Controller Area Network Protocol For Vehicle System

1st Sheikh Muhammad Adib Bin Sh Abu Bakar
Hochshule Hamm-Lippstadt
B.Eng. Electronic Engineering
Lippstadt, Germany
sheikh-muhammad-adib.bin-sh-abu-bakar@stud.hshl.de

2nd Zafirul Izzat Bin Mohamad Zaidi
Hochshule Hamm-Lippstadt
B.Eng. Electronic Engineering
Lippstadt, Germany
zafirul-izzat-bin.mohamad-zaidi@stud.hshl.de

3rd Muhammad Farid Izwan Bin Mohamad Shabri
Hochshule Hamm-Lippstadt
B.Eng. Electronic Engineering
Lippstadt, Germany
muhammad-farid-izwan.bin-mohamad-shabri@stud.hshl.de

***Abstract*—The modern world is dependent on the availability of vast communication networks that connect computers and other electronic devices all over the world. Clearly, there are several issues that must be addressed. These issues might be numerous and complex. In the framework of network communication challenges, we shall take a theoretical approach to several specific concerns. This paper will serve about communication network. This article will put a light on CAN communication network and the way it solve others flaws.This post would also show a history of Can and also some basic knowledge to assist the reader get a basic and a rough understanding. before go to the approach part, first the reader must know the problem arise using other communication network. Last but not least, the reader may read our goals and what we have accomplished during the preparation of this paper on the outlook and conclusion.**

***Index Terms*—Controller Area Network, Brake System**

I. Introduction

Over the last several decades, the increasing power and cost effectiveness of electronic equipment has had an impact on many fields of human endeavor. This is also true for industrial control systems, which are constantly improving. Although digital controllers eventually superseded analogue control, connections to the field were still made via analogue signals. The move to digital systems prompted the creation of new field and controller communication protocols. The most common name for these communication protocols is fieldbus protocols. Recently, digital control systems have begun to encompass networking at all levels of industrial control, as well as the connectivity of commercial and industrial equipment through the use of Ethernet standards.

An industrial communication network serves as the core of any automation system design since it provides a reliable way of data interchange, data controllability, and the ability to connect many devices. The implementation of proprietary digital communication networks in industries over the last decade has resulted in better end-to-end digital signal accuracy and integrity. Industrial communication networks enable smart manufacturing scenarios by enabling real-time communication between machines and control centres. They ensure that supply chain anomalies are identified and prevented by monitoring processes and activities. Predictive maintenance is a great example of how the Industrial Internet of Things may increase efficiency and cost optimization by connecting and analysing data.

This paper serves as an introduction to industrial communication networks. Industrial networking concerns itself with the implementation of communications protocols between field equipment, digital controllers, various software suites and also to external systems. To assist the reader, the communication network that is widely used specially in industrial field will be explain generally so that the reader can have humongous imagination and deep understanding regarding this topic. The chosen communication network which is CAN will be thoroughly discussed and contrast with those other networks. Many aspects of the operation and philosophy of industrial networks has evolved over a significant period of time and as such a history of the field is provided. The operation of modern control networks is examined, and some popular protocols are described. Any machine with sensors, for example, may collect critical information about its status and interactions with other equipment and operators.

II. Type of communication

Communication is highly important in our lives, especially in any system. The meaning behind communication network is a pattern or shape that is used in an organization to efficiently transmit information. The communication network is the established system in which messages can travel in one or more ways inside the company depending on the requirements. There are two kinds of communication. Wireless communication is the first, while wired communication is the second. For further information, multiple communication

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networks may be built based on their efficacy depending on the system's needs.

A. wireless network

Wireless means that there is no physical touch between two sites. Thus, wireless networks are computer networks that are not connected by any form of cable. The deployment of a wireless network allows businesses to avoid the costly procedure of installing wires in buildings or connecting multiple equipment locations. Radio waves serve as the foundation of wireless systems, acting as a mode of transport for data transmission and reception. The examples of wireless networks are shown below.

1) bluetooth: Bluetooth was developed as an alternative to using cables and wires to build a network. It was designed to unite telecommunications protocols under a single worldwide standard. It is used for wireless communications and broadcasts over short distances. Bluetooth-enabled devices construct ad hoc networks (networks with a single function) with one another to exchange or broadcast data. While Bluetooth was designed to be a cable replacement, it is now extensively utilized because it generates a dynamic Personal Area Network (PAN) [2]

2) wifi: Wifi is a wireless networking protocol. Wi-Fi is simply a very modern digital radio that operates at frequencies in the electromagnetic spectrum ranging from 2 gigahertz to 5 gigahertz, which is roughly the same as microwave ovens. Each standard is an approved modification throughout time. The standards operate at variable frequencies, provide varying bandwidth, and support varying numbers of channels. [3]

B. wired network

A wired network is one of the most popular types of wired arrangement. Ethernet cables are commonly used in wired networks to transport data between linked PCs. A single router may connect all PCs in a small wired network. Larger networks frequently have many routers or switches that communicate with one another. One of these devices is often linked to a cable modem, T1 line, or other sort of Internet connection, which offers Internet access to all network devices. Wired can also refer to peripheral devices. Below are the example of wired network.

1) UART: In UART communication, two UARTs communicate directly with each other. The transmitting UART turns parallel data from a controlling device, such as a CPU, into serial data and transmits it to the receiving UART, which converts the serial data back into parallel data for the receiving device. Only two wires are necessary to transfer data between two UARTs. Data is sent from the Tx pin of the transmitting UART to the Rx pin of the receiving UART. The diagram below depicts the UART connection. [4]

2) I2C: I2C combines the greatest qualities of SPI and UARTs. I2C allows you to connect several slaves to a single master (similar to SPI) and control single or multiple slaves. This is especially useful when many microcontrollers are recording data to a single memory card or displaying text on a single LCD. I2C communication, like UART communication, uses just two wires to send and receive data between devices: Because I2C is synchronous, a clock signal shared by the master and slave syncs the bit output to the bit sampling. The clock signal is always in the hands of the master. SDA (Serial Data) - The data transmission and reception line between the master and slave. Serial Clock Line (SCL) — The line that carries the clock signal. [4]

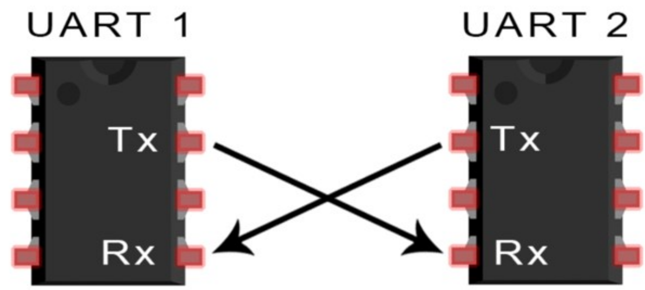

Fig. 1. Connection of UART

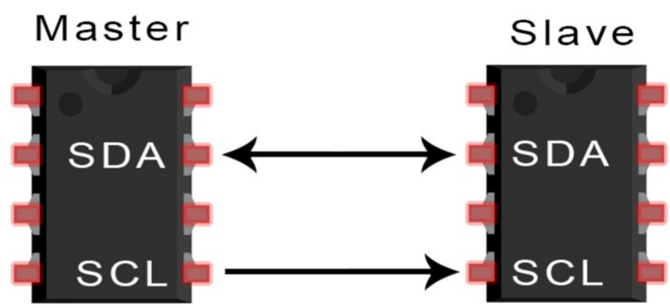

Fig. 2. Connection of I2C

III. Problem

Today's car consist of many electronic components, and they are communicating with each other. For instance, the system that get input from user like pedal brake will communicate with the brake lamp system. The communication may require at least two wire. The input from the user also may be used by other system like safety belt system and door lock system. This communication environment will end up with adding more and more wire. This could be so messy and become more complicate to maintain.

The basic solution concept is using a bus system. The bus system should fulfil our main requirement, whereas we need to used less wire for the whole communication system. One of the most popular bus system protocol is I2C, where only two wires are needed for the whole communication system. After experimenting with I2C, we found out it is not really a solution because the communication become unstable when the length of the wire more than 1 meter. The communication become stable for long distance if we use very low frequency means low data rate transfer.

Considering a situation where a driver need to make an emergency brake, communicating with low frequency can cause slow response on the brake lamp system that could cause the car behind cannot respond immediately. Thus, cause a catastrophic consequence. Means that we need to refine our requirement on the communication protocol by adding new parameter like support high frequency or high data rate transfer for long distance.

To fulfill all this requirement, we need to make another research on protocol that could solve this problem. As result, Controller Area Network is the best solution for this problem or requirement. This protocol will be explained more in the next section

IV. CAN Communication Protocol

The controller area network (CAN) is a highly integrated system that connects intelligent devices for real-time control applications by utilizing serial bus and communications protocol. Control Area Network use a vehicle bus standard that allows communication such as, transferring messages, data or informations between micro-controllers and other devices. CAN is able to operate at data speeds of up to 1 megabits per second (1Mbps) over a possible line length of up to several kilometres, and has outstanding error detection and confinement capabilities. Control Area Network which is also well-known as CAN Communication was introduced by Robert Bosch GmbH in 1983. CAN is purposely created to make automobile industry system more reliable and efficient but it is also widely used in industrial automation and other fields.

A. The CAN Standard

The International Organization for Standardization (ISO) designed the CAN serial communications bus for the automotive industry to replace the complex wiring harness with a two-wire bus. According to the standard, high immunity to electrical interference is necessary, as well as the capacity to self-diagnose and correct data errors. CAN is widely utilized in a variety of industries, including building automation, medical, and manufacturing, because to these qualities.

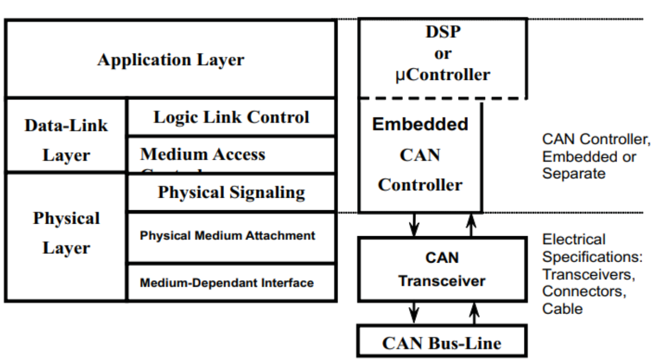

Fig. 3. The Layered ISO 11898 Standard Architecture [5]

The CAN communications protocol, ISO-11898: 2003, specifies how data is transmitted between devices on a network and follows the Open Systems Interconnection (OSI) paradigm, which is divided into layers. The physical layer of the model defines the actual communication between devices connected by the physical medium. as shown Figure 3

B. Standard CAN

The CAN communication protocol is a carrier-sense, multiple-access protocol (CSMA/CD+AMP) that includes collision detection and message priority arbitration. Each node on a bus must wait for a certain duration of idleness before attempting to send a message, according to CSMA. CD+AMP denotes that collisions are resolved using bit-wise arbitration, with each message's priority preprogrammed in the identification field. Bus access is always granted to the identification with the highest priority. That example, because the last logic high in the identification has the highest priority, it continues to transmit. An arbitrating node knows if it placed the logic-high bit on the bus because every node on the bus participates in writing every bit "as it is written."

C. A CAN Message

1) Arbitration: The opposing logic state between the bus and the driver input and receiver output is a basic CAN property, as shown in Figure 4. A logic high is normally linked with a one, and a logic low with a zero, however this is not the case on a CAN bus. This is why the driver input and receiver output pins of TI CAN transceivers are internally passively pushed high, such that the device defaults to a recessive bus state on all input and output pins in the absence of any input.

Bus access is based on events and occurs at random. If two nodes try to occupy the bus at the same time, nondestructive bit-wise arbitration is used to provide access. Nondestructive means that the node that wins arbitration keeps sending the message without it being deleted or corrupted by another node.

A feature of CAN that makes it particularly appealing for application in a real-time control environment is the allocation of priority to messages in the identification. The higher the priority, the smaller the binary message identifying number. Because it keeps the bus dominant the longest, a message with an identification made entirely of zeros is the highest priority message on a network. As a result, if two nodes start transmitting at the same time, the node that sends a zero (dominant) as the last identifying bit while the others send a one (recessive) holds control of the CAN bus and continues to complete its message. On a CAN bus, a dominant bit always overwrites a recessive bit.

2) Message Types: There are four different message types (or frames) that can be transmitted on a CAN system as below:

- The Data Frame
- The Remote Frame
- The Error Frame
- The Overload Frame

3) A Valid Frame: When the last bit of a message's terminating EOF field is received in the error-free recessive state, the message is considered error-free. The transmitter repeats a broadcast if a dominating bit in the EOF field is present.

4) Error Checking and Fault Confinement: The abundance of error-checking mechanisms in CAN contributes to its robustness. The CAN protocol has five error-checking methods: three at the message level and two at the bit level. If a message fails to pass any of these error detection mechanisms, it is not accepted, and the receiving node generates an error frame. This compels the transmitting node to relay the message several times until it is appropriately received. If a malfunctioning node hangs up a bus by repeatedly repeating an error, its controller disables its transmit capacity if an error limit is reached.

1) Message Level

A form check is performed at the message level. This check examines the message for fields that must always be recessive bits. An error is generated if a dominating bit is discovered. The SOF, EOF, ACK delimiter, and CRC delimiter bits are all examined.

2) Bit Level

Each bit transferred is monitored at the bit level by the message's transmitter. An error is caused if a data bit (not an arbitration bit) is written onto the bus and its opposite is read. The message identity field, which is used for arbitration, and the acknowledge slot, which requires a recessive bit to be replaced by a dominant bit, are the only exceptions.

D. The CAN Bus

The CAN standard establishes a communication network that connects all bus nodes and allows them to communicate with one another. A central control node may or may not exist, and nodes may be added at any moment, even while the network is operational (hot-plugging)

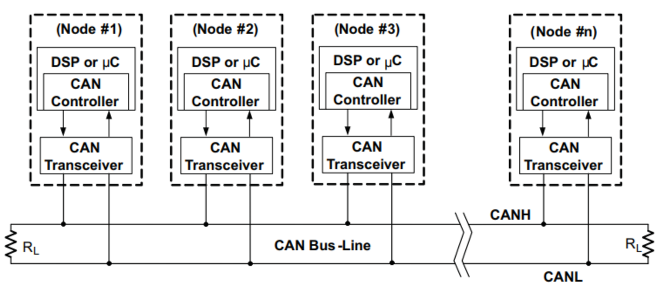

Fig. 4. Details of a CAN Bus [5]

1) CAN Transceiver Features: 1) 3.3V Supply Voltage
2) ESD Protection
3)Common- Mode Voltage Operating Range
4) Common-Mode Noise Rejection
5) Controlled Driver Output Transistion Times
6) Low-Current Bus Monitor, Standby and Sleep Modes
7) Low-Current Bus Monitor, Standby and Sleep Modes
8) Thermal Shutdown Protection
9) Bus Input Impedance
10) Glitch-Free Power Up and Power Down
11) Unpowered Node Protection
12) Reference Voltage
13) V-Split
14) Loopback
15) Autobaud Loopback

V. Application of CAN Protocol

Now we will go through our project in developing a prototype subsystem in a car that use CAN protocol as its communication standard. For that, we use the problem as state in problem section as our main reference for our prototype.

After we analyse the problem, we refine our requirement in requirement diagram as shown in Figure 5. As we mention before, the protocol should work for long distance at high frequency.

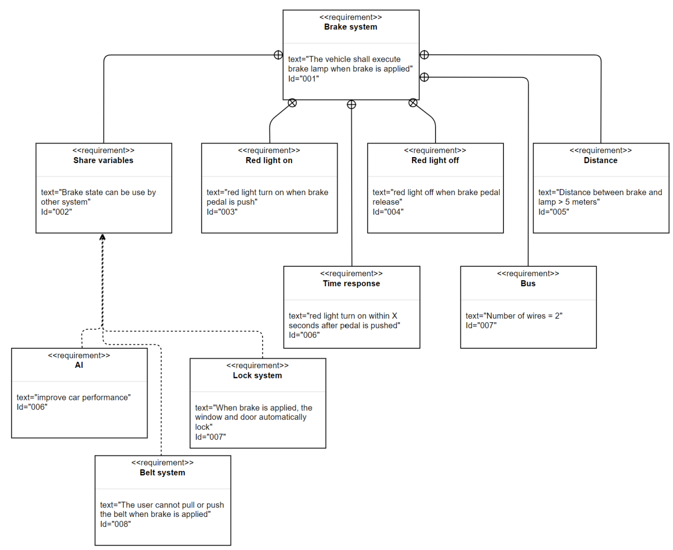

Fig. 5. Requirement Diagram

As we explain in the problem section, we choose Controller area network because it supports high data rate transfer as stated in the pervious section. Next, we will explain how we model our solution base on the requirement.

A. Application Model

Our aim at this stage, which is modelling our solution, is to have a concrete system architecture including communication system where we will implement the communication protocol, so that it will be clear for us to do the implementation. The steps in this stage will be discussed in this section.

After analysing the scenario, requirements and protocol that we want to use, we create a use case diagram to have a clear boundary of the system as shown in Figure 6.

Next, we extend each use case using activity diagrams to understand their behaviour as pictured in Figure **??**, and **??**. later we use all this diagram to make a sequence diagram to

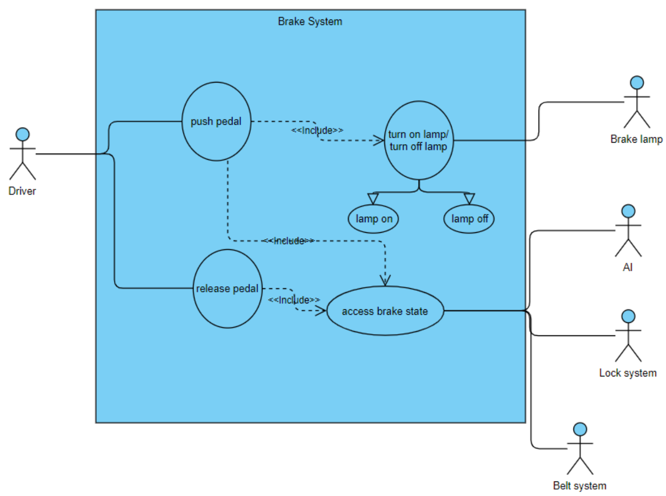

Fig. 6. Use Case Diagram

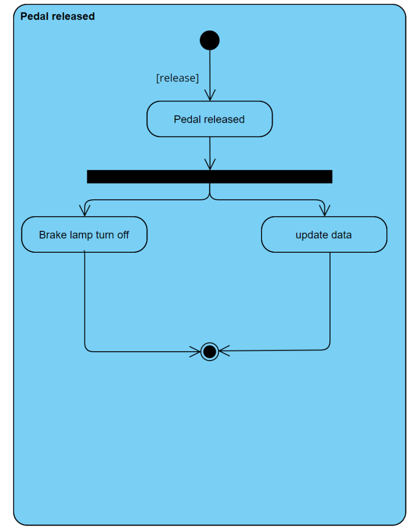

Fig. 8. Activity diagram when the is pedal released

illustrate how object in the subsystem interact with each other as shown in Figure 9.

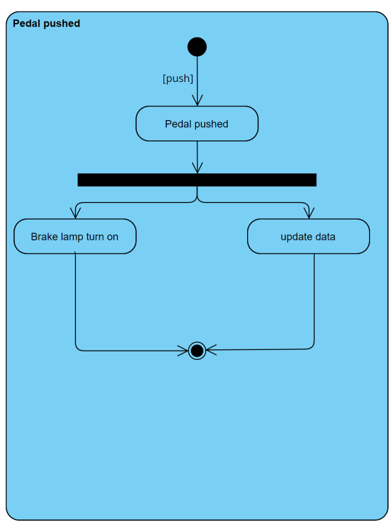

Fig. 7. Activity diagram when the pedal pedal pushed

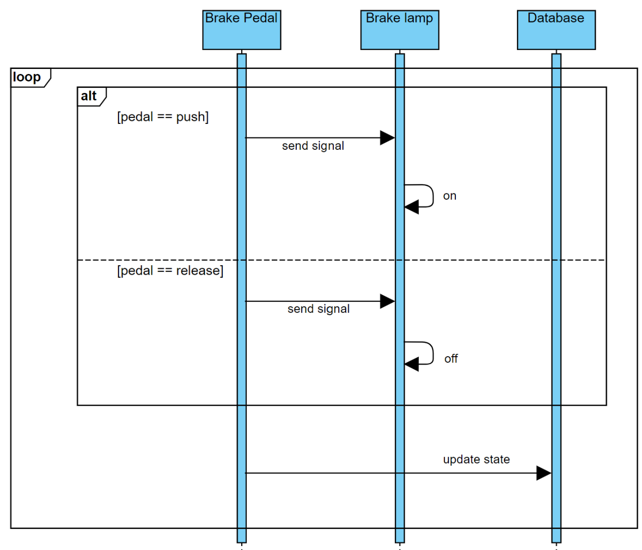

Fig. 9. Sequence Diagram

Eventually, by analysing all the pervious diagram, we are able to refine our system architecture as shown in Figure 10. This indicates that we are ready for implementation stage, which will be the focus of the following subsection.

B. Implementation

For the implementation we divide it into two parts which is hardware and software part. We will first explain the hardware part followed by software part.

1) Hardware: For the hardware setup we will use Arduino UNO with CAN module as shown in Figure 11 to represent each subsystem as drawn in the system architecture that we present before in Figure 10 which are pedal system, database system and brake lamp system as shown in figure 12, 13,14. The CAN module that we are used is MCP2515. For the connection with between the Arduino and the CAN module, we use SPI communication protocol. Considering that the protocol should work for long distance, we also use ca. 1.5 meter for the connection between subsystem. After we have done the setup as illustrate in Figure 15 we proceed to the next step which is the software implementation.

2) Software: Since we use Arduino as our subsystem platform, we use Arduino IDE to implement our software. To make the communication works as we had planned, we use CAN library provided by Arduino. In proving that It could work at high frequency, we set the data rate transfer to 1MBps. The code for each subsystem can be found in https://www.instagram.com/_sheikh_adib/?hl=en.

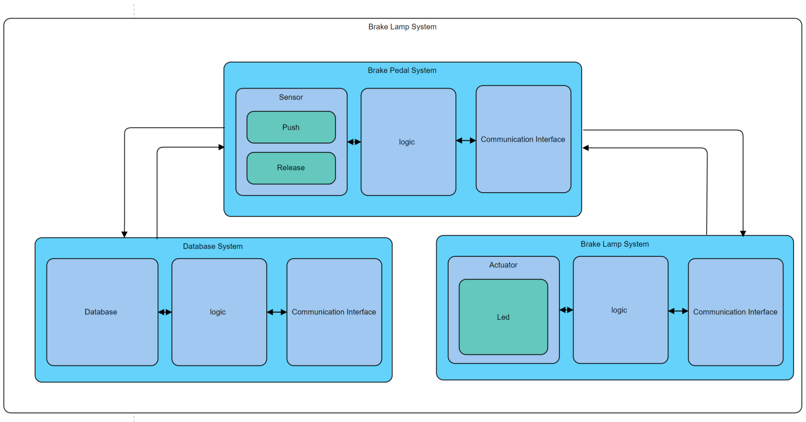

Fig. 10. System Architecture

Fig. 11. MCP2521

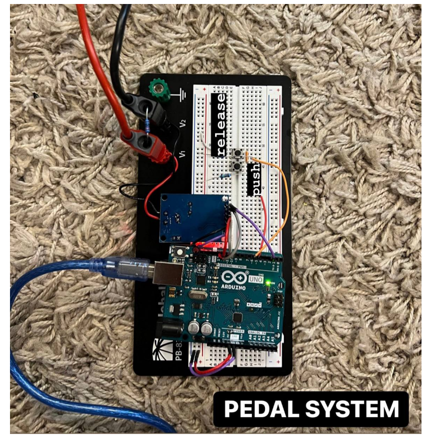

Fig. 12. Pedal subsystem

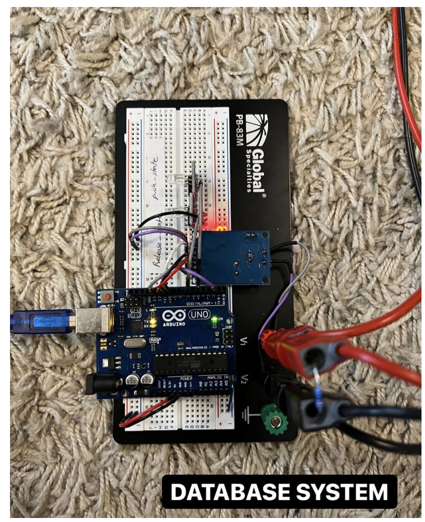

Fig. 13. Database subsystem

VI. State Of The Art

The CAN bus has played an essential role in the industry since its inception in 1987. Many companies, notably those in the automotive industry, are concentrating on CAN development. BMW, for example, first employed CAN bus technology in 1995. They used a star topology network with five electronic control units in their 7 Series automobiles. They then expanded the concept by integrating a second network for body electronics. This allowed two separate CAN-BUS networks to be linked via gateway connections. CAN systems gain trust in the automotive sector through protocol standardization and security testing to ensure system compatibility. [5] The CAN bus has established a name for itself not just in the automobile industry, but also in the medical arena. Philips Medical Systems, for example, was one of the first medical equipment manufacturers to employ the CAN bus for internal networking of their X-ray machines. [6] It's probable that vending machines will be created in the near future. As observed, a Chinese start-up company developed a prototype and deployed a CAN network. The prototype has the ability to make coffee. In other cases, it might be supplied with vending machines that sell vegetables and other meal supplies. Shuttle services using self-driving vehicles and autonomous freight will also be possible. A CAN-compliant vehicle control unit is installed in the vehicle. It controls the lights, horn, windshield wiper, handles, accelerator, and other functions. The electric steering unit also supports CAN connectivity. [7]

VII. Discussion

VIII. Conclusion

Acknowledgment

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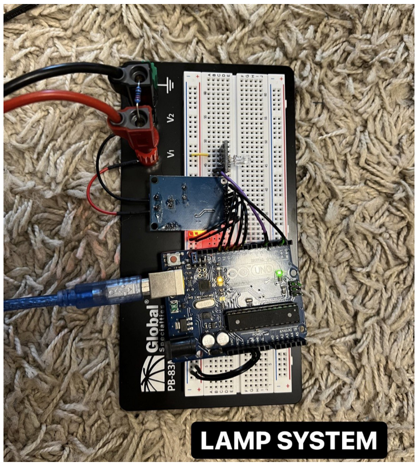

Fig. 14. Brake lamp subsystem

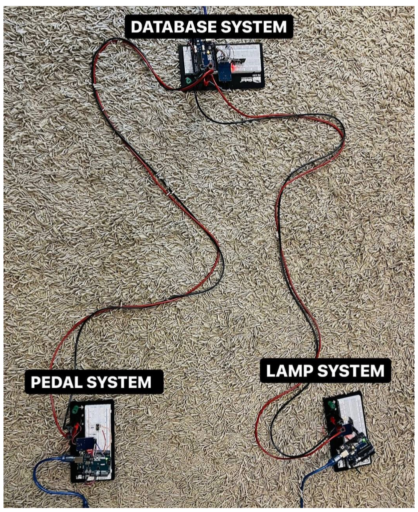

Fig. 15. Hardware setup

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