Hitachi's ETC and AHS Supporting Intelligent Transport Systems

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OVERVIEW: Roads and highways, which provide a means of transport and distribution, occupy a very important position in terms of economic activities. A wide variety of road infrastructures have been created up to now to ensure safe, smooth road traffic. In recent years, ITS (intelligent transport systems) has seen significant advances as a result of improvements in IT and other related technologies, and its evolution is continuing. ITS provides a broad range of road application services aimed at improving the convenience, economy, and safety of road traffic society. Up to now, we have seen practical applications of systems designed for functions such as provision of road traffic information, automatic toll collection, and hazard warnings, and these systems are becoming increasingly familiar as time goes on. Hitachi, Ltd. is currently conducting activities targeting the development of ITS, based on technologies that it has cultivated over long years of experience in fields such as communication technology, security technology, control technology, and image application technology.

INTRODUCTION

ITS (intelligent transport systems), which has gained attention as a next-generation road system, is a comprehensive service aimed at creating better road traffic environments (see Fig. 1). Among the various development fields that ITS encompasses, VICS (vehicle information and communication system) and ETC (electronic toll collection system) have already been implemented.

VICS provides drivers with road traffic information, for example regarding traffic jams and required time to reach a given destination, thus contributing to smooth road traffic. This service became available in Japan from April 1996.

ETC is designed to eliminate traffic jams resulting from the time required to collect tolls at tollbooths. ETC services began in November 2001 on major highways throughout Japan, and the number of users continues to grow.

Meanwhile, development is progressing in the field of AHS (advanced cruise-assist highway systems), which supports safe driving by providing drivers with information and hazard warnings. In Japan, Advanced Cruise-Assist Highway System Research Association (AHSRA) was established in 1996; as a member of this association, Hitachi is involved in the development and testing of AHS technologies.

The goal of AHS is to secure safe driving

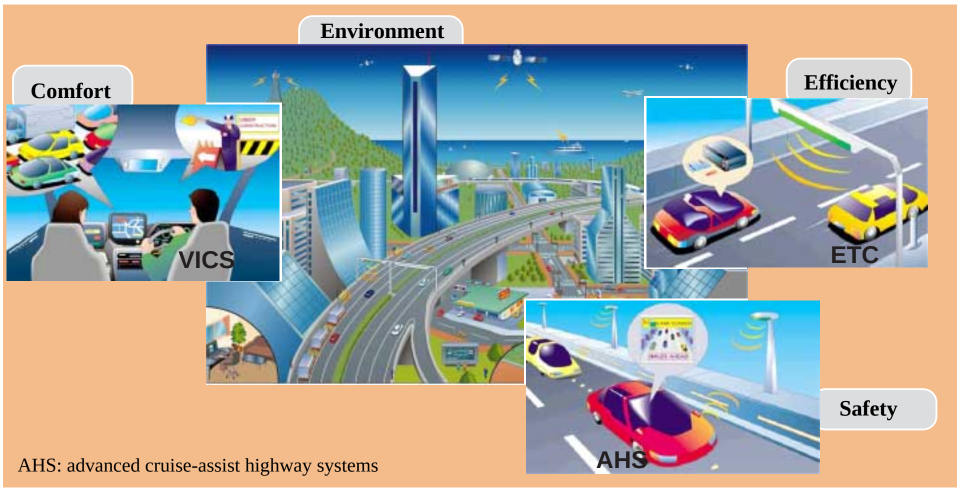

Fig. 1—Road Infrastructures Using ITS.
Road infrastructures using ITS technologies will contribute to the creation of highways that pursue comfort, safety, efficiency, and consideration to the environment.

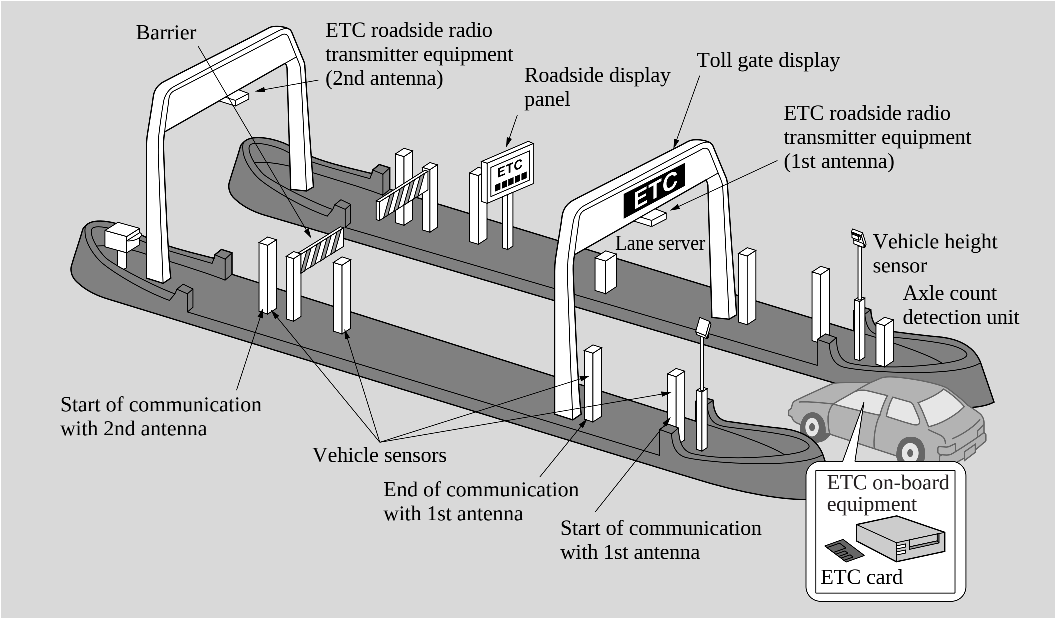

Fig. 2—ETC Device Configuration at Entrance Tollbooth.
Antennas are installed in two locations in the entrance tollbooth, controlling the opening and closing of the passage control gate.

environments in the future by combining independent vehicle operation with road infrastructures that will support this operation. One example already available is that of danger warning systems, which provide advance notification of risks in locations that are as yet out of sight of the driver.

Here, we will discuss several issues related to ITS, including ETC tollbooth systems and case studies of AHS installations, as well as the propagation simulators, ITS simulators, and image sensors that support these systems.

ETC TOLLBOOTH SYSTEMS

ETC Tollbooth Systems

Hitachi has installed ETC tollbooth systems on a number of major highways in Japan, including the Tomei Expressway, the Yokohama-Yokosuka Line, the Dai-San Keihin Line, the Joban Line, and the Tohoku Line (all operated by Japan Highway Public Corporation), and in some locations on the Metropolitan Expressway. Fig. 2 shows the configuration for roadside devices in ETC lanes at regular entrance tollbooths operated by Japan Highway Public Corporation.

Following are some of the main devices installed in ETC lanes:

(1) ETC roadside radio transmitter equipment (hereafter referred to as “antennas”): conducts wireless communication with ETC on-board equipment;

(2) Lane server: controls roadside devices;

(3) Vehicle sensor: senses the passage of vehicles;

(4) Vehicle height sensor/axle count detection unit: determines vehicle type

(5) Roadside display panel: indicates whether vehicle can pass through

(6) Passage control gate: controls the passage of vehicles

TABLE 1. ETC Wireless Communication Specifications
This table shows specifications for roadside wireless communication devices installed in ETC lanes of entrance tollbooths operated by Japan Highway Public Corporation.

Item	Specifications
Frequency band	5.8 GHz, 2 wave directions
Transmission and reception frequency interval	40 MHz
Transmitted electric power	10 mW or less (tollbooth)
Radio access method	TDMA, FDD
Communication area	1m above ground × 4 m in direction of movement × 3 m across lane
Correspondence vehicle speed	Stationary – 80 km/h
Access speed	1,024 Mbit/s
Modulation method	ASK
BER	10^{-5} or less

TDMA: time division multiplex access
FDD: frequency division duplex
ASK: amplitude shift keying
BER: bit error rate

The wireless communication area for ETC applications is quite small (roughly the size of a single vehicle: 3 m wide, 4 m long), because wireless communication must be conducted separately for each vehicle arriving at the tollbooth (see Table 1).

Vehicle sensors are installed at the starting point and ending point of the communication area; these sensors attempt to make contact with on-board equipment as the car passes through this area, to determine whether the vehicle has the on-board equipment installed. The antenna uses wireless communication to obtain payment-related information recorded in the ETC card, as well as vehicle type and other information. Meanwhile, the vehicle type is also determined by the vehicle height sensor and axle count detection unit, and this result is crosschecked against the information obtained through the antenna.

Antennas are installed at two locations in the entrance tollbooths. The first antenna reads information from the vehicle via wireless communications, and the second antenna writes information on the confirmed vehicle type and tollbooth entrance information onto the ETC card. The results of the information obtained through the first antenna are displayed on the roadside display panel, and are used to control the passage control gate. For example, if the wireless communication via the first antenna is executed properly, then a message indicating "ETC Passage OK" is shown on the roadside display panel, and the passage control gate opens.

Exit tollbooths are equipped with a single antenna. This antenna reads the entrance information and vehicle type information recorded in the ETC card via wireless communication, and the toll fee is calculated by the lane server. The toll fee is indicated in the roadside display panel, and the passage control gate opens.

With the above process, vehicles that pass through the ETC lanes do not need to stop in front of the control gate; this relieves traffic jams at tollbooths, and also contributes to reductions in engine noise and CO_2 emissions from idling vehicles.

ETC On-board Equipment: Vehicle-side Terminals in the ETC Tollbooth System

Concurrent with the startup of ETC operations in the Chiba region of Japan in March 2001, Hitachi released a commercial version of the ETC on-board equipment mentioned in the previous section. The three main features of these products are: (1) a separate-antenna configuration that enabled the user to freely select the installation location in the vehicle; (2) attention to the vehicle's installation environment, in that the IC card is inserted completely into the on-board device for protection from the heat, and from potential theft, etc.; and (3) a simple HMI (human-machine interface) that emphasizes ease of operability.

In April 2002, the Wireless Telegraph Law in Japan was amended with a view toward future developments in DSRC (dedicated short range communication) applications and usage by the general public. Accompanying standards [ARIB (Association of Radio Industries and Businesses) STD-T75] were implemented at the same time.

Fig. 3—ETC On-board Equipment (in Conformance with ARIB STD-T75).
Dimensions: (W) 70 mm × (D) 99 mm × (H) 29 mm; Weight: 150 g; features an easy-to-read 8-digit dot matrix display, and 12/24 V compatibility with no adaptor required. The antenna is installed above the dashboard.

Hitachi is gradually releasing new on-board equipment units that conform to these new standards (see Fig. 3). Like the previous models, the new models feature a separate-antenna configuration, full insertion of IC cards, and simple HMIs to ensure maximum ease of use.

DANGER WARNING SYSTEMS

Danger warning systems are designed to draw the driver's attention to the road conditions ahead in locations where visibility is poor—for example due to sudden curves or large obstructions—and by doing so to avoid accidents and other hazards. Fig. 4 is an illustration of a danger warning system in operation.

This system provides two types of service: a stopped and low-speed vehicle warning service, and an oncoming vehicle warning service.

Using a warning display, the stopped and low-speed vehicle warning service encourages the driver to slow the vehicle's speed before entering a curve. This service makes the driver aware of the presence of vehicles stopped, or driving slowly, in the lane ahead, thus preventing risks such as rear-end collisions or lane departure resulting from attempts to avoid the obstructing vehicle.

The goal of the oncoming vehicle warning service is to use warning displays to make drivers aware of the presence of oncoming vehicles, and thus to promote

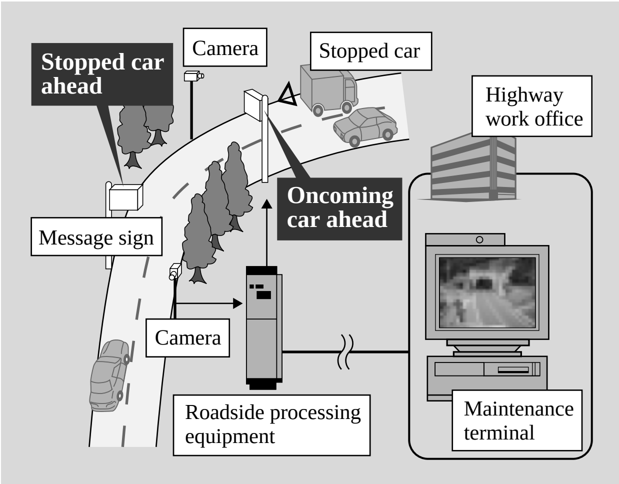

Fig. 4—Typical Configuration of the Danger Warning System.
Warns drivers of potential risks ahead when visibility is poor.

Fig. 5—Information Displayed on Variable Message Sign.
Warnings are displayed in text format on the message sign to draw drivers' attention to conditions ahead of curves in the road.

safe driving by encouraging drivers to reduce speed on curved road segments, or to avoid drifting into the oncoming lane. This service contributes to the prevention of frontal collisions, sideswipe accidents, and other related risks.

(1) Vehicle detection

In order to implement stopped and low-speed vehicle warning services, it is necessary to adopt a sensing method that covers a surface area the width of the lane plus several tens of meters, so as to detect vehicles ahead and in poor visibility sections of the road.

This system adopts image processing as the method of sensing the road surface conditions. Image processing technologies determine the position and speed of a vehicle based on camera images; for this reason, when used in outdoor environments, these technologies must respond to changes in the brightness of the images between daytime and nighttime.

Hitachi uses image processing technologies cultivated over many years in this field, including traffic flow measurement systems and accidents detection systems, to accommodate vehicle detection in outdoor environments.

(2) Judgment processing

In the event of a malfunction in the camera, processing equipment, or other devices, status judgment processing stops messages from being sent to the driver. Furthermore, when oncoming cars are passing by continuously, messages are provided with additional time-related information to prevent the oncoming vehicle warnings from blinking constantly.

(3) Warnings to the driver

As a method of providing warnings to drivers, the system uses a variable message sign, displaying warning messages in text format. Characters are large and brightly colored, in order to effectively draw the driver's attention (see Fig. 5).

(4) Applications in road management

This system can be used in the monitoring operations of road administrators, by forwarding images recorded near curves to highway work offices and other locations.

System operation records—including device operation status and warning messages sent to drivers via display boards—can be confirmed on maintenance terminals installed at highway work offices and related locations.

(5) Future developments

In existing systems, message signs represent the most common method of providing warnings, but studies are currently ongoing with regard to warning systems that even more closely match the current conditions, by providing messages directly to the on-board equipment via antennas on the road.

FUNDAMENTAL TECHNOLOGIES[3)]

Many system configuration tools and system components will be required to achieve practical installation of the intelligent transport systems described above. Here, we will discuss some of these tools and parts; namely, propagation simulators, ITS simulators, and image sensors.

Propagation Simulators

Multi-path propagation of radio waves to roadside structures and moving vehicles is essential to the

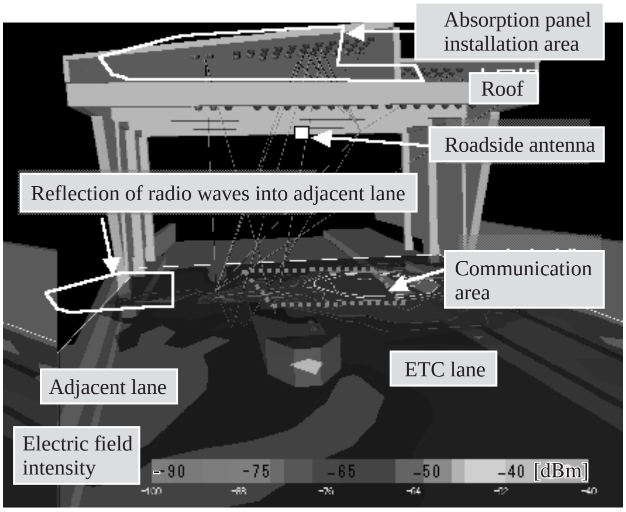

Fig. 6—Example of Propagation Simulation Application.
In a study of radio wave conditions at a tollbooth, the optimum installation area for radio frequency absorption panels is calculated using propagation simulation.

design of systems using wireless communication, as are prior studies to ensure that communication errors be prevented. For this reason, Hitachi has developed a propagation simulator for evaluating the radio wave environment, and for studying appropriate roadside antenna installations, antenna characteristics, and radio frequency absorption panel installations. Following is a case study of an application of this simulator in an ETC tollbooth system.

Fig. 6 shows the results of a propagation calculation conducted at an actual tollbooth. In this case, it was found that because the roadside antenna is located under a roof in the tollbooth, some leakage of radio waves into the adjacent lane had occurred as a result of reflection. Measures were adopted for controlling these reflected waves through the installation of radio frequency absorption panels, and prior studies were conducted regarding the targeted area for installation of absorbing materials in the roof. The installation area was determined as the focus of reflection points for radio waves that were leaking outside the communication area.

In the case of tollbooths located on elevated structures, there are concerns regarding radio wave leakage to the road below these structures. On expanding the scope of the simulation, it was found that there was a clear possibility of radio wave leakage (induced by diffraction, reflection, and fading) reaching standard roads under such elevated structures. In this sense, prior studies using propagation simulations are very meaningful in terms of preventing communication error at the system design stage.

ITS Simulators

When introducing ITS, it is important to predict the effects beforehand, and to ensure reliability. Simulators are effective tools for investigating these factors. The ITS simulator developed by Hitachi is unique in that it is made up of a traffic simulator, which simulates the behavior of individual moving vehicles, along with a driving simulator and a camera view simulator, all of which are connected in to enable concurrent real-time operation (see Fig. 7).

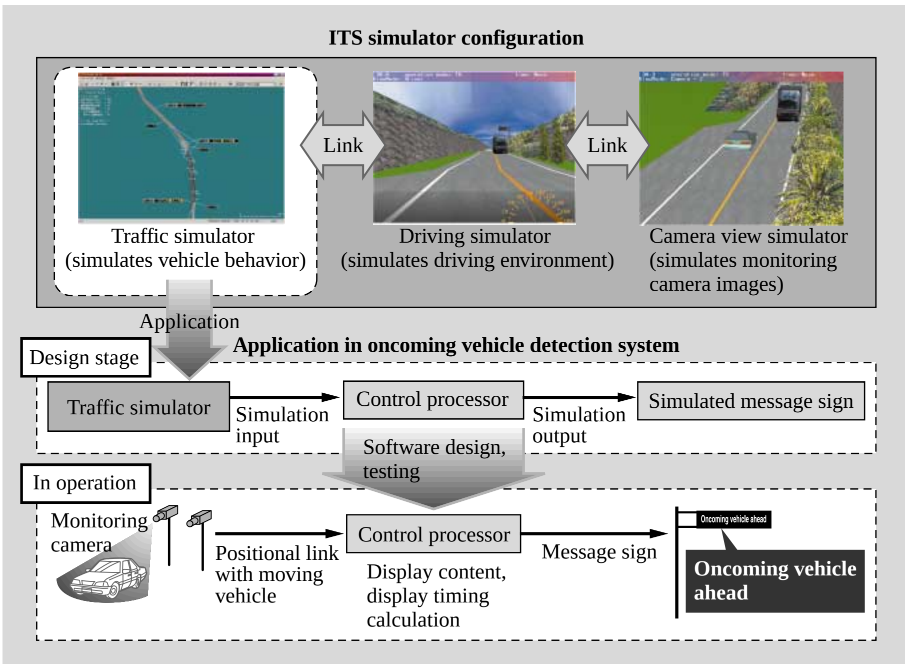

Fig. 7—ITS Simulator Configuration and Application Example.
Application of the ITS simulator in design and testing of a system implemented by Nakamura Work Office, in the Shikoku Regional Bureau of Ministry of Land, Infrastructure and Transport of Japan, contributed to shorter construction time and increased reliability.

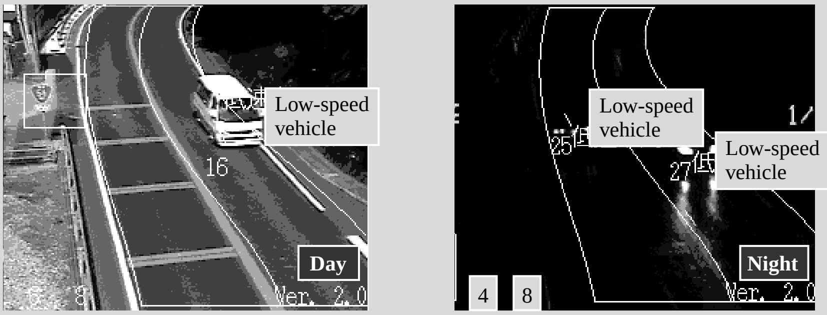

Fig. 8—Example of Image Processing.
Day (left) and night (right). Image sensor enables 24-hour monitoring.

Here, we will discuss a case study of an application for the traffic simulator segment of the ITS simulator in the design, production, and testing of oncoming vehicle detection system implemented by Nakamura Work Office, in the Shikoku Regional Bureau of Ministry of Land, Infrastructure and Transport of Japan.

First of all, Hitachi produced a device installation plan based on the results of an on-site survey, creating a simulated road structure within the traffic simulator including poor visibility sections, and incorporated four simulated visible-image sensors and two simulated display boards. Next, the simulator was connected with the actual control processor installed at the site, and the simulator was used to generate a range of simulated traffic conditions from off-peak to peak traffic times. These traffic conditions were sensed using a simulated visible-image camera, and the sensed information was input into a control processor. The control processor then output the information displayed on the simulated display board based on logic decisions from the sensed information, enabling the functions of the actual installations to be verified.

In this way, the simulator application facilitated tests using recreations of traffic conditions that would be difficult to test on-site, and enabled design changes based on these test results. It was thus possible to build a highly reliable system in a short time.

Image Sensors

Up to now, various types of sensor systems have been developed and introduced to monitor road traffic conditions. One of the most common of these is the image sensor. Here, we will discuss sensors that utilize visible-image cameras installed on the roadside.

Image recognition systems that monitor roads using roadside cameras incorporate functions such as traffic flow measurement, traffic jam monitoring, and detection of accidents in tunnels. These recognition systems target moving objects (cars), and so require high-speed hardware. Hitachi has been developing image processing LSIs (large-scale integrations) for these applications for over ten years. In 2001, the company developed a single-chip image processing LSI[4)], which achieved processing speeds three to ten times faster than its earlier units, enabling real-time calculations of optical flow. This in turn led to substantial improvements in the accuracy of vehicle detection.

Fig. 8 shows an application of image sensors in a danger warning system. In this system, the camera monitors the curve segment of the road, quickly locates oncoming vehicles or stopped/slow-moving vehicles, and provides a display of these conditions. Because this is an outdoor system, extensive processing is required to accommodate changes in brightness, weather, and other environmental conditions. Given that this type of system can be extended to driver support systems currently being targeted by Ministry of Land, Infrastructure and Transport, among other agencies, Hitachi plans to continue its efforts in the future to improve recognition accuracy, and to create more compact, low-cost equipment.

FUTURE ACTIVITIES AT HITACHI

(1) ETC application systems

In terms of ETC applications, there is an increasing demand for the establishment of flexible toll systems that take into consideration time, location, and traffic volumes, and Hitachi intends to focus on responding to these needs. It is also studying applications of ETC technologies in areas other than highway tolls, such as parking lots and road pricing.

(2) AHS

Hitachi will continue to work toward providing drivers with support that reflects the driving conditions of individual vehicles, by transmitting information directly to moving vehicles via wireless

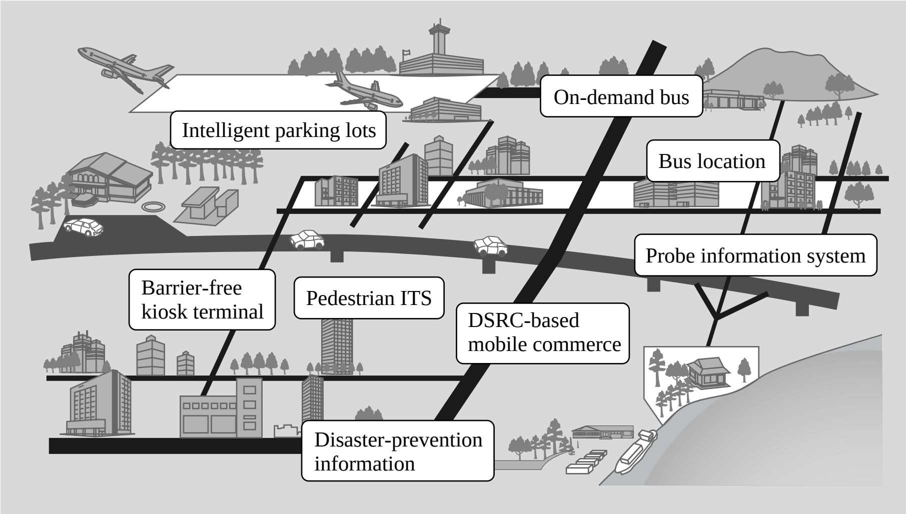

Fig. 9—Regional ITS.
System integration and selection of services with consideration to traffic access networks and other unique characteristics of specific regions.

communication.

(3) Regional ITS

ITS infrastructures can be expected to evolve into a very flexible format, for example with nationwide VICS and ETC services, as well as local services that match the unique needs of specific regions. Hitachi will continue its work in system integration and provision of services to accommodate these changing circumstances. Fig. 9 shows an image of "Regional ITS."

CONCLUSIONS

Here, we have discussed road transport systems with a particular focus on examples of systems implemented by Hitachi.

The "road traffic society" brought about by the evolution of ITS will most certainly give rise to a demand for driver support services and detailed information provision services designed to accommodate diversifying driver tastes and the needs of an aging society.

Hitachi will continue to promote technological development aimed at contributing to an even more safe and comfortable road traffic environment for the future.

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