看雪·第四届

SDC·2020

安全开发者峰会

10.23 | 上海

麒麟框架：现代化的逆向分析体验

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目录

1. 演讲者介绍
2. 麒麟框架介绍
3. MBR插桩分析
4. 麒麟框架调试层支持
5. 反OLLVM平坦化
6. 展望

演讲人介绍

演讲者介绍

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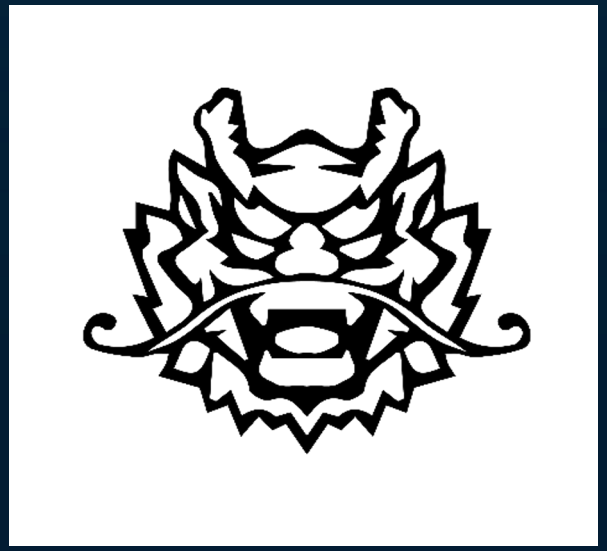


麒麟框架介绍

麒麟框架介绍：总览

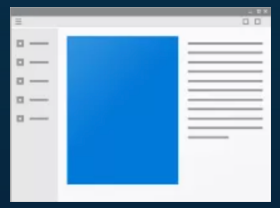
- 在沙箱环境内模拟执行二进制文件。
- 在模拟的基础上提供统一的分析API。
- 插桩分析、快照、系统调用和API劫持等。
- 跨系统：Windows, MacOS, Linux, BSD, UEFI, MBR
- 跨架构：x86, x86_64, arm, arm64, mips, 8086
- 跨二进制：PE, MachO, ELF, UEFI(PE), COM
- GDB 调试支持以及我们自己的调试器 Qdb。
- IDA 插件赋予 IDA 动态插桩分析能力。

	8086	x86	x86-64	ARM	ARM64	MIPS
Windows (PE)	-	☑	☑	☐	☐	-
Linux (ELF)	☐	☑	☑	☑	☑	☑
MacOS (MachO)	-	☐	☑	-	-	-
BSD (ELF)	☐	☐	☑	☐	☐	☐
UEFI	-	☑	☑	-	-	-
DOS (COM)	☑	-	-	-	-	-
Architecture independent						
MBR		☑				

麒麟框架介绍：总览

Windows PE

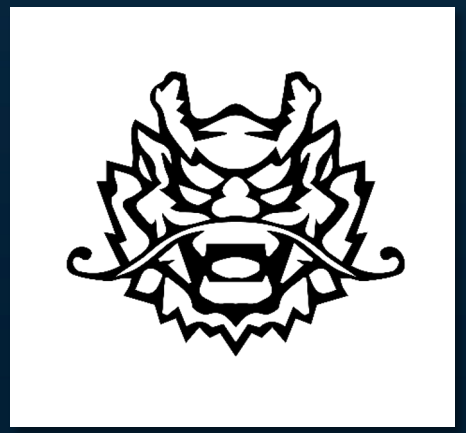
DOS COM



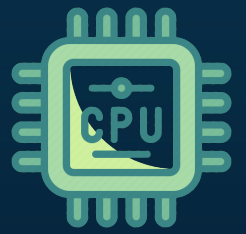
UEFI Executable

Linux ELF

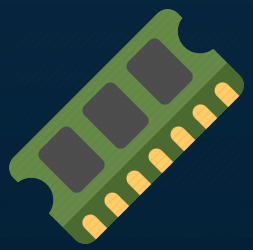
MacOS MachO



Qiling Framework



Instrumentation API



Memory API

Snapshot API

Disk API

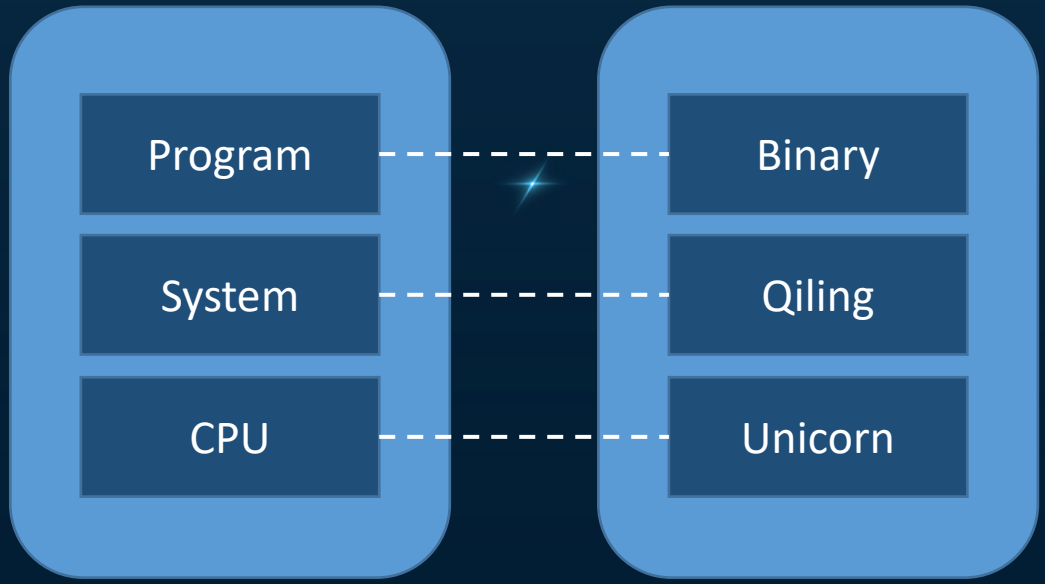
麒麟框架介绍：模拟实现

Unicorn

- 基于 Qemu 的 CPU 模拟器
- 对上层系统无任何感知

Qiling

- 解析二进制，设置内存
- 实现关键的系统调用
- 从二进制文件的入口点开始执行



麒麟框架介绍：架构设计

Arch

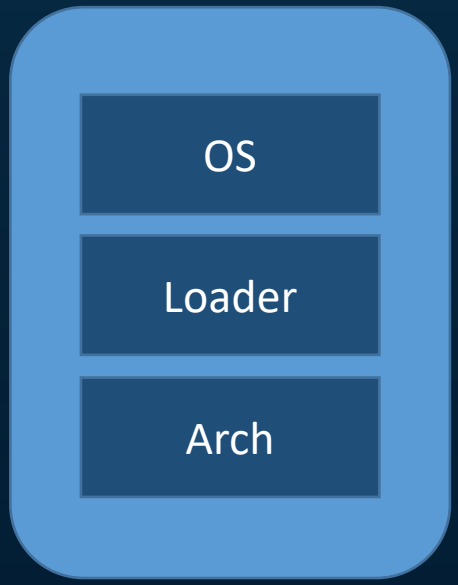
- 设置寄存器、内存、栈等
- 负责架构相关的底层实现，比如x86的GDT

Loader

- 解析二进制，判断系统类型和架构类型，重定位
- 解析代码段加载进内存，设置堆栈
- 为运行程序做好准备工作

OS

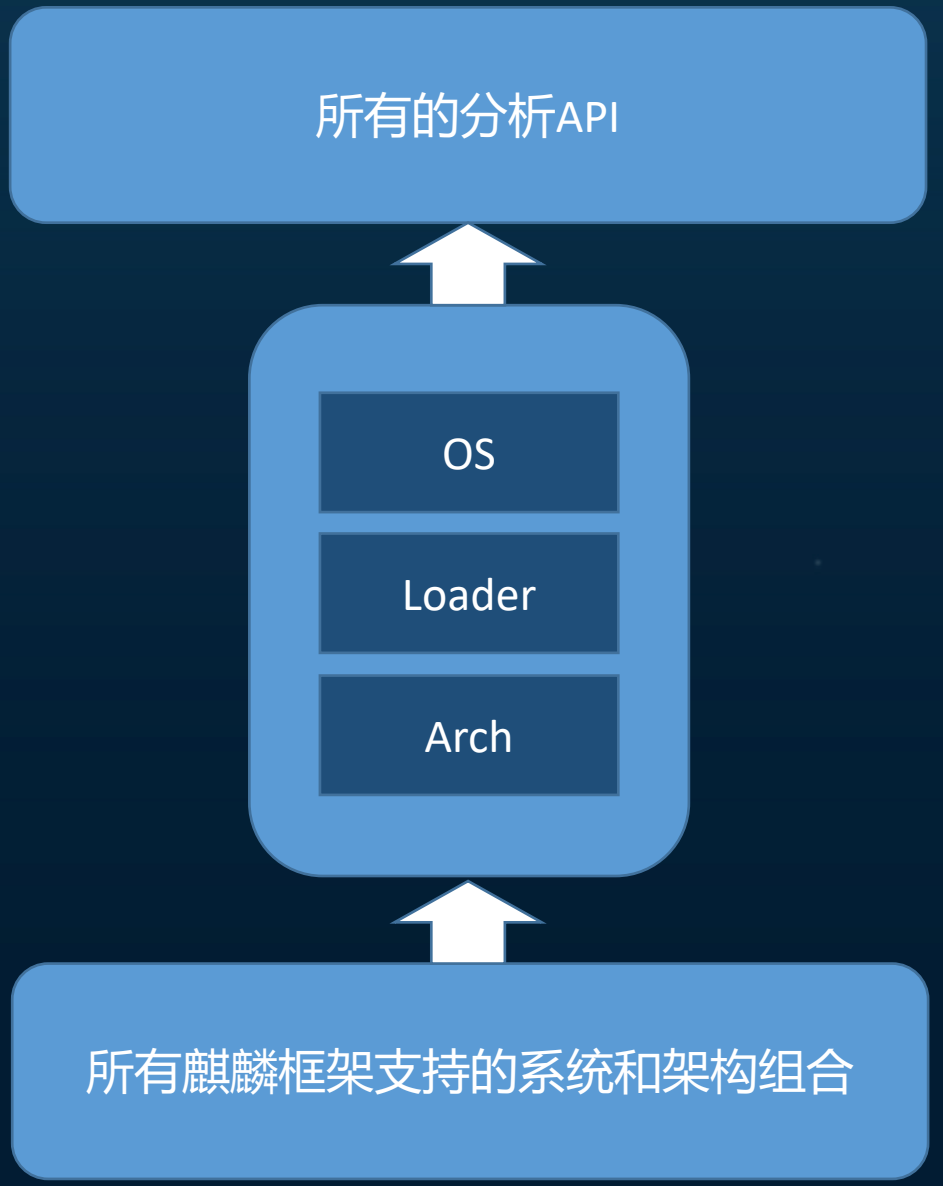
- 核心实现，包括了系统调用的实现
- 提供操作系统相关抽象，比如磁盘、文件路径等等



Qiling

麒麟框架介绍：分析API

- Registers API 读取/设置寄存器
  - ql.reg.eax = 1
- Memory API 读取/设置/搜索 内存
  - ql.mem.read / ql.mem.write
  - ql.mem.search
- Hook API 插桩分析
  - ql.hook_code / ql.hook_mem
  - ql.set_syscall / ql.set_api
- Disk API 磁盘/路径模拟
  - ql.os.add_fs_mapper
- Snapshot API 快照保存/恢复
  - ql.save / ql.restore



MBR插桩分析

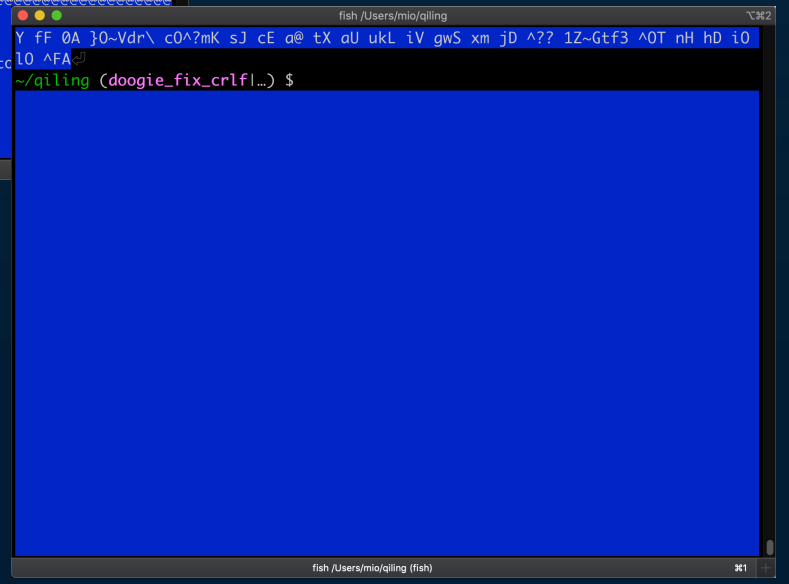
MBR插桩分析

- MBR(Master Boot Record)
- Arch层实现 20 位地址线的转换
- Loader层解析COM文件或者MBR Dump
  - 同时设置硬盘的映射
- OS层实现了BIOS中断
  - 通过 ncurse 来实现BIOS图形服务和键盘服务
  - 通过硬盘映射来实现磁盘服务
- 目前唯一一个可以对MBR进行插桩分析的框架

MBR插桩分析：样本分析

- Flare-On Challenge 8 – doogie
- MBR file
- 使用 qltool 可以直接运行
  - python3 qltool run -f examples/rootfs/8086/doogie/doogie.bin --rootfs examples/rootfs/8086/ --console False
- 输入后会得到一些乱码
- 注意到有一个日期 Feb 06, 1990

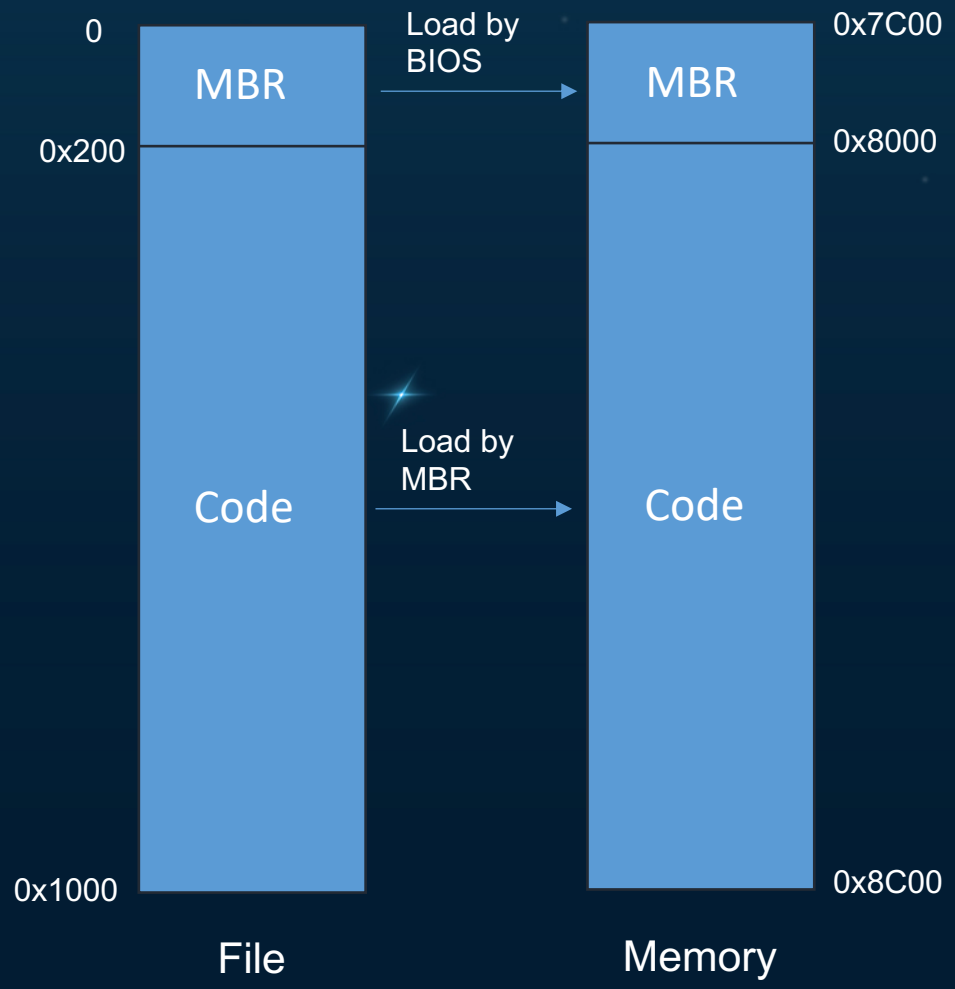
```
~/q/e/r/8/doogie (doogie|…) $ file doogie.bin
doogie.bin: DOS/MBR boot sector; partition 1 : ID=0x7, active, start-CHS (0x0,32,33), end-CHS (0x3ff,254,63), startsector 2048, 41938944 sectors
~/q/e/r/8/doogie (doogie|…) $
```



February 06, 1990... Despite being a 16-year-old reverse engineering genius, I seem to have forgotten the password to my PC. Can you help me???

MBR插桩分析：样本分析

- 和其他MBR代码一样，运行分为两阶段
  - 第一阶段 BIOS 把 MBR 加载到 0x7c00开始执行
  - 第二阶段 MBR 把剩余代码通过磁盘服务加载到内存，然后跳转执行



MBR插桩分析：核心逻辑

- 分析的重点在第二阶段的代码
  - 通过系统调用获取当前时间
  - 把当前时间和固定字符串异或
  - 读取输入
  - 把输入和刚才的结果异或
  - 输出两次异或的结果

```
seg000          segment byte public 'CODE' use16
                assume cs:seg000
                ;org 8000h
                assume es:nothing, ss:nothing, ds:nothing, fs:nothing, gs:nothing
                call    sub_805B
                push    ds:word_87F2
                call    get_date_and_write_to_87EE
                push    4
                push    offset date_87EE
                call    xor8809
                add     sp, 4
                push    87F4h
                call    read_input
                add     sp, 4
                push    ax
                push    87F4h
                call    xor8809
                add     sp, 4
                call    initialize_screen
                push    0
                push    8809h
                call    print_ascii_art
                add     sp, 4
                mov     cx, 2607h
                mov     ah, 1
                int     10h             ; - VIDEO - SET CURSOR CHARACTERISTICS
                                        ; CH bits 0-4 = start line for cursor in character cell
                                        ; bits 5-6 = blink attribute
                                        ; CL bits 0-4 = end line for cursor in character cell

loc_803D:                               ; CODE XREF: seg000:803E↓j
                hlt
; ---------------------------------------------------------------------------
                jmp     short loc_803D
```

MBR插桩分析：实现

- 麒麟框架的工作：
  - 模拟MBR文件运行
  - Hook BIOS中断 INT 1A 返回 Feb 06, 1990
  - 动态读写内存获取缓冲区的字符串
  - 通过部分执行和程序快照自动测试所有可能的 Key
- 破解的过程分为三个阶段

```python
if __name__ == "__main__":
    ql = first_stage()
    # resume terminal
    curses.endwin()
    keys = second_stage(ql)
    for key in keys:
        print(f"Possible key: {key}")
    # The key of this challenge is not unique. The real
    # result depends on the last ascii art.
    print("Going to try every key.")
    time.sleep(3)
    third_stage(keys)
    # resume terminal
    curses.endwin()
```

- Hook API
- Partial execution
- FS Mapper

获取和指定日期异或后的字符串

- Memory API

读取内存并且搜索所有可能的Key

- Hook API
- Partial execution
- Memory API
- Snapshot API

测试每一个Key

MBR插桩分析：第一阶段

- ql.set_api hook BIOS 中断来设置时间
- ql.os.fs_mapper 映射磁盘
- 在和日期异或完后停止执行

```
# In this stage, we get the encrypted data which xored with the specific date.
def first_stage():
    ql = Qiling(["rootfs/8086/doogie/doogie.bin"],
                "rootfs/8086",
                console=False,
                log_dir=".")
    ql.add_fs_mapper(0x80, QlDisk("rootfs/8086/doogie/doogie.bin", 0x80))
    # Doogie suggests that the datetime should be 1990-02-06.
    ql.set_api((0x1a, 4), set_required_datetime, QL_INTERCEPT.EXIT)
    # A workaround to stop the program.
    hk = ql.hook_code(stop, begin=0x8018, end=0x8018)
    ql.run()
    ql.hook_del(hk)
    return read_until_zero(ql, 0x8809)
```

```
February 06, 1990...  Despite being a 16-year-old reverse engineering genius, I seem to have forgotten the password to my PC. Can you help me???
```

```
def set_required_datetime(ql: Qiling):
    ql.nprint("Setting Feburary 06, 1990")
    ql.reg.ch = BIN2BCD(19)
    ql.reg.cl = BIN2BCD(1990%100)
    ql.reg.dh = BIN2BCD(2)
    ql.reg.dl = BIN2BCD(6)
```

MBR插桩分析：第二阶段

- 使用 Memory API 读取内存
- 猜测 Key 的长度然后在假设最后结果是可打印 ASCII 码的情况下搜索所有有可能的 Key

```
# In this stage, we crack the encrypted buffer.
def second_stage(ql: Qiling):
    data = bytes(read_until_zero(ql, 0x8809))
    key_size = guess_key_size(data) # Should be 17
    seqs = []
    for i in range(key_size):
        seq = b""
        j = i
        while j < len(data):
            seq += bytes([data[j]])
            j += key_size
        seqs.append(seq)
    seqs_keys = cal_count_for_seqs(seqs)
    keys = search_possible_key(seqs, seqs_keys)
    return keys


def read_until_zero(ql: Qiling, addr):
    buf = b""
    ch = -1
    while ch != 0:
        ch = ql.mem.read(addr, 1)[0]
        buf += pack("B", ch)
        addr += 1
    return buf
```

MBR插桩分析：第三阶段

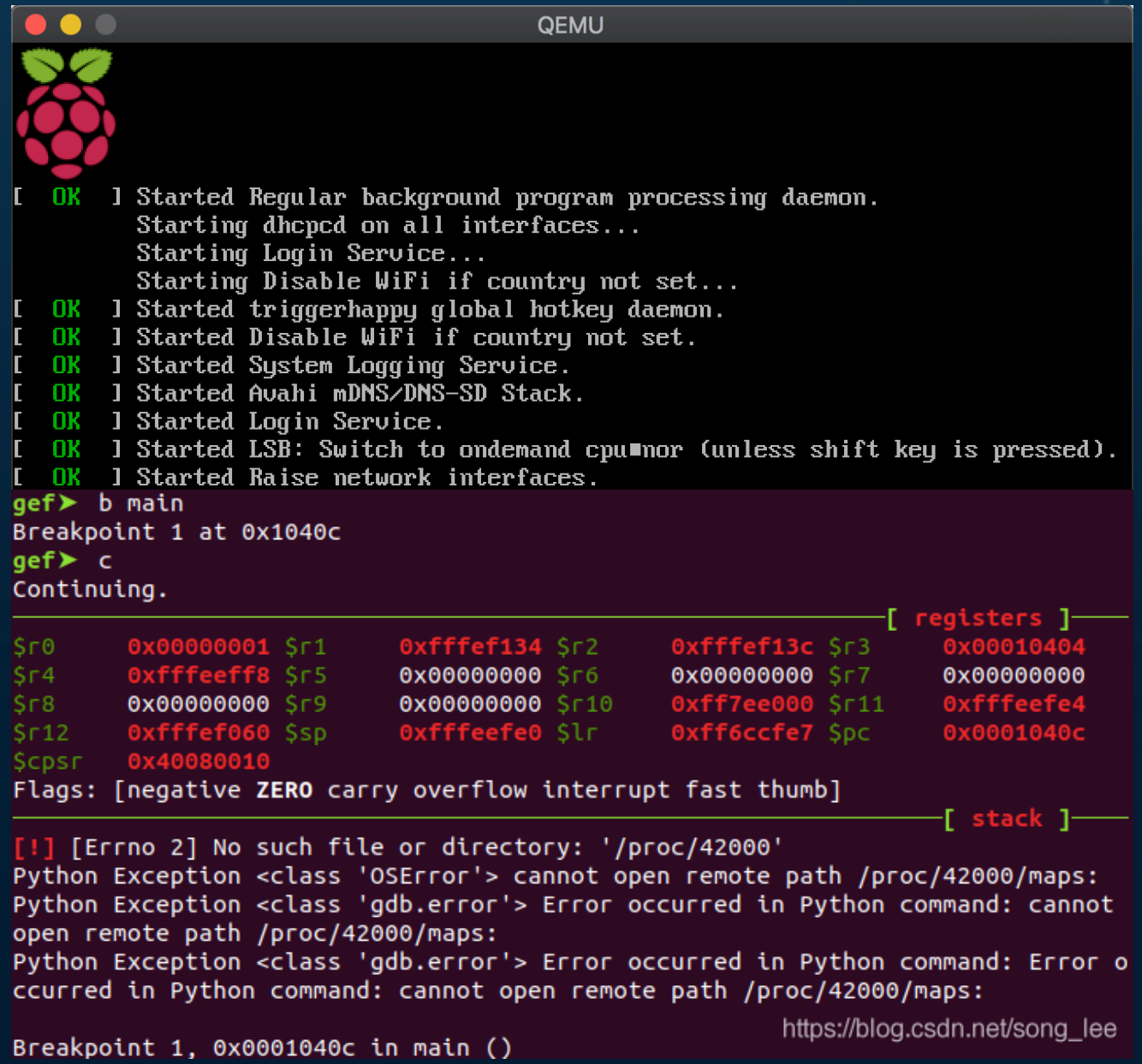
- 部分执行直接跳过输入读取，然后保存快照
- 通过 Memory API 填入 Key
- 从读取后开始部分执行到打印字符
- 观察结果可以得到 Flag


```python
def show_once(ql: Qiling, key):
    klen = len(key)
    ql.reg.ax = klen
    ql.mem.write(0x87F4, key)
    # Partial exectution to skip input reading
    ql.run(begin=0x801B, end=0x803d)
    echo_key(ql, key)
    time.sleep(3)

# In this stage, we show every key.
def third_stage(keys):
    # To setup terminal again, we have to restart the whole program.
    ql = Qiling(["rootfs/8086/doogie/doogie.bin"],
                "rootfs/8086",
                console=False,
                log_dir=".")
    ql.add_fs_mapper(0x80, QlDisk("rootfs/8086/doogie/doogie.bin", 0x80))
    ql.set_api((0x1a, 4), set_required_datetime, QL_INTERCEPT.EXIT)
    hk = ql.hook_code(stop, begin=0x8018, end=0x8018)
    ql.run()
    ql.hook_del(hk)
    # Snapshot API.
    ctx = ql.save()
    for key in keys:
        show_once(ql, key)
        ql.restore(ctx)
```

麒麟框架调试层支持

逆向调试的痛点

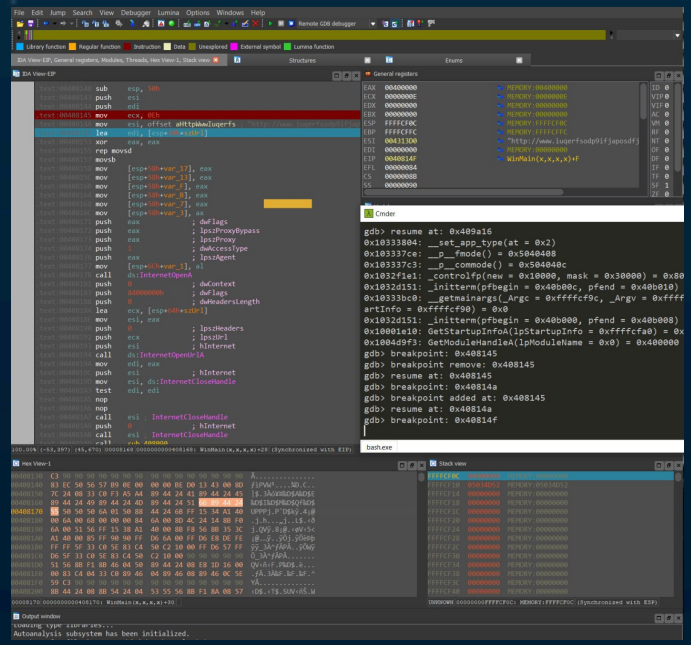
- PC
  - 缺乏HOOK工具
  - OS限制
- IoT
  - 环境搭建困难
  - 调试困难

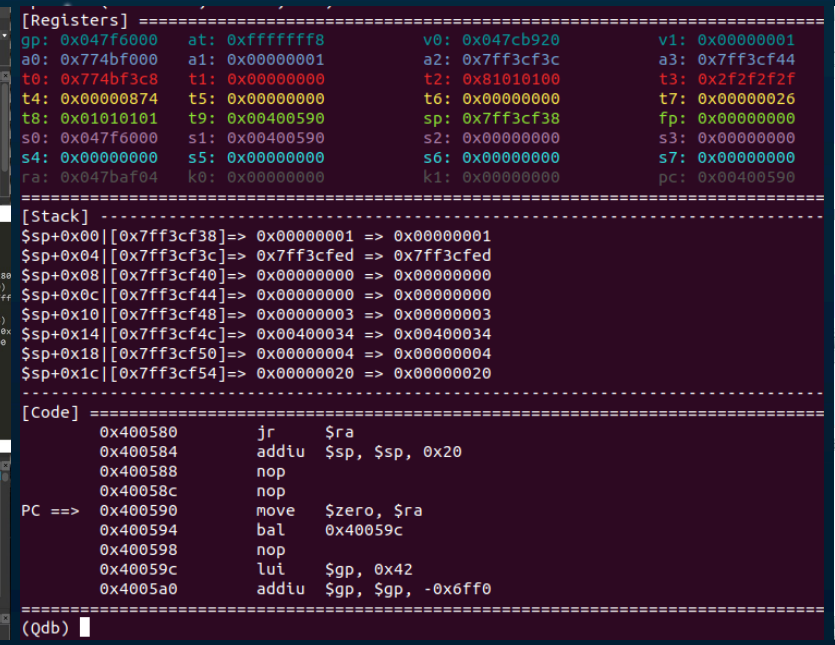


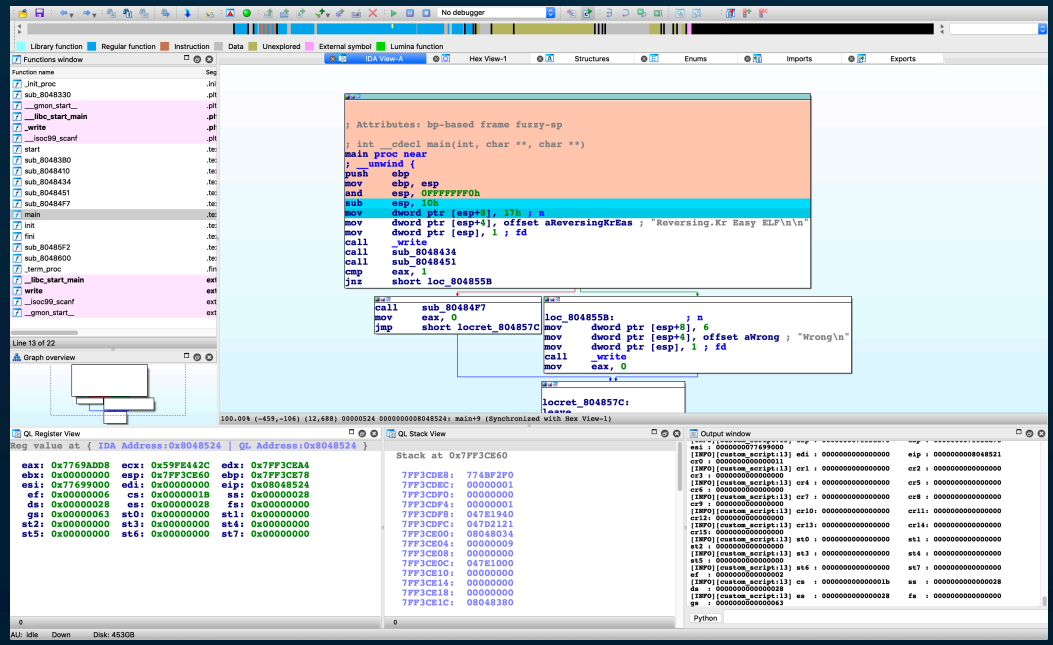
GDB Server

qdb

IDA Plugin





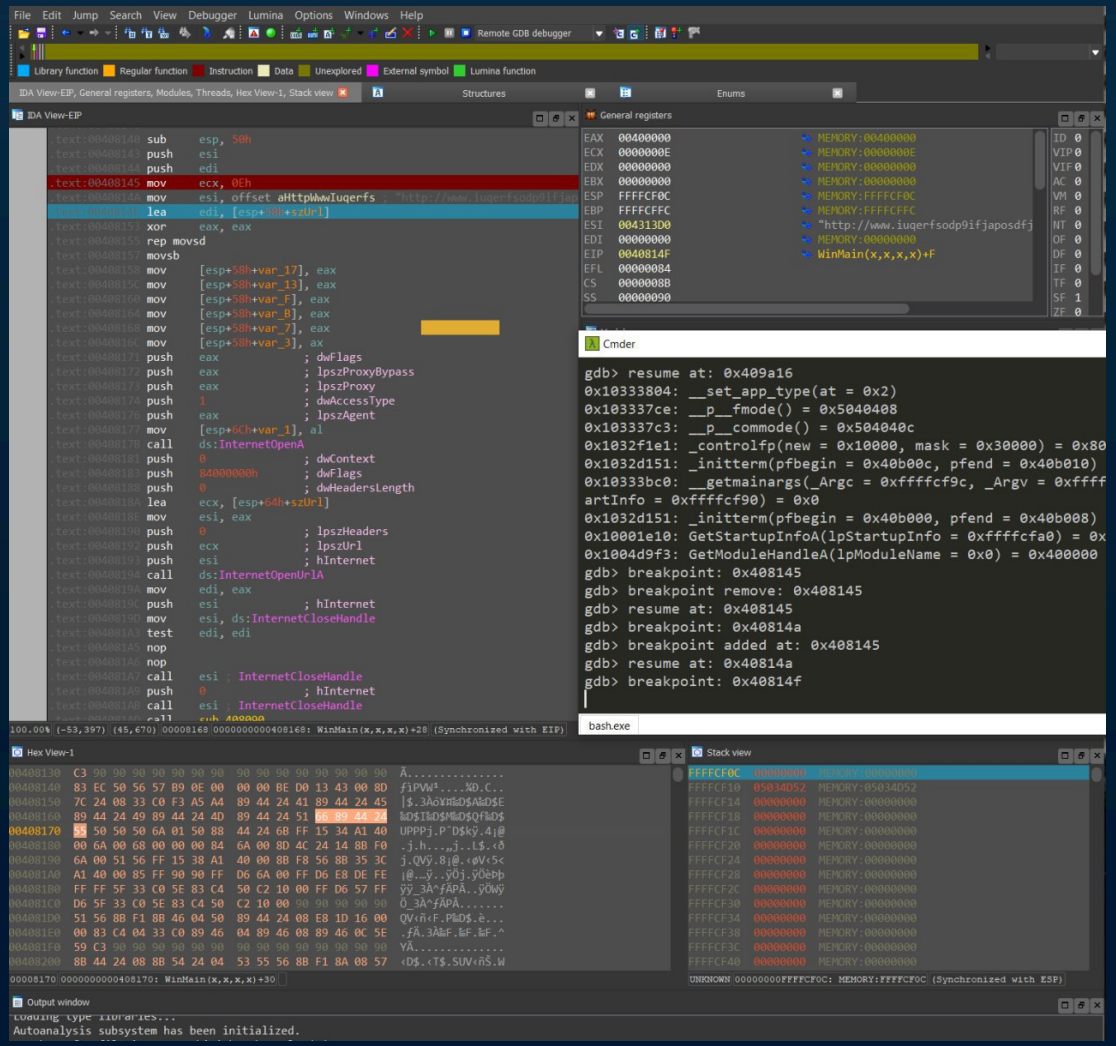


Qiling GDBServer

Terminal

```
gdb
There is NO WARRANTY, to the extent permitted by law.
Type "show copying" and "show warranty" for details.
This GDB was configured as "x86_64-linux-gnu".
Type "show configuration" for configuration details.
For bug reporting instructions, please see:
<http://www.gnu.org/software/gdb/bugs/>.
Find the GDB manual and other documentation resources online at:
    <http://www.gnu.org/software/gdb/documentation/>.

For help, type "help".
Type "apropos word" to search for commands related to "word".
(gdb) target remote 127.0.0.1:9999
Remote debugging using 127.0.0.1:9999
warning: No executable has been specified and target does not support
determining executable automatically.  Try using the "file" command.
0x00409a16 in ?? ()
(gdb) break *0x00408192
Breakpoint 1 at 0x408192
(gdb) i b
Num     Type           Disp Enb Address    What
1       breakpoint     keep y   0x00408192
(gdb) c
Continuing.

Breakpoint 1, 0x00408192 in ?? ()
(gdb) disas 0x0408192,0x0408198
Dump of assembler code from 0x408192 to 0x408198:
=> 0x00408192:  push   %ecx
   0x00408193:  push   %esi
   0x00408194:  call   *0x40a138
End of assembler dump.
(gdb) x/s $ecx
0xffffcf14:     "http://www.iuqerfsodp9ifjaposdfjhgosurijfaewrwergwea.com"
(gdb)
```

GUI



Qiling IDA Plugin

Setup
Reload User Scripts

Execute Till
Execute Selection
Continue
Set PC
Step ^⇧F9
Edit Register

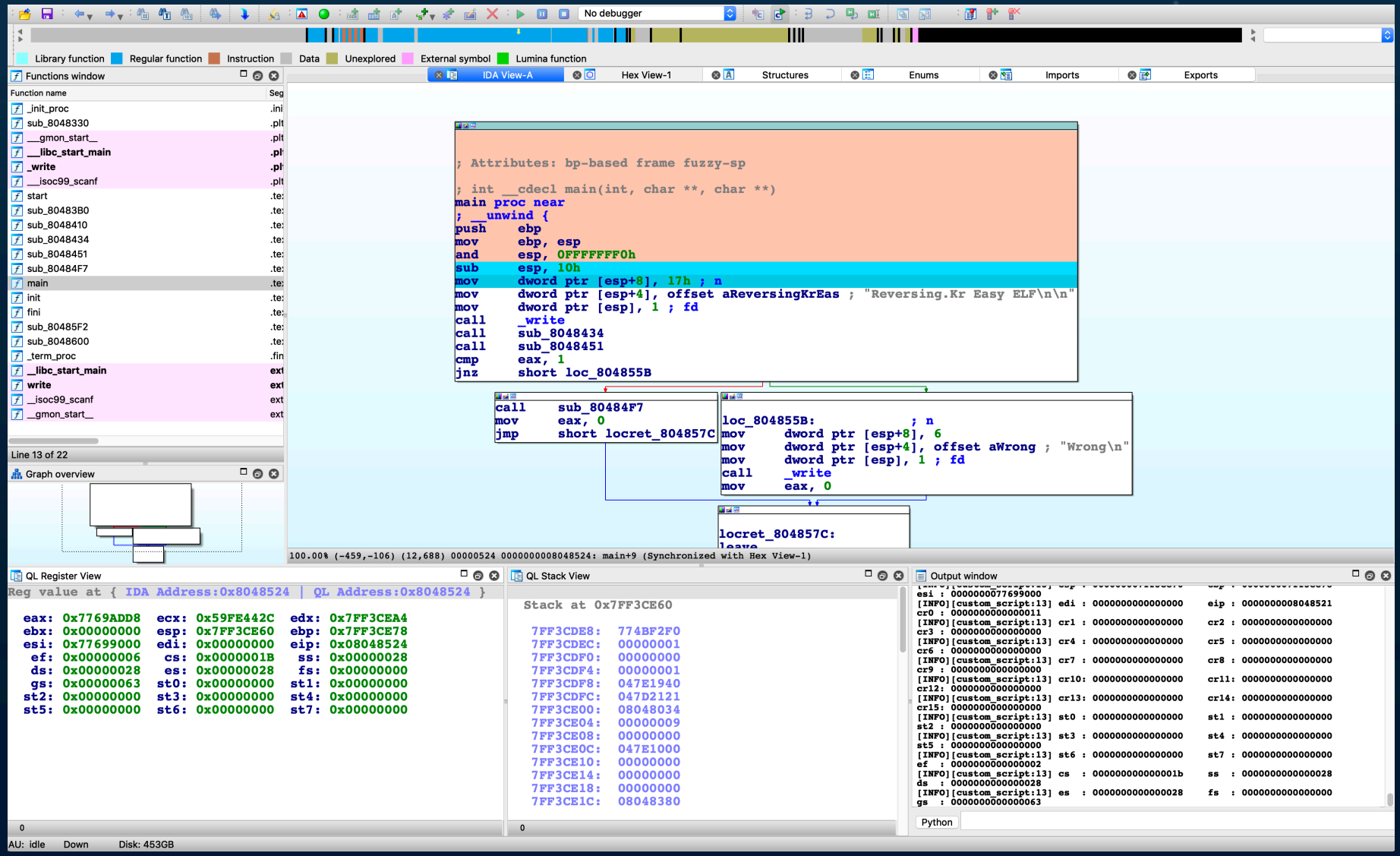
Restart

View Register
View Stack
View Memory

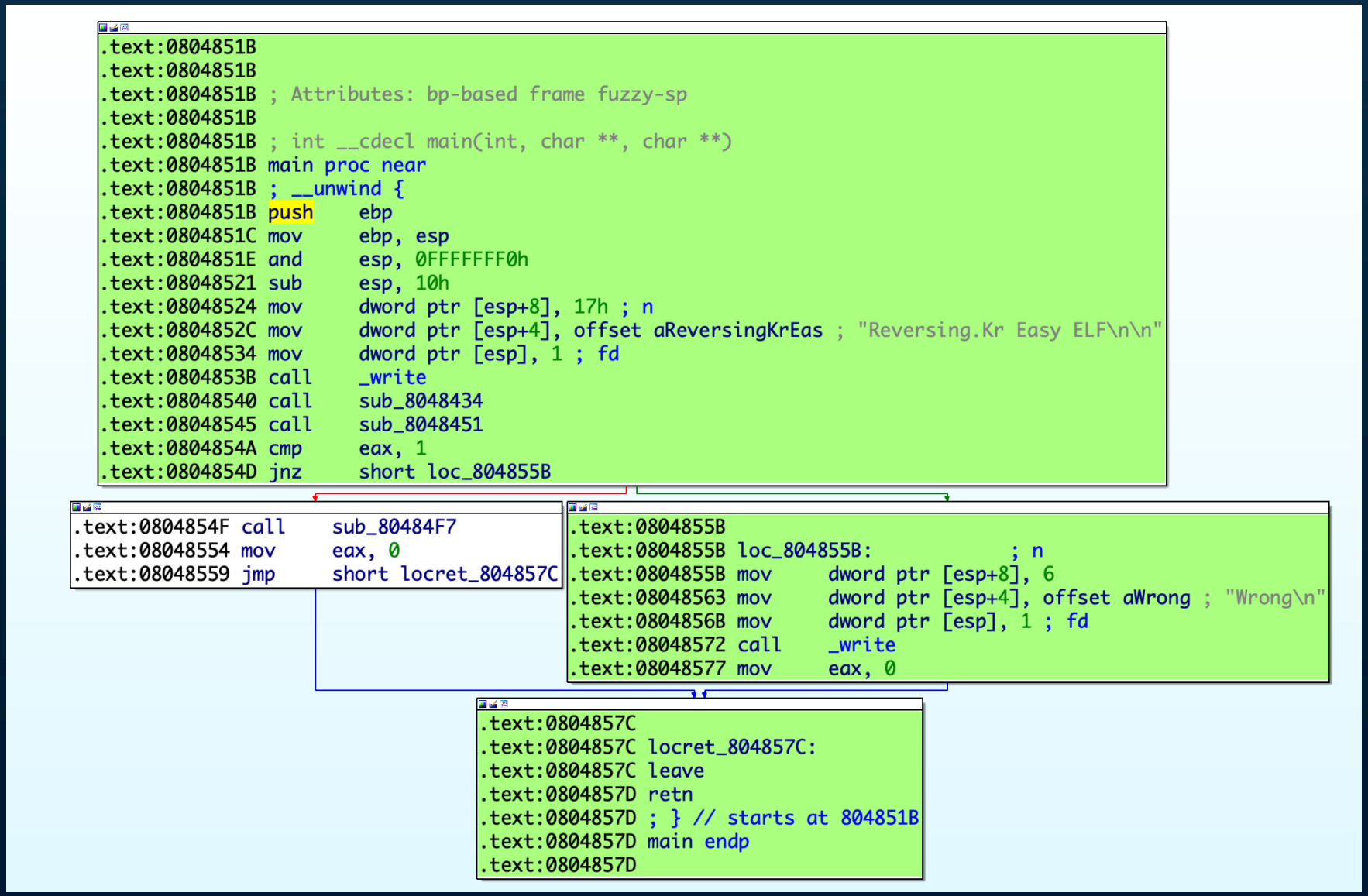
Save Snapshot
Load Snapshot

Auto Analysis For Deflat
Mark as Real Block
Mark as Fake Block
Mark as Return Block
Deflat

Remove Junk Code by Patterns
Nop Items without Color



程序执行路径绘制


.text:0804851B
.text:0804851B
.text:0804851B ; Attributes: bp-based frame fuzzy-sp
.text:0804851B
.text:0804851B ; int __cdecl main(int, char **, char **)
.text:0804851B main proc near
.text:0804851B ; __unwind {
.text:0804851B push ebp
.text:0804851C mov ebp, esp
.text:0804851E and esp, 0FFFFFFF0h
.text:08048521 sub esp, 10h
.text:08048524 mov dword ptr [esp+8], 17h ; n
.text:0804852C mov dword ptr [esp+4], offset aReversingKrEas ; "Reversing.Kr Easy ELF\n\n"
.text:08048534 mov dword ptr [esp], 1 ; fd
.text:0804853B call _write
.text:08048540 call sub_8048434
.text:08048545 call sub_8048451
.text:0804854A cmp eax, 1
.text:0804854D jnz short loc_804855B
.text:0804854F call sub_80484F7
.text:08048554 mov eax, 0
.text:08048559 jmp short locret_804857C
.text:0804855B
.text:0804855B loc_804855B: ; n
.text:0804855B mov dword ptr [esp+8], 6
.text:08048563 mov dword ptr [esp+4], offset aWrong ; "Wrong\n"
.text:0804856B mov dword ptr [esp], 1 ; fd
.text:08048572 call _write
.text:08048577 mov eax, 0
.text:0804857C
.text:0804857C locret_804857C:
.text:0804857C leave
.text:0804857D retn
.text:0804857D ; } // starts at 804851B
.text:0804857D main endp
.text:0804857D

Qiling IDA插件自定义脚本

使用 Qiling 和 IDAPython 提供的所有API


```python
from qiling import *
import logging

class QILING_IDA():
    def __init__(self):
        pass

    def custom_prepare(self, ql:Qiling):
        logging.info('Context before starting emulation:')
        self._show_context(ql)

    def custom_continue(self, ql:Qiling):
        logging.info('custom_continue hook.')
        self._show_context(ql)
        hook = []
        return hook

    def custom_step(self, ql:Qiling):
        def step_hook(ql, addr, size):
            logging.info(f"Executing: {hex(addr)}")
            self._show_context(ql)

        logging.info('custom_step hook')
        hook = []
        hook.append(ql.hook_code(step_hook))
        return hook

    def custom_execute_selection(self, ql:Qiling):
        logging.info('custom execute selection hook')
        hook = []
        return hook
```

Qiling IDA插件自定义脚本

```
ql.hook_address(show_func_size, 0x402EA6)
ql.hook_address(patch_to_ida, 0x402F03)
ql.hook_address(force_jmp, 0x402F08)
ql.hook_address(rewrite_mem, 0x403B3E)


custom_continue(self, ql:Qiling):
hook = []
hook.append(ql.hook_address(show_enc_func, 0x402F06))
```

```
def show_func_size(ql:Qiling):
    func_size_bytes = bytes(ql.mem.read(ql.reg.read('RAX')+0x8, 0x4))
    func_size_str = hex(struct.unpack('<I', func_size_bytes)[0])
    print('Function size is -> '+func_size_str)
    global func_size
    func_size = int(func_size_str, 16)
```

```
def patch_to_ida(ql:Qiling):
    global func_size
    base_addr = ql.reg.read('RCX')
    print('Encode function from -> '+hex(base_addr)+' to -> '+hex(base_addr+func_size))
    enc_func_bytes_list = list(bytes(ql.mem.read(ql.reg.read('RCX'), func_size)))

    for i in range(func_size):
        patch_byte(base_addr+i, enc_func_bytes_list[i])
```

```
def force_jmp(ql:Qiling):
    ql.reg.write('RAX', 0x1)
```

```
def rewrite_mem(ql:Qiling):
    ql.mem.write(ql.reg.read('RAX'), b'a'*128)
```

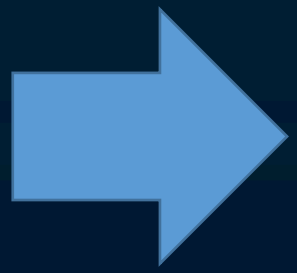
```
def show_enc_func(ql:Qiling):
    global func_size, func_size_list
    base_addr = ql.reg.read('RCX')
    create_data(base_addr,byte_flag(),func_size,BADNODE)
    is_create_func = add_func(base_addr, base_addr+func_size)

    if not is_create_func:
        for i in range(func_size):
            del_items(base_addr+i)
        create_insn(base_addr)
        add_func(base_addr, base_addr+func_size)

    if 'Verify_' not in get_func_name(base_addr) and func_size not in set(func_size_list):
        set_name(base_addr, 'Verify_'+hex(base_addr), SN_CHECK)
        func_size_list.append(func_size)
```

反OLLVM平坦化

反OLLVM平坦化：介绍

- 取出所有的基本块
- 用一个大 while 和 switch 来控制基本块之间的跳转
  - 例子中引入了变量 b
- 随着逻辑变复杂，case快速增长，可以很好的迷惑逆向工程师。

```
int main(int argc, char** argv) {
  int a = atoi(argv[1]);
  if(a == 0)
    return 1;
  else
    return 10;
  return 0;
}
```



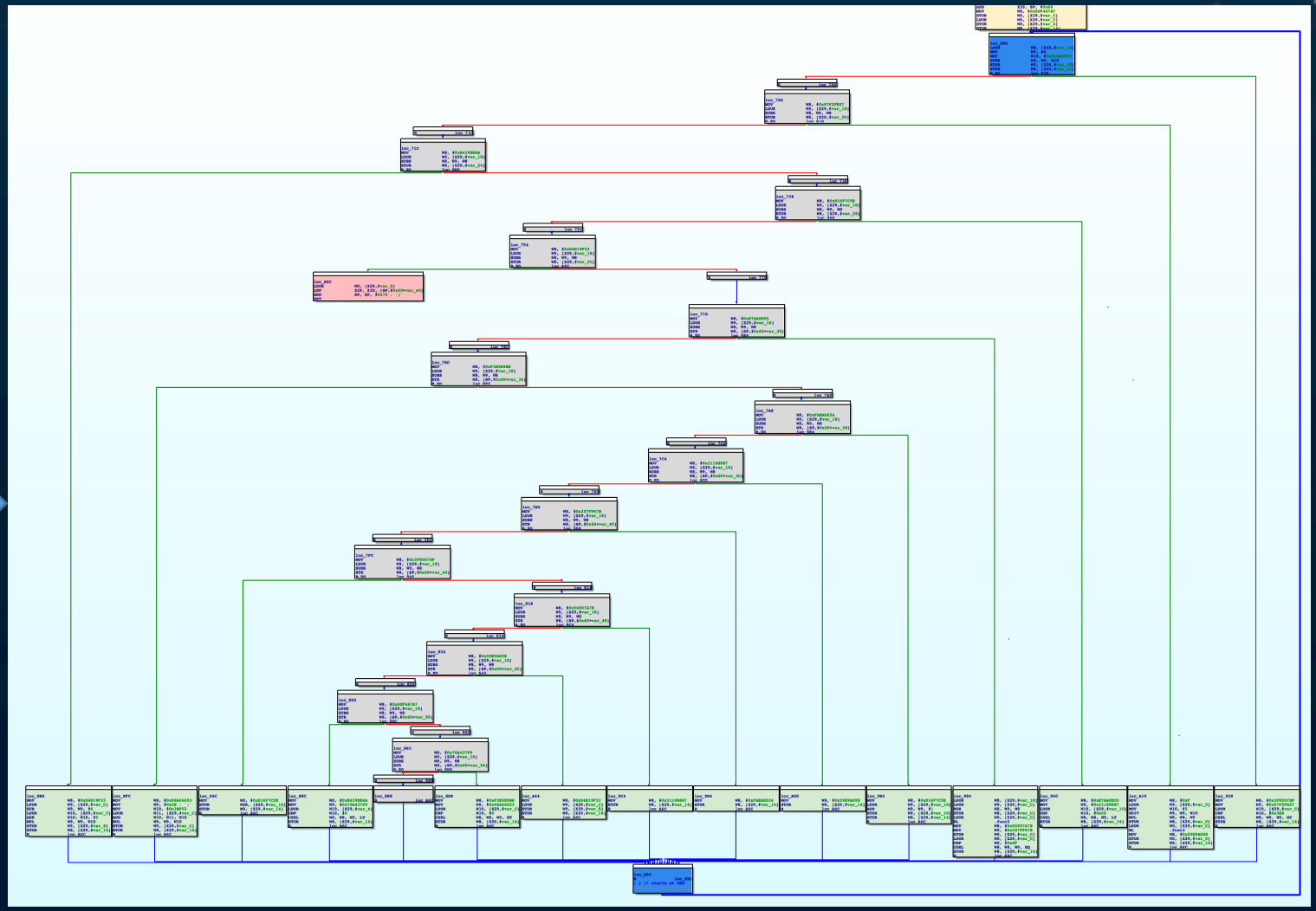
```
int main(int argc, char** argv) {
  int a = atoi(argv[1]);
  int b = 0;
  while(1) {
    switch(b) {
      case 0:
        if(a == 0)
          b = 1;
        else
          b = 2;
        break;
      case 1:
        return 1;
      case 2:
        return 10;
      default:
        break;
    }
  }
  return 0;
}
```

反OLLVM平坦化：样本

```
int func3(int v){
        return v+v/2+v*v;
}

int func2(int v){
        return v*v*4;
}

int func(int v){
        if(v<0)
                return (v - 6)*(v>>5);
        if(v>0)
                v = 59 * (v + 114514);
        if(v > 1000){
                for(int i =0;i<198;i++){
                        v ^= i;
                        v = func2(v);
                        if(v == 223)
                                break;
                }
        }else{
                v = 15 * (v / 5);
                v = func3(v);
        }
        return v;
}

int main(){
        func(1);
}
```

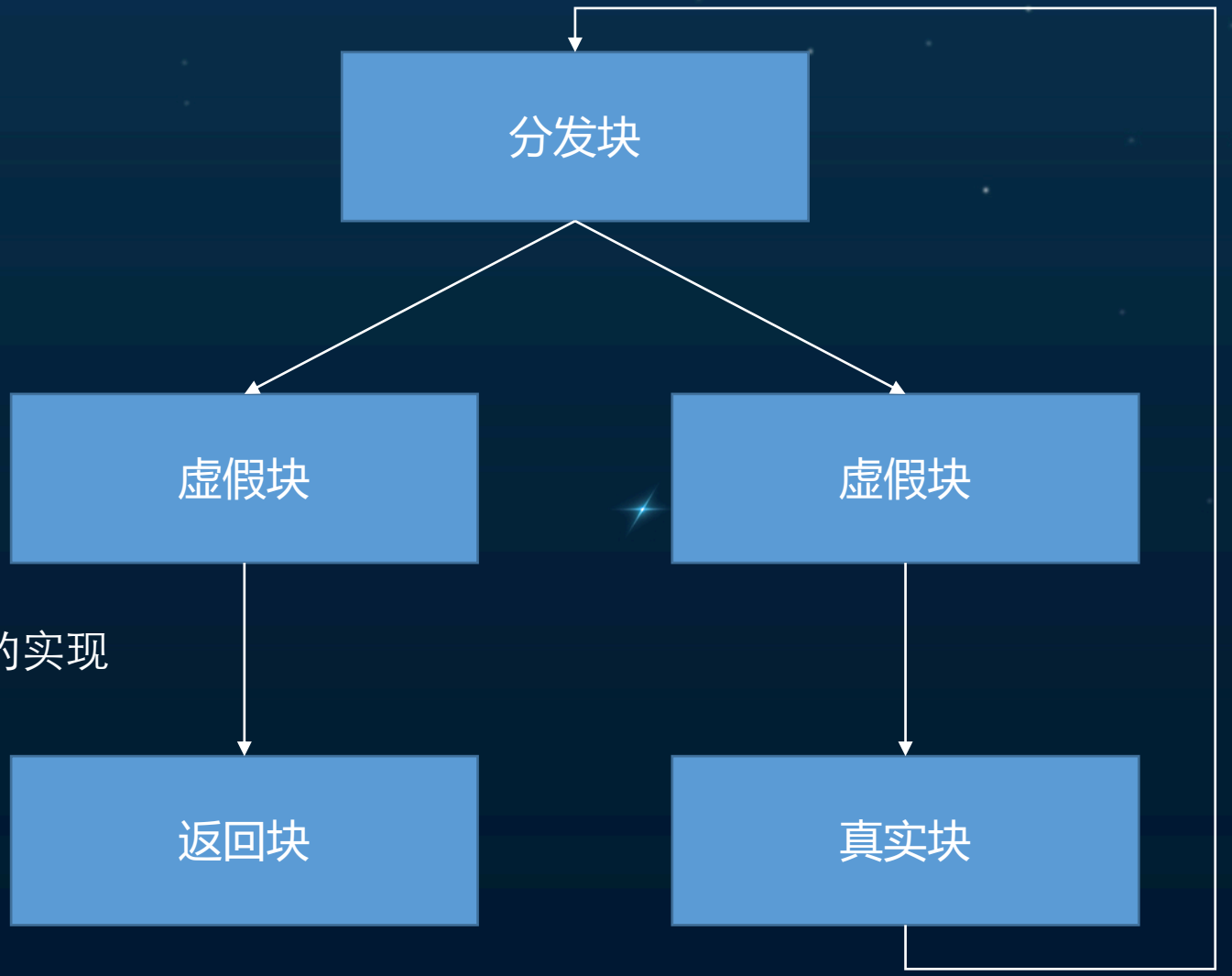
NDK配合

ollvm编译



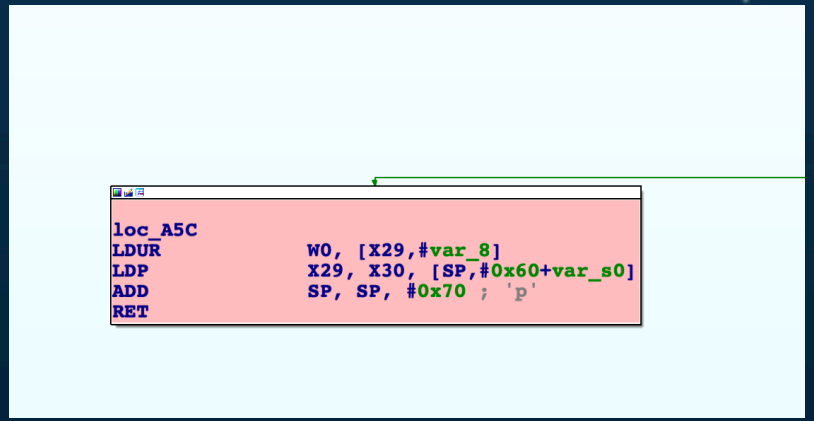
反OLLVM平坦化：识别

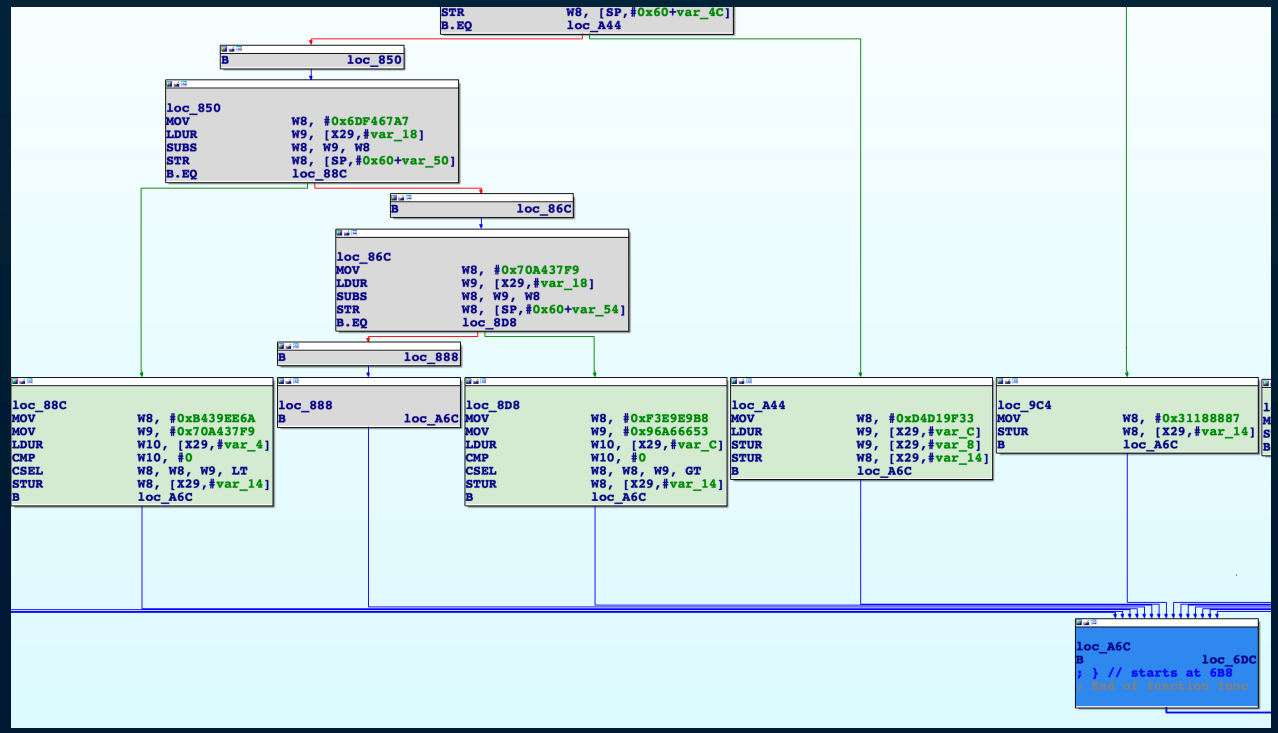
- 变形后的基本块可以分为四种
- 真实块
  - 包含了混淆前程序真实的逻辑
  - 可能包含一次条件语句
- 虚假块
  - 没有任何原逻辑，仅负责 switch case 的实现
- 返回块
  - 结束函数的执行
- 分发块
  - 相当于 switch 语句，决定控制流走向
  - 反混淆的核心是识别分发块



反OLLVM平坦化：识别

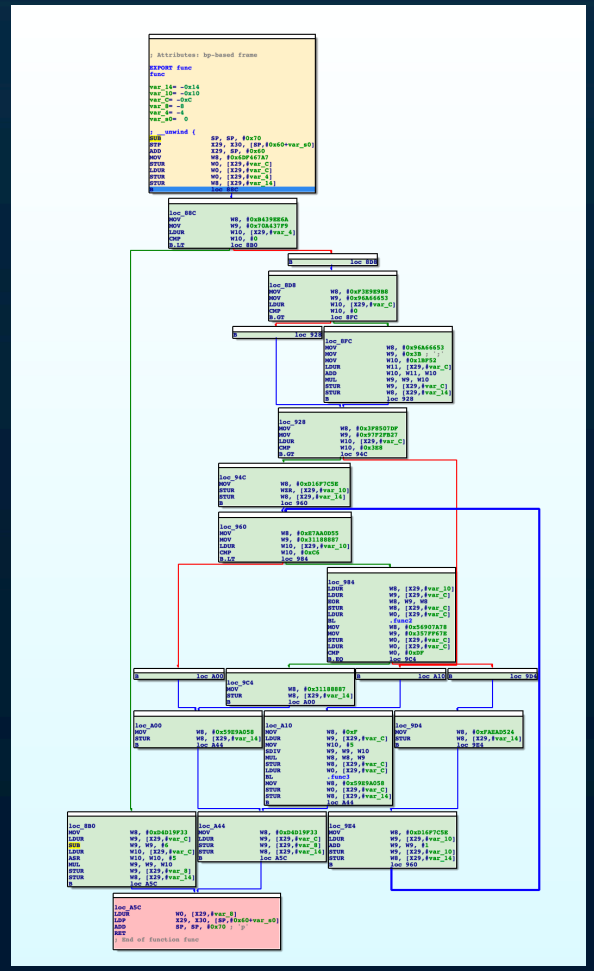
- 由于所有的真实块后继都是分发块，因此分发块可以简单通过计算引用次数查找
- 后继是真实块而且指令大于1条的可以判断是真实块
- 包含了返回语句比如 ret 的是返回块
- 其余均为虚假块
- 在 IDA 中四种代码块用不同的颜色表示
  - 方便用户手动调整自动分析的结果





反OLLVM平坦化：模拟执行

- 识别出各个块后，需要搜索真实控制流
- 利用麒麟的部分执行和快照来快速搜索
  - 保存快照然后从真实块的起始开始执行
  - 遇到分支则分别各执行一次
  - 遇到返回块或者另一个真实块停止
  - 记录控制流然后恢复快照
  - 此外需要 Hook 内存读写来跳过对堆的读写
- 通过 Keystone 来 patch
  - 最后程序流图里应该只剩下真实块和返回块



```
__int64 __fastcall func(int a1)
{
  int i; // [xsp+50h] [xbp-10h]
  int v3; // [xsp+54h] [xbp-Ch]
  unsigned int v4; // [xsp+58h] [xbp-8h]

  v3 = a1;
  if ( a1 >= 0 )
  {
    if ( a1 > 0 )
      v3 = 59 * (a1 + 114514);
    if ( v3 > 1000 )
    {
      for ( i = 0; i < 198; ++i )
      {
        v3 = func2(v3 ^ (unsigned int)i);
        if ( v3 == 223 )
          break;
      }
    }
    else
    {
      v3 = func3((unsigned int)(15 * (v3 / 5)));
    }
    v4 = v3;
  }
  else
  {
    v4 = (a1 - 6) * (a1 >> 5);
  }
  return v4;
}
```

反OLLVM平坦化：IR

- 一些细节和难点
  - 真实块内有外部函数调用
  - 不同架构的条件指令有区别
- 解决办法：IR(Intermedia Representation)
  - 实现中使用了 IDA 7.1 引入的微码
  - 通过微码可以直接识别函数调用然后设置PC跳过
  - 此外通过匹配微码的特征来避免硬编码识别不同架构的条件指令

```
.text:000000000000088C loc_88C                                 ; CODE XREF: func+1AC↑j
.text:000000000000088C                 MOV     W8, #0xB439EE6A
.text:0000000000000894                 MOV     W9, #0x70A437F9
.text:000000000000089C                 LDUR    W10, [X29,#var_4]
.text:00000000000008A0                 CMP     W10, #0
.text:00000000000008A4                 CSEL    W8, W8, W9, LT
.text:00000000000008A8                 STUR    W8, [X29,#var_14]
.text:00000000000008AC                 B       loc_A6C
```

```
====================0x86c==================== id=16 0x8a4
0x8a4:   jge       %var_4.4  {1}          ,                    #0.4
>>>>>>>>>>>>>>>>>>>0x884<<<<<<<<<<<<<<<<<<<
====================0x8a4==================== id=17 0x8a4
0x8a4:   mov         #0xB439EE6A.4                 ,           w8.4
0x8a4:   goto      @19
>>>>>>>>>>>>>>>>>>>0x8a8<<<<<<<<<<<<<<<<<<<
====================0x8a4==================== id=18 0x8a8
0x8a4:   mov         #0x70A437F9.4                 ,           w8.4
```

展望

- 底层模拟同步Qemu5支持的架构和指令集
- Android Java层模拟和插桩
- IOS模拟支持
- 完善Windows支持
  - 引入wine&&cygwin来进行完整支持
- 智能合约模拟
- 单片机模拟
- arm mac

Q&A Time

项目地址：https://github.com/qilingframework/qiling

Thanks