SICE Annual Conference 2015
July 28-30, 2015, Hangzhou, China

# Vehicle to Vehicle Communication and Platooning for EV with Wireless Sensor Network

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**Abstract:** Driving assistant systems with cameras and sensors are expected as a solution of safe driving, congestion prevention and driving load reduction and vehicle to vehicle (V2V) communication systems that utilize wireless technology has been proposed as an auxiliary system of the existing systems. On the other hand, as long with the increasing of the aging rate of society, traffic accident of seniors become a serious problem to be solved. Smarty automatic driving system has been developed to realize a smarty platooning control system based on the automatic driving system for senior drivers. In this research, an embedded communication system is developed for small automatic electric vehicle, and an algorithm to avoid transmit collision is implemented in the developed system. Based on the vehicle to vehicle communication, a platooning control system including vehicle interruptions and separations is successfully designed. Some experiment results of several platooning patterns for small EV represent the effectiveness of the developed system.

**Keywords:** Platooning, Autonomous driving system, Digimesh, Vehicle to vehicle communication

## 1. INTRODUCTION

Driving assistant systems with cameras and sensors are studied by the automobile makers as an important part of ITS technology. They also have been expected as a solution of safe driving, congestion prevention and driving load reduction. However, cameras and sensors got performance limitation at some situations such as an intersection with poor outlook. Therefore, vehicle to vehicle (V2V) communication systems that utilize wireless technology has been proposed as an auxiliary system of the existing systems. Take a platooning system of heavy trucks with high reliability V2V communication technology as an example. This system performs a high density platoon run of heavy trucks with vehicle-to-vehicle distance 4m on the highway to realize the fuel efficiency improvement and the traffic congestion reduction. However, because of the dependency to the traffic situation and the constraint of cost, this system didn't realize in general road.

On the other hand, as long with the increasing of the aging rate of society, traffic accident of seniors become a serious problem to be solved. Moreover, complex traffic situation such as the slope road, dense residential area and narrow roads makes it difficult to drive. As a solution to decrease the burden of senior driver and guarantee safety drive, a V2V communication system based on small electric-vehicles (EV) is gathering attention worldwide.

Therefore, the purpose of this research is to make a embedded communication system in a low cost to construct a dynamic wireless network. This network contains nodes with relay function so that a car can relay the transmit data from other cars.

## 2. SYSTEM CONSTRUCTION

### 2.1 Introduction of Ultra small EV COMS

In our research, we use the ultra-small single-seat EV COMS shown in Fig.2.1. The COMS is remodeled with stereo camera, ultrasonic sensor, and GPS, IMU and control systems to realize autonomous driving. A sensor-fusion technology is used to identify the obstacles. The ultrasonic sensor with high sensitivity and low price is used for short distance detection. The ultrasonic sensor is strong with the affective of color and brightness and is easy to be transmitted. For long distance obstacle detection, we developed an algorithm for obstacle recognition by utilizing parallax coming from stereo camera. GPS and IMU are used for measure the vehicles' body angle information and current position information.

Fig.2 shows the structure of control system. This system contains a monitor PC, a remote monitoring PC, an image processing PC, a router and an EV controller. The monitor PC is used to collecting IMU and GPS data, route generation and outputting the calculation result. The remote monitoring PC is used for remote monitoring and emergency handling. The camera data collecting, obstacle recognition, white line recognition realized by the image processing PC and it is also used for outputting the calculation result. The EV controller is in charge of collecting all data, executing control model calculation and sending control values. Wireless LAN network is used to connect the remote monitoring PC so that the EV status can be monitored remotely. And a router is used to construct a LAN network of the monitor PC, the remote monitoring PC and EV controller.

Fig.2.1 Ultra small EV COMS

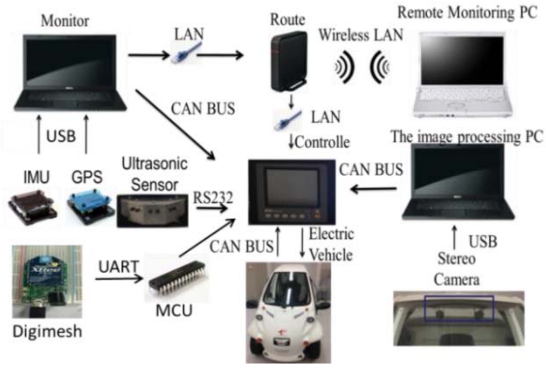

Fig.2.2 Structure of control system

## 2.2 Introduction of embedded communication system

In our research, we made an embedded communication system with XBee PRO S1 module for wireless communication and PIC18F25K80 MCU for CAN communication. This system contains two layers of communication network to complete vehicle to vehicle communication:

1) The CAN communication network to get the status data information of the COMS which is used to make the COMS drive automatically when vehicles are driving in the platooning situation(3).
2) The Digimesh communication network to transmit information remotely between vehicles' central controller.

Fig.2.3 shows the specific image of the vehicle to vehicle communication system and Fig.2.4 shows the flow of communication. Central controller collects the information from the sensors of the COMS which are used to achieve automatically driving. And the MCU will collects the information and send it to the XBee module. Then the XBee sends the information to other vehicles by the Digimesh network, and the received information will be send to the controller via MCU. Through this, the following vehicles can drive in the platooning mode using the received information..

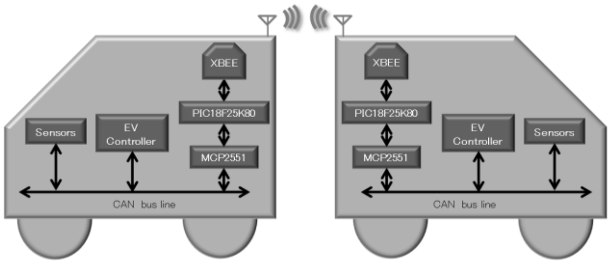

Fig.2.3 The specific image of the communication system

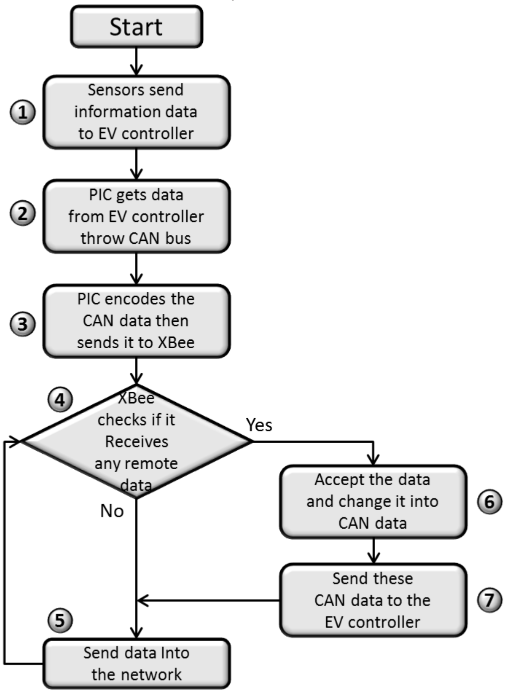

Fig.2.4 Flow chart of communication

We choose the PIC18F25K80 MCU to control the communication system. The PIC18F25K80 is a 28-pin enhanced flash MCU with ECAN module which full backward compatibility with the existing CAN modules. The ECAN module support CAN1.2, CAN2.0A and CAN2.0B versions of the protocol. With this MCU, we can take an access to the CAN bus and communicate with other CAN nodes. And the PIC18F25K80 is also support the UART communication. The UART communication is a kind of serial communication and we use this interface to make the MCU communicate with the XBee module.

# 3. SYSTEM ALGORITHM

## 3.1 Remote communication algorithm

Since the vehicles as nodes in the network are moving at high speed, the positional relationship between the vehicles varies from seconds to seconds. A collision will be easily occur while data transmitting. We used the token ring protocol to avoid the collision of multiple nodes communication. Token ring is commonly used in LAN but the scheme can also be used with bus topology network such as CAN.

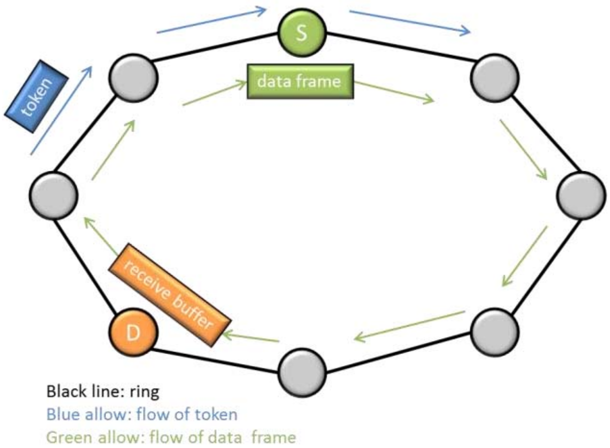


Fig.3.1 process of data transmission

The process of the data transmission of the token ring protocol is shown in Fig.3.1. A 3bytes frame called token is circulating around the ring(black lines) between nodes. The source node will seize the token and will be enabled to send the data frame to the ring. The data frame will be checked by each node it passed by. The node that identifies itself as the destination node will copy the data to the receive buffer and change the token to 0. Finally, the source node will receive its own data frame. Then it will confirm the data was been received and remove the data. Then the token will travel around the ring again. To determine which node will be able to send, we use the local system time of each node. The equation to calculate the number of node to be able to send is shown as Eq. (1)

$$\frac{X_n + (X_n - Y_n)}{T}\ Mod\ Z = N \quad (1)$$

where $X_n$ is the start local system time of source node, $Y_n$ is the start local system time of destination node. T is the transmission frequency. Z is the number of nodes, N is the source node number.

A node will see if the node number is itself to determine if it will seize the token.

With the token ring, only the node that seized the token is able to send data. It will ensure the collision not occur when the number of the nodes is getting larger.

### 3.2 Platooning driving algorithm

A platooning system is designed to verify the communication system. The Google earth is utilized to get the map information and the pathway of the platooning shown as Fig.3.2 is designed with it.


Fig.3.2 platooning path way

A platooning algorithm is used for the control of stable distance vehicle platooning. The vehicles' driving state data is gathered to calculate the actual acceleration of the vehicles with PID control. Eq. (2) shows the equation that is used.

$$u(t) = K\big(e(t)\big) + \frac{1}{T_I}\int_0^1 e(\tau)d\tau + T_D\frac{d}{dt}e(t) \quad (2)$$

Where u is the vehicle actual acceleration command vector, K is the feedback gain.

In this platooning system, 3 COMS are used and 3 platooning patterns shown as follow will be realized.

(1) Tracking. 3 COMS drive in a line with a stable distance and the following car will get the information of the leading car
(2) Interrupt. 2 COMS drive in a line and another COMS will break into the middle of the 2 COMS.
(3) Separate. 3 COMS drive in a line and the one to be separate will leave the ranks.

The flow chart of the platooning is shown as Fig.3.3. First, the EV controller gets the driving state information from the sensors such as IMU etc. and the information data will be read by the PIC. Also, PIC will check if it received other vehicles' state data from the XBee. If there is no data, the vehicle will identifies itself to be the leading car and switch into the automatically driving mode. Otherwise, it will switch modes from Tracking, Interrupt or separate. In tracking mode, the vehicle will determine the distance to the leading car. In interrupt and separate mode, a lane change command will be sent and the interrupt or separate COMS will change its lane. Then a distance error between the leading and following car will be calculated. The distance error is the error of the set distance and the real distance. After this, the vehicle will control the acceleration to remain in a stable vehicle distance. Then the acceleration data will be used to calculate the acceleration command value. And finally, the value will be sent to the EV controller for platooning.

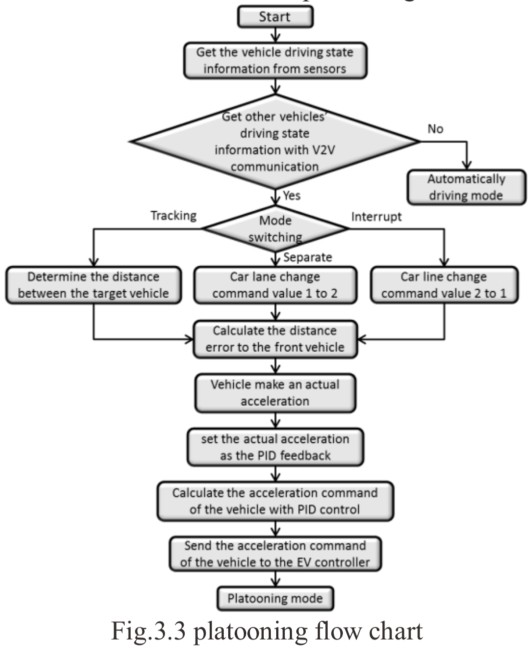


Fig.3.3 platooning flow chart

## 4. EXPERIMENT

To verify the effectiveness of our system, we did simulations and experiments of the 3 platooning patterns explained in chapter 3. We designed a running course based on the real pathway shown in Fig.3.2 for simulations.

First, for tracking pattern, we made the 3 CMOS do a platooning run at a speed of 8km/h in a stable vehicle distance of 2.5m and then turn at the corner of the course road. This situation is explained in Fig.4.1.

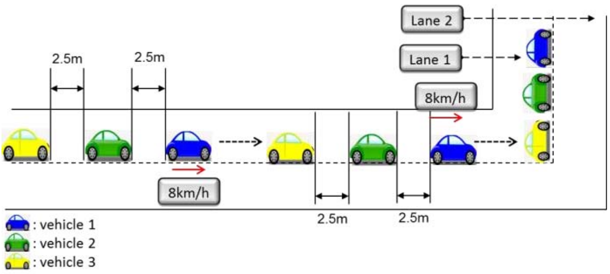


Fig.4.1 tracking situation

The simulation result shown in Fig.4.2 shows the relationship of steering angle and time. Fig.4.3 shows the image of the real tracking experiment. From the result, we can see the 3 COMS ran in a stable rank and made same steering in the corner. We know the V2V communication system and the CAN communication system are effective. And the algorithm we used to avoid the collision is also effective. The effectiveness of the normal platooning is verified.

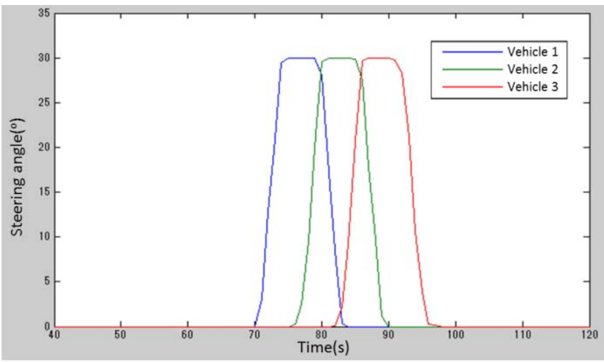


Fig4.2 result of tracking simulation

Fig.4.3 image of tracking experiment

Next, we did an interrupt experiment. In this experiment, 2 COMS are running in line with a distance of 2.5m at a speed of 8km/h. The interrupt COMS is running beside them with a width distance of 1m at a same speed. Then the interrupt COMS will accelerate up to 10 km/h to break into the rank while the following COMS slow down to 6km/h. After the interrupt COMS is in position, it, also the following COMS will adjust their speed to form a rank with a distance of 2.5m. Finally they will turn at the corner in rank. This situation is explained in Fig.4.4

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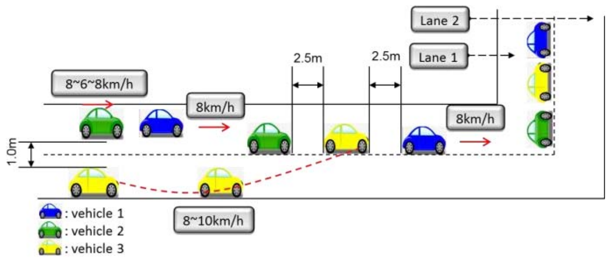


Fig.4.4 interrupt situation

The simulation result is shown in Fig.4.5, and the image of the experiment is shown in Fig.4.6. From the result, we can see the interrupt vehicle and the following vehicle completed their action accurately. Also they turned at the corner like the experiment1.The algorithm to control the interruption in platooning is verified to be effective.

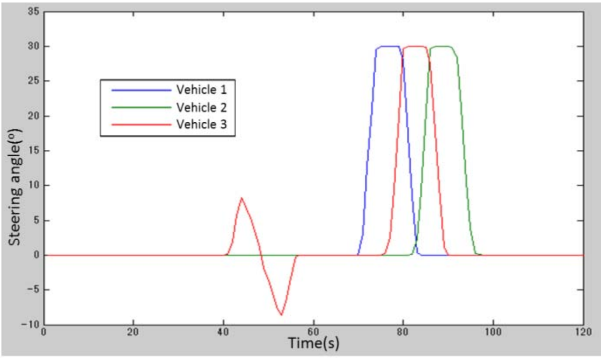


Fig4.5 result of interrupt simulation

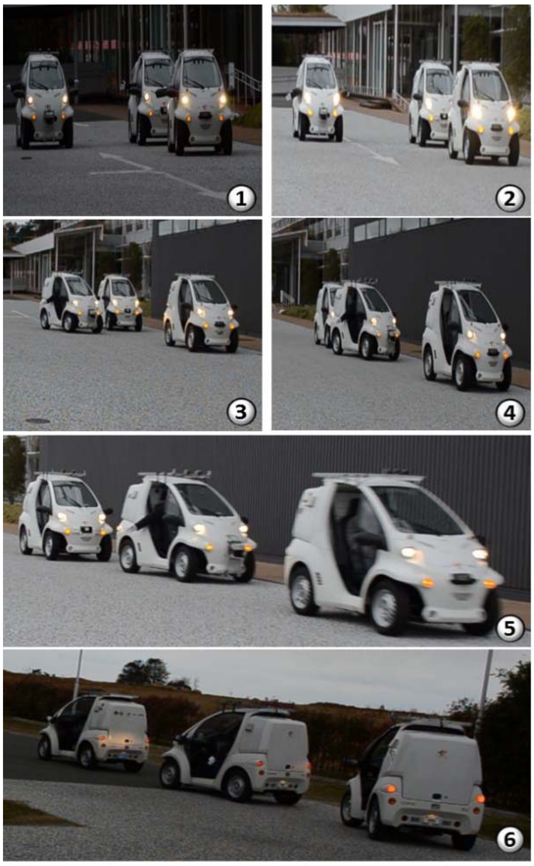

Fig.4.6 image of interrupt experiment

In the separate experiment, 3 COMS running in rank at first with a stable distance of 2.5m. The speed is 8km/h. Then the separate COMS will leave the rank and accelerate up to 10km/h while the following COMS will accelerate up to 10km/h, too. Then the leading and following COMS will form a rank and the separate COMS will run beside them. This situation is explained in Fig.4.7.

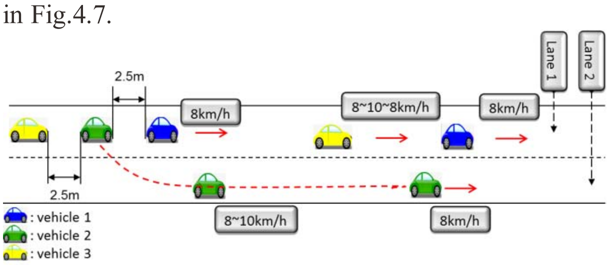


Fig.4.7 separate situation

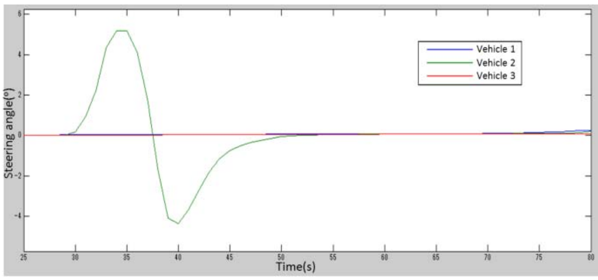


Fig.4.8 result of separate simulation

Fig.4.9 image of separate experiment

The simulation result is shown in Fig.4.8, and the image of the experiment is shown in Fig.4.9.From the result, we can see the separate vehicle left the rank smoothly and the other 2 vehicles formed to platooning drive successfully. The effectiveness of the algorithm to control separation in platooning is verified.

## 5. CONCLUSION AND FUTURE WORK

In our research, with the aging society getting more serious, we designed and modified the small electric vehicle for elder and build automatic driving system. More important, we designed a platooning system including vehicle interruptions and separations for a variety of traffic situations.

We used Digimesh to exchange driving data between vehicles remotely and MCU with ECAN module to realize the data transmission on vehicle CAN bus. A token ring is used to avoid transmit collision. The platooning experiments also verified the effectiveness of our system.

As a conclusion:

(1) V2V communication system is working smoothly. These 3 vehicles can keep a safety distance to drive in platooning with V2V communication without transmit collision.
(2) The communication system with PIC18F25K80 can get access to the CAN bus and send data to the XBee as designed.
(3) Vehicles can realize platooning of driving in a line and complete interruption or separation successfully and accurately. .

In the future, there are three aspects work need to be finished.

(1) The research about sensors for position recognition should be more completely and the improving of riding comfort for senior drivers and the stability of surrounding recognition at high speed.
(2) The platooning research including supporting more vehicles and improving the communication stability.
(3) The development of a flexible communication network for variable number of vehicles.
(4) The development of a communication system between the vehicle and road or between vehicle and pedestrian.

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