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Yubico YubiHSM Monitor

Test utility for the YubiHSM

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Introduction

Yubico is the leading provider of simple, open online identity protection. The company's flagship product, the YubiKey®, uniquely combines driverless USB hardware with open source software. More than a million users in 100 countries rely on YubiKey strong two-factor authentication for securing access to computers, mobile devices, networks and online services. Customers range from individual Internet users to e-governments and Fortune 500 companies. Founded in 2007, Yubico is privately held with offices in California, Sweden and UK.

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Contents

1 Document Information

1.1 Purpose

This document provides a quick reference to the YubiHSM monitor application. The purpose of the monitor application is to provide a simple tool to evaluate YubiHSM concepts and functionality under the Microsoft Windows operating system.

1.2 Audience

YubiHSM developers

1.3 Related documentation

- YubiHSM manual
- YubiHSM Python framework
- Yubikey Configuration Utility manual
- Yubico online forum – http://forum.yubico.com

1.4 Document History

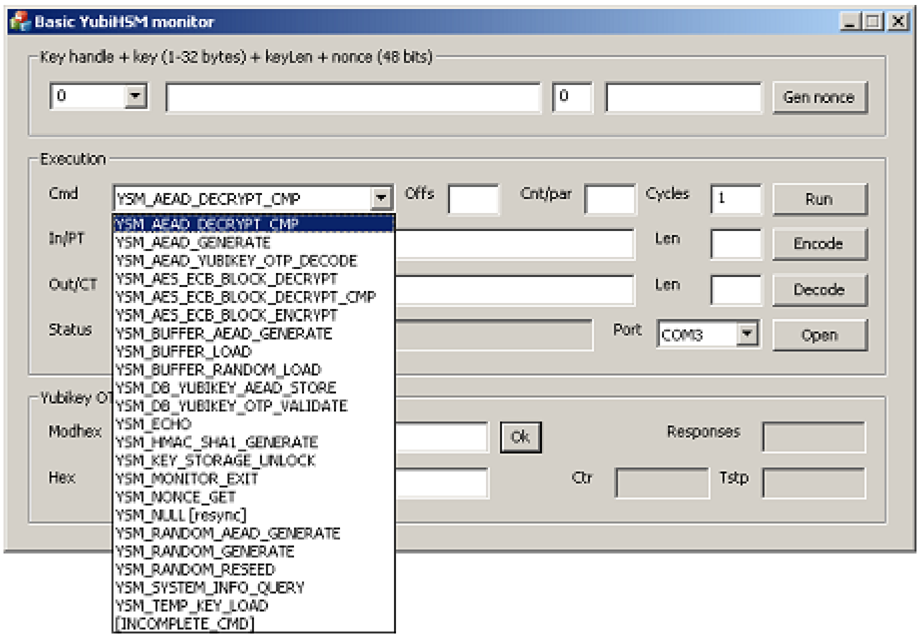
Date	Version	Author	Activity
2011-05-04	1.0	JE	First release
2012-05-24	1.1	ZD	Changed document template

2 Introduction and concepts

The Yubico YubiHSM test monitor is a simple utility designed to allow quick test and evaluation of YubiHSM HSM mode functionality and concepts. The tool is by no means indented to be used in a production setting.

Please refer to the YubiHSM manual for a detailed description of the YubiHSM functionality and concepts.

The utility is provided as a single Windows executable. The Windows registry is used to store persistent settings.



Here, the command combo box drop down is shown, where all YubiHSM commands are available.

The screen is divided into three sections

- Key handle and nonce
  Here, key handles and nonces can be entered

- Execution
  Here, all YubiHSM commands with associated parameters are entered and returned. Functions for decoding and encoding of AEADs are provided to allow evaluation and test, just like if a second YubiHSM was present. This type of functionality is by nature not a part of a real production setting.

- Yubikey OTP output
  Here, output from a Yubikey can be inserted and for automatic parsing and command wrapping.

The following sections provide a few examples how to use the tool together with a YubiHSM. For a complete command reference, please refer to the YubiHSM manual.

3 Sample setup and test

Please follow the instructions in section 8 of the YubiHSM manual how to enter configuration mode and get a basic understanding of the configuration process.

3.1 Configuring HSM mode

From the terminal, type `hsm`

```
NO_CFG> hsm
Enabled flags 7fffffff = YSM_AEAD_GENERATE,YSM_BUFFER_AEAD_GENERATE,YSM_RANDOM
_AEAD_GENERATE,YSM_AEAD_DECRYPT_CMP,YSM_DB_YUBIKEY_AEAD_STORE,YSM_AEAD_YUBIKEY
_OTP_DECODE,YSM_DB_YUBIKEY_OTP_VALIDATE,YSM_AES_ECB_BLOCK_ENCRYPT,YSM_AES_ECB_
BLOCK_DECRYPT,YSM_AES_ECB_BLOCK_DECRYPT_CMP,YSM_HMAC_SHA1_GENERATE,YSM_TEMP_KE
Y_LOAD

a:YSM_AEAD_GENERATE                 b:YSM_BUFFER_AEAD_GENERATE
c:YSM_RANDOM_AEAD_GENERATE          d:YSM_AEAD_DECRYPT_CMP
e:YSM_DB_YUBIKEY_AEAD_STORE         f:YSM_AEAD_YUBIKEY_OTP_DECODE
g:YSM_DB_YUBIKEY_OTP_VALIDATE       h:YSM_AES_ECB_BLOCK_ENCRYPT
i:YSM_AES_ECB_BLOCK_DECRYPT         j:YSM_AES_ECB_BLOCK_DECRYPT_CMP
k:YSM_HMAC_SHA1_GENERATE            l:YSM_TEMP_KEY_LOAD
m:FLAG_DEBUG

Toggle bit (space = all, enter = exit)
Enter cfg password (g to generate)
Enter hsm password (g to generate)
Confirm current config being erased (type yes) yes - wait - done
HSM>
```

The device is now configured to operate in HSM mode, but we need to load keys in order to proceed.

In order to allow debugging, the flag ‘m’ can be toggled. The key store and the Yubikey database can then be read in clear text.

3.2 Creating keys

From the terminal, type `keygen 1 2` to create 2 random keys, starting with number 1

```
HSM> keygen 1 2 - using flags 7fffffff and len 032
00000001,463b39720b3af66b9835c88be50fd9c7b5b50c63793c2c23112a51ccdf61d5b1
00000002,9a4aa8285539df0183e0356709e5c812e48fd4c466b70b5258599fcd5c8a3a1c
HSM>
```

The YubiHSM now has basic information to allow the first tests to be conducted.

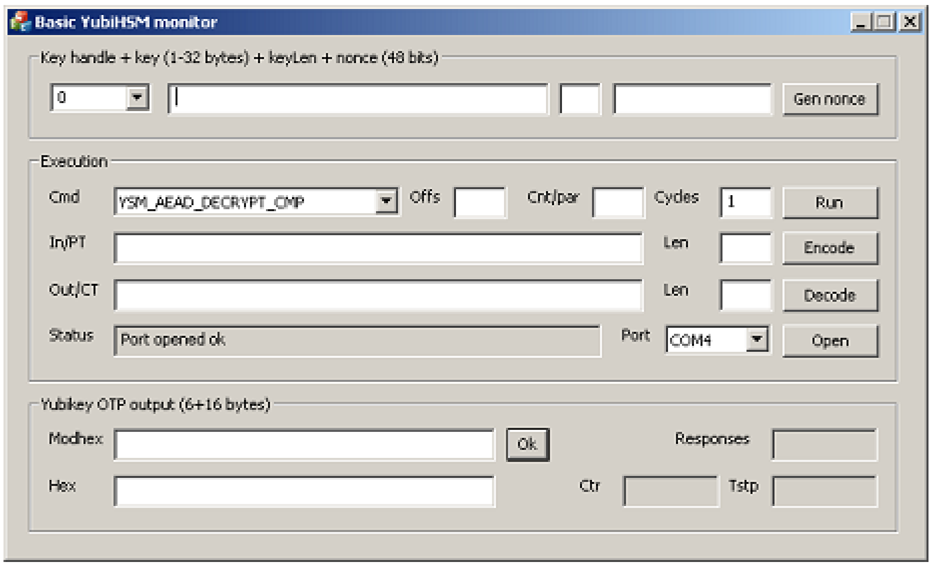
3.3 Exiting the configuration mode

Type `exit` to exit configuration mode. The YubiHSM LED now switches to a faster flashing to indicate that the YubiHSM has entered HSM mode.

Now, close the terminal program to allow the COM port to be opened with the monitor program

3.4 Starting the YubiHSM monitor

The YubiHSM monitor is provided as a self-contained executable file that does not require any additional files.


Basic YubiHSM monitor

Key handle + key (1-32 bytes) + keyLen + nonce (48 bits): 0

Execution

Cmd: YSM_AEAD_DECRYPT_CMP   Offs   Cnt/par   Cycles: 1

In/PT   Len

Out/CT   Len

Status: Port opened ok   Port: COM4

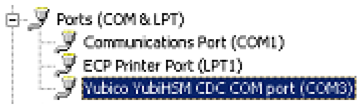
Yubikey OTP output (6+16 bytes)

Modhex   Responses

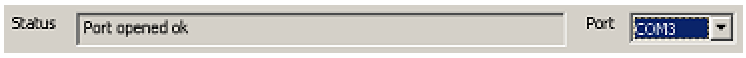
Hex   Ctr   Tstp

3.5 Selecting the YubiHSM port

In this case, the YubiHSM is present on COM3, which can be verified in the Windows Device Manager.


Ports (COM & LPT)
Communications Port (COM1)
ECP Printer Port (LPT1)
Yubico YubiHSM CDC COM port (COM3)

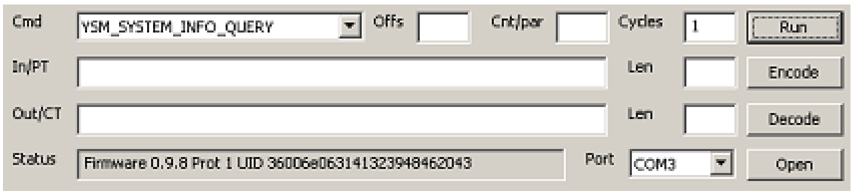
From the Port combo box in the Execution group, select the port where the YubiHSM is connected.


Status: Port opened ok   Port: COM3

The status field shall show “Port opened ok”. Make sure the terminal program is closed before opening the port, as this otherwise prevents the port from being opened.

3.6 Testing the YubiHSM connection

Now, select the YSM_SYSTEM_INFO_QUERY command from the Cmd combo box in the Execution group.


Cmd: YSM_SYSTEM_INFO_QUERY   Offs   Cnt/par   Cycles: 1

In/PT   Len

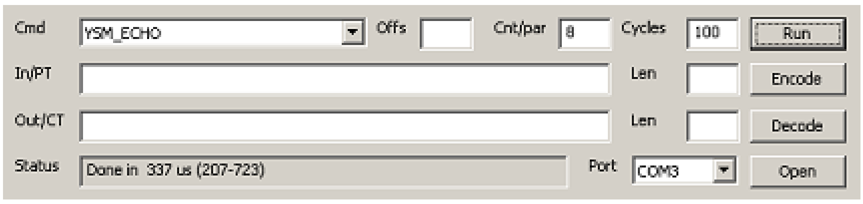
Out/CT   Len

Status: Firmware 0.9.8 Prot 1 UID 36006e063141323948462043   Port: COM3

Press the Run button and the firmware version and ID string shall appear in the status window.

3.7 Monitoring roundtrip time and throughput

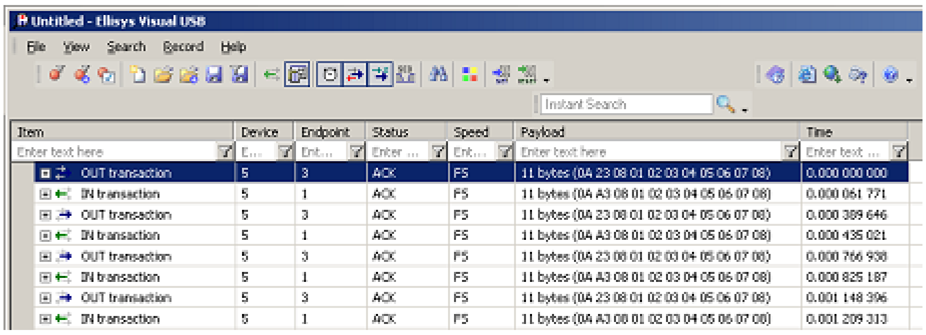
Command execution time and the application-to-device roundtrip time can be measured. In this case, the YSM_ECHO command can be used, which simply echoes back what is being sent.



Cmd	YSM_ECHO	Offs		Cnt/par	8	Cycles	100
In/PT						Len	
Out/CT						Len	
Status	Done in 337 us (207-723)					Port	COM3

In this example, 8 bytes (Cnt/par field) are sent to the YubiHSM and echoed back 100 times (Cycles field). The average roundtrip time is 337 µs, varying between 207 and 723 µs.

For a more precise tracking of the throughput and response times, an external USB hardware analyzer can be used.



Item	Device	Endpoint	Status	Speed	Payload	Time
OUT transaction	5	3	ACK	FS	11 bytes (0A 23 08 01 02 03 04 05 06 07 08)	0.000 000 000
IN transaction	5	1	ACK	FS	11 bytes (0A A3 08 01 02 03 04 05 06 07 08)	0.000 061 771
OUT transaction	5	3	ACK	FS	11 bytes (0A 23 08 01 02 03 04 05 06 07 08)	0.000 389 646
IN transaction	5	1	ACK	FS	11 bytes (0A A3 08 01 02 03 04 05 06 07 08)	0.000 435 021
OUT transaction	5	3	ACK	FS	11 bytes (0A 23 08 01 02 03 04 05 06 07 08)	0.000 766 938
IN transaction	5	1	ACK	FS	11 bytes (0A A3 08 01 02 03 04 05 06 07 08)	0.000 825 187
OUT transaction	5	3	ACK	FS	11 bytes (0A 23 08 01 02 03 04 05 06 07 08)	0.001 148 396
IN transaction	5	1	ACK	FS	11 bytes (0A A3 08 01 02 03 04 05 06 07 08)	0.001 209 313

In this case, an Ellisys USB Explorer 200 analyzer was used to monitor the traffic and verify the turnaround times. As seen, the raw data packet sent out at t = 0 gets its response after 62 Ls, which gives an idea of the YubiHSM processing time. Given the average turnaround time of 337 Ls, the remaining 337 – 62 = 275 Ls is a sum of operating system- and USB stack latencies.

4 Sample AEAD generation

The utility can generate and verify AEADs, which can then be used to test the YubiHSM functionality. Several commands, options and modes are available and two simple examples are shown below.

4.1 Storing AEAD keys in the persistent storage

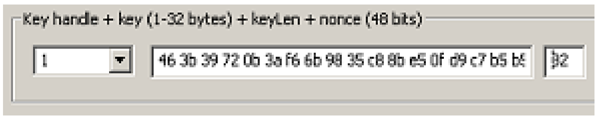
The first step is to store the keys created in the configuration (step 3.2 above) in the monitor's persistent storage.

This step is just for the sake of using this test utility as the "real" keys are already stored in the persistent YubiHSM.

Please recall the keys used in step 3.2

```
00000001,463b39720b3af66b9835c88be50fd9c7b5b50c63793c2c23112a51ccdf61d5b1
00000002,9a4aa8285539df0183e0356709e5c812e48fd4c466b70b5258599fcd5c8a3a1c
```

Type 1 into the key handle combo box and paste in the first key.



1 | 46 3b 39 72 0b 3a f6 6b 98 35 c8 8b e5 0f d9 c7 b5 b5 | 32

The key length field shows 32 as an indication that the key is 32 bytes in length.

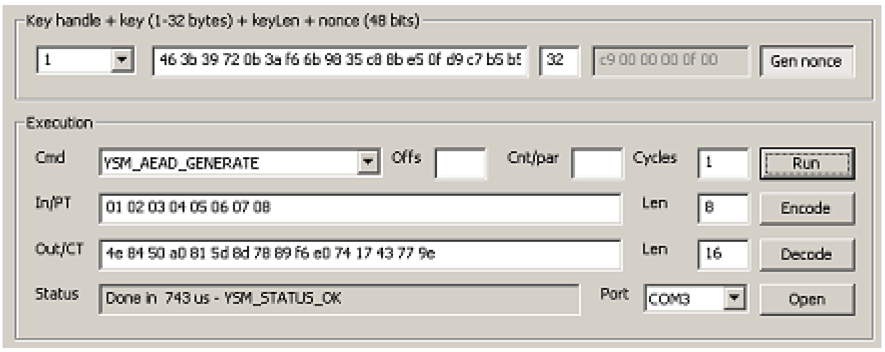
Then, type in 2 and paste in the other key in the key field in the same way as above.

The keys are now stored in the registry and can be conveniently selected using the combo box. Please make sure these keys are just for test purposes as this otherwise could be a security risk.

4.2 Using the YubiHSM to generate an AEAD

There are several ways to create AEADs and please refer to the appropriate manual sections for a detailed description of these concepts.

The simplest way to create an AEAD is to provide some clear text data and then let the YubiHSM create an AEAD from these bytes.



Key handle: 1 | 46 3b 39 72 0b 3a f6 6b 98 35 c8 8b e5 0f d9 c7 b5 b5 | 32 | c9 00 00 00 0f 00

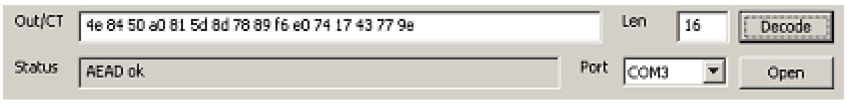
Cmd: YSM_AEAD_GENERATE | Offs: | Cnt/par: | Cycles: 1
In/PT: 01 02 03 04 05 06 07 08 | Len: 8
Out/CT: 4e 84 50 a0 81 5d 8d 78 89 f6 e0 74 17 43 77 9e | Len: 16
Status: Done in 743 us - YSM_STATUS_OK | Port: COM3

In this example, the plain text bytes 01 02 03 04 05 06 07 08 are entered in the In/PT field. The input length is 8 bytes, shown by the Len field. The AEAD generation requires a nonce, which can either be supplied or be uniquely generated by the YubiHSM. Check the Gen nonce button to use automatic generation.

Press the Run button when done. The generated AEAD is displayed in the Out/CT field. The AEAD length is always 8 bytes more than the length of the clear text string, which in this case equals 16 bytes, shown by the Len field.

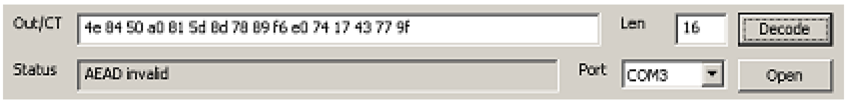
The generated nonce, associated with this AEAD is inserted into the nonce field up in the right corner.

The AEAD generated by the YubiHSM can be verified by the utility by pressing the Decode button.



Out/CT	4e 84 50 a0 81 5d 8d 78 89 f6 e0 74 17 43 77 9e	Len	16	Decode
Status	AEAD ok	Port	COM3	Open

If the AEAD is invalid or cannot be verified with the selected key handle or nonce, an error is displayed. For example, change the last 9e to 9f and press Decode.



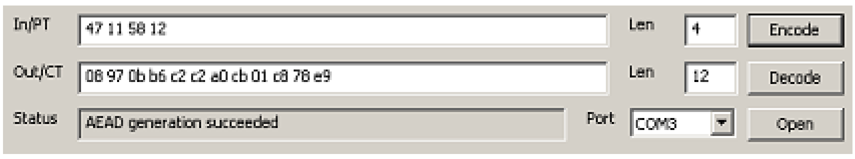
Out/CT	4e 84 50 a0 81 5d 8d 78 89 f6 e0 74 17 43 77 9f	Len	16	Decode
Status	AEAD invalid	Port	COM3	Open

The decoding now fails.

4.3 Using the tool to generate an AEAD

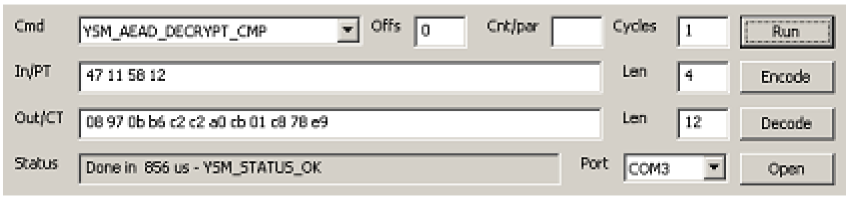
The tool can generate an AEAD, which can then be used by AEAD operations in the YubiHSM.

Enter 47 11 58 12 in the clear text field and press Encode.



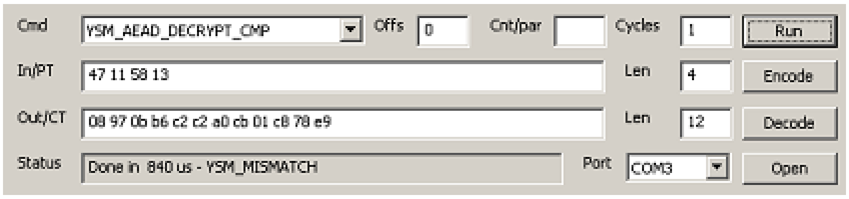
In/PT	47 11 58 12	Len	4	Encode
Out/CT	08 97 0b b6 c2 c2 a0 cb 01 c8 78 e9	Len	12	Decode
Status	AEAD generation succeeded	Port	COM3	Open

Now, the YubiHSM can be used to verify this AEAD. Select the `YSM_AEAD_DECRYPT_CMP` command and press Run.



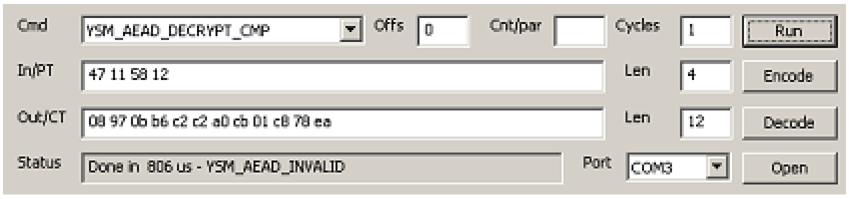
Cmd	YSM_AEAD_DECRYPT_CMP	Offs	0	Cnt/par		Cycles	1	Run
In/PT	47 11 58 12					Len	4	Encode
Out/CT	08 97 0b b6 c2 c2 a0 cb 01 c8 78 e9					Len	12	Decode
Status	Done in 856 us - YSM_STATUS_OK					Port	COM3	Open

By changing the plaintext, the AEAD is still valid, but the compare fails:



Cmd	YSM_AEAD_DECRYPT_CMP	Offs	0	Cnt/par		Cycles	1	Run
In/PT	47 11 58 13					Len	4	Encode
Out/CT	08 97 0b b6 c2 c2 a0 cb 01 c8 78 e9					Len	12	Decode
Status	Done in 840 us - YSM_MISMATCH					Port	COM3	Open

However, if the AEAD is changed, another error message is generated



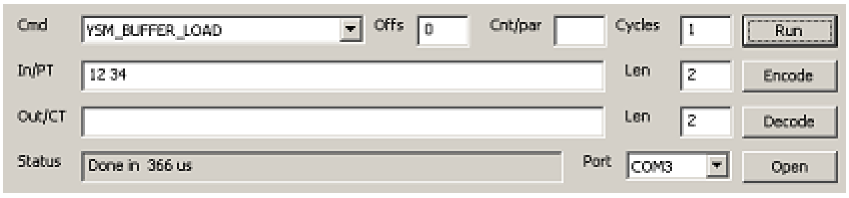
Cmd	YSM_AEAD_DECRYPT_CMP	Offs	0	Cnt/par		Cycles	1
In/PT	47 11 58 12					Len	4
Out/CT	08 97 0b b6 c2 c2 a0 cb 01 c8 78 ea					Len	12
Status	Done in 806 us - YSM_AEAD_INVALID			Port	COM3		

Here, the AEAD cannot be decoded as the last byte was changed from e9 to ea

4.4 Using the buffer to create AEADs

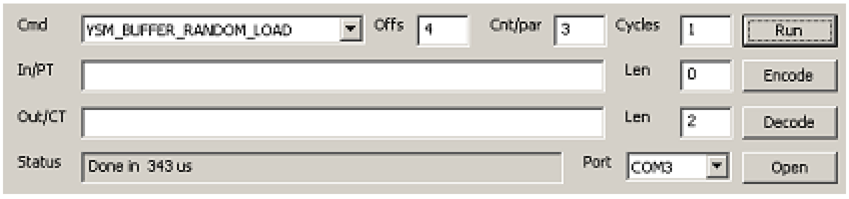
The Offs field can be used to specify a buffer offset when working with the YubiHSM AEAD data buffer.

Enter 12 34 in the plaintext field and 0 in the Offs field, select the `YSM_BUFFER_LOAD` command and press Run



Cmd	YSM_BUFFER_LOAD	Offs	0	Cnt/par		Cycles	1
In/PT	12 34					Len	2
Out/CT						Len	2
Status	Done in 366 us			Port	COM3		

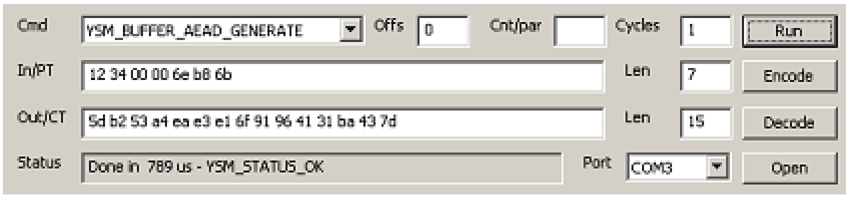
Enter 4 in the offset field and 3 in the Cnt/par field and, select the `YSM_RANDOM_BUFFER_LOAD` command and press Run



Cmd	YSM_BUFFER_RANDOM_LOAD	Offs	4	Cnt/par	3	Cycles	1
In/PT						Len	0
Out/CT						Len	2
Status	Done in 343 us			Port	COM3		

Now, two fixed bytes are inserted in position 0 and 1 of the buffer and three random bytes are generated by the YubiHSM into positions 4, 5 and 6. Bytes 2 and 3 are set to zero when writing to offset zero.

Generate an AEAD of the buffer using the `YSM_BUFFER_AEAD_GENERATE` command:



Cmd	YSM_BUFFER_AEAD_GENERATE	Offs	0	Cnt/par		Cycles	1
In/PT	12 34 00 00 6e b8 6b					Len	7
Out/CT	5d b2 53 a4 ea e3 e1 6f 91 96 41 31 ba 43 7d					Len	15
Status	Done in 789 us - YSM_STATUS_OK			Port	COM3		

A 15 bytes AEAD is generated, which equals 7 bytes buffer data. Here, the utility automatically decodes the AEAD and the plaintext is shown *(which is of course NOT returned by the YubiHSM)*. The random bytes created in the previous step were obviously 6e b8 6b and as seen, bytes 2 and 3 are zero.

5 Using AEADs to verify Yubico OTPs

One of the main use cases for the YubiHSM is to verify Yubico OTPs, with secrets stored on external media, such as a database on a validation server. This setting typically involves one secure station with a YubiHSM where the secrets are created and the Yubikeys are personalized. The secrets are then converted into AEADs and are then transmitted to the validation server(s) over a potentially unsecure channel. Each validation server then has a YubiHSM to verify received OTPs using these AEADs.

Please refer to the YubiHSM manual for a more detailed description of this setting.

Validation of Yubico OTPs can also be done using the internal YubiHSM database. This is shown in section 6.

5.1 Generation of Yubikey secrets

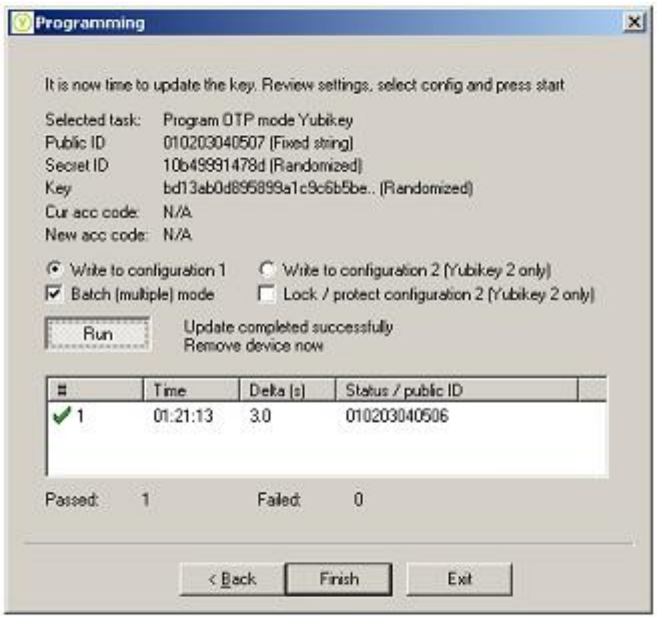
The Yubikey secrets consisting of the private identity and the AES key can be packed into a specially formatted AEAD, defined in the yubihsm_if.h file:

```
// 22-bytes Yubikey secrets block

typedef struct {
      uint8_t key[KEY_SIZE];         // AES key
      uint8_t uid[UID_SIZE];         // Unique (secret) ID
} YSM_YUBIKEY_SECRETS;
```

The resulting AEAD is then 22 + 8 = 30 bytes in length.

Several options for generation of secrets exist but the following example uses the Yubikey Configuration Tool to configure a single Yubikey with a random private id and key.



Programming

It is now time to update the key. Review settings, select config and press start

Selected task:	Program OTP mode Yubikey
Public ID	010203040507 (Fixed string)
Secret ID	10b49991478d (Randomized)
Key	bd13ab0d895899a1c9c6b5be.. (Randomized)
Cur acc code:	N/A
New acc code:	N/A

[✓ Write to configuration 1] Write to configuration 2 (Yubikey 2 only)
[✓ Batch (multiple) mode] Lock / protect configuration 2 (Yubikey 2 only)

Update completed successfully
Remove device now

#	Time	Delta (s)	Status / public ID
✓ 1	01:21:13	3.0	010203040506

Passed: 1 Failed: 0

Make sure the output log file option is set.

The log file gives the following output:

```
010203040506,52715ba12c82,0a187fd2fbb7ac628c540514c0fd30b1
```

The format is public-id, private-id, aes-key

Concatenate the AES key and private ID into a single string to match the `YSM_YUBIKEY_SECRETS` format.

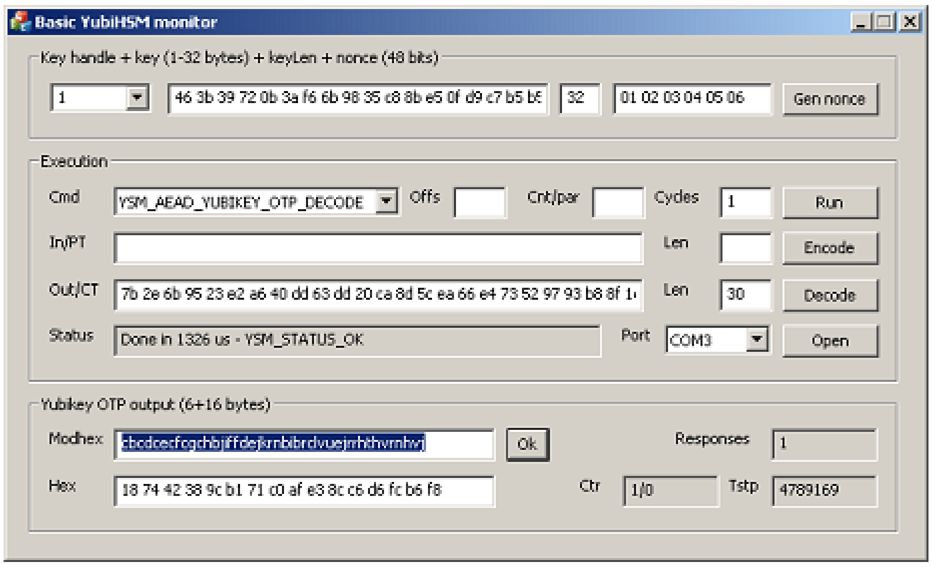
```
0a187fd2fbb7ac628c540514c0fd30b152715ba12c82
```

Paste this string into the plaintext field and paste the public id into the nonce field. Make sure the Gen nonce button is unchecked. Press Run

The resulting 30-byte AEAD is shown in the Out/CT field.

5.2 Testing the OTP validation

Now, place the cursor into the Modhex field of the Yubikey OTP output group and press the button



Basic YubiHSM monitor

Key handle + key (1-32 bytes) + keyLen + nonce (48 bits)

1 | 46 3b 39 72 0b 3a f6 6b 98 35 c8 8b e5 0f d9 c7 b5 b6 | 32 | 01 02 03 04 05 06 | Gen nonce

Execution

Cmd: YSM_AEAD_YUBIKEY_OTP_DECODE Offs: Cnt/par: Cycles: 1 Run

In/PT: Len: Encode

Out/CT: 7b 2e 6b 95 23 e2 a6 40 dd 63 dd 20 ca 8d 5c ea 66 e4 73 52 97 93 b8 8f 1 Len: 30 Decode

Status: Done in 1326 us - YSM_STATUS_OK Port: COM3 Open

Yubikey OTP output (6+16 bytes)

Modhex: cbcdcecfcgchbjiffdejkrnbibrdvuejrrhthvrnhvj Ok Responses: 1

Hex: 18 74 42 38 9c b1 71 c0 af e3 8c c6 d6 fc b6 f8 Ctr: 1/0 Tstp: 4789169

The YubiHSM now uses the AEAD supplied in the Out/CT field together with the key handle, nonce and decoded Modhex string to verify the OTP. The result is shown in the Status field and the decoded counter- and timestamp values in the Ctr and Tstp fields.

6 Using the internal OTP database

The YubiHSM internal OTP database has storage for a limited number of secrets. The database can either be populated during configuration from a text file compatible with the Yubico Yubikey provisioning format, via the HSM function `YSM_DB_YUBIKEY_AEAD_STORE` or a combination of both.

Please refer to the YubiHSM manual for a more detailed description of this setting.

Validation of Yubico OTPs can also be done using the external AEAD storage. This is shown in section 5.

6.1 Populating the OTP database during configuration

The OTP database can be populated during configuration by uploading a Yubico supplied key file, such as

```
99950,cccccccbjhhu,fe37a81ab606,46d917606afe4d81830b8822d65a70ca,75467b86adb8,
2010-12-30T21:14:16,
99951,cccccccbjhhv,f9fc0cf39012,bf0af3bf814bc8250b4fbb0e806ed8a0,6ba06c87e191,
2010-12-30T21:14:16,
99952,cccccccbjhic,8b99376dc0af,ccf6e1e61b93f2cec00dc88cbd1c03bd,905f7390364d,
2010-12-30T21:14:16,
```

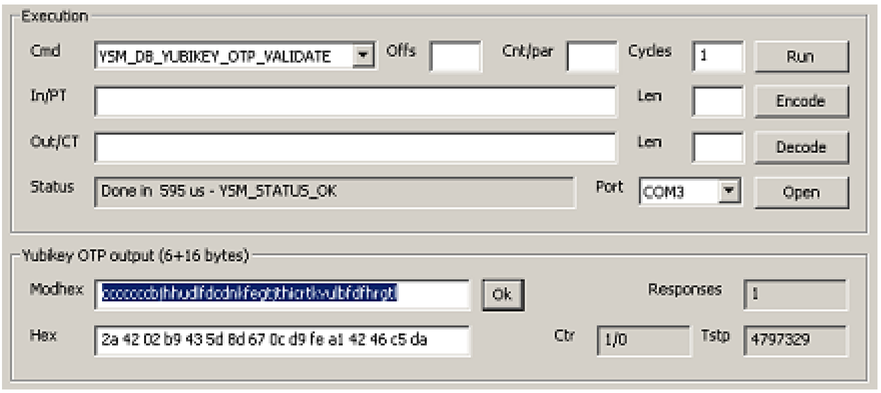
During the configuration phase, use the terminal program’s upload facility together with the `dbload` command:

```
HSM> dbload - Load id data now. Press ESC to quit
99950 - inserted ok
99951 - inserted ok
99952 - inserted ok
```

Exit back to HSM mode and start the YubiHSM monitor

6.2 Verifying a Yubico OTP

Now, select the YSM_DB_YUBIKEY_OTP_VALIDATE command, place the cursor into the Modhex field and insert a Yubikey configured within this range. Press the button

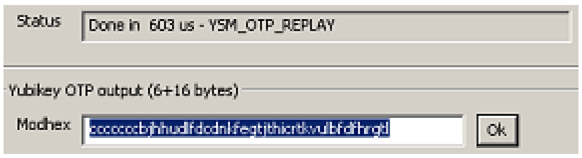


Execution
Cmd: YSM_DB_YUBIKEY_OTP_VALIDATE
Offs:
Cnt/par:
Cycles: 1
In/PT:
Len:
Out/CT:
Len:
Status: Done in 595 us - YSM_STATUS_OK
Port: COM3

Yubikey OTP output (6+16 bytes)
Modhex: cccccccbjhhudlfdcdnkfegtjthicrtkvulbfdfhrgtl
Responses: 1
Hex: 2a 42 02 b9 43 5d 8d 67 0c d9 fe a1 42 46 c5 da
Ctr: 1/0
Tstp: 4797329

In this setting, only the OTP is needed where all other data is taken from the internal database. The result is shown in the Status field and the decoded counter- and timestamp values in the Ctr and Tstp fields.

As the counters are checked and maintained in this mode, replay detection is provided as well:


Status: Done in 603 us - YSM_OTP_REPLAY

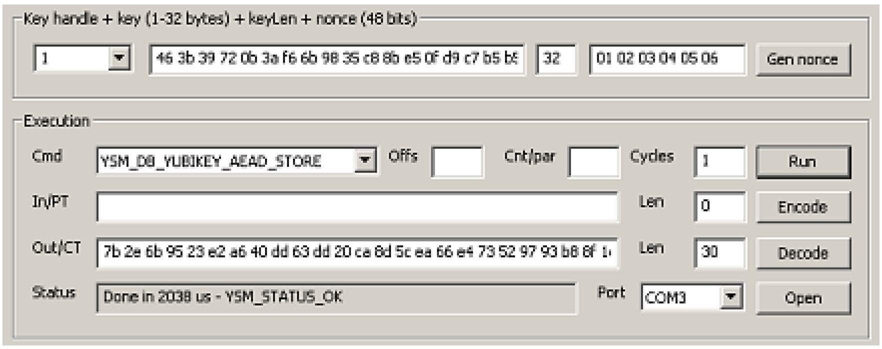
Yubikey OTP output (6+16 bytes)

Modhex: ccccccbjhhudlfdcdnkfegtjthicrtkvulbfdfhrgtl

By sending the same OTP again, the YubiHSM detects the replay and reports `YSM_OTP_REPLAY`.

6.3 Adding additional database entries

In HSM mode, additional database entries can be added using the `YSM_DB_YUBIKEY_AEAD_STORE` command. AEADs are created as described in section 5.1.


Key handle + key (1-32 bytes) + keyLen + nonce (48 bits)

1 | 46 3b 39 72 0b 3a f6 6b 98 35 c8 8b e5 0f d9 c7 b5 b5 | 32 | 01 02 03 04 05 06

Execution

Cmd: YSM_DB_YUBIKEY_AEAD_STORE Offs: Cnt/par: Cycles: 1

In/PT: Len: 0

Out/CT: 7b 2e 6b 95 23 e2 a6 40 dd 63 dd 20 ca 8d 5c ea 66 e4 73 52 97 93 b8 8f 1 Len: 30

Status: Done in 2038 us - YSM_STATUS_OK Port: COM3

Switching back to configuration mode and returning to the terminal allows us to verify that the newly inserted record exists

```
HSM> dblist
00000,cccccccbjhhu,00001/000
00001,cccccccbjhhv,00000/000
00002,cccccccbjhic,00000/000
00003,cbcdcecfcgch,00001/004
Entries 00004 invalid 00000 free 01020
```

As seen here, a few OTPs have been generated here so the counters for the newly added record cbcdcecfcgch is now 2/1.