Distributed & Parallel Systems in Truck Platooning

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*Abstract*—To explore and understand the need of distributed and parallel systems, a real time and challenging system development of Truck Platooning technology is discussed in this paper.

Keywords—Platooning, mechanized driving, lower carbon

# Introduction

Transportation is vital to society and economy, and street cargo transportation accounts for about 60% of all surface cargo transportation. The request for street cargo transport is anticipated to extend within the coming a long time. As appeared within the American Trucking Association’s 2015 report, the trucking industry comprises about 80% of a 1.33 trillion-dollar shipping and coordination’s industry within the US. In any case, bounty of fuel utilization and nursery gas outflow have been created. For case, street transport speaks to around 27% of the vitality utilization of the European Union. Furthermore, indicated that vehicles account for 20% of the entire carbon emanation of which a quarter comes from overwhelming obligation vehicles (HDVs). Subsequently, the natural impacts amid the method of transport got to be diminished direly. In expansion, the fetched of fuel has an expansive share of add up to transportation costs. Fuel fetched spoken to about 30% of the life cycle taken a toll of owning and working a truck. Additionally, agreeing to the American Transportation Investigate Institute’s (ATRI) later report, fuel is respected as the moment biggest taken a toll, where the most elevated is faculty cost. With a huge sum of HDVs and the expanding request for street cargo, it can be anticipated that indeed small advances in fuel efficiency can decipher into significant taken a toll diminishment [1]. And it is additionally advantageous to realize the objective of natural assurance due to less deplete gas. As a result, it is of awesome advantage to move forward fuel economy, and how to decrease fuel utilization amid traveling has turned into a prevalent theme in later a long time. Luckily, the improvements of shrewdly transportation frameworks (ITSs) have empowered strategies to improve the vitality productivity of transportation systems. A promising approach to managing with that issue is to decrease the crevice between vehicles on the street, which is ordinarily called truck companies. Truck companies, moreover, known as caravans, are a set of vehicles shaping a street prepare by traveling closely in single record to encounter diminished discuss drag. This may altogether diminish fuel utilization since around one-fourth of the fuel utilization is important to streamlined drag. As a result, fuel economy can be progressed, and natural invitingness can be accomplished due to less nursery gas emanation in a unit. Separated from fuel reserve funds, truck units can contribute to an increment of street capacity and can ease activity blockage by a littler hole between vehicles. In later a long time, with the advancement of independent driving innovation, vehicles are prepared with a few sensors that empower them to watch their environment and choose in genuine time what activity ought to be taken, which are called “autonomous vehicles” or “driverless vehicles.” Driverless vehicles can arrange their way when driving, and they can travel in a company with littler interims to diminish fuel utilization [2]. Moreover, when driving naturally in a company, it is conceivable to diminish the hazard of rear-end collisions and to move forward activity security. With incredible points of interest said over, vehicle companies have pulled in the consideration from numerous governments and inquire about teach. As a result, a few ventures related to companies were proposed. The primary thinks about on truck computerization were “Chauffeur” inside the EU venture T-TAP from the mid-1990s to the starting of 2000. Amid the extend, Cap and Fritz conducted an explore with two trucks coupled by an “Electronic Tow Bar” to measure the fuel reserve funds. A while later, the California Way program begun it inquire about on heavy truck platooning. Within the Way program, all vehicles were completely mechanized, counting the pioneer. For case, in 2004, the program performed a fuel utilization test with two pair trucks connected by an electronic control framework for diverse spaces.

This paper [4] really speaks clearly about the important terms in the platooning, and it have the definitions of String Stability, Stability Margin, and Coherence behaviour. Achieving all these definitions are very important for the platooning system.

# Analysis

## Interaction and Communication [Author: Omer]

The.

## Control Behaviour [Author: Omer]

The.

## Concurrent Programming [Author: Omer]

The.

## Architecture[Author: VigneshArumugam]

A concrete and successful system needs an architectural model before its implementation. It can be the outline, base and primary one for the structure of an any system. The model needs to fulfill both present and future requirements [1]. The architecture deals with communication entities, communication paradigm, roles & responsibility of the entities and the pattern of the network structure. And in the paper [2], the research has been done in the electronic coupling in the freight truck and trial implementation has been done And their main technology source of dependence is on Advance Driving Assistance System (ADAS), Vehicle infrastructure communication (UMTS) for communication between the trucks and the central server, Adaptive cruise control (ACC) for front sensor between the trucks to manage the cruise, Automatic Guidance (AG) to calculate the distance gap required to maintain the platoon, and vehicle to vehicle communication for remaining interactions between the trucks. And for handling the communication messages in the platoon, this paper [3] suits more. This research paper proposes a new type of Intelligent Transportation Systems (ITS) message called ECE messages based on the Cooperative-ITS (C-ITS) message structure as Cooperative Awareness Message (CAM), Decentralized Environmental Notification Message (DENM), Signal Phase and Timing (SPAT), and Map message (MAP). The message was handled by the Edge computing.

The nodes of the platooning distributed system are the trucks (A leading truck and all following trucks).

And the communication paradigm is going to be “message passing”. This comes under Request -reply protocols, but this is varies with the message synchronization. In Request-reply protocol, the sender sent message and wait till the reply message receives from the receiver, i.e., synchronous. Whereas it is also possible to have the Request- reply protocol to be asynchronous, here the sender doesn’t need to wait. It is not mandatory for the sender and receiver to be aligned with the message and aware of each other.

# Implementation Section

After the analysis and design part, the realization has started with implementation section in the following order.

## Code Implementation[Author: Namik & Nico]

The code implementation is done in CPP language, and the hardware used is Arduino ESP32. The realization of platooning control unit component is performed with the input documents such as state machine diagram and other analysis diagrams. For witnessing a working prototype, the platooning control unit (PCU) is created with other important components which are required for its execution. The supporting components are added with only basic functions required for communicating with PCU component. So, the overall realization includes PCU, GPS, Lidar, Camera and Wi-Fi components.

Since the output is tried with real hardware ESP32, the software package and hardware for LiDAR and Camera not available. So, to replicate only the behavior a 3-Channel Wide FOV Distance Sensor based on the OPT3101 IC from Texas Instruments is used. This sensor helps to replicate the Lidar and camera component working scenario. Whenever an object is detected in the close range to the OPT3101 sensor, then the Camera and Lidar module consider it as “Vehicle intruded” and “Distance measured is less than Desired Value”.

The PCU component is added with all the operations mentioned same as PCU block of the truck platooning bbd. Pcu\_loop() operation is considered as the task which shall be considered as task during scheduling. The outputs of the console “without intruder” and “with intruder” are shown in the Fig. 16 and Fig. 17 respectively.

Text

Description automatically generated

Figure 16: Output console without intruder maintaining Speed

Text

Description automatically generated

Figure 17: Output console intruder detected decreasing speed

Form the outputs it can be clearly seen that without intruder detection the truck will maintain its speed, whereas during intruder detection it reduces its speed.

## Scheduling[Author: Namik & Nico]

This truck platooning system is a hard real-time system. So, all the task’s deadline in this system needs to be completed within all circumstances. For this system only one CPU core is used, and five tasks are assigned to the core. The five tasks are gps\_task, lidar\_task, camera\_task, pcu\_task, and wifi\_task shown in Fig. 18. The software called Simso has been used to show the schedulable of the tasks.

Graphical user interface, application, table

Description automatically generated

Figure 18: Tasks scheduling

While performing the scheduling, three main constraints are considered, they are timing, precedence, and resource constraints [LEC 2]. The gps\_task, lidar\_task and camera\_task are having higher precedence than pcu\_task. And all the tasks have their periodicity as timing constraints which are referred from constraint diagrams. Shared resources like DistanceGap, coordinates and intruderDetected need to be properly accessed and updated. So, considering all these constraints, the EDF (Earliest Deadline First) scheduling seems promising for this system. To achieve the schedulable, the gps\_task, camera\_task and lidar\_task are given earlier deadline than pcu\_task. The task simulation can be seen in the fig. 19

A picture containing text, keyboard, electronics

Description automatically generated

Figure 19: Scheduling Simso

This process also performed in pyCPA(Python Compositional Performance Analysis) tool. The same simso type of task configuration is done in the pyCPA format and achieved the similar output Fig. 20.

Text

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Figure 20: pyCPA Output

# Simulation

Via this project, we explored the life cycle of system development. It started from the requirement elicitation process to the

# Conclusion

Via this project, we explored the life cycle of system development. It started from the requirement elicitation process to the testing of those requirements. In each phase of this cycle, the solidity of attaining the system requirements increased gradually. Sometimes, later parts of the life cycle give more data to the former section. For instance, the initial design section documents had some inaccuracies, but they got more influences during the implementation section. That triggered the need for a second iteration for updating the design document. From this scenario, we understood the importance of the designing phase, which is very important to shape the requirements into a system. And this architect or designer needs to think in all aspects like implementation and testing feasibility, and even modifiability.

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##### References

1. G. F. Coulouris, Ed., Distributed systems: concepts and design, 5th ed. Boston: Addison-Wesley, 2012
2. R. Ramakers, K. Henning, S. Gies, D. Abel and H. M. A. Max, "Electronically coupled truck platoons on German highways," 2009 IEEE International Conference on Systems, Man and Cybernetics, 2009, pp. 2409-2414, doi: 10.1109/ICSMC.2009.5346393.
3. N. Bouchemal and J. -Y. Jun, "V2X Architecture for Autonomous Platoon Management In Urban Environment," 2021 International Conference on Computer, Information and Telecommunication Systems (CITS), 2021, pp. 1-6, doi: 10.1109/CITS52676.2021.9617911.
4. S. E. Li, Y. Zheng, K. Li and J. Wang, "An overview of vehicular platoon control under the four-component framework," 2015 IEEE Intelligent Vehicles Symposium (IV), 2015, pp. 286-291, doi: 10.1109/IVS.2015.7225700.