EndCryptor

Version 2.5.4 www.endcryptor.com. Product of Enternet Inc., Finland.
TIP: Use Bookmarks for navigation

Contents

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Overall description

Superior protection for the real world

EndCryptor protects old encrypted emails even if a hacker gets current encryption keys. Recently viruses (which were undetected for a decade) were found that stole encryption keys of known email encryption solutions – thus enabling the decryption of earlier messages. EndCryptor is designed to protect old messages and also to recover from attack – the attacker will lose the ability to decrypt new incoming messages.

Easy to use

No knowledge of cryptography is required. The user interface is similar to a typical email client. User's current email account is used to deliver the encrypted emails.

End to End Encryption

The email is encrypted at sender's computer and decrypted at receiver's computer. Only the true receiver can decrypt the email.

Quantum attack resistant

It may be possible that within 10-15 years there will be computers that can break current classical public keys. EndCryptor uses classical public keys and new quantum attack resistant public keys.

Patented technology, state of the art cipher and public keys

The protocol that provides the features has been patented in USA. The implementation of symmetric encryption and public keys uses publicly available source code developed by the scientists who designed the systems.

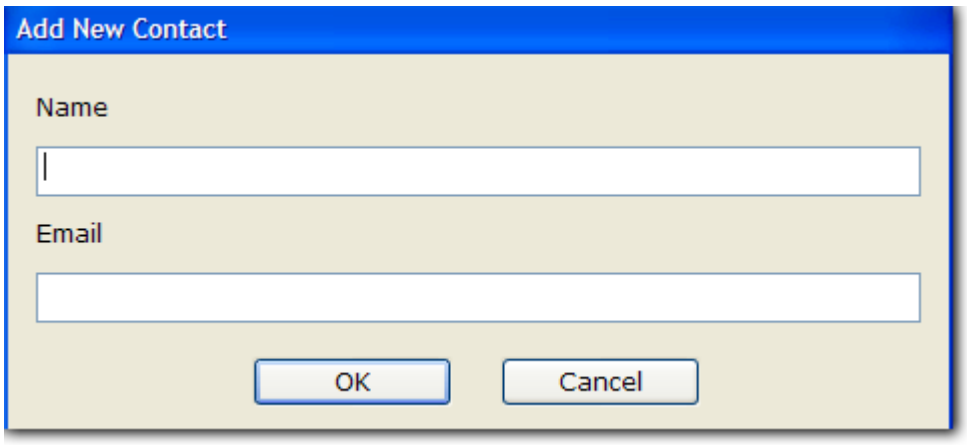
Quick start guide

Install EndCryptor. After sending one and receiving two verification emails you can start sending encrypted emails to other users of EndCryptor – this is an automated process. They also can send to you.

See the YouTube videos about installing and using EndCryptor:

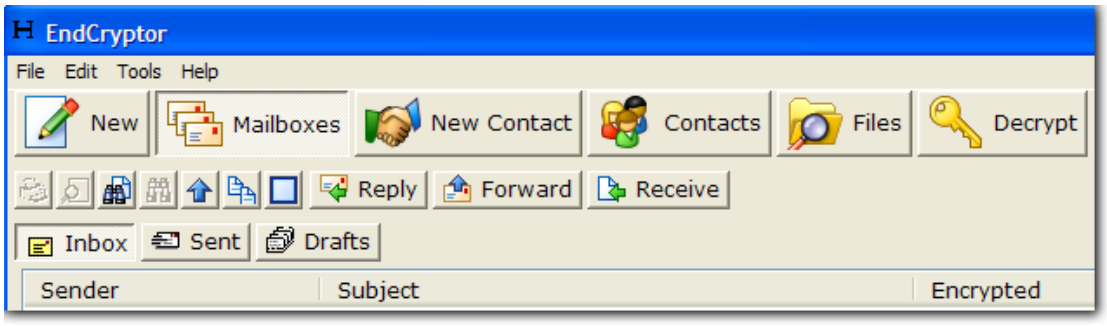
https://www.youtube.com/channel/UCAiIkQf2kRmcULg86GIQWRA

The verification emails check that you are in control of your email address. After verification your email address and long term public key are put into the Web Directory of EndCryptor. If someone wants to start sending encrypted emails to you he/she must know your email address – it is typed into EndCryptor and the Web Directory is searched for the public key associated with the email address.



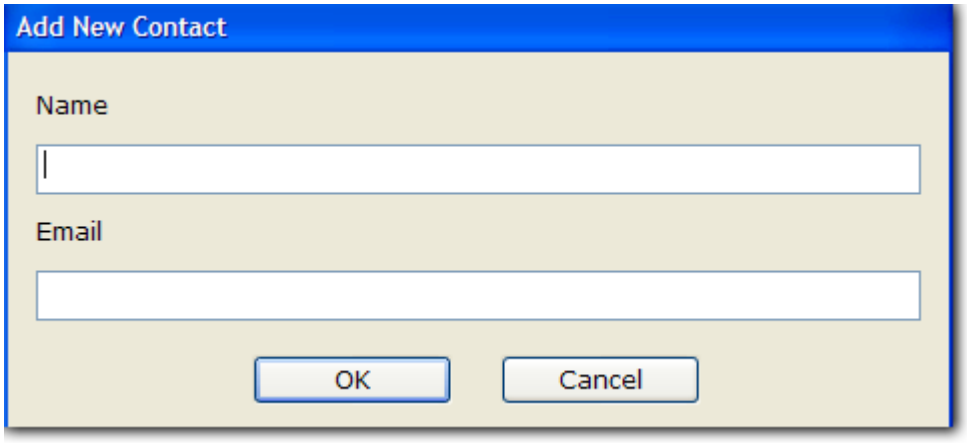
It is not mandatory to use the Web Directory. In this case the user must know the public key of a new contact.

Main window when new encrypted email has arrived:



Add new contacts

If you are using the default settings and using the Web Directory then the dialog for adding new contacts is the one below:

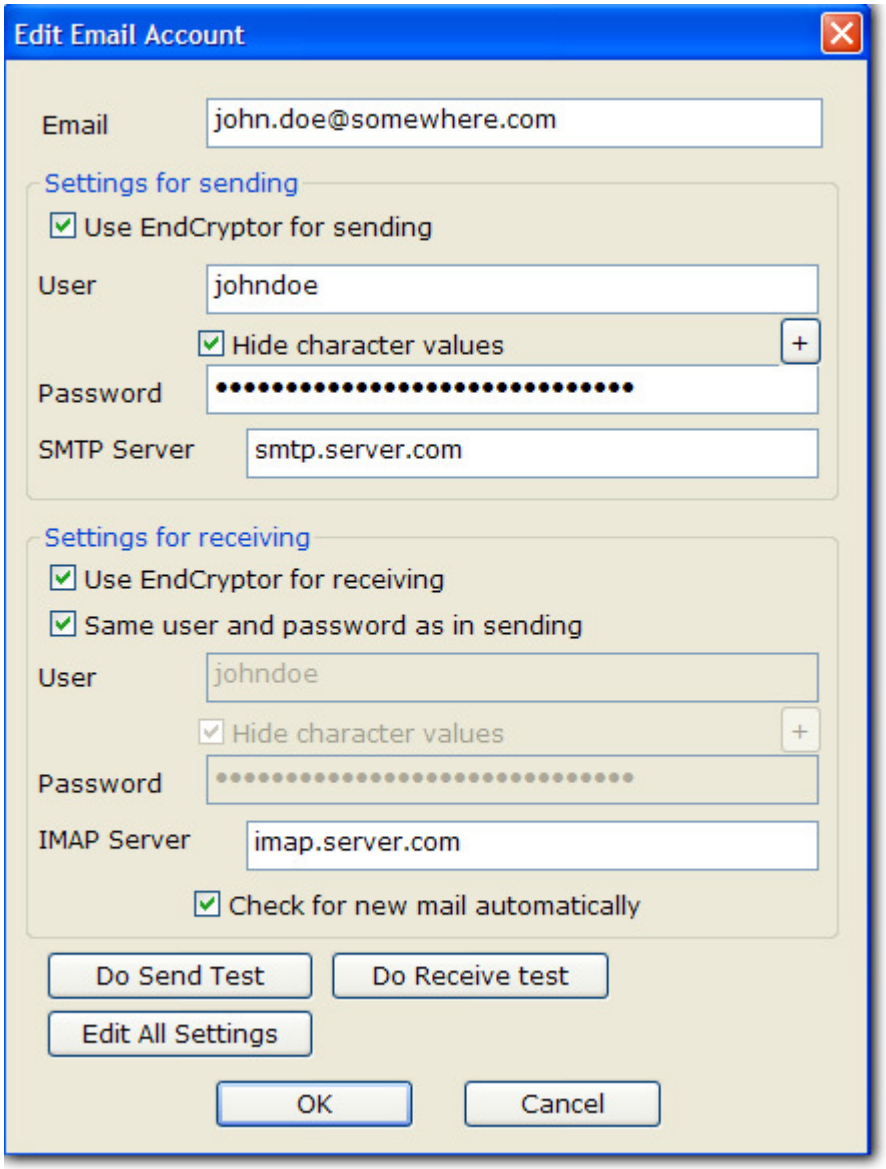


After pressing the ‘OK’ button the email given is used to search the Web Directory for this contact’s public key. The contact is ready for use after it is found.

If you receive an encrypted email from someone whose contact details you have not inserted before then EndCryptor will get the details automatically from the encrypted email. If the sender is using the Web Directory then the incoming email will also contain signed proof that the sender is the true holder of the public key related to contact’s email.

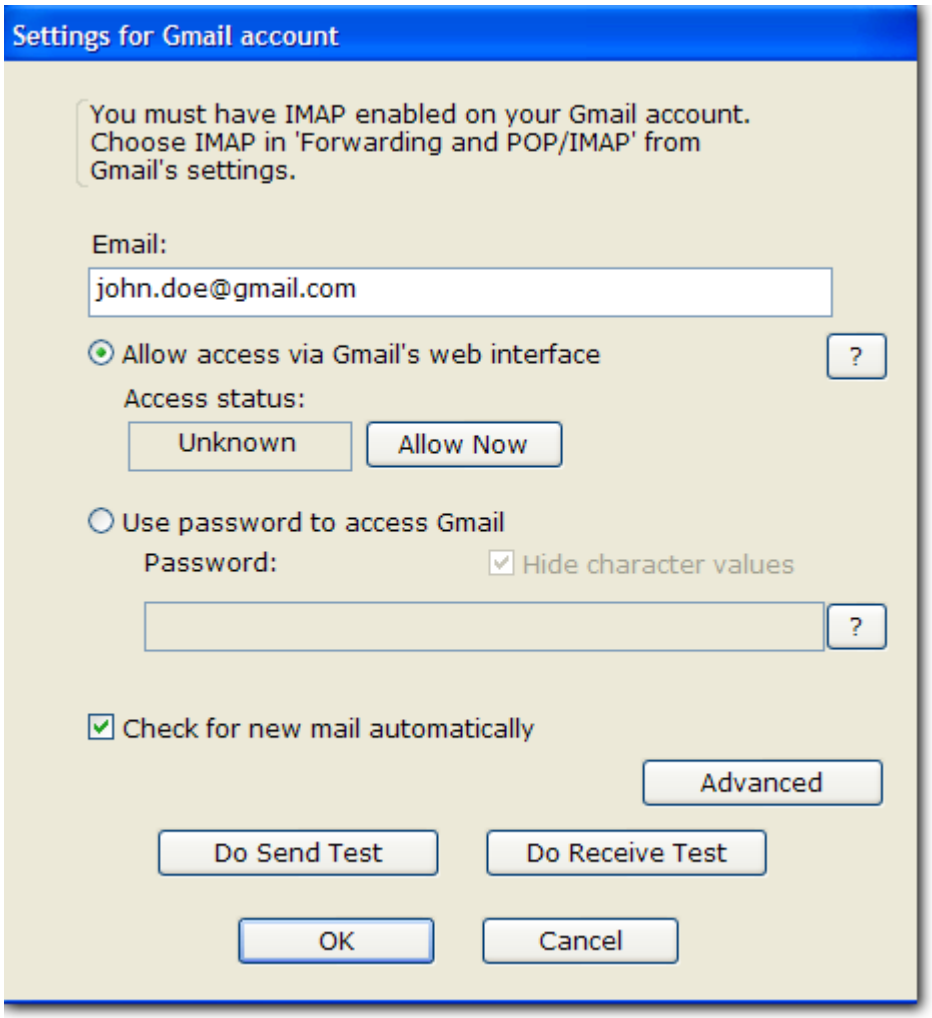
Send and receive

Below are the example settings when EndCryptor does the sending and receiving. Use Menu's Email Accounts.



To automatically receive new mail check the 'Check for new mail …' checkbox. After configuration the 'Receive' button's colors indicate the state of the connection: blue – no connection, green - connection, yellow - waiting (used only when 'Start a new session …' selection is checked in Edit All Settings). If the 'Check for new mail …' checkbox is not selected then receiving is done by pressing the 'Receive' button.

Definitions for a Gmail account:



Receiving using default email client:

If EndCryptor is not configured for receiving then use some of the methods listed below and press after that the 'Decrypt' button. The EndCryptor files (.ndd –files) are attachments in normal emails, do *one* of the following:

- *Double-click the attachment in email.* EndCryptor must be in its initial screen or not running.

- *Save the attachment and in Windows Explorer drag the file to the EndCryptor in the taskbar. Windows now activates EndCryptor, drop then the file into EndCryptor*, which must be in the initial screen.

- *Save the attachments and Click the files in EndCryptor*. After saving the attachments into a folder navigate using EndCryptor's Files button to this folder and select the just saved files by clicking them.

- *Save the attachment and Double-click the file in Windows Explorer*. EndCryptor must be in its initial screen or not running.

Send manually using the Save -button

From Tools->Options from the Send options select either the 'Manually saving to disk' or 'Choose at time of sending' option. This enables the showing of the Save button at the time of sending. Press the Save button to save the .ndd file into the Outgoing folder that can be accessed from Tools->Explore->Outgoing Folder. Send the file using the method of your choice. This option is for situations that consider an Internet connection a security risk. The encrypted message is moved to the actual sending machine e.g. by using a USB stick. The .ndd file can also be dragged from its mailbox by dragging it from its name on the right side of the header.

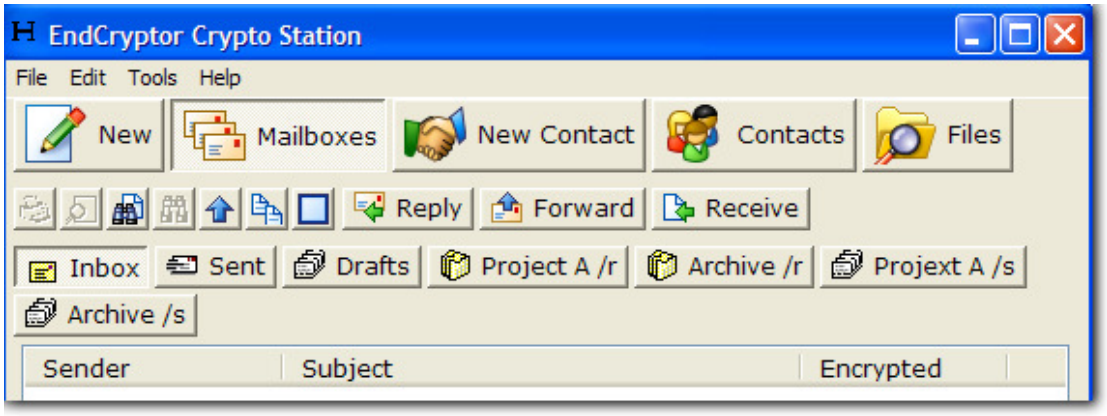
The outgoing .ndd file can be saved to user given folder. The folder is defined in Tools->Options.

Send using custom made program

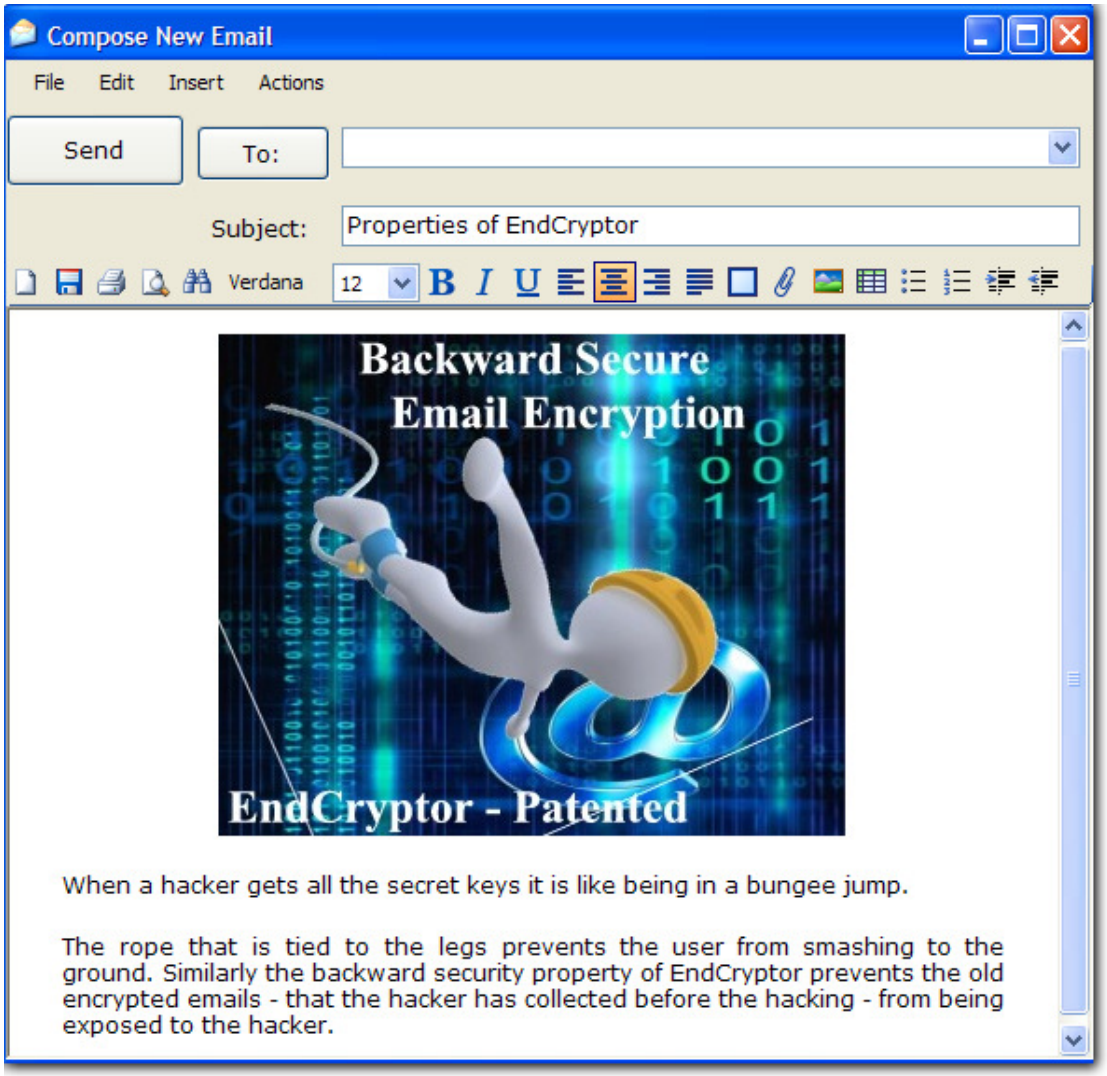
Define in Tools->Options a program that does the sending. EndCryptor gives the program as parameters the file to be sent and a file that contains the list of recipients.

Useful tips

It might be convenient to create temporary project based mailboxes whose contents can be moved to ‘Archive /r’ and ‘Archive /s’ mailboxes.



Example of email composing window:



Options

Signature text

This is the text inserted at the bottom of the message - typically user's name and company.

Show images

EndCryptor shows messages using the MSHTML rendering engine - a component that also Internet Explorer uses. The images of the message are delivered within the message. Sometimes a bug is found in some of the image processing libraries that the MSHTML uses. This could open up a potential possibility for an attack via a faulty and hostile image. When the image processing libraries are updated via the Windows Update feature the bugs are fixed. The MSHTML component will also be updated via the Windows Update feature and this will happen whether or not Internet Explorer is installed. If images are not shown and a message containing images is forwarded or replied then the images will be in the message and whether or not they are shown on the receiving end will depend on the receiver's setting of this option.

Decide if received attachments are stored in plaintext

Select the 'When receiving files do not store their plaintext copies' if upon receiving messages that contain files (attachments) only encrypted instances of received files are stored. The files in messages can be decrypted at any time later.

Use Bcc (Blind Carbon copy) field in email envelope

If this option is selected the outgoing email envelope will contain a Bcc: field. If the first item in the New Message's recipient list is a person then that person is placed into the email envelope's To: field and the other recipients into the Bcc: field. If the first item is not a person but a group then someone of the recipients is placed into the To: field. It depends on the email server used whether or not it places the Bcc: field into a specific recipient's envelope. Test how your email account works. The wanted behavior is such that there is only the To: field in every recipient's envelope when they receive it. This feature is used if EndCryptor is used for sending. If some other email client is used then the recipients are placed into the To: field.

Wipe method

Wiping a file means that the file is overwritten using the specified method and then deleted.

Amount of random characters added to messages

Required amount of random bytes are added to hide the length of the plaintext - encrypted messages have different sizes even if their decrypted content is the same.

Compression settings

Use the ‘Advanced compression’ button to define new file types that will not be compressed. This setting is important if large files of new file types that do not compress are sent. If the ‘Compress by default’ is not selected the message content and file attachments are not compressed. ‘Automatic detection of noncompressibility’ means that larger attachment files that are during compression found to be non-compressing are not compressed.

Send

To display only Send button select the ‘Using Internet’ option, to display only the Save button select the ‘Manually saving to disk’ and to display both buttons select the ‘Choose at time of sending’ option. To use custom made program define its path.

‘Save list of receivers when saving encrypted file that is to be sent manually’ setting is for such situations when a message is not sent by default email program by pressing the ‘Send now’ button but instead the ‘Save’ button is pressed.

The message is encrypted and stored in the folder for outgoing files (accessible from Menu Tools->Explore or by its name on the right side of the message’s header in the Sent Mailbox) or to the user given folder for saving. If this setting is selected then when the encrypted message has been stored then also a plaintext file containing the receiver(s) of this message is stored. These files have the same name, only the file endings differ: encrypted message has the ‘.ndd’ ending and the address list has the ‘.txt’ ending. The motivation for this is that otherwise the user may not remember the recipient(s) of the message (a message may also have more than one recipient). The contents of the .txt file can be pasted into the ‘To:’ field of an email program. The contents of the .txt file are in Unicode format.

The .txt file is also important in such situations where extreme security is required and EndCryptor and its encrypted security database are in a machine that is not connected to the network. When messages are encrypted they are saved together with the recipient list. From that folder the encrypted messages and the lists of their recipients are copied to the actual machine connected to the network.

If the ‘Using this custom made program’ option is selected then the specified program is called whenever sending happens. The parameter of the custom made program is one Unicode string containing the actual parameters, values is separated using the ‘*’ character, example:

*3*C:\ProgramData\Enternet\EndCryptor\files\outgoing_123_456_789.ndd

The numbers used:
1 – first initialization file, 2 – reply initialization file
3 – encrypted message, 4 – contact group file, in plaintext
5 – order of license(s), encrypted

Note: Contact group files are no longer used

To allow future changes design the program to allow more than two '*' separated values.

When the custom made program is called there is in the disk the file to be sent and another .txt file containing the list of recipients (using the conventions described above). The files are stored into EndCryptor's outgoing folder. The program doing the sending should delete (or move to another place) the created files after sending.

Monitor this folder for incoming .ndd files

EndCryptor starts a program 'efw.exe' - EndCryptor File Watcher - that asks for the operating system to inform it whenever a new .ndd ending file is created in this folder. The efw.exe' also scans the folder in 5 minute intervals. The new file is moved to EndCryptor's incoming folder and the user is alerted.

If the folder is in the cloud then the cloud software may not inform operating system and thus EndCryptor of new file creation. Also the cloud software may show the file being in the folder before it is totally written - this may cause problems when 'efw.exe' tries to move the file to incoming folder: if the cloud software allows the file to be moved before it has been totally written it will not decrypt, also the moved file is no more updated by the cloud because it is no more in the cloud folder.

When the 'efw.exe' is running there is a small icon in the notification area of the task bar.

A program writing a file to the monitored folder should write the file first as having .tmp ending. When the file has been written it must be renamed (i.e. moved) as having the .ndd ending. The 'efw.exe' will be notified by the operating system after the renaming.

Delete the sent encrypted email file from disk after sending

After successful sending the encrypted .ndd file is deleted, but not overwritten.

Delete files from 'processed' folder if they are older than 14 days

These files are encrypted .ndd messages that have been decrypted successfully. They cannot be decrypted again. The deletion is a deletion without any overwriting.

Publish My Public Key in Config folder

If this option is selected the long term public key is written to the Configuration folder whenever it is changed. The motivation is that it can be picked up from there by automated software and included in company's public key directory. See the chapter 'Automatic licensing and configuration'.

Tools

Email Accounts

Define here your email accounts. Only one of them is the active one that is used.

My Web Directory

Check that the values (your email and public key) are correct in the Web Directory. Remove all your data from the Web Directory.

My Public Key

View and copy your public key. Generate a new public key.

Options

See the Options chapter.

Backup Options

See the Backing up and restoring chapter.

Licensing

A license is either a license file or a license string. A license string is intended for one user only. A license file can be used to license many computers as defined in the order. Install a license from Tools->Licensing->Receive license. A license can also be automatically installed if it is placed into the Configuration folder. See the chapter 'Automatic licensing and configuration'.

Calculate Hash of File

The calculated value is a cryptographic checksum - use it to compare files.

Other way to do this is to use mouse's right click in Files and then select Hash Value.

Wipe All Plaintext Attachments

All files and subfolders in the folder **…EndCryptor_store** in a subfolder named: **pltxt_files** will be wiped and deleted. Warning: if you have edited files in these folders, your modifications will be lost. The attachments itself can be decrypted again from their encrypted versions.

Explore

This selection in Menu: Tools invokes the Windows Explorer either for the outgoing folder or the current folder of the Files.

In Windows XP the folder

C:\Documents and Settings\All Users\Application Data\Enternet\EndCryptor\files\

and in Vista, Windows 7 and 8 the folder

C:\ProgramData\Enternet\EndCryptor\files\

contains these subfolders:

Folder	Usage
erroneous	Received messages that were originally in incoming folder and produced errors during processing
incoming	Recently received new messages
outgoing	Messages you encrypted
processed	Received and properly processed messages that were originally in incoming folder

You may want to sometimes delete files from outgoing, processed and erroneous folders. If EndCryptor is used for sending then it can be configured to delete the just sent file from the Outgoing folder. Do not delete files from incoming folder unless there is some error situation that requires their moving from this folder.

Archiving Tools

The 'Check If Tampered' verifies if eml format exported messages have been changed after their export. The 'Extract File Identifier' extracts a string from an encrypted .ndd file that can be used to search the corresponding decrypted message from an email archiving solution. Read the 'Export messages for archiving' section for more detailed explanation.

The backed up files are encrypted/decrypted using Export Keys. Using the 'Manage Export Keys' and 'Manage Company Export Key' those keys can be generated and the password of the key files changed. Note that only the administrator of Company Export Key needs to use the 'Manage Company Export Key' selection. Other users should import the Company Export Key using the 'Manage Export Keys' selection. Read the chapter 'Backing up and exporting stored emails' for additional information.

View Received Certificates

If EndCryptor is configured for sending or receiving this involves receiving X509 certificates from email servers. The idea of the certificates is to enable the SSL/TLS encryption of the traffic from user's computer to the email server. The received certificates are stored and the number of times they are used is counted and their properties are shown. Certificates can be imported and exported to/from the collection of certificates. It can be specified which certificates are allowed to be received – if the certificate is one of the not-allowed ones the connection to the server is disconnected. If the user has selected the option to accept only allowed certificates and a new

certificate is received from the server then the user is prompted whether to accept the certificate or not. **This is a highly advanced option** and is motivated by the so-called **"compelled certificate creation attack"** or a hacking attack against some Certificate Authority. In those attacks some Certificate Authority has written a certificate of the email server to a wrong party or a hacker has gained the ability to write certificates in the name of the Certificate Authority. Note that some Certificate Authorities have stopped their business because of a successful hacking attack. The possible forgery of certificates is very annoying because the whole idea of certificates is that they can be trusted. To read more of these kinds of attacks see the Risks of SSL part of this document.

If the above mentioned attacks succeed and the SSL/TLS protection fails the already encrypted EndCryptor message that is an attachment in the email stays protected but the attacker may gain user's username and password to the email server. EndCryptor supports the SCRAM-SHA-1 authentication mechanism which gives some protection to the password even if the SSL/TLS protection fails.

By allowing only trusted certificates the user avoids this attack – if an attack occurs the user is informed of non-allowed and new certificates. The received discarded new certificate may however be such one of the true servers' certificates that the user has just not received before (if the server uses different certificates e.g. for different geographical IP addresses). Certificates have also expiration dates and a new one should be introduced by the server when the expiration day approaches. So the usage of the protection mechanism is not trivial.

The reader should be also aware that if the user uses some other email client - that does not have protection against this attack - to access the email server (which he will do to read/send the unencrypted emails) he may then become victim of the attack. Typically email clients don't have protection against this attack because the certificates are considered trustable.

Note that EndCryptor counts the number of times a certificate has been received. Even if the user has chosen not to use the protection option this number may help in identifying a certificate used in an attack. For example the user travels abroad and there falls victim to this attack. Later it is seen that one of the certificates has been used maybe only once!

Proxy Settings

If proxy is used EndCryptor directs email sending and receiving traffic to proxy. A proxy can exist in the local computer (address 127.0.0.1) or somewhere in the web. Sometimes proxies are used for anonymization purposes - in this case socks5 proxies are used, e.g. the Tor anonymization network can be used by using local socks5 proxy (127.0.0.1, port 9150) and installing the Tor Browser Bundle.

Security professionals seem to agree that it is difficult to achieve absolute anonymization even if very specialized software is being used. In case of email if e.g. the email leaves the sender's server and goes to the receiver's server it traverses in many cases without even the SSL encryption, sender's and receiver's email addresses can be seen.

Note that EndCryptor's default certificate checking option (Revocation Check Online) may leak the target website. If this option is selected Windows may download new certificates and certificate revocation lists from the certification path, the certificate checking may also send the target server's certificate's serial number to certificate's issuer (using Online Certificate Status Protocol). To avoid this situation use 'Tools->View received SSL Certificates' and select the option 'Accept if allowed and has not expired' (you may have to import the certificate first).

If Gmail is used as active email account with Oauth2 authentication then there will sometimes be a https connection to www.googleapis.com along with a DNS query.

Backing up and restoring

From the viewpoint of backups EndCryptor consists of the security database and the stored emails. The security database contains e.g. the secret encryption keys and other data that EndCryptor needs in order to function. The security database is encrypted. The contents of the encrypted stored emails can be viewed by user if the proper entry password to the security database has been given – this is the normal way of viewing the exchanged emails. Another method to view the stored emails is to use Export Keys and export the stored emails from backup to plaintext files – any user who knows the proper Export Keys can do that.

EndCryptor can take backups of the security database and the stored emails. Another alternative is that company's backup software does this.

When EndCryptor starts and does not find a security database it gives as one option the possibility to restore it. This happens e.g. when EndCryptor starts the first time after its first installation. To simulate the situation rename the folder containing the security database (see the location of 'EndCryptor_store' below) into some other than 'EndCryptor_store' and start EndCryptor. Those backups of the security database taken by EndCryptor can then be used. The backup of the security database can be encrypted with user's Personal Export Key.

After the restoration of the security database EndCryptor asks the location of the backup of the stored emails and then EndCryptor copies those files that are indexed by the security database to the proper folder.

EndCryptor can copy the current stored emails to backup storage when EndCryptor closes or immediately when such a file has been written to user's hard disk. **It is thus possible to be able to decrypt every received and sent email even if a hard disk crash occurs in their original location.**

To configure EndCryptor's own backup mechanism use Menu's Tools->Backup Options.

The backed up stored email files can be viewed (i.e. exported) without the security database that originally stored them. In this case the exporter needs the original user's Personal Export Key File or the company's Company Export Key File (if it is being used) and the required password for the Export Key File in question. Use menu's File->Export From Backup. For more information about exporting see the next chapter.

If company's own software takes the backups of the security database EndCryptor must be closed, the following items should be backed up:

File : C:\ProgramData\Enternet\EndCryptor\\EndCryptor_pwd_0.dat
Files in folder: C:\ProgramData\Enternet\EndCryptor\EndCryptor_store
Files in folder: C:\ProgramData\Enternet\EndCryptor\EndCryptor_store\house_kp

If the user has placed the security database into another location than the default one then the folder …EndCryptor_store and its subfolders given above in the user given location contains the security database.

EndCryptor backs up the security database into one file which can be encrypted using the Personal Export Key. Only 5 most recent backups are kept for each day and at most 2 previous backup days are stored. If according to these rules a backup file is not kept it is wiped and deleted. EndCryptor assumes that it can read and write to the backup folder and that it can delete files from it. The folder can be a network folder.

The stored emails are in folder:

C:\ProgramData\Enternet\EndCryptor\EndCryptor_store\emsgs

unless the user has placed the security database folder 'EndCryptor_store' into another than the default location.

The stored email files can be copied at any time.

Exporting to plaintext

When an encrypted email is sent or received it is encrypted again for storage on user's computer (using different encryption keys than those in the email that is traversing the internet). These locally stored and encrypted emails can be backed up by copying them to proper media. If needed they can later be decrypted and exported from the backup media without the original security database but by using either Personal Export Key or Company Export Key.

When EndCryptor is started the first time it saves a Personal Export key file and the user is asked to create that file's password. These items can be used to decrypt and export user's emails from backup media. Additionally a Company Export Key can be used. In this case many users insert the public key corresponding to the Company Export Key. An administrator who has created the Company Export Key can then decrypt and export stored emails from backup media. An organization need not necessarily use the same Company Key for all users but different keys can be used based on the organizational unit of the user.

Note that if the user or company has stored the Export Key and its associated password on removable media and a hard disk crash occurs then those emails that are backed up can be decrypted and exported.

Stored encrypted emails are files that originally by default exist in the folder:

C:\ProgramData\Enternet\EndCryptor\EndCryptor_store\emsgs .

A company may take backups of the abovementioned folder. Individual files in the folder look like:

10_1885387336_a_1663277279_789AF06969FC0275.dat for a message body file and like
10_1885387336_b_1984071552_789AF06969FC0275.dat for an attachment file.

The storage files are named so that their names are unique.

An email is exported in eml format. **These files can be imported into an email archiving system and can also be viewed by many email client programs or dragged and dropped into an existing local email folder (e.g. into Mozilla Thunderbird).**

An exported .eml file contains exported message's attachments and its conversation. Eml format files are digitally signed by EndCryptor and if they are tampered (changed) after their creation this tampering can be detected using Menu's Tools->Archiving Tools->Check If Tampered -selection. The digital signature created by EndCryptor is implemented using the X-headers of the .eml file. If an email archiving system is used and it does not change the .eml file its signature can be verified also after it has been exported from the archiving solution (e.g. Thunderbird 13.0.1 keeps the message unaltered). Note that if the .eml file is later sent by email as an attachment the signature usually will not verify to be untampered because the various email servers modify certain "boundary" strings in the .eml file. Although the

contents the user sees are not altered the signature will not verify. It is anyway unwise to send an exported .eml file as attachment (i.e. in cleartext) since it has originally been considered confidential and has been sent in encrypted form.

When a user exports messages they are always signed using the same private/public key pair specific to this user's security database. The user can be the actual user or an administrator who is exporting using a Company Key. The public key is included into the .eml file. The verification checks that the .eml file is created by the holder of the private key of the public key and that it has not been changed. When checking many .eml files of a specific user they thus all must contain the same public key. The verification tool in EndCryptor can sort files into folders according to the public key and it also tells the number of different exporters (the number of different public keys) in the set of analyzed .eml files. If a user deletes his security database and creates a new one the export private/public key pair will be different, the various fields specific in the .eml file will also be different.

When a company uses email archiving usually every incoming and outgoing email is automatically stored into the archiving system. Now the archiving system has an encrypted .ndd file that traversed the internet and for some reason it is wanted to know if the archiving system contains its decrypted content. EndCryptor provides a tool that extracts a File Identifier from the encrypted .ndd file. This File Identifier is shown in the corresponding exported .eml file and can be found using the search features of the archiving system. The tool is in Tools->Archiving Tools->Extract File Identifier.

Example of a body of exported .eml file as shown in an email client:

Message id: 7A9DD8CFC757ACDD366BAC2681EB2C2603C678C7C5F6EC13

From:	John Doe	John.Doe@somewhere.com	own_DE7419E54EEC0DFE_
To:	Jane Doe	Jane.Doe@somewhere.com	s2r_BABDBE4E10F559E7_

Created: 2010-04-03 10:25:28 (UTC time 2010-04-03 07:25:28)
Filename: _2010-04-03_102528.ndd, File id: E6A16A56285EBCC6DB82D830304E70E04C9BBAC137187412
File number: 59
Exported by: 29F732E7EE7FD700FB01458CB3E7813F52AE55676310AEA5
Subject: Test

```
This is a test message.
```

The identifier starting with 'own_' is the 'Owner' identifier. To find all messages sent and received by John Doe search the archiving system using this string 'own_DE7419E54EEC0DFE_'. The identifier starting with 's2r_' is the 'Sender to Receiver' identifier. To find all messages John Doe has sent to Jane Doe search using the string 's2r_BABDBE4E10F559E7_'. Jane Doe has this same string in her corresponding 'From:' column. Thus if John and Jane are in the same archiving system the same message appears twice if searched by the 's2r_' –identifier. The 'Message id' is identical in a same message exported by sender and receiver. The 'Filename' is the name of the .ndd file that contained the message. The 'File id' is the File Identifier that can be extracted from an encrypted .ndd file. 'File number' is the consecutive number of messages sent from John to Jane. This number cannot be shown in the sending end if the message has many recipients, the receiving end shows

the number always. Note that if a user deletes a contact and creates it again, the ‘s2r_’ –string for this contact will change.

Example when a message with 2 recipients is exported by one of the recipients:

Message id: 1BE0708B6C66EB42FE1B1CBE1A0C1D3BE2B77B8F695A6E0F

From:	John Doe	John.Doe@somewhere.com	s2r_BABDBE4E10F559E7_
To:	Jane Doe	Jane.Doe@somewhere.com	own_CE4B8EF1A2034840_
To:	Unknown name	Unknown email	s2r_435282EFA93363F7_

Created: 2010-05-06 14:09:38 (UTC time 2010-05-06 11:09:38)
Filename: _361_877_810.ndd, File id: FE7BC9BEA8FEEB421D55663F75B849BD7467DCEC21765DBB
File number: 60
Exported by: 52DCDC88A60EFFD50A65EE605B006F8C6EA8D8D3E6C02057
Subject: Test

```
This is a test message.
```

The recipient Jane Doe has exported the above example. The other recipient appears as ”Unknown name” and his email as ”Unknown email” because the encrypted message does not carry this information. The string ’s2r_435282EFA93363F7_’ however appears in this message when exported by the unknown person and by John Doe i.e. it appears in every message that John Doe sends to this person regardless which one of the different recipients exports the message.

When exporting from user’s security database EndCryptor keeps track of which messages have been exported. User can export either all messages or only currently unexported messages.

If unauthorized access to your computer is suspected you may not want to store the exported emails permanently on your computer. The folder containing the exported messages can be wiped by using Files button and right clicking the mouse over the folder and selecting ‘Wipe Folder’.

Exporting can be done from EndCryptor targeting:

1) those emails that are currently indexed in the security database.

2) those emails that are on backup media.

3) those emails in a backup folder that were created later than the current restored security database’s last email

To export from currently stored emails select: Menu: File->Export Messages.

To export from backup media select: Menu: File->Export From Backup.

To export newer files than a restored database knows select: Menu: File->Export From Backup Special

To manage export keys select Menu: Tools->Archiving Tools->Manage Export Keys and Tools->Archiving Tools->Admin Tools->Manage Company Export Key.

Search Emails

The search feature can be activated from Menu: File->Search Messages or by placing the mouse above a Mailbox and using right mouse click. By placing the mouse above a Search results mailbox previous search results can be searched.

Messages can also be searched for attachment's name or hash value. Because the hash value is unique this is a useful way to find one specific attachment whose hash value is known. This search can also be started from the Files using right mouse click – the hash value will be calculated before the search is started.

Move security database

The security database can be placed e.g. on a USB disk and used from it. This enables EndCryptor's usage on two different machines (e.g. office computer/laptop) using the same security database. The software license of EndCryptor grants the right to such an installation. If two different persons want to use EndCryptor on different machines then they both need a separate license – if they both use EndCryptor only on one and same machine then one license is required.

To move the security database onto USB memory:

1. Install EndCryptor on both machines and put the USB memory stick to that machine that is currently being used.
2. Use Windows Explorer to navigate to the security database. The default place in Windows XP for the security database is: C:\Documents and Settings\All Users\Application Data\Enternet\EndCryptor\EndCryptor_store\. Windows Vista and Windows 7 use this location: C:\ProgramData\Enternet\EndCryptor\EndCryptor_store.
3. Place the mouse over the folder 'EndCryptor_store' and right click the mouse. Select 'Send To' and from there select the USB device. Windows now copies the security database to the USB device.
4. Rename the source of the copy, the folder 'EndCryptor_store' on the hard disk as 'EndCryptor_store_old'.
5. Start EndCryptor, a dialog 'Define security database' appears. Check the selection 'Locate existing security database' and click OK. From the list click the '+' mark on left side of the USB device and then select the folder 'EndCryptor_store' and click OK. EndCryptor uses now the security database of the USB device. Check that you can view the stored messages.
6. Use EndCryptor's Files button and navigate to the old security database on the hard disk. Place the mouse over this 'EndCryptor_store_old' folder and right click the mouse. Select 'Wipe Folder'. EndCryptor now wipes and deletes the old security database. To save time you may only want to delete the folder without wiping it - use Windows Explorer for this.

Please note that it is not possible to use the new security database on the USB and then start using the old security database on the hard disk. When messages are sent/received the security database is updated to contain latest public keys of the contacts. This received information is lost if an older version of the security database is used. To move the security database to the hard disk from the USB follow a procedure like that one above.

Forgotten entry password

There is *no recovery of a forgotten entry password*. Only using the correct entry password can the needed parts of the security database be decrypted. The security database is encrypted, some parts with AES, others with ChaCha20, key size is 256 bits.

What you can use immediately are the decrypted plaintext attachments of messages in the folder …EndCryptor_store\ in a folder named: pltxt_files.

You can export the stored emails to plaintext

You can use Export Keys and export the stored emails to plaintext files. In this case the exporter needs the original user's Personal Export Key File or the company's Company Export Key File (if it is being used) and the required password for the Export Key File in question. Use menu's File->Export From Backup. Note that because only the password is lost then the stored emails are on disk, typically in:

C:\ProgramData\Enternet\EndCryptor\EndCryptor_store\emsgs

Use the following procedure:

1. Rename the current folder ‘EndCryptor’ to ‘EndCryptor_old’ so that the path to it is C:\ProgramData\Enternet\EndCryptor_old\
2. Start EndCryptor and select the option ‘Start evaluation period of 60 days’ and proceed as installing a new instance of EndCryptor.
3. When EndCryptor has started select from Menu: File->Export From Backup.
4. Select the input folder: C:\ProgramData\Enternet\EndCryptor_old\EndCryptor_store\emsg
5. Select the output folder for plaintext emails.
6. Export the stored emails by following the instructions on the form.

The default place in Windows XP for the security database is: C:\Documents and Settings\All Users\Application Data\Enternet\EndCryptor\EndCryptor_store\

Windows Vista and Windows 7, 8, … use this location:
C:\ProgramData\Enternet\EndCryptor\EndCryptor_store\

You may have moved the security database into another location.

See the chapters ’Backing up and restoring’ and ‘Exporting to plaintext’.

Hard disk crash

For backing up stored encrypted emails see the chapter ‘Backing up and restoring’.

The best backup of the security database containing internal secret keys is such one that does not miss any change. EndCryptor continuously exchanges new public keys with the contacts when messages are encrypted and decrypted and this requires synchronization between the parties. If an older security database is restored from a backup then the receiver of an encrypted message may not be able to decrypt the received message. A backup of the security database should be taken when EndCryptor is closed. The stored emails can be copied at any time.

If a hard disk crash occurs and a backup of the security database is available use the backup to decrypt those current unreceived messages you can. There is a tool in Menu’s File->Export From Backup Special that compares the entries in a restored security database to a backup of stored emails. The tool finds out which emails in the backup folder are created later than the latest indexed email in the security database. Such backed up stored emails must be exported if their contents need to be viewed. In other words those emails were sent or received after the restored backup of the security database was taken. The tool exports them to plaintext – an Export Key is needed. It is possible to take a backup of a successfully received (decrypted) or sent email immediately when it has been written to local hard disk, use Tools->Backup Options. It is thus possible to be able to decrypt every received and sent email even if a hard disk crash occurs in their original location.

If you know that after the restored backup was taken you communicated with say contact John Doe then delete the contact John Doe from your EndCryptor and ask him to do the same with you in his EndCryptor. The deleting of a contact does not affect the emails in Mailboxes. Give John your current public key or a website where it is and ask him to send you one encrypted email (or alternatively you can find out John’s current public key and send him an encrypted email).

If no backup of the security database is available install EndCryptor and inform your contacts that they should delete you from their contacts and then they should send you an encrypted email. Inform them about your current public key.

The size of an empty database without any contacts is about 1 MB.

Obtaining a license

The program stops sending/receiving after the evaluation period of 60 days has passed unless a license is obtained. This happens also if a time based license expires.

Licenses can be ordered using the program's order form or from product's website www.endcryptor.com. If the order form in Menu: Tools->Licensing->Order is used the payment method is bank transfer. Use this form to order more than say 50 licenses. Licenses can be also purchased from the product website. Payment method is then credit card. Licenses purchased from the product website are delivered immediately upon payment.

If the order form in the program is used the order is encrypted and sent to orders@endcryptor.com. The order processing may take one working day. One person in the organization places the order and receives the license file which can contain many licenses. The license file is given to those in the organization who need it. A license can be installed automatically without any user action, see the next chapter. The license file is sent to the address mentioned in the order. To use 1 license from the license file select from Menu: Tools->Licensing->Receive license file.

There are two kinds of licenses: time based and version based.

Time based one or two year licensing gives the right to use the latest version and its updates up to the expiration date of the license. Renew existing time based licenses when there is less than 1 month to expiration. When the new license file is received the new licensed time is added to the end of the existing license in each such case. In other cases the license's starting time is its issue date.

Version based licensing gives the right to use a certain version and all its updates any number of years, a version based license to version 2.x is a license for all values of x.

It is possible to change the licensing scheme from annual to version based. One year's annual unit price is subtracted from each license's version based unit price in this case. All the installations which will use such a license must have used a time based scheme before.

Payment info if the payment method is bank transfer:

Enternet Inc.
Finland
VAT number: FI 08210504

BANK: Nordea Bank Finland Plc, Helsinki
SWIFT: NDEAFIHH
IBAN Account number: FI08 1220 3000 2499 00

Technical details:

Individual encrypted messages do not contain user's values Enternet Inc. knows. This implies that if Enternet Inc. is shown an encrypted message created by a licensed customer then Enternet Inc. cannot determine the customer in question.

Automatic licensing and configuration

It is possible to do licensing and email account configuration without any or with very little user action needed. This is accomplished via a **Configuration folder** which EndCryptor checks when it starts. This folder is a subfolder of the local application data folder. Windows allows the logged in user and administrators to access this user specific folder. By inserting files into this folder company's system administrators can help users in maintaining EndCryptor.

Installation of a license can be done without any user action needed. Also the first configuration of an email account when EndCryptor is run the first time can be done without any user action – the configuration file must then include all the needed parameters e.g. a password to the email server. Later an email account can be configured automatically but then the user is asked to accept the action.

The **location of the Configuration folder** is determined by the technical term CSIDL_LOCAL_APPDATA.

In Windows XP it is:

C:\Documents and Settings\<User in question>\Local Settings\ Application Data\Enternet_FI\EndCryptor\Config\

Vista, Windows 7 and 8:

C:\Users\<User in question>\AppData\Local\Enternet_FI\EndCryptor\Config\

The administrator responsible for installation should test the different configuration settings by creating a test installation in a test machine. If the folder C:\ProgramData\Enternet\EndCryptor is deleted the program's security database is deleted and the next run of the program is considered as the first run. Note that this deletes the security database and all the settings and every stored emails etc. **If the configuration file contains passwords then the passwords are removed from the file after the file has been processed.**

Automatic installation of a license

The license can be installed via the menu item 'Receive License' or it can be renamed appropriately and placed into the Configuration folder by company's personnel and be installed automatically at program startup.

If the license is a string then the file containing only the string should be renamed as: 'EndCryptor_license_string.txt'.

If the license is a file then the file should be renamed as:
'EndCryptor_license_file.dat'.

If the file name contains word 'silent' no user action is needed for installation and if the word 'delete' is in the name then the license file is deleted after success or failure. Now if the file is named as 'EndCryptor_license_file_silent_delete.dat' the installation of the license requires no user action and the license file will be deleted after success or failure. If the file is not deleted it is moved to the folder above the Config folder and if any errors occurred a file ending with …errors_log.txt is placed to the same folder where the file is moved.

Automatic configuration of an Email Account

User's email account can be configured automatically at EndCryptor's first run and it can also be updated at later time each time when EndCryptor starts. All or only some of the needed parameters can be decided on behalf of the user. To enable the automatic configuration a file containing the parameters is placed into the Configuration folder.

When EndCryptor is run at first time this configuration can be done silently without any action needed by the user, at later times the user is asked whether or not the new configuration should be applied.

Certain values need not to be defined in the configuration file, instead the user can be prompted to provide them: user's name, email address, username and the password to the servers.

Since the email protocols are very standardized it may be possible to give only a few values in the configuration file, other values are filled by EndCryptor or the user. Example of a simple configuration file:

my_name: ;
email: ;
smtp_server: smtp.someserver.com;
smtp_username: ;
smtp_password: ;
imap_server: imap.someserver.com;
publish_public_key_here_01: 1 ;

When the above file is processed during first run of EndCryptor the user needs to give values for his/her name, the email address and username and the password. The names of the email servers must be given in the configuration file. If all the fields in the above example would contain values then the user would not be prompted for any values. The email account would be configured to use e.g. the standard communication ports i.e. 587 for SMTP and 993 for IMAP.

The line: 'publish_public_key_here_01: 1 ;' means that user's public key is written to the Configuration folder. It can be picked up from there by automated software and put into company's directory of public keys. There is a corresponding setting in the Options dialog. Whenever this setting is on and the user's public key is changed the

new value is written to the Configuration folder as UTF8 encoded file 'my_public_key.txt'.

The above example file must be named as 'email_settings_first_run_std.txt'.

Suppose a situation where company's email servers change. To update users' configuration when they use standard settings the configuration file must be named as 'email_settings_update_std.txt'. The just configured new email account is marked as the active email account, and the previously active email account is marked as not active. If the user later marks the old account as the active account then the old settings are in effect.

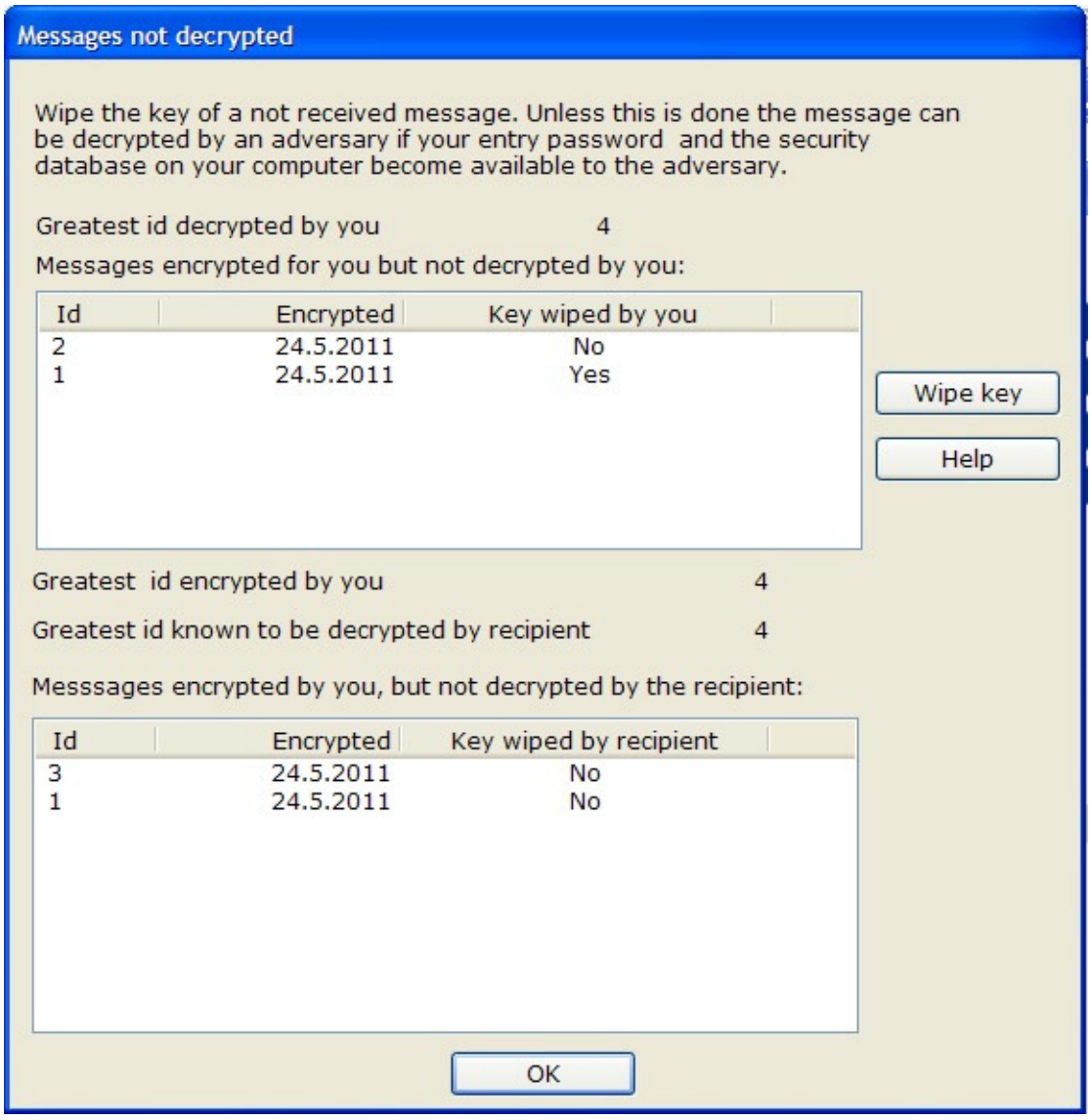
If all the parameters are given in the file then the corresponding file names are 'email_settings_first_run_all.txt' and 'email_settings_update_all.txt'. The Program Files folder for EndCryptor's code will contain examples of configuration files. They must be in unicode and they must start with unicode BOM character 65279 or with character '/' or character 'm'.

If the configuration file contains passwords then the passwords are removed from the file after the file has been processed. The 'first run' file is left to the configuration folder and the 'update' file is moved to one folder up. If an error occurs it is in the …_errors_log… file in the folder that is above the Configuration folder.

Advanced features

Wipe the key of a missing message

Press the ‘Contacts’ button, select a contact and press the ‘Advanced’ button and then press the ‘Using continuously changing keys’ button. This is shown:



The above example shows a situation where messages 1-4 have been encrypted for you (upper list). Of these files you have not decrypted messages 1 and 2 and you have wiped the key of message 1.

A hacker may capture a message and then prevent you to receive the message (the email “disappears”) thus making its decryption impossible. Then if the security database can be fetched from your computer and a successful capture of the entry password (e.g. using an advanced keyboard logger) is performed then this captured message can be decrypted. To prevent the hacker to decrypt this captured message in such occasions you can now press the ‘Wipe key’ button. The information needed to

decrypt the message is wiped from the security database. Neither you nor a hacker can decrypt the message in question. If a user tries to decrypt a message whose key is wiped then similar error information is shown as if the file had already been decrypted.

Please note that if you have received many encrypted messages and happen to decrypt at first the one with the greatest Id then the other ones appear on this list. Perform the wipe only after careful consideration.

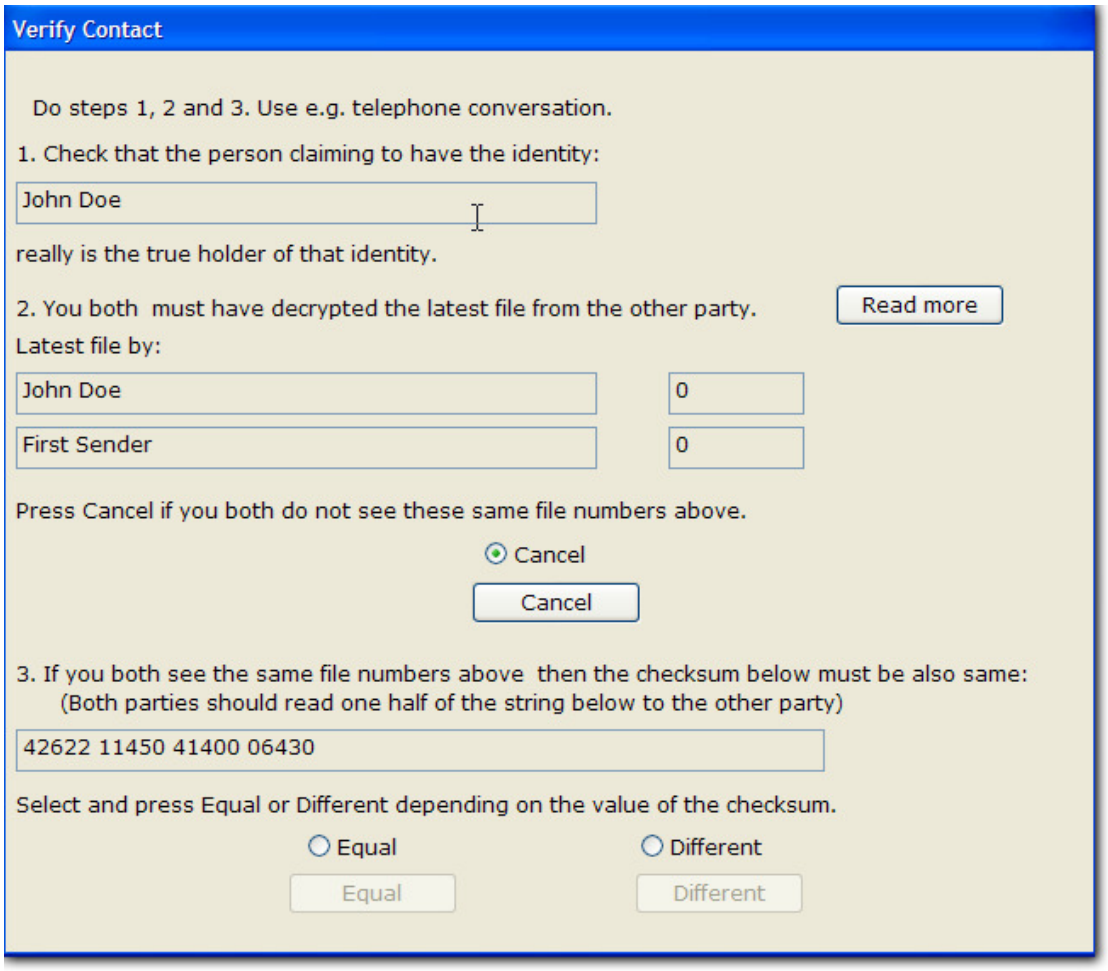
If we consider again the previous example you notice that you have encrypted 4 messages and of these the recipient has not decrypted messages 1 and 3. This is the situation when the recipient encrypted the latest message to you (also numbered 4). If the recipient now decrypts the message 3 but does not after that send you a message then you don't know of this decryption of message 3.

The list 'Messages encrypted by you …' tells you what the receiver has done to the messages you have encrypted for him. The information is based on the latest message that you have decrypted from him.

Man In The Middle tester

Press the Contacts button, select a contact and press then Advanced button and from there press the Test for MITM button.

Testing means that a contact's identity is checked and confirmed to correspond to the claimed identity (step 1). At step 3 the verification also ensures that the internal state of the communication protocol is the same for both parties. If this is the case there is currently no man-in-the-middle attack between the parties.



The testing can be done at any point in time, even many times.

Security features explained

EndCryptor protects against attacks done by current classical and future quantum computers. Scientists consider that it may be possible that such quantum computers could be built within 10-15 years that could break current classical public keys. Therefore cryptographers are developing new kind of public keys - which currently are understood to resist quantum attacks. There are several possible solutions. The quantum attack resistant public keys used in EndCryptor are called supersingular isogeny Diffie-Hellman keys. The reader should keep in mind that encrypted communication can easily be stored and if quantum computers become reality they can be used to decrypt stored old communication.

EndCryptor offers features that are essential for real world protection: **backward security** and **recovery from an attack**. It is important that there is protection when a hacker gets access to current secret encryption/decryption keys.

Comparison between EndCryptor and the S/MIME and the PGP-family of email encryption products (PGP, OpenPGP, GnuPG,...) in case of a successful spying attack which reveals current secret keys - like private keys of public keys - to the attacker

	EndCryptor	**S/MIME and PGP -family**
Backward security (= are encrypted messages sent to the victim before the attack protected?)	YES	NO
Recovery from the attack will happen	When the next message from the victim is decrypted. In quantum attack when next quantum attack resistant Diffie-Hellman key exchange is done.	When the new public key of the victim is received. This usually happens at predetermined intervals - after several months or years. No protection against quantum attacks.
Identity theft will be revealed	YES	NO

To enable fast recovery from hacking EndCryptor uses a lot of classical public keys. Quantum attack resistant public keys are used more seldom – they are much slower to use. In typical usage quantum attack resistant Diffie-Hellman key exchange is done at least once a week.

Recently this kind of attack has been done e.g. by **malwares Sauron, APT30, Red October, TeamSpy** and **Mask** - which operated undetected about 5, 10, 5, 10 and 7 years, respectively - and stole among other things encryption keys.

The main targets of e.g. Mask fall into the following categories: government institutions, diplomatic / embassies, energy, oil and gas companies, research, private equity firms, activists[1].

Without **backward security**[2] and **recovery from attack** a single successful spying attack into your computer leads to the exposure of all previous and future encrypted communication sent **to** you! In some solutions also all communication sent **from** you is exposed – this happens if the solution is such that the sender of a message can decrypt it after its encryption! After a successful attack the adversary does not need to access your computer anymore. What the adversary then needs is *encrypted messages* created before and after the attack. Using the information provided via the attack they can be decrypted. In the light of recent leaks about state level data interception and collection it is known that encrypted messages (emails, chats …) are routinely collected and stored.

The spying attack can e.g. be the utilization of dedicated spyware, worm, virus or the usage of a newly published security hole through which the computer can be accessed from the network and then using a keylogger to capture the entry password to the encryption software's database (S/MIME certificate, keyring or whatever it is called) and the password's and the data's transmittal to the attacker. This exposure of the security data can happen other ways also: the user turns **from friend to foe** and reveals his own security data to the adversary; or is **forced** (e.g. by a court order) or **lured** to reveal current security data; etc.

After the exposure old and new **encrypted messages** sent to (from) the victim **can be decrypted** unless the software is prepared to face the exposure of its security database.

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[1] On August 2016 security companies Kaspersky and Symantec revealed a spying operation named as Project Sauron or Remsec which had run undetected about 5 years. The operation according to Kaspersky was: "designed to enable long-term cyber-espionage campaigns" and "has high interest in communication encryption software widely used by targeted governmental organizations. It steals encryption keys, configuration files, and IP addresses of the key infrastructure servers related to the software." Symantec says about the malware that there is a "module that contains a string named "Sauron" in its code. Given its capabilities, it is possible the attackers have nicknamed the module after the all-seeing villain in Lord of the Rings." On April 2015 security company FireEye reported that malware named APT30 had been found to have been spying 10 years mainly in South East Asia. Among data it collected were files ending with .pgp. On July 2014 F-Secure reported about CosmicDuke malware which had attacked against NATO and European government agencies. This malware stole among other things certificates and their private keys. On February 2014 Kaspersky Lab announced that they had found and analyzed Mask - "an advanced threat actor that has been involved in cyber-espionage operations since at least 2007 ... one of the most complex APT we observed ... more than 380 unique victims in 31 countries ... could be a nation-state sponsored campaign ..." The Red October malware which was also found and analyzed by Kaspersky Lab (results published in January 2013) collected *.crt, *.cer (these are certificate related), *.pgp, *.gpg, pubring.*, secring.* (PGP, and GPG related) files and recorded key presses and values in password fields. The Red October was operating about 5 years. A report published on March 2013 from CrySys Lab in Hungary says about TeamSpy malware: "Many of the victims appear to be ordinary users, but some of the victims are high profile industrial, research, or diplomatic targets". First example of a virus that stole PGP's security database 'keyring' was Caligula virus (1999), this attack did not use a keylogger, but was a proof of concept attack.

[2] In online communication (e.g. chatting, SSL or https) the corresponding term for **backward security** is **Perfect Forward Secrecy (PFS)** – which means that if a message is decrypted securely now it cannot be decrypted again in the future by opponent even if the opponent obtains the encryption keys of that future time.

If **recovery from attack** is provided then after the recovery the attacker must be able to obtain the security data again in order to be able to continue decrypting new messages - this may, however, now be impossible e.g. if the program containing the security hole has been fixed by installation of a proper update.

EndCryptor is a solution that considers the unwanted but realistic possibility that at some point in time the security data - private keys, etc. - are revealed to an adversary. Our results in case of a classical attack: old sent and received communication of the victim is protected and also future sent communication from the victim is protected. The restoration of total security happens when the next message from the victim has been decrypted.

Detailed Features

- Both the sender and the receiver must have EndCryptor installed. An email account on email server is needed - same account (i.e. user's current email account) can be used for unencrypted emails and encrypted emails. Encrypted emails are typed using EndCryptor and they are sent and received using EndCryptor. A encrypted email is a file that is an attachment in an ordinary email. The sending and receiving is enabled by defining user's email account's SMTP and IMAP settings into EndCryptor, e.g. Gmail can be used.
- The cipher used is 256-bit key size ChaCha20.
- Encryption keys of messages are determined using **elliptic curve public key technology** (classical: Edwards curve Ed25519 and corresponding Curve25519, quantum attack resistant: SIDH 2.0 and 3.0 supersingular isogeny Diffie-Hellman keys designed by Microsoft).
- At the beginning of the email exchange the user published long term public keys are responsible for the protection of the email. **EndCryptor puts inside the first encrypted emails newly created short term public keys that initialize the patented protocol that continuously exchanges internal short term public keys when emails are being exchanged.**
- Each message ends with an authentication mac and signature. This ensures to the receiver that the message was created by the claimed sender and that the file was not altered during traversal.
- After the decryption the correctness of the plaintext is verified using Poly1305 authentication code.
- The sent and received messages are stored in encrypted form on a user’s computer – the user can view their decrypted contents when correct entry password to EndCryptor has been given. The stored messages can be searched and moved between different user creatable mailboxes.
- **Messages can be exported** in eml format. They can be imported into email archiving solutions. The exported files are digitally signed to detect tampering. They can also be viewed by many email client programs or dragged and dropped into an existing local email folder (e.g. into Mozilla Thunderbird). The export feature allows the user to have a complete cleartext archive of the communication.
- The stored messages can be backed up by copying and the **backups can be decrypted using a personal or a companywide (optional) export key**.

EndCryptor can take a backup of the security database and restore it. That backup can be encrypted. The stored emails can also be backed up by EndCryptor immediately after they have been written to disk.

- **Properties under classical attack when the security database of user Alice is exposed by hacker:**

  - Old and future encrypted messages sent from Alice are protected.
  - Backward security: encrypted messages that have been decrypted by Alice are protected.
  - Recovery from an attack: when the next new message from Alice to Bob has been decrypted then the messages from Bob to Alice cannot anymore be decrypted by adversary.
  - Certain kind of protection against identity theft: either the theft attempt fails or it succeeds but then all future messages exchanged between the fooled party and Alice will be rejected. Protection against identity theft is important since a user may have blind reliance on the protection given by a digital signature. If the security data is exposed to a hacker then identity theft can be tried.

- Reports messages that have not been decrypted. The sender can be sure that the receiver has decrypted the message. Important e.g. when the message contains some latest technical document that must be used by the receiver.
- **Possibility to delete the keys of missing messages** - if a message is encrypted but not received then the receiver can delete its decryption keys. This requires that the receiver has received a newer message from the sender.
- **Protection against a replay attack** where an adversary intercepts and copies an encrypted message and later resends it: 1) a message can be decrypted only once 2) the decryption keys of missing messages can be deleted.
- If EndCryptor is used for sending or receiving it stores the received certificates from the email server. Certificates can be imported and exported to/from the collection of certificates. It can be specified which certificates are allowed to be received – if a new certificate is received the user is prompted for acceptance. This is a highly advanced option and is motivated by the so-called **"compelled certificate creation attack"** or a hacking attack against some Certificate Authority. In those attacks some Certificate Authority has written a certificate of the email server to a wrong party or a hacker has gained the ability to write certificates in the name of the Certificate Authority. Note that some Certificate Authorities have stopped their business because of a successful hacking attack. The possible forgery of certificates is very annoying because the whole idea of certificates is that they can be trusted. If the above mentioned attacks succeed the already encrypted EndCryptor message that is an attachment in the email stays protected but the attacker may gain user's username and password to the email server. For more details read the 'Options' and 'The risks of SSL' part of this document.

- Compression of plaintext. Required amount of random bytes are added to hide the length of this compressed plaintext - encrypted files have different sizes even if their decrypted content is the same. Selected files from the Canterbury Corpus:

File	Size	**EndCryptor**	bpc
e.coli	4,638,690	1,223,810	2.11
bible.txt	4,047,392	853,556	1.69
world192.txt	2,473,400	474,528	1.53
kennedy.xls	1,029,744	130,285	1.01

  bpc = bits per character (byte). EndCryptor was used with the default setting.
- A message may have more than one receiver. Contacts can be grouped.
- File wiping, calculation of a cryptographic hash value (checksum) of a file.
- If an Internet connection is considered to be too risky then EndCryptor **can be run entirely disconnected from the network**. When a message is encrypted a list of its receivers can be stored in a text format, the message and the list of its recipients can be stored in user given folder. The encrypted message and this list are moved to the actual sending machine using removable media. When decryption is needed the encrypted message is delivered to the receiving EndCryptor again using removable media. EndCryptor can be set to monitor some user given folder for new encrypted messages. A custom made program can be defined so that it is used whenever a message is being sent.
- The security database and the stored sent and received messages can be moved to removable media and accessed from it. Thus it is possible to use EndCryptor both from office and laptop computers. The size of an empty database is about 1 MB.
- The licensing and email account configuration can be done automatically during program startup without user action if a proper file is placed into a specific folder on user's computer.

Tutorial on public key technology

Public key technology is the basis of modern protected communication. This short tutorial explains briefly without technical details the most important things to know about public keys. We also explain briefly some of our protection mechanisms against the known attack points of public key based systems.

We use public keys for these reasons:

- To form a shared secret
- To recover from attack
- To form a digital signature

Main attack types:

- Stealing of a private key
- Man-in-the-middle during key exchange

Public keys enable the formation of a shared secret.

When two persons exchange public keys which they have created they can calculate a value that only they know. A third person that sees the public keys exchanged cannot calculate this value. The calculated value is called a shared secret. It is typically used later as an encryption key to encrypt the communication between the parties. This method is called Diffie-Hellman key exchange according to its inventors Whitfield Diffie and Martin Hellman.

This solves a very important problem: how to communicate securely an encryption key to the other person? By sending and receiving a public key.

Each public key has a corresponding private key. The creator of the public key automatically knows this private key. The shared secret is calculated by the help of this private key and the other person's public key.

Public keys enable the recovery from attack.

Now the third person that watches the exchange of public keys cannot calculate the shared secret that the creators of the public keys can calculate. However, if he successfully sends a spy program and **steals a private key** from one of the parties then the shared secret becomes known to him and he can decrypt messages created after this public key exchange.

We have now a new problem: how to recover from this spying attack? EndCryptor solves this by creating new public keys and sending them.

The attacker must again be able to steal a private key – if he cannot do this he cannot anymore decrypt new messages.

Some public key based systems use a same public key for years. If its private key becomes available to an adversary e.g. via hacking all communication under shared

secrets calculated from this key become known to the adversary. Computer viruses that search for private keys are known to exist.

EndCryptor creates a lot of public keys. Each encrypted message after the first messages that use the long term public keys contain new short term public keys of the sender. These public keys are specific to the receiver in question. When a person whose private key has been stolen sends a new message and when it is received by the other party then a new shared secret can be calculated – the attacker has lost his ability to decrypt messages sent to the victim.

There is still another problem: how to protect old messages received prior to the attack?

Please note that a person may have received several messages without sending new messages and then the stealing of the private key happens. How to protect these messages received between a Diffie-Hellman key exchange and an attack? The answer is a bit complicated and we give here only the result:

Using our patented solution those encrypted messages that the attacker has captured and the proper receiver decrypted prior to the attack cannot be decrypted by the attacker.

More information about our solution can be found on cryptographic technical details page.

Public keys enable the formation of a digital signature.

Each message has a digital signature as the last part of the message. The signature is formed by first calculating the cryptographic hash value (checksum or digest) of the actual message and then with the help of a private key the digital signature is calculated and appended to the end of the message.

The person who receives the message and the signature then verifies the signature with a public key and by calculating the cryptographic hash value of the message.

If the message or the signature itself has been modified by an attacker during traversal in the net then the signature will not verify – only the person who has the private key can create proper signatures which will verify correctly only by the corresponding public key.

This solves the problem: how to prevent the modification of messages and the falsification of the sender's identity?

Man-in-the-middle attack

This attack can happen if a person sends a public key to another person. A third person, an attacker Mallory can replace the sent public key with the public key he has created:

Alice sends a public key to Bob but Mallory intercepts it and creates his own public key and sends it to Bob. Bob creates his reply that has his public key and sends it to Alice but again Mallory intercepts the message and the public key and creates another public key and sends it to Alice. Now Mallory can impersonate both parties.

Man-in-the-middle attack: Alice ← → Mallory ← → Bob.

Alice and Bob do not know that there is Mallory between their communication who replaced their public keys with the public keys created by Mallory.

To protect against this attack EndCryptor's Web Directory stores user's long term public key and email address. When the email address verification has been done the public key and the email address are signed by a public key which has a signature chain to public key that EndCryptor knows. When a user's long term public key is fetched from the Web Directory or an encrypted email contains sender's long term public key this signature is checked by EndCryptor. A user can check that the values in the Web Directory correspond to his/her email address and public key.

EndCryptor provides a method to reveal a man-in-the-middle attack after some messages have been exchanged: e.g. telephone conversation can be done to compare checksums. Also checksums at the start of the email exchange are stored into the database and can be viewed any time later.

EndCryptor, S/MIME and PGP under attack

We study here the exposure of a private key under attack by classical computer.

Exposure of a private key

The reader should recall that the exposure of a private key to an adversary exposes all communication that uses the shared secret calculated with this private key. In practice this means that in PGP and in S/MIME all communication sent to the victim are revealed to the adversary.

The S/MIME email encryption method uses a public key infrastructure (pki) which means that there is a Certificate Authority that digitally signs every new public key. Users already have the public key of the Certificate Authority and use this public key to verify the signature of a certificate that contains the new public key of a user. When a new public key is introduced it must first be certified by a Certificate Authority and then delivered in a certificate to a user.

In S/MIME and PGP the public keys are changed usually at intervals of years.

In EndCryptor at the beginning of the email exchange the user published long term public keys are responsible for the protection of the email. EndCryptor puts inside the first encrypted emails new public keys that initialize the patented protocol that continuously changes internal short term public keys when emails are being exchanged.

Suppose now that Alice starts communicating with Bob using EndCryptor and sends an encrypted email to Bob using Bob's long term public key. After receiving the email Bob replies to it. Later an adversary finds out Bob's long term private key. In EndCryptor only the first Alice's email to Bob can be decrypted by the adversary whereas the traditional systems expose all Alice's later emails to Bob which were sent to Bob’s public key.

Using our method the short term public keys are changed more frequently: if the parties communicate in turns one public key is used only once. An exposed private key has a very short life time in our solution. Our solution for the renewal of short term public keys is cost free.

The Risks of SSL

This chapter is about the risks of relying on TLS/SSL encryption - which is currently the only universal encryption protocol supported by all web browsers when connecting to websites (the web browser typically displays then a lock on the address bar - trying to convince the user of the security of the connection - and may also show the protocol name 'https').

On March 2017 WikiLeaks published leaks from the hacking arsenal of the CIA (USA's Central Intelligence Agency). In some of those documents there are advices to malware writers: **'DO NOT solely rely on SSL/TLS to secure data in transit. Numerous man-in-middle attack vectors and publicly disclosed flaws in the protocol.'** and 'Because **this outer layer may be decrypted by an attacker (e.g., SSL Man-in-the-Middle) any transport encryption must be used for traffic blending only and not for secrecy.'**

On November 2011 the Wall Street Journal published the 'Surveillance Catalog' and the WikiLeaks organization provided a list of International surveillance companies and their equipments on the 'WikiLeaks Spy Files' publication. Some examples from the brochures that describe the properties of the equipments: **"It can also decrypt SSL traffic if installed in MITM** (man-in-the-middle) **configuration ..."; "Track the suspect's encrypted communication using Gmail, Hush mail etc., Track the suspects banking transactions etc."; "Intercept any communication within Secure Socket Layer (SSL) or Transport Layer Security (TLS) sessions. Once in place, devices have the capability to become a go-between for any TLS or SSL connections ... users are lulled into a false sense of security afforded by web, e-mail or VoIP encryption."; "But with a 'man in the middle,' the … technology is able to intercept the traffic and the certificate and send along its own fake certificate to the computer, making the computer think traffic is flowing normally."** Read below a detailed explanation of how this is possible.

When a user connects to a HTTPS/ (SSL or TLS) server, the server sends a certificate to the user which ensures to the user that he really is connecting to the wanted server. How can a certificate do that? The owner of the server has – before starting his services - contacted a Certificate Authority (CA) and proved to him that he owns and controls the server. The owner of the server has sent a public key of the server to the CA and the CA has signed this public key using the private key of the CA. When a user receives the certificate his web browser checks that the CA's signature is valid using the stored public keys of the well known CA. There are about 600 CAs and current web browsers store their public keys and also update them if that is needed. When the CA's signature has been checked then the user's browser checks that the data coming from the server has a valid signature which is signed by the public key of the server (which is in the certificate).

Note that currently any CA can issue a certificate for any website. If the CA decides so it can write a certificate for any website and can use any public key as the public key of the server – this is against the rules but no one can prevent the CA from actually doing this. It may also happen that no one notices these actions – certificates are not normally shown neither are they stored for later inspection. An improvement

to this situation is the Certificate Transparency project started by Google which is explained in more detail later in this chapter.

There is special equipment available that is designed to use also intermediate level CA certificates – they can generate the needed certificates as a need arises[1]. The equipment is placed in the middle of the communication between the victim and the server.

[1] Certificate Authority Trustwave admitted on February 4, 2012 that they had given one private customer an intermediate certificate authority certificate inside a special machine which generated certificates for any website. This was done to decipher and monitor all company's online SSL/TLS communication regardless whether the devices used were company provided or not – because the certificate was issued by a Certificate Authority no new certificates were needed in users' computers.

On January 3, 2013 Google reported that they had on December 24, 2012 detected an unauthorized digital certificate for the "*.google.com" domain. The certificate was issued by an intermediate certificate authority linking back to TURKTRUST, a Turkish certificate authority. Intermediate CA certificates carry the full authority of the CA, so anyone who has one can use it to create a certificate for any website they wish to impersonate. See Google's blog entry, (googleonlinesecurity.blogspot.com/2013/01/enhancing-digital-certificate-security.html).

TURKTRUST told Google that in August 2011, they had mistakenly issued two intermediate CA certificates to organizations that should have instead received regular SSL certificates. Please note that this kind of certificate is exactly that kind of certificate that can be used in the man-in-the-middle machines to monitor any intercepted traffic to any website, the fake certificates generated by this intermediate certificate may have been used during about 16 months.

Following are certificate related attacks:

1. CA (established for the purposes of intelligence gathering for a country A's intelligence agency) issues a certificate for a server in a country B to a public key of this intelligence agency.

2. CA has been hacked. The attacker has obtained the private key of the CA and can issue certificates which the user's web browser decides to be valid[1].

[1] Certificate Authorities can be targeted by viruses, e.g. Duqu targeted certificate authorities and used stolen and forged certificates for its purposes. Electronic Frontier Foundation's SSL Observatory project report (2011-10-27, https://www.eff.org/deeplinks/2011/10/how-secure-https-today) that the following reasons for certificate revocations were found in Certificate Revocation Lists:

reason	**occurrences**
NULL	921683
Affiliation Changed	41438
CA Compromise	248
Certificate Hold	80371
Cessation Of Operation	690905
Key Compromise	73345
Privilege Withdrawn	4622
Superseded	81021
Unspecified	168993

The researchers say (2011-10-27) that: "In at least 248 cases, a CA chose to indicate that it had been compromised as a reason for revoking a cert. Such statements have been issued by 14 distinct CA organizations." When the statistics from earlier 4 months are compared to above findings: "So, from this data, we can observe that at least 4 CAs have experienced or discovered compromise incidents in the past four months. Again, each of these incidents could have broken the security of **any HTTPS website**."

3. CA has been forced (by an order from the country's authorities) to issue a certificate for the public key of the attacker (law enforcement). This is called **'compelled certificate creation attack'**[1].

4. The private key of the SSL server has been exposed. If the server has not been configured to use **Perfect Forward Secrecy** (PFS) the recorded old SSL sessions can be decrypted. If PFS is used a man-in-the-middle attack is required at session time for decryption of the traffic. The attack is now easier to do since no additional fake certificate is needed since server's private key is known[2]. The **Heartbleed vulnerability** in OpenSSL that was found in April 2014 exposed server's memory (private keys etc.). The bug was undetected in the code for 2 years but even older recorded SLL sessions (without PFS) can be opened using an exposed private key[3].

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[1] The term 'compelled certificate creation attack' was introduced by Christopher Soghoian and Sid Stamm in their paper 'Certified Lies: Detecting and Defeating Government Interception Attacks Against SSL', in Financial Cryptography and Data Security '11 March 2011.

On December 2013 Google noticed that several unauthorized certificates were issued for Google's domains. The certificates were issued by a French governmental certificate authority ANSSI who said that the issuing of the certificates was a human error.

On July 8, 2014 Google reported (https://security.googleblog.com/2014/07/maintaining-digital-certificate-security.html) that they had found fake certificates issued for several Google domains and one Yahoo domain and maybe for some other domains also. The issuer of the certificates was India's National Informatics Centre. India's Controller of Certifying Authorities said that the issuer's issuance policies were compromised.

On March 23, 2015 Google reported (https://security.googleblog.com/2015/03/maintaining-digital-certificate-security.html) that an intermediate certificate authority based in Egypt had used an intermediate level certificate in a proxy to create certificates for user's SSL sessions. The used intermediate level certificate was issued by Chinese certification authority CNNIC.

[2] Recent revelations of state level spying have emphasized the importance of PFS and some big service providers have started to use it. **Note that PFS is just that what EndCryptor provides in email encryption: future attacks can't expose old traffic.**

[3] See www.heartbleed.com , "We attacked ourselves from outside, without leaving a trace. Without using any privileged information or credentials we were able steal from ourselves the secret keys used for our X.509 certificates, user names and passwords, instant messages, emails and business critical documents and communication."

5. The attacker uses vulnerability in some software and then installs the attacker created certificate into a trusted certificate store on victim's computer - this enables the attacker to perform man-in-the-middle attack on victim's SSL/TLS web browsing sessions. The attacker needs no software on victim's machine - the installed certificate enables the attack[1].

In the abovementioned attacks 1-3 the attacker must be able to mimic the real server and/or do a man in the middle attack where he gets the data from the user and sends it to the real server and also sends the server's response back to the user. The attack allows the attacker to see and modify user's traffic to/from the server in unencrypted form. **Note that in these attacks 1-3 the attacker does not need access to user's computer or to the server.** One has to consider also the possibility that also non law enforcement parties may have obtained the equipment for the man in the middle handling and can use it in the attacks. The attack number 1 is challenging because the traffic needs to be routed via another country, it is however possible to change the routing tables of Internet or hacked routers to achieve this.

The SSL attack can be applied on 'normal' SSL or TLS based email and webmail solutions and on email encryption solutions that are web-based. There are also Virtual Private Network solutions that use the web browser and SSL. These systems can be attacked always when the SSL connection is done. The vulnerable systems usually use marketing argument that no software is needed on user's computer because only a web browser is needed. If the traffic between sender's and recipient's email server is encrypted using SSL/TLS then it can be decrypted using the man-in-the-middle attack, there can even be many attacks going on at the same time.

One of the equipments is advertised to be able to decrypt web based **Hushmail** emails – which are OpenPGP encrypted. On a client machine Hushmail user's browser downloads the OpenPGP Java applet when a session starts. It seems that the surveillance company has developed a modified applet and delivers it to the victim. It is admitted in Hushmail's documentation that a condition for secure operation is that the user is using a legitimate copy of the applet. We have to remember that the attacker can deliver to the user an entire different web page that the browser has ordered - only the name and appearance are the same.

EndCryptor encrypts the message before contacting an email server; even a successful SSL attack cannot expose the message. In case of EndCryptor the attacker thus can only gain the userid and password to the email server. EndCryptor also stores every certificate it receives, they can later be analyzed if an SSL attack is suspected. EndCryptor can be configured so that when it connects to an email server using SSL it accepts only certain already received certificates – this prevents the attack, the dishonest certificate has not been seen before and is rejected. This technique is called certificate pinning.

[1] This technique is mentioned in the leaked material of Hacking Team company that sells spyware to governments ad law enforcement agencies who can easily perform the MITM attack by compelling the internet service providers to place the MITM machines at proper places.

There are also devices that do SSL DPI (SSL Deep Packet Inspection, another term used is 'SSL bridging') inside a specific company using the man-in-the-middle method to decrypt SSL traffic flowing in and out of the company. Also some firewalls, antivirus and parental control programs can be configured so that they decrypt and re-encrypt the SSL traffic in order to examine the decrypted traffic. In these settings an intermediate level certificate is placed into the man-in-the-middle device or software and its root certificate is placed into company's computers[1] - the intermediate level certificate and its root are self-signed by the company in question and thus only this company's traffic can be monitored without users noticing anything. If the user's computer does not contain company's certificate then user's web browser issues a warning – which the user, however, may choose to bypass (this depends on the browser and its settings)[2]. On mobile devices certain browsers (Nokia's Xpress Browser on old Nokia devices and Opera Mini browser) use man-in-the-middle technique to decrypt and re-encrypt SSL/TLS traffic in a proxy server, the motivation is to compress data and lessen the computing resources needed on the mobile device.

The Certificate Transparency project by Google tries to improve the certification infrastructure. According to https://www.certificate-transparency.org/benefits : "Indeed, incidents that at one time were concealed and downplayed, and in fact caused the shutdown of an entire CA, could be exposed much earlier and mitigated by simply revoking a single certificate."

This project tries to log all CA issued SSL/TLS certificates in the world, major CAs take part of it and also search engines may submit certificates they see into the logs. Certificates issued after April 30, 2018 will not be accepted as secure by the Chrome browser unless they have a signed statement (an extension embedded into the certificate) that the certificate will be logged.

An owner of a domain (e.g. example.com) can query from the logs all the certificates issued to a domain and check that there are only proper ones. The logging of certificates is not done to local certificates that are not created by a publicly accepted CA (Certification Authority) and that are added to the certificate store of user's computer by the user or by some program like antivirus, firewall and parental control program or malware.

Other browsers will probably soon follow Chrome's practice.

[1] The Web Debugging Proxy Fiddler uses the same technique to log all HTTPS traffic between a computer and the Internet. Another tool is SSLsniff which is designed to MITM all SSL connections on a LAN, and dynamically generates certificates for the domains that are being accessed on the fly.

[2] Citizen Lab's report 'Planet Blue Coat: Mapping Global Censorship and Surveillance Tools' (https://citizenlab.org/2013/01/planet-blue-coat-mapping-global-censorship-and-surveillance-tools/) describes how SSL interception machines intended for legitimate use for monitoring a specific company's traffic are also used by countries with a history of concerns over human rights.

Cryptographic technical details

Both parties that send and receive messages need that EndCryptor is installed in order to encrypt and decrypt. No third parties are used (e.g. to provide public keys, to provide online connection to a third party machine, etc.) neither an online Internet connection between the sender and the receiver is needed. New contact's public key can be fetched from the Web Directory if wanted - this public key is signed by a signature chain that the program code trusts. When encrypting/decrypting the stored information on the EndCryptor's security database on the used computer is used together with the information that the message in question provides. The security database is encrypted, some parts with AES, others with ChaCha20, key size is 256 bits. User's entry password to the security database is hashed using salted password hashing pbkdf2 with hmac sha256 using 10000 iterations.

Used classical elliptic curves in emails are the Edwards curve Ed25519 and the corresponding Curve25519. The Edwards curve is used for signing and the Curve25519 for Diffie-Hellman calculation. The classical security of Curve25519 is 128 bits.

Quantum attack resistant public keys are supersingular isogeny SIDH (p751) 2.0 and 3.0 keys designed by Microsoft. The classical security of a SIDH key is 192 bits. In scientific papers authors of SIDH (p751) construction state that its quantum security is 128 bits, in NIST's Post-Quantum Cryptography project they classify it as "matching the post-quantum security of AES192" - this refers to NIST's Quantum Security Strength Categories III.

Compare classical cryptographical strengths:

Symmetric	Elliptic (classical)	DH or RSA
80	163-223	1024
112	224-255	2048
128	256-383	3072
192	384-511	7680
256	512+	15360

The classical security of curve25519 is 128 bits and matches that of a 3072 bit RSA/Diffie-Hellman public key. Note that the classical security of 192 symmetric bits corresponds to 7680 DH or RSA public key bits. The reader should note that usually cryptographic construction's security is expressed as the security of its weakest link – this is usually the public key.

This table appears in NIST Special Publication 800-57 from July 2012 titled 'Recommendation for Key Management – Part 1: General(Revision 3)'. NIST means National Institute of Standards and Technology (USA).

If the parties communicate in turns then the first email's classical security is 128 bits, after that the classical security is 192 bits. The quantum protection starts from the

second email (included). The patented protocol starts after the second email has been received.

The first messages encrypted using long term public keys consist of classical part and SIDH part. The SIDH part is appended to the end of the classical part. If the parties communicate in turns there are 2 messages of this kind.

EndCryptor's security properties rely on the protocol that needs to be initialized with 2 short term (ephemeral) classical public keys created at the time of the contact creation. These keys are included as an encrypted part of the first exchanged emails' classical part.

The first emails' SIDH part contains SIDH 2.0 quantum attack resistant public keys. After the initial exchange the SIDH keys are version 3 keys if both parties have at least version 2.5.4.62. The SIDH keys are later exchanged at intervals of 7 days if parties communicate frequently.

The encryption of a first message to a receiver's long term public key consists of creating an ephemeral Ed25519 public key which is used to calculate a shared secret with receiver's long term public key. Additional ephemeral Ed25519 public key is created and put into that part of the classical part that will be encrypted. The whole classical part is signed with sender's long term classical public key. That part of the message which is encrypted includes the signature at the end of the classical part. The hashed value of shared secret is used as an encryption key for ChaCha20, key size is 256. The last SIDH part of the message contains newly created SIDH keys and a signature of the whole message signed with sender's long term classical public key.

When the above message has been received and a first message to its sender is sent the sender creates an ephemeral Ed25519 public key and new SIDH keys and calculates a shared secret with that Ed25519 key that was inside the received encrypted message.

The actual encryption/decryption key of the second message is calculated by computing a Keccak hash value over a value derived from the classical shared secret and the SIDH shared secret i.e key=hash(A || B) where || is the concatenation operation, A is the hash of classical shared secret and B is derived from the SIDH shared secret. In more detail: the SIDH shared secret is 192 or 188 (version 3.0) bytes long, it is Sha3-512 hashed. The first 32 bytes of the result are used in this encryption/decryption key computation as value B.

An above described message's classical part contains 4 latest classical public keys of its sender. An older one signs the next newer one.

After the exhange of initial messages the protocol is initialized. Then a shared secret is calculated with each pair of exchanged protocol initialization classical public keys i.e. two shared secrets are calculated. They are concatenated and a Keccak hash is calculated over the above mentioned two classical shared secrets and a value derived from the SIDH shared secret i.e initialization value=hash(A1 || A2 || B), where A1 and A2 are classical shared secrets and B is derived from the SIDH shared secret. The result is to be used as initialization value to form protocol's initial states. The reader

should note that an attacker has to find out every calculated shared secret to find out the resulting Keccak hash value. In more detail: the SIDH shared secret is 192 or 188 (version 3.0) bytes long, it is Sha3-512 hashed. The last 32 bytes of the result are used in this initialization value computation as value B.

The rest of the discussion below considers the situation when the initialization set of public keys has been received by both participants and the protocol is working. The idea of the protocol is to continuously exchange new classical and post quantum public keys to enable fast recovery from hacking attack. The protocol also protects old emails so that they cannot be decrypted by the attacker if they have been previously decrypted by the true receiver.

An encrypted message is signed by a previously delivered classical public key that the receiver is known to have – these public keys in messages are delivered to the receiver in encrypted form; they are encrypted together with the plaintext. The signature is encrypted and the message ends also with a Keccak mac, also the ephemeral public key in the message is encrypted (the encryption key for the ephemeral key and the signature and the key for the Keccak mac is either derived from the initial shared secret or is a hash of a public key that was delivered in encrypted form). A reader may ask why there are two authentication methods: signature and mac. The signature is useful if one of the parties is hacked: an attacker cannot impersonate the unhacked party based on information obtained from the hacked party. The Keccak mac is checked first, then the signature. Note that a message is accepted as original only if the plaintext's authentication code evaluates correctly – see the end of this chapter. Why the additional encryption of the ephemeral public key and the signature? Why not? The less information is given to an observer the better. When EndCryptor was initially released these values were not encrypted – later it was realized that it can be done without affecting the protocol and that there was a value available that could be used as encryption key. One can also argue that a quantum computer cannot break a symmetrically encrypted classical public key.

Encryption of the messages is done using 256 bit key sized ChaCha20.

The plaintext ends with an authentication code, the authenticator is Poly1305 one time authenticator. During encryption both the plaintext and the authentication code are encrypted. After the decryption the authentication code is calculated over the plaintext and checked.

The implementation of the Ed25519, Curve25519, Chacha20 and Poly1305 is the reference source code implementation available from SUPERCOP benchmark suite and NaCl crypto library (European Network of Excellence in Cryptology II projects funded by European Commission). These primitives are designed to give protection against side channel attacks like cache timing attacks. The implementation of the SIDH 2.0 and 3.0 public keys is from GitHup: PQCrypto-SIDH. The code is also constant time code.

The signatures in encrypted messages use Keccak-256 which is constructed according to the specification that won the SHA3 competition (bit rate is 1088 and capacity is 512).

The private keys of public keys are made using a Goldreich-Levin hard-core bit generator. The initial seed consists of events like mouse movements and the operating system's state and bytes provided by the CryptGenRandom system call.

An outline of the methods used:

Backward security: Every EndCryptor message is encrypted with different symmetric 256-bit key and after the message has been decrypted there is no information in the security database from which the decryption keys could be deduced again. A message can thus be decrypted only once.

Recovery from attack: Every message EndCryptor encrypts contains new classical public keys of the sender that are specific to the receiver; these public keys are created at the time of sending - when the receiver decrypts the message the security is restored. These classical public keys are delivered in encrypted form; they are encrypted together with the plaintext. Quantum attack resistant public keys are also delivered in encrypted form but more seldom – if the parties communicate regularly the exchange happens at 7 day intervals.

Identity theft will be revealed even under spying attack: the stored security data that is used to build symmetric key changes after every decryption and depends on the just decrypted message.

The protocol is a stateful protocol. It means that two states are maintained for each contact: one for sending and one for receiving. A new state and the needed symmetric keys for encryption/decryption and plaintext's mac calculation are constructed from the current state and a calculated Diffie-Hellman (DH) shared secret whenever sending or receiving happens. The calculation of a new state and the symmetric keys is irreversible i.e. one-way and done using a Goldreich-Levin hard-core pseudo random bit generator (PRG): **PRG(state, DH shared secret) -> list of bits.** From the generated list of bits a new state and the needed symmetric keys are separated. The generated bits pass the next-bit test – it is infeasible to predict bit $i+1$ if the first i bits are known. The irreversibility of the construction and the next bit property cause the backward security property of the protocol. The recovery property is caused by using new public keys in messages – which affect the DH shared secret parameter of the PRG.

The produced new state and the symmetric keys from the construction:

PRG(state, DH shared secret) -> new state and symmetric keys

will be unknown to the attacker if the attacker knows only one but not both parameters of the PRG. The state consists of more than 256 bits and it is stored in encrypted form on user's computer.

If there is available a quantum attack resistant DH result then the actual DH shared secret used in above and below formulas is a Sha3-256 hash over the classical and quantum attack resistant DH shared secrets.

If the attacker has accessed user's computer and has found out all data on the encrypted security database and then loses access to the computer he/she will know the classical public key of an outgoing message but has to break it (or its DH counterpart which the attacker now knows) in order to decrypt the message. When the receiver of this message sends next message to the victim the attacker cannot decrypt it without breaking a public key (if the attacker was not able to decrypt the message from the victim of the hack then he/she must break 256 bit symmetric cipher to get the victim's public key and then break one of the public keys).

To understand the PRG construction the reader needs to be skilled in cryptography.

Hash(x) uses ChaCha20 to produce 768 bits that form the 256 bit sized blocks h1, h2 and h3.
State consists of 256 bit sized blocks s1, s2 and s3.
GL(r,x) produces one Goldreich-Levin hard core bit from x using random bits r.
+ is the xor operation.

PRG(state,DH shared secret) =

Hash(DH shared secret) to produce blocks h1, h2, h3
b1 = s1 + h1
b2 = s2 + h2
b3 = s3 + h3
For (i=0;i<1280;i++)
{
    b1, b2 = SHA512(b1,b2)
    produce bit GL(b3,b2)
}

The produced list of bits form the next state's blocks s1, s2 and s3 and the required symmetric encryption/decryption and Poly1305 mac keys. The SHA512 calculation is done using NaCl library's reference, constant time implementation. The GL calculation neither indexes arrays nor branches using secret data.

Security professionals wishing to know more about the protocol should consult the **US Patent 7,899,184 B2** titled "ENDS - Messaging protocol that recovers and has backward security".

Description of encryption of storage files

When an encrypted email is sent or received it is encrypted again for storage on user's computer (using different encryption keys than those in the email that is traversing the internet). Each storage file is encrypted using different ChaCha20 256 bit key.

When EndCryptor is started the first time it saves a Personal Export key file and the user is asked to create that file's password. These items can be used to decrypt and export user's emails from backup media. Additionally a Company Export Key can be used.

The Personal Export key is actually two keys: a public key/private key pair of an Ed25519 curve and a symmetric Chacha20 256 bit key.

An encrypted storage file has a field F which stores in encrypted form the file's actual encryption key so that the file can be decrypted and exported from backup media.

For Personal Export key the encryption of the field F happens followingly:

1. Create an ephemeral public key.
2. Compute Diffie-Hellman shared secret with this ephemeral key and user's Personal Export public key.
3. Use Keccak to hash the shared secret to key K. Encrypt file's encryption key with this key K. Store the encrypted value of F on the storage file and store the hash of user's Personal Export public key on the storage file.
4. Encrypt the used ephemeral public key with a symmetric Chacha20 256 bit sized key and store it on the storage file.

The user's Personal Export key file stores the private key of user's Personal Export public key and the symmetric key that is used to encrypt the ephemeral public key. The private key is not stored on user's security database but the public key and the symmetric key are.

Company Export Key consists of a public/private key pair.

For a Company Export key the encryption of the field F happens followingly:

1. Create an ephemeral public key.
2. Compute Diffie-Hellman shared secret with this ephemeral key and company's Export public key.
3. Use Keccak to hash the shared secret to key K. Encrypt file's encryption key with this key K. Store the encrypted value of F on the storage file and store the hash of Company Export public key on the storage file.
4. Store the ephemeral public key on the storage file.

The company's Export key file stores the private key of company's public key. If a user wants to use a Company Key the user imports Company's public Export key which is used as described above.

In above storage file calculations the Ed25519 curve points are converted to the corresponding Curve25519 points when calculating the Diffie-Hellman shared secret. The password hashing scheme in Export Key files is a salted password hashing pbkdf2 with hmac sha256 using 30000 iterations.

To: Really security conscious user

A really security conscious reader should notice that the attacker's possibilities increase if he has the possibility and knowledge to modify the contents of the security data or the software in participants' computers. He could e.g. try to install his modified copy of the encryption software that behaves like the proper one but delivers to the attacker the required information.

To prevent software modification EndCryptor.exe is digitally signed using Microsoft Authenticode, the signer is "Enternet Oy". When the program starts however the Windows loader will not check the signature – this is because the checking may be very time consuming. The user can check the signature by placing the mouse over the file and using the right mouse click to select properties and Digital Signatures tab and then by pressing the Details button. Please note also that if the signature does not verity the program will still run. EndCryptor.exe itself checks that the cryptographic hash values of its own program files are as defined in the program code of EndCryptor.exe. The hash value of EndCryptor.exe (that of the running program from the media where it is started) is compared to a value stored on the security database (protected by user's entry password). If a reinstallation of previous installation is done EndCryptor should not give any program code modification message at startup. Such a message is given if the running code's checksum differs from that of a previous installation. As further protection EndCryptor can be run from read-only media.

Sometimes it is claimed that encryption products prevent antivirus programs to find viruses because the viruses in encrypted attachments are encrypted and thus undetectable. Typically the antivirus programs check a file when it is written on disk and in case of EndCryptor the virus will be found then. To test your antivirus program with EndCryptor use the EICAR Anti-Virus or Anti-Malware test file from the European Expert Group for IT-Security.

Note that the newest or specially targeted viruses are not detected by antivirus programs. Thus the most secure but uncomfortable usage that protects EndCryptor's program code and encrypted security database is such that EndCryptor is used on a machine not connected to any network and if messages contain attachment files the attachment files are never opened/activated on this machine but moved to another machine for reading/editing. In other words the machine containing EndCryptor should be used for encryption/decryption purposes only. There should be one machine connected to outside world via network that sends/receives encrypted messages, the second machine containing EndCryptor and third or more machines possibly in internal network that are used to manipulate (read/edit) received and sent attachment files in messages. The motivation for separating the machine containing EndCryptor also from the internal network is to minimize the possibility of hostile code being run in that machine if an attachment containing hostile code is opened.

Avoid security through obscurity

When you are considering buying a crypto product demand that you get a clear written description of the cryptographic essentials of the product – this can be a number identifying a patent or another written description. The purpose of this is to enable the verification of the claimed cryptographic properties. Also when new crypto attacks become known their effectiveness against the product can be checked via the description. The software vendor will also be more willing to improve the defenses when the newly discovered vulnerabilities are publicly known.

The hiding of the security design principles is not a good idea – this is called security through obscurity. In cryptography it must be assumed that eventually the design will become known to the opponent and it is much better if the design has been analyzed by many people before this happens.

The software vendor should also have analyzed the consequences of certain possible successful attacks and what damage they cause to the security. Especially attacks that can be made possible via human error or dishonesty are important. In practice this means that the vendor must consider what damage a successful hacking into user's computer or into a server (if one is used) can cause. In the light of recent attacks against the SSL/TLS protocol one should have analyzed the consequences of fake certificates. Recent revelations of how a government compels companies to give user data in servers should discourage the storing of sensitive data to third party servers – certainly in the case where the data is in unencrypted form even for a millisecond time and much consideration should be given also to the (seemingly more secure) case where the data is encrypted and the keys are only in the hands of the true owner of the data. If at later time the encryption keys can be stolen the stored data in third party servers may become vulnerable – depending on the cryptosystem's design.

Essential things:

The general workflow, how the keys are derived, standards used, used ciphers and their modes of operation.