Research on Traffic Participants Trajectory Tracking Scheme in Proving Ground Based on Roadside Intelligence Technology

Disi Zhang*, Xinhai Chen, Liang Zhou, Bo Xie and Dirui Wu
Chongqing Vehicle Test & Research Institute Co., Ltd., Chongqing, China

*Corresponding author e-mail: zhangdisi85@haoxueshu.com.cn

Abstract. To enhance the road intelligent ability and enable it actively perceive vehicles, an architecture based on Multi-access Computing (MEC) technology and lidar equipment is designed. Firstly, the full coverage of regional perception is realized through multi-lidar combination. The point cloud data of traffic participants sensed by lidar is analyzed in real time by edge computing unit. After processing, the structured data of traffic participants are obtained, which are transmitted to visual interface through middleware system. At the same time, the virtual ID and physical ID of the traffic participants are matched through manual or dynamic pairing scheme, so that the administrators of the closed area can accurately obtain the track information of traffic participants without the OBUs.

Keywords: Trajectory Tracking, Multi-access Computing, Lidar

1. Introduction
Generally, the method to obtain traffic participants’ information like location, speed and direction mainly depends on On-Board Unit(OBU). This is also a common trajectory tracking method in public roads, which is simple and direct. However, the vehicle mobility in proving ground is relatively large, so that the distribution and installation procedures of the OBUs will be time-consuming and complicated. In that case, it will dramatically increase the workload of staffs and affect the customers experience. In practice, it is found that with the passage of time, the staffs and customers often get tired of the OBUs procedures and gradually no longer require vehicles to install OBUs [1]. Therefore, this trajectory tracking method relying on OBUs is probably not suitable in typical areas with large mobility.

With the development of edge computing and roadside intelligence, a new approach for trajectory tracking that roads can actively percept the traffic participants has been cultivated, which no longer completely depends on OBUs [2]. This paper will elaborate the application of this scheme.

2. Review of the Method Relying on OBUs
An intelligent upgrade was carried out in a proving ground in 2018. The most significant improvement is to increase the visual supervision function of vehicles: staffs and customers can inspect the movements of the vehicles at any time on the large screen or mobile phone, including the position,
speed and direction. Also, the historical trajectory of the vehicles can be reviewed. This is mainly achieved by the OBUs [1].

The high-precision positioning modules in OBUs continuously receive satellite and differential signals from RTK station in the ground. After correction, the location information is transmitted to the visual interface through the cellular network, and the visual interface realizes the visual display of vehicles.

As mentioned in the introduction, the working environment of the proving ground is different from that of open roads and other closed areas: the vehicle mobility is relatively large, which brings great workload of OBUs management to staffs. Therefore, in the past two years of operation, the utilization of the scheme is below the expectation. It is mainly reflected in the following aspects:

1. The installation and disassembly procedures are complicated: two GPS antennas and one cellular communication antenna need to be installed outside the vehicle each time.
2. Handover procedure is time-consuming: Tedious operations need to be repeatedly performed when the OBUs are loaned and withdrawn.
3. The actual performance is affected by various factors: as the OBUs are non-standard product commissioned by a third party, there are occasional system instability and loss of positioning signal, which may bring negative effect. In addition, in areas with poor satellite signals such as tunnels, the positioning function is also affected [2].

As a result of the above drawbacks, the original design of regional billing functions can not be achieved, and the visual display effect has also been below expectation.

As the trend that intelligence migrating from vehicles to roads becomes clearer and clearer, the roads will be granted more responsibilities. It also provides an inspiration of the intelligent scheme for proving grounds: instead of using the OBUs to obtain the vehicles’ information, it is better for the roads to actively perceive the vehicles (See Figure 1).

3. Critical Factors of Roadside Intelligence Technology

3.1 Roadside Sensing Devices
Roadside sensing devices are the essentials of the roadside intelligence architecture, which are mainly composed of cameras, lidars, millimeter wave radars. By analyzing sensors’ signals, they can obtain the distance, position, speed, size, shape and other information of objects.

There are advantages and disadvantages in the performance of the three sensors. The cameras have a good performance in target identification, but has a poor ability to detect distance and speed. Millimeter-wave radars have a high accuracy in speed detection, but a poor accuracy in lateral displacement recognition of targets and a poor ability to recognize static objects. The lidar detection capability is balanced especially for distance. With the support of point cloud analysis algorithm, it can also identify the shape, type and other parameters of the target. In addition, the splicing of multiple lidars enables the object to maintain the unique ID within the splicing range. This feature is an important basis to realize the global track perception in the proving ground. Therefore, lidar is the best choice among current roadside sensing devices [3]. At the same time, incorporation with sensors such as camera and millimeter-wave radar, the target recognition effect can be greatly improved with the help of fusion sensing algorithm (see Table 1).
### Table 1. Comparison of three common sensors

| Perception Dimension          | Camera | MMW Radar | Lidar |
|------------------------------|--------|-----------|-------|
| Angle of FOV                 | ++     | +         | +++   |
| Detection Distance           | ++     | ++        | ++    |
| Horizontal Accuracy          | +      | -         | ++    |
| Distance Accuracy            | -      | +         | ++    |
| Speed Accuracy               | -      | ++        | +     |
| Ability in Bad Weather       | -      | ++        | +     |
| Ability in Night or Floodlight| -      | ++        | ++    |
| Object Detection and Classification | ++ | -         | ++    |
| Detection for Small Object   | ++     | -         | +     |

#### 3.2 Multi-Access Edge Computing Architecture

Edge computing architecture provides powerful computing support and low latency communication for road intelligence. Sensor devices based on lidar generate amazing amounts of data per second. An 80-line lidar has millions of points per second, and the amount of data is as much as 5MB/s. In the case of multi-radar splicing, the amount of data will reach an astonishing scale. If all the data is returned to the traditional center for processing, it will cause a great burden on the network [4]. Therefore, we need to set up an edge computing unit at the edge of the network, analyze a large amount of radar point cloud data, and get the structured data (position, speed, type, size, direction angle, etc.) that we ultimately need and distribute to the upper application level. Since the edge computing unit is located on the edge of the network, it can quickly send information to the end user and obtain better delay performance [5](see Figure 2).

Depending on the location, network size and actual use of the edge computing unit deployment, the edge computing architecture is divided into different grades: central grade, convergence grade, edge level, access grade and field grade. The first four grades rely on the public network, which are complex and costly. And the field grade mainly depends on the user's local area network, which is appropriate for scenarios that do not require high network latency and has a fixed user group.

![Figure 2. The advantage of MEC over traditional architecture](image)

#### 3.3 Multi-access Edge Computing Unit

Multi-access Edge Computing Unit can be understood as a high performance industrial computer[6]. Its main function is to process and analyze the enormous amount of data generated by sensors on the edge side, avoiding the network burden caused by the return center, and transmit the results to the end user through a low-latency channel. There are various ways to deploy Multi-access edge computing units as needed, such as RSU backends for C-V2X networks or access networks for operators [7][8]. On open roads, Multi-access edge computing units are generally deployed on roadside poles and
towers, which require high dust and water proof and heat dissipation performance. In areas with relatively good conditions, such as proving grounds and car parks, Multi-access edge computing units can be deployed in central computer rooms, which can greatly reduce the requirements for environmental adaptability, thereby reducing costs and prolonging their life[9][10] (see Figure 3).

Figure 3. Typical Multi-Access Edge Computing unit

4. Architecture Design of Trajectory Tracking System Based on Road Intelligence
The system architecture is divided into perceptual fusion layer, information interaction layer and application layer by use and function.

4.1 Perception Fusion Layer
The perception fusion layer is mainly composed of sensors array and edge computing unit. To achieve the full coverage of the proving ground, we need to rely on the splicing technology of multiple lidars. Limited by the graphics processing ability of a single edge computing unit, an unit can only process the point cloud data of two lidars, so we use two processing levels to realize the point cloud splicing. As shown in Figure 4, the first layer is composed of multiple edge computing units with strong floating-point performance connected by optical fiber, which analyzes the point cloud data and outputs the structured data of traffic participants in their respective regions; The second layer is composed of an edge computing unit with strong integer performance. Its main function is to summarize the structural information output by the first layer edge computing unit array, and then to perform the target deduplication and corrections, and finally to output the target structured data of the whole region. Generally, we use UDP mode to output, and set the frequency to 10Hz.

Figure 4. Framework of the system
4.2 Transportation Layer
The transport layer consists of an MQTT middleware that encapsulates structured data from the perceptual fusion layer into RSM messages and delivers messages to the upper application in a publish/subscribe manner. Publish/Subscribe is a decoupled transmission method. Sender and receiver need not know each other's location but the interface address of the middleware to achieve flexible deployment. It is widely used in the Internet of Things architecture and is suitable for systems with a large number of terminals, fast state changes and a large amount of transmission information.

Considering the universality of the system, messages in the information transmission layer should follow the RSM (Roadside Safety Message) message stipulations in CSAE53-2017 "Application Layer and Application Data Interaction Standard for Automotive Communication Systems of Cooperative Intelligent Transport System" or YD/T3709-2020 "Technical Requirements for Message Layer of Wireless Communication Technology for Vehicle Networking Based on LTE". RSM messages are defined in ASN.1 standard format to eliminate differences between implementation languages and are effectively compressed using the Unaligned Packet Encoding Rules encoding rule UPER (See Figure 4).

4.3 Application Layer
The application layer is composed of graphical display system and scenes trigger system; graphical display system subscribes to related topics such as RSM, and displays on the GIS map after parsing the data to get the coordinates of the vehicle location; at the same time, it can record the historical location of the vehicle continuously, so as to achieve the functions of track tracing; Scene trigger system obtains the location, speed and other information of all traffic participants by parsing RSM information, generates warning events by judging the location relationship between them and calculating TTC (TIME TO COLLISION) parameters, encapsulates related subject information and sends it to MQTT middleware. Usually, this module can send alert messages to related terminals through the Uu port of C-V2X (cellular network).

5. Implementation of Trajectory Tracking Scheme

5.1 Deployment of Roadside Perception Devices
Based on the narrow east-west and long north-south terrain of the current ground, we chose to install lidars on the lawn in the east-west direction to the center so that the lidars can cover the roads on both sides of the East and west (See Figure 5).

In addition, according to our test, although the detection distance of the mainstream 80-line lidar can reach about 200-250 meters at 10% reflectivity, the recognition distance can only cover about 120 meters with guaranteed effect. Therefore, in order to ensure the performance, we set the interval distance between the lidars to about 200 meters (See Figure 6).

**Figure 6. Deployment of Lidars**

In obscured areas such as tunnels, 32-line radars are deployed to eliminate blind areas and ensure the continuity of the perceived range.

**Figure 7. Installation of Lidar**

At the same time, in order to easily adjust the angle of the lidars, so that the lidars’ beam can cover more effective areas of the lanes, a special universal joint base is also designed.

5.2 Bindings of Physical IDs and Virtual IDs

The global track perception of the proving ground means that the system continuously knows the location of the vehicle during the whole process.

**Table 2. The output of Perception Fusion Layer**

| No | Filed Name   | Data Type | Field Length | Remarks                                                                 |
|----|--------------|-----------|--------------|-------------------------------------------------------------------------|
| 1  | Area of Obstacles | Uint16    | 2            | The Number of the area                                                  |
| 2  | Type of Obstacles | Uint16    | 2            | 0-undefined, 1-Pedestrians, 2-Non-motors, 3-Small Vehicles, 4-Large Vehicles, 5-Extra large vehicles |
| 3  | Obstacles' Length | Uint4     | 4            | ID remains consistent in perception area                                |
| 4  | Obstacles 'Width | Float     | 4            | Unit: meter                                                            |
| 5  | Obstacles 'Height | Float     | 4            | Unit: meter                                                            |
| 6  | Obstacles’ Orientation | Float | 4            |                                                                        |
| 7  | Obstacles' Acceleration | Float | 4            | Unit: m/s²                                                             |
When a vehicle enters a lidar-aware area, it is assigned an ID number, the Obstacle ID in Table 2, which we define as virtual ID. This ID is theoretically unique within the perceptual range and can be restored by an algorithm even after a brief signal loss.

The physical ID can be interpreted as the unique identification of a real vehicle, similar to the VIN number; the ID remains unique all the time. This ID can be used as an index to get specific information stored in business management system about the manufacturer, model, test project, responsible person of the test vehicle.

In the absence of an association between a physical ID and a virtual ID, the specific information of the vehicles cannot be displayed on a GIS map.

Therefore, we need to associate the above physical IDs with virtual IDs. Simply speaking, physical IDs represent the soul of a vehicle and contain inherent information such as vehicle type, vehicle manufacturer, etc. Virtual IDs represent the body of a vehicle and enable it to appear in the visualization system. By combining the two, we can get all the information of a vehicle and displayed on the GIS system.

Initialization of physical ID and virtual ID bindings is performed at the gate of proving ground, and the associations are maintained in the scenes trigger system in Figure 4, which sends subject information to MQTT when the associations change. Initialization process as shown in Figure 8: When the vehicle arrives at the gate, the gate guard uses the mobile phone connected to the business management system to scan the QR code posted on the vehicle window, which corresponds to the physical ID of the vehicle; after the scan is completed, the business management system will push a subject containing the physical ID; The Scenes Trigger module receives the theme message and parses the RSM message sent by the perceptual fusion layer to find the virtual ID of the vehicle at the entrance and complete the initialization operation.

Similarly, when the vehicle exits, the gate scans the QR code again, and the business management system pushes the subject containing the physical ID; Scenes Trigger module receives the theme message and parses the RSM message sent by fusing the perception layer cycle, finds the virtual ID of the vehicle at the exit, and completes the unbundling operation.

In addition, it is possible for a vehicle to lose its signal in the perception system (that is, the perception system has not detected the vehicle for a period of time), and the virtual ID of the vehicle will change once the signal is restored. In order to cope with this situation, we also need to design the rematching operation in the process; without using other perceptions, we can make a preliminary remedy based on the algorithm logic, for example, if only one vehicle A's virtual ID in the site is lost and another unfamiliar virtual ID appears, then we can directly re-associate the unfamiliar virtual ID with A's physical ID. However, if multiple vehicles disappear at the same time, we need to use other sensors in the site to assist, such as camera license plate recognition, RFID tags, and so on. In this scheme, once the virtual ID is lost and the logical remedy fails, the system will temporarily turn on the GPS module of the vehicle-mounted HMI, record the locus of movement for a certain time, and compare with the locus of several unfamiliar virtual IDs to find the one with the most similar matching degree and rematch it.
5.3 Implementation Effect
As can be seen from Figure 9, deploying a lidar at an interval of 200 meters can basically satisfy the full coverage of the proving ground's perceived signals and enable the roads to actively perceive traffic participants globally.

Figure 9. Perception Coverage
As can be seen from Figure 10, after analysis of the edge computing unit, the lidar point cloud can identify traffic participants including pedestrians, small vehicles, large vehicles, and output formatted data.

Figure 10. Traffic participant perception
From Figure 11, it can be seen that the vehicle can correctly display the location, manufacturer, responsible person and other basic information in the GIS interface, and basically achieve global track awareness in the entire area of the proving ground.

Figure 11. Traffic Participants in GIS interface

6. Conclusion

Compared with the vehicle-based intelligent scheme described in Chapter 2, this scheme achieves global track perception by road active perception of vehicles. It has the features of convenient operation, high reliability, good reusability, and maximizes the efficiency of proving ground management and user experience. In terms of perception, the vehicle-based intelligent scheme relies entirely on the OBUs and cannot perceive the units without the OBUs installed, while the roadside intelligent scheme can perceive almost all traffic participants on the road. In terms of expense, vehicle-based scheme spent on OBUs, while roadside intelligence is mainly used for deployment of perception devices, computing units, and networks. From the actual cost of both, they are almost identical. In terms of scalability, the roadside intelligence scheme can also undertake road scene data collection for auto-driving simulation test. In addition, with the continuous improvement of data quality and the decrease of network latency, the data obtained by road awareness system may participate in auto-driving decision-making and execution in the future, effectively share the end computing power to reduce the cost of auto-driving equipment, thus promote the popularization of auto-driving technology.

However, there are still many drawbacks in this road-based scheme, such as the disappearance of signals in the perceived range of vehicles and the aging of lidar, which need further research and improvement (See Table 3).

|                      | Vehicle-base Intelligence | Roadside Intelligence |
|----------------------|--------------------------|-----------------------|
| Convenience          | Complicated              | Easy                  |
| GPS dependency       | Absolute                 | Low                   |
| Scalability          | Poor                     | Good                  |
| Perception ability   | Poor                     | Good                  |
| Deployment           | Identical                |                       |
| Expense              |                          |                       |

Table 3. Comparison of two ways

References

[1] Zhang DiSi, Zu Hui, Chen XinHai, Wang BoSi. Research on the application of v2x and high precision positioning technology in the management of test site. Technological innovation and application, 2018 (10): 14-17(in Chinese).

[2] Chen XinHai, Zu Hui, Wang BoSi, Zhang DiSi, Wu Chao. Design of vehicle road collaborative high precision positioning service system. Laser magazine, 2019, 40 (11): 109-113(in Chinese).

[3] Gao Liang. Research on the mode of intelligent road traffic management. Automotive practical technology, 2020 (03): 211-213(in Chinese).
[4] Yu Bingyan. Application of edge computing enabled e-v2x [n]. People's Posts and telecommunications, 2020-09-10 (006) (in Chinese).

[5] Qiu Jiahui, Zhou Zhichao, Lin Xiaobo, Xiao Yu, Cai Chao, Liu Liu. Research and application of Internet of vehicles technology based on MEC. Telecom Science, 2020, 36 (06): 45-55 (in Chinese).

[6] Li Fangwei, Zhang Haibo, Prince Xin. V2X collaborative cache and resource allocation based on MEC in vehicle networking. Journal of Communications: 1-14 (in Chinese).

[7] Xu Zhexin, Gao Kaimeng, Jia Wenkang, Wu Yi. Load-constrained C-V2X vehicle cache node selection algorithm. Journal of Communications: 1-12 (in Chinese).

[8] Wang Tianjun, Ye Zenan, Zeng Fanjun, Yao Xifeng, Liu Min. 5G communication technology in V2X application. Automotive Utility Technology, 2020, 45(23): 20-22. (in Chinese).

[9] Sumin. Research and application of V2X communication technology based on intelligent driving scene in open-air mining area. Digital Communications World, 2020 (11): 160-161+164. (in Chinese).

[10] Liu Hua. Study on the Implementation of Open Road Scene Based on V2X System. Information Communication, 2020 (10): 178-180. (in Chinese).