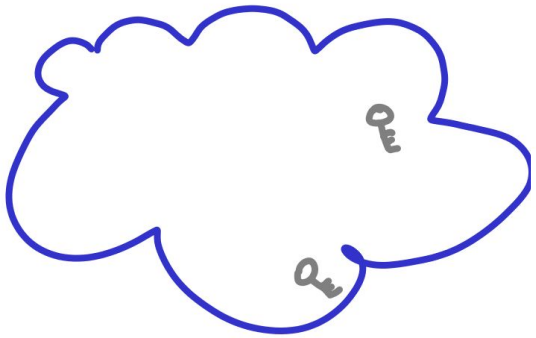
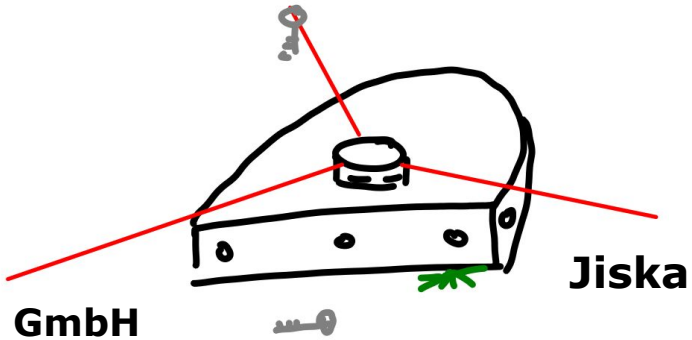
Vacuums in the Cloud

Analyzing Security in a Hardened IoT Ecosystem





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Technische Universität Darmstadt, Germany

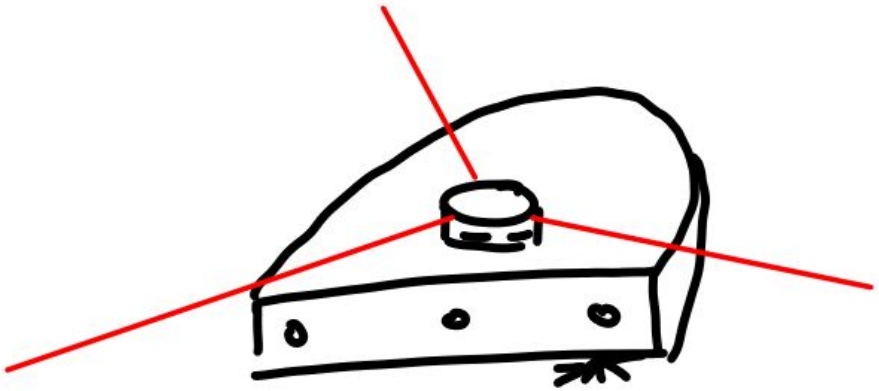
ERNW providing security. | CRISP Center for Research in Security and Privacy | CYSEC Cybersecurity TU Darmstadt | Technische Universität Darmstadt | SEEMOO | DFG Deutsche Forschungsgemeinschaft

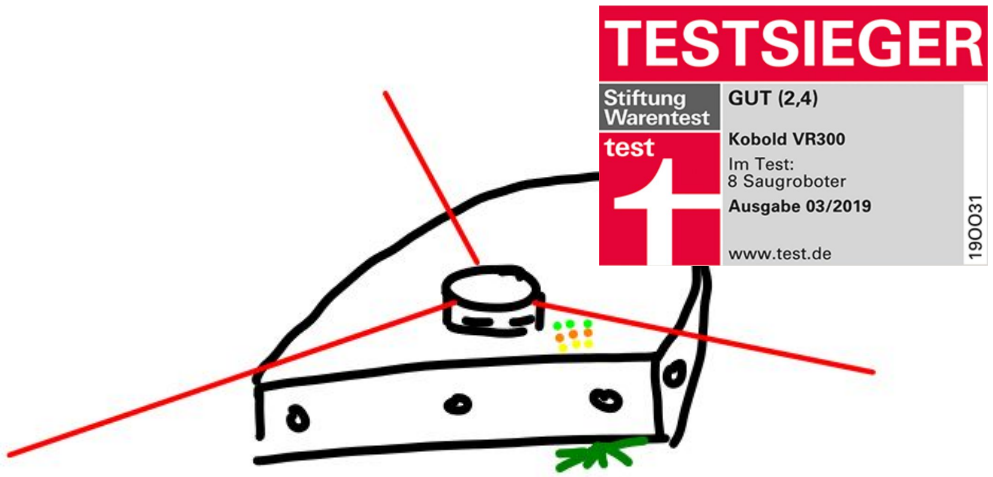
Motivation

- A vacuum cleaning robot is in your house, has **access to your Wi-Fi** and knows many of your **personal habits**.
- **Who of you owns a vacuum cleaning robot?**
- (Own as it's YOUR robot, neither your neighbor's nor someone's on the Internet!)

Motivation

- A vacuum cleaning robot is in your house, has **access to your Wi-Fi** and knows many of your **personal habits**.
- **Who of you owns a vacuum cleaning robot?**
- **Neato** is one of the top vacuum cleaning robot models in the US.
- In Germany, **Vorwerk** has been selling vacuum cleaners forever (founded 1883). Their top model, a robot, is a rebranded Neato.
- Vorwerk won the test comparisons in Germany with their VR300/VR200.



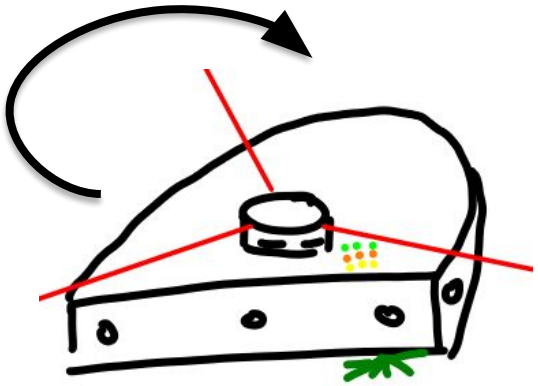


Responsible Disclosure

- **Robots were harmed** during our experiments! (Sorry for that…)
- No customer data was leaked.
- **Neato** was informed and **fixed all issues** in time.

Infrastructure & Security Features

UI & USB console



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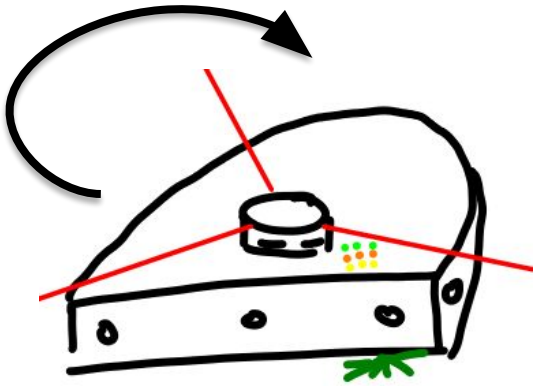
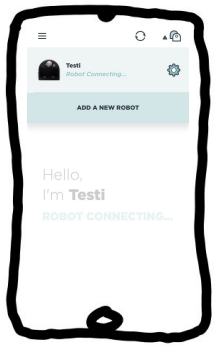


Manual robot commands



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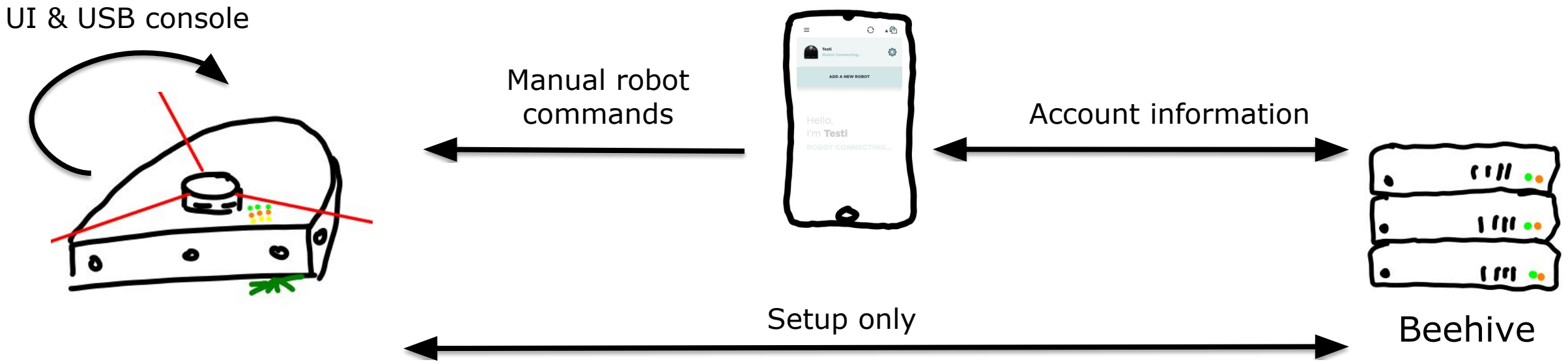

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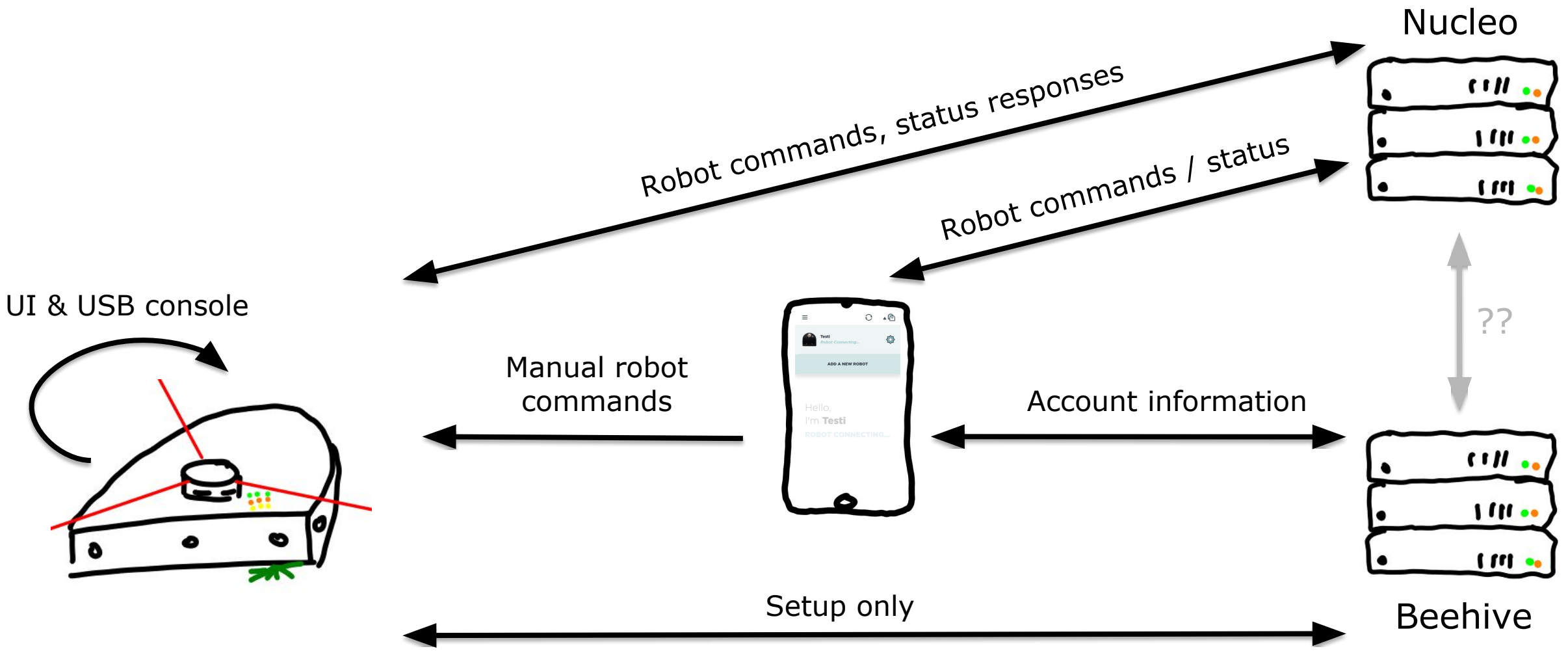

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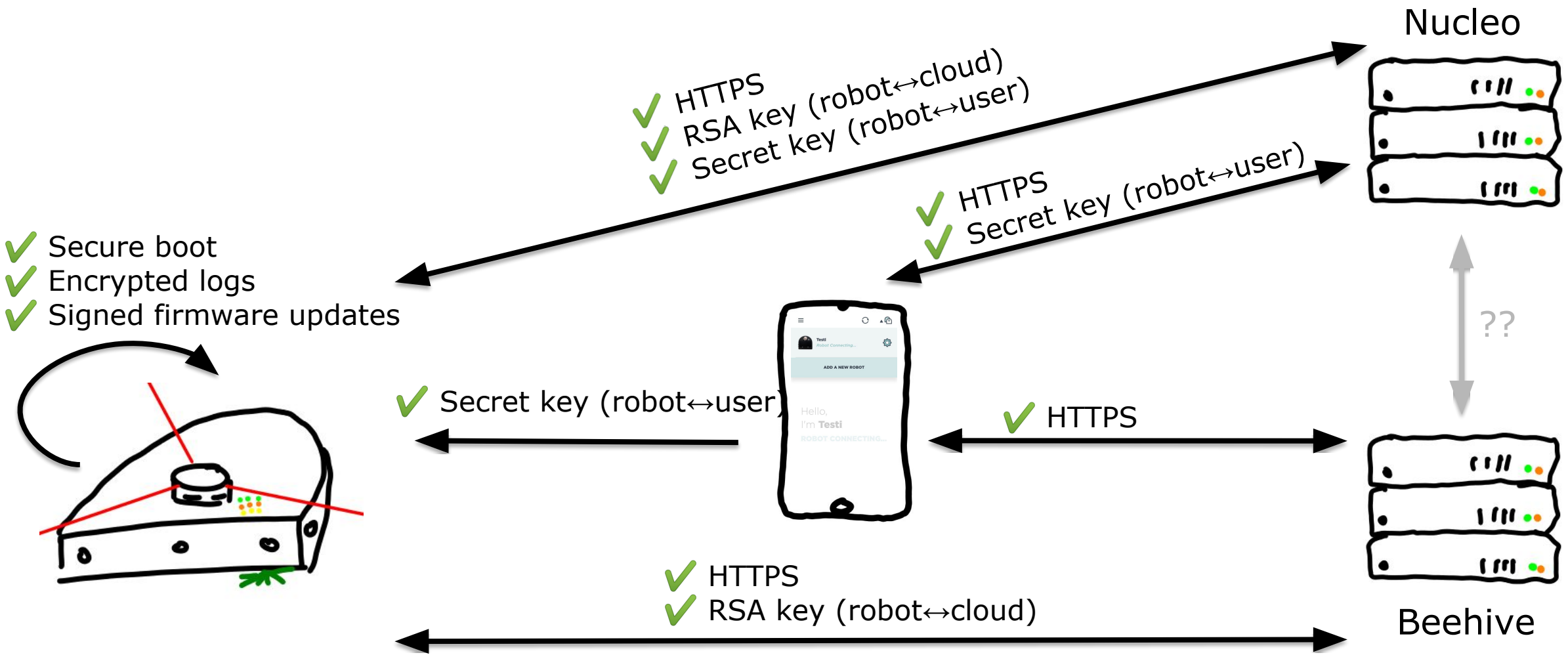

Contributions

- With all these security features, what could possibly go wrong?

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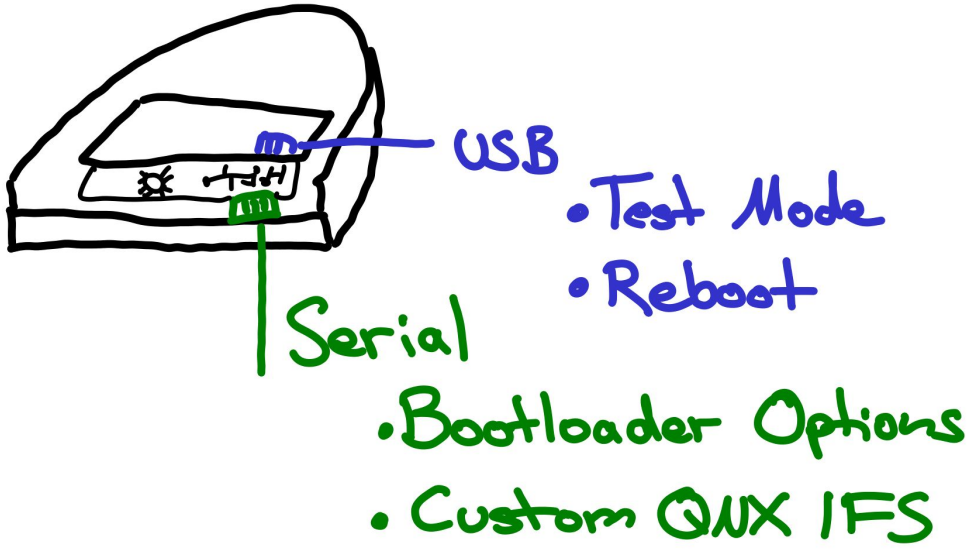
- With all these security features, what could possibly go wrong?
- We bypass secure boot on a vacuum cleaning robot to extract its memory.
- Our key findings are…
  … **key findings**!

- We also gained unauthenticated RCE on robots over the cloud.

Secure Boot Bypass

- Custom *AM335x* chip (guessed by size factor).
- **QNX 6.5 image** from *Foundry27* is bootable but crashes.

- Get QNX SDP, modify image, skip hardware initialization, reboot Neato system into custom image for **cold boot** attack, print all **RAM to the serial port**.



Jiska found this, got assigned CVE-2018-20785, fixed in Neato BotVac Connected D7 4.4.0-72 in December 2018 and for Vorwerk somewhen after January 2019.

Keys and their Purpose (1)

Secret Key

- Generated when associating a **robot** with a **user account**.
- Known by: robot, app and cloud components.
- **Individual** key for each **robot/user account** relation!

  Used for **authenticating commands to robot**.

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Header = Authorization: NEATOAPP [signature]

1 string_to_sign = serial + date + message_body
2 signature = HMAC_SHA256(secret_key, string_to_sign)
```

Keys and their Purpose (2)

RSA Key

- Robots have to initially send the secret key
  - Has to be **authenticated.**
- Secret key not that secret
  - Several third parties know it.
  - Cannot be used to authenticate the robot in the cloud.

  RSA Key used to **authenticate robot to cloud.**

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```
Header = Authorization: NEATOBOT [serial]:[signature]


1 string_to_sign = serial + http_method + URI + date + body
2 signature = sign_rsa_sha256(string_to_sign, rsa_private_key)
```

Secret Key Entropy Reduction

```
1  rnd = rand();
2
3  time_shift[0:3] = time_now;
4  time_shift[4:6] = 0;
5  time_shift[7] = 16;
6  time_shift[8] = rnd + rnd / 0xFFFF;
7  time_shift[9] = entropy_reducing_math(rnd + rnd / 0xFFFF);
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- Entropy relies on **time of robot linkage**.
  - One year = 25 bit
  - One hour = 12 bit

- There are multiple **offline attack** scenarios.

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RSA Keys for Robot Authenticity (1)

- Encrypted RSA keys in `/var/keys`.
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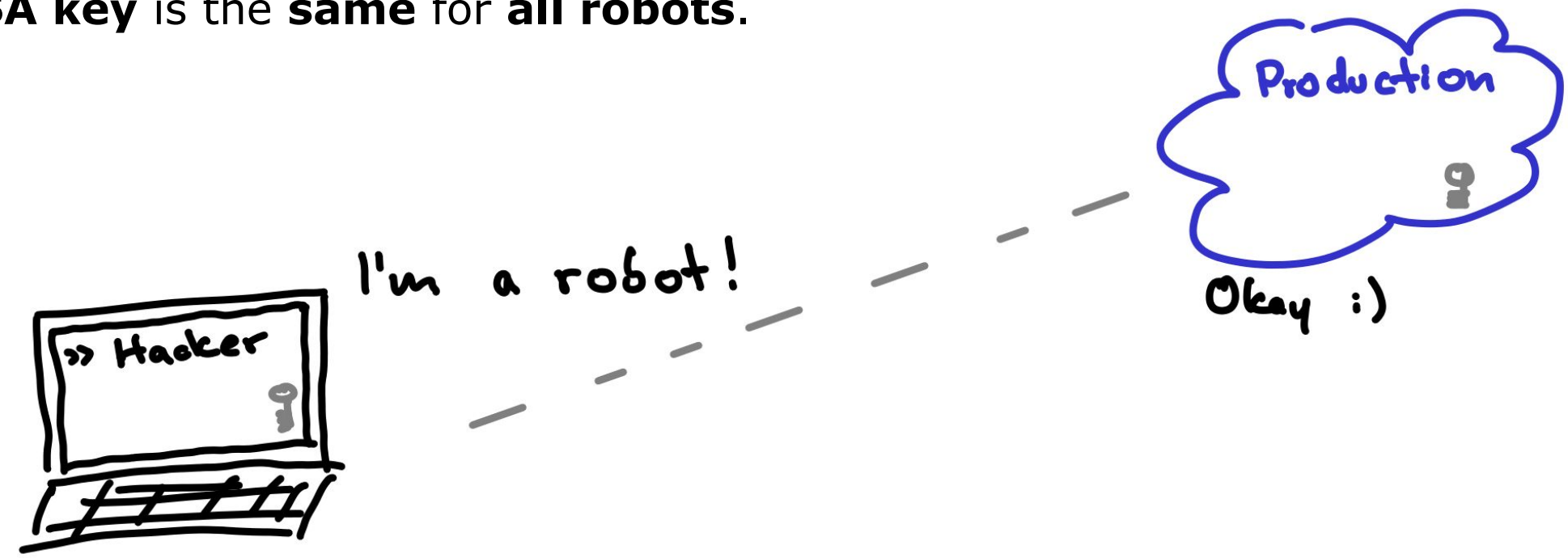

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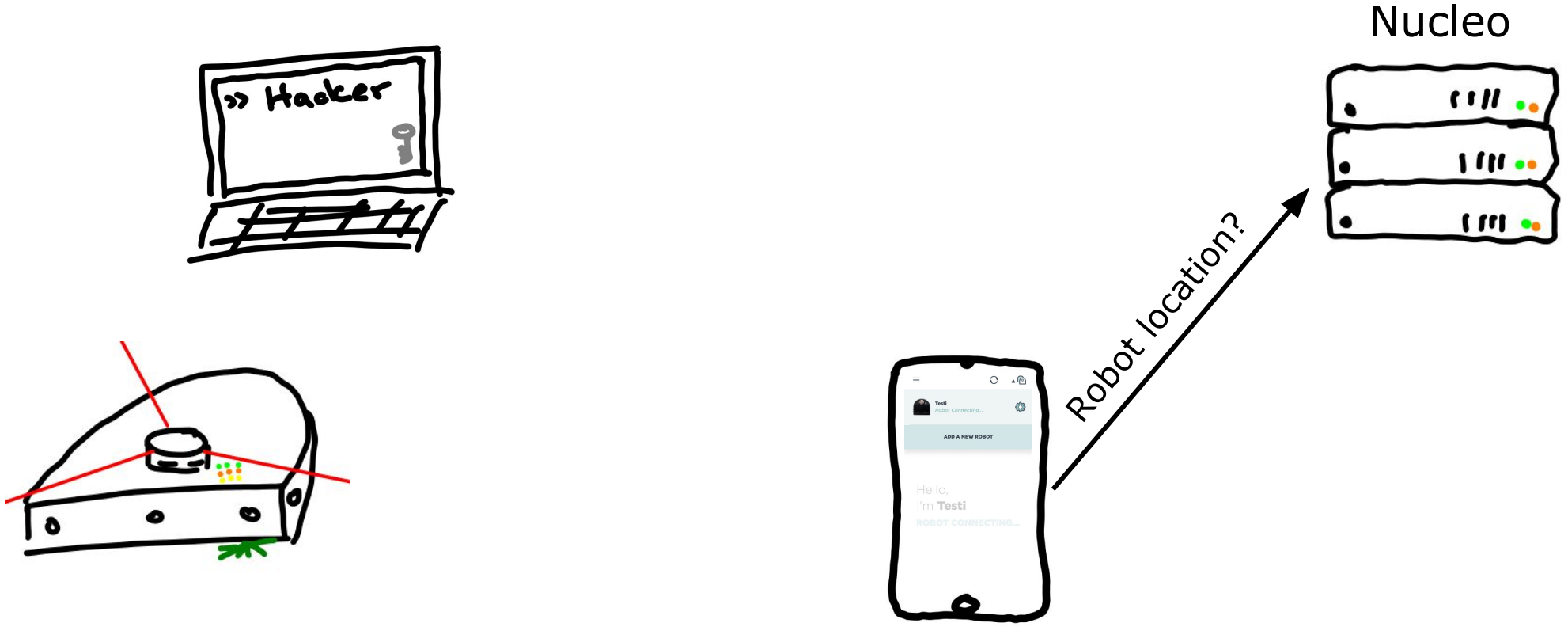
- We are able to **impersonate arbitrary robots.**
  - Allows for multiple other attacks.
  - For example: **Leak victim's smartphone IP**



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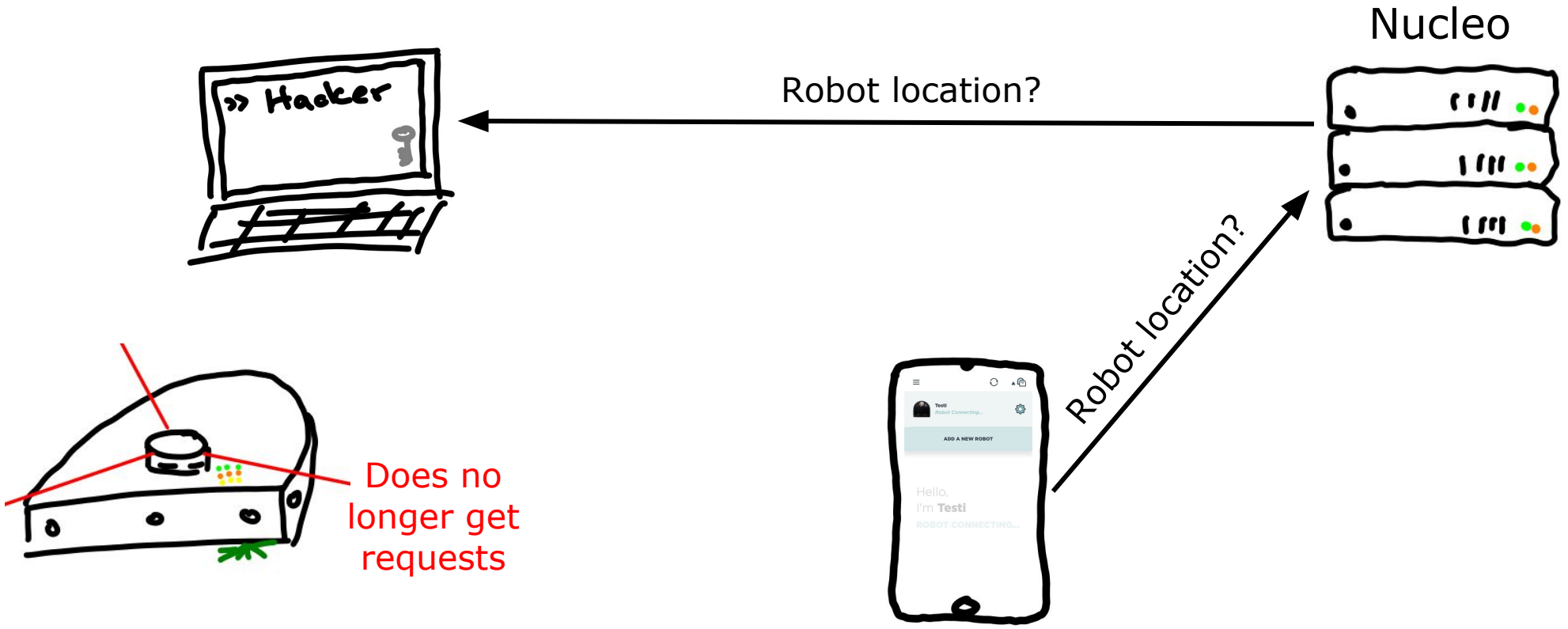

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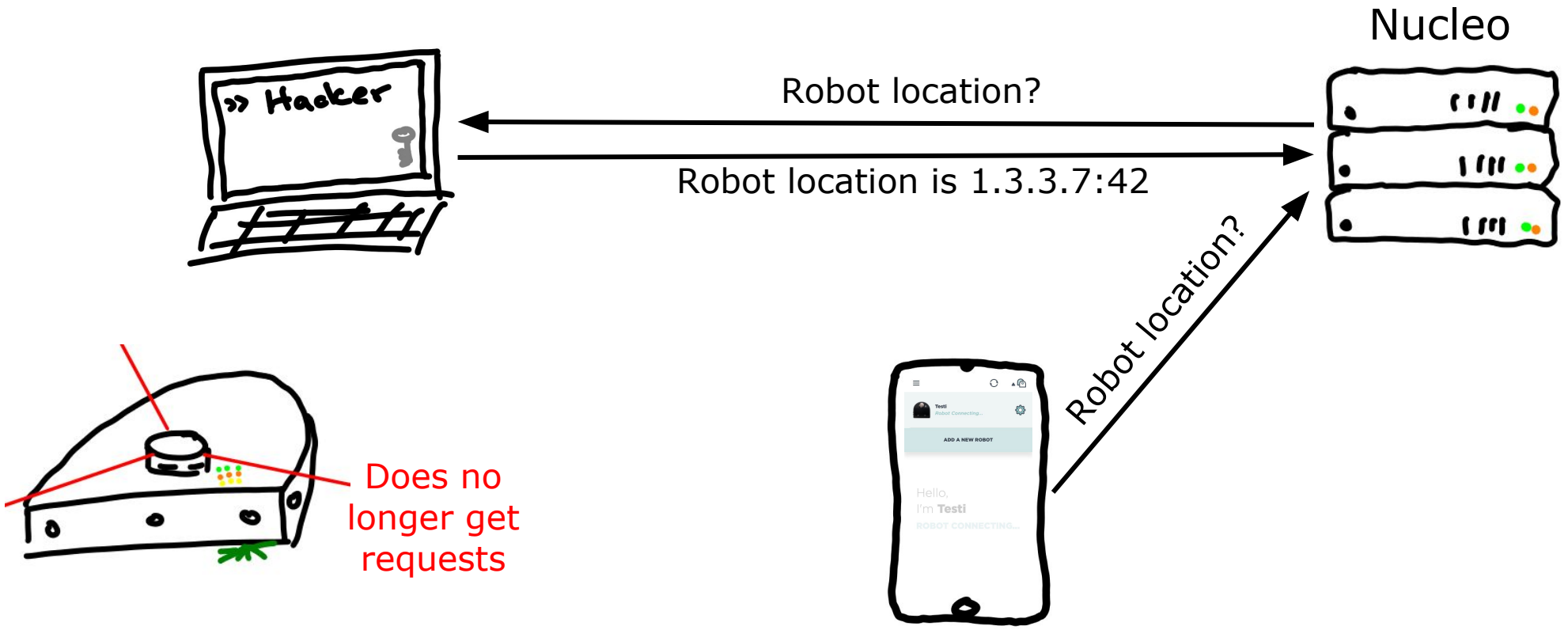

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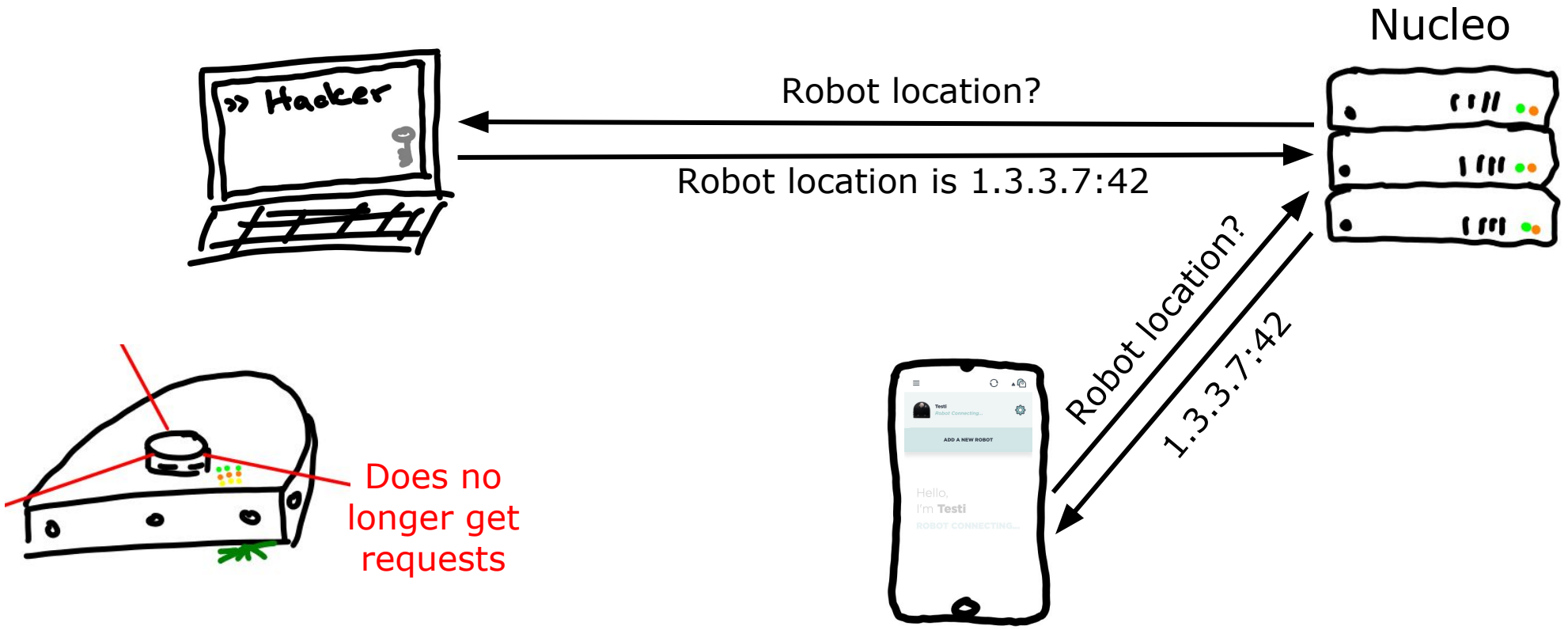

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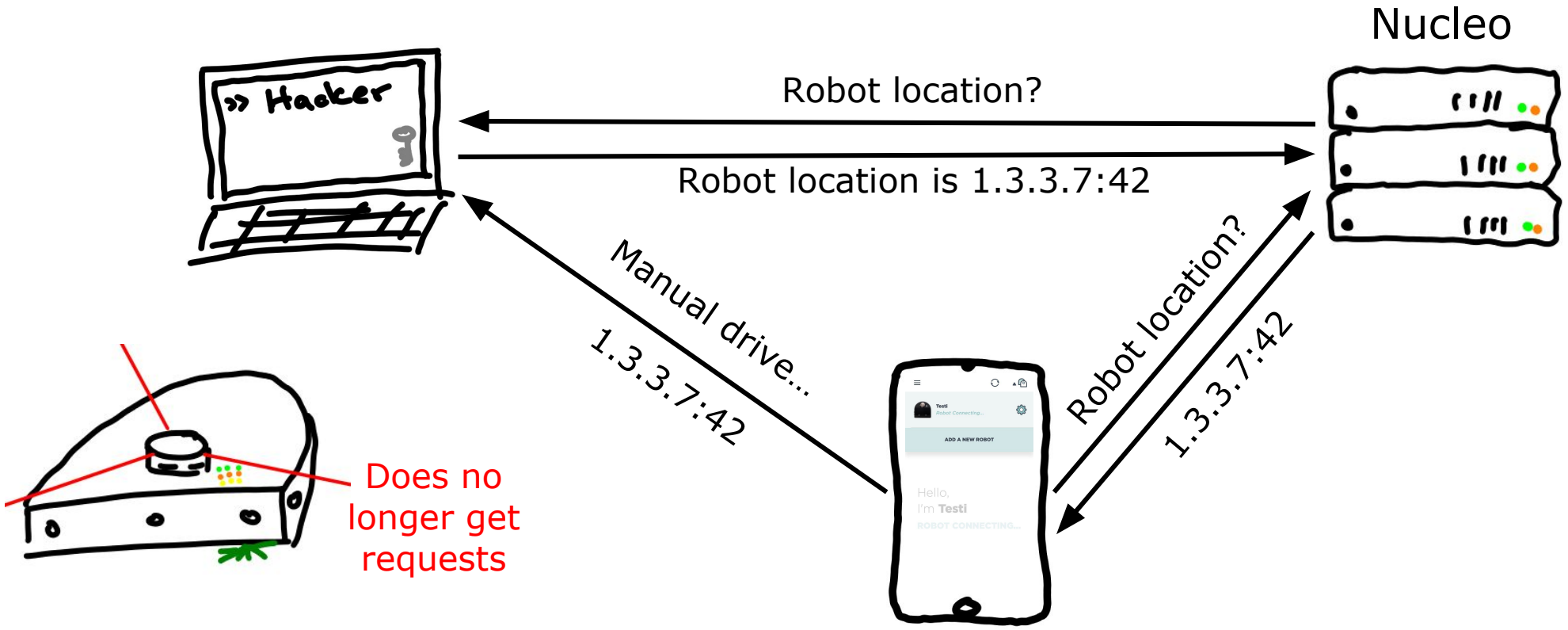


Log and Coredump Encryption Key

```
local_10 = fopen(acStack120,"rb");
if (local_10 != (FILE *)0x0) {
  sVar2 = fread(local_c,local_11c,1,local_10);
  if (sVar2 != 0xffffffff) {
    fclose(local_10);
    rc4_ksa("*^JEd4W!I",9,0);
  …
```

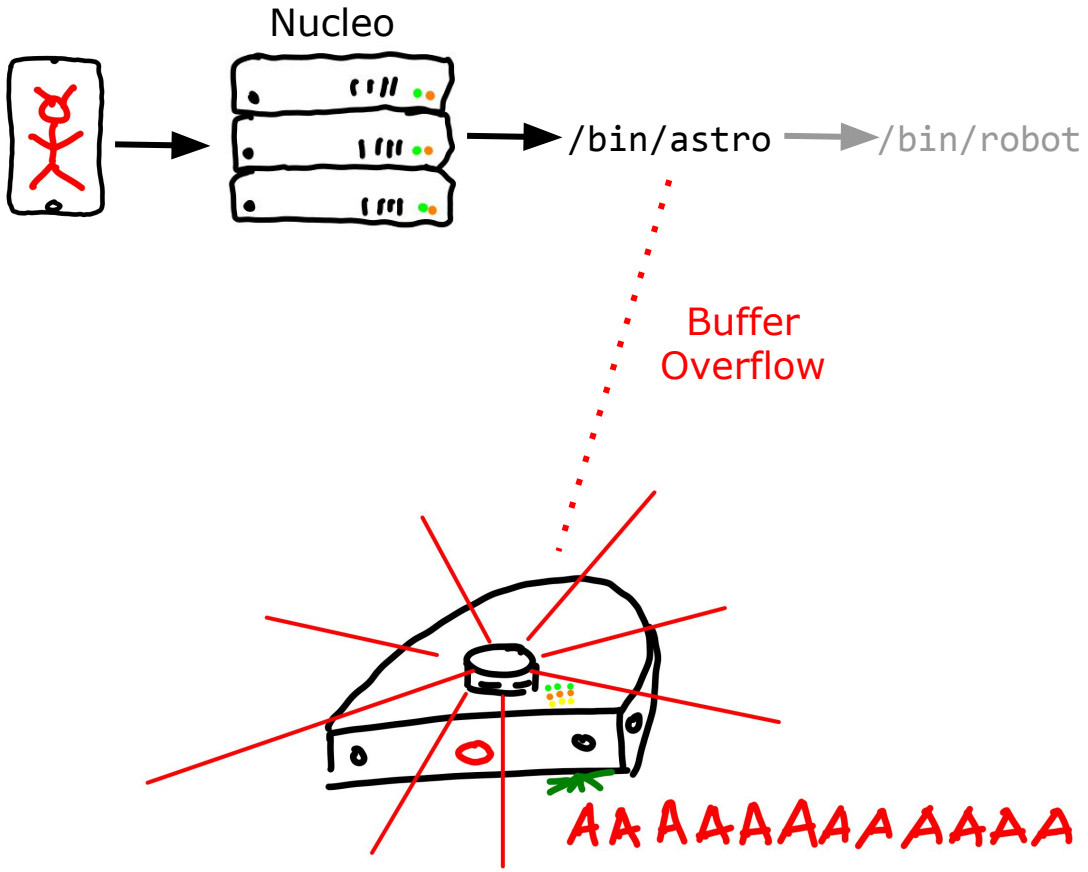
Decrypts coredumps copied to USB

- Binary `/bin/rc4_crypt` is called without arguments and contains a hardcoded key.
- Coredumps contain the complete binary that crashed (`/bin/robot`, `/bin/astro`, …)
  - …get binaries from robots without secure boot bypass!
- Yes, even `/bin/robot` can crash!
  - …got a `/bin/robot` coredump from a non-connected Neato Botvac 85 (SW 1.2.1)

Jiska found this and got assigned CVE-2018-17177.

Unauthenticated RCE

- **Buffer overflow** in Nucleo cloud connection daemon.

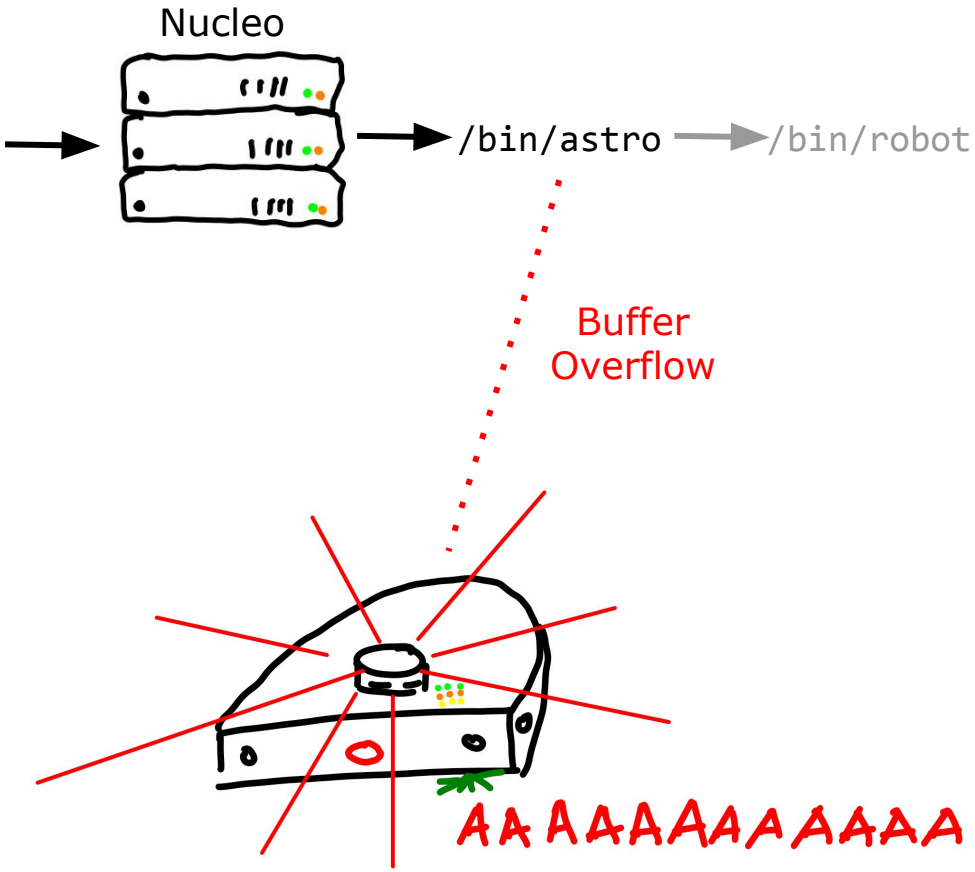


Fabian found the crash and performed analysis, Jiska decrypted the coredump, Johannes did further analysis and implemented a PoC (CVE-2018-19442).

Unauthenticated RCE

- **Buffer overflow** in Nucleo cloud connection daemon.
- Can be triggered with requests to https://nucleo.neatocloud.com:4443/vendors/neato/robots/[robot_serial]/messages.
- The overflow is within parsing the authentication header, which means that we found an **unauthenticated RCE**!
- All services run as **root**.

- Fix: Authentication headers are validated on Nucleo.



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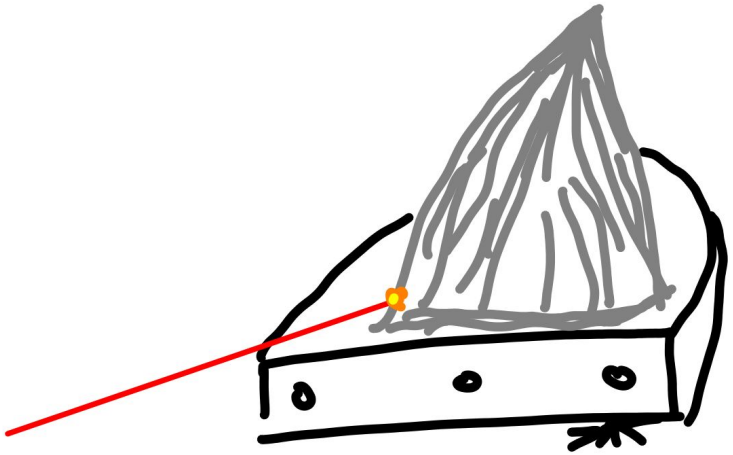
Security Implications (1)

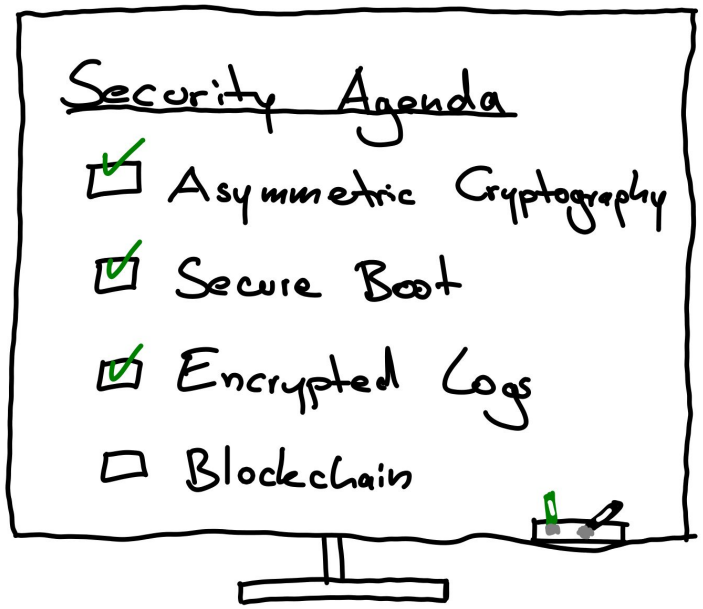
- **IoT** product at home? **Keep it offline!**

- As a **customer**:
  - **Update** your robot.
  - **Hide your robot's serial number**!



Security Implications (2)

- Connected ecosystem **developers**:
  - Using RSA, RNG, hashing, secure boot, encrypted logs, signed firmware updates sounds good...
  - Review cryptographic key components and **root of trust** assumptions.
  - **Dissecting one of your products** should not compromise security of the other products, i.e., similar keys.
  - Test your security relevant code in practice to uncover issues like the static secret key "random" function—check entropy before hashing.



Security Implications (3)

- Lessons learned during **responsible disclosure**:
  - Scientifically **proven secure** methods are insecure if applied wrong.
  - Normal **developers** are not aware of ASLR, DEP, …, they **just write code**.
  - Lack of easy to understand **guides** of how to build connected infrastructures.
    - Too many guides?
    - No reasoning why certain measures are needed in an infrastructure.
  - Penetration testing often does not cover specific **implementation details**.
    - Web API only tests...

Q&A