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Strategy to Overcome the Boundaries of Performances and Constraints in a Utility Vehicle

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Abstract

For the overall effectiveness of a utility vehicle, attributes of the automotive control systems has to encounter the challenge of handling the boundaries and fixing the constraints in the interaction, integration and deployment of individual system components in the vehicle. This article deals with the research outcome in handling these boundaries and constraints to incorporate overall system effectiveness. Structural integration, system behavior, interconnectivity of components, their interdependence, achieving the objectives of the overall system and subsystem has to be dealt predominantly to work upon the ACS constraints. To overcome constraints, acceptance criteria and protocols are explored to achieve a multi objective optimization. Variables influencing the strategic information and operational information of the automotive control system elements are analyzed with an object oriented approach and validated with the impact and timeframe to handle, functions and quality. Synergies of communication system, navigation system, entertainment systems, etc. with their ECUs, network nodes, messages and signals are explored to achieve boundaries of performances in integration of ACS. Whereas vehicle related, process related and framework related features are explored for various opportunities of improvement in handling the boundaries and constraints in interaction and deployment of ACS. In addition to that for effective deployment of ACS, Subsystem I/O components' viz. sensors and actuators are also individually explored across varieties of vehicles. Thus beneficial modifications are recommended for overall system effectiveness.

Keywords: Network nodes, on board diagnostics, End of line, object oriented approach, multi objective optimization

1.0 Introduction

In a utility vehicle, to overcome the boundaries and constraints, the inter-vehicle network needs to be strategically fine-tuned. Fine tuning desperately requires a special strategy, as the vehicle parameters are handled at numerous stages like component level, subsystem level, system level, network level, vehicle level at idle state, vehicle level at dynamic state, vehicle level at various specific conditions, on board diagnostics, diagnostics beyond OBD, End Of Line etc. With unlimited parameters, hardware and software available in a utility vehicle, identifying the key parameters for a quick and effective fine tuning is where the strategy remains. The strategic points for optimization should be scrutinized after a various examinations of input, output, process, control, feedback and interfaces in the overall vehicle network. Strategic information, operational information and management information of electronic control system components needs to be fine-tuned focusing on these key elements to transform and arrive at the required targets. To overcome the boundaries and constraints in varies stages like testing, analysis, implementation, maintenance etc. a converging system effective Inter network architecture with a multi-disciplinary optimization and object oriented approach becomes essential. The key parameters defines this strategy is identified in this article. Engine control module, Powertrain Control Module or PCM, Body Control Module or BCM, Transmission Control Module or TCM, ABS Control Module, HVAC Control Module, Airbag Control Module, ESP, HVAC, electronic break control, IC, Immobilizer, SAS, TCC, TCM, HS, YRS etc. can accommodate to fine tune the same strategic key parameters to overcome limitations and achieve acceptance criteria with ideal features, optimized functions, excellent system behavior, structural order, optimal inter dependence and predominant performance in a utility vehicle.

2.0 Customary systems:

Conventionally, at level wise, vehicle controller component actions were monitored, providing the functions of key-normal driving while performing energy and power check for battery and brake energy feedback, network management, fault diagnosis and handling, and monitoring vehicle status. A recognition technique to directly estimate distance was proposed by Van Mierlo and Maggetto15. A unique electric vehicle control system that has been validated by experiments proposed by Guo et al. [8].

In shared control, the automated system uses torque feedback to communicate its desired goal to the driver. This communication channel, however, is a one-manner and does now no longer adhere to the layout standards proposed with the aid of using the metaphors, which advocate a bidirectional interaction among the two agents [9] [11] [12] [13] [14] [15].

Therefore, while referring the various control algorithms with respect to their properties, Pros and Cons (Refer Table 1 and 2) [16], there is a wide research scope for introducing novel methodology to overcome the boundaries of performances and constraints in a utility vehicle.

Control Algorithms	Strength	Perfection	Smartness	Tracing Quality	Complexity	Correctness
PID	Small	Small	Small	Satisfying	Large	Small
Fuzzy Logic	Small	Small	Large	Small	Small	Small
Neural Network	Small	Large	Large	Small	Small	Small
Back stepping	Satisfying	Medium	Medium	Large	Medium	Satisfying
Slide-mode-controller	Medium	Medium	Satisfying	Large	Medium	Large
Adaptive- Control	Satisfying	Medium	Medium	Medium	Small	Satisfying
Linear-Quadratic-Regulator	Small	Medium	Small	Medium	Medium	Small

Table: 1 Properties associated with various control algorithms [16]

Algorithms	Advantages	Issues
PID	Due to mixed algorithms, it is highly creative.	Producing robust and efficient results is a critical task
Back stepping	It provides good results in simulations results are reliable with less number of computations and the speed of the convergence is high	Metrics analysis is difficult
Slide-mode-controller	It provides good results in simulations results with optimization and integration with different algorithms	Managing a complex situation is challengeable and create high noise
Adaptive-Controller	It provides good results in simulations results with reduced control the implementation is easy	Speed of convergence is less
Linear-Quadratic-Regulator	It provides good simulations results in a dynamic situation and mixing with other algorithms is easy	Controlling is very difficult
Fuzzy Logic and Neural Network	Implementation of real-time applications are possible and membership functions tuning is easy	Executing the neuron system of a buried layer is difficult and has high complexity due to the multi-layers.

Table 2. Summary of Pros and Cons in control techniques [16]

3.0 Methodology:

- Usually, routing in system integration organizes subsystems. Our methodology is to introduce an exclusive innovative algorithm by making hierarchy of hierarchies for creating a novelty for multicore object oriented approach in integration.
- Thus, instead of handling the traditional optimization techniques using mathematical

homogenization calculations and quantitative evaluation of metrics, we are adapting new patterns of ideologies for a problem independent multi-disciplinary optimization when all systems work together in six modules.

3.1.0 Module - 1:

In the first module, for reliable operations, critical operations are segregated from enormous and composite systems and sub systems of vehicle control modules. For sample subsystems with associated functions refer Table 3. Some of the sample composite systems are as follows.

- Cloud control systems
- Shared control systems
- Model free-coupled shared controllers &
- Other controllers

1. Engine control module
2. Powertrain control module
3. Transmission control module
4. ABS Control module
5. Body control module
6. HVAC control module
7. Air bag control module
8. ESP
9. Electronic brake control
10. Immobilizer
11. TCM

Sample subsystems	Sample functions explored in parametric analysis
Air flow sensor	Measurement of density & volume entering combustion chamber
Camshaft position sensor	Camshaft timing and position monitoring
Engine speed sensor	Crank shaft spinning speed & position monitoring
Engine knock sensor	Monitoring engine knocking to ensure air fuel mixture for ignition correction
Voltage sensor	Vehicle idling speed management
Throttle position sensor	Throttle valve position monitoring
MAP Sensor (Manifold absolute pressure sensor)	Engine load monitoring by estimating difference between outside and manifold pressure
Temperature sensor	Engine temperature measurement
NOx sensor	Exhaust gas NOx measurement
Oxygen sensor	O2 level in exhaust gas measurement
Speed sensor	Wheel speed measurement
Fuel temperature sensor	Monitoring engine inlet fuel temperature
Rain sensor	Rain detection for wiper activation
Parking sensor	Vehicle front and rear obstacle recognition

Table 3. Sample subsystems for parametric analysis

3.2.0 Module - 2:

In the second module, analysis of variables influencing the strategic information and operational information of the automotive control system elements are done in four method namely,

- Downstream co-ordination

- Supervisory control method
- Upstream co-ordination &
- Centralized control method

Building blocks representing flow of sequences for the above methods are represented in Figure. (1 – 4)

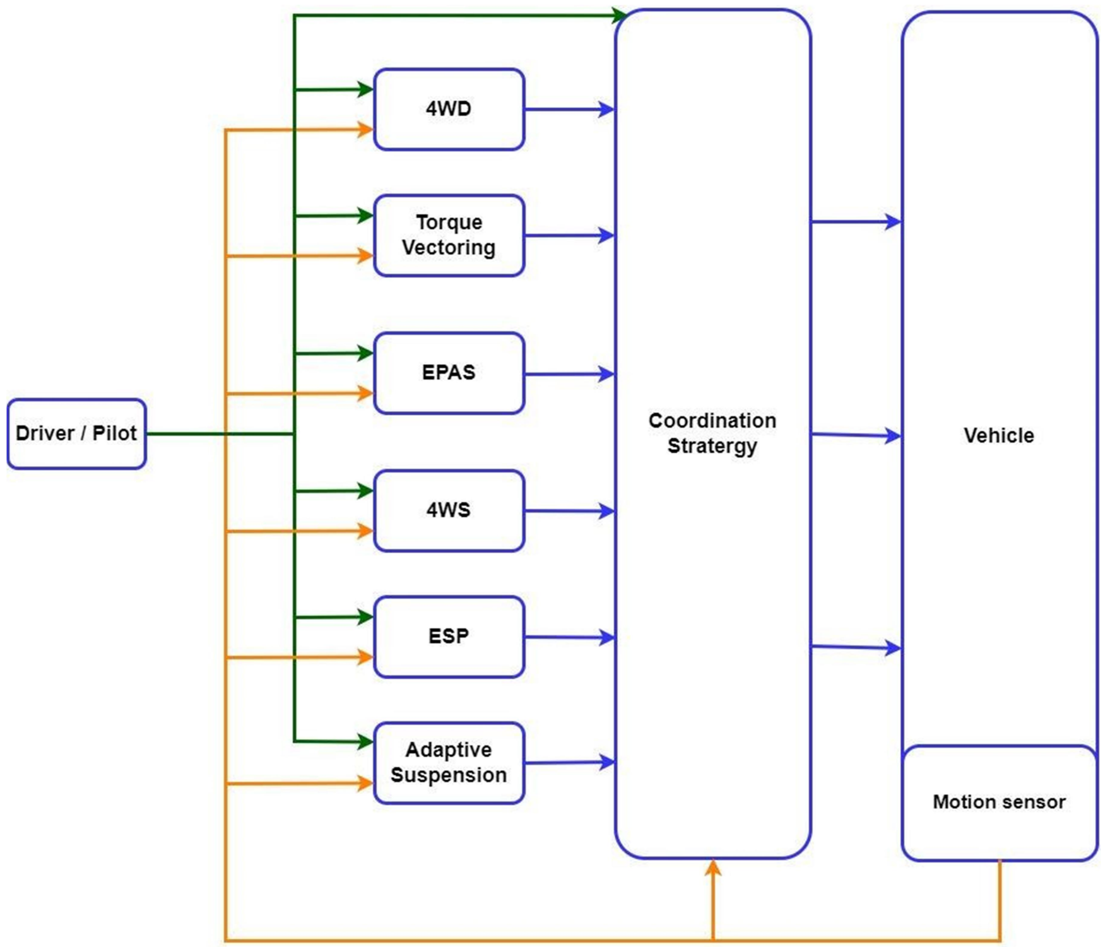

Figure. 1 Basic blocks of the downstream coordination system [10]

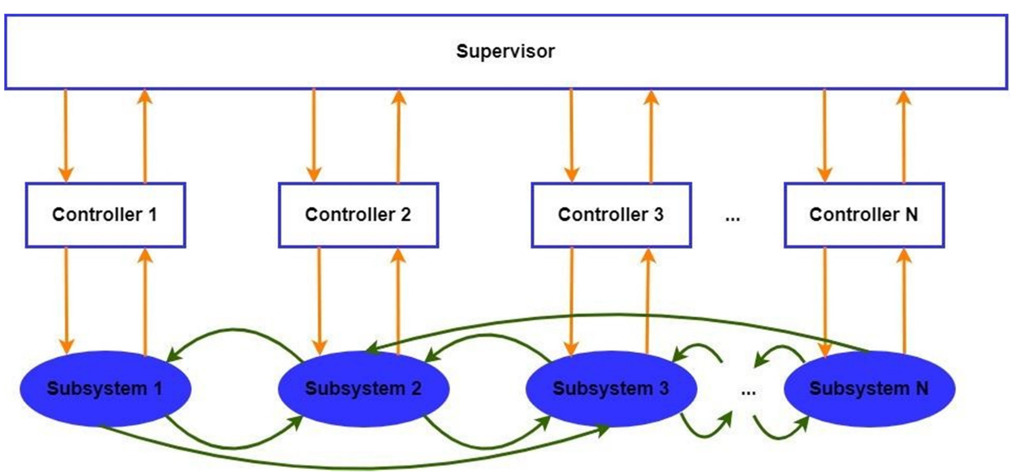

Figure. 2. Supervisory control method [10]

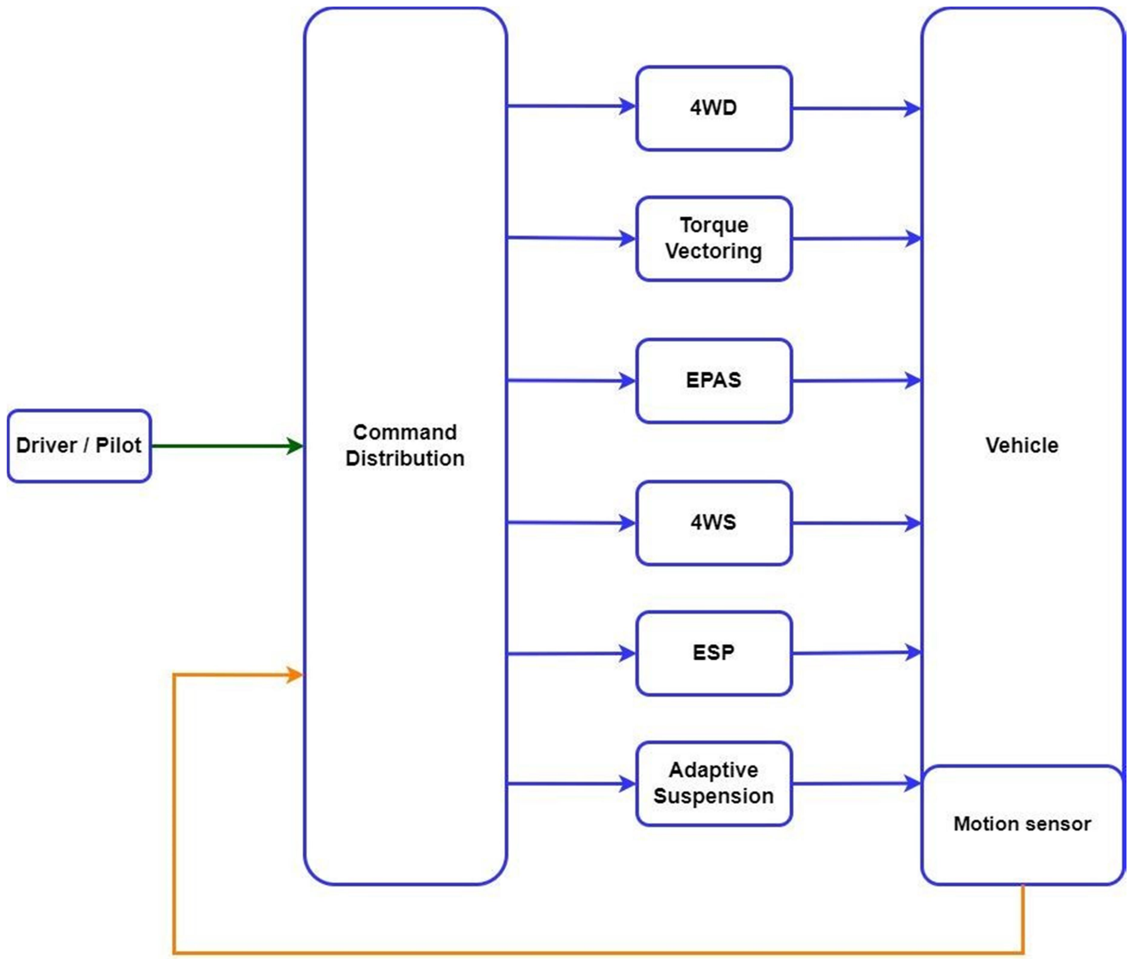

Figure. 3 Upstream co-ordination method [10]

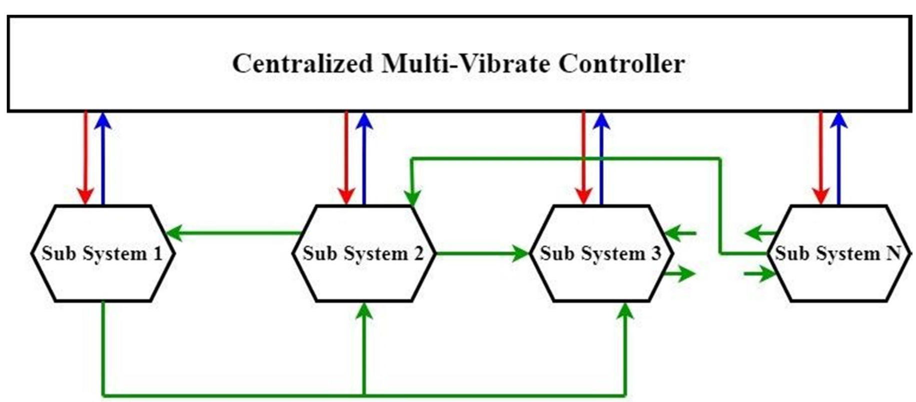

Figure. 4 Centralized-control architecture [10]

3.2.1 System effectiveness

ECUs are in charge of controlling the vehicle's electrical subsystems. Examples of simple ECUs are ECUs that electrically move passenger seats and examples of complicated ECUs are ECUs that ensure optimal engine performance depending on input from different sensors. As the next evolution in ECUs, DCUs combines the functions of multiple ECUs into a single, as a more cost-effective unit. ECU or DCU refers to the entire "box" of all the components, such as the PCB, input/output connectors (I/O), and integrated circuit components [1] During the CAV transition phase, effects are crucial for the powerful real-international positioning of CAV controllers in blended heavy-traffic conditions [2] The CAN peripheral connectivity and the independent power supply produced the quality output signals [3] Adaptive cruise control (ACC) is an attractive driver safety package with a less work for the driver. This gadget primarily based totally on an energetic braking algorithm. The higher choice-making system is developed based on algorithm named as predictive manipulation [4] PID remarks manipulate, version predictive manipulate, fuzzy common sense manipulate, and premier manipulate are the maximum, not unusual place ACC choice algorithms so far [5–7]

3.2.2 Effective Integration

Sharing of sensor data and exchanging of information in the vehicle network handles thousands of functions like climate control, exterior light, central locking, engine management, driveline management, etc. Feedback control, discrete control, super structure, safety critical control systems also has many variants. Intra vehicle networking has major categories like wired and wireless networks.

Wired networks are further classified with electrical and optical buses and other sub categories are as mentioned in Figure. 5. Controlled Area Network, Local Interconnected area Network and time triggered protocol, flex ray and byte – light are the major protocol categories in which CAN is the most standardized protocol.

In these typical network systems, the key strategic factors for fine tuning are synergies of nodes, messages and signals. Resulting optimized outcome, overcomes overall boundaries and constraints in the In-vehicle network communication perspective.

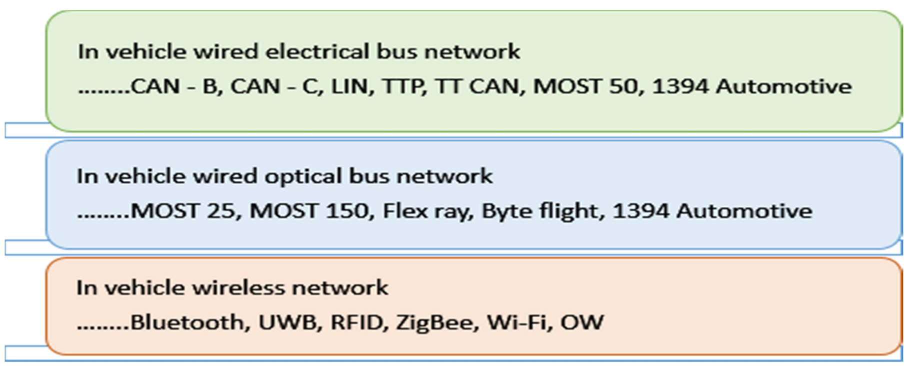

Figure. 5 In- vehicle intra network

3.3.0 Module - 3:

In module three, derivation of boundaries of performances and constraints are done under individual category.

3.3.1 Synergies of network nodes

Key components of network nodes are operating systems (RTOS), communication software, diagnostic kernel and the interface of hardware with the application layer. Refer Figure. 6 for a standard node structure. By increasing the standard of nodal structure in software with an enhanced interface, effective bandwidth, predictability and fault-tolerance can be achieved for a cost effective performance orientation system without limitations.

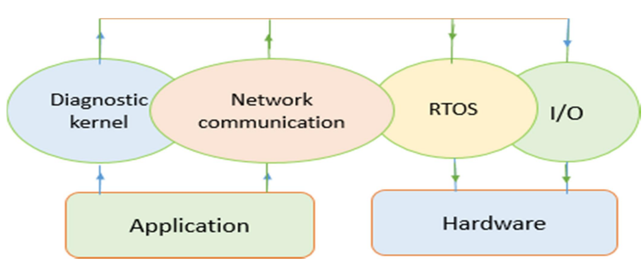

Figure. 6 Node structure

3.3.2 Synergies of messages

Changeover of a partial networking can be realized with the power master in a CAN network. Cluster formation helps to switch over mode to a low power and then wake them together again. Refer Figure. 7 for power master with partial CAN Networking. Transformation of messages happens only during configuration. Processed information are transceiver. Here the key factor that needs to be focused upon in the synergy of messages is change over. It is critical because there are chances to lose the message during wake up process in a controlled area network.

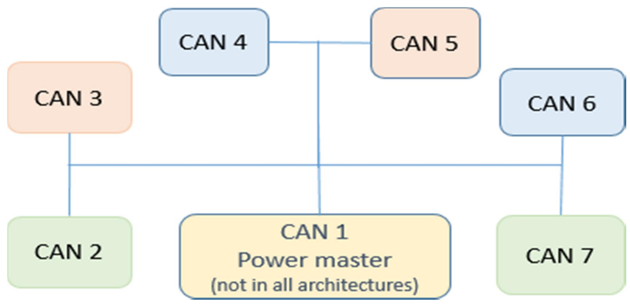

Figure. 7 Power master with partial CAN networking

3.3.3 Synergies of signals

For effective handling of signals virtual computing environment supports to the core in reusing the OS, Software entities and the models. Refer Figure. 8 for virtual VCS network structure. In house ECUs with a virtual computing environment to meet network standards improves commonality, scalability and partitioning. With numerous configuration of vehicles the synergies of signals remains the key factor to handle to overcome performance limitations via virtual computing environment.

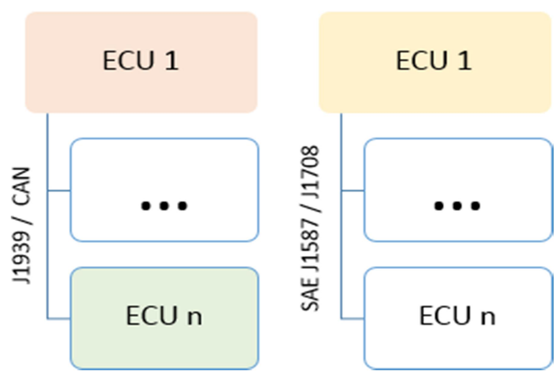

Figure. 8 Virtual VCS network structure

3.4.0 Module - 4:

In fourth module, multi-core use cases for quick and effective fine tuning is deployed.

3.4.1 Multi objective optimization

3.4.1.1 Effective deployment

While various synergies of signals, messages and nodes remained the fine tuning factors in software of a vehicle network, a multi objective optimization becomes critical as hardware optimization is another key factor that results in part reduction and performance improvement thus results in cost reduction. To achieve effective deployment of electronic components, various constructive amendments has to be done in the individual entities of the Network of vehicle electronic components.

3.4.1.2 Constructive amendment of vehicle electronic components:

Constructive amendment of sensors, actuators, solenoid, switches, gauges and ECU with respect to their network dependency factors, location, serviceability, performance, part replacement etc.

is standardized in this article through thorough physical examination of Electronic components of the vehicle networks. Refer Figure. 9 for network of vehicle electronic components. Some of the amendment recommendations are given below:
Virtual sensing to meet OBD norms in place of post lambda sensors can become the key strategic factor for cost reduction and performance improvement. Catcon for over heat indication can enhance key functional factor. Injector with a fabricated rail, as an integral part of intake manifold must have a lighter rail for heavy duty purpose. In addition to ECU, an injector driver unit improves performance efficient.

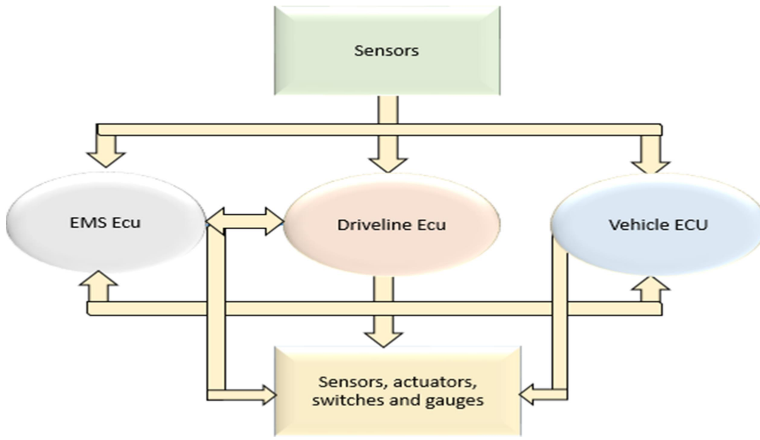

Figure. 9 Network of vehicle electronic components

Meeting emission norms without EGR cooler is a cost effective solution. Solenoid in EGR needs to be a removable part and not an integral part of EGR, so that in case of faulty entire EGR valve need not be replaced and it reduces service cost. Placing an EGR on EGR cooler can be easy for access rather than placing it on intake manifold for better serviceability.

To increase cost reduction scope of individual entity in a cluster of control system components, a comparative study of technical specification of sensors / actuators / solenoids / switches / gauges of popular vendors can be done and a standard cost effective vendor list for electronic components can be standardized for all vehicle variants to bring down overall system cost.

A '2 in 1' ignition coil remains cost effective. Local made connectors can be cheaper. ETB – Electronic throttle Body to be used in place of mechanical throttle body (with TPS and ISA) which is technically superior. Crank speed sensor can be placed on clutch housing or at the ride side of engine and not oil sump which improves accessibility and in turn serviceability.

Camphase sensor and solenoid with a cable improves connection and accessibility. Solenoids and TPS can be chosen with dust cover as it is advantageous. Temperature sensor can have a better control when placed over rail. Individual MAP and Temperature sensor can be replaced with a single TMAP sensor which reduces part and improves performance.

In a Fuel switch with three way valve namely fuel filling mode, parking mode and running, a Normally Closed fuel switch with cap and flap is better than a Normally Open switch. There are vehicles where mechanical fuel gauge is omitted, which is one of the amendable solutions. TPS is not required while using an ETB.

Instead of using an Air temperature sensor a single TMAP sensor can be effective. Instead of placing the solenoid in fuel pipeline location placing it near gas lock valve is convenient and using a fuel tank guard can avoid mishandling. Physical design of ECU must be simple, compact and light weighted. Placing a breather hole on the ECU at the back side can have low moisture absorption. Instead of a connector lock in ECU press fit lock can be used for better serviceability.

3.5.0 Module - 5:

In fifth module, system integration with object oriented approach is deployed.

3.5.1 Object oriented approach

3.5.1.1 Effective interaction:

Normally the interaction of electronic components is process based. However viewing and handling the control system as a collection of components instead of a process can result in effective interaction overcoming the performance boundaries. It also enhances performance by enabling the modeling of bottom up approach of system architecture with reusable algorithms and codes. Thus the use cases, components, models etc. describes the object oriented control system. Refer Table 4 for customary method vs object oriented method. Vehicle related, process related and framework related features of an object oriented method can focus upon individual components performance thus resulting in overall system performance by overcoming constrains.

System integration in customary method	System integration in object oriented method
Control system is approached as a process collection	Control system is approached as components & subsystems collection
Generation of reusable algorithms / codes is not applicable	General of reusable algorithms / codes applies
Structures / Process flow defines control system	Models, use cases, components etc. defines control system
Non iterative process involved	Iterative method observed
Top down modeling approach handled	Bottom up modeling approach handled

Table 4. System integration in customary method vs. objected oriented method

3.6.0 Module - 6:

In sixth module, multi-disciplinary optimization in integrated systems is deployed.

3.6.1 Vehicle related synchronization

In EOL validation instead of handling the standard approach, an object oriented approach to be handled by synchronizing components such as EGR valve, ETB crank sensor and cam sensor to examine the ideal system performance. Refer Table 5 for ideal synchronization condition for EOL. With a vehicle ramp up, actuate EGR valve and action the ETB to check its value in diagnostic tool. Before ensuring synchronization, crank and cam sensors values to be confirmed in diagnostic tool to ensure vehicle reaches its maximum limit.

Components	Condition
EGR Valve	Ramp up vehicle and actuate
Crank Sensor	Check value at max limit
Cam Sensor	Check value at max limit
ETB	Ramp up vehicle and Actuate

Table 5. Ideal synchronization condition for EOL

3.6.2 Process and framework related synchronization:

Manual flashing and diagnostic system is inadequate. Calibration files needs to be listed in the manual flashing tool rather than server loading to overcome server related issues. Online flashing and diagnostics software is essential. Regular DTC codes are not able to point exact performance issues of Injector, ignition coil, gas pressure sensor, temperature sensor, spark plug, coolant temperature sensor, rail gas leakages and many such. A holistic guided troubleshooting to be done for this. Also DTCs are recorded only when sensor line is open not when it is damaged or underperforming. A calibration based algorithm to indicate errors in such cases to be developed. Implementation of dynamic diagnostic solution is essential to prevent quality issues and enable algorithm based error capture.

4.0 Conclusion

As a result of phenomenal examination of the overall utility vehicle characteristics, key strategic fine tuning factors of vehicle are identified in the automotive control systems with exclusive strategies for the vehicle parameters refinement at software architecture level, electronic component level, subsystem level, system level, network level, vehicle level at idle state, vehicle level at dynamic state, vehicle level at various specific conditions, diagnostics scope beyond OBD, End Of Line scenarios etc. Fine tuning elements like synergies of nodes, messages and signals in a communication network, multi objective optimization in vehicle networking with constructive recommendations of vehicle electronic components and an object oriented approach with vehicle/process/framework related features are identified as key factors to overcome performance limitations and constraints in the utility vehicle. They not only determined multi-core use cases and all additional use cases for overcoming the boundary of performances and constraints with assured redundancy check in data transmission but also it had overcome performance boundaries and constraints for an effective interaction, integration and amended deployment. Thus efficiency and reliability in the integration of vehicle control systems are improved with effective and quick communication, reduced complexity, better serviceability, better predictability, technically superior performance, enhanced interface and cost effectiveness with fault – tolerance via. multipart reduction in a multidisciplinary enhancement.

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