2021-01-0158 Published 06 Apr 2021

Right First Time: Cloud-Based Cyber-Physical System for Data Acquisition and Remote Diagnostics to Optimize the Service Quality

Peter Subke and Muzafar Moshref Softing Automotive Electronics GmbH

Citation: Subke, P. and Moshref, M., "Right First Time: Cloud-Based Cyber-Physical System for Data Acquisition and Remote Diagnostics to Optimize the Service Quality," SAE Technical Paper 2021-01-0158, 2021, doi:10.4271/2021-01-0158.

Abstract

This paper describes a system and a process to significantly decrease the downtime of commercial vehicles that are immobilized for the purpose of Inspection and Maintenance (I/M) in the workshop.

The process is based on a data acquisition system that is installed in the vehicles and collects data from a fleet under real driving conditions. The collected data is sent to the cloud and merged with other data sources, such as diagnostic data requested from the vehicles in the workshop, history data, test drive data, and so on.

The target-oriented analysis of selected data items results in predictive maintenance sequences. The sequences are described in OTX [1] and downloaded to the workshop tester that processes OTX sequences. In combination with Qtr.-based GUIs, the service technician is guided thru the maintenance process. If required, an external technical expert can access the vehicle remotely and support the local service technician to do his job right the first time.

Introduction

For commercial vehicle owners (e.g. a truck driver who runs his own business) and fleet managers, vehicles are assets. Any downtime is expensive.

For them, an Inspection & Maintenance (I/M) process that meets the "Right First Time" requirement and serves the reduction of downtime to a minimum is existential. They expect error-free inspection, maintenance, and repair. An important measure to reduce unexpected breakdowns is the periodic inspection, which is a scheduled process, performed at regular service intervals. It includes but is not limited to reading and analyzing fault codes, inspection, cleaning, and lubrication, but also the exchange of fluids, filters, spark plugs and timing or drive belts.

Predictive maintenance is similar to periodic inspection but performed only when necessary. It consists of measures such as the exchange of a component that still functions but became conspicuous, because specific parameters indicate that a failure is about to occur. Examples include smoke from the exhaust and an increased consumption of engine oil, a starter battery with reduced cold cranking amps (CCA), rattling valves or a noisy bearing.

Predictive maintenance is performed by the service technician only when needed. The need is a result of the analysis of data acquired from as many vehicles as possible, preferably from a fleet of identical series production vehicles on the road and under comparable operating conditions meaning that the vehicle data shall be accompanied by environmental data indicating the real driving conditions.

Data Sources

Periodic maintenance procedures and their schedules are based on the analysis of data collected from pre-series test drives and previous series (reflecting experience). Data for predictive maintenance is a subset of Big Data acquired for Condition Monitoring of a fleet of vehicles on the road and under similar driving conditions.

The most important data source is the vehicle itself. Each second, numerous connected Electronic Control Units (ECUs) create and update thousands of data frames, check the content for plausibility and exchange them via in-vehicle networks. In the following, this kind of data is referred to as in-vehicle data.

In addition, ECUs perform self-diagnostic functions and monitor sub-systems. If a fault is detected, they activate a warning lamp and store Diagnostic Trouble Codes (DTCs) with associated Freeze Frames containing data about the environmental conditions, being present at the fault event.

The most prominent monitoring system is the legally required On-Board Diagnostic (OBD) system that monitors the emission control system of the vehicle´s powertrain, for example the Exhaust Gas Recirculation (EGR) valve [2]. Besides the legally mandated emission-related DTCs, a vehicle may report numerous OEM-specific DTCs, self-test results, and measurement values.

With additional sensors and E/E components, a vehicle may also acquire its position, acceleration and rotation, but also the weather, the road grade and the road condition.

One of many other security measures is the patented method for securely authenticating the xTCU and the MQTT server. The method comprises establishing the connection using a pre-shared server key, establishing the identity of the xTCU using a pre-shared client key (stored on the eSIM of the xTCU), and cryptographically generating a session key for authentication of the xTCU.

Another example is the powerful rule-based security engine of Cluu, whereby any combination of logical expressions can be used to define access permission rules.

All security mechanisms are regularly tested with penetration tests where thousands of attack scenarios are run through. If a security vulnerability is discovered, processes are prepared on how to fix it, how to inform the stakeholders and how to distribute the hotfix.

Conclusion

An extended TCU (xTCU) is permanently installed in the vehicle, and connected to the in-vehicle network (CAN). It reads on-board signals and requests diagnostic data via OBD and UDS communication protocols. In addition, it records the position (GPS), the acceleration and the motion direction of the vehicle and transfers all the data as MQTT packages via a mobile network channel (4G LTE) to a server in the cloud. The fleet data, acquired under real driving conditions, are used for condition monitoring and merged with other data to predict failures before they occur. Depending on the results of the diagnostic communication with the single, immobilized vehicle in the workshop, predictive maintenance sequences are downloaded to the local tester in the workshop. To further assist and support the service technician, the system can be used by an external service expert to remotely access the diagnostic system of the vehicle. The expert may start specific test routines or read data that is not available for the service technician.

The quality of predictive maintenance measures depends on the availability of data, the selection of the right data and the quality of the data analysis. Machine Learning (ML) as a subset of Artificial Intelligence (AI) comes into account.

In this system, the remote tester does not have access to the fleet, meaning that there is no diagnostic communication with vehicles on the road. However, the system can be used for remote diagnostic functions such as updating firmware over the air (FOTA), but the vehicle has to be in a safe environment, such as a workshop and in a safe state, meaning immobilized. Remote diagnostics of vehicles on the road needs a different architecture of the CPS [6] and an extended set of cyber security measures [9].

Depending on specific requirements, for example of autonomous vehicles or automated machines, the quality of periodic and predictive I/M and diagnostic procedures becomes essential, not only for economic but also for safety reasons.

References

1. "ISO 13209: Road Vehicles - Open Test Sequence Exchange Format (OTX)."
2. Dadam, S.R., Jentz, R., Ienzen, T., and Meissner, H., "Diagnostic Evaluation of Exhaust Gas Recirculation (EGR) System on Gasoline Electric Hybrid Vehicle," SAE Technical Paper 2020-01-0902, 2020, https://doi.org/10.4271/2020-01-0902.
3. Subke, P., *Diagnostic Communication with Road-Vehicles and Non-Road Mobile Machinery* (SAE International, 2019), Product Code: R-474, ISBN:978-0-7680-9367-4.
4. Subke, P., "Internationally Standardized Technology for the Diagnostic Communication of External Test Equipment with Vehicle ECUs," SAE Technical Paper 2014-01-0281, 2014, https://doi.org/10.4271/2014-01-0281.
5. Hanc, M., Dietze, M., and Subke, P., "Qt and QML Based HMI Widgets and OTX Scripts for Diagnostic Test Equipment," SAE Technical Paper 2018-01-1358, 2018, https://doi.org/10.4271/2018-01-1358.
6. Subke, P., Moshref, M., and Erber, J., "In-Vehicle Diagnostic System for Prognostics and OTA Updates of Automated / Autonomous Vehicles," *SAE Int. J. Advances & Curr. Prac. in Mobility* 2(5):2963-2968, 2020, doi:10.4271/2020-01-1373.
7. "ISO/SAE 21434: Road Vehicles - Cybersecurity Engineering."
8. "OWASP Top 10 - 2017: The Ten Most Critical Web Application Security Risks," https://owasp.org/www-project-top-ten/.
9. Subke, P., and Moshref, M., "Improvement of the Resilience of a Cyber-Physical Remote Diagnostic Communication System against Cyber Attacks," SAE Technical Paper 2019-01-0112, 2019, https://doi.org/10.4271/2019-01-0112.
10. Subke, P., and Moshref, M., "APP-Based Diagnostics of E/E Systems with ISO Standardized Technology (MVCI, ODX, OTX, and UDS on DoIP)," SAE Technical Paper 2016-01-0073, 2016, https://doi.org/10.4271/2016-01-0073.
11. Subke, P., "Softing Envisions Secure, Reliable Predictive Maintenance," SAE Truck & Off-Highway Engineering (TOHE) Magazine, August 3, 2020.

Contact Information

Peter Subke
Softing Automotive Electronics
Munich Germany
Peter.Subke@softing.com

Uli Held
Softwarehelden GmbH & Co KG
Stuttgart Germany
Uli.Held@softwarehelden.com

Alois Widmann
Globalmatix AG
Vaduz Liechtenstein
Alois.Widmann@globalmatix.vom

Definitions/Abbreviations

CAN - Controller Area Network (ISO 11898)

CQL - Cluu Query Language