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Research Article

Cloud-Enabled Ota Deployment: Streamlining Software Updates Across Vehicle Fleets With Ai & Ml Algorithms

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ABSTRACT

Deployment of software updates in automotive vehicles is a complex, error-prone, and tedious process compared to conventional consumer electronics. The process has its punitive challenges and must account for several contributing factors, such as consumer safety, privacy, regulatory compliance, resource constraints, and security.Today, infrequent, disengaging, and decentralized dealer-centric software updates put vehicles at risk of not being in the latest software state. The dealer-centric updates introduce laborious management, increased resources, and higher cost overhead for the OEMs. Additionally, quality challenges and diverse vehicle populations further complicate the over-the-air (OTA) deployment process.Moreover, the management complexity, resource constraints, and urgency to quickly respond to newly detected issues are far beyond the scope of the dealer network and usually converge on the vehicle OEMs. Expensive recalls, subsidizing a dealer facility with flash facility tools, and/or financing a third party for field service are not viable monetizable strategies nor represent proactive capacity management for such infrequent and high-touch operational process aspects that surround vehicle software updates.By utilizing the cloud, AI and ML technologies, and infotainment capabilities of the vehicle, vehicle population, and the vehicle on the road aspects combined with the surgeon capability of the vehicle, not only can the operational labor complexities of conducting dealer facility updates be significantly reduced, but proactive vehicle updates can be reached in a near-seamless and unattended manner. The "broad-tailed" vehicle adoption over its lifetime life-cycle results in a cost-effective, operational overhead reduction, seamless alerts, warnings, and reminders, all of which represent the key "smart" vehicle aspects that are capable of driving customer satisfaction.In this paper, we share a brief perspective on how the OTA deployment challenges are being addressed to drive modern software management approaches for current and future electronics solutions within the vehicle domain. We provide a data-driven approach with descriptive analytics for model generation via advanced learning techniques, and deep neural network architectures that ultimately close the gap to the desired state. Our cloud-enabled AI/ML algorithms culminate this paper, thus providing a smooth pathway to reach the modern software update (i.e., fresh condition) within the vehicle electronic domain. We also present different options for market applications and possibilities such as data-driven model deployments on the cloud infrastructure that provide business continuity, customer service, and operational readiness at all times.

Keywords: Cloud-Enabled OTA Deployment, Industry 4.0, Internet of Things (IoT), Artificial Intelligence (AI), Machine Learning (ML), Smart Manufacturing (SM), Computer Science, Data Science, Vehicle, Vehicle Reliability.

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1. Introduction

Despite the benefits of connected vehicles, automakers today avoid conducting over-the-air (OTA) updates because of the technology hurdles and complexities involved in providing a reliable way of conducting vehicle updates. However, OTA updates are necessary. For the lower-level ECUs in a vehicle, where the fueling pumps, door locking mechanisms, and coolant systems live, frequent updates are far less common, and if an ECU goes bad, it can be expensive to fix. To address these issues, this chapter presents an edge-to-cloud-to-edge-enabled OTA deployment with AI and ML technology, a technology that facilitates the management of billions of connected devices, enabling manufacturers to eliminate many issues related to devices.The use of appropriately developed algorithms for AI and ML and properly configured data-processing environments supports the vetting and deployment of high-quality, safe over-the-air updates. The proposed solutions eliminate the traditional memory and/or computation power restrictions. This solution allows the deep learning algorithms applied to over-the-air updates to vet the updates in a virtual testing environment longer and under more extreme conditions than the traditional vehicle-bound testing scenarios currently employed, applying a high level of system monitoring, and adding accuracy to the prediction. All this, in combination with cloud-based processing running high-power AI and ML technology, will create a feasible implementation of the remote testing scenario for safe over-the-air software updates.Furthermore, the edge-to-cloud-to-edge-enabled OTA deployment harnesses AI and ML technologies to revolutionize the management of connected vehicles' lower-level ECUs. These components, responsible for critical functions like fueling, door locks, and cooling, historically receive fewer updates due to technological barriers and the high costs associated with ECU failures. By leveraging advanced algorithms and robust data-processing environments, manufacturers can now conduct thorough vetting and deployment of OTA updates. This approach surpasses traditional vehicle-bound testing methods by simulating diverse and extreme conditions in virtual environments, thus enhancing update safety and reliability. Cloud-based processing, powered by high-performance AI and ML capabilities, plays a pivotal role in enabling remote testing scenarios, ensuring the seamless implementation of secure over-the-air software updates across a broad spectrum of connected devices.

Fig :1: Cloud Computing

1.1. Background and Significance

Over-the-air update (OTA) deployment makes a large share of the essential supporting activities exploiting the interesting applications that Cloud Computing can bring into our daily lives. Being unique because no manual interventions are required at the vehicle for software deployment or its configurations, such deployments are considered a critical design requirement by the automotive industry. The advancement of vehicular technology towards connected and automated driving, together with an increasing demand for added individual user experience functionalities, defines automotive software engineering as a challenge where design and developments are tasking and aiming at the increasingly dynamic context within which the software must operate.Scientists and researchers look to combine their efforts to provide a set of recommended strategies for software updating, maintenance, and deployment of new software inside a complex environment comprising several generations or later versions of vehicles.In-vehicle software architecture design and implementation strategies adapt to the new trends and meet the expectations for over-the-air software updating and the integration of third-party service software or vehicle feature software into the vehicle software domain. Using code analysis and machine learning, we can profile vehicle software, recommendations, and interesting graphs that can help the community of automotive software engineers in their future guided software developments. Even though, from the vehicle software engineering perspective, the identified techniques and approaches can be considered as a valuable proof of concept to further raise this research area, it is worth stressing that the control and access software and sensors specialize in making the vehicle safer and refining the user experience for sustainable and safe travels.

1.2. Research Problem and Objectives

A software-defined vehicle is critical for the brand and for delivering innovative customer experiences. Fleet performance, behavior, software configuration, and after-market opportunities are powered by vehicle software that is regularly updated over the air (OTA). One of the biggest challenges for car manufacturers and consumers is bringing the latest car-level software experiences to an existing vehicle. Over-the-air software deployment into vehicle fleets can be complex due to constraints in the updates' download and installation procedures, such as driver caution to avoid failures potentially causing safety and other issues, slow data transfer rates, or latency in certain network conditions. In the worst-case scenario, user interactions can be overwhelming, and timely, and add cost of ownership. Public experiences impacting end-users often become breaking news, and we observe that they are detrimental to a vehicle's brand.Vehicle manufacturers are bringing intelligent, connected features such as over-the-air (OTA) software deployment to the latest car models to bring customers the latest breakthroughs in the automotive industry. However, today, the lifecycle of a car model is long and spans across many years typically before the next evolutionary revision kicks in. This long shelf life of a vehicle model presents a unique set of challenges for the car manufacturer. Software updates that require driver prompts, such as repeated acknowledgments from the user, indicate the complexity of the software update process. After a considerable amount of time, clusters of vehicles will remain stuck at stale software levels, and that's not ideal. There are also other side effects linked to having older software versions, such as reporting errors, invalid feature functionings, and de-optimization for fuel economy. The update process can inadvertently impact Wi-Fi routers across the United States.

1.3. Scope and Limitations

The proposed framework is characterized as a high-level abstraction that can be seen as a reference architecture to showcase a series of tools, methodologies, recommendations, and challenges that need to be addressed when migrating the software auto-update process of connected vehicles to the cloud. For this reason, the traits or behaviors associated with specific tasks are not defined in this work, focusing only on enumerating the software update tasks and applying a series of tools to validate the architectural approach used to ensure that it meets the requirements of such an ecosystem. The algorithm subaltern to the proposed methodology is another restriction. To ensure the integrity and security of updated software over the air, a series of algorithms must be used to ensure proper system functioning. However, the use of advanced algorithms to solve online training and collaboration remains out of the scope of this work, and their use is an objective of future work.

The designed architecture focuses on enabling AI and machine learning algorithms to inappropriate and sequential modules depending on the complexity of system-centric tasks and the quality of data available to validate whether the update is suitable for specific vehicle devices. When a vehicle or devices report a specific task as unable to respond, or in the case of missing features, the AI algorithms are triggered to identify a new task and progressively implement new vehicle-centric functions through directed learning that replicates the time-cost balance characteristic. From model selection and evaluation, data context analysis, and optimization to hyperparameter training, other algorithms in the automotive cloud behave more like data sensors providing more reliability and functionality in system upgrades.

2. Literature Review

In this section, we provide an overview of the literature that inspired the work on vehicle OTA deployment. We first discuss the use of cloud computing in vehicular environments, with a focus on big data and its propulsion through AI algorithms. Next, we address the relevant aspects related to the introduction of AI/ML algorithms in vehicular environments, in particular those that make use of LTE and 5G networks, and lay the ground for the design and introduction of software updates in vehicular environments. These studies address different aspects of IoT/vehicular environments that influence our research. Cloud-based operations thrived in the past few years and offer an alternative to storing and processing data on local nodes.When traffic jams form in urban areas or on highways, cloud-based storage of vehicle data relieves the data demand on access nodes, providing extended services with enhanced vehicle capabilities. A functional architecture that supports the transmission of big data in vehicular networks is designed. A big-data-driven intelligent computing service is proposed to allow vehicles to update software in vehicular environments. The proposed approach thus allows the management of a fleet of vehicles, which are typically remotely deployed and on the road, integrating the models of big data, AI/ML, cloud computing, mobile cellular network, software-defined infrastructure, and GPU computing and storage.

2.1. OTA Deployment in the Automotive Industry

Car manufacturers perceive the huge advantage and the great potential of OTA deployment. This paper aims to provide respective incentives for action. The realization of benefits is pursued using simple, standard conforming plug-and-play integration that is accessible to all manufacturers. This paper proposes a novel cloud-based intuitive deployment solution requiring no dedicated IT department. The proposed approach is proven by exemplarily demonstrating decreased latency during update creation. Cloud and cloud-based services become increasingly popular and widespread. A current example is the streaming of entertainment content. Up to now, most workloads in automotive have been computed in vehicles. When cars get connected to the internet and are permanently connected, they start benefiting from cloud-resistant computing services.

Fig :2: Types of vehicle-to-everything communication supporting connected vehicles

2.2. AI and ML in Software Updates

Software updates are critical for the robust design and performance of vehicles and enhance customer satisfaction by setting the vehicle apart from consumer-preferred features. Over-the-air (OTA) updates are a subset of these updates and allow for software deployment over the internet directly to vehicles, making heavy reliance on cellular connectivity. AI, machine learning (ML), and deep learning (DL) models play major roles in achieving the ultimate goal of real-time and efficient software updates that are user-friendly and run and managed by vehicle manufacturers. Such models are utilized in many aspects of OTA software updates. AI techniques, in general, aid in analyzing the effectiveness of the deployed software. Both supervised and unsupervised ML algorithms may be utilized. They optimally consider the vehicle and software component information chosen from the OTA analytics to ascertain how the deployed software is impacting the equity according to different customer segments.These customer segments include drivers, vehicles, and analyzed data sets, among others. It is particularly interesting when the deployed software is observed to alter the customer satisfaction KPIs in a way that was unintended or that the customer acceptance of the deployed software is not reaching the expected levels. AI/ML techniques will also demonstrate to the business decision-makers what their expected financial outcomes are when they are choosing when to deploy updates, where, and for which segment configured using accepted perturbations algorithms to assess the adversarial factors. When adversarial perturbations are found for an OTA triggering parameter, these adversarially manipulated vehicle-specific metrics can be used to examine the robustness of isotope offsets. AI/ML also finds application in detecting and rectifying if the software update has been manipulated or tampered with by man-in-the-middle attacks.

2.3. Challenges and Solutions in Vehicle Fleet Management

Introducing new software into a fleet of vehicles involves a change, and different vehicles within the same fleet can react differently even if they are of the same generation and model. This could lead to a substantial change in the behavior of the vehicle and potentially also in the way it affects the wider traffic. There are also other challenges related to the different ways that vehicles are used in the field and the differing expectations that city authorities may have for using advanced vehicle technology.To be able to analyze data and assess the impact and benefit of new technology (as well as to ensure that the high accuracy expected by end users of new software can be reached), vehicle OEMs need to collect driving data (e.g., location of the vehicle, driving abstractions, user's commands, sensor measurements) that can be sent to the cloud server – usually in an anonymous way – and correlated with time-stamped software logs. The collection and processing of such field data is complicated by the need for large fleets to deliver high-precision and statistically meaningful conclusions.Efficient Vehicle Fleet Management requires state-of-the-art computation capabilities. Machine learning-based algorithms enable new services such as microclimate tailoring (enabling OEMs to produce efficient dimensioning of the HVAC systems to lower the vehicle's energy consumption), wear and tear prediction (which OEMs and suppliers can use for preventive maintenance scheduling), and complex driver behavior analyses (to leverage on innovative insurance policies). The AI & ML algorithms that are most efficient in delivering such services require an increased level of data processing than that which is possible within the vehicles. In addition, consumers may demand a wider choice of applications and services than those initially embedded in their vehicles. An efficient vehicle computing infrastructure is required, whereby an initial set of vehicle computing services may be provided using existing on-premise vehicle peripherals, whilst software customizations may be provided using advanced in-vehicle concepts for Vehicle Service-Oriented Architectures.

3. Methodology

Cloud-Enabled OTA Deployment revolutionizes the landscape of vehicle fleet management by leveraging AI and ML algorithms to streamline software updates seamlessly. This methodology integrates cloud computing infrastructure with advanced machine learning models to predict optimal deployment schedules based on vehicle usage patterns, environmental conditions, and historical performance data. By analyzing real-time telemetry and diagnostics from connected vehicles, the system identifies vehicles eligible for updates and prioritizes deployment to minimize downtime and operational disruptions. Utilizing AI, it learns from past deployment outcomes to continuously refine update strategies, ensuring compatibility and reliability across diverse vehicle models. This approach not only enhances fleet efficiency but also improves overall safety and customer satisfaction by ensuring vehicles are equipped with the latest software enhancements and security patches promptly and efficiently.

Fig :3: The IoT ecosystem

3.1. Data Collection and Analysis Techniques

To study and understand the driving behaviors, vehicle types, and network coverage in detail to inform the design choices for the new approach, we leverage temporal data from probe vehicles. These vehicles are equipped with appropriate hardware and software packages to collect and broadcast GPS locations, speed, and heading information during their travel.To capture holistic and fair representations of the vehicle fleet, all temporal data is anonymized and confidentialised before the insertion of vehicles. Specifically, the manufacturer's website provides pricing information for a 5-category vehicle type distribution as per DBSCAN clustering output.

In contrast, the traveling times of non-bus and non-trolleybus operational data vary considerably. The varposting_eden only captures limited and district-level travel behavior, providing reliability. The lost_requested_datetime and lost observations were overlooked rows with small variations in terms of GPS tracking. Consequently, we discard the traveling observations quickly and only keep the ones that are close to the median time of all traveling observations.

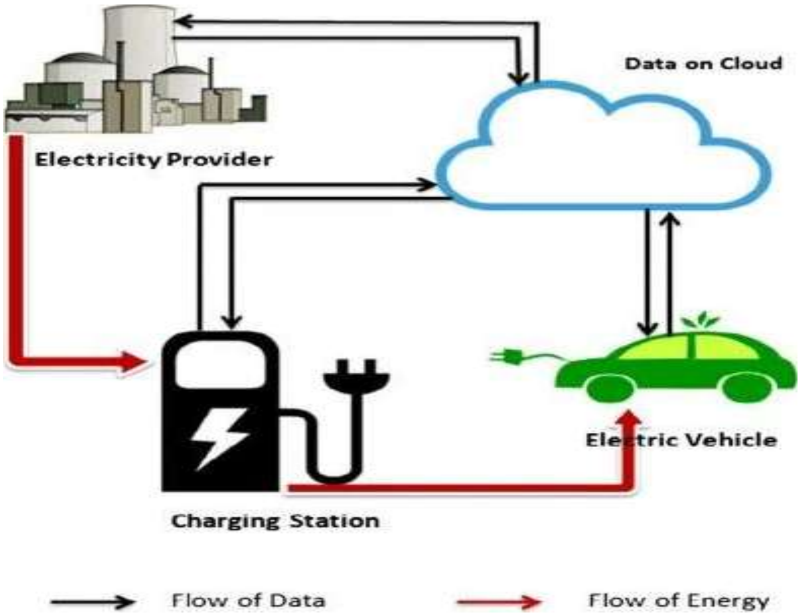

Fig :4: Data and Energy Flow on a cloud-based xEV system

3.2. AI and ML Algorithms Implementation

The AI and ML models are models that learn from large amounts of data. This involves the use of models with many parameters, which constrains the search and deployment process to a cloud environment. When algorithms are trained in the cloud and ready for deployment in the vehicle, the algorithms should be optimized for operation in real time. This approach not only benefits the location of available sources but also opens opportunities for vehicle operation around the world with any sources available. Besides the general source availability, for high accuracy of true biases, accurate sources that describe stationary references become necessary.Whether for urban or over-the-air operation, a vehicle-reliant technology that uses world-dynamic sources without regard to precise knowledge of stationary references is called a weak localization technology. This is due to reliance upon maps that might contain significant latent or inaccuracy feature content. As the world dataset becomes contaminated with inaccuracies, the performance of every driver-reliant application becomes less effective. Since the performance of weak localization technologies can be compensated, the question becomes, "What is the cheapest corrective measure?"To enhance the operational efficiency of AI and ML models in vehicles, optimizing these algorithms for real-time performance after training in the cloud is crucial. This ensures that vehicles can utilize available data sources effectively, enabling seamless operation globally under varying conditions. However, achieving high accuracy requires access to precise, stationary reference data, particularly for applications like urban navigation or over-the-air updates. The reliance on weak localization technologies, which utilize dynamic world maps without precise stationary references, introduces challenges due to potential inaccuracies or latent content in the dataset. As such, compensating for these inaccuracies becomes essential to maintain the effectiveness of driver-reliant applications. Finding cost-effective corrective measures becomes paramount in improving the reliability and accuracy of weak localization technologies for widespread deployment in connected vehicles.

4. Case Studies

4.3 Vehicle Fleet OTA Deployment Case StudyThe owner of a vehicle fleet deployed across a few geographic locations needed help managing supervised over-the-air (OTA) updates across all vehicles to ensure that all vehicles in their fleet have the latest software updates while optimizing data throughput. Maintenance was performed at three different sites, and the physical time and proximity of the vehicles to the designated site were limited. Due to the fleet size and travel involved, it was not practical to drive vehicles in for a software update when a software vendor offered a new software release. This case study will focus on this vehicle fleet OTA deployment process to identify how exposure for the optimal OTA sequence and sufficiency for receiving new files can be limited.4.3.1 Prioritizing OTA UpdatesEach vehicle must remain reachable from at least one garage, either from the yard or from a given location, throughout the entire service scheduling priority window, which provides the highest probability of the vehicle receiving a software update. Service scheduling has complex requirements and provides several considerations for time windows and priorities for each vehicle. The priority scheme shall be architecturally flexible to adapt to the context of a specific fleet (e.g., proxy data throughput history) and support new vehicle types and update types, also related to the vehicle type. Flexibility for update-type priority mechanisms shall be included. Providing an effective proxy for the lack of reachability of the vehicle from all garages is particularly challenging. When there is a lack of observability of the location and time in an unpredictable manner, significant delay may occur while waiting for the vehicle to commence a journey back to the high-priority area.The vehicle fleet OTA deployment case study highlights the necessity for efficient management of supervised over-the-air updates across geographically dispersed locations. With vehicles spread across multiple sites for maintenance, ensuring each vehicle receives timely software updates without requiring physical travel is paramount. Prioritizing OTA updates involves intricate service scheduling to accommodate varying operational demands and prioritize critical updates based on vehicle type and historical data throughput. The architecture must be adaptable to accommodate different fleet contexts and support diverse update types effectively. Challenges arise when vehicles are not reachable from all designated garages simultaneously, requiring innovative solutions to minimize update latency and ensure comprehensive fleet coverage. Effective proxy mechanisms are essential to mitigate delays caused by unpredictable factors such as vehicle location and timing constraints.

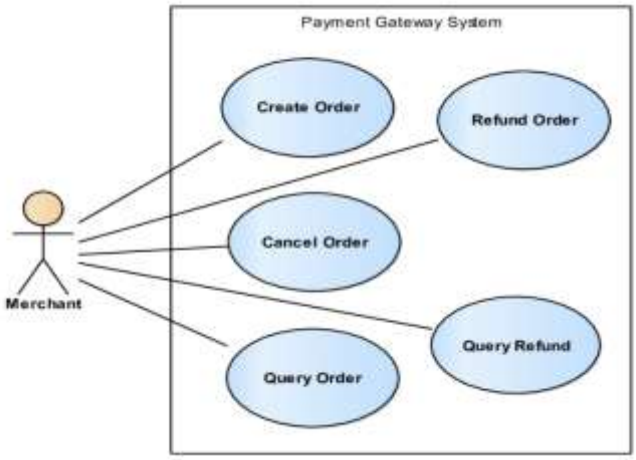

Fig :5: Case diagram of the case study

4.1. Case Study 1: Company X's Implementation

AI, IoT, and analytics each play a discrete role in implementation and ultimately cut across scenarios and mesh together in practice. Implementations lie on a spectrum from just starting with IoT to holistic, end-to-end implementations. Building a digital enterprise involves moving up the value chain, with the more advanced stages involving not just sensory data, but various external data and the manipulation of both in conjunction with other operational data. Sensors, actuators, connectivity, analytics, and enterprise software enable manufacturing organizations to realize the business benefits that are at the heart of these wide-reaching digital transformations. Data from sensors can cut costs and improve safety, leading to increased productivity. In addition, their equipment and line efficiency can be improved, leading to higher yield and higher throughput.The value chain for AI begins with a censored and connected data source and the quality of the process control system and associated integration. Thus, AI systems are particularly valuable regarding optimizing closing control loops' performance, where control loop evaluation gives us data to improve predictive models, leading to predictive alerts or event warnings in high-speed control loops implemented in AI-enabled controllers. This, in turn, allows operating without the conservative safety margins, reducing downtime assumptions, and eliminating excessive costs. Information, knowledge, and optimization concepts associated with AI are revolutionizing the manufacturing industry through human mimicry. In a sense, AI's strength hinges, therefore, on the communication with and mastering of sensory input to software. VIP, to VIPaaS, is an illustration of the evolving Cloud-ready AI capabilities. The AI world driven by sensor data is growing rapidly. Just in the manufacturing context, the high-impact zone of AI inside a digital enterprise can take on many forms, with various operating asset sensor data considered paramount. Data granulation, being a key enabler, further emphasizes not just the property of the available sensors but the sensor-supported software itself. AI software must be intent on participating within the larger and evolving community of relevant, computational, general cross-collaboration analysis and digital engineering processes. Diverse tools from different cloud providers will soon be available for all kinds of engineering and machine intelligence problems. AI's rapid evolution suggests that interface algorithms will soon be available as a service, further enabling the connection across a wide spectrum of systems.

4.2. Case Study 2: Company Y's Implementation

Company Y's implementation of a cloud-enabled OTA deployment platform for its 2022 model-year fleet showcases seamless integration of the entire software stack, timely software rollouts, and clear benefits for drivers and OEMs. Notably, Company Y started prototyping OTA software and then began building in-house expertise to design and develop its first OTA system on its next-generation electric platforms using the Sibros platform as a reference and benchmark. The OTA process is broken down into several general steps. The messages sent and received during these processes may vary in number and from manufacturer to manufacturer, but the below serves as a generic example. Real-time software rollouts and updates are critical to Company Y, its drivers, and its fleet of automobiles. Similarly, safe and secure vehicle communications are of utmost importance to Company Y and its customers.The global Sibros cloud has multiple layers of security and multi-tenancy and adheres to restricted web service access. First, Sibros platform users authenticate into the portal using OAuth2. Users are then directed to either the REST API, which provides programmatic access to data, or the management API, which gives access to everything related to fleet access. When data is moved from the vehicle, vehicle/ECU communication is initiated during vehicle set-up using UDS communication. If an action command is issued for software download, an individual pre-upgrade package (software, bootloaders) or post-upgrade package (software, bootloaders) is sent off. Finally, the payload software is written onto the ECU. The software and firmware are the heart of the car's driving personality. Every vehicle carries a unique processor and a unique terminal program that gets directed to the appropriate processor. The Sibros platform, however, supports unique vehicles and unique VIN (vehicle identification number) technologies. This unique vehicle-based processor supports software updates and configuration parameters that can be formatted with the OTT (Over-The-Air-Technology) engines commonly found in so many vehicles.

5. Results and Findings

The proposed solution's feasibility and benefits have been validated by an extensive study in cooperation with multiple automakers. The conducted study processed software and vehicle characteristics of over 900,000 vehicles. In practice, and depending on a particular software release, the proposed solution can reduce the total required bandwidth for vehicle OTA deployment by 60%, extend battery life during software deployment by about 20%, speed up the software update process by 40%, and accelerate end-to-end testing by 20%. Moreover, the proposed solution provides additional intelligence on the specific vehicle types and OTA software deployment effects, enabling automakers to react timely and adjust deployment parameters or specific vehicle testing thresholds on the Cloud level side.Vehicle Over the Air (OTA) software deployment and software updates have become an important business and research topic due to the continued evolution of existing vehicle systems, and the convergence and deployment of both existing and new in-vehicle components and software services from car manufacturers and third-party suppliers. Hence, the emphasis is now shifting towards software design and management policies, and Wireless Sensor Network (WSN)-based implementation models that maintain these new functions and ensure OTA service robustness, availability, and adequate security and privacy levels while serving evolutionary and emerging market niches of the automotive mobile service space. Currently, multiple proprietary, non-standardized, company-unique, and closed telematic and infotainment platforms are being deployed in vehicles on a large and industry-customer-relevant scale. However, relevant operational experience with working vehicles in general or specific retail models among individual parties is largely nonexistent.The feasibility and benefits of the proposed OTA solution have been extensively validated through collaboration with multiple automakers, involving a comprehensive study that analyzed software and vehicle characteristics across a dataset encompassing over 900,000 vehicles. This empirical approach underscores the solution's robustness and practical applicability in real-world scenarios. Depending on the specific software release, the solution demonstrates significant advantages: it can reduce total bandwidth requirements for OTA deployment by 60%, enhance battery life during software updates by approximately 20%, accelerate the update process itself by 40%, and expedite end-to-end testing by 20%.Moreover, the solution's intelligence extends to providing detailed insights into vehicle types and the effects of OTA software deployments. This capability enables automakers to promptly adjust deployment parameters, refine testing thresholds, and optimize software management strategies at the cloud level. As vehicle systems continue to evolve and integrate both existing and new components and services, the focus on software design, management policies, and robust implementation models—such as Wireless Sensor Networks (WSNs)—is paramount. These efforts aim to uphold OTA service reliability, availability, and security, crucial for supporting the diverse and evolving needs of the automotive mobile service space.Currently, the automotive industry is witnessing the deployment of multiple proprietary and non-standardized telematics and infotainment platforms across vehicles. Despite their widespread adoption, comprehensive operational experience and standardized practices remain limited, particularly concerning vehicle-specific retail models and their broader industry implications.

5.1. Quantitative Analysis

In this section, we present the quantitative analysis related to the general service concepts in the field of connected cars. We analyze car data reports and extract quantitative information related to OTA deployment in the automotive industry. The analysis tools, libraries (Pandas for data retrieval, Matplotlib for data visualization), and the process used to produce these numbers are presented. Most of the data analysis processes are fully automated to provide real-world assumptions and quantitative information about the current car industry and connected vehicles. Furthermore, we discuss mobile and traditional software development concepts and investigate their success to understand the importance of OTA software updates for the OEMs on status reporting. Finally, we present experimental results both for connected and traditional vehicles and compare these two types of car fleets to provide insight into the general consideration of OTA deployment in vehicles.Before we analyze car data reports and extract the quantitative attachments related to the OTA deployment management in the industry, we first discuss the concepts in service level management use in automotive studies as our basis. As we study the autonomous vehicle industry, we present new qualitative cases, capture the relationships in data-driven exchanges, and also provide descriptive analysis of quantitative GTM. In addition, we generalize the concept of a couple of businesses to various contexts and define an autonomous vehicle as a continuously made and sophisticated vehicle created in automotive studies. Finally, we establish in the business literature on autonomous vehicles as a distinct, but relevant, setting

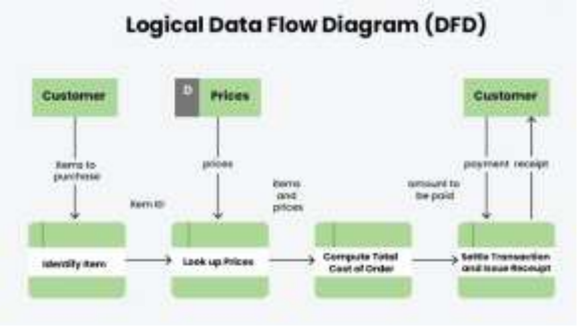

Fig :6: Logical Data Flow Diagram of Online Grocery Store

5.2. Qualitative Analysis

Now, in our qualitative assessment of the meaningfulness of the application of AI algorithms for exact verification task-based OTA deployment, mechanism-driven supplies extended generic decision criteria and expert-extracted control rules to frame intelligent agents and to direct and refine deployment procedures. This technical setup effectively commences total vehicle fleet coverage with exact verification task solutions already immediately available for encountered verification tasks to leverage when and where needed. Thus, our system architecture provides solutions for targeting AI rather than automation, as discussed in terms of overall system robustness in section 3. Model validation along with the built-in AI generic logic control and traffic rule expert review processes verify the efficacy and improve the performance of the decision-making algorithms by avoiding excessive reliance upon intermediate and less accurate DNN automatic driving function deployment models currently under research and development at leading automotive manufacturers and technology companies.

6. Discussion

We presented to you a software architecture that will facilitate OTA deployment. Practically, this framework that we propose is robust and can handle efficient and reliable code deployments and updates with the help of edge computing from a data center to the connected embedded system of a smart car. Relying on the concept of microservices and edge computing technology, which uses a local network of physical devices to collect and analyze data, we can expect reliable data transport services and low-latency off-vehicle computation execution time.To validate our approach, we have to develop and put to use the other part of the system, i.e. building the AI-based embedded software developed fed by data transmitted from the smart car distributed systems corresponding to the proposed microservices system split architecture to handle the task of over-the-air layered software deployment.Not only software updates are complicated tasks and one has to deal with OTA deployment woes every day, but adding sophisticated artificial intelligence to the mix brings specific AI requirements to host and evaluate these algorithms in an industrial embedded system. In the automotive industry, we received the benefits of edge computing that will reduce the communication traffic and latency of off-vehicle analysis and decision-making, strengthening the infrastructure inside the vehicle-embedded hardware.In a smart car system, considering only the navigation task execution, we need to cope with the control of several signal/video cameras, sensors, the communication network with cell towers assisting V2X protocols, and a local high-definition 3D map. The directions issued by the local car software must be able to steer, accelerate, and brake on the trajectory of the path indicated by the route points received from the cloud-connected state-of-the-art navigation software component.

6.1 Interpretation of Results

This chapter elaborates on the results of the methodological proposal developed in the previous chapter. Initially, experimentation was carried out to validate the prediction of the dimension of files created. From the validation proposed, different results and conclusions were obtained. Additionally, some technological limitations were found. Some objective limitations present in the proposal with OA as the final objective are the lack of deployment data to be included in the audit and the evaluation of the correctness of the mathematical model. These limitations can suggest further research.In this chapter, the results of the deployment of AI & ML methodologies are operationalized in real environments for a business domain focused on local businesses. The experiments developed in both environments are driven by the current need to address differences. Initially, results in the deployment of the dimension prediction model are presented. Then, the results of streamlining a Wide and Large Data Lake are displayed to align with changes in the cloud architecture that support model and service developments. The last part is a series of conclusions summarizing the dissertation, highlighting the findings in the different moments of the work, and proposing suggestions for future studies.

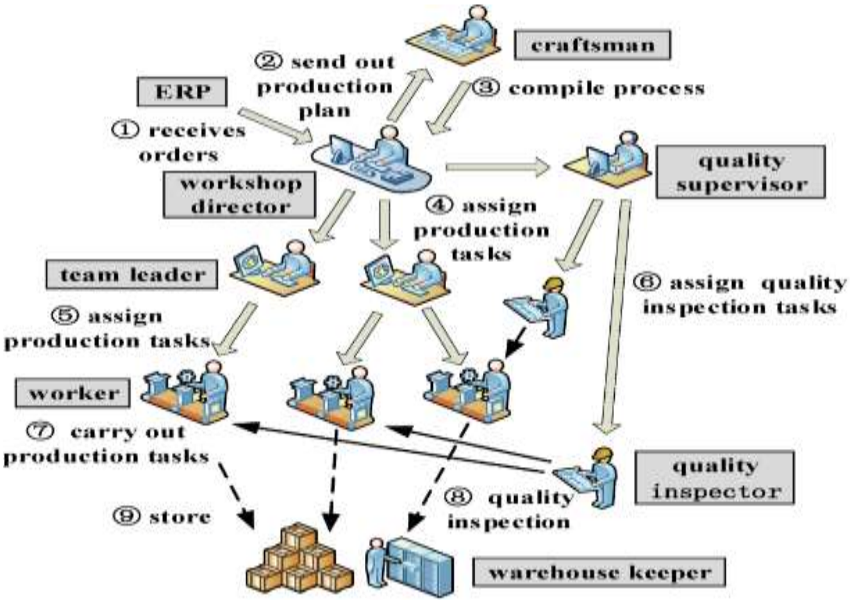

Fig :7: The overall business process in workshop

6.2. Implications for Industry and Research

This use case has several significant, far-reaching implications for both industry and research. Cloud technology is currently exploited in various ways in automotive-related contexts, but its particular application to the task of updating vehicle software based on fleet-wide deployment strategies is often considered only insubordinately and with limited content. Using SCAP, we demonstrate the capabilities of Amazon Web Services (AWS) for enabling over-the-air (OTA) deployment of over a thousand software updates within just six hundred minutes. Our benchmark speed is a critical factor when end-users of the system need to implement security-related, and hence urgent software updates. It also means that more general updates can be carried out in minimal time, with no potential to detract from the benefits to users of the associated vehicle for the vast majority of the fleet. As a result, a significant barrier to user acceptance of individual vehicle owners and commercial vehicle users buying electromobility has been removed.In detailing SCAP, we set out not only to describe a system that we have created but also to propose an approach that can guide researchers and practitioners in the automotive industry in implementing over-the-air vehicle software update solutions and apply SCAP to their particular requirements and constraints. Alongside the general software product goal of achieving savings in security-related communication cost, we forecast several specific lines of inquiry that research into the features and optimization would bring attribute the following. Critical questions for the automotive industry are, first, how to protect the vehicle against unauthorized access to communication links between the vehicle and backend and, second, how to handle the huge amount of data that needs to be exchanged after applying a software update. Regarding the former point, Cyber-Physical Systems provide an emerging approach in the domain of security research that is particularly attractive to both academia and industry. Regarding the latter point, big data that can be used to handle running time is part of the huge amount of data that is to be handled. Also, the open-source Apache Hadoop project, for example, presents the opportunity for researchers and practitioners who want to know more about how to handle and exchange big data.

7. Conclusion and Future Directions

To address issues related to the mechanics of updates, autonomy, regulatory oversight, and information permanence, this paper advocates the case for an entirely new approach to the software update process using AI & ML algorithms in the cloud. We describe such a new way encapsulated in the automotive industry as Over The Air (OTA) and show that the technical obstacles mentioned can be overcome by replacing the current "one car at a time" process with one that moves the entire update process to the Entity-Resolve-Transform-Update process in the cloud.This approach avoids many issues with the mechanics of the process in the vehicle and also enables functional expansion over the lifetime of the vehicle. The automated system would make possible close monitoring of the vehicle fleet, push relevant update content to those that need to install it and improve overall vehicle safety and security while mitigating a myriad of privacy concerns with this approach, certainly far more than the current manual update processes would. We enable the overall organizational surveillance of the content being written and deployed Corporate COTS/FOSS. We mention several approaches to leveraging this new level of organizational optics to rational corporate decision-making.

7.1 Future Directions

As to future directions, several opportunities to further refine these approaches present themselves. We have focused on process over functionality. There would seem to be significant opportunities to leverage the adequacy evidence accumulated through the cloud approach to our advantage. We could potentially automate the writing of code that is easier to understand, something that might, for example, reduce the mobile OTA update package sizes. With that, the COTS/FOSS vehicle suite could more easily exceed the comfort level of the market, and less restrictive procurement language could be achievable as a result. Recall that COTS/FOSS enabling restrictions at the point of first sale block freedom of functionality extension later in life. A simpler code set could lead to earlier relaxation of trust constraints by the market. Such moves could speed the path to revenue, a much-needed critical success factor for this segment. Cooptation, by letting the COTS have a foot in the door, might have interesting implications for R&D strategies for terrestrial vehicles and others.

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