TEMPA

Demystifying Tesla’s Bluetooth Passive Entry System

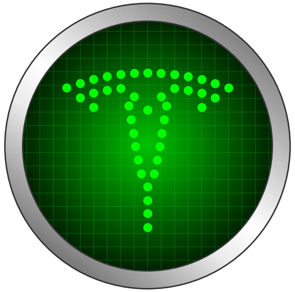
www.sect.org

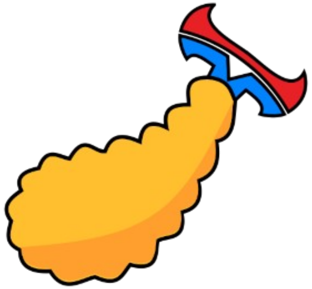
trifinite.org

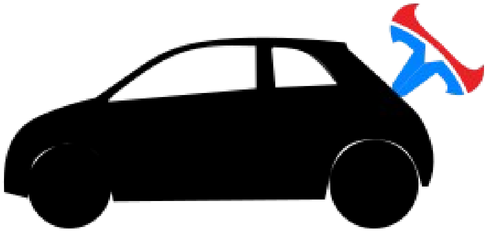
Video: The Tesla Parking Lot Job

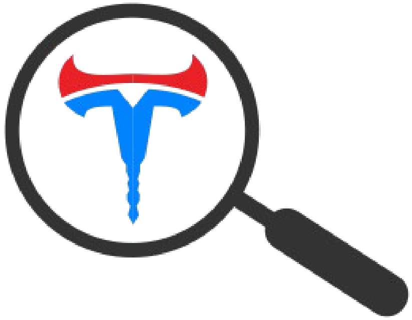
https://youtu.be/eDbSzVTYqBY

What to expect?









About **trifinite**.org

- Group founded in August 2004 by
  - Collin Mulliner
  - Martin Herfurt (me)
- Pioneered in Bluetooth (Classic) Security
- Participation in tech. Testing events organized by the Bluetooth SIG – helping vendors with security
- Webpage renewed in 2022 !

About Me

- Martin Herfurt
- Livng in Salzburg/Austria
- Regular participant/speaker at C3 since 1998
- Author of App „Tesla Radar“ (teslaradar.com)
- Owner of a black 2019 Tesla Model 3

Project TEMPA – Investigating BLE

- Technical Background about Tesla’s Passive Entry system
  - Found on all Tesla Models 3/Y
  - Found on Tesla Model S/X 2021+
  - About **2 million+** vehicles to date
- Identifying/Tracking vehicles
- Exchanging messages with vehicles via Bluetooth LE
- Possible impacts on vehicle’s security

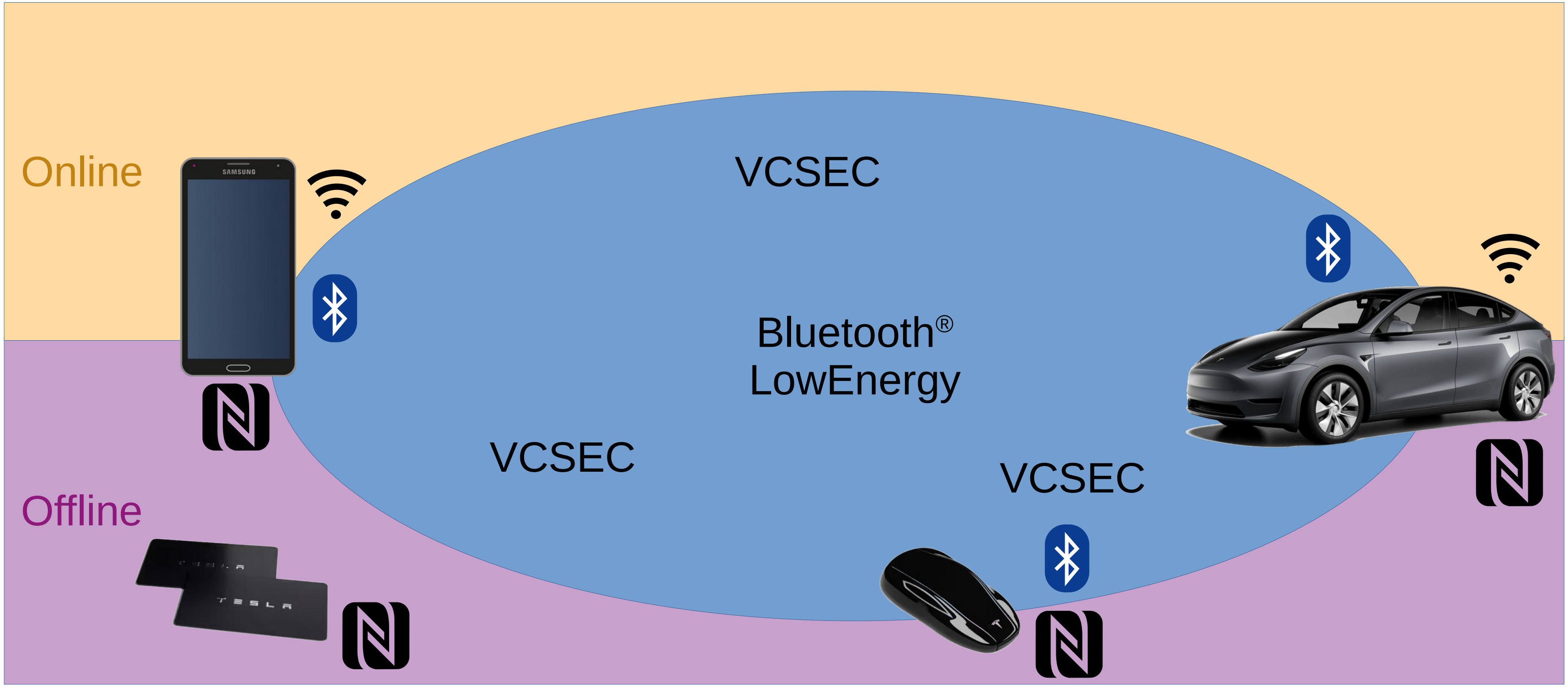
Project TEMPA – Investigating BLE

- Some of the things have been (partially) fixed and improved during the time of this research
- Findings reverse-engineered from the official Tesla app for Android and from observed messages
- Research started in 06/2019
- Research intensified in 06/2021 with VCSEC

PhoneKey

- Tesla’s BLE-based Passive Entry System
- Introduced with Model 3 in 2018
- Idea: The owner’s phone replaces the car key/fob
- Now also in use in Model Y and 2021 Facelift S/X
- Very likely to be part of future Tesla Models

Ways to Unlock a Tesla (S/3/X/Y)



Tesla (S/3/X/Y) Unlock Methods (1)

- NFC-Card
  - Owners get two whitelisted NFC-Cards with car
  - Different form-factors sold on Internet (e.g. KeyRing)
- Usage
  - card is held to driver-side B-pillar to unlock
  - card is held to middle-console to drive/authorize
  - No passive entry!

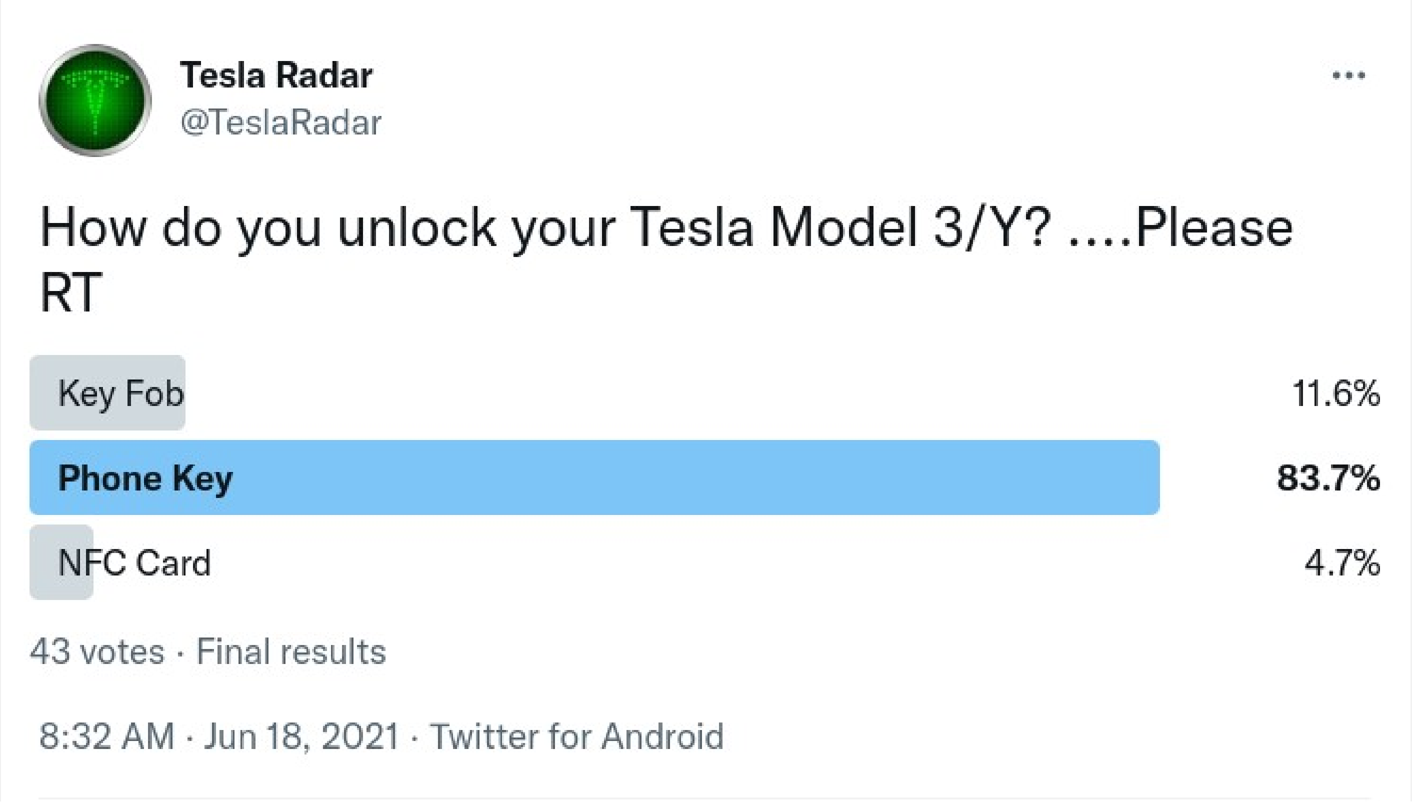
Tesla (S/3/X/Y) Unlock Methods (2)

- PhoneKey
  - Feature of the official iOS/Android app
  - Based on Bluetooth LE (BLE) / NFC
  - Allows „passive entry“ and basic security functions
- Usage
  - Phone is carried by owner
  - Authorization to unlock/drive via BLE / NFC / Online

Tesla (S/3/X/Y) Unlock Methods (3)

- KeyFob
  - Small Device (sold extra for 160€)
  - Based on Bluetooth LE (BLE)
  - Allows “passive entry“ (in later versions (starting with V. P60))
- Usage
  - Keyfob is carried by owner
  - Authorization to unlock/drive via BLE / NFC
  - Authorization via tap on B-pillar or middle console

Twitter Poll (1)



Tesla Radar
@TeslaRadar

How do you unlock your Tesla Model 3/Y? ....Please RT

Key Fob	11.6%
Phone Key	**83.7%**
NFC Card	4.7%

43 votes · Final results

8:32 AM · Jun 18, 2021 · Twitter for Android

How does PhoneKey BLE work?

1. Smartphone with app finds vehicle
   - Smartphone identifies vehicle
   - Smartphone connects to vehicle
2. App on smartphone communicates with car
3. Car (un)locks / starts / opens etc.

1. Smartphone with app finds vehicle

- Car advertises GATT services via BLE (Peripheral)
  - Name (standard)
  - To Vehicle (Tesla)
  - From Vehicle (Tesla)
- manufacturer data has iBeacon structure
  - UUID, major ID, minor ID
- There used to be four visible beacons per vehicle!

BLE Advertisement

- Manufacturer-Data (uses iBeacon format)
  - enables iPhone background vehicle detection
- UUID
  - 74278BDA-B644-4520-8F0C-720EAF059935
- Major/Minor ID (2 bytes each)
  - Random values (collissions possible but unlikely)

2. Smartphone identifies vehicle

- BLE device name(s)
  - Structure: **S<*8 bytes in hex*>C** (D,P,R)
  - Guess: C(enter) D(river side) P(assenger side) R(ear)
- Major/Minor ID (mainly for iPhone)
- <8 bytes in hex>
  - Seemed random at first
  - Unique to vehicle

Unique to vehicle!

- Always turned on
- Visible to anyone with BLE radio
- Privacy issue!
- Stalking
  - Compare: Privacy dicussion concerning Apple AirTag (AirTag even randomizes ID)
  - Similarities to Tesla’s PhoneKey

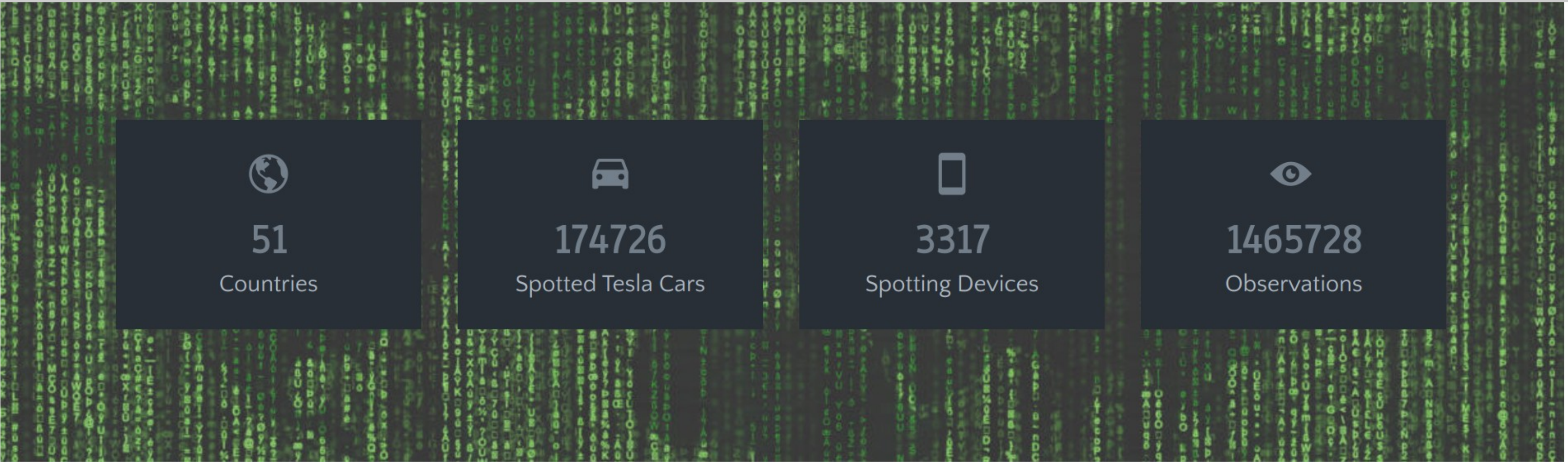
Correspondence with Tesla (in 2019)

- Complaint concening unique identifier
  - Does not change over time
  - Owners cannot turn signal off
- Tracking cars/owners becomes possible
- Tesla acknowledged this fact and wrote that this this situation and its implications are accepted risks/circumstances

Tesla Radar

- Project first published in August 2019 (Chaos Camp)
- With no understanding of all the inner workings
- Android App (available in Play Store)
- Crowdsourcing vehicle discovery
- First: Showcasing privacy issues
- Then: Game for the Tesla fan community with rankings etc.
- And: data-collection for research

Tesla Radar

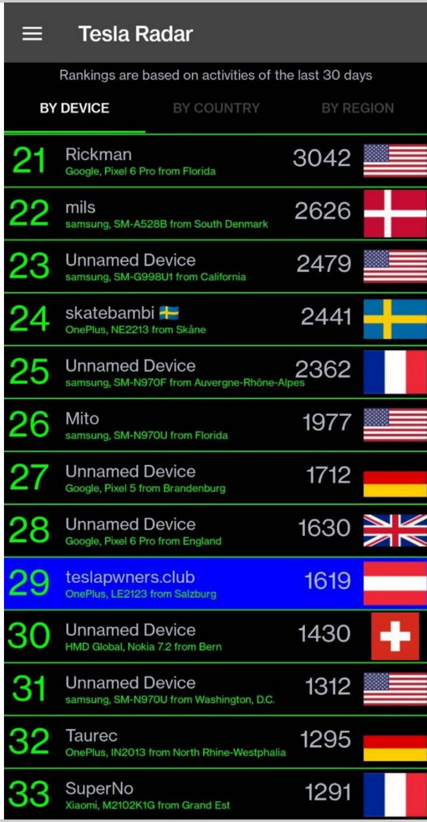


51
Countries

174726
Spotted Tesla Cars

3317
Spotting Devices

1465728
Observations

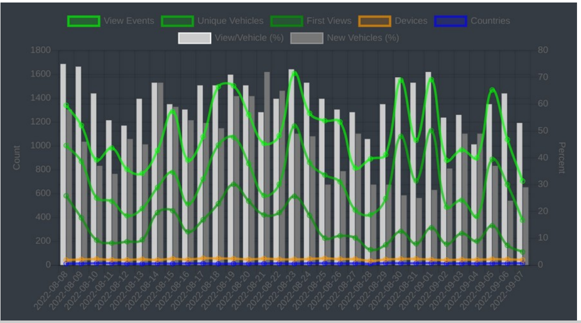


Tesla Radar

Rankings are based on activities of the last 30 days

BY DEVICE | BY COUNTRY | BY REGION

21	Rickman Google, Pixel 6 Pro from Florida	3042	
22	mils samsung, SM-A528B from South Denmark	2626	
23	Unnamed Device samsung, SM-G998U1 from California	2479	
24	skatebambi 🇸🇪 OnePlus, NE2213 from Skåne	2441	
25	Unnamed Device samsung, SM-N970F from Auvergne-Rhône-Alpes	2362	
26	Mito samsung, SM-N970U from Florida	1977	
27	Unnamed Device Google, Pixel 5 from Brandenburg	1712	
28	Unnamed Device Google, Pixel 6 Pro from England	1630	
29	teslapwners.club OnePlus, LE2123 from Salzburg	1619	
30	Unnamed Device HMD Global, Nokia 7.2 from Bern	1430	
31	Unnamed Device samsung, SM-N970U from Washington, D.C.	1312	
32	Taurec OnePlus, IN2013 from North Rhine-Westphalia	1295	
33	SuperNo Xiaomi, M2102K1G from Grand Est	1291	



www.teslaradar.com

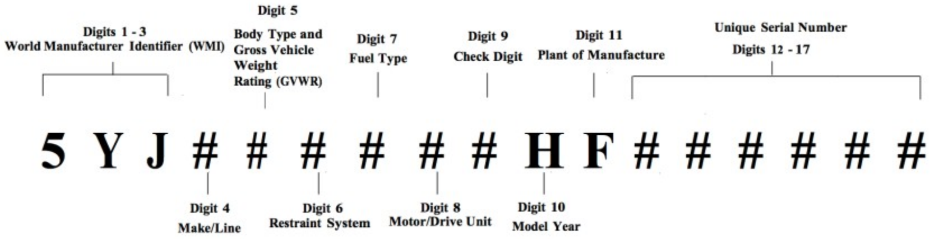
TEMPA

Martin Herfurt @ SEC-T 0x0EXPAND

trifinite.org

VIN Structure (17 Digits)

- Manufacturer ID
- Model Type
- Manufacturing Plant
- Manufacturing Year
- Serial Number
- Check-Digit



- Stadard/Dual/ Performance
- LHD/RHD?
- Battery Type

VIN Detection

- 16 character String used as part of the iBeacon name (8 hex-encoded bytes)
- Created from SHA1-hash over Vehicle VIN
  - VIN Identifier
- Reverse ID->VIN via special Rainbow-Table
- Used for identifying vehicles in Owner-List

VIN Index

- All possible Tesla VINs (with PhoneKey)
  - Research about production numbers in different plants
  - Research on web-pages for used Teslas
- Size: 217140601 objects ~ 20GB
- Hit-Rate: 98.75%
- Used for model-detection in TeslaRadar app

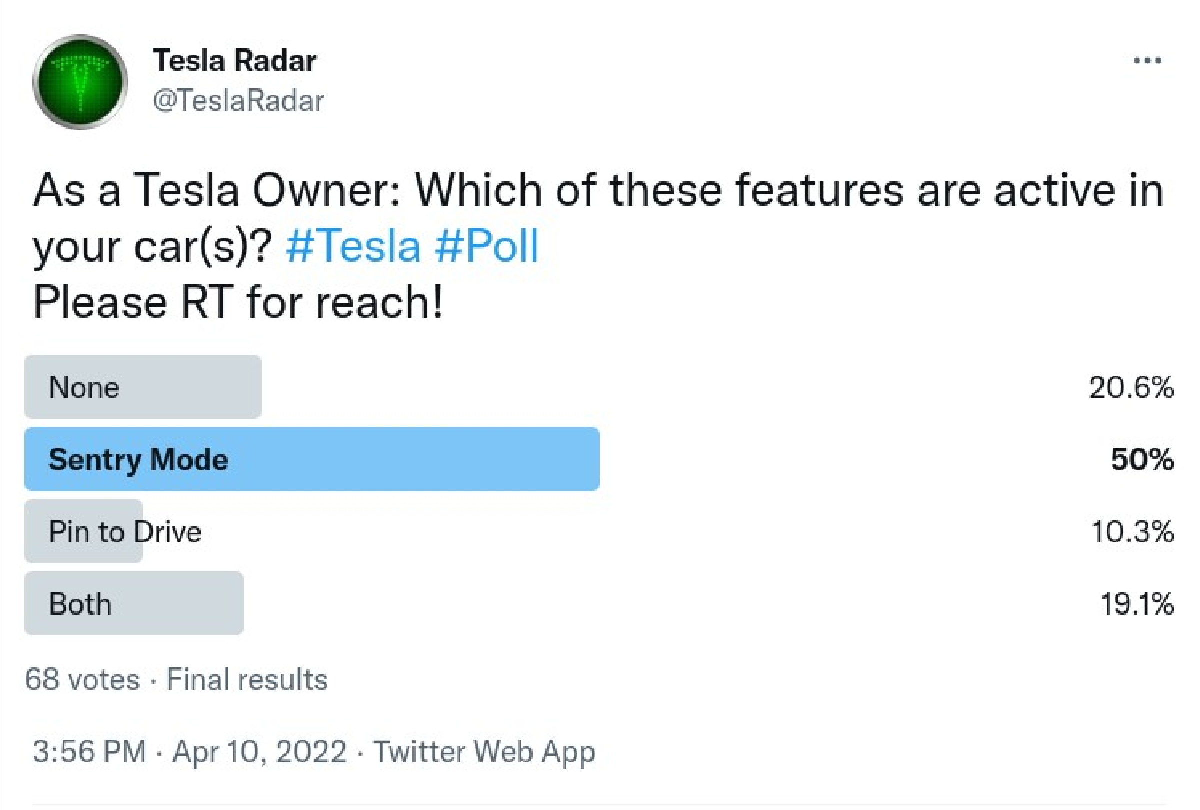
Wardriving 2.0 (BLE)

TESLA
Tesla Gigafactory 4 Berlin Brandenburg
Edeka Leergutabteilung
Eichenstraße
Tesla Str.
L38
Frachtunion GmbH & Co.
Lidl Vertriebs-GmbH & Co.
Gebr. Pfeil Garten- und Landschaftsbau
Liqvis-LNG-Tankstelle
Fritzenschaft und Partner

Correspondence with Tesla (in 2021)

- Bug-Bounty request concerning relay attack
  - Attackers can open car (and maybe steal it or at least some parts / stuff)
- Tesla acknowledged this fact and wrote that this this is “a known limitation“ of the Phone Key Feature and that people should use PIN2Drive

Twitter Poll (2)



Tesla Radar
@TeslaRadar

As a Tesla Owner: Which of these features are active in your car(s)? #Tesla #Poll
Please RT for reach!

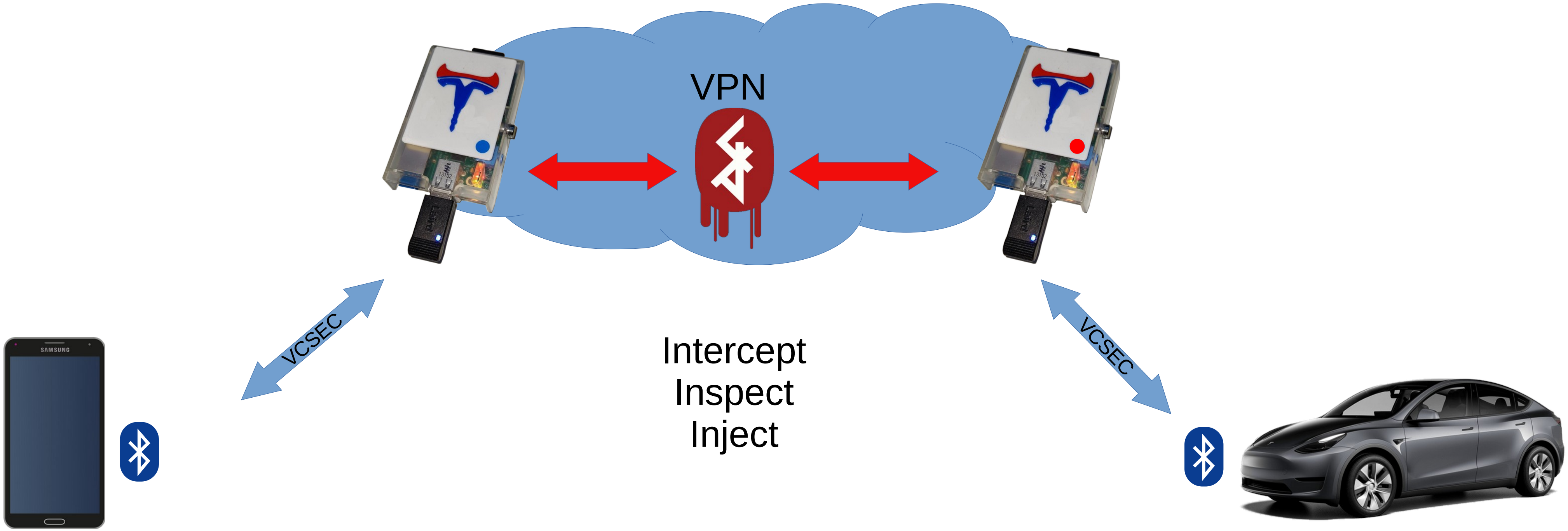
None	20.6%
Sentry Mode	**50%**
Pin to Drive	10.3%
Both	19.1%

} 29.4%

68 votes · Final results

3:56 PM · Apr 10, 2022 · Twitter Web App

MitM Relay Attack from Video



VPN

VCSEC

VCSEC

Intercept
Inspect
Inject

BLE-Endpoints (Characteristics)

- Service
  - 00000211-B2D1-43F0-9B88-960CEBF8B91E
- Characteristic: **To Vehicle** (write)
  - 00000212-B2D1-43F0-9B88-960CEBF8B91E
- Characteristic: **From Vehicle** (read/subscribe)
  - 00000213-B2D1-43F0-9B88-960CEBF8B91E

VCSEC Protocol

- Based on Google Protocol Buffers (protobuf), later Square/Wire
  - Perfect match for limited bandwidth in BLE
- Defines interaction between Security Devices and the Vehicle
- Deducted Use-cases
  - PhoneKey
  - KeyFob
  - TP (Tire Pressure Subsystem)
  - Backend-Communication (?)
  - Maybe even more use-cases

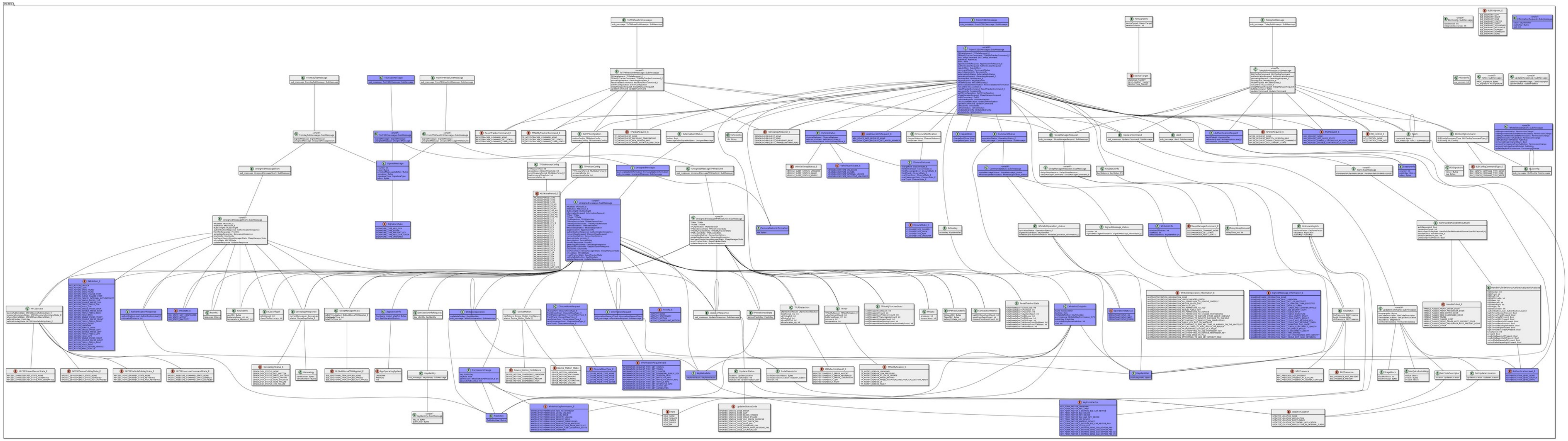
VCSEC History (1)

- Introduced in App V3.3.5-344 (April 2018)
- App Version 3 makes use of Google/Protobuf
  - Extractable with pbtk tool
- Current App Version 4 uses Square/Wire
  - Very similar output – but no extraction with pbtk
  - Custom script to extract proto-file from POJOs from decompiled Android app (experimental)
  - Further obfuscation of VCSEC starting with app 4.9.0

VCSEC History (2)

- Introduced in App V3.3.5-344 (April 2018)
- Four major iterations so far
  - VCSEC.proto v1 (2018-04-12 - V3.3.5-344)
    - 22 Messages and 9 Enums
  - VCSEC.proto v2 (2019-11-28 - V3.10.2-388)
    - 53 Messages and 27 Enums
  - VCSEC.proto v3 (2020-06-21 - V3.10.6-407)
    - 62 Messages and 32 Enums
  - VCSEC.proto v4 (2022-05-13 – V4.8.1-1032)
    - 77 Messages and 45 Enums

VCSEC – App Version 4.8.1 (05/22)



77 Messages 45 Enumerations

Colored entities are referenced in decompiled BLE plugin code

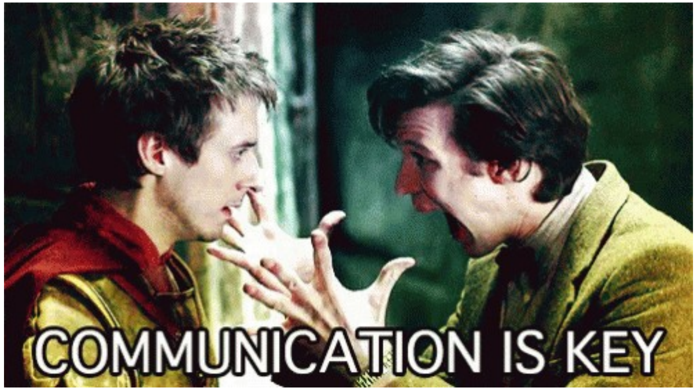
(De)Serializing messages via shell

- Serialized messages are often represented as hex-encoded strings (e.g. 00040a021001)
- Size prefix (2 octets) – not compatible with protoc
- Shell scripts in Tesla VCSEC Archive (github)

```
$> cat message.txt | protoc --encode=VCSEC.ToVCSECMessage
-I . VCSEC.proto | xxd -p -l 100

$> cat message.hex | xxd -r -p | protoc --
decode=VCSEC.FromVCSECMessage VCSEC.proto
```

Whitelisted Keys (InformationReq)

```
whitelistInfo {
  numberOfEntries: 9
  whitelistEntries {
    publicKeySHA1: "$\206\202d"
  }
  whitelistEntries {
    publicKeySHA1: "S`\031\375"
  }
  ...
  whitelistEntries {
    publicKeySHA1: "\221=\210\205"
  }
  whitelistEntries {
    publicKeySHA1: ";\223\300\027"
  }
  slotMask: 511
}
```



Service Key (Most likely NFC)

```
whitelistEntryInfo {
  keyId {
    publicKeySHA1: "$\206\202d"
  }
  publicKey {
    PublicKeyRaw: "\004\333\243\225\271\237\217:\"\022*yCX\000\3741_\
357b\261w\216\315\\\367\313j\037\201wH\006q\204\350\264V\025\0054Sc\
305L\356\234\216\343\nZ\033\005>/L\032\214\373W7Q\322\255\244"
  }
  keyRole: ROLE_SERVICE
}

sessionInfo {
  token: "\256\006Mj\270\237\277Y\310\223\023w\235\221<I\270\375,5"
  publicKey: "\004M)d\2136\372\201J\rh\253\354\220cZ\307_\
276\320\3568\212G\016\202f\223\025m\267\360\241!}\232\372vH\304_\
3532\244\023\016@1hbA\315\276g(+22q\235\3663R.\367"
}
```

Example (NFC)

```
whitelistEntryInfo {
  keyId {
    publicKeySHA1: "S`\031\375"
  }
  publicKey {
    PublicKeyRaw: "\004\323\332\321U-\320;=\215\014\331\025)C\303c*/\\\
024\016\007\207\347dd\r\216Q5\342v\362\360\2
67\336{\224\354R\376\332\203\243Z\377_\3267D\3577\215V\343P\315A\306\3603}\3027"
  }
  metadataForKey {
    keyFormFactor: KEY_FORM_FACTOR_NFC_CARD
  }
  slot: 1
  keyRole: ROLE_OWNER
}

sessionInfo {
  token: "^v\355*\345\374#\242Y\374\277N\277\347\202\303\355\265\t\177"
  publicKey: "\004M)d\2136\372\201J\rh\253\354\220cZ\307_\276\320\3568\212G\016\202f\
223\025m\267\360\241!}\232\372
vH\304_\3532\244\023\016@1hbA\315\276g(+22q\235\3663R.\367"
}
```

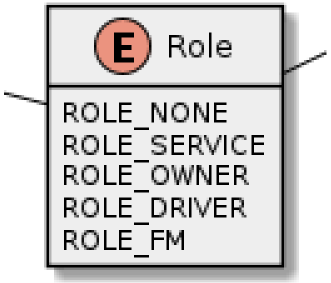
Example (PhoneKey)

```
whitelistEntryInfo {
  keyId {
    publicKeySHA1: "U\2346\373"
  }
  publicKey {
    PublicKeyRaw: "\004>\347\274l[\240\372\030\334h\017\034Z\251\304o\272\202$\
320\010N3\374\005\362\032\316#}\323\270\241\262\'\337\375\243\200\316d\
245\007\337\266F\017\036\335\201pM\017\254S\022\274\200\320W\210\307\3230"
  }
  metadataForKey {
    keyFormFactor: KEY_FORM_FACTOR_ANDROID_DEVICE
  }
  slot: 4
  keyRole: ROLE_OWNER
}

sessionInfo {
  token: "h\234*\257\022\234o\375\223+\367}\330\030a\021r)/\301"
  counter: 44
  publicKey: "\004M)d\2136\372\201J\rh\253\354\220cZ\307_\276\320\3568\212G\016\202f\
223\025m\267\360\241!}\232\372vH\304_\3532\244\023\016@1hbA\315\276g(+22q\235\3663R.\
367"
}
```

Example (KeyFob)

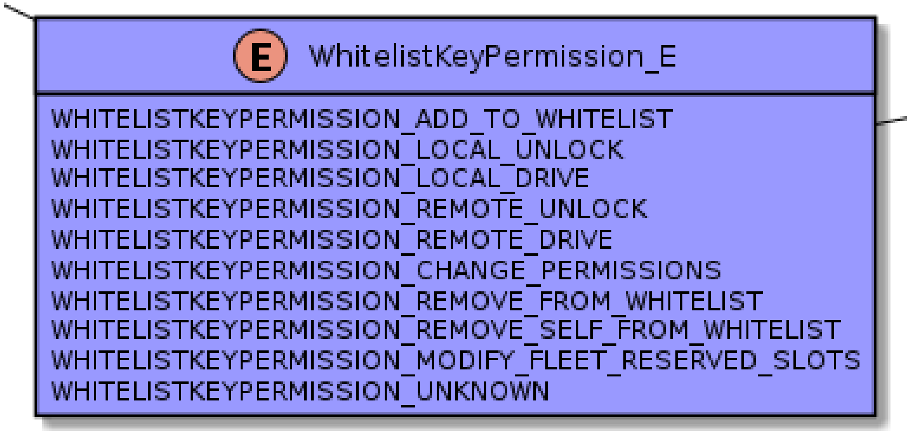
```
whitelistEntryInfo {
  keyId {
    publicKeySHA1: "\007\273\036o"
  }
  publicKey {
    PublicKeyRaw: "\004\005\375\367G]\235\32235\253\255\207\007HL\"\177S\225=]\
016\211\237\377Rs)v\370\274\307@#\016]$\276\342\314\024\261\373\2067\342\316\337TA\
262\017\330\004\353\353J\337\307\265{\007V\002"
  }
  metadataForKey {
    keyFormFactor: KEY_FORM_FACTOR_3_BUTTON_BLE_CAR_KEYFOB_P60
  }
  slot: 5
  keyRole: ROLE_OWNER
}

sessionInfo {
  token: "\322\304J\250\277>\036i(\0229\022{\255$\323v\027\\\245"
  counter: 2479
  publicKey: "\004M)d\2136\372\201J\rh\253\354\220cZ\307_\276\320\3568\212G\016\202f\
223\025m\267\360\241!}\232\372vH\304_\3532\244\023\016@1hbA\315\276g(+22q\235\3663R.\
367"
}
```

Roles and Permissions



E Role

ROLE_NONE
ROLE_SERVICE
ROLE_OWNER
ROLE_DRIVER
ROLE_FM



E WhitelistKeyPermission_E

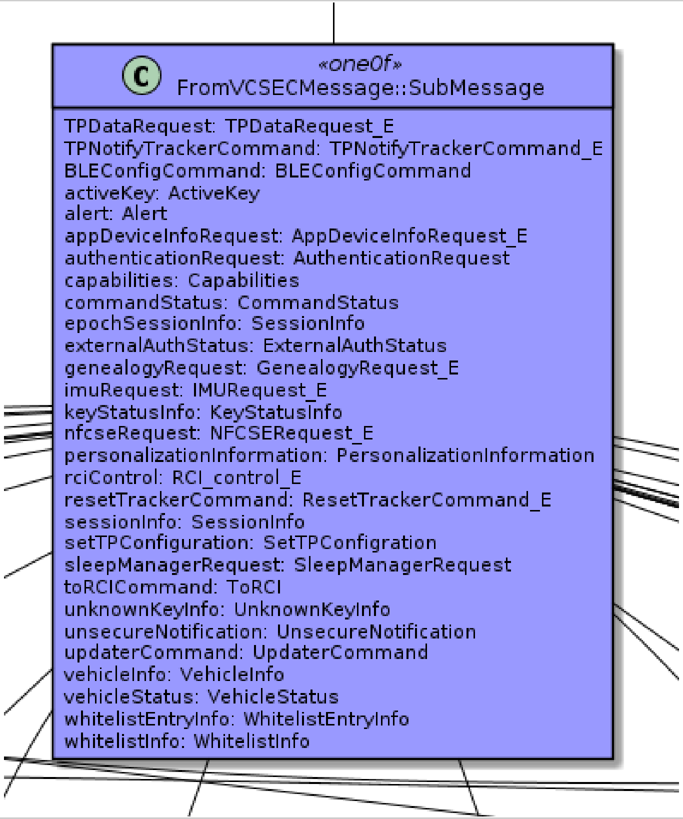
WHITELISTKEYPERMISSION_ADD_TO_WHITELIST
WHITELISTKEYPERMISSION_LOCAL_UNLOCK
WHITELISTKEYPERMISSION_LOCAL_DRIVE
WHITELISTKEYPERMISSION_REMOTE_UNLOCK
WHITELISTKEYPERMISSION_REMOTE_DRIVE
WHITELISTKEYPERMISSION_CHANGE_PERMISSIONS
WHITELISTKEYPERMISSION_REMOVE_FROM_WHITELIST
WHITELISTKEYPERMISSION_REMOVE_SELF_FROM_WHITELIST
WHITELISTKEYPERMISSION_MODIFY_FLEET_RESERVED_SLOTS
WHITELISTKEYPERMISSION_UNKNOWN

FM = Fleet Manager (?)

Service Key Permissions

```
WHITELISTKEYPERMISSION_ADD_TO_WHITELIST
WHITELISTKEYPERMISSION_LOCAL_UNLOCK
WHITELISTKEYPERMISSION_LOCAL_DRIVE
WHITELISTKEYPERMISSION_REMOTE_UNLOCK
WHITELISTKEYPERMISSION_REMOTE_DRIVE
WHITELISTKEYPERMISSION_CHANGE_PERMISSIONS
WHITELISTKEYPERMISSION_REMOVE_FROM_WHITELIST
WHITELISTKEYPERMISSION_REMOVE_SELF_FROM_WHITELIST
WHITELISTKEYPERMISSION_MODIFY_FLEET_RESERVED_SLOTS
```

FromVCSEC



«oneOf»
FromVCSECMessage::SubMessage

```
TPDataRequest: TPDataRequest_E
TPNotifyTrackerCommand: TPNotifyTrackerCommand_E
BLEConfigCommand: BLEConfigCommand
activeKey: ActiveKey
alert: Alert
appDeviceInfoRequest: AppDeviceInfoRequest_E
authenticationRequest: AuthenticationRequest
capabilities: Capabilities
commandStatus: CommandStatus
epochSessionInfo: SessionInfo
externalAuthStatus: ExternalAuthStatus
genealogyRequest: GenealogyRequest_E
imuRequest: IMURequest_E
keyStatusInfo: KeyStatusInfo
nfcseRequest: NFCSERequest_E
personalizationInformation: PersonalizationInformation
rciControl: RCI_control_E
resetTrackerCommand: ResetTrackerCommand_E
sessionInfo: SessionInfo
setTPConfiguration: SetTPConfigration
sleepManagerRequest: SleepManagerRequest
toRCICommand: ToRCI
unknownKeyInfo: UnknownKeyInfo
unsecureNotification: UnsecureNotification
updaterCommand: UpdaterCommand
vehicleInfo: VehicleInfo
vehicleStatus: VehicleStatus
whitelistEntryInfo: WhitelistEntryInfo
whitelistInfo: WhitelistInfo
```

- All VCSEC messages that originate from Vehicle
- Most frequent messages:
  - vehicleStatus
  - authenticationRequest
  - commandStatus
- Observation: No cryptographically protected messages from vehicle!

FromVCSEC – Examples (1)

001c1a1a12160a14d658de76f3a930b63410c6b6382a554781979d041802

```
--- FromVCSECMessage ---
authenticationRequest {
  sessionInfo {
    token: "\326X\336v\363\2510\2664\020\306\2668*UG\201\227\235\004"
  }
  requestedLevel: AUTHENTICATION_LEVEL_DRIVE
}
-------------
```

FromVCSEC – Examples (2)

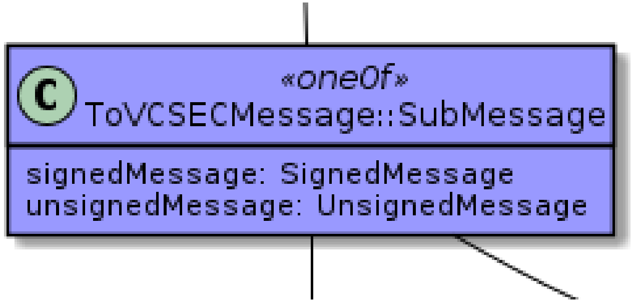
00072205120308de15

```
--- FromVCSECMessage ---
commandStatus {
  signedMessageStatus {
    counter: 2782
  }
}
-------------
```

00040a021001

```
--- FromVCSECMessage ---
vehicleStatus {
  vehicleLockState: VEHICLELOCKSTATE_LOCKED
}
```

ToVCSEC

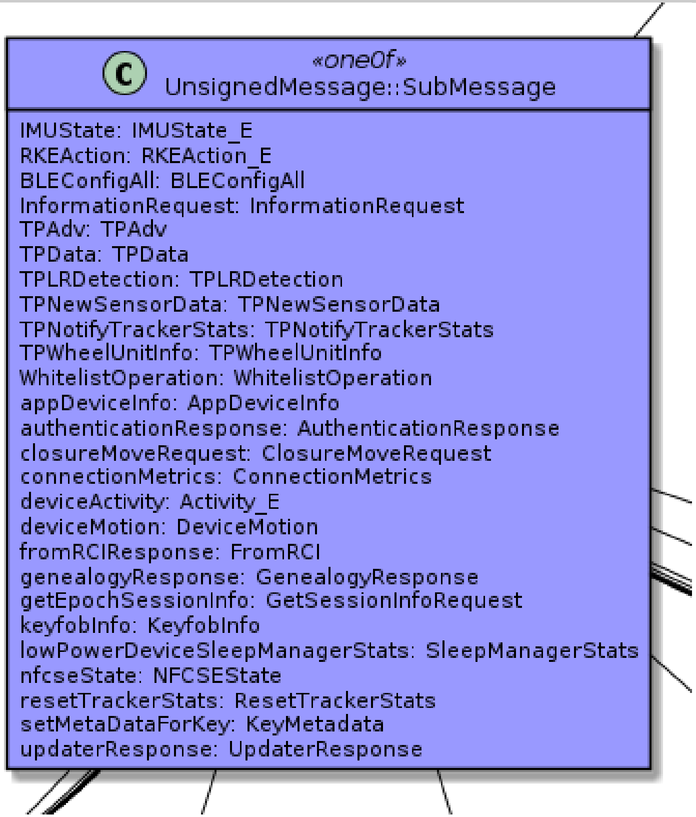


C «oneOf»
ToVCSECMessage::SubMessage

signedMessage: SignedMessage
unsignedMessage: UnsignedMessage

- All VCSEC messages that are sent to vehicle
- Depending on use-case:
  - unsignedMessage
    - Not cryptographically protected
  - signedMessage
    - Crypto: AES-GCM (AEAD)

unsignedMessage

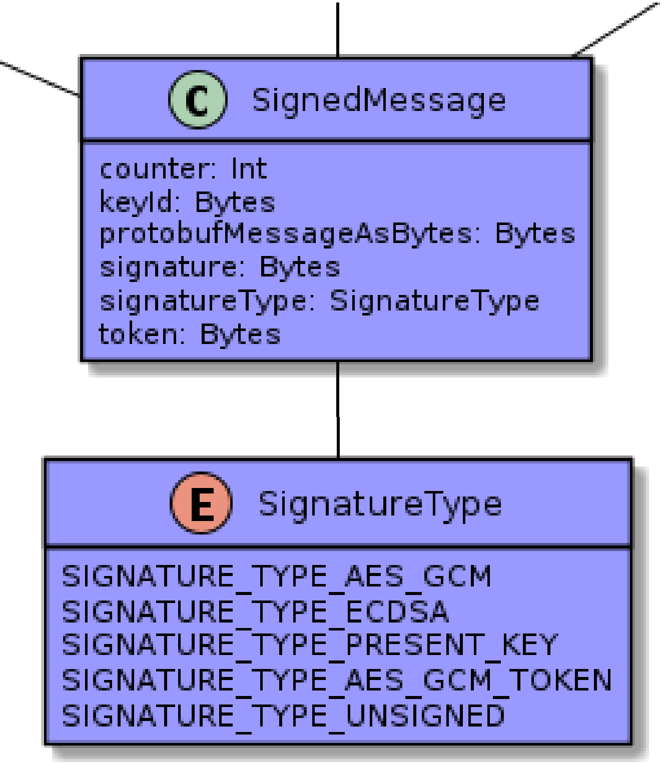


C «oneOf»
UnsignedMessage::SubMessage

IMUState: IMUState_E
RKEAction: RKEAction_E
BLEConfigAll: BLEConfigAll
InformationRequest: InformationRequest
TPAdv: TPAdv
TPData: TPData
TPLRDetection: TPLRDetection
TPNewSensorData: TPNewSensorData
TPNotifyTrackerStats: TPNotifyTrackerStats
TPWheelUnitInfo: TPWheelUnitInfo
WhitelistOperation: WhitelistOperation
appDeviceInfo: AppDeviceInfo
authenticationResponse: AuthenticationResponse
closureMoveRequest: ClosureMoveRequest
connectionMetrics: ConnectionMetrics
deviceActivity: Activity_E
deviceMotion: DeviceMotion
fromRCIResponse: FromRCI
genealogyResponse: GenealogyResponse
getEpochSessionInfo: GetSessionInfoRequest
keyfobInfo: KeyfobInfo
lowPowerDeviceSleepManagerStats: SleepManagerStats
nfcseState: NFCSEState
resetTrackerStats: ResetTrackerStats
setMetaDataForKey: KeyMetadata
updaterResponse: UpdaterResponse

- Used for messages **without** direct security context
- Used as encapsulating message for signedMessage cryptograms

signedMessage



C SignedMessage

counter: Int
keyId: Bytes
protobufMessageAsBytes: Bytes
signature: Bytes
signatureType: SignatureType
token: Bytes

E SignatureType

SIGNATURE_TYPE_AES_GCM
SIGNATURE_TYPE_ECDSA
SIGNATURE_TYPE_PRESENT_KEY
SIGNATURE_TYPE_AES_GCM_TOKEN
SIGNATURE_TYPE_UNSIGNED

- Used for messages **with** direct security context
- Used as encapsulating message for signedMessage cryptograms
- IMUState: used for mitigating relay attack(!?)

Cryptographic Keys

- VCSEC uses asymmetric encryption based on ECC Keypairs
  - Based on prime256v1 curve

```
$> openssl ecparam -name prime256v1 -genkey -noout -out created_key.pem
```

- Shared secret is derived used via Diffie-Hellman key exchange
  - 128 bit
- Used for authentication/encryption

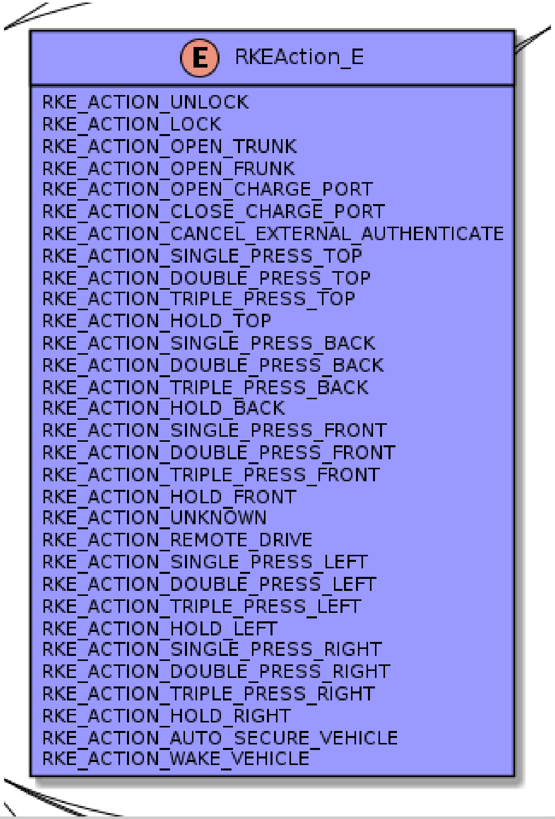
Signed Messages

- Galois Counter Mode with Associated Data AES-GCM AEAD
  - Intends to prevent replay attacks (counter)
    - Rolling Code
  - Additional Data (session token data in requests)
    - Works as challenge for the correct response
    - Also intends to prevent replay attacks

GCM Structure (Tesla)

- SharedSecret 16 octets
- Invocation-Counter only 4 octets (not 8) (counter)
- Signature/Tag (GMAC) 16 octets
- Additional Data (optional) 20 octets (session token)
  - `SIGNATURE_TYPE_AES_GCM`
  - `SIGNATURE_TYPE_AES_GCM_TOKEN`
  - `SIGNATURE_TYPE_PRESENT_KEY`

RKAction_E

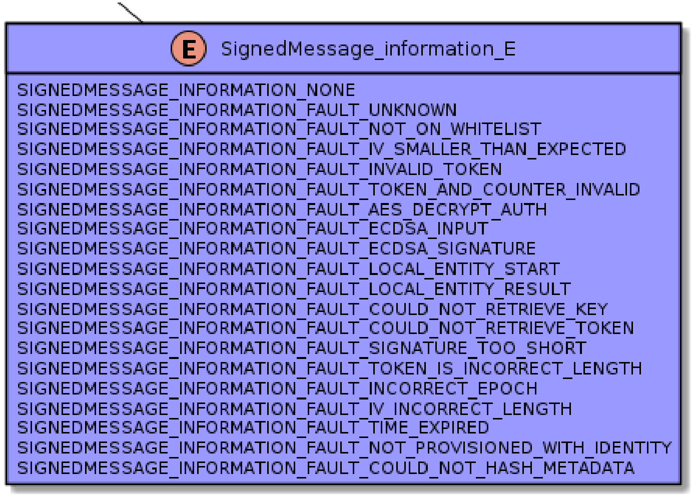


E RKEAction_E

RKE_ACTION_UNLOCK
RKE_ACTION_LOCK
RKE_ACTION_OPEN_TRUNK
RKE_ACTION_OPEN_FRUNK
RKE_ACTION_OPEN_CHARGE_PORT
RKE_ACTION_CLOSE_CHARGE_PORT
RKE_ACTION_CANCEL_EXTERNAL_AUTHENTICATE
RKE_ACTION_SINGLE_PRESS_TOP
RKE_ACTION_DOUBLE_PRESS_TOP
RKE_ACTION_TRIPLE_PRESS_TOP
RKE_ACTION_HOLD_TOP
RKE_ACTION_SINGLE_PRESS_BACK
RKE_ACTION_DOUBLE_PRESS_BACK
RKE_ACTION_TRIPLE_PRESS_BACK
RKE_ACTION_HOLD_BACK
RKE_ACTION_SINGLE_PRESS_FRONT
RKE_ACTION_DOUBLE_PRESS_FRONT
RKE_ACTION_TRIPLE_PRESS_FRONT
RKE_ACTION_HOLD_FRONT
RKE_ACTION_UNKNOWN
RKE_ACTION_REMOTE_DRIVE
RKE_ACTION_SINGLE_PRESS_LEFT
RKE_ACTION_DOUBLE_PRESS_LEFT
RKE_ACTION_TRIPLE_PRESS_LEFT
RKE_ACTION_HOLD_LEFT
RKE_ACTION_SINGLE_PRESS_RIGHT
RKE_ACTION_DOUBLE_PRESS_RIGHT
RKE_ACTION_TRIPLE_PRESS_RIGHT
RKE_ACTION_HOLD_RIGHT
RKE_ACTION_AUTO_SECURE_VEHICLE
RKE_ACTION_WAKE_VEHICLE

- Used for control commands in app/fob
- Is encapsuled in unsignedMessage before encryption

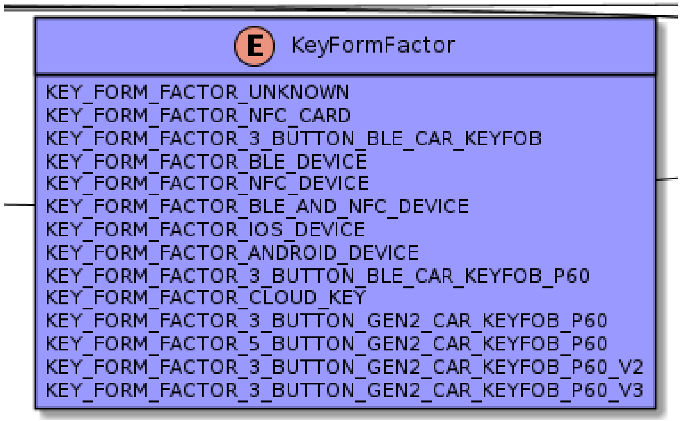
SignedMesage_information_E



```
E SignedMessage_information_E
SIGNEDMESSAGE_INFORMATION_NONE
SIGNEDMESSAGE_INFORMATION_FAULT_UNKNOWN
SIGNEDMESSAGE_INFORMATION_FAULT_NOT_ON_WHITELIST
SIGNEDMESSAGE_INFORMATION_FAULT_IV_SMALLER_THAN_EXPECTED
SIGNEDMESSAGE_INFORMATION_FAULT_INVALID_TOKEN
SIGNEDMESSAGE_INFORMATION_FAULT_TOKEN_AND_COUNTER_INVALID
SIGNEDMESSAGE_INFORMATION_FAULT_AES_DECRYPT_AUTH
SIGNEDMESSAGE_INFORMATION_FAULT_ECDSA_INPUT
SIGNEDMESSAGE_INFORMATION_FAULT_ECDSA_SIGNATURE
SIGNEDMESSAGE_INFORMATION_FAULT_LOCAL_ENTITY_START
SIGNEDMESSAGE_INFORMATION_FAULT_LOCAL_ENTITY_RESULT
SIGNEDMESSAGE_INFORMATION_FAULT_COULD_NOT_RETRIEVE_KEY
SIGNEDMESSAGE_INFORMATION_FAULT_COULD_NOT_RETRIEVE_TOKEN
SIGNEDMESSAGE_INFORMATION_FAULT_SIGNATURE_TOO_SHORT
SIGNEDMESSAGE_INFORMATION_FAULT_TOKEN_IS_INCORRECT_LENGTH
SIGNEDMESSAGE_INFORMATION_FAULT_INCORRECT_EPOCH
SIGNEDMESSAGE_INFORMATION_FAULT_IV_INCORRECT_LENGTH
SIGNEDMESSAGE_INFORMATION_FAULT_TIME_EXPIRED
SIGNEDMESSAGE_INFORMATION_FAULT_NOT_PROVISIONED_WITH_IDENTITY
SIGNEDMESSAGE_INFORMATION_FAULT_COULD_NOT_HASH_METADATA
```

- What could possibly go wrong with encryption?
- Some attacks play with these

RKAction_E



E KeyFormFactor

```
KEY_FORM_FACTOR_UNKNOWN
KEY_FORM_FACTOR_NFC_CARD
KEY_FORM_FACTOR_3_BUTTON_BLE_CAR_KEYFOB
KEY_FORM_FACTOR_BLE_DEVICE
KEY_FORM_FACTOR_NFC_DEVICE
KEY_FORM_FACTOR_BLE_AND_NFC_DEVICE
KEY_FORM_FACTOR_IOS_DEVICE
KEY_FORM_FACTOR_ANDROID_DEVICE
KEY_FORM_FACTOR_3_BUTTON_BLE_CAR_KEYFOB_P60
KEY_FORM_FACTOR_CLOUD_KEY
KEY_FORM_FACTOR_3_BUTTON_GEN2_CAR_KEYFOB_P60
KEY_FORM_FACTOR_5_BUTTON_GEN2_CAR_KEYFOB_P60
KEY_FORM_FACTOR_3_BUTTON_GEN2_CAR_KEYFOB_P60_V2
KEY_FORM_FACTOR_3_BUTTON_GEN2_CAR_KEYFOB_P60_V3
```

- Used for control commands in app/fob
- Is encapsuled in unsignedMessage before encryption

SignedMessage Example

0018ea02150a1308f4051801320c080418012077287306d386f

```
--- ToVCSECMessage ---
signedMessage {
  protobufMessageAsBytes: "h\001\251\242"
  signatureType: SIGNATURE_TYPE_AES_GCM_TOKEN
  signature: "}\246l\023E\306\257/\274\037\026\032\375#\355\222"
  keyId: "\'\365\030\021"
  counter: 2781
}
-------------
```

Key Enumeration (unrestricted)

- Formfactors (what kind of devices?)
- Active Keys (how many users/keys)
- Counters (which key is used over time?)
- Service Key ID (maybe service region?)
  - Two alternating keys identified (Europe?)

Whitelisting Keys

- Process requires key with OWNER_ROLE & NFC
- Max. 19 keys can be enrolled per vehicle
  - More keys / slots / channels possible?
  - **`WHITELISTKEYPERMISSION_MODIFY_FLEET_RESERVED_SLOTS`**
  - Fleet mgmt is a business feature introduced in 02/22
- Whitelisted keys are referenced with keyID
  - KeyID = first 4 bytes of SHA1(public key)

Process: Whitelisting a Key (1)

- Log in to Tesla Account
- Get assigned Vehicle VIN(s) from Owner-API
- Get VIN Identifier
  - SHA1 over VIN and get first 8 bytes
- Find Vehicle
- Begin Whitelisting Process

Process: Whitelisting a Key (2)

- Send:

  `INFORMATION_REQUEST_TYPE_GET_EPHEMERAL_PUBLIC_KEY`

- Receive: Vehicle’s public key
- Send:

  `INFORMATION_REQUEST_TYPE_GET_WHITELIST_INFO`

- Receive: Number of currently whitelisted keys

Process: Whitelisting a Key (3)

- Generate WhitelistOperation message
  - Use your previously generated keypair (ECC prime256v1)
- Send WhitelistOperation (wrapped in SignedMessage) with SignatureType

  `SIGNATURE_TYPE_PRESENT_KEY`
- Tap NFC-Key for Authorization (Fascia or B-Pillar)
- Receive: WhitelistOperationStatus

Process: Whitelisting a Key (4)

- Send:

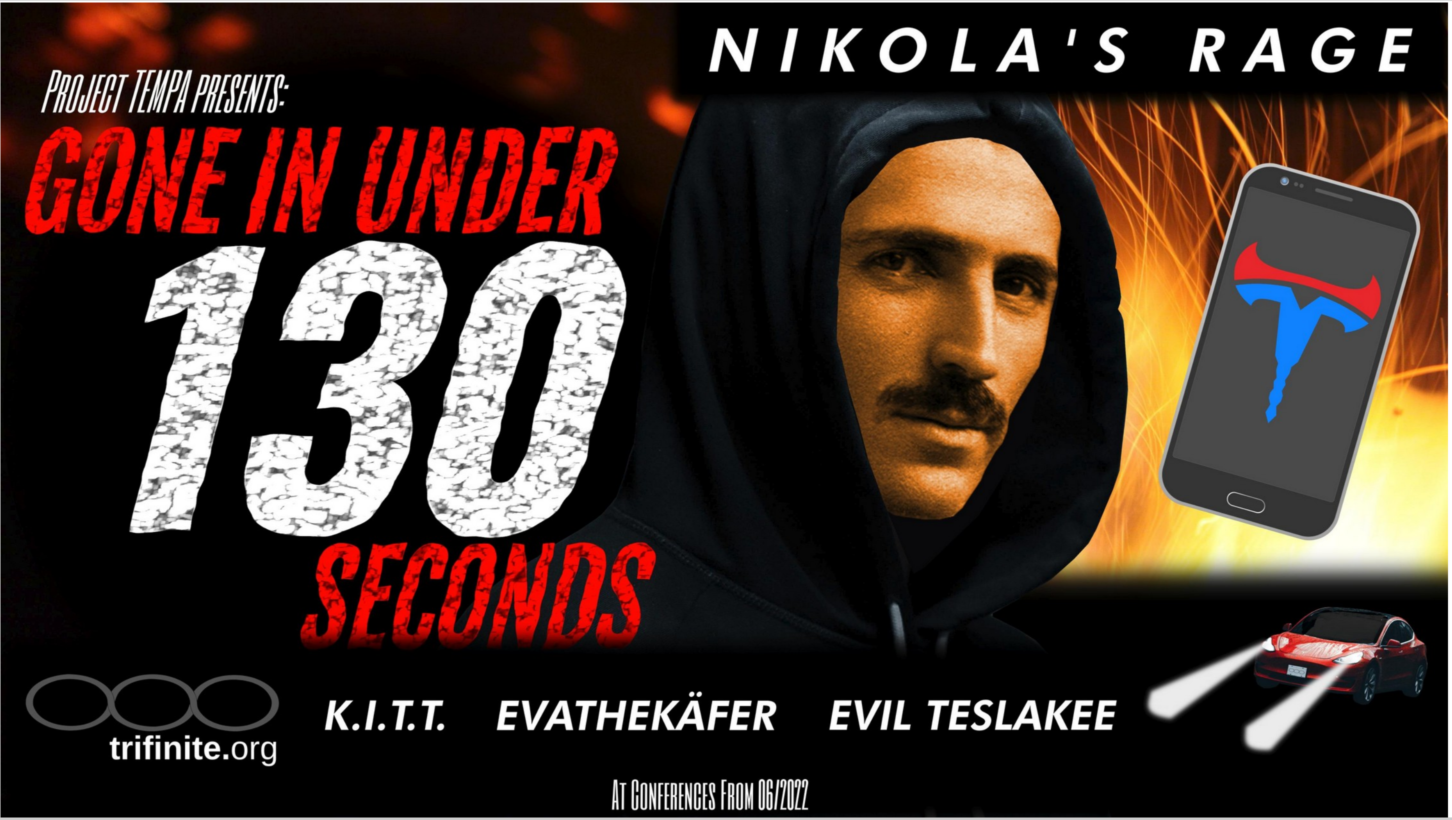
```
INFORMATION_REQUEST_TYPE_GET_WHITELIST_INFO
```

- Receive: Number of currently whitelisted keys
- Verify that your new key is in the list
  - KeyID: First 4 Bytes from SHA1 over your public key
- Start using your key

Authorization Timer (130 seconds)

- Introduced in August 2021
  - https://bit.ly/3ansIsl (driveteslacanada.ca)
- For more convenience with NFC-KeyCard
- No extra NFC swipe is required during this time
  - Allows starting car
  - Allows whitelisting a key

Gone in under 130 seconds

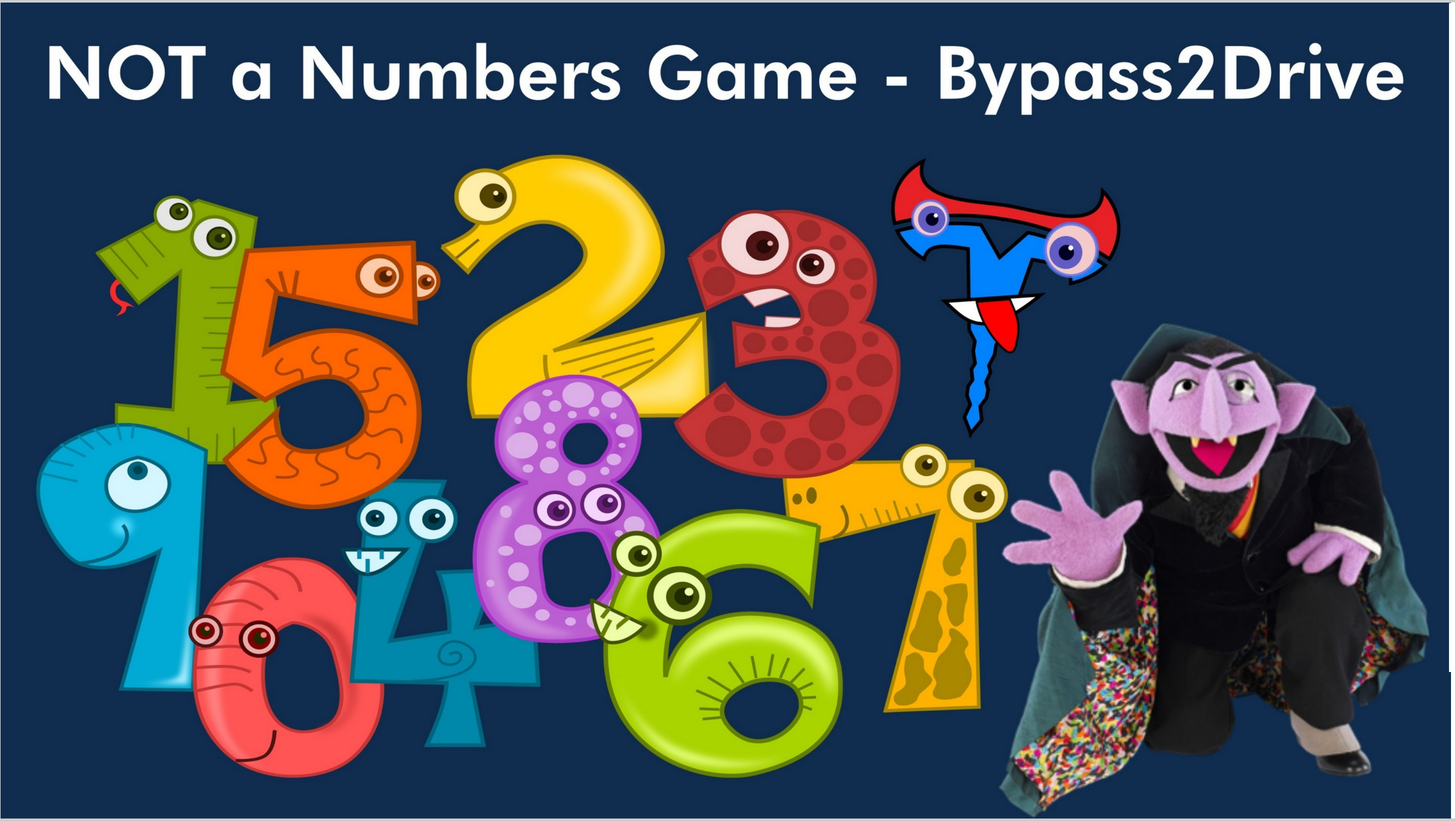


https://youtu.be/yfG4JS71eUY

Owning a key allows

- Unlocking/Locking the vehicle
- Drive the vehicle
  - PIN2Drive as recommended mitigation
  - PIN2Drive: 4-digit PIN has to be entered in order to drive

NOT a numbers game - Bypass2Drive



https://youtu.be/vWM98f3-vvc

Tesla's Broken Trust Model

HOWTO: Emulating a Tesla Vehicle

- Expose iBeacon structure
- Use of EIR Advertising (not with bluez dbus-api)
  - EIR: 0201061aff4c00021574278bdab64445208f0c720eaf05993500001337c5
    green: length, blue: iBeacon UUID, orange: iBeacon major, purple: iBeacon minor
  - ScanResponse: 030222111309533066373838356332616631613665663943
    green: length, blue: Vehicle Name (VIN identifier)
- Implement Service with *FromVehicle* and *ToVehicle* Characteristics
- Tool on github: temparary

Key Drop Attack

- PhoneKey App sends signed message
- Attacker answers for vehicle:
  - `SIGNEDMESSAGE_INFORMATION_FAULT_NOT_ON_WHITELIST`
- PhoneKey app invalidates whitelisted Key
- User is locked out (and has to use NFC)

Key Enrollment vs. Key Restoration

- Keydrop attack: Phone holds on to key
- Restoration: Vehicle „remembers key“
  - Restoration process also possible via B-Pillar
- Full Whitelisting process only for keys that are not known to vehicle

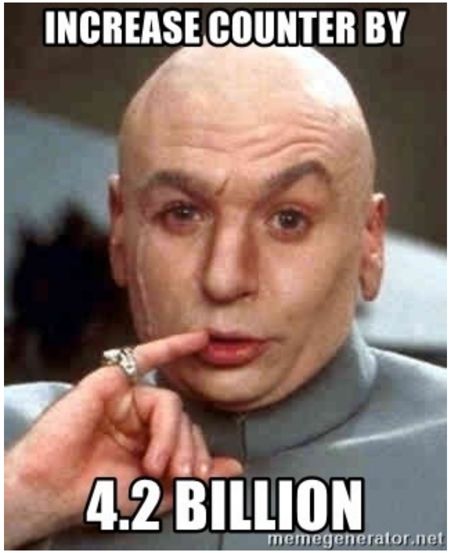
Crypto Counter Confusion Attack

NEW!

- PhoneKey App sends signed message
- Attacker answers for vehicle:

```
SIGNEDMESSAGE_INFORMATION_FAULT_IV_SMALLER_THAN_EXPECTED
```

- PhoneKey app will ask vehicle for correct counter value
- Attacker answers for vehicle with maximum value of 32-Bit integer (unsigned)
- Owner is in trouble (app re-install required)



Crypto Counter Confusion Attack

- iOS app allows max value of 4294967295 (uint32)
- Android app allows only 2147483647 (int32)
- When set to the highest value, counter cannot be increased anymore → disfunctional key → app has to be re-installed
- Also recovery after KeyDrop leads to a strange situation
- Re-opens vector for key enrollment attack

Preview: Fun With Temparary Pt. 1

VCSEC SessionInfo

- Unsigned request

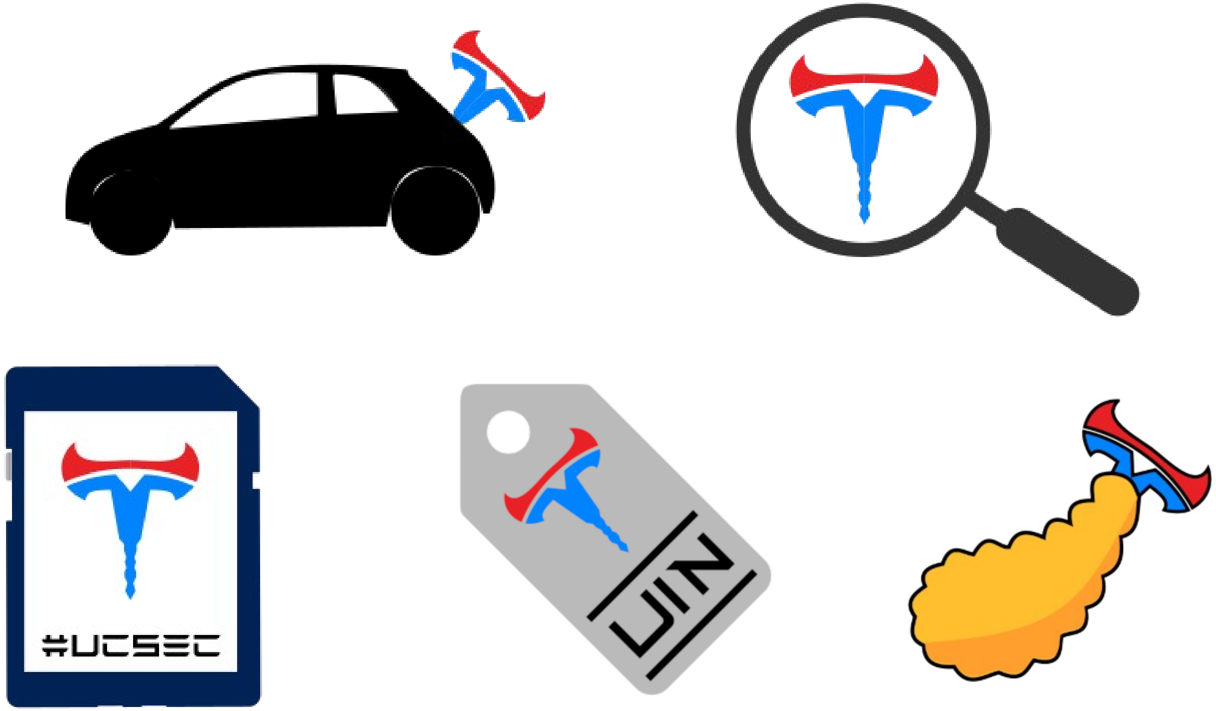
```
--- FromVCSECMessage ---
sessionInfo {
  token: "\377\377\226\300\270\017Z$ v\312{\337\225$\341\275x\332y"
  counter: 3051
  publicKey: "\004M)d\2136\372\201J\rh\253\354\220cZ\307_\
276\320\3568\212G\016\202f\223\025m\267\360\241!}\232\372vH\304_\
3532\244\023\016@1hbA\315\276g(+22q\235\3663R.\367"
}
```

Authorization Replay Attack

NEW!

- Vehicle sends token for GCM-AEAD (mainly used for passive entry functions)
- Token can be requested from car (SessionInfo)
- Use token in order to collect Authorization Responses via temparary™ tool
- Dispense Responses via tempara™ tool when asked by vehicle

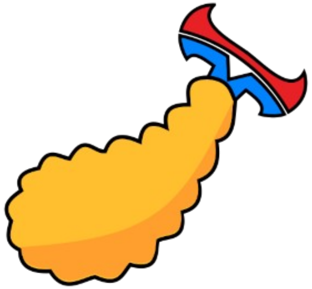
Tools and Resources on github



https://github.com/trifinite

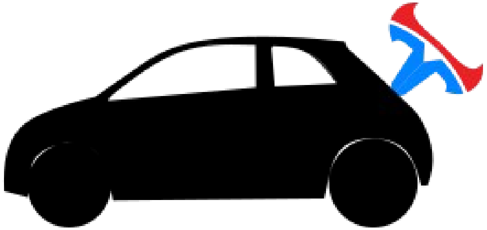
Tool: tempara

- tempara.py (on github)
  - Tesla VCSEC client based on Bleak library
  - For **your** Tesla, only!
- Version 0.1.1
  - template for key enumeration
  - de/encoding of VCSEC messages



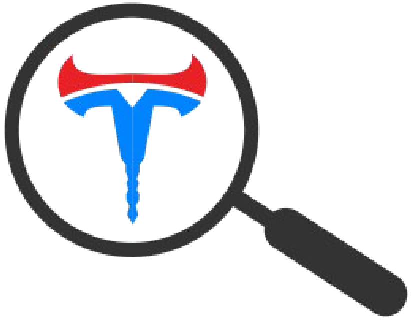
Temparary – impersonate a Tesla

- temparary.py (on github)
  - BLE Tesla Vehicle emulator
  - Based on bleno (pybleno)
- Version 0.1.3
  - Key drop attack
  - Crypto counter attack
  - de/encoding of VCSEC messages



New for SEC-T: Temparary-Profiler

- temparary-profiler.py (on github)
  - BLE Tesla Vehicle emulator helper
  - Based on bleak
- Version 0.1.0 retrieves
  - Bluetooth Device Address
  - Extended Inquiry Response
  - Scan Response
  - Vehicles Public Key



Resource: VCSEC Archive

- All VCSEC.proto files to date (on github)
- Provided for educational purposes
- Derived from decompiled Android app
- Shell scripts to get started (protoc rquired)
  - decode.sh script
  - encode.sh script

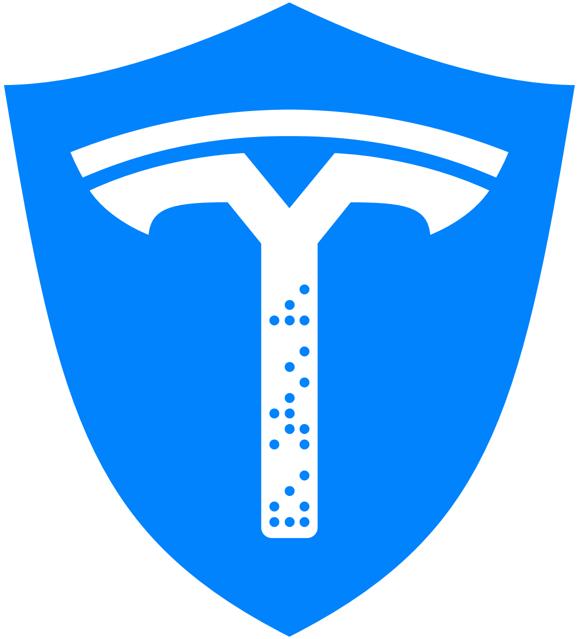
Tool: VINTag

- VINTag.py (on github)
  - API Client for VIN decoding
  - Requires free RapidAPI account / API key
- API Endpoints:
  - https://rapidapi.com/trifinite/api/tesla-vin-identifier
  - s3xy: resolves Model Type
  - location: manufacturing location
  - year: manufacturing year
  - vin: complete VIN detection (not free)

TeslaKee: Doesn’t talk to strangers!

- Does talk to your car
- Replacement for Tesla’s PhoneKey
- Protection against:
  - Relay Attacks
  - Theft
  - Soon (Q3/2022) available for Android… and maybe later for iOS

www.teslakee.com - Please leave your contact to stay in the loop!



Conclusion (1)

- Relay-Attacks are possible
  - PIN2Drive feature should be used / promoted better
  - Tesla PhoneKey really talks to anyone
- NFC-KeyCard
  - Autorization Timer permissions have to be restricted
- App
  - Online- and Offline-Realms have to be united

Conclusion (2)

- VCSEC does **not** stand for “**V**ehicle **C**ontrol **Sec**urity“
  - It stands for **V**ehicle **C**ontrol **Sec**ondary
- Convenience/UX trumps™ Security
  - PhoneKey cannot easily be deactivated, etc.
  - Authorization Timer Issues

What about the KeyFob?

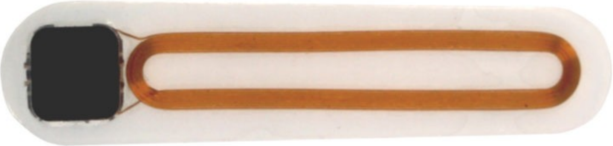
- Research in Progress
- Vehicle initiates connection to KeyFob
- GATT-Structure similar to Vehicle when connection via PhoneKey
- Only connectable when in motion (10s Timeout)
- Shorter Messages compared to PhoneKey comm

Credits

- Slawomir Jasek, SecuRing (gattacker.io)
- Sandeep Mistry, noble/bleno
- Skylot, jadx
- Lex Nastin (similar work) https://teslabtapi.lexnastin.com/
- Josh Welder / Samed Ozdemir

Already too late?

TeslaFlex “Key Card” Implant



Sold out (!) at https://dangerousthings.com/product/teslaflex/

Thanks for your attention!

Questions?
trifinite.org/martin

Slides:
trifinite.org/tempa

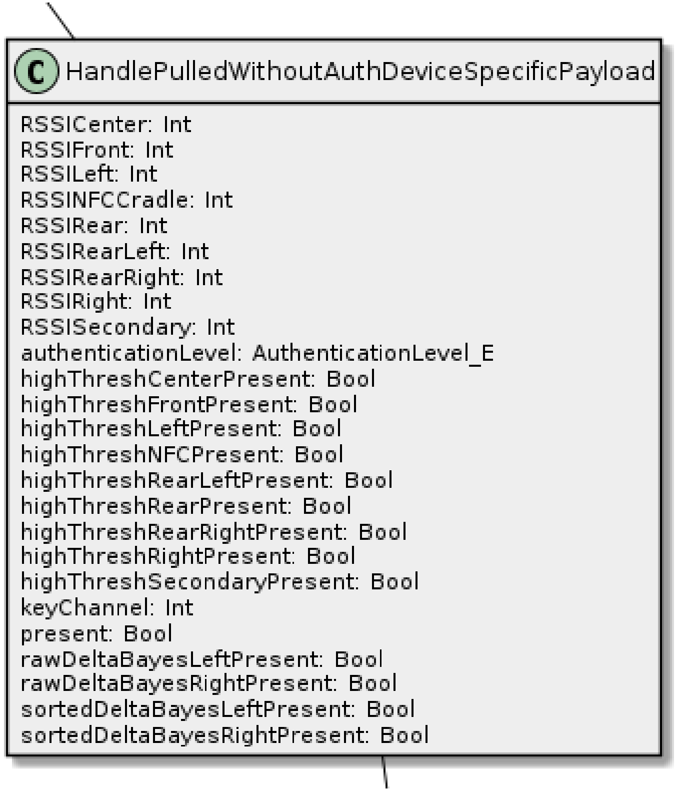
Twitter:
@mherfurt @trifinite_org

Patreon:
patreon.com/mherfurt

https://thehackermind.com

A little more background in Episode 48

HandlePulledWithoutAuthSpecificPayload



```
HandlePulledWithoutAuthDeviceSpecificPayload
RSSICenter: Int
RSSIFront: Int
RSSILeft: Int
RSSINFCCradle: Int
RSSIRear: Int
RSSIRearLeft: Int
RSSIRearRight: Int
RSSIRight: Int
RSSISecondary: Int
authenticationLevel: AuthenticationLevel_E
highThreshCenterPresent: Bool
highThreshFrontPresent: Bool
highThreshLeftPresent: Bool
highThreshNFCPresent: Bool
highThreshRearLeftPresent: Bool
highThreshRearPresent: Bool
highThreshRearRightPresent: Bool
highThreshRightPresent: Bool
highThreshSecondaryPresent: Bool
keyChannel: Int
present: Bool
rawDeltaBayesLeftPresent: Bool
rawDeltaBayesRightPresent: Bool
sortedDeltaBayesLeftPresent: Bool
sortedDeltaBayesRightPresent: Bool
```

- Alert-Message
- Introduced in app Version 4.3.0
- First vehicle firmware 2022.12.3

FromVCSEC – Alert with Payload

0023ea02200a1e08d8061801280132150806180120752 87b305f38676801700178018801 88 0101

```
--- FromVCSECMessage ---
alert {
  alertHandlePulledWithoutAuth {
    timeSinceAlertSet_ms: 856
    connectionCount: 1
    authRequested: true
    deviceSpecificPayload {
      keyChannel: 6
      present: true
      RSSILeft: -59
      RSSIRight: -62
      RSSIRear: -48
      RSSICenter: -52
      highThreshLeftPresent: true
      highThreshRightPresent: true
      highThreshCenterPresent: true
      highThreshRearPresent: true
    }
  }
}
```

FromVCSEC – Alert with less details

0018ea02150a1308f4051801320c0804180120772877306d386f

```
alert {
  alertHandlePulledWithoutAuth {
    timeSinceAlertSet_ms: 756
    connectionCount: 1
    deviceSpecificPayload {
      keyChannel: 4
      present: true
      RSSILeft: -60
      RSSIRight: -60
      RSSIRear: -55
      RSSICenter: -56
    }
  }
}
```