SECURITY ANALYSIS OF ANDROID AUTOMOTIVE

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Agenda

Introduction

Related Work

Threat Model and Background

Security Analysis

Recommendations

Next Generation of IVIs

ALEX DAVIES GEAR 05.26.15 08:00 AM

ANDROID AUTO: THE FIRST GREAT IN-CAR INFOTAINMENT SYSTEM

Source: https://www.wired.com/2015/05/android-auto-first-great-car-infotainment-system/

Google Unveils Android Automotive OS on the 2020 Polestar 2 EV

By Ryan Whitwam on May 3, 2019 at 2:15 pm | 4 Comments

11 SHARES

Source: https://www.extremetech.com/mobile/290792-google-unveils-android-automotive-os-on-the-2020-polestar-2

Android Auto vs Android Automotive

Android Auto

- Runs **outside** vehicles (on phone)
- Phone connection required, since mirroring
- **Cannot** use data from IVN
- Only restricted to media and messaging apps

Source: https://www.funzen.net/2019/11/20/how-android-auto-works-everything-you-need-to-know/

Android Automotive

- Runs **inside** vehicles (on IVI)
- **No** phone connection required
- **Can** use data from IVN
- Richer 3rd party apps possible

Source: https://www.engadget.com/2019-05-04-android-automotive-hands-on.html/

\+ Restricted Permissions
\+ Restricted Attack Surfaces
\- Phone Integration

\+ No Phone
\- More Attack Surfaces
\- Access to IVN data
→ Data Injection & Privacy

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Android Auto

- Static analysis of infotainment apps in Google Play Store
- Vulnerabilities limited to operational damage, but also driver safety (distraction)
- Study found 60% of all apps have some sort of vulnerability
  - 25% of all apps have JavaScript vulnerabilities

Android Automotive

- Focus on third-party app analysis
- Developed tool for vehicle-specific code analysis
- PoC attacks for driver disturbance, availability, privacy

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Classification of Attacks

Attack Landscape is changing...

First-Generation Attacks (~2010-2015)	Second-Generation Attacks (~2015-2020)	Third-Generation Attacks (~2020-?)
Using physical interfaces	Using wireless interfaces (e.g., IVI and TCU)	Using app eco-system on IVIs

Scalability

Risk / Damage Potential

Classification of Attacks

... so is the risk.

Infrastructure Vulnerabilities

- Network
- OS
- Runtime Environment
- Hypervisor
- Backend

Can be patched

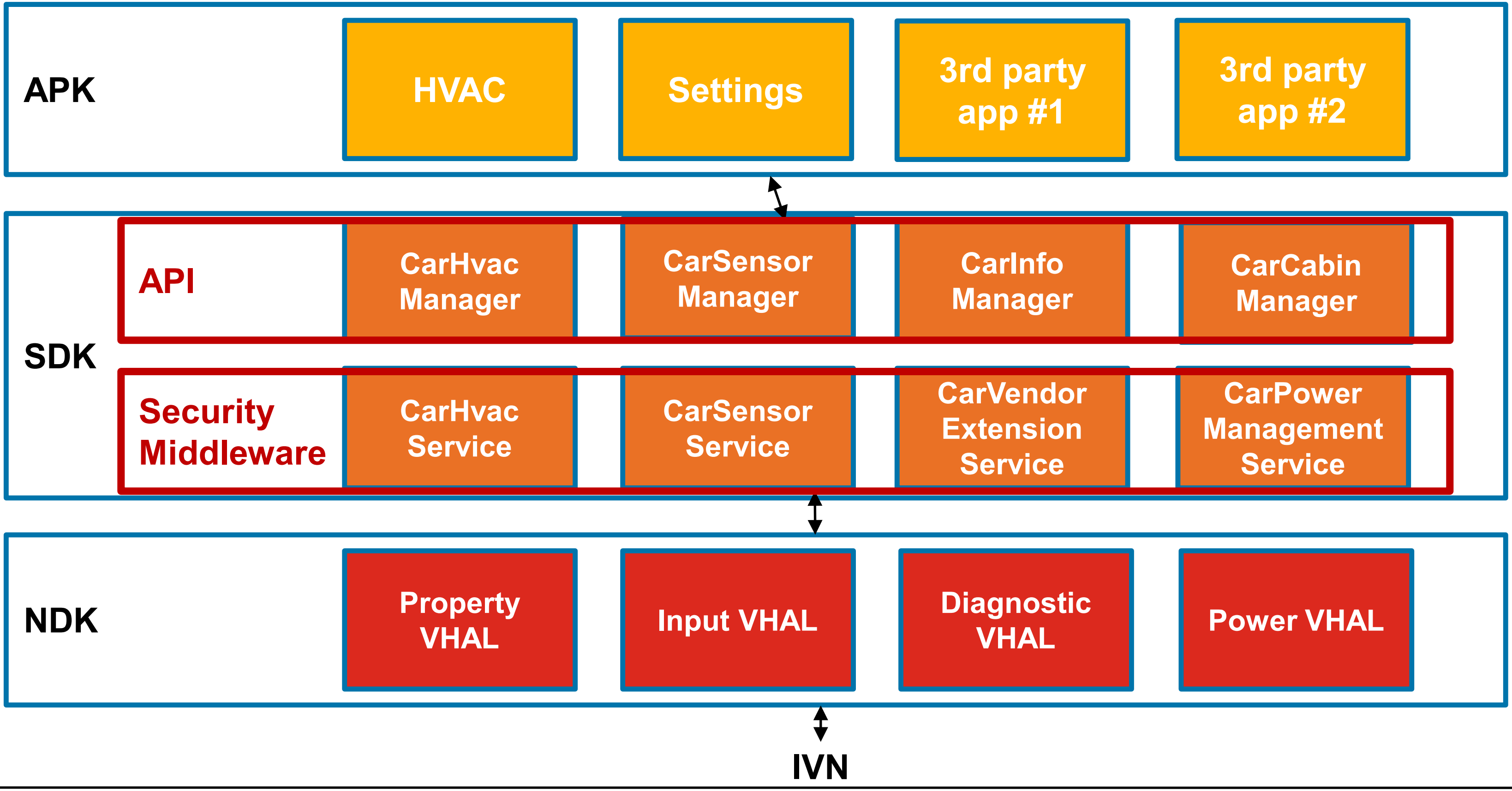
(Programming) Framework Design Vulnerabilities

- APIs
- Permission Model
- Unauthorized Access to IVN

Far-reaching impact, significant disruption once adapted system

Early analysis and disclosure to Google is vital!

Architecture



Permission Model

Four levels of protection level

- **Normal:** No explicit consent needed
- **Dangerous:** Explicit user consent required
- **Signature:** Cryptographically signed with platform certificate
- **signature|privileged:** Cryptographically signed or pre-installed

Third-party applications only have access to normal and dangerous permissions ☺

Permission Model

47 permissions defined in android.car.permission as of October 2019

Permission Name	Protection Level
READ_CAR_DISPLAY_UNITS	Normal
CONTROL_CAR_DISPLAY_UNITS	Normal
CAR_ENERGY_PORTS	Normal
CAR_INFO	Normal
CAR_EXTERIOR_ENVIRONMENT	Normal
CAR_POWERTRAIN	Normal
CAR_SPEED	Dangerous
CAR_ENERGY	Dangerous
BIND_VMS_CLIENT	Signature
BIND_PROJECTION_SERVICE	Signature
BIND_INSTRUMENT_CLUSTER_RENDERER_SE RVICE	Signature
BIND_CAR_INPUT_SERVICE	Signature

CAR_MOCK_VEHICLE_HAL	signature|privileged
READ_CAR_STEERING	signature|privileged
CAR_IDENTIFICATION	signature|privileged
CAR_MILEAGE	signature|privileged
CAR_TIRES	signature|privileged
CAR_ENGINE_DETAILED	signature|privileged
CAR_DYNAMICS_STATE	signature|privileged
CAR_VENDOR_EXTENSION	signature|privileged
CAR_PROJECTION	signature|privileged
ACCESS_CAR_PROJECTION_STATUS	signature|privileged
CONTROL_CAR_SEATS	signature|privileged
CONTROL_CAR_MIRRORS	signature|privileged
CONTROL_CAR_WINDOWS	signature|privileged
CONTROL_CAR_DOORS	signature|privileged
CONTROL_CAR_CLIMATE	signature|privileged

Vehicle Properties

Implemented by VHAL

Vendor-extendable Android module to abstract vehicle data for SDK, APK

Mapping properties to CAN signals provided by DBCs

```
VEHICLEPROPERTY_INVALID = 0x0
VEHICLEPROPERTY_INFO_VIN = 0x11100100
VEHICLEPROPERTY_INFO_MAKE = 0x11100101
VEHICLEPROPERTY_INFO_MODEL = 0x11100102
VEHICLEPROPERTY_INFO_MODEL_YEAR = 0x11400103
VEHICLEPROPERTY_INFO_FUEL_CAPACITY = 0x11600104
VEHICLEPROPERTY_INFO_FUEL_TYPE = 0x11410105
VEHICLEPROPERTY_INFO_EV_BATTERY_CAPACITY = 0x11600106
VEHICLEPROPERTY_INFO_EV_CONNECTOR_TYPE = 0x11410107
VEHICLEPROPERTY_INFO_FUEL_DOOR_LOCATION = 0x11400108
VEHICLEPROPERTY_INFO_EV_PORT_LOCATION = 0x11400109
VEHICLEPROPERTY_INFO_DRIVER_SEAT = 0x1540010a
VEHICLEPROPERTY_PERF_ODOMETER = 0x11600204
VEHICLEPROPERTY_PERF_VEHICLE_SPEED = 0x11600207
VEHICLEPROPERTY_ENGINE_COOLANT_TEMP = 0x11600301
VEHICLEPROPERTY_ENGINE_OIL_LEVEL = 0x11400303
VEHICLEPROPERTY_ENGINE_OIL_TEMP = 0x11600304
VEHICLEPROPERTY_ENGINE_RPM = 0x11600305
VEHICLEPROPERTY_WHEEL_TICK = 0x11510306
VEHICLEPROPERTY_FUEL_LEVEL = 0x11600307
VEHICLEPROPERTY_FUEL_DOOR_OPEN = 0x11200308
VEHICLEPROPERTY_EV_BATTERY_LEVEL = 0x11600309
VEHICLEPROPERTY_EV_CHARGE_PORT_OPEN = 0x1120030a
VEHICLEPROPERTY_EV_CHARGE_PORT_CONNECTED = 0x1120030b
VEHICLEPROPERTY_EV_BATTERY_INSTANTANEOUS_CHARGE_RATE = 0x1160030c
VEHICLEPROPERTY_RANGE_REMAINING = 0x11600308
VEHICLEPROPERTY_TIRE_PRESSURE = 0x17e00309
VEHICLEPROPERTY_GEAR_SELECTION = 0x11400400
VEHICLEPROPERTY_CURRENT_GEAR = 0x11400401
VEHICLEPROPERTY_PARKING_BRAKE_ON = 0x11200402
VEHICLEPROPERTY_PARKING_BRAKE_AUTO_APPLY = 0x11200403
VEHICLEPROPERTY_FUEL_LEVEL_LOW = 0x11200405
VEHICLEPROPERTY_NIGHT_MODE = 0x11200407
VEHICLEPROPERTY_TURN_SIGNAL_STATE = 0x11400408
VEHICLEPROPERTY_IGNITION_STATE = 0x11400409
VEHICLEPROPERTY_ABS_ACTIVE = 0x1120040a
VEHICLEPROPERTY_TRACTION_CONTROL_ACTIVE = 0x1120040b
```

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EVITA Security Threats

Create PoC attacks based on severity classification of EVITA

Security threat severity class	Aspects of security threats			
	Safety	**Privacy**	**Financial**	**Operational**
0	No injuries	No unauthorized access to data	No financial loss	No impact on operational performance
1	Light or moderate injuries	Anonymous data only (no specific driver of vehicle data)	Low-level loss (≈ € 10)	Impact not discernible to driver
2	Severe injuries (survival probable); light/moderate injuries for multiple vehicles	Identification of vehicle or driver; anonymous data for multiple vehicles	Moderate loss (≈ € 100); low losses for multiple vehicles	Driver aware of performance degradation; indiscernible impacts for multiple vehicles
3	Life threatening (survival uncertain) or fatal injuries; severe injuries for multiple vehicles	Driver or vehicle tracking; identification of driver or vehicle for multiple vehicles	Heavy loss (≈ € 1000); moderate losses for multiple vehicles	Significant impact on performance; noticeable impact for multiple vehicles
4	Life threatening or fatal injuries for multiple vehicles	Driver or vehicle tracking for multiple vehicles	Heavy losses for multiple vehicles	Significant impact for multiple vehicles

Attack #1: Privacy

Goal: Malicious 3rd party app obtains privacy-sensitive driver information

Speed has *dangerous* permission

– Explicit user consent necessary

Gear position and RPM have *normal* permission

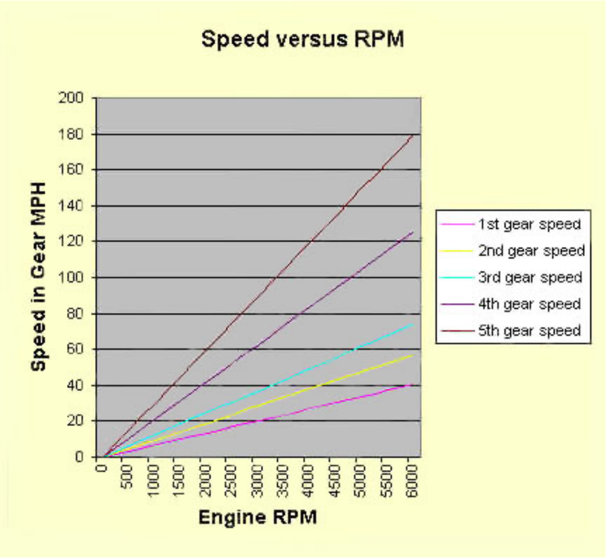
– Can be read by any app without user consent

Speed = f(gear, RPM)

Dangerous permission is circumvented

– More examples possible

– Physical signals have certain relationships with each other...



Source:http://homepages.bw.edu/~katchins/csc131common/a_papers/student2/gearmath.htm

Attack #2: Financial/Operational

Goal: Malicious 3rd party app breaks instrument cluster

CONTROL_CAR_DISPLAY_UNITS has *normal* permission

- Display units for distance, fuel, tire pressure, EV battery, fuel consumption can be modified

Examples: Switch from min. to max. fuel level, force TPMS light to come on etc.

- Bound by 1 Hz frequency (1 change per second)

Financial damage: Needle will break eventually

Operational damage: Driver realizes something is wrong with tires and brings car to dealership/tire shop

Source: https://www.cornwalllive.com/news/uk-world-news/how-far-can-you-drive-697463

Attack #3: Safety

Goal: Malicious 3rd party app accelerates the vehicle instead of displaying value on instrument cluster

Not all CAN signals mapped to vehicle properties

- Acceleration/Gas pedal does not need to be read/written

Option #1: Reverse engineering of the IVI FW

- DBCs and mapping table are stored on IVI
- Change mapping
- Reflash

Option #2: Access via ADB shell

Source: https://www.wired.com/2015/07/jeep-hack-chrysler-recalls-1-4m-vehicles-bug-fix/

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Fine-grained permission model

- Problem: Multiple properties summarized in one permission
- Assign unique permission for property
- Quantify privacy risk of each property, assign protection levels accordingly

Further standardization from Google

- Problem: Vendors given too much free space for implementation design
- Google should define security recommendations and standardize more modules
- Example: DBC mapping without physically storing DBC file, use lookup table in Trusted Execution Environment (TEE)

Recommendations

Separation of domains in IVN architecture

- Problem: IVI might control other (safety-critical) ECUs
- Implement access control, e.g., by firewall, in gateway

Protection against runtime attacks

- Problem: Android still suspectible to Return-Oriented Programming (ROP) attacks, can lead to buffer overflows
- Vendor-specific C/C++ code (device drivers, etc.) most vulnerable

Restrict ADB shell access (USB and WiFi!)

- Disable USB debugging by default in production
- Never allow default user to run as root

THANK YOU

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