Technical Note

Technical Note: PKCS#11

Background, setup, configuration, troubleshooting

Version 2.1

pdftools

Contents

1 Introduction

PKCS#11 is a widely used standard for providing extensive support in the area of digital signatures, including cryptographic algorithms and storage for certificates and keys.

Pdftools products rely on the PKCS#11 infrastructure for creating and verifying digital signatures. It constitutes the preferred infrastructure when dealing with hardware tokens and hardware security modules (HSMs).

For applications using soft certificates, there exist suitable software token implementations, such as openCryptoki for Linux, or the PKCS#11 softtoken on Solaris platforms.

This how-to manual explains how to prepare a PKCS#11 softtoken infrastructure for use with Pdftools products.

1. Prepare a PKCS#11 provider so it can be used with software of Pdftools, such as the 3-Heights® PDF Security or the 3-Heights® PDF to PDF/A Converter.
2. Some useful tools for working with a PKCS#11 provider are described.
3. In case an issue occurs during the installation, configuration or in production, there is a troubleshooting guide.

1.1 Interoperability support

The following cryptographic token interface (PKCS#11) products have been successfully tested:

- SafeNet Protect Server
- SafeNet Luna
- SafeNetAuthentication Client
- IBM OpenCrypTokI
- CryptoVision
- Siemens CardOS
- Gemalto IDBridge CT30 and others
- Utimaco HSM

The PKCS#11 interface is a widely used standard and an interface offered by most cryptographic devices. As a result, cryptographic devices not contained in the list above are likely to work as well.

1.2 Terms and definitions

Signature Cryptographic procedure to ensure the integrity and/or authenticity of a document. The signature is embedded in the PDF document in the form of a CMS (PKCS#7) message.

Certificate A certificate is an electronic confirmation of the identity of a natural or legal person.

Key The certificate contains a public key for the validation of the signature. The public key must match a private key, which is used for the creation of the signature.

Token The token is a logical view of a cryptographic device defined by the PKCS#11 library. All devices (slots) managed by the same PKCS#11 library are part of the same token.

> **Note:** This is not the same as an USB token.

Slot A “plug-in position” inside a token. So this might be separate partitions on a HSM. Alternatively, this might be different USB tokens of the same type.

The slot contains cryptographic objects and protects against unauthorized access.

PIN A secret number, which is required to access the slot on the token.

1.3 Abbreviations

CA	Certification Authority
CMS	Cryptographic Message Syntax
CRL	Certificate Revocation List
CSP	Cryptographic Service Provider
HSM	Hardware Security Module
OCSP	Online Certificate Status Protocol
PIN	Personal Identification Number
PKCS	Public Key Cryptography Standards
QES	Qualified Electronic Signature
TSA	Timestamp Authority
TSP	Timestamp Protocol

1.4 PKCS#11 object structure

This section describes the objects and their organization within a PKCS#11 store, such that they can be used for signature creation and validation by the 3-Heights® product of Pdftools.

1.4.1 Certificate

For the creation of a signature, a valid signing certificate must be installed. The certificate must not be marked as private (`CKA_PRIVATE=FALSE`).

The German Federal Network Agency requires the following algorithms and key strengths for qualified digital signatures, valid until the year 2017.

Hash: SHA-256
RSA: 2048 Bit

Therefore, it is recommended that you use certificates that meet these requirements.

1.4.2 Private key

For the creation of a signature, a private key is required. The key must be associated to the certificate (same value for `CKA_ID`). The private key must be marked as private (`CKA_PRIVATE=TRUE`) to ensure the signature can only be applied in combination with providing a PIN. The key must be suitable for signature creation (`CKA_SIGN=TRUE`).

The private key is not required for signature validation.

1.4.3 Trust chain

Embedding of the trust chain in the signature requires all certificates of the issuer (certificate authority) up to and including the root certificate. They must be installed in the same slot as the signing certificate itself.

Certificates must not be marked private (`CKA_PRIVATE=FALSE`) and the subject attribute (`CKA_SUBJECT`) should be set to the certificate's subject.

For signature validation, all certificates in the keystore are regarded as trusted.

1.4.4 Slot

The number of the slot containing the objects must be known. It is required by the signature software.

1.4.5 Test certificate

A test certificate should be available, which can be used to test the signature software.

While it would be possible to use a simple self-signed certificate for testing, it is recommended to use a test certificate that is similar to the signing certificate used in production.

2 Installation instructions

The following sections describe installation instructions for different types of PKCS#11 devices.

2.1 USB token or smartcard (e.g. SuisseID)

2.1.1 Installation

To use your USB token, you have to install its middleware (driver) first. Make sure you install PKCS#11 support as well.

2.1.2 Initial configuration

Follow the installation instructions provided with the USB token.

2.1.3 Certificate installation and management

On USB tokens and smartcards, it is usually not possible to install or modify certificates. On some USB tokens, the certificates of the trust chain are not installed. In this case, consult the chapter on PKCS#11 cryptographic providers in the user manual of your 3-Heights® product. There is a section describing the use of PKCS#11 stores with missing issuer certificates.

2.1.4 Use of the device

On Windows, the device must always be used in an interactive session for two reasons.

First, the middleware requires the user to enter the PIN interactively to create a qualified electronic signature. Second, USB tokens and smartcards are managed by Windows such that the device is available only to the user currently using the computer's console.

So services, remotely logged in users and applications running in locked sessions have no access to the device. This issue can be overcome by using the 3-Heights® Signature Creation and Validation Service, which is available from http://www.pdf-tools.com.

2.1.5 Provider configuration for 3-Heights® products

The Provider configuration string used in 3-Heights® Products should be:

`Provider = "‹PKCS11Library›;‹slotid›;‹pin›"`

Where:

- `‹PKCS11Library›`: Is the PKCS#11 library of your USB token's middleware. It is recommended to specify an absolute path to the library.
  - SuisseID: The library is typically called `cvP11.dll` or `libcvP11.so`
  - Gemato IDBridge CT30: The library is called `iidp11.dll` and located middleware's installation directory, e.g. `C:\Program Files (x86)\Buypass Access\iidp11.dll`
  - Other Gemato hardware: The library is usually called `gclib.dll` and located in the bin directory of the middleware's installation directory, e.g. `XXXX\Gemalto\Classic Client\BIN\gclib.dll`
- `‹slotid›`: Is the ID of the slot. If you are uncertain about which slot ID to use, list your slots using `cticert`.
- `‹pin›`: Is your user PIN for the USB token.

2.2 HSM (e.g. SafeNet Luna or Protect Server)

2.2.1 HSM installation

The HSM must support the PKCS#11 interface. The manual of the manufacturer states if this interface is supported. The interface is normally provided in the form of a library (DLL on Windows, or shared object on Linux or macOS) as part of the client software.

2.2.2 Client installation

The client software of the HSM must be installed on the same computer as where the signature software is used. The client software also installs a DLL for the PKCS#11 interface. The name of the library, e.g. `cryptoki.dll` and the path on the file system must be known for the configuration of the signature software.

2.2.3 Certificate installation and management

The steps below describe the setup of a SafeNet Luna SA using the CMU tool. Even if your HSM does not support the CMU tool, you can follow the same steps with your HSMs management software.

Generate a new key pair:

```
$ cmu gen -modulusBit=2048 -publicExp=65537 -sign=1 -verify=1 -labelPublic=
"Public Key X" -labelPrivate="Private Key X"
```

Create a new certificate signing request (CSR). Use the handles of the newly created keys:

```
$ cmu requestCert -privatehandle=XXX -publichandle=XXX -C=CH -OU="My Unit" -O=
  "My Organization " -CN="My Signing Certificate S" -outputFile=cert.req
```

Submit the CSR to your certificate authority (CA). Download your new certificate and all certificates of the trust chain.

Import the signing certificate into the keystore:

```
$ cmu import -inputFile=certificate.cer -label="My Signing Certificate X"
```

List all objects and their handles:

```
$ cmu list -display=handle,class,label
```

Associate the signing certificate with its private key using the `CKA_ID` attribute. First, a unique ID must be chosen.

For example, the certificate's fingerprint is suitable:

```
$ openssl x509 -in certificate.cer -fingerprint -noout | sed -e 's/://g'
```

Set the ID of the certificate:

```
$ cmu setAttribute -handle=XX -id=3c62ddcee426701f1fae3fdc690f7d89ffe18326
```

Set the ID of the private key:

```
$ cmu setAttribute -handle=XX -id=3c62ddcee426701f1fae3fdc690f7d89ffe18326
```

Import all certificates of the trustchain:

```
$ cmu import -inputFile=ca1.cer -label="CA Certificate XX"
$ cmu import -inputFile=ca2.cer -label="CA Certificate XX"
```

Use the cticert tool to list the contents on your HSM. Verify that all certificates of the trustchain have been imported and the private key of your signing certificate can be found.

The public key is part of the certificate. So the separate public key object not needed anymore and may be deleted:

```
$ cmu delete -handle=XX
```

2.2.4 Provider configuration for 3-Heights® Products

The Provider configuration string used in 3-Heights® Products should be:

`Provider = "‹PKCS11Library›;‹slotid›;‹pin›"`

Where:

- `‹PKCS11Library›`: Is the PKCS#11 library of your HSM's middleware. It is recommended to specify an absolute path to the library.
  - SafeNet Luna: The library is typically called `cryptoki.dll` or `libCryptoki2_64.so`
- `‹slotid›`: Is the ID of the slot. If you are uncertain about which slot ID to use, list your slots using `cticert`.
- `‹pin›`: Is your user PIN for the HSM partition.

2.3 openCryptoki soft store on Linux

2.3.1 Installation

IBM uses openCryptoki to support its cryptographic hardware. You can disregard any platform requirements related to IBM hardware, as you are only interested in the software token that comes along as a bundled feature.

The following links provide extensive information about openCryptoki:

https://www-01.ibm.com/support/knowledgecenter/linuxonibm/com.ibm.linux.z.lxce/lxce_stackoverview.html

http://sourceforge.net/projects/opencryptoki/

Please check if your Linux distribution already contains a binary package of `openCryptoki`. If so, this is the preferred way to install it on your platform. Alternatively, you can download the source kit and compile it for your Linux platform.

For convenient use, create a symbolic link in `/usr/lib` to the `libopencryptoki.so` shared library as appropriate for the installation location you have chosen. Also, make sure that the slot daemon (sbin/pkcsslotd) is started at system startup.

2.3.2 Initial configuration

Make sure to complete the initial configuration using the `pkcsconf` tool (as documented on the IBM web page).

> **Note:** Some of these initial steps might have been executed by your distribution's package manager already.

Execute the setup script:

```
$ sudo pkcs11_startup
```

The script does the following:

- Create a user group called `pkcs11`
- Creates the slot configuration

Start the service:

```
$ rcpkcsslotd start
```

Token configuration: The token is configured using the following tool.

```
$ pkcsconf
```

or (on some installations):

```
$ pkcsconf
```

Token initilization: Initialize the token and use slotid 0.

```
$ pkcsconf -I -c 0
Enter the SO PIN: ********
Enter a unique token label: zlinux64bit
```

The default value of the SO (security officer) PIN is 87654321.

Initialize the user PIN, e.g. to 123456:

```
$ pkcsconf -u -c 0
```

```
Enter the new user PIN: ********
Re-enter the new user PIN: ********
```

PINs can be changed. SO-PIN:

```
$ pkcsconf -P -c 0
```

User-PIN:

```
$ pkcsconf -p -c 0
```

User setup: Add the user to the group `pkcs11`.

All users that need access to the token must be added to the group `pkcs11`.

```
$ usermod -G pkcs11 user-name
```

Note that the user's group settings will not take effect until after the user logs in again. Verify the settings:

```
$ groups
```

2.3.3 Certificate installation and management

openCryptoki does not comprise the utilities that you need to manage certificates and keys in the PKCS#11 store. Certificates can be installed, listed, and deleted using the tool `cticert`. Refer to the separate chapter on this tool for more information.

2.3.4 Provider configuration for 3-Heights® products

The Provider configuration string used in 3-Heights® products should be:

`Provider = "libopencryptoki.so;‹slotid›;‹user-pin›"`

Where:

- `libopencryptoki.so`: is the PKCS#11 library. This assumes that the library is on your library path. If not the library should be specified as an absolute path.
- `‹slotid›`: Is the ID of the slot you have created. If you are uncertain about which slot ID to use, list your slots using `cticert`.
- `‹user-pin›`: Is your user PIN for the slot.

2.4 PKCS#11 soft token on Solaris

2.4.1 Verification of PKCS#11 soft token

The PKCS#11 soft token comes pre-installed on Solaris platforms. Use the following commands to verify proper functioning and availability of the documentation:

```
$ man pkcs11_softtoken
```

```
$ man pktool
```

```
$ pktool help
```

```
$ pktool tokens
```

2.4.2 Initial configuration

Initialize the `libpkcs11` provider's password with `pktool`:

```
$ pktool setpin
```

2.4.3 Certificate installation and management

Certificates can be installed, listed and deleted using the tool `cticert`. Refer to the separate chapter on this tool for more information.

2.4.4 Provider configuration for 3-Heights® products

The Provider configuration string used in 3-Heights® Products should be:

`Provider = "libpkcs11.so;‹slotid›;‹pin›"`

Where:

- `libpkcs11.so`: is the PKCS#11 library for the Solaris softtoken.
- `‹slotid›`: Is the ID of the slot. If you are uncertain about which slot ID to use, list your slots using `cticert`.
- `‹pin›`: Is your PIN for the slot.

3 Tools

For management tasks of your tokens and the objects contained therein, it is recommended to use the tools provided with your cryptographic device. When creating objects such as certificates and key material, take special care to meet the requirements explained in chapter PKCS#11 Object Structure.

3.1 cticert (Certificate store utility for PKCS#11)

For troubleshooting of issues or if your cryptographic device does not come with suitable tools, the `cticert` tool is helpful.

The tool's features include:

- List slots of a token.
- List certificates and their properties.
- Import certificates, including their private keys.
- Export certificates.
- Delete certificates and other objects.

3.1.1 Installation

The `cticert` tool can be downloaded from the Pdftools website:

- Log in to your personal customer area on http://www.pdf-tools.com.
- Go to "Utilities & Tools".
- Download the "Certificate store utility for PKCS#11".
- Extract the archive to a suitable installation directory.
- Run the usage of the tool and verify that its version matches the version of your 3-Heights® product you use to create signatures.

The tool requires a valid license for any product of PDF Tools AG.

3.1.2 Usage

The usage of the tool is printed, if cticert is executed with no arguments:

```
Certificate Store Utility for PKCS#11. Version 4.8.25.0 of Dec 18 2016.
Import, export and list certificates.
cticert: [options]
options:
    -cp prov        Provider (interface library, slot number and PIN number)
    -cps name str   Set provider property bag string
    -d i            Delete certificate number 'i'
    -i file         Import X.509 certificate (PEM or DER) or PKCS#12 file
    -p passwd       Password for PKCS#12 file
    -t              Mark imported certificate trusted (requires SO login and
                    PKCS#11 version 2.11 or later)
    -lb label       Set label of imported certificate
    -l              List all certificates (get certificate numbers)
    -ls lib         List all available slots (tokens) of interface library
                    List certificates of tokens in combination with -l
    -c i            Clear store
                      1: expired certificates
```

```
                    2: certificates with private keys
                    4: all certificates
                    8: all token objects (certs, keys, ...)
    -x file.cer i   Export X.509 certificate number 'i' to file
    -v              Verbose mode
    -lk key         Set license key

error codes:
    0   success
    1   invalid provider / cannot open input file
    2   cannot create output file
    3   parameter / switch error
   10   license error
```

3.1.3 Identify the ID of a slot

All slots of a token can be listed as follows:

```
$ cticert -ls "<PKCS11Library>"
```

Unfortunately, many tokens have slot descriptions that are not useful to identify a particular slot.

Therefore the cticert can list all slots and all their certificates:

```
$ cticert -ls "<PKCS11Library>" -l
```

3.1.4 Import a soft certificate (PKCS#12)

A soft certificate can be imported using the following command:

```
$ cticert -cp "<PKCS11Library>;<slotid>;<USERPIN>" -i <PKCS12FILE>
  -p <PKCS12PASSWORD>
```

All content of the file is imported, which includes the signing certificate, the private key and all certificates of the trust chain.

If you get a cryptic error message, you have most likely specified the wrong password for your PKCS#12 file.

After importing, use cticert to list the certificates. Verify that all certificates of the trust chain are available. If not proceed with importing the missing certificates.

If importing a certificate fails, try to add the following option to the command above:

```
-cps CRYPTOKI_VERSION 513
```

This will use PKCS#11 attributes of version 2.01 (0x201 = 513) only. By default, these attributes are used that a token claims to support. But the PKCS#11 version reported by some tokens is not correct.

3.1.5 Import certificates of the trust chain

For certificates of the trust chain or trusted certificates, no private key is required.

Certificates of the trust chain can usually be downloaded from your CA's website. Certificates must be available as X.509 files that are either DER or PEM encoded.

Use the following command to import each certificate of the trust chain:

```
$ cticert -cp "<PKCS11Library>;<slotid>;<USERPIN>" -i <CERTIFICATE>
```

3.1.6 Verify the PKCS#11 object structure

List all objects of a slot:

```
$ cticert -cp "<PKCS11Library>;<slotid>;<USERPIN>" -l -v
```

Verify that:

1. All signing certificates are available and valid.
2. The signing certificates have a private key.
3. The trust chain of all signing certificates is available:
   a. Get the certificate's ISSUER.
   b. Verify that a certificate of that name exists.
   c. Proceed with 3a, until the root certificate, where the certificate's issuer is the certificate itself.
4. All your trusted certificates are available (necessary for signature validation only).

3.2 pkcs11-tool

There is another cryptographic toolset available for Linux: opensc (http://www.openscproject.org/opensc).

opensc comes ready to use with several Linux distributions. If this is not the case for a particular platform, you have the option to make the binaries from the source distribution kit.

The tool of interest for our purposes is `pkcs11-tool`.

3.2.1 Usage

For a quick introduction, have a look at the usage listing of `pkcs11-tool`:

```
Usage: pkcs11-tool [OPTIONS]
Options:
  --show-info, -I           Show global token information
  --list-slots, -L          List slots available on the token
  --list-mechanisms, -M     List mechanisms supported by the token
  --list-objects, -O        Show objects on token
  --sign, -s                Sign some data
  --hash, -h                Hash some data
  --mechanism, -m <arg>     Specify mechanism (use -M for a list of supported
                            mechanisms)
  --login, -l               Log into the token first
```

```
                          (not needed when using --pin)
  --pin, -p <arg>         Supply User PIN on the command line
                          (if used in scripts: careful!)
  --so-pin <arg>          Supply SO PIN on the command line
                          (if used in scripts: careful!)
  --init-token            Initialize the token, its label and its SO PIN
                          (use with --label and --so-pin)
  --init-pin              Initialize the User PIN (use with --pin)
  --change-pin, -c        Change your User PIN
  --keypairgen, -k        Key pair generation
  --key-type <arg>        Specify the type and length of the key to create,
                          for example rsa:1024
  --write-object, -w <arg>  Write an object (key, cert) to the card
  --read-object, -r       Get object's CKA_VALUE attribute (use with --type)
  --application-id <arg>  Specify the application id of the data object
                          (use with --type data)
  --type, -y <arg>        Specify the type of object
                          (e.g. cert, privkey, pubkey)
  --id, -d <arg>          Specify the id of the object
  --label, -a <arg>       Specify the label of the object
  --slot <arg>            Specify number of the slot to use
  --slot-label <arg>      Specify label of the slot to use
  --set-id, -e <arg>      Set the CKA_ID of an object,
                          <args>= the (new) CKA_ID
  --attr-from <arg>       Use <arg> to create some attributes
                          when writing an object
  --input-file, -i <arg>  Specify the input file
  --output-file, -o <arg> Specify the output file
  --module <arg>          Specify the module to load
  --test, -t Test         (best used with the --login or
                          --pin option)
  --moz-cert, -z <arg>    Test Mozilla-like keypair gen and
                          cert req, <arg>=certfile
  --verbose, -v           Verbose operation. Use several times
                          to enable debug output.
```

3.2.2 Import a trusted certificate

You generally want to store the certificates needed for signature creation or validation purposes as trusted in the PKCS#11 store.

Starting with a basic certificate file, you need to convert it into the DER encoding, and have it marked as trusted, prior to using the `pkcs11-tool`'s certificate import feature:

```
openssl x509 -trustout < certificate.cer > trusted.cer
openssl x509 -outform DER < trusted.cer > certificate.DER
```

```
pkcs11-tool --module libopencryptoki.so -y cert -w certificate.DER -label NAME \
  --id <ID> -l
```

> **Tip:** Always specify a label and the correct ID. This permits you to selectively delete or update anentry.

3.2.3 Import private key

Unless the private key is already stored in DER formatted file, you need to convert it accordingly:

```
openssl rsa -outform DER -out private-key.DER < private-key.pem
```

The DER encoded private key is imported into the store as follows:

```
pkcs11-tool --module libopencryptoki.so -y privkey -w private-key.DER
  --label NAME --id <ID> --pin PIN -l
```

> **Note:** It is important to specify the ID value identical to the ID of the corresponding certificate, as this is the relevant criterion for matching the two objects in the store for the purpose of creating signatures.

4 Troubleshooting

With most issues, it is a good idea to verify the PKCS#11 Object Structure the cticert tool as described in Verify the PKCS#11 object structure.

4.1 Return values versus error codes

Many functions in the Pdftools software return a Boolean value.

- The return value indicates whether the function generally completed successfully or not.
- The property ErrorCode provides additional information about the result of the previous function call.

The return value is more important than the error code. A function that returns false always indicates an error. If the return value is true and in error code is different from 0, the error code describes a warning, which does not invalidate the process per se (e.g. applying a digital signature), but may still be of importance (e.g. OSCP server not available).

A complete list of all errors is available as part of the documentation of the software.

C `pdferror.h`

Java `NativeLibrary.java.ERRORCODE`

.NET `libpdfNET.Pdftools.Pdf.PDFErrorCode`

Error messages and possible reasons in relation with HSM are described in the next chapter.

4.2 Error codes and possible causes

4.2.1 SIG_CREA_E_SESSION (0x8A130101)

- PKCS#11 library (e.g. DLL) not found.
  → Specify correct library in provider string. Try using an absolute path to the library.
- The platform of the library is different to the application's (32-bit vs. 64-bit).
  → Specify correct library in provider string.
- The library does not have a PKCS#11 interface.
  → Specify correct library in provider string.
- Initialization of the library failed due to too many applications and/or threads access the library concurrently.
- The slot number is invalid.
  → Identify the correct slot ID using cticert (Certificate store utility for PKCS#11).
- The cryptographic provider has not been set up correctly.
  → Double check your installation and use the provider's tools and log to analyze the cause.

4.2.2 SIG_CREA_E_STORE (0x8A130102)

- This error does not occur in combination with PKCS#11 (Microsoft Cryptographic Provider only).

4.2.3 SIG_CREA_E_CERT (0x8A130103)

- Certificate not found in the defined slot number.
  → Identify the correct slot ID using cticert (Certificate store utility for PKCS#11).
  → Verify your certificate selection parameters using the dedicated chapter in the user manual.

4.2.4 SIG_CREA_E_INVCERT (0x8A13010B)

- The certificate has expired or is not yet valid.
  → Obtain a valid signing certificate.
- The certificate's key usage does not allow signature creation.
  → Obtain a valid signing certificate.
- The downloaded OCSP response or CRL indicates that the certificate has been revoked.
  → Obtain a valid signing certificate.

4.2.5 SIG_CREA_E_OCSP (0x8A130104), SIG_CREA_E_CRL (0x8A130108), SIG_CREA_E_TSP (0x8A130105)

- Failed to establish an HTTP connection (see requirements).
  → Check your HTTP connection and firewall rules (see dedicated chapter in user manual).
- The server of the issuer is not available.
  → Verify the servers are all available.
- The response returned is invalid.
  → Contact your CA.

4.2.6 SIG_CREA_E_PRIVKEY (0x8A130106)

- The private key is not installed in the slot number or does not match the certificate.
  → Verify the PKCS#11 object structure.
- Your PIN is incorrect.
  → Double-check your pin.
- Your certificate has been locked.
  → Some devices lock a certificate, after a wrong PIN has been entered a number of times. Consult your device's user manual for instructions on how to resolve this.
- The private key could not be found.
  → Check that the key object is available in the keystore and properly associated with the signing certificate (see section Private key).
- The signature algorithm is unknown or unsupported by cryptographic provider
  → Try to set the provider session property `"MessageDigestAlgorithm"` to `"SHA-1"` and check your certificate uses RSA keys.
  → Do not set the provider session property `"SigAlgo"` to an algorithm not supported by the provider.

5 Contact

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