OS X ROOTKITS

-[OS X Kernel Rootkits]-

fG!

HITCON - 2013

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Who Am I

- Don't take me too seriously, I fuzz the Human brain!
- The capitalist "pig" degrees: Economics & MBA.
- Worked for the evil banking system!
- Security Researcher at COSEINC.
- "Famous" blogger.
- Wannabe rootkits book writer.
- Love a secondary curvy road and a 911.

Today's subject

- OS X Kernel rootkits.
- Ideas to improve them.
- Sample applications.
- Raise awareness and interest in this area.

Assumptions

(the economist's dirty secret that makes everything possible)

- Reaching to uid=0 is your problem!
- The same with startup and persistency aka APT.
- Should be easier to find the necessary bugs.
- Less research = Less audits = More bugs.
- Main target is Mountain Lion.
- Also works with Mavericks (tested with DP1).

Current state of the “art”

- OS X rootkits are a rare "species".
- Interesting hardware rootkits (Dino's Vitriol and Snare's EFI) but NO full code available ☹.
- Commercial rootkits: Crisis from Hacking Team and maybe FinFisher (iOS yes, OS X never saw).
- Crisis is particularly bad.
- Not many detection tools available.

Simple Ideas

Problem #1

- Many interesting kernel symbols are not exported.
- Some are available in Unsupported & Private KPIs.
- Not acceptable for stable rootkits.
- Solving kernel symbols from a kernel extension is possible since Lion.
- Not in Snow Leopard and previous versions.

Simple Ideas

- __LINKEDIT segment contains the symbol info.
- Zeroed up to Snow Leopard.
- OS.X/Crisis solves the symbols in userland and sends them to the kernel rootkit.

```
__text:0000E4EB             loc_E4EB:                           ; CODE XREF: _solveKernelSymbolsForKext+C7↑j
__text:0000E4EB 89 3C 24                mov     [esp], edi      ; mmap'ed kernel start address
__text:0000E4EE C7 44 24 04+            mov     dword ptr [esp+4], 0DD2C36D6h ; symbol to solve
__text:0000E4F6 E8 3C 85 FF+            call    _findSymbolInFatBinary
__text:0000E4FB C7 85 68 FF+            mov     [ebp+var_98], 0DD2C36D6h
__text:0000E505 89 85 6C FF+            mov     [ebp+var_94], eax ; kmod address
__text:0000E50B 8B 86 8D 95+            mov     eax, ds:(pfcpu_filedescriptor - 0E067h)[esi]
__text:0000E511 8D 9D 68 FF+            lea     ebx, [ebp+var_98]
__text:0000E517 89 5C 24 08             mov     [esp+8], ebx
__text:0000E51B 89 04 24                mov     [esp], eax      ; int
__text:0000E51E C7 44 24 04+            mov     dword ptr [esp+4], 807AEEBFh ; send solved symbol request
__text:0000E526 E8 0F AE 03+            call    _ioctl          ; 0x807aeebf
```

Simple Ideas

- One easy solution is to read the kernel image from disk and process its symbols.
- The kernel does this every time we start a new process.
- Possible to implement with stable KPI functions.
- Kernel ASLR slide is easy to obtain in this scenario.

Simple Ideas

Idea #1

- Virtual File System – VFS.
- Read and write any file using VFS functions.
- Using only KPI symbols.
- Recipe for success:

❑ Vnode.

❑ VFS context.

❑ Data buffer.

❑ UIO structure/buffer.

Simple Ideas

❑ How to obtain the vnode information.

- vnode_lookup(const char* path, int flags, vnode_t *vpp, vfs_context_t ctx).
- Converts a path into a vnode.

```
vnode_t kernel_node = NULLVP;
int error = vnode_lookup("/mach_kernel", 0, &kernel_vnode, NULL);
```

Simple Ideas

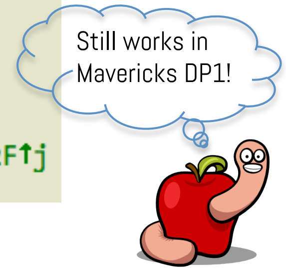
- Apple takes care of the ctx for us!

```
errno_t
vnode_lookup(const char *path, int flags, vnode_t *vpp, vfs_context_t ctx)
{
    struct nameidata nd;
    int error;
    u_int32_t ndflags = 0;

    if (ctx == NULL) {      /* XXX technically an error */
        ctx = vfs_context_current(); // <- thank you! :-)
    }
(...)
}
```

```
4C 8D 25 DC 72 52 00                lea     r12, __stack_chk_guard
49 8B 0C 24                         mov     rcx, [r12]
48 89 4D D8                         mov     [rbp+var_28], rcx
48 85 C0                            test    rax, rax
75 05                               jnz     short loc_FFFFFF80003DB3B6
E8 BA BD 01 00                      call    _vfs_context_current

                loc_FFFFFF80003DB3B6:               ; CODE XREF: _vnode_lookup+2F↑j
89 DA                               mov     edx, ebx
```



Simple Ideas

- ❑ Data buffer.
  - Statically allocated.
  - Dynamically, using one of the many kernel functions:
    - kalloc, kmem_alloc, OSMalloc, IOMalloc, MALLOC, _MALLOC.
  - __LINKEDIT size is around 1Mb.

Simple Ideas

- UIO buffer.
  - Use uio_create and uio_addiov.
  - Both are available in BSD KPI.

```
char buffer[PAGE_SIZE_64];
uio_t uio = NULL;
uio = uio_create(1, 0, UIO_SYSSPACE, UIO_READ);
int error = uio_addiov(uio, CAST_USER_ADDR_T(buffer), PAGE_SIZE_64);
```

Simple Ideas

- Recipe for success:

☑ vnode of /mach_kernel.

☑ VFS context.

☑ Data buffer.

☑ UIO structure/buffer.

- We can finally read the kernel from disk…

Simple Ideas

- Reading from the filesystem:
- VNOP_READ(vnode_t vp, struct io* uio, int ioflag, vfs_context_t ctx).
- "Call down to a filesystem to read file data".
- Once again Apple takes care of the vfs context.
- If call was successful the buffer will contain data.
- To write use VNOP_WRITE.

Simple Ideas

- To solve the symbols we just need to read the Mach-O header and extract some information:
  - __TEXT segment address (to find KASLR).
  - __LINKEDIT segment offset and size.
  - Symbols and strings tables offset and size from LC_SYMTAB command.

Simple Ideas

- Read __LINKEDIT into a buffer (~1Mb).
- Process it and solve immediately all the symbols we (might) need.
- Or just solve symbols when required to obfuscate things a little.
- Don't forget that KASLR slide must be added to the retrieved values.

Simple Ideas

- To compute the KASLR value find out the base address of the running kernel.
- Using IDT or a kernel function address and then lookup Mach-O magic value backwards.
- Compute the __TEXT address difference to the value we extracted from disk image.
- Or use some other method you might have.

Checkpoint #1

- We are able to read and write any file.
- For now the kernel is the interesting target.
- We can solve any available symbol - function or variable, exported or not in KPIs.
- Compatible with all OS X versions.

Problem #2

- Many interesting functions & variables are static.
- Cross references not available (IDA spoils us!).
- Hex search is not very reliable.
- Internal kernel structures fields offsets, such as proc and task.

Idea #2

- Integrate a disassembler in the rootkit!
- Tested with diStorm, my personal favorite.
- Works great.
- Be careful with some inline data.
- One second to disassemble the kernel.
- In a single straightforward sweep.

Checkpoint #2

- Ability to search for static functions, variables, and structure fields.
- We still depend on patterns.
- These are more common between all versions.
- Possibility to hook calls by searching references and modifying the offsets.

Simple Ideas

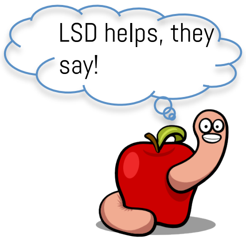
- We can have full control of the kernel.
- Everything can be dynamic.
- Stable and future proof rootkits.

```
/* system call table */
/* Before OS X Mavericks */
struct sysent {
    int16_t       sy_narg;
    int8_t        sy_resv;
    int8_t        sy_flags;
    sy_call_t     *sy_call;
    sy_munge_t    *sy_arg_munge32;
    sy_munge_t    *sy_arg_munge64;
    int32_t       sy_return_type;
    uint16_t      sy_arg_bytes;
};
```

```
/* system call table */
/* OS X Mavericks */
struct sysent {
    sy_call_t     *sy_call;
    sy_munge_t    *sy_arg_munge32;
    sy_munge_t    *sy_arg_munge64;
    int32_t       sy_return_type;
    int16_t       sy_narg;
    uint16_t      sy_arg_bytes;
}
```

Simple Ideas

- Can Apple close the VFS door?
- That would probably break legit products that use them.
- We still have the disassembler(s).
- Kernel anti-disassembly ? ☺
- **Imagination is the limit!**



Practical applications

- Executing userland code.
- Playing with DTrace's syscall provider & Volatility.
- Zombie rootkits.
- Additional applications in the SyScan slides and Phrack paper (whenever it comes out).

Userland cmds

- It can be useful to execute userland binaries from the rootkit or inject code into them.
- Many different possibilities exist:
  - Modify binary (at disk or runtime).
  - Inject shellcode.
  - Inject a library.
  - Etc…
- This particular one uses last year's Boubou trick.
- Not the most efficient but fun.

Userland cmds

Idea!

- Kill a process controlled by launchd.
- Intercept the respawn.
- Inject a dynamic library into its Mach-O header.
- Dyld will load the library, solve symbols and execute the library's constructor.
- Do whatever we want!

Requirements

- ❑ Write to userland memory from kernel.
- ❑ Kernel location to intercept & execute the injection.
- ❑ A modified Mach-O header.
- ❑ Dyld must read modified header.
- ❑ A dynamic library.
- ❑ Luck (always required!).

Userland cmds

- Write to userland memory from kernel.
  - Easiest solution is to use vm_map_write_user.
  - vm_map_write_user(vm_map_t map, void *src_p, vm_map_address_t dst_addr, vm_size_t size);
  - "Copy out data from a kernel space into space in the destination map. The space must already exist in the destination map."

Userland cmds

- ❑ Write to userland memory from kernel.
  - Map parameter is the map field from the task structure.
  - proc and task structures are linked via void *.
  - Use proc_find(int pid) to retrieve proc struct.
  - Or proc_task(proc_t p).
  - Check kern_proc.c from XNU source.

Userland cmds

☑ Write to userland memory from kernel.

- The remaining parameters are buffer to write from, destination address, and buffer size.

```
struct proc *p = proc_find(PID);
struct task *task = (struct task*)(p->task);
kern_return_t kr = 0;
vm_prot_t new_protection = VM_PROT_WRITE | VM_PROT_READ;
char *fname = "nemo_and_snare_rule!";
// modify memory permissions
kr = mach_vm_protect(task->map, 0x1000, len, FALSE, new_protection);
kr = vm_map_write_user(task->map, fname, 0x1000, strlen(fname)+1);
proc_rele(p);
```

Userland cmds

- **Kernel location to intercept & execute the injection.**
  - We need to find a kernel function within the new process creation workflow.
  - Hook it with our function responsible for modifying the target's header.
  - We are looking for a specific process so new proc structure fields must be already set.
  - Vnode information can also be used.

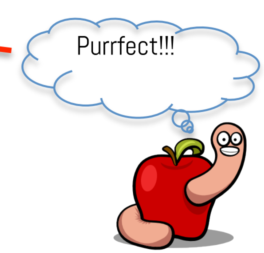
Userland cmds

```
execve() -> __mac_execve()
                 |
                 v
         exec_activate_image()
                 |
                 v
             Read file
                 |
                 v
     .----> exec_mach_imgact() -> run dyld -> target entry point
     |           |
     |           v
     |       load_machfile()
     |           |
     |           v
     |      parse_machfile()   [maps the load commands into memory]
     |           |
     |           v
     |       load_dylinker()   [sets image entrypoint to dyld]
     |           |
     |           v
     `--------- (...)
```

Userland cmds

- There's a function called proc_resetregister.
- Located near the end so almost everything is ready to pass control to dyld.
- Easy to rip and hook!
- Have a look at Hydra (github.com/gdbinit/hydra).

```
void proc_resetregister(proc_t p)
{
    proc_lock(p);
    p->p_lflag &= ~P_LREGISTER;
    proc_unlock(p);
}
```



Userland cmds

☑ **Modified Mach-O header.**

- Very easy to do.
- Check last year's HiTCON slides.
- OS.X/Boubou source code (https://github.com/gdbinit/osx_boubou).

Userland cmds

```
.-------------------.      .-------------------.
|      HEADER       |      |      HEADER       |<- Fix this struct
|-------------------|      |-------------------| struct mach_header {
|   Load Commands   |      |   Load Commands   |  ...
|  .------------.   |      |  .------------.   |  uint32_t  ncmds;      <- add +1
|  | Command 1  |   |      |  | Command 1  |   |  uint32_t  sizeofcmds; <- size of new cmd
|  |------------|   |      |  |------------|   |  ...
|  | Command 2  |   |      |  | Command 2  |   |  };
|  |------------|   |      |  |------------|   |
|  |    ...     |   |      |  |    ...     |   |
|  |------------|   |      |  |------------|   |
|  | Command n  |   |      |  | Command n  |   |
|  `------------'   |      |  |------------|   |
|                   |---->|  | Command n+1 |   |<- add new command here
|                   |---->|  `------------'   | struct dylib_command {
|-------------------|---->|-------------------|  uint32_t       cmd;
|       Data        |---->|       Data        |  uint32_t       cmdsize;
| .---------------. |---->| .---------------. |  struct dylib   dylib;
| |   | Section 1 | |---->| |   | Section 1 | | };
| | 1 |-----------| |      | | 1 |-----------| |
| |   | Section 2 | |      | |   | Section 2 | |
| `---------------' |      | `---------------' |
| .---------------. |      | .---------------. |
| |   | Section 1 | |      | |   | Section 1 | |
| | 2 |-----------| |      | | 2 |-----------| |
| |   | Section 2 | |      | |   | Section 2 | |
| `---------------' |      | `---------------' |
|       ...         |      |       ...         |
`-------------------'      `-------------------'
```

Userland cmds

☑ **Dyld must read modified header.**

- Adding a new library to the header is equivalent to DYLD_INSERT_LIBRARIES (LD_PRELOAD).
- Kernel passes control to dyld.
- Then dyld to target's entrypoint.
- Dyld needs to read the Mach-O header.
- If header is modified before dyld's control we can inject a library (or change entrypoint and so on).

Userland cmds

☑ A dynamic library.

- Use Xcode's template.
- Add a constructor.

```
extern void init(void) __attribute__ ((constructor));
void init(void)
{
    // do evil stuff here
}
```

- Fork, exec, system, thread(s), whatever you need.
- Don't forget to cleanup library traces!

Userland cmds

- **Problems with this technique:**
- Requires library at disk (can be unpacked from rootkit and removed if we want).
- Needs to kill a process (but can be used to infect specific processes when started).
- Proc structure is not stable (get fields offset using the disassembler).

Hide & seek

- OS X is “instrumentation” rich:
  - DTrace.
  - FSEvents.
  - kauth.
  - kdebug.
  - TrustedBSD.
  - Auditing.
  - Socket filters.

Hide & seek

- Let's focus on DTrace's syscall provider.
- Nemo presented DTrace rootkits at Infiltrate.
- Siliconblade with Volatility "detects" them.
- But Volatility is vulnerable to an old trick.

Hide & seek

- Traces every syscall entry and exit.
- mach_trap is the mach equivalent provider.
- DTrace's philosophy of zero probe effect when disabled.
- Activation of this provider is equivalent to sysent hooking.
- Modifies the sy_call pointer inside sysent struct.

Hide & seek

```
Before:
gdb$ print *(struct sysent*)(0xffffff8025255840+5*sizeof(struct sysent))
$12 = {
  sy_narg = 0x3,
  sy_resv = 0x0,
  sy_flags = 0x0,
  sy_call = 0xffffff8024cfc210,          <- open syscall, sysent[5]
  sy_arg_munge32 = 0xffffff8024fe34f0,
  sy_arg_munge64 = 0,
  sy_return_type = 0x1,
  sy_arg_bytes = 0xc
}

dtrace_systrace_syscall is located at address 0xFFFFFF8024FDC630.

After enabling a 'syscall::open:entry' probe:
gdb$ print *(struct sysent*)(0xffffff8025255840+5*sizeof(struct sysent))
$13 = {
  sy_narg = 0x3,
  sy_resv = 0x0,
  sy_flags = 0x0,
  sy_call = 0xffffff8024fdc630,        <- now points to dtrace_systrace_syscall
  sy_arg_munge32 = 0xffffff8024fe34f0,
  sy_arg_munge64 = 0,
  sy_return_type = 0x1,
  sy_arg_bytes = 0xc
}
```

Hide & seek

- Not very useful to detect sysent hooking.
- fbt provider is better for detection (check SyScan slides).
- Nemo's DTrace rootkit uses syscall provider.
- Can be detected by dumping the sysent table and verifying if _dtrace_systrace_syscall is present.
- False positives? Low probability.

Hide & seek

```
$ python vol.py mac_check_syscalls --profile=Mac10_8_3_64bitx64 \
-f ~/Forensics/dtrace/Mac\ OS\ X\ 10.8\ 64-bit-12e6095b.vmem
Volatile Systems Volatility Framework 2.3_alpha
Table Name      Index  Address            Symbol
--------------- ------ ------------------ ------------------------------
SyscallTable         0 0xffffff80085755f0 _nosys
SyscallTable         1 0xffffff8008555430 _exit
SyscallTable         2 0xffffff8008559730 _fork
SyscallTable         3 0xffffff8008575630 _read
SyscallTable         4 0xffffff8008575d00 _write
SyscallTable         5 0xffffff80085db440 _dtrace_systrace_syscall  <- syscall::open:entry probe
SyscallTable         6 0xffffff8008549f30 _close
SyscallTable         7 0xffffff8008556660 _wait4
SyscallTable         8 0xffffff80085755f0 _nosys
SyscallTable         9 0xffffff80082fbc20 _link
SyscallTable        10 0xffffff80082fc8c0 _unlink
SyscallTable        11 0xffffff80085755f0 _nosys
```

Hide & seek


HINDSIGHT HEROES
S
C
W
Captain Hindsight
With his sidekicks, Shoulda, Coulda, and Woulda

Hide & seek

" Nemo's presentation has shown again that known tools can be used for subverting a system and won't be easy to spot by a novice investigator, but then again nothing can hide in memory ;) "

@ http://siliconblade.blogspot.com/2013/04/hunting-d-trace-rootkits-with.html

Hide & seek

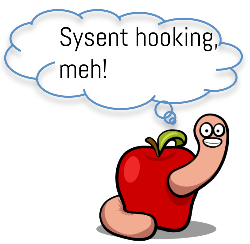
- It's rather easy to find what you know.
- How about what you <u>don't</u> know?
- Sysent hooking is easily detected by memory forensics (assuming you can get memory dump!).
- But fails at old sysent shadowing trick.
- Check http://siliconblade.blogspot.pt/2013/07/offensive-volatility-messing-with-os-x.html

Hide & seek

```
$ python vol.py mac_check_syscalls --profile=Mac10_8_3_64bitx64 \
-f ~/Forensics/dtrace/Mac\ OS\ X\ 10.8\ 64-bit-no\ hooking.vmem
Volatile Systems Volatility Framework 2.3_alpha
(...)
SyscallTable       339 0xffffff800854a490 _fstat64
SyscallTable       340 0xffffff80082fd620 _lstat64
SyscallTable       341 0xffffff80082fd420 _stat64_extended
SyscallTable       342 0xffffff80082fd6c0 _lstat64_extended
SyscallTable       343 0xffffff800854a470 _fstat64_extended
SyscallTable       344 0xffffff8008300c20 _getdirentries64
SyscallTable       345 0xffffff80082f9c60 _statfs64
SyscallTable       346 0xffffff80082f9e80 _fstatfs64
SyscallTable       347 0xffffff80082fa2a0 _getfsstat64
SyscallTable       348 0xffffff80082fa7c0 ___pthread_chdir
SyscallTable       349 0xffffff80082fa640 ___pthread_fchdir
SyscallTable       350 0xffffff8008535cb0 _audit
SyscallTable       351 0xffffff8008535e20 _auditon
(...)
```

Hide & seek

```
$ python vol.py mac_check_syscalls --profile=Mac10_8_3_64bitx64 \
-f ~/Forensics/dtrace/Mac\ OS\ X\ 10.8\ 64-bit-hooking1.vmem
Volatile Systems Volatility Framework 2.3_alpha
(...)
SyscallTable         339 0xffffff800854a490 _fstat64
SyscallTable         340 0xffffff80082fd620 _lstat64
SyscallTable         341 0xffffff80082fd420 _stat64_extended
SyscallTable         342 0xffffff80082fd6c0 _lstat64_extended
SyscallTable         343 0xffffff800854a470 _fstat64_extended
SyscallTable         344 0xffffff7f89a2dce0 HOOKED  <- getdirentries64 hooked
SyscallTable         345 0xffffff80082f9c60 _statfs64
SyscallTable         346 0xffffff80082f9e80 _fstatfs64
SyscallTable         347 0xffffff80082fa2a0 _getfsstat64
SyscallTable         348 0xffffff80082fa7c0 ___pthread_chdir
SyscallTable         349 0xffffff80082fa640 ___pthread_fchdir
SyscallTable         350 0xffffff8008535cb0 _audit
SyscallTable         351 0xffffff8008535e20 _auditon
(...)
```



Hide & seek

```
$ python vol.py mac_check_syscalls --profile=Mac10_8_3_64bitx64 \
-f ~/Forensics/dtrace/Mac\ OS\ X\ 10.8\ 64-bit-hooking2.vmem
Volatile Systems Volatility Framework 2.3_alpha
(...)
SyscallTable         339 0xffffff800854a490 _fstat64
SyscallTable         340 0xffffff80082fd620 _lstat64
SyscallTable         341 0xffffff80082fd420 _stat64_extended
SyscallTable         342 0xffffff80082fd6c0 _lstat64_extended
SyscallTable         343 0xffffff800854a470 _fstat64_extended
SyscallTable         344 0xffffff8008300c20 _getdirentries64
SyscallTable         345 0xffffff80082f9c60 _statfs64
SyscallTable         346 0xffffff80082f9e80 _fstatfs64
SyscallTable         347 0xffffff80082fa2a0 _getfsstat64
SyscallTable         348 0xffffff80082fa7c0 ___pthread_chdir
SyscallTable         349 0xffffff80082fa640 ___pthread_fchdir
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SyscallTable         351 0xffffff8008535e20 _auditon
(...)
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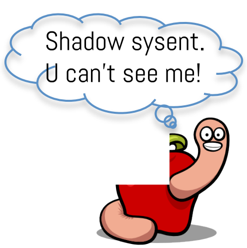


Hide & seek

- Volatility plugin can easily find sysent table modification(s).
- But fails to detect a shadow sysent table.
- Nothing new, extremely easy to implement with the kernel disassembler!
- **Hindsight is always easy!**

Hide & seek

- **How to do it in a few steps:**
- Find sysent table address via IDT and bruteforce, or some other technique.
- **Warning:** Mavericks has a modified sysent table.
- Use the address to find location in __got section.
- Disassemble kernel and find references to __got address.

Hide & seek

- Allocate memory and copy original sysent table.
- Find space inside kernel to add a pointer (modifying __got is too noisy!).
- Install pointer to our sysent copy.
- Modify found references to __got pointer to our new pointer.
- Hook syscalls in the shadow table.

Checkpoint

- Many instrumentation features available!
- Do not forget them if you are the evil rootkit coder.
- Helpful for a quick assessment if you are the potential victim.
- Be very careful with tool's assumptions.

Zombies

Idea!

- Create a kernel memory leak.
- Copy rootkit code to that area.
- Fix permissions and symbols offsets
- That's easy, we have a disassembler
- Redirect execution to the zombie area.
- Return KERN_FAILURE to rootkit's start function.

Zombies

☑ Create a kernel memory leak.

- Using one of the dynamic memory functions.
- kalloc, kmem_alloc, OSMalloc, MALLOC/FREE, _MALLOC/_FREE, IOMalloc/IOFree.
- No garbage collection mechanism.
- Find rootkit's Mach-O header and compute its size (__TEXT + __DATA segments).

Zombies

- Fix symbols offsets.
  - Kexts have no symbol stubs as most userland binaries.
  - Symbols are solved when kext is loaded.
  - RIP addressing is used (offset from kext to kernel).
  - When we copy to the zombie area those offsets are wrong.

Zombies

- Fix symbols offsets.
  - We can have a table with all external symbols or dynamically find them (read rootkit from disk).
  - Lookup each kernel symbol address.
  - Disassemble the original rootkit code address and find the references to the original symbol.
  - Find CALL and JMP and check if target is the symbol.

Zombies

☑ Fix symbols offsets.

- Not useful to disassemble the zombie area because offsets are wrong.
- Compute the distance to start address from CALLs in original and add it to the zombie start address.
- Now we have the location of each symbol inside the zombie and can fix the offset back to kernel symbol.

Zombies

- **Redirect execution to zombie.**
  - We can't simply jump to new code because rootkit start function must return a value!
  - Hijack some function and have it execute a zombie start function.
  - Or just start a new kernel thread with kernel_thread_start.

Zombies

☑ Redirect execution to zombie.

- To find the zombie start function use the same trick as symbols:
- Compute the difference to the start in the original rootkit.
- Add it to the start of zombie and we get the correct pointer.

Zombies

☑ Return KERN_FAILURE.

- Original kext must return a value.
- If we return KERN_SUCCESS, kext will be loaded and we need to hide or unload it.
- If we return KERN_FAILURE, kext will fail to load and OS X will cleanup it for us.
- Not a problem because zombie is already resident.

Zombies

Advantages

- No need to hide from kextstat.
- No kext related structures.
- Harder to find (easier now because I'm telling you).
- Wipe out zombie Mach-O header and there's only code/data in kernel memory.
- It's fun!

Zombies

Demo

(Dear Spooks: all code will be made public, don't break my room! #kthxbay)

Zombies

```
7. ssh
mountain-lion-64:~ reverser$ uname -an
Darwin mountain-lion-64.local 12.3.0 Darwin Kernel Version 12.3.0: Sun Jan  6 22:37:10 PST 2013; root:xnu-2050.22.13~1/RELEASE_X86_64 x86_
64
mountain-lion-64:~ reverser$ ls /
Applications    System          bin             etc             mach_kernel_new opt             tmp
Library         Users           cores           home            mach_kernel_old private         usr
Network         Volumes         dev             mach_kernel     net             sbin            var
mountain-lion-64:~ reverser$ sudo sh
sh-3.2# chown -R root:wheel the_flying_circus.kext/; kextload the_flying_circus.kext/
/Users/reverser/the_flying_circus.kext failed to load - (libkern/kext) kext (kmod) start/stop routine failed; check the system/kernel logs
 for errors or try kextutil(8).
sh-3.2# ls /
.DS_Store               .fseventsd              System                  home                    sbin
.DocumentRevisions-V100 .hotfiles.btree         Users                   mach_kernel_new         tmp
.Spotlight-V100         .vol                    bin                     mach_kernel_old         usr
.Trashes                Applications            cores                   net                     var
.VolumeIcon.icns        Library                 dev                     opt
.file                   Network                 etc                     private
sh-3.2#
```

Zombies

9. ssh

```
uilt Aug 21 2012 21:49:26
memctl: Opening balloon
memctl: Instrumenting bug 151304...
memctl: offset 0: 72
memctl: offset 1: 16
memctl: offset 2: 56
memctl: offset 3: 64
memctl: offset 4: 76
memctl: Timer thread started.
[AppleBluetoothHCIControllerUSBTransport][start] -- completed
[IOBluetoothHCIController][staticBluetoothHCIControllerTransportShowsUp] -- Received Bluetooth Controller regis
ter service notification
Sandbox: sandboxd(105) deny mach-lookup com.apple.coresymbolicationd
**** [AppleBluetoothHCIControllerUSBTransport][configurePM] -- ERROR -- waited 30 seconds and still did not get
 the commandWakeup() notification -- this = 0xffffff8006cfe800 ****
Bluetooth: Adaptive Frequency Hopping is not supported.
[IOBluetoothHCIController::setConfigState] calling registerService
[SendHCIRequestFormatted] ### ERROR: [0x0C3F] (Set AFH Host Channel Classification) -- Send request failed (err
 = 0x0001 (kBluetoothHCIErrorUnknownHCICommand))
sh-3.2# 
```

Zombies

9. ssh

```
 5 4 3 1>
   66    0 0xffffff7f818ea000 0xc000     0xc000     com.apple.driver.ApplePolicyControl (3.3.0) <65 64 55 10 9
7 5 4 3 1>
   67    0 0xffffff7f8109a000 0x5000     0x5000     com.apple.Dont_Steal_Mac_OS_X (7.0.0) <62 7 4 3 1>
   68    0 0xffffff7f80ed5000 0xb0000    0xb0000    com.apple.iokit.IOBluetoothFamily (4.1.3f3) <41 7 5 4 3 1>
   69    0 0xffffff7f80d07000 0x14000    0x14000    com.apple.iokit.IOSurface (86.0.4) <7 5 4 3 1>
   70    0 0xffffff7f80a65000 0x7000     0x7000     com.apple.iokit.IOUserEthernet (1.0.0d1) <31 6 5 4 3 1>
   71    2 0xffffff7f81742000 0xf000     0xf000     com.apple.iokit.IOHDAFamily (2.3.7fc4) <5 4 3 1>
   72    1 0xffffff7f81755000 0x16000    0x16000    com.apple.driver.AppleHDAController (2.3.7fc4) <71 55 10 6
5 4 3 1>
   73    1 0xffffff7f80d1b000 0x4000     0x4000     com.apple.iokit.IOSMBusFamily (1.1) <5 4 3>
   74    1 0xffffff7f8168a000 0x11000    0x11000    com.apple.driver.AppleSMBusController (1.0.11d0) <73 10 9 5
 4 3>
   75    0 0xffffff7f8169b000 0xd000     0xd000     com.apple.driver.AppleMCCSControl (1.1.11) <74 55 10 9 7 5
4 3 1>
   76    0 0xffffff7f81511000 0x5000     0x5000     com.apple.driver.AppleUpstreamUserClient (3.5.10) <55 10 9
7 5 4 3 1>
   77    2 0xffffff7f811ed000 0x7000     0x7000     com.apple.kext.OSvKernDSPLib (1.6) <5 4>
   78    3 0xffffff7f811f4000 0x3a000    0x3a000    com.apple.iokit.IOAudioFamily (1.8.9fc11) <77 5 4 3 1>
   79    1 0xffffff7f8176b000 0xc2000    0xc2000    com.apple.driver.DspFuncLib (2.3.7fc4) <78 77 6 5 4 3 1>
   80    0 0xffffff7f8182d000 0x7d000    0x7d000    com.apple.driver.AppleHDA (2.3.7fc4) <79 78 72 71 64 55 6 5
 4 3 1>
   83    1 0xffffff7f80b88000 0x7000     0x7000     com.apple.driver.AppleUSBComposite (5.2.5) <41 4 3 1>
   85    0 0xffffff7f80b7f000 0x9000     0x9000     com.apple.iokit.IOUSBHIDDriver (5.2.5) <41 26 5 4 3 1>
   86    1 0xffffff7f811dd000 0x5000     0x5000     com.apple.kext.triggers (1.0) <7 6 5 4 3 1>
   87    0 0xffffff7f811e2000 0x9000     0x9000     com.apple.filesystems.autofs (3.0) <86 7 6 5 4 3 1>
   88    0 0xffffff7f819fa000 0x5000     0x5000     com.vmware.kext.vmmemctl (0081.82.01) <7 5 4 3 1>
   89    0 0xffffff7f80e99000 0xa000     0xa000     com.apple.iokit.IOBluetoothSerialManager (4.1.3f3) <57 7 5
4 3 1>
   90    0 0xffffff7f80ead000 0x28000    0x28000    com.apple.iokit.AppleBluetoothHCIControllerUSBTransport (4.
1.3f3) <41 10 9 7 5 4 3 1>
   91    0 0xffffff7f819ff000 0xa000     0xa000     com.vmware.kext.vmhgfs (0081.82.01) <5 4 3 1>
   92    0 0xffffff7f80be2000 0x7000     0x7000     com.apple.driver.AppleUSBMergeNub (5.5.5) <83 41 4 3 1>
   93    0 0xffffff7f8122e000 0x5000     0x5000     com.apple.driver.AudioAUUC (1.60) <78 55 10 9 7 5 4 3 1>
sh-3.2#
```

Problems

- Unstable internal structures!
  - Proc structure is one of those.
  - We just need a few fields.
  - Find offsets by disassembling stable functions.
  - Possible, you just need to spend some time grep'ing around XNU source code and IDA.

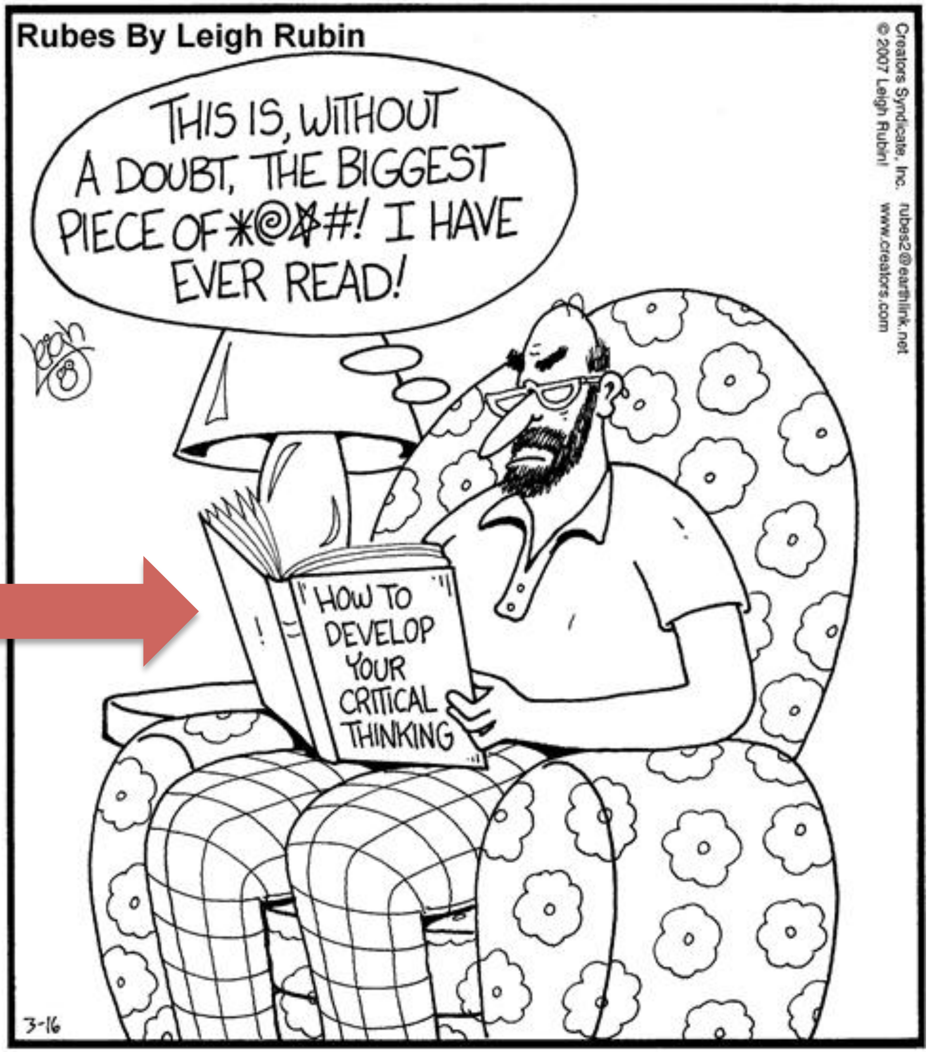
Problems

- Memory forensics.
  - A worthy rootkit enemy.
  - But with its own flaws.
  - In particular the acquisition process.
  - Some assumptions are weak.
  - Needs more features.

Problems

- And so many others.
- It's a cat & mouse game.
- Any mistake can be costly.
- When creating a rootkit, reduce the number of assumptions you have.
- Defenders face the unknown.
- Very hard game – abuse their assumptions.

Conclusions



In his own mind, Jerry quickly mastered the art.

Conclusions

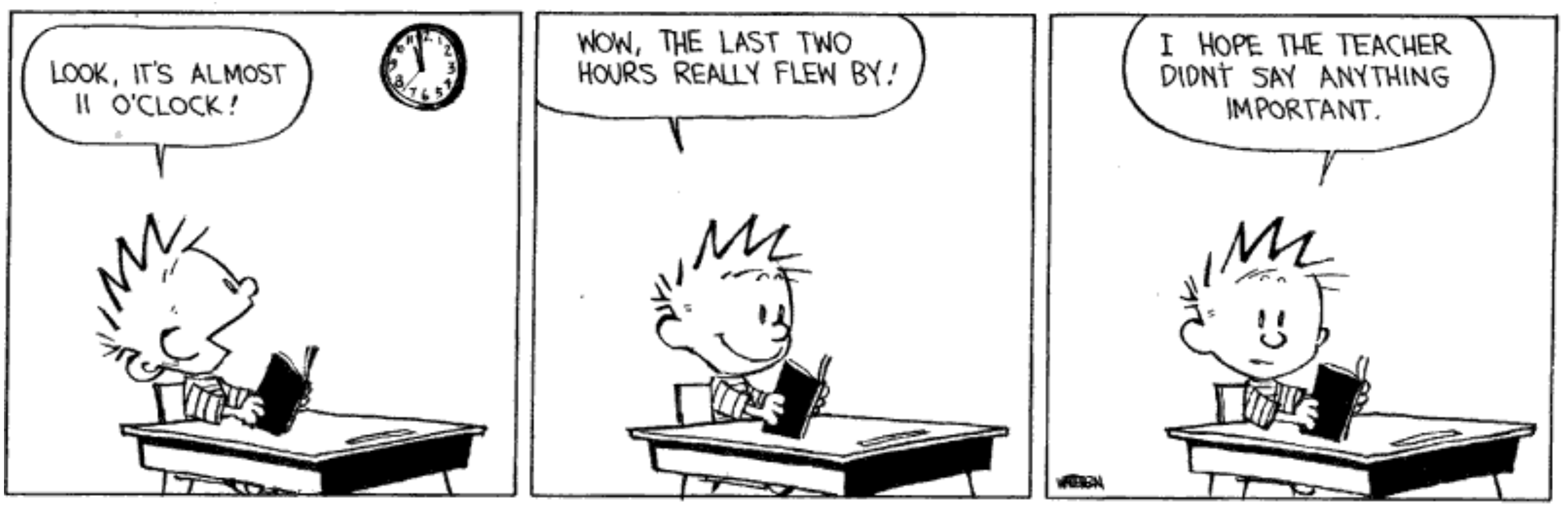
- Improving the quality of OS X kernel rootkits is very easy.
- Stable and future-proof requires more work.
- Prevention and detection tools must be researched & developed.
- Kernel is sexy but don't forget userland.
- OS.X/Crisis userland rootkit is powerful!
- Easier to hide in userland from memory forensics.

Conclusions

- Attackers have better incentives to be creative.
- Defense will always lag and suffer from information asymmetry.
- Economics didn't solve this problem and I doubt InfoSec will (because it's connected to Economics aka MONEY).
- **Always question assumptions**. This presentation has a few ;-).

Greets

nemo, noar, snare, saure, od, emptydir, korn, g0sh, spico and all other put.as friends, everyone at COSEINC, thegrugq, diff-t, #osxre, Gil Dabah from diStorm, A. Ionescu, Igor from Hex-Rays, NSA & friends, and you for spending time of your life listening to me ☺.



We are hiring!

- Software Engineers.
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- 2 years experience.
- You know C and Python better than me!
- Can communicate in English.
- $80000NT monthly salary.
- Housing provided.
- 2 Years contract.

Contacts

http://reverse.put.as

http://github.com/gdbinit

reverser@put.as

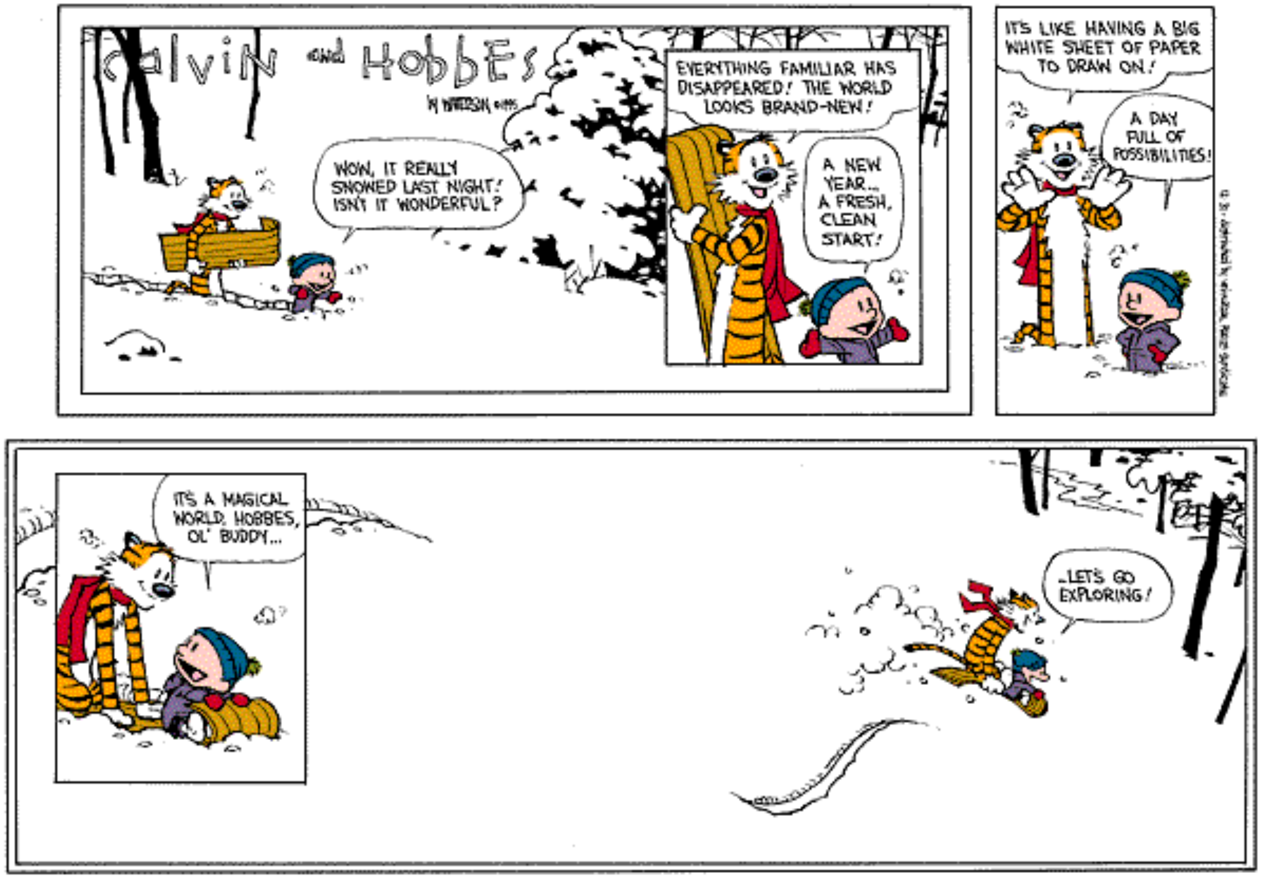
pedro@coseinc.com

@osxreverser

#osxre @ irc.freenode.net

And iloverootkits.com maybe soon!

A day full of possibilities!



Let's go exploring!