Outline of Safety Support Systems for Intersections and NEC's Activity

ITAGAKI Suguru, NODA Yuichi, TANAKA Toshiaki

Abstract

"Vehicle-Infrastructure Cooperation Systems" are systems that aim to improve the safety and convenience of road traffic by communication and sensing between vehicles and roadside infrastructures.

At the present time the vehicle-infrastructure cooperation systems are being developed around the world and in this paper we focus on one of the applications that deal with intersection safety. We also introduce three actual projects related to these systems from around the world. These are "Vehicle Infrastructure Integration (VII)" in the U.S., "PReVENT" in Europe and "Driving Safety Support Systems (DSSS)" in Japan. Finally, we describe NEC's activity in DSSS.

Keywords

Vehicle-Infrastructure Cooperation Systems, DSSS, VII, CICAS, PReVENT, INTERSAFE

1. Introduction

To reduce the number of fatalities caused by traffic accidents is an important step in dealing with a difficult social problem. In Japan, the government has set a goal of achieving less than 5,000 fatalities by 2012. In order to achieve this goal, the government expects that the safety systems between vehicles and infrastructures could be an effective measure.

The U.S. and Europe are each facing the same issues that face us in Japan, which is that the number of fatalities is more than 40,000 for each region and they have also been conducting countermeasures that are aimed at reducing such seriously high levels of fatalities. For example, the U.S. Department of Transportation (USDOT) has been conducting a project called "Vehicle Infrastructure Integration (VII)", and in Europe, the European Union (EU) has been conducting a project called "PReVENT".

"Vehicle-Infrastructure cooperation systems" are systems that improve the safety and convenience of road traffic users by communication and sensing between vehicles and roadside infrastructures. Notable projects related to these systems in Japan are the "Driving Safety Support Systems (DSSS)", which is conducted by the National Police Agency, and the "Advanced Cruise-assist Highway Systems (AHS)", which is conducted by the Ministry of Land, Infrastructure and Transport. DSSS are mainly deployed at intersections, while AHS are mainly deployed on highways and on single-track roads.

In this paper, we focus in particular on intersection safety and we introduce an overview of VII, PReVENT and DSSS as actual case studies of intersection focused systems.

We also describe our activities related to the application of our products by DSSS, such as infrared cameras for sensing and Dedicated Short Range Communications (DSRC) roadside units for wireless communication between vehicles and infrastructures.

2. Outline of the VII Project in the U.S.

The VII project is being conducted by the DOT, which is an organization similar to the Ministry of Land, Infrastructure and Transport in Japan. VII has been tackling many subjects regarding the vehicle-infrastructure cooperation systems. **Fig. 1** schematically depicts the VII system.

The framework of the VII system consists of many organizations, such as USDOT, State DOTs, affiliated organizations, private companies and so on. VII is concerned with multidisciplinary subjects such as technology, policy and business. Currently, an experiment called "Proof of Concept (POC)" is being conducted, which is aimed at the validation of the technology used by VII. POC is being conducted in suitable experimental environments in Michigan, Virginia and California. After POC, another experiment called "Field Operational Test (FOT)" will be carried out at the actual roadsides in order to validate applications, and these activities aim at conclusion by 2009.

The core technology of the VII system is DSRC, which is

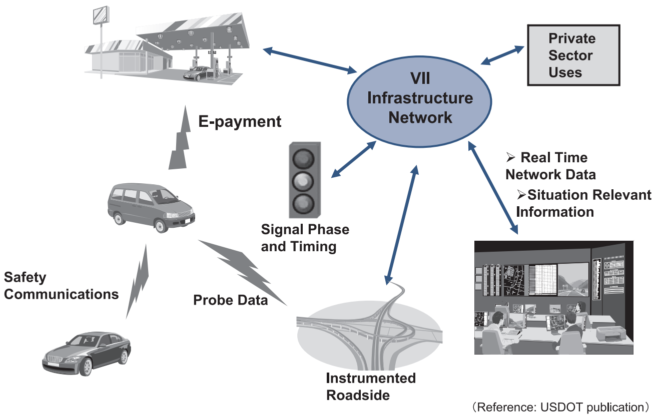


Fig. 1 VII system image.

Table 1 Specifications of the 5.9GHz DSRC in U.S.

	DSRC (U.S.)	Reference: DSRC (Japan)
Spectrum	5.850MHz - 5.925MHz	5.775MHz - 5.845MHz
Channel	10MHz × 7 (Control: 1, Service: 6)	7 (ETC: 2, TBD: 5)
Maximum vehicle's speed	Maximum 120 mile/h (Approximately 190 km/h)	No definition (depends on services)
Communication area	Maximum 300m (1,000m for special purpose vehicle)	No definition (Maximum about 200m)
System delay	Less than 50msec	No definition
Throughput	6Mbit/s - 27Mbit/s	4Mbit/s (QPSK)
Throughput per vehicle	Maximum 20kB/s	Maximum 500kB/s
Maximum output	30W (RSE), 2W (OBE)	0.3W (RSE), 0.01W (OBE)

(Reference: USDOT/ARIB Publication)

utilized not only for vehicles to infrastructure communication, but vehicle to vehicle communication is also covered (**Table 1**).

Among the many applications of VII, in this paper, we introduce the safety applications for intersections called "Cooperative Intersection Collision Avoidance System (CICAS)". Originally CICAS was an independent project. However, due to a policy change by USDOT the CICAS project is now one of the collaborative projects of VII. The following is an overview of the CICAS applications.

1) CICAS-V (Violation): Warning on a sign board or an on-board terminal in vehicles on coming to an intersection, when drivers likely to commit violations, especially running through the intersection in contravention of a red light or a stop line.

2) CICAS-SLTA (Signalized Left Turn Assistance): Giving information on a sign board or an on-board terminal in vehicles to advise if drivers can make a left turn safely or not. Information can be provided from sensors which sense on-coming vehicles from the opposite direction.

3) CICAS-TSA (Traffic Signal Adaptation): Changing the timing of signals when a traffic accident is likely to occur at an intersection. This application works for example, if a driver tries to run through an intersection even if a signal is at amber.

4) CICAS-SSA (Stop Sign Assist): Giving information on a sign board or an on-board terminal in vehicles, to advise drivers coming from a subordinate road to stop at a stop line before making a turn into a main road.

According to the USDOT announcement, if they make a decision to deploy the VII system, they are going to deploy approximately 200,000 to 250,000 DSRC roadside units across the country (80,000 to 125,000 at the initial deployment).

3. Outline of the PReVENT Project in Europe

PReVENT is the project that the EU has been conducting for traffic safety. PReVENT was initiated in 2003 and will be completed in 2007.

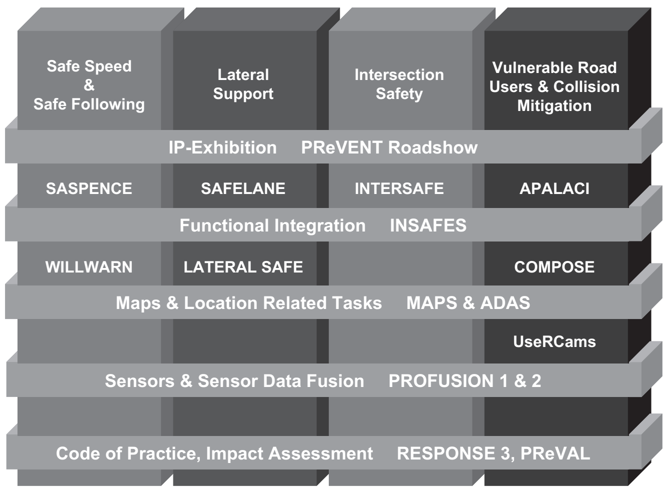
In PReVENT, a reduction of traffic accidents of 50% by 2010 has been set as the target. In order to achieve this goal efforts are being made to accumulate knowledge, reinforce collaborations among the participant countries and encourage economic growth in the EU.

PReVENT consists of several subprojects, that deal with both technology and policy aspects as shown in **Fig. 2** .

With regard to intersection safety, the subproject called "INTERSAFE" has been tackling this issue.

In the case of INTERSAFE, two technical validations have been conducted. One is performing experiments on the element technologies and the other is simulation performed by a driving simulator. With regard to the element technologies, two radar sensors and one visible camera are mounted on a vehicle in the experiments. By using this equipment, the vehicle is enabled to sense other vehicles, pedestrians, facilities at the roadside and so on. Another challenge was posed by the need to assimilate geographical information, by which the vehicle is able to acquire better positional accuracy. Both of these element technologies were combined and evaluated together. Various traffic situations were simulated by the driving simulator, which had no risk of actual incidents and the needs of the element technologies were evaluated.

Applications of INTERSAFE are developed by assuming



Reference: PReVENT publication

Fig. 2 Functions and subprojects of PReVENT.

hazardous situations that are chosen from the data resulting from the past record of traffic accidents at intersections. These provide information about an intersection to oncoming drivers, such as signal color or a stop line. They also indicate a recommendation of an appropriate speed to be observed by an oncoming driver.

Currently, the accepted wireless communication method between vehicles and infrastructures is IEEE802.11p, which is a wireless standard specification for ITS that is now under preparation for publication. Results of this project were exhibited in France as one of the demonstrations of PReVENT in September 2007. In the future these research activities will be succeeded by other projects that were initiated in 2006. Details of these projects are as follows.

(1) SAFESPOT

Using wireless communication between vehicles and infrastructures as well as among vehicles, this project aims to develop safety systems called "Safety Margin Assistant" by focusing especially on maintaining a safe distance between vehicles. An intersection collision avoidance system is also one of the targets.

(2) COOPERS (Co-operative Systems for Intelligent Road Safety)

In this project, route guidance using wireless communication between vehicles and infrastructures and traffic management using probe information are the main objectives.

(3) CVIS (Cooperative Vehicle-Infrastructure Systems)

Technical issues such as the standardization of the wireless technology between vehicles and infrastructures and a method for calculating the position of a vehicle are the main objectives of this project.

4. Outline of DSSS in Japan

DSSS is one of the categories of the vehicle-infrastructure cooperation systems that aims to reduce careless driving accidents by providing neighborhood traffic information obtained from roadside infrastructures.

Statistics of domestic traffic accidents show that most accidents were categorized by rear-end collision or head-on collision encounters; both of these were mainly caused by driver mistakes, such as a lack of concentration. The Universal Traffic Management Society of Japan (UTMS,) designed nineteen DSSS subsystems and three service levels, corresponding to accident categories and the degree of interference to drivers, as shown respectively in **Table 2** below. The table defines the various combinations of these two factors.

Table 2 DSSS subsystems.

Service type	Subsystem	Service level
1 Rear-end collision	1-1 Rear-end collision information provision system	Unconditional
	1-2 Rear-end collision information provision system (Right turn waiting vehicle)	Unconditional
	1-3 Standing/slow speed vehicle information provision system	**Conditional/Override**
2 Head-on collision encounter	2-1 Head-on collision information provision system (Preference road → non-preference road)	Conditional/Override
	2-2 Head-on collision information provision system (Non-preference road → preference road)	Conditional
	2-3 Blind spot image provision system	Unconditional
3 Right-turn collision	**3-1 Right-turn collision avoidance information provision system**	**Unconditional**
	3-2 Right-turn collision avoidance image provision system	Unconditional
	3-3 Two-wheeled vehicle information provision system	Unconditional
4 Left-turn accident	4-1 Left-turn accident information provision system	Unconditional
	4-2 Pedestrian crossing information provision system	Unconditional
5 Head-on collision	5-1 Opposite lane vehicle information provision system	Unconditional
6 Merging-assist	6-1 Merging-assistance information provision system	Unconditional
7 Regulatory information	7-1 Speed information provision system	Conditional
	7-2 Stop sign information provision system	Unconditional/Conditional
	7-3 Danger zone avoidance control system	Conditional/Override
8 Signal information	**8-1 Signal information provision system**	**Conditional**
	8-2 Signal information provision system	Conditional/Override
9 Accident information	9-1 High-accident information provision system	Unconditional

(Reference: http://www.utms.or.jp/english/system/dsss.html)

- **Level I: Unconditional Information**
Provide safety information unconditionally
- **Level II: Conditional Information**
Provide safety information conditionally depending on vehicle status
- **Level III: Override**
Provide safety information and forced control conditionally depending on vehicle status

Currently, several working groups corresponding to each of the prefectures of Tochigi, Kanagawa, Aichi and Hiroshima are operated under the UTMS, where the National Police Agency, each Prefectural Police Department and related manufactures are cooperatively conducting research and actual verification experiments. In addition, cooperative experiments between DSSS and ASV (Advanced Safety Vehicle), which is mainly driven by automotive manufactures, are now being considered for the coming large scale ITS verification experiments that are scheduled for 2008.

5. NEC's Activity for DSSS

NEC has been proposing and conducting experiments for its driving safety support system, in which its successful infrared camera (**Fig. 3**) and DSRC techniques are utilized. NEC especially pays its attention to three DSSS subsystems of 1-3, 3-1 and 8-1 in Table 2 as shown below, and each of them is now under preparation for actual verification experiments in Hiroshima (1-3) and Aichi (3-1, 8-1).

- 1-3 Standing/slow speed vehicle information provision system
- 3-1 Right-turn collision avoidance information provision system
- 8-1 Signal information provision system

Fig. 3 Infrared camera (Hybrid of visible and infrared).

5.1 Aichi DSSS Working Group

NEC has been acquiring the image data of actual traffic flows since 2006 by placing its infrared cameras at a major intersection in Toyota-City, a location where many traffic accidents have been recorded. The data recorded in various meteorological conditions has been utilized to improve the vehicle detection algorithm, which has been optimized for use with far-infrared light.

In 2007, NEC placed two reference cameras such that detailed measurements of both vehicle positions and speeds could be performed. Also, NEC has positioned DSRC roadside units to evaluate the propagation characteristics of radio waves both in and adjacent to an intersection. Furthermore, in 2008 NEC will integrate these infrared camera and DSRC roadside units in order to verify experiments of both the right-turn collision avoidance information provision system and the signal information provision system.

As described above, NEC is now conducting a thorough examination of both image processing and radio communication techniques and will thus be able to provide a sophisticated driving safety support system for intersections based on this work (**Fig. 4**).

5.2 Hiroshima DSSS Working Group

National highway route 2, the principal road in Hiroshima-City, has a blind curve on a high-level road, where traffic congestion originated by the downstream intersection is frequently observed. As rear-end collisions have frequently been recorded on this curve, NEC is now preparing to implement its standing/slow speed vehicle information provision system in 2008. This will consist of both its infrared camera for

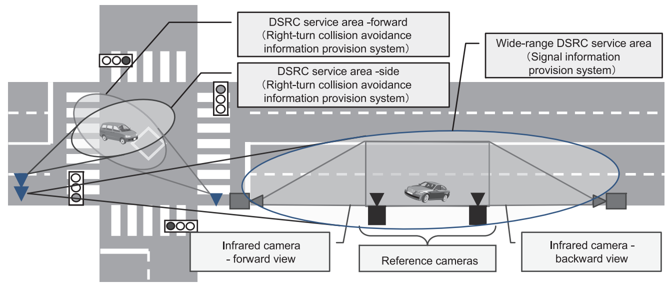


Fig. 4 System outline in Toyota-City.

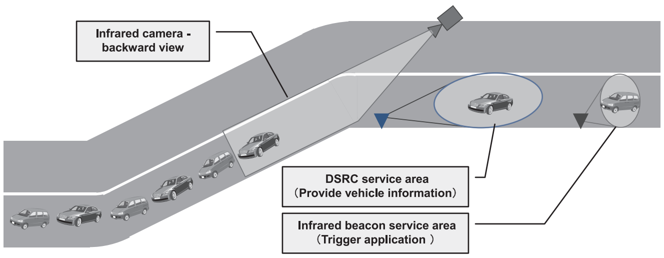


Fig. 5 System outline in Hiroshima-City.

detection and the combined roadside unit of DSRC and infrared beacons for communication. With regard to the Hiroshima DSSS, NEC aims to utilize the anticipated results of both image processing and radio communication techniques from Aichi DSSS and will focus on service-level evaluation, such as driver acceptability. As described above, NEC is going to provide a sophisticated driving safety support system for uninterrupted flow roads based on this knowledge (**Fig. 5**).

6. Conclusions

In this paper we introduce the vehicle-infrastructure cooperation systems that are currently attracting considerable attention in the ITS field and the related trends in U.S., Europe and Japan. NEC's activities with regard to DSSS are also briefly discussed.

NEC is a pioneer in road monitoring systems with its infrared cameras for AHS, having achieved a successful history of support for advanced safe driving systems. By utilizing the benefits of detection performance and equipments/construction costs NEC is able to make a significant contribution to the ITS field by providing sophisticated products.

Finally, NEC expresses its deep gratitude to the National Police Agency, the Universal Traffic Management Society of Japan and other related organizations for their kind guidance and assistance.

References

1) USDOT homepage
http://www.its.dot.gov/vii/
2) PReVENT homepage
http://www.prevent-ip.org/
3) UTMS Society homepage
http://www.utms.or.jp/
4) UTMS Society, DSSS working group report 2006

Authors' Profiles

ITAGAKI Suguru
ITS Business Promotion Center,
Broadcast and Control Systems Operations Unit,
NEC Corporation
Member of Universal Traffic Management Society of Japan

NODA Yuichi
Basis Development Department,
Transportation and Public Network Division,
Broadcast and Control Systems Operations Unit,
NEC Corporation
Member of Universal Traffic Management Society of Japan

TANAKA Toshiaki
Basis Development Department,
Transportation and Public Network Division,
Broadcast and Control Systems Operations Unit,
NEC Corporation
Member of Universal Traffic Management Society of Japan,
Member of Marine Acoustics Society of Japan