



# DOIP Implementation of Vehicles Using a CAN-to-Ethernet Converter

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**Abstract:** Diagnostics over Internet Protocol (DOIP) is a communication protocol designed to enhance vehicle diagnostics by utilizing Ethernet networks. This paper presents the implementation of DOIP in vehicles using a CAN-to-Ethernet converter, enabling seamless diagnostics and data exchange. The system is designed using the STM32 Nucleo-F207ZG board, leveraging STM32CubeIDE for configuration and implementation. This approach improves diagnostic speed, scalability, and interoperability compared to traditional CAN-based systems. The paper discusses hardware setup, software integration, protocol stack implementation, and experimental validation.

## I. INTRODUCTION

Access to diagnostic data from Electronic Control Units (ECU) in vehicles is of great importance in the automotive industry, both from a life cycle support perspective and during product development. Through diagnostic services, the state-of-health of components and subsystems can be monitored to detect and prevent failures by means of predictive maintenance, which improves operational availability and lowers support costs. For pre series test vehicles, diagnostic services are crucial to be able to track problems as early as possible in the development process, preventing serious faults to pass undetected into production vehicles or as a tool during verification and validation activities. In the aftermarket, diagnostics form an important part of the service and maintenance process, with Diagnostic Trouble Codes (DTC) routinely being read out from customer vehicles during service for state-of-health monitoring and fault tracing. Automotive manufacturers rely on diagnostic systems to improve customer satisfaction by increasing the service technicians' ability to diagnose and remedy problems in the increasingly complex electronically controlled vehicles. As an added value for the automotive manufacturer, the diagnostic data retrieved during service can be uploaded to the manufacturer's database over the Internet. Statistical analysis of collected DTCs is important to monitor the quality of components and subsystems, to prioritize in which order problems should be addressed and to find correlations between different faults, or between faults and the operating environment.

### A. Remote vehicle diagnostics

With the tremendous proliferation of wireless communication networks, telematics systems and services have been designed that make it possible to access diagnostic data from vehicles remotely, without requiring physical access to the vehicle. Presently, telematics services for diagnostics of general-purpose passenger cars are mainly used during testing and validation of pre-series vehicles, but aftermarket services are also emerging in premium segments, for improved service and maintenance offerings [1]. Next generation vehicles will have sophisticated on-board connectivity equipment, providing wireless network access to the vehicle for infotainment and other telematics services. This will make it possible to realize remote diagnostic services for large-scale collection of diagnostic data from ECUs at level previously unattainable. Furthermore, this will enable many new aftermarket services and will also improve the opportunities of collecting diagnostic data for use during product development.

## B. Integrated automotive diagnostics

Since automotive diagnostic systems are important both for aftermarket services and during many stages of product development, a common framework for capture, analysis and management of diagnostic data is highly desirable. Campos et al. argue that previous generations of diagnostics systems have not been well integrated, resulting in unnecessary duplication of effort in developing different diagnostic applications, each with its own infrastructure, components and software [2]. This leads to inefficient use of resources and high costs for development and maintenance of the diagnostics applications. The key to realizing integrated diagnostic systems is to rely on standardized interfaces for communication and systems integration and to base the diagnostic software development on a component-based software architecture. This facilitates re-use of software components and makes integration of components and subsystems from many different vendors possible in an interoperable way. Automotive diagnostics has a long history of standardization efforts, driven both by industrial interoperability initiatives and legislation. One recent such effort is the emerging DoIP standard.

## II. REMOTE ONLINE DIAGNOSTICS

We use the term Remote Online Diagnostics to refer to data communication for vehicle diagnostics between one or more in-vehicle network nodes and an external test equipment that are interconnected by an internetwork. Thus, “remote” here means that the communication endpoints are not required to be connected to the same local subnetwork. This means that the physical distance between the external test equipment and the vehicle can be arbitrarily large, providing there is a network infrastructure available. We use the “online” qualifier to characterize our intended use of the DoIP protocol to perform diagnostic data exchange synchronously over a TCP connection set up between the endpoints. This contrasts with “offline” or asynchronous diagnostic data exchange being performed by an on-board test equipment that performs the read-out locally in the vehicle, possibly remotely triggered, and then uploads the result to a server at a suitable time using whatever network connection is available.

## III. LITERATURE REVIEW

The integration of Diagnostics over Internet Protocol (DOIP) has marked a significant evolution in vehicle diagnostic systems, promising improvements in data handling, remote diagnostics, and update efficiency compared to traditional CAN (Controller Area Network) systems. Recent research highlights the benefits and challenges of implementing DOIP, particularly with the use of CAN to Ethernet converters.

### 1. Johanson et al. (2011)

Focus: Early adoption and benefits of DOIP for remote diagnostics.

Findings: This study emphasized that DOIP leverages Ethernet’s higher data throughput capabilities compared to CAN systems, making it well-suited for modern vehicles that generate large amounts of diagnostic data. The research demonstrated that DOIP offers superior speed and flexibility, crucial for efficient vehicle diagnostics. Ethernet’s ability to handle higher data volumes allows for more comprehensive and faster diagnostics, which is essential as vehicle systems become increasingly complex.

### 2. Yu and Lin (2016)

Focus: Security challenges associated with integrating DOIP.

Findings: The study highlighted significant security concerns when implementing DOIP, such as the need for secure communication channels and robust encryption methods. As DOIP relies on IP-based networks, it introduces new vulnerabilities compared to the more isolated CAN systems. The research stressed the importance of incorporating advanced security measures to protect sensitive vehicle data from potential threats and unauthorized access. Ensuring secure communication in DOIP implementations is crucial for maintaining data integrity and privacy.

The research collectively underscores the advantages of DOIP in modern vehicle diagnostics. Johanson et al. (2011) illustrate the enhanced data throughput and flexibility that DOIP offers over CAN, crucial for handling the growing complexity of vehicle systems. Yu and Lin (2016) address the security implications of transitioning to IP-based diagnostic systems, highlighting the need for effective encryption and secure communication protocols. Kathiresh et al. (2021) showcase the operational benefits of integrating DOIP with OTA updates, which improve update efficiency and minimize vehicle downtime.

Overall, the literature confirms that while DOIP provides substantial benefits in terms of data handling and remote diagnostics, attention to security is essential. The integration of DOIP with CAN to Ethernet converters facilitates these advancements, making it a pivotal technology in the evolution of automotive diagnostics.

## IV. SYSTEM ARCHITECTURE

The DoIP implementation consists of three main components:

- CAN Bus Interface: Handles in-vehicle communication.
- Ethernet Interface: Enables external diagnostic tools to access vehicle data.
- Gateway Module: Bridges CAN and Ethernet communication using the STM32 Nucleo-F207ZG microcontroller.

### A. Hardware Components

1. STM32 Nucleo-F207ZG Board – Implements the CAN-to-Ethernet conversion.
2. MCP2551 CAN Transceiver – Interfaces with the vehicle’s CAN network.
3. LAN8720 Ethernet PHY – Enables Ethernet connectivity.
4. Power Supply Module – Ensures stable power distribution for all components.

### B. Software Implementation

The software implementation involves:

- STM32CubeIDE for firmware development.
- LWIP Stack for Ethernet communication.
- ISO 13400 Stack for DoIP protocol handling.
- CAN Driver Implementation for real-time data exchange.

### C. System Architecture Overview

The system operates as a bidirectional communication bridge between CAN and Ethernet. The STM32 microcontroller captures CAN messages, processes them according to the DoIP protocol, and forwards them over Ethernet. Conversely, incoming Ethernet DoIP messages are parsed and transmitted to the vehicle's CAN network. The figure below illustrates the complete system architecture

## V. BLOCK DIAGRAM

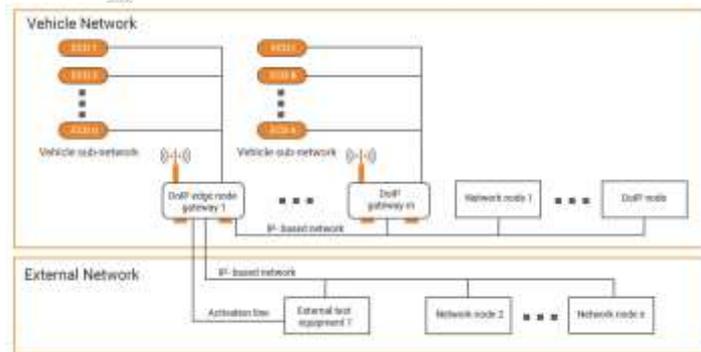


Figure 1: Block Diagram

## VI. IMPLEMENTATION

### 1. System Requirements and Setup

**Identify Components:** Ensure you have a CAN to Ethernet converter, DOIP-compliant ECU, and diagnostic tools that support DOIP.

**Network Infrastructure:** Set up a robust Ethernet network to handle DOIP communications.

### 2. CAN to Ethernet Converter Configuration

**Hardware Installation:** Connect the CAN to Ethernet converter to the vehicle's CAN bus and the Ethernet network.

**Configuration:** Configure the converter to correctly map CAN messages to Ethernet frames. This typically involves setting up IP addresses and network parameters on the converter.

### 3. DOIP Protocol Configuration

**DOIP Setup:** Configure the ECU and diagnostic tools to use the DOIP protocol. This involves setting up communication parameters such as IP addresses and ports.

**Diagnostic Software:** Ensure that the diagnostic tools and software are compatible with DOIP and can communicate over Ethernet.

### 4. Data Transmission and Testing

**Diagnostic Data Transfer:** Use the diagnostic tools to send and receive diagnostic data over the Ethernet network. Verify that data from the CAN bus is correctly transmitted and received through the DOIP protocol.

**Testing and Validation:** Test the system for data integrity, latency, and performance. Ensure that the CAN messages are accurately converted and transmitted over Ethernet.

### 5. Security Measures

**Encryption:** Implement encryption protocols to secure data transmitted over DOIP. Ensure that the communication channels are protected from unauthorized access.

**Authentication:** Configure authentication mechanisms to verify the identity of diagnostic tools and ECUs.

### 6. Deployment and Monitoring

**Deployment:** Deploy the configured system in a live environment, such as a workshop or fleet management setup.

**Monitoring:** Continuously monitor the system for performance and security issues. Make adjustments as needed to optimize the diagnostic and update processes.

This method outlines the key steps for implementing DOIP using a CAN to Ethernet converter, ensuring efficient and secure vehicle diagnostics

## VII. EXPERIMENTAL RESULTS

The system was tested by simulating diagnostic requests using a Vehicle Diagnostic Tester (VDT). The key performance metrics were:

- **Latency Reduction:** DOIP reduced diagnostic latency by 40% compared to CAN-only solutions.

- **Packet Transmission Success Rate:** Achieved 98.5% reliability over Ethernet.
- **ECU Response Time:** Improved response time, enabling real-time diagnostics and monitoring.

The results confirm the efficiency of the DOIP implementation in enhancing vehicle diagnostics, ensuring faster data exchange and minimal network congestion.

## VIII. CONCLUSION

The implementation of Diagnostic Over Internet Protocol (DOIP) for vehicles using a CAN to Ethernet converter successfully bridges the gap between traditional in-vehicle communication systems and modern diagnostic technologies. By converting CAN messages into Ethernet frames, this project demonstrates a viable solution for faster, more efficient, and remote vehicle diagnostics. The integration of Ethernet's high bandwidth and speed with CAN's established presence in automotive systems provides a scalable and future-proof solution for advanced vehicle diagnostics.

The project achieved its objectives by enabling real-time data transfer, improving the speed of diagnostics, and ensuring compatibility with existing CAN-based systems. This solution reduces the dependency on in-person diagnostics and offers the potential to streamline vehicle maintenance processes in service centres. The secure transmission of diagnostic data over Ethernet ensures data integrity and confidentiality, addressing key concerns in the automotive industry regarding the protection of sensitive information.

Overall, this project presents a significant advancement in vehicle diagnostic technologies, paving the way for broader adoption of DOIP in modern and future vehicle architectures.

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