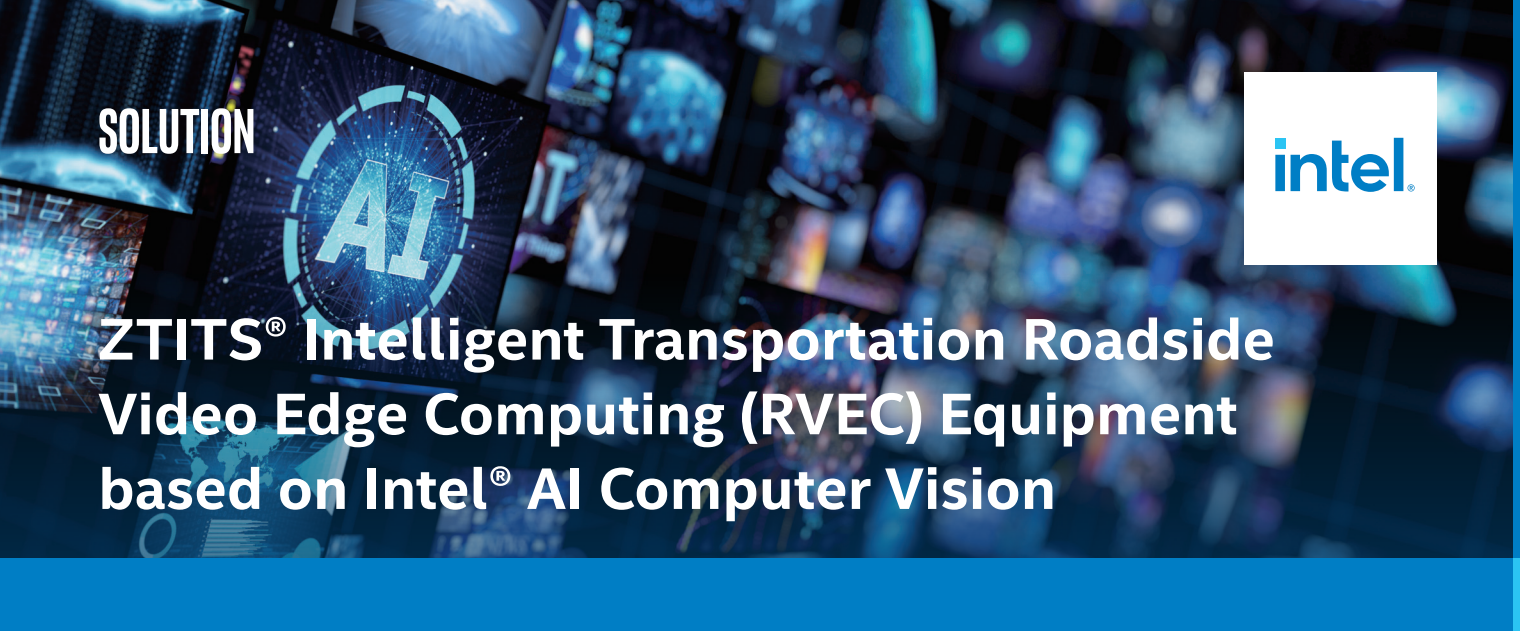

ZTITS® Intelligent Transportation Roadside Video Edge Computing (RVEC) Equipment based on Intel® AI Computer Vision

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Content

Overview

At present, China is vigorously advancing the construction of the new infrastructure including the Artificial Intelligence (AI), 5G and Industrial Internet of Things (IoT), injecting new momentum into the development of smart cities. Among them, the city's Intelligent Transportation System (ITS) is a vital component. Through the application of technologies such as AI, Computer Vision (CV), Cloud Computing and Big Data, the Intelligent Traffic Management System (ITMS) will enable the road users (people and various vehicles) to interact harmoniously with the road infrastructure, help improve traffic safety and efficiency (including alleviating traffic congestion), thereby improve people's travel experience.

For the application scenarios of intelligent traffic management, Shenzhen ZTITS Information Technology Development Co., Ltd. (hereinafter referred to as **ZTITS**) has launched an Intelligent Transportation Roadside Video Edge Computing (RVEC) equipment based on **Intel® AI Computer Vision** (hereinafter referred to as **RVEC equipment**), suitable for different scenarios such as the intersections, urban roads and expressways. The RVEC equipment deployed at the edge of the network is equipped with Intel® Celeron® CPU (Central Processing Unit) and Intel® Movidius™ Myriad™ X VPU (Vision Processing Unit), and is based on OpenVINO™ toolkit for rapid development of high-performance AI computer vision algorithms, achieving excellent performance. Taking a city intersection as an example, the RVEC equipment can detect and recognize the motor vehicles (including special vehicles), non-motor vehicles, pedestrians, traffic lights, road traffic signs, traffic flow status and traffic incidents; it can further provide video analytics data for the automatic control of the roadside infrastructure (such as the traffic signal lights, etc.).

Background: ITMS based on "Terminal-Edge-Cloud" architecture

To fully improve the traffic safety and efficiency, in addition to improving urban spatial layout and increasing road supply, it is also necessary to actively develop an advanced ITMS based on the “Terminal-Edge-Cloud” architecture. As shown in Figure 1, the core concept of this system is based on the comprehensive perception of traffic conditions on the terminal side, accurate and comprehensive analysis of traffic data at the edge and the cloud, and real-time control of roadside infrastructure, thus completing a variety of Intelligent traffic management functions.

ZTITS® ITMS's accurate perception and intelligent management of traffic conditions are mainly based on the five main subsystems:

- Automatic traffic signal management (ATSM) subsystem;
- Traffic flow video detection subsystem;
- High-definition video based violation alarm subsystem;
- Large-screen LED automatic induction subsystem;
- Traffic situation prediction and release subsystem.

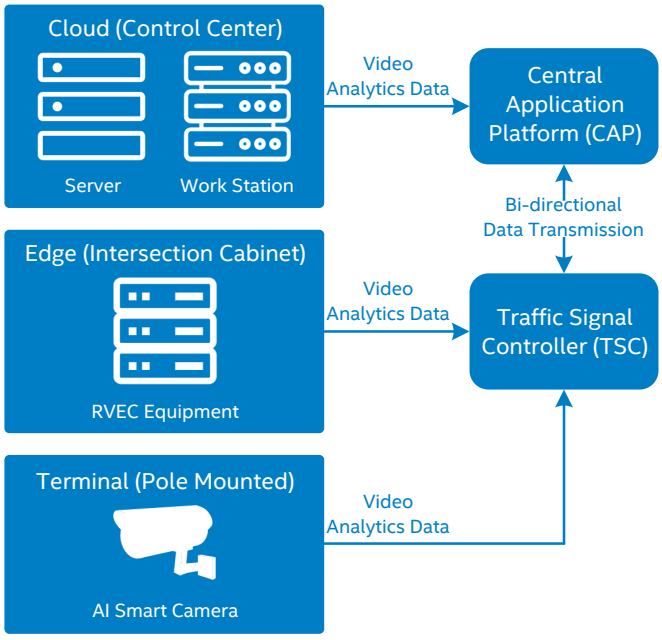

Figure 1. ITMS based on the "Terminal-Edge-Cloud" architecture.

The ATSM subsystem includes various types of servers and workstations contained in the control center located in the cloud, the RVEC equipment deployed in the intersection cabinet located at the edge, and the AI smart cameras deployed on the intersection poles.

These different equipment interact with the Central Application Platform (CAP) and the Traffic Signal Controller (TSC). The control center can use the aggregated video information to support comprehensive applications such as traffic incident perception and traffic situation analysis. The AI smart cameras are generally used in new projects. It integrates the capabilities of video capturing, general-purpose computing and computer vision based on AI inference to provide video analytics data for the TSC.

In ITMS, the RVEC equipment based on edge computing and AI computer vision is an extremely important basic equipment. This equipment is responsible for the real-time calculation and analysis of the visual information (including video and images) collected by the roadside sensing devices such as cameras, and when necessary, interacts with the control center located in the cloud, and inputs the optimized Signal Phase and Timing (SPaT) to the roadside TSC. Combined with other input signals, the TSC uses its specific algorithm to determine the final SPaT to control the traffic signals at the intersection.

Compared with the traditional detection technologies such as the inductive loops, magnetometers and LiDARs, the AI computer vision based on the information collected by various cameras for the detection and analysis of the traffic objects, situation and events has significant cost advantages and is very suitable for large-scale deployment. In addition to the traffic information, the equipment can also sense the environmental information such as weather (rain, snow, fog, etc.), and transfer these information and the local analysis results to the control center for further processing. The popularization of this equipment will help improve the traffic safety and efficiency in an all-round way.

Challenges: Edge computing equipment for intelligent traffic management

The RVEC equipment needs to realize the detection and recognition of motor vehicles (including special vehicles), non-motor vehicles, pedestrians, traffic lights, road traffic signs, traffic flow status and traffic incidents, so it is necessary to connect the equipment with a variety of cameras (including intersection central camera, checkpoint camera, traffic flow camera, spherical camera and pedestrian camera) to collect the video information.

- **Intersection central camera:** Mainly used to photograph the rear of the vehicle; usually installed on the intersection traffic poles (20-25 meters from the stop line); one camera can cover 1-3 lanes.
- **Checkpoint camera:** Mainly used to photograph the front of the vehicle; usually installed on the intersection traffic poles; one camera can cover 1-3 lanes.
- **Traffic flow camera:** Mainly used to photograph the front or rear of vehicles, detect traffic flow, lane occupancy time, queue length, congested road conditions, etc., and provide video analytics data to the TSC for optimization of SPaT; usually installed on the intersection traffic poles or the traffic signal poles; one camera can cover 4-8 lanes.
- **Spherical camera:** Mainly used for monitoring the intersection, and can also be used for detecting the backflow (congestion) at downstream of the intersection; the shooting direction and focal length can be changed at any time through remote control; usually installed on the intersection traffic poles.
- **Pedestrian camera:** Mainly used to cover pedestrian waiting areas and zebra crossings; usually installed on the pedestrian signal light poles or nearby roadside facilities.

This equipment is a key equipment related to traffic safety. In actual deployment and use, technical challenges from various aspects such as the data processing performance under low cost and low power consumption, reliability and stability, connectivity and compatibility need to be solved.

Data processing performance under low cost and low power consumption

The equipment is responsible for the video encoding and decoding of multiple cameras, real-time detection and analysis of vehicles and pedestrians based on deep learning computer vision, real-time analysis of vehicle flow and pedestrian flow, and SPaT analysis of intersection traffic signals. The performance of the equipment is mainly reflected in the number of video channels that can be processed simultaneously, processing latency and accuracy. Because it involves the control of the traffic signals, the processing latency and accuracy are particularly important to ensure the traffic safety. For the traffic management departments as the end user, the performance is also reflected in the improvement of traffic safety and efficiency. The improvement of the performance of this equipment poses new challenges to the processing capacity of the chip, and at the same time, it must also meet customer requirements for overall equipment cost and power consumption. Therefore, cost-effective and energy-efficient chip products and system architecture design are required.

Reliability and stability

The equipment is mostly deployed around roads with harsh environments, where the temperature and humidity change drastically, and the impacts from foreign objects are very common. This requires the equipment to have strong environmental adaptability, to adapt to changes in temperature and humidity, to be water-proof, dust-proof, corrosion-proof, and shock-proof, as well as to have excellent electromagnetic compatibility and anti-interference capabilities. The equipment needs to ensure uninterrupted provision of stable and reliable services throughout the product life cycle.

Connectivity and compatibility

This equipment needs to be connected to a variety of roadside devices such as cameras and TSC, and can interact with the various intelligent traffic management subsystems mentioned in this article. Therefore, its connectivity and compatibility are critical to the overall performance.

Solution: RVEC equipment based on Intel® Architecture

The ZTITS® RVEC equipment is equipped with Intel® Celeron® CPU and Intel® Movidius™ Myriad™ X VPU, and has the powerful processing capabilities of both traditional computer vision and deep learning based computer vision. Its hardware and software architectures are shown in Figure 2 and Figure 3 respectively. When used for the automatic traffic signal control, its connection with other equipment is shown in Figure 4.

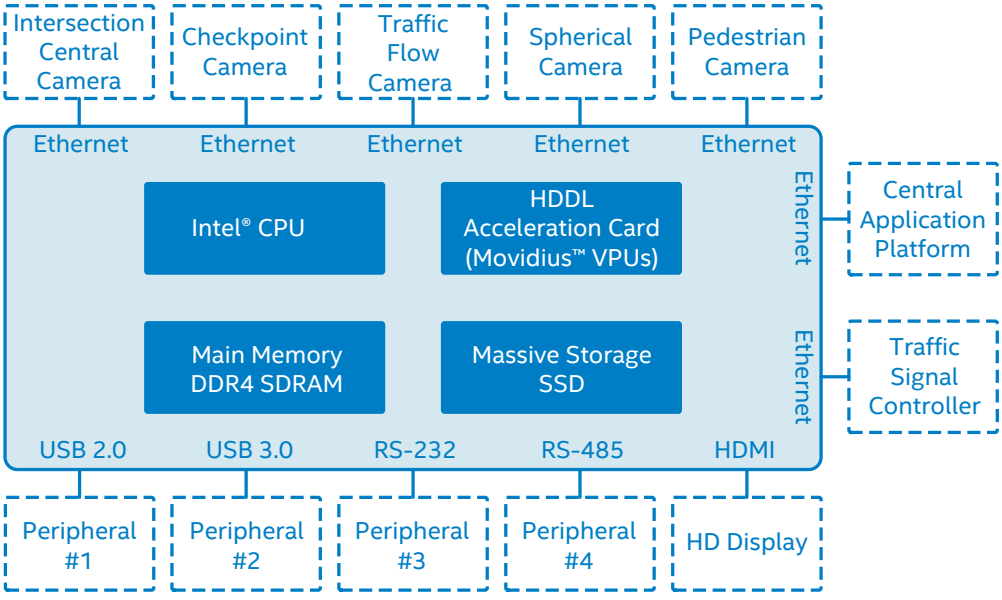

Figure 2. Hardware architecture of RVEC equipment.

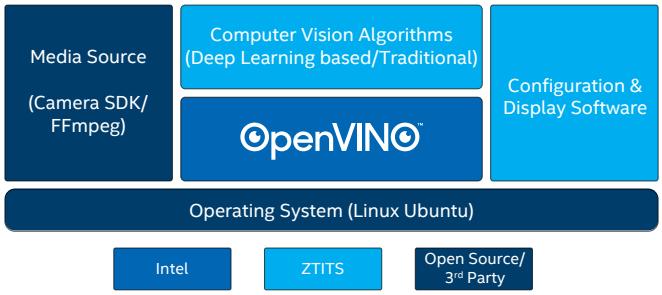

Figure 3. Software architecture of RVEC equipment.

- **Intel® Celeron® CPU**

  Intel® Celeron® CPU has industry-leading performance, support different operating systems, and can meet a wide range of business needs. This series of CPUs not only have strong computing power, but also have the advantages of high cost performance, high energy efficiency ratio, high security and high reliability. This CPU is embedded with Intel® HD graphics and has strong video encoding and decoding capabilities. The RVEC equipment based on it is not only fully capable of computing, storing and forwarding related data, and controlling various connected devices, but also has significant advantages of low cost and low power consumption.

- **Intel® Movidius™ Myriad™ X VPU**

  The Myriad™ X VPU is Intel's first VPU to feature the Neural Compute Engine (NCE): a dedicated hardware accelerator for deep neural network inference. The NCE in conjunction with the 16 powerful SHAVE cores and high throughput intelligent memory fabric makes Myriad™ X VPU ideal for on-device deep neural networks and computer vision applications. The Myriad™ X VPU is programmable with the Intel® Distribution of the OpenVINO™ toolkit for porting neural network to the edge, and via the Myriad Development Kit (MDK) which includes all necessary development tools, frameworks and APIs to implement custom vision, imaging and deep neural network workloads on the chip. In practical applications, Myriad™ X VPU shows unique advantages such as strong computing power at low power consumption.

- **Intel® Distribution of OpenVINO™ Toolkit**

  ZTITS is using the OpenVINO™ toolkit to improve the accuracy of video analytics algorithms, speed up the inference and save computing resources. The OpenVINO™ toolkit is a very comprehensive and excellent toolkit from Intel, which supports the rapid development of rich and diverse applications and solutions to emulate human vision[1,2]. The toolkit is based on the Convolutional Neural Network (CNN), which can deploy the workload of Computer Vision (CV) in a variety of Intel® hardware platforms to achieve superior performance. The OpenVINO™ toolkit supports a wide variety of applications of both traditional computer vision and deep learning based computer vision. Its main functional modules are shown in Figure 5.

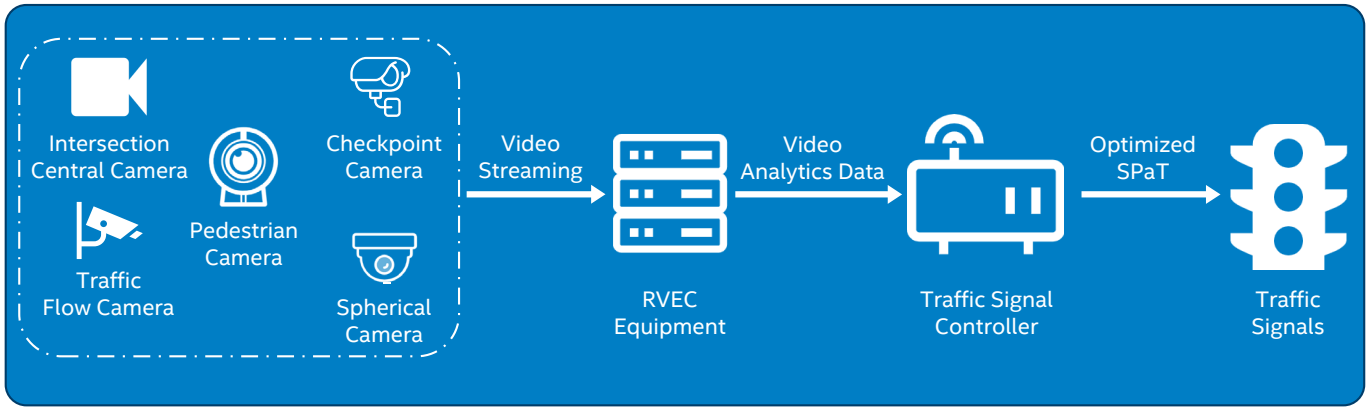

Figure 4. RVEC equipment for automatic traffic signal control.

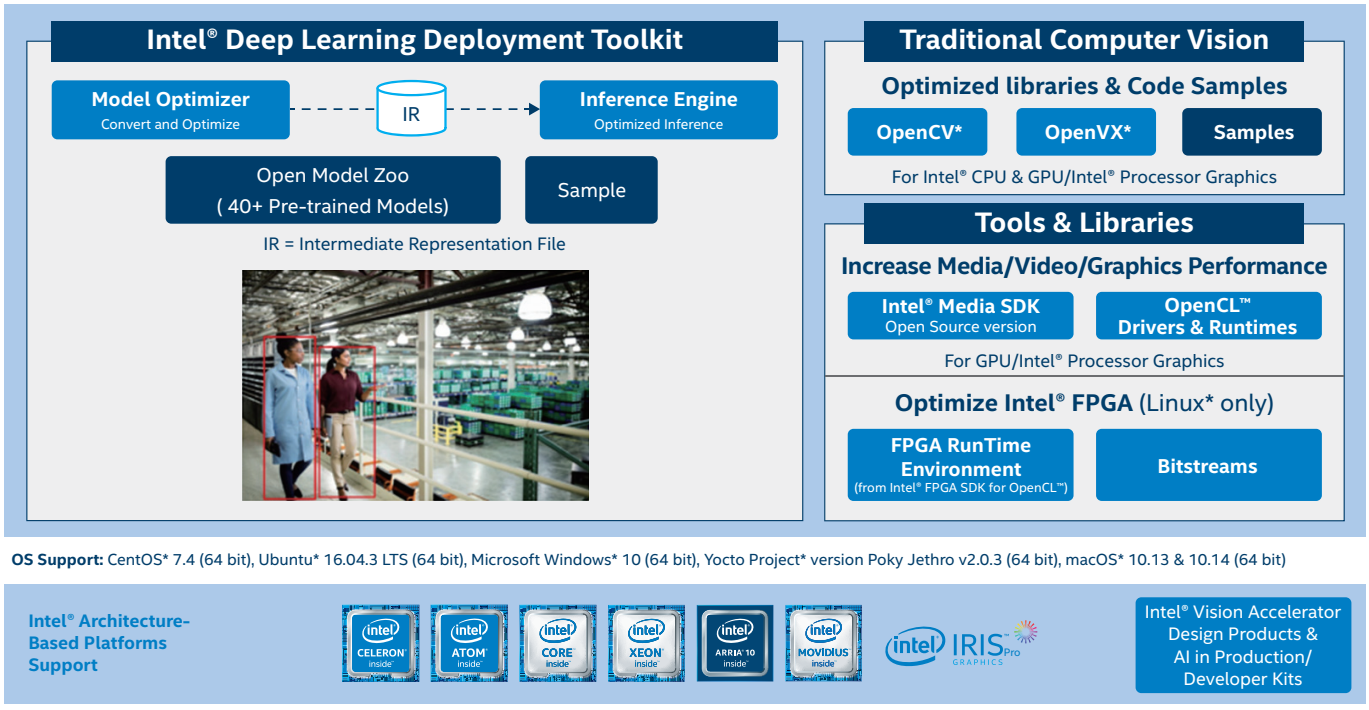

Figure 5. Main functional modules of OpenVINO™ toolkit.

The OpenVINO™ toolkit has the following features:

- Written in C++ and Python;
- Supports multiple operating systems including Windows, Linux and Mac OS;
- Supports acceleration of high-performance AI deep learning inference deployed from the edge to the cloud;
- Supports heterogeneous execution across Intel® Deep Learning Inference Accelerators, using common APIs for different Intel® hardware platforms, including CPUs, integrated GPUs, Neural Computing Sticks (NCS) and HDDL visual processing acceleration cards containing Movidius™ VPUs, FPGA, etc., can help customers achieve cross-architecture algorithm migration and optimization;
- Accelerates product development and time to market (TTM) with easy-to-use computer vision function libraries and pre-optimized kernels;
- Includes standard optimization calls for computer vision, including OpenCV, OpenCL and OpenVX.

In addition to using the AI computer vision function in the OpenVINO™ toolkit, the RVEC equipment also uses the Intel® Media SDK, which supports high-performance video encoding and decoding on Intel® HD graphics.

Thanks to the powerful general-purpose computing and AI computer vision inference capabilities provided by Intel® Celeron® CPU and Myriad™ X VPU, the equipment can process the video or image information collected by the various cameras mentioned above, carry out position coordinate calibration for vehicles and pedestrians in the video images, and realize the detection and recognition of motor vehicles (including special vehicles), non-motor vehicles, pedestrians, traffic lights, road traffic signs, traffic flow status and traffic incidents. Taking the traffic flow status as an example, the equipment can detect the status of each lane and each vehicle in real time, including the entry/exit status of each vehicle, lane occupancy time, total number of vehicles, speed, the location of the last vehicle, the length of the fleet and the classification of vehicle types. It can further perform statistical analysis of the detection data.

> "The RVEC equipment is an important basic equipment for intelligent traffic management, which can comprehensively enhance the traffic management department's perception of traffic conditions, and perform efficient management based on the analysis of real-time data, thereby improving traffic safety and efficiency. In addition to the detection and recognition of motor vehicles (including special vehicles), non-motor vehicles, pedestrians, traffic lights, road traffic signs, traffic flow status and traffic incidents, we will further extend the function to monitor the road surface and weather conditions. This will meet the needs of more refined and predictable traffic management."
>
> **– Changjun Zhou**
> Chief R&D Engineer, ZTITS

Effect: Significantly improve traffic safety and efficiency

At present, the ZTITS® RVEC equipment based on **Intel® AI Computer Vision** has been widely deployed in Beijing, Jiangxi, Shandong and other provinces and cities. In user practice, the equipment has shown the following significant advantages:

- Fully meet the stringent performance requirements of intelligent traffic management for AI computer vision

  By making full use of the excellent capabilities of multimedia processing, deep learning acceleration and multi-tasking processing of Intel's various chip products, the equipment can process up to 12 channels of video at the same time, enable the real-time detection of vehicles and pedestrians and the real-time analysis of vehicle flow and human flow, and provide relevant data for intelligent traffic management.

  In addition, the equipment transfers the video processing workload to the edge, which can effectively reduce the latency, relieve the bandwidth pressure of the network and the load pressure of the central processing servers, better guarantee information security, and can enable the location-based service in the future.

- Fully support accurate detection and analysis of multiple traffic objects

  Thanks to the innovation of the core algorithms of AI computer vision and the full exploration of the potential of Intel hardware and software, the equipment can accurately detect and analyze the characteristic information of each vehicle and the traffic status on each lane. And according to these analytics data, the traffic signals and other systems can be finely controlled. The equipment can also detect different vehicle types and provide a variety of new services such as the priority access for special vehicles (ambulances or fire trucks) and public transportation vehicles.

- Support high scalability and workload consolidation

  The equipment realizes the interconnection with a variety of external devices and built-in devices through external interfaces such as Ethernet, RS-232, RS-485, USB and HDMI, and internal interfaces such as PCIe and mSATA. Thanks to the maturity and compatibility of Intel® Architecture, the equipment can fully support all existing camera types in the field of transportation. In terms of software architecture, ZTITS uses the Intel® Workload Consolidation Technology to integrate multiple applications that are relatively independent but need to be coordinated into the same hardware device. Under the premise of fully ensuring the performance of each application, the equipment fully utilizes the computing power of the hardware device, and significantly reduces the technical difficulty and cost of system integration and maintenance.

  In a commercial deployment in Hunan Province, 110 ZTITS® RVEC equipment were deployed at 110 various urban intersections and a total of 395 traffic videos were processed. The equipment sends the real-time data such as the traffic volume, queue length, the number of vehicles in the area of interest, the location of the last vehicle, lane occupancy time, vehicle speed and vehicle models to the TSC; it sends the statistical data including the lane-by-lane traffic, average speed, traffic of vehicle models, lane occupancy rate, vehicle head distance, vehicle head time interval and road congestion level to the CAP. The equipment helps the local traffic management departments to efficiently detect and analyze multiple traffic objects, comprehensively improve the traffic safety and efficiency, and lay a solid foundation for the development of the ITMS.

> "Based on Intel® AI Computer Vision, the ZTITS® ITMS solution has been proven in practice to significantly improve the traffic safety and efficiency. In the future, we will further promote the in-depth integration of this solution with more intelligent traffic management platforms. The real-time analysis of the traffic status information and the real-time control of roadside traffic management equipment will help traffic management departments better manage the city's traffic."
>
> **– Changjun Zhou**
> Chief R&D Engineer, ZTITS

Outlook: Intel® AI Computer Vision accelerates the development of intelligent transportation

ZTITS has outstanding advantages in the fields of traffic data collection and video analytics, while Intel has the "Terminal-Edge-Cloud" complete hardware and software solutions for different application scenarios of intelligent transportation. The in-depth cooperation between ZTITS and Intel can promote the commercial deployment of edge computing based on AI computer vision in various fields of intelligent transportation and significantly improve traffic safety and efficiency.

For example, in the future ITS, the RVEC equipment can be used as the Multi-access Edge Computing (MEC) equipment in the roadside infrastructure to support the Vehicle-Infrastructure Integration (VII). As shown in Figure 6, on the gantry above the road, not only the cameras, radars and other sensing devices for monitoring the road traffic conditions can be deployed, but also the V2X RSU for wireless communication and the roadside MEC equipment for AI computer vision (i.e., the RVEC equipment) can be deployed. When the sensing devices (such as cameras) detect abnormal conditions or temporary events, such as road obstacles, traffic accidents and road construction, the roadside MEC equipment can determine the type of event or condition based on AI computer vision, generate safety message, and notify nearby vehicles or pedestrians in time through the wireless links of V2X RSU to avoid accidents. The meteorological sensors can also be deployed on the gantry. They can detect the abnormal weather conditions (such as the heavy fog, mass fog, cross wind or hail, etc.), generate relevant safety message and send it to the vehicles through RSU to ensure driving safety.

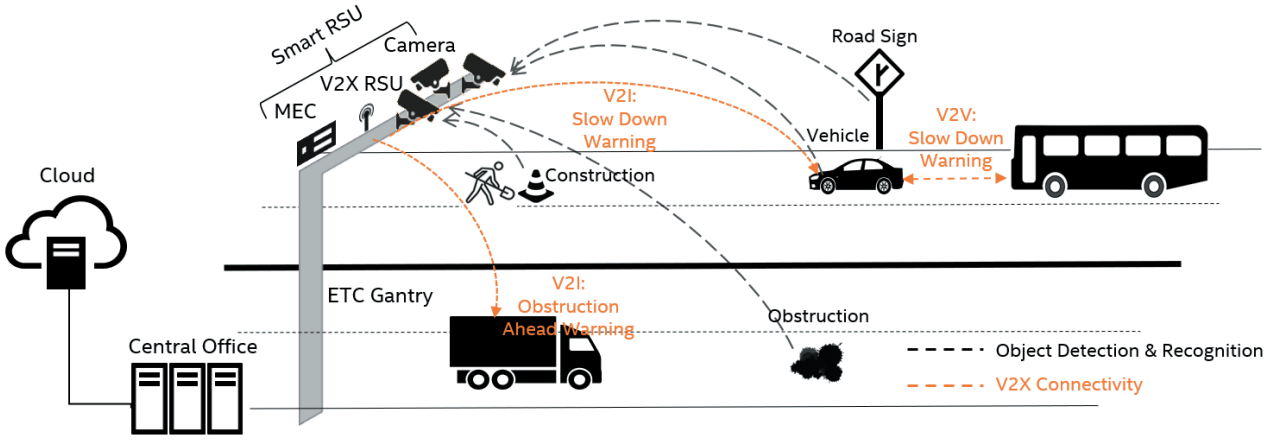

Figure 6. Vehicle-Infrastructure Integration (VII) based on MEC and C-V2X.

Many scenarios of VII need to be analyzed by AI computer vision, which will have a high demand for the computing power of the roadside MEC equipment. Intel has deep technology accumulation in the fields of AI computer vision and edge computing, and can provide a rich and diverse portfolio of high-performance products.

As shown in Figure 7, for AI computer vision applications, Intel provides various general-purpose processors with different computing powers (including Intel Atom®, Core™ and Xeon® series CPUs), and dedicated vision processors (including Intel® Movidius™ VPU), and hardware acceleration processing solutions based on VPU or FPGA. In addition, in order to support the development across different chip platforms, Intel provides the OpenVINO™ toolkit which contains a wealth of software tools. It can greatly improve the work efficiency of developers and shorten the product development time. With its world's leading end-to-end AI computer vision technology, Intel joins industry partners to lay a solid foundation for the global ITS development.

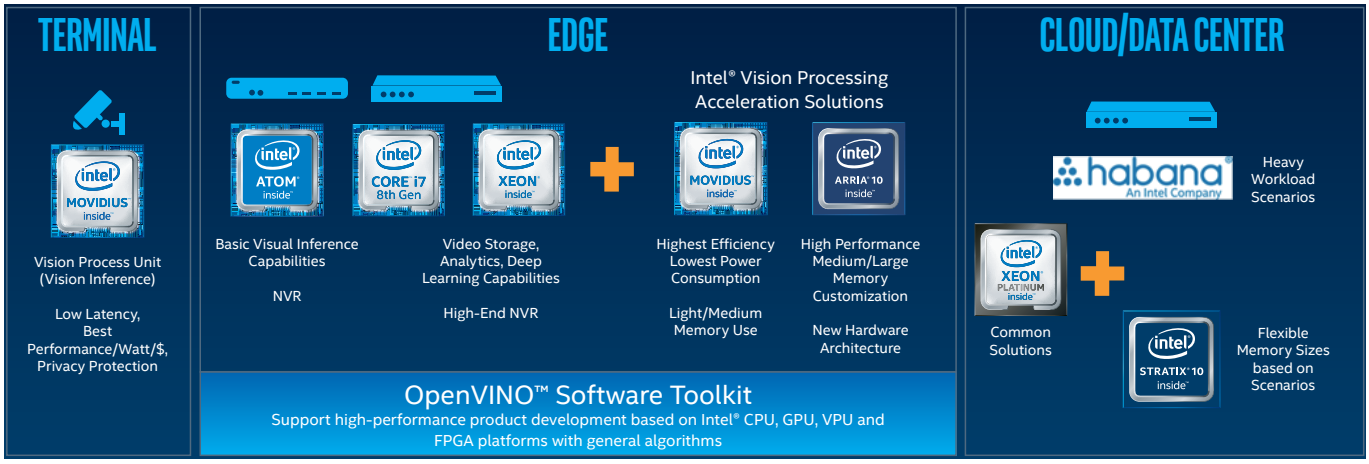

Figure 7. Intel® AI Computer Vision products support terminals, edges and clouds.

About ZTITS

ZTITS is a high-tech enterprise specialized in the product development, manufacturing and system integration in the fields of video detection and analysis. It is also a leading professional service provider for traffic data collection in China. At present, it mainly provides reliable video solutions, products and services for application scenarios such as the urban traffic and expressways. ZTITS has nearly two decades of accumulation in video technology, and has strong R&D capabilities including the development of core algorithms, the design of embedded software and hardware products, and the integration of overall mature systems.

About Intel

Intel (NASDAQ: INTC), as an industry leader, creates technologies that change the world, promotes global progress and enriches life. Inspired by Moore's Law, we are continuously committed to advancing semiconductor design and manufacturing to help our customers meet the most significant challenges. By integrating intelligence into the cloud, network, edge, and various computing devices, we unleash the potential of data and help businesses and society become better. For more information on Intel's innovation, please visit Intel China News Center (newsroom.intel.cn) and the official website (intel.cn).

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