A New Look at Old Dragonfly Malware (Goodor) – One Night in Norfolk

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From time to time, new tools emerge that make it significantly easier to examine older malware. In 2017, Symantec's threat intelligence team published research regarding the Dragonfly group, an adversary with an apparent interest in performing reconnaissance against energy sector companies. One of the reported malware families, "Backdoor.Goodor," is written in Golang and the blog post states that it "provides the attackers with remote access to the victim's machine."

In recent years, several free options have become available to help reverse engineer these types of Golang binaries, replacing premium (but extremely well documented) methods and making this type of analysis particularly more accessible.

This post walks through the reverse engineering of a Goodor file, examining its capabilities and discussing key principles of these types of files.

Key Concepts

This blog notes that there are a few key concepts relevant to understanding Golang binaries:

– When first disassembled, Golang binaries will have a nearly unreadable number of unlabeled functions
– Golang binaries contain a section referred to as "gopclntab" that stores function information.
– For Linux/Unix binaries, this is an actual named section. For Windows binaries, it is not.
– This section has the same "magic bytes" in both types of binaries and follows a uniform structure.

In particular, this blog recommends that those interested in a deeper understand of the subject start by watching Joakim Kennedy's two presentations which provide significant detail regarding the structure of Golang binaries. Mr. Kennedy's tool, Redress, is a key part of current Golang reverse engineering and is used in this analysis.

Finally, this analysis uses Cutter, a GUI-based implementation of the Radare2 framework. When a Golang Linux binary is opened in Radare2 or Cutter, both tools automatically identify the gopclntab section, parse function names from this section, and relabel the assembly as needed. However, this blog noted that they did not behave this way for Windows binaries, where this section is not explicitly created. Redress provides a workaround for this issue.

This post relies on a Linux VM for Cutter, Radare2, and Redress, as the Windows version of Cutter didn't allow for the execution of Redress in the command line and the Windows version of Radare2 functioned poorly with #!pipe commands. The debugging itself takes place in a Windows VM.

Technical Analysis – Initial File

File: ntdll_installer.exe
MD5: f2edff3d0e5a909c8d05b04905642105
SHA1: c8c8329449c18445330903dd6a59d0b4098d9670
SHA256: 5a7ace894461c2432fe9b52254cbc5c3f5bbce0c91a416154511a554dba6f913

This blog revisits an older malware family with newer tools to obtain a better understanding of the file. One place to start is Symantec's original write-up, which stated:

1. "Backdoor.Goodor… opens a backdoor on the compromised computer"
2. "When the Trojan is executed, it copies itself to the following location…"
3. It "creates the following registry entry…"
%AppData%\NT\ntdll.exe ddd-073d7bac5d624bb40adbb25f55eb693d

This blog notes that the current Google-indexed page for this malware leads to a Broadcom page that states, "You have arrived at this page either because you have been alerted by your Symantec product about a risk, or you are concerned that your computer has been affected by a risk." As neither statement is true, this blog has linked to the archived version instead.

As this analysis will show, Symantec's write-up is a close approximation that's not *quite* forensically accurate. The "copied" file is actually a dropped embedded file, and the registry entry changes slightly from device to device.

Identify Function Names

The first step for this analysis is to use the Redress tool with the -src switch to identify function names. When run against this file, the tool produces the following output:

Package main: C:\Users\User\go\src\i
File: i_main.go
main Lines: 15 to 19 (4)
TryDoMain Lines: 19 to 29 (10)
TryDoMainfunc1 Lines: 20 to 24 (4)
DoMain Lines: 29 to 61 (32)
GetFn Lines: 61 to 76 (15)
CreateBat Lines: 76 to 110 (34)
StartA Lines: 110 to 113 (3)
File: r.go.template.impl.go
init Lines: 6 to 6 (0)
Package e: C:\Users\User\go\src\e
File: e.go
Decode Lines: 53 to 93 (40)
Decodefunc1 Lines: 70 to 155 (85)
FromB64 Lines: 93 to 121 (28)
Decrypt Lines: 121 to 144 (23)
HashStr Lines: 144 to 150 (6)

RandomHashString Lines: 150 to 153 (3)
init Lines: 155 to 155 (0)

This output represents the author-added functions to a Golang binary. Golang binaries are large as they also incorporate dozens (or hundreds) of additional library functions, and so this output separates the most important sections.

The output also provides some hints: we can postulate that the malware likely performs some sort of Base64 decoding and decryption (FromB64, Decode, Decrypt) and may also create a .bat file (CreateBat). Notably, we *don't* see anything indicative of command-and-control (C2) traffic.

Create a Function Map

With the primary functions identified, we can map them out. Open the binary in Cutter with the slider for analysis all the way to the left, indicating *no* analysis. Using #!pipe, run the Redress tool. Finally, run "aaaa" to perform analysis and go to View-> Refresh Contents.

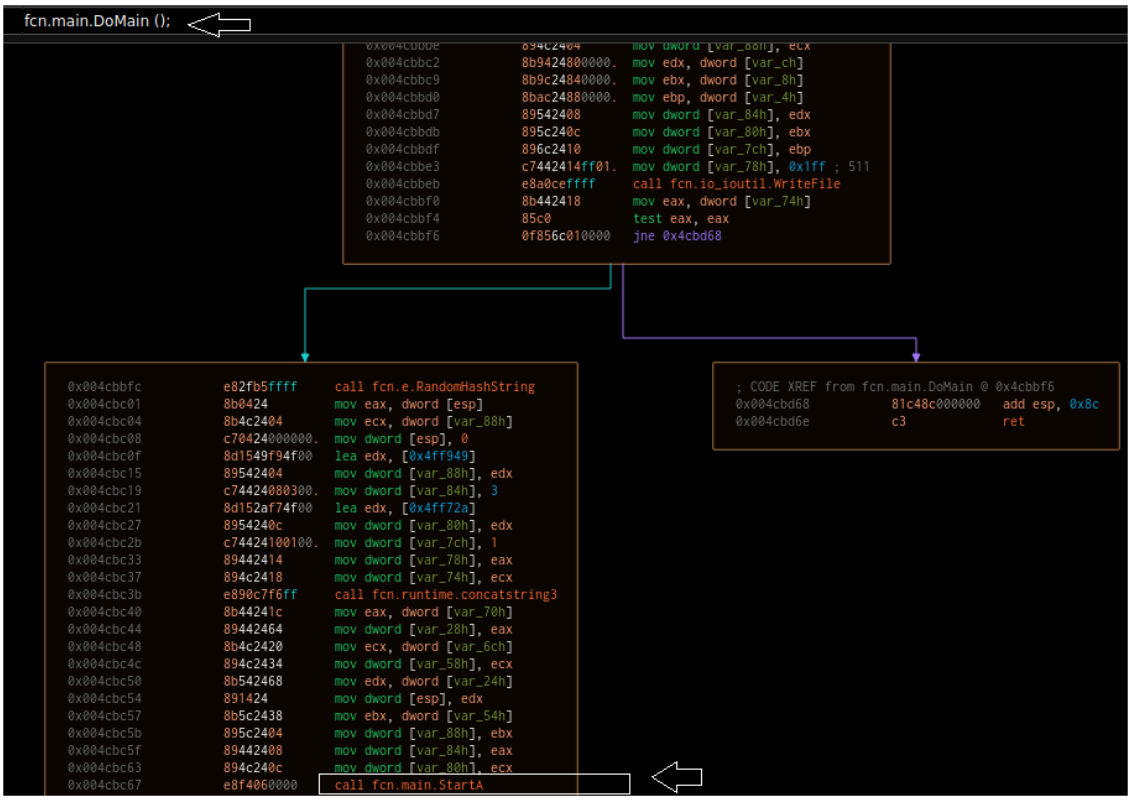
```
[0x00447ef0]> #!pipe /home/     /Downloads/redress
Compiler version: go1.8 (2017-02-16T17:12:24Z)
49 packages found.
2319 function symbols found
1545 type symbols found
Cannot open ttyname(0) (null)

[0x00447ef0]> aaaa
[x] Analyze all flags starting with sym. and entry0 (aa)
[x] Analyze function calls (aac)
[x] Analyze len bytes of instructions for references (aar)
[x] Check for objc references
[x] Check for vtables
[x] Type matching analysis for all functions (aaft)
[x] Propagate noreturn information
[x] Use -AA or aaaa to perform additional experimental analysis.
[x] Finding function preludes
[x] Enable constraint types analysis for variables
```

#!pipe command used within the Cutter console to launch Redress. Note that some error messages were cropped for readability. These can be ignored.

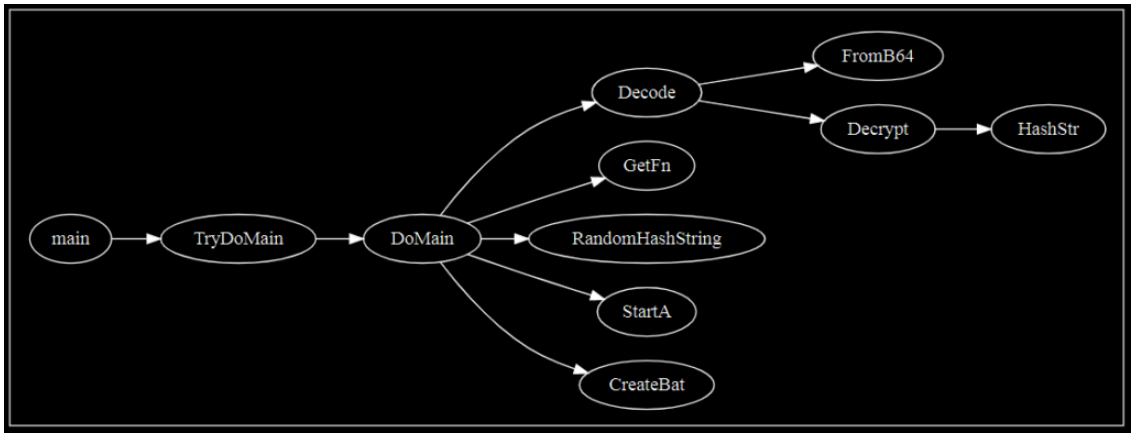
With the function names populated, we can begin mapping out a smaller call-tree. As with other disassemblers, we can select each function name in graph mode or use the cross-referencing features to identify function relationships. For example, DoMain makes several additional calls in the following order:

– Decode
– GetFn
– RandomHashString
– StartA
– CreateBat

Decode, in turn, calls "FromB64" and "Decrypt." Using this information, we can construct a simple call map.



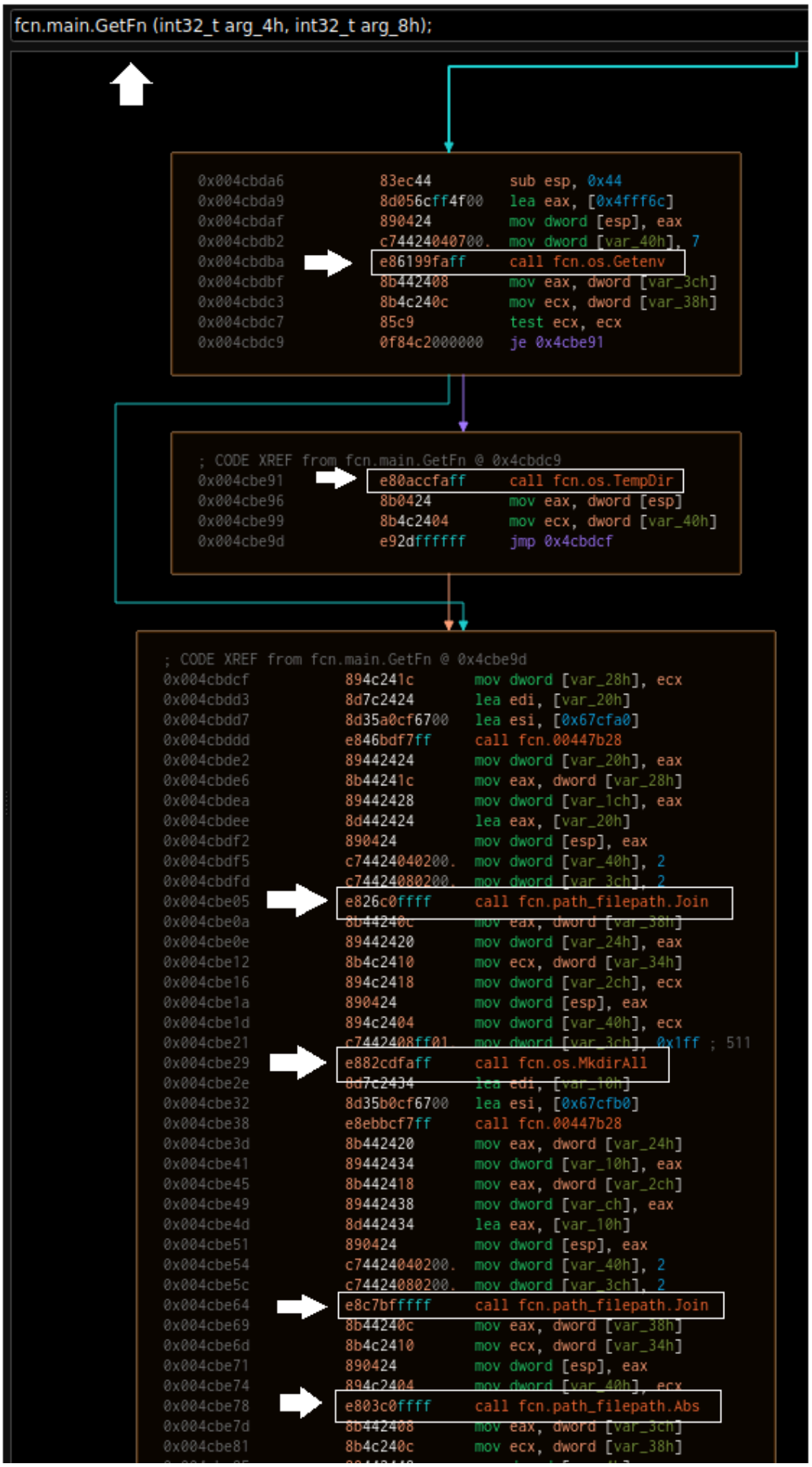
DoMain calling StartA



Simplified function map. Calls are ordered from left-to-right and top-to-bottom.

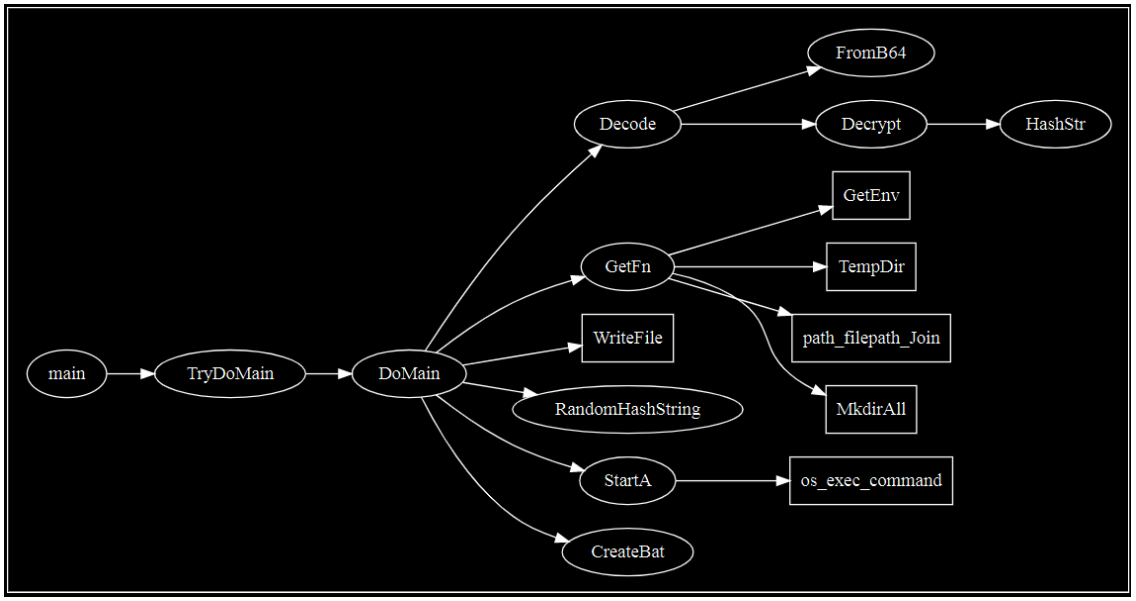
This particular sample only uses each of these functions one time, providing an easy-to-understand workflow. This is of course not necessarily typical for all malware. The graph above may also be *too* simple, as it omits several important native Golang calls that could provide a broader understanding of some of these functions.

Consider the GetFN function: within this function are calls such as “GetEnv,” “TempDir,” and “MkdirAll” that strongly suggest that a file and/or folder is being written to a specific path. Without this information, one might have assumed “GetFN” was simply obtaining the name of a file (or the file running). With that in mind, we can create a more complete graph, with boxes differentiating the native calls.


fcn.main.GetFn (int32_t arg_4h, int32_t arg_8h);
0x004cbda6 83ec44 sub esp, 0x44
0x004cbda9 8d056cff4f00 lea eax, [0x4fff6c]
0x004cbdaf 890424 mov dword [esp], eax
0x004cbdb2 c74424040700. mov dword [var_40h], 7
0x004cbdba e86199faff call fcn.os.Getenv
0x004cbdbf 8b442408 mov eax, dword [var_3ch]
0x004cbdc3 8b4c240c mov ecx, dword [var_38h]
0x004cbdc7 85c9 test ecx, ecx
0x004cbdc9 0f84c2000000 je 0x4cbe91
; CODE XREF from fcn.main.GetFn @ 0x4cbdc9
0x004cbe91 e80accfaff call fcn.os.TempDir
0x004cbe96 8b0424 mov eax, dword [esp]
0x004cbe99 8b4c2404 mov ecx, dword [var_40h]
0x004cbe9d e92dffffff jmp 0x4cbdcf
; CODE XREF from fcn.main.GetFn @ 0x4cbe9d
0x004cbdcf 894c241c mov dword [var_28h], ecx
0x004cbdd3 8d7c2424 lea edi, [var_20h]
0x004cbdd7 8d35a0cf6700 lea esi, [0x67cfa0]
0x004cbddd e846bdf7ff call fcn.00447b28
0x004cbde2 89442424 mov dword [var_20h], eax
0x004cbde6 8b44241c mov eax, dword [var_28h]
0x004cbdea 89442428 mov dword [var_1ch], eax
0x004cbdee 8d442424 lea eax, [var_20h]
0x004cbdf2 890424 mov dword [esp], eax
0x004cbdf5 c74424040200. mov dword [var_40h], 2
0x004cbdfd c74424080200. mov dword [var_3ch], 2
0x004cbe05 e826c0ffff call fcn.path_filepath.Join
0x004cbe0a 8b44240c mov eax, dword [var_38h]
0x004cbe0e 89442420 mov dword [var_24h], eax
0x004cbe12 8b4c2410 mov ecx, dword [var_34h]
0x004cbe16 894c2418 mov dword [var_2ch], ecx
0x004cbe1a 890424 mov dword [esp], eax
0x004cbe1d 894c2404 mov dword [var_40h], ecx
0x004cbe21 c7442408ff01 mov dword [var_3ch], 0x1ff ; 511
0x004cbe29 e882cdfaff call fcn.os.MkdirAll
0x004cbe2e 8d7c2434 lea edi, [var_10h]
0x004cbe32 8d35b0cf6700 lea esi, [0x67cfb0]
0x004cbe38 e8ebbcf7ff call fcn.00447b28
0x004cbe3d 8b442420 mov eax, dword [var_24h]
0x004cbe41 89442434 mov dword [var_10h], eax
0x004cbe45 8b442418 mov eax, dword [var_2ch]
0x004cbe49 89442438 mov dword [var_ch], eax
0x004cbe4d 8d442434 lea eax, [var_10h]
0x004cbe51 890424 mov dword [esp], eax
0x004cbe54 c74424040200. mov dword [var_40h], 2
0x004cbe5c c74424080200. mov dword [var_3ch], 2
0x004cbe64 e8c7bfffff call fcn.path_filepath.Join
0x004cbe69 8b44240c mov eax, dword [var_38h]
0x004cbe6d 8b4c2410 mov ecx, dword [var_34h]
0x004cbe71 890424 mov dword [esp], eax
0x004cbe74 894c2404 mov dword [var_40h], ecx
0x004cbe78 e803c0ffff call fcn.path_filepath.Abs
0x004cbe7d 8b442408 mov eax, dword [var_3ch]
0x004cbe81 8b4c240c mov ecx, dword [var_38h]

```
0x004cbe89          894c244c        mov dword [arg_8h], ecx
0x004cbe8d          83c444          add esp, 0x44
0x004cbe90          c3              ret
```

GetFN function with native calls



Function call graph with native calls added in as rectangles.

With these functions mapped out, we can hypothesize a workflow such as:

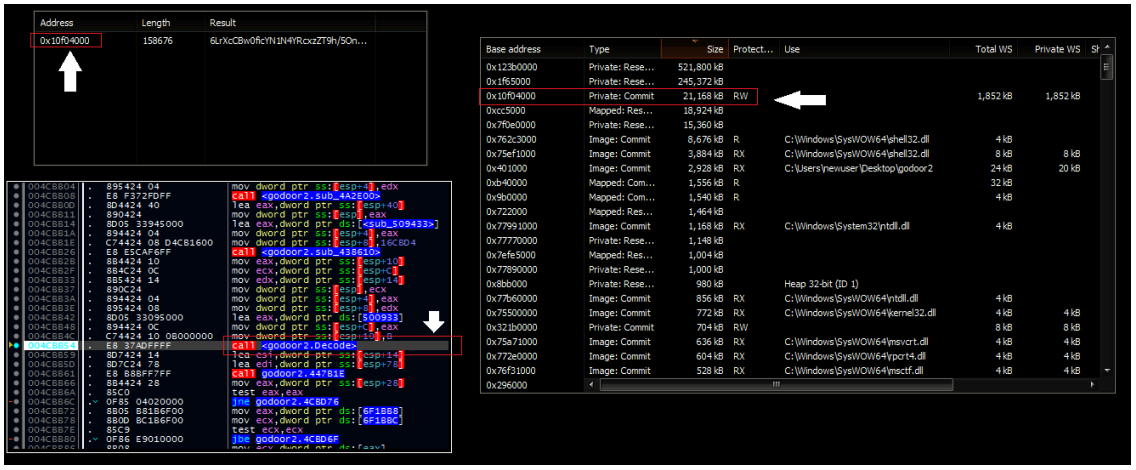
1. The malware Base64 decodes and then decrypts *something*.
2. The malware creates a filename and/or directory *somewhere*, possibly in the Temp directory.
3. The malware writes *something* to the disk.
4. The malware calls StartA, which executes *something*.
5. The malware creates and runs a .bat file.

It's time to begin debugging to test these hypotheses.

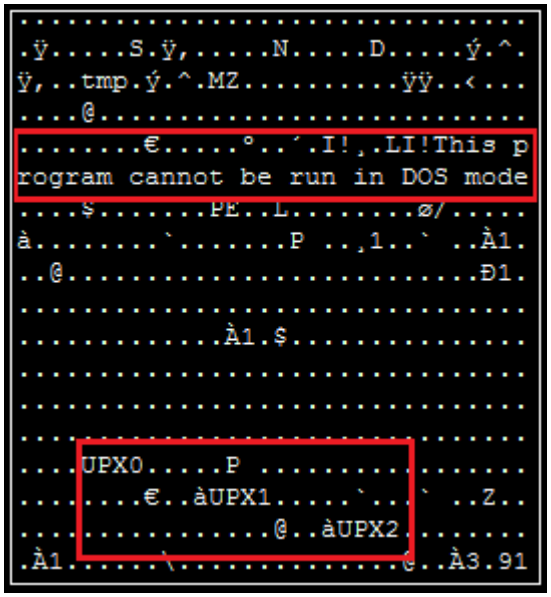
Debugging

I prefer the x96 suite for debugging. The most important thing to do before actually running the debugger is to rename the key functions we've identified. These include the author-added Golang functions plus any other interesting ones, such as those within the GetFN call. There are a few options here; in this case, I opted to do this manually, but you can also use Radare/Cutter + Redress + the "aaaa" and "afl" commands to get an address-function pair list (copying it to a file), and then create a comment or label script for x96dbg. For a larger file, that might be the most practical approach.

The first order of business is to examine the decoding hypothesis. The malware contains a large block of Base64-encoded data, visible in the strings via Process Hacker. As the string is several thousand characters long, it is easy to stop in a single memory section. After stepping over the Decode function (which in turn triggers the FromB64 and Decrypt calls), this section will populate with the decoded and then decrypted data:



Decoding and Decrypting



Executable decrypted in memory

Next, is the GetFN function call. Earlier, we hypothesized that this should create a file path or directory in the user's Temp folder. Stepping through this function, we can see it creates a directory at AppData\Roaming\NT\

Directory creation within GetFN function.

The malware will also create a filename, ntdll.exe, and append it to this path. When the function exits, it uses the WriteFile call to write the decoded executable to this location. The StartA function then issues a system command to run this. For the purposes of this analysis, I copied the executable to the desktop and replaced it with a renamed FakeNet Mini executable to examine the CreateBat function.

From a static perspective, CreateBat demonstrates a string load. The program identifies the address and length (in this case, 25 characters) of a string containing a ping command. The rest of the function also performs a string replacement for a registry key value to be added. The end result is a .bat file written to disk:

```
ping 127.0.0.1 -n 1 > nul
reg add HKCU\Software\Microsoft\Windows\CurrentVersion\Run /t REG_SZ /f /v ntdll /d "\"C:\Users\newuser\AppData\Roaming\NT\ntdll.exe\" ddd-7f6f6b28da861b0ef68851c080867117"
DEL /Q /S "C:\Users\newuser\Desktop\godoor2"
DEL /Q /S "%~f0"
```

.bat file written to disk

This file creates an HKCU runkey that will cause the dropped payload to execute any time the user logs in. It will also silently delete the initial dropper and delete itself. Following the execution of this batch file, the program terminates itself. At this point, we can look at the dropped payload.

Technical Analysis – Dropped Payload

The dropped payload is a UPX-packed Windows executable.

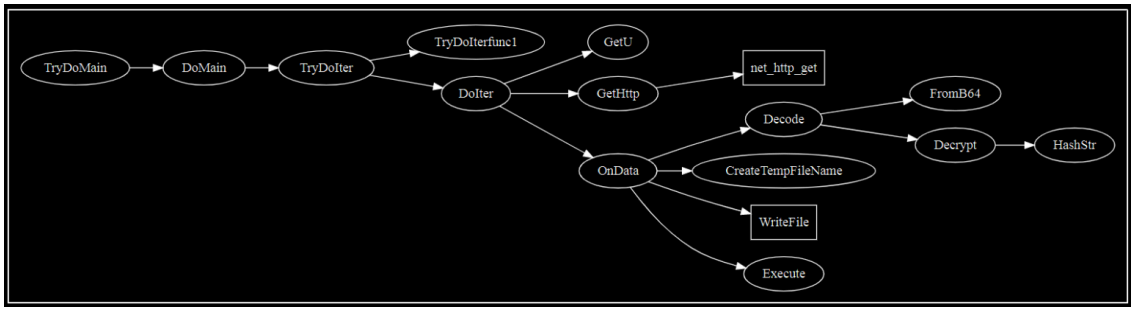
Filename: ntdll.exe
MD5 (packed): 8943E71A8C73B5E343AA9D2E19002373
MD5 (unpacked): ca818c14f69bef7695c0e2ff127e6d9b
SHA1 (unpacked): 115d12e0fb73445a788ebe7bdf3cab552b3cb9af
SHA256 (unpacked): b5278301da06450fe4442a25dda2d83d21485be63598642573f59c59e980ad46

Following the same steps as above, we can identify the author-created functions.

Package e: C:\Users\User\go\src\e
File: e.go
Decode Lines: 53 to 93 (40)
Decodefunc1 Lines: 70 to 155 (85)
FromB64 Lines: 93 to 121 (28)
Decrypt Lines: 121 to 144 (23)
HashStr Lines: 144 to 150 (6)
RandomHashString Lines: 150 to 153 (3)
init Lines: 155 to 155 (0)
Package main: C:\Users\User\go\src\m
File: m_main.go
main Lines: 17 to 21 (4)
TryDoMain Lines: 21 to 31 (10)
TryDoMainfunc1 Lines: 22 to 44 (22)
DoMain Lines: 31 to 43 (12)
TryDoIter Lines: 43 to 57 (14)
TryDoIterfunc1 Lines: 44 to 166 (122)

DoIter Lines: 57 to 100 (43)
GetU Lines: 100 to 117 (17)
OnData Lines: 117 to 146 (29)
Execute Lines: 146 to 151 (5)
GetHttp Lines: 151 to 160 (9)
CreateTempFileName Lines: 160 to 164 (4)
init Lines: 166 to 166 (0)

A few things should stand out. First, the “e” package appears to be reused, alongside all of the decoding and decryption functions. However, this is clearly *not* a “copy” of the initial dropper. The primary package has new functions, such as GetHttp, OnData, CreateTempFileName, and execute. Using the same strategy as before, we can map some key functions out.



Function tree for dropped Goodor payload

As with the previous graph, the code structure (for this particular example – again, most samples are less linear) is such that we can read left-to-right and top-to-bottom. We might expect that:

1. The malware runs GetU. Perhaps this obtains the username (it does not, but that was my initial guess).
2. The malware establishes an HTTP connection.
3. The malware checks to see if it gets a response, and if so, Base64 decodes and then decrypts that response.
4. The malware creates a filename for a target in the Temp directory.
5. The malware writes the decoded data to this file.
6. The malware executes this file.

For this example, I opted to use radare2 + redress, followed by piping the output of the “afl” function to a file. With some Notepad++ regex, I used the function addresses to make a basic x96dbg script to re-label all of the addresses. See here for an example from another analyst (replacing cmt with lbl). I mainly did this for performance reasons, and to demonstrate an additional option readers.

```
[0x0044a7e0]> #!pipe /home/     /Downloads/redress
Compiler version: go1.8 (2017-02-16T17:12:24Z)
87 packages found.
4139 function symbols found
3095 type symbols found
[0x0044a7e0]> aaaa
[x] Analyze all flags starting with sym. and entry0 (aa)
[x] Analyze function calls (aac)
[x] Analyze len bytes of instructions for references (aar)
[x] Check for objc references
[x] Check for vtables
[x] Type matching analysis for all functions (aaft)
[x] Propagate noreturn information
[x] Use -AA or aaaa to perform additional experimental analysis.
[x] Finding function preludes
[x] Enable constraint types analysis for variables
[0x0044a7e0]> afl > flist_un
```

Redress and dumping a function list

```
lbl 0x00409fe0, "fnc.runtime.additab"
lbl 0x00442b40, "fnc.runtime____type_.uncommon"
lbl 0x00443350, "fnc.runtime____type_.typeOff"
lbl 0x00443030, "fnc.runtime.resolveTypeOff"
lbl 0x00443830, "fnc.runtime_name.pkgPath"
lbl 0x00443390, "fnc.runtime____type_.textOff"
lbl 0x0040ab50, "fnc.runtime.assertE2I"
lbl 0x004016d0, "fnc.runtime_internal_atomic.Load64"
lbl 0x004015b0, "fnc.runtime_internal_atomic.Casuintptr"
lbl 0x00423a00, "fnc.runtime.semacreate"
lbl 0x004015c0, "fnc.runtime_internal_atomic.Loaduintptr"
lbl 0x00423890, "fnc.runtime.semasleep"
lbl 0x00424070, "fnc.runtime.osyield"
lbl 0x0044aad0, "fnc.runtime.onosstack"
lbl 0x00449460, "fnc.runtime.procyield"
lbl 0x004239c0, "fnc.runtime.semawakeup"
lbl 0x00423db0, "fnc.runtime.nanotime"
lbl 0x00423cc0, "fnc.runtime.systime"
lbl 0x0040b460, "fnc.runtime.notetsleep_internal"
lbl 0x0042cb20, "fnc.runtime.entersyscallblock"
lbl 0x00424950, "fnc.runtime.testdefersizes"
lbl 0x00410da0, "fnc.runtime.sysReserve"
lbl 0x00423f70, "fnc.runtime.stdcall4"
lbl 0x0041c3f0, "fnc.runtime___mheap_.init"
lbl 0x0040fda0, "fnc.runtime.allocmcache"
lbl 0x004108e0, "fnc.runtime.sysAlloc"
lbl 0x00420660, "fnc.runtime.mSysStatInc"
lbl 0x00410c70, "fnc.runtime.sysFree"
lbl 0x00420710, "fnc.runtime.mSysStatDec"
lbl 0x00423f30, "fnc.runtime.stdcall3"
lbl 0x0044a8a0, "fnc.runtime.getlasterror"
lbl 0x0040dab0, "fnc.runtime__mheap_.mapBits"
```

Example of a labeling script for x96dbg

Debugging the malware, we can get through the GetU function before we start to run into some obstacles that will hinder a full analysis. Recall that we hypothesized that GetU could return the username. It actually creates the string for the GET request sent to the C2 server:

C2 string building function

Right click and open in a new tab to zoom in a bit. The GetU function pulls one of five hardcoded C2 servers and appends an identifier string to it:

hxxp: // 176.53.11[.]130/aspnet_client/system_web/4_0_30319/update/DefaultForm.txt
hxxp: // 82.222.188[.]18/aspnet_client/system_web/4_0_30319/update/DefaultForm.txt
hxxp: // 130.25.10[.]158/aspnet_client/system_web/4_0_30319/update/DefaultForm.aspx
hxxp: // 41.205.61[.]221/aspnet_client/system_web/4_0_30319/update/DefaultForm.aspx
hxxp: // 5.150.143[.]107/aspnet_client/system_web/4_0_30319/update/DefaultForm.aspx

One of these values, boxed in red above, remained consistent through different runs of the malware. This value, 881456fc, also appears in VirusTotal runs of the malware in the behavior tab. If the file is run with a command line argument (as the runkey would cause), this value is appended with that argument. If not, the value is appended with “no” instead. One possibility is that this serves as a campaign ID and a device identifier.

At this stage, the analysis ran into some hurdles that could not be overcome. The malware didn’t appear to call out to the C2 server during the GetHTTP call, limiting confirmation of the remainder of the suspected functionality. Still, we can make some pretty strong inferences from the final call of the workflow, OnData:

OnData workflow

The workflow strongly suggests that something is Base64 decoded and decrypted, written to disk at a generated location, and then executed. Symantec's original report suggested that several other backdoors were deployed against victims. It is therefore possible that Goodor was used to deliver a tool such as a screen grabber, the Karagany backdoor, or one of several other payloads.

Concluding Thoughts

A few simple contemporary tools make analyzing Golang malware significantly easier than it was in the past, particularly for those lacking access to premium tools such as IdaPro. Radare2, Cutter, and Redress can combine to create a workflow where the user can rename Golang functions, navigate a graph, and debug malware significantly easier than in the past.

During this research, I ran a retrohunt to try to identify additional samples that contained the same encoding functions or matched other function names from the dropper and payload. Unfortunately, while I found other

hashes, none were “new.” This may have been a one-time use tool from the threat actor, or the function names may have been renamed in different versions.
