还没尝试用英语写过文章，试试我的语法, 提前申明，THIS article will only be used in acadameic usage.

The Fortigate you might not know

`From China Moew Moew Moew Security Research Team`

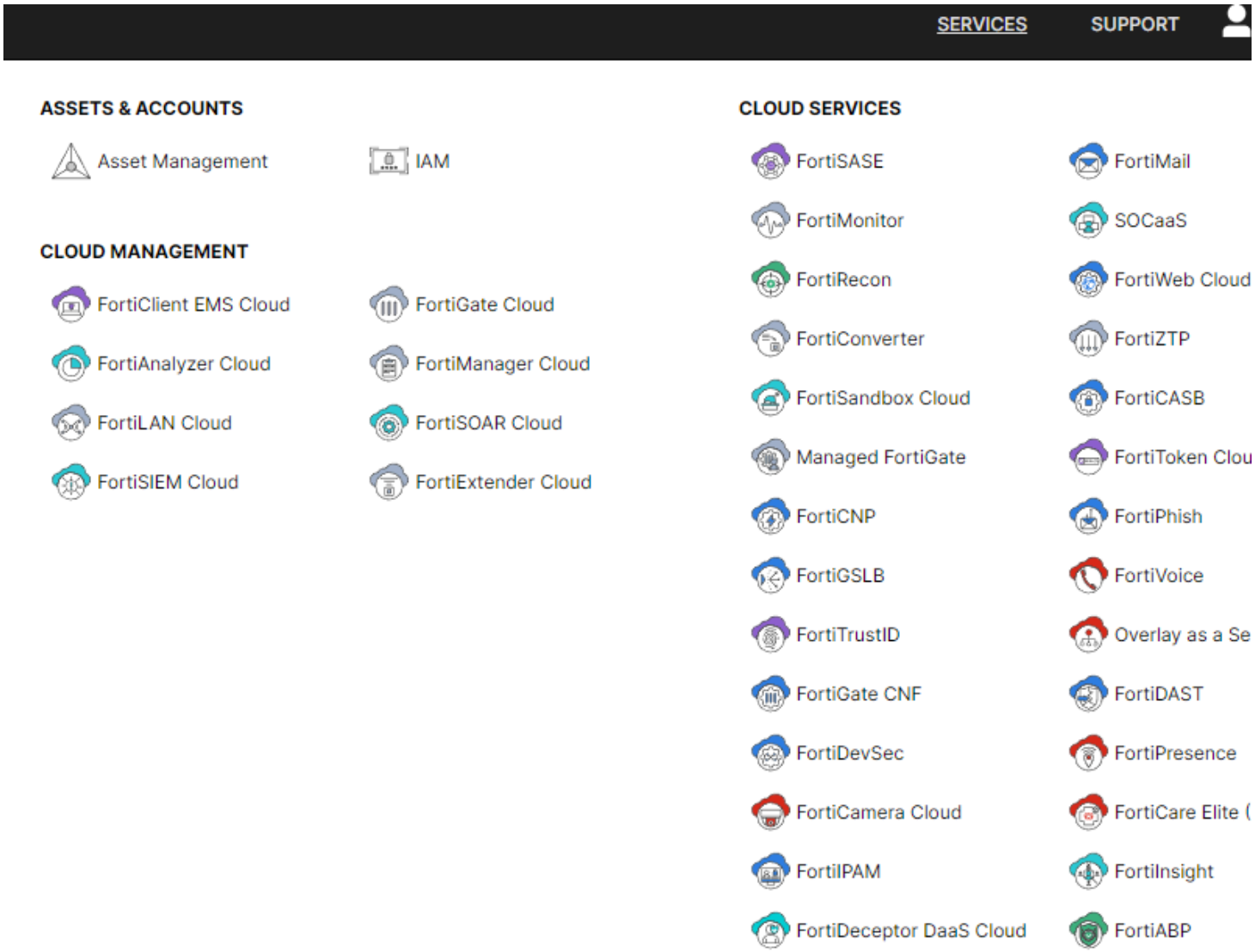
Hello, you. I am a blue team security researcher from `moew moew moew` . Recently I realize that the network device is a good path for CTF pwn player to real vulnerablity researcher.The network device security analysis is not a hard way like broswer or CPU hardware to get a binary secuirty job. And as the rising conflict of the world, keeping your assests secure is getting more and more complicated.

The FortiGate Next-Generation Firewall (NGFW), part of the Fortinet Security Fabric, is a robust firewall solution designed to protect organizations from both internal and external threats. It has a large group of customer with varaieties of good aspect:FortiGate NGFW provides automated protection against attacks, malware, and other vulnerabilities.It offers end-to-end security across your entire network, including internal segmentation, perimeter, cloud, data center, distributed, and small business deployments.

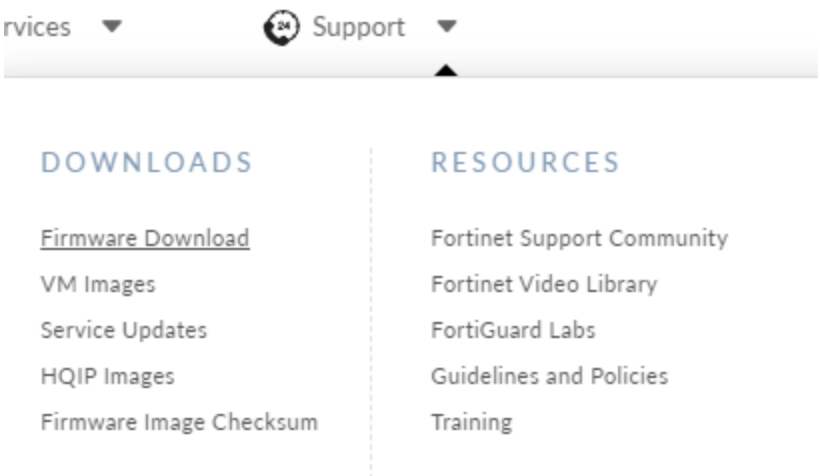
FortiGate NGFW is known for its unparalleled AI-powered security performance, But i never used it. threat intelligence, and full visibility. It converges networking and security into a single operating system, making it easy to manage. With features like SD-WAN, switching, wireless, and 5G integration, FortiGate NGFW ensures robust protection for various use cases.

Getting firmware

After register a fortigate account, download Fortigate image rom fortigate download website, click `SERVICE` and then it will pop a page like the following.



Then click `Asset Management` , The firware download button like this:



Download image with `FGT` prefix and after that, three parameters should be configured in order to run fortigate correctly.

1. default gatway
2. ip and subnet mask of port1
3. DNS primary and secondary

In order to activate fortigate to use at most functions. You must configure the DNS. I prefer to set gateway to NAT.

Extremely easiest way to debug-environment deployment after FGT-7.4.0

c01c114317a6681fa7b31a97e0f187f7

Bofore you should know first:

> 1. GDB use command: `dump` to dump memory in to host machine, use command: `restore` to do the reverse——put a file into guest memory
> 2. DebugStub is a vmware feature that can trace the kernel after bootloader executed.
> 3. Busybox is a software that include almost common command of linux.such as `ls`, `ps`, `cp` ... Always been used in the embedded system.

Then there's a idea comes from my mind.What about write a shellcode to download busybox, download

So what about write shellcode to get a busybox

```
debugStub.listen.guest64 = "TRUE"
debugStub.listen.guest64.remote = "TRUE"
debugStub.port.guest64 = "4321"
monitor.debugOnStartGuest64 = "TRUE"
debugStub.hideBreakpoints = "TRUE"
```

1. get flatkc
2. get decrypted rootfs.gz

in 7.4.4， This is decrypted function,use "debugstub" to control rip to that xwrite, dump rsi[rdx]

```
__int64 sub_FFFFFFFF8170D56B()
{
  int v0; // esi
  __int64 v1; // rax
  int v2; // edx
  int v3; // ecx
  int v4; // r8d
  int v5; // r9d
  __int64 v6; // r12
  int v7; // edx
  int v8; // ecx
  int v9; // r8d
  int v10; // r9d
  int v11; // eax
  unsigned int v12; // ebx
  __int64 v13; // rax
  int v14; // ecx
  int v15; // r8d
  int v16; // r9d

  v0 = (int)off_FFFFFFFF817DD3D8;
  v1 = sub_FFFFFFFF8170D2E8(a070701000002d1, off_FFFFFFFF817DD3D8);
  if ( v1 )
    panic((unsigned int)&aS_24[1], v1, v2, v3, v4, v5);
  if ( qword_FFFFFFFF8183B080 )
  {
    printk((unsigned int)&unk_FFFFFFFF813D2010, v0, v2, v3, v4, v5);
    v6 = sub_FFFFFFFF8170D2E8(qword_FFFFFFFF8183B080, qword_FFFFFFFF8183B078 - qword_FFFFFFFF8183B080);
    if ( !v6 )
    {
LABEL_9:
      free_initrd();
      goto LABEL_10;
    }
    sub_FFFFFFFF8170CF83();
    sub_FFFFFFFF8170D2E8(a070701000002d1, off_FFFFFFFF817DD3D8);
    printk((unsigned int)&unk_FFFFFFFF813D2048, v6, v7, v8, v9, v10);
    v11 = do_sys_open(4294967196LL, aInitrdImage, 32833LL, 448LL);
    v12 = v11;
    if ( v11 >= 0 )
    {
      v13 = xwrite((unsigned int)v11, qword_FFFFFFFF8183B080, qword_FFFFFFFF8183B078 - qword_FFFFFFFF8183B080);
      if ( qword_FFFFFFFF8183B078 - qword_FFFFFFFF8183B080 != v13 )
        printk((unsigned int)&unk_FFFFFFFF813D2088, v13, qword_FFFFFFFF8183B078 - qword_FFFFFFFF8183B080, v14, v15, v16);
      _close_fd(*(_QWORD *)(__readgsqword((unsigned int)&off_14D80) + 1576), v12);
      goto LABEL_9;
    }
  }
LABEL_10:
  flush_delayed_fput();
  load_default_modules();
  return 0LL;
}
```

you could get a unpacked rootfs.gz.

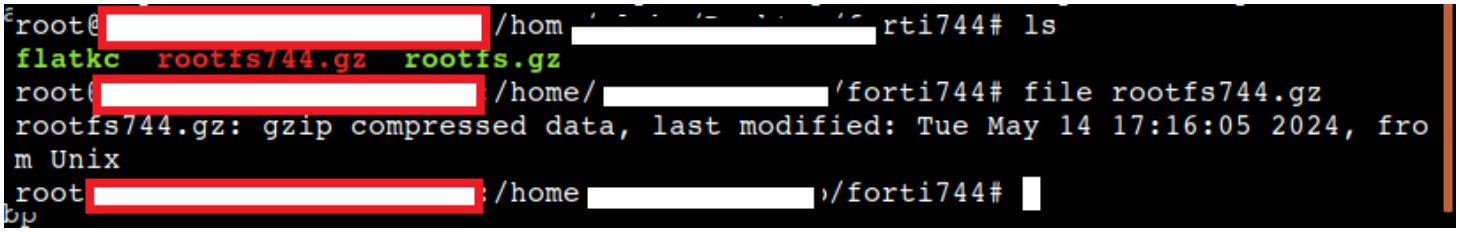
Force to set $rip into do_sys_open function.

```
Breakpoint 3, 0xffffffff8170d631 in ?? ()
1: x/30i $rip
=> 0xffffffff8170d631:  callq  0xffffffff8170cf26
   0xffffffff8170d636:  mov    %rax,%rsi
   0xffffffff8170d639:  mov    0x12da38(%rip),%rdx        # 0xffffffff8183b078
   0xffffffff8170d640:  sub    0x12da39(%rip),%rdx        # 0xffffffff8183b080
   0xffffffff8170d647:  cmp    %rax,%rdx
   0xffffffff8170d64a:  je     0xffffffff8170d658
   0xffffffff8170d64c:  mov    $0xffffffff813d2088,%rdi
   0xffffffff8170d653:  callq  0xffffffff803405f8
   0xffffffff8170d658:  mov    %gs:0x14d80,%rax
   0xffffffff8170d661:  mov    0x628(%rax),%rdi
   0xffffffff8170d668:  mov    %ebx,%esi
   0xffffffff8170d66a:  callq  0xffffffff804688b2
   0xffffffff8170d66f:  callq  0xffffffff8170d102
   0xffffffff8170d674:  callq  0xffffffff8044ba95
   0xffffffff8170d679:  callq  0xffffffff8170aa2a
   0xffffffff8170d67e:  xor    %eax,%eax
   0xffffffff8170d680:  pop    %rbx
   0xffffffff8170d681:  pop    %r12
   0xffffffff8170d683:  pop    %rbp
   0xffffffff8170d684:  retq
   0xffffffff8170d685:  push   %rbp
   0xffffffff8170d686:  mov    %rsp,%rbp
   0xffffffff8170d689:  push   %r13
   0xffffffff8170d68b:  push   %r12
   0xffffffff8170d68d:  push   %rbx
   0xffffffff8170d68e:  movl   $0x3,0x88d4c(%rip)        # 0xffffffff817963e4
   0xffffffff8170d698:  movl   $0x7,0x88d3e(%rip)        # 0xffffffff817963e0
   0xffffffff8170d6a2:  mov    0x88d07(%rip),%r12        # 0xffffffff817963b0
   0xffffffff8170d6a9:  mov    $0xffffffff813d1f8b,%rsi
   0xffffffff8170d6b0:  mov    %r12,%rdi
(gdb) i r rsi
rsi            0xffff88807ba24000       -131389565288448
(gdb) x/s $rsi
0xffff88807ba24000:     "\037\213\b"
(gdb) x/100xb $rsi
0xffff88807ba24000:     0x1f    0x8b    0x08    0x00    0x55    0x9c    0x43    0x66
0xffff88807ba24008:     0x00    0x03    0xa4    0xd7    0x63    0x8c    0x2e    0xc0
0xffff88807ba24010:     0xf3    0x20    0xea    0xb1    0x6d    0xdb    0xd6    0x19
0xffff88807ba24018:     0xdb    0xb6    0x6d    0x1b    0xef    0xd8    0xb6    0x7d
0xffff88807ba24020:     0xc6    0xb6    0x6d    0xdb    0xf6    0x9c    0xb1    0x6d
0xffff88807ba24028:     0xee    0x2f    0xd9    0x2c    0xee    0xe6    0xfe    0xb3
0xffff88807ba24030:     0xc9    0xbd    0xf5    0xa9    0x92    0x4e    0xd5    0xd3
0xffff88807ba24038:     0xfd    0xa1    0x2b    0xdd    0x4c    0x1c    0x4c    0x1c
0xffff88807ba24040:     0x4c    0xcc    0x4c    0xcc    0x7f    0x58    0xfe    0x18
0xffff88807ba24048:     0x1b    0x31    0x33    0xfd    0x27    0xd8    0x98    0xcd
0xffff88807ba24050:     0x4c    0x99    0xfe    0xdf    0xc3    0x94    0x9d    0x9d
0xffff88807ba24058:     0x8d    0xc5    0x88    0x8b    0xf3    0xbf    0x58    0x66
0xffff88807ba24060:     0xff    0xaf    0xea    0x58
(gdb) i r rdx
rdx            0x44bb28b        72069771
(gdb) i r rip
rip            0xffffffff8170d631       0xffffffff8170d631
(gdb)
```

then run this command to dump the decrypted rootfs.gz

```
(gdb) i r rip
rip            0xffffffff8170d631       0xffffffff8170d631
(gdb) dump binary memory rootfs744.gz $rsi $rdx
Invalid memory address range (start >= end).
(gdb) dump binary memory rootfs744.gz $rsi $rsi+$rdx
```

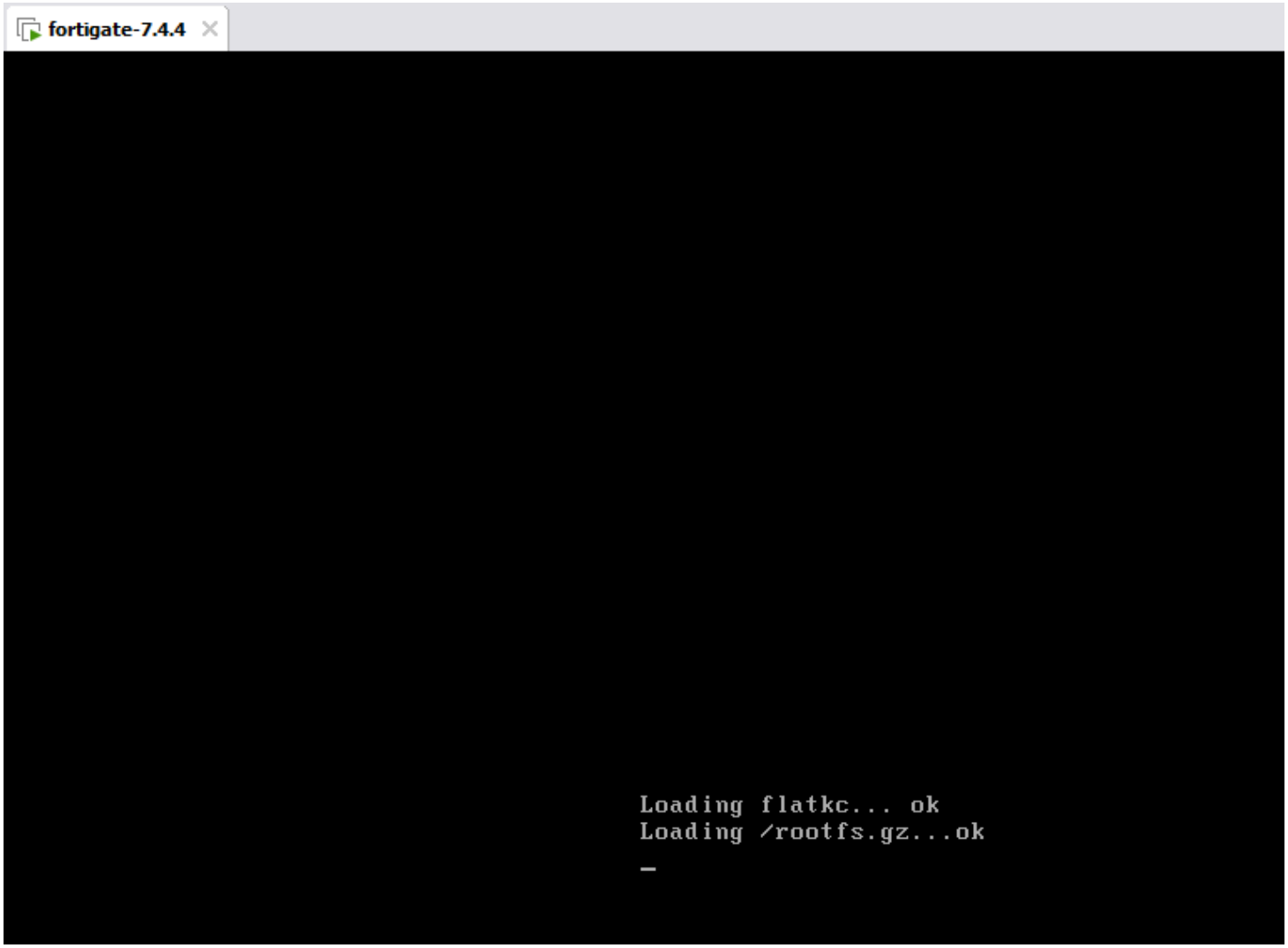
Good job. after few minutes to wait, we just get a holy decrypted rootfs.gz, which can be recogonised as gzip compressed file.



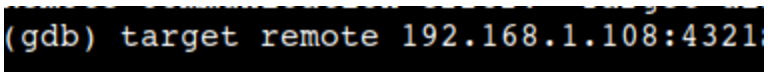
then use gunzip to decompress this file, and use `cpio -idmv < ./rootfs744` to get every single files

If your fortigate is in higher version, you can then execute `tar -xvf ./bin.tar.xz` to unpack bin.
but in the lower version, fortigate gives sbin/ftar sbin/xz to de-xz and de-tar.This is already written by many articles, so i will not discuzz lower version.

After boot the Fortigate, the vm machine will waiting for dubugger to attach to the kernel because of debugstub.
By the way, before you attah to it, do not try to do anything stupid to the vm machine, do not poweroff or take a snapshot, or the vm machine will suspend until you restart VMX process and VMware process.(restart your computer is a easy way).



Then get your windows host ip, on the windows cmd panel, run `ipconfig` to get your host ip, such as 192.168.xxx.xxx or 10.xxx.xxx.xxx. Attention, debugstub listend on the ip and port of your vmware host machine, not on the ip of fortigate. use gdb command `target remote 192.168.1.108:4321` to attach to debugstub



run `display/30i $rip` to show asm code.

```
warning: No executable has been specified and target does not support
determining executable automatically.  Try using the "file" command.
0x0000000000100200 in ?? ()
1: x/30i $rip
=> 0x100200:    xor    %eax,%eax
   0x100202:    mov    %eax,%ds
   0x100204:    mov    %eax,%es
   0x100206:    mov    %eax,%ss
   0x100208:    mov    %eax,%fs
   0x10020a:    mov    %eax,%gs
   0x10020c:    mov    $0x200000,%rbp
   0x100213:    mov    0x260(%rsi),%ebx
   0x100219:    sub    $0x71b000,%ebx
   0x10021f:    add    %rbp,%rbx
   0x100222:    lea    0x711980(%rbx),%rsp
   0x100229:    xor    %rax,%rax
   0x10022c:    callq  0x100231
   0x100231:    pop    %rdi
   0x100232:    sub    $0x231,%rdi
   0x100239:    callq  0x7f48a3
   0x10023e:    lea    0x6fd54b(%rip),%rax        # 0x7fd790
   0x100245:    mov    %rax,0x6fd536(%rip)        # 0x7fd782
   0x10024c:    lgdt   0x6fd52d(%rip)         # 0x7fd780
   0x100253:    push   %rsi
   0x100254:    mov    %rsi,%rdi
   0x100257:    callq  0x7f85f0
   0x10025c:    pop    %rsi
   0x10025d:    mov    %rax,%rcx
   0x100260:    lea    0xc(%rip),%rdi         # 0x100273
   0x100267:    pushq  $0x8
   0x100269:    lea    0x1000(%rax),%rax
   0x100270:    push   %rax
   0x100271:    lretq
   0x100273:    lea    0x711980(%rbx),%rsp
(gdb) S
```

This is code is in decompressed `flatkc` , which is implemented in /boot directory.

Remember our target is to find an easists way to implement a debug environment in FGT newest version.
I think use Vmware debugstub and try to write shellcode to get to it.

So our solution is :

> 0. do something to bypass security check.
> 1. find a address to hook
> 2. alloc a memory
> 3. use gdb `restore` command to put busybox in memory.

4. write the busybox in /bin and chmod 777
5. use gdb `restore` command to put smartctl in memory.
6. write the backdoor to smartctl and chmod 777
7. run `diagnose hardware smartctl` to execute busybox shell.

Let me explain above:

0. security check is important, i will talk later.
1. The hook address i choose is `ping` . because `ping` code is less impact on Fortigate system runtime.
   the address is `0x299DA68` in /bin/init.

```
.text:000000000299DA68 loc_299DA68:                            ; CODE XREF: sub_299DA20+1C↑j
.text:000000000299DA68                 mov     edi, offset aSPingStatistic ; "\n--- %s ping statistics ---\n"
.text:000000000299DA6D                 xor     eax, eax
.text:000000000299DA6F                 call    _printf
.text:000000000299DA74                 mov     esi, cs:dword_C310B48
.text:000000000299DA7A                 mov     edi, offset aDPacketsTransm ; "%d packets transmitted, "
.text:000000000299DA7F                 xor     eax, eax
.text:000000000299DA81                 call    _printf
.text:000000000299DA86                 mov     esi, cs:dword_C310B4C
.text:000000000299DA8C                 mov     edi, offset aDPacketsReceiv_1 ; "%d packets received, "
.text:000000000299DA91                 xor     eax, eax
.text:000000000299DA93                 call    _printf
```

2. when hooked success, use `mmap` syscall to alloc a big big big big big big big big memory, a little bit larget than busybox file.
3. `memset` the memory to 0 (In kernel if you mmap a the page will not be allocated instantly then we restore file in memory will fail

resources here

backdoor smartctl:

```
#/bin/busybox ash
/bin/busybox ash
```

hooked shellcode

only change memset addr is enough.

```
[BITS 64]
sub rsp, 8
call delete
call alloc_mem
mov r13, rax
mov rdi, r13
mov rsi, 0
mov rdx, 0x71fb38
mov rax,0x43B3B0                        ;memset
call rax


lea rdi, [rel busybox]            ; 文件名指针
mov r15, 0xed96a                  ; len
nop
call write_file

lea rdi, [rel smartctl]           ; smartctl
mov r15, 0x25             ; len
nop
call write_file

lea rdi, [rel gdb]
mov r15, 0x3f927f
nop
call write_file


lea rdi, [rel busybox]           ; 第一个参数：命令字符串
xor rsi, rsi
xor rdx, rdx
mov rax, 59                      ; execve系统调用的系统调用号是59
syscall
ret

write_file:
        mov r10, rdi
        mov rax, 2                        ; 系统调用号（sys_open）
        mov rsi, 0x41                      ; 标志
        mov rdx, 777                       ; 权限（rw-r--r--）
        syscall                           ; 调用内核
        mov r14, rax
```

```
        mov rdi, rax
        mov rax, 1                      ; 系统调用号 (sys_write)
        mov rsi, r13
        mov rdx, r15                ; len
        syscall                         ; 调用内核

        ; 关闭文件
        mov rax, 3                      ; 系统调用号 (sys_close)
        mov rdi, r14                    ; 文件描述符
        syscall                         ; 调用内核

        ; chmod
        mov rax, 90                 ; syscall number for chmod
        mov rdi, r10            ; pointer to the filename
        mov rsi, 0777           ; set permissions to 777 (octal)
        syscall                     ; make the system call
        ret


father:
add rsp, 8
ret

;readfile:
;       mov rax, 2                      ; 系统调用号 (sys_open)
;       lea rdi, [rel filename]         ; 文件名指针
;       mov rsi, 0x0                    ; 标志
;       mov rdx, 0x1ff                      ; 权限 (rw-r--r--)
;       syscall                         ; 调用内核
;       mov r14, rax
;
;       nop
;
;       mov rdi, rax
;       mov rax, 1                      ; 系统调用号 (sys_write)
;       mov rsi, r13
;       mov rdx, 0x100                  ; 消息长度
;       syscall                         ; 调用内核
;
;       nop

;       mov rax, 3                      ; 系统调用号 (sys_close)
;       mov rdi, r14                    ; 文件描述符
```

```
;       syscall

alloc_mem:
        mov rax, 9
        mov rdi, 0x8000000
        mov rsi, 0x71fb38
        mov rdx, 7
        mov rcx, 0x22
        mov r10, 0x22
        mov r8, -1
        mov r9, 0
        syscall
        ret



delete:
        ; 设置系统调用为unlink（系统调用号为87）
        mov rax, 87
        ; 设置第一个参数为文件名的地址
        ; 调用系统调用
        syscall
        ret
section .data
    tmpaddr db 0,0,0,0,0,0,0,0
    smartctl db '/bin/smartctl', 0        ; 文件名和路径
    app db "ash", 0,0,0,0,0,0,0,0,0,0,0,0

    busybox db '/bin/busybox',0      ; busybox字符串，以null结尾
    ash db 'ash',0                   ; ash字符串，以null结尾
    gdb db '/bin/gdb', 0
    envlist dq 0                     ; 环境变量列表
```

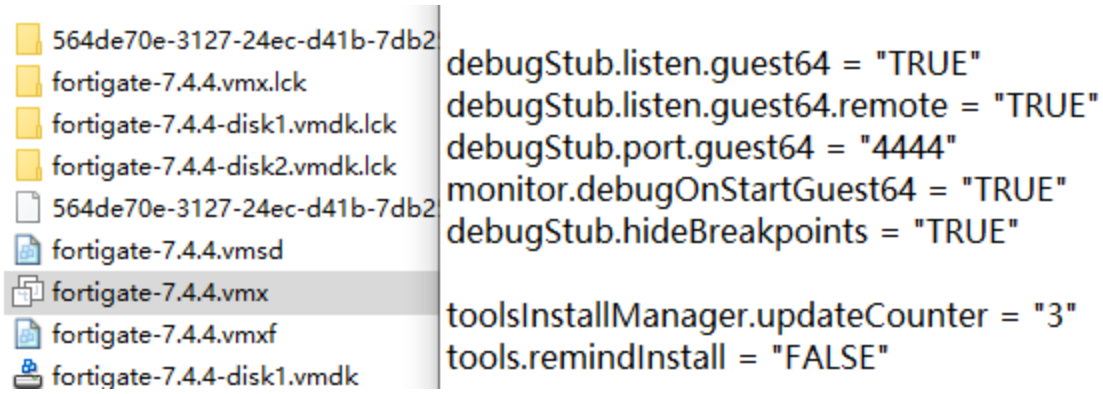
1. gdb script: the `$func` is hook addr we mentioned (hijack ping command at 0x299da68).

```
set {char [5]}(char *)0xFFFFFFFF80553104="\x31\xc0\xc3"
# bypass fos_process_appraise


set $func = 0x2366158
hbreak *$func
command
        restore 1.o binary $rip
end
# 1.o is hooked shellcode(above asm code compiled)


hbreak *($func+0x32)
command
        restore busybox binary  $r13
end

hbreak *($func+0x45)
command
        restore smartctl binary  $r13
end

hbreak *($func+0x58)
command
        restore gdb binary  $r13
end
```

4. busybox:
   download at your will and compile it.

after you prepared all resources, let's start:

1. write debugstub setting in your fortigate vmx file



2. turn on the fortigate vm machine
3. use gdb to attach to debugstub, ensure that your gdb is at resources directory, which has `busybox` `smartctl` (backdoor),
4. paste hooked shellcode to 1.asm, run command `nasm 1.asm -o 1.o` to get 1.o

```
/Desktop/fortigate-utils-744# nasm 1.asm -o 1.o
```

5. press C continue to run
6. paste the gdb script to gdb

```
(gdb) set {char [5]}(char *)0xFFFFFFFF805512EB="\x31\xc0\xc3"
(gdb)
(gdb) set $func = 0x299DA68
(gdb) hbreak *$func
Hardware assisted breakpoint 58 at 0x299da68
(gdb) command
Type commands for breakpoint(s) 58, one per line.
End with a line saying just "end".
>restore 1.o binary $rip
>end
(gdb)
(gdb) hbreak *($func+0x33)
Hardware assisted breakpoint 59 at 0x299da9b
(gdb) command
Type commands for breakpoint(s) 59, one per line.
End with a line saying just "end".
>restore busybox binary  $r13
>end
(gdb)
(gdb) hbreak *($func+0x46)
Hardware assisted breakpoint 60 at 0x299daae
(gdb) command
Type commands for breakpoint(s) 60, one per line.
End with a line saying just "end".
>restore smartctl binary  $r13
>end
```

if you want to change version

just modify 4 things:

1. In gdb script: modify addr of fos_process_appraise
2. In gdb script: modify hooked address (as I choose ping command in this example)
3. In hooked shellcode: modify addr of memset
4. In hooked shellcode: modify addr of

New safe feature in Fortigate

Since fortigate 7.4.0 has imported a new feature, some functions was added to improve the secuirty preformance.I didn't find any article to introduce this, only in offcial web page after my research has done.

https://docs.fortinet.com/document/fortigate/7.4.0/new-features/249947/enhance-bios-level-signature-and-file-integrity-checking

The main function is `fos_process_appraise` :

In 7.4.4, flatkc kernel decompressed, IDA hexray persudo C code:

```
nt64 __fastcall fos_process_appraise_constprop_0(__int64 a1)

nsigned __int64 v1; // rax
nt v2; // edx
nt v3; // ecx
nt v4; // r8d
nt v5; // r9d
nsigned __int64 v6; // rbx
_int64 v7; // r14
nt v8; // r13d
nsigned int i; // edx
_int64 result; // rax
nt v11; // r13d
nt v12; // r8d
nt v13; // r9d
_int64 v14; // rax
nt v15; // edx
nt v16; // ecx
nt v17; // r8d
nt v18; // r9d
_int64 v19; // rax
_int64 v20; // rax
nt v21; // [rsp+8h] [rbp-4B0h]
_int64 v22; // [rsp+10h] [rbp-4A8h]
nt v23[11]; // [rsp+18h] [rbp-4A0h] BYREF
har v24; // [rsp+44h] [rbp-474h] BYREF
_int16 v25; // [rsp+45h] [rbp-473h]
har v26; // [rsp+47h] [rbp-471h]
_int64 v27[8]; // [rsp+48h] [rbp-470h] BYREF
har v28[512]; // [rsp+88h] [rbp-430h] BYREF
har v29[512]; // [rsp+288h] [rbp-230h] BYREF
nsigned __int64 v30; // [rsp+488h] [rbp-30h]

30 = __readgsqword(0x28u);
22 = *(_QWORD *)(a1 + 32);
1 = d_path(a1 + 16, v28, 511LL);
6 = v1;
f ( v1 > 0xFFFFFFFFFFFFF000LL )

 printk((unsigned int)&unk_FFFFFFFF81405ED8, (unsigned int)v28, v2, v3, v4, v5);
 ((void (*)(__int64, __int64, __int64, __int64, _QWORD, const char *, ...))off_FFFFFFFF816BAD48[0])(
   36864LL,
   255LL,
   255LL,
   20233LL,
   0LL,
   "severity=alert msg=\"[The length of executable filename is longer than 512](%s).\"",
```

This function will be called when execute a binary or do sys_write syscall. If you try to:

1. write files in /bin /migadmin ... : syscall return -24.

```
.rodata:FFFFFFFF81404F50 aBin           db '/bin',0
.rodata:FFFFFFFF81404F55 aMigadmin      db '/migadmin',0
.rodata:FFFFFFFF81404F5F aNodeScripts   db '/node-scripts',0
.rodata:FFFFFFFF81404F6D aSbin          db '/sbin',0
.rodata:FFFFFFFF81404F73 aTools         db '/tools',0
.rodata:FFFFFFFF81404F7A aUsr           db '/usr',0
.rodata:FFFFFFFF81404F7F aLib64         db '/lib64',0
.rodata:FFFFFFFF81404F86                align 8
```

2. execute binary outside will reboot immediately.
   [I have no picture]

fortigate 7.4.4 flatkc decompress, kernel. hexray prrsudo code:

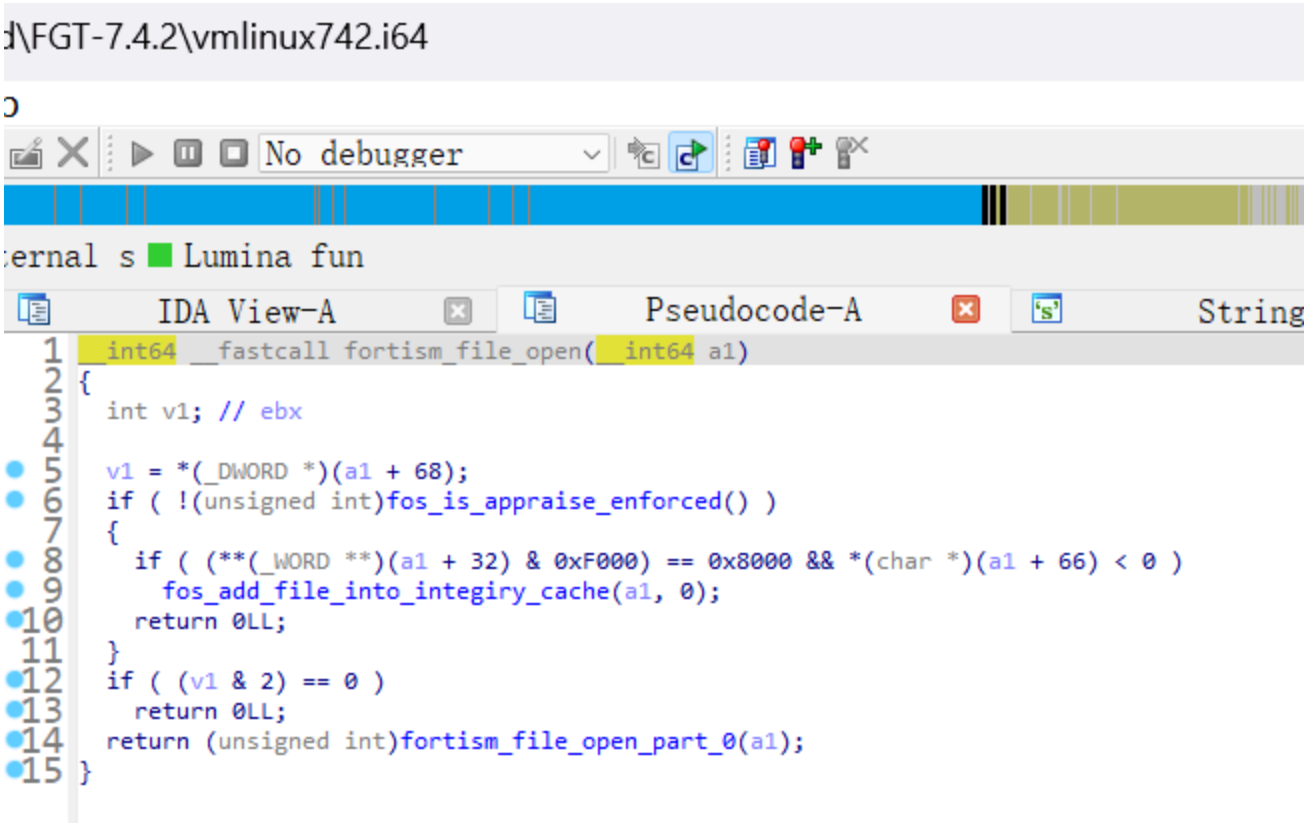
```
__int64 __fastcall fos_process_appraise_constprop_0(__int64 a1)
{
  unsigned __int64 v1; // rax
  int v2; // edx
  int v3; // ecx
  int v4; // r8d
  int v5; // r9d
  unsigned __int64 v6; // rbx
  __int64 v7; // r14
  int v8; // r13d
  unsigned int i; // edx
  __int64 result; // rax
  int v11; // r13d
  int v12; // r8d
  int v13; // r9d
  __int64 v14; // rax
  int v15; // edx
  int v16; // ecx
  int v17; // r8d
  int v18; // r9d
  __int64 v19; // rax
  __int64 v20; // rax
  int v21; // [rsp+8h] [rbp-4B0h]
  __int64 v22; // [rsp+10h] [rbp-4A8h]
  int v23[11]; // [rsp+18h] [rbp-4A0h] BYREF
  char v24; // [rsp+44h] [rbp-474h] BYREF
  __int16 v25; // [rsp+45h] [rbp-473h]
  char v26; // [rsp+47h] [rbp-471h]
  __int64 v27[8]; // [rsp+48h] [rbp-470h] BYREF
  char v28[512]; // [rsp+88h] [rbp-430h] BYREF
  char v29[512]; // [rsp+288h] [rbp-230h] BYREF
  unsigned __int64 v30; // [rsp+488h] [rbp-30h]

  v30 = __readgsqword(0x28u);
  v22 = *(_QWORD *)(a1 + 32);
  v1 = d_path(a1 + 16, v28, 511LL);
  v6 = v1;
  if ( v1 > 0xFFFFFFFFFFFFF000LL )
  {
    printk((unsigned int)&unk_FFFFFFFF81405ED8, (unsigned int)v28, v2, v3, v4, v5);
    ((void (*)(__int64, __int64, __int64, __int64, _QWORD, const char *, ...))off_FFFFFFFF816BAI
      36864LL,
      255LL,
```

```
    255LL,
    20233LL,
    0LL,
    "severity=alert msg=\"[The length of executable filename is longer than 512](%s).\"",
    *(const char **)(*(_QWORD *)(a1 + 24) + 40LL));
  msleep(10000LL);
  kernel_restart(0LL);
  return (unsigned int)v6;
}
else
{
  v7 = sub_FFFFFFFF8055107D(v1);
  if ( v7 )
  {
    v8 = 3;
    v24 = dword_FFFFFFFF8165F6D4;
    for ( i = 0; ; i = 0 )
    {
      do
      {
        v27[i] = 0LL;
        v27[i + 1] = 0LL;
        v27[i + 2] = 0LL;
        v27[i + 3] = 0LL;
        i += 4;
      }
      while ( i < 8 );
      result = ima_calc_file_hash(a1, &v24);
      if ( !(_DWORD)result )
        break;
      if ( !--v8 )
      {
        if ( (int)result < 0 )
          return result;
        break;
      }
      v25 = 0;
      v26 = 0;
      v24 = dword_FFFFFFFF8165F6D4;
    }
    result = memcmp(*(_QWORD *)(v7 + 584) + 4LL, v27, *(unsigned __int8 *)(*(_QWORD *)(v7 + 58
    if ( (_DWORD)result )
    {
```

```
    ima_pr_emerg(3LL, v6);
    sub_FFFFFFFF80551250(aNew, v27, *(unsigned __int8 *)(*(_QWORD *)(v7 + 584) + 1LL));
    sub_FFFFFFFF80551250(aOld, *(_QWORD *)(v7 + 584) + 4LL, *(unsigned __int8 *)(*(_QWORD *
    printk((unsigned int)&unk_FFFFFFFF81405E83, *(_QWORD *)(v22 + 80), v15, v16, v17, v18);
    time64_to_tm(*(_QWORD *)(v22 + 104), 0LL, v23);
    v21 = v23[0];
    printk(
      (unsigned int)&unk_FFFFFFFF81405F68,
      (unsigned int)aModifiedTime,
      v23[6] + 1900,
      v23[4] + 1,
      v23[3],
      v23[2]);
    v19 = sub_FFFFFFFF80552372(3LL);
    ((void (__fastcall *)(__int64, __int64, __int64, __int64, _QWORD, __int64, unsigned __i
      36864LL,
      255LL,
      255LL,
      20234LL,
      0LL,
      v19,
      v6,
      v21);
    msleep(5000LL);
    kernel_restart(0LL);
    return 4294967283LL;
  }
}
else
{
  v11 = (int)off_FFFFFFFF8165F6C0[0];
  if ( !(unsigned int)strcmp(off_FFFFFFFF8165F6C0[0], v6)
    || (v11 = (int)off_FFFFFFFF8165F6C8, !(unsigned int)strcmp(off_FFFFFFFF8165F6C8, v6)) )
  {
    memset(v29, 0, sizeof(v29));
    snprintf((unsigned int)v29, 511, (unsigned int)aSX_0, v11, v12, v13);
    if ( (int)sub_FFFFFFFF80551F40(a1, v6, v29) < 0 )
    {
      ima_pr_emerg(0LL, v6);
      v20 = sub_FFFFFFFF80552372(0LL);
      ((void (__fastcall *)(__int64, __int64, __int64, __int64, _QWORD, __int64, unsigned __
        36864LL,
        255LL,
```

```
            255LL,
            20233LL,
            0LL,
            v20,
            v6);
          msleep(5000LL);
          kernel_restart(0LL);
          return 4294967283LL;
        }
        else
        {
          return 0LL;
        }
      }
      else
      {
        ima_pr_emerg(1LL, v6);
        v14 = sub_FFFFFFFF80552372(1LL);
        ((void (__fastcall *)(__int64, __int64, __int64, __int64, _QWORD, __int64, unsigned __i
          36864LL,
          255LL,
          255LL,
          20233LL,
          0LL,
          v14,
          v6);
        msleep(5000LL);
        kernel_restart(0LL);
        return 4294967283LL;
      }
    }
  }
  return result;
}
```

and some fucking little functions such as do_sys_open, `fortism_file_open` in 7.4.2



The latest version I found this symbol is 7.4.2.

The latest version I didn't found this symbole is 7.4.4(latest)

The key to find this function is :

```
__int64 __fastcall fortism_file_open_part_0_cold(__int64 a1, __int64 a2, __int64 a3, __int64 a4, int a5, int a6)
{
  const char *v6; // r13

  printk((unsigned int)&unk_FFFFFFFF81401450, (unsigned int)aFortismFileOpe, 78, (_DWORD)v6, a5, a6);
  ((void (*)(__int64, __int64, __int64, __int64, _QWORD, const char *, ...))off_FFFFFFFF816B8888[0])(
    36864LL,
    255LL,
    255LL,
    20230LL,
    0LL,
    "msg=\"[Write Violation: try to write readonly file](%s).\"",
    v6);
  return 4294967283LL;
}
```

So we can found this function in 7.4.4

```
unsigned __int64 __fastcall sub_FFFFFFFF805503D3(__int64 a1)

unsigned __int64 result; // rax
const char *v2; // r13
_QWORD *v3; // rbx
__int64 v4; // rax
__int64 v5; // rbx
__int64 v6; // rax
int v7; // r8d
int v8; // r9d
char v9[496]; // [rsp+270h] [rbp-220h] BYREF
unsigned __int64 v10; // [rsp+470h] [rbp-20h]

v10 = __readgsqword(0x28u);
result = d_path(a1 + 16, v9, 511LL);
v2 = (const char *)result;
v3 = &unk_FFFFFFFF8165F640;
if ( result <= 0xFFFFFFFFFFFFF000LL )
{
  while ( 1 )
  {
    v4 = strlen(*v3);
    if ( !(unsigned int)strncmp(v2, *v3, v4) )
      break;
    if ( ++v3 == (_QWORD *)&unk_FFFFFFFF8165F698 )
      return 0LL;
  }
  v5 = 0LL;
  while ( 1 )
  {
    v6 = strlen((&off_FFFFFFFF8165F5E0)[v5]);
    result = strncmp(v2, (&off_FFFFFFFF8165F5E0)[v5], v6);
    if ( !(_DWORD)result )
      break;
    if ( ++v5 == 5 )
    {
      printk((unsigned int)&unk_FFFFFFFF81405040, (unsigned int)aFortismFileOpe, 80, (_DWORD)v2, v7, v8);
      ((void (*)(__int64, __int64, __int64, __int64, _QWORD, const char *, ...))off_FFFFFFFF816BAD48[0])(
        36864LL,
        255LL,
        255LL,
        20230LL,
        0LL,
        "msg=\"[Write Violation: try to write readonly file](%s).\"",
        v2);
      return 4294967283LL;
    }
  }
}
return result;
```

When attempting to `sys_write` to a runtime directory (such as /migadmin), it will return an error and log this critical operation. However, the oversight is that it uses `dpath` to obtain the absolute path, which prevents symbolic link attacks. Yet, it didn't check the parent directory. As a result, you can rename /migadmin to /test and create a symbolic link from /bin to /test do bypass this check.

```
        if ( !--v19 )
        {
          v16 = d_path(a1 + 16, (__int64)v24, 511);
          if ( v16 > 0xFFFFFFFFFFFFF000LL )
            ima_pr_emerg(4LL, 0LL);
          else
            ima_pr_emerg(5LL, v16);
          return v5;
        }
        v21 = 0;
        v22 = 0;
        v20 = c01c114317a6681fa7b31a97e0f187f7;
      }
```

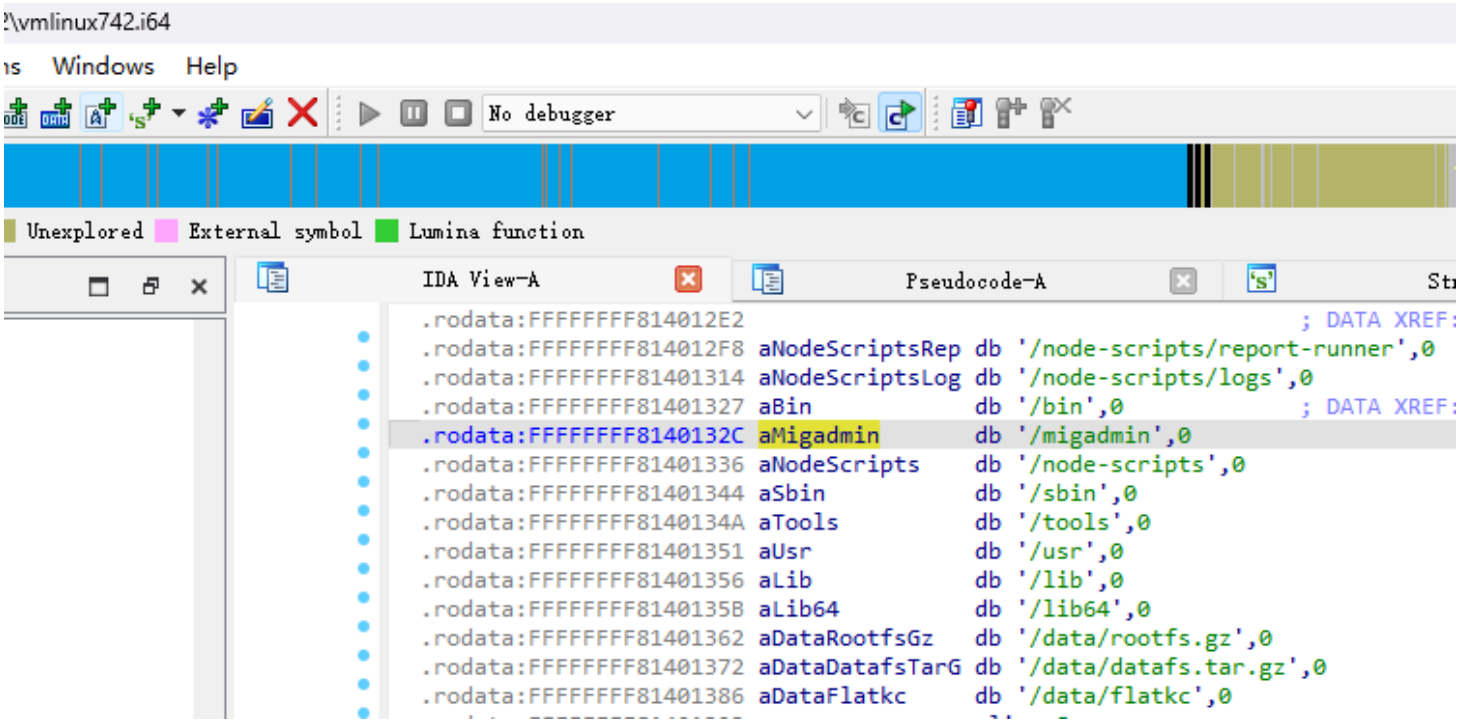
dpath的检查

debug enviroment conclusion

As I indroduced the new security policy in new fortigate, How to bypass it?
For fos_process_appraiase

1. rename migadmin to another name such as testtest
2. create a link named migadmin to testtest
3. modify testtest.
   So you can change web runtime enviroment
   (can use this to Persistence exploit, not only for debug environment deploy)

For fos_fileopen
edit memory in vmlinux in debugstub, change string /bin to /ain to avoid check, change string /migadmin to /aaaa



After do that

find a addr to hook into shellcode, I choose this position

search string "packets transmitted"

```
.rodata:00000000039ABC29 ; const char aDPacketsTransm[]
.rodata:00000000039ABC29 aDPacketsTransm db '%d packets transmitted, ',0
.rodata:00000000039ABC29                                        ; DATA XREF: sub_2
```

find this function

```
void sub_28019B0()
{
  if ( qword_FE498E0 )
  {
    if ( dword_FE499D0 )
      goto LABEL_3;
    printf("\n--- %s ping statistics ---\n", (const char *)qword_FE498E0);
    printf("%d packets transmitted, ", (unsigned int)dword_FE49900);
    printf("%d packets received, ", (unsigned int)dword_FE49904);
    if ( dword_FE49908 )
      printf("%d duplicates, ", (unsigned int)dword_FE49908);
    if ( dword_FE49900 )
      printf("%d%% packet loss\n", 100 * (dword_FE49900 - dword_FE49904) / (unsigned int)dword_FE49900);
    if ( SHIDWORD(qword_4B5E360) > 7 && dword_FE49904 )
      printf(
        "round-trip min/avg/max = %lu.%lu/%lu.%lu/%lu.%lu ms\n",
        qword_4B5E410 / 0xAuLL,
        qword_4B5E410 % 0xAuLL,
        qword_FE49920 / (unsigned __int64)(unsigned int)(dword_FE49908 + dword_FE49904) / 0xA,
        qword_FE49920 / (unsigned __int64)(unsigned int)(dword_FE49908 + dword_FE49904) % 0xA,
        qword_FE49918 / 0xAuLL,
        qword_FE49918 % 0xAuLL);
    fflush(stdout);
  }
  dword_FE499D0 = 1;
LABEL_3:
  dword_FE499C0 = 1;
  if ( dword_4B5E408 >= 0 )
    close(dword_4B5E408);
  dword_4B5E408 = -1;
}
```

set hbreak on this function in debugstub gdb

```
(gdb) hbreak *0x00000000028019B0
Hardware assisted breakpoint 3 at 0x28019b0
(gdb) c
Continuing.
```

in fortigate, use `exec ping 1.1.1.1` and `ctrl-c` to get into break

```
FortiGate-VM64 # exec ping 1.1.1.1
^C_
```

write gdb script into debugstub gdb

```
(gdb) set $func = 0x2366158
(gdb) hbreak *$func
Hardware assisted breakpoint 4 at 0x2366158
(gdb) command
Type commands for breakpoint(s) 4, one per line.
End with a line saying just "end".
>restore 1.o binary $rip
>end
(gdb)
(gdb)
(gdb)
(gdb) hbreak *($func+0x32)
Hardware assisted breakpoint 5 at 0x236618a
(gdb) command
Type commands for breakpoint(s) 5, one per line.
End with a line saying just "end".
>restore busybox binary  $r13
>end
(gdb)
(gdb) hbreak *($func+0x45)
Hardware assisted breakpoint 6 at 0x236619d
(gdb) command
Type commands for breakpoint(s) 6, one per line.
End with a line saying just "end".
>restore smartctl binary  $r13
>end
(gdb)
(gdb) hbreak *($func+0x58)
Hardware assisted breakpoint 7 at 0x23661b0
(gdb) command
Type commands for breakpoint(s) 7, one per line.
End with a line saying just "end".
>restore gdb binary  $r13
>end
(gdb)
```

press continue and you will get a debug environment if you run

`diagnose hardware smartctl`

Thanks

Some lower version might now run this procedure correctly.
I tried a lot and at last know the reason is `Kernel too old`

But Thanks tools for swing (Bestswing.me) offers a tool named elf-to-shellcode which could help me to address the issue and fix it.
https://bestswing.me
He is the sympathy man and a good researcher which have a good talent and hardworking man

If you don't know why your binary didn't executed in expected then try to use elf-to-shellcode to convert sh command `./busybox ash` or `./busybox ls /` to shellcode to replace `1.o` in gdb script

discribed above.

```
https://github.com/H4ckF0rFun/elf_to_shellcode
```