FTF 2016
TECHNOLOGY FORUM

TRENDS IN VEHICLE ARCHITECTURES

FTF-AUT-N1813

ROBERT MORAN
AUTOMOTIVE CONNECTIVITY & SECURITY SYSTEMS
FTF-AUT-N1813
MAY 17, 2016
ROBERT.MORAN@NXP.COM

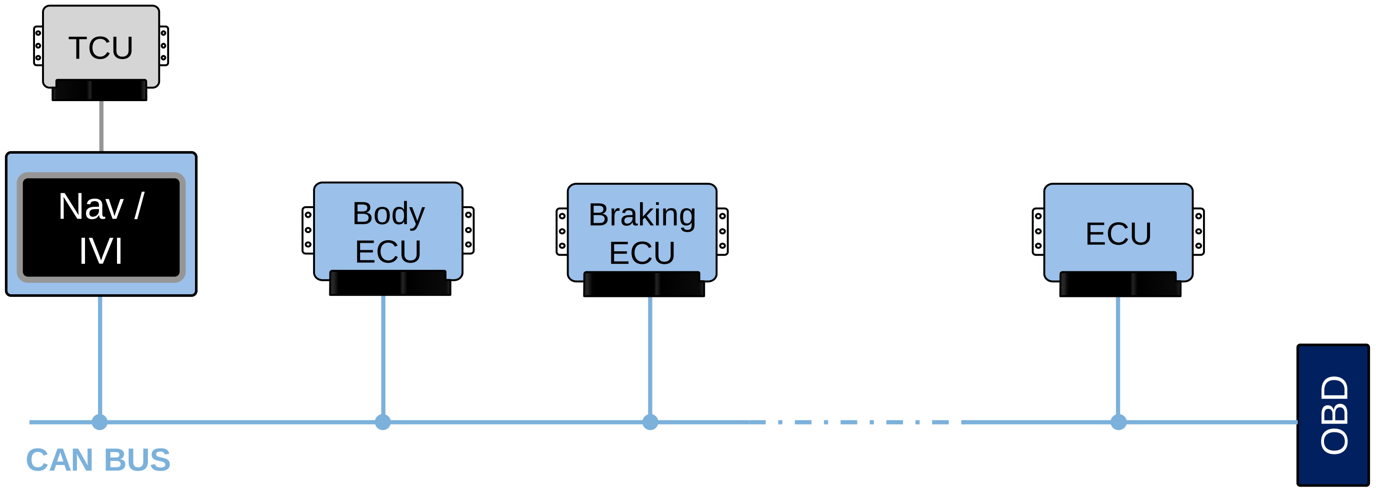
PUBLIC USE

AGENDA

- Trends in Vehicle Architecture
- Security of Vehicle Architecture
- Network Protocol Security
- Firmware Over-The-Air (FOTA)

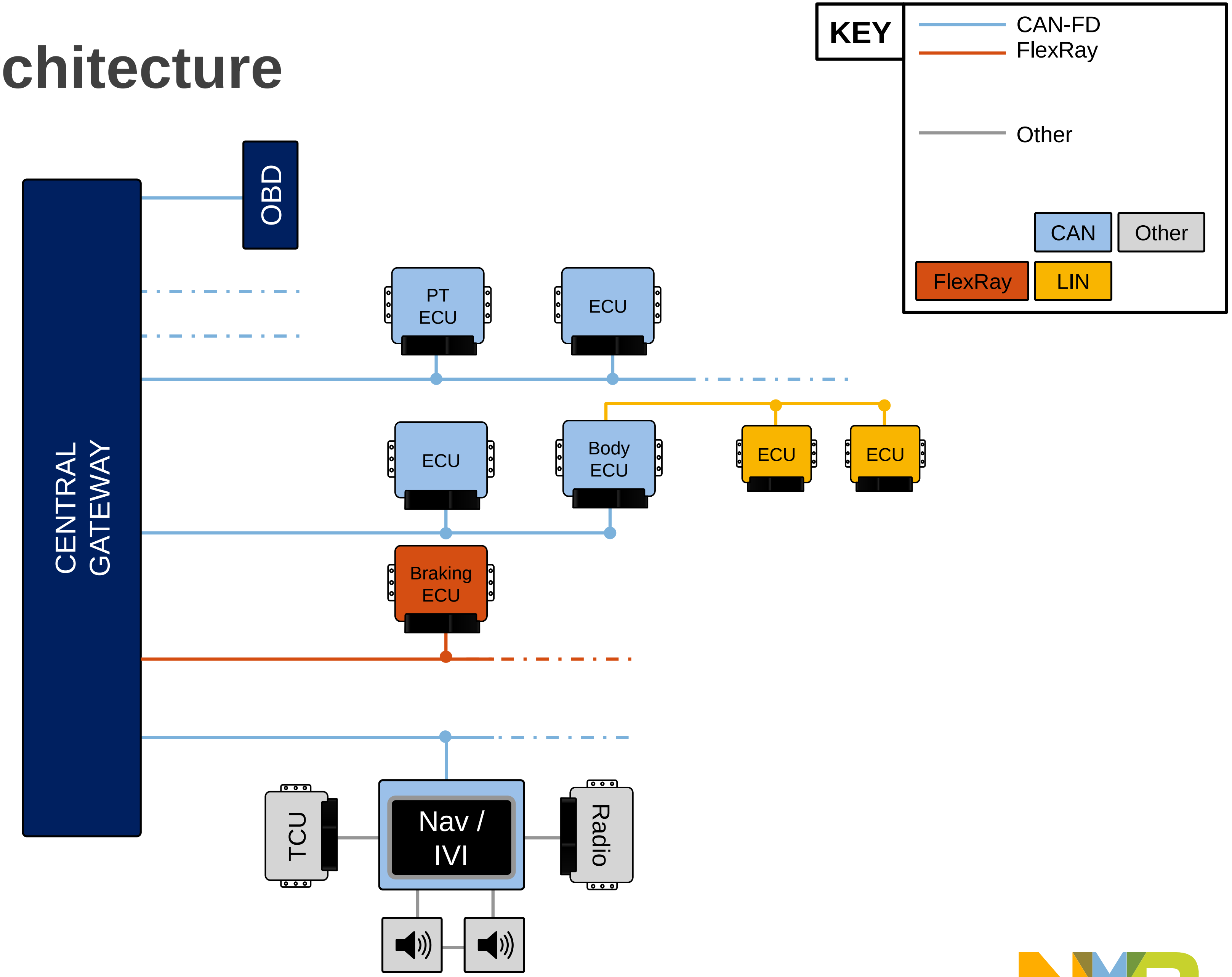
Evolution of Vehicle Architecture

- Flat bus architecture
  - Single / Twin CAN bus
  - Simple
- Security weakness
  - Shared medium between safety & non-safety ECUs
- Scalability limited
  - BW ÷ #ECUs



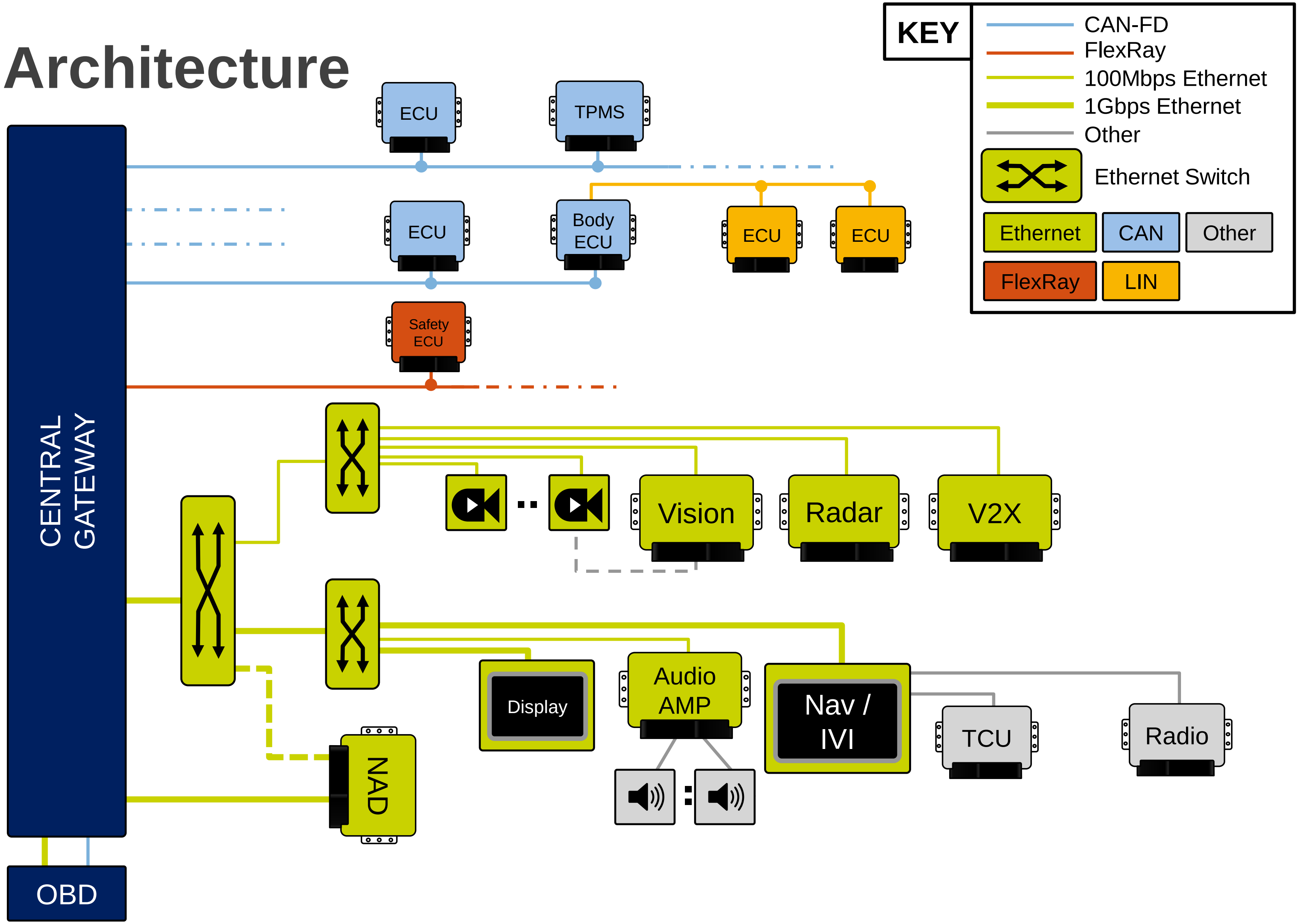
Evolution of Vehicle Architecture

- CAN Central Gateway architecture
  - Typically 3-8 CAN networks
  - Typically 1-2 FlexRay networks
- Increased bandwidth
  - but, small compared to consumer / networking world
  - Proprietary protocols for higher bandwidth (e.g. MOST)
- Physical Isolation
  - Functional domains
  - Safety / Non-safety
- Gateway role
  - Firewall internal traffic
  - Protocol translation



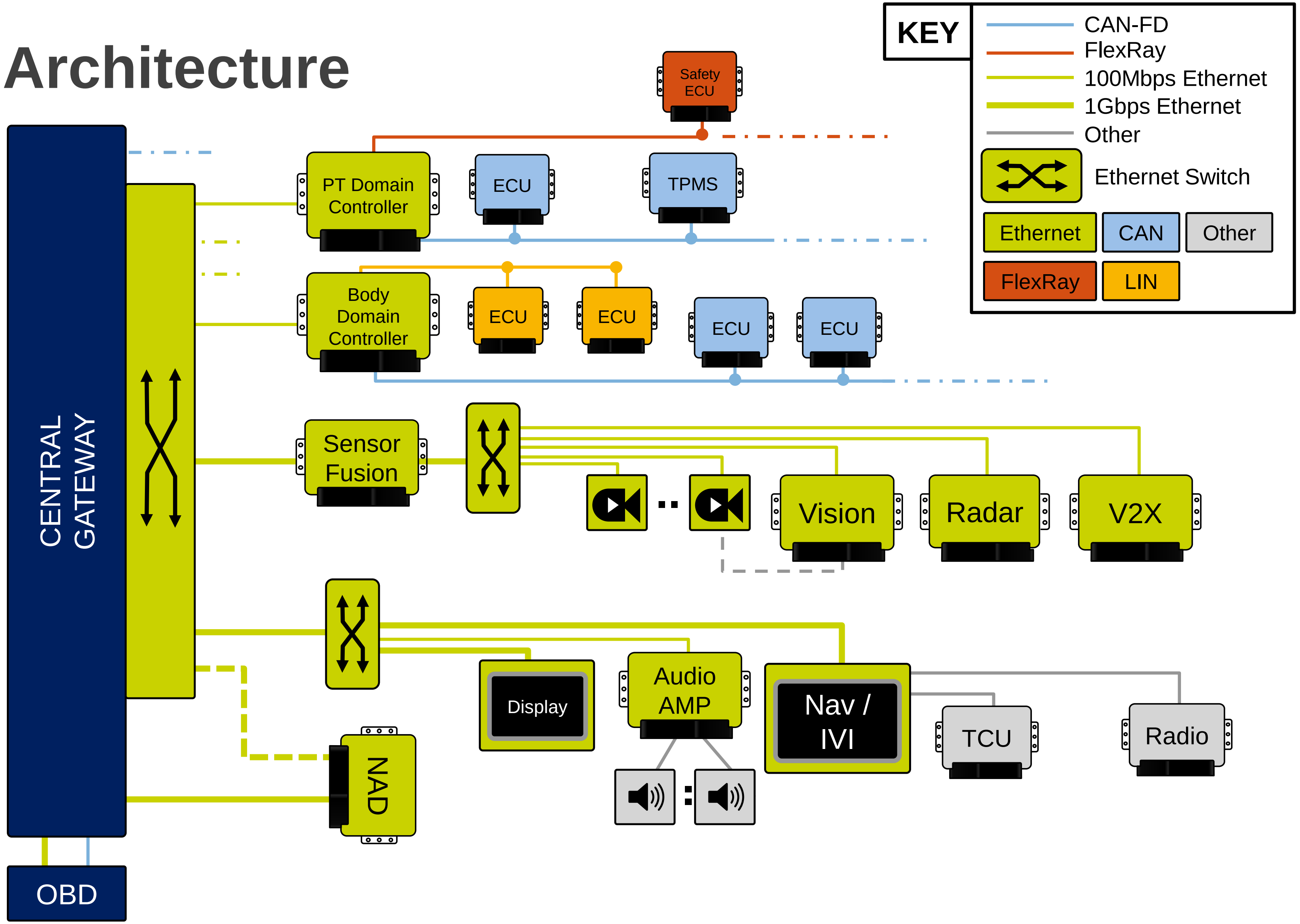
Evolution of Vehicle Architecture

- Hybrid Ethernet architecture
  - CAN, FlexRay & Ethernet
- High bandwidth
  - 100Mbit / 1Gbit Ethernet
  - Improved ECU program time in factory
- Gateway role
  - Firewall internal & external
  - Efficient protocol translation
  - ECU consolidation



Evolution of Vehicle Architecture

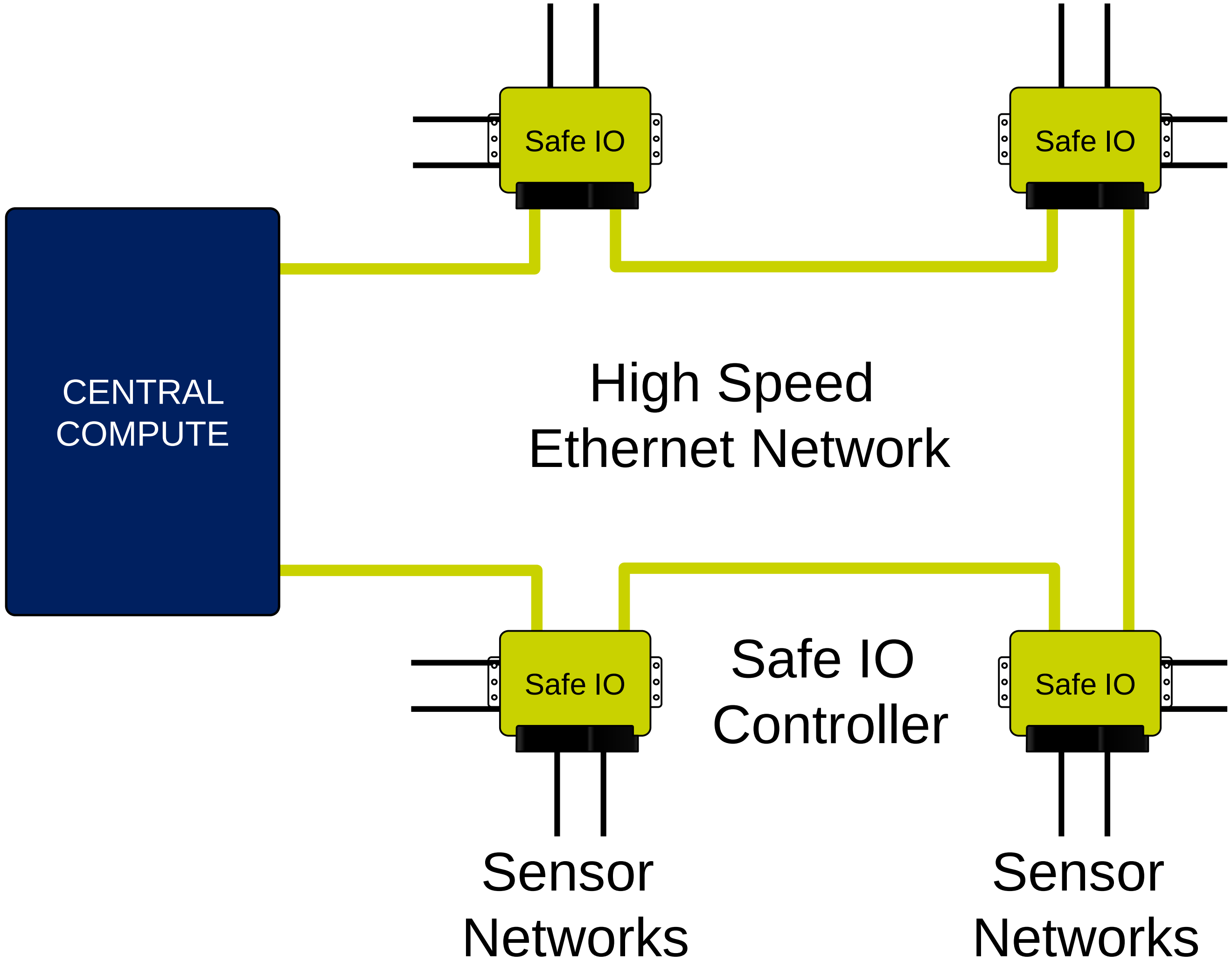
- Ethernet Backbone with Domain controllers
  - ECU consolidation
  - Distributed gateway
- Determinism over Ethernet
  - Time Sensitive Networking (TSN)
- High performance firewall



Evolution of Vehicle Architecture

- Central Compute Platform
  - High performance compute
  - Distributed safe IO processing

- High performance network
  - Bandwidth / Latency
  - Determinism
  - Strong firewall & security



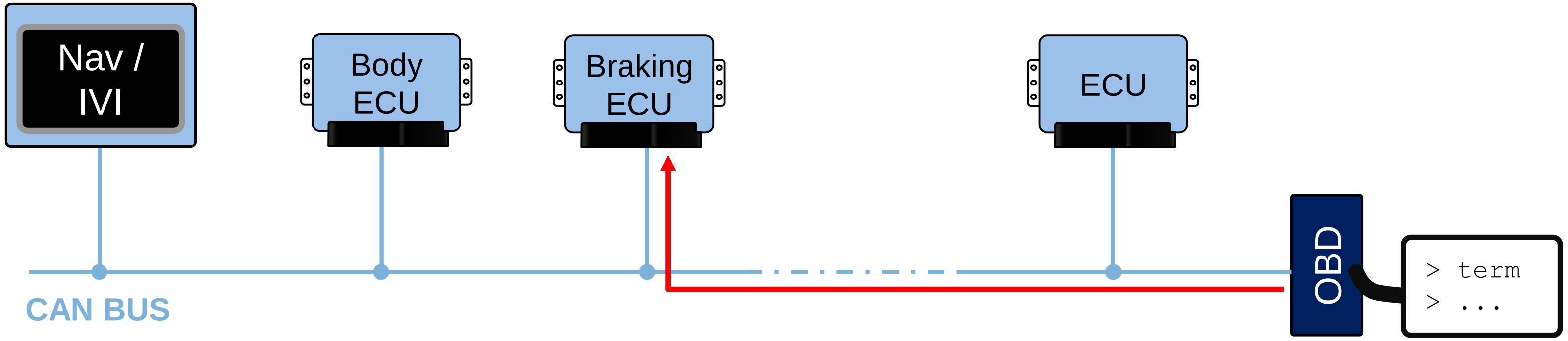
SECURITY OF VEHICLE ARCHITECTURE

Flat Architecture: Vulnerabilities

- Wide attack surface
  - OBD port direct onto network
  - One hacked ECU can access entire network

- No monitoring of bus traffic

- No firewall of traffic to safety ECUs



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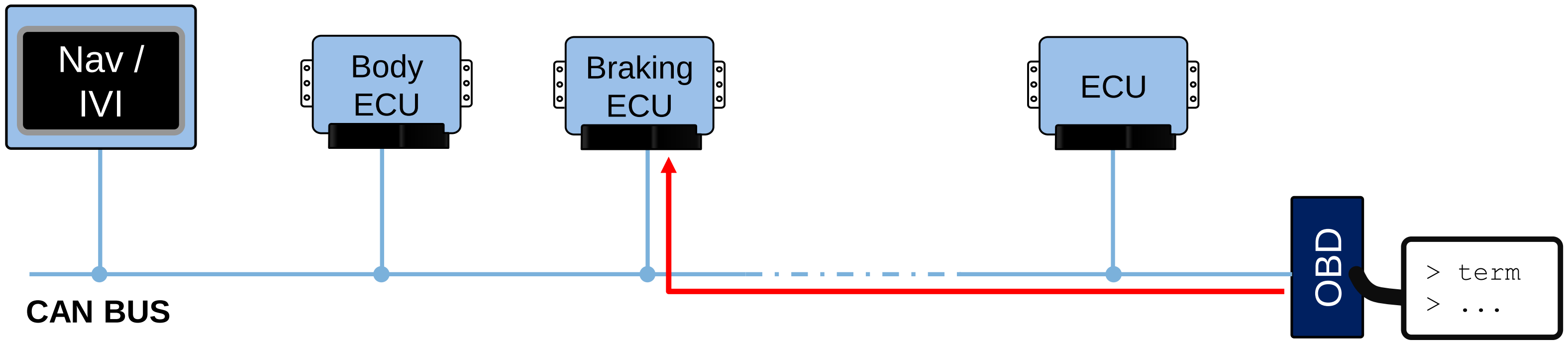
Flat Architecture: Physical Attack

- Physical access required to attack
  - OBD port in cabin
  - CAN bus in wing mirror

- Gains?
  - Visible damage



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> term
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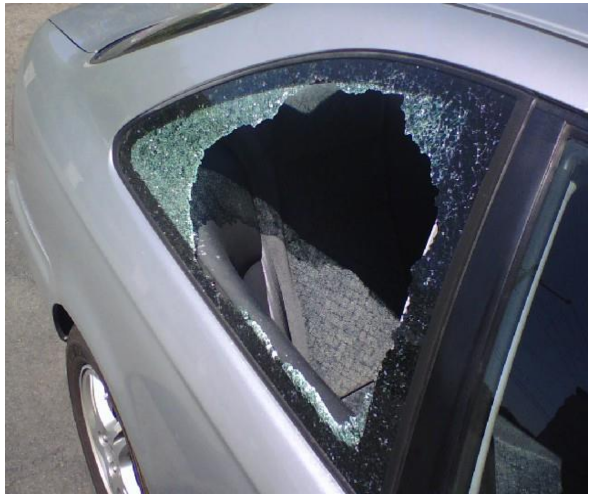
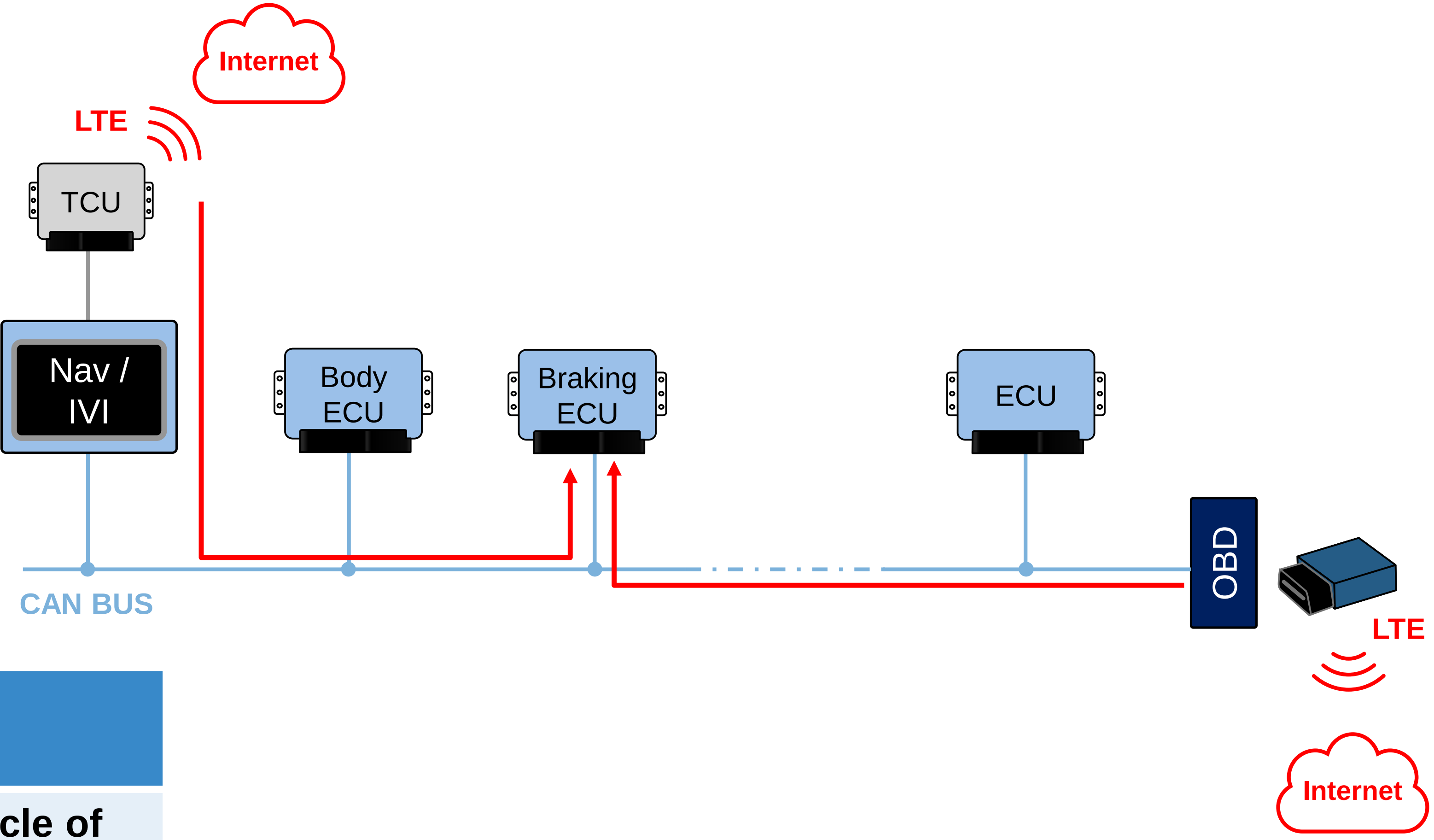
Hackers Motivation	Risk of occurring	Impact	Comments
Direct harm to occupants	Low	Single vehicle	e.g. Cannot remotely trigger brakes. Could plant a virus
Theft of vehicle / contents	High	Single vehicle	Easier than a brick through window?
Theft of OEM software	High	All models of vehicle	Basic security on ECU could prevent (e.g. secure boot)



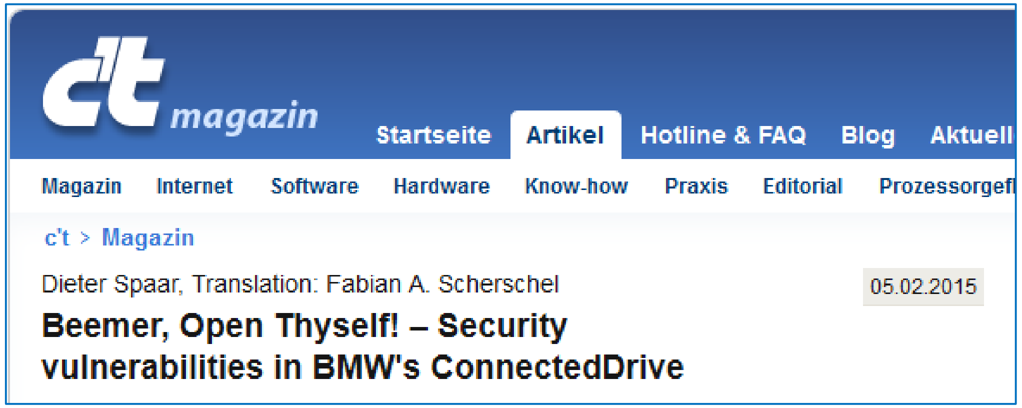
Flat Architecture: Remote Attack

- Remote attack coming into the mainstream
  - Telematics Control Unit (TCU) for entertainment / apps
  - 3rd Party Connected OBD dongles for insurance, fleet, eco-driving, etc…



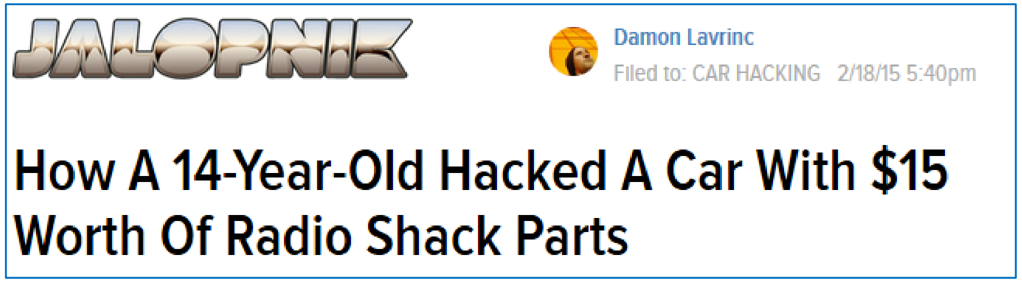
Hackers Motivation	Risk	Impact
Direct harm to occupants	High	**Any vehicle of same model**

Remote Attacks Are Happening…



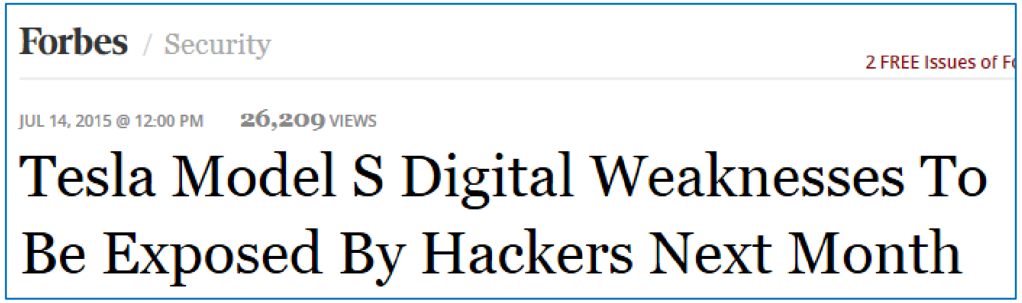
Dieter Spaar, Translation: Fabian A. Scherschel 05.02.2015

Beemer, Open Thyself! – Security vulnerabilities in BMW's ConnectedDrive



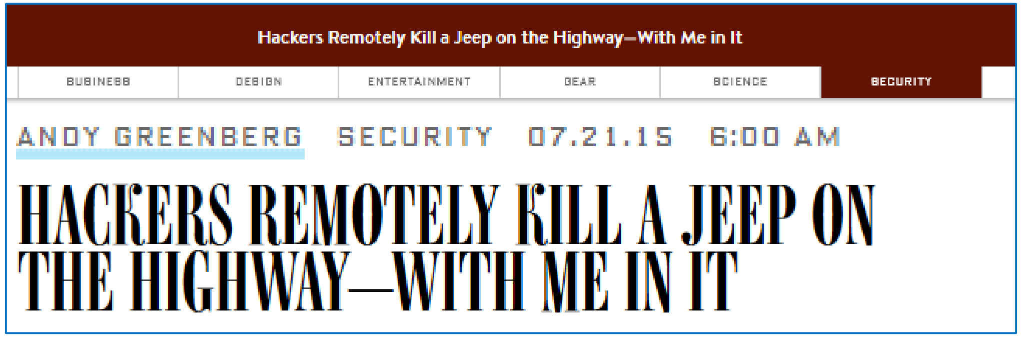
Damon Lavrinc
Filed to: CAR HACKING 2/18/15 5:40pm

How A 14-Year-Old Hacked A Car With $15 Worth Of Radio Shack Parts



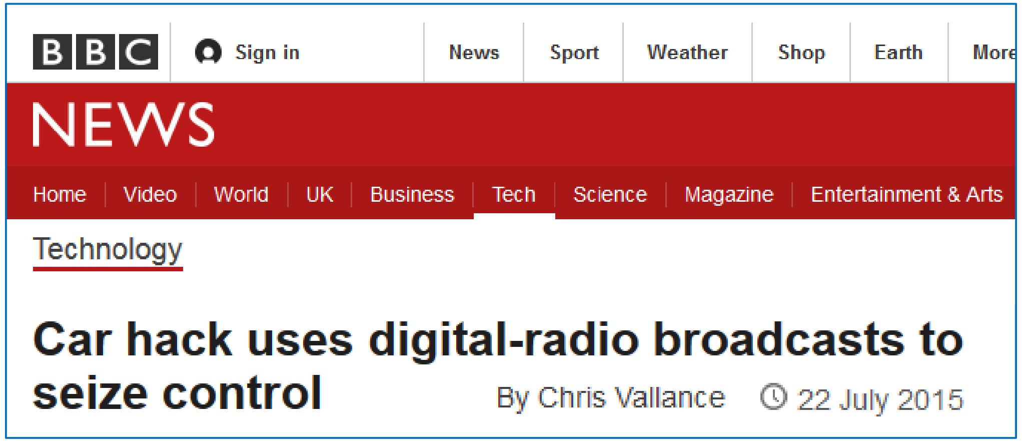
JUL 14, 2015 @ 12:00 PM 26,209 VIEWS

Tesla Model S Digital Weaknesses To Be Exposed By Hackers Next Month



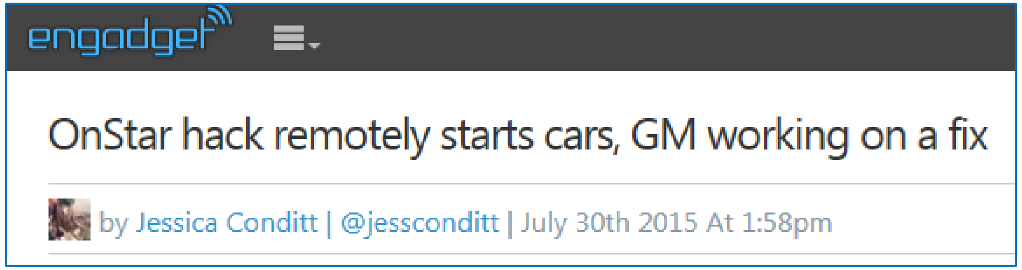
ANDY GREENBERG SECURITY 07.21.15 6:00 AM

HACKERS REMOTELY KILL A JEEP ON THE HIGHWAY—WITH ME IN IT



Car hack uses digital-radio broadcasts to seize control

By Chris Vallance 22 July 2015



OnStar hack remotely starts cars, GM working on a fix

by Jessica Condit | @jesscondit | July 30th 2015 At 1:58pm

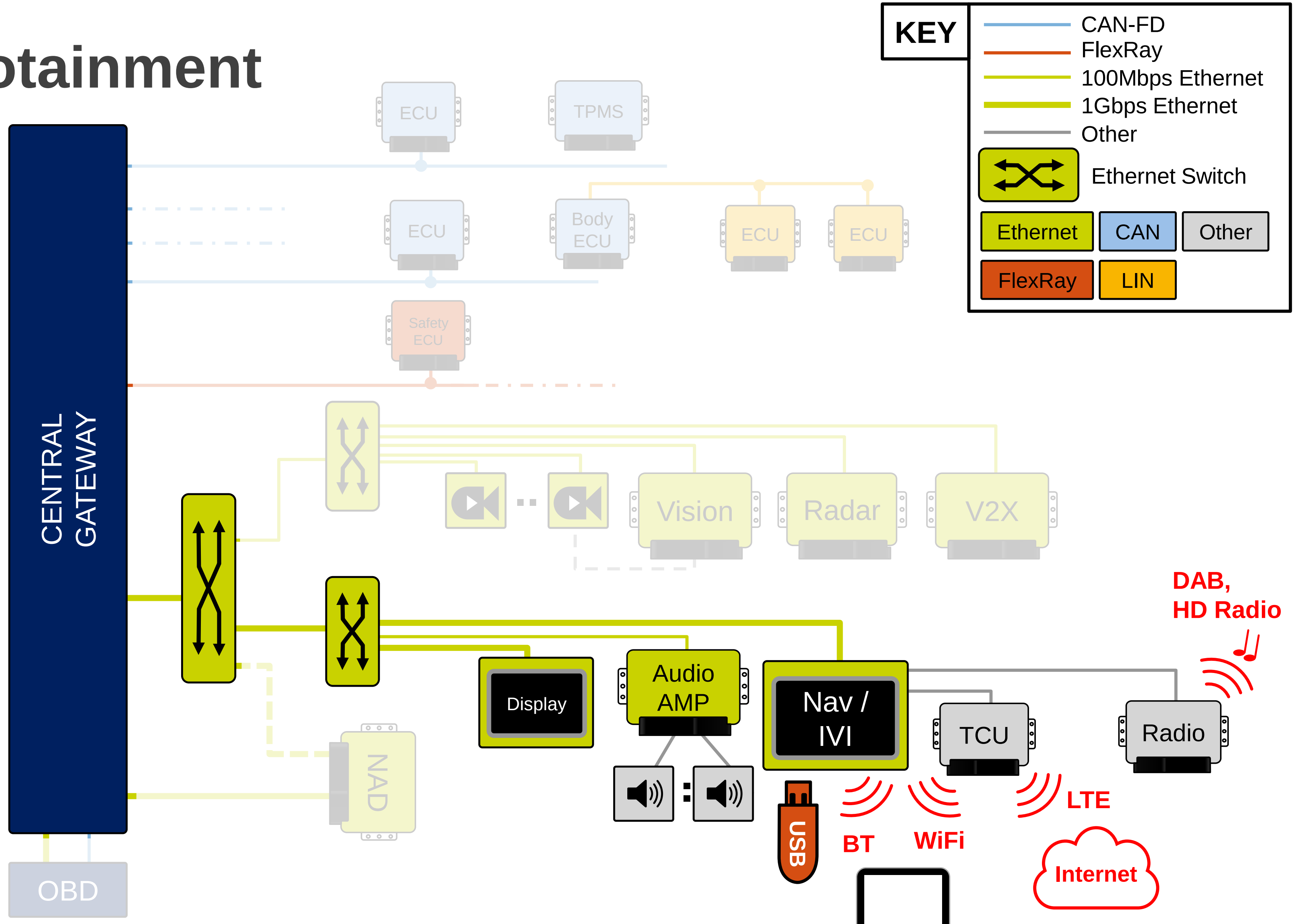
Remote Attacks: Infotainment

- Range of connected interfaces & features

I/F	Cellular (e.g. LTE)
Use Case	Internet, Video & Audio stream
Range	(1) Anywhere (Remote IP address) (2) KMs (Spoof cell tower)

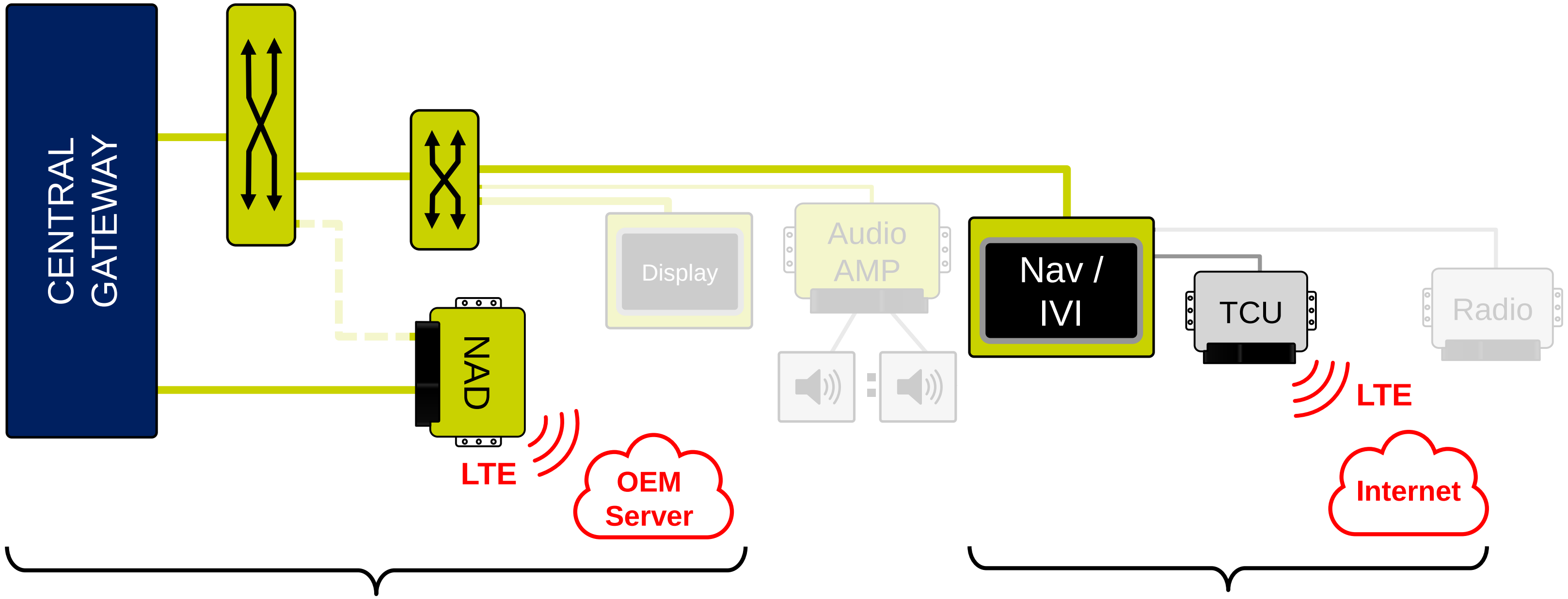
I/F	WiFi
Use Case	Hotspot, Carplay, Android Auto
Range	<30M

I/F	Digital Radio (DAB, HD-Radio)
Use Case	Radio, Digital Service (backdoor)
Range	KMs (DAB transmitter)



Connected Apps Location

- New OEM services being introduced to vehicles
  - Firmware Over-The-Air (FOTA)
  - Big Data
- Requires strong security
- Trusted: Gateway
  - Dedicated NAD
  - OEM software only
- Untrusted: IVI
  - Many 3rd Party SW
  - User Interface/Interaction



OEM Apps Only
(e.g. FOTA, Big Data)

Trusted

3rd party Apps (e.g. Spotify, Pandora)

Untrusted

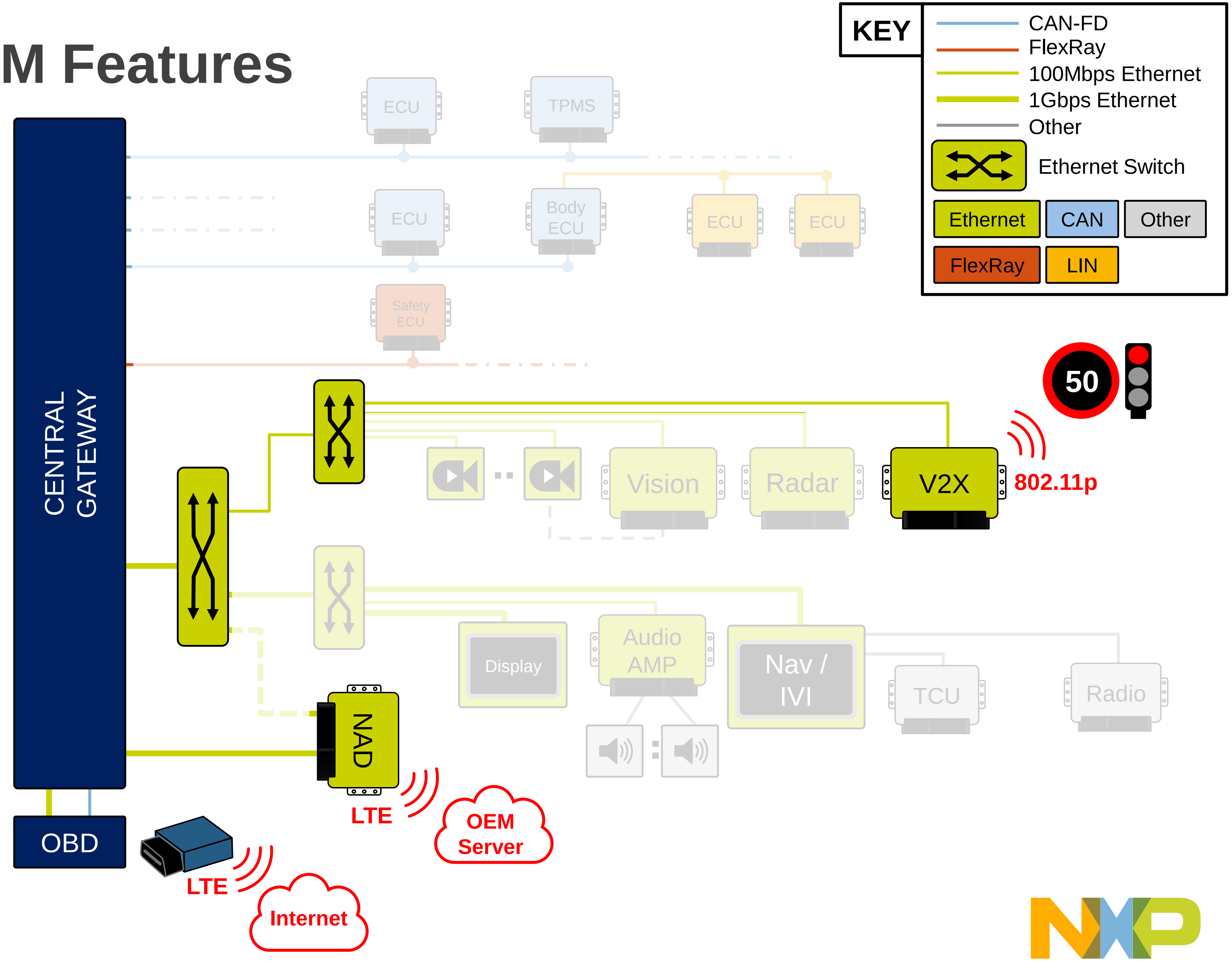
Remote Attacks: OEM Features

- New connected features being introduced by OEMs

I/F	NAD – Cellular (e.g. LTE)
Use Case	Over-the-Air Updates, Big Data
Range	(1) Anywhere (Remote IP address) (2) KMs (Spoof cell tower)

I/F	DSRC – 802.11p
Use Case	Vehicle to Infrastructure, Vehicle to Vehicle
Range	< 2KM

I/F	3rd Party OBD - Cellular (e.g. LTE)
Use Case	Insurance, Fleet, Eco-driving
Range	(1) Anywhere (Remote IP address) (2) KMs (Spoof cell tower)

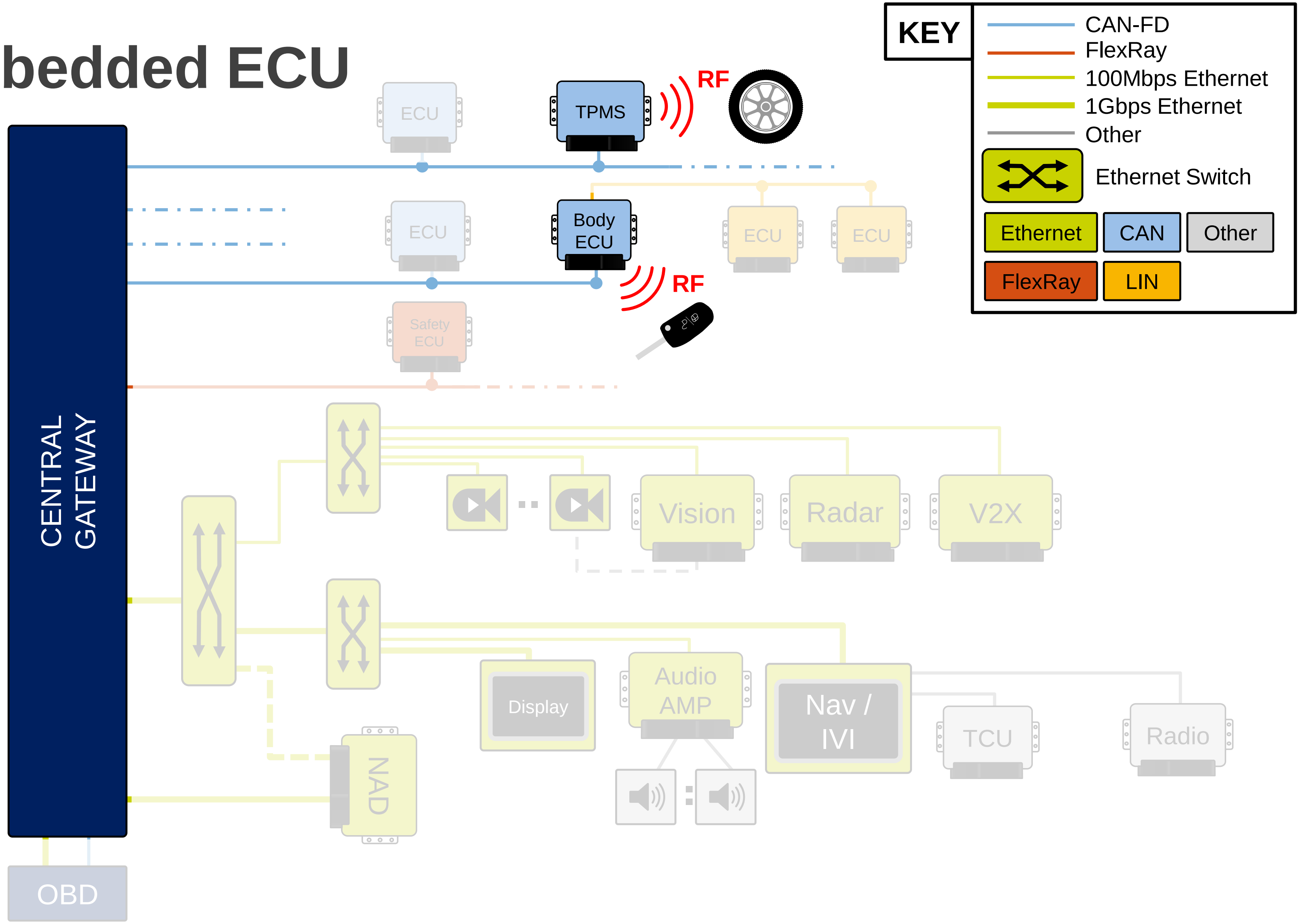


Remote Attacks: Embedded ECU

- Wireless interfaces for highly embedded systems could expose backdoor

I/F	TMPS – Low Freq RF
Use Case	Tire Pressure Monitoring System (TMPS)
Range	<10M

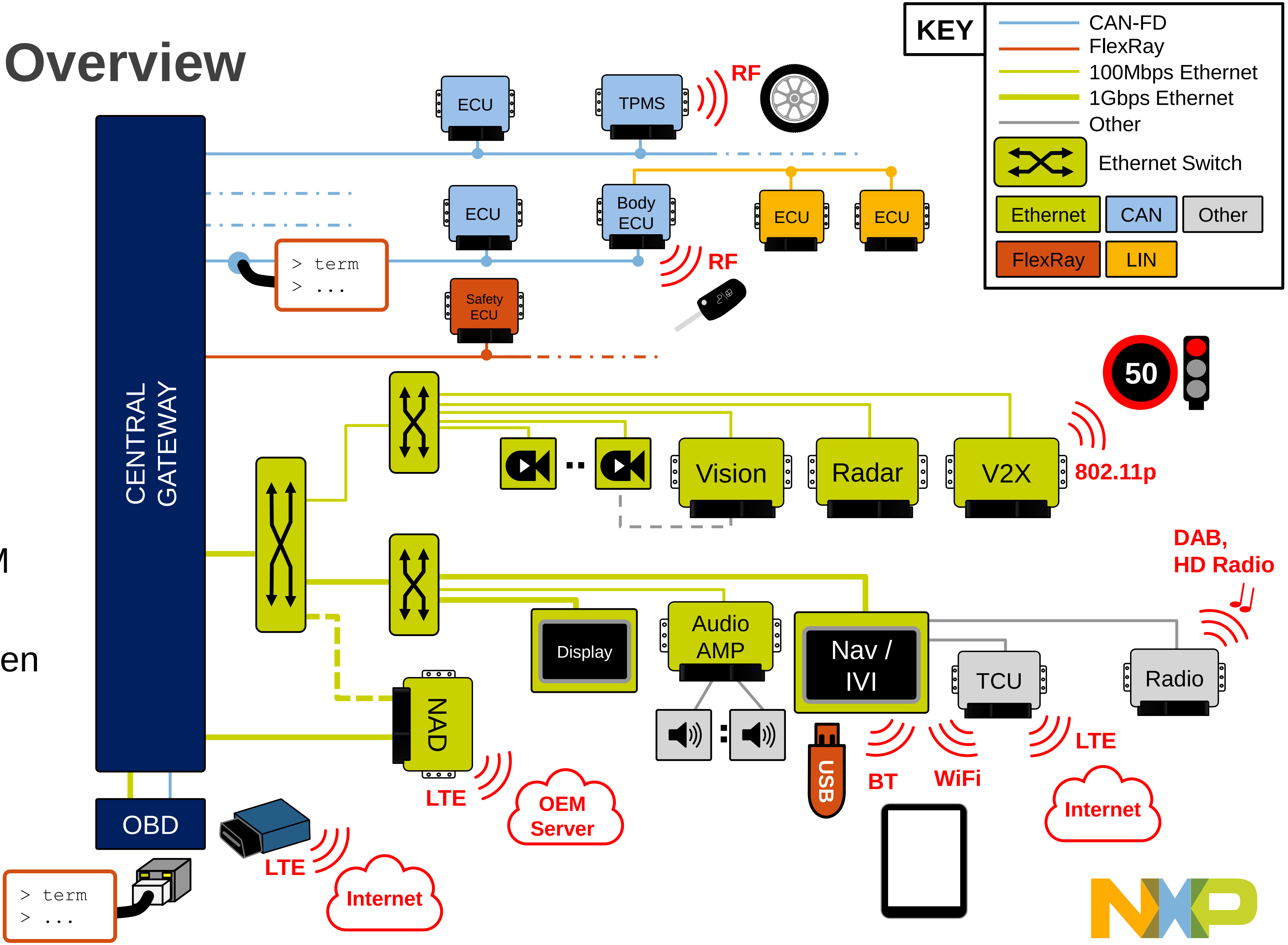
I/F	RKE - RF
Use Case	Remote Keyless Entry
Range	<100M



Remote Attacks: Overview

- Wide Range of Remote Entry Points
  - Range limitations to be considered
  - Analysis vs Direct Manipulation

- Central Gateway
  - Physical Isolation
  - Secure location for OEM connected applications
  - Strong firewalling between sub-networks is key
    - Stateless & Stateful

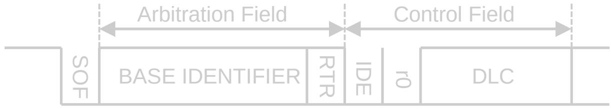


NETWORK PROTOCOLS

The ‘traditional’ Automotive Protocols

CAN Classic

Classic CAN Base Format



Unsecure Payload

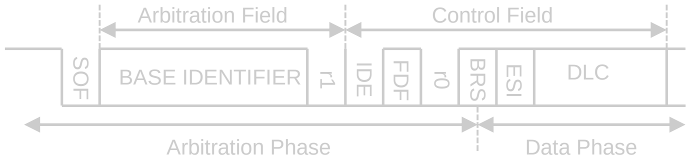
Data

8-bytes

Effective Data Rate @ 500kHz ~ **4MB/s**

CAN-FD

CAN FD Base Format



Secure Payload

Data	CMAC (full/truncated)
8-bytes	16-bytes

Effective Data Rate @ 1.5MHz ~ **4MB/s**

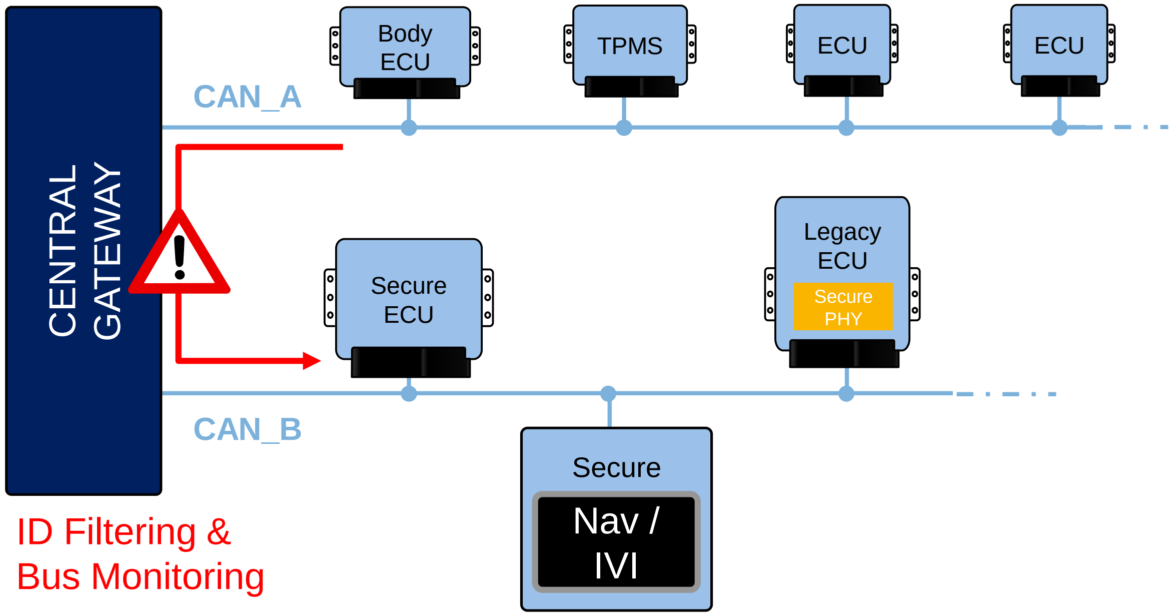
- Traditional Network Protocols
  - LIN, FlexRay, etc…
  - CAN is dominant for vehicle network

Protocol	Max Payload Data Rate	Max Payload Size
CAN (Classic)	1MBit/s	8-bytes
CAN-FD	2MBit/s (runtime) 5MBit/s (diag.)	64-bytes

- CAN has no security requirements in protocol
  - AutoSAR SecOC provides methods for integrity / authentication of PDU in CAN payload
    - Full or Truncated CMAC

Gateway Firewall of CAN traffic

- Static Firewall
  - Static ID filter in GW will provide isolation between buses
- Stateful Firewall
  - Bus snooping monitors characteristic of traffic & detects anomalies
    - Intrusion Detection System (IDS)

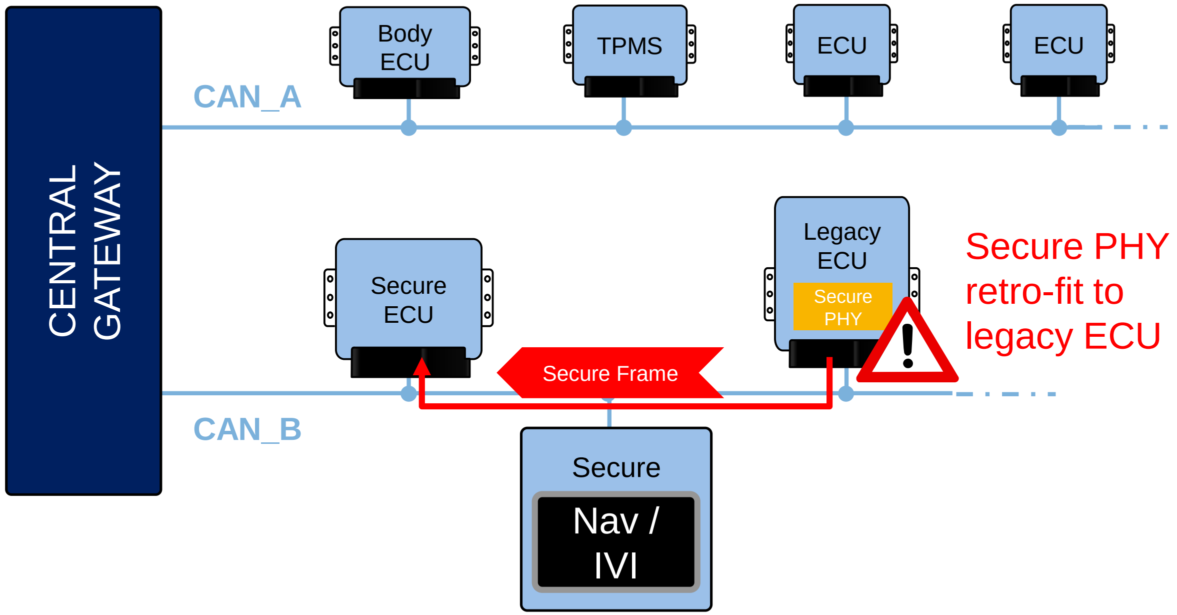


ID Filtering & Bus Monitoring

Challenges of Securing CAN

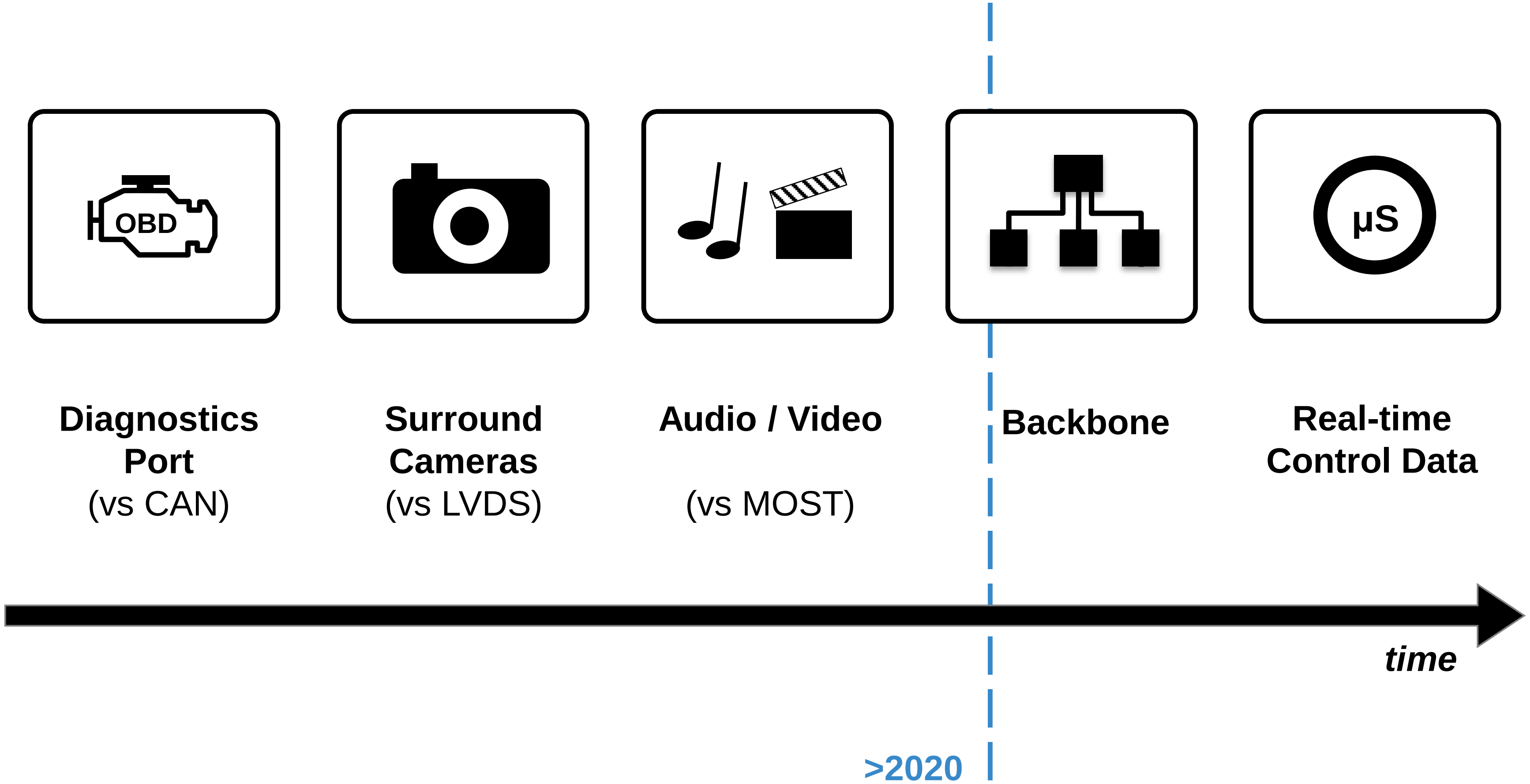
- How to block an invalid message within same CAN bus
  - Secure MCU can terminate in software (e.g. bad CMAC)

- Legacy ECU considerations
  - Many legacy ECU have no security support
  - Desire to avoid complete ECU redesign
  - Add secure functionality into PHY



Secure PHY retro-fit to legacy ECU

Evolution of Ethernet in the Vehicle



Diagnostics Port
(vs CAN)

Surround Cameras
(vs LVDS)

Audio / Video
(vs MOST)

Backbone

Real-time Control Data

time

>2020

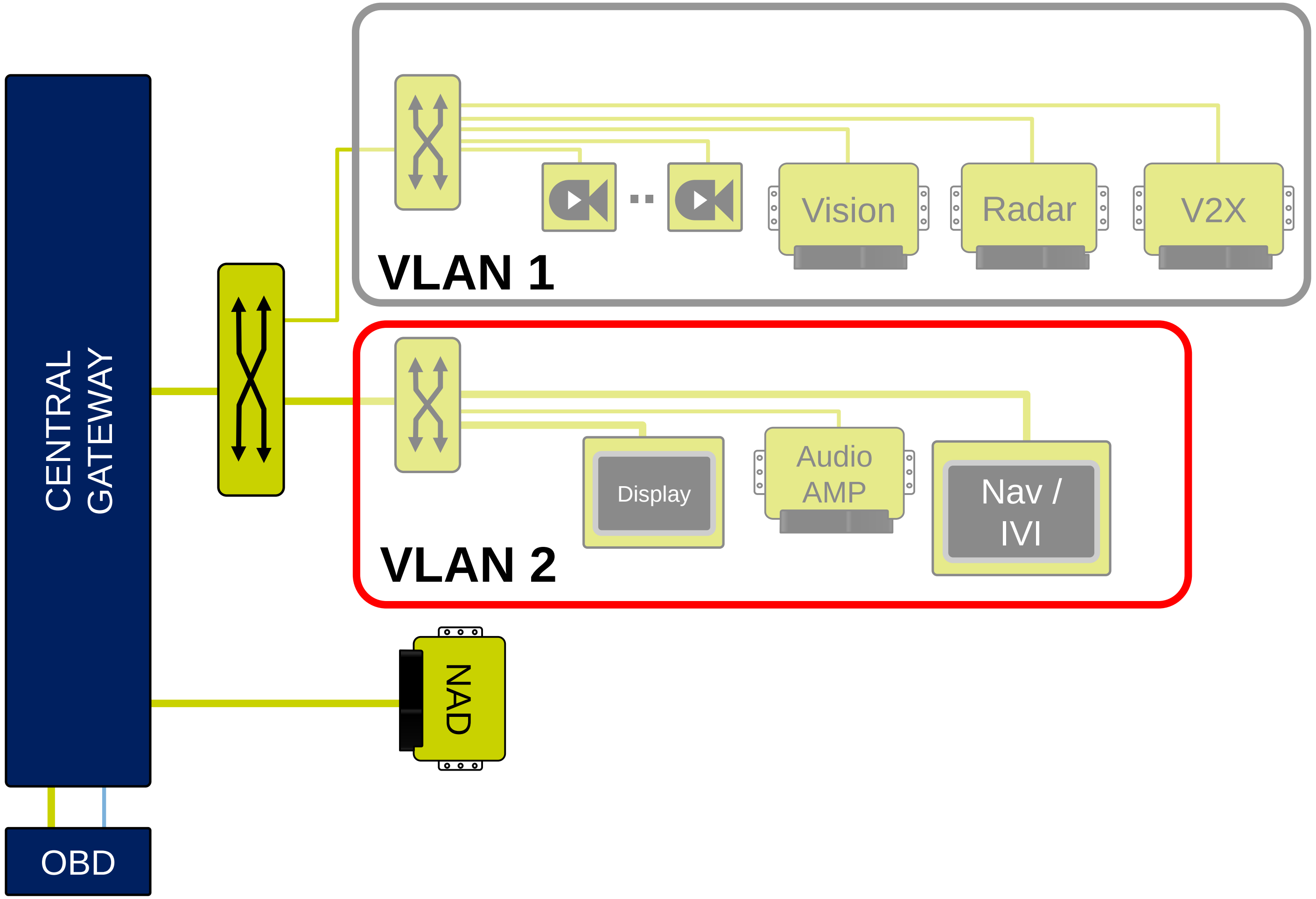
Ethernet in the Vehicle

	Web, Network Control, Address Config, etc...	Diagnostics	Non-Deterministic Control Data	Audio / Video Streaming	Deterministic Control Data
Layer 7	HTTPS	DoIP	SOME/IP	Media Control + Streaming	Data Control + Streaming (e.g. CANopen)
Layer 6					
Layer 5	TLS				
Layer 4	TCP	TCP	UDP / TCP		
Layer 3	IPv4 / 6	IPv4 / 6	IPv4 / 6	IEEE 1722(a)	IEEE 1722(a)
Layer 2	802.3 (MAC / VLAN)	802.3 (MAC / VLAN)	802.3 (MAC / VLAN)	802.3 (MAC / VLAN) 802.1AS (IEEE 1588)	802.3 (MAC / VLAN) 802.1AS (IEEE 1588)
Layer 1	100BASE-TX	100BASE-TX	1TPCE / OABR	1TPCE / OABR	1TPCE / OABR

Ethernet in Automotive Network

- Introduce organisation of Ethernet network with VLANs

- Typically be domain or shared function
  - e.g. ADAS

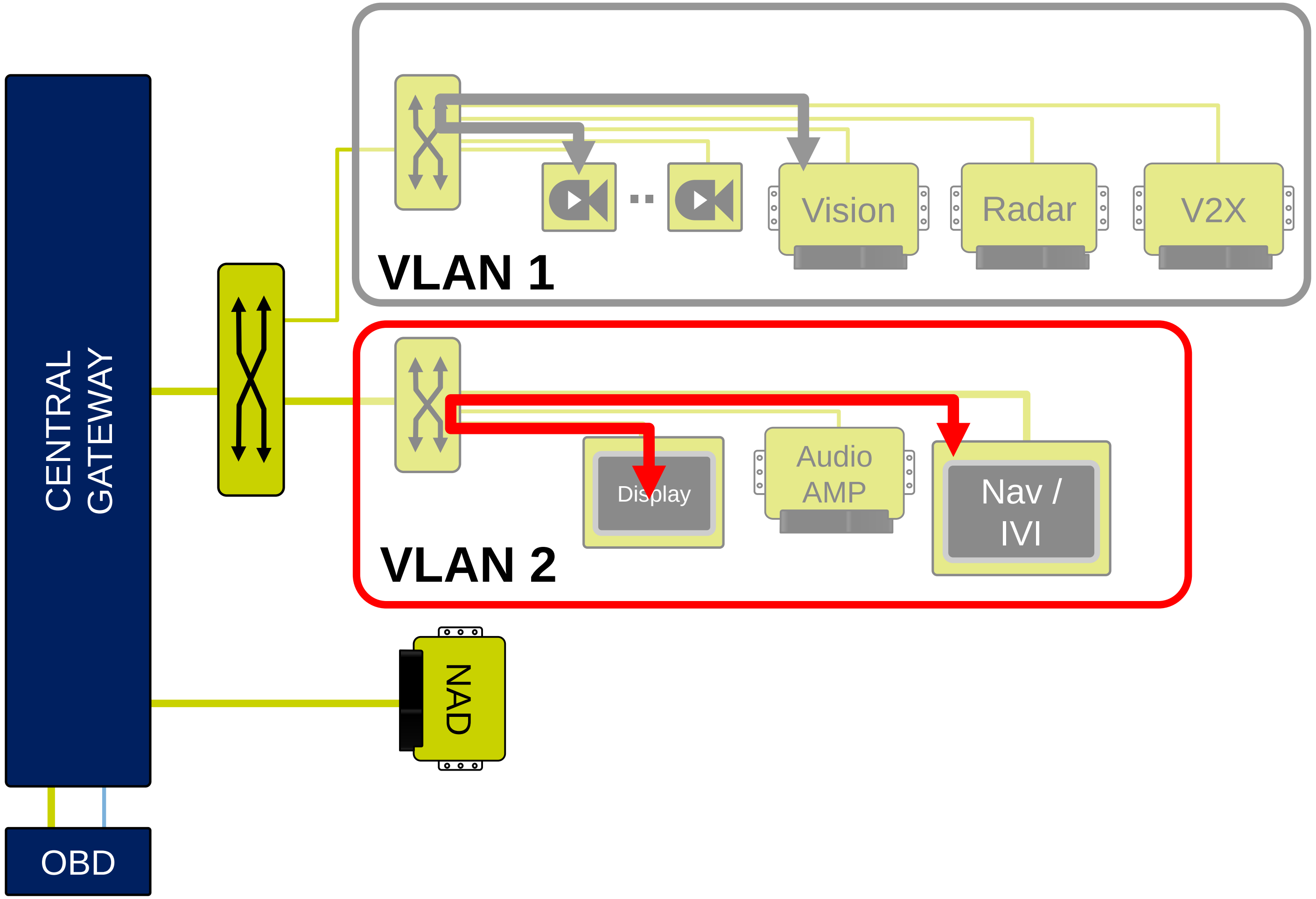


Communication inside VLAN

- Layer 2 switch handles inter-VLAN traffic
  - MAC address resolution

- Policing on switch ports
  - VLAN tag
    - Port assigned (tag on port)
    - Source assigned (tag at source)
  - Directional policing
    - E.g. Uni-directional VLAN for ADAS video to IVI
  - Filtering: MAC + VLAN tag

- Broadcast traffic only within VLAN
  - E.g. ICMP broadcast attack

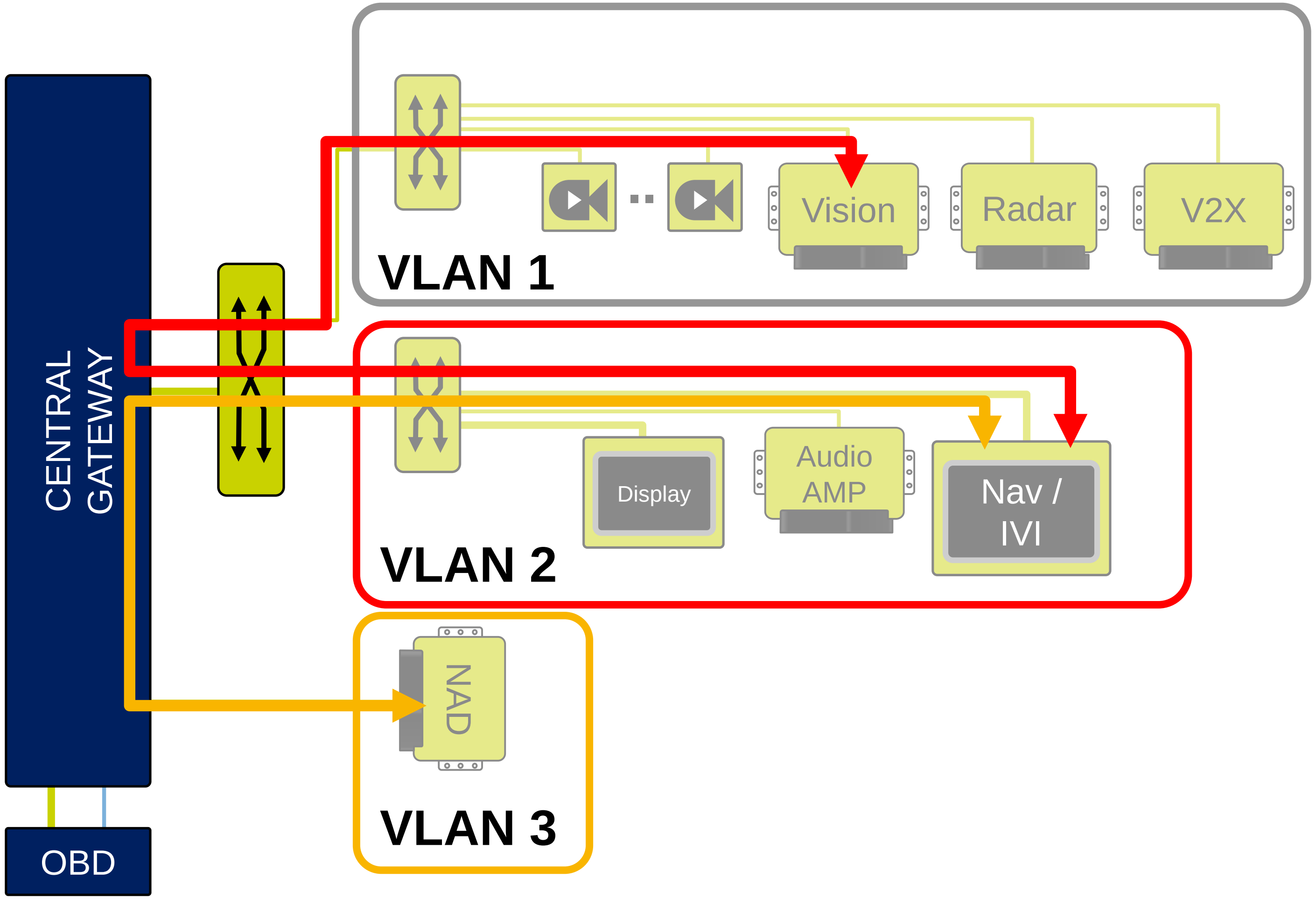


Communication between VLAN – IP Routing Need

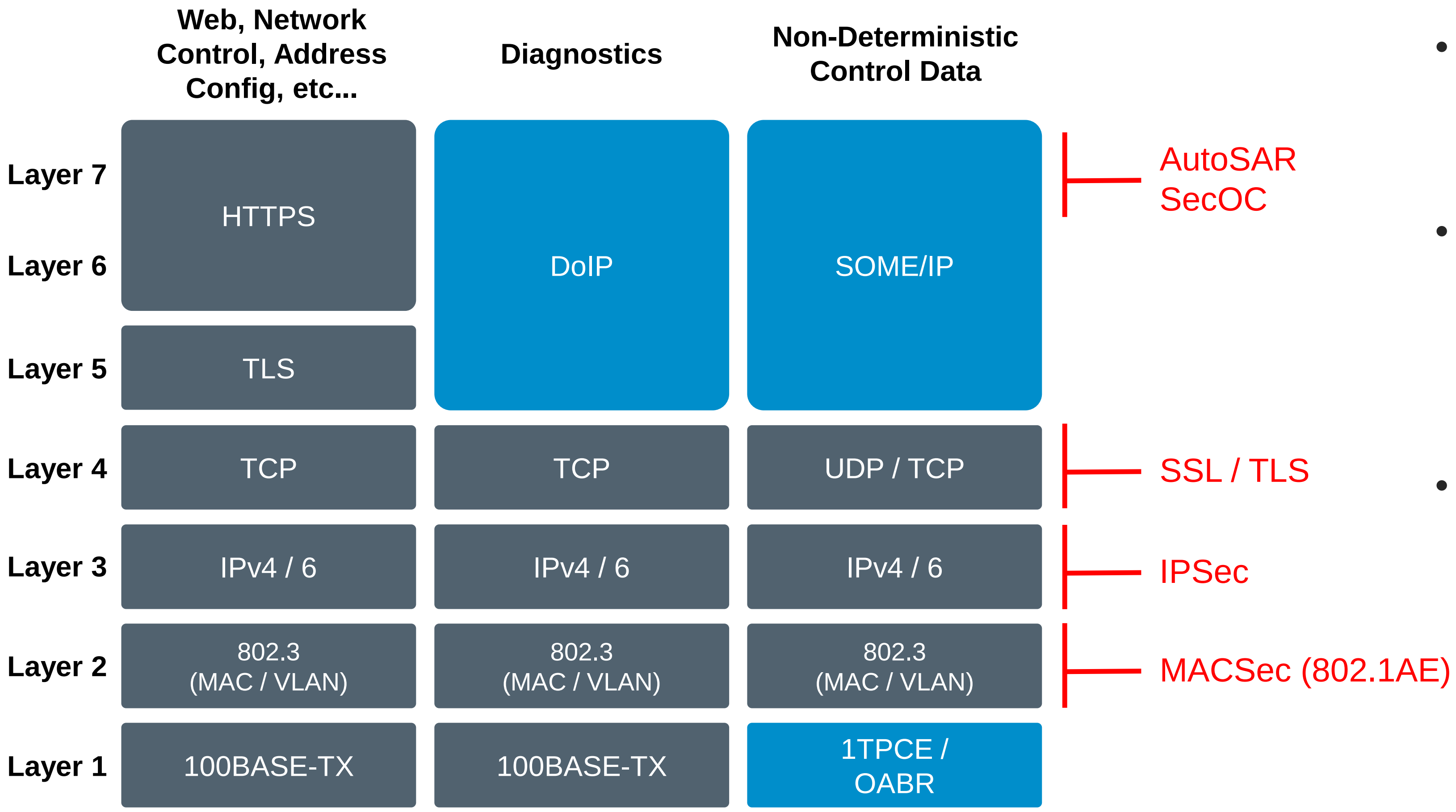
- L2 Switch cannot resolve VLAN-to-VLAN route

- Default Gateway / IP Router
  - Resolve VLAN-to-VLAN route
  - IP address to MAC address resolution

- Inspection / Firewall of traffic
  - Layer 3 (IP addr), Layer 4 (Port#) header inspection
  - Stateful Inspection



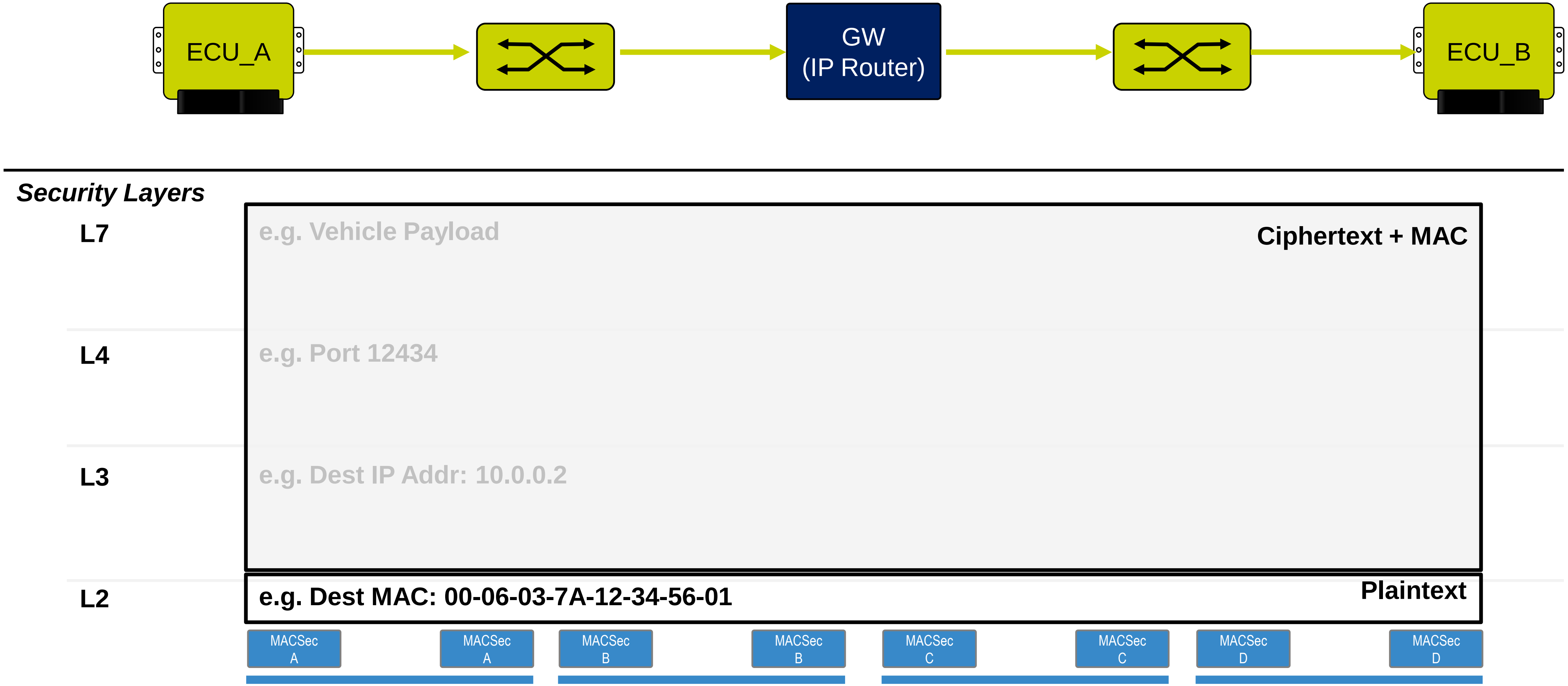
Authentication / Encryption over Ethernet



	Web, Network Control, Address Config, etc...	Diagnostics	Non-Deterministic Control Data	
Layer 7	HTTPS	DoIP	SOME/IP	AutoSAR SecOC
Layer 6				
Layer 5	TLS			
Layer 4	TCP	TCP	UDP / TCP	SSL / TLS
Layer 3	IPv4 / 6	IPv4 / 6	IPv4 / 6	IPSec
Layer 2	802.3 (MAC / VLAN)	802.3 (MAC / VLAN)	802.3 (MAC / VLAN)	MACSec (802.1AE)
Layer 1	100BASE-TX	100BASE-TX	1TPCE / OABR	

- Several possibilities for security over Ethernet
- External traffic
  - e.g. to Internet/OEM
  - Internet stds: TLS
- Internal traffic
  - Need: Auth + Integrity
  - Opt: Encryption
  - No industry consensus on which layer to protect
  - Balance cost vs protection

MACSec – 802.1AE



ECU_A

GW
(IP Router)

ECU_B

Security Layers

L7 e.g. Vehicle Payload

Ciphertext + MAC

L4 e.g. Port 12434

L3 e.g. Dest IP Addr: 10.0.0.2

L2 **e.g. Dest MAC: 00-06-03-7A-12-34-56-01**

Plaintext

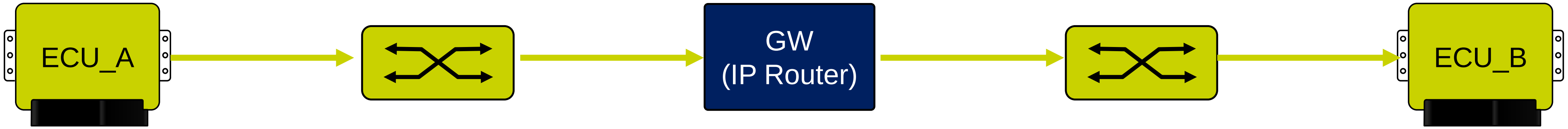
MACSec A — MACSec A

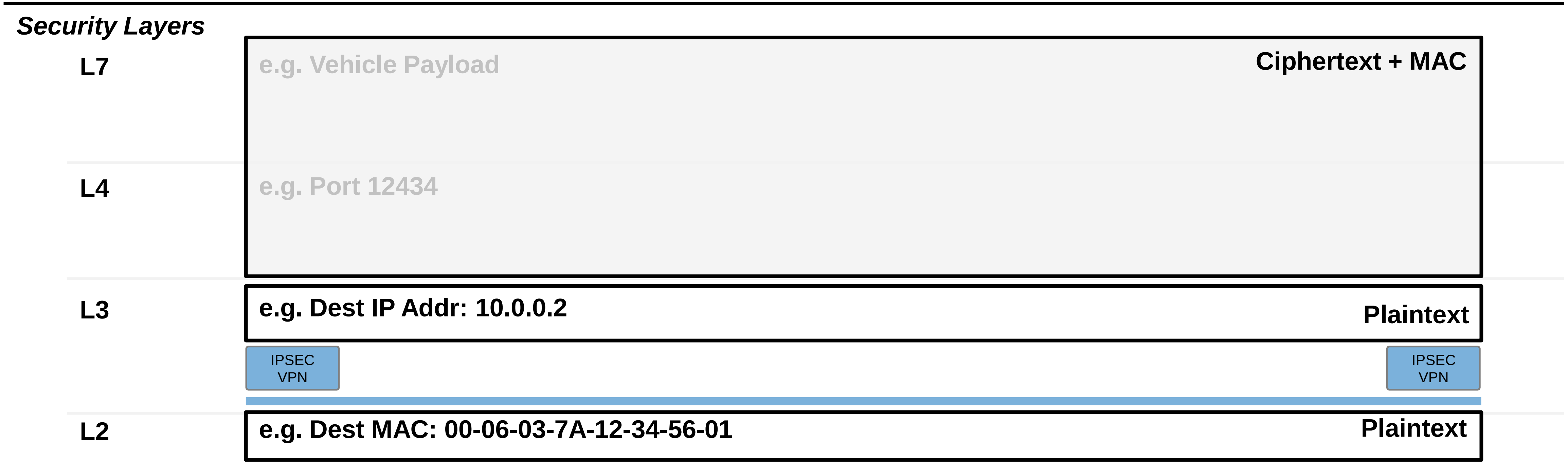
MACSec B — MACSec B

MACSec C — MACSec C

MACSec D — MACSec D

IPSec VPN





Security Layers

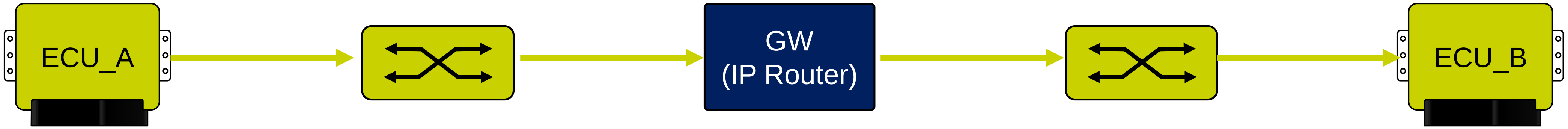
L7 e.g. Vehicle Payload **Ciphertext + MAC**

L4 e.g. Port 12434

L3 **e.g. Dest IP Addr: 10.0.0.2** **Plaintext**

L2 **e.g. Dest MAC: 00-06-03-7A-12-34-56-01** **Plaintext**

Transport Layer Security (TLS)



Security Layers

L7 — e.g. Vehicle Payload — **Ciphertext + MAC**

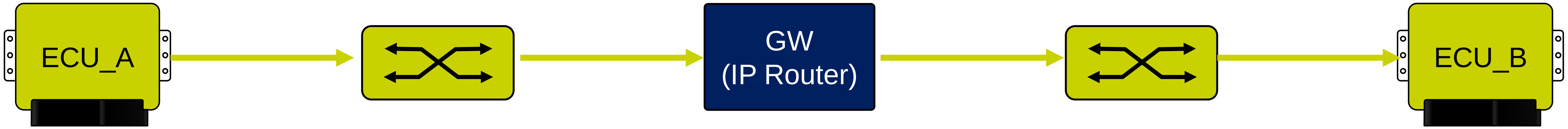
L4 — **e.g. Port 12434** — **Plaintext**

TLS TLS

L3 — **e.g. Dest IP Addr: 10.0.0.2** — **Plaintext**

L2 — **e.g. Dest MAC: 00-06-03-7A-12-34-56-01**

Application Layer (e.g. AutoSAR SecOC)



Security Layers

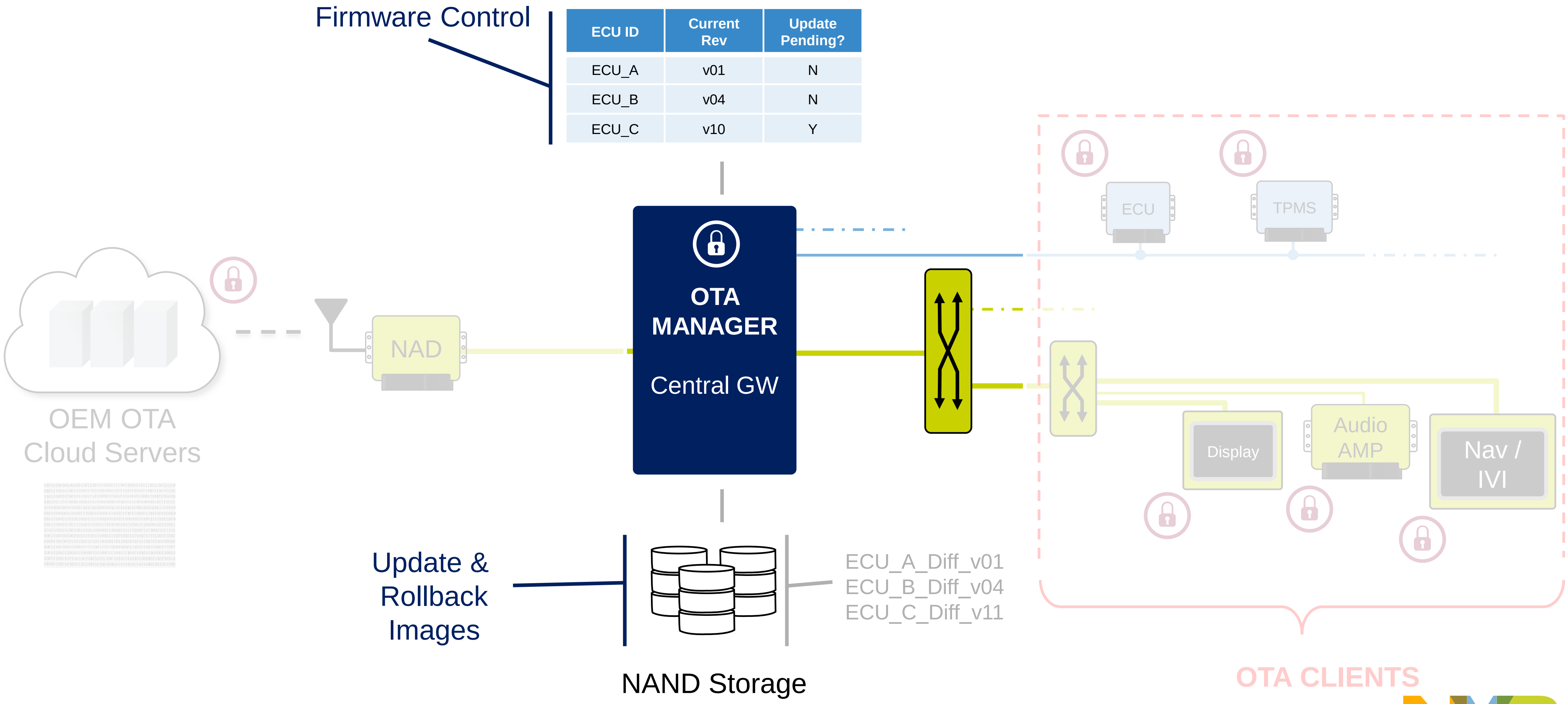
L7	e.g. Vehicle Payload	**Plaintext + MAC**
	SecOC	SecOC
L4	**e.g. Port 12434**	**Plaintext**
L3	**e.g. Dest IP Addr: 10.0.0.2**	
L2	**e.g. Dest MAC: 00-06-03-7A-12-34-56-01**	

FOTA

Firmware Over-the-Air (FOTA)

- Static software is a security vulnerability
  - Lifespan of vehicle >10 years
- Examples in recent years of safety issues resulting from SW bugs.
  - How long before security issues?
- Strong need to remotely update & patch application software and security weaknesses
  - Controlled by a trusted entity in vehicle

Firmware Over-the-Air (FOTA) Architecture

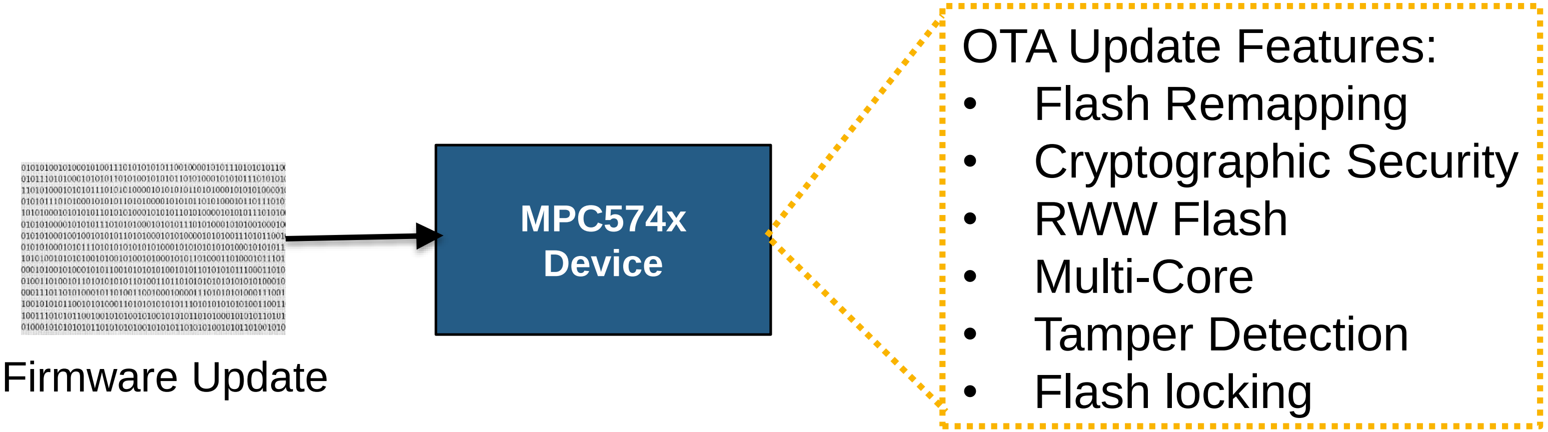


ECU ID	Current Rev	Update Pending?
ECU_A	v01	N
ECU_B	v04	N
ECU_C	v10	Y

ECU_A_Diff_v01
ECU_B_Diff_v04
ECU_C_Diff_v11

OTA Client (ECU) Features

The MPC574x family is OTA update enabled and contains hardware features to help with each stage of the OTA process!



OTA Update Features:

- Flash Remapping
- Cryptographic Security
- RWW Flash
- Multi-Core
- Tamper Detection
- Flash locking

OTA Benefits for OEM:

- Save money on recalls
- Ability to immediately patch critical bugs
- Allow addition of new features, post-purchase

OEM Demands:

- Minimal affect on drivers (e.g. no vehicle down time during update)
- no risk of failed update leaving car unusable.

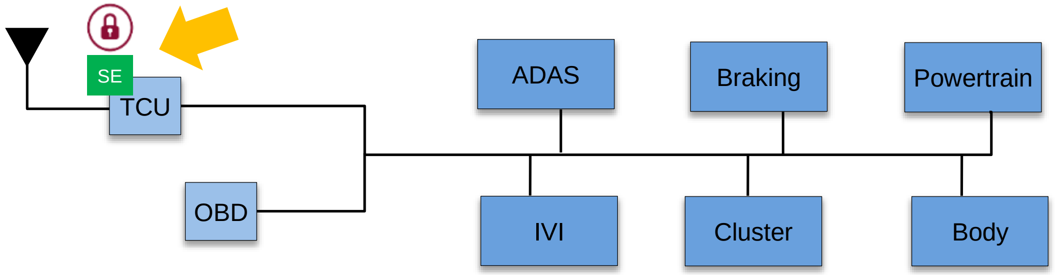
The MPC574x family is designed to support **secure** OTA updates which can occur seamlessly as a background task with **no vehicle downtime.**

LAYERED SECURITY MODEL

4 LAYERS TO SECURING A CAR

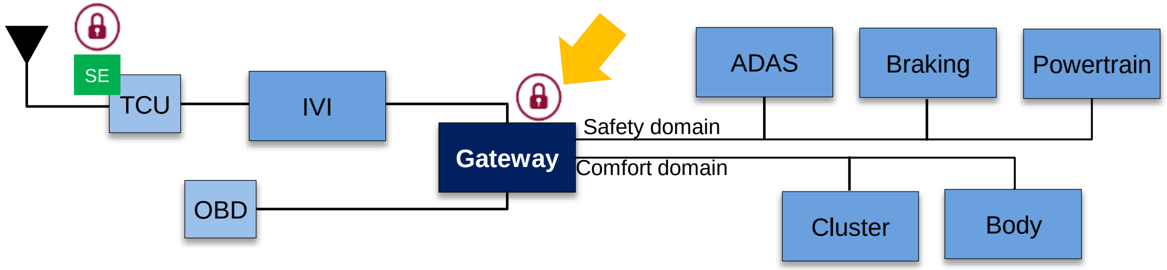
Layer 1: Secure Interface

Secure M2M authentication, secure key storage



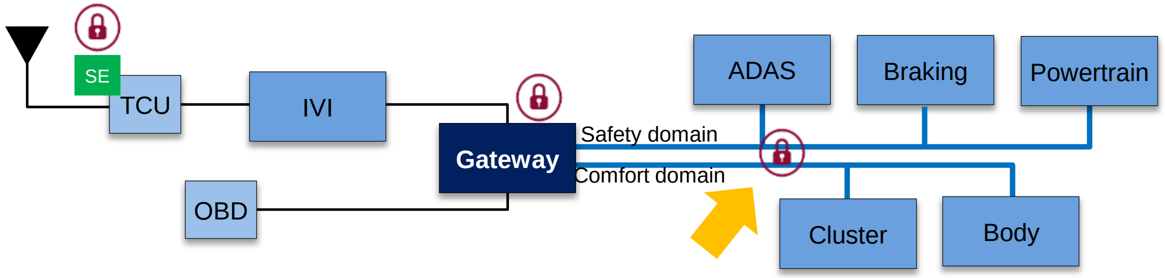
Layer 2: Secure Gateway

Domain isolation, firewall/filter, centralized intrusion detection (IDS)



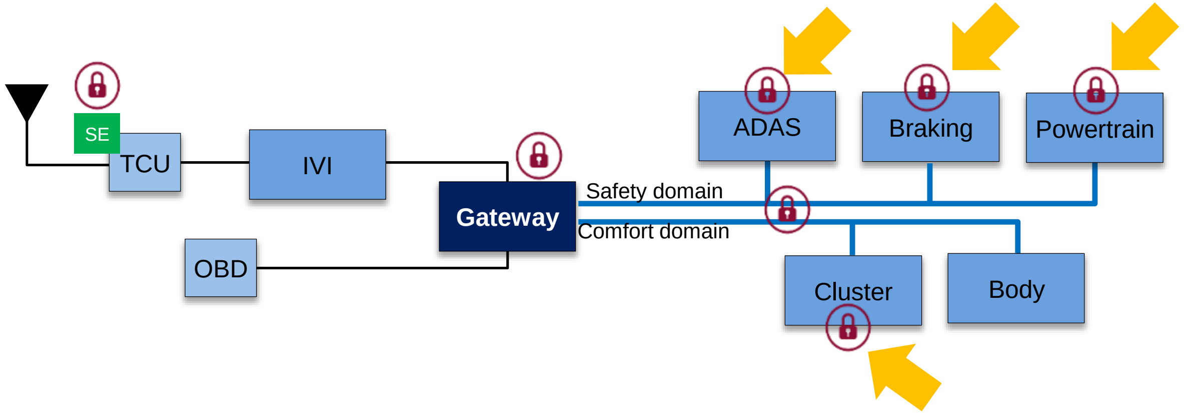
Layer 3: Secure Network

Message authentication, CAN ID killer, distributed intrusion detection (IDS)

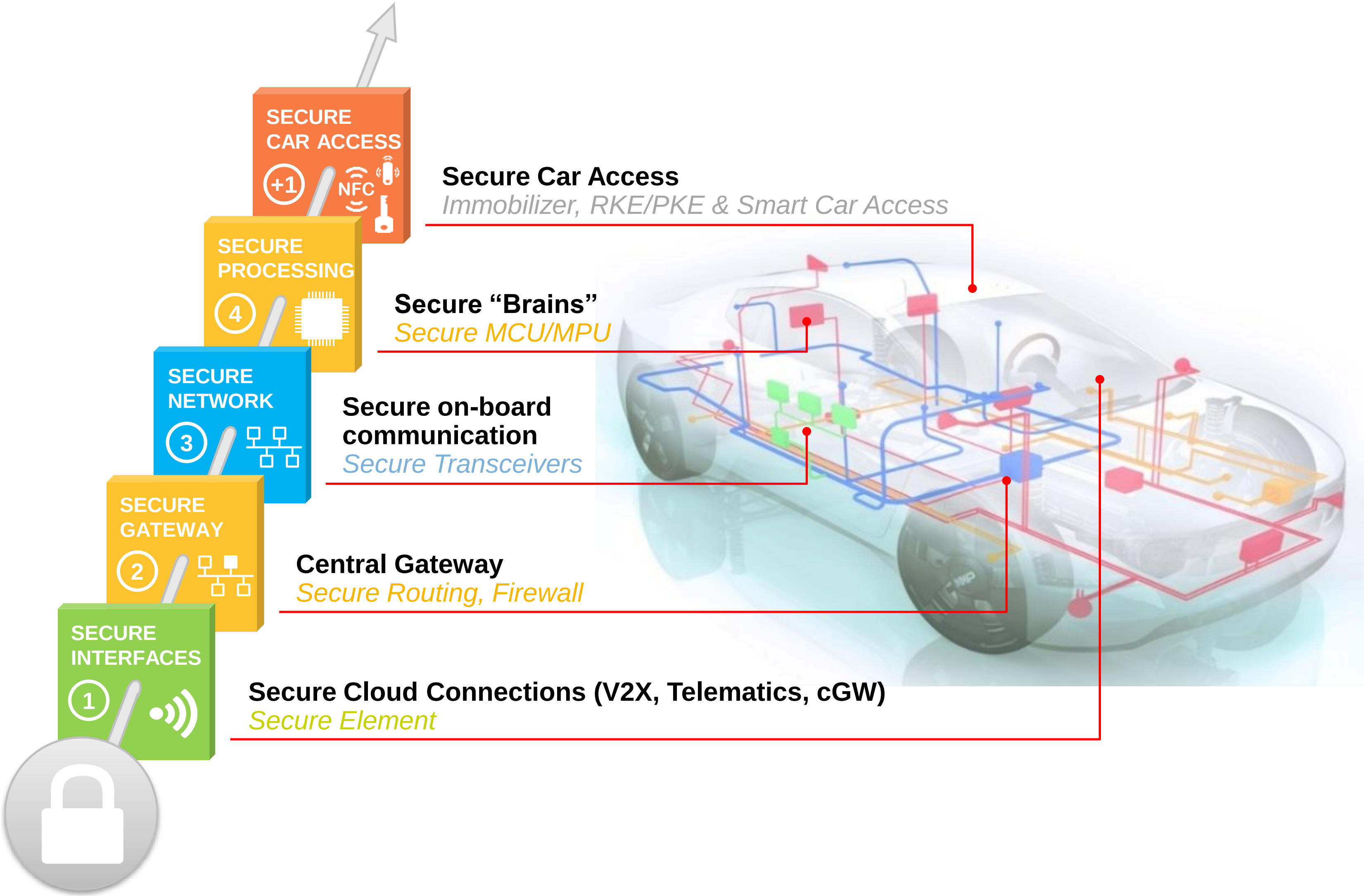


Layer 4: Secure Processing

Secure boot, run time integrity, OTA updates



NXP AUTOMOTIVE SECURITY (4+1 SOLUTION)



Secure Car Access
Immobilizer, RKE/PKE & Smart Car Access

Secure "Brains"
Secure MCU/MPU

Secure on-board communication
Secure Transceivers

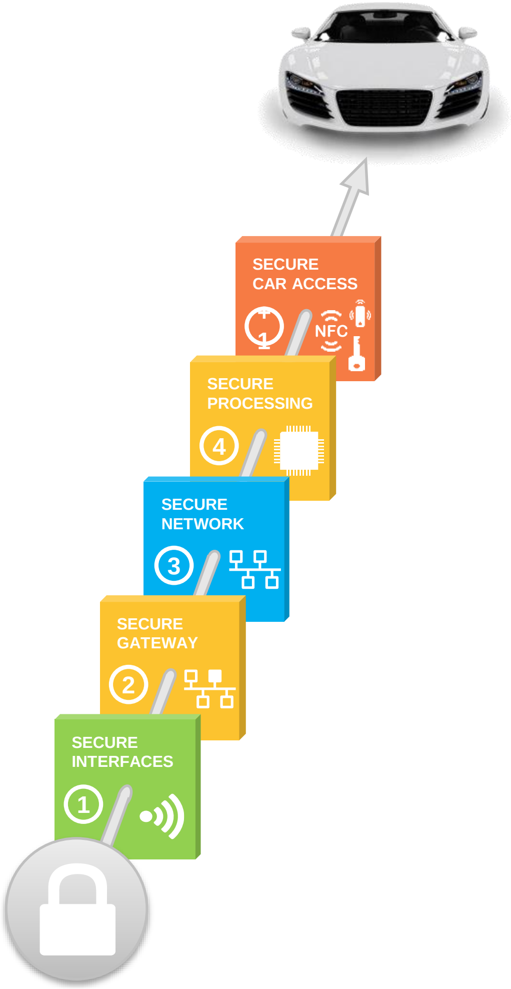
Central Gateway
Secure Routing, Firewall

Secure Cloud Connections (V2X, Telematics, cGW)
Secure Element

- **NXP #1 in Auto HW Security**
- **4-Layer Cyber Security Solution**
- **Plus 'Best In Class' Car Access Systems**
- **Recognized Thought & Innovation Leader**
- **> 900 security patent families, ~ 200 specific to Automotive**
- **Partner of Choice for OEMS, T1s & Industry Alliances**

MORE DETAILS IN THE FOLLOWING SESSIONS

Topic	Session	Type	Timeslot
4 Layers of Automotive Security for Connected Cars	FTF-AUT-N1811	Lecture	Mon 2:00 PM
Future RF Technologies - **UltraWideBand** for Car Access	FTF-INS-N1777	Lecture and demo	Mon 4:15 PM
Secure Car Access and Remote Management	FTF-AUT-N1776	Lecture and demo	Tue 12:00 PM
Trends in Vehicle Architectures: **Central Gateway**	FTF-AUT-N1813	Lecture	Tue 11:00 AM
Recent Advances in **Secure MCU** Security Offerings	FTF-AUT-N1812	Lecture	Mon 3:15 PM
Maximizing Security using the **Secure MCU** Features	FTF-AUT-N1810	Lunch & Learn	Tue 1:15 PM
Creating Secure Networks for **V2X Communications**	FTF-AUT-N1764	Lecture	Tue 2:30 PM
Techniques for **Crypto Key Management** Using i.MX Application Processors	FTF-DES-N1894	Lecture	Tue 3:30 PM
NFC for Connected Cars	FTF-AUT-N1781	Lecture	Tue 4:45 PM
CAN Security (L3)	FTF-AUT-N1815	Lecture	Tue 5:45 PM
Automotive Gateway Security Made Easy	FTF-AUT-N1792	Hands-on workshop	Wed 2:30 PM
Security vs Functional Safety - Complementary or Contradictory?	FTF-AUT-N1814	Lecture	Wed 4:45 PM
Secure CAN Networks	FTF-AUT-N1783	Hands-on workshop	Wed 4:45 PM
Automotive Cyber Security: A Tough Issue Needing Robust Solutions	FTF-AUT-N1763	Panel discussion	Wed 4:45 PM



SECURE CONNECTIONS
FOR A SMARTER WORLD

ATTRIBUTION STATEMENT

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