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The Transition of Electric Vehicle Communication Architectures from CAN to Diagnostic Over IP Protocols and 48-Volt Power Systems

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Abstract

The article examines the transition of electric vehicle communication and low-voltage power architectures from the Controller Area Network bus and the 12-volt subsystem to Diagnostics over Internet Protocol and 48-volt solutions as a regular stage in the evolution of software-defined transportation. The relevance of the study is determined by the growth in the number of electronic control units, the increase in telemetry volume, the spread of over-the-air updates, remote diagnostics, and connected services, which create new requirements for bandwidth, scalability, maintainability, and security of the onboard architecture. The aim of the article is to substantiate the engineering logic of this transition and to identify its technical and production effects. The scientific novelty of the article lies in the joint consideration of communication and power modernization of the electric vehicle within a single systemic requirements framework. It is shown that the most rational form of transformation is a hybrid architecture in which local control loops remain with CAN, while diagnostics, reflashing, and exchange of large data packets are transferred to the DoIP environment. It is established that introducing a 48-volt subsystem reduces current loads and wiring mass. In addition, a phased roadmap for the transition to the new architecture is proposed. The article will be useful to researchers, automotive electronics engineers, developers of electric vehicle architecture, manufacturers, and component suppliers.

Keywords: *Electric Vehicle, Onboard Architecture, CAN, DoIP, 48-Volt Subsystem.*

INTRODUCTION

The transition to a new electric vehicle architecture is driven by the simultaneous growth of computational, network, and power-system complexity. Modern vehicles increasingly operate as integrated digital systems, which makes architectures based on numerous isolated control units less suitable. Research shows that the expansion of electronic control units increases mass, energy consumption, complexity, and lifecycle costs, while growing functional density requires greater software scalability and maintainability (Ayres et al., 2024; Jin et al., 2025).

This shift is unfolding together with the rise of software-defined vehicles, over-the-air updates, and permanently connected services. Vehicles now continue to gain functions after sale, exchange data with cloud platforms, and support remote diagnostics. At the same time, the spread of connectivity strengthens demands for reliable and secure data handling, since automotive data flows create risks of leakage, substitution, and unauthorized access (Abdelkader et al., 2021; Xu et al., 2024).

In these conditions, the Controller Area Network and the 12-volt subsystem no longer meet the full range of new requirements. The Controller Area Network remains useful for local control traffic, yet it is poorly suited to large diagnostic transfers and centralized computing, while the 12-volt network faces growing current loads, wiring mass, and conversion demands. Studies therefore support the move toward Internet Protocol–based diagnostics and 48-volt subsystems as a more suitable foundation for next-generation electric vehicles (Maier & Reuss, 2023; Kotb et al., 2023).

MATERIALS AND METHODOLOGY

The article is based on an analysis of the contemporary body of scientific publications and normative materials on the transformation of onboard electrical and electronic architectures of electric vehicles, the evolution of in-vehicle data exchange, and the modernization of low-voltage power supply. The material base of the study consists of works that reveal the reasons for the transition from a distributed model with numerous electronic control units to centralized

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and zonal solutions, as well as publications on connected services, diagnostics, cybersecurity, and 48-volt subsystems (Ayres et al., 2024; Jin et al., 2025; Abdelkader et al., 2021; Xu et al., 2024; Maier & Reuss, 2023; Kotb et al., 2023). A separate supporting role was played by studies that examine the functional capabilities and limitations of the Controller Area Network bus, the architectural prerequisites for the introduction of Diagnostics over Internet Protocol, as well as the requirements of the ISO 13400 standard as the normative basis of DoIP (Douss et al., 2023; Oh et al., 2023; Wachter & Kleber, 2022; ISO, 2025).

From a methodological standpoint, the study combines comparative architectural analysis, systematization of engineering requirements, and interpretation of literature review results within the logic of a phased transition to a new platform. A comparative analysis compares CAN and DoIP in terms of bandwidth, payload size, role within the vehicle structure, integration capabilities, and compatibility with centralized and zonal architectures (Wang et al., 2024; de Andrade et al., 2023; Douss et al., 2023). In addition, a systemic analysis of the power domain is applied, which makes it possible to link the growth of computational and actuation load with the need to transition to a 48-volt power level in order to reduce current loads, wiring mass, and architectural congestion of the platform (Kotb et al., 2023; Maier & Reuss, 2023). On this basis, a methodological framework is formed in which the transition to DoIP and 48-volt subsystems is viewed as a unified engineering process covering communication, diagnostics, software support, security, and energy distribution (Ayres et al., 2024; Xu et al., 2024).

RESULTS AND DISCUSSION

CAN took a central place in on-board communication due to its combination of qualities valued in mass automotive engineering. This network provided predictable delivery of short messages, resistance to interference, simple physical organization, and an acceptable cost of implementation in large-scale production. A review of onboard communication protocols indicates that a modern vehicle typically contains 30-70 electronic control units that interact via standard network protocols (Douss et al., 2023). It was in such an environment that CAN became the basic technology for coordinating signals between power electronics, body systems, braking control, battery subsystems, and diagnostic interfaces. In a later study on the protection of the automotive CAN network, it is described as the de facto standard for inter-unit communication in vehicles, reflecting its historical role in the transition from isolated wiring to a unified digital bus (Kousar et al., 2025).

The strengths of CAN were particularly evident in architectures where the main load was generated by short control frames with strict timing requirements (Wang et al., 2024). Priority-based arbitration enabled the transmission of critical messages with high frequency, and the network's logic was well-suited to a distributed set of actuators and sensors. For this reason, CAN maintained a convenient balance between functionality and engineering economy for a long period. It was used in powertrain control, stabilization systems, comfort subsystems, electronic locks, instrument panels, charging, and service diagnostics (Wang et al., 2024). In modern EVs a lot of local inter-unit communication is still localized on CAN, especially in areas where the network load is still not too large, and where the stability and maturity of the network are of advantage to the production process (Kousar et al., 2025). As centralized and zonal architectures have started to gain a foothold, the distributed architecture can no longer be scaled as easily as before, due to the constantly growing number of functions, the amount of telemetry or the increasingly complex inter-unit communication (Mauser & Wagner, 2024).

The shortcomings of CAN are most apparent in the automotive domain of electric vehicles, where wireless software updates, growth in computing nodes and volume of data outrun the in-vehicle automation domain. In the study by Oh et al. (2023) on a gateway between CAN and an automotive computing network, it is stated that CAN bandwidth is limited to 1 Mbit/s. The same work notes that as network traffic grows, bus overload arises, leading to increased delay for low-priority messages and a risk of missing permissible timing windows. An additional limitation is associated with the small payload size. The publication by de Andrade et al. (2023) on the architecture of secure automotive communication states that classical CAN carries up to 8 bytes of payload, whereas CAN with flexible data rate expands this volume to 64 bytes. For large software packages, diagnostic traces, and parameter arrays, this remains insufficient, as the data must be fragmented into many frames, resulting in additional overhead (Douss et al., 2023). The same studies on cybersecurity of automotive networks show that the original CAN architecture lacks built-in cryptographic mechanisms, which, as a result, makes growth in connectivity, operation through fifth-generation networks, and the transition to centralized computing sharply increase the visibility of these weaknesses.

It is against this background that interest in DoIP has intensified as a next-generation diagnostic protocol. Its meaning lies in transferring diagnostic exchange into the Internet Protocol environment over an automotive computing network, which opens access to much higher transmission speed, more convenient routing, and better compatibility with remote software support (Wachter & Kleber, 2022). The key normative foundation here is the ISO 13400 series (ISO, 2025). ISO 13400-2:2025 defines the transport protocol and network services for diagnostic communication over DoIP. The contents of the standard separately identify packet handling over datagram and transmission control protocols, diagnostic messages, connection activity control, and secure communication modes using transport protection. This shows that DoIP is a full part of the high-speed vehicle architecture. Vehicle manufacturers implement DoIP above all because servicing software images, remote diagnostics, reflashing of units, and life-cycle management of software functions require a different network environment, one that is more naturally connected with centralized computing platforms and connected services (Wang et al., 2024).

Table 1. A Comparison of CAN and DoIP in Automotive Networks

Parameter	**CAN**	**DoIP**
Primary role	Core in-vehicle communication bus	Diagnostics over IP
Data type	Short control messages	Diagnostics, reflashing, remote service
Speed	Up to 1 Mbit/s	Significantly higher
Payload	8 bytes. Up to 64 bytes in CAN FD	Suitable for large data packets
Strengths	Reliability, predictability, low cost	High speed, routing, remote access support
Limitations	Low speed, small payload, weak built-in security	More complex network integration
Architectural fit	Distributed systems	Centralized and zonal systems

Compared with diagnostics built on the controller network, diagnostics over Internet Protocol provide a different level of performance. The main advantage is the much higher data transmission speed, which is important when working with large software packages, event logs, calibrations, and service procedures. Under these conditions, the time required to reflash electronic control units is reduced, and installation of over-the-air updates is accelerated. Additional significance lies in the more natural compatibility of such an architecture with cloud platforms, remote monitoring, and centralized management of vehicle software functions. As the transition to a zonal and centralized electronics organization proceeds, this communication environment also becomes more convenient from a scaling standpoint, since it enables handling growing data volumes without the ongoing complexity of local buses. An essential advantage is also the stronger support for contemporary protection tools, since exchange is built on network principles that align more closely with mechanisms such as authentication, encryption, and access control.

At the same time, the controller network will not lose its significance in the near term. Its properties remain well-suited for transmitting short control messages that are sensitive to delay and require stable, repeatable performance over time. In current next-generation architectures, a division of roles is emerging in which high-speed diagnostics and software operations move into the Internet Protocol environment, while local control loops remain with the controller network and its more advanced, flexible data-rate version. Such an approach allows avoiding a sharp break with the already mastered engineering base, preserving compatibility with existing units, and, at the same time, preparing the platform for further centralization of computing. The transition stage is therefore constructed as a hybrid model in which both technologies coexist and complement each other within the general logic of electric vehicle development.

The next regular step in this evolution is the transition from the 12-volt subsystem to the 48-volt subsystem. The traditional 12-volt scheme places increasing limits on vehicle development as the number of energy consumers, actuators, computing modules, and auxiliary electric drives grows. At equal power, a higher voltage allows for lower current, lower conductor losses, and smaller cable cross-section requirements. This directly affects harness mass, packaging convenience, and the system's thermal regime. For electric vehicles, such a solution enables more efficient energy distribution between nodes, reduced structural congestion, and a more rational use of space. As a result, the 48-volt subsystem becomes an important element of the new architecture, in which improvements in data exchange and the power domain develop as interrelated directions of a single technological transformation.

The transition to a new architecture for onboard communication and power supply should be viewed as a phased engineering process in which each decision is preliminarily verified at the function, interface, and risk levels. At the first stage, an initial map of the current platform is formed. For this purpose, all electronic control units, exchange channels, diagnostic procedures, software update routes, and low-voltage power chains are identified. At the same time, it is determined which functions are critical with respect to delay, which require large volumes of data transmission, and which already create network overload or excessive load on the wiring. Such an analysis enables the future architecture to be divided into three layers. The first layer includes local control loops. The second layer includes diagnostic and service exchanges with a large data volume. The third layer contains nodes for which transitioning to a 48-volt subsystem will provide the greatest benefit in terms of mass, thermal regime, and packaging. These include unit reflashing time, network load, cable harness mass, energy losses, and integration complexity.

At the second stage, a transitional architecture is constructed that allows the old and new operating logics to coexist within a single platform. In practical terms, this means implementation of a hybrid scheme. Control messages and parts of the local exchange remain in the controller network, while diagnostics, remote service, and the transmission of large software packages are gradually transferred to the Internet Protocol environment. In parallel, an intermediate 48-volt power domain is created for the most energy-intensive auxiliary nodes. To keep such a transition manageable, it should be carried out across a limited number of pilot domains. The first candidates usually include the telematics unit, the central gateway, the software update unit, and auxiliary electric drives and converters. After that, the interaction logic between the old and new parts of the system is designed. Routing rules, protocol conversion points, reserve operating modes, and rollback mechanisms in case of failure are defined. Such a step reduces integration risk and enables experience accumulation without halting the current production line.

The third stage involves validating and industrializing the solution. Here, the architecture's stability is tested under real load across multiple diagnostic scenarios, during simultaneous software updates and normal control exchanges, and under deviations in temperature, voltage, and electromagnetic compatibility. For the 48-volt subsystem, thermal regimes, converter behavior, current distribution, and the effect on harness layout are assessed separately. In the Internet Protocol environment, connection security, resistance to routing errors, authentication correctness, and the predictability of response time in a mixed network acquire particular importance. After bench testing, the architecture undergoes pilot operation on a limited series of vehicles. At this step, telemetry on failures should be collected, service operation speed, update stability, and the actual reduction in network load. Only after confirmation of the target indicators can the project be transferred into the production cycle.

The implementation roadmap in the next generation of electric vehicles is usually structured in four successive waves. The first wave includes platform audit, selection of pilot functions, and formation of technical requirements. At this stage, the transition must already be assessed against hardware constraints, including the capabilities of existing electronic control units, gateway performance, wiring harness topology, connector availability, thermal margins, and the current limits of the 12-volt network. The second wave covers hybrid integration, in which the new diagnostic environment and the 48-volt domain are introduced in a targeted manner, without abandoning the previous base. In hardware terms, this phase depends on the ability of legacy and new components to coexist within one platform, with particular attention to gateway load, protocol conversion latency, electromagnetic compatibility, packaging space for converters, and protection coordination.

The third wave is devoted to expanding architectural domains, shifting a growing share of service exchange to the high-speed network, and increasing the number of consumers connected to 48 volts. Here, the main limitations are Ethernet switch capacity, harness routing volume, connector pin count, converter thermal load, and the ability of the platform to scale without excessive mass, overheating, or reduced serviceability. The fourth wave completes the transition at the level of platform logic, when the controller network remains above all in local control loops, while diagnostics, software support, and part of the power distribution operate according to the new model. As a result, the transition becomes a manageable program of vehicle renewal grounded in both functional requirements and physical engineering constraints. Figure 1 shows a phased engineering process for transitioning onboard communications and power supply.

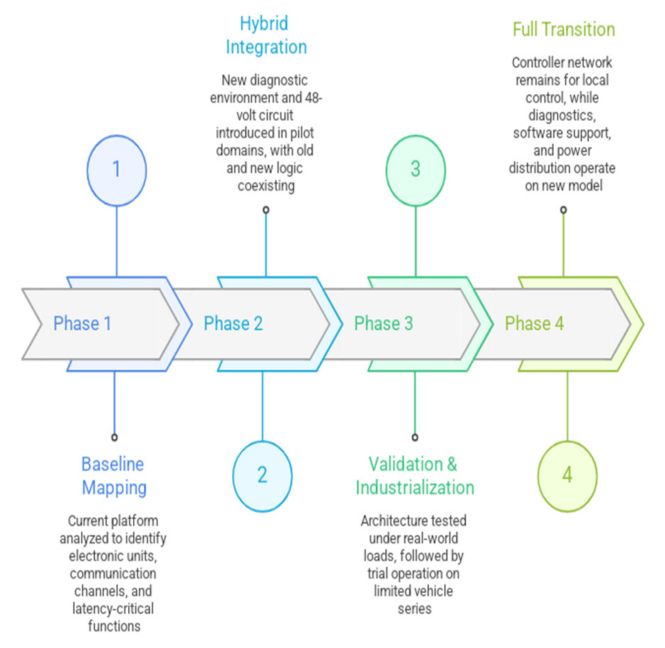

Fig. 1. Phased Engineering Process for Onboard Communications and Power Supply Transition

As the transition to a new architecture of onboard communication and power supply proceeds, the main engineering difficulty lies in coordinating all system elements within a unified requirements framework. The architecture of diagnostics over Internet Protocol must, from the outset, be designed to be resistant to overload, routing errors, connection interruptions, and conflicts between service and control traffic. For this purpose, it is necessary to define in advance domain boundaries, rules for exchange between central and local nodes, redundancy mechanisms, and conditions for a safe return to the previous state in the event of an unsuccessful update or communication disruption. A separate complexity arises from integration with existing electronic control units and transitional gateways, since the new high-speed environment must maintain correct interaction with local control loops, diagnostic procedures, and the vehicle power domain. The higher the degree of centralization of computing, the greater the importance of precision in architectural decisions at an early stage, since even a local error in the distribution of functions can cause cascading problems in network operation, software, and power supply.

For this reason, validation, certification, and integration readiness come to the forefront even before the start of serial implementation. It is the entire chain from the remote request and data transmission to the response of a specific actuator inside the vehicle. Within this framework, it is necessary to confirm interface compatibility, resistance to cyber threats, correctness of software component updates, stability of exchange in a mixed network, and the platform's readiness for industrial production. Certification procedures in such an environment become more complex, as they affect functional safety, electromagnetic compatibility, network security, and the reliability of interaction between hardware and software components. For this reason, end-to-end systems engineering is of great significance, as it views the vehicle as a unified technical environment in which the communication architecture, software support, diagnostic mechanisms, and power subsystem must be developed and verified together. Key engineering requirements for transition to next-generation onboard communication and power architectures are shown in Table 2.

Table 2. Key engineering requirements for transition to next-generation onboard communication and power architectures

Engineering area	**Key requirement**
Architecture	Unified coordination of communication and power
Reliability	Resistance to overloads, routing faults, and connection loss
Integration	Compatibility with legacy ECUs, gateways, and control loops
Risk	Early design errors can cascade across subsystems
Validation	End-to-end testing from remote request to actuator
Certification	Safety, EMC, cybersecurity, and software–hardware reliability
Engineering logic	Joint development of communication, software, diagnostics, and power

From an industrial and economic standpoint, the transition to a new communication and power architecture has a direct effect by reducing cable harness complexity, decreasing wiring volume, and simplifying vehicle assembly. This reduces material consumption, production labor intensity, and the cost of integration of electronic systems at the plant. At the same time, such an architecture better supports scalable software-defined electric vehicle platforms, in which function updating, service expansion, and node unification become part of the manufacturer's long-term strategy. As a result, vehicle manufacturers and component suppliers gain a more stable foundation for serial platform development, bring new solutions to market faster, and strengthen their competitive positions amid the industry's accelerating technological restructuring.

CONCLUSION

The analysis shows that the transition from an onboard communication architecture based on the Controller Area Network bus to Diagnostics over Internet Protocol and 48-volt subsystems represents a regular stage in the evolution of the electric vehicle as a complex digital and power system. Growth in the number of electronic control units, increased telemetry volume, the development of remote diagnostics, over-the-air updates, and connected services create new requirements for bandwidth, scalability, maintainability, and architectural resilience. Under these conditions, the traditional Controller Area Network and the 12-volt subsystem retain significance only for those tasks for which their properties remain engineering-justified.

The study establishes that the most rational form of transition is a hybrid model in which local control loops continue to use the mature and predictable Controller Area Network, while diagnostics, reflashing, remote service, and exchange of large data packets are transferred to the Internet Protocol environment. At the same time, the introduction of the 48-volt subsystem enables reducing current loads, decreasing cable harness mass, improving packaging, and increasing the efficiency of energy distribution between vehicle nodes. This combination of communication and power modernization forms a unified architectural basis for further centralization of computing and the development of software-defined platforms.

Thus, the transition to DoIP and 48-volt systems should be viewed as a systemic engineering program that requires phased implementation, deep validation, and coordination of network, software, and power solutions within a unified requirements framework. Compatibility with existing units, resistance to overloads and routing errors, connection security, correctness of updates, and the platform's readiness for serial production acquire key significance. From an industrial and economic standpoint, such a transformation creates the basis for reducing material and labor costs, increasing platform flexibility, and strengthening the competitiveness of electric vehicle manufacturers and component suppliers.

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