Solution Blueprint
Internet of Things (IoT)

Building an Intelligent Transportation System with the Internet of Things (IoT)

TransWiseway* solution based on Intel technologies helps improve the efficiency, safety, reliability, and convenience of commercial vehicle fleets.

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Paving the way for a data revolution in transportation

Executive Summary

Across the globe, the delivery of products and services relies on a wide assortment of commercial vehicles. For many businesses, vehicles are a means of production, thus creating a pressing need to continuously improve their efficiency, safety, and convenience, while reducing overall costs.

Likewise, strong governmental support and growing societal concerns are driving requirements for improved remote management and service of commercial vehicles. For example, the People's Republic of China recently mandated the use of standard global positioning devices in commercial vehicles, including sightseeing buses, passenger vehicles over class three, road transport vehicles for dangerous goods and heavy cargo, and semi-trailer towing vehicles.[1]

By the end of 2014, nearly 500,000[2] National Key transport vehicles were equipped with terminals that communicated with BeiDou*, a Chinese satellite navigation system consisting of two separate satellite constellations.

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When commercial vehicles are outfitted with the latest information technology, the possibilities around vehicle dynamics monitoring, intelligent navigation, fleet management, and value-added services are endless. These capabilities and more are enabled by a connected commercial vehicle solution developed by Intel and TransWiseway*, a telematics solution and service provider in China. The solution incorporates technologies from the Internet of Things (IoT) that can connect nearly anything with an electronics subsystem to the existing Internet infrastructure.

In this case, commercial vehicle terminals securely connect to a cloud-based platform running big data analytics. Intel® architecture computing platforms products are used to build an end-to-end solution that enhances the user experience, improves reliability and security, and helps reduce operational costs.

Key Business Objectives

Increase the profitability and productivity of commercial fleets using the latest information technologies to improve efficiency and lower operational costs.

Solution Benefits

Revolutionizing the transportation industry in the IoT era, connected commercial vehicles deliver many benefits, including:

- **Greater Efficiency**
Reduce fuel consumption through fuel-saving advice based on driving distance, road conditions, and driving patterns; or eliminate costly delays with alerts when roads are congested, blocked, under construction, or have width and height restrictions.

- **Improved Safety**
Maintain driver and vehicle safety with remote vehicle diagnostics that make it easier for service centers to respond to driver drowsiness, vehicle theft, accidents, natural disasters, and requests for towing, repair, gasoline supply, and tire changes.

- **Higher Reliability**
Avoid downtime and expensive unplanned repairs with a vehicle performance tracking system that sends notifications of imminent maintenance issues.

- **More Conveniences**
Enable drivers to access information on weather conditions, scenic spots, gasoline stations, rest stops, hotel rates, restaurants, parking lots, etc.

Solution Overview

Based on IoT and Intel technologies, the connected commercial vehicle solution developed by TransWiseway has three main architectural layers, as shown in Figure 1 and described in the following:

The **Sensing Layer** employs a vehicle terminal that interacts with the drivers and acts as a gateway for in-vehicle technologies and sensors:

- Microwave detection technology
- Speed sensor
- RFID
- Camera
- Vehicle monitoring equipment
- Payment device
- Infrared sensing equipment for obtaining information on passenger count, vehicles, roads, cargo, and networks

The **Communications Layer** ensures real-time, secure, and reliable transmission from a vehicle terminal to the service layer across different networks, such as IP, 3G/4G, Wi-Fi, wired and private networks, and optical fiber.

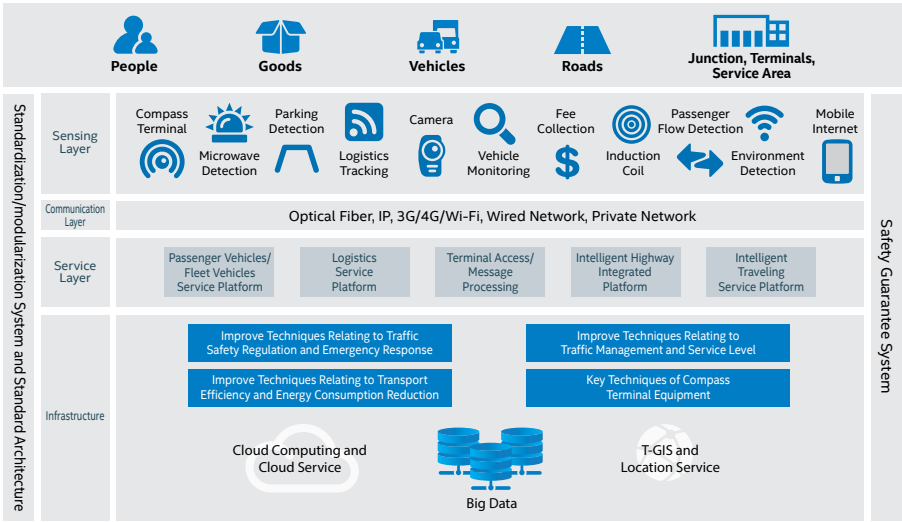

Figure 1. Overall System Architecture

The **Service Layer** supports diverse applications using various technologies such as cloud computing, data analytics, and data and information processing. There are two general categories of applications:

- Services applications process various types of transportation information: passenger-vehicle-classified, trunk-classified, logistics, vehicle-after-sales, road-network-classified, travel, etc.
- Big data applications are used to analyze massive amounts of data and information in the commercial vehicle field.

Usage Models

The following covers four transportation usage models geared toward improving efficiency, safety, reliability, and convenience of commercial vehicle fleets:

1. **Remote Monitoring and Diagnosis – Greater Efficiency**
   The connected commercial vehicle solution provides owners and drivers with real-time, all-around safety protection. In-vehicle sensors and controllers acquire and upload environmental and performance data to a cloud-based platform that runs service and big data applications. Results from the analysis can be sent to a driver's smart phone or vehicle terminal any time of day. Vehicle status is monitored so that when an abnormal situation occurs, the driver is alerted by alarms in the vehicle. When a vehicle is parked, monitoring continues.

   The solution can also offer fuel saving advice according to statistical data from the same vehicle type, guidance from vehicle experts, and journey information (e.g., driving distance, road conditions, and fuel consumption) sent by the connected vehicle.

2. **Alerts – Improved Safety**
   When drivers do not take sufficient breaks, the connected commercial vehicle solution can remind them, as well as notify the vehicle owner and the service center. Video from in-vehicle cameras can be analyzed by the cloud platform to detect when drivers deviate from their typical driving patterns, allowing alerts to be sent to drivers who are at risk of falling asleep.

3. **Preventive Maintenance – Higher Reliability**
   The cloud platform can track vehicle performance and recommend when a pre-emptive repair (e.g., replace brake pads, worn tires) could prevent a breakdown or an expensive major repair. The service center can also send vehicle maintenance notices to drivers and repair crews based on driving history and sensor inputs.

4. **Relevant Information – More Conveniences**
   The connected vehicle can help drivers and passengers enrich their lives. Music, apps, and audio books can be downloaded to the vehicle along with customized services. For example, when the driver needs food and rest, a speaking application can provide valuable information such as, "There is a service area 800 meters ahead", "There is a restaurant with a half-price discount 300 meters ahead", or "Special price for a single room, 50 meters ahead on the right".

Technologies

This section describes the technologies used to develop the connected commercial vehicle solution.

Sensing Layer

In-vehicle sensors connect to a vehicle terminal, which is responsible for collecting, storing, processing, and reporting information, and responding to commands from supervision platforms. The vehicle terminal consists of the microprocessor, data storage, GPS module, vehicle condition collection module, wireless communication transmission module, real-time clock, and data communication interfaces. It also has peripherals like displays, printers, card readers, etc.

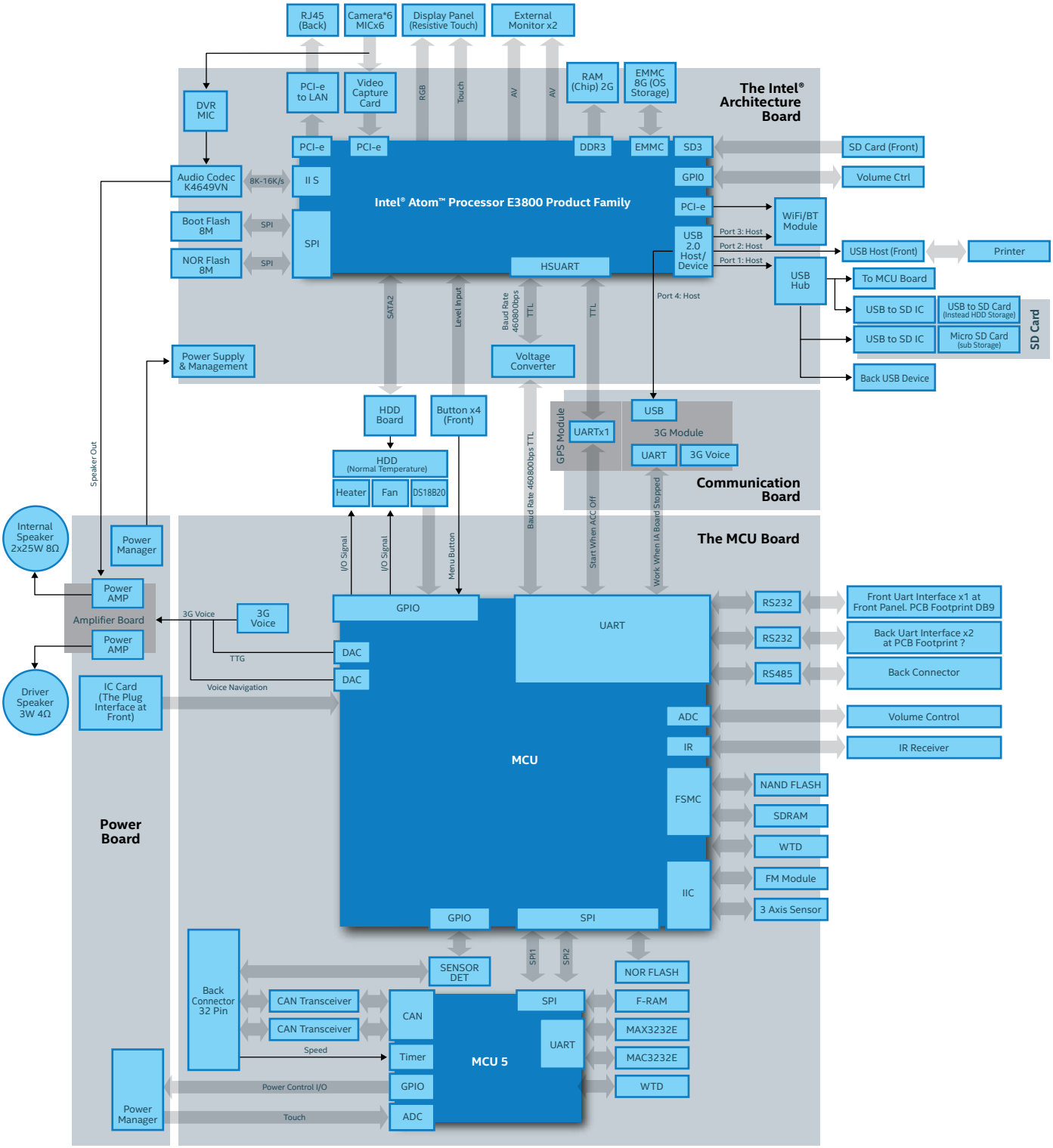

Figure 2. Vehicle Terminal Hardware Architecture

The vehicle terminal may also be part of an infotainment system that provides computing and video processing capable of satisfying basic demands from governments and enterprises requiring vehicle video monitoring and driving recording. In combination with H.264 video compression/ decompression technology, network technology, positioning technology, and RFID technology, it can support the following functions:

- Video recording
- Vehicle travel information recording
- Wireless data uploading
- Centralized monitoring
- Remote management
- Playback analysis in association with central software
- Multimedia playback
- Navigation
- Fence computing

1) Vehicle Terminal Hardware Architecture

The vehicle terminal hardware architecture shown in Figure 2 is based on proven Intel® IoT Gateways that deliver application-ready platforms with pre-validated, industry-leading software.

The solution includes:

- Choice of Intel® processors for the development kits: Intel® Quark™ SoC X1000, Intel® Quark™ SoC X1020D, and Intel® Atom™ processor E3826
- Wind River* Intelligent Device Platform XT development environment
- McAfee* Embedded Control* security technologies

Intel IoT Gateways provide the following security features:

- **Secure Boot** – Verifies the integrity and authenticity of every piece of software in the boot chain
- **Secure Runtime** – Detects compromised systems and proactively protects without signature updates
- **Secure Updates** – Ensures software images and applications are securely updated through trusted channels

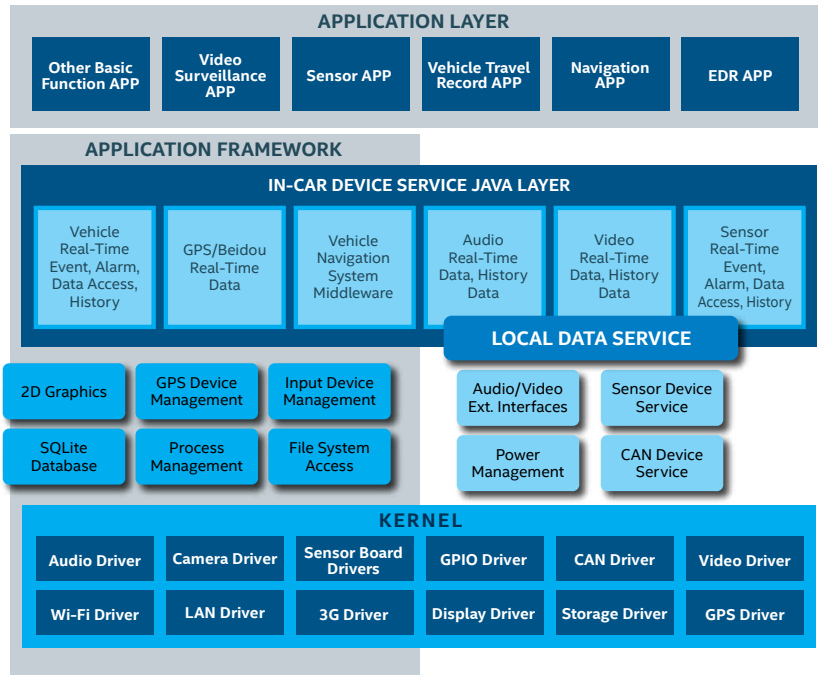

Figure 3. Vehicle Terminal Software Architecture

2) Vehicle Terminal Software Architecture

The vehicle infotainment terminal software system is shown in Figure 3. In general, the software architecture can be divided into three layers from bottom to top: system kernel layer, application framework layer, and application layer.

3) System Kernel

The kernel is the basis of the whole software system, responsible for:

- Managing and distributing system hardware and software resources
- Providing basic services, such as managing and configuring the memory
- Controlling input and output equipment
- Operating the network
- Managing the file system

Other kernel functions are storage management, CPU and process management, file system, equipment management and driving, network communication, system initialization (guidance), system calls, etc.

4) Application Framework Layer

The application framework layer is the collection of multiple system services, including the activity manager, view and content provider, resource manager, and notification manager. All these services constitute the environment required for running and managing applications. As the core for running all the applications, it participates in all operations on the application layer and performs global planning.

In addition, this layer has two dedicated data service modules:

1. Vehicle data service reads vehicle-infotainment-specific data (e.g., speed, mileage, fuel consumption, etc.) from the vehicle bus control board and manages it for the applications.
2. Audio/video data service imports, manages, and controls the video streams from the vehicle's surveillance camera, which are processed by the application layer.

The cloud platform can track vehicle performance and recommend when a pre-emptive repair (e.g., replace brake pads, worn tires) could prevent a breakdown or an expensive major repair.

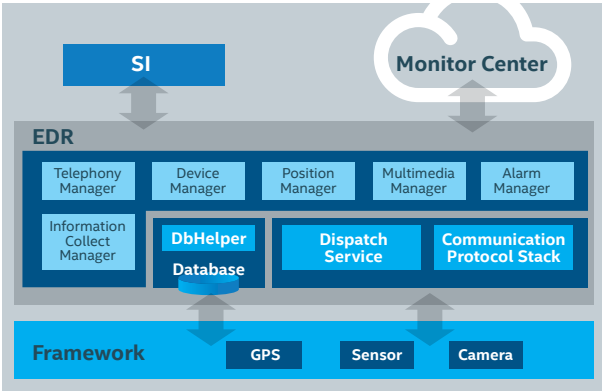

Figure 4. Vehicle Terminal Software Architecture

5) Application Layer

The event data recorder (EDR) software is responsible for satisfying the requirements for trunk and dangerous goods transport established by the Ministry of Communications of China in standards JT/T808 and JT/T794.

Figure 4 shows the main structure of EDR, consisting of an application service and a user interface. The application service contains independent components to manage telephony, devices, position, multimedia, alarms, information collection databases, JT/T808 communication protocol stack, etc.

6) Video Processing Technology

In recent years, video processing capabilities have become one of the critical functions in certified commercial vehicle terminals, especially as many countries require them to integrate video capture functions. Moreover, real-time video recording and video analytics play an important role in helping vehicle management companies improve operating efficiency and public safety.

Enabling vehicle terminals to satisfy these requirements, the Intel® Atom™ processor E3800 product family features an integrated hardware video accelerator that can provide full high definition (HD), multi-channel video processing. This quad core CPU processor also accelerates video analytics processing with its system-on-chip (SoC) architecture with high processing capability.

The vehicle terminal incorporates the video processing technology shown in Figure 5, which includes must-have capabilities such as video recording and transcoding. Video analytics is

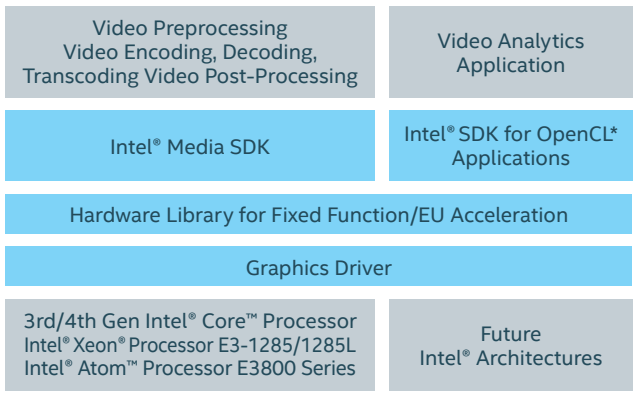

Figure 5. Video Processing Technology

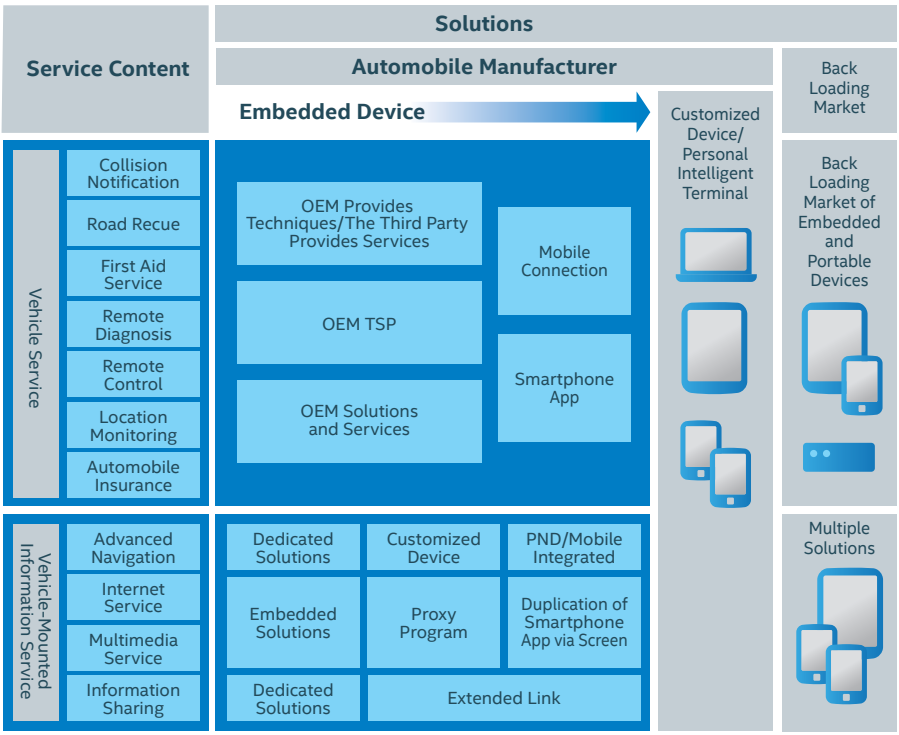

Figure 6. Service Architecture

becoming more popular in monitoring driver behavior, collision avoidance detection, passenger safety, business intelligence (such as passenger counting), and automatic fining for illegal lane use by non-public buses.

7) Driving Assistance Technology

Advanced driver assistance systems (ADAS) usually implement radar or visual computing. This connected commercial vehicle solution uses visual technology, such as cameras (i.e., front, rear, side) and a visual processor. The system supports panoramic parking assistance and blind spot detection to help drivers avoid accidents.

Service Layer

The service layer has two main parts, as shown in Figure 6:

1. **Vehicle services** are supported by a cloud-based, back-end platform that has a network connection to vehicles and runs advanced data analytic applications. Services include collision notification, roadside rescue, emergency rescue, remote diagnosis, remote control, positioning monitoring, vehicle insurance, etc. They may be before-market and after-market products, depending on the support of embedded equipment, vehicle terminals, customized terminals, or smart phones. OEMs may provide vehicle networking solutions, services, and operations.
2. **Vehicle mounted-information services** combine mature products such as advanced navigation, Internet services, multimedia services, and information sharing (e.g., social networks) with in-vehicle networking. The vehicle terminals connect to drivers' smart phones, smart screens, or a combination of multiple screens, providing diversified vehicle information services.

TransWiseway developed a business application that can connect millions of commercial vehicles to the Internet and each other using IoT technologies.

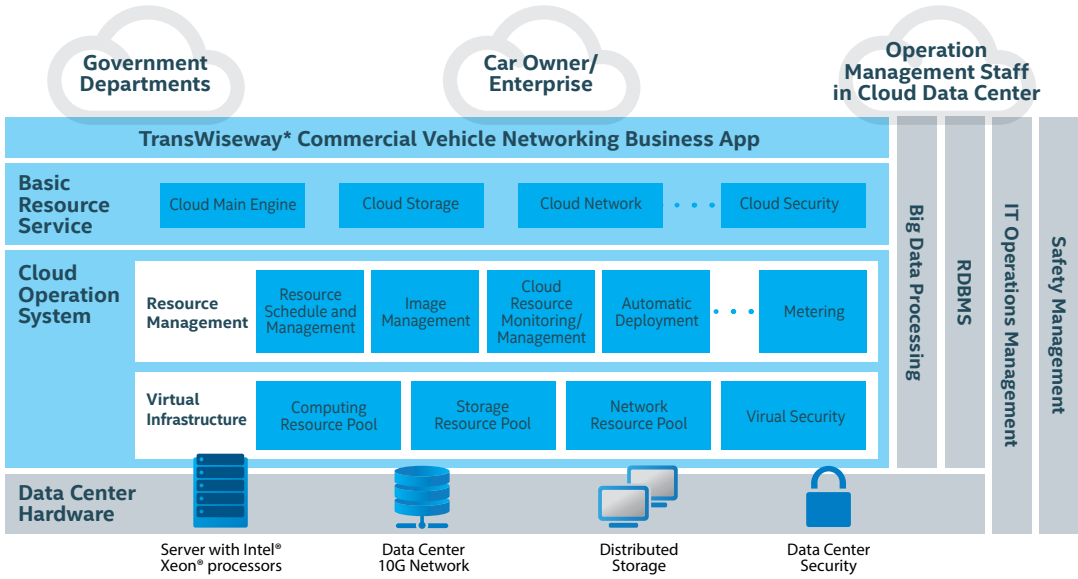

Figure 7. Overall Architecture of Back-End Platform

Cloud-Based Platform Technology

The connected commercial vehicles solution enables vehicle services via a back-end platform (Figure 7) that controls the flow of data between front-end and back-end users. This high-performance platform is designed to acquire data from vehicle terminals in real time, deliver information promptly and accurately to users and supervisory authorities, and support large fleets of commercial vehicles.

The back-end platform addresses the following challenges:

- Promptly acquire, process, store, analyze, and present huge amounts of real-time data from vehicle terminals
- Check, analyze, monitor, and process real-time services for hundreds of thousands of users (vehicle terminals)
- Allow capacity to be expanded dynamically and flexibly to accommodate increased service scope
- Enable highly-efficient, cost-effective support by the operations and maintenance department

While considering total cost of ownership (TCO), these challenges have been solved to satisfy the various service demands from connected commercial vehicles. This was done by taking into account current trends in the Internet of Things, cloud computing, big data, distributed storage, and mobile Internet. The solution incorporates open source and commercial software and hardware technologies.

The following sections describe the key technologies of the back-end platform: TransWiseway application, basic resource service, cloud operation system, data center hardware, big data processing, and relational database management system (RDBMS).

1) TransWiseway* Commercial Vehicle Networking Business Application[3]

TransWiseway developed a business application that can connect millions of commercial vehicles to the Internet and each other using IoT technologies. Running on a cloud-based platform, the application uses big data analytics to turn data from vehicle sensors, GPS systems, operations, and service providers into actionable information that drivers and authorities can access via web-based consoles, mobile devices, and vehicle terminals.

The TransWiseway commercial vehicle networking business application provides secure APIs to independent software vendors (ISVs) who are developing new capabilities and services for companies in the transportation industry. This includes applications that improve efficiency and lower operations costs such as fuel-saving advice, road condition updates, remote vehicle diagnostics, and driver safety alerts.

This product helps achieve the objectives of the People's Republic of China by improving the safety and satisfying requirements of an Internet-connected transportation system in the future. The TransWiseway solution currently connects to about 300,000 trucks in nine provinces, with 1.5 million expected in 2015, and ultimately 10 million in two to three years thereafter.

2) Basic Resource Services

Basic resource services (IaaS) consists of mature open-source cloud computing technology solutions running on Intel® Xeon® processor. Through the addition of servers, the solution supports on-line capacity

expansion to meet future demands for vehicle services. The basic services also support on-line operation and maintenance management services, such as dropping failed servers from resource pools and configuring new servers to expand capacity. The solution supports dynamic resource balancing and load migration in the resource pools to meet the needs of operations and maintenance management.

3) Data Center Hardware

The cloud computing requirements are satisfied by a highly-dense data center containing servers based on the Intel® Xeon® processor E5-2600 v3 product family. These processors deliver exceptional performance in virtualized environments to support the access and data processing requirements of very large numbers of vehicle terminals and final users.

Storage supporting the cloud platform uses cross-device distribution; thus, data center servers require 10G network connections. In order to guarantee the IOPS and bandwidth requirements of distributed storage, the Intel® Solid-State Drive DC S3700 Series is used as a cache, supporting up to 10 thousand IOPS, thereby ensuring high-speed data access for service applications.

The suggested hardware platform for the connected commercial vehicle solution based on open-source cloud management solutions is shown in Figure 8.

4) Cloud Operation System

The connected commercial vehicle solution supports two mainstream, open-source cloud computing technologies: CloudStack* / XenServer* and OpenStack* / KVM. Both technologies provide customers with a choice of mature solutions, major technical support providers, and lively open-source communities.

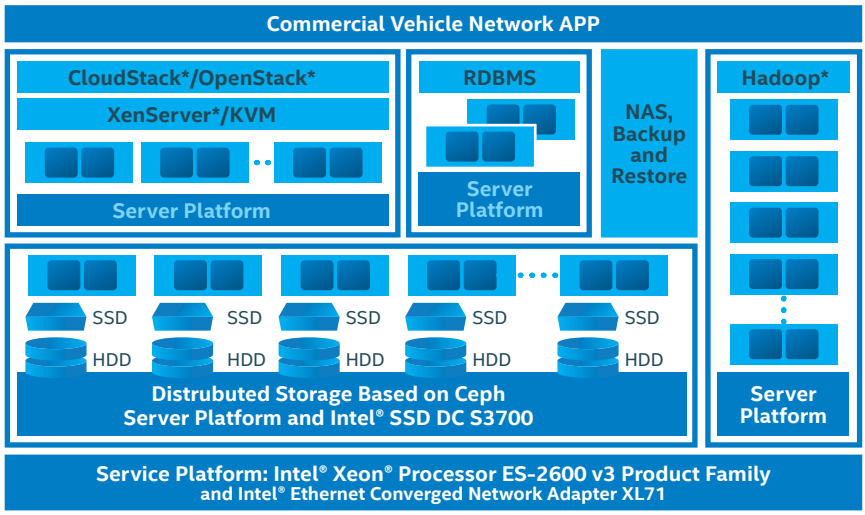

Figure 8. Suggested Hardware Platform

5) Big Data Processing

The connected commercial vehicle solution supports both offline and online big data analysis. Offline analysis creates statistics, such as the average vehicle speed of each road, and predictive and inferential analysis such as predicting traffic jams, and automatically detecting and classifying unknown points of interest (POI). Online big data analysis processes data generated by sensors and vehicle instruments for applications such as logistic management, vehicle management, and financial management systems.

- **Offline Analysis:** Hive, an open-source data warehouse, is used to query SQL databases to facilitate statistical analysis. HBase stores dimensional data generated by off-line analysis, and performs fast data drilling and query. Mahout, an open-source machine learning framework, helps with predictive and inferential analysis.
- **Online Analysis:** Since analysis speed is essential, memory storage technology, including Memcached, Redis, Coherence, Infinispan, Gemfire, etc., is critical. Software components are mainly characterized by performing CRUD (create, read, update, and delete) operations for objects or key/value pair data on the basis of distributed memory object caching systems. The mainstream open source software in the memory computing technology mostly consists of Spark and Shark. They are characterized by memory-based cluster computing frameworks, which cache datasets in memory to shorten access delays. VoltDB and SAP Hana support memory storage and memory computation functions, use SQL access, support the ACID models of traditional databases, and provide CRUD operations for data.

6) Relational Database Management System

Basic data is saved in relational databases, and some other key system data usually requires daily backup. This backup data, as well as video data, can be saved in the distributed storage system.

The connected commercial vehicle solution developed by Intel and TransWiseway is designed to provide security and interoperability from edge to cloud.

7) Data Security Technology

The connected commercial vehicle solution implements multiple levels of data security, including:

- Access control prevents unauthorized users from entering the system and ensures only authorized users can read and write to datasets
- Data flow control distributes datasets to authorized users and prevents data from diffusing to unauthorized users
- Inference control protects databases that can be counted in order to prevent users from inferring confidential information through well-designed query sequences
- Data encryption prevents confidential information from being disclosed in an unauthorized way during transmission or storage
- Data security prevents accidental or malicious destruction of data, thus ensuring data availability and completeness.

IoT Tenets

The connected commercial vehicle solution developed by Intel and TransWiseway is designed to provide security and interoperability from edge to cloud in keeping with five key tenets defined by Intel:

- **World-class security** as the foundation
  - The solution protects the entire manufacturing environment with state-of-the–art security solutions.
- **Automated discovery and provisioning of edge devices** to ease deployment
  - The TranWiseway application authenticates and manages authorized vehicle terminals.
- **Data normalization** through protocol abstraction to improve interoperability
  - Vehicle terminals maintain various device and communication protocols used by vehicle sensors.
- **Broad analytics infrastructure** from commercial vehicle to cloud to realize customer value
  - The back-end platform supports both online and offline big data analytics.
- **Infrastructure** to monetize hardware, software, and data management from edge to cloud
  - The connected commercial vehicle solution enables fleet operators to benefit from significant savings through improved efficiency and lower operations costs.

Summary

According to data gathered, the number of remote information processing terminals for commercial vehicles will reach 22 percent over the coming years to around five million by 2020. A large number of the processing terminals will be installed in commercial vehicles, thereby helping to improve the efficiency, safety, reliability, and convenience of commercial vehicle fleets. Intel and TransWiseway developed an IoT-based connected commercial vehicle solution that realizes these benefits and paves the way for a data revolution in transportation.

Resources

Intel® IoT Gateway Development Kits

Intel IoT Gateway development kits enable solution providers to quickly develop, prototype, and deploy intelligent gateways. Available for purchase from several vendors, the kits also maintain interoperability between new intelligent infrastructure and legacy systems, including sensors and data center servers.

For more information about transportation products from TransWiseway, visit **http://transwiseway.com/index.aspx**.

For more information about Intel® solutions for the IoT, visit **www.intel.com/iot**.

[1] On July 1st, 2014, "Dynamic Supervision and Management of Road Transport Vehicles" formulated by the Ministry of Transport, the Ministry of Public Security and the State Administration of Work Safety Supervision took effect. http://english.gov.cn/archive/publications/2014/08/23/content_281474983043377.htm.

[2] Source: 2014 TransWiseWay Commercial Vehicle monitoring system.

[3] Source: IBM website, "TransWiseway and IBM Improve Driver Experience With Connected Vehicle Platform," http://www-03.ibm.com/press/us/en/pressrelease/44053.wss.

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