on terms that prohibit them from making any copies of your copyrighted material outside their relationship with you.

Conveying under any other circumstances is permitted solely under the conditions stated below. Sublicensing is not allowed; section 10 makes it unnecessary.

3. Protecting Users' Legal Rights From Anti-Circumvention Law.

No covered work shall be deemed part of an effective technological measure under any applicable law fulfilling obligations under article 11 of the WIPO copyright treaty adopted on 20 December 1996, or similar laws prohibiting or restricting circumvention of such measures.

When you convey a covered work, you waive any legal power to forbid circumvention of technological measures to the extent such circumvention is effected by exercising rights under this License with respect to the covered work, and you disclaim any intention to limit operation or modification of the work as a means of enforcing, against the work's users, your or third parties' legal rights to forbid circumvention of technological measures.

4. Conveying Verbatim Copies.

You may convey verbatim copies of the Program's source code as you receive it, in any medium, provided that you conspicuously and appropriately publish on each copy an appropriate copyright notice; keep intact all notices stating that this License and any non-permissive terms added in accord with section 7 apply to the code; keep intact all notices of the absence of any warranty; and give all recipients a copy of this License along with the Program.

You may charge any price or no price for each copy that you convey, and you may offer support or warranty protection for a fee.

5. Conveying Modified Source Versions.

You may convey a work based on the Program, or the modifications to produce it from the Program, in the form of source code under the terms of section 4, provided that you also meet all of these conditions:

- a. The work must carry prominent notices stating that you modified it, and giving a relevant date.
- b. The work must carry prominent notices stating that it is released under this License and any conditions added under section 7. This requirement modifies the requirement in section 4 to “keep intact all notices”.
- c. You must license the entire work, as a whole, under this License to anyone who comes into possession of a copy. This License will therefore apply, along with any applicable section 7 additional terms, to the whole of the work, and all its parts, regardless of how they are packaged. This License gives no permission to license the work in any other way, but it does not invalidate such permission if you have separately received it.
- d. If the work has interactive user interfaces, each must display Appropriate Legal Notices; however, if the Program has interactive interfaces that do not display Appropriate Legal Notices, your work need not make them do so.

A compilation of a covered work with other separate and independent works, which are not by their nature extensions of the covered work, and which are not combined with it such as to form a larger program, in or on a volume of a storage or distribution medium, is called an “aggregate” if the compilation and its resulting copyright are not used to limit the access or legal rights of the compilation’s users beyond what the individual works permit. Inclusion of a covered work in an aggregate does not cause this License to apply to the other parts of the aggregate.

6. Conveying Non-Source Forms.

You may convey a covered work in object code form under the terms of sections 4 and 5, provided that you also convey the machine-readable Corresponding Source under the terms of this License, in one of these ways:

- a. Convey the object code in, or embodied in, a physical product (including a physical distribution medium), accompanied by the Corresponding Source fixed on a durable physical medium customarily used for software interchange.
- b. Convey the object code in, or embodied in, a physical product (including a physical distribution medium), accompanied by a written offer, valid for at least three years and valid for as long as you offer spare parts or customer support for that product model, to give anyone who possesses the object code either (1) a copy of the Corresponding Source for all the software in the product that is covered by this License, on a durable physical medium customarily used for software interchange, for a price no more than your reasonable cost of physically performing this conveying of source, or (2) access to copy the Corresponding Source from a network server at no charge.
- c. Convey individual copies of the object code with a copy of the written offer to provide the Corresponding Source. This alternative is allowed only occasionally and noncommercially, and only if you received the object code with such an offer, in accord with subsection 6b.

- d. Convey the object code by offering access from a designated place (gratis or for a charge), and offer equivalent access to the Corresponding Source in the same way through the same place at no further charge. You need not require recipients to copy the Corresponding Source along with the object code. If the place to copy the object code is a network server, the Corresponding Source may be on a different server (operated by you or a third party) that supports equivalent copying facilities, provided you maintain clear directions next to the object code saying where to find the Corresponding Source. Regardless of what server hosts the Corresponding Source, you remain obligated to ensure that it is available for as long as needed to satisfy these requirements.
- e. Convey the object code using peer-to-peer transmission, provided you inform other peers where the object code and Corresponding Source of the work are being offered to the general public at no charge under subsection 6d.

A separable portion of the object code, whose source code is excluded from the Corresponding Source as a System Library, need not be included in conveying the object code work.

A “User Product” is either (1) a “consumer product”, which means any tangible personal property which is normally used for personal, family, or household purposes, or (2) anything designed or sold for incorporation into a dwelling. In determining whether a product is a consumer product, doubtful cases shall be resolved in favor of coverage. For a particular product received by a particular user, “normally used” refers to a typical or common use of that class of product, regardless of the status of the particular user or of the way in which the particular user actually uses, or expects or is expected to use, the product. A product is a consumer product regardless of whether the product has substantial commercial, industrial or non-consumer uses, unless such uses represent the only significant mode of use of the product.

“Installation Information” for a User Product means any methods, procedures, authorization keys, or other information required to install and execute modified versions of a covered work in that User Product from a modified version of its Corresponding Source. The information must suffice to ensure that the continued functioning of the modified object code is in no case prevented or interfered with solely because modification has been made.

If you convey an object code work under this section in, or with, or specifically for use in, a User Product, and the conveying occurs as part of a transaction in which the right of possession and use of the User Product is transferred to the recipient in perpetuity or for a fixed term (regardless of how the transaction is characterized), the Corresponding Source conveyed under this section must be accompanied by the Installation Information. But this requirement does not apply if neither you nor any third party retains the ability to install modified object code on the User Product (for example, the work has been installed in ROM).

The requirement to provide Installation Information does not include a requirement to continue to provide support service, warranty, or updates for a work that has been modified or installed by the recipient, or for the User Product in which it has been modified or installed. Access to a network may be denied when the modification itself

materially and adversely affects the operation of the network or violates the rules and protocols for communication across the network.

Corresponding Source conveyed, and Installation Information provided, in accord with this section must be in a format that is publicly documented (and with an implementation available to the public in source code form), and must require no special password or key for unpacking, reading or copying.

7. Additional Terms.

“Additional permissions” are terms that supplement the terms of this License by making exceptions from one or more of its conditions. Additional permissions that are applicable to the entire Program shall be treated as though they were included in this License, to the extent that they are valid under applicable law. If additional permissions apply only to part of the Program, that part may be used separately under those permissions, but the entire Program remains governed by this License without regard to the additional permissions.

When you convey a copy of a covered work, you may at your option remove any additional permissions from that copy, or from any part of it. (Additional permissions may be written to require their own removal in certain cases when you modify the work.) You may place additional permissions on material, added by you to a covered work, for which you have or can give appropriate copyright permission.

Notwithstanding any other provision of this License, for material you add to a covered work, you may (if authorized by the copyright holders of that material) supplement the terms of this License with terms:

- a. Disclaiming warranty or limiting liability differently from the terms of sections 15 and 16 of this License; or
- b. Requiring preservation of specified reasonable legal notices or author attributions in that material or in the Appropriate Legal Notices displayed by works containing it; or
- c. Prohibiting misrepresentation of the origin of that material, or requiring that modified versions of such material be marked in reasonable ways as different from the original version; or
- d. Limiting the use for publicity purposes of names of licensors or authors of the material; or
- e. Declining to grant rights under trademark law for use of some trade names, trademarks, or service marks; or
- f. Requiring indemnification of licensors and authors of that material by anyone who conveys the material (or modified versions of it) with contractual assumptions of liability to the recipient, for any liability that these contractual assumptions directly impose on those licensors and authors.

All other non-permissive additional terms are considered “further restrictions” within the meaning of section 10. If the Program as you received it, or any part of it, contains a notice stating that it is governed by this License along with a term that is a further restriction, you may remove that term. If a license document contains a further restriction but permits relicensing or conveying under this License, you may add to a covered work material governed by the terms of that license document, provided that the further restriction does not survive such relicensing or conveying.

If you add terms to a covered work in accord with this section, you must place, in the relevant source files, a statement of the additional terms that apply to those files, or a notice indicating where to find the applicable terms.

Additional terms, permissive or non-permissive, may be stated in the form of a separately written license, or stated as exceptions; the above requirements apply either way.

8. Termination.

You may not propagate or modify a covered work except as expressly provided under this License. Any attempt otherwise to propagate or modify it is void, and will automatically terminate your rights under this License (including any patent licenses granted under the third paragraph of section 11).

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, you do not qualify to receive new licenses for the same material under section 10.

9. Acceptance Not Required for Having Copies.

You are not required to accept this License in order to receive or run a copy of the Program. Ancillary propagation of a covered work occurring solely as a consequence of using peer-to-peer transmission to receive a copy likewise does not require acceptance. However, nothing other than this License grants you permission to propagate or modify any covered work. These actions infringe copyright if you do not accept this License. Therefore, by modifying or propagating a covered work, you indicate your acceptance of this License to do so.

10. Automatic Licensing of Downstream Recipients.

Each time you convey a covered work, the recipient automatically receives a license from the original licensors, to run, modify and propagate that work, subject to this License. You are not responsible for enforcing compliance by third parties with this License.

An “entity transaction” is a transaction transferring control of an organization, or substantially all assets of one, or subdividing an organization, or merging organizations. If propagation of a covered work results from an entity transaction, each party to that transaction who receives a copy of the work also receives whatever licenses to the work the party’s predecessor in interest had or could give under the previous paragraph, plus a right to possession of the Corresponding Source of the work from the predecessor in interest, if the predecessor has it or can get it with reasonable efforts.

You may not impose any further restrictions on the exercise of the rights granted or affirmed under this License. For example, you may not impose a license fee, royalty, or other charge for exercise of rights granted under this License, and you may not initiate litigation (including a cross-claim or counterclaim in a lawsuit) alleging that any patent claim is infringed by making, using, selling, offering for sale, or importing the Program or any portion of it.

11. Patents.

A “contributor” is a copyright holder who authorizes use under this License of the Program or a work on which the Program is based. The work thus licensed is called the contributor’s “contributor version”.

A contributor’s “essential patent claims” are all patent claims owned or controlled by the contributor, whether already acquired or hereafter acquired, that would be infringed by some manner, permitted by this License, of making, using, or selling its contributor version, but do not include claims that would be infringed only as a consequence of further modification of the contributor version. For purposes of this definition, “control” includes the right to grant patent sublicenses in a manner consistent with the requirements of this License.

Each contributor grants you a non-exclusive, worldwide, royalty-free patent license under the contributor’s essential patent claims, to make, use, sell, offer for sale, import and otherwise run, modify and propagate the contents of its contributor version.

In the following three paragraphs, a “patent license” is any express agreement or commitment, however denominated, not to enforce a patent (such as an express permission to practice a patent or covenant not to sue for patent infringement). To “grant” such a patent license to a party means to make such an agreement or commitment not to enforce a patent against the party.

If you convey a covered work, knowingly relying on a patent license, and the Corresponding Source of the work is not available for anyone to copy, free of charge and under the terms of this License, through a publicly available network server or other readily accessible means, then you must either (1) cause the Corresponding Source to be so available, or (2) arrange to deprive yourself of the benefit of the patent license for this particular work, or (3) arrange, in a manner consistent with the requirements of this License, to extend the patent license to downstream recipients. “Knowingly relying” means you have actual knowledge that, but for the patent license, your conveying the covered work in a country, or your recipient’s use of the covered work in a country, would infringe one or more identifiable patents in that country that you have reason to believe are valid.

If, pursuant to or in connection with a single transaction or arrangement, you convey, or propagate by procuring conveyance of, a covered work, and grant a patent license to some of the parties receiving the covered work authorizing them to use, propagate, modify or convey a specific copy of the covered work, then the patent license you grant is automatically extended to all recipients of the covered work and works based on it.

A patent license is “discriminatory” if it does not include within the scope of its coverage, prohibits the exercise of, or is conditioned on the non-exercise of one or more of the rights that are specifically granted under this License. You may not convey a covered work if you are a party to an arrangement with a third party that is in the business of

distributing software, under which you make payment to the third party based on the extent of your activity of conveying the work, and under which the third party grants, to any of the parties who would receive the covered work from you, a discriminatory patent license (a) in connection with copies of the covered work conveyed by you (or copies made from those copies), or (b) primarily for and in connection with specific products or compilations that contain the covered work, unless you entered into that arrangement, or that patent license was granted, prior to 28 March 2007.

Nothing in this License shall be construed as excluding or limiting any implied license or other defenses to infringement that may otherwise be available to you under applicable patent law.

12. No Surrender of Others' Freedom.

If conditions are imposed on you (whether by court order, agreement or otherwise) that contradict the conditions of this License, they do not excuse you from the conditions of this License. If you cannot convey a covered work so as to satisfy simultaneously your obligations under this License and any other pertinent obligations, then as a consequence you may not convey it at all. For example, if you agree to terms that obligate you to collect a royalty for further conveying from those to whom you convey the Program, the only way you could satisfy both those terms and this License would be to refrain entirely from conveying the Program.

13. Use with the GNU Affero General Public License.

Notwithstanding any other provision of this License, you have permission to link or combine any covered work with a work licensed under version 3 of the GNU Affero General Public License into a single combined work, and to convey the resulting work. The terms of this License will continue to apply to the part which is the covered work, but the special requirements of the GNU Affero General Public License, section 13, concerning interaction through a network will apply to the combination as such.

14. Revised Versions of this License.

The Free Software Foundation may publish revised and/or new versions of the GNU General Public 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.

Each version is given a distinguishing version number. If the Program specifies that a certain numbered version of the GNU General Public License “or any later version” applies to it, you have the option of following the terms and conditions either of that numbered version or of any later version published by the Free Software Foundation. If the Program does not specify a version number of the GNU General Public License, you may choose any version ever published by the Free Software Foundation.

If the Program specifies that a proxy can decide which future versions of the GNU General Public License can be used, that proxy's public statement of acceptance of a version permanently authorizes you to choose that version for the Program.

Later license versions may give you additional or different permissions. However, no additional obligations are imposed on any author or copyright holder as a result of your choosing to follow a later version.

15. Disclaimer of Warranty.

THERE IS NO WARRANTY FOR THE PROGRAM, TO THE EXTENT PERMITTED BY APPLICABLE LAW. EXCEPT WHEN OTHERWISE STATED IN

WRITING THE COPYRIGHT HOLDERS AND/OR OTHER PARTIES PROVIDE THE PROGRAM “AS IS” WITHOUT WARRANTY OF ANY KIND, EITHER EXPRESSED OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. THE ENTIRE RISK AS TO THE QUALITY AND PERFORMANCE OF THE PROGRAM IS WITH YOU. SHOULD THE PROGRAM PROVE DEFECTIVE, YOU ASSUME THE COST OF ALL NECESSARY SERVICING, REPAIR OR CORRECTION.

16. Limitation of Liability.

IN NO EVENT UNLESS REQUIRED BY APPLICABLE LAW OR AGREED TO IN WRITING WILL ANY COPYRIGHT HOLDER, OR ANY OTHER PARTY WHO MODIFIES AND/OR CONVEYS THE PROGRAM AS PERMITTED ABOVE, BE LIABLE TO YOU FOR DAMAGES, INCLUDING ANY GENERAL, SPECIAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES ARISING OUT OF THE USE OR INABILITY TO USE THE PROGRAM (INCLUDING BUT NOT LIMITED TO LOSS OF DATA OR DATA BEING RENDERED INACCURATE OR LOSSES SUSTAINED BY YOU OR THIRD PARTIES OR A FAILURE OF THE PROGRAM TO OPERATE WITH ANY OTHER PROGRAMS), EVEN IF SUCH HOLDER OR OTHER PARTY HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

17. Interpretation of Sections 15 and 16.

If the disclaimer of warranty and limitation of liability provided above cannot be given local legal effect according to their terms, reviewing courts shall apply local law that most closely approximates an absolute waiver of all civil liability in connection with the Program, unless a warranty or assumption of liability accompanies a copy of the Program in return for a fee.

END OF TERMS AND CONDITIONS

How to Apply These Terms to Your New Programs

If you develop a new program, and you want it to be of the greatest possible use to the public, the best way to achieve this is to make it free software which everyone can redistribute and change under these terms.

To do so, attach the following notices to the program. It is safest to attach them to the start of each source file to most effectively state the exclusion of warranty; and each file should have at least the “copyright” line and a pointer to where the full notice is found.

one line to give the program's name and a brief idea of what it does.
Copyright (C) year name of author

This program is free software: you can redistribute it and/or modify it under the terms of the GNU General Public License as published by the Free Software Foundation, either version 3 of the License, or (at your option) any later version.

This program is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU

General Public License for more details.

You should have received a copy of the GNU General Public License along with this program. If not, see <http://www.gnu.org/licenses/>.

Also add information on how to contact you by electronic and paper mail.

If the program does terminal interaction, make it output a short notice like this when it starts in an interactive mode:

```
program Copyright (C) year name of author
This program comes with ABSOLUTELY NO WARRANTY; for details type 'show w'.
This is free software, and you are welcome to redistribute it
under certain conditions; type 'show c' for details.
```

The hypothetical commands ‘show w’ and ‘show c’ should show the appropriate parts of the General Public License. Of course, your program’s commands might be different; for a GUI interface, you would use an “about box”.

You should also get your employer (if you work as a programmer) or school, if any, to sign a “copyright disclaimer” for the program, if necessary. For more information on this, and how to apply and follow the GNU GPL, see <http://www.gnu.org/licenses/>.

The GNU General Public License does not permit incorporating your program into proprietary programs. If your program is a subroutine library, you may consider it more useful to permit linking proprietary applications with the library. If this is what you want to do, use the GNU Lesser General Public License instead of this License. But first, please read <http://www.gnu.org/philosophy/why-not-lgpl.html>.

Concept Index

A

Alert protocol 11
Anonymous authentication 18

C

Callback functions 7
Certificate authentication 22
Certificate requests 25
certtool 106
Ciphersuites 233
Client Certificate authentication 12
Compression algorithms 10
constant 236
Contributing 3

D

debug server 104
Digital signatures 27
Download 2

E

enumerate 236
Error codes 227
errors 238
Example programs 32
exceptions 238

F

FDL, GNU Free Documentation License 260
Function reference 111

G

gnutls-cli 101
gnutls-cli-debug 102
gnutls-error 238
GnuTLS-extra functions 213
gnutls-serv 103
GPL, GNU General Public License 274

H

Hacking 3
Handshake protocol 11
homogeneous vector 237
HTTPS server 104

I

Inner Application (TLS/IA) functions 221
Installation 2
Internal architecture 253

K

key sizes 14

L

LGPL, GNU Lesser General Public License ... 266
License, GNU GPL 274
License, GNU LGPL 266

M

Maximum fragment length 13

O

Opaque PRF Input 100
OpenPGP functions 214
OpenPGP Keys 16, 25
OpenPGP Server 79
OpenSSL 100

P

PCT 15
PKCS #10 25
PKCS #12 25
PSK authentication 19

R

Record protocol 9
Reporting Bugs 3
Resuming sessions 13

S

Server name indication 14
SRFI-4 237
SRP authentication 18
srptool 101
SSL 2 14
Symmetric encryption algorithms 10

T

TLS Extensions 13, 14
TLS Inner Application (TLS/IA) functions 221
TLS Layers 8
Transport protocol 9

V

Verifying certificate paths 24

X

X.509 certificates 16, 22
X.509 Functions 165

Function and Data Index

A

alert-description->string	250
alert-get	248
alert-level->string	250
alert-send	248
anonymous-client-credentials?	249
anonymous-server-credentials?	249

B

bye	248
-----------	-----

C

certificate-credentials?	249
certificate-request->string	250
certificate-status->string	250
certificate-type->string	250
certificate-verify->string	249
cipher->string	251
cipher-suite->string	247
close-request->string	250
compression-method->string	250
connection-end->string	250
credentials->string	250

D

dh-parameters?	249
digest->string	250

E

error->string	238, 249
---------------------	----------

G

gnutls-version	249
gnutls_alert_get	111
gnutls_alert_get_name	111
gnutls_alert_send	111
gnutls_alert_send_appropriate	111
gnutls_anon_allocate_client_credentials	112
gnutls_anon_allocate_server_credentials	112
gnutls_anon_free_client_credentials	112
gnutls_anon_free_server_credentials	112
gnutls_anon_set_params_function	113
gnutls_anon_set_server_dh_params	113
gnutls_anon_set_server_params_function	113
gnutls_auth_client_get_type	113
gnutls_auth_get_type	113

gnutls_auth_server_get_type	114
gnutls_bye	114
gnutls_certificate_activation_time_peers	114
gnutls_certificate_allocate_credentials	115
gnutls_certificate_client_get_request_status	115
gnutls_certificate_client_set_retrieve_function	115
gnutls_certificate_expiration_time_peers	115
gnutls_certificate_free_ca_names	116
gnutls_certificate_free_cas	116
gnutls_certificate_free_credentials	116
gnutls_certificate_free_crls	116
gnutls_certificate_free_keys	116
gnutls_certificate_get_ours	117
gnutls_certificate_get_peers	117
gnutls_certificate_send_x509_rdn_sequence	117
gnutls_certificate_server_set_request	117
gnutls_certificate_server_set_retrieve_function	118
gnutls_certificate_set_dh_params	118
gnutls_certificate_set_openpgp_key	215
gnutls_certificate_set_openpgp_key_file	214
gnutls_certificate_set_openpgp_key_mem	214
gnutls_certificate_set_openpgp_keyring_file	214
gnutls_certificate_set_openpgp_keyring_mem	214
gnutls_certificate_set_params_function	118
gnutls_certificate_set_rsa_export_params	118
gnutls_certificate_set_verify_flags	119
gnutls_certificate_set_verify_limits	119
gnutls_certificate_set_x509_crl	120
gnutls_certificate_set_x509_crl_file	119
gnutls_certificate_set_x509_crl_mem	119
gnutls_certificate_set_x509_key	121
gnutls_certificate_set_x509_key_file	120
gnutls_certificate_set_x509_key_mem	120
gnutls_certificate_set_x509_simple_pkcs12_file	121
gnutls_certificate_set_x509_trust	122
gnutls_certificate_set_x509_trust_file	122
gnutls_certificate_set_x509_trust_mem	122
gnutls_certificate_type_get	123
gnutls_certificate_type_get_id	123
gnutls_certificate_type_get_name	123
gnutls_certificate_type_list	123
gnutls_certificate_type_set_priority	123
gnutls_certificate_verify_flags	24

gnutls_certificate_verify_peers	124	gnutls_handshake_set_private_extensions	137
gnutls_certificate_verify_peers2	124	gnutls_hex_decode	138
gnutls_check_version	124	gnutls_hex_encode	138
gnutls_cipher_get	125	gnutls_ia_allocate_client_credentials ..	221
gnutls_cipher_get_id	125	gnutls_ia_allocate_server_credentials ..	222
gnutls_cipher_get_key_size	125	gnutls_ia_enable	222
gnutls_cipher_get_name	125	gnutls_ia_endphase_send	222
gnutls_cipher_list	125	gnutls_ia_extract_inner_secret	223
gnutls_cipher_set_priority	126	gnutls_ia_free_client_credentials	223
gnutls_cipher_suite_get_name	126	gnutls_ia_free_server_credentials	223
gnutls_cipher_suite_info	126	gnutls_ia_generate_challenge	223
gnutls_compression_get	127	gnutls_ia_get_client_avp_ptr	224
gnutls_compression_get_id	126	gnutls_ia_get_server_avp_ptr	224
gnutls_compression_get_name	127	gnutls_ia_handshake	224
gnutls_compression_list	127	gnutls_ia_handshake_p	224
gnutls_compression_set_priority	127	gnutls_ia_permute_inner_secret	224
gnutls_credentials_clear	127	gnutls_ia_recv	225
gnutls_credentials_set	128	gnutls_ia_send	225
gnutls_db_check_entry	128	gnutls_ia_set_client_avp_function	226
gnutls_db_get_ptr	128	gnutls_ia_set_client_avp_ptr	226
gnutls_db_remove_session	128	gnutls_ia_set_server_avp_function	226
gnutls_db_set_cache_expiration	129	gnutls_ia_set_server_avp_ptr	227
gnutls_db_set_ptr	129	gnutls_ia_verify_endphase	227
gnutls_db_set_remove_function	129	gnutls_init	138
gnutls_db_set_retrieve_function	129	gnutls_kx_get	139
gnutls_db_set_store_function	129	gnutls_kx_get_id	138
gnutls_deinit	130	gnutls_kx_get_name	139
gnutls_dh_get_group	130	gnutls_kx_list	139
gnutls_dh_get_peers_public_bits	130	gnutls_kx_set_priority	139
gnutls_dh_get_prime_bits	130	gnutls_mac_get	140
gnutls_dh_get_pubkey	131	gnutls_mac_get_id	139
gnutls_dh_get_secret_bits	131	gnutls_mac_get_key_size	139
gnutls_dh_params_cpy	131	gnutls_mac_get_name	140
gnutls_dh_params_deinit	131	gnutls_mac_list	140
gnutls_dh_params_export_pkcs3	131	gnutls_mac_set_priority	140
gnutls_dh_params_export_raw	132	gnutls_malloc	140
gnutls_dh_params_generate2	132	gnutls_openpgp_cert_check_hostname	215
gnutls_dh_params_import_pkcs3	132	gnutls_openpgp_cert_deinit	215
gnutls_dh_params_import_raw	133	gnutls_openpgp_cert_export	215
gnutls_dh_params_init	133	gnutls_openpgp_cert_get_creation_time ..	216
gnutls_dh_set_prime_bits	133	gnutls_openpgp_cert_get_expiration_time ..	216
gnutls_error_is_fatal	133	gnutls_openpgp_cert_get_fingerprint	216
gnutls_error_to_alert	133	gnutls_openpgp_cert_get_id	216
gnutls_extra_check_version	213	gnutls_openpgp_cert_get_key_usage	216
gnutls_fingerprint	134	gnutls_openpgp_cert_get_name	217
gnutls_free	134	gnutls_openpgp_cert_get_pk_algorithm	217
gnutls_global_deinit	134	gnutls_openpgp_cert_get_version	217
gnutls_global_init	134	gnutls_openpgp_cert_import	217
gnutls_global_init_extra	213	gnutls_openpgp_cert_init	218
gnutls_global_set_log_function	135	gnutls_openpgp_cert_verify_ring	218
gnutls_global_set_log_level	135	gnutls_openpgp_cert_verify_self	218
gnutls_global_set_mem_functions	135	gnutls_openpgp_keyring_check_id	218
gnutls_handshake	137	gnutls_openpgp_keyring_deinit	219
gnutls_handshake_get_last_in	136	gnutls_openpgp_keyring_import	219
gnutls_handshake_get_last_out	136	gnutls_openpgp_keyring_init	219
gnutls_handshake_set_max_packet_length ..	136	gnutls_openpgp_privkey_deinit	219
gnutls_handshake_set_post_client_hello_			
function	136		

<code>gnutls_openpgp_privkey_get_pk_algorithm</code>	219	<code>gnutls_protocol_get_name</code>	146
<code>gnutls_openpgp_privkey_import</code>	220	<code>gnutls_protocol_get_version</code>	146
<code>gnutls_openpgp_privkey_init</code>	220	<code>gnutls_protocol_list</code>	146
<code>gnutls_openpgp_privkey_sign_hash</code>	220	<code>gnutls_protocol_set_priority</code>	146
<code>gnutls_openpgp_send_cert</code>	140	<code>gnutls_psk_allocate_client_credentials</code>	146
<code>gnutls_openpgp_set_recv_key_function</code>	220	<code>gnutls_psk_allocate_server_credentials</code>	147
<code>gnutls_oprfi_enable_client</code>	141	<code>gnutls_psk_free_client_credentials</code>	147
<code>gnutls_oprfi_enable_server</code>	141	<code>gnutls_psk_free_server_credentials</code>	147
<code>gnutls_pem_base64_decode</code>	142	<code>gnutls_psk_server_get_username</code>	147
<code>gnutls_pem_base64_decode_alloc</code>	141	<code>gnutls_psk_set_client_credentials</code>	148
<code>gnutls_pem_base64_encode</code>	142	<code>gnutls_psk_set_client_credentials_function</code>	147
<code>gnutls_pem_base64_encode_alloc</code>	142	<code>gnutls_psk_set_params_function</code>	148
<code>gnutls_perror</code>	142	<code>gnutls_psk_set_server_credentials_file</code>	148
<code>gnutls_pk_algorithm_get_name</code>	143	<code>gnutls_psk_set_server_credentials_function</code>	148
<code>gnutls_pkcs12_bag_decrypt</code>	165	<code>gnutls_psk_set_server_dh_params</code>	149
<code>gnutls_pkcs12_bag_deinit</code>	165	<code>gnutls_psk_set_server_params_function</code>	149
<code>gnutls_pkcs12_bag_encrypt</code>	165	<code>gnutls_record_check_pending</code>	149
<code>gnutls_pkcs12_bag_get_count</code>	165	<code>gnutls_record_disable_padding</code>	149
<code>gnutls_pkcs12_bag_get_data</code>	166	<code>gnutls_record_get_direction</code>	149
<code>gnutls_pkcs12_bag_get_friendly_name</code>	166	<code>gnutls_record_get_max_size</code>	150
<code>gnutls_pkcs12_bag_get_key_id</code>	166	<code>gnutls_record_get_max_size</code>	150
<code>gnutls_pkcs12_bag_get_type</code>	166	<code>gnutls_record_recv</code>	150
<code>gnutls_pkcs12_bag_init</code>	167	<code>gnutls_record_send</code>	150
<code>gnutls_pkcs12_bag_set_crl</code>	167	<code>gnutls_record_set_max_size</code>	151
<code>gnutls_pkcs12_bag_set_cert</code>	167	<code>gnutls_rehandshake</code>	151
<code>gnutls_pkcs12_bag_set_data</code>	167	<code>gnutls_rsa_export_get_modulus_bits</code>	152
<code>gnutls_pkcs12_bag_set_friendly_name</code>	167	<code>gnutls_rsa_export_get_pubkey</code>	152
<code>gnutls_pkcs12_bag_set_key_id</code>	168	<code>gnutls_rsa_params_cpy</code>	152
<code>gnutls_pkcs12_deinit</code>	168	<code>gnutls_rsa_params_deinit</code>	152
<code>gnutls_pkcs12_export</code>	168	<code>gnutls_rsa_params_export_pkcs1</code>	152
<code>gnutls_pkcs12_generate_mac</code>	168	<code>gnutls_rsa_params_export_raw</code>	153
<code>gnutls_pkcs12_get_bag</code>	169	<code>gnutls_rsa_params_generate2</code>	153
<code>gnutls_pkcs12_import</code>	169	<code>gnutls_rsa_params_import_pkcs1</code>	153
<code>gnutls_pkcs12_init</code>	169	<code>gnutls_rsa_params_import_raw</code>	154
<code>gnutls_pkcs12_set_bag</code>	169	<code>gnutls_rsa_params_init</code>	154
<code>gnutls_pkcs12_verify_mac</code>	169	<code>gnutls_server_name_get</code>	154
<code>gnutls_pkcs7_deinit</code>	170	<code>gnutls_server_name_set</code>	155
<code>gnutls_pkcs7_delete_crl</code>	170	<code>gnutls_session_enable_compatibility_mode</code>	155
<code>gnutls_pkcs7_delete_cert</code>	170	<code>gnutls_session_get_client_random</code>	155
<code>gnutls_pkcs7_export</code>	170	<code>gnutls_session_get_data</code>	156
<code>gnutls_pkcs7_get_crl_count</code>	170	<code>gnutls_session_get_data2</code>	155
<code>gnutls_pkcs7_get_crl_raw</code>	171	<code>gnutls_session_get_id</code>	156
<code>gnutls_pkcs7_get_cert_count</code>	171	<code>gnutls_session_get_master_secret</code>	156
<code>gnutls_pkcs7_get_cert_raw</code>	171	<code>gnutls_session_get_ptr</code>	156
<code>gnutls_pkcs7_import</code>	171	<code>gnutls_session_get_server_random</code>	157
<code>gnutls_pkcs7_init</code>	172	<code>gnutls_session_is_resumed</code>	157
<code>gnutls_pkcs7_set_crl</code>	172	<code>gnutls_session_set_data</code>	157
<code>gnutls_pkcs7_set_crl_raw</code>	172	<code>gnutls_session_set_ptr</code>	157
<code>gnutls_pkcs7_set_cert</code>	172	<code>gnutls_set_default_export_priority</code>	157
<code>gnutls_pkcs7_set_cert_raw</code>	172	<code>gnutls_set_default_priority</code>	158
<code>gnutls_prf</code>	143	<code>gnutls_sign_algorithm_get_name</code>	158
<code>gnutls_prf_raw</code>	143	<code>gnutls_sign_callback_get</code>	158
<code>gnutls_priority_deinit</code>	144	<code>gnutls_sign_callback_set</code>	158
<code>gnutls_priority_init</code>	144	<code>gnutls_srp_allocate_client_credentials</code>	159
<code>gnutls_priority_set</code>	145	<code>gnutls_srp_allocate_server_credentials</code>	159
<code>gnutls_priority_set_direct</code>	145	<code>gnutls_srp_base64_decode</code>	159
<code>gnutls_protocol_get_id</code>	146		

gnutls_srp_base64_decode_alloc	159	gnutls_x509_crq_init	182
gnutls_srp_base64_encode	160	gnutls_x509_crq_set_attribute_by_oid....	182
gnutls_srp_base64_encode_alloc	160	gnutls_x509_crq_set_challenge_password..	182
gnutls_srp_free_client_credentials	160	gnutls_x509_crq_set_dn_by_oid	182
gnutls_srp_free_server_credentials	160	gnutls_x509_crq_set_key	183
gnutls_srp_server_get_username	160	gnutls_x509_crq_set_version	183
gnutls_srp_set_client_credentials	161	gnutls_x509_crq_sign	184
gnutls_srp_set_client_credentials_function		gnutls_x509_crq_sign2	183
.....	161	gnutls_x509 crt_check_hostname	184
gnutls_srp_set_server_credentials_file..	161	gnutls_x509 crt_check_issuer	184
gnutls_srp_set_server_credentials_function		gnutls_x509 crt_check_revocation	184
.....	162	gnutls_x509 crt_cpy_crl_dist_points	185
gnutls_srp_verifier	162	gnutls_x509 crt_deinit	185
gnutls_strerror	162	gnutls_x509 crt_export	185
gnutls_transport_get_ptr	163	gnutls_x509 crt_get_activation_time	185
gnutls_transport_get_ptr2	163	gnutls_x509 crt_get_authority_key_id	185
gnutls_transport_set_errno	163	gnutls_x509 crt_get_basic_constraints ..	186
gnutls_transport_set_global_errno	163	gnutls_x509 crt_get_ca_status	186
gnutls_transport_set_lowat	164	gnutls_x509 crt_get_crl_dist_points	186
gnutls_transport_set_ptr	164	gnutls_x509 crt_get_dn	188
gnutls_transport_set_ptr2	164	gnutls_x509 crt_get_dn_by_oid	187
gnutls_transport_set_pull_function	164	gnutls_x509 crt_get_dn_oid	188
gnutls_transport_set_push_function	165	gnutls_x509 crt_get_expiration_time	188
gnutls_x509_crl_check_issuer	172	gnutls_x509 crt_get_extension_by_oid	189
gnutls_x509_crl_deinit	173	gnutls_x509 crt_get_extension_data	189
gnutls_x509_crl_export	173	gnutls_x509 crt_get_extension_info	189
gnutls_x509_crl_get_crt_count	173	gnutls_x509 crt_get_extension_oid	190
gnutls_x509_crl_get_crt_serial	173	gnutls_x509 crt_get_fingerprint	190
gnutls_x509_crl_get_dn_oid	174	gnutls_x509 crt_get_issuer	192
gnutls_x509_crl_get_issuer_dn	174	gnutls_x509 crt_get_issuer_dn	191
gnutls_x509_crl_get_issuer_dn_by_oid	174	gnutls_x509 crt_get_issuer_dn_by_oid	190
gnutls_x509_crl_get_next_update	175	gnutls_x509 crt_get_issuer_dn_oid	191
gnutls_x509_crl_get_signature	175	gnutls_x509 crt_get_key_id	192
gnutls_x509_crl_get_signature_algorithm		gnutls_x509 crt_get_key_purpose_oid	192
.....	175	gnutls_x509 crt_get_key_usage	193
gnutls_x509_crl_get_this_update	175	gnutls_x509 crt_get_pk_algorithm	193
gnutls_x509_crl_get_version	176	gnutls_x509 crt_get_pk_dsa_raw	193
gnutls_x509_crl_import	176	gnutls_x509 crt_get_pk_rsa_raw	194
gnutls_x509_crl_init	176	gnutls_x509 crt_get_proxy	194
gnutls_x509_crl_print	176	gnutls_x509 crt_get_raw_dn	194
gnutls_x509_crl_set_crt	177	gnutls_x509 crt_get_raw_issuer_dn	194
gnutls_x509_crl_set_crt_serial	177	gnutls_x509 crt_get_serial	195
gnutls_x509_crl_set_next_update	177	gnutls_x509 crt_get_signature	195
gnutls_x509_crl_set_this_update	177	gnutls_x509 crt_get_signature_algorithm	
gnutls_x509_crl_set_version	177	195
gnutls_x509_crl_sign	178	gnutls_x509 crt_get_subject	197
gnutls_x509_crl_sign2	178	gnutls_x509 crt_get_subject_alt_name	196
gnutls_x509_crl_verify	178	gnutls_x509 crt_get_subject_alt_name2 ...	195
gnutls_x509_crq_deinit	179	gnutls_x509 crt_get_subject_alt_othername_	
gnutls_x509_crq_export	179	oid	196
gnutls_x509_crq_get_attribute_by_oid	179	gnutls_x509 crt_get_subject_key_id	197
gnutls_x509_crq_get_challenge_password ..	179	gnutls_x509 crt_get_version	197
gnutls_x509_crq_get_dn	181	gnutls_x509 crt_import	197
gnutls_x509_crq_get_dn_by_oid	180	gnutls_x509 crt_init	198
gnutls_x509_crq_get_dn_oid	180	gnutls_x509 crt_list_import	198
gnutls_x509_crq_get_pk_algorithm	181	gnutls_x509 crt_list_verify	198
gnutls_x509_crq_get_version	181	gnutls_x509 crt_print	199
gnutls_x509_crq_import	181	gnutls_x509 crt_set_activation_time	199

gnutls_x509_cert_set_authority_key_id..... 200
 gnutls_x509_cert_set_basic_constraints... 200
 gnutls_x509_cert_set_ca_status..... 200
 gnutls_x509_cert_set_crl_dist_points..... 200
 gnutls_x509_cert_set_crq..... 201
 gnutls_x509_cert_set_dn_by_oid..... 201
 gnutls_x509_cert_set_expiration_time..... 201
 gnutls_x509_cert_set_extension_by_oid..... 201
 gnutls_x509_cert_set_issuer_dn_by_oid..... 202
 gnutls_x509_cert_set_key..... 203
 gnutls_x509_cert_set_key_purpose_oid..... 202
 gnutls_x509_cert_set_key_usage..... 202
 gnutls_x509_cert_set_proxy..... 203
 gnutls_x509_cert_set_proxy_dn..... 203
 gnutls_x509_cert_set_serial..... 204
 gnutls_x509_cert_set_subject_alternative_
 name..... 204
 gnutls_x509_cert_set_subject_key_id..... 204
 gnutls_x509_cert_set_version..... 204
 gnutls_x509_cert_sign..... 205
 gnutls_x509_cert_sign2..... 205
 gnutls_x509_cert_verify..... 206
 gnutls_x509_cert_verify_data..... 205
 gnutls_x509_dn_get_rdn_ava..... 206
 gnutls_x509_dn_oid_known..... 206
 gnutls_x509_privkey_cpy..... 207
 gnutls_x509_privkey_deinit..... 207
 gnutls_x509_privkey_export..... 208
 gnutls_x509_privkey_export_dsa_raw..... 207
 gnutls_x509_privkey_export_pkcs8..... 207
 gnutls_x509_privkey_export_rsa_raw..... 208
 gnutls_x509_privkey_fix..... 209
 gnutls_x509_privkey_generate..... 209
 gnutls_x509_privkey_get_key_id..... 209
 gnutls_x509_privkey_get_pk_algorithm..... 209
 gnutls_x509_privkey_import..... 211
 gnutls_x509_privkey_import_dsa_raw..... 210
 gnutls_x509_privkey_import_pkcs8..... 210
 gnutls_x509_privkey_import_rsa_raw..... 210
 gnutls_x509_privkey_init..... 211
 gnutls_x509_privkey_sign_data..... 211
 gnutls_x509_privkey_sign_hash..... 212
 gnutls_x509_privkey_verify_data..... 212
 gnutls_x509_rdn_get..... 213
 gnutls_x509_rdn_get_by_oid..... 212
 gnutls_x509_rdn_get_oid..... 213

H

handshake..... 248
 handshake-description->string..... 250

I

import-openpgp-certificate..... 252
 import-openpgp-keyring..... 251
 import-openpgp-private-key..... 252
 import-x509-certificate..... 244

import-x509-private-key..... 244

K

key-usage->string..... 249
 kx->string..... 251

M

mac->string..... 250
 make-anonymous-client-credentials..... 246
 make-anonymous-server-credentials..... 246
 make-certificate-credentials..... 246
 make-dh-parameters..... 246
 make-psk-client-credentials..... 244
 make-psk-server-credentials..... 244
 make-rsa-parameters..... 237, 246
 make-session..... 249
 make-srp-client-credentials..... 244
 make-srp-server-credentials..... 245

O

openpgp-certificate-algorithm..... 251
 openpgp-certificate-fingerprint..... 251
 openpgp-certificate-fingerprint!..... 251
 openpgp-certificate-format->string..... 252
 openpgp-certificate-id..... 251
 openpgp-certificate-id!..... 251
 openpgp-certificate-name..... 251
 openpgp-certificate-names..... 251
 openpgp-certificate-usage..... 251
 openpgp-certificate-version..... 251
 openpgp-certificate?..... 252
 openpgp-keyring-contains-key-id?..... 251
 openpgp-keyring?..... 252
 openpgp-private-key?..... 252

P

params->string..... 251
 peer-certificate-status..... 245
 pk-algorithm->string..... 250
 pkcs1-export-rsa-parameters..... 237, 246
 pkcs1-import-rsa-parameters..... 246
 pkcs3-export-dh-parameters..... 246
 pkcs3-import-dh-parameters..... 246
 pkcs8-import-x509-private-key..... 244
 protocol->string..... 250
 psk-client-credentials?..... 249
 psk-key-format->string..... 250
 psk-server-credentials?..... 249

R

record-receive!..... 238, 247
 record-send..... 238, 247

rehandshake 248
 rsa-parameters? 249

S

server-session-psk-username 244
 server-session-srp-username 244
 session-authentication-type 248
 session-certificate-type 248
 session-cipher 236, 248
 session-client-authentication-type 248
 session-compression-method 248
 session-kx 248
 session-mac 248
 session-our-certificate-chain 248
 session-peer-certificate-chain 248
 session-protocol 248
 session-record-port 238, 247
 session-server-authentication-type 248
 session? 249
 set-anonymous-server-dh-parameters! 246
 set-certificate-credentials-dh-parameters!
 246
 set-certificate-credentials-openpgp-keys!
 251
 set-certificate-credentials-rsa-export-
 parameters! 246
 set-certificate-credentials-verify-flags!
 245
 set-certificate-credentials-verify-limits!
 245
 set-certificate-credentials-x509-crl-data!
 245
 set-certificate-credentials-x509-crl-file!
 245
 set-certificate-credentials-x509-key-data!
 245
 set-certificate-credentials-x509-key-files!
 246
 set-certificate-credentials-x509-keys! .. 245
 set-certificate-credentials-x509-trust-
 data! 245
 set-certificate-credentials-x509-trust-
 file! 245
 set-log-level! 243
 set-log-procedure! 243

set-psk-client-credentials! 244
 set-psk-server-credentials-file! 244
 set-server-session-certificate-request!
 247
 set-session-certificate-type-priority! .. 247
 set-session-cipher-priority! 247
 set-session-compression-method-priority!
 247
 set-session-credentials! 247
 set-session-default-export-priority! 247
 set-session-default-priority! 247
 set-session-dh-prime-bits! 246
 set-session-kx-priority! 247
 set-session-mac-priority! 247
 set-session-protocol-priority! 247
 set-session-transport-fd! 237, 247
 set-session-transport-port! 237, 247
 set-srp-client-credentials! 244
 set-srp-server-credentials-files! 245
 sign-algorithm->string 250
 srp-base64-decode 244
 srp-base64-encode 244
 srp-client-credentials? 249
 srp-server-credentials? 249

X

x509-certificate-authority-key-id 243
 x509-certificate-dn 244
 x509-certificate-dn-oid 243
 x509-certificate-format->string 250
 x509-certificate-issuer-dn 244
 x509-certificate-issuer-dn-oid 243
 x509-certificate-key-id 243
 x509-certificate-key-usage 243
 x509-certificate-matches-hostname? 243
 x509-certificate-public-key-algorithm ... 243
 x509-certificate-signature-algorithm 243
 x509-certificate-subject-alternative-name
 243
 x509-certificate-subject-key-id 243
 x509-certificate-version 243
 x509-certificate? 249
 x509-private-key? 249
 x509-subject-alternative-name->string ... 250

Bibliography

[SELKEY]

Arjen Lenstra and Eric Verheul, "Selecting Cryptographic Key Sizes", 2003, available from <http://www.win.tue.nl/~klenstra/key.pdf>.

[CBCATT]

Bodo Moeller, "Security of CBC Ciphersuites in SSL/TLS: Problems and Countermeasures", 2002, available from <http://www.openssl.org/~bodo/tls-cbc.txt>.

[GPGH]

Mike Ashley, "The GNU Privacy Handbook", 2002, available from <http://www.gnupg.org/gph/en/manual.pdf>.

[GUTPKI]

Peter Gutmann, "Everything you never wanted to know about PKI but were forced to find out", Available from <http://www.cs.auckland.ac.nz/~pgut001/>.

[RFC2246]

Tim Dierks and Christopher Allen, "The TLS Protocol Version 1.0", January 1999, Available from <http://kaizi.viagenie.qc.ca/ietf/rfc/rfc2246.txt>.

[RFC4346]

Tim Dierks and Eric Rescorla, "The TLS Protocol Version 1.1", March 2006, Available from <http://kaizi.viagenie.qc.ca/ietf/rfc/rfc4346.txt>.

[RFC2440]

Jon Callas, Lutz Donnerhacke, Hal Finney and Rodney Thayer, "OpenPGP Message Format", November 1998, Available from <http://kaizi.viagenie.qc.ca/ietf/rfc/rfc2440.txt>.

[RFC4211]

J. Schaad, "Internet X.509 Public Key Infrastructure Certificate Request Message Format (CRMF)", September 2005, Available from <http://kaizi.viagenie.qc.ca/ietf/rfc/rfc4211.txt>.

[RFC2817]

Rohit Khare and Scott Lawrence, "Upgrading to TLS Within HTTP/1.1", May 2000, Available from <http://kaizi.viagenie.qc.ca/ietf/rfc/rfc2817.txt>

[RFC2818]

Eric Rescola, "HTTP Over TLS", May 2000, Available from <http://kaizi.viagenie.qc.ca/ietf/rfc/rfc2818.txt>.

[RFC2945]

Tom Wu, "The SRP Authentication and Key Exchange System", September 2000, Available from <http://kaizi.viagenie.qc.ca/ietf/rfc/rfc2945.txt>.

[RFC2986]

Magnus Nystrom and Burt Kaliski, "PKCS 10 v1.7: Certification Request Syntax Specification", November 2000, Available from <http://kaizi.viagenie.qc.ca/ietf/rfc/rfc2986.txt>.

- [RFC3280] Russell Housley, Tim Polk, Warwick Ford and David Solo, "Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile", April 2002, Available from <http://kaizi.viagenie.qc.ca/ietf/rfc/rfc3280.txt>.
- [RFC3749] Scott Hollenbeck, "Transport Layer Security Protocol Compression Methods", May 2004, Available from <http://kaizi.viagenie.qc.ca/ietf/rfc/rfc3749.txt>.
- [RFC3820] Steven Tuecke, Von Welch, Doug Engert, Laura Pearlman, and Mary Thompson, "Internet X.509 Public Key Infrastructure (PKI) Proxy Certificate Profile", June 2004, available from <http://www.ietf.org/rfc3820>.
- [PKCS12] RSA Laboratories, "PKCS 12 v1.0: Personal Information Exchange Syntax", June 1999, Available from <http://www.rsa.com>.
- [RESCOLA] Eric Rescola, "SSL and TLS: Designing and Building Secure Systems", 2001
- [SSL3] Alan Freier, Philip Karlton and Paul Kocher, "The SSL Protocol Version 3.0", November 1996, Available from <http://wp.netscape.com/eng/ssl3/draft302.txt>.
- [STEVENS] Richard Stevens, "UNIX Network Programming, Volume 1", Prentice Hall PTR, January 1998
- [TLSEXT] Simon Blake-Wilson, Magnus Nystrom, David Hopwood, Jan Mikkelsen and Tim Wright, "Transport Layer Security (TLS) Extensions", June 2003, Available from <http://kaizi.viagenie.qc.ca/ietf/rfc/rfc3546.txt>.
- [TLSPGP] Nikos Mavrogiannopoulos, "Using OpenPGP keys for TLS authentication", April 2004, November 2007. Available from <http://kaizi.viagenie.qc.ca/ietf/rfc/rfc5081.txt>.
- [TLSSRP] David Taylor, Trevor Perrin, Tom Wu and Nikos Mavrogiannopoulos, "Using SRP for TLS Authentication", November 2007. Available from <http://kaizi.viagenie.qc.ca/ietf/rfc/rfc5054.txt>.
- [TLSPSK] Pasi Eronen and Hannes Tschofenig, "Pre-shared key Ciphersuites for TLS", December 2005, Available from <http://kaizi.viagenie.qc.ca/ietf/rfc/rfc4279.txt>.
- [TOMSRP] Tom Wu, "The Stanford SRP Authentication Project", Available at <http://srp.stanford.edu/>.
- [WEGER] Arjen Lenstra and Xiaoyun Wang and Benne de Weger, "Colliding X.509 Certificates", Cryptology ePrint Archive, Report 2005/067, Available at <http://eprint.iacr.org/>.