A Model-Driven Methodology for Automotive Cybersecurity Test Case Generation

SRCNAS/STRIVE WS @ IEEE EURO S&P�much 21

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The Need for Industrialized Automotive Cybersecurity Testing

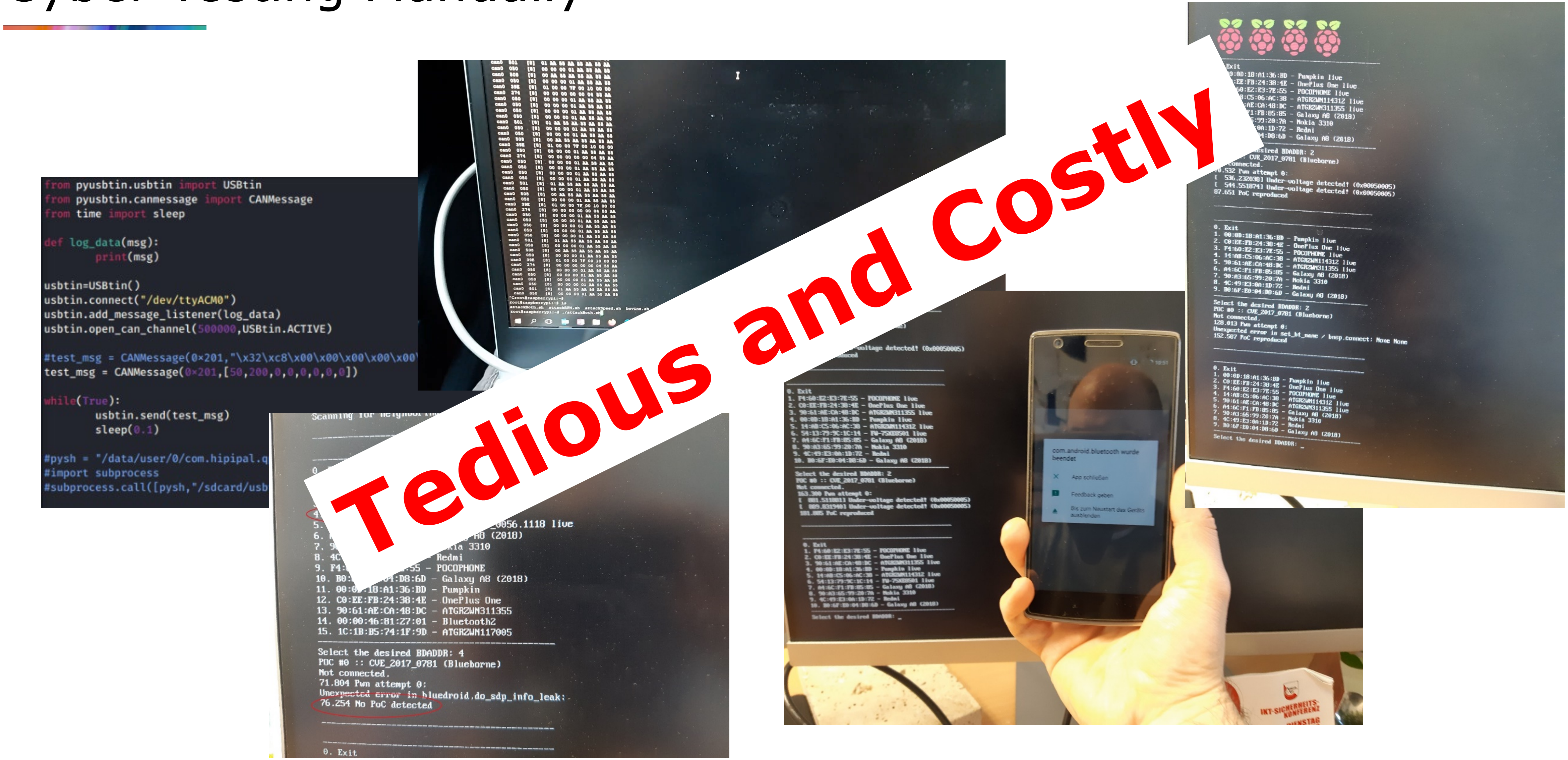
- UNECE
  - Regulation R.155
  - Mandates cybersecurity and cybersecurity management
  - Requires testing of measures
  - Adopted in EU, Japan and Korea
  - Effective in EU for new types 2022 and for all new vehicles 2024
- ISO/SAE 21434
  - Cyber security management system for automotive systems
  - Risk-based approach
  - Also demands testing, however, does not specify details
  - To be supplemented for testing by ISO PWI 8477 (V&V) and ISO/SAE PWI 8475 (CAL &TAF)

=> Need for automated testing

Why Black Box Testing?

- Providing an attacker’s view
- Long supply chain – source might not be available
- Unwillingness (or inability) to disclose internals

Cyber Testing Manually



Tedious and Costly

```
from pyusbtin.usbtin import USBtin
from pyusbtin.canmessage import CANMessage
from time import sleep

def log_data(msg):
        print(msg)

usbtin=USBtin()
usbtin.connect("/dev/ttyACM0")
usbtin.add_message_listener(log_data)
usbtin.open_can_channel(500000,USBtin.ACTIVE)

#test_msg = CANMessage(0×201,"\x32\xc8\x00\x00\x00\x00\x00
test_msg = CANMessage(0×201,[50,200,0,0,0,0,0,0])

while(True):
        usbtin.send(test_msg)
        sleep(0.1)

#pysh = "/data/user/0/com.hipipal.q
#import subprocess
#subprocess.call([pysh,"/sdcard/usb
```

```
Scanning for neighboring
-------------------------------------------
-------------------------------------------
0
4
5.                              _0056.1118 live
6.                                  A8 (2018)
7. 9                             kia 3310
8. 4C                            Redmi
9. F4:          :55 - POCOPHONE
10. B0:      04:D8:6D - Galaxy A8 (2018)
11. 00:0  :18:A1:36:BD - Pumpkin
12. C0:EE:FB:24:38:4E - OnePlus One
13. 90:61:AE:CA:48:DC - ATGRZWN311355
14. 00:00:46:81:27:01 - Bluetooth2
15. 1C:1B:B5:74:1F:9D - ATGRZWN117005
-------------------------------------------
Select the desired BDADDR: 4
POC #0 :: CVE_2017_0781 (Blueborne)
Not connected.
71.804 Pwn attempt 0:
Unexpected error in bluedroid.do_sdp_info_leak:
76.254 No PoC detected
-------------------------------------------
-------------------------------------------
0. Exit
```

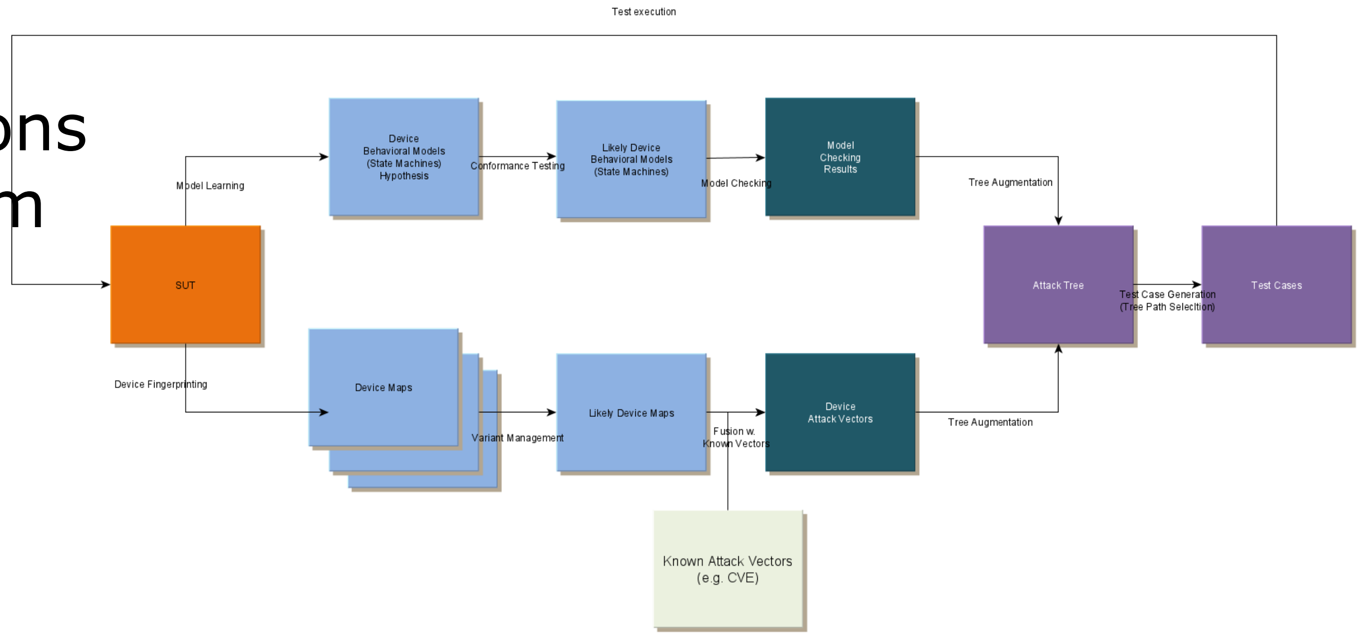
```
-------------------------------------------
                    -voltage detected! (0x00050005)
                    duced
-------------------------------------------
-------------------------------------------
0. Exit
1. F4:60:E2:E3:7E:55 - POCOPHONE live
2. C0:EE:FB:24:38:4E - OnePlus One live
3. 90:61:AE:CA:48:DC - ATGRZWN311355 live
4. 00:0D:18:A1:36:BD - Pumpkin live
5. 14:AB:C5:06:AC:38 - ATGRZWN114312 live
6. 54:13:79:9C:1C:14 - FW-75XE8501 live
7. A4:6C:F1:FB:85:85 - Galaxy A8 (2018)
8. 90:A3:65:99:20:7A - Nokia 3310
9. 4C:49:E3:0A:1D:72 - Redmi
10. B0:6F:E0:04:D8:6D - Galaxy A8 (2018)
-------------------------------------------
Select the desired BDADDR: 2
POC #0 :: CVE_2017_0781 (Blueborne)
Not connected.
163.300 Pwn attempt 0:
[  881.511881] Under-voltage detected! (0x00050005)
[  889.831940] Under-voltage detected! (0x00050005)
181.885 PoC reproduced
-------------------------------------------
-------------------------------------------
0. Exit
1. F4:60:E2:E3:7E:55 - POCOPHONE live
2. C0:EE:FB:24:38:4E - OnePlus One live
3. 90:61:AE:CA:48:DC - ATGRZWN311355 live
4. 00:0D:18:A1:36:BD - Pumpkin live
5. 14:AB:C5:06:AC:38 - ATGRZWN114312 live
6. 54:13:79:9C:1C:14 - FW-75XE8501 live
7. A4:6C:F1:FB:85:85 - Galaxy A8 (2018)
8. 90:A3:65:99:20:7A - Nokia 3310
9. 4C:49:E3:0A:1D:72 - Redmi
10. B0:6F:E0:04:D8:6D - Galaxy A8 (2018)
-------------------------------------------
Select the desired BDADDR: _
```

com.android.bluetooth wurde beendet

```
-------------------------------------------
 Exit
 0:0D:18:A1:36:BD - Pumpkin live
  :EE:FB:24:38:4E - OnePlus One live
  60:E2:E3:7E:55 - POCOPHONE live
  B:C5:06:AC:38 - ATGRZWN114312 live
   :AE:CA:48:DC - ATGRZWN311355 live
   F1:FB:85:85 - Galaxy A8 (2018)
   5:99:20:7A - Nokia 3310
    0A:1D:72 - Redmi
    4:D8:6D - Galaxy A8 (2018)
-------------------------------------------
   esired BDADDR: 2
   : CVE_2017_0781 (Blueborne)
 connected.
 0.532 Pwn attempt 0:
[  536.232038] Under-voltage detected! (0x00050005)
[  544.551874] Under-voltage detected! (0x00050005)
87.651 PoC reproduced
-------------------------------------------
-------------------------------------------
0. Exit
1. 00:0D:18:A1:36:BD - Pumpkin live
2. C0:EE:FB:24:38:4E - OnePlus One live
3. F4:60:E2:E3:7E:55 - POCOPHONE live
4. 14:AB:C5:06:AC:38 - ATGRZWN114312 live
5. 90:61:AE:CA:48:DC - ATGRZWN311355 live
6. A4:6C:F1:FB:85:85 - Galaxy A8 (2018)
7. 90:A3:65:99:20:7A - Nokia 3310
8. 4C:49:E3:0A:1D:72 - Redmi
9. B0:6F:E0:04:D8:6D - Galaxy A8 (2018)
-------------------------------------------
Select the desired BDADDR: 2
POC #0 :: CVE_2017_0781 (Blueborne)
Not connected.
128.013 Pwn attempt 0:
Unexpected error in set_bt_name / bnep.connect: None None
152.587 PoC reproduced
-------------------------------------------
-------------------------------------------
0. Exit
1. 00:0D:18:A1:36:BD - Pumpkin live
2. C0:EE:FB:24:38:4E - OnePlus One live
3. F4:60:E2:E3:7E:55 - POCOPHONE live
4. 14:AB:C5:06:AC:38 - ATGRZWN114312 live
5. 90:61:AE:CA:48:DC - ATGRZWN311355 live
6. A4:6C:F1:FB:85:85 - Galaxy A8 (2018)
7. 90:A3:65:99:20:7A - Nokia 3310
8. 4C:49:E3:0A:1D:72 - Redmi
9. B0:6F:E0:04:D8:6D - Galaxy A8 (2018)
-------------------------------------------
Select the desired BDADDR: _
```

Holistic Testing

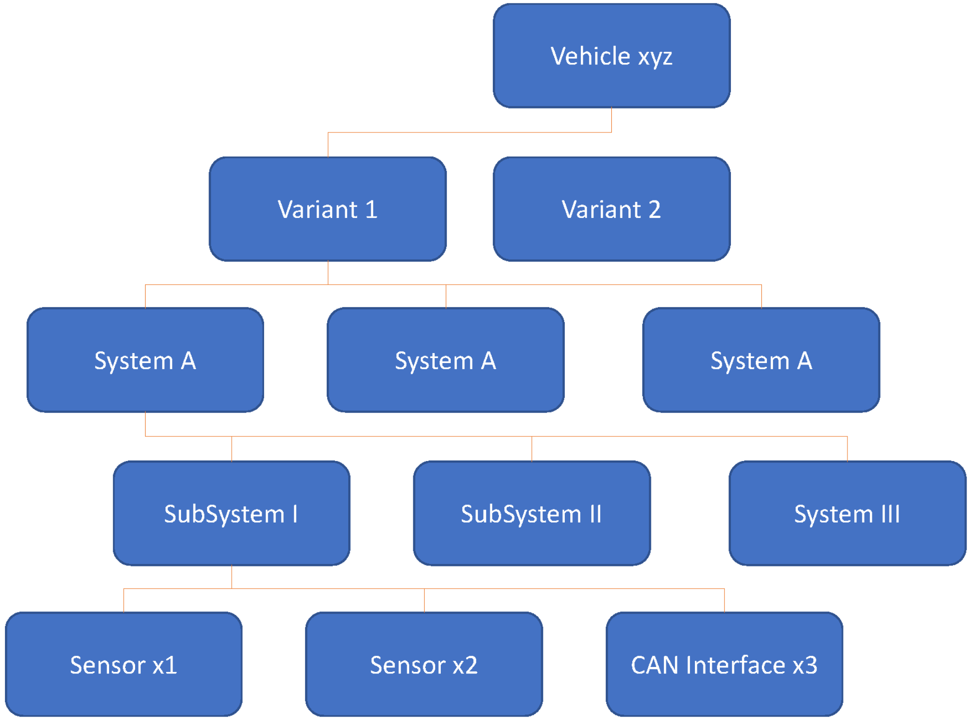
- System level
- Including architecture
- Conducted on the communications networks inside an actual system



System Reconnaissance

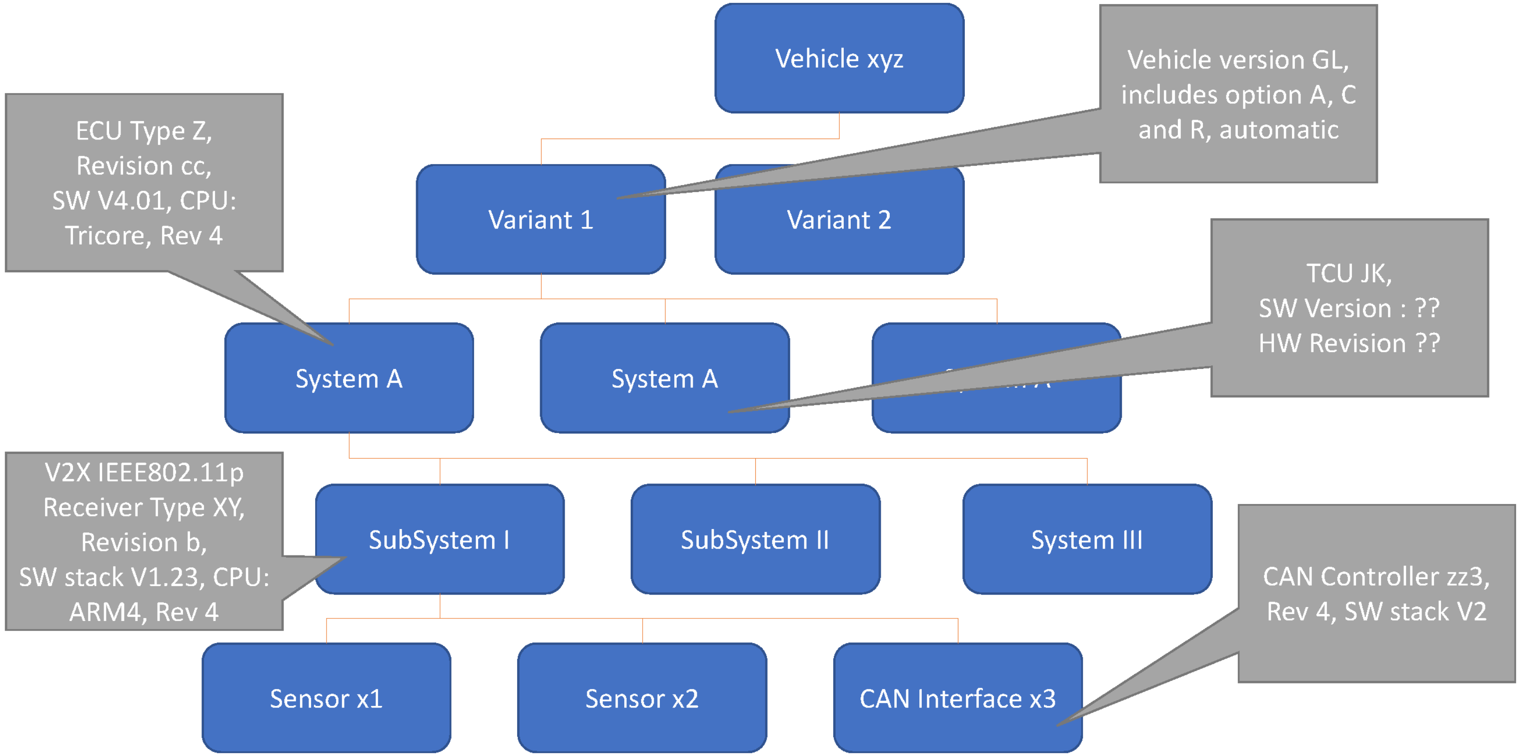
- Use a variety of interfaces
  - Wireless UIs (WiFi, BlueTooth,..)
  - Wired UIs (USB,)
  - Diagnostic (OBD)
  - Wiretapping (CAN, LIN)
- Active (sending messages)
- Passive (listening only)

- More complete picture of the SUT
- Ability to segment attacks



Fingerprinting

- Passively:
  - Deviation
  - Kurtosis
  - Clock skew
  - …
- Actively:
  - Sending (CAN) messages
    - Well formatted
    - Malformed
- Attribute a component according to the detecting interface



Vehicle xyz

Vehicle version GL, includes option A, C and R, automatic

Variant 1

Variant 2

ECU Type Z, Revision cc, SW V4.01, CPU: Tricore, Rev 4

System A

System A

TCU JK, SW Version : ?? HW Revision ??

V2X IEEE802.11p Receiver Type XY, Revision b, SW stack V1.23, CPU: ARM4, Rev 4

SubSystem I

SubSystem II

System III

CAN Controller zz3, Rev 4, SW stack V2

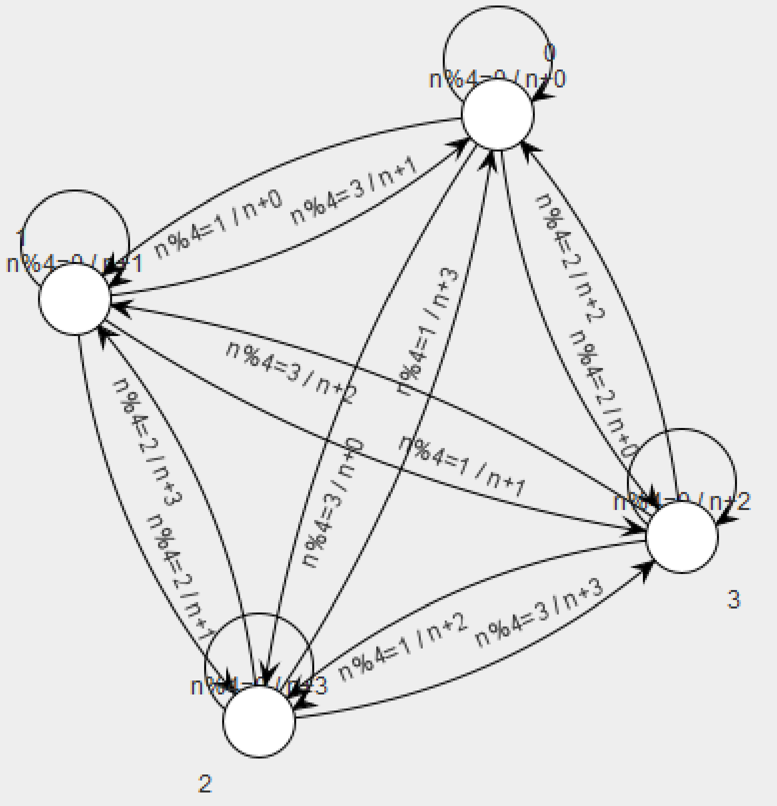
Sensor x1

Sensor x2

CAN Interface x3

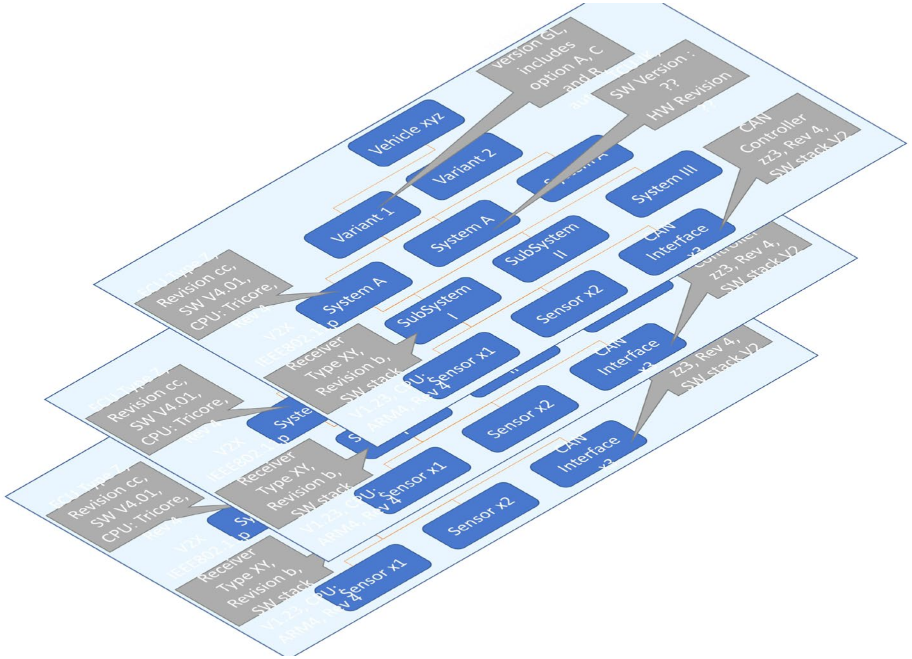
Model Generation

- Use (abstract) automata learning to learn a *behavioral* model
- Use model checking for test case generation



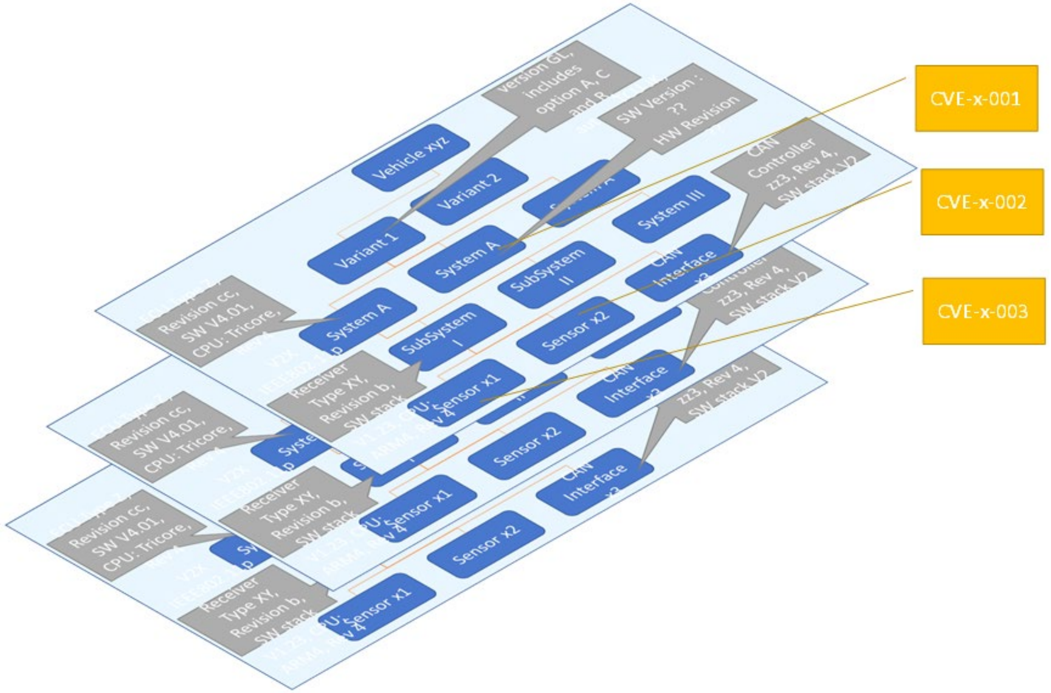
Variant Management

- Without a priori knowledge, a plethora of candidate models is available
- This set is narrowed down with every piece of information
- Each test case touches a number of assumed components, allowing for gathering data for fingerprinting
- Test cases will not only be chosen according to a potential attack vector, but also considering pivot elements to exclude or verify an optimal number of candidate models


Vehicle xyz
Variant 1
Variant 2
System A
System A
System III
SubSystem I
SubSystem II
Sensor x1
Sensor x2
CAN Interface x3
version GL, includes option A, C and B
SW Version : ?? HW Revision ??
CAN Controller zz3, Rev 4, SW stack V2
ECU Type Z, Revision cc, SW V4.01, CPU: Tricore, Rev 4
V2X IEEE802.11p
Receiver Type XY, Revision b, SW stack V1.23, CPU: ARM4, Rev 4

Attack Model

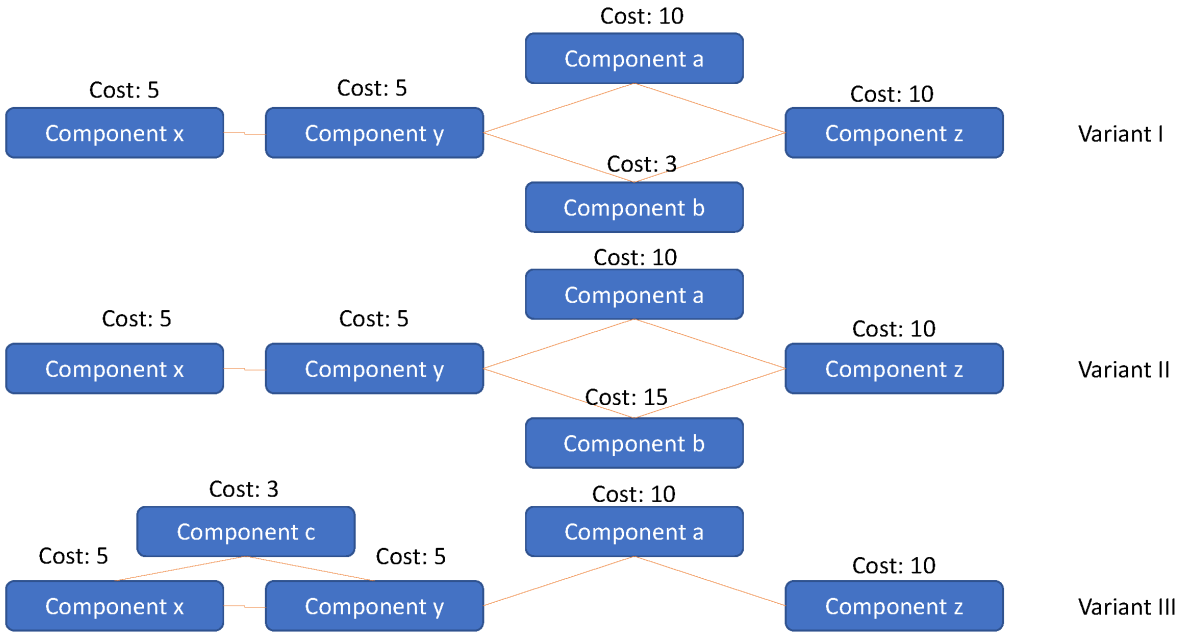
- Augmenting the system model with attack information
  - Using CVE information
  - Using other public sources (Auto-ISAC, research, darknet)
  - Analysis - see previous presentation of this workshop ;)
- Should occur both component and function-wise



Vehicle xyz
Variant 1
Variant 2
System A
System III
SubSystem II
SubSystem I
Sensor x1
Sensor x2
CAN Interface x2
CAN Controller zz3, Rev 4, SW stack V2
Revision cc, SW V4.01, CPU: Tricore,
Receiver Type XY, Revision b, SW stack
SW Version: ?? HW Revision
CVE-x-001
CVE-x-002
CVE-x-003

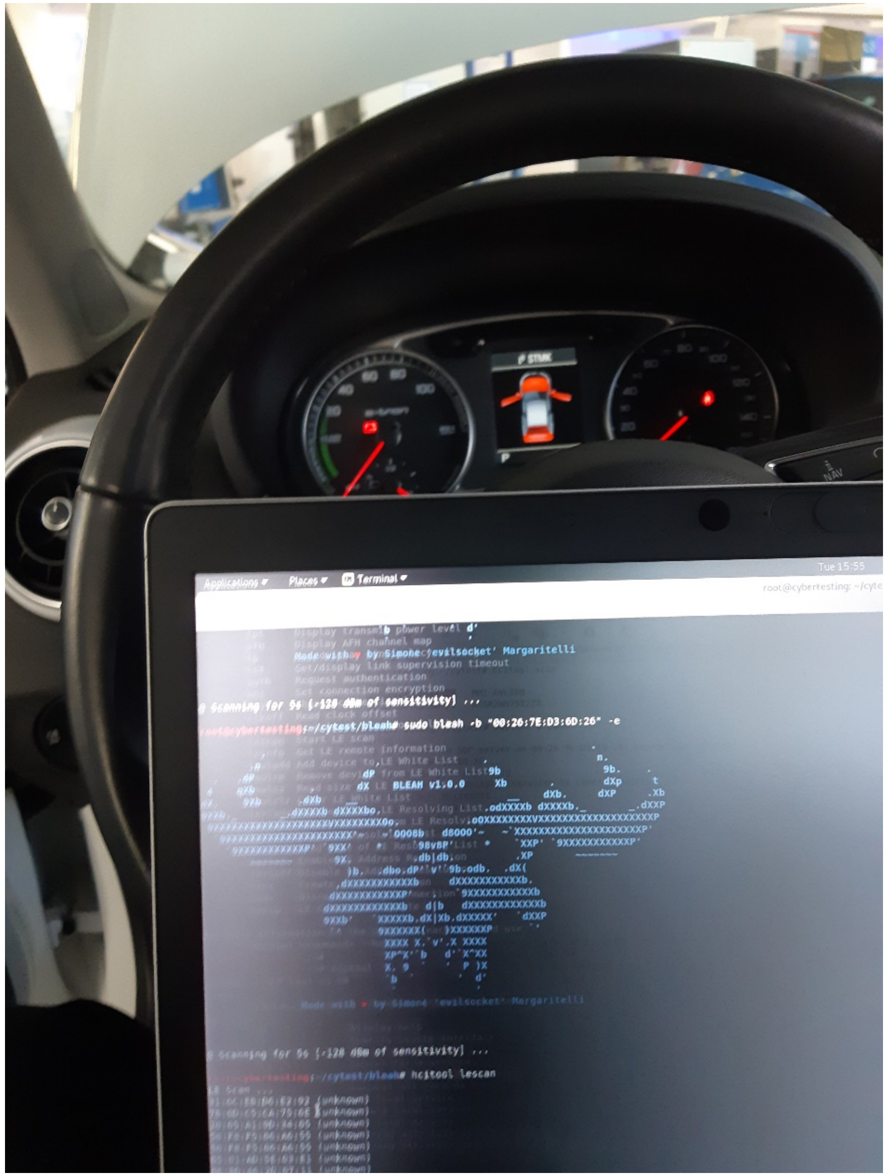
Attack Tree

- Assign cost to attacks on a specific component
- Shortest path (per cost) => most feasible attack
- Shortest path will be tested first, in conjunction with variant management considerations
- Test pass if the cost of the shortest path is above a certain threshold => *sufficiently secure*



Conclusion

- Concept for holistic zero-knowledge testing of automotive systems
- Combining fingerprinting and attack trees for test case generation
- Coping with variants that result from fuzziness



```
Made with by Simone 'evilsocket' Margaritelli
@ Scanning for 5s [-128 dBm of sensitivity] ...
root@cybertesting:~/cytest/bleah# sudo bleah -b "00:26:7E:D3:6D:26" -e
BLEAH v1.0.0
@ Scanning for 5s [-128 dBm of sensitivity] ...
root@cybertesting:~/cytest/bleah# hcitool lescan
LE Scan ...
```

Thank you for your attention!

Thanks!

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