Offensive and Defensive Cybersecurity

–

Reversing

21-22

Reverse Engineering

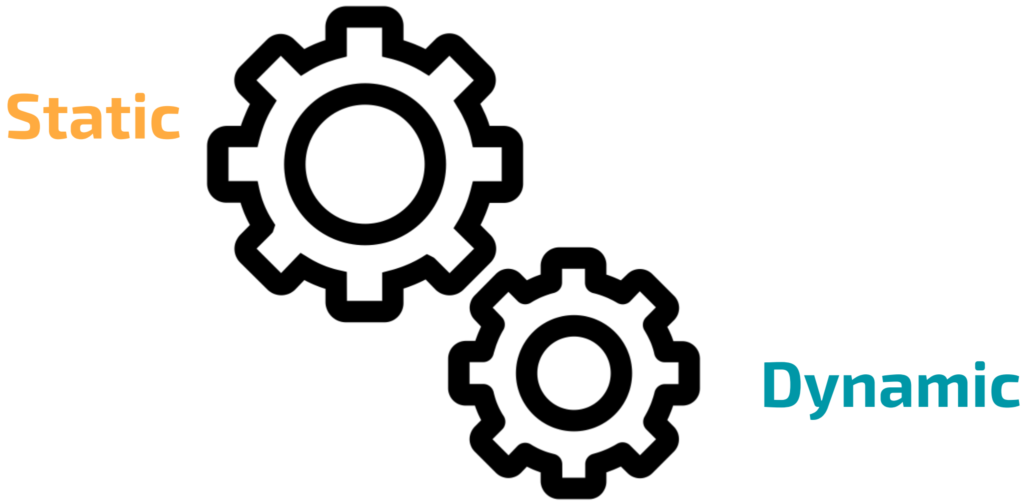
- *“is the process by which a **man-made object** is **deconstructed** to reveal its designs, architecture, or to **extract knowledge** from the object **similar to scientific research**.”*

Reverse Engineering - Software

- Probe the software to gain knowledge
  - **Static**ally
    - Binary is not running
  - **Dynami**cally
    - Running the binary

Static and Dynamic Analysis

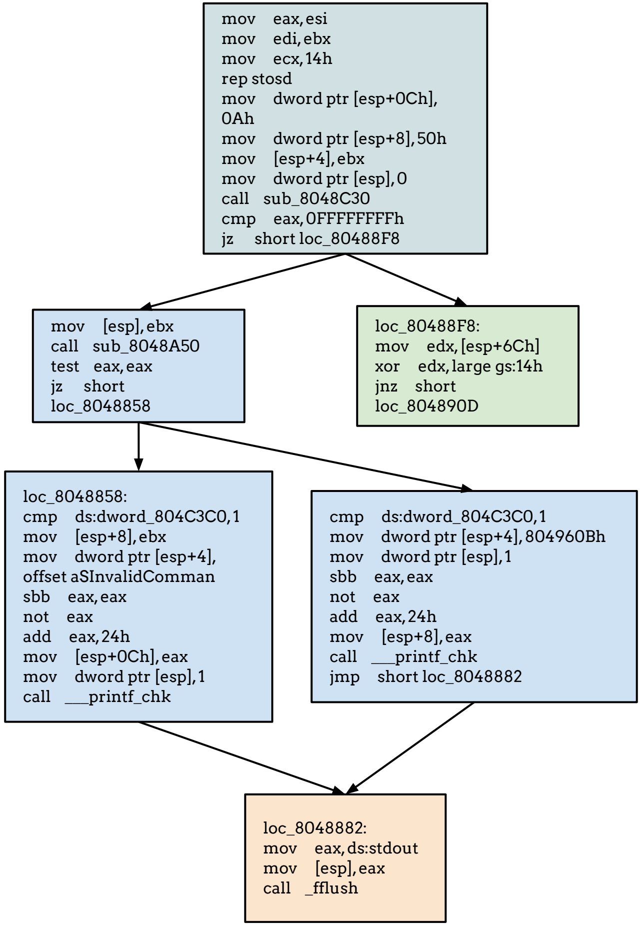
The reverse engineering process is a **sequence** of **static** and **dynamic** analysis that slowly **refine** your knowledge about the malware sample.



Static Analysis

Understand the functionalities of a binary looking at its code.

- Disassemble instructions
- Recover CFG
- Recover Functions
- Recover Types
- Decompile
- Fingerprints



Reverse Engineering - Static

Developer

```
le <stdio.h>
le <stdlib.h>

int foo(int a, int b) {
  int c = 14;
  c = (a + b) * c;
  return c;
}

int main(int argc, char * argv[]) {
  int avar;
  int bvar;
  int cvar;
  char * str;
  avar = atoi(argv[1]);
  bvar = atoi(argv[2]);
  cvar = foo(avar, bvar);
  gets(str);
  puts(str);
  printf("foo(%d, %d) = %d\n", avar, bvar, cvar);
  return 0;
}
```

Compiler

```
        .cfi_startproc
        pushl   %ebp
        .cfi_def_cfa_offset 8
        .cfi_offset 5, -8
        movl    %esp, %ebp
        .cfi_def_cfa_register 5
        andl    $-16, %esp
        subl    $32, %esp
        movl    12(%ebp), %eax
        addl    $4, %eax
        movl    (%eax), %eax
```

Assembler

Machine

```
0000000: 01111111 01000101 01001100 01000110 00000001 00000001
0000006: 00000001 00000000 00000000 00000000 00000000 00000000
000000c: 00000000 00000000 00000000 00000000 00000010 00000000
0000012: 00000011 00000000 00000001 00000000 00000000 00000000
       : 11000000 10000011 00000100 00001000 00110100 00000000
       : 00000000 00000000 10110100 00001100 00000000 00000000
0000024: 00000000 00000000 00000000 00000000 00110100 00000000
000002a: 00100000 00000000 00001000 00000000 00101000 00000000
```

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Disassembler

```
push   %ebp
mov    %esp,%ebp
and    $0xfffffff0,%esp
sub    $0x20,%esp
mov    0xc(%ebp),%eax
add    $0x4,%eax
mov    (%eax),%eax
mov    %eax,(%esp)
call   80483b0 <atoi@plt>
mov    %eax,0x1c(%esp)
mov    0xc(%ebp),%eax
```

Decompiler

```
#include <stdint.h>
#include <stdio.h>
#include <stdlib.h>

int32_t foo(int32_t a, int32_t b);

// From module:   layout.c
// Address range: 0x80484ac - 0x80484cd
// Line range:    5 - 10
int32_t foo(int32_t a, int32_t b) {
    int32_t c = 14 * (b + a); // 0x80484c4
    return c;
}

// From module:   layout.c
// Address range: 0x80484cf - 0x8048559
// Line range:    13 - 30
int main(int argc, char **argv) {
    int32_t apple = (int32_t)argv; // 0x80484d8
    int32_t str_as_i = atoi((int8_t *)*(int32_t *)(apple + 4));
    int32_t str_as_i2 = atoi((int8_t *)*(int32_t *)(apple + 8));
    int32_t banana = foo(str_as_i, str_as_i2); // 0x804850f
    gets(NULL);
    puts(NULL);
    printf("foo(%d, %d) = %d\n", str_as_i, str_as_i2, banana);
    return 0;
}
```

Static Analysis - Disassembler

- Linear Sweep

- Recursive

```
0000000: 01111111 01000101 01001100 01000110 00000001 00000001
0000006: 00000001 00000000 00000000 00000000 00000000 00000000
000000c: 00000000 00000000 00000000 00000000 00000010 00000000
0000012: 00000011 00000000 00000001 00000000 00000000 00000000
0000018: 11000000 10000011 00000100 00001000 00110100 00000000
000001e: 00000000 00000000 10110100 00001100 00000000 00000000
0000024: 00000000 00000000 00000000 00000000 00110100 00000000
000002a: 00100000 00000000 00001000 00000000 00101000 00000000
```

```
push   %ebp
mov    %esp,%ebp
and    $0xfffffff0,%esp
sub    $0x20,%esp
mov    0xc(%ebp),%eax
add    $0x4,%eax
mov    (%eax),%eax
mov    %eax,(%esp)
call   80483b0 <atoi@plt>
mov    %eax,0x1c(%esp)
mov    0xc(%ebp),%eax
```

Static Analysis - Disassembler Tools

objdump - Disasm

radare2 - Disasm

capstone - **Programmable** Disasm

Binary Ninja - Disasm + Primitive Decompiler

GHIDRA - Disasm + Decompiler (**https://ghidra-sre.org/**)

IDA Pro - Disasm + Decompiler (de facto standard)

Static Analysis - Decompile

You can go back to pseudo code:

```
push   %ebp
mov    %esp,%ebp
and    $0xfffffff0,%esp
sub    $0x20,%esp
mov    0xc(%ebp),%eax
add    $0x4,%eax
mov    (%eax),%eax
mov    %eax,(%esp)
call   80483b0 <atoi@plt>
mov    %eax,0x1c(%esp)
mov    0xc(%ebp),%eax
```

```
#include <stdint.h>
#include <stdio.h>
#include <stdlib.h>

int32_t foo(int32_t a, int32_t b);

// From module:   layout.c
// Address range: 0x80484ac - 0x80484cd
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int32_t foo(int32_t a, int32_t b) {
    int32_t c = 14 * (b + a); // 0x80484c4
    return c;
}

// From module:   layout.c
// Address range: 0x80484cf - 0x8048559
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int main(int argc, char **argv) {
    int32_t apple = (int32_t)argv; // 0x80484d8
    int32_t str_as_i = atoi((int8_t *)*(int32_t *)(apple + 4));
    int32_t str_as_i2 = atoi((int8_t *)*(int32_t *)(apple + 8));
    int32_t banana = foo(str_as_i, str_as_i2); // 0x804850f
    gets(NULL);
    puts(NULL);
    printf("foo(%d, %d) = %d\n", str_as_i, str_as_i2, banana);
    return 0;
}
```

Static Analysis - Decompile

Binary Ninja - Disasm + Primitive Decompiler

GHIDRA - Disasm + Decompiler (**https://ghidra-sre.org/**)

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Static Analysis - Struct

Building correct types make decompilation more readable.

```
void __fastcall sub_1413(__int64 a1)
{
  signed int i; // [rsp+10h] [rbp-10h]
  signed int v2; // [rsp+14h] [rbp-Ch]
  void *v3; // [rsp+18h] [rbp-8h]

  for ( i = 0; i <= 15; ++i )
  {
    if ( !*(_DWORD *)(24LL * i + a1) )
    {
      printf("Size: ");
      v2 = sub_1AD5();
      if ( v2 > 0 && v2 <= 88 )
      {
        v3 = calloc(v2, 1uLL);
        if ( !v3 )
          exit(-1);
        *(_DWORD *)(24LL * i + a1) = 1;
        *(_QWORD *)(a1 + 24LL * i + 8) = v2;
        *(_QWORD *)(a1 + 24LL * i + 16) = v3;
        printf("Chunk %d Allocated\n", (unsigned int)i);
      }
      else
      {
        puts("Invalid Size");
      }
      return;
    }
  }
}
```

```
void __fastcall allocate(nota *notes)
{
  signed int i; // [rsp+10h] [rbp-10h]
  signed int sz; // [rsp+14h] [rbp-Ch]
  void *chunk; // [rsp+18h] [rbp-8h]

  for ( i = 0; i <= 15; ++i )
  {
    if ( !notes[i].state )
    {
      printf("Size: ");
      sz = get_long();
      if ( sz > 0 && sz <= 0x58 )
      {
        chunk = calloc(sz, 1uLL);
        if ( !chunk )
          exit(-1);
        notes[i].state = 1;
        notes[i].size = sz;
        notes[i].data = (__int64)chunk;
        printf("Chunk %d Allocated\n", (unsigned int)i);
      }
      else
      {
        puts("Invalid Size");
      }
      return;
    }
  }
}
```

```c
signed int i; // [rsp+10h] [rbp-10h]
signed int v2; // [rsp+14h] [rbp-Ch]
void *v3; // [rsp+18h] [rbp-8h]

for ( i = 0; i <= 15; ++i )
{
  if ( !*(_DWORD *)(24LL * i + a1) )
  {
    printf("Size: ");
    v2 = sub_1AD5();
    if ( v2 > 0 && v2 <= 88 )
    {
      v3 = calloc(v2, 1uLL);
      if ( !v3 )
        exit(-1);
      *(_DWORD *)(24LL * i + a1) = 1;
      *(_QWORD *)(a1 + 24LL * i + 8) = v2;
      *(_QWORD *)(a1 + 24LL * i + 16) = v3;
      printf("Chunk %d Allocated\n", (unsigned
int)i);
    }
    else
    {
      puts("Invalid Size");
    }
    return;
  }
}
```

```c
signed int i; // [rsp+10h] [rbp-10h]
signed int sz; // [rsp+14h] [rbp-Ch]
void *chunk; // [rsp+18h] [rbp-8h]

for ( i = 0; i <= 15; ++i )
{
  if ( !notes[i].state )
  {
    printf("Size: ");
    sz = get_long();
    if ( sz > 0 && sz <= 0x58 )
    {
      chunk = calloc(sz, 1uLL);
      if ( !chunk )
        exit(-1);
      notes[i].state = 1;
      notes[i].size = sz;
      notes[i].data = (__int64)chunk;
      printf("Chunk %d Allocated\n",
(unsigned int)i);
    }
    else
    {
      puts("Invalid Size");
    }
    return;
  }
}
```

Static Analysis - Struct IDA (local type)

Building correct types make decompilation more readable.

```
struct __attribute__((aligned(8))) nota
{
  int state;
  int unk1;
  __int64 size;
  __int64 data;
};
```

Static Analysis - Other Tools (Lifter)

You can Lift binary to perform program analysis tasks.

Angr - Binary Analysis (VEX IR) + Symbolic Execution (http://angr.io/)

rev.ng - Binary analysis with LLVM IR + Binary translationtion

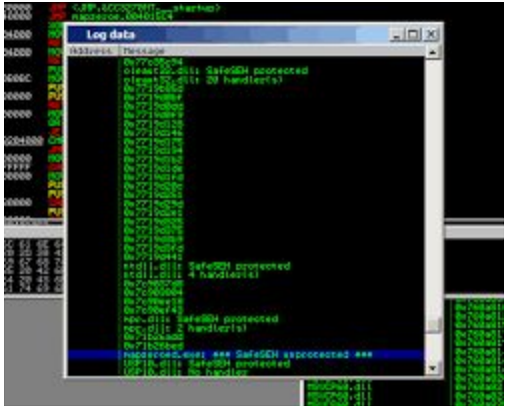
BAP - Binary analysis with BIL IR

Dynamic Analysis - Debuggers

- Run the executable and see/modify process state live.
- Step by step Debugging

- BreakPoints
    - **Hardware breakpoints**
- **Watchpoints**
- syscall catch
- signal catch
- **Scriptable**

- Tools: windbg, ollydbg, Immunity dbg, IDA pro, GDB, etc.



Dynamic Analysis - GDB

disassemble	set disassembly-flavor intet	#sets syntax
	disass *address	#disassemble
execution	step (s)	#exec nextline - enter fun
	next(n)	#exec nectline - jump call
	finish (f)	#exec til ret
	continue (c)	#continue execution
examine	x/numF *address	#show num data of type F (useful Fs are bx, wx, gx, c, s)
	printf "%c", $reg	#print char from register

Dynamic Analysis - GDB

breakpoints	b *address	#set software breakp at addr
	hb *address	#set hardware breakp at addr
	b *address if $reg==val	#set conditional breakp
	del br_num	#remove breakpoint br_num
watchpoints	w *address	#set watch for write at addr
	rw *address	#set watch for read at addr

Dynamic Analysis - GDB

Setting registers to a certain value:

```
set $reg = val
```

Change return value of a function, to jump into some memory are, etc.

You can also call a function with:

```
call address
```

Dynamic Analysis - GDB Automate

Create command that are runned **after** a break point

```
commands br_num
   command_list
end
```

Dynamic Analysis - GDB Automate - new command

```python
import gdb
class MyCommand(gdb.Command):
    def __init__(self):
        super(MyCommand, self).__init__(
            "thisisacommand",
            gdb.COMMAND_OBSCURE,
            gdb.COMPLETE_NONE,
            True
        )
        self.hystory = []
    def invoke(self, args, from_tty):
        gdb.execute("set $rsi=0x30000000")
        gdb.execute("set $edx=0x30")
        gdb.execute("set $rip=0x555555559818")
        gdb.execute("b *0x55555555981d")
```

```
~/.gdb_init

source ./gdb_cmd.py
```

https://sourceware.org/gdb/onlinedocs/gdb/Python-API.html

Reversing in Adversarial Contest - Static

- Complex **CFG**
  - not aligned jmp
  - dead code
- **Packing**
- **Header** Corruption

Reversing in Adversarial Contest - Dynamic

- Debugging only **Once**
  - ptrace
- **Check** for Debugger
  - 0xcc
- **Divert** Execution
  - Signals / multithread