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SOFTWARE TECHNOLOGIES LTD.

STUMPING THE MOBILE CHIPSET

New 0days from down under

Adam Donenfeld

AGENDA

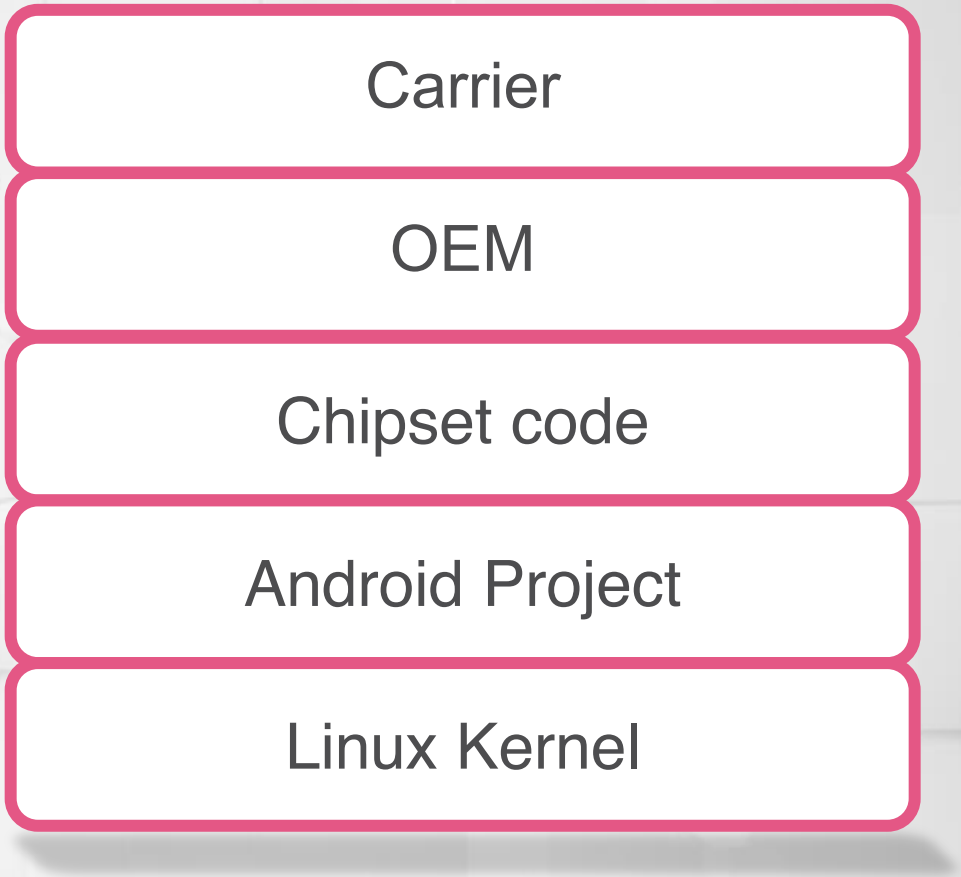
- Android chipsets overview in ecosystem
- Qualcomm chipset subsystem’s overview
- New kernel vulnerabilities
- Exploitation of a new kernel vulnerability
- Conclusions

~ $ man Adam

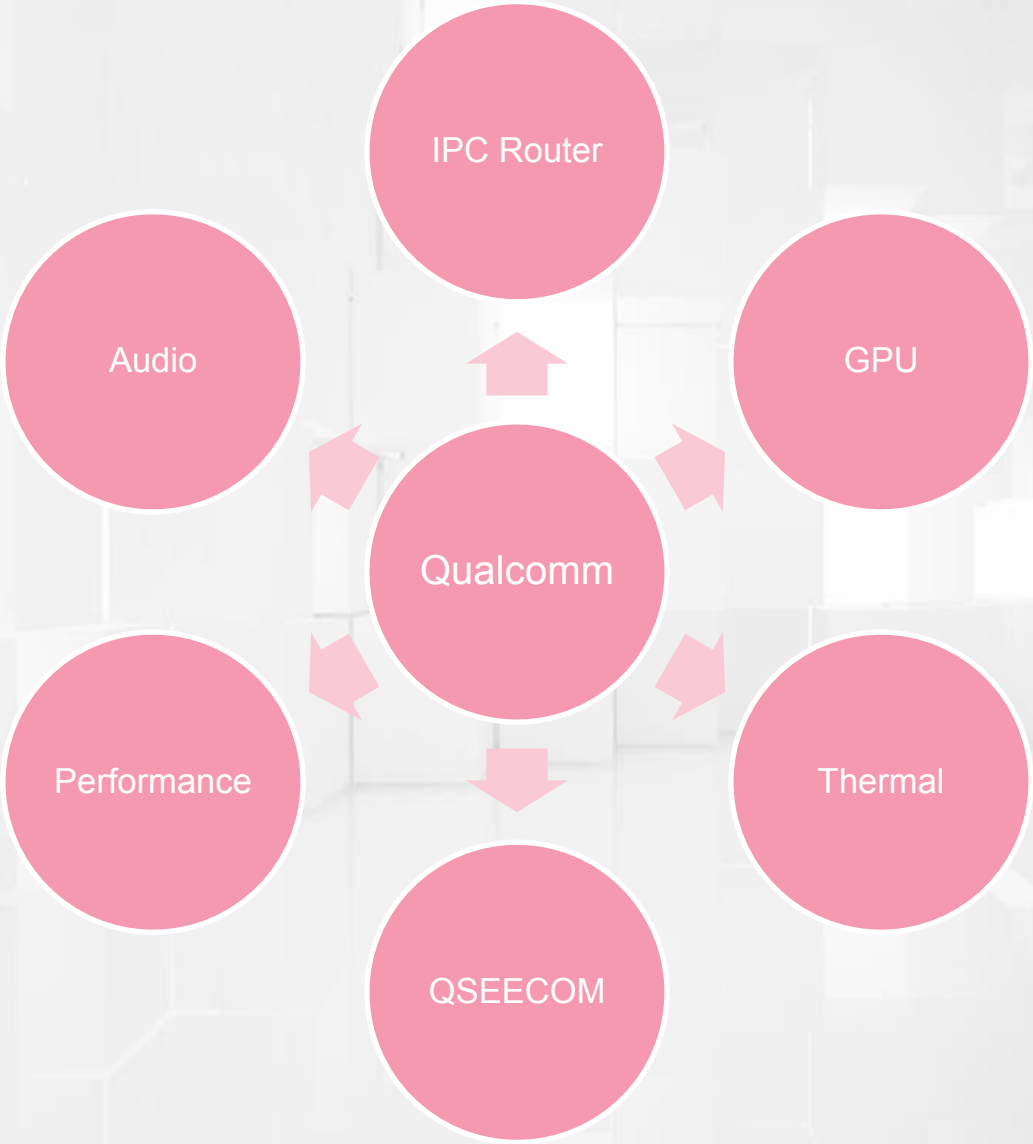
ADAM DONENFELD

- Years of experience in research (both PC and mobile).
- Vulnerability assessment
- Vulnerability exploitation
- Senior security researcher at Check Point
- In meiner Freizeit, lerne ich Deutsch gern ☺

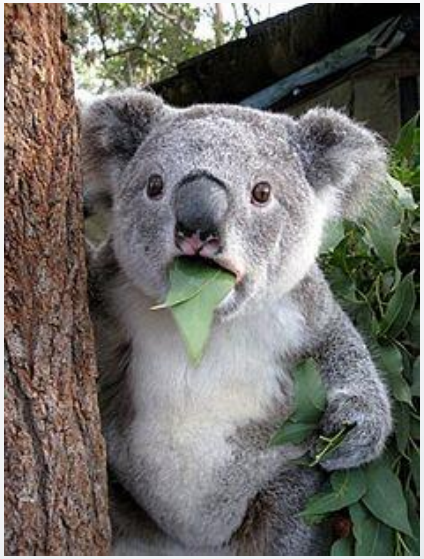
How Android gets to your device



Qualcomm’s chipset subsystems



The Rooting Zoo



ASHmenian Devil (ashmem vulnerability) CVE-2016-5340

- Qualcomm ‘expands’ ashmem for the GPU
  - Map ashmem to GPU
- Passing ashmem fd to map

ASHmenian devil (ashmem vulnerability)

```
int get_ashmem_file(int fd,
 struct file **filp,
  struct file **vm_file,
    unsigned long *len)
{
    int ret = -1;
    struct ashmem_area *asma;
    struct file *file = fget(fd);
    if (is_ashmem_file(file)) {
        asma = file->private_data;
        *filp = file;
        *vm_file = asma->file;
        *len = asma->size;
        ret = 0;
    } else {
        fput(file);
    }
    return ret;
}
```

ASHmenian devil (ashmem vulnerability)

- Qualcomm ‘expands’ ashmem for the GPU
  - Map ashmem to GPU
- Passing ashmem fd to map

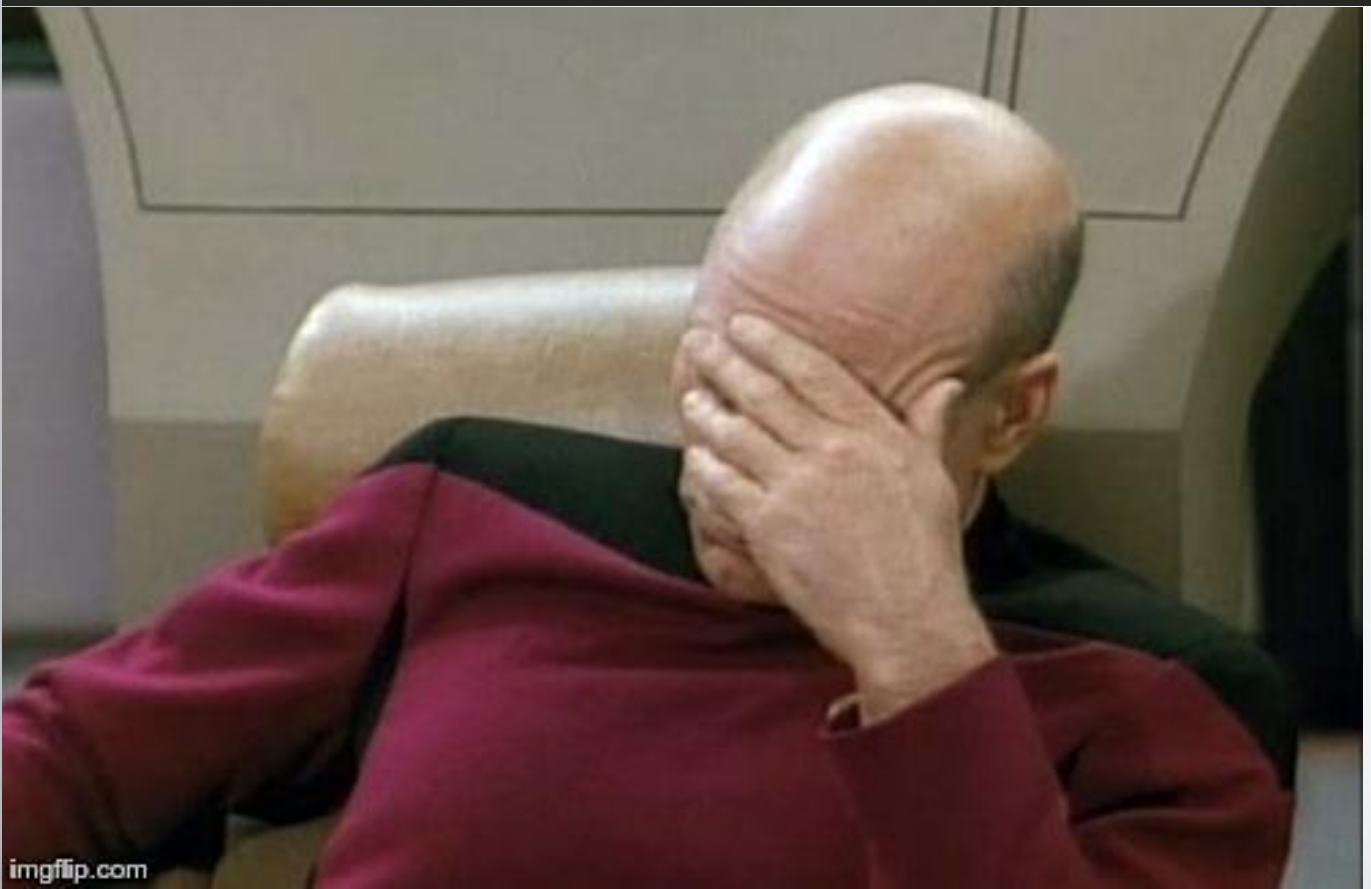
- Is our fd an ashmem file descriptor?

ASHmenian devil (ashmem vulnerability)

```
struct some_file_struct *some_file_fdget(int fd)
{
    struct file *file = fget(fd);

    if (file == NULL)
        return NULL;

    /* fd type check */
    if (file->f_op != &some_file_fops)
        goto err;

    return file->private_data;

err:
    fput(file);
    return NULL;
}
```

ASHmenian devil (ashmem vulnerability)

```
static int is_ashmem_file(struct file *file)
{
    char fname[256], *name;
    name = dentry_path(file->f_dentry, fname, 256);
    return strcmp(name, "/ashmem") ? 0 : 1; /* Oh my god */
}
```



ASHmenian devil – PoC

- Filename on root path == “ashmem”

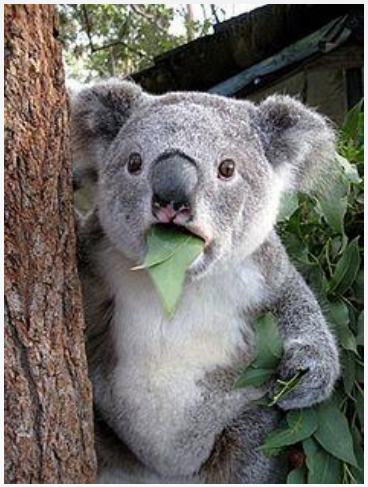
- / is read-only ☹
- /sdcard is a symlink

- Obb (Opaque Binary Blob)

ASHmenian devil – PoC

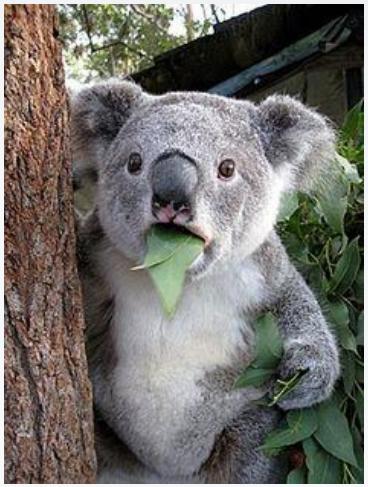
- Create an OBB
  - With “ashmem” in it’s root directory
- Mount the OBB
- Map “ashmem” memory to the GPU
  - Pass a fd to your fake ashmem file

Qualaroot (IPC Router vulnerability) CVE-2016-2059



- Qualcomm's IPC router
- Special socket family
  - *AF_MSM_IPC* (27)
- Unique features
  - "Whitelist" for services that are permitted to communicate
  - Everyone gets an "address" for communication
  - Creation\destruction can be monitored by anyone
- Requires no permission ☺

Qualaroot



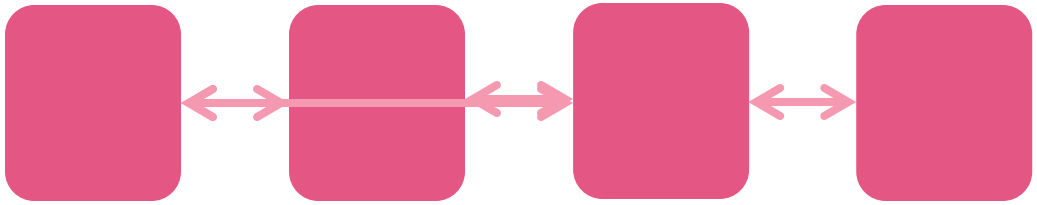
- AF_MSM_IPC socket types
  - *CLIENT_PORT*
  - *SERVER_PORT*
  - *IRSC_PORT*
  - *CONTROL_PORT*
    - Conversion via IPC_ROUTER_IOCTL_BIND_CONTROL_PORT
- Each new socket is a *CLIENT_PORT* socket

Qualaroot

```
static int msm_ipc_router_ioctl(
    struct socket *sock,
    unsigned int cmd,
    unsigned long arg)
{
    struct sock *sk = sock->sk;
    struct msm_ipc_port *port_ptr;

    lock_sock(sk);
    port_ptr = msm_ipc_sk_port(sock->sk);
    switch (cmd) {
    ....
    case IPC_ROUTER_IOCTL_BIND_CONTROL_PORT:
        msm_ipc_router_bind_control_port(
            port_ptr);
    ....
    }
    release_sock(sk);
    ....
}
```

```
int msm_ipc_router_bind_control_port(struct msm_ipc_port *port_ptr)
{
    if (!port_ptr)
        return -EINVAL;

    /* Lock clients list */
    down_write(&local_ports_lock_lhc2);

    /* Remove our socket from its current list */
    list_del(&port_ptr->list);

    /* Unlock clients list */
    up_write(&local_ports_lock_lhc2);

    /* Lock control ports list */
    down_write(&control_ports_lock_lha5);

    /* Add our socket to the control ports list */
    list_add_tail(&port_ptr->list, &control_ports);

    /* Unlock control ports list */
    up_write(&control_ports_lock_lha5);

    return 0;
}
```

Client list

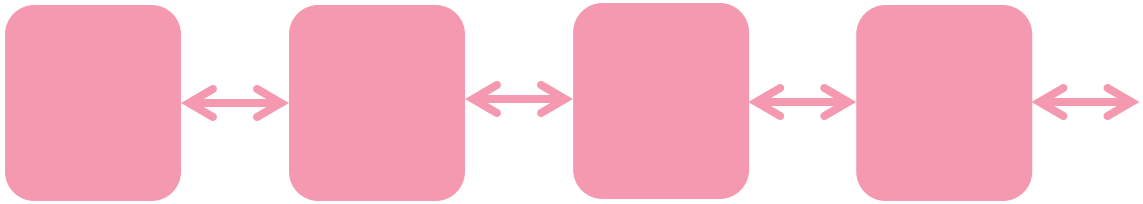


Client list

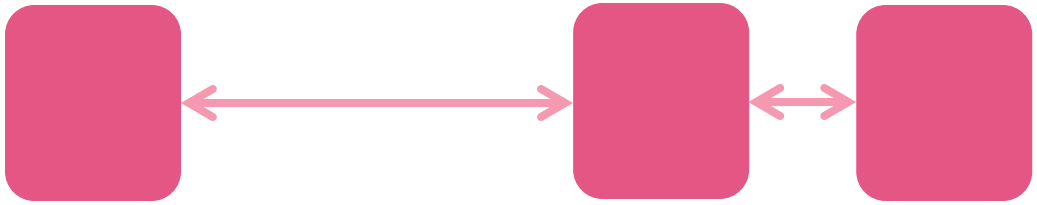

```
down_write(&local_ports_lock_lhc2);
list_del(&port_ptr->list);
up_write(&local_ports_lock_lhc2);
down_write(&control_ports_lock_lha5);
list_add_tail(&port_ptr->list, &control_ports);
up_write(&control_ports_lock_lha5);
```

Control list

Control list



Client list

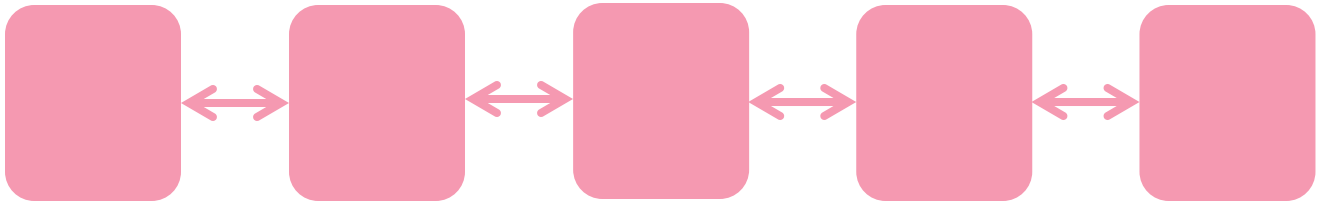


Client list

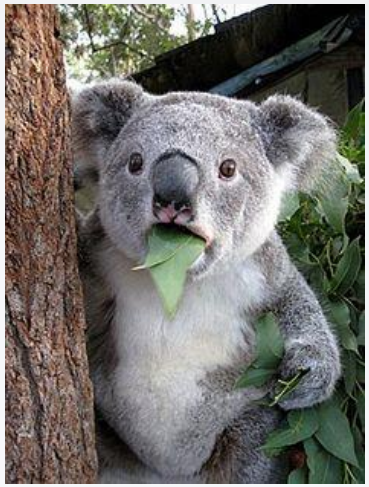

```
down_write(&local_ports_lock_lhc2);
list_del(&port_ptr->list);
up_write(&local_ports_lock_lhc2);
down_write(&control_ports_lock_lha5);
list_add_tail(&port_ptr->list, &control_ports);
up_write(&control_ports_lock_lha5);
```

Control list

Control list

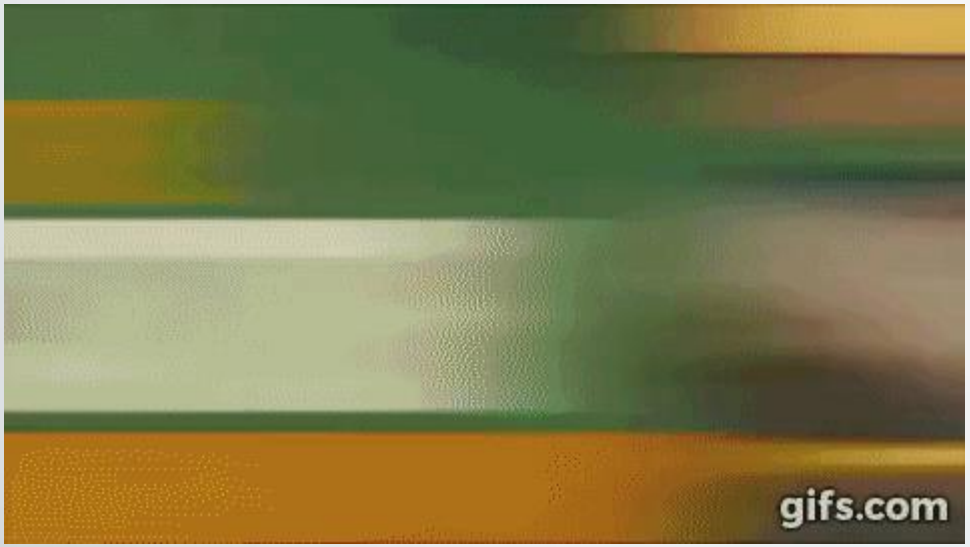


Qualaroot – the vulnerability

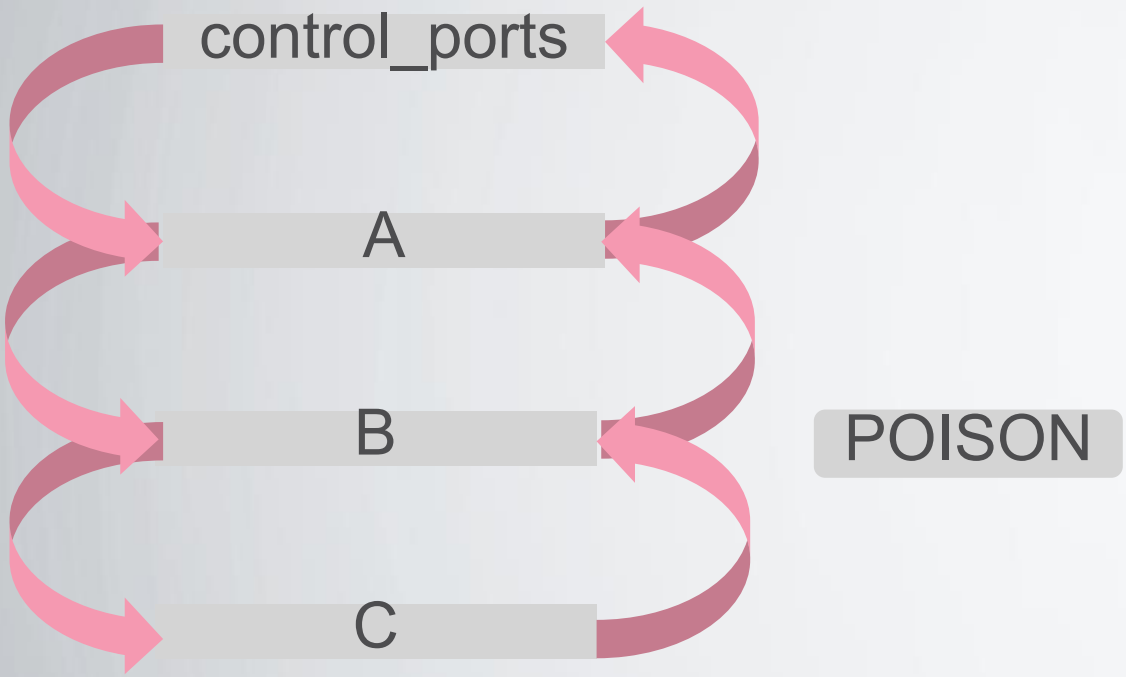


- *control_ports* list is modified without lock!
- Deleting 2 objects from *control_ports* simultaneously!

RACE CONDITION

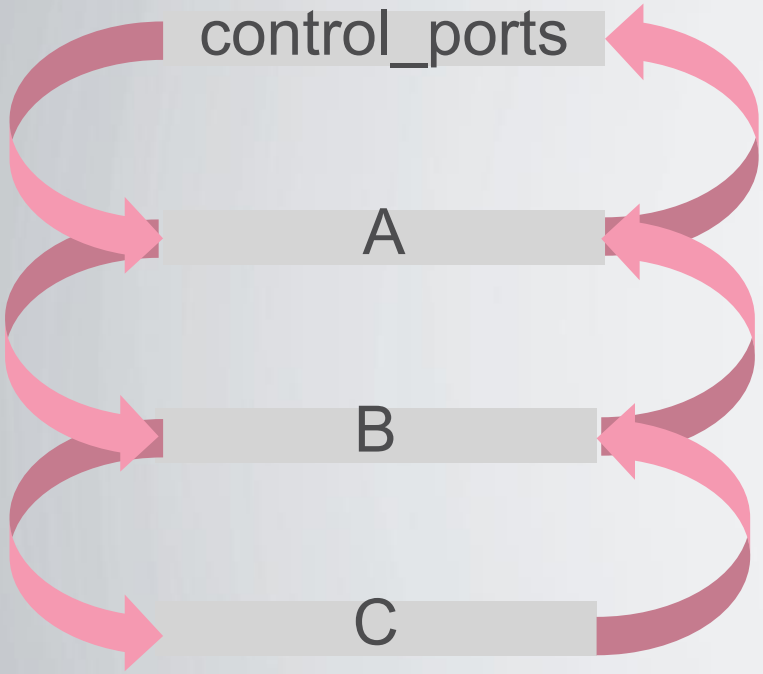


Qualaroot - implementation




```
static inline void list_del(
    struct list_head *entry)
{
    next = entry->next;
    prev = entry->prev;
    next->prev = prev;
    prev->next = next;
    entry->next = LIST_POISON1;
    entry->prev = LIST_POISON2;
}
```

Qualaroot - implementation



POISON

```
static inline void list_del(
    struct list_head *entry)
{
    next = entry->next;
    prev = entry->prev;
    next->prev = prev;
    prev->next = next;
    entry->next = LIST_POISON1;
    entry->prev = LIST_POISON2;
}
```

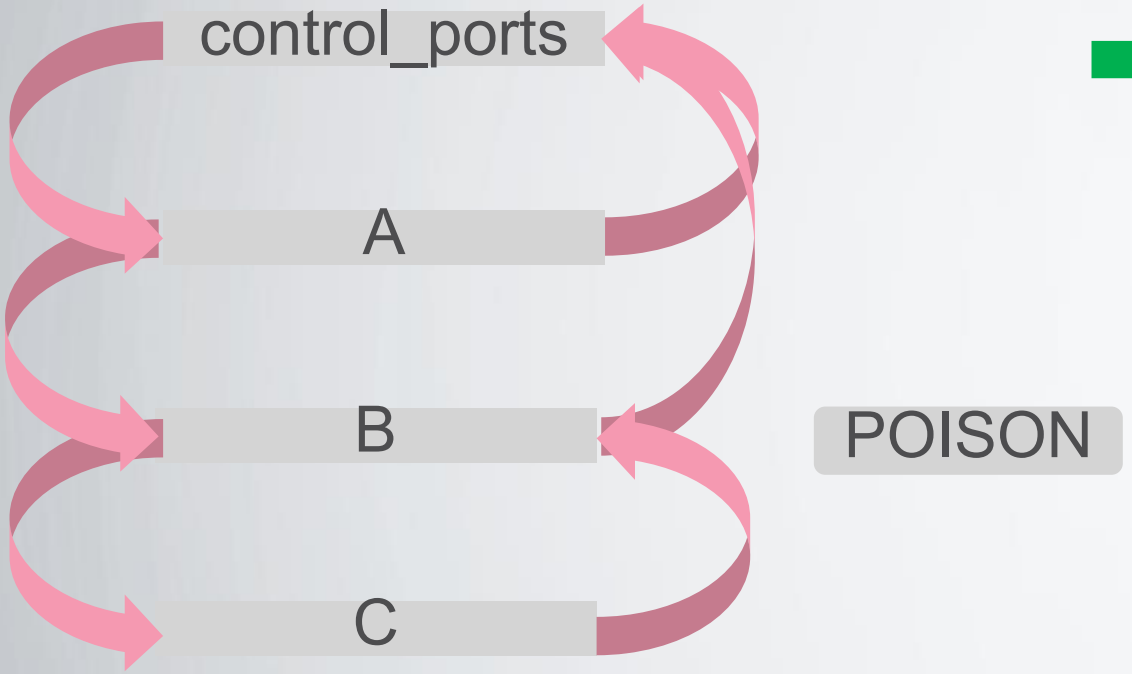
entry = A

next = B

prev = control_ports

B->prev = control_ports

Qualaroot - implementation

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    entry->next = LIST_POISON1;
    entry->prev = LIST_POISON2;
}
```

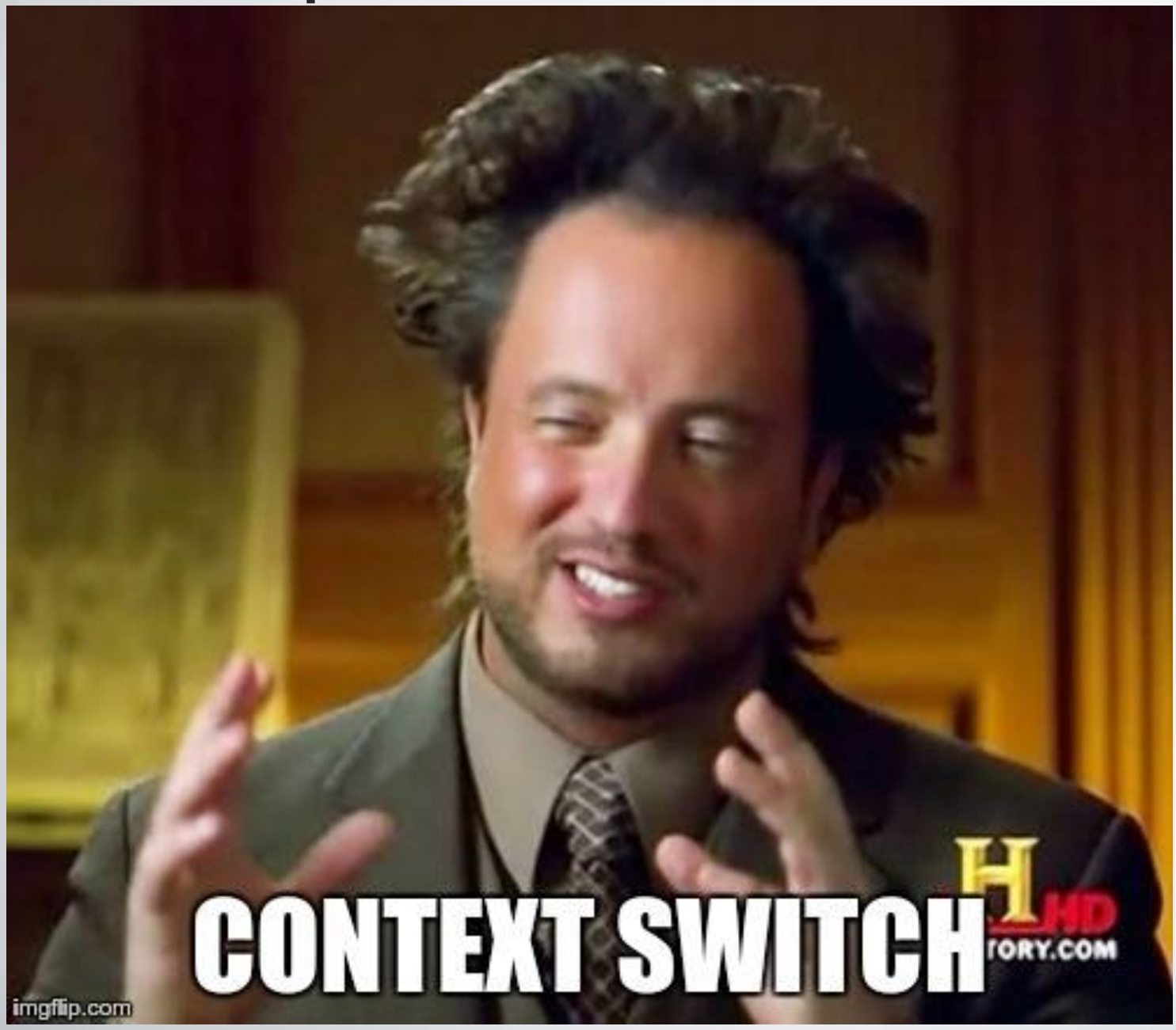
entry = A

Next = B

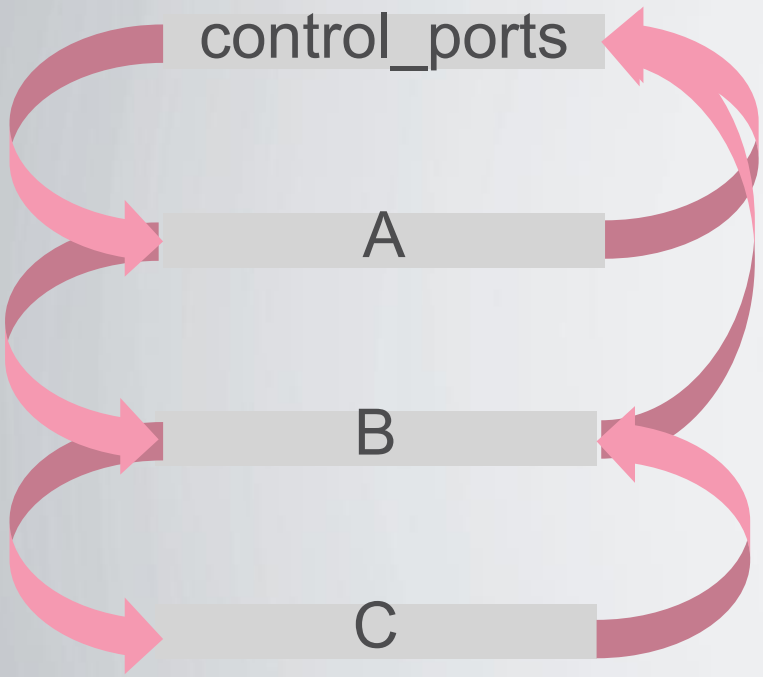
Prev = control_ports

B->prev = control_ports

Qualaroot - implementation



Qualaroot - implementation



POISON

```
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{
    next = entry->next;
    prev = entry->prev;
    next->prev = prev;
    prev->next = next;
    entry->next = LIST_POISON1;
    entry->prev = LIST_POISON2;
}
```

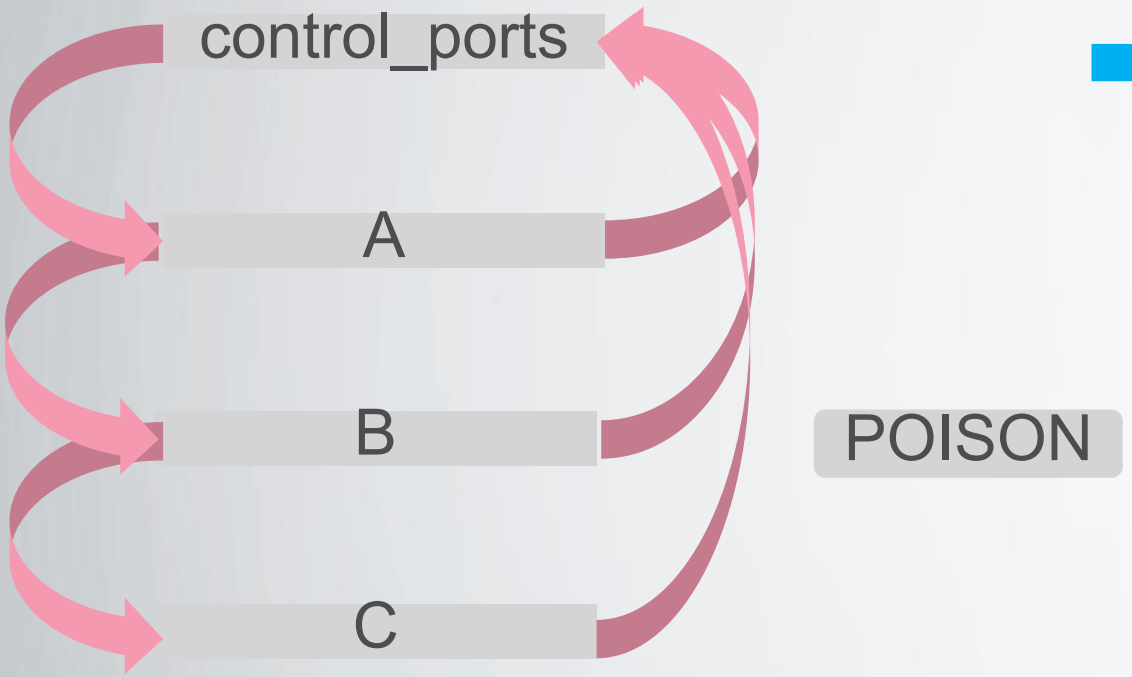
entry = B

Next = C

Prev = control_ports

C->prev = control_ports

Qualaroot - implementation




```
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    struct list_head *entry)
{
    next = entry->next;
    prev = entry->prev;
    next->prev = prev;
    prev->next = next;
    entry->next = LIST_POISON1;
    entry->prev = LIST_POISON2;
}
```

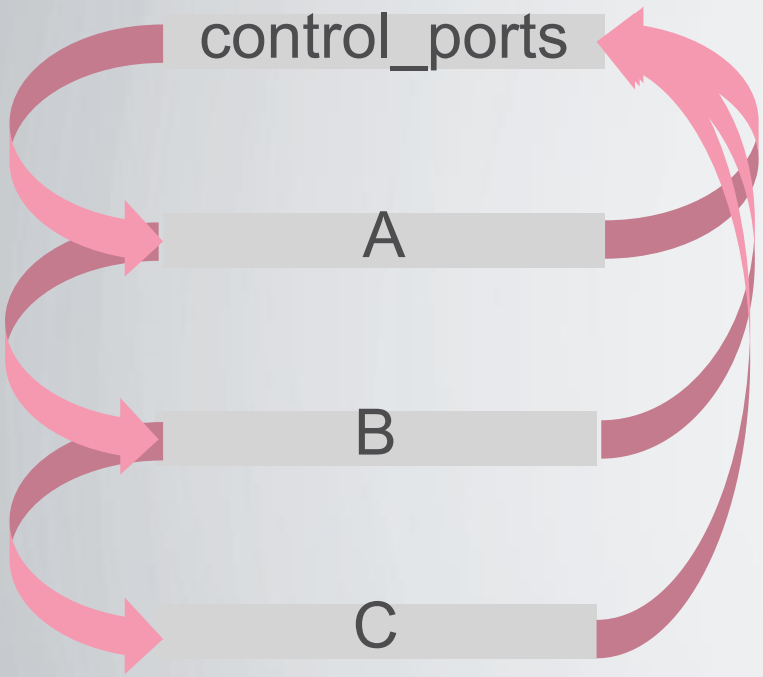
entry = B

Next = C

Prev = control_ports

C->prev = control_ports

Qualaroot - implementation



POISON

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    prev->next = next;
    entry->next = LIST_POISON1;
    entry->prev = LIST_POISON2;
}
```

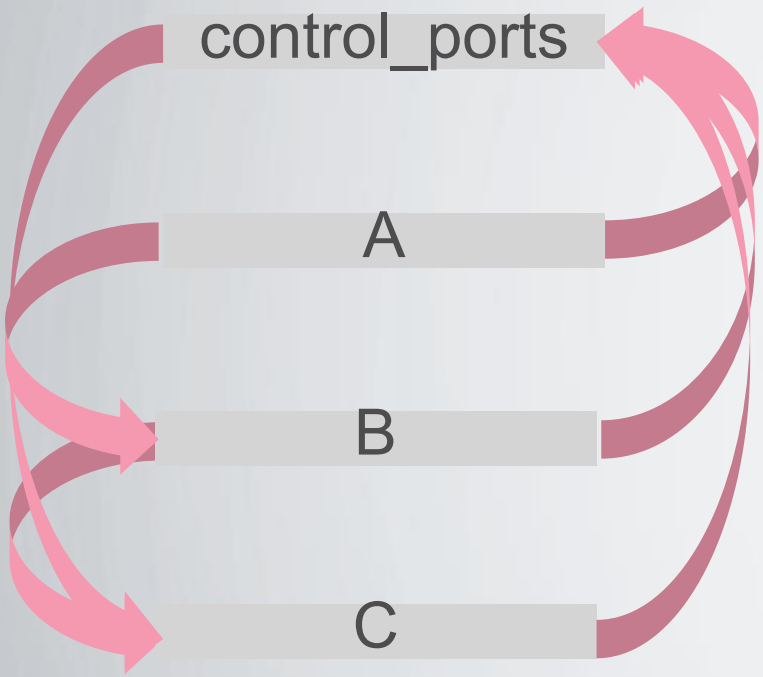
entry = B

Next = C

Prev = control_ports

control_ports->next = C

Qualaroot - implementation



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}
```

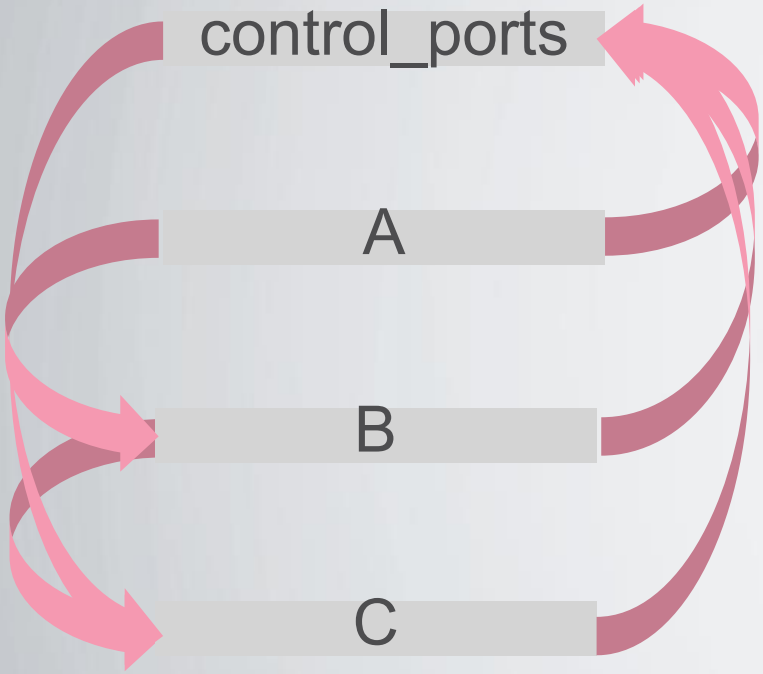
entry = B

Next = C

Prev = control_ports

control_ports->next = C

Qualaroot - implementation



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    entry->next = LIST_POISON1;
    entry->prev = LIST_POISON2;
}
```

entry = B

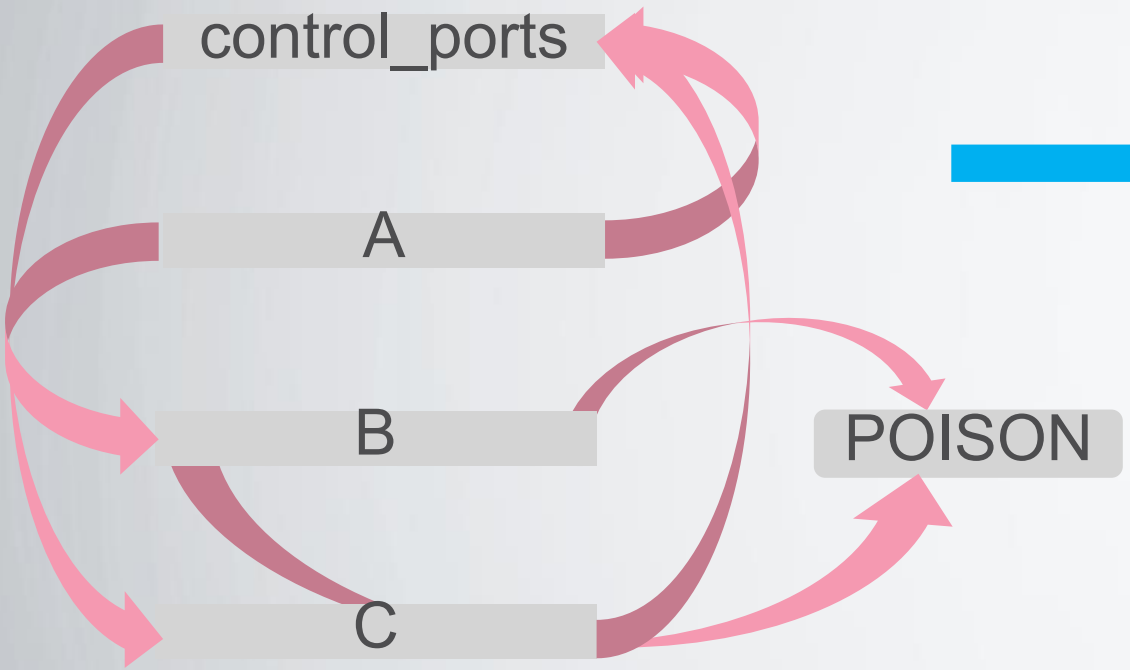
Next = C

Prev = control_ports

entry is freed

next = prev = LIST_POISON

Qualaroot - implementation

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entry = B

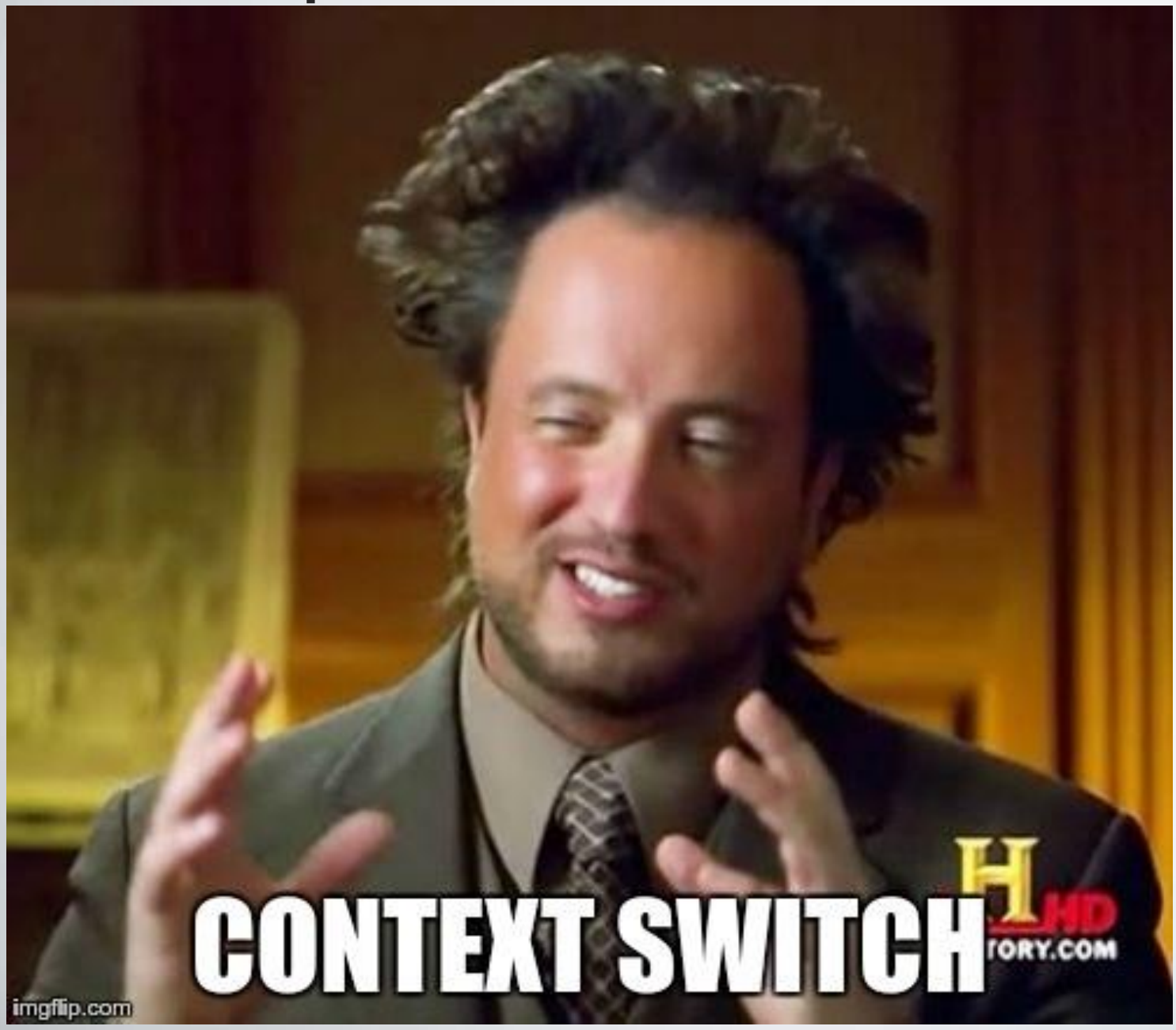
Next = C

Prev = control_ports

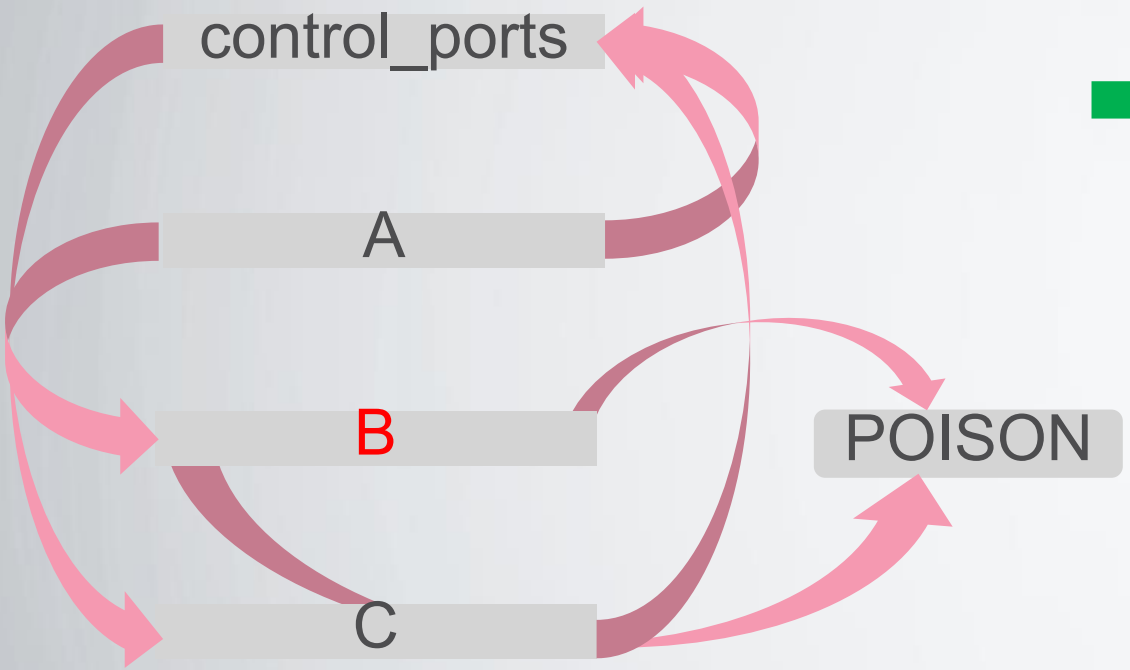
entry is freed

next = prev = LIST_POISON

Qualaroot - implementation



Qualaroot - implementation

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    entry->next = LIST_POISON1;
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}
```

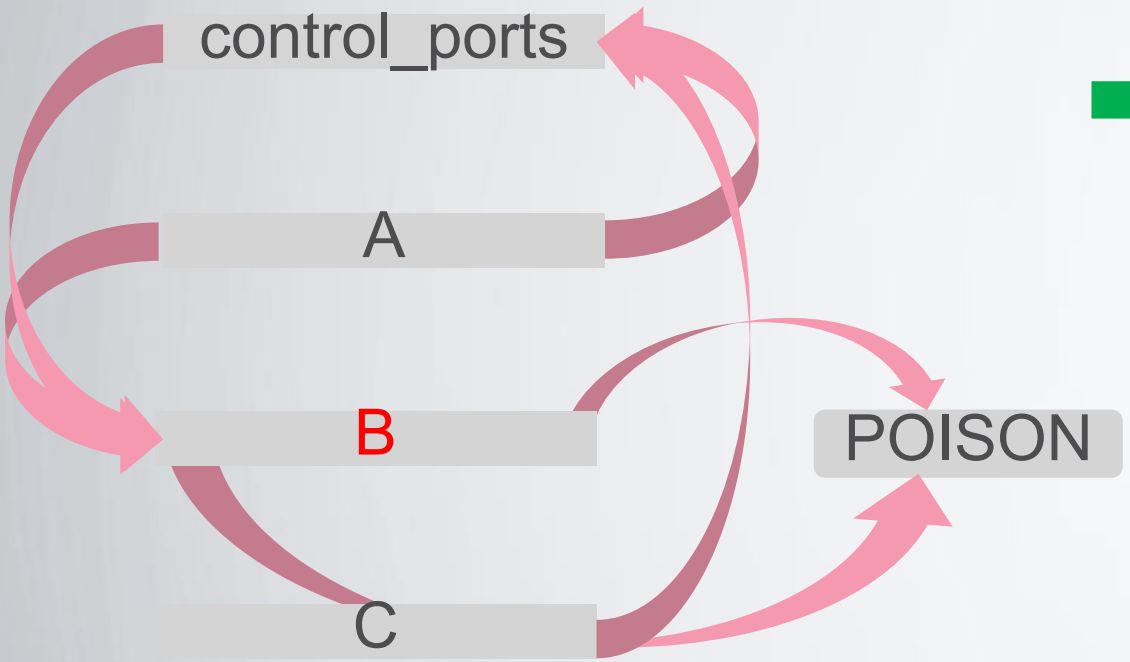
entry = A

Next = B

Prev = control_ports

control_ports->next = B

Qualaroot - implementation

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    entry->next = LIST_POISON1;
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}
```

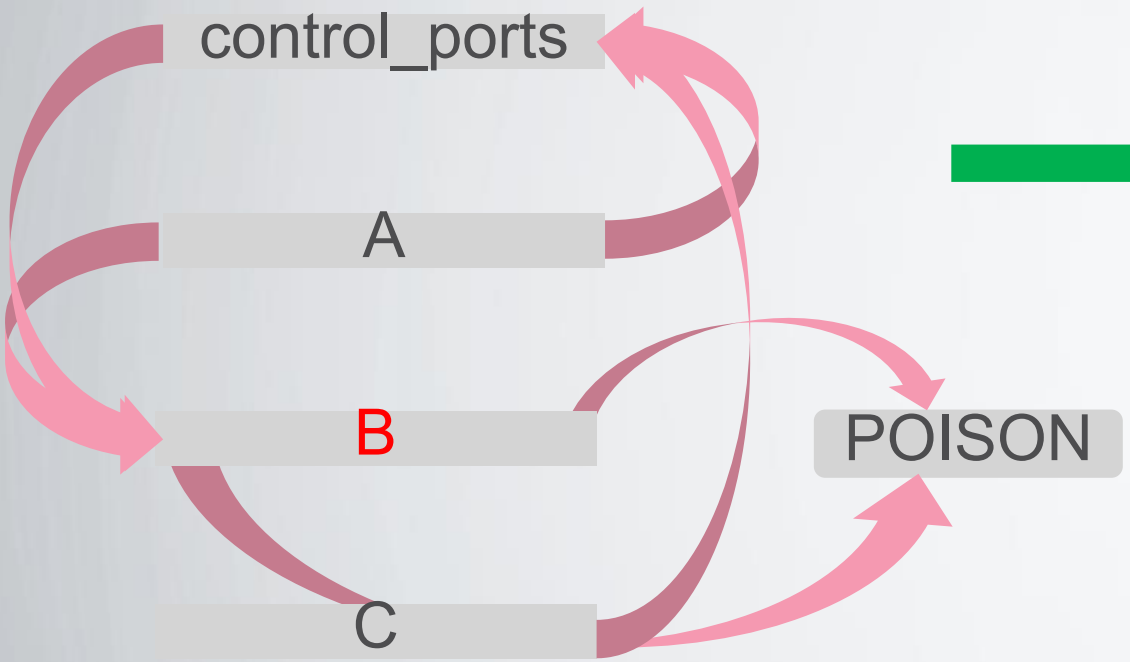
entry = A

Next = B

Prev = control_ports

control_ports->next = B

Qualaroot - implementation

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    next->prev = prev;
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}
```

entry = A

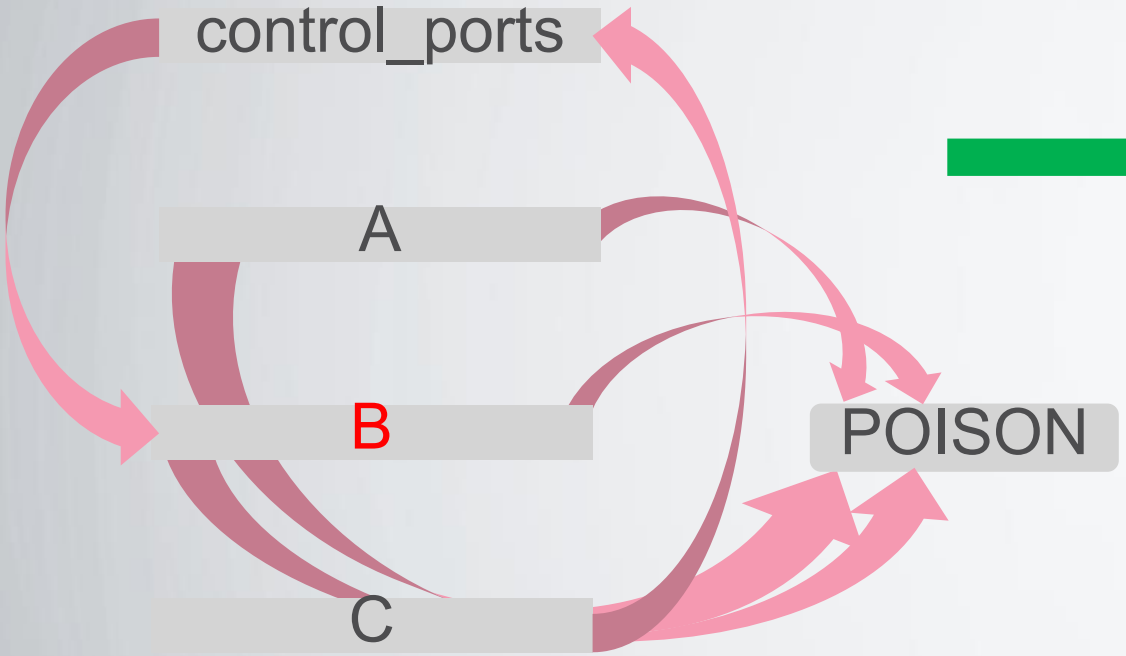
Next = B

Prev = control_ports

entry is freed

next = prev = LIST_POISON

Qualaroot - implementation

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}
```

entry = A

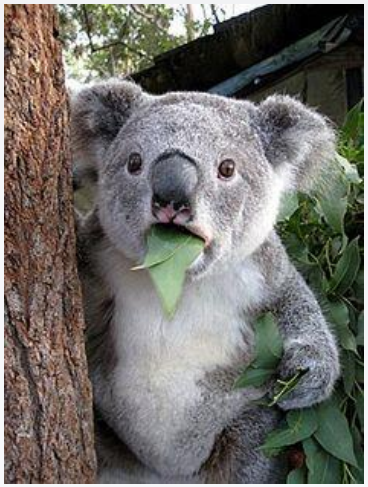
Next = B

Prev = control_ports

entry is freed

next = prev = LIST_POISON

Qualaroot - implementation

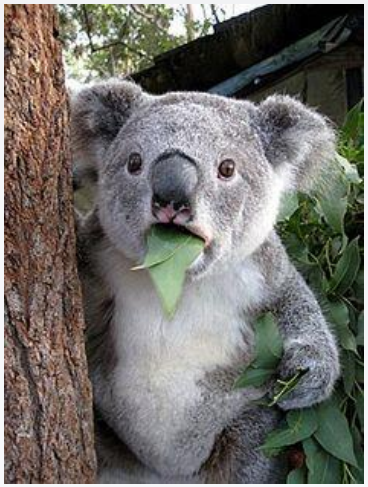


- Two following objects are deleted
  - Simultaneously!
- *control_ports* points to a **FREE** data
  - *LIST_POISON* ~~worked~~
    - No longer mappable
  - Spraying *af_unix_dgram* works
- Iterations on *control_ports*?
  - Just close a client_port!
    - Notification to all control_ports with *post_pkt_to_port*

Qualaroot - implementation

```
static int post_pkt_to_port(struct msm_ipc_port *UAF_OBJECT,
                            struct rr_packet *pkt, int clone)
{
    struct rr_packet *temp_pkt = pkt;
    void (*notify)(unsigned event, void *oob_data,
                   size_t oob_data_len, void *priv);
    void (*data_ready)(struct sock * sk, int bytes) = NULL;
    struct sock *sk;

    mutex_lock(&UAF_OBJECT->port_rx_q_lock_lhc3);
    __pm_stay_awake(UAF_OBJECT->port_rx_ws);
    list_add_tail(&temp_pkt->list, &UAF_OBJECT->port_rx_q);
    wake_up(&UAF_OBJECT->port_rx_wait_q);
    notify = UAF_OBJECT->notify;
    sk = (struct sock *)UAF_OBJECT->endpoint;
    if (sk) {
        read_lock(&sk->sk_callback_lock);
        data_ready = sk->sk_data_ready;
        read_unlock(&sk->sk_callback_lock);
    }
    mutex_unlock(&UAF_OBJECT->port_rx_q_lock_lhc3);
    if (notify)
        notify(pkt->hdr.type, NULL, 0, UAF_OBJECT->priv);
    else if (sk && data_ready)
        data_ready(sk, pkt->hdr.size);

    return 0;
}
```

Qualaroot - implementation

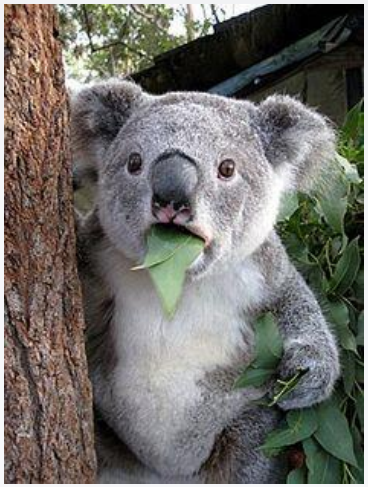


- *wake_up* function
  - Macros to *__wake_up_common*

Qualaroot - implementation

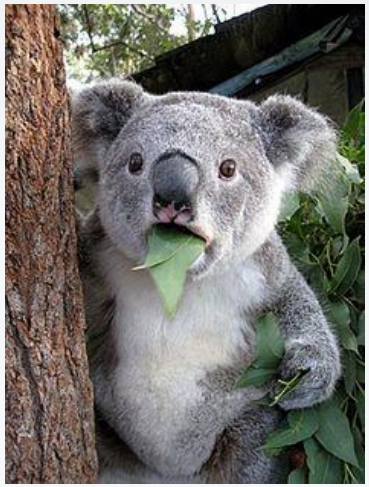
```
static void __wake_up_common(
        wait_queue_head_t *q,
        .......)
{
        wait_queue_t *curr, *next;

        list_for_each_entry_safe(curr, next,
         &q->task_list, task_list) {
                ...
                if (curr->func(curr, mode,
                 wake_flags, key))
                        break;
        }
}
```

Qualaroot - implementation

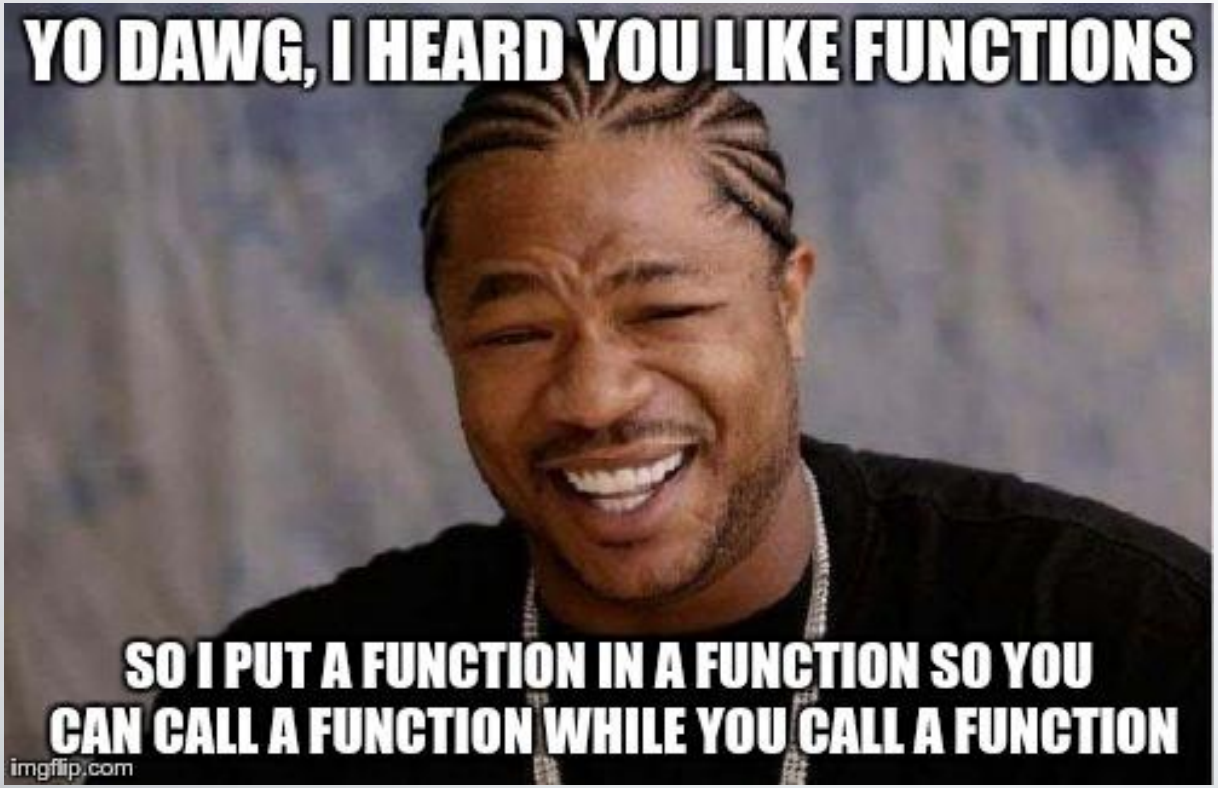


- *wake_up* function
  - Macros to *__wake_up_common*
- New primitive!
  - Call to function with first controllable param!
  - We can’t control the *address* though ☹
- *Not good enough for commit_creds…*

Qualaroot - implementation



- Upgrade primitives
- Find a function that can call an arbitrary function with *address-controlled* parameters

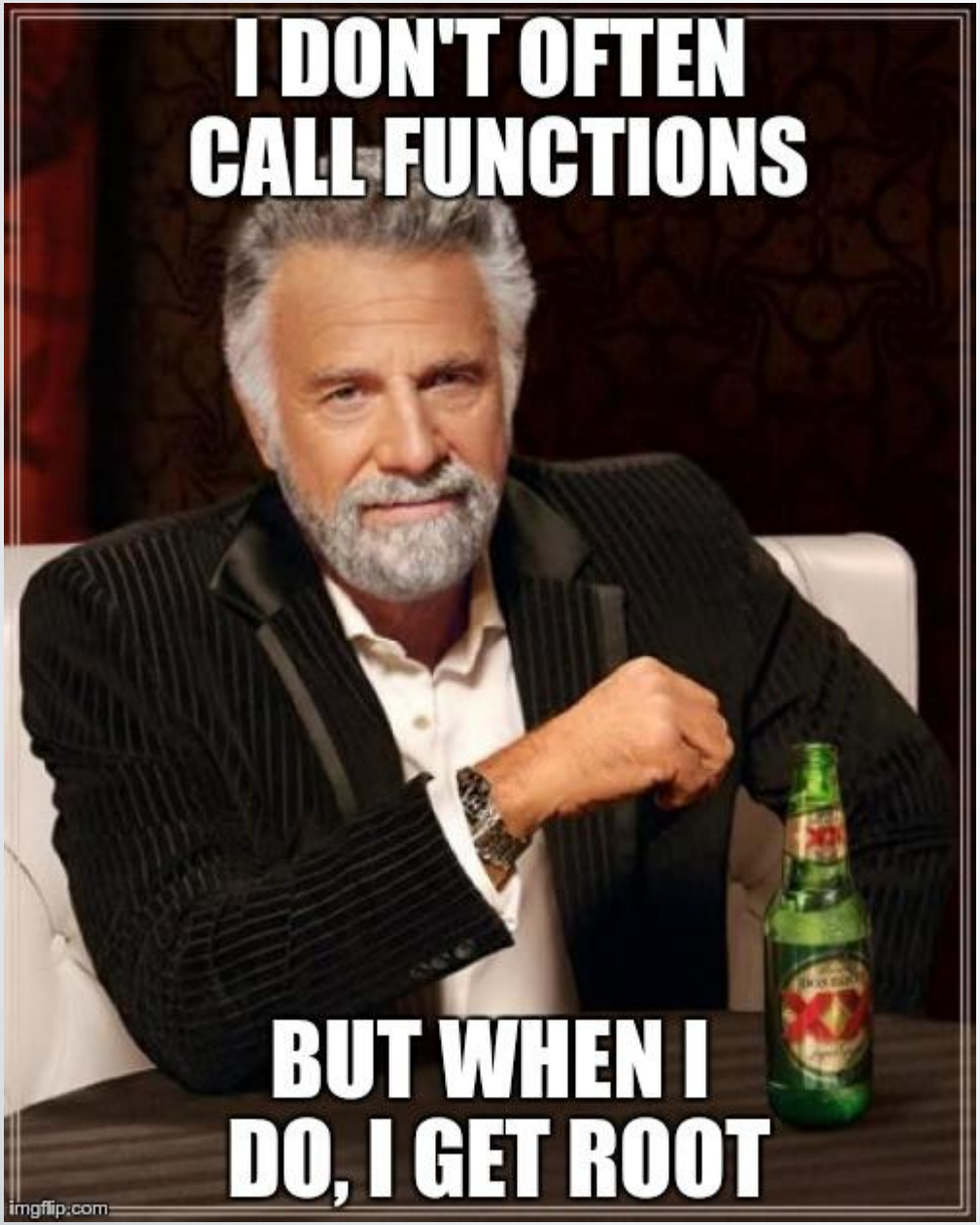


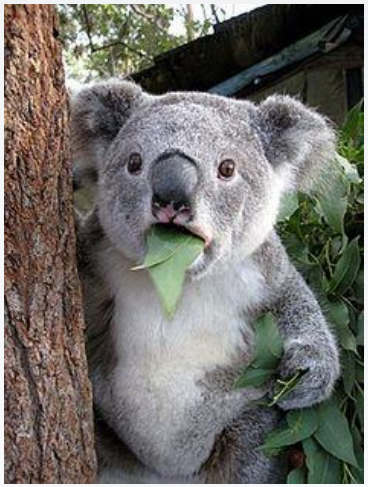
Qualaroot - implementation

- *usb_read_done_work_fn* receives a function pointer and a function argument!

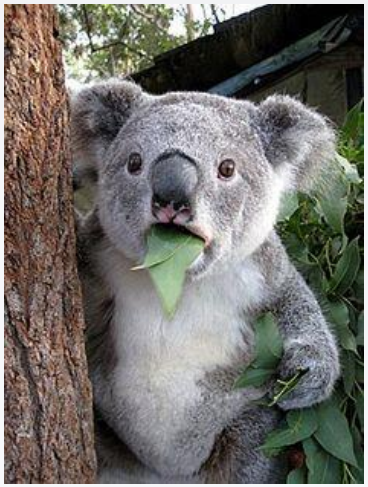
```
static void usb_read_done_work_fn(
    struct work_struct *work)
{
    struct diag_request *req = NULL;
    struct diag_usb_info *ch = container_of(
        work, struct diag_usb_info,
        read_done_work);
    ...
    req = ch->read_ptr;
    ...
    ch->ops->read_done(req->buf,
        req->actual,
        ch->ctxt);
}
```

Qualaroot - implementation





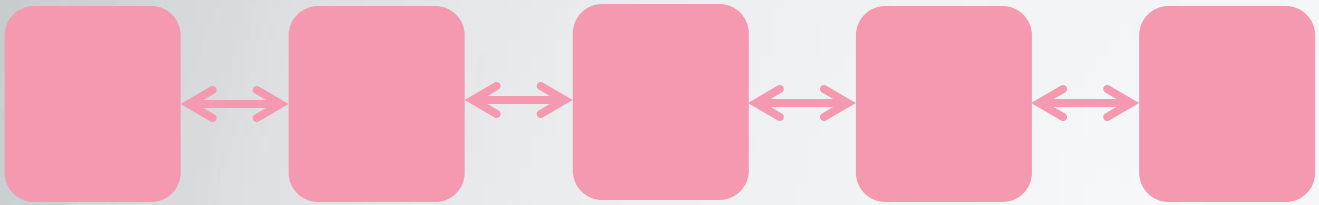
Qualaroot - implementation

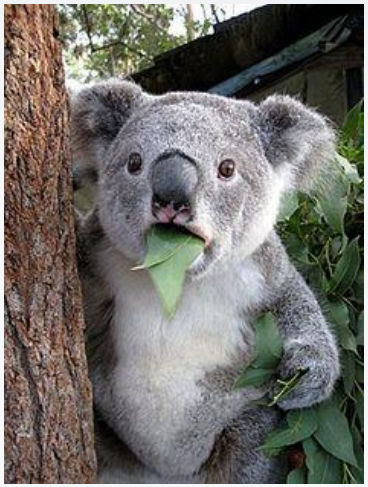


- Chain function calls
  - __wake_up_common
    - *usb_read_done_work_fn*
      - any function

```
static void __wake_up_common(
    wait_queue_head_t *q,
    .......)
{
    wait_queue_t *curr, *next;

    list_for_each_entry_safe(curr, next,
     &q->task_list, task_list) {
        ...
        if (curr->func(curr, mode,
         wake_flags, key))
            break;
    }
}
```

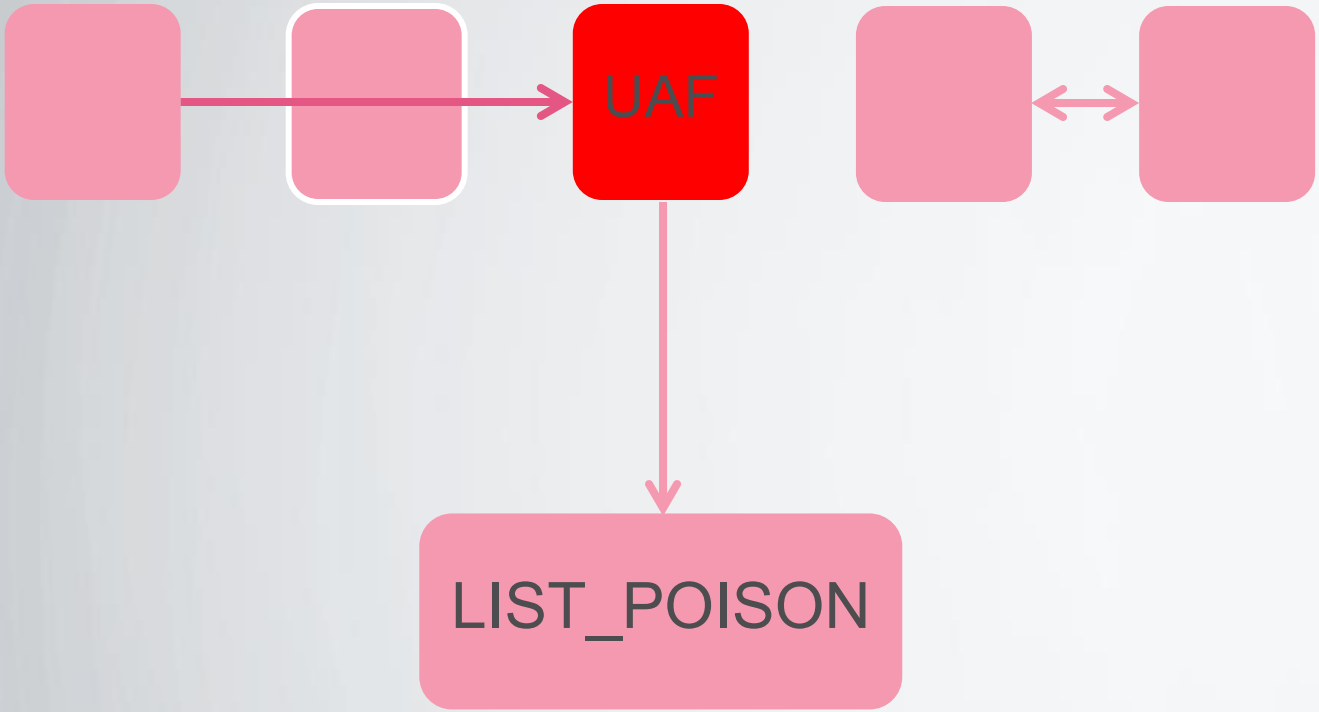
Qualaroot – Exploitation flow

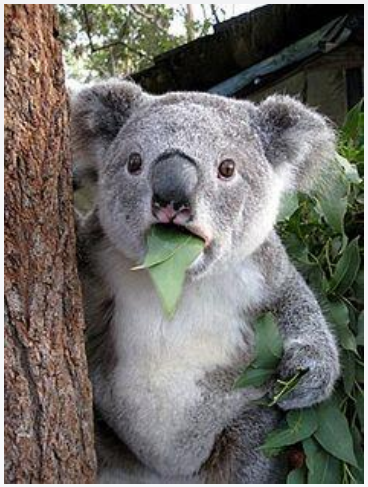




Create UAF situation using the vulnerability

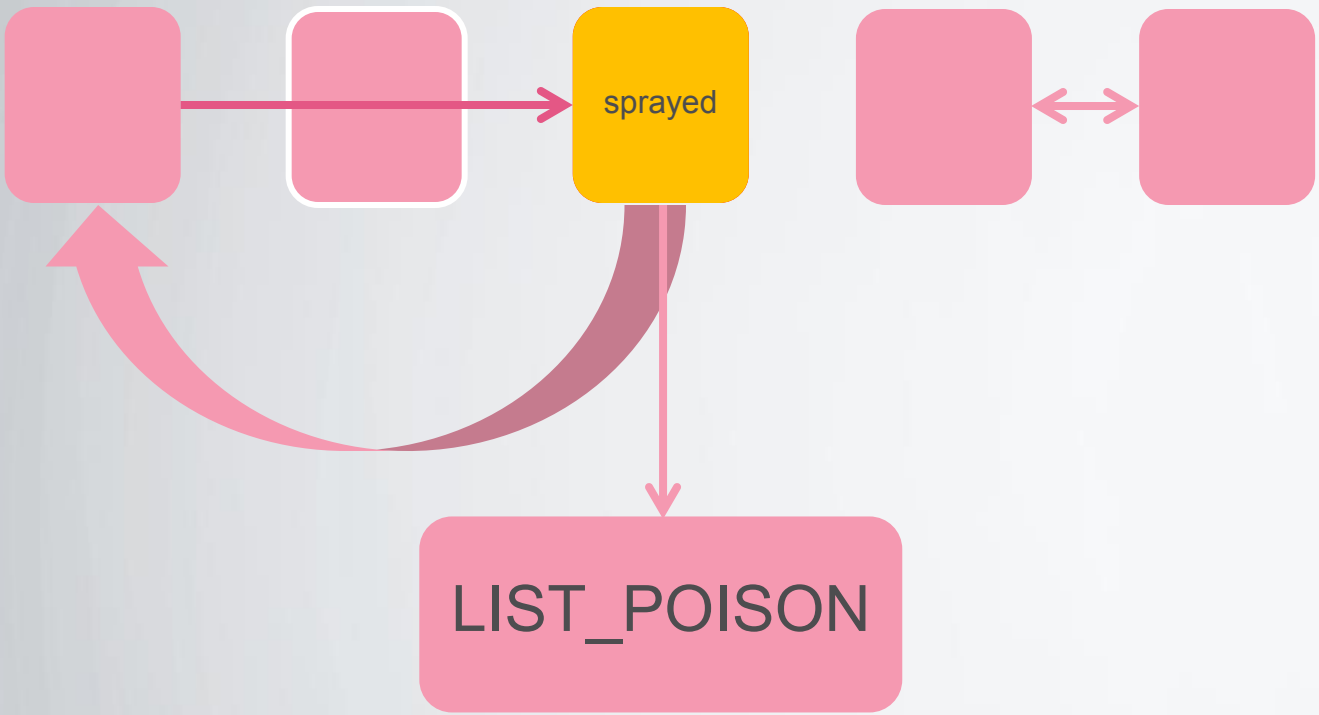
Qualaroot – Exploitation flow

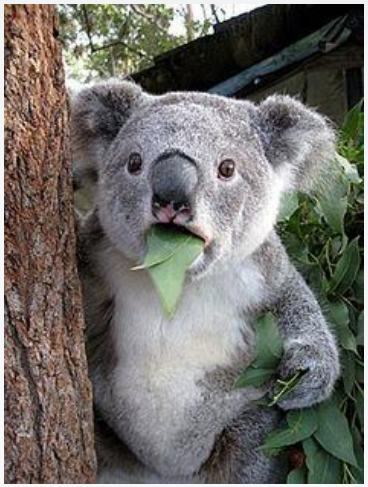




Spray af_unix_dgrams to catch the UAF

Qualaroot – Exploitation flow



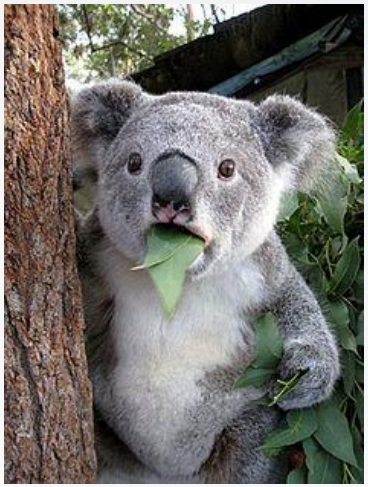


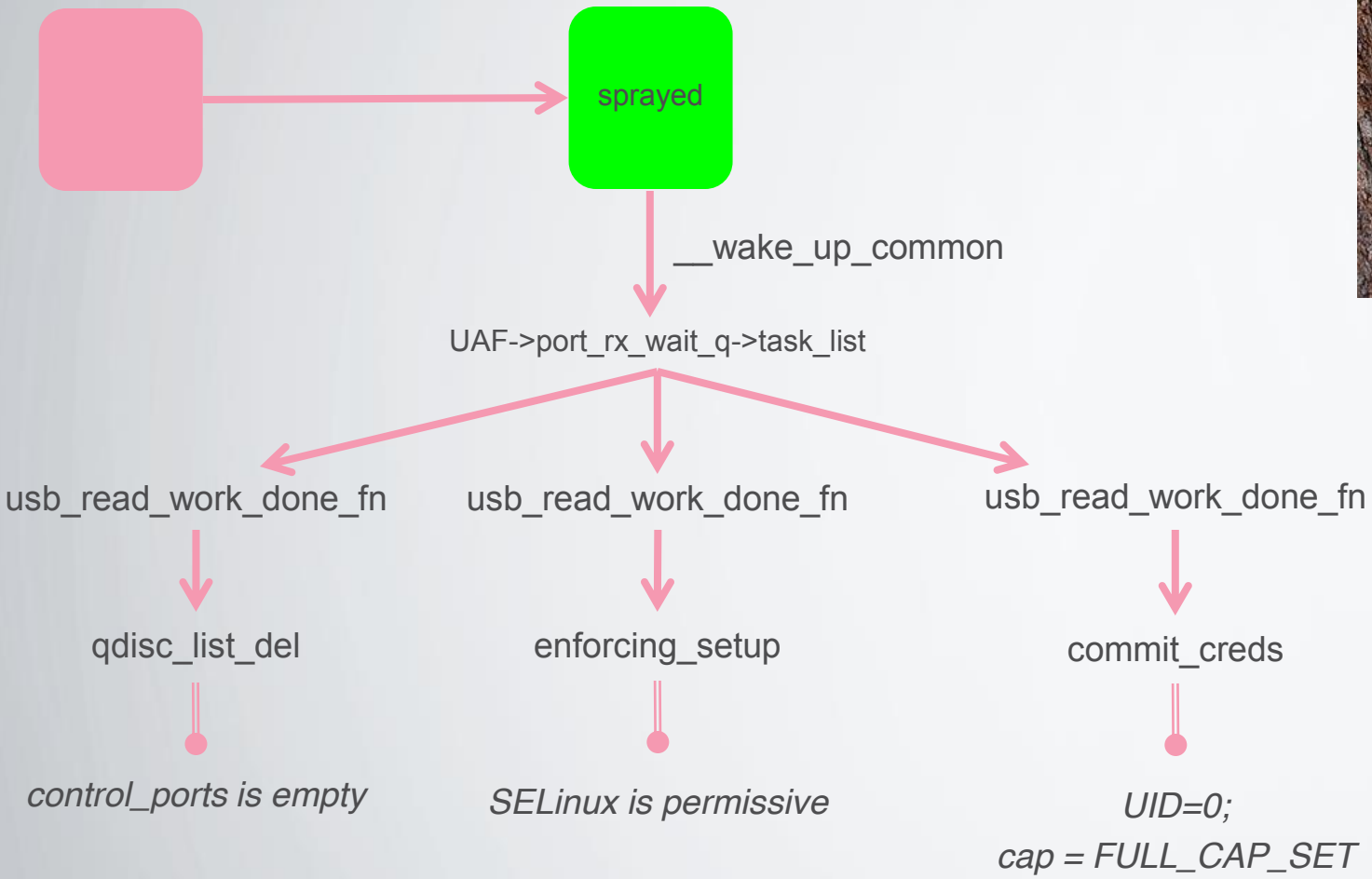
Spray af_unix_gc_list to catch the UAF

Trigger the vulnerability

Trix gc_list to catch

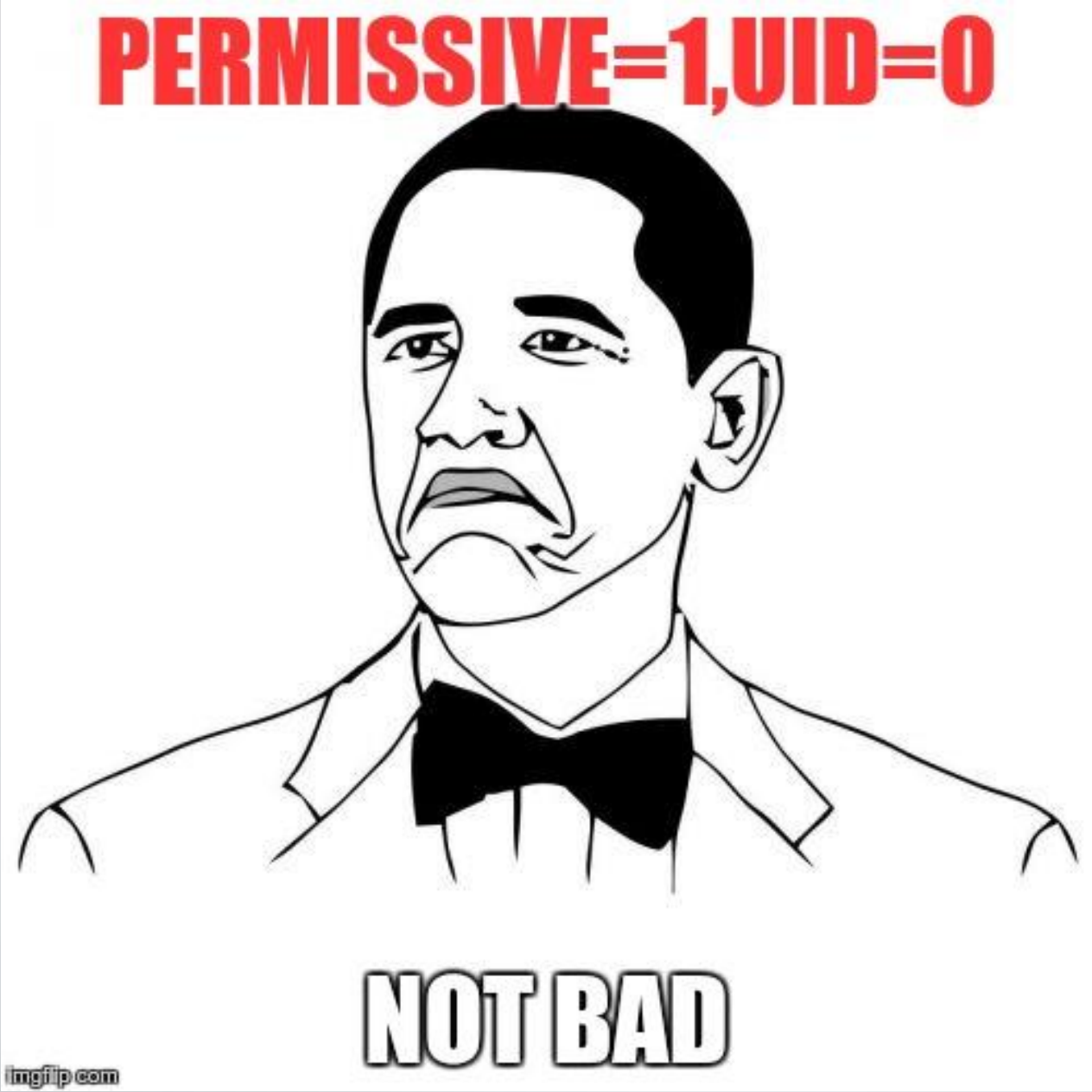
Qualaroot – Exploitation flow





Trigger list iteration

Qualaroot



Disclosure

Google

#3 ad...@lacoon.com

Hey,

Attached is a full exploit for Nexus 6 devices running Android Marshmallow, build MRA58K.
The binary itself should be run from an application context, i.e. from an APK, (otherwise SELinux prevents the exploitation) and no extra privileges are required in order to successfully exploit the vulnerability.
Please note that on other Qualcomm based devices or versions it might still cause a kernel panic, however the current exploitation requires a modification for each device.

The exploit currently sets SELinux to permissive mode, grants root privileges to the process, modifies the system partition to read-write and writes a suid file there named "zugang" (full path /system/zugang).
The payload can easily be changed in the function do_root, file qualroot.c.

If you wish to test the exploit without creating an extra APK for that, let me know, and I will supply you with an APK.

To build, extract the NDK using the make-standalone-toolchain.sh to the same directory with the qualroot exploit, and run build_and_strip.sh.

---

qualroot.tar.gz
8.6 KB Download

Delete

Project Member #4 qua...@google.com

Thanks Adam.

Qualcomm also notified us that they received this report as well and they have assigned an ID for it: QPSIIR-170.

Quan

Project Member #5 qua...@google.com

Hello,

Thank you for submitting this vulnerability report.
The engineering team has reviewed the issue and set the severity to Low.

For reference, the severity classification is documented here:
https://source.android.com/security/overview/updates-resources.html

Quan

Labels: Severity-Low Triaged-yes

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Check Point
SOFTWARE TECHNOLOGIES LTD.

Syncockaroot (syncsource vulnerability) CVE-2016-2503

- SyncSource objects are used to synchronize the activity between the GPU and the application.
- Can be created using IOCTLs to the GPU
  - IOCTL_KGSL_SYNCSOURCE_CREATE
  - IOCTL_KGSL_SYNCSOURCE_DESTROY
- Referenced further with the “idr” mechanism

Syncockaroot (syncsource vulnerability)

```
long kgsl_ioctl_syncsource_destroy(
    struct kgsl_device_private *dev_priv,
    unsigned int cmd, void *data)
{
    struct kgsl_syncsource_destroy *param = data;
    struct kgsl_syncsource *syncsource = NULL;

    syncsource = kgsl_syncsource_get(
        dev_priv->process_priv,
         param->id);

    /* put reference from syncsource creation */
    kgsl_syncsource_put(syncsource);
    /* put reference from getting the syncsource above */
    kgsl_syncsource_put(syncsource);
    return 0;
}
```

Any lock on “to-be-destroyed” object?

Syncockaroot - PoC

- Create a syncsource object
  - A predictable *idr* number is allocated
- Create 2 threads constantly destroying the same *idr* number
- Ref-count will be reduced to -1
  - Right after getting to zero, we can spray it

Use After Free ☺

KanGaroot (KGsl vulnerability) CVE-2016-2504

- GPU main module (kgsl-3d0)
- Map user memory to the GPU
  - IOCTL_KGSL_MAP_USER_MEM
  - IOCTL_KGSL_GPUMEM_FREE_ID
- Referenced by a **predictable** ID
  - IDR mechanism

KanGaroot (KGsl vulnerability)

```
static int
kgsl_mem_entry_attach_process(
    struct kgsl_mem_entry *entry,
    struct kgsl_device_private *dev_priv)
{
    ...
    id = idr_alloc(&process->mem_idr,
     entry, 1, 0, GFP_NOWAIT);
    ...
    ret = kgsl_mem_entry_track_gpuaddr(
        process, entry);
    ...

    ret = kgsl_mmu_map(pagetable,
     &entry->memdesc);
    if (ret)
        kgsl_mem_entry_detach_process(entry);
    return ret;
}
```

Should it already be accessible here?

KanGaroot (KGsl vulnerability)

- GPU main module (kgsl-3d0)
- Map user memory to the GPU
  - IOCTL_KGSL_MAP_USER_MEM
  - IOCTL_KGSL_GPUMEM_FREE_ID
- Referenced by a **predictable** ID
  - IDR mechanism
- No locks!
  - Free can be called before map ends

KanGaroot - PoC

- Map memory
- Save the IDR
  - We always get the first free IDR -- **predictable**
- Another thread frees the object with IDR
  - *Before the first thread returns from the IOCTL

UAF in kgsl_mem_entry_attach_process on 'entry' parameter

Suggestions/Special thanks

commit_creds for always being there for me

Absense of kASLR,
for not breaking me and commit_creds apart

SELinux, for being liberal,
letting anyone access mechanisms like Qualcomm's IPC

Check Point
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Thank You!