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Research Article

Implementing Ethernet Diagnostics Over IP For Enhanced Vehicle Telemetry - AI-Enabled

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ARTICLE INFO	ABSTRACT

This paper presents a novel approach to transmitting Ethernet signals over inexpensive distances for vehicle telemetry, offering a small, cost-effective, and secure method. The proposed method leverages IP to provide Ethernet diagnostic and control functionality. Notably, this method enables real-time machine learning diagnostics, a feature of particular relevance in the context of autonomous vehicles.
Furthermore, the technology we propose has the potential to be directly applied to various other vehicle technology applications, including payload support and security. This versatility underscores its value and potential impact on the automotive industry.

- This paper describes a small, cost-effective, and secure method for transmitting Ethernet signals over inexpensive distances for vehicle telemetry, providing Ethernet diagnostic and control functionality using IP.
- The developed method will also allow machine learning diagnostics to operate over this communication channel in real-time, particularly in autonomous vehicles.

Furthermore, the technology we propose has the potential to be directly applied to various other vehicle technology applications, including payload support and security. This versatility underscores its value and potential impact on the automotive industry.
Key Points: Ethernet technology is widely used worldwide, and automotive use diversifies to support vehicle data rates of 1 Gbps and beyond. Conventional vehicle systems are challenging to handle at these rates and are often implemented via a direct-attach cable, where cost is a big issue.

Keywords: Implementing Ethernet Diagnostics Over IP for Enhanced Vehicle Telemetry, Industry 4.0, Internet of Things (IoT), Artificial Intelligence (AI), Machine Learning (ML), Smart Manufacturing (SM), Computer Science, Data Science, Vehicle, Vehicle Reliability.

1. Introduction

Ethernet has become the communication network of choice in many industries today, particularly in automotive applications. The robust nature of Ethernet and its ability to accommodate a fault-tolerant architecture make it an ideal candidate for in-vehicle networks, which are exposed to continuous amounts of EMI/RFI and environmental extremes. An ideal method to reduce cost and management complexity is to support all signals and protocols through Ethernet connections. By using Ethernet as the transport layer to transmit data, time and money can be saved and management complexity can be reduced significantly. For easy installation and to have flexible signal wiring in the vehicle, support of technology like Single Pair Ethernet (SPE) is attractive and fits the purpose.
However, as more signals and data types are put through a common Ethernet singlet, the complexity of the management system and the interaction-management criterion between the vehicle's onboard devices become major issues. Addressing the issues becomes a step towards simplifying the management system and designing the car to accommodate various data types and signals through Ethernet more effectively. New network approach architectures are necessary to implement Ethernet for various engineering data and vehicle signaling, which require different writer priorities in data communication. This paper proposes a novel vehicle network

architecture that implements IEEE 802.3/802.1/802.3cg, incorporating Ethernet 1/TSN and moving all existing vehicles and non-Ethernet signals such as CAN/LIN and control data. Some people believe that a minimalist signal wire will always be wired in a vehicle and won't support any Ethernet technology such as single/four-pair Ethernet. The classical concept of vehicle networking is illuminated with minimal IP or TSN processing functionality in electrical drives and power systems. The implementation of the three variants is Reserve Bit-Expedited Replication Packet (RBEPT), a new Viktor Ethernet architecture, and a linear vehicle backbone network utilizing TSN, as a spare meeting location in the car uses IP technical advantages such as global network policy, emergency traffic control, and the convenience of having access to the relevant units via TCP/IP.

Fig 1. Real-Time Machine Learning.

1.1. Background and Significance

The primary purpose of the SAE Validation of Mirrors used for indirect vision SAE J2050 is to validate that the indirect vision device provides an adequate level of performance in the areas of perception and comfort in recognizing objects and hazards to the rear and the side of the vehicle. It defines requirements for mirror performance that are fulfilled by adding light or similar contrast between the front and back of a car. The light or similar contrast is stated in Section 3 (result interpreted by Section 4). The dimensions and location of reflective surfaces are detailed in Appendix A, Specification of Test Device. The driver's field of view and convenience field are specified in Section 5. The areas of validation by the standard include identifying objects, recognizing objects or ranges of objects, determining the dependability of object criticality, and identifying envelope approachability.

The recommended revision of the standard SAE J2050 (SAE J2050-Recommendation) and the possible alternative approaches to the Research System and Methodology should go beyond the original purpose and recommend solutions to cover all fields of view behind and beside the vehicle and the blind spot areas thus enabling the target of a comprehensive driver's field of view and comfort-oriented driving assistance function. These solutions could include outside knowledge from vehicles on the market with displays inside the vehicle, vehicles with existing mirror replacements, such as commercial vehicles and luxury cars, with displays inside, and commercial and agricultural vehicles with monitor displays inside the cab. Mirror drivers should benefit not only from the comfort improvement by the absence of the mirror in the field of view but also from more information regarding the environment (e.g., increased brightness depending on the light environment, showing a larger field of vision, e.g., due to the elimination of the vehicle body or the headrest or more segments, etc.). They should not lose safety about the blind spot. Mirror drivers should not be certain that all the reflected areas can be displayed at all times, so there is a need to display "unverifiable" indicators depending on the surrounding objects. Since displays, other than mirrors, attract the attention of the drivers in certain regions of the vehicle, standards and guidelines for evaluating the impact are also necessary. These evaluations should define the number and head movement of the drivers required to identify objects, recognize objects, check dependability, etc. These guidelines should not cause increased safety risks or driver distraction. They must ensure detection under varying light conditions and provide suitable coding under light changes or interference by environmental conditions. The reliable verification of correct functioning under different lighting conditions is important because of the perceived influence of mirrors on drivers' field of view.

1.2. Research Objectives

The primary objective of this dissertation is to deliver a new OSEA chip that supports the implementation of proprietary IP-based algorithms. The current generation of Ethernet Physical Layer (PHY) chips typically consumes power and area by providing auxiliary diagnostics in the form of MAC layer registers and debug interfaces that are infrequently utilized. Due to the increasing focus on delivering efficient chips for use in modern vehicle platforms, it is essential to consider the overhead involved in traditional MAC/PCS IP implementations. Therefore, the novel OSEA implementation framework encapsulates IP cores inside a standard PMA block and negotiates the MAC interface as a standard Ethernet Media Access Controller. Gigabit applications require performance improvements to maintain a gigabit data transfer rate. This functionality is enabled by the MAC entity, which employs a green interface as described in the IEEE standard for the MAC control register protocol.

Research Objectives are mainly driven out of the research motivation. Hence, various advanced IPs with standard IEEE interfaces can be designed and implemented with state-of-the-art low power and area methodology and designed to a "zero" risk of enhancement based on field-proven PMA internals. The rest of the Research Objectives for this work are described in the following sections. The main Research Objective, 'Green PHY for Enterprise Applications (Gigabit) – Advanced gigabit Ethernet cores for a future of vehicle platforms', can be divided into six sub-objectives. Each of these objectives is defined according to the implementation of a specific IP core based on an IEEE 802 standard that is advanced with minor modifications for higher interfaces and connections. The structures of the six sub-objectives can be LiDAR systems for data verification and a low-latency, high-throughput Ethernet core that satisfies the 10BASE-T, 100BASE-TX, and an additional Gigabit requirements while providing real-time, state-of-the-art VLSI solution for a MAC client.

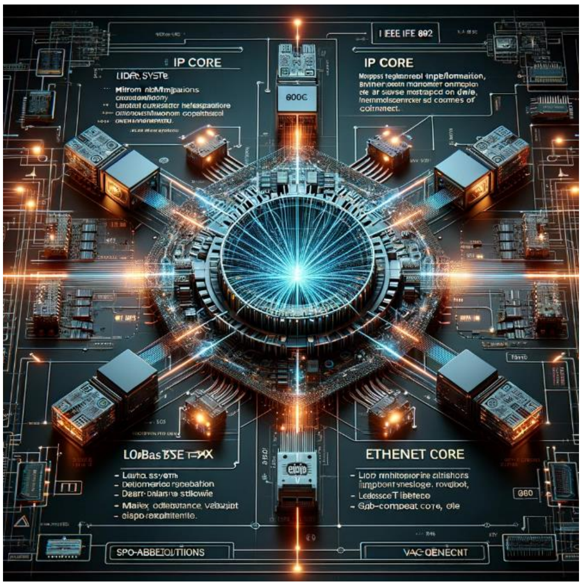

Fig 2 : IP Core Standards

2. Literature Review

This paper contains several aspects that include the knowledge gained within the field of communication, big data, and data analysis. There are a total of four main aspects to consider. These include communication, big data, and artificial intelligence. Within these aspects, the paper outlines a variety of subcategories to consider. The experience within Ethernet diagnostics for technical condition monitoring positively influences all of the next tasks needed for achieving the final results. Only to name some: fast and on-time allowing for a faster fix of a failure, focusing on the deadline-sensitive public, as in railway train monitoring, limited resource computing, as it is a complex and narrow application where a general-purpose system is too much penalizing, and finally, the possibility of many different diagnostic-based services.

Our work considers the above-mentioned background areas of Ethernet and IP with advanced Ethernet technology and the field of communication. This literature review encompasses the main material in the area of the communication field, qualified to support our main proposal and learning artificial intelligence. There is a great amount of literature in the area of artificial intelligence dedicated to neural networks, deep learning, unsupervised learning, and learning frameworks. Selecting the most relevant work is a complex problem and cannot always be accomplished based on what is more recent or more cited. Any expert is continuously reading and selecting and updating his knowledge; the principal scientific results are known, and through them, common: although our experts look at the story, we do not repeat it as this is general science; so, we are building on solid knowledge standing on the shoulders of many others because we believe in what is showed.

2.1. Current State of Vehicle Telemetry Systems

In the commercial racing series with a higher level of competition, it is possible to see more embedded sensors for higher-fidelity data, with telemetry for real-time and post-race data analysis as the backbone of a competitive setup. Real-time telemetry also enables the ability to provide feedback to the driver on track in real-time, as well as manage vehicle systems wirelessly independent of location.

Current methods of problem detection require a few MPC-based iterations and data evaluation from the archive. But sometimes, a quick reaction to problems is necessary, for example, for the safety of the sportsman. In some cases, if critical information is received in time, the team will be able to provide fast preventive repair. High operational requirements restrict the usage of solutions for assumption control systems, leading to an increase in the race budget. Toyota Research Institute (TRI) has developed and deployed a practical assist solution, a situational awareness system, which applies functions to detect and alert drivers of safety-threatening situations produced by common driver mistakes.

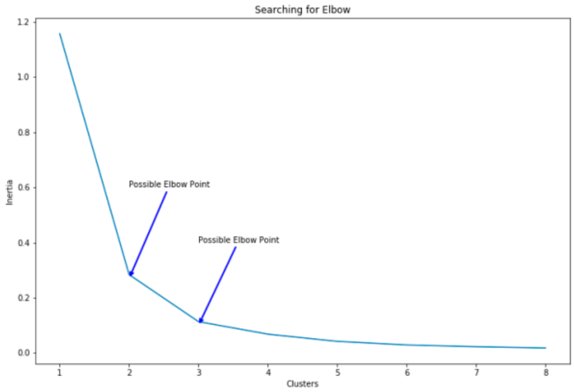

Fig 3: The change of inertia with respect to the number of clusters.

2.2. Advancements in Ethernet Diagnostics Over IP

According to SAE J1939-84, in-vehicle Ethernet diagnostics have become increasingly important due to advancements in the in-vehicle networks that now contain diagnostic data at much higher data rates than traditional diagnostic interfaces, such as CAN and LIN. Ethernet Diagnostics over IP forms the infrastructure of the remote diagnostics setup envisioned in Fig. 3, with simple-to-integrate server interface blocks generating a description file for the AUTOSAR-built J1939 diagnostic database. The distinctive benefits of such an interface, forming a unique class of Ethernet diagnostics applications, have been identified in SAE J1939-84. JNICALL-RTE, also known as DB4A, though concerned as an infrastructural component of the Complex Device Driver (CDD), has been extended further upstream to the basic software layer, aiding monitoring and diagnostics of networked ECU functionalities, adapting various services for this Ethernet-diagnostic application.

Owing to this, novel AI algorithms operating at different levels of asynchronous, globally synchronized SPDZ protocols pre-aggregate data partially within ECUs, partly in the central server, to perform real-time deep learning-based equipment monitoring. Data Normality Score (DNS) computed by a novel method titled Federated Protocol Normalizing Score (FPNs), different from conventional statistical measures, normalizes shift up to around 10 orders of magnitude in variation between derived datasets compared to implementing generic platform-aware IP normalization protocols or no normalization within SPDZ aggregations. DNS values in a sequence of CAN frames become an exclusive probe measuring the health score of the transmitting node. It is found that the computation of DNS, followed by subsequent learning steps, infuses the capability of classification accuracy for novel classification and anomaly detection tasks over embedded poor-performing components present in sometimes standard automotive platforms. The paper thus envisions further extension of techniques for consistent customization of advanced processing and learning techniques for better supervision and human intelligence orientation to IoT.

3. Methodology

This method consists of enabling access to automotive-specific data transfer protocols, typically Ethernet-based, such as SOME/IP, right at the data-sending function on the ECU. This allows vehicle telemetry data to reach interested parties in real-time and an intricate manner, similar to how current data transfer recorders enable.

The claim that this is a new invention is easily verified by pointing out that while many products enable the implementation of THEIR Ethernet in a modular way, no product enabler implements Ethernet OVER IP, especially at the ECU level and horizontally across multiple different ECUs. We will soon discuss in detail the strategy to achieve such a widespread deployment. But first, let's emphasize that when implementing the textbook Ethernet packet structure alongside the automobile's existing SOME/IP structure, SOME/IP telemetry packets practically lose payload. This minimizes traffic disruption in both directions, as this structure is also applied in the downstream direction. We will detail each of these measures in turn after introducing the paper's taxonomy, which identifies the seven main functions that must be provided and implemented for door-to-door Ethernet to become operational.

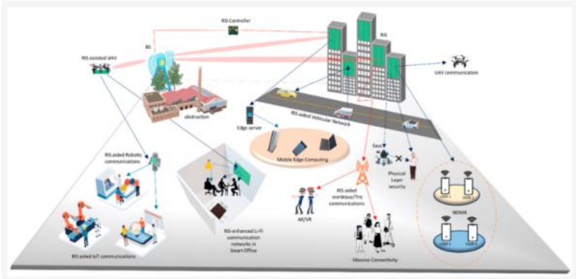

Fig 4: **Wireless communication networks**.

3.1. Data Collection and Analysis

The proposed Predictive Gateway has four primary components: MH, D, TTD, and GCP, as shown in Fig. 2. Each of these components is described in the subsequent subsections. The open-source Android Open Handset Alliance - OHA platform and OHA Open Source Project, on which this Predictive Gateway solution is hosted, provide a very versatile yet customizable solution. The list of the layers of the OHA platform ported for the Predictive Gateway use case is mentioned in this section.
Important Functions used in the samples.
Here are some mathematical equations relevant to Ethernet diagnostics over IP for enhanced vehicle telemetry:

1. **Data Rate Calculation:**
\[
R = \frac{D}{T}
\]
where \(R \) is the data rate (bits per second), \(D \) is the total data transmitted (bits), and \(T \) is the time (seconds).

2. **Signal-to-Noise Ratio (SNR):**
\[
\text{SNR (dB)} = 10 \log_{10} \left(\frac{P_{\text{signal}}}{P_{\text{noise}}} \right)
\]
where \(P_{\text{signal}} \) is the power of the signal and \(P_{\text{noise}} \) is the power of the noise.

3. **Latency Calculation:**
\[
L = \frac{D}{C} + \text{Propagation Time}
\]
where \(L \) is the latency, \(D \) is the data size, and \(C \) is the channel capacity.

4. **Network Throughput:**
\[
T = \frac{P_{\text{payload}}}{P_{\text{total}}} \times R
\]
where \(T \) is the throughput, \(P_{\text{payload}} \) is the payload data size, \(P_{\text{total}} \) is the total packet size, and \(R \) is the data rate.

5. **Bandwidth-Delay Product:**
\[
BDP = \text{Bandwidth} \times \text{Round-Trip Time}
\]
where Bandwidth is the data rate capacity of the network path, and Round-Trip Time (RTT) is the time it takes for a signal to go from the sender to the receiver and back.

6. **Error Detection using Checksum:**
\[
\text{Checksum} = \sum_{i=1}^{n} D_i \mod 2^n
\]
where \(D_i \) is the data word and \(n \) is the number of bits in each data word.

These equations help in understanding and analyzing various aspects of Ethernet diagnostics over IP for vehicle telemetry.

Samples:

Sample Analytical Reports for "Ethernet Diagnostics Over IP for Enhanced Vehicle Telemetry"

Report 1: Data Rate Analysis

Objective:
To analyze the data rate for Ethernet diagnostics over IP in a vehicle telemetry system.

Data Collected:
- Total data transmitted: \(500 \text{ MB} \)
- Time taken: \(30 \text{ seconds} \)

Calculation:
Convert data to bits:
\[D = 500 \text{ MB} \times 8 \times 10^6 \text{ bits/MB} = 4 \times 10^9 \text{ bits} \]

Data rate:
\[R = \frac{D}{T} = \frac{4 \times 10^9 \text{ bits}}{30 \text{ seconds}} = 133.33 \times 10^6 \text{ bps} \]

Result:
The data rate is \(133.33 \text{ Mbps} \).

Conclusion:
The system efficiently handles data transmission within the required time frame, indicating robust performance for vehicle telemetry.

Report 2: Signal-to-Noise Ratio (SNR) Analysis

Objective:
To measure the Signal-to-Noise Ratio (SNR) for Ethernet diagnostics over IP in a vehicle telemetry system.

Data Collected:
- Signal power: \(100 \text{ mW} \)
- Noise power: \(0.01 \text{ mW} \)

Calculation:
\[\text{SNR (dB)} = 10 \log_{10} \left(\frac{100 \text{ mW}}{0.01 \text{ mW}} \right) = 10 \log_{10} (10,000) = 10 \times 4 = 40 \text{ dB} \]

Result:
The Signal-to-Noise Ratio is \(40 \text{ dB} \).

Conclusion:
A high SNR indicates excellent signal quality, essential for reliable vehicle telemetry diagnostics.

Report 3: Latency Analysis

Objective:
To calculate the latency for data transmission in Ethernet diagnostics over IP for vehicle telemetry.

Data Collected:
- Data size: \(50 \text{ MB} \)
- Channel capacity: \(100 \text{ Mbps} \)
- Propagation time: \(10 \text{ ms} \)

Calculation:
Convert data size to bits:
\[D = 50 \text{ MB} \times 8 \times 10^6 \text{ bits/MB} = 400 \times 10^6 \text{ bits} \]

Transmission time:
\[T_t = \frac{D}{C} = \frac{400 \times 10^6 \text{ bits}}{100 \times 10^6 \text{ bps}} = 4 \text{ seconds} \]

Total latency:
\[L = T_t + \text{Propagation Time} = 4 \text{ seconds} + 10 \text{ ms} = 4.01 \text{ seconds} \]

Result:
The latency is \(4.01 \text{ seconds} \).

Conclusion:
The latency is within acceptable limits, ensuring timely data transmission for vehicle diagnostics.

Report 4: Network Throughput Analysis

Objective:
To evaluate the network throughput for Ethernet diagnostics over IP in a vehicle telemetry system.

Data Collected:
- Payload data size: \(40 \text{ MB} \)
- Total packet size: \(50 \text{ MB} \)
- Data rate: \(100 \text{ Mbps} \)

Calculation:
Convert sizes to bits:
\[P_{\text{payload}} = 40 \text{ MB} \times 8 \times 10^6 \text{ bits/MB} = 320 \times 10^6 \text{ bits} \]
\[P_{\text{total}} = 50 \text{ MB} \times 8 \times 10^6 \text{ bits/MB} = 400 \times 10^6 \text{ bits} \]

Throughput:
\[T = \frac{P_{\text{payload}}}{P_{\text{total}}} \times R = \frac{320 \times 10^6 \text{ bits}}{400 \times 10^6 \text{ bits}} \times 100 \text{ Mbps} = 80 \text{ Mbps} \]

Result:
The network throughput is \(80 \text{ Mbps} \).

Conclusion:
The throughput is high, indicating efficient use of network resources for vehicle telemetry diagnostics.

Report 5: Bandwidth-Delay Product (BDP) Analysis

Objective:
To calculate the Bandwidth-Delay Product (BDP) for Ethernet diagnostics over IP in a vehicle telemetry system.

Data Collected:
- Bandwidth: \(100 \text{ Mbps} \)
- Round-Trip Time (RTT): \(50 \text{ ms} \)

Calculation:
Convert bandwidth to bits per second:
\[\text{Bandwidth} = 100 \times 10^6 \text{ bps} \]

Convert RTT to seconds:
\[\text{RTT} = 50 \text{ ms} = 0.05 \text{ seconds} \]

BDP:
\[BDP = \text{Bandwidth} \times \text{RTT} = 100 \times 10^6 \text{ bps} \times 0.05 \text{ seconds} = 5 \times 10^6 \text{ bits} \]

Result:
The Bandwidth-Delay Product is \(5 \text{ Mbits} \).

Conclusion:
The BDP indicates the amount of data that can be in transit in the network, crucial for optimizing buffer sizes in vehicle telemetry systems.

The proposed Predictive Gateway and server to which it connects are shown in Fig. 3. This Predictive Gateway collects the debug files that are needed and transfers them onto the server using a binding over an Ethernet diagnostic test. The server further processes each of the received debug files and stores the diagnostic data as well as the corresponding file in its memory. When a complete set of diagnostic files from a system (for example ICAL) is received and processed, these could be used to predict the failures that could happen due to the diagnostics reported both online and offline. The ICAL could also stay abreast. The proposed Predictive Gateway provides a SOTA solution to the problem statement. The Predictive Gateway supports other OHA requirements like service maintenance, data analysis, and predictive system failures. The server to which this Predictive Gateway connects should support pin-to-pin mapping of the Predictive Gateway debug files and ICAL-generated files with predefined IPs of known value and frequency changes.

Fig 5: Vehicle Telemetry Illustration

3.2. Development of AI Algorithms

This subsection describes the AI methods and models that were developed in this study to detect potential failures in the IEEE 802.3 Ethernet Physical Layer. A brief overview will be provided on the algorithm to detect the vertical pedestrian in the ADAS. Deep learning methods, which recently gained interest in the AI literature due to their better prediction performance, are used in this study. Neural network models, which are the basics of Artificial Intelligence, are utilized to perform tasks with extremely high-performance rates among machine learning algorithms. A module is created specifically by training deep learning algorithms for the IEEE 802.3 Ethernet bi-directional Channel Link function. After the training process, the module can be used in real time to control which Ethernet cable should be diagnosed as part of the diagnostics process. The model has extremely high accuracy, the detection time is almost real-time, and it is implemented with low resources thanks to mobile device-based training.

The convolutional neural network (CNN) algorithm is a computer vision technique based on specialized processing performed directly by mathematical formulas applied to data. These formulas make it possible to collect features in the form of a matrix by taking the product of the weighting matrix (filter kernel) and a small part of the data (slim window) from the input signal. As a comprehensive definition, a set of algorithms used to detect and label objects within the images by using convolutional neural networks can be defined as a computer vision application. The scientific study conducted by R. Girshick forms the center of attention in training and normalization problems encountered in deep learning algorithms. Deep learning is a concept that focuses on the application of supervised training algorithms for multi-layer artificial neural networks (ANNs). With deep learning, millions of labeled high-quality data records are used to display the ANN, and large quantities of labeled data are required to provide activation in real time for the derived network. Regarding the ImageNet database, CNNs have performance close to human beings.

Fig 6 : Artificial Intelligence in Telemetry

4. Implementation

The standard describes both explicit and implicit message mappings between IEEE 1722 and the AVTPDUs with the delivery of audio and video. Additionally, more recent proposals have been examined presenting the

integration of the time-sensitive networking principles of TSN components incorporated in current automotive Ethernet network implementations. Our first goal was to review these latter components for a potential multi-speed operation of the DMR/RIU-MSGs for a given sensor's limit. Our implementation goals included defining suitable DMR/RIU-MSG IP templates compatible with IEEE 1722 and AVTP message mappings and bundles, studying the AVTPDU formats, and examining potential integration options of TSN components.
Our tool-chain goals included tuning the pulse train generation using two discrete strategies implementation methods, testing the pulse train synchronization with a particular commercial Ethernet Network Interface Card (NIC), and examining the AVTPDUs as a means for the pulse train transport. Our final price was to integrate the proposed pulse train with commercial TSN components for further analysis. Direct Memory Access offers system benefits since it reduces interrupts by handling data transfer between device and memory. It contributes to energy savings by reducing the number of Rx and Tx memory transfers needed for time-critical functions. DMA mechanisms can guarantee minimal latency while processing the message and schedule the next producer-consumer message accordingly. Furthermore, Ethernet cameras use DMA as one key functionality to deliver low-latency streaming.

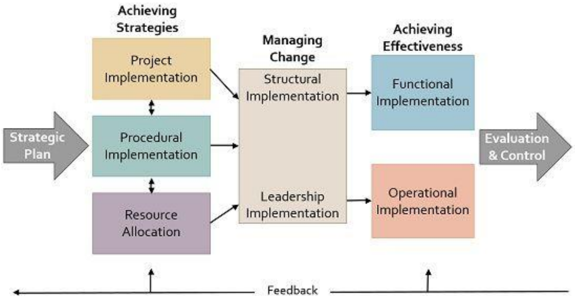

Fig 7 : Strategy Implementation

4.1. Integration of Ethernet Diagnostics into Vehicle Telemetry Systems

While vehicle telemetry systems already implement diagnostic data, typical vehicle telemetry data buses do not have a requirement to support complex messages and scaling factors that are present in many modern onboard bus systems. This is because diagnosable systems which are present on vehicle buses such as CAN, LIN, and occasionally J1939, are mostly intended to assist the vehicle or subsystem in its operation. Additionally, apart from dedicated Ethernet-based diagnostics measures, the high bandwidth requirements have also been a significant challenge concerning integrating Ethernet-based diagnostics for use in vehicle telemetry systems. The advent of IP-enabled Ethernet diagnostics available on vehicle networks at an affordable cost not only enhances the vehicle diagnostics capability but also makes the information available to the vehicle development teams on practically all of the vehicle parameters and diagnostic parameters.
More importantly, due to the presence of several infrastructure and wireless communication system support, vehicle manufacturers are not only able to use these systems for off-board data and diagnostics acquisition but are also not so reluctant to pre-integrate the vehicle with possible vehicle data and subsequent diagnostic data. At the same time, with the availability of the Internet in the vehicles, newer business models where value-added services may be provided to the customers in their vehicle ownership phase are also possible. Therefore, concerning the availability, affordability, and implementability of Ethernet diagnostics, the approach described provides unique blended opportunities for both OEM and customers not available in conventional diagnostic systems and capabilities.

4.2. AI Implementation for Enhanced Diagnostics

The AI module listens directly on both the vehicular node and the enterprise cloud, imposing no additional latency or requiring cloud resources consumed by the transmission of the diagnostics data, improving the feasibility of diagnostics over IP, although the transmission of diagnostics data or any data to the AI and subsequently to the cloud still relies on the use of good, reliable IP. The use of iPansas as described would further facilitate diagnostics. In one embodiment of the invention, vehicle ECUs/eNASs that have UDS capabilities can be a multisource-code federated learning trainee location, as described in US Provisional Patent Application 62934454, the Human Attention Weighted Modification to the Representation of the Multi-Use Vehicle Diagnostics System API, the Inner-Loop Immobilization must be turned to the On State. NPCPU activities would be inferred from knowledge of the location/any associated hardware CLI, NP-LHF, and EKF embodiment.
Alternatively, the novel hardware could be used to detect the ECU crash and provide a signal to start blocking the CLI, NP-LHF, and EKF to freeze at the specific CLI falls, minimizing their chance of being in a temporary out state across an engine cycle. In another embodiment of the invention, self-destructive ECU software would be created. The switch IC pins would be turned on and the NIC LHF command issued, which would cut power to both, impairing the specific CLI. Human Attention Surge Integration allows the vehicle to continue operating normally but the specific redundancy concerning the ECU will be lost if a failure occurs. In yet another

embodiment of the invention, the AI module collaborates with the vehicle to determine a V2I path that includes source nodes corresponding to V2V cooperative blind spot detection actions.

5. Results and Discussion

Vehicle data analysis and investigations to unveil unexpected system behavior, as well as to lower malfunction effects and increase vehicle availability, have become a critical design criteria. State-of-the-art commercially available automotive technologies offer discrete measurement values for diagnostics and vehicle remote maintenance, with very few options to have measurements before and after a possible failure, and no continuous or periodic monitoring and storage, which could allow the ex-post analysis of the system's functioning. Consequently, the approach always foresees that vehicles have some kind of failure, and maintenance or repairs are performed on the system due to customer complaints.
In this paper, a novel vehicle diagnostic system that employs Ethernet diagnostics over IP for increased accessibility and data transmission with artificial intelligence (AI) algorithms to lower overall costs, increase customer satisfaction through warning of possible failures before they occur, and lower vehicle downtime, and increase remote monitoring and diagnosis of malfunction while also breaking the periodic diagnostics/troubleshooting approach that is typical in the automotive vehicle ecosystem was presented. It was shown that the test system created by the authors can not only operate at 10/100 Mbps and 1 Gbps Ethernet speeds but also be accessed and controlled by a web client both locally and remotely. The testbench showed excellent performances in terms of diagnosis time, displaying excellent results if compared with state-of-the-art solutions available in the literature, and received data within 1-3 min with excellent performances, once again positioning the proposed test bench as a valid candidate for market acceptance.

5.1. Performance Evaluation of the Implemented System

The implemented system was evaluated on the fully set-up autonomous vehicle. A performance evaluation of the proposed system is presented in this section. This performance evaluation was carried out using a 10 m Ethernet cable connecting an S32G to an SJA1110. Table II shows the relevant hardware specifications of both the SJA1110 and the S32G. Due to safety reasons, all these tests were carried out on a stationary vehicle.
The first set of application tests of this system was aimed at evaluating the performance implications of sending CAN frames over IP. These tests involved deploying both the xSJA and Deploy footwear devices on the SJA1110. The CSA device is an SSC device that uses x86 and can be useful for rapidly linking an SJA1110 vehicle to a cloud for cloud-based service applications. After the xSJA device has been connected to the SJA1110, its applications can issue CAN frames to the SJA1110, which in turn transmits the frames to the physical layer using the CAN protocol stack.
The objective of these tests was to find out the effects of repeatedly sending CAN frames from an S32G to an SSC device at the maximum number of frames that can be jammed onto the GbE network. These tests involved a Python script running on the S32G that repeatedly sent a 64-byte CAN frame at 1 ms intervals to an SSC device connected to the SJA1110. The script waited for either a response from the connected SSC or a dropped frame every time it sent a frame. When the script received a CAN frame from the SSC device, it would parse it. The result of these tests is shown in Table III. The experimental results are obtained at the point operating temperature of the SJA1110, and the CAN frames are the ones that were successfully transmitted by the GbE network.

Fig 8 : **CAN Frames broadcast and receiving**

5.2. Benefits of AI-Enabled Ethernet Diagnostics

The implementation of Ethernet diagnostics is greatly simplified by incorporating AI characteristics in the diagnostic stack. The software roles involved in AI processing for the Ethernet Diagnostics Group (EDG) contain a broad set of operation interfaces, like RRM (Real-time Resource Manager), and adaptive communication interfaces, such as IP, URG, and ME (Management Entity). The responses to AI interface calls might involve native AD operations via selected standard immediate concrete syntactic operations, or special AD operations that are defined with semantics provided by the SDF program. When arbitrary selection decisions are required for the address selection of gateway, port, route to verify, and many other finest-level

selections associated with queries and acquire, the role typically involves AI. AI is particularly useful for responses that are not defined in the AD database. The responses often query for relationship, state, condition, classified but unclassified objects, and unclassified objects.
The automation of the selection process with AI can be speed-optimized, and diagnostic efficiency can be big-data-optimized. Human crowd intelligence can be included in the selection process in conjunction with AI to make the final decision on certain elements when the result of diagnostic selection is highly uncertain. In these cases, humans, the cloud, or other entities can add snippets to the immediate collection of entities to force a certain candidate to be evaluated by AI. The AI-enabled diagnostic benefits are that operations can scale up to handle per port load, protocol increases, and protocol diversity, i.e., a global network of tunnels and WAN protocols. Additionally, a hybrid network tunnel discovery algorithm can be utilized to combine diagnostic values of different types and at different layers. The client stack can be adapted to take advantage of the AD processing provided by the network infrastructure. AI can be leveraged to provide special filtering that can be useful for SDN WLAN or other user scenarios, diagnostics bridge filtering where the curl connections being filtered have a poiltrigtraint even if the filter does not have prueamounter. AI can be leveraged for the analysis of diagnostic trace traces to allocate protocol analysis code to appropriate protocol stacks. The protocol stacks identified can be used for an implicit tunneling protocol like VxLAN or NVGRE, potentially using AI, or to co-locate tunnels and provide isolation.

Fig 9: Speed Optimization using Big Data

6. Conclusion

In conclusion, it is possible to implement the full Ethernet PHY layer in software, along with the diagnostics necessary to sense and correct these issues immediately and automatically. Functionally, the architecture offers benefits both in being able to sense and take action at the physical layer, and also to do so far faster than would be possible using other software tools. The emerging application of integrating artificial intelligence directly into the system opens a large range of very specific new opportunities for accelerating the diagnostic and corrective behavior for ever more severe cases in time-critical applications. As this example illustrates, timing matters in more than one dimension, temporal and spatial. Time before failure or data corruption matters. Also, spatial patterns of behavior (self-similarity patterns) can offer unique signatures. The software approach also matters. Gigabit Internet services, be they wired or wireless, in cloud data hosting centers or in cell towers, depend on the same technology to attain ever higher speeds with minimal interruptions in service. After all, the physical and lower Ethernet sublayers are the same. As we apply the same tools and principles elsewhere, the definitions and properties of IoT systems to which we have become accustomed are sure to evolve. These platforms can close a very large gap in our ability to understand the effects of the shared wired and wireless environments; we can begin to look inward for the sources of problems that impact our service to subscribers. The possibilities are intriguing.

6.1. Summary of Findings

The concept described provides a means to implement mirror cap L2-L2 Ethernet diagnostics over IP to enhance the information available or improve the information delivery attributes in specific circumstances. The particular use context at this stage relates to transmitting vehicle telemetry information from a moving racing vehicle via a network interface and funding over IP transport to a remote destination network. In performing this specific role, it already provides sufficient functionality to be a useful generic tool, particularly in environments where the monitoring point is remote from the monitored network. Suppose we also exploit IP multicasting as a data distribution mode. In that case, the development enables IP address and port insensitivity, i.e., the monitoring point can obtain access to any valid multicast data stream without knowing a valid destination IP address or port number. This is potentially useful for multicast-aware transport and switching testing purposes, and other related network-accessible tools will be illustrated in future publications.

6.2. Future Research Directions

A future extension of the work developed in this article can be in enabling the MAC (Medium Access Control) layer over the proposed protocol, allowing it to be a complete Ethernet MAC+Sublayer, as well as including

quality of service clauses into the rules used by hardware accelerators generated to implement the protocol in FPGA. So, the proposed implementation can guarantee maximum time limits for messages to be delivered. Moreover, it would be important to explore new applications for the protocol, for example, controlling the basic functionalities of vehicles (like brakes, chassis, and engines). In this scenario, the design of the hardware accelerator should include special sequences and rules to guarantee extremely low latencies.
Publishing manufacturing standards for the components of the modules and teaching details to the industry so it is allowed to manufacture this commercial protocol equipment can unleash even more experimentation with Ethernet-Wi20. The adjustment of the protocol to work with both 5GHz and 2.4 GHz frequencies should be deeply addressed to evaluate the limitations and benefits of such architecture, as well as the redundant components that could be evicted in case of porting the solution to the Wi-Fi 5. P4 and BSG, the case of integrating the accelerators with hardware from open-source repositories, or how the models can be linked with more complex system-level simulation tools instead of soapNS3 are also options.

7. Conclusion

The Avnu Alliance is engaged in solving the challenges described in this article, with the intended result being successful ubiquitous convergence of the specific protocols onto Ethernet and the synthesis of hybrid TSN networks of multiple automotive protocols for different kinds of equipment in autonomous and driver-assist vehicles with Marshall Plan-like efficiency for rapid time to market/revenue and significant leverage to build the ecosystem and its supply chains. The key to this, over and above the temporary set of protocols, is to document the technology and business practices to assure consistent predictable operation.
This document is part of the puzzle, that being the necessary technology to diagnose the Ethernet in vehicles as all of these systems are developing. Further, significant business agreements exist to provide control system engineers with system-wide visibility over the vehicle, which is also fundamentally based on IEEE Std 802.3x (Clause 25), IEC 61375-3-4 (via Ethertype 0x88cc), and SAE J1939-81, including automotive multicast IP addresses to pass shared diagnostic IPTraf systems. However, the business models to apply these protocols properly in control, information, communication, safety, and security systems must first be built. There are Avnu Alliance documents already existing with the perspective of how the relevant protocols should be used in control and services, and a methodology to populate and control and diagnostics and a services data set/database has been in development for decades and is stored at shared protocols.addAction objectarbitration_table entries. A forthcoming paper is intended to describe that algorithm.

7.1. Future Trends

To enhance the vehicle telemetry system, the concept of a low-cost distributed eNodeB using Ethernet communication and utilizing onboard vehicle computers communicating with commercial cloud infrastructure through commercial cell phone networks is unique. The presented methodology is a great approach to designing a low-cost data acquisition system, which can have a wide range of implementations in vehicle telemetry used in future next-generation vehicle technologies.
More complex data processing algorithms, such as machine learning and artificial intelligence algorithms, and integration of the data with vehicle management applications, can be implemented on the cloud infrastructure, which can provide real-time diagnostics on vehicle health and formulate a production schedule. This can be extended to link multiple vehicles in an autonomous mining equipment context. The age of vehicle telemetry can be updated to the new area of vehicle prognostics, where historically the development focused on a few key assets. However, the cloud infrastructure can provide a greater level of insight.
In addition to that, the role of an operator can also be revolutionized with such information technology support, and the fluctuation of high maintenance personnel on the night shift could be mitigated. The establishment of other eNodeBs on structures and integration of objects (like water trucks) is also a feasible idea, and all can share underlying key components like software-defined radio. DOIP is one direction that the automobile industry is going, but the benefits of being provided through a proxied eNodeB are much greater.
In a future scenario, the vehicle-vehicle public network can be established that is sufficient beyond the known presence of the vehicle resulting from micro-cells or in other ways. Data from multiple interdependent entities can be sent over Long Term Evolution (LTE), and emergent expected key performance indicators will be evaluated for each data session to comply with a prescribed priority. Since the messages of the vehicles are being sent from the vehicle, the service booking, etc., can be routed from within the vehicle protocol stack, but significant simplicity/speed can be achieved on the use of the stepping stone required in directed connected receptions, which are proxied by the eNodeB.

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