Communication Module for V2X Applications using Embedded Systems

Salim A. Mohammed Ali, Emad H. Al-Hemairy
Al-Nahrain University, College of Information Engineering, Department of Computer Networks Engineering, Baghdad, Iraq
Email: salimm@ieee.org, emad@coie-nahrain.edu.iq

Abstract. Smart cars are becoming the future of vehicle industry, most newly developed vehicles are equipped with communication modules that transmits and receive data for many purposes including insurance policy requirements, vehicle security, and for safety purposes. Cellular V2X requires all vehicles to have this module to transmit vehicle data and to receive feedback, so that V2X services can be implemented successfully. However, not all vehicles are equipped with such communication modules; therefore, the purpose of this paper is to design a communication module that enables all vehicles that has OBDII (On-Board Diagnostic module) standard to reliably transmit and receive related V2X data using Cellular networks, such as 3G, 4G, etc. through using affordable embedded system.

1. Introduction

The 2016 Global Automotive Executing Survey of Klynveld Peat Marwick Goerdeler (KPMG) [1] suggested that automotive developments are quickly changing year after year. For example, vehicle’s connectivity and digitalization were ranked tenth in 2015, but in 2020 were ranked as second. This has a momentous impact in near future because the fact that vehicles will transform to moving semi-computers, which can lead to virtual product structures and facilities [1]. One of the well-known technologies regarding this trend is the Tesla autopilot feature which is composed of autosteer, autopark, driver assistance visualization, etc. [2]. Additionally, the later vehicles technology has the ability to receive updates from time to time through internet. All these emerging technologies are core and key for smart connected cars. One popular vehicle service is smart mobility services such as travelling and car sharing or rental, while car makers invest in vehicle management features such as safety and autonomous driving, lastly, auto suppliers embed some advance driver assistance systems such as infotainment, human machine interface, connectivity and cloud-based services [3].

In this research, we adopted a small device called as,”Raspberry Pi”. A Raspberry Pi is a small sized computer, firstly introduced for education labs, inspired by the 1981 BBC Micro. The Raspberry Pi has lower specifications than a commodity laptop or desktop but it can operate a full feature Linux Operating System and can deliver all the solutions that is expected from a standard computer. It consumes low power and can be operated by batteries [4]. Raspberry Pi 3 model B is used for the project. The device is shown in Fig. 1.
This device has the ability to run many operating systems designated to for IOT applications, one of which is the “Raspbian”, which is an open source OS based on Linux-Debian designated for the device hardware specifications. “Raspbian” OS has the set of elementary software programs that enable Raspberry Pi to run many applications. Nevertheless, “Raspbian” not only offers a semi-full OS functionality but also it has plenty of third-party software packages, which can be easily installed on a Raspberry Pi [5].

The following section reviews the current technologies and facilities that enable the concept of connected vehicles. After then, it is followed by the design section, which includes the hardware design of the prototype, then followed with the real implementation of the module that enables the vehicles to communicate with a main server. Then the paper ends with conclusions and future work.

2. Literature Review

In this section, the paper presents some cited works that define vehicles communication steps and its evolution with time by using a simple overview of each.

2.1. Vehicle to Vehicle (V2V): Overview

A V2V communication technology, recognized as the connected vehicle safety model and Vehicular Ad-hoc Networks (VANETs), was presented by the U.S Department of Transportation’s (DOT) National Highway Traffic Safety Administration (NHTSA) in 2014. The main purpose of this communication technology is to increase the safety of small and mid-sized vehicles through allowing messages to be exchanged among vehicles. These messages comprises of vehicles information such as car position, size, motion direction, etc. and can be shared among vehicles through V2V protocols such as IEEE 802.11P, Dedicated Short Range Communication (DSRC), and Bluetooth, etc. Hence, some of the safety features includes: Lane Departure Warning (LDW), Blind Spot Warning (BSW, and Forward Collision Warning (FCW) [6], [7].

2.2. Vehicle to Everything (V2X): Overview

The concept behind V2X is to enable vehicles to connect to various entities that is within the proximity of a road such as traffic lights, pedestrians, mobile devices and other road infrastructure elements. V2V protocols has limited connectivity features, which cannot be encompassed by V2X wide range connectivity requirement. Therefore, new wireless network connectivity is required to be used rather than, DSRC or IEEE 802.11P. Fast and low latency cellular network infrastructure such as LTE-Advance (LTE-A) and the promising 5G networks are currently under research to adopt V2X connectivity, which is recognized as Cellular-V2X (C-V2X) [8], [9]. Moreover, it is anticipated that 5G will introduce new abilities to the world of smart connected vehicle because of the high data rates and low latency, and smooth connectivity. The concept of V2V, V2X and Vehicle to Infrastructure (V2I) is shown in Fig. 2 below [10].
2.3. Connected Cars: Overview

Several studies showed the concept of connected cars can be reinforced by implementing data collecting solutions to store and process data to implement V2X services. In [11], a big data solution is implemented for analyzing various vehicle data such as GPS coordinates, vehicle destination and velocity, engine sensors, etc., which are collected through using OBDII adapter. The research also included a mobile app to show users the diagnostic information of the vehicle on Internet. In [12], the research shows a proposition to use European On-Board Diagnostics (EOBD), GPS, a General Packet Radio Service (GPRS), and Universal Mobile Telecommunications System (UMTS) to evaluate the danger associated with car driving as part of a “Pay As You Drive (PAYD)” insurance program used for the calculation of insurance payments.

2.4. Design

Based on the information of the previous review section, one can suggest the main components of the system:

a. A database, which comprises of the following tables: vehicle information, rides and vehicle location history.

b. Vehicle data measurements module, which OBDII module can be used to read the necessary data from the vehicle. Extra sensors can be embedded to collect more valuable information such as location-based information.

c. On board processing module, this will overcome of needing vast processing power at the server-side, the on board processing module will data to useful information to be sent to the main server.

d. Telecommunication module, to ensure vehicles information to be reliably sent to the main server plus the ability to receive feedback from the server.

e. The main component of IoT concept is the connectivity to the internet, this can be achieved through using data networks of 2G, 3G, and 4G.

With these design points, the complete system building components is illustrated in Fig. 3. The system mainly has three segments: collecting sensors data, processing data, and transmitting information to the main server.

![Figure 2. The overall concept of V2V, V2I, and V2X](image)

![Figure 3. Hardware design modules](image)
A significant factor of the design is to calculate the End-to-End (E2E) latency of the system. The E2E latency can be calculated based of the following equation [10],

\[ T_{E2E} = T_{UL} + T_{BH} + T_{TN} + T_{CN} + T_{Exc} + T_{DL} \]  (1)

Where \( T_{UL} \) is the radio UL transmission latency, \( T_{BH} \) is the Backhaul (BH) network latency, \( T_{TN} \) is the Transmission latency, \( T_{CN} \) is the Cellular network latency, \( T_{Exc} \) is the processing latency and \( T_{DL} \) is the downlink latency. E2E calculation is considered but not calculated because the server processing and downlink delay was left as a future work.

2.5. Implementation

The whole implementation of the design is explained as steps, each block as a subsection.

a) Sensors Data (OBDII module)

In United States, vehicles have been obligated to have an “On Board Diagnostics port (OBDII)” since 1996. The rest of the world embedded the interface later. Fig. 4.a shows the adoption of many countries chronologically of the standard [13]. The OBDII interface enables us to connect and read essential data about the vehicle such as malfunctions, VIN numbers, vehicle speed, temperature sensors, engine’s RPM, etc. This information is vital to V2X applications. However, not all vehicles provides the same kind of information, due to the variety of vendors, which requires to append a facility device to interpret the data provided by the vehicles to universal information to be sent to remote data centers. For this purpose an OBDII reader is used to access the required data from the vehicle. Fig. 4.b shows the OBDII reader. And the data is transformed to unified information by the on-board processing module.

![Figure 4. (a) OBDII port adoption by countries over the time. (b) OBDII Reader Bluetooth](image)

b) Processing data (Raspberry Pi module)

As explained previously in the introduction part, Raspberry Pi adopts the accumulation of the required data by accessing the OBDII reader via Bluetooth. The script used in Raspberry Pi is mainly coded using Python. The script reads sensor data as hex-decimal coded data, which then interpreted into vehicles information such as, vehicle speed, temperature, fuel efficiency, etc. Fig. 5 shows a speed reading example using hexa-decimal notation with explanation of each digit.

![Figure 5. Vehicle speed reading using Raspberry Pi](image)
c) Transceiver (Cellular Network Module)

For telecommunication, an additional module is appended to the Raspberry Pi to enable it to communicate with GSM/3G cellular network for internet access. Additionally, a GPS module is appended with the communication module to obtain location information of the Vehicle, assuming that the vehicle has no GPS. Fig. 6 shows the SIM5320A transceiver module with the GPS antenna.

![Figure 6. GSM/3G Module with GPS antenna](image)

d) Cloud Server and Database

After reading the sensors data and interpreting the codes into information, a vehicle information schema is sent periodically to the server, which then is stored in a database. The database is big data compatible so further processing of the information is possible. The server can receive as many vehicle information as possible based on its specification. For this research, a simple public server is used to receive vehicles information from any place in the world. The server has web service enabled to automatically receive vehicles information and stores it in the database for further processing. The database tables of the data are shown in Fig. 7.

![Figure 7. Database tables structure](image)

3. Result and Discussion

All the components are mentioned above are integrated and tested to store vehicle information. The transceiver is tested to send and receive information from the server. The stored information comprises of selected vehicle sensors data and location based information extracted from the GPS module, since not all vehicles have built-in GPS modules. The data is transmitted as binary coded digits based on the vehicle vendor codes, at the server side the codes can be transformed to useful information such as current vehicle speed (e.g. whether it is Mile per hour or Kilo per hour). This will allow of sending as few bits as possible to prevent extra burden to the communication towers, which will be congested if too many vehicles send their data simultaneously. The communication module is tested on many vehicles from different vendors such as Hyundai Accent and Nissan Qashqai. The connection was successful with the server and vehicles information are successfully stored inside the database. Feedback channelling and big data transformation was left as future work. Fig. 8 shows the proposed system configuration for V2X connectivity and use of the designed communication module.
4. Conclusion

In this paper, an affordable communication device is implemented to enable all the vehicles that support OBDII port to have accessibility to cellular V2X services and features, which are becoming the future of the vehicle industry, because the most newly developed vehicles are equipped with similar communication modules. Cellular V2X requires all vehicles to have this module to transmit vehicle data and to receive feedback, so that V2X services can be implemented promisingly. Furthermore, the device can be upgraded to support other cellular communication systems such as LTE, and 5G by replacing the transceiver with a new upgraded one without affecting other components of the system.

References
[1] KPMG, "KPMG’s Global Automotive Executive Survey," KPMG 2020, [Online]. Available: https://automotive-institute.kpmg.de/GAES2020/megatrends/obvious-automotive-key-trends.  
[2] Tesla, "Model S Software Release Notes v7.1. 2016," Tesla, [Online]. Available: https://www.tesla.com/sites/default/files/pdfs/release_notes/tesla_model_s_software_7_1.pdf.  
[3] E. Baker, D. Crusius, M. Fischer, W. Gerling, K. Gnanaserakan, H. Kerstan, F. Kuhnert, J. Kusber and J. Mohs, "Connected Car Report 2016: Opportunities, Risk, and Turmoil on the Road to Autonomous," 2016. [Online]. Available: https://www.strategyand.pwc.com/gx/en/insights/2016/connected-car-2016-study.html.  
[4] "What is a Raspberry Pi," Open Source, [Online]. Available: https://opensource.com/resources/raspberry-pi. [Accessed 18 2020].  
[5] "Welcome to Raspbian," Raspbian, [Online]. Available: https://www.raspbian.org/. [Accessed 18 2020].  
[6] J. Harding, G. Power, R. Yoon, J. Fikentscher, C. Doyle, D. Sade, M. Lukuc, J. Simons and J. Wang, "Vehicle-to-Vehicle Communications: Readiness of V2V Technology for Application," 2014. [Online]. Available: https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/readiness-of-v2v-technology-for-application-812014.pdf. [Accessed 15 July 2020].  
[7] Vegni and T. Little, "Hybrid vehicular communications based on V2V-V2I protocol switching." International Journal of Vehicle Information Communication Systems, vol. II, no. 3/4, pp. 1-18, 2011.  
[8] G. Araniti, C. Campolo, M. Condoluci, A. Lera and A. Molinaro, "LTE for Vehicular Networking: A Survey," IEEE Communication Magazine, vol. II, pp. 148-157, 2013.  
[9] N. Le, M. Hossain, A. Islam, D. Kim, Y. Choi and Y. Jang, "Survey of Promising Technologies for 5G," Mobile Information Systems, no. 2016, pp. 1-25, 2016.  
[10] S.A. Mohammed Ali and E. H. Al-Hemairy, " Minimizing E2E Delay in V2X over Cellular Networks: Review and Challenges," in Iraqi Journal of Information & Communications Technology, vol. 2, no.4, pp. 31-42, 2019.  
[11] L. Nkenyereye and J. Jang, "Addressing Big Data Solution enabled Connected Vehicle Services using Hadoop," Journal of Korea Institute of Information Communication Engineering, vol. 19, pp. 607-612, 2015.  
[12] L. Boquete, J. Rodriguez-Ascariz, R. Barea, J. Cantos, J. Miguel-Jiménez and S. Ortega, "Data Acquisition, Analysis and Transmission Platform for a Pay-As-You-Drive System," Sensors, vol. 10, pp. 5395-5408, 2010.
[13] D. Klinedinst and C. King, On Board Diagnostics: Risks and Vulnerabilities of the Connected Vehicle, Pittsburgh PA: Carnegie Mellon University, 2016.