Architecture Design and Key Technology Research of Urban Intelligent Transportation Integrated Control System Based on Edge Cloud Cooperation Technology

Fengxin Zhang
Lianyungang jari electronics co., LTD,Jiangsu Province and Tongji University, Shanghai, China
zhangfengxin3@163.com

Keshuang Tang
Tongji University, Shanghai, China
tang@tongji.edu.cn

Huixin Zhang
Henan Zhongtian High-tech Intelligent Technology Co., LTD, Henan Province, China
15065671@qq.com

Peng Zhang
Lianyungang jari electronics co., LTD, Jiangsu Province, China
18036675196@163.com

ABSTRACT

With the development of vehicle-road collaborative technology and the popularity of unmanned vehicles, smart cars and smart roads have brought a wide range of impacts on urban intelligent transportation systems, which has made great changes in front-end equipment perception, front-end and back-end information interaction, and traffic collaborative command and control. This paper mainly studies the new application scenarios of urban intelligent transportation vehicle-road collaboration. With edge-cloud collaboration technology as the core, the container cloud technology is used to construct the system, which supports edge intelligent analysis, cloud big data fusion and multi-level deployment of system design theory, implementation methods and related collaborative technologies. Finally, the integrated management and control system of cloud, edge and end for urban intelligent transportation management is developed.

CCS CONCEPTS

• **Software and its engineering**; • **Software creation and management**; • **Designing software**; • **Software implementation planning**; • **Software design techniques**;

KEYWORDS

Edge computing, Cloud computing, Cloud native, Intelligent transportation, Integrated control system

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At present, the architecture of intelligent transportation system is designed by integrating multiple sets of subsystem services with one center. The system has the following outstanding problems: For example, the storage and application of video resources are heavily dependent on the bandwidth and storage resources of the central network, which makes the intelligent video analysis unable to be applied in a wide range; For road traffic signal control business, due to the limitation of the calculation performance of the signal controller, the traffic control of single or multiple intersections must first collect the sensor data to the center, and the center calculates and generates the control scheme before sending it to the signal controller through the network, so there is a problem that the network fault affects the control results and the control is not real-time. With the development of car-road collaboration technology, a large number of sensing devices and video detection devices of the Internet of Things are connected to the intelligent transportation system. The traditional architecture mode has been unable to meet the requirements of new application scenarios, and it is urgent to upgrade and transform the overall device access capacity, data processing capacity and real-time control capacity of the system.

At present, there are two schemes to solve the above problems: One scheme is to use cloud computing technology to cloud the calculation, storage and network resources of the center, and provide greater flexible resource support for the business system through the scalability of the cloud. The problem of this scheme is that there is a huge investment in the early stage. In the vehicle-road collaborative scenario, the average amount of data generated by a single car is about 20 GB per day. If all these data are transmitted to the cloud for processing,the cloud platform cannot support the collection and analysis of full data in the collaborative vehicle-road scenario, let alone realize real-time control of all vehicles and roadside devices. The other is to use the central cloud and N edge nodes. The central cloud and N edge nodes are deeply coordinated to sink the storage and calculation to N edge nodes. This method has the problem of multi-dimensional interaction between the center and multiple edge nodes.

Therefore, this paper adopts the architecture design of a central cloud and N edge nodes based on cloud native technology, studies the collaborative interaction between the central cloud and the edge nodes, and introduces the implementation method of the new architecture in detail through five dimensions, including data, intelligent algorithm, application, service and management, so as to improve the processing level of the intelligent transportation system for the full traffic data of the global massive sensor equipment and the safety, real-time and high intelligence of the comprehensive traffic control under the background of vehicle-road collaboration.

The first chapter of this paper briefly introduces the specific problems existing in the existing transportation system architecture, as well as the new scenarios and new technical problems brought by vehicle-road coordination. The second chapter briefly introduces the system structure and specific requirements. The third chapter carries out system architecture design for business needs. The fourth chapter further deepens the architecture design through the introduction of multi-dimensional collaboration. The fifth chapter describes the combined application of key technologies and business scenarios involved in the architecture.The sixth chapter is the prospect of the application of this system in the future vehicle-road collaboration scenarios.

1 SYSTEM STRUCTURE AND FUNCTIONS

The system adopts three-tier fusion design of cloud, edge and end, with multi-dimensional collaboration as a means of implementation, in order to improve the efficiency of real-time data acquisition and analysis, the intelligent level of traffic emergency command, the ability of video AI analysis and the ability to improve the overall perception of the system as the goal, further deepen the application of artificial intelligence technology in the field of traffic video analysis, and realize the command and scheduling business driven by video event warning , deepen the application of big data technology in multi-source heterogeneous traffic data to realize data-driven traffic state analysis and prediction , deepen the application of edge computing and cloud native technology in the field of traffic data acquisition and traffic control, and realize holographic, global data acquisition and accurate, real-time traffic control.

Basic applications provide such functions as visual map operation, video preview playback, historical data query, system parameter configuration, equipment and facilities management. This functional unit is the basis of system application, which meets the general configuration requirements and public application requirements of the system.

Command and scheduling is the core of intelligent control of the system, and its main functions include visual command, video AR real scene, and inspection and control. The business unit is supported by the in-depth analysis and integration of traffic data, with multi-system linkage control as the means of implementation, and the visualization of traffic status and future trends as the way of presentation, which provides a trinity Multi-system Cooperative command and scheduling functions, that is ,intelligent analysis, multi-dimensional visualization and linkage control.

Traffic big data are the driving force of the business system, providing functions such as vehicle big data, personnel big data, flow big data and travel big data.Through data mining, we can further discover and integrate the correlation between system services, so as to provide more intelligent traffic management and travel service functions.

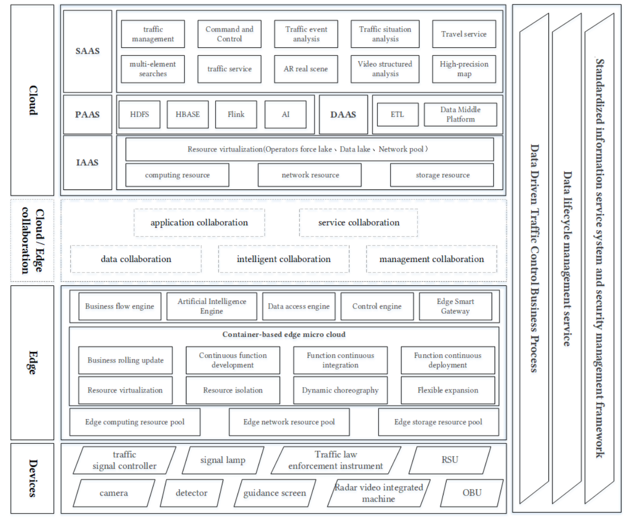

Figure 1: System Architecture.

Edge data acquisition and control provides multiple functions, such as access to heterogeneous data from multiple sources, real-time control of devices, storage and analysis of edge data, etc.The business unit is the core of multi-source traffic data acquisition and real-time control in the scenario of high bandwidth, low delay and large connection. If the traditional data processing and business management architecture is used, it is bound to be unable to meet the needs of traffic control under the background of vehicle-road collaboration [1]. Therefore, this paper proposes a multi-dimensional collaborative architecture to solve the above problems and realize new business requirements.

2 SYSTEM ARCHITECTURE DESIGN

The system architecture is designed around the core contents of data-driven integrated traffic control business, data life-cycle management, data standardization and data security.The overall architecture is divided into four layers: cloud layer, side cloud collaborative logic layer, side end layer and device layer. The design of each layer is shown in the Figure 1

2.1 Cloud

Cloud is built on the traditional cloud architecture system, including IAAS, PAAS, SAAS three layers, and increases the DAAS (data is service) layer. Cloud computing is adopted to meet the requirements of larger data collection and analysis in the vehicle-road collaborative scenario. The IASS layer realizes the virtualization of computing resources, network resources and storage resources, and meets the flexible configuration requirements of dynamic application, configuration and release. PaaS layer includes distributed file system, distributed database, streaming computing, artificial intelligence and other middleware services, which can support the analysis and storage of large-scale data; DAAS completes ETL of traffic data, and develops and realizes the release of data services such as data mart and theme library.In the SaaS layer, each functional unit of the integrated traffic control system is constructed to support the development of various businesses.

2.2 Edge Cloud Collaborative Logic Layer

The Edge cloud collaborative logic layer with dotted line frame, is called logic layer because it contains five types of collaboration (data collaboration, intelligent collaboration, application collaboration, service collaboration, management collaboration). These five types of collaboration do not only play a role between the cloud and the edge, but also between the edge and the device layer, and even between the cloud and the device layer.

2.3 Edge

The edge uses cloud native technology to construct the edge micro cloud located in the roadside or regional convergence node. The edge micro cloud node is responsible for the collection, analysis and storage of roadside equipment data in the specified area, and can interact with the central cloud for data, information and instructions in real time.

There are multiple edge micro-cloud centers in the city, which can realize the tasks of distributed data collection, analysis and storage in a wide range of cities.They can also realize the function of dynamically adjusting the system load, upload all kinds of information required by the cloud when necessary, and play the role of collaborative service. Edge micro-cloud is based on lightweight ’ containerized ’ cloud computing technology to build the underlying architecture. This architecture can easily implement the rolling update of side business;it can better adapt to the type increase and function change of roadside equipment, realize the continuous development, integration,and deployment of functions; container technology can also be fully used to realize the isolation and dynamic arrangement of resources to meet the requirements of dynamic expansion of resources.Based on this architecture, the edge-side business flow micro-engine, artificial intelligence micro-engine, data service micro-engine, edge control micro-engine and edge intelligent gateway are built to realize the high cohesion model of business, data, algorithm, control and other sub-fields to meet the needs of service cloud and roadside equipment.

2.4 Device Layer

The device layer is the front-end device and facilities that serve the integrated management and control business of intelligent transportation, Including RSU, road traffic signal, video camera, detector, induction display, law enforcement instrument, vehicle-mounted terminal equipment, traffic signal lamp, and vision integrated machine.These devices use Internet of Things protocol or traditional communication protocol to upload device data and receive control instructions in real time.

3 MULTIDIMENSIONAL COLLABORATIVE DESIGN

Multidimensional collaboration is carried out around the five aspects of data, intelligence (algorithm), application, service and management among cloud, edge and end. By improving the collaboration process of these five aspects, the distributed collaboration among one cloud center, multiple edge cloud nodes and N traffic equipment is supported.

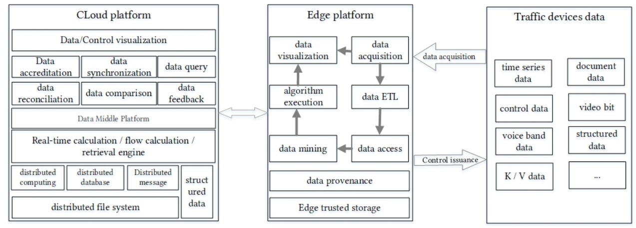

Figure 2: Data Collaboration.

3.1 Data Collaboration

Data collaboration is to solve the problems of limited storage capacity, less data storage types and inconsistent data standards. The data lake service capability of the IaaS layer in the cloud provides the data storage pool needed for global traffic data collection. Based on the central cloud platform, it can meet the needs of massive, multi-class and heterogeneous data collection, storage and management of vehicle-road collaboration.

The data lake also provides the data open sharing capability, which can open and share the multi-type and standardized data to the edge and upper business for analysis and application.

Based on heterogeneous data collection, unified data storage, standard data governance and open data sharing capabilities of the data lake, a cloud, side and end data collaboration system for the new generation of transportation system is constructed. The data collaboration process is shown in the Figure 2

3.2 Intelligent Collaboration

Intelligent collaboration [2] serves the development, training, synchronization, verification, and feedback of business models such as cloud and edge video analysis, traffic flow prediction, and comprehensive control. Cloud has massive and multi-source data, and has strong computing, storage and other resources. Based on the above resources, a traffic management model library is established to facilitate the iterative upgrading of the model.

The trained model is packaged into standard algorithm mirrors using the cloud delivery pipeline and stored in the mirror warehouse. The edge is closely related to the cloud algorithm library. The cloud model can be selected according to different edge application scenarios and deployed automatically in the edge container environment. The input data of the edge algorithm comes directly from the equipment. The results of the analysis will be shared to the cloud. The change of the edge business needs will be synchronized to the cloud. The cloud will adjust the existing model according to the change of the demand, so as to achieve the goal of cyclic iteration and gradual optimization. The intelligent collaboration process is show in the Figure 3

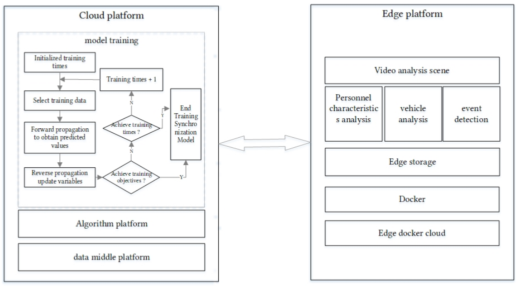

Figure 3: Intelligent Collaboration.

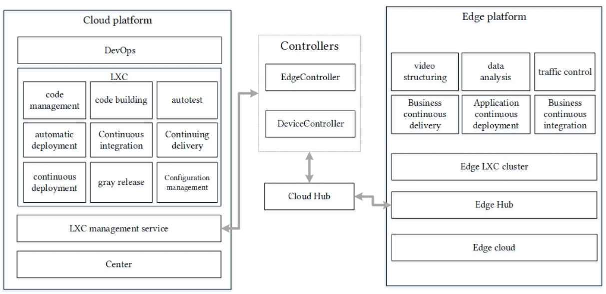

Figure 4: Application Collaboration.

3.3 Application Collaboration

There are many problems in intelligent transportation system, such as many requirements, complex scenes, difficult application deployment and maintenance management. For example, there are various types of roadside and vehicle equipment. On the one hand, the edge data acquisition and analysis software needs to be customized according to the different types of equipment and communication protocols. On the other hand, it is necessary to periodically upgrade and redeploy according to the changes in system requirements, but the edges are scattered in different locations of the city. If the upgrading is carried out manually, it is not only time-consuming and error-prone, but also affects the overall stability of the system.

To solve the above problems, the application collaboration [2] is designed to serve the application development, upgrade and maintenance between cloud and edge. Relying on micro-services and DevOps technology, an integrated application collaborative management system for continuous development, continuous integration, continuous testing and grayscale release of transportation system, edge access and mobile applications can be built, which can further improve the timeliness and stability of the whole system. The application collaboration process is show in the Figure 4

3.4 Service Collaboration

Traffic command dispatching needs real-time control of traffic equipment and facilities and needs to send real-time dispatch instructions to relevant personnel Vehicle-road collaborative scenarios need to provide real-time travel services and security services to unmanned vehicles. The above business scenarios contain two types of data, one is traffic information after analysis, and the other is control instructions.

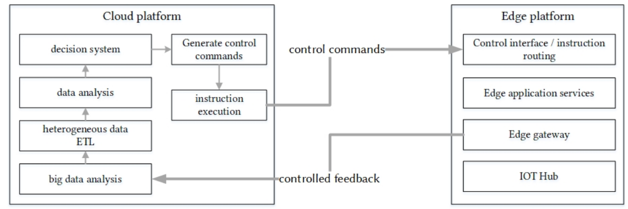

Figure 5: Service Collaboration.

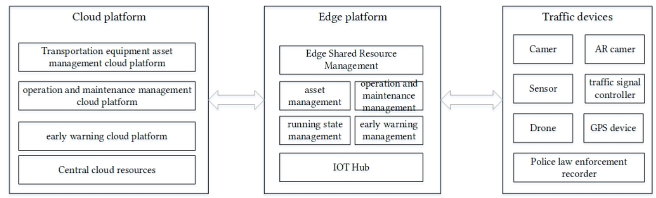

Figure 6: Management Collaboration.

Traffic information is obtained by a large number of traffic data through complex analysis. Due to the weak computing and storage capabilities of the edge, it is necessary to call the computing and storage services of the cloud center. The edge service will quickly distribute the traffic information received from the cloud to the target group. The control command needs to reach the target device in near real time. If the control command is sent from the cloud, the overall operation efficiency of the system will be greatly reduced. Therefore, the edge service will bear the generation and issuance of most control decisions and security strategies, which are generated and assisted by the relevant information provided by the cloud. Service collaboration [3] opens up data and business among cloud, edge and equipment, and realizes the high integration of system data and business. The process of service collaboration is shown in the Figure 5

3.5 Management Collaboration

The system cloud, edge, and device layers have a large number of sensing devices, edge devices, cloud center devices, and various types of resources (such as data, middleware, software systems). The management collaboration [2] takes the above equipment and resources as the management objects, uses multi-agent as the metadata collection method, and relies on big data analysis technology and visualization display technology to construct the management collaboration function unit to achieve the goal of fine management of cloud, edge and end. The management collaboration process is shown in the Figure 6

4 KEY TECHNOLOGIES

The key technologies involved in the design of urban intelligent transportation system architecture based on edge cloud collaboration include cloud computing, big data, edge computing, artificial intelligence, and the most critical is cloud native technology.

As is known to all, cloud computing technology includes IaaS, PaaS and SaaS. Cloud can support the distributed deployment of multiple nodes, but the investment of each sub-node is huge, and the requirements for the operation environment of sub-nodes and the technical threshold of operation and maintenance are high. A large number of edge nodes need to be deployed in the vehicle-road collaboration scenario. These nodes can share most of the functions of real-time calculation, localized storage and real-time control of the cloud center. However, the operation environment of edge nodes is poor, the overall stability of the system is high, and the resource demand of a single node is low. Therefore, the heavy-weight deployment method of traditional cloud has the problems of high investment cost and large waste of resources. But cloud native technology is a new software architecture idea based on cloud computing technology. It is a set of methodologies for software design, development, testing, deployment and implementation based on cloud. After adopting cloud native technology, it can give full play to the advantages of cloud platform flexibility and scalability, and better meet the needs of traffic management and services in the future vehicle-road collaborative scene.

The cloud native computing foundation (CNCF) defines the following key technologies included in the Cloud native computing DevOps, Continuous delivery, Microservices, Containers. DevOps is the integration of development, testing, and operation and maintenance, which provides an efficient collaborative way for software development. In view of the changing needs of intelligent transportation service objects and management parties, DevOps can realize efficient development, rapid business response, and provide guarantee for responding to the changing business demands.

Continuous delivery is an agile development model, which can realize the software delivery mode of small-step fast running, and finally deliver the mature business model through multiple iterations. In view of the current lack of in-depth understanding of vehicle-road collaborative scenarios, the continuous delivery mode of software products can quickly eliminate immature business functions and accelerate the maturity of vehicle-road collaborative business models.

Micro-service is to servitize the business, divide the complex business, and realize the loose coupling and high cohesion among services. The advantage of micro-services splitting traditional single applications is to avoid repeated development of a large number of common functions. Through service composition, complex business systems can be quickly constructed. There are a large number of common functional units in the intelligent transportation platform, such as map operation, data retrieval service, user management, device management, etc. Micro-service technology can greatly reduce the cycle of business development.

Container is based on Linux LXC technology implementation. Docker is currently a relatively popular containerization solution.Container technology provides implementation guarantee for micro services [4], which can realize isolation between applications, dynamic load balancing and container choreography. The types of equipment, communication mode, communication protocol and communication pressure in the vehicle-road collaborative scene are complex and changeable. In order to cope with the uncertainty of matching between application scenarios and equipment, the system encapsulates the application of data acquisition and analysis of different types of traffic equipment into different containers in the form of micro-service. The container arrangement tool realizes the rapid deployment of applications for different business scenarios. And the characteristics of container dynamic load balancing and operation environment isolation are used to solve the performance bottleneck and single point failure problems in vehicle-road collaborative system.

5 CONCLUSIONS

Vehicle-road collaborative autonomous driving is pushing the urban intelligent transportation system to a new stage of development. The urban intelligent transportation system is not only a business system for traffic managers, but also a traffic information service platform with holographic, global data fusion perception, intelligent decision-making and multi-dimensional collaborative control. With the application of new technologies and methods, this platform will further accelerate the pace of the construction of hardware and software systems related to vehicle-road coordination, bring better experience to people's travel, bring broader development space to related industries, promote social harmony and drive high-quality economic development.

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