Session 4
Binary Executable Analysis

Security Summer School

ACS/Ixia/Hexcellents

Binary Executables

- Non-text files
    - contain non-human-readable characters
- Executed by computers
- Formats
    - Linux - ELF (Executable Linking Format)
    - Windows - PE (Portable Executable)

Generating Binary Files

Source Code

```
int main()
{
        return 0;
}
```

compile

Assembly Code

```
main:
        push    ebp
        mov     ebp, esp
        mov     eax, 0
        pop     ebp
        ret
```

assemble

Machine Code

```
0000000: 55 89 e5 b8
0000004: 00 00 00 00
0000008: 5d c3
```

execute!

Restoring Source Files

Machine Code

```
0000000: 55 89 e5 b8
0000004: 00 00 00 00
0000008: 5d c3
```

disassemble

Assembly Code

```
main:
        push    ebp
        mov     ebp, esp
        mov     eax, 0
        pop     ebp
        ret
```

decompile

Source Code

```
int main()
{
        return 0;
}
```

read?

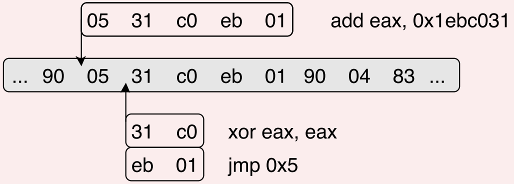
Disassembly

- Retrieve the assembly code from the machine code
- Static analysis
- Linear sweep - `objdump`
- Recursive traversal - `IDA`

Disassembly - Limitations

- Instructions
  - have variable lengths
  - can overlap
  - can be unaligned

Example



Linear Sweep

- Starts from the beginning of each section
- Decode one instruction after another
- $+$ parses the entire program
- - cannot detect unaligned instructions

Recursive Traversal

- Starts from the program's main entry point
- Performs linear sweep until a branch/jump instruction is encountered
- Follows the control instructions in a recursive manner
- Similar to control flow analysis
- $+$ parses only code that is explicitly hit
- - cannot handle indirect branches, PIC

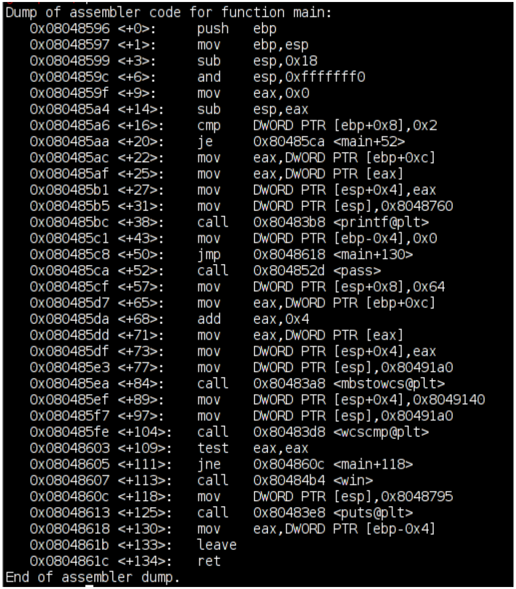
What next?

- Disassembly is not 100% precise
- Static analysis cannot detect all execution paths
- For everything else -

What next?

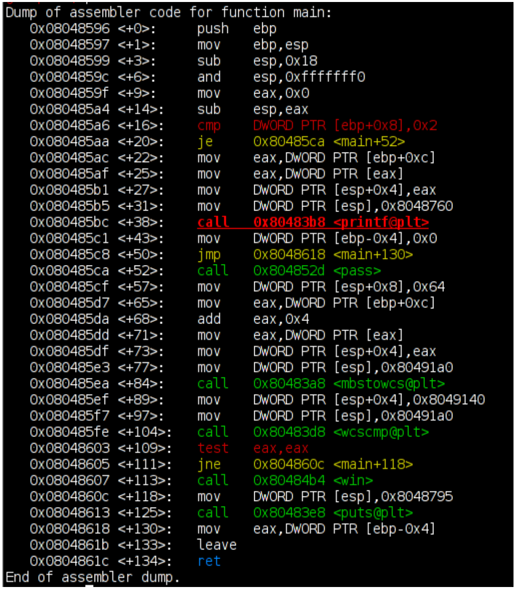
- Disassembly is not 100% precise
- Static analysis cannot detect all execution paths
- For everything else - there's GDB

GDB



```
Dump of assembler code for function main:
   0x08048596 <+0>:     push   ebp
   0x08048597 <+1>:     mov    ebp,esp
   0x08048599 <+3>:     sub    esp,0x18
   0x0804859c <+6>:     and    esp,0xfffffff0
   0x0804859f <+9>:     mov    eax,0x0
   0x080485a4 <+14>:    sub    esp,eax
   0x080485a6 <+16>:    cmp    DWORD PTR [ebp+0x8],0x2
   0x080485aa <+20>:    je     0x80485ca <main+52>
   0x080485ac <+22>:    mov    eax,DWORD PTR [ebp+0xc]
   0x080485af <+25>:    mov    eax,DWORD PTR [eax]
   0x080485b1 <+27>:    mov    DWORD PTR [esp+0x4],eax
   0x080485b5 <+31>:    mov    DWORD PTR [esp],0x8048760
   0x080485bc <+38>:    call   0x80483b8 <printf@plt>
   0x080485c1 <+43>:    mov    DWORD PTR [ebp-0x4],0x0
   0x080485c8 <+50>:    jmp    0x8048618 <main+130>
   0x080485ca <+52>:    call   0x804852d <pass>
   0x080485cf <+57>:    mov    DWORD PTR [esp+0x8],0x64
   0x080485d7 <+65>:    mov    eax,DWORD PTR [ebp+0xc]
   0x080485da <+68>:    add    eax,0x4
   0x080485dd <+71>:    mov    eax,DWORD PTR [eax]
   0x080485df <+73>:    mov    DWORD PTR [esp+0x4],eax
   0x080485e3 <+77>:    mov    DWORD PTR [esp],0x80491a0
   0x080485ea <+84>:    call   0x80483a8 <mbstowcs@plt>
   0x080485ef <+89>:    mov    DWORD PTR [esp+0x4],0x8049140
   0x080485f7 <+97>:    mov    DWORD PTR [esp],0x80491a0
   0x080485fe <+104>:   call   0x80483d8 <wcscmp@plt>
   0x08048603 <+109>:   test   eax,eax
   0x08048605 <+111>:   jne    0x804860c <main+118>
   0x08048607 <+113>:   call   0x80484b4 <win>
   0x0804860c <+118>:   mov    DWORD PTR [esp],0x8048795
   0x08048613 <+125>:   call   0x80483e8 <puts@plt>
   0x08048618 <+130>:   mov    eax,DWORD PTR [ebp-0x4]
   0x0804861b <+133>:   leave
   0x0804861c <+134>:   ret
End of assembler dump.
```

GDB++



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Dump of assembler code for function main:
   0x08048596 <+0>:     push   ebp
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   0x080485bc <+38>:    call   0x80483b8 <printf@plt>
   0x080485c1 <+43>:    mov    DWORD PTR [ebp-0x4],0x0
   0x080485c8 <+50>:    jmp    0x8048618 <main+130>
   0x080485ca <+52>:    call   0x804852d <pass>
   0x080485cf <+57>:    mov    DWORD PTR [esp+0x8],0x64
   0x080485d7 <+65>:    mov    eax,DWORD PTR [ebp+0xc]
   0x080485da <+68>:    add    eax,0x4
   0x080485dd <+71>:    mov    eax,DWORD PTR [eax]
   0x080485df <+73>:    mov    DWORD PTR [esp+0x4],eax
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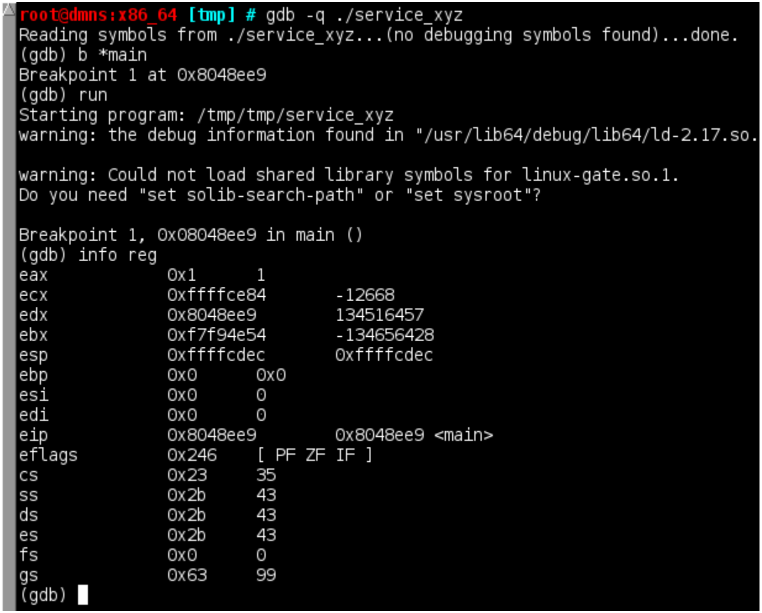
   0x0804860c <+118>:   mov    DWORD PTR [esp],0x8048795
   0x08048613 <+125>:   call   0x80483e8 <puts@plt>
   0x08048618 <+130>:   mov    eax,DWORD PTR [ebp-0x4]
   0x0804861b <+133>:   leave
   0x0804861c <+134>:   ret
End of assembler dump.
```

Runtime analysis

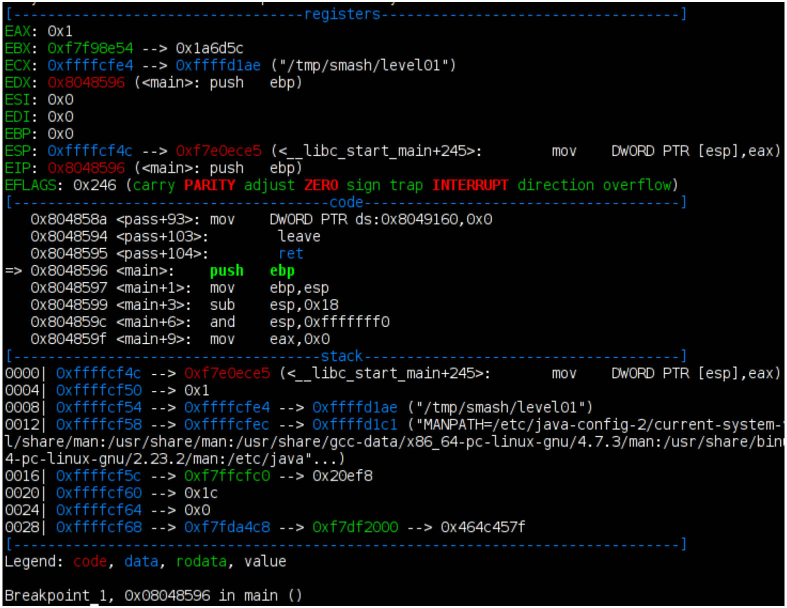


```
root@dmns:x86_64 [tmp] # gdb -q ./service_xyz
Reading symbols from ./service_xyz...(no debugging symbols found)...done.
(gdb) b *main
Breakpoint 1 at 0x8048ee9
(gdb) run
Starting program: /tmp/tmp/service_xyz
warning: the debug information found in "/usr/lib64/debug/lib64/ld-2.17.so.

warning: Could not load shared library symbols for linux-gate.so.1.
Do you need "set solib-search-path" or "set sysroot"?

Breakpoint 1, 0x08048ee9 in main ()
(gdb) info reg
eax            0x1      1
ecx            0xffffce84       -12668
edx            0x8048ee9        134516457
ebx            0xf7f94e54       -134656428
esp            0xffffcdec       0xffffcdec
ebp            0x0      0x0
esi            0x0      0
edi            0x0      0
eip            0x8048ee9        0x8048ee9 <main>
eflags         0x246    [ PF ZF IF ]
cs             0x23     35
ss             0x2b     43
ds             0x2b     43
es             0x2b     43
fs             0x0      0
gs             0x63     99
(gdb)
```

Runtime analysis++



```
[----------------------------------registers-----------------------------------]
EAX: 0x1
EBX: 0xf7f98e54 --> 0x1a6d5c
ECX: 0xffffcfe4 --> 0xffffd1ae ("/tmp/smash/level01")
EDX: 0x8048596 (<main>: push   ebp)
ESI: 0x0
EDI: 0x0
EBP: 0x0
ESP: 0xffffcf4c --> 0xf7e0ece5 (<__libc_start_main+245>:       mov    DWORD PTR [esp],eax)
EIP: 0x8048596 (<main>: push   ebp)
EFLAGS: 0x246 (carry PARITY adjust ZERO sign trap INTERRUPT direction overflow)
[-------------------------------------code-------------------------------------]
   0x804858a <pass+93>: mov    DWORD PTR ds:0x8049160,0x0
   0x8048594 <pass+103>:        leave
   0x8048595 <pass+104>:        ret
=> 0x8048596 <main>:    push   ebp
   0x8048597 <main+1>:  mov    ebp,esp
   0x8048599 <main+3>:  sub    esp,0x18
   0x804859c <main+6>:  and    esp,0xfffffff0
   0x804859f <main+9>:  mov    eax,0x0
[------------------------------------stack-------------------------------------]
0000| 0xffffcf4c --> 0xf7e0ece5 (<__libc_start_main+245>:       mov    DWORD PTR [esp],eax)
0004| 0xffffcf50 --> 0x1
0008| 0xffffcf54 --> 0xffffcfe4 --> 0xffffd1ae ("/tmp/smash/level01")
0012| 0xffffcf58 --> 0xffffcfec --> 0xffffd1c1 ("MANPATH=/etc/java-config-2/current-system-
l/share/man:/usr/share/man:/usr/share/gcc-data/x86_64-pc-linux-gnu/4.7.3/man:/usr/share/bin
4-pc-linux-gnu/2.23.2/man:/etc/java"...)
0016| 0xffffcf5c --> 0xf7ffcfc0 --> 0x20ef8
0020| 0xffffcf60 --> 0x1c
0024| 0xffffcf64 --> 0x0
0028| 0xffffcf68 --> 0xf7fda4c8 --> 0xf7df2000 --> 0x464c457f
[------------------------------------------------------------------------------]
Legend: code, data, rodata, value

Breakpoint 1, 0x08048596 in main ()
```

Keywords

- executable
- PE
- ELF
- compile
- assemble
- decompile
- disassembly
- `IDA`
- `objdump`
- `gdb`

Resources

- https://www.hex-rays.com/products/ida/
- http://resources.infosecinstitute.com/linear-sweep-vs-recursive-disassembling-algorithm/