Cooperative Inter-Infrastructure Communication System Using 700 MHz Band

Kengo KISHIMOTO*, Masaya YAMADA and Masayuki JINNO

In Japan, as part of the Intelligent Transport System (ITS), research, development and deployment of the Universal Traffic Management System (UTMS) have been promoted for the purposes of environmental preservation, safety support and traffic congestion reduction. For the application of UTMS, infrastructure-to-vehicle (I2V/V2I) and inter-infrastructure (I2I) communications are vitally important. As one of the possible solutions to these needs, we are studying the use of the 700 MHz radio band. This paper reports on our research and development for the practical application of UTMS using the 700 MHz band for I2V/V2I, I2I and vehicle-to-vehicle (V2V) communications. We have focused particularly on I2I communications for enhanced traffic signal control.

Keywords: I2I communication, cooperative system, wireless ITS, 700 MHz band, signal control

1. Introduction

In Japan, research and development for practical application of the Universal Traffic Management System (UTMS) are being carried out mainly by the UTMS Society of Japan aiming at environmental preservation, traffic safety and congestion reduction. Currently, diverse applications have become available of the system, and traffic control technologies have been increasingly sophisticated. Communications media are also making remarkable progress particularly for wireless broadband technology such as mobile phones and wireless LANs. The linkage of these technologies is essential for the advancement of the Intelligent Transport System (ITS) in the future. For instance, use of radio wave media allowing geographically widespread and seamless infrastructure-to-vehicle/vehicle-to-infrastructure (I2V/V2I) communications is being considered as a means of enhancing the Driving Safety Support Systems (DSSS) which reduce accidents by providing safe driving supporting information to drivers via infrared beacons.

Enhanced traffic control requires communications between roadside terminal units. However, in recent years, the installation of cables for transmitting information between terminals has become a problem in terms of landscape and maintenance, resulting in the difficulty of wired communication. For this reason, and for the further effective use of radio wave and installed facilities, we are studying the possibility of wireless communication between the roadside terminal units, i.e., infrastructure-to-infrastructure (I2I) communications by using wireless roadside units (hereinafter referred to as "RSU") for I2V/V2I communications installed at intersections.

This paper illustrates I2V/V2I, I2I, and vehicle-to vehicle (V2V) communications systems that use wireless 700 MHz ITS to enhance traffic signal control, and introduces the requirements of RSUs. Also, the paper presents experimental plans and discusses tasks to be reviewed in the future.

2. What Is 700MHz Band Wireless ITS

Recent years have seen remarkable advances in wireless broadband technologies such as mobile phones and wireless LAN, and progressing alongside with them are communication media. The Japanese government announced in December 2011 that 760 MHz band would be allocated for ITS. Later communication standards in compliance with this announcement were established (ARIB STD T-109. See **Fig. 1** and **Table 1**). For ITS, in accordance with these standards, the communication period is divided by time between I2V/V2I and V2V communications with the bandwidth of 10 MHz taken for one channel. RSU transmits the information during the I2V/V2I communications period by the time division multiple access (TDMA)

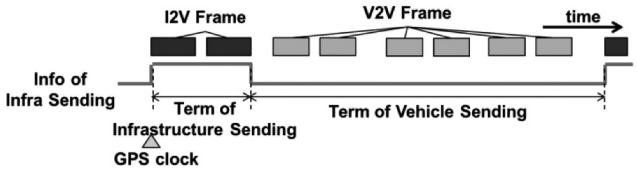

Fig. 1. Media access control of wireless 700 MHz band ITS

Table 1. Specifications of wireless 700 MHz band ITS

Conditions	Specifications
Center frequency	760 MHz (Single frequency)
Occupied bandwidth	9 MHz or lower
Error correction	Convolution FEC R=1/2, 3/4
Modulation method	BPSK OFDM / QPSK OFDM / 16QAM OFDM
Transmission power	10 mW/MHz or lower
Communication method	Broadcast
Media access control	CSMA/CA + TDMA

method[*1] while the on-vehicle unit (hereinafter referred to as "OBU") transmits the information during the V2V communications period by the carrier sense multiple access/collision avoidance (CSMA/CA) method[*2] to share the frequency channels.

Since the choices of media which can be used for ITS are thus increasing, building systems that make effective use of these media will lead to efficient realization of multiple applications.

3. V2V, I2V/V2I, and I2I Communications Systems

From the viewpoint of enhancing cost performance for spreading the equipment and devices, rational construction of systems is desirable. We therefore considered the possibility of having multiple systems share the 700 MHz band wireless ITS and link to each other. **Table 2** shows application examples of the systems and **Fig. 2** illustrates connection between the systems.

Table 2. Application examples of V2V, I2V/V2I, and I2I communications systems

	V2V communications	I2V/V2I communications	I2I communications
Kinds	-Driving Safety Support -Smooth driving	-Driving Safety Support, -Smooth driving	-Enhancement of signal control

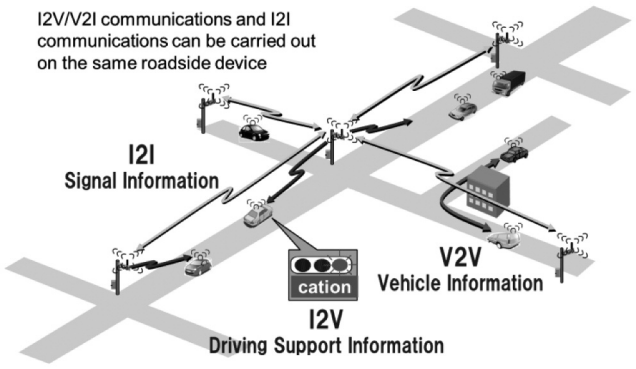

Fig. 2. Illustration of V2V, I2V/V2I, and I2I communications systems

Here, we focused on wireless I2I communications needs that have not been addressed to date. By sharing frequency resources and the RSUs for I2V/V2I communications installed at intersections with I2I communications, radio wave and facilities can be further effectively used. We also studied the possibility of using I2I communications by the methods that would have minimum effects on V2V and I2V/V2I communications. **Figure 3** shows the study flow.

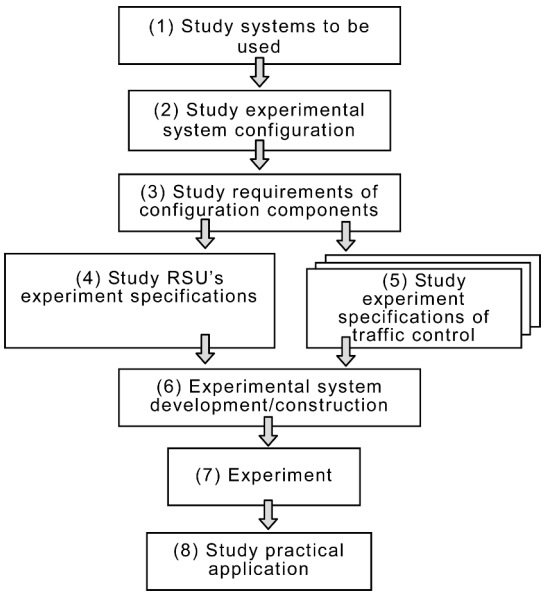

Fig. 3. Workflow

4. Applications Using I2I Communications

First, we selected applications using I2I communications which can enhance traffic control. **Table 3** shows the results.

Table 3. Applications using I2I communications

Type	Application	Outline
Emergency vehicle passage support	FAST	Perform signal control, etc. to give emergency vehicles driving priority.
Traffic flow control	Profile signal control	Predict traffic volume coming into intersection, and control signals to maximum number of vehicles which can pass through that intersection.
Disaster measures	Intelligent intersection	Carry out detour during intensification of terminal lines and when communications channels are cut off in disasters.

Figure 4 illustrates these applications.

We determined to clarify the communications requirements related to these applications and carry out field experiments on public roads to confirm the compatibility of wireless 700 MHz band ITS I2I communications for each application.

First, we set the priority order of the experiments, and decided to carry out demonstration experiments of applying I2I communications to FAST out of the applications given in **Table 3**. FAST is an advanced traffic signal control system designed to give driving priority to emergency vehicles. Information on the approach of an emergency vehicle exchanged in V2V communications is received by the infrastructure which in turn controls traffic signals ahead of the emergency vehicle to prioritize its passage.

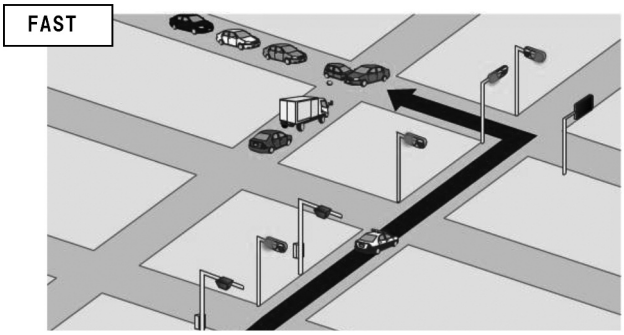

Fig. 4. Illustration of application

We studied the FAST system configuration using wireless 700 MHz band. **Figure 5** shows the system configuration.

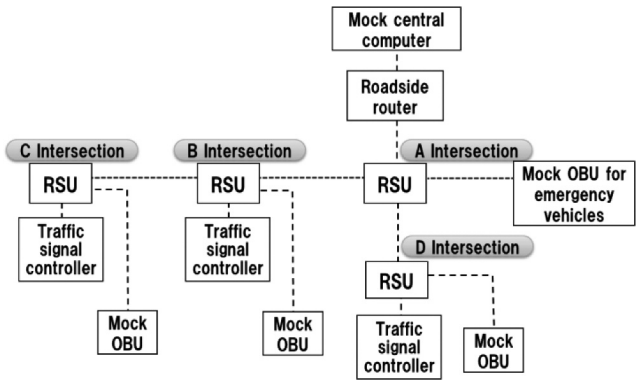

Fig. 5. FAST system configuration

5. Requirements of RSU

Next, we studied and summarized the main requirements for applying I2I communications to FAST such as the required communication method, quality and application functions. **Tables 4 and 5** show the results.

The study has confirmed that the requirements in **Table 4** are not independent of the application and common to the menus using I2I communications.

Table 4. Requirements of wireless communications

Item			Requirements
Communication	Communication method	Destination	Specific RSU
		Relay	Yes
	Communication quality	Packet arrival rate	90% or more (Visibility 300 m)
		Transmission delay allowable time	1895 ms or less
	Communication details	Security measures	Encryption, Authentication

Table 5. Requirements of application functions

Item		Requirements
FAST	Signal control	Communication of signal control application data must be possible between central computer and signal controller
	FAST signal control	Must be able to transmit detection information of emergency vehicle to central computer Must be able to instruct FAST signal control from central computer
	Provision of emergency vehicle approach information	Must be able to transmit approach information of emergency vehicle to OBU

In the demonstration experiments, based on the information from the mock OBU for emergency vehicles, information will be sent to terminal units from the central computer via I2I communications that meet the above requirements to verify that wireless 700 MHz band I2I communications can be applied to the existing FAST system's traffic signal control.

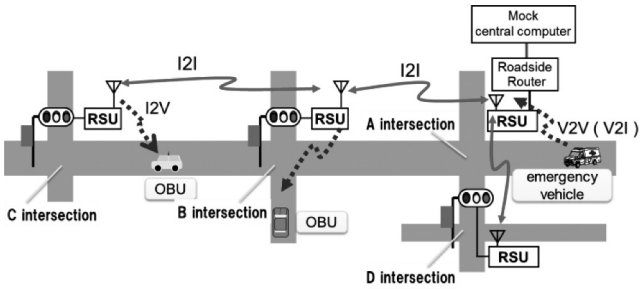

Fig. 6. Illustration of FAST demonstration experiment

Figure 6 illustrates FAST demonstration experiment. First, presence information is sent to the RSUs by V2V communications from the mock OBU for emergency vehicles to verify that emergency vehicle detection information is generated at the RSUs from the V2V communications information, and that the detection information is received by the mock central computer.

It will also be verified that the mock central computer having received the emergency vehicle detection information sends a FAST signal control command to the concerned signal controller to perform FAST signal control at the appropriate traffic lights.

Furthermore, it will also be confirmed that emergency vehicle approach information is sent from the concerned RSU and received by the mock OBU. The information transmission time (minimum/maximum/average value) via I2I communications will also be measured.

6. Experiment Schedule

Figure 7 shows the experiment schedule.

The system will be constructed in January 2014 to start experiments. Experiments on the sharing of frequency channels with I2V/V2I communications will also be conducted in FY2014.

For practical application of the system, our future tasks are to study the security, interoperability, and time-phased distribution of data for the sharing of frequency channels between I2V/V2I and V2V communications with the aim of applying communications standards for V2V and I2V/V2I communications to I2I communications.

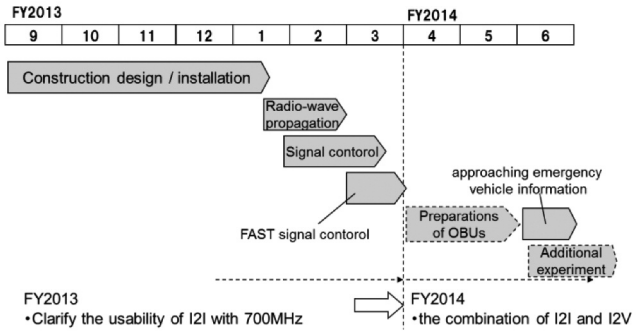

Fig. 7. Experiment schedule

7. Conclusion

This paper illustrated V2V, I2V/V2I, and I2I communications systems that use wireless 700 MHz ITS to enhance traffic signal control, and discussed the requirements of RSUs. Demonstration experiment plans and system configuration were also presented, and our future tasks were clarified.

For the future, we are planning to carry out demonstration experiments to evaluate the communication quality of I2I communications and verify compatibility to applications.

8. Acknowledgements

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Technical Terms

∗1 Time division multiple access (TDMA) method: One frequency channel is divided into several short timeslots and allotted to multiple communications devices to send data.

∗2 Carrier sense multiple access/collision avoidance (CSMA/CA) method: Each communications device confirms that a channel is idle continuously for a certain period of time before sending data.

References

(1) UTMS Society of Japan, "The activity report in 2012" (Jun. 2013)
(2) Association of Radio Industries and Businesses, "ARIB STD T-109" (02.14.2012)
(3) "UTMS Society of Japan" http://www.utms.or.jp/

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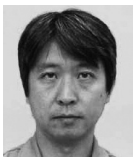

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