

Attacking Samsung Galaxy A* Boot Chain, and Beyond

Maxime Rossi Bellom
Damiano Melotti
Raphaël Neveu
Gabrielle Viala



Quarkslab

Who we are

- Maxime Rossi Bellom [@max_r_b](https://twitter.com/max_r_b)
- Security researcher and R&D leader @ Quarkslab
- Working on mobile and embedded software security

- Damiano Melotti [@DamianoMelotti](https://twitter.com/DamianoMelotti)
- Ex security researcher @ Quarkslab
- Interested in low-level mobile security and fuzzing

- Gabrielle Viala [@pwissenlit](https://twitter.com/pwissenlit)
- Security researcher and R&D leader @ Quarkslab
- Playing with low-level stuff

- Raphaël Neveu
- Security researcher @ Quarkslab
- Working on low-level mobile security

Dissecting the Modern Android Data Encryption Scheme

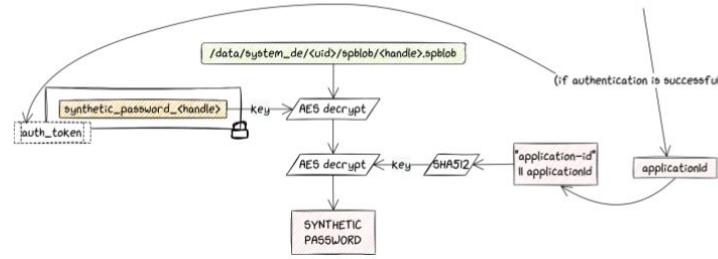
Maxime Rossi Bellom
Damiano Melotti



Quarkslab

Attacking SP derivation

- Need to target the TEE
- Two alternatives
 - Keymaster TA (accessing the first AES key)
 - Gatekeeper TA (validating credentials and minting auth tokens)



22

Bruteforce of the password

1. `pwd = generate new password`
2. `token = scrypt(pwd, R, N, P, Salt)`
3. `Application_id = token || Prehashed value`
4. `Key = SHA512("application_id" || application_id)`
5. `AES_Decrypt(value_from_keymaster, key)`

```
$ python3 bruteforce-tee.py
workers will cycle through the last 5 chars
Found it: 1234
the plaintext is '1234'
Done in 18.031058311462402s
Throughput: 1478.448992816657 tries/s
```

```
Preloader - HW version: 0x0
Preloader - WDT: 0x10007000
Preloader - Uart: 0x11002000
Preloader - Brom payload addr: 0x100a000
Preloader - Dm payload addr: 0x1001000
Preloader - CQ_DWA addr: 0x10212000
Preloader - Vari: 0x25
Preloader - Disabling Watchdog...
Preloader - HM code: 0x707
Preloader - Target config: 0x5
Preloader - SBC enabled: True
Preloader - SLA enabled: False
Preloader - DAA enabled: True
Preloader - SWI2TAG enabled: True
Preloader - SPIR boot at 0x600 after SMC_BOOT/SDMMC_BOOT: False
Preloader - Root cert required: False
Preloader - Mem read auth: True
Preloader - Mem write auth: True
Preloader - Cmd 0xC81 blocked: True
Preloader - Get TEE info...
Preloader - BBROM mode detected.
Preloader - HM subcode: 0x8000
Preloader - HM Ver: 0xc000
Preloader - SW Ver: 0x0
Preloader - HE_ID: 3AC0889C3AC60179BF870155591927F9
Preloader - SOC ID: 8EDAEF3C1CTf12c4BC410E3D879F3D0CD2348AC1C0CBFEBDCDF33658D3F18D
PLTools - Loading payload from mt6768_payload.bin, 0x264 bytes
PLTools - Kamakiri / DA Run
Kamakiri - Trying Kamakiri...
Kamakiri - Done loading...
PLTools - Successfully sent payload: /home/maxime/tools/mtkclient/mtkclient/payments/mt6768_payload.bin
Port - Device detected :)
Main - Connected to device, loading
Main - Using custom preloader: preloader_k69v1_64_titan.buffalo.bin
Mtk - Validated secure boot
Mtk - Patched "seclib_sec_ushld_enabled" in preloader
Mtk - Patched "sec_imq_auth" in preloader
Mtk - Patched "get_vfy_policy" in preloader
Main - Sent preloader to 0x201000, length 0x3ff24
Preloader - Jumping to 0x201000
Preloader - Jumping to 0x201000: ok.
Main - PL Jumped to daaddr 0x201000.
Main - Keep pressed power button to boot.
[] Waiting for device to boot
```



Our Device

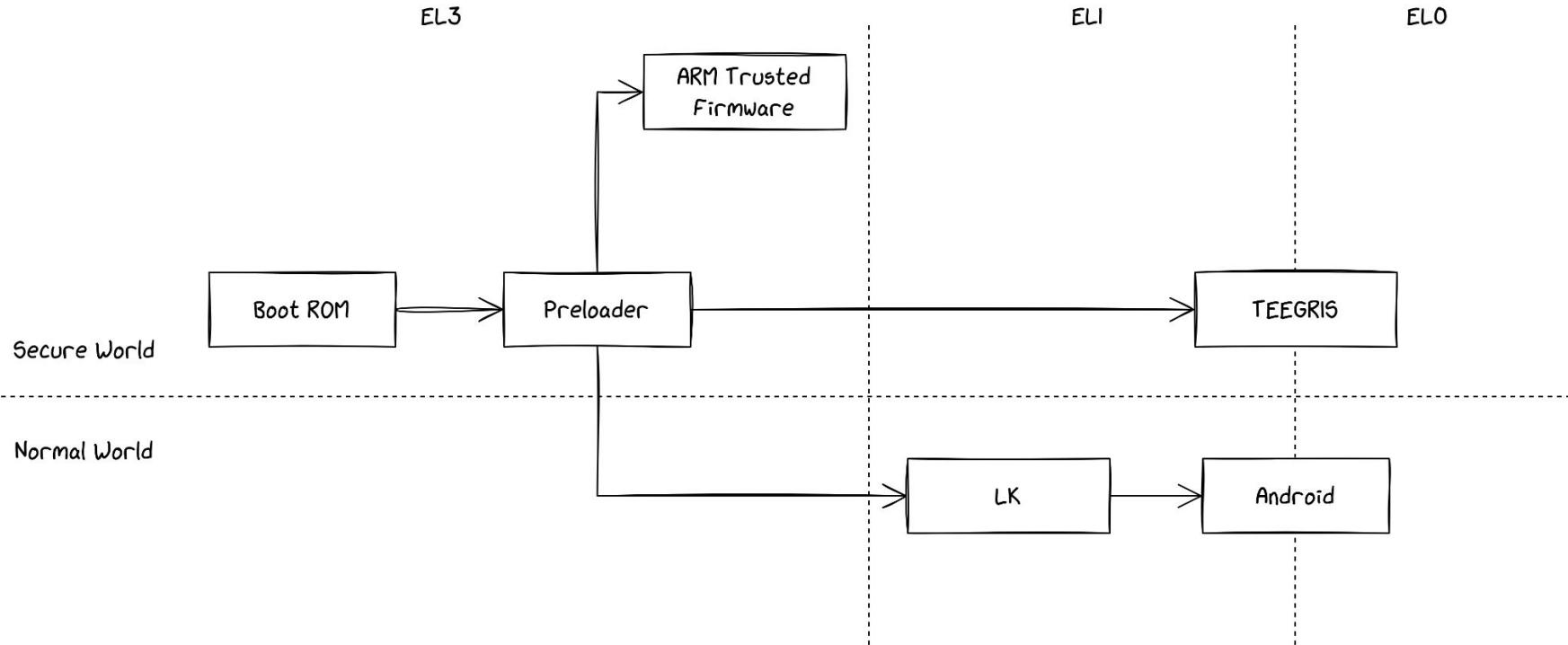
■ Samsung Galaxy A225F

- Cheap (~300€)
- Mediatek SoC MT6769V
- Main OS: Android
- Mix of Mediatek and Samsung code
- Trustzone OS: TEEGRIS
- Secure Boot Bypass using MTKClient¹
 - making debugging easier

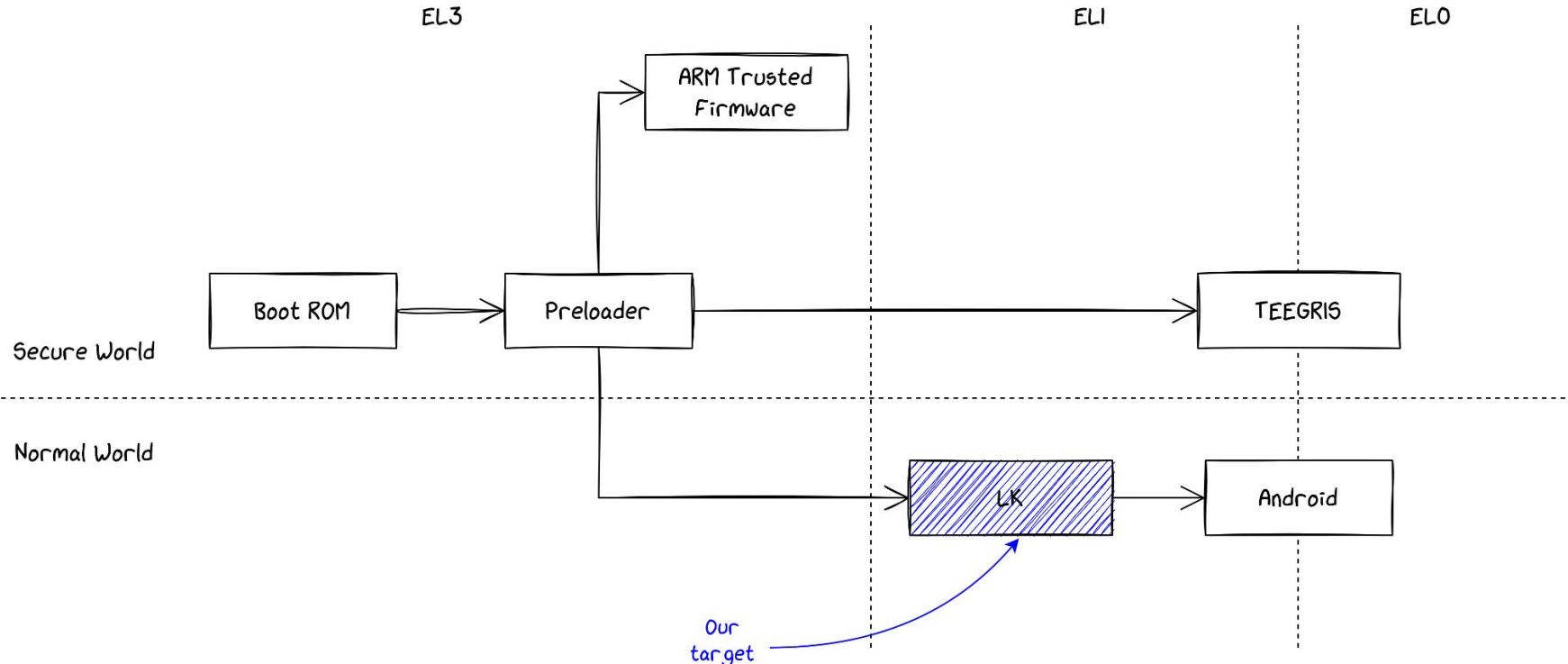


[1]: <https://github.com/bkerler/mtkclient>

Mediatek Secure Boot Process



Mediatek Secure Boot Process



Little Kernel (LK)

- Open-source OS²
- Common as bootloader in the Android world
- Allows to boot Android or other modes
(Recovery)
- Implements **A**ndroid **V**erified **B**oot v2
 - Verification of Android images
 - Involving boot and vboot partitions
 - Anti-rollback



Little Kernel by Samsung

- Samsung modified LK to include:
 - The Odin recovery protocol
 - Knox Security Bit
 - Etc...
 - And a JPEG parser/renderer
- This version is closed source



Why Targeting the JPEG Loader/Parser

- JPEGs are placed in a TAR archive in the *up_param* partition
- The archive is signed... but the signature is not checked at boot
 - ! Anyone able to write the flash can modify these JPEGs
- Parsing JPEG is known to be hard (cf. LogoFail³)

[3]: <https://www.binarly.io/blog/inside-the-logofail-poc-from-integer-overflow-to-arbitrary-code-execution>

Why Targeting the JPEG Loader/Parser

- JPEGs are placed in a TAR archive in the *up_param* partition
- The archive is signed... but the signature is not checked at boot
 - ! Anyone able to write the flash can modify these JPEGs
- Parsing JPEG is known to be hard (cf. LogoFail³)

How are these JPEGs loaded by LK?

Heap Overflow in JPEG Loading

```
_JPEG_BUF = alloc(0x100000);
if (_JPEG_BUF == 0) {
    log("%s: img buf alloc fail\n", "drawimg");
    uVar2 = 0xffffffff;
}
else {
    memset(_JPEG_BUF, 0, 0x100000);
    iVar1 = read_jpeg_file(file_name, _JPEG_BUF, 0);
    if (iVar1 == 0) {
        log("%s: read %s from up_param as 0, size\n", "drawimg", file_name);
        uVar2 = 0xffffffff;
    }
// ...

pimage(*(undefined4 *)(&DAT_4c5107fc + param_1 * 0x3c),
        *(undefined4 *)(&DAT_4c510800 + param_1 * 0x3c),
        0x2d0, 0x640, 1, _JPEG_BUF, iVar1);
```

Heap Overflow in JPEG Loading

Heap allocation of
constant size for the
buffer



```
_JPEG_BUF = alloc(0x100000);
if (_JPEG_BUF == 0) {
    log("%s: img buf alloc fail\n", "drawimg");
    uVar2 = 0xffffffff;
}
else {
    memset(_JPEG_BUF, 0, 0x100000);
    iVar1 = read_jpeg_file(file_name, _JPEG_BUF, 0);
    if (iVar1 == 0) {
        log("%s: read %s from up_param as 0, size\n", "drawimg", file_name);
        uVar2 = 0xffffffff;
    }
    // ...

pimage(*(undefined4 *)(&DAT_4c5107fc + param_1 * 0x3c),
        *(undefined4 *)(&DAT_4c510800 + param_1 * 0x3c),
        0x2d0, 0x640, 1, _JPEG_BUF, iVar1);
```

Heap Overflow in JPEG Loading

Read the JPEG in
the buffer

```
_JPEG_BUF = alloc(0x100000);
if (_JPEG_BUF == 0) {
    log("%s: img buf alloc fail\n", "drawimg");
    uVar2 = 0xffffffff;
}
else {
    memset(_JPEG_BUF, 0, 0x100000);
    iVar1 = read_jpeg_file(file_name, _JPEG_BUF, 0);
    if (iVar1 == 0) {
        log("%s: read %s from up_param as 0, size\n", "drawimg", file_name);
        uVar2 = 0xffffffff;
    }
    // ...

pimage(*(undefined4 *)(&DAT_4c5107fc + param_1 * 0x3c),
        *(undefined4 *)(&DAT_4c510800 + param_1 * 0x3c),
        0x2d0, 0x640, 1, _JPEG_BUF, iVar1);
```

Heap Overflow in JPEG Loading

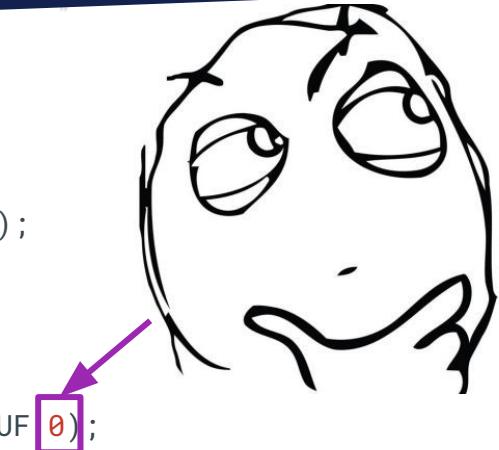
```
_JPEG_BUF = alloc(0x100000);
if (_JPEG_BUF == 0) {
    log("%s: img buf alloc fail\n", "drawimg");
    uVar2 = 0xffffffff;
}
else {
    memset(_JPEG_BUF, 0, 0x100000);
    iVar1 = read_jpeg_file(file_name, _JPEG_BUF, 0);
    if (iVar1 == 0) {
        log("%s: read %s from up_param as 0, size\n", "drawimg", file_name);
        uVar2 = 0xffffffff;
    }
// ...
pimage(*(undefined4 *)(&DAT_4c5107fc + param_1 * 0x3c),
        *(undefined4 *)(&DAT_4c510800 + param_1 * 0x3c),
        0x2d0, 0x640, 1, _JPEG_BUF, iVar1);
```

Parse and render
the JPEG



Heap Overflow in JPEG Loading

```
_JPEG_BUF = alloc(0x100000);
if (_JPEG_BUF == 0) {
    log("%s: img buf alloc fail\n", "drawimg");
    uVar2 = 0xffffffff;
}
else {
    memset(_JPEG_BUF, 0, 0x100000);
    iVar1 = read_jpeg_file(file_name, _JPEG_BUF 0);
    if (iVar1 == 0) {
        log("%s: read %s from up_param as 0, size\n", "drawimg", file_name);
        uVar2 = 0xffffffff;
    }
// ...
pimage(*(undefined4 *)(&DAT_4c5107fc + param_1 * 0x3c),
        *(undefined4 *)(&DAT_4c510800 + param_1 * 0x3c),
        0x2d0, 0x640, 1, _JPEG_BUF, iVar1);
```



Heap Overflow in JPEG Loading

- `read_jpeg_file` takes a size as 3rd argument
- It triggers an error if the file does not fit the size provided

```
file_size = string_to_int(tar_header_file.size, 0, 8);
if (size != 0 && size < file_size) {
    file_size = print("read fail! (%d < %d)\n", size, file_size, size);
    return file_size;
}
iVar1 = read(data_addr, index + 1, file_size, outbuf);
```

Heap Overflow in JPEG Loading

- `read_jpeg_file` takes a size as 3rd argument
- It triggers an error if the file does not fit the size provided
 - 👉 Unless the size provided is 0...

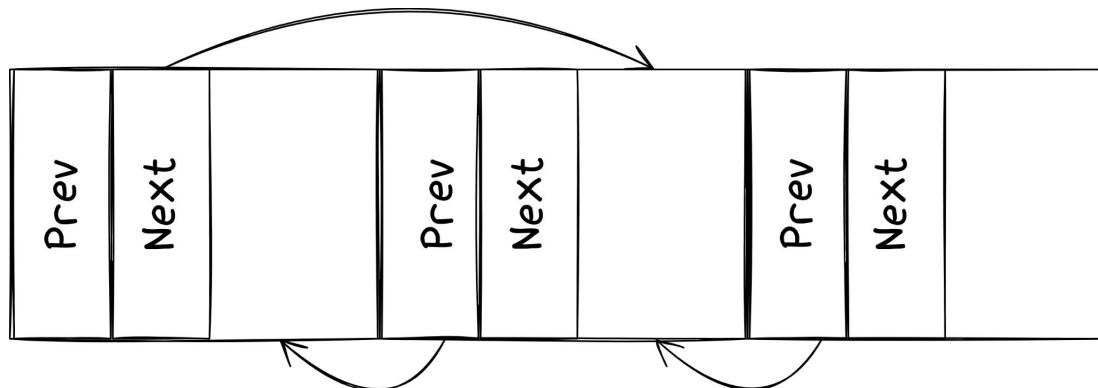
```
file_size = string_to_int(tar_header_file.size, 0, 8);
if (size != 0 && size < file_size) { ←
    file_size = print("read fail! (%d < %d)\n", size, file_size, size);
    return file_size;
}
iVar1 = read(data_addr, index + 1, file_size, outbuf);
```

Is it exploitable?

Exploiting a Heap Overflow in Little Kernel

- The heap algorithm is *miniheap*
 - It relies on a doubly linked list
- Chunks are in a unique memory pool
 - An overflow may overwrite the metadata of next chunk

```
struct free_chunk_head {  
    struct free_chunk_head *prev;  
    struct free_chunk_head *next;  
    size_t len;  
}
```



From Heap Overflow to Arbitrary Write

- After allocation, a chunk is removed from the free list
- `next` and `prev` are dereferenced to change the corresponding nodes
⇒ Controlling a free chunk leads to a write-what-where

```
node->next->prev = node->prev;  
node->prev->next = node->next;  
node->prev = node->next = 0;
```

From Heap Overflow to Arbitrary Write

- After allocation, a chunk is removed from the free list
- `next` and `prev` are dereferenced to change the corresponding nodes
 - ⇒ Controlling a free chunk leads to a write-what-where
 - ! Both values must writable addresses

```
node->next->prev = node->prev;  
node->prev->next = node->next;  
node->prev = node->next = 0;
```

From Arbitrary Write to Code Execution

Important details about LK

- ✗ No ASLR
- ✗ No canaries
- ✗ No bounds checks in the heap algorithm
- ✗ Heap is executable!

From Arbitrary Write to Code Execution

Important details about LK

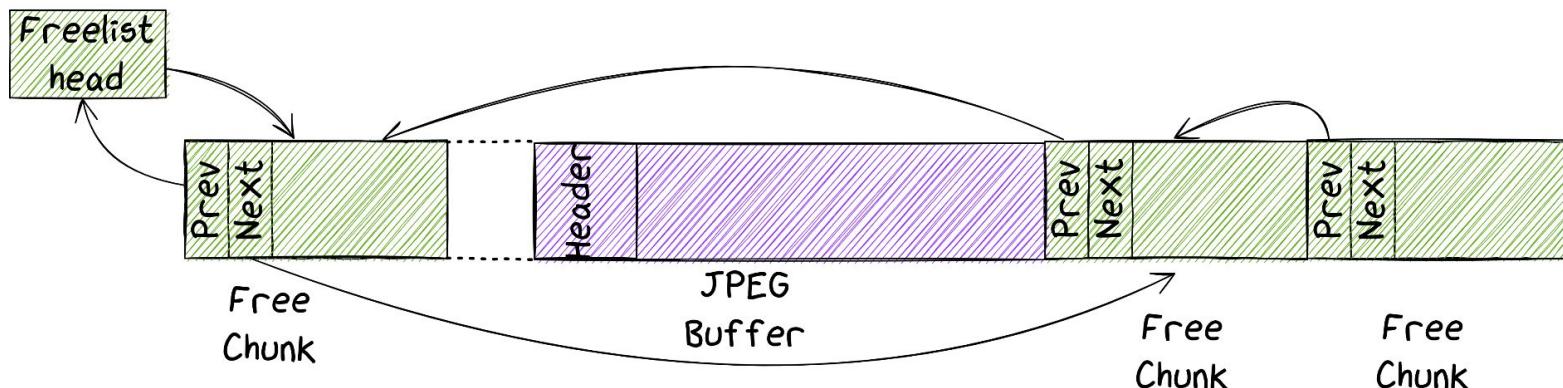
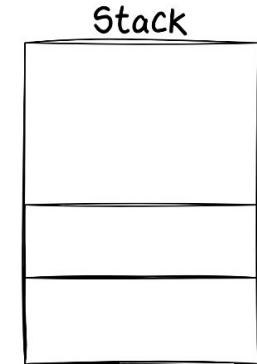
- ✗ No ASLR
- ✗ No canaries
- ✗ No bounds checks in the heap algorithm
- ✗ Heap is executable!

Exploit strategy becomes simple:

1. Overwrite a pointer that the code will jump to
👉 the return address in the stack
2. Make it point to a shellcode in our JPEG buffer

Exploiting a Heap Overflow in Little Kernel

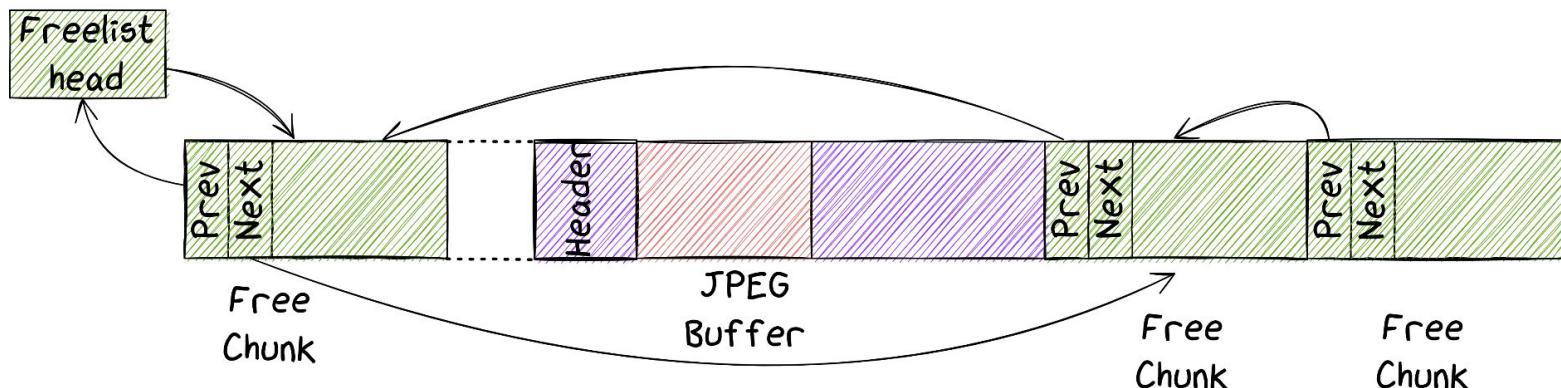
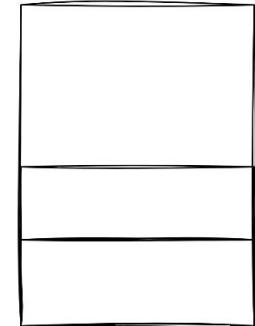
Step 1
JPEG Buffer
Allocation



Exploiting a Heap Overflow in Little Kernel

Step 2
Reading The Jpeg

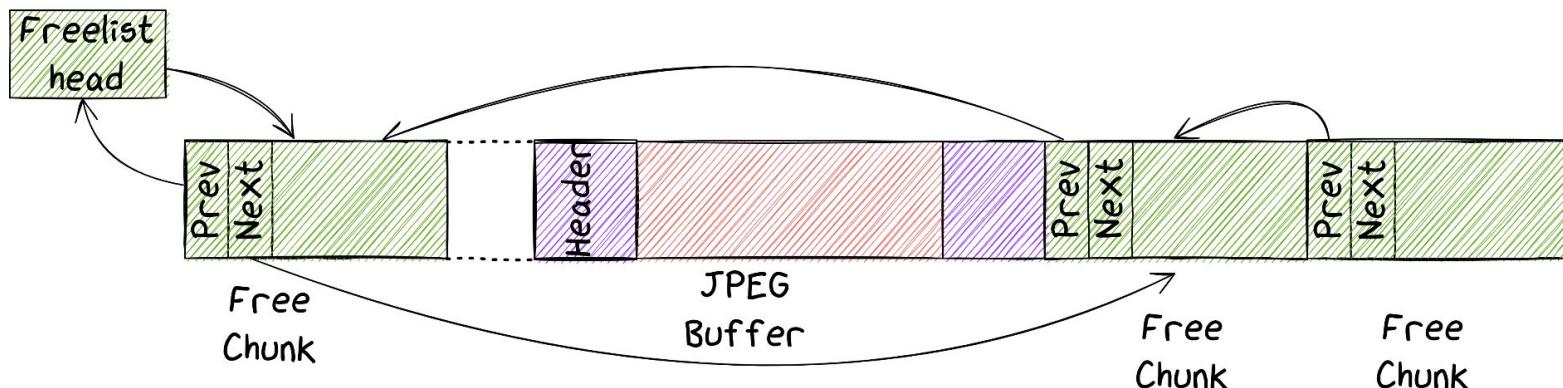
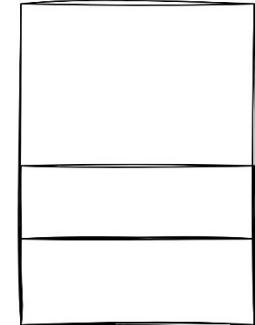
Stack



Exploiting a Heap Overflow in Little Kernel

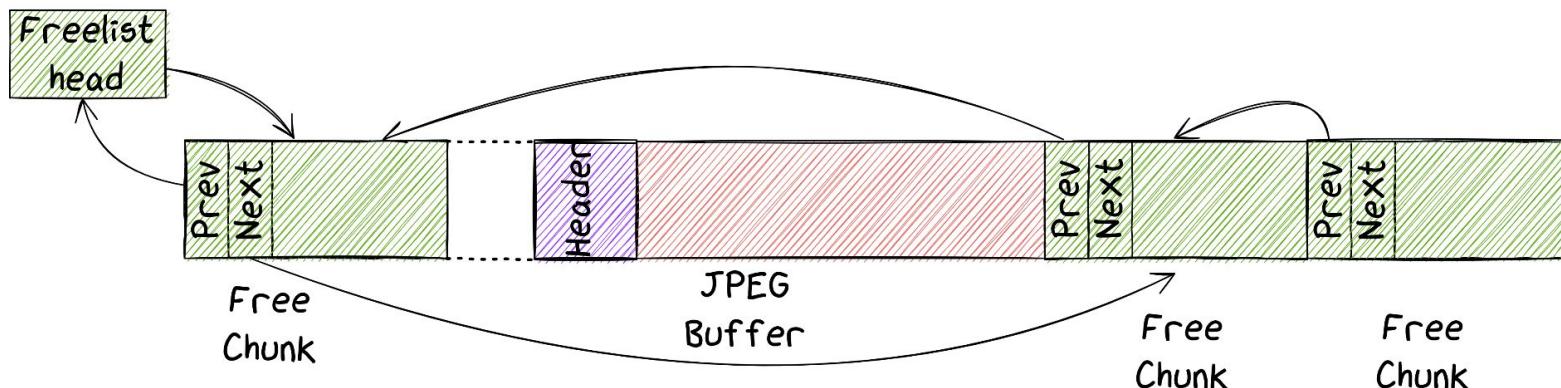
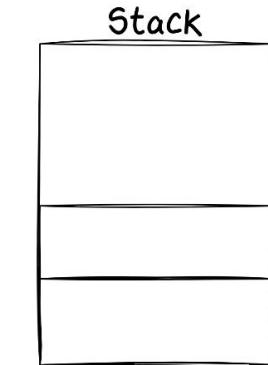
Step 2
Reading The Jpeg

Stack



Exploiting a Heap Overflow in Little Kernel

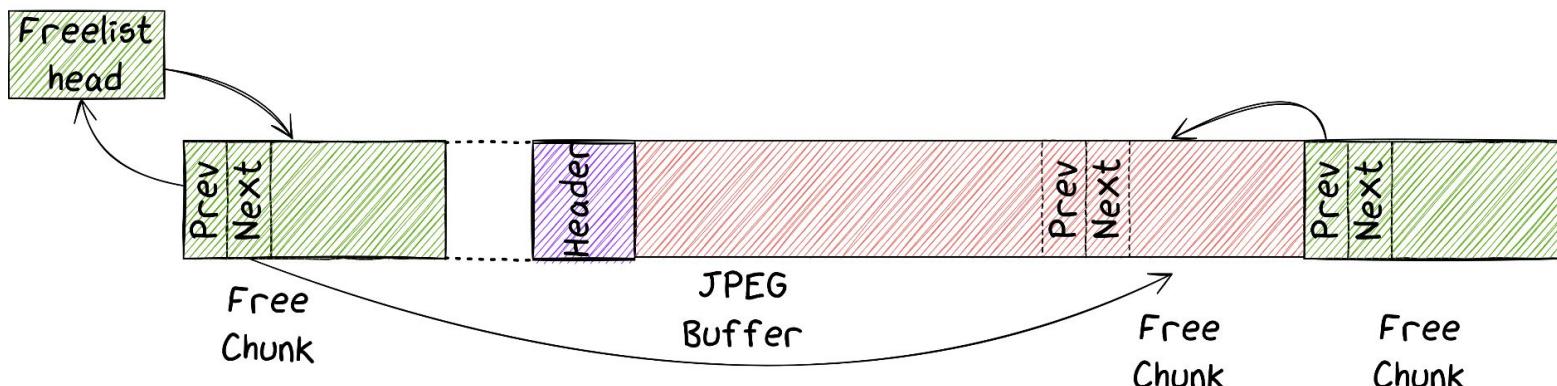
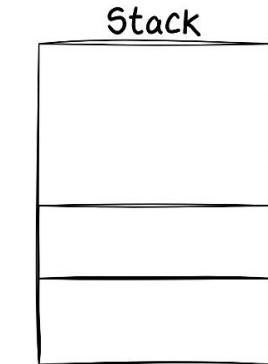
Step 2
Reading The Jpeg



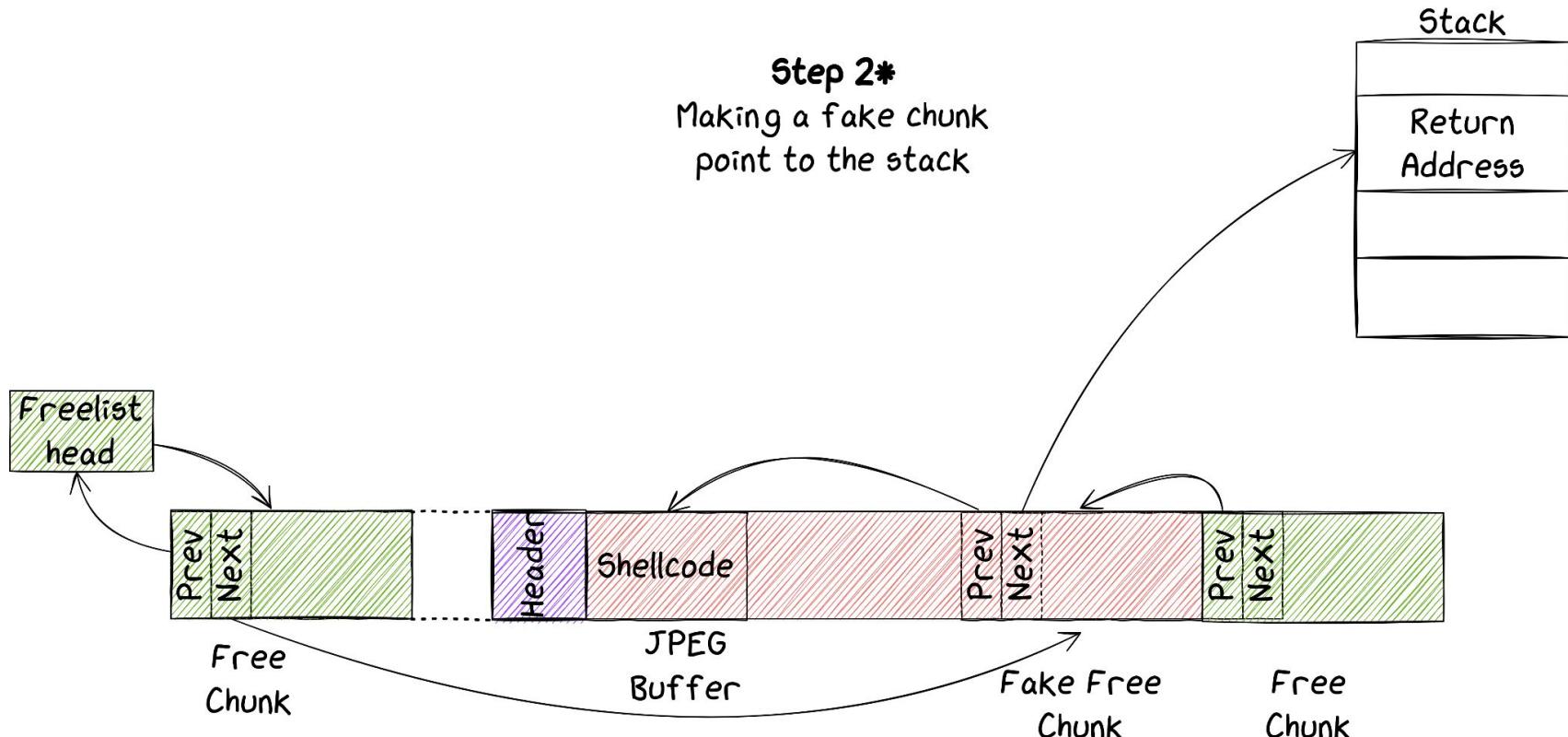
Exploiting a Heap Overflow in Little Kernel

Step 2

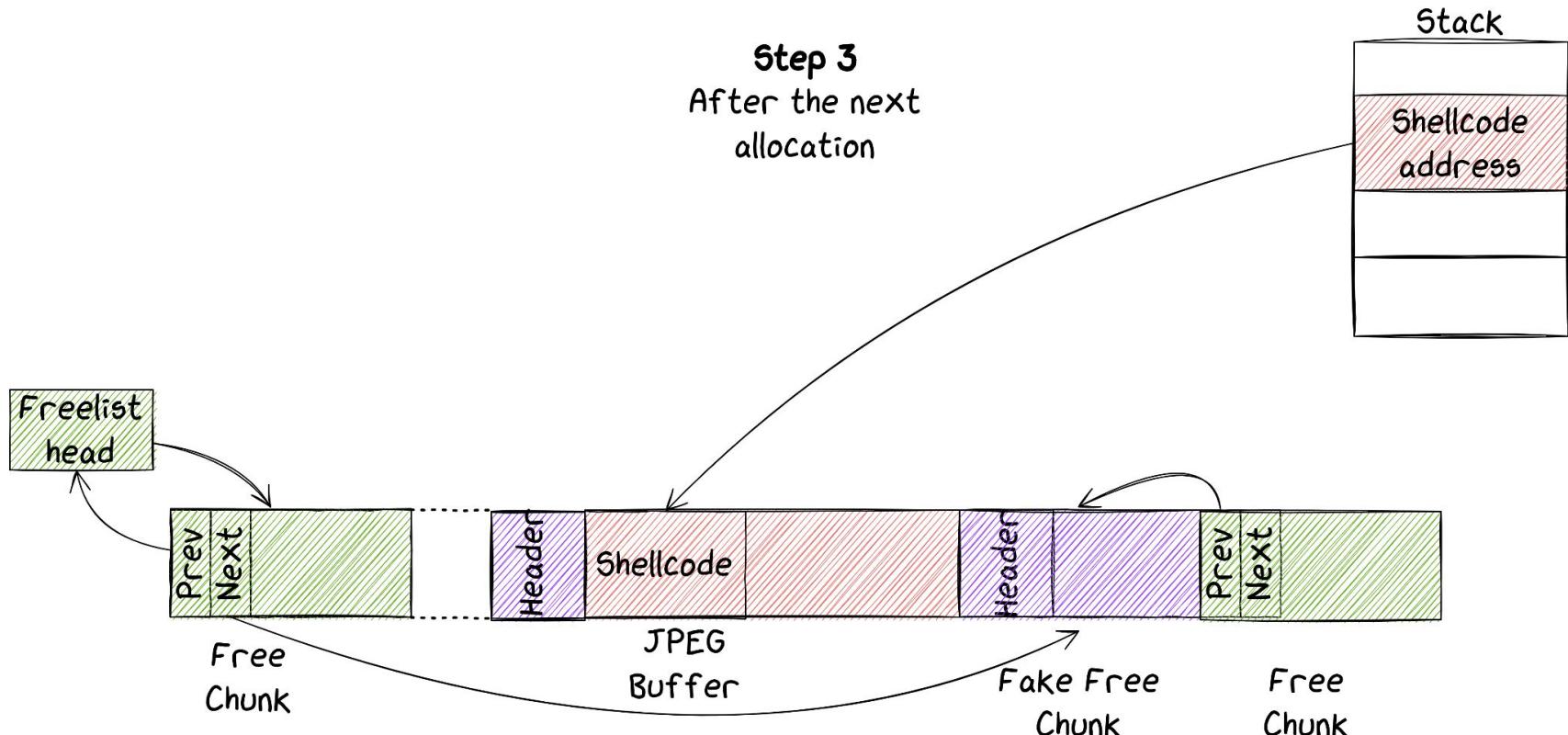
Reading The Jpeg
And overwriting next chunk



Exploiting a Heap Overflow in Little Kernel



Exploiting a Heap Overflow in Little Kernel



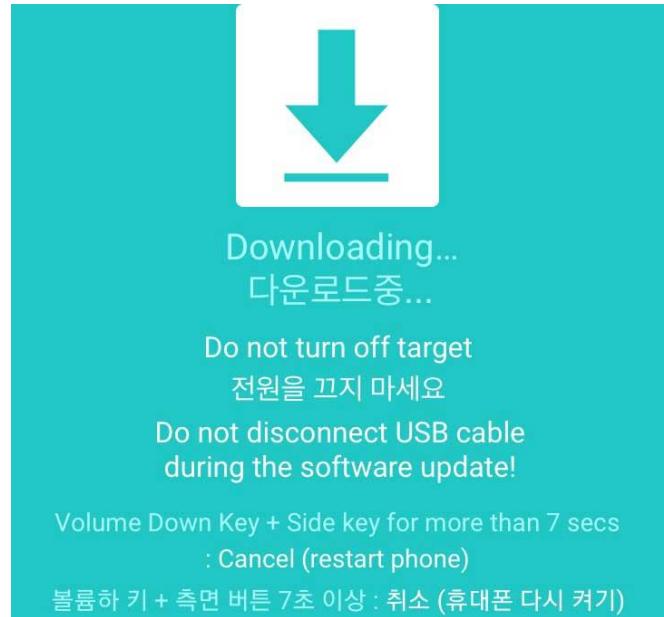
To sum-up

- SVE-2023-2079/CVE-2024-20832
 - ✓ Leads to code execution
 - ✓ Persistent (it survives reboots and factory reset)
 - ✓ Gives full control over Normal World EL1/0
 - ✓ Impacts Samsung devices based on Mediatek SoCs
 - Including those for which MTKClient does not work
 - ✗ Requires to flash the *up_param* partition

*How to write our JPEGs in the
up_param partition?*

Odin: Samsung's recovery protocol

- Odin is implemented in LK
- It is available through the *Download Mode*
 - It allows to flash partitions over USB
- The Odin official client is closed source
- There is an open-source client: Heimdall⁴



[4]: <https://github.com/Benjamin-Dobell/Heimdall>

Odin: Samsung's recovery protocol

- Images are authenticated and contain a footer signature
- Two internal structures indicate which partitions to flash
 - The *Partition Information Table* (PIT)
 - A global structure indicating which partitions to authenticate

53	69	67	6E	65	72	56	65	72	30	32	00	00	00	00	00	SignerVer02.....
36	35	37	33	31	38	36	36	52	00	00	00	00	00	00	00	65731866R.....
41	32	32	35	46	58	58	55	36	44	57	45	33	00	00	00	A225FXXU6DWE3...
00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
32	30	32	33	30	35	32	34	31	32	34	37	30	30	00	00	20230524124700..
53	4D	2D	41	32	32	35	46	5F	43	49	53	5F	53	45	52	SM-A225F_CIS_SER
5F	4D	4B	45	59	30	00	00	00	00	00	00	00	00	00	00	_MKEY0.....
53	52	50	55	42	31	35	42	30	30	36	00	00	00	00	00	SRPUB15B006.....

Odin: Partition Information Table

- PIT is retrieved statically from the eMMC
- It indicates where partitions are stored
 - Memory type, block count, etc
- A partition not present in PIT can't be flashed
- PIT can be updated, but requires a signed image

--- Entry #1 ---

Binary Type: 0 (AP)

Device Type: 2 (MMC)

Identifier: 70

Attributes: Read/Write

Update Attributes: 1

Block Size/Offset: 0

Block Count: 34

Partition Name: pgpt

...

Odin: Image Authentication

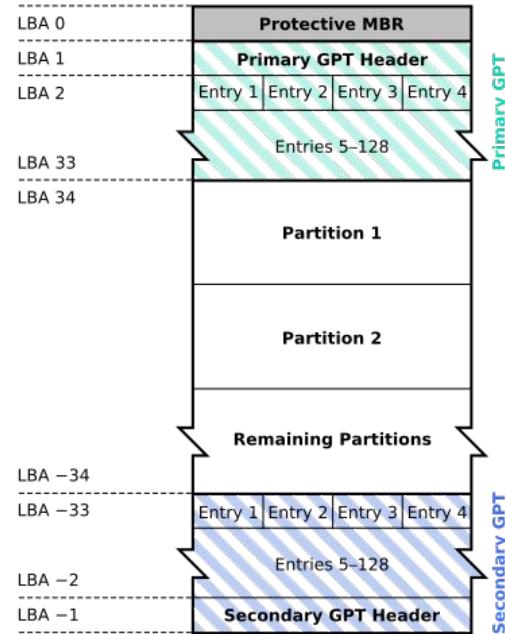
- A global array indicates how an image should be authenticated
- An image not present in this array will not be authenticated
 - (Except for some specific images)
- Comparing this array with PIT gives a set of images flashable without authentication

md5hdr, md_udc, pgpt, sgpt, and vbmeta_vendor

GPT: GUID Partition Table

- **pgpt** points to the Primary GPT Header
- **sgpt** points to the Secondary GPT Header
- Similarly to the PIT, it describes the partitions
 - (Names, sizes, addresses, etc)
- Any GPT can be flashed through Odin
! No authentication required

GUID Partition Table Scheme



GPT vs PIT

- **PIT** and **GPT** are used for the same thing: to describe partitions
 - **PIT** is mainly used for Samsung features in LK
 - Odin, JPEGs loading, etc
 - And **GPT** is used the rest of the time
-
- ! We can't just rename a partition to *up_param* to flash our JPEGs

PIT Loading

```
pit_address = 0x4400;
exist = get_part_table("pit");
if (exist == 0) {
    pit_address = get_partition_offset("pit");
}
type = storage(3);
iVar1 = storage_read(type, 0x4000, (int)pit_address,
                      (int)((ulonglong)pit_address >> 0x20),
                      &ODIN_TEMP_BUF_PIT, 0x4000);
```

PIT Loading

```
pit_address = 0x4400;
exist = get_part_table("pit");
if (exist == 0) {
    pit_address = get_partition_offset("pit");
}
type = storage(3);
iVar1 = storage_read(type, 0x4000, (int)pit_address,
                     (int)((ulonglong)pit_address >> 0x20),
                     &ODIN_TEMP_BUF_PIT, 0x4000);
```

PIT default address

PIT Loading

```
pit_address = 0x4400;
exist = get_part_table("pit");
if (exist == 0) {
    pit_address = get_partition_offset("pit");
}
type = storage(3);
iVar1 = storage_read(type, 0x4000, (int)pit_address,
                     (int)((ulonglong)pit_address >> 0x20),
                     &ODIN_TEMP_BUF_PIT, 0x4000);
```

PIT default address

Check for pit partition
And use it if it exists

PIT Loading

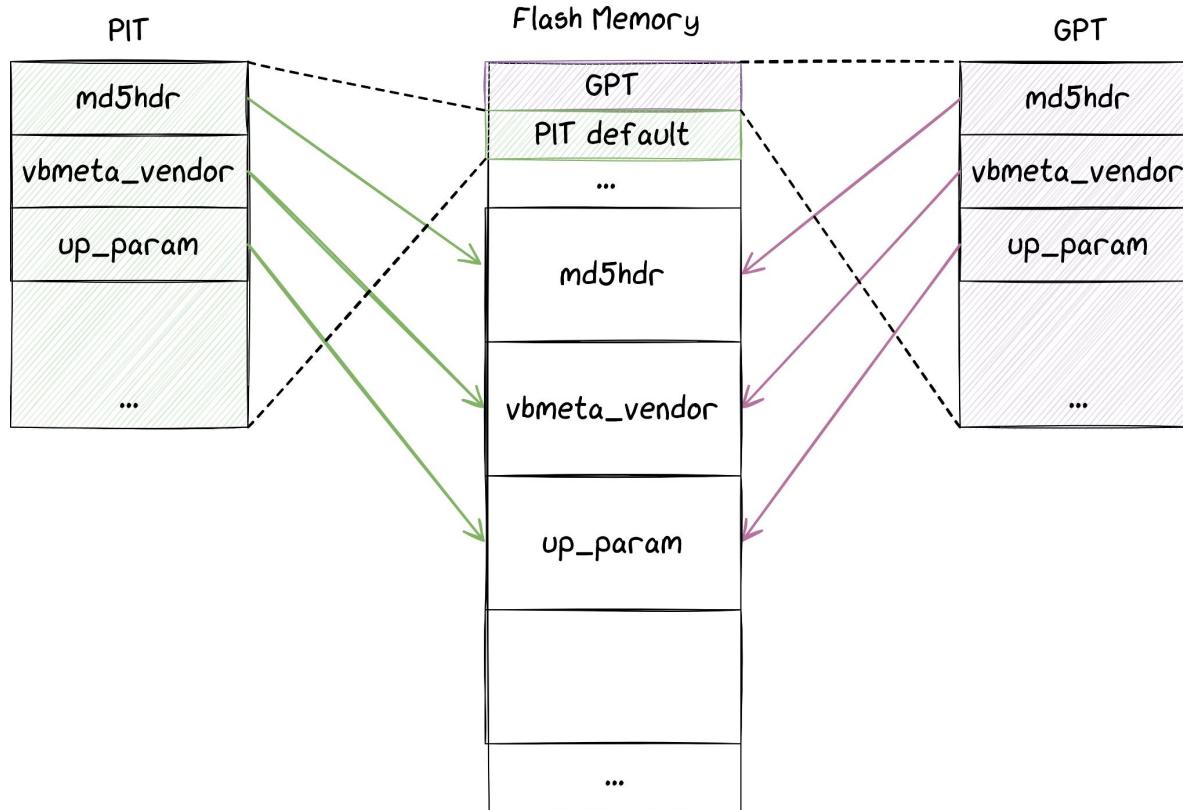
```
pit_address = 0x4400;
exist = get_part_table("pit");
if (exist == 0) {
    pit_address = get_partition_offset("pit");
}
type = storage(3);
iVar1 = storage_read(type, 0x4000, (int)pit_address,
                     (int)((ulonglong)pit_address >> 0x20),
                     &ODIN_TEMP_BUF_PIT, 0x4000);
```

PIT default address

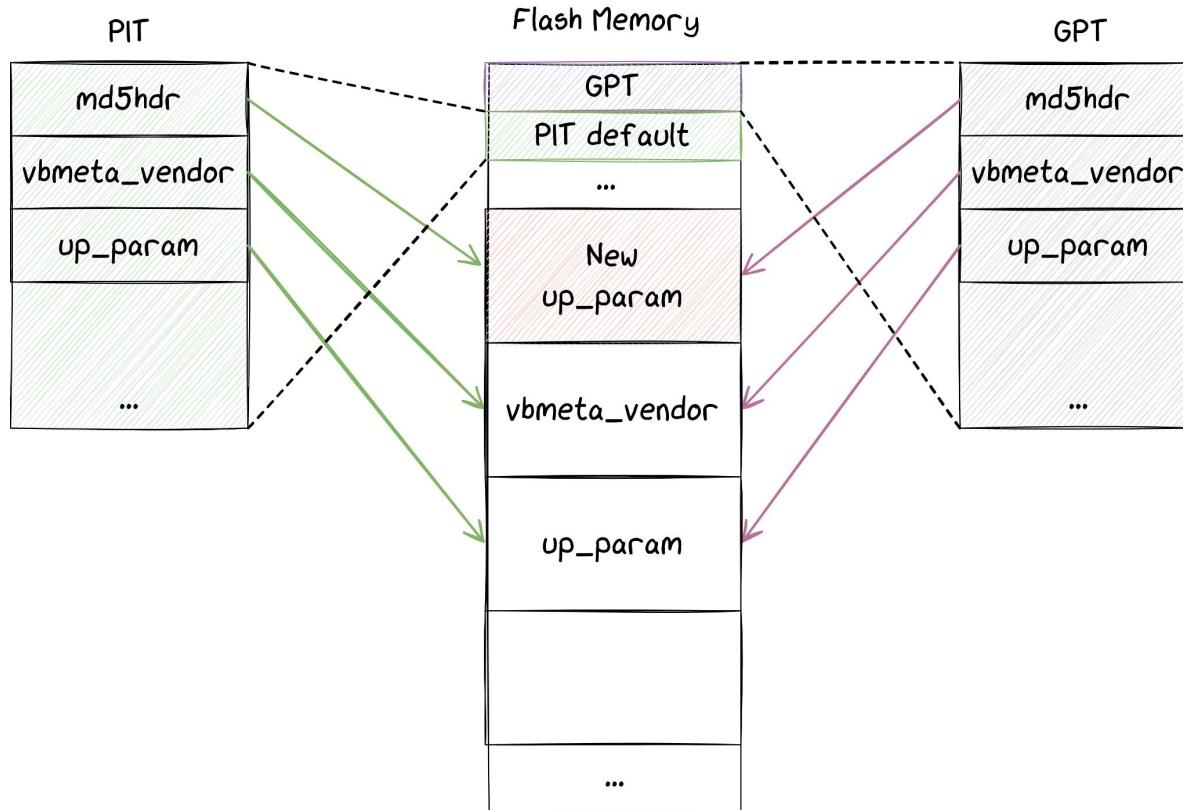
Uses GPT table 😈



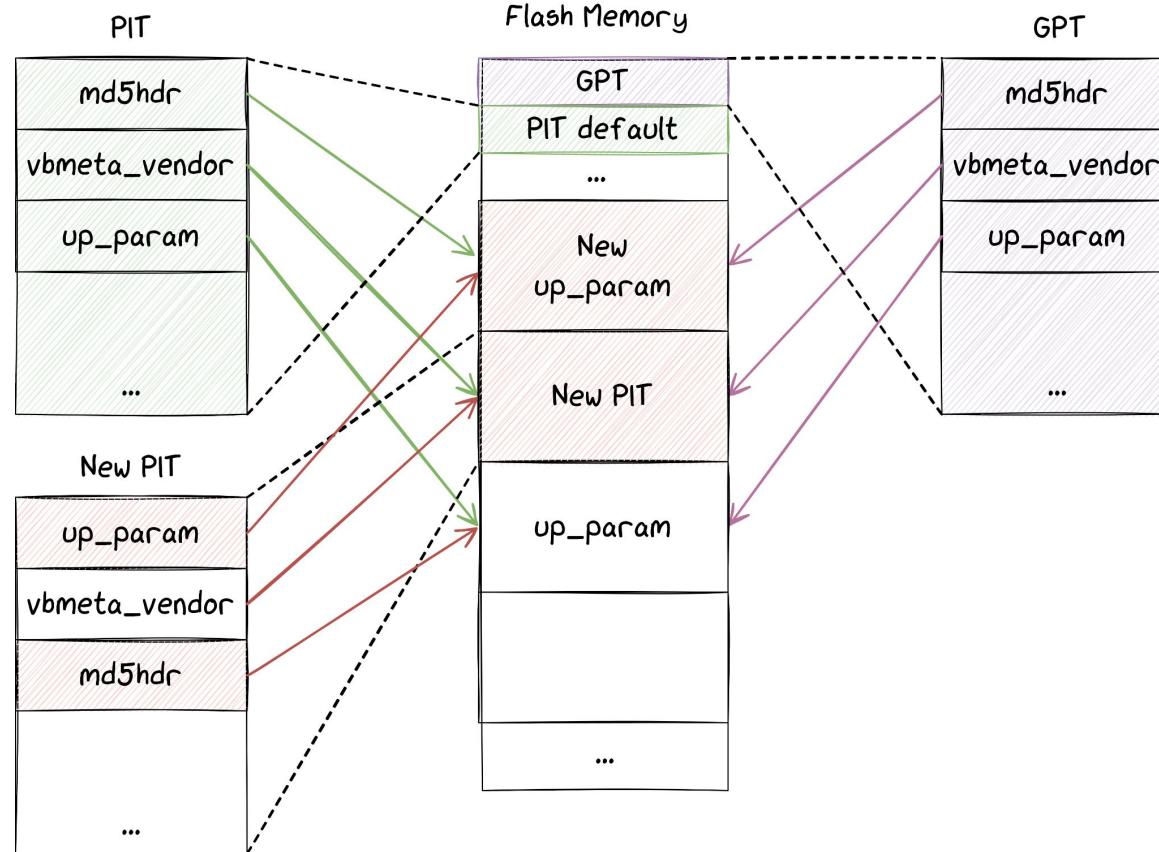
Strategy to Bypass Odin Authentication



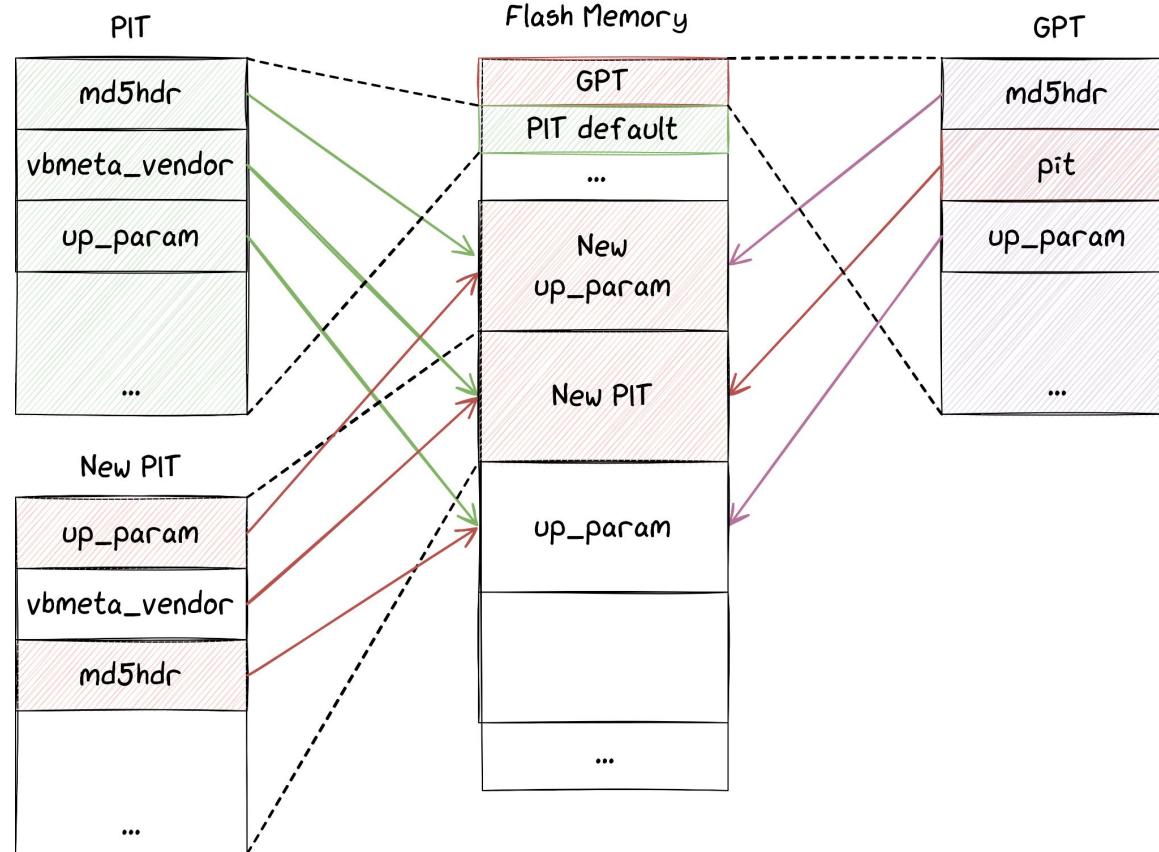
Strategy to Bypass Odin Authentication



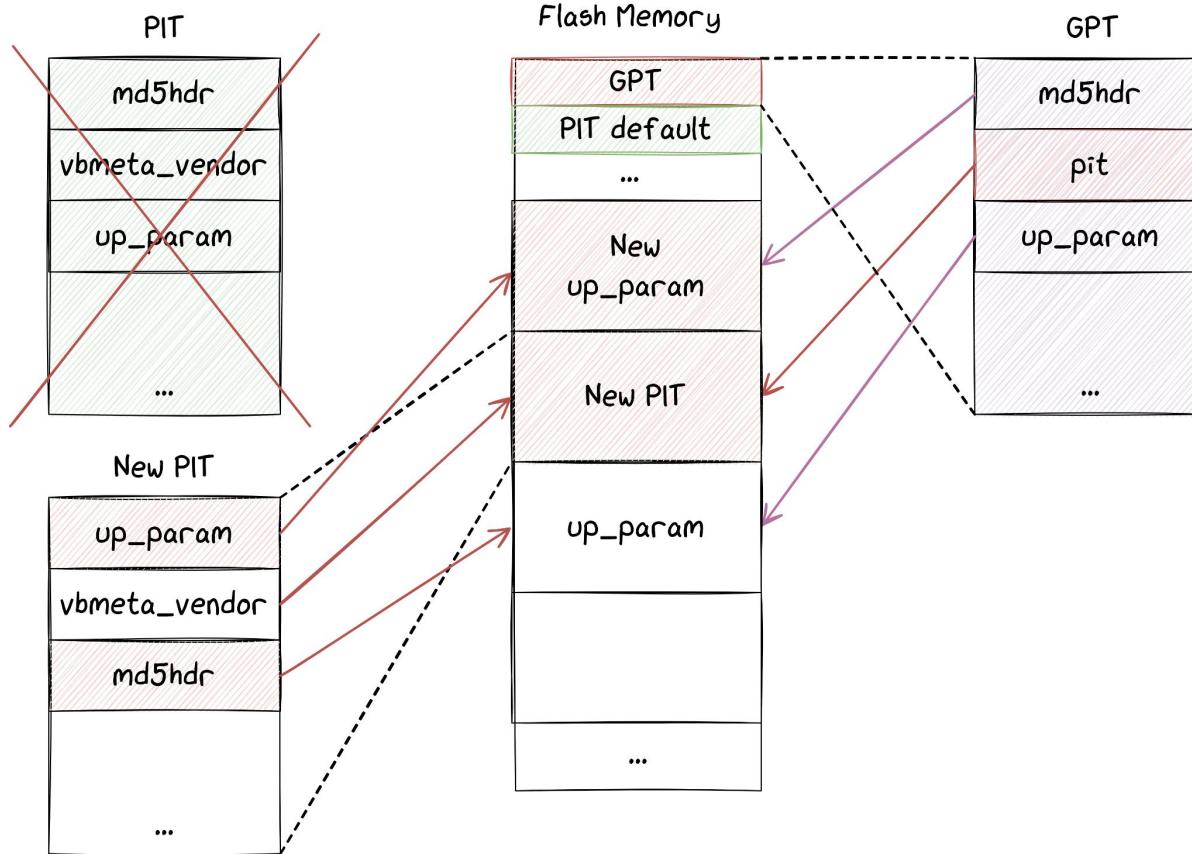
Strategy to Bypass Odin Authentication



Strategy to Bypass Odin Authentication



Strategy to Bypass Odin Authentication

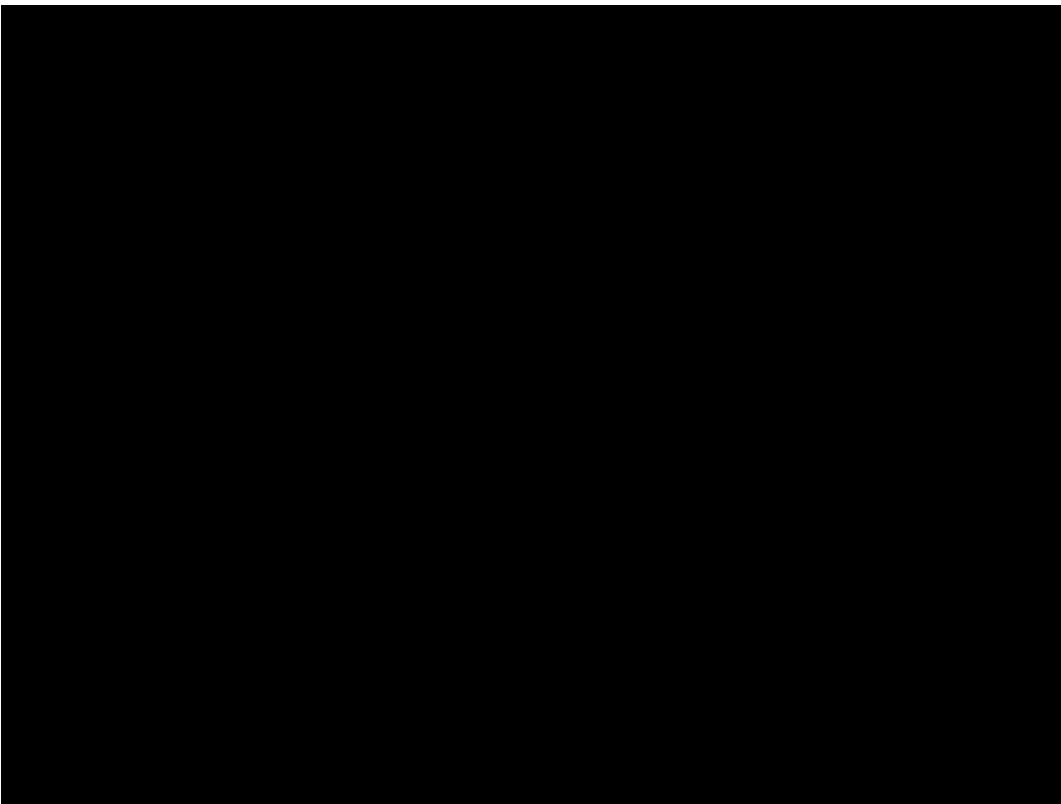


To sum up

- SVE-2024-0234/CVE-2024-20865
 - ✓ Can bypass authentication in Odin
 - ✓ We can flash anything in the eMMC
 - ✓ Including our *up_param* partition
 - ✓ Seems to impact most Samsung using Mediatek SoCs



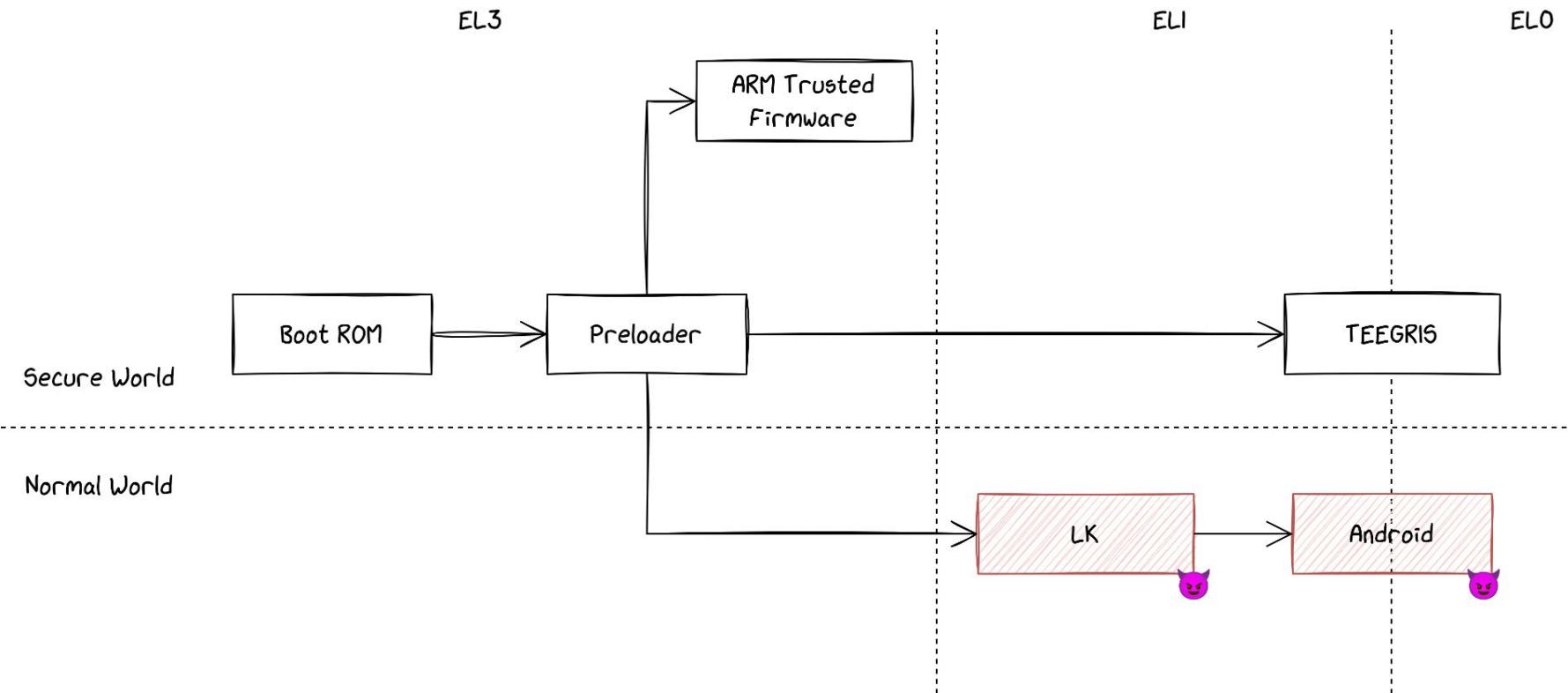
Chaining Everything Together



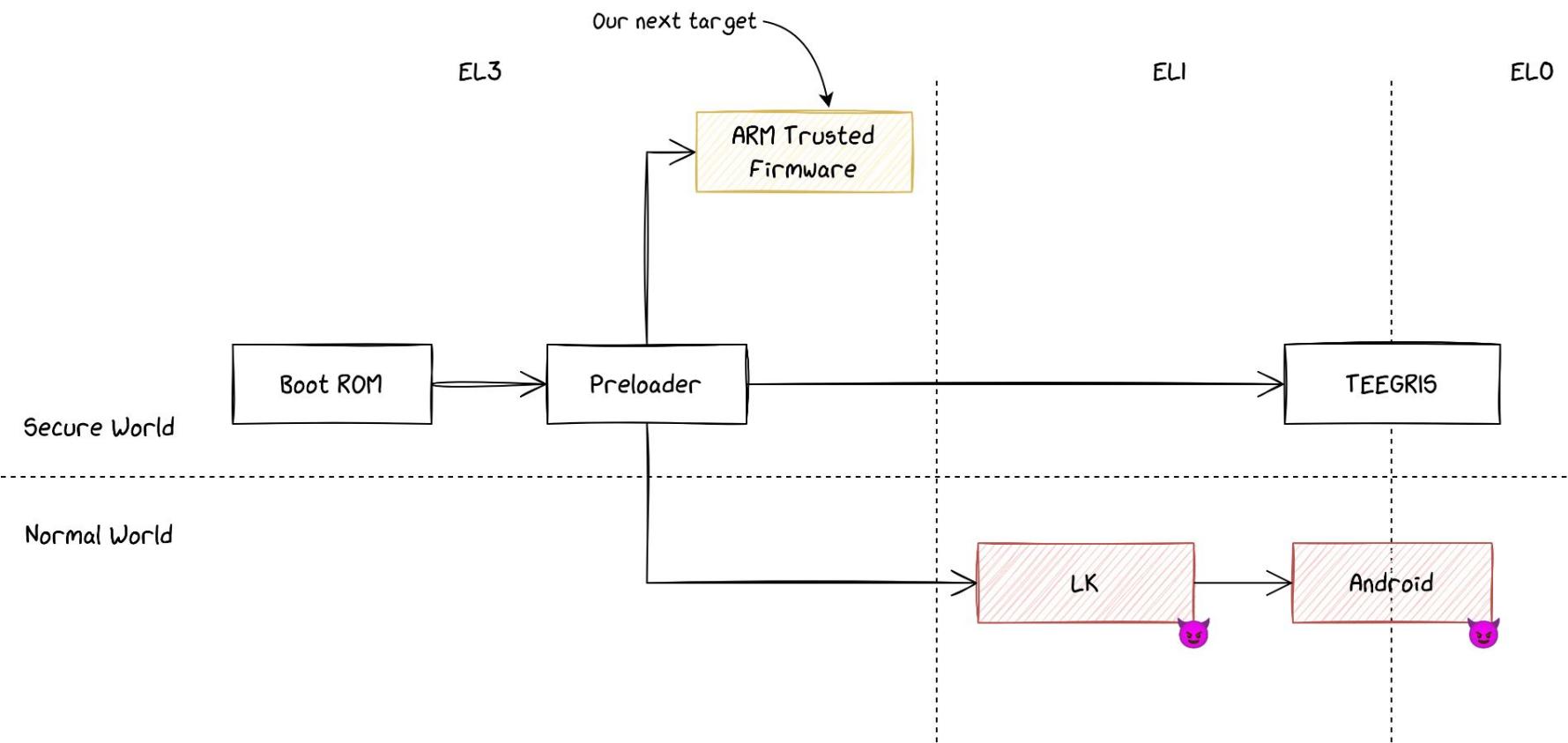
To Conclude

- Chain based on 2 vulnerabilities
 - ✓ Leads to code execution in LK
 - ✓ Persistent (it survives reboots and factory reset)
 - ✓ Impacts Samsung devices based on Mediatek SoCs
 - Including those for which MTKClient does not work
 - ✓ Can be triggered over USB thanks to Odin authentication bypass
 - ✓ Gives full control over Normal World EL1/0
 - ✗ Still no access to secrets stored in Secure World

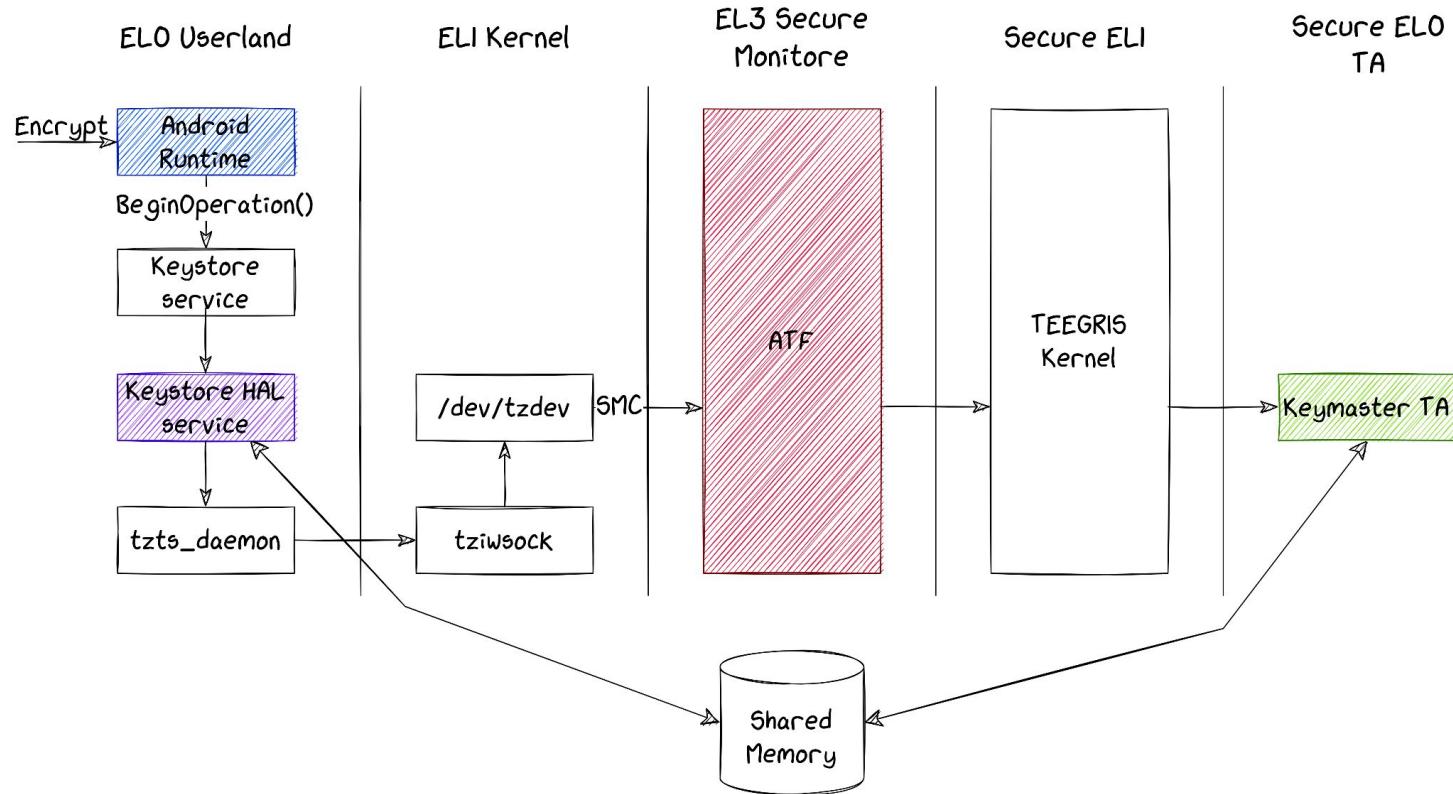
Targeting ARM Trusted Firmware



Targeting ARM Trusted Firmware



Communication between NSW and SW



Vulnerability Research on ATF

- Motivation:
 - Highest privilege level → A bug here can be devastating
 - Reachable from Normal World through SMCs
- Code is simple
- Interacts a lot with HW through unknown registers
 - Fuzzing not particularly interesting in this case
- Our approach: focus on static analysis

Extracting ATF

- Inside an Android ROM Image:
 - tee-verified.img: **ATF**, TEEGRIS kernel, userboot.so...

00000000	88 16 88 58 00 6c 02 00	61 74 66 00 00 00 00 00	...X.l..atf....
00000010	00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00
00000020	00 00 00 00 00 00 00 00	ff ff ff ff 00 00 00 00
00000030	89 16 89 58 00 02 00 00	01 00 00 00 00 00 00 00	...X.....
00000040	00 00 00 00 10 00 00 00	00 00 00 00 00 00 00 00
00000050	ff ff ff ff ff ff ff ff	ff ff ff ff ff ff ff ff

```
00026df0  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 |.....|  
00026e00  88 16 88 58 ad 06 00 00 63 65 72 74 31 00 00 00 |...X....cert1...|
```

SMC Handlers

```
if ((is_secure & 1) == 0) {
    puVar1 = mediatek_plat_sip_handler_secure(smc_id,arg1,arg2,arg3
                                                ,arg4,arg5,output);
    return puVar1;
}
[...]
if ((origin < 2) && (IN_BOOTLOADER == 0)) {
    puVar1 = mediatek_plat_sip_handler_kernel(smc_id,arg1,arg2,arg3
                                                ,arg4,arg5,output);
    return puVar1;
}
```

SMC Handlers

```
if ((is_secure & 1) == 0) {  
    puVar1 = mediatek_plat_sip_handler_secure(smc_id, arg1, arg2, arg3  
                                              , arg4, arg5, output);  
    return puVar1;  
}  
[...]  
if ((origin < 2) && (IN_BOOTLOADER == 0)) {  
    puVar1 = mediatek_plat_sip_handler_kernel(smc_id, arg1, arg2, arg3  
                                              , arg4, arg5, output);  
    return puVar1;  
}
```

Arguments of SMC

Leaking from Virtual Address Space

```
uint* global_array = (uint *)0x4ce2f578;
[...]
if (smcid == 0x82000526) {
    out_value = global_array[arg1 * 4];
    goto exit;
}
[...]
    output[2] = out_value;
    output[1] = arg1;
    *output = 0;
return output;
```

Leaking from Virtual Address Space

```
uint* global_array = (uint *)0x4ce2f578;  
[...]  
if (smcid == 0x82000526) {  
    out_value = global_array[arg1 * 4];  
    goto exit;  
}  
[...]  
    output[2] = out_value;  
    output[1] = arg1;  
    *output = 0;  
return output;
```

Fully controlled by
attacker

Leaking from Virtual Address Space

```
uint* global_array = (uint *)0x4ce2f578;  
[...]  
if (smcid == 0x82000526) {  
    out_value = global_array[arg1 * 4];  
    goto exit;  
}  
[...]  
output[2] = out_value;  
output[1] = arg1;  
*output = 0;  
return output;
```

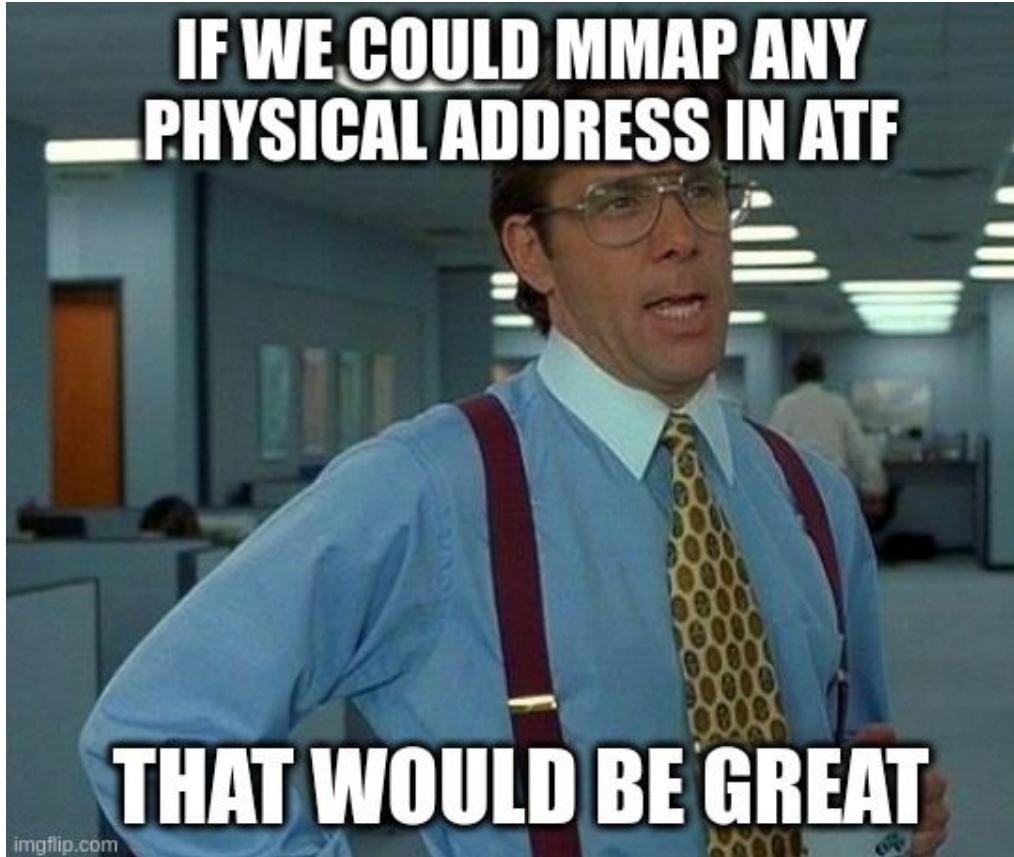
Fully controlled by
attacker... And never
checked



SVE-2023-2215 (CVE-2024-20820)

- In `mediatek_plat_sip_handler_kernel`, reachable from Linux Kernel
- To exploit it, send the SMC `0x82000526` with
 - (**arbitrary_address** - `0x4ce2f578`) / 4
- Bug introduced by Samsung only in some devices (including A225F)
- It leaks 4 bytes from ATF virtual address space
 - We can read all the internal data of ATF
 - But we can't leak anything from other SW components

SVE-2023-2215 (CVE-2024-20820)



Mapping Any Physical Address in ATF

SMC 0x8200022A calls function spm_actions

```
if (smc_id == 0x8200022a) {  
    spm_actions(arg1,arg2,arg3);
```

Mapping Any Physical Address in ATF

SMC 0x8200022A calls function spm_actions

```
undefined * spm_actions(ulong cmdid,undefined *addr,ulong size) {  
    switch(cmdid & 0xffffffff) {  
        [...]  
        case 1:  
            if (size < 0x100001) {  
                mmap_wrap(addr,size);  
            }  
        [...]  
    }  
}
```

Mapping Any Physical Address in ATF

SMC 0x8200022A calls function spm_actions

```
undefined * spm_actions(ulong cmdid,undefined *addr, ulong size) {  
    switch(cmdid & 0xffffffff) {  
        [...]  
        case 1:  
            if (size < 0x100001) {  
                mmap_wrap(addr, size);  
            }  
        [...]  
    }  
}
```

Arguments fully
controlled

Mapping Any Physical Address in ATF

SMC 0x8200022A calls function spm_actions

```
undefined * spm_actions(ulong cmdid,undefined *addr, ulong size) {  
    switch(cmdid & 0xffffffff) {  
        [...]  
        case 1:  
            if (size < 0x100001) {  
                mmap_wrap(addr,size);  
            }  
        [...]  
    }  
}
```

Arguments fully controlled

And still no checks on the address

Mapping Any Physical Address in ATF

SMC 0x8200022A calls function spm_actions

```
undefined * spm_actions(ulong cmdid,undefined *addr, ulong size) {  
    switch(cmdid & 0xffffffff) {  
        [...]  
        case 1:  
            if (size < 0x100001) {  
                mmap_wrap(addr,size);  
            }  
        [...]  
    }  
}
```

Physical Address

And still no checks on the address

CVE-2024-20021

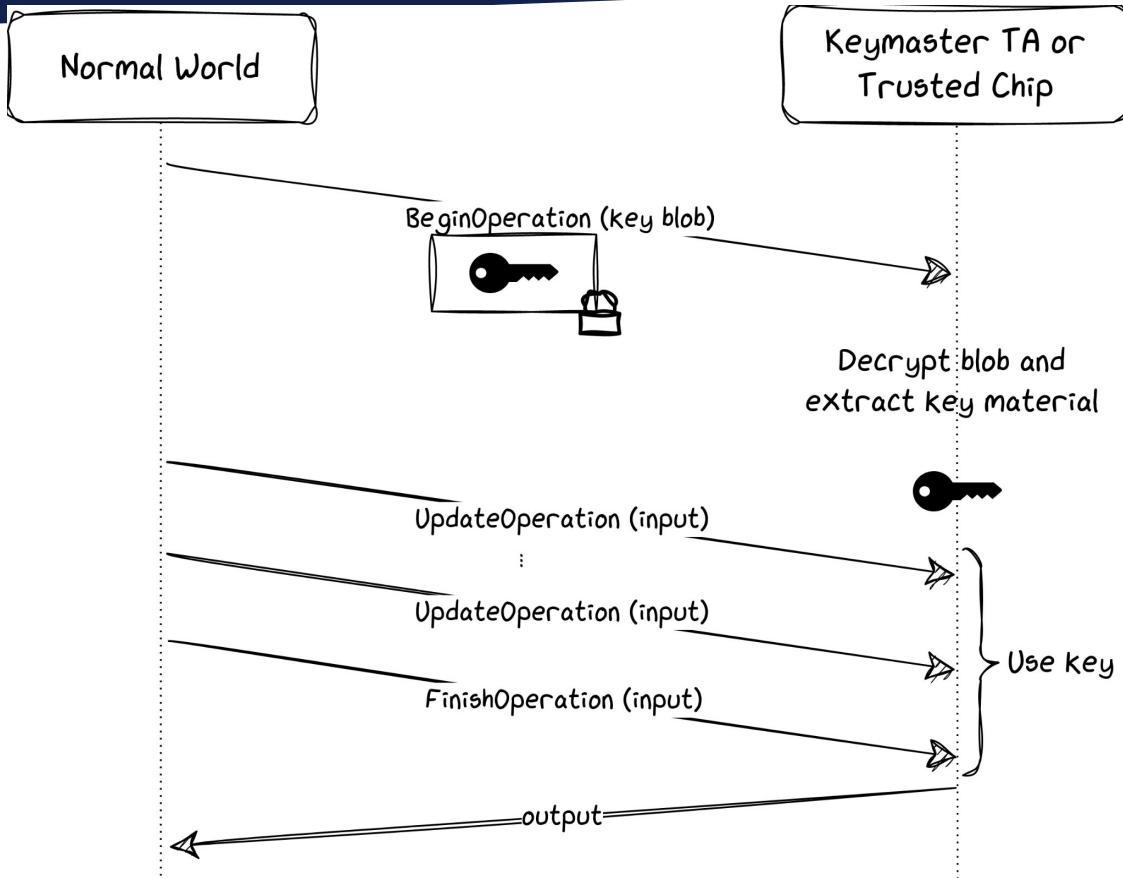
- Also in mediatek_plat_sip_handler_kernel
- Will mmap with physical base address to the same virtual address
 - ... however we can't munmap
 - So we are limited to 8 consecutive mmaps
 - Meaning we can leak up to **8MB** of data
- Introduced by Mediatek (impacts plenty of Mediatek SoCs)
- Chained to our leak, we can read everything in Secure World
 - Including TEEGRIS

*Can we use this vulnerability to leak
Keystore keys?*

Android Keystore system

- Key storage and crypto services
- Keys are stored as encrypted *key blobs*
- Three protection levels:
 - Software only
 - TEE (default)
 - Hardware-backed (StrongBox)
- Raw key should never leave protected environment

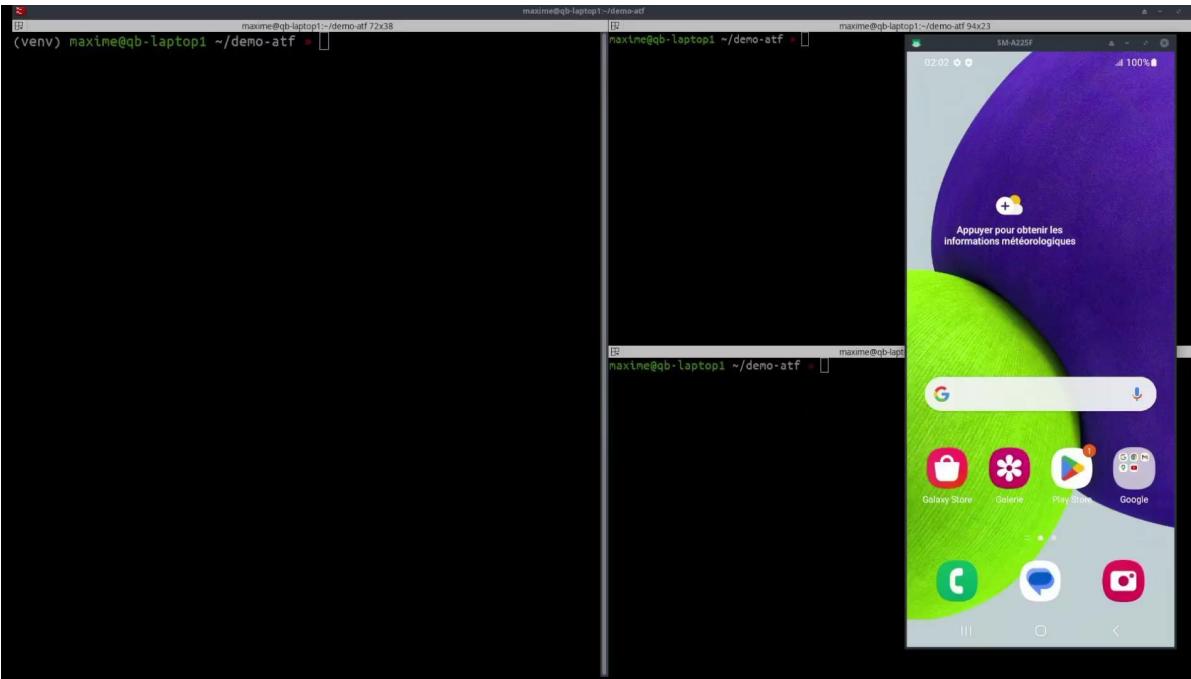
Android Keystore system



Our PoC

1. **Import** a key into the Android Keystore
2. **Encrypt** using that key
3. **Stop the execution** after Begin0peration is called
 - To makes sure the key stays in memory
4. **Leak** the identified region of memory
5. Try all possible keys from leak to decrypt ciphertext

Demo

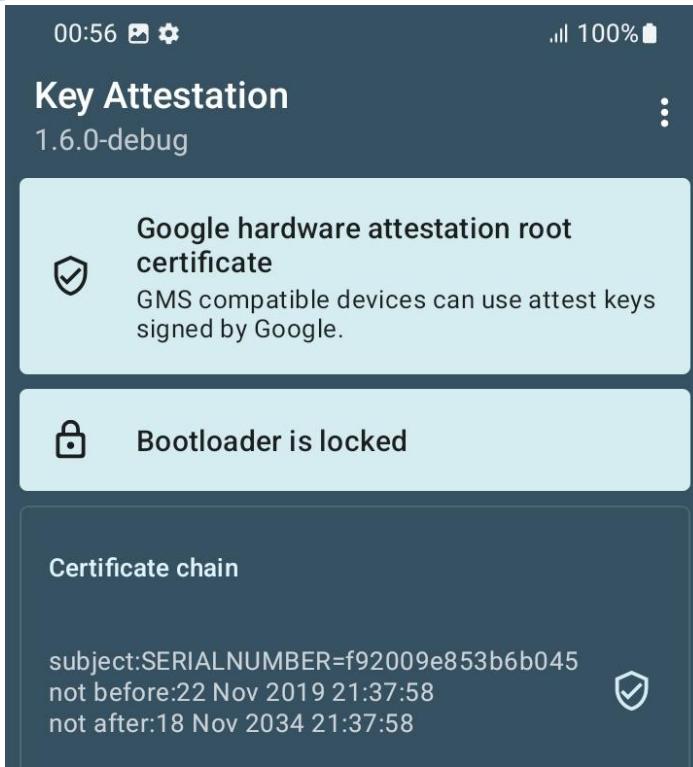


What's next?

Key Attestation

- Proves that a key pair is stored in the secure hardware
 - Trustzone or Security Chip
- Contains information about the device state
 - Such as bootloader locked status and verified boot state
- Used by SafetyNet⁵ to tell if a device has been compromised

First Key Attestation test



- ✓ Attestation generated with a demo app⁶
- 👉 Our exploit seems not detected!

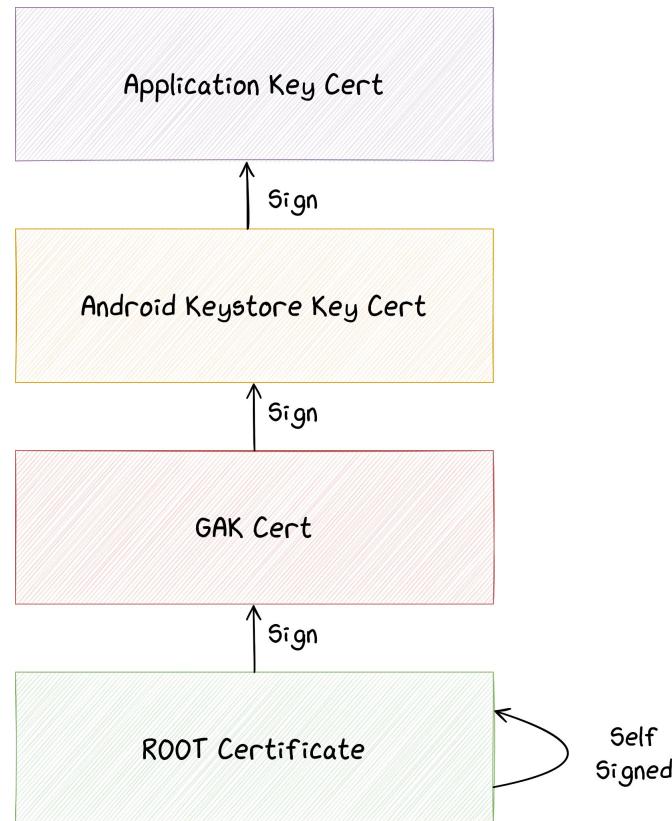
What about SafetyNet?

Device	
Model	SM-A225F (a22)
Android version	13 (API 33)
Security patch level	2023-06-01
Google Play Services version	22.46.17 (190400-491726958)
Result	
Basic integrity	Fail ✘
CTS profile match	Fail ✘
Evaluation type	BASIC
Timestamp	6 Aug 2024 03:12:29

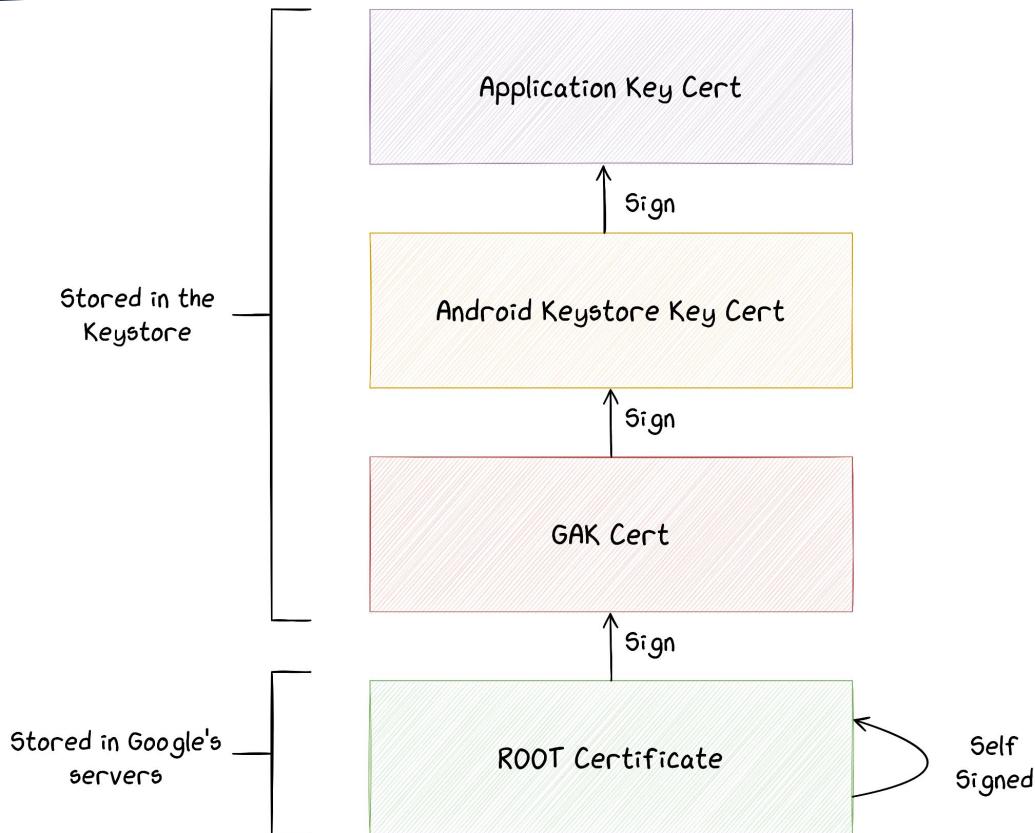


- SafetyNet detects the exploit
 - Possibly through heuristics to detect Magisk

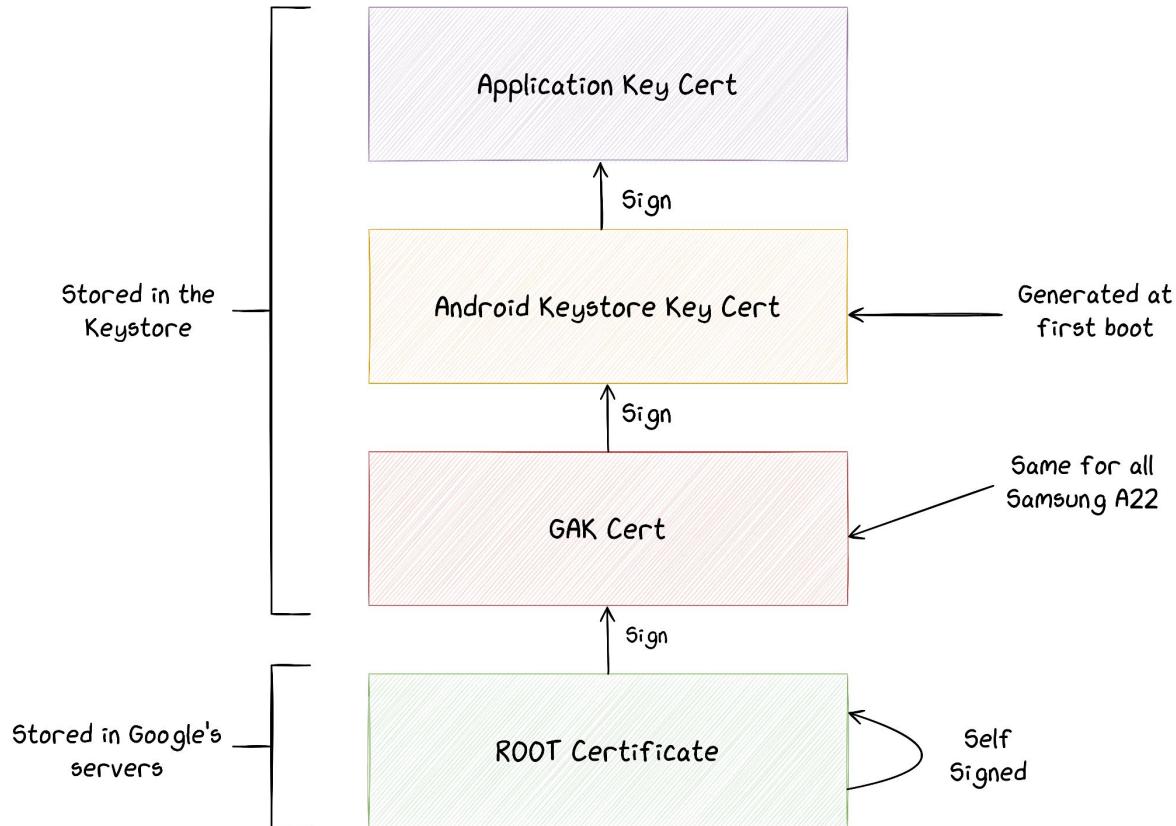
Certificate Chain



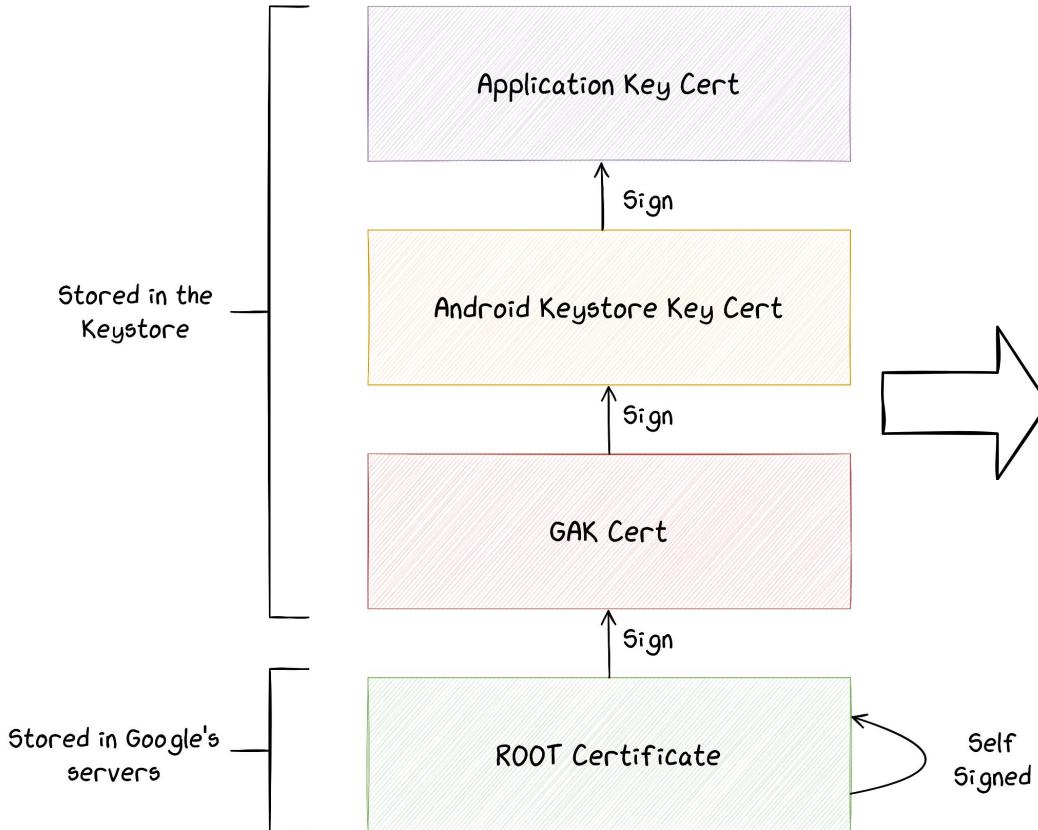
Certificate Chain



Certificate Chain



Certificate Chain



Root of trust

```
verifiedBootKey:  
07EFE057CEBF085AAA79D1FB2090CCCB59  
9D6A51B027FEABF123FD78E84D3D63  
deviceLocked: true  
verifiedBootState: Verified  
verifiedBootHash:  
E07ADF185A36CE4A2FED204CF9C3103D54  
1B7A90305F89785154A460688553E0
```

OS version

130000

OS patch level

202306

Attestation application ID

Package info 1/1:
io.github.vvb2060.keyattestation (version
code 165)

Certificate sha256 digest 1/1:
D8B53693490D6E7467F985165001A547F72
2E75735B34E6AA13BF949F5216F1E

Strategy to leak GAK

- Stored as EKEY in Android Filesystem
 - /mnt/vendor/efs/DAK/GAK_EC.private

Strategy to leak GAK

- Stored as EKEY in Android Filesystem
 - /mnt/vendor/efs/DAK/GAK_EC.private

 1. **Forge a valid** Begin request with GAK keyblob
 2. **Stop the execution** after BeginOperation is called
 3. **Leak** memory (as in previous PoC)
 4. Try to every possible private keys in the dump
 - By generating the public key out of it

Strategy to leak GAK

- Stored as EKEY in Android Filesystem
 - /mnt/vendor/efs/DAK/GAK_EC.private

 1. **Forge a valid** Begin request with GAK keyblob
 2. **Stop the execution** after BeginOperation is called
 3. **Leak** memory (as in previous PoC)
 4. Try to every possible private keys in the dump
 - By generating the public key out of it

→ Still WIP

Strategy to leak GAK

- Stored as EKEY in .apk
 - /mnt/vendor/ekey

- 1. **Forge a valid** Begin
- 2. **Stop the execution**
- 3. **Leak memory** (as
- 4. Try to every possi
 - By generating

→ Still WIP



Conclusion

- We presented 4 vulnerabilities leading to
 - Authentication bypass in Odin
 - Code execution with persistence in LK
 - Leak of SW memory, including Keystore keys
 - Still unclear if we can leak Attestation Keys
- Impact low/middle end Samsung devices
 - Vulnerabilities are simple, and yet super impactful
 - No mitigations in LK nor ATF
- All the vulnerabilities are now fixed

Thank you!

contact@quarkslab.com

Quarkslab



@max_r_b
@DamianoMelotti
@pwissenlit