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ORIGINAL ARTICLE

A Vehicle-to-Vehicle (V2V) Communication Approach Based on Vehicular Cloud Computing for Autonomous Vehicles

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Abstract. In this paper, we propose a new vehicular communication approach for autonomous vehicles by utilizing vehicular cloud computing (VCC) to gather and exchange comprehensive information such as location, speed, and direction. The aim is to enable autonomous vehicles to communicate with each other via cellular and cloud services. Two vehicles were used for this cloud-based vehicle-to-vehicle communication and the communication device was placed in each of the vehicle. The data obtained from each vehicle was stored in cloud service and cellular network was used to send and receive from the cloud service. All vehicles can read each other's location information from the cloud and record the time of sending and receiving information to calculate the delay. Finally, for data visualization, the data was mapped into Open Street Map (OSM) to verify the location.

Keywords: Autonomous Vehicles, V2V Communication, Cloud Computing, Vehicular Technology

1. Introduction

With the rise of artificial intelligence technology, the level of driving automation has been further improved. A higher level of autonomous driving requires an autonomous vehicle (AV) to have more robust environment awareness and the ability to communicate with other autonomous vehicles [1]. Thus, there was an increasing number of sensor technologies that were used for AVs to sense their surrounding environment, such as the camera, lidar, and millimetre-wave radar [2]. Many researchers had also focused on multi-sensor fusion technology to obtain more accurate and reliable sensing information. However, these sensors faced environmental and distance limitations when sensing the external environment. To make up for the lack of sensors, the researchers had proposed advanced driver assistance system (ADAS) technology based on V2V communication [3], and one of the researchers had proposed to use the fusion technology of V2V communication and multi-sensor to construct intersection trajectory prediction and collision warning [2]. However, some of the vehicular communication systems were stand-alone and require proper infrastructures installed on roads such as road-side unit (RSU). In addition, each car manufacturer had their own V2V technology and standards. These issues may cause difficulty to gather the comprehensive information such as location, speed and direction from the vehicles as the vehicles cannot communicate with other vehicles from different manufacturers. Furthermore, as V2V communication used short-range wireless signals, the vehicles could only interact within the communication range. Although V2X communication could detect targets in the non-line-of-sight (NLOS) regions and extend the detection range close to 1 km, but the communication range was degraded by the number of vehicles, obstacles and other interference factors. Meanwhile, the increase in the number of AVs leads to an increase in traffic information data, which affects the transmission and storage of autonomous vehicle data. Therefore, it is critical to develop new vehicular communication approaches for AVs with no distance limitation, higher positioning accuracy and lower delay concurrently. The purpose of this paper is to construct a new vehicular communication approach for AVs by utilizing VCC to gather and exchange comprehensive information such as location, speed, and direction. The vehicles used are equipped with GPS module that can store, calculate and exchange data through cloud service.

2. Related work

The current mainstream self-driving cars basically rely on sensors and cameras. Thus, various types of sensors are used for the environment perception of AVs. Ignatious et al. had highlighted the importance of sensors for AVs and provide a detailed classification and comparison of sensors [4]. Zhang et al. proposed data fusion generated by multiple types of sensors mounted on the vehicle (e.g., radar, lidar and camera) to obtain the information about the surrounding environment of the vehicle [5]. This method could make up for the shortcomings of various sensors and obtain more comprehensive and accurate information about the surrounding environment under certain conditions. However, this sensor fusion method had limitations in terms of reliability and data acquisition range. Thus, a recent study focuses on V2V communication. The researchers had proposed two main wireless access technologies used on the vehicles, including Dedicated short-range communication (DSRC) and Cellular Vehicle to Everything (C-V2X) [6][7]. It enables vehicles to communicate within the communication range. In addition, Zang et al. highlighted that the V2V communication data can be exchanged in any weather condition, while the accuracy and reliability of on-board sensors will be greatly reduced in severe weather conditions such as rain, snow, and fog [8]. However, most of the vehicular communications are used for interaction of the vehicles within the communication range. Thus, cloud computing with big data storage, calculation and transmission capabilities had attracted the attention of researchers. Yang et al. proposed the virtual social connections between vehicles on the cloud [9]. Then, Huang et al. had also explored mobile edge computing by utilizing 5G network to define vehicular network and could computing [10]. In the investigation of real-time video surveillance data protection for autonomous vehicles, vehicular cloud computing (VCC) addresses the limitations of V2V communication on real-time data storage that was used by Alsyfi et al. [11].

3. Method implementation

This section introduces the methodology of this research in detail. The focus of this section is on communication methods for AVs to achieve data exchange on various roads. It covers methodology flowchart of VCC communication and communication framework.

3.1. VCC communication

In this paper, the communication between the vehicles is achieved through cloud service. The information of location, speed and heading between vehicles are stored, calculated and exchanged via Google Cloud. Figure 1 shows the flowchart of the proposed V2V communication based on cloud computing. Firstly, the GPS module with communication function located in the vehicle will receive the location information and send as well as store the data to Google Cloud. Then, the data is visualized using Open Street Map (OSM). In addition, two GPS modules mounted on vehicles can read each other's location information from cloud and calculate the delay of sending and receiving information.

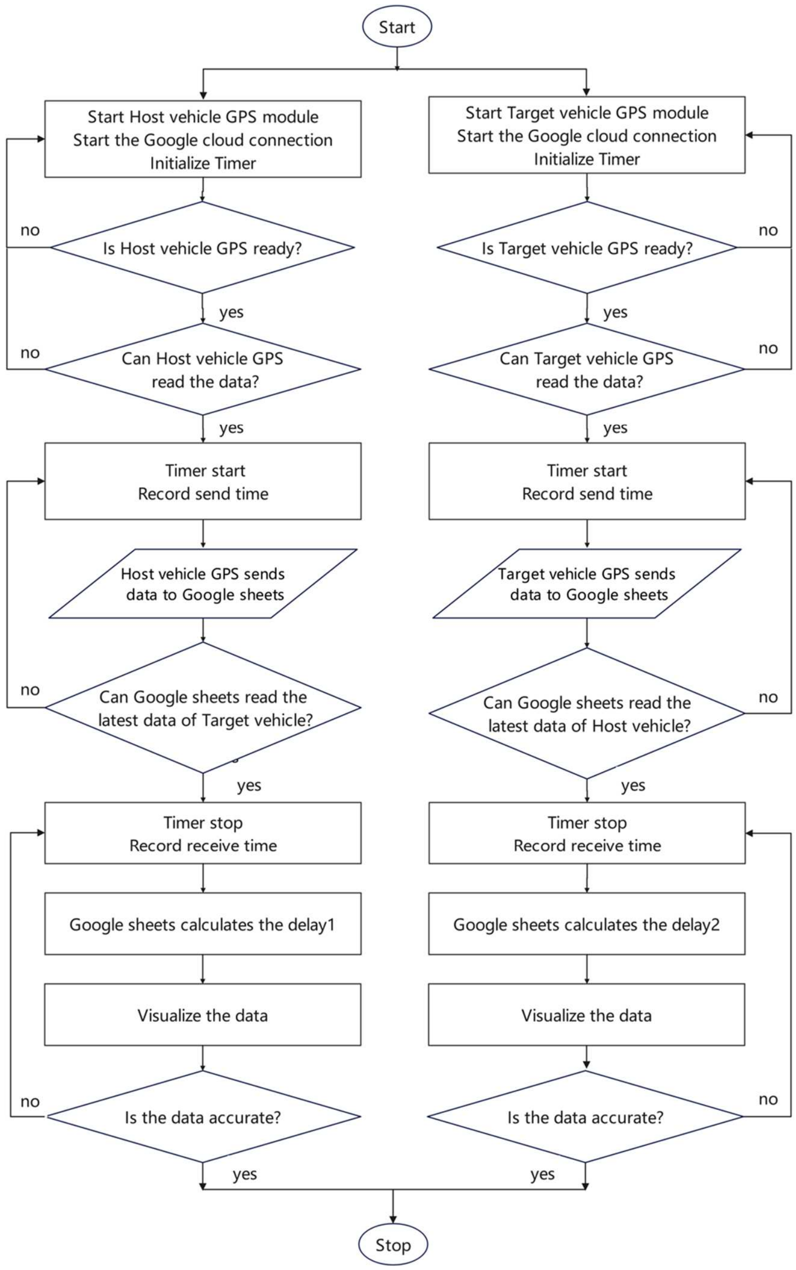

Figure 1. Flowchart of communication and delay calculation between two vehicles

3.2. Communication framework

The communication framework is shown in Figure 2. There are two AVs equipped with the GPS module communication module of the SIM7600E 4G HAT, the host vehicle (HV) and the target vehicle (TV), and the Google Cloud. When the GPS communication module is started and commands are sent normally, the HV and the TV simultaneously send as well as store the data to the cloud. When the HV obtains its position information, the timer starts and after the HV reads the latest data of the TV from cloud, the timer ends this time. If the HV does not read the latest data of the TV, it restarts the timer and waits until the latest data of the TV is obtained. The same process is will execute with the TV.

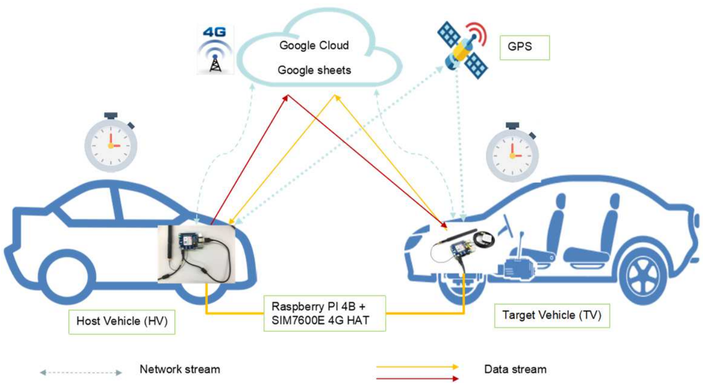

Figure 2. The communication framework.

4. Experiments and data analysis

This section verifies the feasibility of the communication method from two experimental scenarios and visualizes the data to the OSM for visual display. The first scenario is using a single-vehicle communication. This is to ensure that the GPS module with communication function can receive the location information and send as well as store the data to Google Cloud, and visualize the data to OSM through python's drawing library. The second scenario is the communication between two vehicles. A GPS module with communication functions is placed in each of the vehicles to communicate with each another using cloud computing.

4.1. Experiment setup

For the experimental works, The HV and TV were equipped Raspberry PI 4.0 that used to control the GPS module (SIM7600E 4G HAT) in order to send and receive data as shown in Figure 3.

Figure 3. Experiment setup.

4.2. Experiment environment

In the first stage, we tested with one vehicle to ensure the GPS module is working. The GPS data sent by the vehicle is stored in cloud. The data contains date, time and latitude and longitude coordinates. The latitude and longitude data obtained by vehicle GPS visualized on OSM as shown in Figure 5. By setting the zoom level of the map, the detailed level of the regional road segment can be displayed, and the accuracy of GPS to obtain location information can be reflected, as shown in Figure 4.

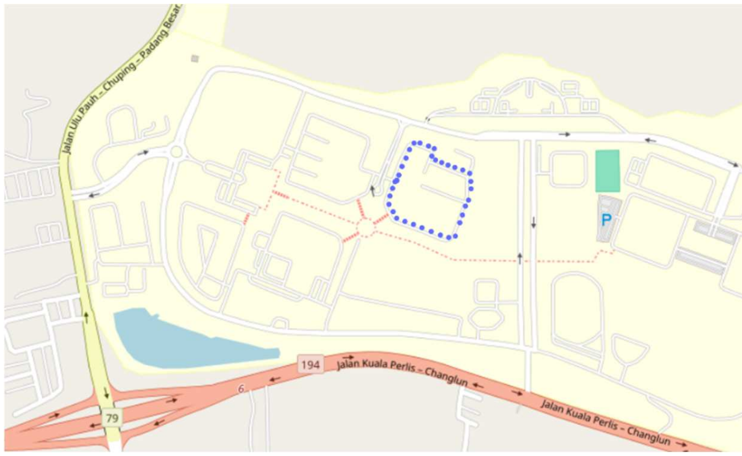

Figure 4. Street level view of road data visualized to OSM.

In the second stage, we had used two vehicles to test the ability to exchange data between the two vehicles and calculate the delay in sending and receiving data. Taking HV as an example, when the TV starts and obtains its position information, the timer is started and recorded as the data transmission time, t_t. When HV reads the latest data of TV from cloud, the timer ends and records the time as the data receiving time, t_r. If the HV does not read the latest data of the TV, it restarts the timer and waits to read the latest data of the TV until the latest data of the TV is read. The formula for calculating the delay is as follows:

$$delay = t_r - t_t \tag{1}$$

From the results, the average delay is 5.5s. The latitude and longitude data of the HV and the TV are visualized on OSM, as shown in Figure 5. By increasing the zoom value in Figure 5, we can clearly see the start and finish positions of the HV and the TV, as well as the positions separated by every two seconds, as shown in Figure 6.

Figure 5. Trajectories of two vehicles at the university campus.

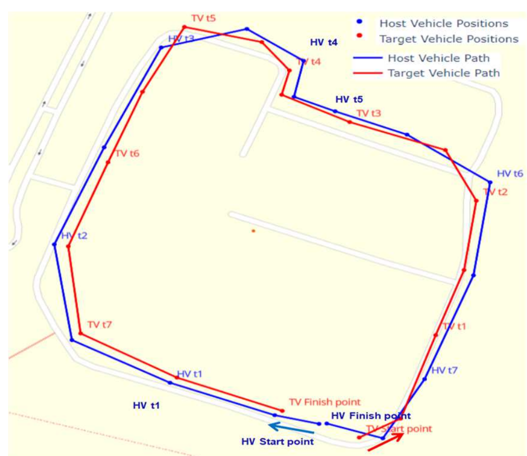

Figure 6. Zoom in for a detailed view.

4 Conclusions

In this paper, we present the development of a new communication approach for autonomous vehicles based on vehicular cloud computing. Through the experiments of two test scenarios, the results show that the feasibility of the communication approach based on vehicle cloud computing. The two vehicles were able communicate with each another through cloud computing. However, there are still some shortcomings, such as the positioning accuracy that can be further improved, and the communication delay can be further reduced.

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