Mobile Communication Platforms for ITS Services

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OVERVIEW: The VICS (vehicle information and communication system) and ETC (electronic toll collection) technologies, which are ITS (intelligent transport systems) services, have been made practical in recent years, and services that apply those technologies are steadily being developed in various fields. On the other hand, network services are becoming global in scope as a result of the rapid proliferation of Internet use. Amidst these trends, one development of the "automobile society" is that, by connection with a cell phone, the automobile has become an information terminal. The network service provision platforms, and particularly the wireless access platforms, include broadband communication networks, dedicated networks for special purposes, broadcast communication, etc. We believe that services will be developed that take advantage of the special features of each of these platforms and their mutually complementary nature. As various kinds of communication platforms for supporting ITS services, Hitachi is grappling with broadband communication services [cdma 2000 1xEV-DO (1x Evolution-Data Only)], HEO (highly-elliptical orbit satellite system) and DSRC (dedicated short-range communication system).

INTRODUCTION

ONE aim of the tide of IT that is engulfing the automobile, in addition to improving the safety and comfort of automobile driving as a means of transportation, is to make the automobile an extension of office space through the creation of seamless network services. What is needed to realize that aim is a mobile network service in which the automobile serves as a mobile terminal (see Fig. 1).

For such broadband communication services, Japanese communication companies have standardized the "W-CDMA" and "cdma 2000 1x" third-generation cell phone services, and the beginning of data communication services with "cdma 2000 1xEV-DO" (referred to as 1xEV-DO in the following) is planned. Data communication at up to 2.4 Mbit/s is possible, and it is expected to serve as mobile access to the Internet.

In a project that involves cooperation between the public and private sector, high-quality content distribution services via a new satellite system (HEO: highly-elliptical orbit satellite system) are being studied. Under government leadership, basic preliminary studies are already under way, while, on the other hand, the solidification of business concepts and technological development are in progress under private-sector leadership.

One service that employs the DSRC (dedicated short-range communication system), the ETC (electronic toll collection), has already been made available as a commercial product, and the AHS (advanced cruise-assist highway systems), a project whose objective is to implement practical support for safe driving, is proceeding under leadership by the Ministry of Land, Infrastructure and Transport Government of Japan in conjunction with the private sector. The project began with research on fundamental technology in 1996, and currently experiments on actual highways, primarily expressways, are in progress. Deployment of this system throughout Japan in stages from 2003 is planned. Furthermore, technological development and commercialization are being studied in a national project with the objective of development into private sector services.

Here, a wireless communication platform for ITS (intelligent transport systems) is described.

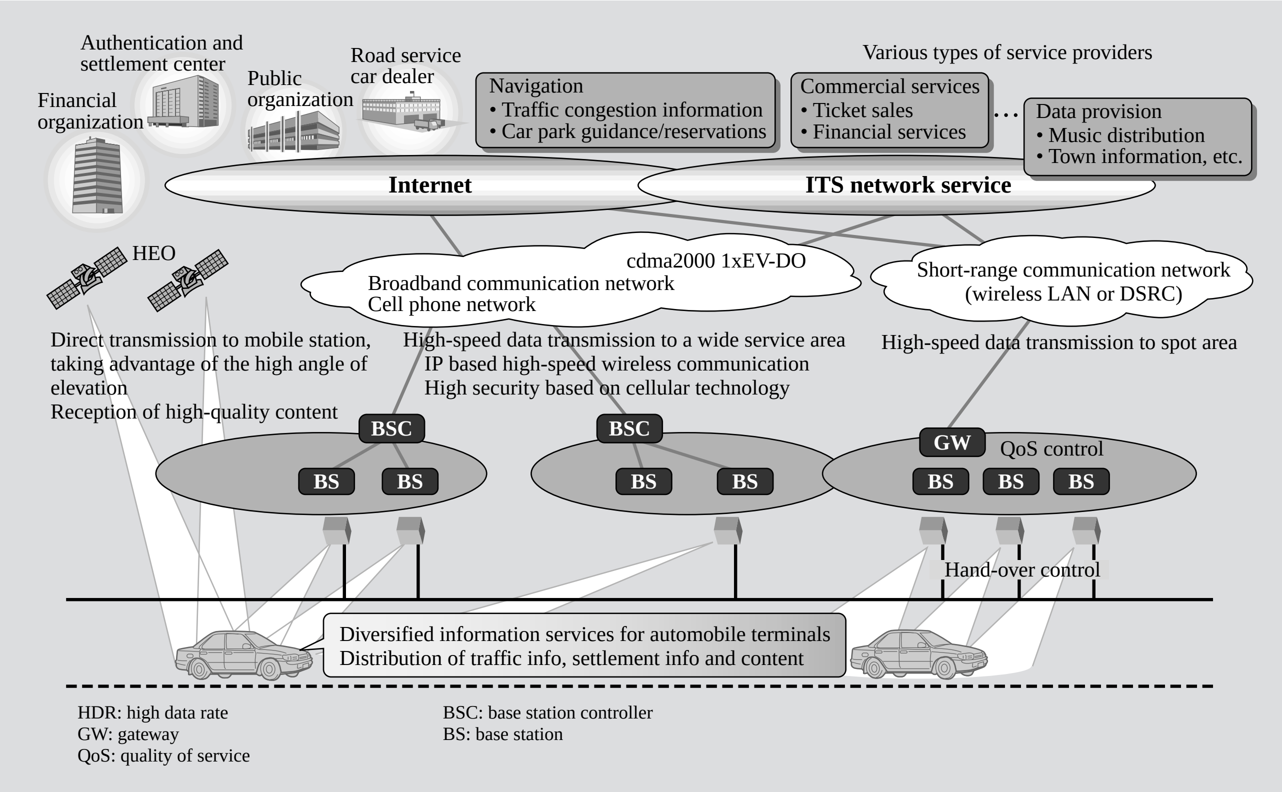


Fig. 1—ITS Wireless Communication System for Providing Seamless Network Services.
By making network services more global and more seamless, the automobile is becoming a data terminal through connection to a cell phone. By making use of the complementary merits of the various wireless infrastructures, provision of information services to automobile will advance.

THE 1xEV-DO HIGH-SPEED PACKET WIRELESS SYSTEM

Market Needs and 1xEV-DO

The proliferation of the Internet and the increasing bandwidth of access to it have given rise to various kinds of applications, including e-commerce, Internet banking, playback of streaming audio and video, and the distribution of music and video files. There is a demand from users for the ability to enjoy these applications anytime, anywhere. To meet that need, wireless access lines are essential, and at the same time, high speed, wide service area, and services for vehicles in motion are necessary.

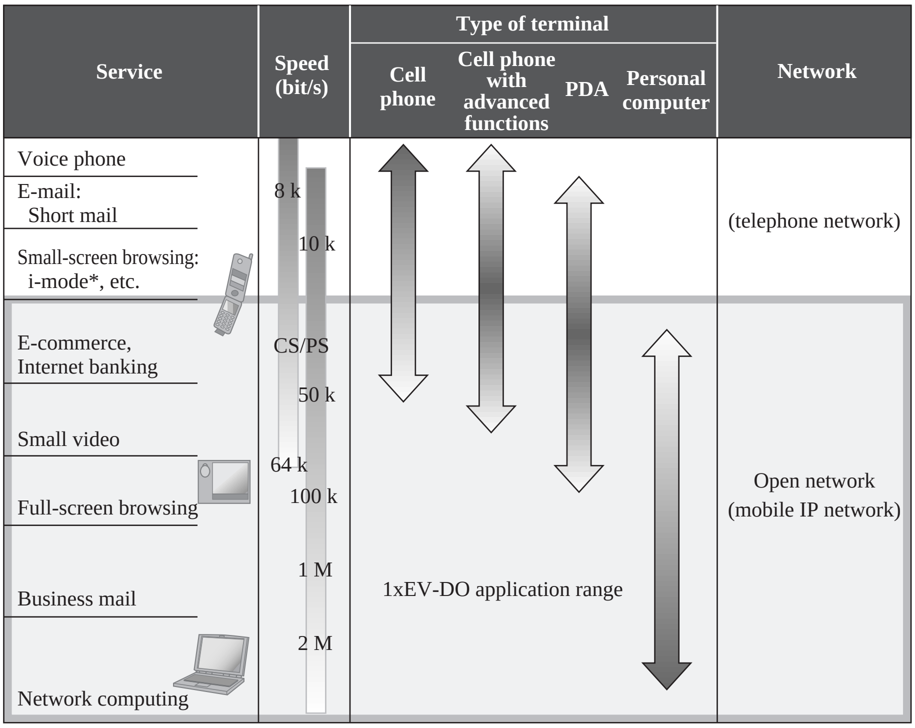
1xEV-DO (1xEvolution-Data Only) is a cell phone system that provides a high-speed mobile Internet environment using a bandwidth of 1.25 MHz. It achieves a maximum down-link data transfer speed of 2.4 Mbit/s, the broad service area that is characteristic of cell phones, and a hand-off function for when the terminal moves from cell to cell (see Fig. 2).

Because this system permits wireless data communication with large-capacity, high-speed and low cost, it promises to realize a wide range of broadband services in a mobile environment, such as cableless high-speed Internet access from personal computers whether indoors or outdoors, reception of music distribution services by PDA (personal digital assistant), downloading of the most up-to-date maps by car navigation equipment, etc.

1xEV-DO and its technical features

1xEV-DO is a high-speed packet wireless system that is based on a 1.2288-Mchip/s chip diffusion rate CDMA (cdmaOne*) system and was developed by QUALCOMM Incorporated of the US as the next-generation wireless packet communication technology for mobile communication. In 1xEV-DO, the terminal (AT: access terminal) sends a transfer speed request (DRC: data rate control) to the base station (AP: access point) according to the incoming pilot C/I (carrier-to-interference) ratio. The AP selects a combination of

*cdmaOne is a registered trademark of the CDG (CDMA Development Group).



CS: circuit switch
PS: packet switch
IP: Internet protocol

* i-mode is a registered trademark of NTT DoCoMo, Inc.

Fig. 2—1xEV-DO Data Communication Network Services.
1xEV-DO is a cell phone system that provides a 1.25-MHz high-speed mobile Internet environment that realizes a maximum downward data transfer rate of 2.4 Mbit/s.

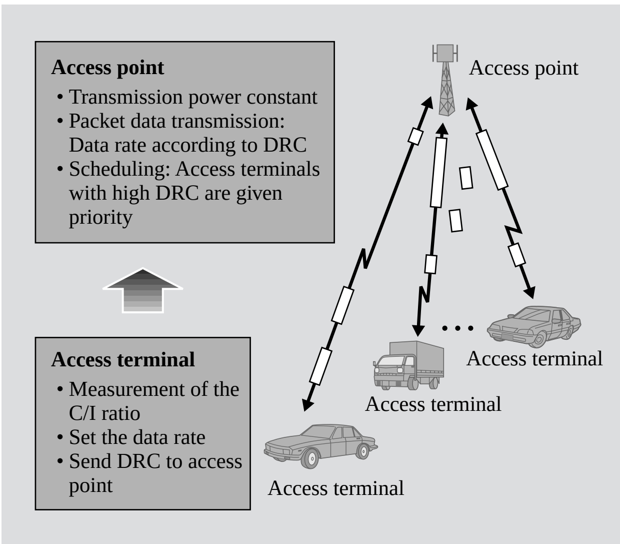


Fig. 3—Features of the 1xEV-DO System.
The data transfer rate setting algorithm, a special feature of this system, is intended to greatly increase throughput.

dispersion rate and modulation scheme (QPSK, 8 PSK, 16 QAM) according to the DRC, and sets the transfer speed. The transmission order of the signals that are encoded and dispersed to the various AT is determined by a scheduling algorithm. One time slot is then allocated to each AT and the signals are transmitted. Furthermore, the aim is for optimization of data communication and a great increase in throughput by application of a strong error correction code (Turbo code) (see Fig. 3).

Another feature is that the cost of introduction can be kept low, because existing antennas and facilities can be used for both systems by simply adding the 1xEV-DO system to existing cdmaOne base stations.

Hitachi and 1xEV-DO

Hitachi has been licensing cdmaOne technology from QUALCOMM since 1996, and in January 2001, we concluded the world's first license agreement as a vendor for 1xEV-DO. Since that time, we have proceeded with joint development of the 1xEV-DO system and a control method for achieving high throughput on one hand, and have also independently developed specialized LSI chips and enclosures, cards, software, etc. KDDI CORPORATION has ordered a 1xEV-DO trial system, and various experiments were begun in July 2002 to verify maintenance of quality under simultaneous access by multiple users in central Tokyo, where the radio interference is high because there is a congestion of radio frequencies, etc. (see Fig. 4). On the basis of this kind of technology and abundant expertise, we are leading other companies in the development of base stations for commercial services (see Fig. 5). The special features of the Hitachi base station system are:

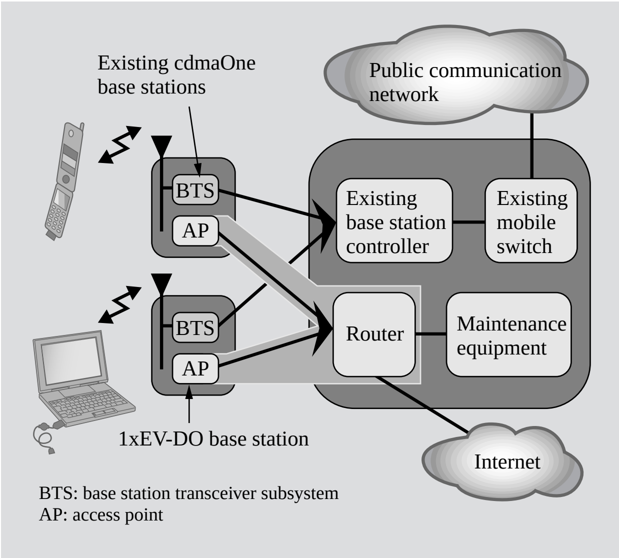


Fig. 4—Basic Configuration of the 1xEV-DO Network.
KDDI has ordered a trial 1xEV-DO system, and verification experiments in the central area of Tokyo began in July 2002.

Fig. 5—Appearance of a 1xEV-DO Base Station.
External appearance of the Hitachi base station. We are leading other companies in the development of base stations for commercial services.

(1) high-speed packet wireless communication with a maximum downward rate of 2.4 Mbit/s and maximum upward rate of 153.6 Mbit/s,
(2) compact design (installed area of 30 cm x 40 cm), assuming co-installation with existing base stations,
(3) built-in radio interference eliminator,
(4) conformance to 3GPP2 (third generation partnership project 2) international specifications, and
(5) the ability of using both built-in BSC (base station controller)(decentralized configuration) and external BSC (centralized configuration).

HEO: HIGHLY-ELLIPTICAL ORBIT SATELLITE SYSTEM

System Overview and Features

Hitachi has taken on the challenge of developing a highly-elliptical orbit satellite system for high-quality communication and broadcasting for mobile stations and services that use that system[1]. This system, unlike conventional stationary satellite systems, has three satellites that have elliptical orbits in different orbital planes, each with the earth at one focus of the elliptical orbit. By switching among those three satellites every eight hours, communication and broadcast services can be provided with the satellite always near the zenith. Accordingly, the probability of receiving the radio waves directly from the satellite is high, making it possible to realize "anytime, anywhere" service uniformly throughout the country, even in urban areas or in the mountains.

Hitachi is developing various services that make use of those characteristics for mobile stations. Examples include audio-video media distribution such as MPEG-4 (Moving Picture Experts Group 4) and AAC (advanced audio coding) data[2], and information distribution, such as news reports, traffic information and local area information[3], and mobile commerce, such as coupon distribution or restaurant reservations.

High-quality Content Distribution Services

Reducing radio wave cut-off is an important issue in the consideration of high-quality services for mobile terminals. In a satellite system that employs highly-elliptical orbit satellites, as described above, the radio waves are received from a satellite that is always near the zenith, so there is little blocking by buildings or other such obstacles. However, reception becomes unstable around the time that satellites switch operation. Furthermore, depending on the frequency that is used, radio reception near the boundary of the satellite beam (which corresponds to the service area covered by a cell phone base station) can also be unstable and radio wave cut-off can occur (see Fig. 6).

Of the various measures that can be considered for dealing with momentary cut-off of the incoming signal, Hitachi has developed a method of reducing content cut-off by restoring lost data. That method reduces radio signal cut-off by multiplexing time-shifted restoration data with the content data of the program. This method was evaluated in mobile station experiments that were conducted under the same radio conditions. An example of tests with mobile stations

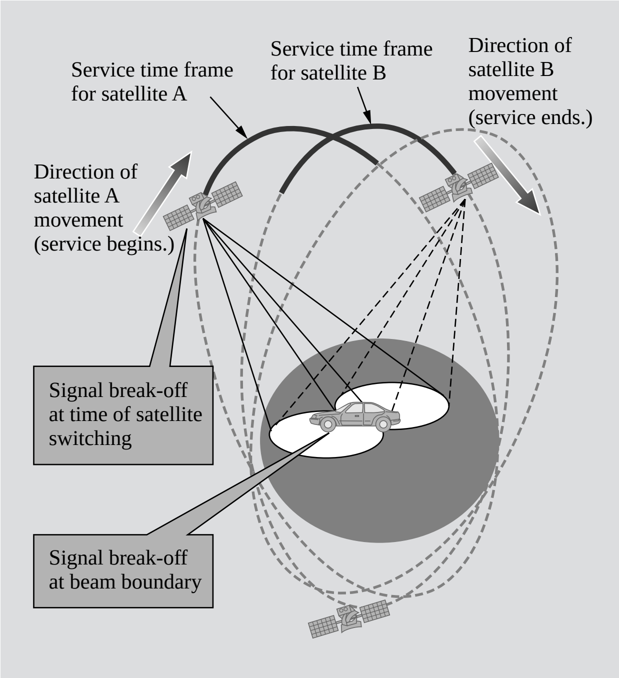


Fig. 6—Cases in Which Reception from the Satellite Is Poor.
In addition to the satellite switching times, which occur every 8 hours, the radio waves from the satellite may deteriorate in quality at the boundary of the satellite beam (which corresponds to the area covered by a cell phone base station), causing a cut-off in the transmitted content.

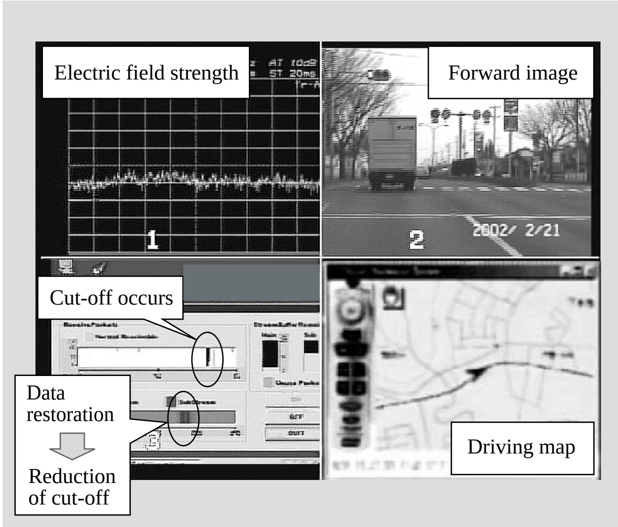


Fig. 7—Example of Mobile Station Movement Experiment.
This is an example of mobile station experiments that take into consideration the same radio wave conditions as when highly-elliptical orbit satellites are used. The electric field strength during movement of the mobile station decreases (upper left), and even if signal cut-off occurs (lower left), the cut-off in sound is reduced by using the multiplexed restoration data.

in motion is shown in Fig. 7. As seen in the lower left of that figure, even though a cut-off of a few seconds occurs during mobile station movement, interruptions in the sound are reduced by using the multiplexed restoration data. We believe this kind of measure against cut-off is essential for mobile services.

DSRC

Overview of DSRC

A DSRC system allows communication between wireless equipment installed in or by the road (base stations) and in-vehicle devices (mobile stations). In Japan, this system was first studied for automated toll collecting and was standardized in November 1997 by the Association of Radio Industries and Businesses (ARIB) as the specification ARIB STD-T55, "Automated Toll Collection System for Toll Roads." The DSRC system features a relatively short communication range (from a few meters to several tens of meters) and a high data transfer speed, so development of applications for providing pinpoint information for parking, drive-through services, cruise control, etc. is expected. For that reason, we consulted with the Technology Council of the former Ministry of Posts and Telecommunications in January 2000 with the objective of setting new DSRC technical conditions that would make it possible to cope with multiple applications. We also made a request for approval of DSRC as a general-use system in October of the same year.

The request was accepted and ARIB STD-T55 was revised. In September 2001, the ARIB STD-T75 "DSRC system" communication specification established the general-purpose use of the DSRC system.

Concerning ETC, the installation of about 900 gates in 2002 was completed, and dissolution of traffic congestion and user convenience from cashless payment are expected to result.

The AHS promoted by the Ministry of Land, Infrastructure and Transport is intended to support safe vehicle operation by using DSRC to distribute road information.

Also, verification experiments for a "smart gateway" are in progress. The smart gateway is centered on a communication and broadcasting mechanism in which DSRC connects vehicles and roadside equipment to provide driving assistance information such as accident reports and various kinds of Internet services for the automobile.

On the other hand, there is also high expectation for business uses for DSRC by the private sector, such as electronic settlement for gas stations and drive-through services, the distribution of music and other such content, etc.

Hitachi and DSRC

(1) AHS

The AHS is a driving support system that provides real-time information to the driver and assists in the operation of the vehicle through cooperation between the highway and the automobile by means of wireless communication. AHS services include provision of information, warnings, and operational support. Those services are planned to begin in stages. Research and development is under way with the aim of making seven specific user services practical, including collision prevention assistance.

In October 2000, the Smart Cruise 21 AHS verification experiments were conducted on the test courses of the National Institute of Land and Infrastructure Management of the Ministry of Land, Infrastructure and Transport (see Fig. 8), with 2,400 participants that included about 200 persons from 18 countries other than Japan. To construct a communication environment for those experiments, Hitachi set up 10 base stations. Later, in December 2001, five base stations that conform to the ARIB STD-T75 wireless specifications for DSRC were set up, and communication experiments using them are currently in progress (see Fig. 9).

The installation of wireless base stations along actual roadways was completed in March 2003. This is for verification experiments under different traffic and natural environments.

In future work, we will prepare systems and standards and, building on the results of the verification experiments, we are aiming for pioneering introduction of the system in 2003. After that, the system is to be expanded throughout the country.

(2) The "Smart Gateway"

Collaborative research and development by six private corporations began in July 2001, focusing on a communication and broadcasting mechanism. The development of an experimental system was completed in March 2002. Verification experiments were carried out at the Oyama test course, and public verification experiments were conducted at the beginning of 2003. Hitachi is in charge of the research and development of the roadside system for those experiments. The technology being developed is explained in the next section.

Hitachi and Smart Gateway

The configuration of a smart gateway system is illustrated in Fig. 10. This system provides services such as accident information and other such driving

Fig. 8—AHS Verification Experiments.
The "Smart Cruise 21" AHS verification experiments were conducted at the test courses of the National Institute of Land and Infrastructure Management of the Ministry of Land, Infrastructure and Transport.

Fig. 9—Interior of the DSRC Wireless Base Station.
Wireless base stations that conform to the DSRC wireless specifications (ARIB STD-T75), have been set up and communication experiments are being conducted.

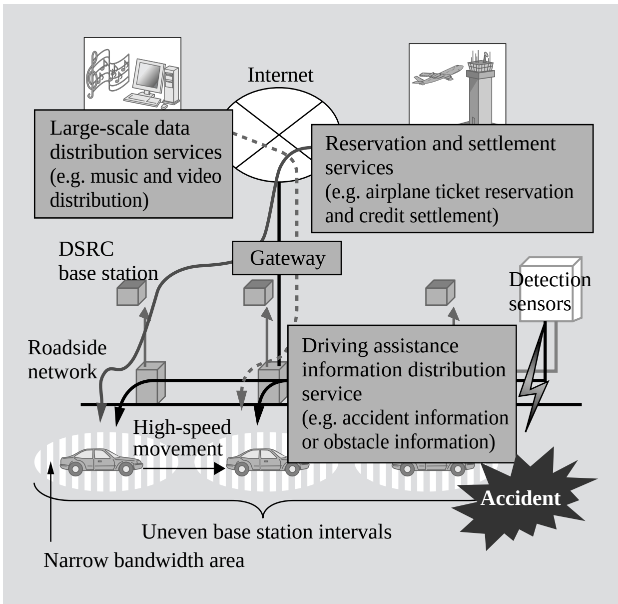


Fig. 10—Roadside System Configuration.
The roadside system consists of DSRC base stations, a roadside network that interconnects them, and a gateway that connects the roadside network to the Internet.

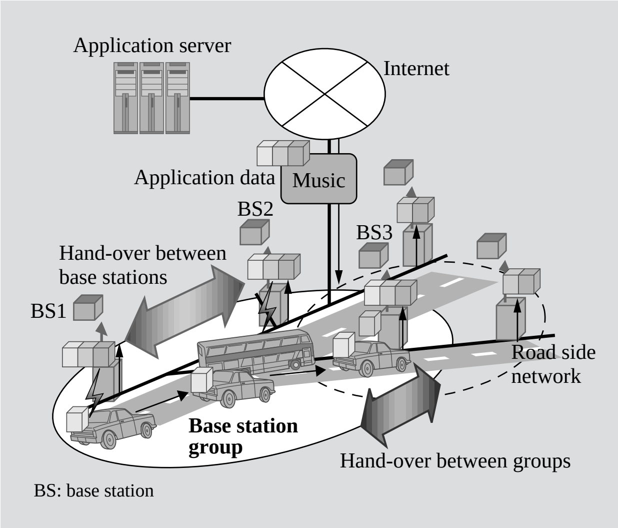


Fig. 11—Overview of Group Hand-over Technology.
Data for transmission and control information are shared in advance by groups of base stations that are formed dynamically on the basis of location information. Each base station transmits data to the target vehicle.

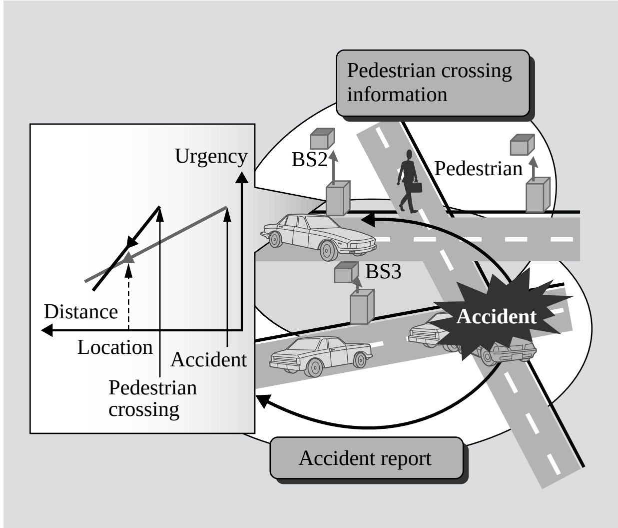


Fig. 12—Overview of High-reliability QoS Technology.
The priority of the data that is to be sent to the mobile station is determined dynamically on the basis of the urgency of the information, which is determined from the attributes of the information, the source of the information and the location of the receiver.

assistance information for vehicles that are traveling at high speed and the distribution of music and video data, reservation and payment for airplane tickets, etc. over the Internet with the objectives of safety and convenience.

The roadside system consists of a roadside network of interconnected DSRC base stations and a gateway that connects the roadside network to the Internet. Hitachi has developed “group hand-over technology” that allows continuous communication even while moving at speeds of up to 180 km/h by using multiple DSRC based on an autonomous, decentralized architecture that we developed for systems that require high reliability and responsiveness, such as railroad control. We have also developed high-reliability QoS (quality of service) technology for the priority distribution of driving assistance information that has a high degree of urgency.

(1) Group hand-over technology

An overview of the group hand-over technology is shown in Fig. 11. Because multimedia content involves large quantities of data, it is assumed to be impossible for a single base station to transmit all of the data to be transmitted to vehicles that are moving at high speed through the small communication area of a DSRC. That makes it necessary to divide the data up among multiple base stations for sequential transmission. With this technology, the base stations needed for the transmission are managed as a group, the data transmitted by this group and management data are shared by those base stations before the transmission starts. Each base station employs the high-speed hand-over technology, which immediately begins data transmission when the target vehicle is verified. If transmission by one group is not completed because of shadowing by a large vehicle or other such reason, a new group is created to continue with the transmission. In other words, there is hand-off between groups.

(2) High-reliability QoS technology

Driving assistance information includes accident information, information about vehicles entering an intersection, pedestrian crossing information, etc. Each of these kinds of information can be considered to have an effective area. Accident information, for example, is useful in a relatively wide area, while pedestrian crosswalk information is effective in a very small area. Thus, the urgency of the information varies according to the type of information, the place where the information originates and the location of the vehicle.

This QoS technology for ITS dynamically determines the priority of data at the time of transmission from the base station to the mobile station on the basis of the urgency of the information as determined from the type of information, its source, and the location of the receiving vehicle (see Fig. 12).

Highly urgent driving assistance information is transmitted to the driver with priority.

This research was done as a part of TAO (Telecommunications Advancement Organization of Japan)'s "Research and Development of Smart Gateway Technology for the Implementation of Driving Assistance Systems", which was commissioned for 2000 to 2001.

CONCLUSIONS

We have described trends in various communication platforms for ITS services, including broadband services (cdma 2000 1xEV-DO), HEO (highly-elliptical orbit satellite system) and DSRC (dedicated short-range communication system), and how Hitachi is involved in each of those technologies.

We believe that these communication platforms are mutually complementary, and that they will continue to spread in use in such a way that advantage can be made of their respective special features. Also, from the viewpoint of using services (applications), further development toward seamless network services is needed to allow users to use the platforms described above selectively or to allow their use without awareness by the user. Hitachi will continue with active development of services for various fields of use.

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