Capgemini engineering

# OPTIMIZE VEHICLE SERVICE WITH EDGE-BASED TELEMATICS

Scheduling vehicle maintenance using intelligent sensors lowers cost and improves performance

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# Executive summary

The automotive industry typically follows the practice of periodic maintenance based on a specific time or distance traveled defined by the carmaker. During routine inspections, the service center maintenance team visually examines certain critical parts. Some parts may need to be replaced to avoid a future breakdown. The challenge with periodic maintenance is that it can lead to higher service costs for certain parts. While the parts in the car might be technically functional, some are replaced to improve performance. However, only one or two components typically require replacement to avoid a breakdown.

A better, more proactive way to manage car maintenance relies on the embedded intelligence in the car. Understanding the working condition of parts requires collecting data at regular intervals from sensors, filtering out the irrelevant data in the car network, and sending the remaining data to the carmaker's service center. There, the maintenance team can predict a failure in advance and provide quick service to meet the terms of the owner's service level agreement (SLA).

Today, the auto industry is undergoing a digital transformation, where cars have cellular connectivity (i.e., 3G, 4G, 5G, and Wi-Fi) that facilitates sharing telematics data with the automaker's service provider over the internet for real-time monitoring and rapid customer service. The shared data from the car includes speed, idling time, sudden acceleration and braking, fuel consumption, miles per gallon or kilometers per liter, coolant temperature, level of coolant, maximum speed, level of engine oil, level of fuel, and distance traveled. Analyzing the data, the service center can take specific actions, such as scheduling an emergency or routine service based on the data collected. The reason for collecting data during run-time/real-time is to avoid the higher service cost of a pre-defined schedule.

Suppose a specific part needs to be replaced immediately but is not scheduled to be replaced. In that case, it could result in a breakdown if the part is not replaced, and the cost of replacement would be significantly higher for the car owner. The whole idea of real-time monitoring in the connected car is to continuously monitor car health using a car data monitoring system (CDMS) and predict a component failure before it happens.

The data collected from the car can be used by family members to create personalized travel plans for a vacation, increase driving enjoyment, ensure safety and reliability, and reduce breakdown costs. The car collects data from sensors connected to the Controller Area Network (CAN) bus. The data is sent to the service center for analysis, and, if necessary, the owner takes the car in to replace one or more parts and improve performance.

The critical challenge of real-time data monitoring of a car is data management. A car can generate millions of measurements every minute from multiple sensors, where data generation can reach 25 GB per hour.[1] Analyzing this real-time data requires computing at the edge because 25 GB of data cannot be transmitted over a wireless network to the carmaker's cloud datacenter for analysis since the mobile network operator (MNO) has limited bandwidth on 3G and 4G cellular networks.

1. Simon Wright, "Autonomous cars generate more than 300 TB of data per year," Jul 2, 2021, Tuxera, https://www.tuxera.com/blog/autonomous-cars-300-tb-of-data-per-year/

Data collection, processing, and analytics must be done at the edge of the car network and only transmit the critical information to the carmaker's cloud datacenter. After processing, filtering, and analyzing the data at the car network's edge, the critical data is transmitted securely to the automaker's datacenter to avoid tampering by hackers. In addition, always-on connectivity is required to avoid interruption during data transfer. (See Figure 1.)

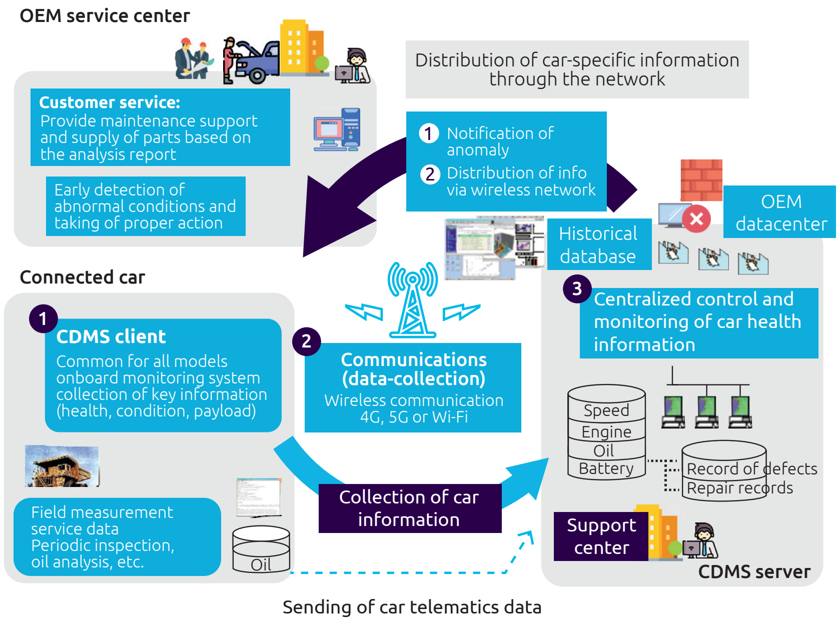



Figure 1: The sequence of the maintenance process flow

*Source: Capgemini Engineering*

# Overview

Installing car data monitoring systems is an emerging trend in the connected car ecosystem. Cellular-based connectivity in the car helps monitor car parts for wear and tear in drive mode based on sensor data. The carmaker's service center uses the information to predict upcoming maintenance needs, which helps prevent drivers from being stuck on the side of the road or paying colossal repair costs. Establishing an "always-on connectivity" communications link securely with the carmaker's service center allows critical data to enrich car performance in the long run and avoid major breakdowns.

The purpose of CDMS is to:

- Lower the cost of maintaining, repairing, and inspecting the car ecosystem
- Reduce downtime due to scheduled or forced maintenance
- Increase performance and usage
- Increase reliability, availability, and maintainability
- Provide intelligence by evaluating the relevant data and how it can be effectively used to achieve performance goals

To realize the promise of CDMS requires a system to diagnose the car's condition at the carmaker's service center and deal with the issues that need attention relating to how the car is driven and its estimated lifetime. (See Figure 2.) Car telematics data is collected, processed, and analyzed to predict possible failures, and the data can be used for maintenance work. If an error is found, action can be taken to delay or prevent failure. The car will be more reliable because of this monitoring.

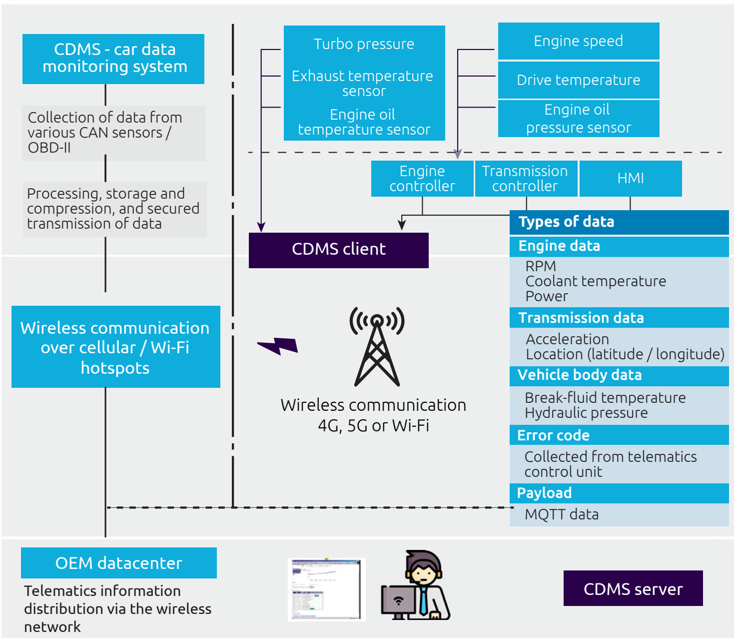



Figure 2: The car telematics system architecture

*Source: Capgemini Engineering*

This white paper focuses on advanced telematics features using CDMS, which not only address monitoring, analysis, and management of data generated by various sensors but include secure data transmission of telematics data from the car to the carmaker's datacenter, data compression techniques for network bandwidth savings, and seamless connectivity between mobile and wireless networks such as 3G, 4G, 5G, and Wi-Fi.

# Industry landscape

Car telematics is an emerging trend that enables the car to diagnose its faults before they become critical. It predicts the life of vital components to ensure operational performance, thereby reducing unnecessary and costly maintenance. The CDMS can measure different parameters and provide support for proactive analysis to display the status of the car components by evaluating the car's current health condition and taking care of driver safety. (See Figure 3.)

There are five elements for handling telematics data to keep the driver safe.

- Data collection and processing
- Data monitoring and management
- Data traffic optimization (compression)
- Secure data transmission
- Seamless connectivity

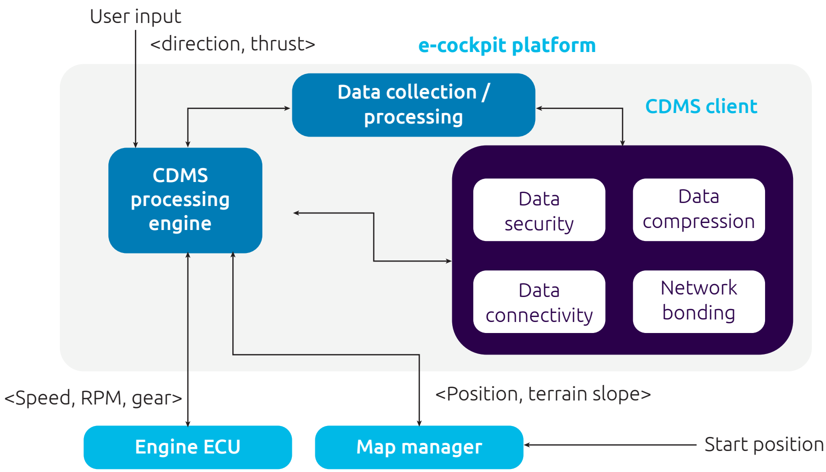



Figure 3: CDMS client software architecture and modules

*Source: Capgemini Engineering*

**1. Data collection and processing**

The CDMS analyzes sensor data such as speed, RPMs, fuel level and efficiency, fuel theft monitoring, fleet tracking, geofencing for safety, remote diagnostics, and pay-as-you-drive insurance data to predict possible issues and warn drivers beforehand. For example, a CDMS application running on an e-cockpit embedded platform can provide driver-specific recommendations based on historical repair and driver behavior data that could impact the longevity of mechanical parts.

The CDMS method for the OEM service center remotely monitoring car performance can predict faults by detecting if and approximately when a part failure will occur. The proactive method is better than the reactive method of maintaining the car's performance. For example, disc-brake shoes can be replaced earlier than scheduled because the sensors detect regular hard braking by the driver. The ideal service date is somewhere between identifying the potential failure (P) and the functional failure (F). (See Figure 4.).

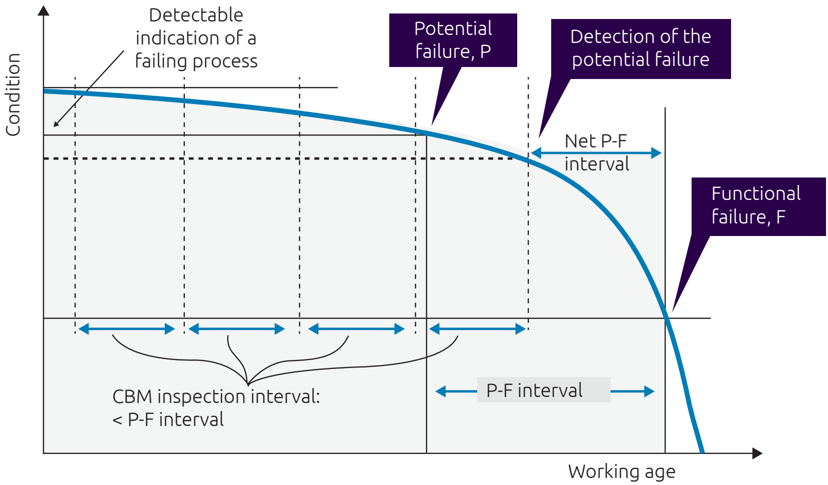
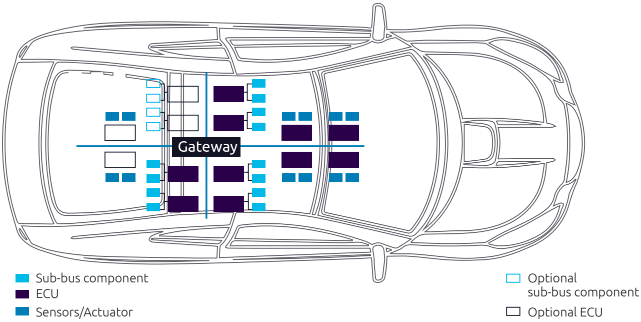



**Figure 4: Fault detection mechanism**

*Source: IEEE*

The CDMS can generate insights into car efficiency, specifically, which critical parts will fail earlier than expected. As a result, the OEM can order the required spare parts well in advance to ensure quick service to meet the owner's expectations. Critical data can be collected from different ECUs in the interconnected car network based on the Automotive Open System Architecture (AUTOSAR) standards. (See Figure 5.)

The sensors in the car gather data on how the driver drives, accelerates, breaks, and stops. Then, the CDMS analyzes and shares a diagnostic report with the owner that includes possible imminent parts failures based on the data.




**AUTOSAR**
Open and standardized layered software architecture for automative ECUs

- The consortium was founded in 2003. Members include BMW, Bosch, Continental, Daimler, Siemens, VW, Ford, Groupe PSA, Toyota, General Motors, and other manufacturers, suppliers, and software and tool developers.

- A modern car may have more than 100 ECUs, with each of them containing thousands of functions that must often be rewritten from scratch when hardware (e.g., processor type) is changed
  - Impact of QoS parameters like delay, jitter, throughput, and packet loss for real-time traffic flow
  - Analysis of QoS measurement mechanism to monitor the status of the QoS parameters during the actual data flow
  - Compare the defined QoS parameters with the actual QoS based on the type of service
- Key features:
  - Strong interaction with hardware (sensors and actuators)
  - Connection to vehicle networks like CAN
  - Microcontrollers (typically 16 or 32 bit) with limited resources of computing power and memory (conmpared with enterprise solution
  - Real-time operating system (RTOS)
  - Program execution from internal or external flash memory
  - Adaptive AUTOSAR
    - Observe the environment using a multitude of sensors
    - Use this data to make many driving decisions, most of which are critical for safety and sometimes to saving lifeWW
- Complaint with all international automative standards such as ISO 5767, ISO 4229, ISO 27145

**Figure 5: Generation of car data from different ECUs**

*Source: Capgemini Engineering*

Using CDMS, car service centers can analyze driver behavior data with remote diagnostics. As a result, the staff maintaining the car can learn how it has been used and how to manage routine maintenance. Also, insurance providers can access the owner's driving habits based on the data and change the policy rates based on driver behavior. Insurance companies use car data to set premiums and provide certain benefits during policy renewal.

### 2. Data monitoring and management: increase driver safety with early-warning systems

Cars today have more than 40 microprocessor-based systems based on the CAN protocol that includes speedometers, accelerometers, thermometers, and pressure sensors to handle telematics data. Parameters such as speed, acceleration, road conditions, tire pressure, distance from moving traffic, and driver focus can be measured. By collecting data, it becomes easy to assess driver behavior, car performance, efficiency, safety, and location. To handle the challenge in the connected car ecosystem, the CDMS requires the support of a data management software module that can identify, acquire, and process data as described in the four bullet points here:

- **Data acquisition:** Specifically, useful telematics data is gathered in the e-cockpit embedded platform. (See Figure 6.) There are two types of data: event and condition monitoring data. The events data is about what occurred, such as a breakdown, and how it was dealt with, such as a minor repair. The condition monitoring data is the measurements related to the health and current state of the car operations.

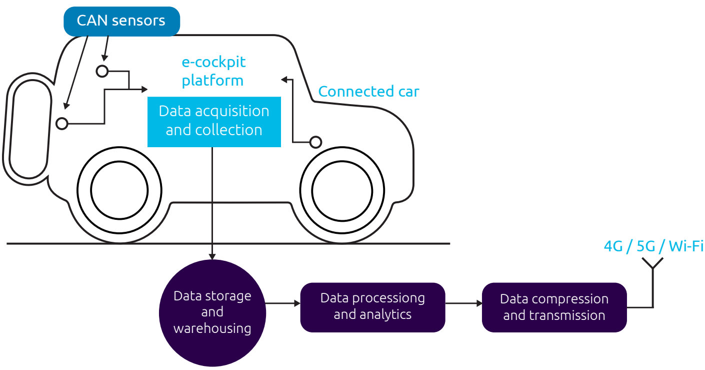



Figure 6: CDMS data acquisition

*Source: Capgemini Engineering*

- **Local data storage:** The e-cockpit embedded platform acts as a caching mechanism to store incoming data from CAN sensors. The data collected is stored in a local database for analysis and processing, and compared to past measurements and pre-defined limits. (See Figure 7.) The data from the interfaces is stored, processed, and analyzed by the e-cockpit platform that acts as an edge gateway. The critical data is then sent to the OEM's data service center over a wireless interface in drive mode for further analysis and processing.

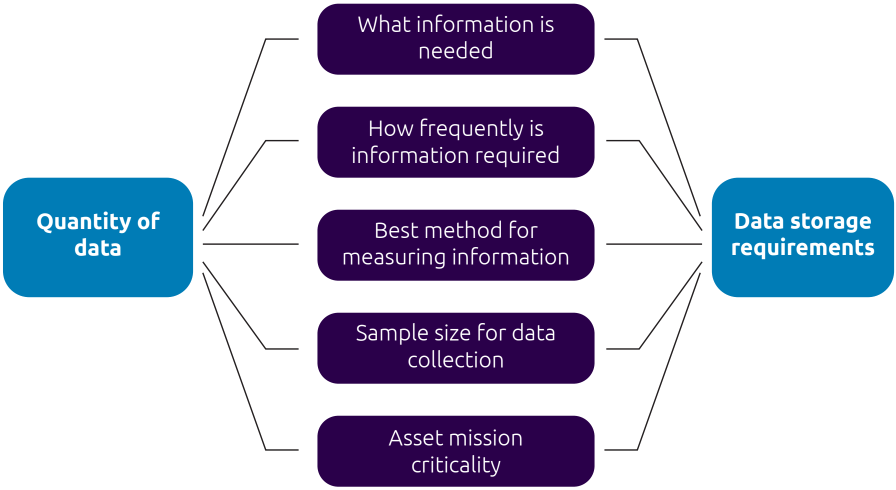



Figure 7: CDMS data storage and warehousing

*Source: Capgemini Engineering*

- **Local data analysis and analytics:** Data analysis is a two-step process: data cleaning and data analytics. Data cleaning ensures the data, specifically the useless data, is removed using algorithms to clean up the errors in the data so that it can be used for modeling, training, and analysis. Data analytics does real-time classification of data generated by various CAN sensors and compares it with the standardized historical data. (See Figure 8.). This module predicts the possible failure of parts using predictive analytics based on historical and situational data and diagnoses itself to prevent incorrect data from causing a failure. For example, unused cars or cars left overnight should have sensors reading close to ambient temperature. If the reading is significantly different, the CAN sensor can report a fault, and the OEM service center could inspect the car. In addition, an AI-based technique can be applied to gather information from large sets of data received from various CAN sensors.

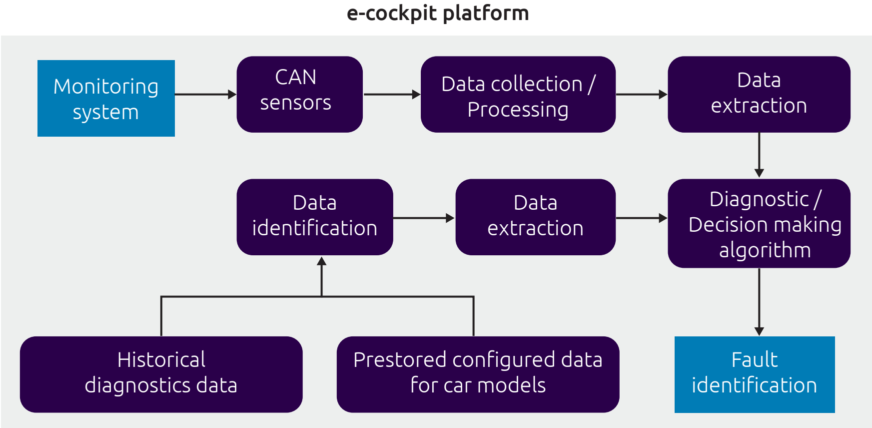



Figure 8: CDMS data analysis

*Source: Capgemini Engineering*

- **Interoperability:** The protocol conversion on the e-cockpit embedded platform generates a unified data format (UDF) communication to the OEM's service datacenter network for managing the message transmission, such as CAN <-> MQTT or SIP <-> CAN, based on the implementation techniques.

The CDMS interoperability module handles unified data packaging and uploads the standard data to the OEM datacenter on the cloud platform. Likewise, the interoperability module unpacks the data and converts it to the standard format during reception from the OEM datacenter. MQTT is a lightweight messaging protocol used between the e-cockpit and OEM datacenter. (See Figure 9.) It is designed to be easy to use for the car ecosystem. A single MQTT server — the MQTT broker – hosted by the OEM datacenter can support thousands of cars. The MQTT broker can subscribe to some of these topics, such as critical alerts on the car's performance and gather the messages on those topics.

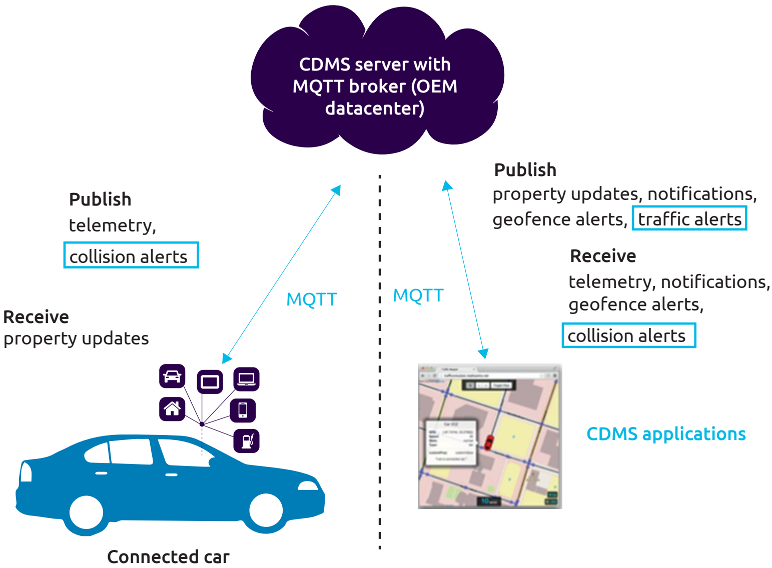



Figure 9: CDMS subscription model using MQTT between the car and OEM datacenter
*Source: Capgemini Engineering*

## 3. Data compression

The car's telematics system creates a large quantity of data that needs to be exchanged between the car and the OEM datacenter. It provides typical data generation based on different sensor types located in the car network. (See Figure 10.)

| Car automation sensors | | |
|---|---|---|
| **Sensor type** | **Quantity** | **Data generated per sensor** |
| Radar | 4-6 | 0.1-15 Mbit/s |
| Lidar | 1-5 | 20-100 Mbit/s |
| Camera | 6-12 | 500-3500 Mbit/s |
| Ultrasonic | 8-16 | <0.01 Mbit/s |
| Vehicle motion, GNSS, IMU | - | <0.1 Mbit/s |

Figure 10: Data traffic in the in-car network
*Source: Tuxera*

Most of the commercial cars on the road today have over thirty sensors based on the CAN protocol embedded in the car ecosystem. The sensors capture data every few milliseconds, such as speed, wear and tear, tire pressure, and driver behavior. According to a Ford Motor Company report, the cars generate about 200 GB of data in eight hours of driving, or about 25 GBs an hour.[2] (See Figure 11.) The flood of data will be significantly more than the volume of data the average person generates today from mobile broadband.

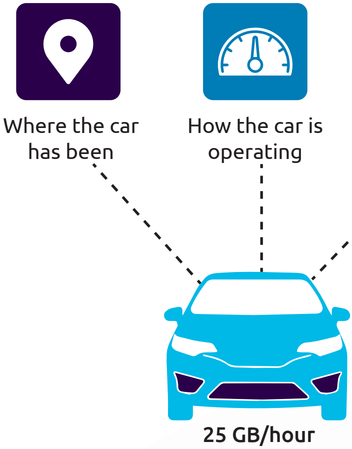



Figure 11: Data and location monitoring

*Source: Ford Motor Company*

2. Ibid. See footnote 1

A typical autonomous car produces about four terabytes of data in 90 minutes.[3] Transmitting such a massive amount of data requires very high network bandwidth, which is impractical. (See Figure 12.)

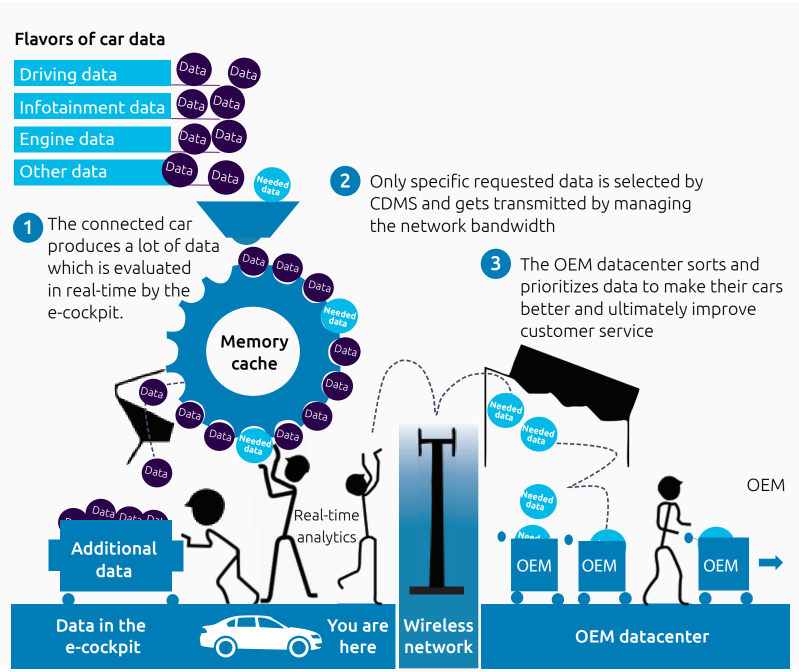



Figure 12: Data filtering and selection technique in CDMS

*Source: Capgemini Engineering*

The connected car will have a separate CAN bus for monitoring car motion, radar-assisted cruise control, parking systems, and lane guidance. There are usually three CAN buses:

- A high-speed CAN offers a baud rate of up to 1 Mbps and connects all crucial systems, such as the engine, anti-lock braking system (ABS), airbags, and body.
- A medium-speed CAN offers a baud rate of up to 500 kbps and connects lighting, power locks, power mirrors, etc.
- A low-speed CAN offers a baud rate of up to 125 kbps and manages non-critical systems such as interior lighting and entertainment.

Cars that support all three CAN bus can generate up to 17 GB of data a day, assuming a 24-hour running time with 725 MB of data per hour. (See Figure 13.)

3. Jason Waxman, "The Datacenter Holds the Keys to Autonomous Vehicles," May 3, 2017, Intel IT Peer Network https://itpeernetwork.intel.com/data-center-holds-keys-autonomous-vehicles/#gs.g0mxuw


Figure 13: Sample data structure

*Source: IEEE*

The CDMS supports increased data traffic speeds on the network to provide more bandwidth and reduce overload when connecting with the cellular network. The data compression engine is the heart of the CDMS framework. It performs end-to-end lossless compression in real-time, covering both upstream and downstream, and achieves the best possible compression of data traffic, all the way from the car to the OEM service center via the MNO.

The data compression and transmission modules deal with large volumes of data transmitted to the OEM datacenter using data compression techniques. The compression logic reduces the communications overhead on the cellular network to perform more advanced tasks such as compression-on-the-fly with a lossless method close to 80%-to-90% for telematics text data. This saves network bandwidth for each car connection to the service center via the cellular operator network. (See Figure 14.) The network overload issues are addressed with the data compression module supported in the CDMS framework, which reduces the network data traffic load.

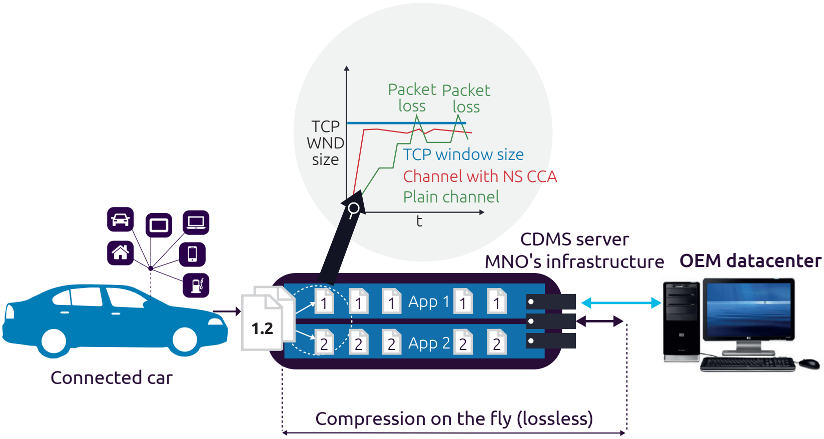



Figure 14: CDMS data compression feature

*Source: Capgemini Engineering*

The OEM service center may only require specific data from the car to analyze and monitor the e-cockpit. It can select and process the relevant data to avoid large unnecessary data transmission over the MNO's network, which adds overhead for more bandwidth.

### 4. Data security

As the car communicates via the cellular network from the e-cockpit, the transmission of certain telematics data is processed locally on the edge, in the e-cockpit embedded platform. This data must be secure to prevent it from being hijacked by hackers who inject false data that can have severe consequences for the car and its occupants. Unfortunately, tech-savvy cybercriminals have shown that hacking the e-cockpit in the car network is easier than hacking Internet of Things (IoT) devices.

The core aspect of car telematics data is a methodology for securely transmitting telematics data. All the data connections are configured and well managed by the security functions in the e-cockpit embedded platform using TEE/Trustzone, a trusted execution environment. The proposed steps include the creation of an SSL tunnel, identity check using root certificate generated from the OEM datacenter for each car, authentication and authorization, and four levels of encryption for data transmission: high, medium, low, and null. These elements are necessary to securely manage data communication between the car and OEM datacenter via the MNO. (See Figure 15.)

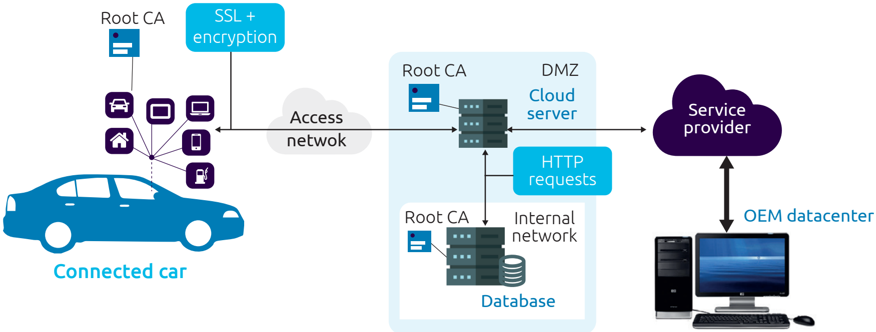



Figure 15: Peer-to-peer data security with CDMS between the integrated car and the OEM service provider

*Source: Capgemini Engineering*

Data and device security in the CDMS system include handling the public/private key pairs, server certificate, e-cockpit device certificate, root certificate, encryption/decryption, and hashing.

**5. Seamless connectivity and handoff to multiple networks**

The telematics data generated from the car should always be on for continuous measurement and monitoring car performance. There are several reasons for a possible connection interuption in the car ecosystem:

- Cellular connectivity is unavailable (e.g., 3G, 4G, 5G) during drive mode; fluctuations in the signal strength are measured over the wireless network from the e-cockpit platform
- Primary wireless network interface has been disabled or is unavailable
- Alternate available network (e.g., Wi-Fi) during park mode for better connectivity

To overcome some of these challenges, the CDMS provides fast, secure, reliable network connectivity for continuous transmission of telematics data and secure data transmission that connects over the primary cellular network (e.g., 3G, 4G, or 5G). It can be configured to establish an alternate connection as a backup tunnel to support the following functionalities:

- A faster, safer, cheaper, better connectivity experience over 3G, 4G, 5G, and Wi-Fi
- Low switching time/latency
- Minimum packet loss
- Continuous (always-on) connectivity across any wireless network
- Session persistence: no drops
- Seamless switching: no drops caused by changes in coverage
- Secure data connectivity and data transmission with the OEM service center
- Network bandwidth management: priority to car telematics data, panic and emergency VoIP data
- Data efficiency: optimized packet transmission using fewer bits for message content
- Reduce data usage costs and prevent network overload

With seamless connectivity, the CDMS reduces switching time in the case of a primary connection failure. (See Figure 16.) Switching between established connections is faster than building up a new connection. The backup tunnel increases the stability and reliability of the connection with the CDMS server interfaced with the e-cockpit from the car network. While the primary connection with the network is active, the seamless connectivity module running on the e-cockpit creates the backup tunnel with the CDMS server according to a defined priority. The CDMS client software enabled on the e-cockpit platform operates with the selected network interface. When the primary network connectivity fails, the e-cockpit embedded platform attempts to connect to the backup tunnel already established to ensure a seamless handoff without packet loss or interruption.

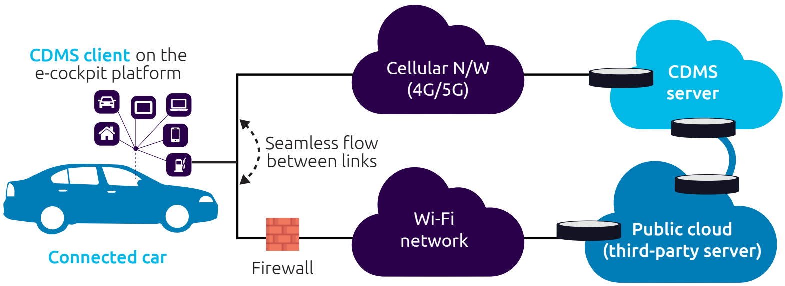



Figure 16: Seamless connectivity with wireless networks

*Source: Capgemini Engineering*

If the wireless connection from the connected car cannot be established within this profile, the CDMS client selects the next prioritized network interface, and so on. The CDMS allows traffic to flow between the links seamlessly without any loss of quality. For example, if one connection is lost or has poor QoS in one wireless network – such as latency, jitter, throughput, or loss of packets – the e-cockpit searches for another network connection. It connects with the new network if in drive mode or with any trusted Wi-Fi network if in park mode to meet the SLA defined by the carmaker. The advantage of using CDMS is that secure data transmission is taken care of with the help of a VPN tunnel created between the car and the CDMS server, which is deployed in the service provider network.

The CDMS offers path selection. It can decide which network link is the best path to forward telematics data based on real-time monitoring of latency observed or based on user preference. The CDMS can monitor all available connections and seamlessly switch to the best available network without any interruption. What constitutes “best” is defined based on user preference and policies. What is best depends on data throughput capacity and the cost of the wireless network. The CDMS persistence module maintains the IP address, allowing it to maintain a connection with the network after re-establishing a broken network connection without re-authentication. The CDMS client enabled in the e-cockpit platform in the car maintains the virtual IP address during switching and reconnection with a different network.

# Setting up the CDMS network

It is challenging to measure, monitor, and analyze telematics data generated from the car network. Analytics, connectivity, data optimization, and security are essential from the design perspective and benchmark performance in real-time to meet user expectations. The typical CDMS network setup covers the e-cockpit platform. For example, a Raspberry Pi with CAN bus interface, LTE/4G network interface support, a tablet or smart phone for remote monitoring of the health of the car by the owner, and the CDMS server hosted on the operator network for monitoring the car's performance by the maintenance team remotely at the OEM service center. (See Figure 17.)

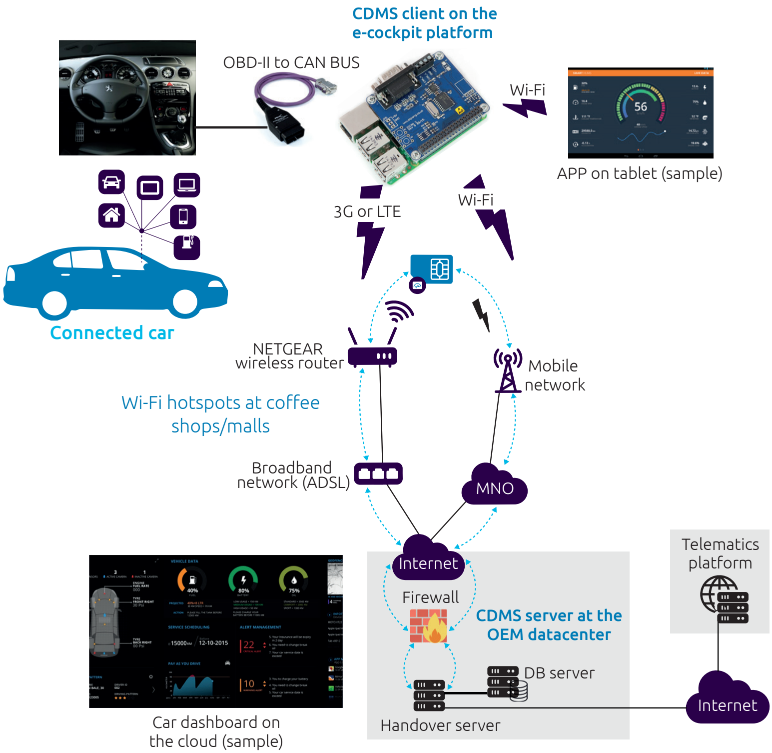



Figure 17: CDMS test bench setup

*Source: Capgemini Engineering*

- **Approach 1: Data monitoring, optimization, and analytics**

Continuous monitoring of the large amounts of bulk data generated from the car network via CAN sensors is a significant challenge for the OEM. (See Figure 18.)

Break sensor
Door sensor
Ultrasonic sensor
Rain sensor
Smoke detecting sensor
Oxygen sensor
Heat sensor
Speed sensor
Navigation sensor
Fuel tank level sensor
Parking sensor
Air pressure sensor
Fuel tank ejection sensor
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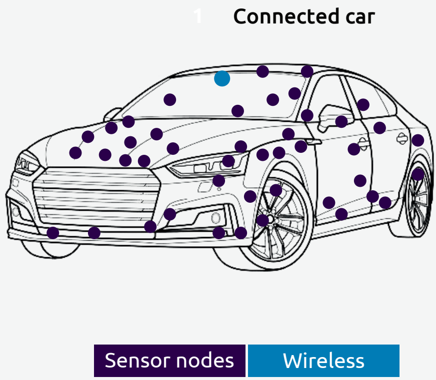
Obstacle sensor
Etc.




**Realistic Data:**

1. Fuel level
2. Tachometer reading (engine RPM gauge)
3. Vehicle speed
4. Battery health
5. Coolant temperature
6. Engine status
7. Status of power windows, doors, and locks
8. Tire pressure
9. Mileage since last oil change
10. Average fuel economy/ consumption
11. Outside temperature and pressure
12. Potential crash events, such as sudden changes in speed
13. Seat belt use
14. Air bag deployment
15. Distance traveled
16. Status of steering angle, brake application
17. Fault/error codes in electronic systems

Figure 18: CAN-based sensors for different forms of data measurement

*Source: IEEE (top), Capgemini Engineering (bottom)*

There are many aspects to managing the data, including collection, processing, filtering, efficient data transmission, and cost-effective analytics. A compression accelerator is required to minimize data transmission for analysis between the car and the OEM's service center over a cellular network. (See Figure 19.) The proposed CDMS framework addresses the data transmission challenges by analyzing the car's current health and the status of its core internal components on the e-cockpit embedded platform. The e-cockpit embedded platform enabled with a CDMS framework receives the data from several CAN controllers. It processes the data based on importance and criticality and manages the internal memory required to process the real-time data.

The types of data that need to be managed include mileage per gallon/liter, the quantity of fuel consumed, total distance covered (m/km), trip distance, distance covered in top gear, fuel level, current temperature, engine oil level, location-based statistics, engine RPM, speed profile, turbo pressure, engine coolant temperature and level, oil condition and pressure, engine power, battery condition and power, driving behavior, final drive temperature, minimum current requirement, alternator power, and ambient temperature.

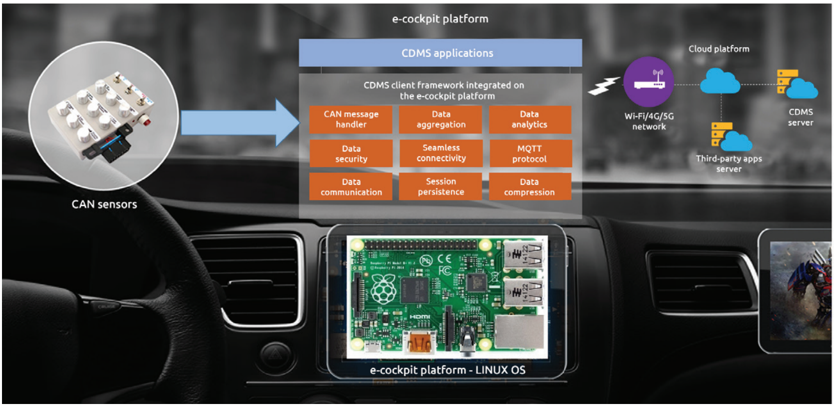



Figure 19: Telematics data collection from CDMS via CAN/OBD-II

*Source: Capgemini Engineering*

The analyzed data is used to make critical decisions, such as an emergency appointment with the OEM service center if a crucial part requires replacement. At the OEM service center, the OBD-II interface exposed in the car is used by technicians to gather data about car parameters. (See Figure 20.) The processed data is transmitted automatically to the OEM datacenter terminal so a technician can monitor the car's health status and compare it to maintenance and repair records that map to individual car models and registration numbers. The critical data stored in the e-cockpit platform is retained, even if the car is deactivated or the battery is disconnected.

**Parameters (Min/Max)**

| Description | Calculate engine Load value | Engine coolant temperature | Fuel pressure | Engine rpm | Vehicle speed | Intake air temperature | MAF air flow rate | Intake manifold absolute temperature |
|---|---|---|---|---|---|---|---|---|
| Min Value | 0 | -40 | 0 | 0 | 0 | -40 | 0 | 0 |
| Max Value | 100 | 215 | 765 | 16383.75 | 255 | 215 | 655.35 | 255 |
| Unit | % | $^0$C | kPa (Guage) | rpm | km/hr | $^0$C | g/s | kPa (absolute) |


Figure 20: Car parameters reported to the OEM service center (top) UI/UX for a 10-inch e-cockpit display (bottom)

*Source: Capgemini Engineering*

If a malfunction requires immediate attention, the e-cockpit dashboard notifies the driver to take appropriate action. The CDMS client software on the e-cockpit platform collects the data and displays it to the driver via the dashboard. The CAN bus integrates the software on the southbound interface via the e-cockpit platform. The collected data is transmitted after analysis over 3G, 4G, or 5G via the northbound interface from the e-cockpit platform with the help of MQTT-based protocol communication.

The CDMS acts as a standalone framework embedded in the e-cockpit platform that receives run-time data to monitor critical parameters. To view the health report of the car, the user logs on to the CDMS portal provided by the OEM service center or views the data on a mobile app. The data collected from the e-cockpit gets displayed with the health usage and monitoring status. (See Figure 21.)


Figure 21: CDMS dashboard

*Source: Capgemini Engineering*

- **Approach 2: Telematics data optimization and tracking**

The proposed CDMS achieves the best possible compression of the data traffic – from the e-cockpit to the OEM service provider – and a compression rate of close to 90%.

CDMS manages all incoming and outgoing pipeline data traffic and sophisticated traffic congestion control, which increases data transfer speed. With CDMS, a substantial reduction of telematics data traffic leads to massively higher data transfer speeds with end-to-end optimization. Figure 22 shows the percent of compression achieved based on the CDMS testbench set up as a prototype. With the results benchmarked, the CDMS module optimizes all transferred car telematics data, both incoming and outgoing traffic, provides lossless compression, and peer-to-peer traffic optimization between the e-cockpit and OEM service center.

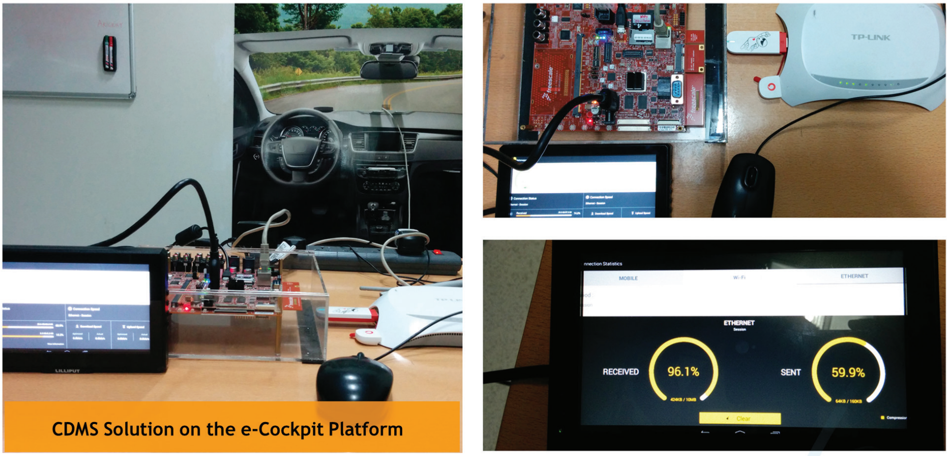



Figure 22: Data traffic parameters

*Source: Capgemini Engineering*

The CDMS data optimization allows network bandwidth expansion, overload reduction, and faster data transfer. The data collected from the sensors is stored in a non-relational database, where some of the data can be visualized on the e-cockpit platform, such as fuel-efficient and high-traffic routes.

# The Capgemini Engineering point of view

The CDMS design for the e-cockpit platform includes remote car access, breakdown service, OEM callback service, car data management, seamless connectivity, enhanced data security, and theft prevention. (See Figure 23.) The CDMS improves operational performance by providing instantaneous telematics data to predict the residual life of critical car parts by analyzing the captured data and the previous record of the car's history. The data is then processed through the analytics model to forecast the replacement schedule for the car's critical parts.

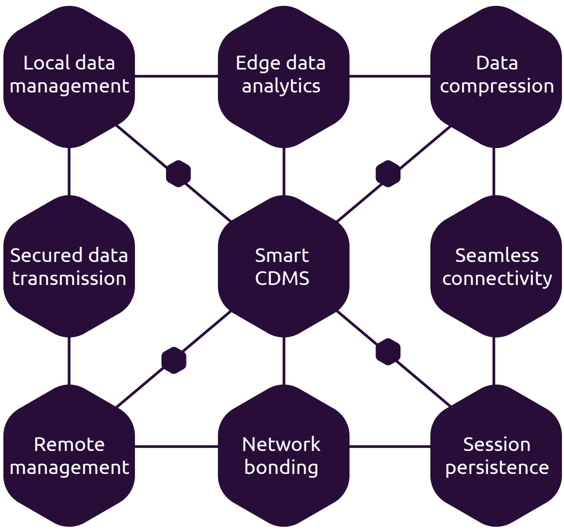



**Figure 23: CDMS benefits and applications**

*Source: Capgemini Engineering*

This information can ensure supply-chain readiness to replace critical parts and subcomponents. The CDMS overcomes other constraints and challenges such as intermittent network links, low bandwidth, and data security. The dashboard design can be incorporated into the e-cockpit platform based on the available data set and end-user requirements.

The key benefits of CDMS include:

- Reduced fuel costs
- Real-time fleet usage data
- Efficient car maintenance

- Improved safety by monitoring driver performance, including speeding, rapid acceleration, hard braking, excessive idling, and other factors
- Scheduling OEM service appointments, including a specific time of arrival and booking the service personnel
- Optimized data acquisition in real-time
- Reduced maintenance costs
- Reduced spare parts costs
- Lower network bandwidth
- Data security
- Seamless handoff
- Session continuity
- Accurate and tailored asset data
- Financial, operational, and strategic decision making

Next-generation autonomous cars will have heterogeneous wireless technologies that transmit data via 4G, 5G, and Wi-Fi networks, potentially transferring terabytes of data per car per market report. Next-generation autonomous cars will use wireless network bonding to increase data transmission and improve reliability. In addition, they can be equipped with a multipath environment, where multiple network interfaces, like 4G and 5G, can be accessed. This is a vast improvement over the conventional single-wireless interface, where wireless network bonding can provide better performance by giving increased throughput and larger bandwidth.

# Rapid growth ahead for automotive digital services

By 2025, automotive OEMs are projected to offer more than one hundred in-car digital services, including twenty to thirty new services that provide predictive analytics, including health, wellness, and wellbeing (HWW), connected living, IoT, and information technology services.

The fleet management market for digital services is expected to grow from USD 20.6 billion in 2021 to USD 33.9 billion by 2026, at a compound annual growth rate (CAGR) of 10.5. [4]

This market includes operations management, vehicle maintenance and diagnostics, performance management, and fleet analytics and reporting. The fleet management market is growing rapidly as it shifts to cloud computing, analytics, hardware and IoT connectivity costs decline, operational efficiency improves, and government mandates are put in place. At the same time, small firms and startups are making their presence felt by providing their offerings worldwide.

4. Press release, "The global fleet management market size is expected to grow from USD 20.6 Billion in 2021 to USD 33.9 Billion by 2026, at a Compound Annual Growth Rate (CAGR) of 10.5%," Jul. 14,2021, Report Linker
https://www.reportlinker.com/p05090303/Fleet-Management-Market-by-Solution-Service-Deployment-Type-Fleet-Type-and-Region-Global-forecast-to.html?utm_source=GNW

# Conclusion

The connected car market is emerging rapidly and has the potential to significantly boost revenue for OEMs, Tier-1 suppliers, and service providers in the next few years. Connected, autonomous, shared, electric technologies are fundamentally transforming the car market, including the maintenance market.

Telematics is a critical component in the car ecosystem. The proposed CDMS framework embedded in the e-cockpit platform collects and processes the data received from the CAN bus enabling seamless switching of available cellular networks. (See Figure 24.) This feature ensures the driver and passengers will obtain fast, stable access to the internet and can access the various services provided by the OEM service center for critical applications via multiple wireless networks with secure end-to-end connections.

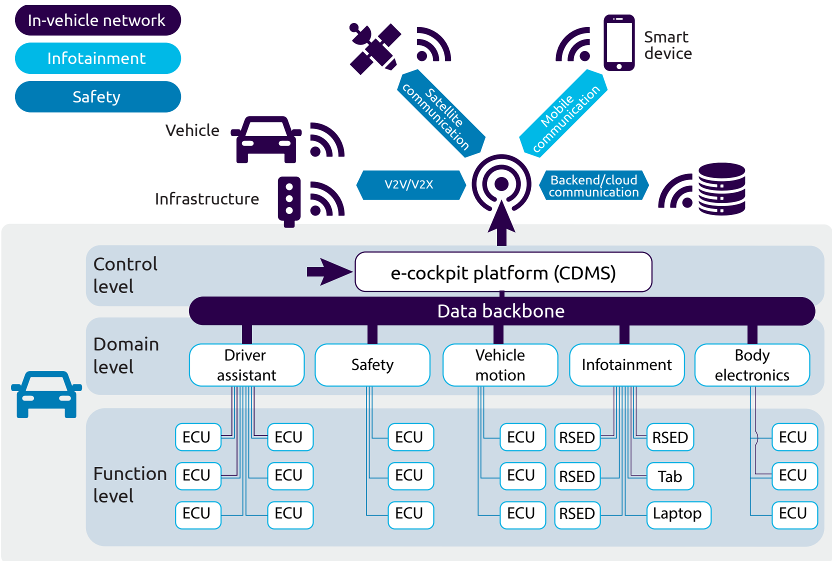



Figure 24: e-cockpit platform with CDMS framework

*Source: Capgemini Engineering*

The CDMS framework on the e-cockpit delivers accurate, real-time information and an intelligence report that allows users to get an accurate operating picture of the maintenance service options before a major breakdown occurs. With the connected car's advanced technology ecosystem, the OEM service center can monitor the car while on the road and determine the schedule for inspection and replacement of critical parts based on their actual condition.

The CDMS framework has many uses, such as car usage monitoring, driver monitoring, critical parts condition monitoring, and situational awareness. Just as important, the CDMS takes care of data security, data compression, high-speed mobility, and seamless connectivity that improves the end-user experience.

Breakdowns will happen and will require roadside assistance. The difference is that the car will be able to share its telematics data with the service technician, who can quickly troubleshoot the problem and get the car back on the road. Utilizing an “always-on” and “best-connected” service approach with end-to-end digital security will ensure rapid response and better service.

# Author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Vijay plays a strategic leadership role building connected IoT solutions in a number of market segments including consumer and industrial IoT. He has over 25 years of experience and has published 19 research papers, including IEEE award-winning articles. He is currently pursuing a Ph.D. at the Crescent Institute of Science and Technology, India.

## About Capgemini Engineering

Capgemini Engineering combines, under one brand, a unique set of strengths from across the Capgemini Group: the world leading engineering and R&D services of Altran – acquired by Capgemini in 2020 – and Capgemini's digital manufacturing expertise. With broad industry knowledge and cutting-edge technologies in digital and software, Capgemini Engineering supports the convergence of the physical and digital worlds. Combined with the capabilities of the rest of the Group, it helps clients to accelerate their journey towards Intelligent Industry. Capgemini Engineering has more than 52,000 engineer and scientist team members in over 30 countries across sectors including aeronautics, automotive, railways, communications, energy, life sciences, semiconductors, software & internet, space & defence, and consumer products.

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