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FLARE Script Series: Automating Obfuscated String Decoding

By Kristen Dennesen On December 28, 2015 · Add Comment

Introduction

We are expanding our script series beyond IDA Pro. This post extends the FireEye Labs Advanced Reverse Engineering (FLARE) script series to an invaluable tool for the reverse engineer – the debugger. Just like IDA Pro, debuggers have scripting interfaces. For example, OllyDbg uses an asm-like scripting language, the Immunity debugger contains a Python interface, and Windbg has its own language. Each of these options isn’t ideal for rapidly creating string decoding debugger scripts. Both Immunity and OllyDbg only support 32-bit applications, and Windbg’s scripting language is specific to Windbg and, therefore, not as well-known. The pykd project was created to interface between Python and Windbg to allow

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debugger scripts to be written in Python. Because malware reverse engineers love Python, we built our debugger scripting library on top of pykd for Windbg.

Here we release a library we call flare-dbg. This library provides several utility classes and functions to rapidly develop scripts to automate debugging tasks within Windbg. Stay tuned for future blog posts that will describe additional uses for debugger scripts!

String Decoding

Malware authors like to hide the intent of their software by obfuscating their strings. Quickly deobfuscating strings allows you to quickly figure out what the malware is doing.

As stated in Practical Malware Analysis, there are generally two approaches to deobfuscating strings: self-decoding and manual programming. The *self-decoding* approach allows the malware to decode its own strings. *Manual programming* requires the reverse engineer to reprogram the decoding function logic. A subset of the *self-decoding* approach is emulation, where each assembly instruction execution is emulated. Unfortunately, library call emulation is required, and emulating every library call is difficult and may cause inaccurate results. In contrast, a debugger is attached to the actual running process, so all the library functions can be run without issue. Each of these approaches has their place, but this post teaches a way to use debugger scripting to automatically self-decode all obfuscated strings.

Challenge

To decode all obfsucated strings, we need to find the following: the string decoder function, each time it is called, and all arguments to each of those instances. We then need to run the function and read out

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the result. The challenge is to do this in a semi-automated way.

Approach

The first task is to find the string decoder function and get a basic understanding of the inputs and outputs of the function. The next task is to identify each time the string decoder function is called and all of the arguments to each call. Without using IDA, a handy Python project for binary analysis is Vivisect. Vivisect contains several heuristics for identifying functions and cross-references. Additionally, Vivisect can emulate and disassemble a series of opcodes, which can help us identify function arguments. If you haven't already, be sure to check out the FLARE scripting series post on tracking function arguments using emulation, which also uses Vivisect.

Introducing flare-dbg

The FLARE team is introducing a Python project, flare-dbg that runs on top of pykd. Its goal is to make Windbg scripting easy. The heart of the flare-dbg project lies in the DebugUtils class, which contains several functions to handle:

- Memory and register manipulation
- Stack operations
- Debugger execution
- Breakpoints
- Function calling

In addition to the basic debugger utility functions, the DebugUtils class uses Vivisect to handle the binary analysis portion.

Example

I wrote a simple piece of malware that hides strings by encoding them. Figure 1 shows an HTTP User-Agent string being decoded by a function I named string_decoder.

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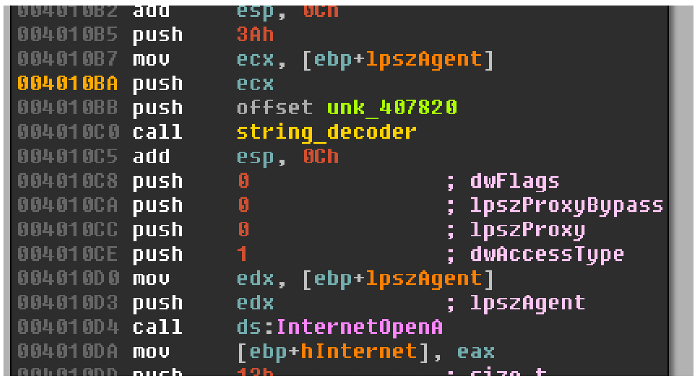

```
004010B2 add      esp, 0Ch
004010B5 push     3Ah
004010B7 mov      ecx, [ebp+lpszAgent]
004010BA push     ecx
004010BB push     offset unk_407820
004010C0 call     string_decoder
004010C5 add      esp, 0Ch
004010C8 push     0                 ; dwFlags
004010CA push     0                 ; lpszProxyBypass
004010CC push     0                 ; lpszProxy
004010CE push     1                 ; dwAccessType
004010D0 mov      edx, [ebp+lpszAgent]
004010D3 push     edx               ; lpszAgent
004010D4 call     ds:InternetOpenA
004010DA mov      [ebp+hInternet], eax
```

Figure 1: String decoder function reference in IDA Pro

After a cursory look at the string_decoder function, the arguments are identified as an offset to an encoded string of bytes, an output address, and a length. The function can be described as the following C prototype:

```
VOID string_decoder(PBYTE input, PCHAR output, DWORD len);
```

Now that we have a basic understanding of the string_decoder function, we test decoding using Windbg and flare-dbg. We begin by starting the process with Windbg and executing until the program’s entry point. Next, we start a Python interactive shell within Windbg using pykd and import flaredbg.

```
0:000> .load pykd
0:000> !py
Python 2.7.10 (default, May 23 2015, 09:40:32) [MSC v.1500 32 bit (Intel)] on win32
Type "help", "copyright", "credits" or "license" for more information.
(InteractiveConsole)
>>> from flaredbg import flaredbg
```

Next, we create a DebugUtils object, which contains the functions we need to control the debugger.

```
>>> dbg = flaredbg.DebugUtils()
```

We then allocate 0x3A-bytes of memory for the output string. We use the newly allocated memory as the second parameter and setup the remainder of the arguments.

```
>>> str_va = dbg.malloc(0x3a)
>>> args = [0x407820, str_va, 0x3a]
```

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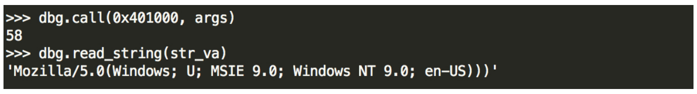
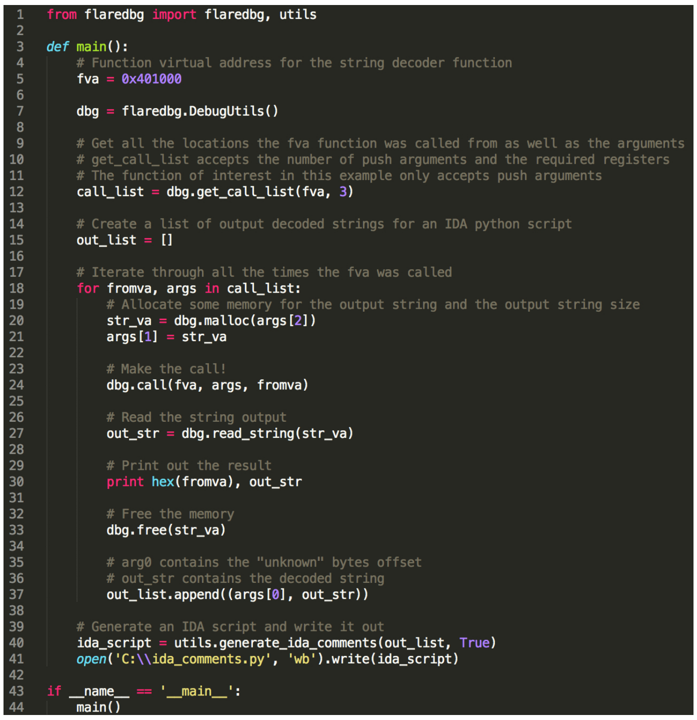
Finally, we call the string_decoder function at virtual address 0x401000, and read the output string buffer.



```
>>> dbg.call(0x401000, args)
58
>>> dbg.read_string(str_va)
'Mozilla/5.0(Windows; U; MSIE 9.0; Windows NT 9.0; en-US)))'
```

After proving we can decode a string with flare-dbg, let's automate all calls to the string_decoder function. An example debugger script is shown in Figure 2. The full script is available in the examples directory in the github repository.



```python
from flaredbg import flaredbg, utils

def main():
    # Function virtual address for the string decoder function
    fva = 0x401000

    dbg = flaredbg.DebugUtils()

    # Get all the locations the fva function was called from as well as the arguments
    # get_call_list accepts the number of push arguments and the required registers
    # The function of interest in this example only accepts push arguments
    call_list = dbg.get_call_list(fva, 3)

    # Create a list of output decoded strings for an IDA python script
    out_list = []

    # Iterate through all the times the fva was called
    for fromva, args in call_list:
        # Allocate some memory for the output string and the output string size
        str_va = dbg.malloc(args[2])
        args[1] = str_va

        # Make the call!
        dbg.call(fva, args, fromva)

        # Read the string output
        out_str = dbg.read_string(str_va)

        # Print out the result
        print hex(fromva), out_str

        # Free the memory
        dbg.free(str_va)

        # arg0 contains the "unknown" bytes offset
        # out_str contains the decoded string
        out_list.append((args[0], out_str))

    # Generate an IDA script and write it out
    ida_script = utils.generate_ida_comments(out_list, True)
    open('C:\\ida_comments.py', 'wb').write(ida_script)

if __name__ == '__main__':
    main()
```

Figure 2. Example basic debugger script

Let's break this script down. First, we identify the function virtual address of the string decoder function and create a DebugUtils object. Next, we use the DebugUtils function get_call_list to find the three push arguments for each time string_decoder is called.

Once the call_list is generated, we iterate all calling addresses and associated arguments. In this example, the output string is decoded to the stack. Because we are only executing the string decoder function and won't have

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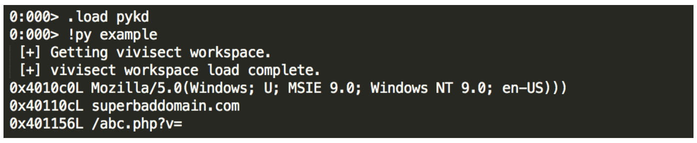
the same stack setup as the malware, we must allocate memory for the output string. We use the third parameter, the length, to specify the size of the memory allocation. Once we allocate memory for the output string, we set the newly allocated memory address as the second parameter to receive the output bytes.

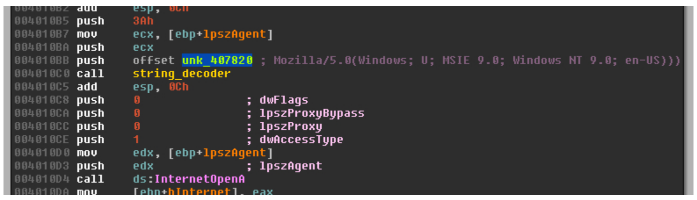
Finally, we run the string_decoder function by using the DebugUtils call function and read the result from our allocated buffer. The call function sets up the stack, sets any specified register values, and executes the function. Once all strings are decoded, the final step is to get these strings back into our IDB. The utils script contains utility functions to create IDA Python scripts. In this case, we output an IDA Python script that creates comments in the IDB.

Running this debugger script produces the following output:



```
0:000> .load pykd
0:000> !py example
 [+] Getting vivisect workspace.
 [+] vivisect workspace load complete.
0x4010c0L Mozilla/5.0(Windows; U; MSIE 9.0; Windows NT 9.0; en-US)))
0x40110cL superbaddomain.com
0x401156L /abc.php?v=
```

The output IDA Python script creates repeatable comments on all encoded string locations, as shown in Figure 3.



```
004010B2 add     esp, 0Ch
004010B5 push    3Ah
004010B7 mov     ecx, [ebp+lpszAgent]
004010BA push    ecx
004010BB push    offset unk_407820 ; Mozilla/5.0(Windows; U; MSIE 9.0; Windows NT 9.0; en-US)))
004010C0 call    string_decoder
004010C5 add     esp, 0Ch
004010C8 push    0               ; dwFlags
004010CA push    0               ; lpszProxyBypass
004010CC push    0               ; lpszProxy
004010CE push    1               ; dwAccessType
004010D0 mov     edx, [ebp+lpszAgent]
004010D3 push    edx             ; lpszAgent
004010D4 call    ds:InternetOpenA
004010DA mov     [ebp+hInternet], eax
```

Figure 3. Decoded string as comment

Conclusion

Stay tuned for another debugger scripting series post that will focus on plugins! For now, head over to the flare-dbg github project page to get started. The project requires pykd,winappdbg, and vivisect.

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