AUTOSAR: In-vehicle Standardization with Certainty of Operations towards Globalization

P.Sivaram
Assistant Professor, Department of Computer Science and Engineering,
Srinivasa Ramanujan Centre, SASTRA University,
Kumbakonam, Tanjore District,
Tamilnadu, India 612001

P.Rajaram
Student, 2st Year M.E., Department of Computer Science and Engineering,
K.Ramakrishnan College of Technology,
Samayapuram, Trichy District,
Tamilnadu, India 621112

Abstract- In the competitive world, irrespective of vendors of automotive manufacturing, the concept of standardization becomes the key to success in the business as well as providing the quality of service to the customers. Increased and efficient functional capabilities of the vehicle functional domain, plays a major role and that decides the market of any vehicle. The standardization of automotive in-vehicle networks can make all further processes of vehicle in ease of use. In this paper, we provide the comparisons between computer network standardization with in-vehicle network standardization, to prove the existing standards of automotive are being successful for development and the maintenance of in-vehicle network. In near future the standardization of automotive in-vehicle network and its relevant implementation will only occupy the manufacturing.

Keywords – AUTOSAR, Vehicle Functional Domains, In-Vehicle Network Architecture.

I. INTRODUCTION

The standards fixed by the International Standards Organization (ISO) for Open System Interconnection (OSI) model of computer networks are now ruling the computer world. The standards by this ISO committee over OSI, helps the developers, network analysts, hardware manufacturers and all computer network peripheral manufactures to follow one common standard. By accepting these common standards, the Original Equipment Manufacturers (OEMs) of computer network peripherals and network software developers get benefit by means of transparency of standards [1]. During the maintenance of computer or network, these standards are very helpful to fix the problems with in short span of time or to identify the root cause of the problem. The success in the field of computer by OSI initiates the need of standard architecture for in-vehicle electronic control unit (ECU) networks. The global standard platform of automotive electronics network, eliminates the hurdles in the maintenance [9]. The automotive electronics networks are in need of architectural changes to achieve the reliability, performance and cost reduction [10].

An automotive in-vehicle network consists of several domains of operations in it [4]. Each of the domains consists of its own internal control unit for its processing. A device named Electronic Control Unit (ECU) controls these control units in in-vehicle network and which is equipped with microcontroller (MC) [2]. This microcontroller is equivalent to a mini computer and is equipped with its own internal memory, processing capability and it is named as System on Chip (SoC) [2]. In an in-vehicle, the numbers of ECUs are connecting the vehicle functional domains towards centralized and cooperated task completion and in nature they are distributed [4]. The small sort of memory of this MC enables the instructions execution with in the chip itself. This atomic simplicity brings the in-vehicle network to equip with several numbers of ECUs to control in-vehicle functional domains.

This is the right time for vendors of automotive manufacturers and suppliers to involve their manufacturing with global common standard of development. The common architecture based modeling of an automotive and implementing control circuits to coordinate entire functional domains reduces the complexity of interconnecting electronic devices and framing in-vehicle networks. The common architecture based components integration gives the consumers of automotive the choice of spare parts of vendors of their own selection based on interest (with quality and quantity based selection). The common architecture has its own expansion of slots by means of adding new peripherals or technological diffusion in near future; where the limited configured vehicle (basic model of the vehicle: low priced vehicle) consists ports for adding additional sophisticated functionalities. When the sophistication functionalities are needed the vehicle owner can add the functionalities based on his/her financial status. The automotive markets are emerged, with the plug and play approach of common architecture and the diagnostic analysis made simple with easy replacement of malfunctioned component irrespective of hardware or software. The reduced complexity of integration with hardware and software leads the entire system towards plug and play approach and gains the market with consumers' interest.

II. Importance of Standardization

A. Open System Interconnection (OSI) –

The computer network communication is a heterogeneous architecture, where in which various platforms of computers are being connected together to perform various operations of users for intended purpose. The purpose of the task completion using this computer network is common for various platforms. Early computer network consist homogeneous platform and architecture and narrow range usage of computers does not care about the various platform synchronization. The adopted network system model carried has uncertainty in practice and the computer scientists were involved in continuous evaluation [1]. The limited operations and communications are carried out in such networks. The vendors of computer components manufacturing also limited in numbers. The various segregation of layered operation of computer network with OSI model, made the software and hardware vendors to develop their products within the specified standards and they are equipped with various communication protocols.

As per current scenario, worldwide interconnectivity of various computer networks are available. The interconnection of heterogeneous networks provides communication throughout the world without any barrier. This concept of heterogeneous leads the complexity of interconnecting various platforms of computer networks with in a single worldwide computer network. There exists a need of interconnecting all various networks with in one common network with its specific rules and regulations. The heterogeneous computer networks' interoperability is governed by its own architecture, protocols, and standards. The common network architecture and standards considerably reduces the complexity of heterogeneous networks interconnection and provides necessary protocol translations, architecture convergence for the networks involved in communication.

B. AUTOSAR –

In the standardization of in-vehicle network Automotive Open System Architecture (AUTOSAR) converged with its standards and projected itself in to the automotive market since 2003 [3]. At present, many of the vendors belonging to automobile manufacturing are following these common standards of development of their vehicle and projecting them with different implementation for competing in the market. This architecture initializes innovative electronic systems integration on various levels of automotive functional domains. The dependent scientific challenges with clear requirements, technology innovations, and new business models under automotive are met with this architecture [4]. Through standardization, the entire in-vehicle system's complexities get flexible throughout the life of the system; more over the maintenance of reliability of the system with full efficiency also possible.

Various technologies diffusion in global market of automotive manufacturing yield much complexities while maintenance of vehicle, when the vendors are not following a common standard. The increase in computerization of vehicle functional domain activities focuses on common architecture of software development. The layered operations of AUTOSAR bring the entire system's cooperation among the various electronic circuits and provides future enhancement with additional updates [3]. As the result, with the common standard of in-vehicle network communication, the mass production by various vendors will help the consumers of automotive to select their desired vehicle and handling the vehicle with free of stress. The globalization of the automotive field will invoke many innovations on standards, sophisticated functionalities, and a unique transport system development throughout the world. The uniqueness of individual vehicle provides the grouping that with in localization and easy identification with in the global. More over the unique identification of the vehicle in the global transport system provides, the details of the vehicle owner to trace the vehicle whenever needed. In the similar manner of computer identification using Internet Protocol (IP) address, the vehicle's identity is made with unique identifier with in the worldwide transport system.

III. VEHICLE FUNCTIONAL DOMAINS AND IMPORTANCE OF SOFTWARE

A. ECU and Functional Domains –

An in-vehicle ECUs network are grouped together to bring the entire operations and controls of an automotive with the drivers intended control on the vehicle. Instead of single processor, the distributed architecture of microcontroller equipped ECUs network helps the driver and passenger of an automotive in many functional ways. An ECU is a processing element, which gets input from sensors of corresponding functional domain and process with its software instructions and reacts with remedy reactions through actuators. The functional domains of an automotive are given in the Table 1 [4, 9].

Table -1 Functional domains of an automotive

Sl.No.	Functional Domain
1	Power Train domain
2	Chassis domain
3	Body domain
4	Multimedia and Telematics domain
5	Passive/Active Safety domain
6	Diagnostic Domain

The computation process rules the world in all field of expertise and converts the complexity of operations in simple functional operations with easy to use GUI and in which the automotive field is not in exception.

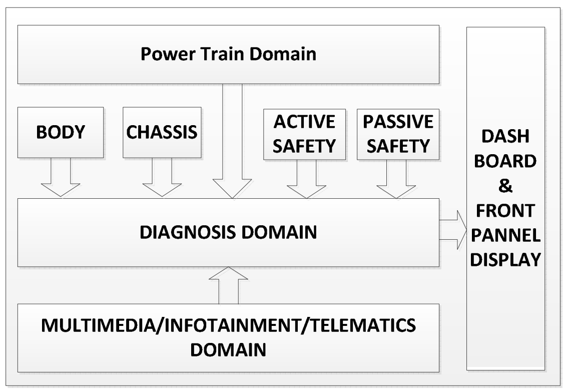

Figure 1. In-Vehicle Functional Domain Block Diagram

Each ECU in in-vehicle network carries specific control, collects input from various sensors of vehicle, processes with its predefined set of instructions, and sends the output to the various actuators of vehicle. This results in computerization of vehicle functional domain operations. The functional domain of an automotive consist various electronic controls of operations such as vehicle traction control, stabilization (motion/breaking) control, in-vehicle body monitoring for active safety (during travel and halt), multimedia/infotainment synchronization, GPS navigation, outside world communication, active/passive safety control, and fault identification/reporting systems. Figure1 provides the blocks of In-vehicle functional domain arrangement in a vehicle.

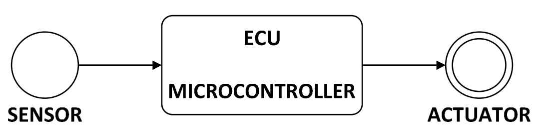

Figure 2. An Electronic Control Unit with sensor and actuator

The communications between varies ECUs available in the networks are responsible for task management, handling complex interrelated operations. Each domain of vehicle is having a single ECU or group of ECUs, according to its nature of operation. A specific functional domain's ECUs are grouped together for task completion purpose, within them (the communication between ECUs happens through message passing). In the same manner, all functional domains are equipped with their own group of ECUs or single ECU for control purpose. Each domain consist of its own group of interconnected ECUs. As for an effective operation of a vehicle is concerned, there is a need of interconnecting all functional domains' networked ECUs. The interconnection of ECUs in a single line leads complexity and vehicle optimization task becomes complex due to the nature of hybrid network integration.

The protocol used for network communication also plays a vital role in integration, where the ECUs are utilizing signals from various sensors and in various forms. The communication from the active safety domain dominates the entire vehicle performance to concentrate towards hard real time messages with restricted time requirements. As for the active safety is concerned, the lives of the passengers are involved and the complete dynamic run of the vehicle system is in need. With an effective and efficient time management, this active safety reduces many risks of the vehicle system. Antilock breaking system (ABS), Electronic Stability Control (ESC) systems are functioning under active safety domain and controlled by specific ECUs. The passive safety domain also play vital role in safe guarding passengers lives during post-accident conditions and airbag system as an example (controlled by a single ECU). Inter-process communication between ECUs within in-vehicle network provides much complexity in integration of all the ECUs and coordinated workflow.

B. ECU and Software Architecture –

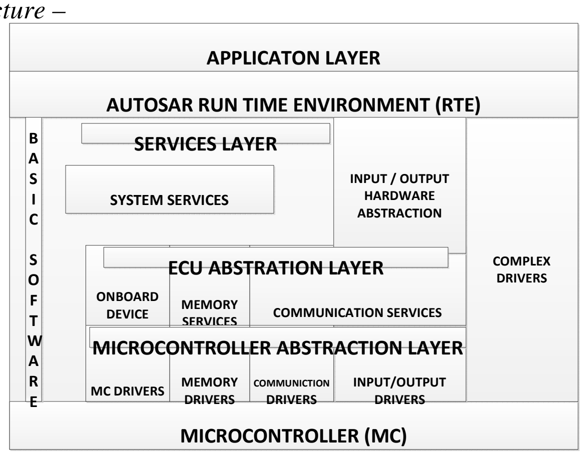

Figure 3. AUTOSAR Layered Software Architecture

The AUTOSAR provides many advantages over these interconnecting complexity and integrity in restrictions. This architecture's layered approach of in-vehicle network development approach gives the foundation for all functional domains' operations with computational ability and distributed ECUs cooperative processing [4]. The concept of common foundation is the AUTOSAR software description, where all functional domain electronic components' specification are described effectively with its ECU level and the API for all ECUs are equipped with centralized operation towards the vehicle performance [5].

The centralized operations of in-vehicle functional domain towards vehicle performance, provide the emerging trend in systematic approach of layered architecture of software development, and is achieved by AUTOSAR [3]. Figure 3, details the AUTOSAR layered software approach. AUTOSAR consist four different components: 1.ECU hardware, 2.Basic Software, 3.AUTOSAR Runtime Environment (RTE), 4.AUTOSAR Software. The layers of AUTOSAR are derived from the components, as for the first component, microcontroller (MC); for the second component, microcontroller abstraction layer, ECU abstraction layer, Services layer, and complex drivers; for the third component RTE (virtual function) layer; for the fourth component, application layer are equipped with this architecture [3]. In this, RTE maps the functional domain requirements with Software Component (SWC) and initializes the work of Basic Software (BSW). As soon as BSW takes its part of work from RTE, RTE leaves the current job submission, and takes care of next functional requirement of the in-vehicle system as per the priority assigned by functional domain description. This fashion of synchronized act upon functional domain operations of ECU, RTE, SWC, and BSW brings the concept of Real Time Systems (RTS) adopted with in-vehicle network operations [3].

AUTOSAR S/W components (set of instructions) are developed individually according to the functionality of the automotive. The size of the component is not limited in nature and defined with restriction. The application requirement and functional descriptions for a particular ECU must meet their standard operation; in such manner they (SWCs) get developed. Each SWC is treated atomic in nature, and have the capability of communicating with networked ECUs. The BSW's three layers of operation reduces the complexity in the integration of microcontroller to the RTE. The microcontroller abstraction layer handles the internal complex drivers operations with all necessary task completion with MC. The ECU abstraction layer consist the external device drivers and it interfaces the MC abstraction layer to the RTE. The services layer takes care of application program task with basic software modules. The layer RTE serves as a communication interface between the application software of various sensors/actuators to the basic software. This layer makes the AUTOSAR software component to integrate independently into ECU. The application layer works with the dashboard front panel and display system (Figure1), which is running with application software and synchronizes the remaining three layers of operation towards effective centralized vehicle performance, and provides better GUI interface to the driver/passenger of the vehicle.

C. Certainty of Operations with Standardized Software Architecture –

The term certainty plays a vital role in engineering operations and expected up to the lifetime of any system. The quality characteristics of any engineering system's components must be high in evaluation, prior and post implementation of the system. The standardization of the automotive system improves the quality in considerable manner and the technical characteristics of the in-vehicle electronic components and their parameters are important while designing an automotive system. An effective selection on technical characteristics of the electronics components and their network communication protocols are providing consistency in operations with standard base architecture [6]. In the place of standard architecture, the AUTOSAR occupies with all its merits in automotive in-vehicle system integration [3].

In in-vehicle functional domain alone, the variables belonging to this is finite in nature and treated within standalone domain. A vehicle's functional domain and its elements are finite set and are defined with in family of set (with their functional domain elements). The vehicle family of set $(\mathcal{F}_V)$ consist members and it is also a set. The set consists various members of the same family.

$$\mathcal{F}_V = \{PT, BD, CH, AS, PS, MT, DS, FD\} \quad (1)$$

In the members are Power Train Domain, Body Domain, Chassis Domain, Active Safety Domain, Passive Safety Domain, Multimedia & Telematics Domain, Diagnosis Domain, and Front Panel Display [3][4][7]. Table 2, provides the detail about the members of vehicle family of set.

Table - 2 Members of Vehicle Family of set

Member	Description
PT	Power Train domain
BD	Body domain
CH	Chassis domain
AS	Active Safety domain
PS	Passive Safety domain
MT	Multimedia and Telematics domain
DS	Diagnostic Domain
FD	Front Panel Display

The index set *I* defines, the properties of the set elements belonging to the family of set [7].

$$I = \{S, A, ECU, SD, HD, FR, PV, TV, TY, AU\} \quad (2)$$

In *I*, the members are Sensor, Actuator, Electronic Control Unit, Software Description, Hardware Description, Functional Requirements, Preset Values, Tolerance Value, Domain Network Topology, and AUTOSAR.

Table - 3 Members of Vehicle Family of set

Member	Description
S	Sensor
A	Actuator
ECU	Electronic Control Unit
SD	Software Description
HD	Hardware Description
FR	Functional Requirement
PV	Preset Value
TV	Tolerance Value
TY	Domain Network Topology
AU	AUTOSAR

The index set members have common properties for all members of $\mathcal{F}_V$ and share equal relations with them. The members of $\mathcal{F}_V$ and their relationship with indices are [3][4][7]:

$$PT = \{PT_S, PT_A, PT_{ECU}, PT_{SD}, PT_{HD}, PT_{FR}, PT_{PV}, PT_{TV}, PT_{TY}, PT_{AU}\} \quad (3)$$

$$BD = \{BD_S, BD_A, BD_{ECU}, BD_{SD}, BD_{HD}, BD_{FR}, BD_{PV}, BD_{TV}, BD_{TY}, BD_{AU}\} \quad (4)$$

$$CH = \{CH_S, CH_A, CH_{ECU}, CH_{SD}, CH_{HD}, CH_{FR}, CH_{PV}, CH_{TV}, CH_{TY}, CH_{AU}\} \quad (5)$$

$$AS = \{AS_S, AS_A, AS_{ECU}, AS_{SD}, AS_{HD}, AS_{FR}, AS_{PV}, AS_{TV}, AS_{TY}, AS_{AU}\} \quad (6)$$

$$PS = \{PS_S, PS_A, PS_{ECU}, PS_{SD}, PS_{HD}, PS_{FR}, PS_{PV}, PS_{TV}, PS_{TY}, PS_{AU}\} \quad (7)$$

$$MT = \{MT_S, MT_A, MT_{ECU}, MT_{SD}, MT_{HD}, MT_{FR}, MT_{PV}, MT_{TV}, MT_{TY}, MT_{AU}\} \quad (8)$$

$$DS = \{DS_S, DS_A, DS_{ECU}, DS_{SD}, DS_{HD}, DS_{FR}, DS_{PV}, DS_{TV}, DS_{TY}, DS_{AU}\} \quad (9)$$

$$FD = \{FD_S, FD_A, FD_{ECU}, FD_{SD}, FD_{HD}, FD_{FR}, FD_{PV}, FD_{TV}, FD_{TY}, FD_{AU}\} \quad (10)$$

When the domain and its variables are finite then the system can be modelled with certainty of operation. Here the system means the vehicle system and the operations are satisfying the certainty with in the life time of the vehicle. Any mechanical system is subjected to wear and tear due to continuous run during production and it's treated as reliability of the vehicle system. The high reliability of the vehicle system leads the system towards certainty.

IV.CONCLUSION

From the traditional hydromechanics Systems, functional domains the operational inefficiency of the vehicle, observed by the driver and passenger in early days is converted with x-by-wire methodologies of electronic control systems. The considerable cost reductions in the in-vehicle network electronic components leads the entire electronic network design towards the standardization and complete integration. The common base of distributed electronic control units in in-vehicle brings the topology with in atomicity, less complexity in implementation and integration. The reduction in complexity of integration of in-vehicle provides the customers and vendors, a tension free maintenance, flexible upgrade of any available additional components. Moreover, the globalized standard architecture of AUTOSAR initiates many advantages in vehicle performance. The globalization view of standardization of in-vehicle networks with AUTOSAR confirms the certainty of systematic operations with higher efficiency.

REFERENCES

[1] James L. Pelkey.: A History of Computer Communications 1968–1988. (Online). Available: http://www.historyofcomputercommunications.info/, 2014.

[2] Marshall Brain: How Microcontrollers Work, Founder of HowStuffWorks. (Online) Available: http://electronics.howstuffworks.com/microcontroller.htm, 2014.

[3] AUTomotive Open System Architecture. (Online) Available: http://autosar.org/index.php?p=2&up=1&uup=1&uuup=0

[4] Nicolas Navet, Francoise Simonot-Lion: Automotive Embedded Systems Handbook. Taylor & Francis, pp.1-470, 2008.

[5] Daehyun Kum, Gwang-Min Park, Seonghun Lee, Wooyoung Jung: AUTOSAR migration from existing automotive software. In: International Conference on Control, Automation and Systems (ICCAS 2008), Conference Publications, 558 – 562, 2008.

[6] David Hoyle: Automotive Quality Systems Handbook. Butterworth-Heinemann Ltd., ISBN 0 7506 7243 9, 2000.

[7] Charalambos D. Aliprantis, Owen Burkinshaw: Principles of Real Analysis. 3rd Edition, Academic Press, 1998.

[8] James A. Freeman, David M. Skapura: Neural Networks: Algorithms, Applications and Programming Techniques. Addison-Wesley Publishing Company, 1991.

[9] Karl-Erik Arzen, Antonio Bicchi, Gianluca Dini, Stephen Hailes, Karl H. Johansson, John Lygeros, Anthony Tzes: A Component-Based Approach to the Design of Networked Control Systems. European Journal of Control (13), pp. 261–279, 2007.

[10] Ajeet Kumar Pandy, Smith Jessy, Vivek Diwanji: Cost Effective Reliability Centric Validation Model for Automotive ECUs. In: IEEE 23rd International Symposium on Software Reliability Engineering Workshop, DOI:10.1109/ISSREW.2012.29, 2012

[11] Danil Prokhorov: Neural Networks in Automotive Applications. Springer Berlin Heidelberg, Computational Intelligence in Automotive Applications, Studies in Computational Intelligence Volume 132, pp 101-123, 2008.