DPAPI exploitation during pentest and password cracking

When 26/04/2017

For Univershell 2017

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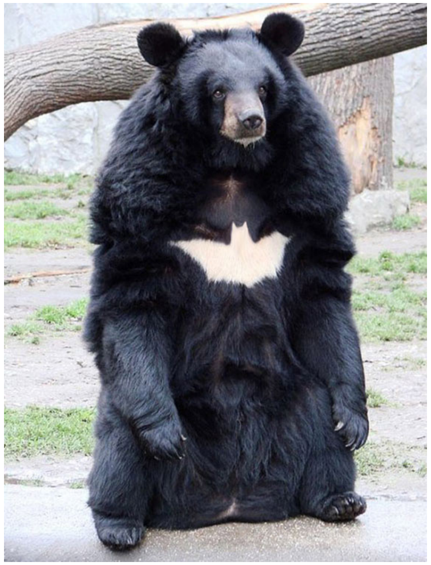
whoami /groups



- **Jean-Christophe Delaunay - @Fist0urs**
- **Jiss/Fist0urs on IRC**
- **Synacktiv – www.synacktiv.ninja**

- Microsoft Windows Active Directory (*kerberom*)
- Passcracking - User and contributor to *John The Ripper* and *hashcat* (krb5tgs, axcrypt, keepass, dpapimk, etc.)

Roadmap

- What is DPAPI?
- For real, what is DPAPI?
- DPAPI during pentest
- What’s next?
- Questions

What is DPAPI – a bit of history

- Data Protection Application Programming Interface
- Helps protect secrets (passwords, certificates, etc.)
- Exists since *Windows 2000*!
- Evolved a lot but core is globally the same
- Transparent for the end-users

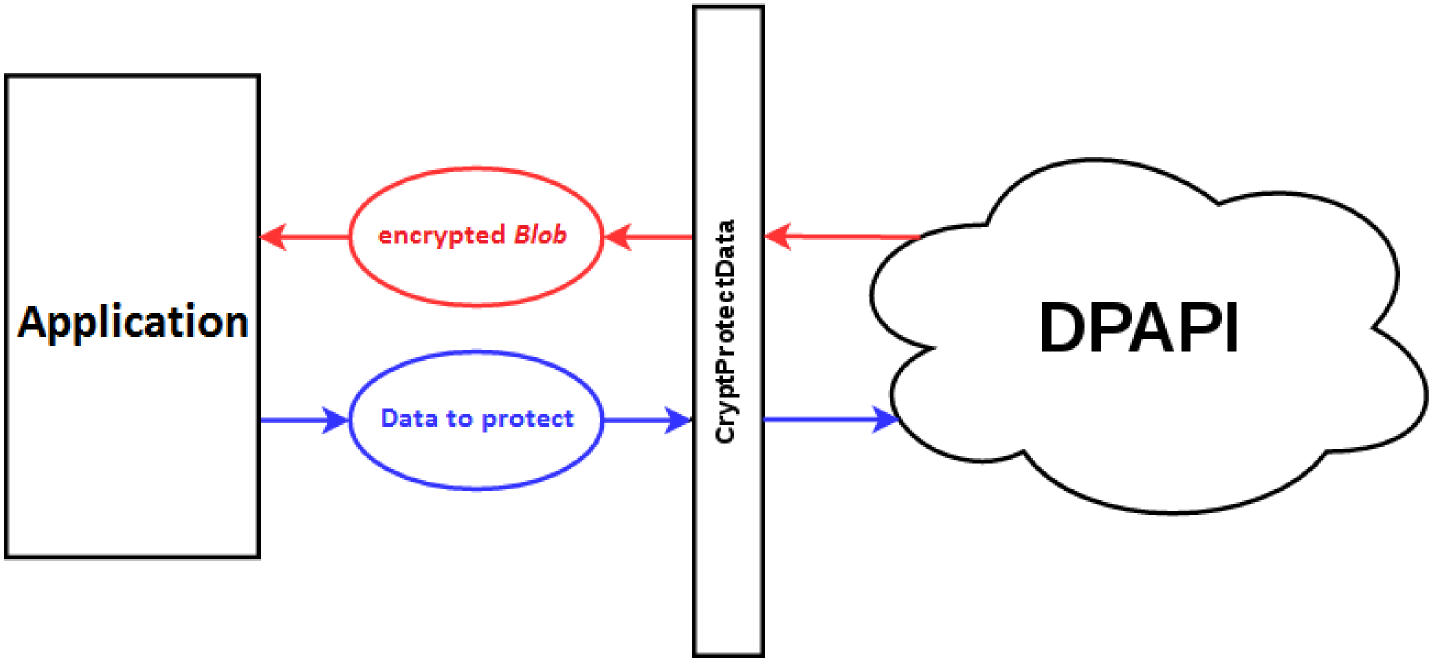
What is DPAPI – wtfbbq?

- Cryptography based on user’s password (not exactly in fact)
- Easy to implement for developers:
  - *CryptProtectData*
  - *CryptUnprotectData*
- Widely used:
  - Credential Manager, Windows Vault, IE, Wi-Fi, Certificats, VPN, etc.
  - Google Chrome, Google Talk, Skype, Dropbox, iCloud, Safari, etc.

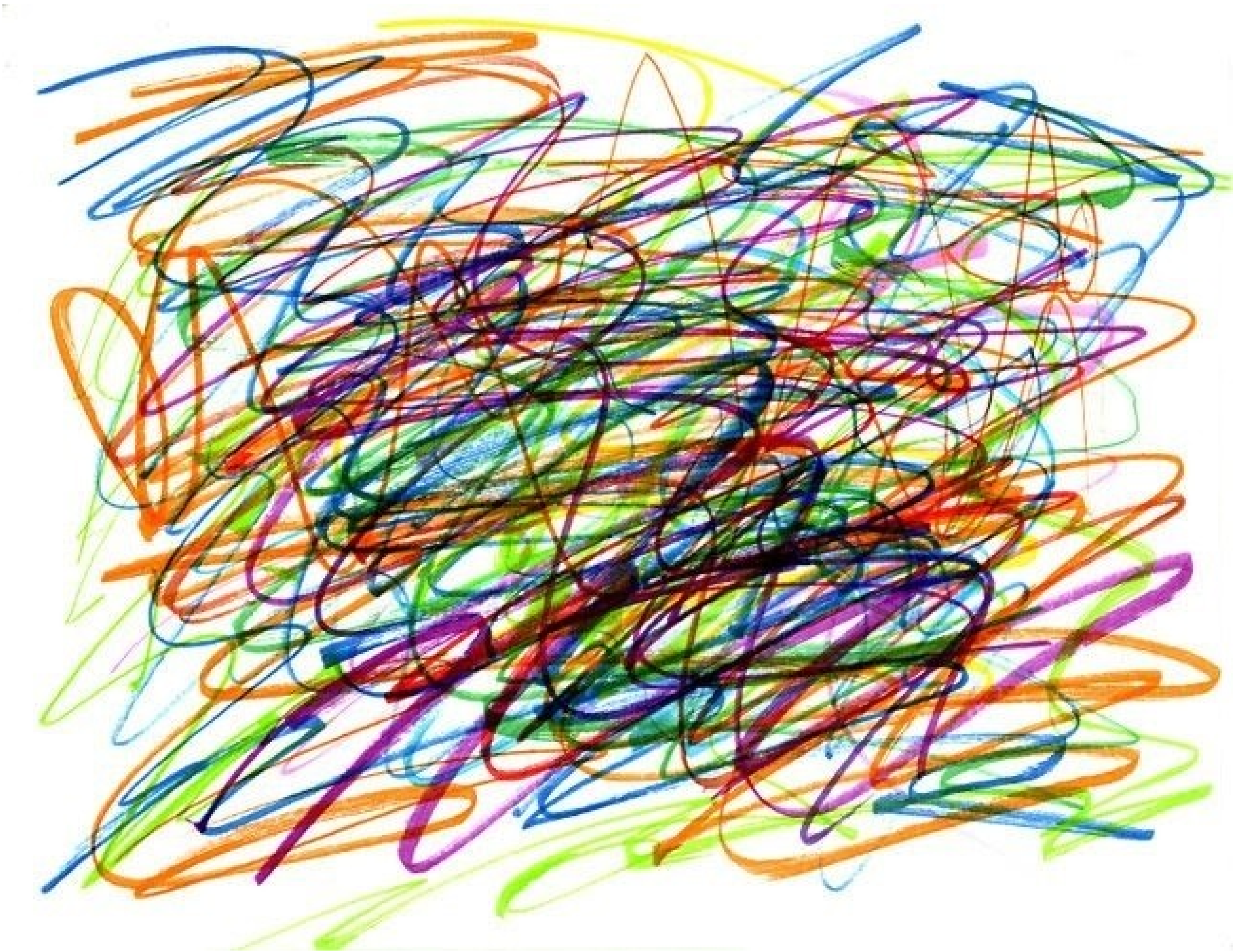
DPAPI Internals

- DPAPI is:
  - Transparent for the end-users
  - Easy to use for developers
  - … Hard when you want to really understand the internals

DPAPI Internals – developers view



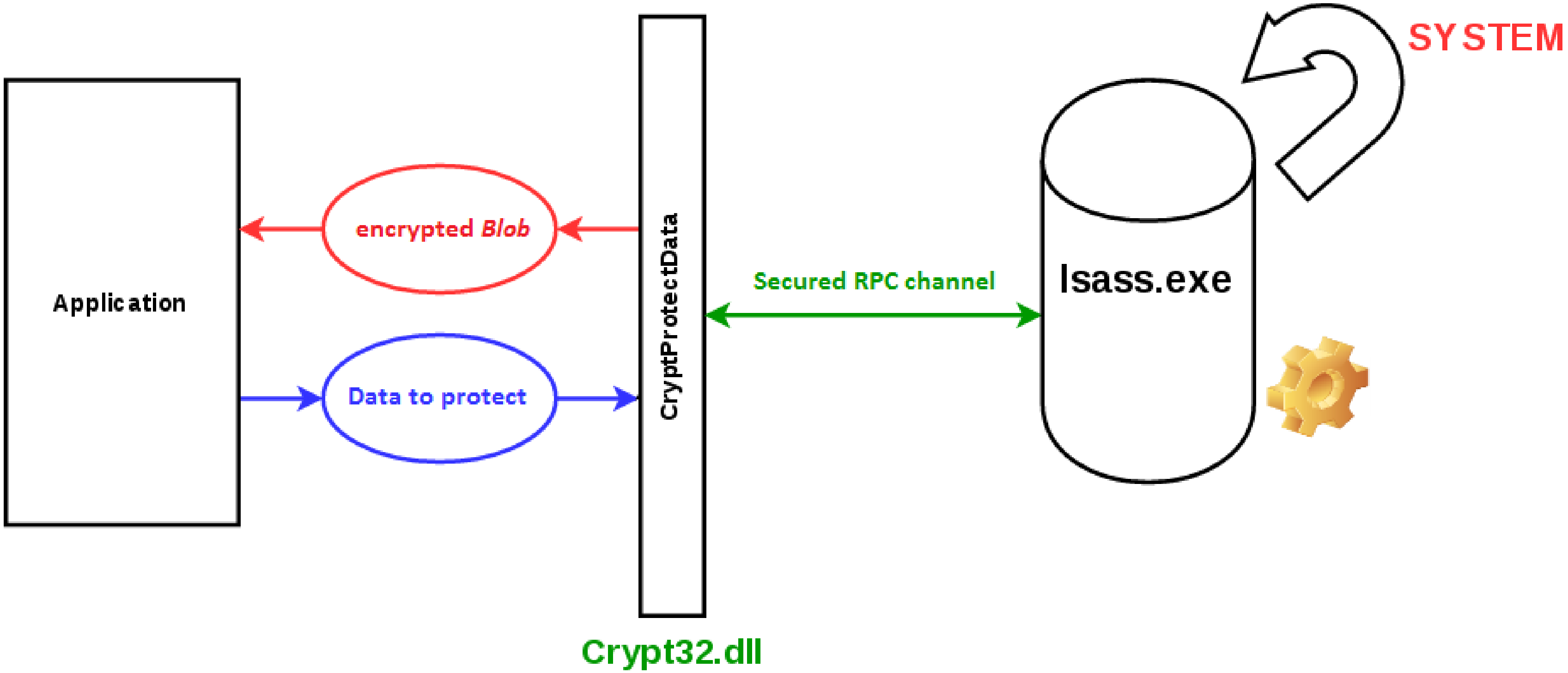
DPAPI Internals – reverser view



DPAPI Internals – developers view

```
BOOL WINAPI CryptProtectData(
  _In_             DATA_BLOB *pDataIn,
  _In_opt_         LPCWSTR szDataDescr,
  _In_ opt_        DATA_BLOB *pOptionalEntropy,
  _Reserved_       PVOID pvReserved,
  _In_opt_         CRYPTPROTECT_PROMPTSTRUCT
*pPromptStruct,
  _In_             DWORD dwFlags,
  _Out_            DATA_BLOB *pDataOut
);
```

DPAPI Internals – crypto



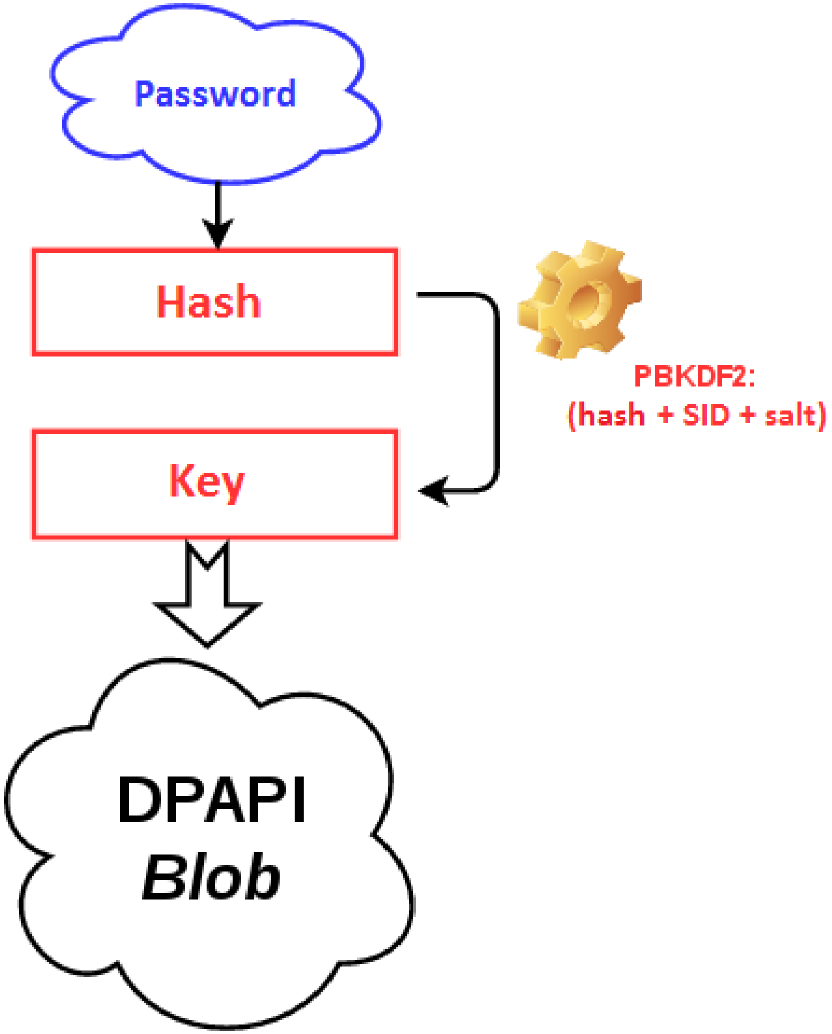
DPAPI Internals – crypto

- Secret based on user’s password… is it sufficient?
  - what about password changing?
  - what about *Rainbow Tables* attacks?

DPAPI Internals – crypto

- Secret based on user’s password… is it sufficient?
  - what about password changing?
  - what about *Rainbow Tables* attacks?
- … but this is not sufficient, *master keys* are used. These masterkeys are stored in *blobs*, each containing:
  - a GUID
  - a *salt*
  - *master key* structure (containing *master key**s***)

DPAPI Internals – crypto



DPAPI Internals – DPAPI *Blob*

DWORD dwVersion

[…]

GUID **guidMasterKey**

ALG_ID algCrypt

DWORD dwCryptAlgLen

BYTE **pSalt[dwSaltLen]**

BYTE pHmac[dwHmacKeyLen]

ALG_ID algHash

DWORD dwHashAlgLen

[…]

BYTE **pData[dwDataLen]**

BYTE pSign[dwSignLen]

DPAPI Internals – *master keys*

DWORD dwVersion

[…]

GUID **guidMasterKey**

ALG_ID algCrypt

DWORD dwCryptAlgLen

BYTE **pSalt[dwSaltLen]**

BYTE pHmac[dwHmacKeyLen]

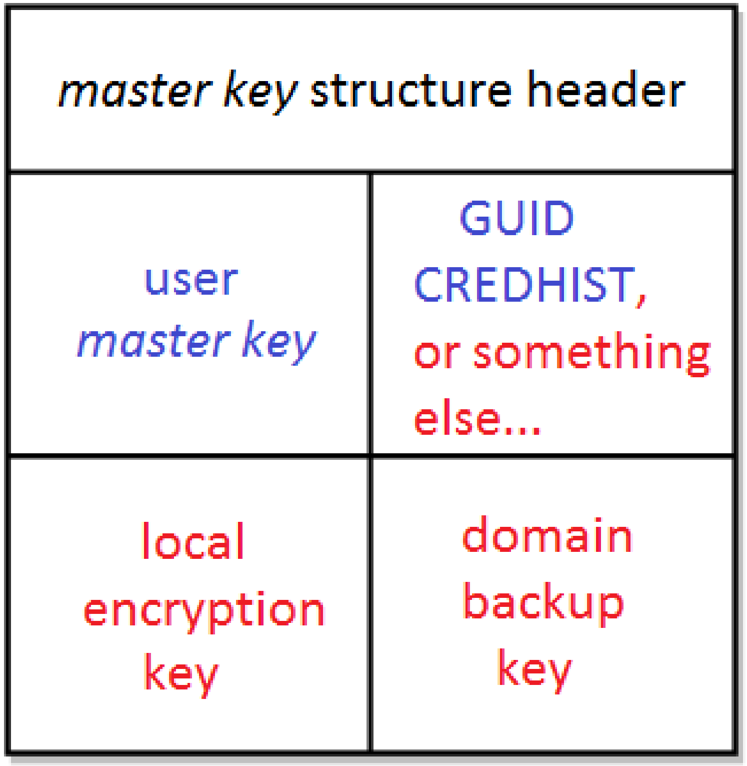
ALG_ID algHash

DWORD dwHashAlgLen

[…]

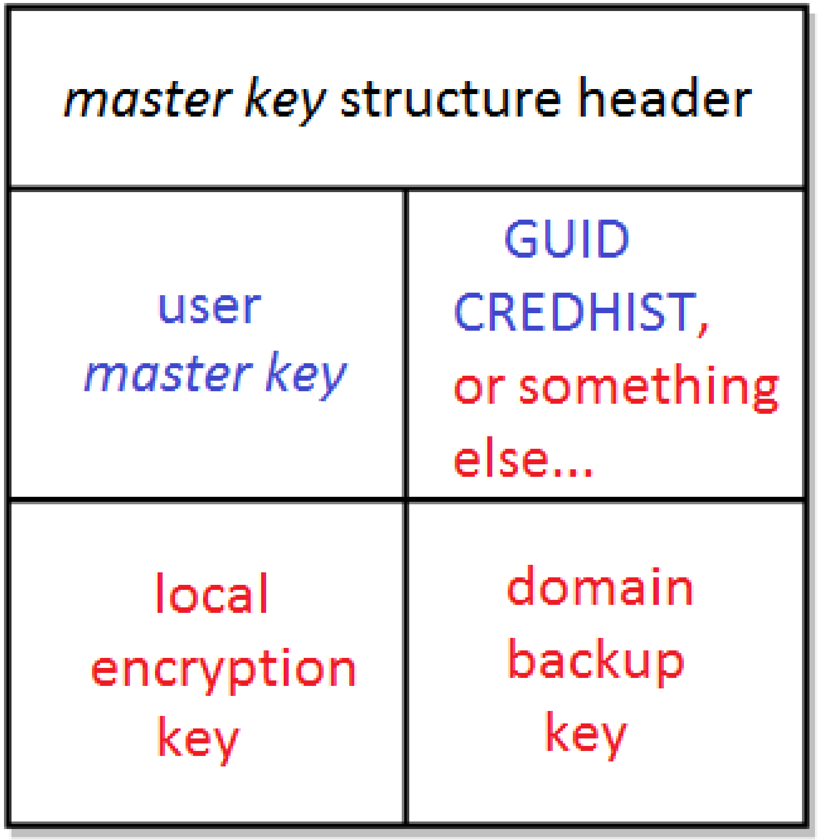
BYTE **pData[dwDataLen]**

BYTE pSign[dwSignLen]



master key structure header	
user *master key*	GUID CREDHIST, or something else...
local encryption key	domain backup key

DPAPI Internals – *master key* header



master key structure header

user *master key*

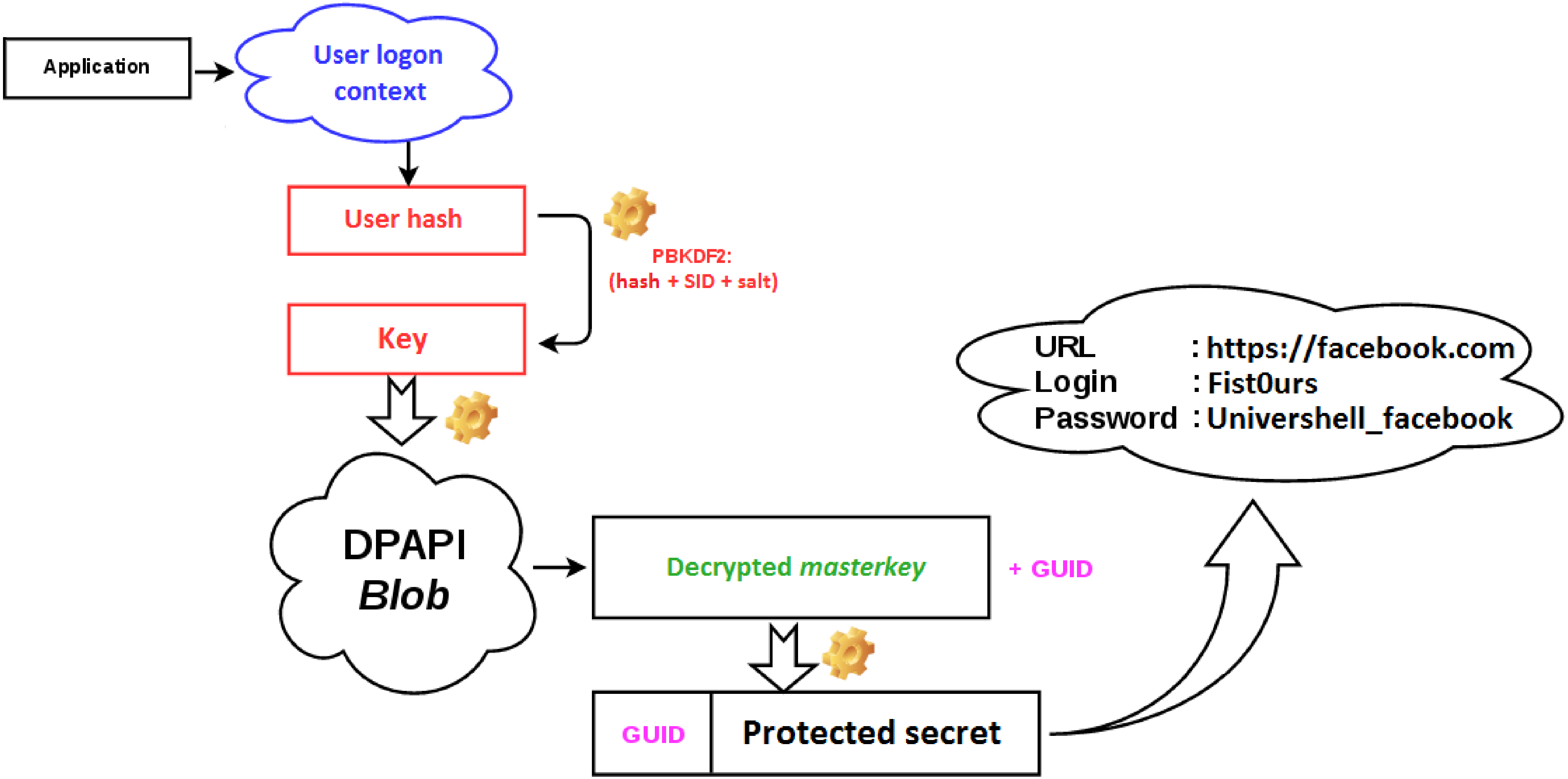
GUID CREDHIST, or something else...

local encryption key

domain backup key

```
DWORD dwVersion;
[ … ]
WCHAR szGuid[0x24];
[ … ]
DWORD dwUserKeySize;
DWORD dwLocalEncKeySize;
DWORD dwLocalKeySize;
DWORD dwDomainKeySize;
```

DPAPI Internals – WTH is he talking about?... ¯ \ (º_o)/¯



URL : https://facebook.com
Login : Fist0urs
Password : Univershell_facebook

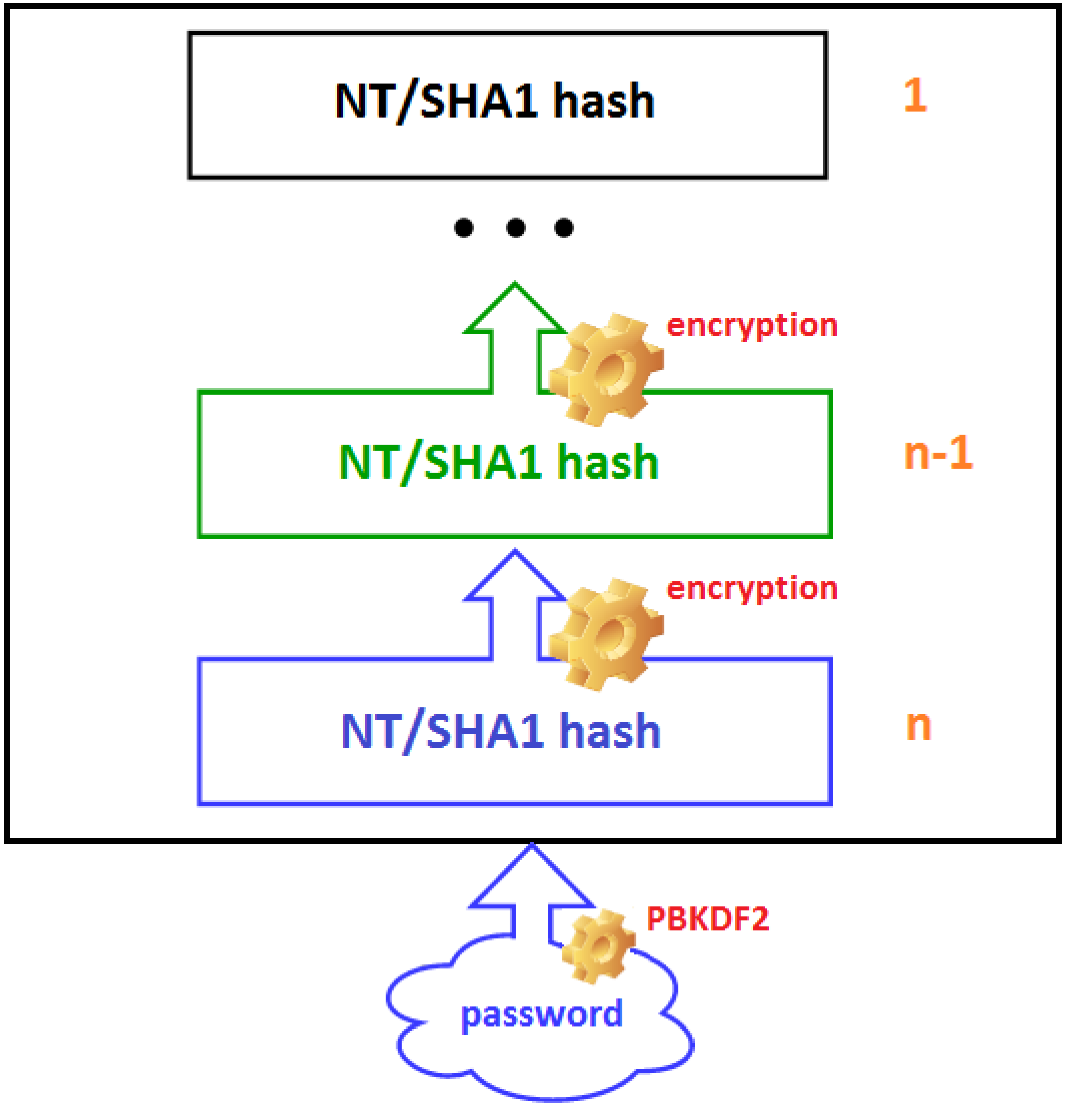
DPAPI Internals – can I attack it?

OS	Ciphering algo	Hashing algo	PBKDF2 iterations
Windows 2000	RC4	SHA1	1
Windows XP	3DES	SHA1	4000
Windows Vista	3DES	SHA1	24000
Windows 7	AES256	SHA512	5600
Windows 10	AES256	SHA512	8000

DPAPI Internals – CREDHIST

- Is used to decrypt master keys protected by older passwords
- Stores all previous passwords' hashes
- An old hash is protected by the first most recent one
- Stores hashes in NTLM and SHA1 formats

DPAPI Internals – CREDHIST



DPAPI Internals – what's next…?

- *master keys* backup?
- Entropy?
- DPAPI system?
- SHA1 and NTLM?
- What about domain and local contexts?

DPAPI Internals – stored…?

- In the user’s profile (%APPDATA%/Roaming/Microsoft)
  - *Protect/CREDHIST*
  - *Protect/SID*
  - *Protect/SID/Preferred*
  - *Credentials*
  - *Vault*
  - etc.
- In the registry
- In *system32*
- etc.

DPAPI – pentest

- 2 possibilities:
  - I can execute some code on the remote host
  - I can’t...

DPAPI – existing tools

- Passcape: shareware + *Windows* only [1]
- impacket: does not decrypt DPAPI protected secrets directly [2]
- mimikatz: extracts secrets *online* and *offline* but *Windows* only [3]
- dpapick: extracts secrets *offline*! First tool published to manage DPAPI *offline*, incredible work! [4]
- dpapilab: an extension of dpapick [5]

DPAPI – what can I do? I can execute commands

- I am in user’s (not admin!) authentication context but do not have his password:
  - Use Windows API to extract some DPAPI protected secrets, using implicit authentication (*mimikatz*, *CredMan.ps1*, etc.)
  - But I would like to have his session password...

DPAPI – what can I do? I can execute commands

- But I would like to have his session password…
- Wait, you told us that secrets are protected by user’s password?...
- ...and *master keys* are also protected by user’s password?
- …
- Profit! (format merged in *John the Ripper* yesterday \o/) [6]

DPAPI – what can I do? I can execute commands

```
$ python DPAPImk2john.py -h
usage: DPAPImk2john.py [-h] [-S SID] [-mk MASTERKEY] [-d] [-c CONTEXT]
                       [-P PREFERRED] [--password PASSWORD]

optional arguments:
  -h, --help                                show this help message and exit
  -S SID, --sid SID                         SID of account owning the masterkey
                                            file.
  -mk MASTERKEY, --masterkey MASTERKEY      masterkey file (usually in %APPDATA
                                            %\Protect\<SID>).
  -d, --debug
  -c CONTEXT, --context CONTEXT             context of user account. Only 'domain'
                                            and 'local' are possible.
  -P PREFERRED, --preferred PREFERRED       'Preferred' file containing GUID of
                                            masterkey file inuse (usually in
                                            %APPDATA%\Protect\<SID>). Cannot be
                                            used with any other command.
  --password PASSWORD                       password to decrypt masterkey file.
```

DPAPI – what can I do? I can execute commands

```
Fist0urs@mongodabest:~/univershell$
python DPAPImk2john.py -P Preferred
1b4ac82b-1a40-456e-83bb-ca5e1d91024c
```

DPAPI – what can I do? I can execute commands

```
Fist0urs@mongodabest:~/univershell$ python DPAPImk2john.py
--sid="S-15-21-478900483-410193244-460175230-1818"
--masterkey= "1b4ac82b-1a40-456e-83bb-ca5e1d91024c"
--context="local"

$DPAPImk$1*1*S-15-21-478900483-410193244-460175230-
1818*des3*sha1*24000*2c227152554a45e37ebef7d244c8bc85*208*
6d7b48964c5a451ee267c46abf31a5d67980f4b738629d65cb65534daa
d9bd252eb25af55dc08d514b2385cf9bf3575ff8954b764b4175467d76
ee5bbdb52dd29e1aa012129486d7de38e3a7a1dc059fe4a0aab2a5c16c
93f6d592b9616333ebbce5016036d58aad
```

DPAPI – what can I do? I can execute commands

```
Fist0urs@mongodabest:~/univershell$ john
univershell.dump --wordlist=dpapi_extracted.dic
--rules=custom.rule

Using default input encoding: UTF-8
Loaded 1 password hash (DPAPImk, DPAPI masterkey file v1
and v2 [SHA1/MD4 PBKDF2-(SHA1/SHA512)-DPAPI-variant
3DES/AES256 256/256 AVX2 8x])
Will run 8 OpenMP threads
Press 'q' or Ctrl-C to abort, almost any other key for
status
Univershell_synacktiv (?)
1g 0:00:00:00 DONE (2017-04-26 12:07) 4.761g/s 14.28p/s
14.28c/s 14.28C/s ..Univershell_synacktiv
Use the "--show" option to display all of the cracked
passwords reliably
Session completed
```

DPAPI – what can I do? I can **not** execute commands

- I still can get the masterkey files and retrieve user’s password, but no dpapi stuff
- ...for the moment !

DPAPI – meet *dpapeace*!

- Based on work done on *dpapick* and *dpapilab* + its Core
- Recoded and completed what *dpapick* et *dpapilab* do
- Plugins handling
- parser/writer handling (XML only at the moment)
- Still a POC for the moment...

DPAPI – dpapeace.py --conf

```
<?xml version="1.0"?>
<dpapi>
    <computer name="Fist0urs-PC" ip="192.168.0.1">
        <hives>
            <system>/home/Fist0urs/DPAPI/DATA/sys/sys</system>
            <security>/home/Fist0urs/DPAPI/DATA/sys/sec</security>
        </hives>
        <sysmasterkey>/home/Fist0urs/DPAPI/DATA/sys/S-1-5-18/User/</sysmasterkey>
        <wifi>/home/Fist0urs/DPAPI/DATA/Wifi/Wlansvc/Profiles/Interfaces/{747AXXXX-XXXX-XXXX-XXXX-
XXXX81530EE7}</wifi>
        <account name="Fist0urs" sid="S-1-5-21-478900483-410193244-460175230-1818" domain="WORKGROUP">
            <masterkey>/home/Fist0urs/DPAPI/DATA/Protect/S-1-5-21-478900483-410193244-460175230-
1818</masterkey>
            <credhist>/home/Fist0urs/DPAPI/DATA/Protect/CREDHIST</credhist>
            <credentials>
                <password>Univershell_synacktiv</password>
                <context>local</context>
                <hash>**</hash>
            </credentials>
            <worker name="chrome">
                <target>/home/Fist0urs/DPAPI/DATA/Chrome/Login Data</target>
            </worker>
            <worker name="credman">
                <target>/home/Fist0urs/DPAPI/DATA/Credentials</target>
            </worker>
            <worker name="winvault">
[...]
```

DPAPI – *dpapeace* output

```
<?xml version="1.0"?>
<dpapi>
    <computer ip="192.168.0.1" name="Fist0urs-PC">
        <account domain="WORKGROUP" name="Fist0urs" sid="S-1-5-21-478900483-410193244-460175230-1818">
            <credentials type="chrome">
                <url name="http://crackmes.de/">
                    <username>Fist0urs</username>
                    <password>****</password>
                </url>
                <url name="https://websec.fr/login">
                    <username>Fist0urs</username>
                    <password>****</password>
                </url>
            </credentials>
            <credentials type="credman">
                <cred persist="Entreprise" type="Domain password">
                    <target>Domain:target=trolololol.fr</target>
                    <username>mwa</username>
                    <password>**</password>
                    <last_modified>2016-09-17T20:33:32+00:00</last_modified>
                </cred>
                <cred persist="Entreprise" type="Domain password">
                    <target>Domain:target=Fist0urs@timmy.com</target>
                    <username>Fist0urs</username>
                    <password>****</password>
                    <last_modified>2016-09-18T17:43:20+00:00</last_modified>
                </cred>
[...]
```

DPAPI – pentest conclusions

- It is really useful during pentests:
  - Retrieve many secrets protected by user’s password
  - Possibly retrieve user’s password (useful when *phishing* or exploiting a context-based vulnerability)
  - Also an alternative to *MSCashvX* (if admin), in case a workstation is harden (0 or 1 credential cached) as masterkeys are imported in his roaming profil when one connects interactively on a workstation
  - Much more stealth as it only requires to copy some files from the filesystem
  - Difficult to spot :)

DPAPI – pentest

```
Fist0urs@mongodabest:~/univershell$ john --format=mscash2 --test
&& john --format=dpapimk --test
Will run 8 OpenMP threads
Benchmarking: mscash2, MS Cache Hash 2 (DCC2) [PBKDF2-SHA1
256/256 AVX2 8x]... (8xOMP) DONE
Warning: "Many salts" test limited: 19/256
Many salts:   9228 c/s real, 1225 c/s virtual
Only one salt:   8447 c/s real, 1152 c/s virtual

Will run 8 OpenMP threads
Benchmarking: DPAPImk, DPAPI masterkey file v1 and v2 [SHA1/MD4
PBKDF2-(SHA1/SHA512)-DPAPI-variant 3DES/AES256 256/256 AVX2
8x]... (8xOMP) DONE
Speed for cost 1 (iteration count) of 24000
Raw:   2115 c/s real, 256 c/s virtual
```

Not that bad regarding the iterations count!

DPAPI – future work

1) ~~Implement the algorithm in John the Ripper~~

2) Implement the algorithm in hashcat

3) Continue development of *dpapeace* (in particular Windows implicit authentication)

4) Publish *dpapeace* once everything is clean

5) More :)

ANY QUESTIONS?

Thank you for your attention!

Bibliography

- [1] https://www.passcape.com/
- [2] https://github.com/CoreSecurity/impacket
- [3] http://blog.gentilkiwi.com/mimikatz
- [4] http://dpapick.com/
- [5] https://github.com/dfirfpi/dpapilab
- [6] https://github.com/magnumripper/JohnTheRipper/pull/2521