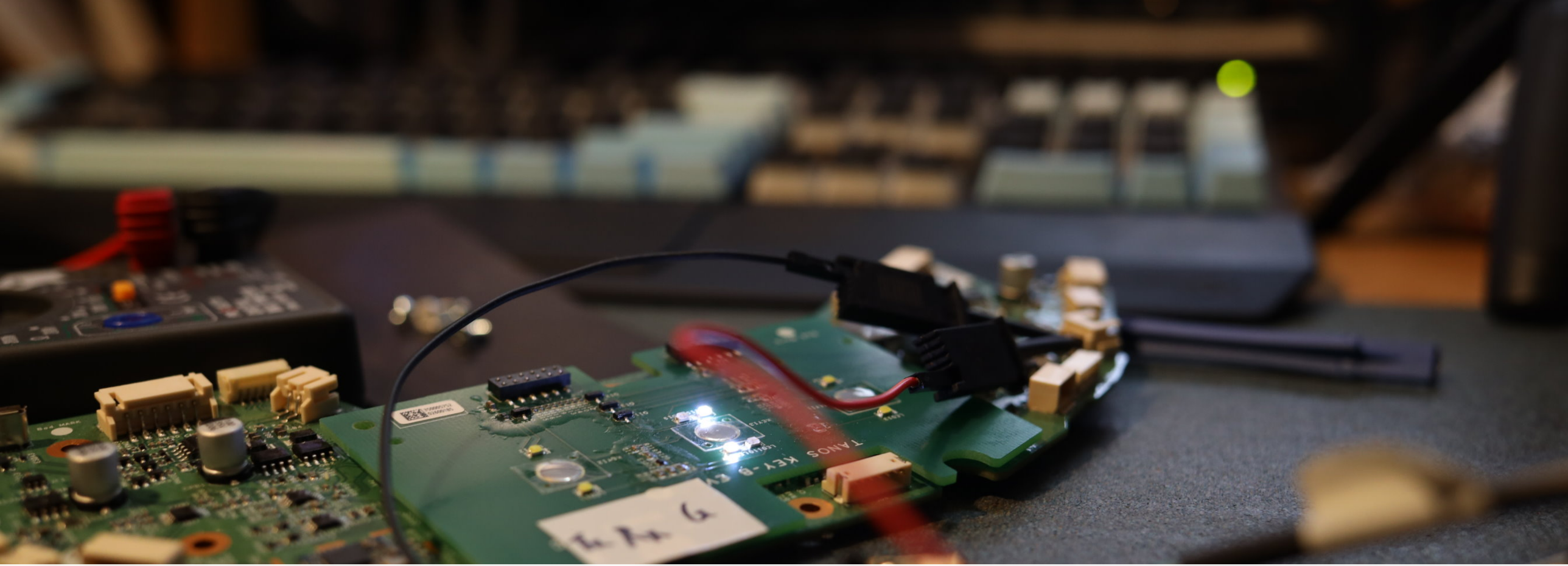


“Smart” Vacuum Cleaners

An Audit Into The Security and Integrity of IoT Systems

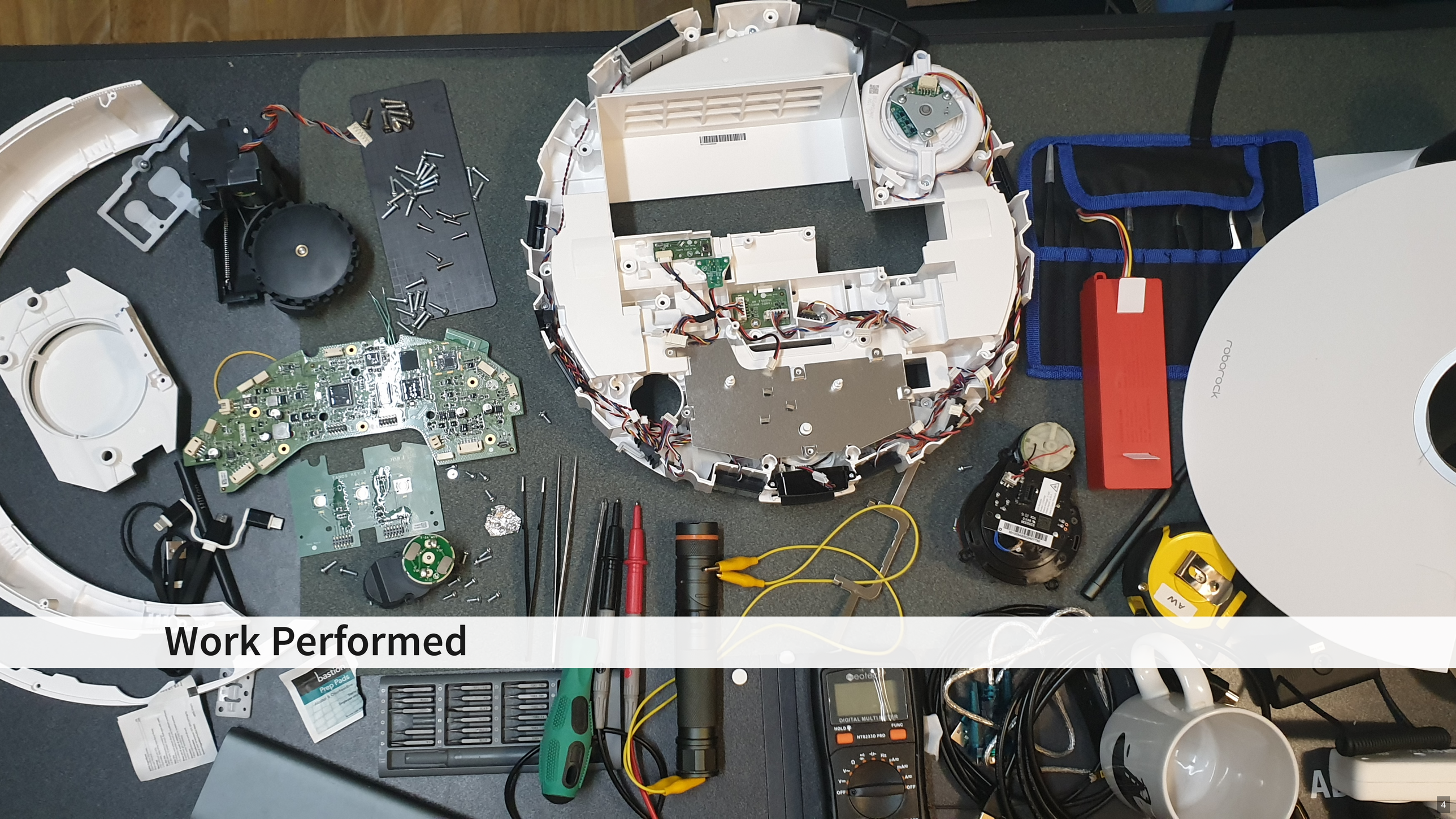
Andrew Wong | UNSW Sydney

Today’s Agenda

Statement

How have manufacturers of IoT / smart home devices addressed the increasing concerns of digital privacy and product security?

- Digital Privacy - Investigate the nature of network data (i.e. content, frequency, destination) and how the data is used.
- Product Security - Investigate potential security vulnerabilities and assess the effectiveness of current security fortifications.



Work Performed

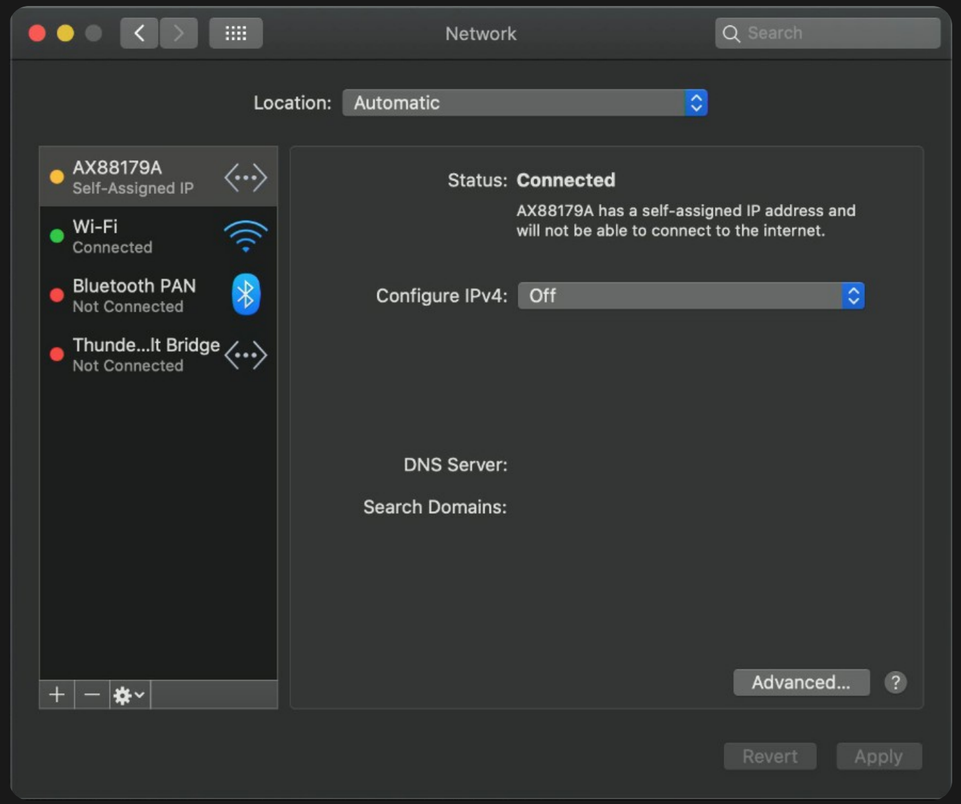
More logging

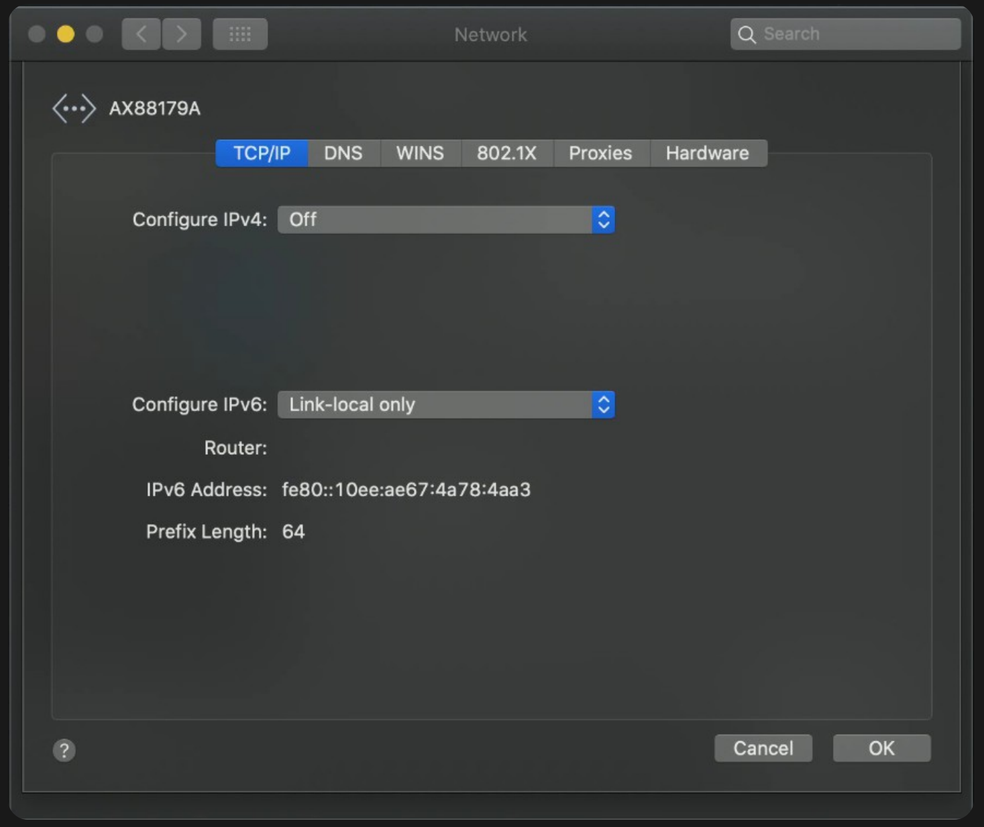
Previously packet captures only logged WAN traffic… now port mirroring from a switch (TP-Link TL-SG105E)

- Now getting all LAN data too! (port mirrored from AP)

More logging

Previously packet captures only logged WAN traffic… now port mirroring from a switch (TP-Link TL-SG105E)





- The switch doesn’t offer true port mirroring - so also seeing sink data
- Disabled IPv4 and (attempt to disable) IPv6 on the network adapter

Fingerprinting

System

```
[ 0.340]U-Boot 2011.09-rc1-dirty (Mar 25 2020 - 20:45:43) Allwinner Technology
[ 0.000000] Linux version 3.4.39 (rockrobo@apimg) (gcc version 4.8.4 (Ubuntu/Linaro 4.8
[ 0.000000] CPU: ARMv7 Processor [410fc075] revision 5 (ARMv7), cr=10c5387d
[ 0.000000] Machine: sun8i
...
```

CPU: Allwinner R16 (ARM Cortex-A7) - ARMv7l / armhf

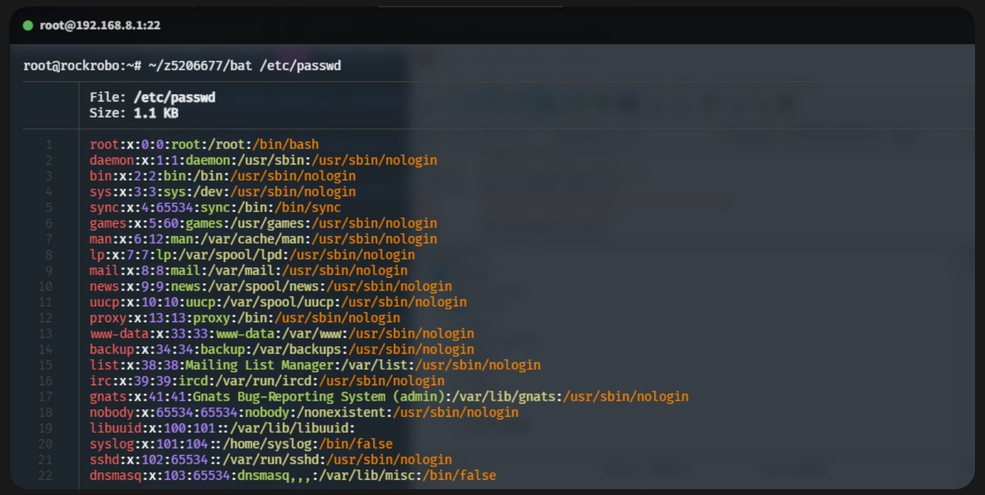
ACU: STM32F103VCT6 (ARM Cortex-M3)

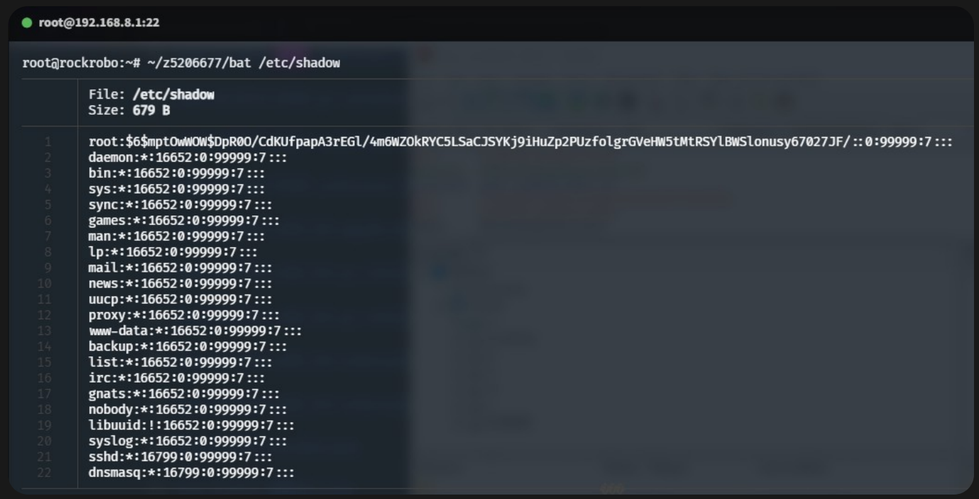
Roborock Firmware version: 3.5.4_1558

Operating system: Ubuntu 14.04.3 LTS

Fingerprinting

Users





No additional users

```
root@rockrobo:~# ls /home
ruby
```

`/home/ruby` exists but no user `ruby`, though exists in `/etc/passwd`~

Fingerprinting

Processes

- Everything is running as root

Fingerprinting

Ports

```
root@rockrobo:~# netstat -nltp
Active Internet connections (only servers)
Proto Recv-Q Send-Q Local Address           Foreign Address         State       PID/Progra
tcp        0      0 127.0.0.1:54322         0.0.0.0:*               LISTEN      991/miio_c
tcp        0      0 127.0.0.1:54323         0.0.0.0:*               LISTEN      991/miio_c
tcp        0      0 0.0.0.0:22              0.0.0.0:*               LISTEN      1644/sshd
tcp        0      0 127.0.0.1:55551         0.0.0.0:*               LISTEN      998/rriot_
tcp        0      0 0.0.0.0:6668            0.0.0.0:*               LISTEN      998/rriot_
tcp6       0      0 :::22                   :::*                    LISTEN      1644/sshd
```

`tcp/22` and `tcp/6668` are exposed

Fingerprinting

Firewall

At least port 22 is blocked by `iptables`

```
root@rockrobo:~# iptables -L
Chain INPUT (policy ACCEPT)
target     prot opt source               destination
DROP       udp  --  anywhere             anywhere             udp dpt:6665
DROP       tcp  --  anywhere             anywhere             tcp dpt:6665
DROP       tcp  --  anywhere             anywhere             tcp dpt:ssh

Chain FORWARD (policy ACCEPT)
target     prot opt source               destination

Chain OUTPUT (policy ACCEPT)
target     prot opt source               destination
```

- What runs on port `6665`
  - `player`
  - Why not file-based IPC?

Fingerprinting

```
root@rockrobo:~# ip6tables -L
Chain INPUT (policy ACCEPT)
target     prot opt source               destination

Chain FORWARD (policy ACCEPT)
target     prot opt source               destination

Chain OUTPUT (policy ACCEPT)
target     prot opt source               destination
```

… except IPv6 isn’t..

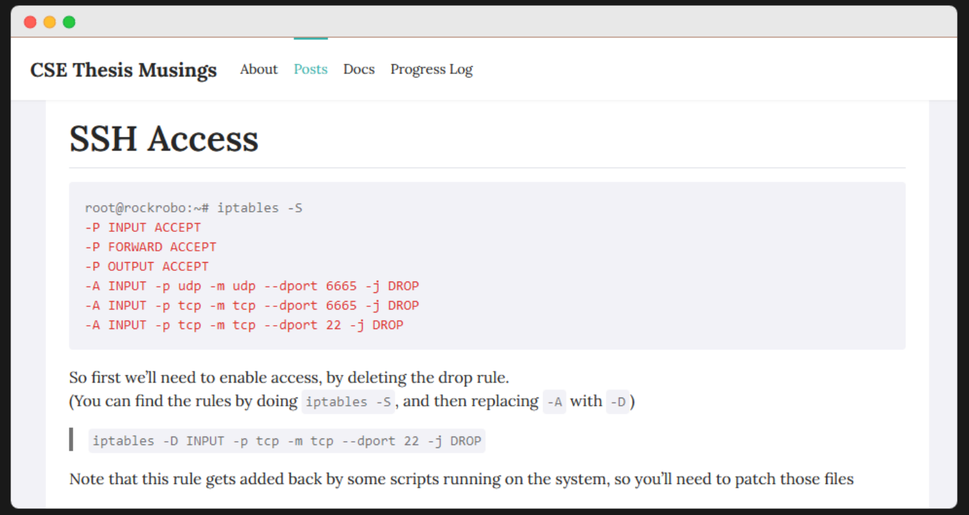
Future work: Test IPv6

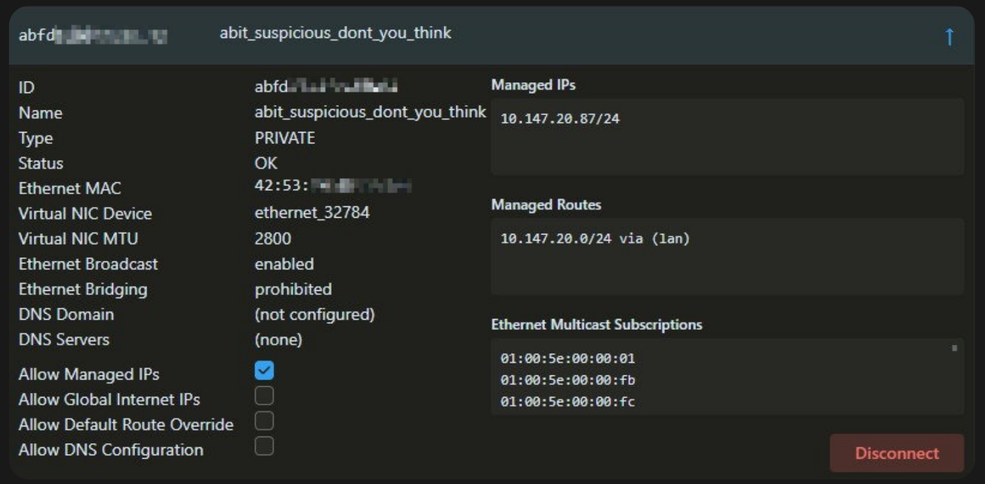
Fingerprinting

Other small tests

- Can I ping the internet?
  - Yes
- Can I run my own software
  - Yes (`armhf`)

Going wireless - establishing SSH

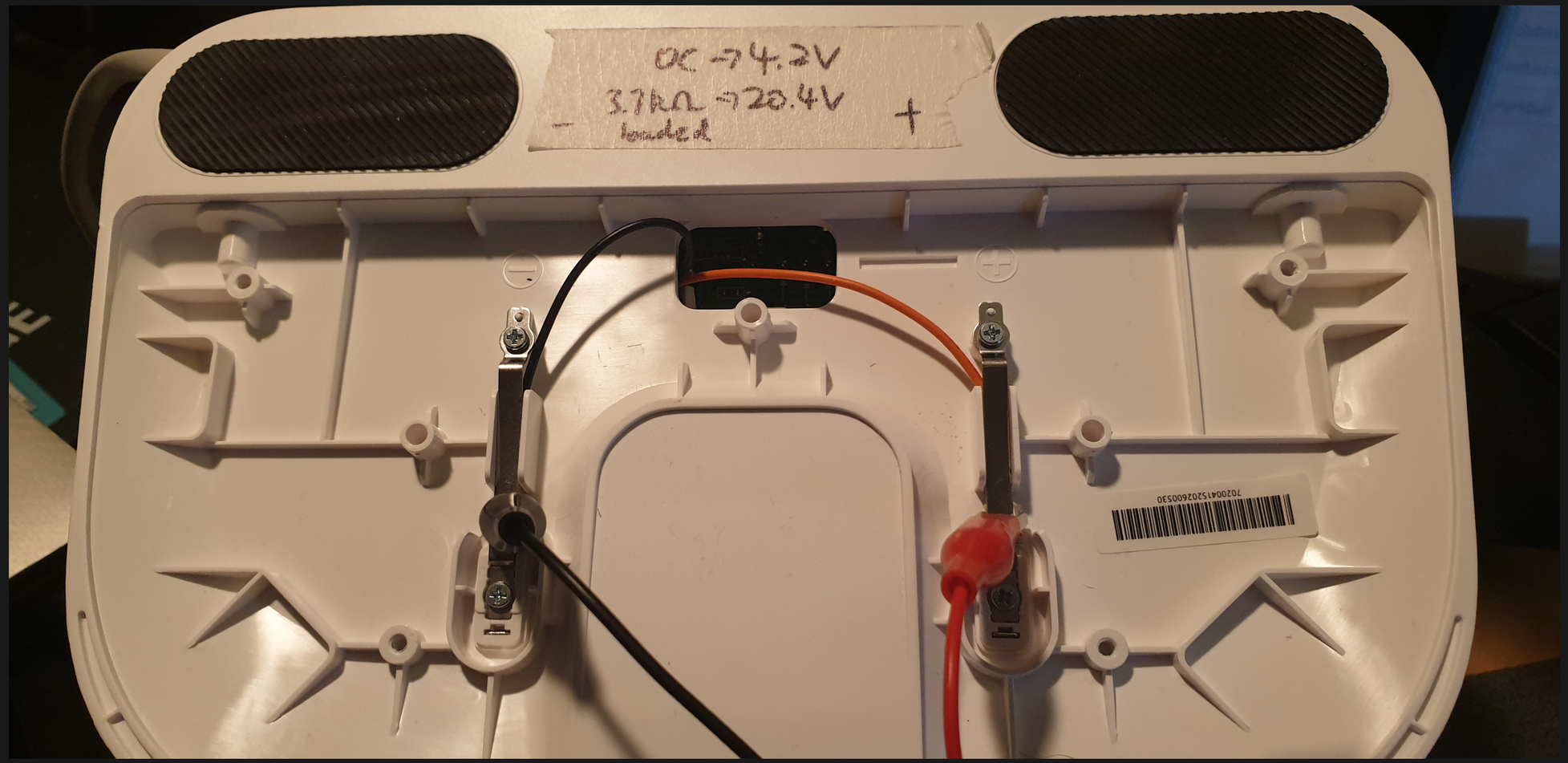




- Remove iptables rule to gain access
  - (and so could an attacker)
- Can I add persistent access?
  - Yes, modify `rrwatchdoge.conf`
- Can also add remote access
  - e.g. ZeroTier

Trivial Power Analysis

Batteries dont’t last forever!



Test: What if I unplug the battery?

- No change in output during boot
- But device will turn off after around 20 seconds

```
Ubuntu 14.04.3 LTS rockrobo ttyS0

rockrobo login:                                          #### Usual login prompt
wait-for-state stop/waiting
haveged: haveged Stopping due to signal 15               #### Shutdown SIGTERM

 * Stopping rsync daemon rsync                                        [ OK ]
 * (not running)
 * Asking all remaining processes to terminate...                     [ OK ]
 * All processes ended within 1 seconds...                            [ OK ]
umount: /tmp: device is busy.
        (In some cases useful info about processes that use
         the device is found by lsof(8) or fuser(1))
 * Unmounting temporary filesystems...                                [fail]
 * Deactivating swap...                                               [ OK ]
 * Unmounting local filesystems...                                    [ OK ]
 * Will now halt
[   26.948171] [MCU_UART] sent ap poweroff event to mcu          #### Device turns off
```

See 2-wire log, 4-wire log

File System Imaging

The eMMC only has 4GB of storage, so we can’t (also shouldn’t) image the flash onto itself… but we can image it remotely!

```
IP=10.10.10.8
for partition in `ssh root@$IP "ls /dev/mmcblk0?* -1"`
do
    ssh root@$IP "sudo dd if=$partition bs=1M" | dd of=$(basename $partition).img
done
```

File System Structure

partition	label	size	description
mmcblk0p1	UDISK	1.5 GB	user data
mmcblk0p2	boot-res	8 MB	bootloader stuff
mmcblk0p5	env	16 MB	
mmcblk0p6	app (RO)	64 MB	device data
mmcblk0p7	recovery	512 MB	stock firmware
mmcblk0p8	system_a	512 MB	Main OS (boot)
mmcblk0p9	system_b	512 MB	Backup OS
mmcblk0p10	Download	528 MB	Update temp
mmcblk0p11	reserve	16 MB	blackbox???

Recovery Reset

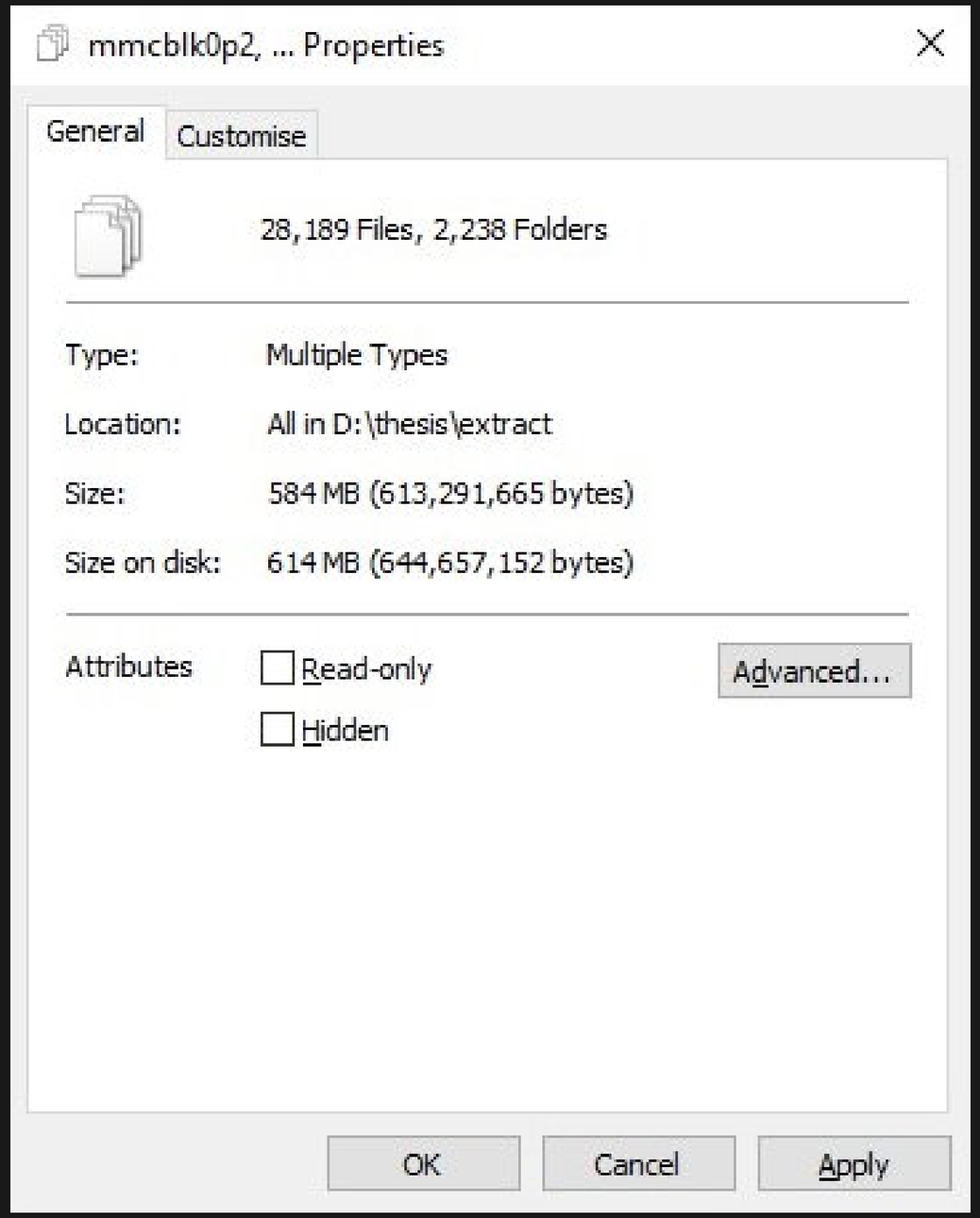
Recovery supposedly resets `system_a`, `system_b`, `UDISK` and `Download`

```
flag a=2,flag b=4,will be recover system
play opt/rockrobo/resources/sounds/en/bl_recovery_bootfailed.wav
Loading file "opt/rockrobo/resources/sounds/en/bl_recovery_bootfailed.wav" from mmc device 2:7
195238 bytes read
sunxi codec request dma 0x5ebb47b4
rr_recovery_pre_check:716:found recovery num 3
Loading file "/boot/zImage" from mmc device 2:7
3882616 bytes read
part recovery valid
recovery from "recovery" to "system_a"
cover init begin
found recovery
set src start=0,src_size=0
found system_a
set dest start=645922816,dest_size=536870912
real_cover:141:total size=536870912,block=1048576

MMC read: dev # 2, block # 253952, count 8192 ... 8192 blocks read: OK

MMC write: dev # 2, block # 1302528, count 8192 ... 8192 blocks write: OK
```

- What about the other partitions?
- Can we plant malicious software in `recovery`? A: Yes



28,189 files…

Well there's for sure a lot of files to look at…

I did a thing - Commentree

Plain-text annotation / commentary tool

Interesting Files

- mmcblk0p1/miio/device.token=utnevRELra5sqef3
- mmcblk0p1/miio/device.uid=1738271950
- mmcblk0p1/rockrobo/
- mmcblk0p11/endpoint.bin - AWS address + key?
- mmcblk0p7/boot/zImage - bootloader

vinda usage

passwords syslogs

Look for any emails

```
Look for IPs, emails, host/domains, passwords, keys
Check where DID and UID is used
Dummy data to check if it’s logged
```

What other files were changed?

compare against base ubuntu system?

Logs

/var/log/apt/history.log

```
Start-Date: 2016-01-25  11:18:05
Commandline: /usr/bin/apt-get install rsync
Install: rsync:armhf (3.1.0-2ubuntu0.2)
End-Date: 2016-01-25  11:18:11

Start-Date: 2016-04-05  12:30:59
Commandline: /usr/bin/apt-get install ccrypt
Install: ccrypt:armhf (1.10-4)
End-Date: 2016-04-05  12:31:01

Start-Date: 2016-04-25  09:58:29
Commandline: /usr/bin/apt-get install tcpdump
Install: tcpdump:armhf (4.5.1-2ubuntu1.2), libpcap0.8:armhf (1.5.3-2, automatic)
End-Date: 2016-04-25  09:58:33
```

tcpdump

/usr/sbin/tcpdump

```
root@rockrobo:/var/log# cat dpkg.log | grep "install "
2016-04-25 09:58:30 install libpcap0.8:armhf <none> 1.5.3-2
2016-04-25 09:58:31 install tcpdump:armhf <none> 4.5.1-2ubuntu1.2
2016-05-03 12:06:01 install pigz:armhf <none> 2.3-2
2016-05-23 09:41:25 install lsof:armhf <none> 4.86+dfsg-1ubuntu2
2016-06-23 15:02:26 install gcc-6-base:armhf <none> 6.1.1-3ubuntu11~14.04.1
2016-06-23 15:06:01 install gcc-5-base:armhf <none> 5.3.0-3ubuntu1~14.04
root@rockrobo:/var/log#
```

miio mmcblk0p7\opt\rockrobo rrlog rriot

ADB

adb

- Custom ADB binary
- Had a brief look (more)
- mmcblk0p6\adb.conf
- mmcblk0p8\var\log\upstart\adbd.log

rsync and tcpdump

Static binaries

```
./htop --sort-key=PID -C
```

Compare against standards (i.e. Xiaomi’s standard)

Issues, thoughts & discussions

How have manufacturers of IoT / smart home devices addressed the increasing concerns of digital privacy and product security?

Wireless credentials are stored in plain text

- Anyone with physical access to the machine can gain wireless credentials
- However, takes a lot of effort to open up the device
- Why? `wpa_supplicant` is part of the underlying Linux framework

Issues, thoughts & discussions

How have manufacturers of IoT / smart home devices addressed the increasing concerns of digital privacy and product security?

SSH server exposed on `tcp/22`

- Why does this server exist?
- When / where is it used?
  - Allow rule inside the `rrlogd` binary
- Roborock has made an attempt to protect their product with `iptables`
- But did not fully product their product against access via IPv6

Issues, thoughts & discussions

How have manufacturers of IoT / smart home devices addressed the increasing concerns of digital privacy and product security?

Processes are running as `root`

- Any vulnerability in any of the programs can result in elevated access
  - Dropping of iptables restrictions
  - Persistence planting
  - System takeover
- Should run as a de-privileged user
- Why? Compatibility, perhaps ease of development
  - i.e. `udev` rules

Issues, thoughts & discussions

How have manufacturers of IoT / smart home devices addressed the increasing concerns of digital privacy and product security?

Recovery partition is modifiable

- Can be modified to contain malicious software that persists a factory reset
- Mountable - `mount /dev/mmcblk0p7 ...`
- Why? Allows easy updates of the ‘factory image’
- But the partition could somehow be encrypted

Issues, thoughts & discussions

How have manufacturers of IoT / smart home devices addressed the increasing concerns of digital privacy and product security?

A note on hardware

> *“Once you have access to the hardware, it’s game over”*

- netcat, tcpdump, ccrypt?

How easy is it for someone to attack the system?

What’s Good

- iptables
- some logs are encrypted locally
- Hands-on access a system = game over
  - But should it be?

Are there any backdoors? outbound requests persistent software (install to recovery + system_a)

```
root@rockrobo:/proc# cat misc
 48 android_adb
 49 mali
 50 network_throughput
 51 network_latency
 52 cpu_dma_latency
 53 xt_qtaguid
 54 leds
236 device-mapper
130 watchdog
200 tun
 55 lds_motor
 56 jiffies
 57 uart_lds
 58 uart_mcu
237 loop-control
 59 sw_sync
 60 cuse
229 fuse
 61 sunxi-reg
 62 cachefiles
 63 ion
```

- Can I plant software (y)

- Why is netcat installed but not curl, wget?
- TODO: Check what gets cleared during a format / update

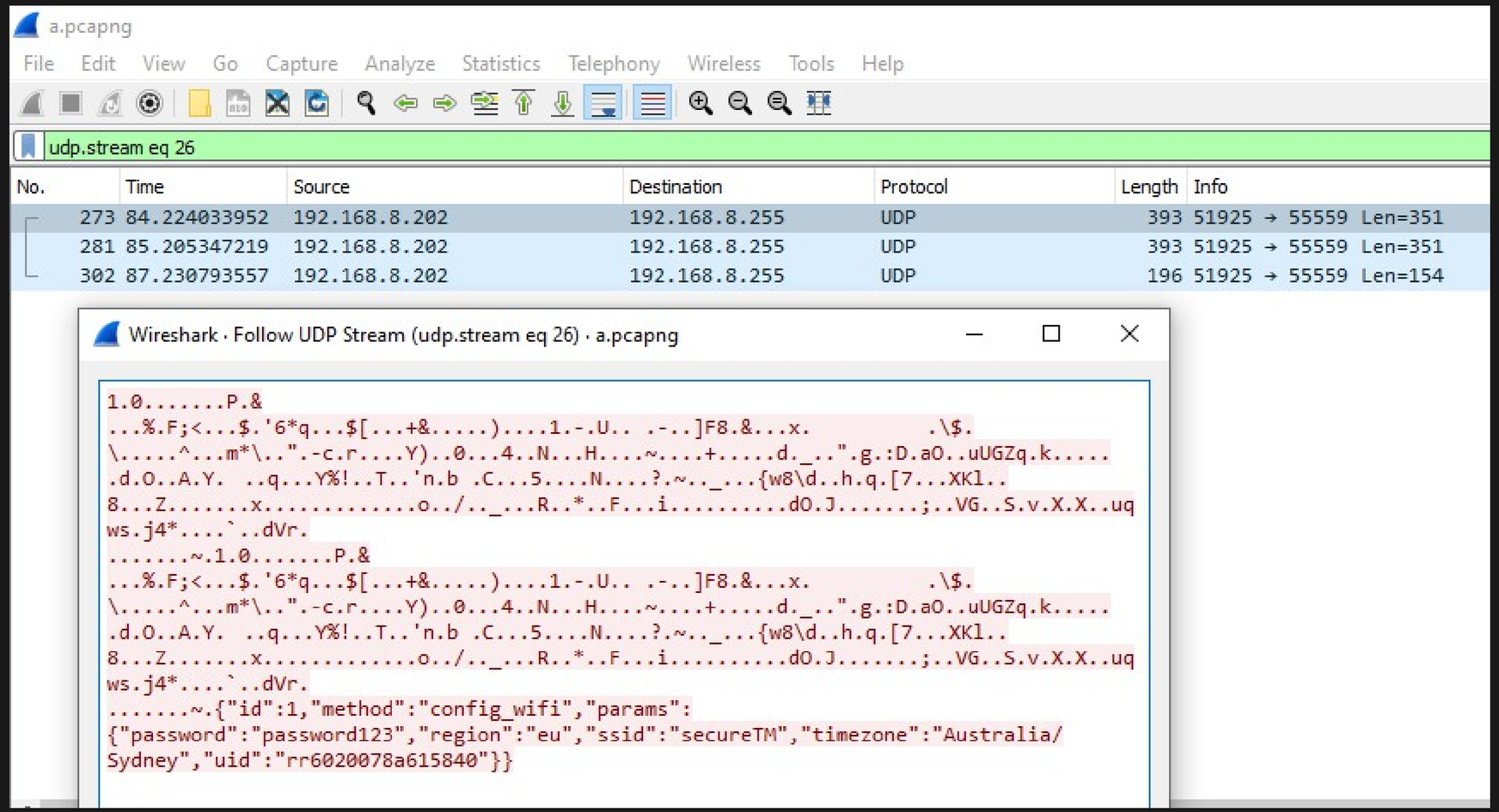
Capturing network data during device registration

- Have shell access but
- PolarProxy is too new for Ubuntu 14.04
- apt update doesn’t work with socks5:// or http proxies properly

On the smart app side

Frida nope windows env nope https://github.com/NickstaDB/patch-apk https://blog.silentsignal.eu/2020/05/04/decrypting-and-analyzing-https-traffic-without-mitm/ RoboRock app

during pairing the password is transmitted in plaintext


a.pcapng
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
udp.stream eq 26
No. Time Source Destination Protocol Length Info
273 84.224033952 192.168.8.202 192.168.8.255 UDP 393 51925 → 55559 Len=351
281 85.205347219 192.168.8.202 192.168.8.255 UDP 393 51925 → 55559 Len=351
302 87.230793557 192.168.8.202 192.168.8.255 UDP 196 51925 → 55559 Len=154
Wireshark · Follow UDP Stream (udp.stream eq 26) · a.pcapng
1.0.....P.&
...%.F;<...$.'6*q...$[...+&.....)....1.-.U.. .-..]F8.&...x. .\$.
\.....^...m*\..".-c.r....Y)..0...4..N...H....~....+.....d._..".g.:D.aO..uUGZq.k.....
.d.O..A.Y. ..q...Y%!..T..'n.b .C...5....N....?.~.._...{w8\d..h.q.[7...XKl..
8...Z.....x.....o../.._...R..*..F...i.....dO.J.....;..VG..S.v.X.X..uq
ws.j4*....`..dVr.
.....~.1.0.....P.&
...%.F;<...$.'6*q...$[...+&.....)....1.-.U.. .-..]F8.&...x. .\$.
\.....^...m*\..".-c.r....Y)..0...4..N...H....~....+.....d._..".g.:D.aO..uUGZq.k.....
.d.O..A.Y. ..q...Y%!..T..'n.b .C...5....N....?.~.._...{w8\d..h.q.[7...XKl..
8...Z.....x.....o../.._...R..*..F...i.....dO.J.....;..VG..S.v.X.X..uq
ws.j4*....`..dVr.
.....~.{"id":1,"method":"config_wifi","params":
{"password":"password123","region":"eu","ssid":"secureTM","timezone":"Australia/
Sydney","uid":"rr6020078a615840"}}

Current Challenges - Equipment

- Electricity is dangerous
- Using personal equipment is not a good idea for a test-bench
- Thank you Gigabyte for having ESD-protected USB ports

rrlogd

Logs are encrypted at rest (after being packed)

rrlogd

Possible functionality to perform any arbitrary command?

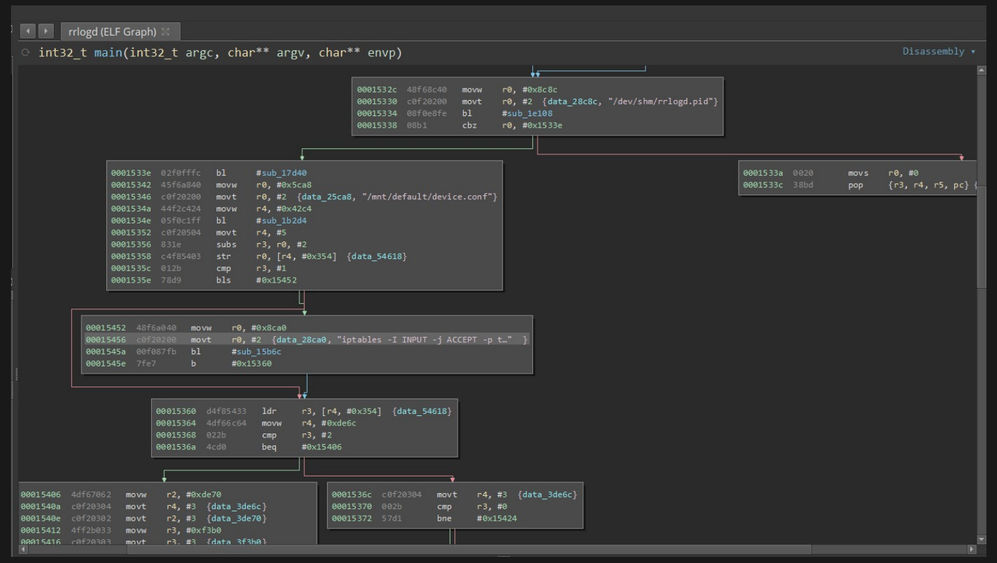
rrlogd (ELF Linear)

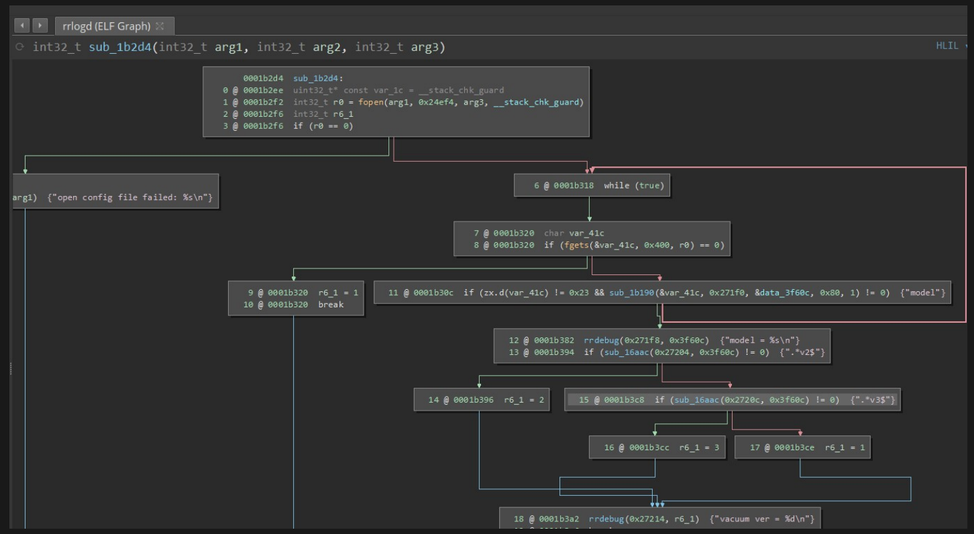
```
int32_t __saved_r6  {Frame offset -8}
int32_t var_4  {Frame offset -4}
int32_t arg1  {Register r0}

sub_15b6c:
00015b6c  70b5      push    {r4, r5, r6, lr} {var_4} {__saved_r6} {__saved_r5} {__saved_r4}
00015b6e  0021      movs    r1, #0
00015b70  0546      mov     r5, r0
00015b72  1120      movs    r0, #0x11
00015b74  fff7a0e8  blx     #signal
00015b78  2946      mov     r1, r5
00015b7a  0646      mov     r6, r0
00015b7c  46f23800  movw    r0, #0x6038
00015b80  c0f20200  movt    r0, #2  {data_2601c[0x1c], "%s\n"}
00015b84  08f074fa  bl      #rrdebug
00015b88  2846      mov     r0, r5
00015b8a  fff7aee8  blx     #system
00015b8e  3146      mov     r1, r6
00015b90  0446      mov     r4, r0
00015b92  1120      movs    r0, #0x11
00015b94  fff790e8  blx     #signal
00015b98  621c      adds    r2, r4, #1
00015b9a  1fd0      beq     #0x15bdc

00015b9c  6306      lsls    r3, r4, #0x19
00015b9e  c4f30721  ubfx    r1, r4, #8, #8
00015ba2  09d1      bne     #0x15bb8
```

rrlogd





Logging program has the potential to unblock port 22?

```
iptables -I INPUT -j ACCEPT -p tcp --dport 22
```

Unfinished Work

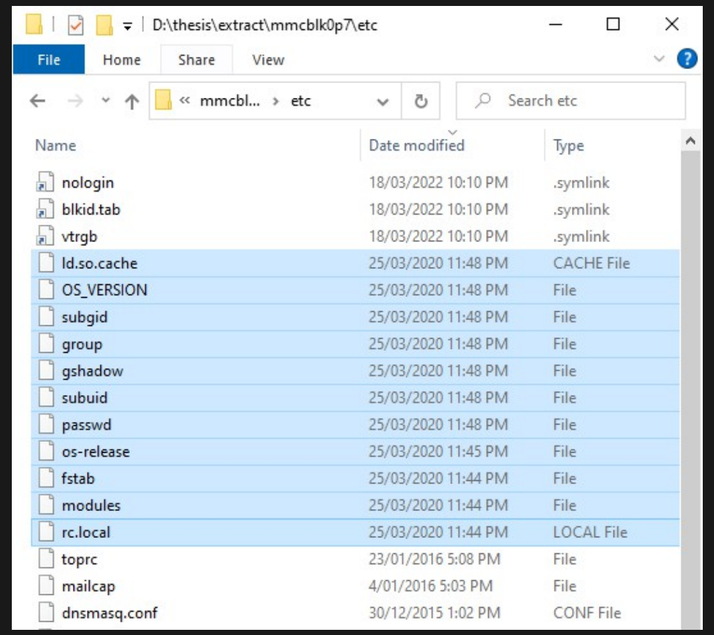
- Still a lot of files to look at
- Need to figure out which files are worthwhile to inspect

Unfinished Work

- Still a lot of files to look at
- Need to figure out which files are worthwhile to inspect

Approach 1 - Filter by date modified

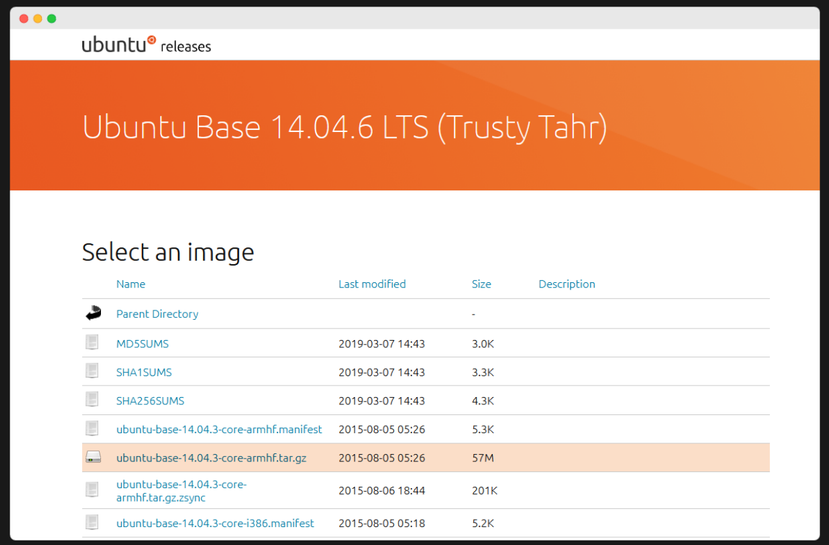
> *Ubuntu 14.04.3 LTS was released back in 2014, any changes would have a later timestamp*



Unfinished Work

- Still a lot of files to look at
- Need to figure out which files are worthwhile to inspect

Approach 2 - File Comparisons



Compare executable files and find differences in binary function

bindiff, binwalk, ssdeep, sdhash

As seen in A Large-Scale Analysis of the Security of Embedded Firmwares - Andrei C, Jonas Z, Aur'elien F, Davide B

Retrospective

- Time management / busy / other work
- Could have done more work

Project Timeline

Thesis A

- Initial research and research environment setup
- Teardown and initial hands-on of Roborock S6

Thesis B - Binary Assessment

- Disassembly and analysis of firmware binaries to identify vulnerabilities
  - inc. ADB binary functionality
- Search for unsecured secrets, logs, configurations

Thesis C - Connectivity Assessment

- Inspection of outbound internet traffic - security, PII, etc
- Inspection of local network traffic
- Inspection of interaction with nearby devices
- Protocol analysis

[Static] Binary assessment

In the mean time

Findings

Project Plan

Revised Project Plan

Next Steps

- Dump the firmware and begin RE / forensics
- Redo (and further investigate) live system analysis
  - i.e. Properly capture *all* network traffic

Any Questions?

Andrew Wong

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