Development of pedestrian-to-vehicle communication system prototype for pedestrian safety using both wide-area and direct communication

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Abstract

We propose a prototype pedestrian-to-vehicle communication system which uses a cellular phone and wireless communication to improve the safety of pedestrians. One of the effectual measures against pedestrian-to-vehicle accidents is to make each of pedestrians and drivers find the others and recognize the risk from out of sight and with time to spare for avoidance of accidents. A pedestrian-to-vehicle communication system was developed by using a cellular phone and a car navigation system equipped with GPS and wireless communication function. We focused on intersections as a traffic scene to be covered by the system. After data was exchanged via FOMA in a wide area, information could be exchanged between a pedestrian and a vehicle via WLAN 20m, 100m away from an intersection to different directions in about 20ms. And, the system could give an alarm to pedestrians and cars with collision risk.

1. Introduction

With the widespread of the Internet and information devices, various information systems have been built for supporting social activities. In recent years, with the aim of realizing a safer and more comfortable road traffic environment, ITS has been promoted by making use of the developed information and communications technology [1]. This is because traffic safety measures have been required continuously in Japan for a high incidence of traffic accidents. The road-to-vehicle communication and the inter-vehicle communication that use microwave and millimeter wave are just beginning to be introduced as ITS for safety. Actually, a technological study of wireless communication standard was carried out and the formulation of the communication specification of 5.8GHz band based on DSRC has been advanced. And the research and development of the inter-vehicle millimeter wave communication by cooperation with the in-vehicle radar used as an autonomous accident prevention system has been undertaken [2]. These efforts are certainly effective as measures against car collisions. But, they are not enough to prevent pedestrian accidents. The ratio of pedestrian accidents in Japan is high compared with other advanced countries. Over 30% of road accident fatalities in 2005 are occupied in walking [3]. Under such circumstances pedestrian-to-vehicle communication is needed to get pedestrian information by making an information network of pedestrians, vehicles, and roads.

The principal reasons of pedestrian-to-vehicle accidents are errors of recognition and judgment. Therefore, the effectual measures against accidents are to make each of pedestrians and drivers find the others and recognize the risk correctly. A technique for recognizing pedestrians who can be detected with a camera installed in a vehicle has been put to practical use partly. However, there is not a technique for recognizing each other from out of sight without road infrastructure which limits the applied area.

In Japan cellular phones and car navigation systems are widely used and the number grew to about 99 million and 26 million units, respectively. In addition, GPS locator-equipped cell-phone penetration rate in 2011 is estimated about 90 percent. The aim of this research is to develop the system for contributing to the prevention of pedestrian accidents. We present a prototype system that we developed by using the positional measurement function and the network function of a cellular phone and a car navigation system. The system obtains the location information from each of pedestrians and vehicles, sends the response based on the risk estimation, and makes the target pair exchange each other's information directly in the case of high collision risk. From the analysis results of accident situations, it is certain that pedestrian accidents often occur around intersections at which pedestrians are out of sight of drivers. We focused on intersections as a traffic scene to be covered by the system. To use wireless LAN as a direct

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DOI 10.1109/AINA.2008.126

communication method, the non-line-of-sight propagation property and communication characteristics at intersections were specifically examined. And the system function was verified at intersections.

2. Pedestrian-to-vehicle communication by wireless LAN

Via a cellular phone network the terminals can widely send and receive information through a center server. But, it has at least 400ms of communication delay. It is necessary to introduce P2P communication method which has little delay in conjunction with cellular network communication which covers a wide area but has more delay so as to exchange information between pedestrians and vehicles with enough time and distance to prevent a collision. Wireless LAN (IEEE802.11b) is considered to be one of the best P2P communication methods between pedestrians and vehicles in terms of baud rate, communication range, power consumption, size, cost, and possibility to be installed in a cellular phone and a car navigation system at this time. Therefore, the characteristics of WLAN were evaluated.

2.1. Radio wave propagation property

The radio wave propagation property of wireless LAN depends on the environment and the situation highly because of the fading variation and the shadowing effect. For this reason, it has been studied under certain conditions of frequency band, antenna, and path in each situation [4]-[7]. To investigate the property in the case of direct communication between a pedestrian and a vehicle without a radio repeater, a simulation was run by the ray tracing method. As a typical road environment in a suburb, a model of intersections was selected. The roads of 5.0m in width run at right angles to one another with the concrete walls on both sides (Fig.1). The road distance from the center of an intersection to the antenna was varied within 100m. The height of a transmitting antenna and a receiving antenna was 1.0m and 1.5m, respectively.

The result showed that the distribution of the propagation loss on a road in non-line-of-sight direction is affected by the distance from a transmitting antenna to a corner. It could be seen that the degree of reflection and diffraction changes significantly by the shape of the corner and there are some areas of road where it is difficult for radio waves to penetrate sufficiently. Fig.2 is an example. In this way, the propagation property in some models can be analyzed by the simulation. But, it lacks versatility because that in real road environments changes greatly depending on the surroundings such as running and parked vehicles, buildings, trees, and road traffic signs around the road. Therefore, it was necessary to survey it in the field.

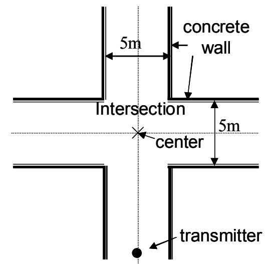

Fig.1 Environmental condition of simulation

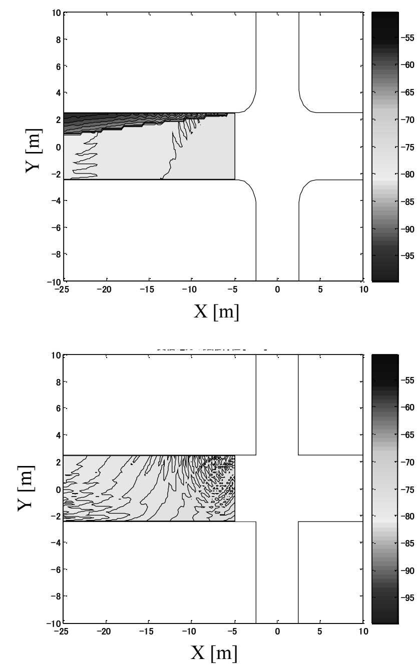

Fig.2 Distance property of received power
(above: curved corner, bottom: square corner)

2.2. Measurement of WLAN communication characteristics at out-of-sight intersections

To verify the over-the-horizon propagation property, the communication characteristics were examined at intersections of 5.0m in width in a residential district. WLAN-equipped PDA DELL Axim X51 and WLAN access point buffalo WHR-HP-G54 were used. The specifications of WLAN devices are shown in Table.1. First, by using WLAN analyzer AirMagnet, the signal distribution and S/N distribution in the right turn direction were measured when the access point was put on the points of 15, 20, 30, 50, 75, and 100m from the center of the intersection. As a result, more than a certain level of signal intensity was observed over several tens of meters from the corner for reflection and diffraction of radio wave. Next, on condition that the data of 1220 bytes was transmitted from a client of 25m away from the center, the time for connecting and the baud rate were measured at the receiving points of 20, 50, 75, and 100m away from the center three times, respectively (Fig.3). One of the results is shown in Table.2 and Fig.4. The time for connecting was 2~4s. The baud rate varied for retransmission occurred when cars passed through the intersection in measuring. But, the result shows that it was possible to communicate from the distance of 75m away from the center of the intersection.

Table.1 Specifications of Wireless LAN devices

WLAN device	PDA	Access point
Range (catalog)	100m	220m (20Mbps)
Baud rate	11Mbps	54Mbps
Standard	IEEE802.11b	IEEE802.11 a/g/b

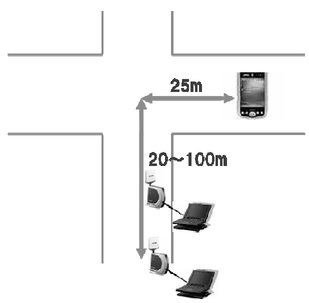

Fig.3 Measurement environment at an intersection

Table.2 Measurement result of Wireless LAN

	1st		2nd		3rd	
	Time for connecting(s)	Baud rate (Mbps)	Time for connecting(s)	Baud rate (Mbps)	Time for connecting(s)	Baud rate (Mbps)
20m	3	1.92	3	4.18	2	3.75
50m	3	0.17	3	1.23	3	0.37
75m	3	—	4	0.24	3	1.53
100m	×	—	×	—	×	—

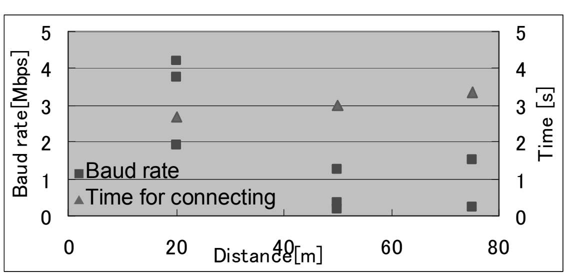

Fig.4 Measurement result of Wireless LAN

2.3. Mobile measurement of communication characteristics

To examine the influence on the communication characteristics when an access point moves at high speed, the time for connecting, the transmission rate, and the communication-enabled distance were measured with the access point in a car running and parked by the method similar to 2.2. At a blind intersection of 5.0m in width, the transmitting side was located at both near and far sides of 10 and 20m from the center (Fig.5). The receiving side moved at 20 km/h from the points of 50, 75, 100, and 125m to the center or got still at the points. As a result, in the access point not moved, it took 6~9s to send data and the communication-enabled distance was up to 75m away from the corner. On the other hand, in the access point moved, it took 6~8s to send data when accessed from within 100m and it was possible to communicate at the point of more than 75m away from the corner as shown in Fig.6. It means that these communication characteristics would not get worse when an access point was moved. Therefore, WLAN was considered to be able to be used as a method of direct communication between a pedestrian and a vehicle.

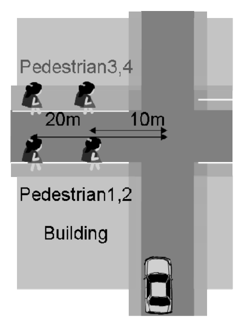

Fig.5 Positional relationship between a pedestrian and a vehicle at an intersection

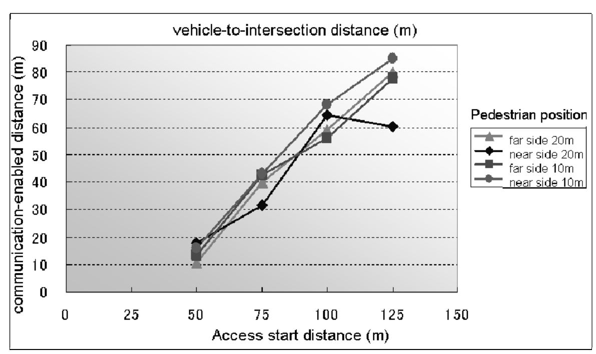

Fig.6 Communication-enabled distance at an intersection

3. Location measurement accuracy of GPS

It is necessary to measure the location of pedestrians and cars on streets in real time in order to recognize their situation and judge the collision risk. Location accuracy of a car navigation system is said to be high because of its correction technique based on map matching and dead reckoning. On the other hand, that of a cellular phone is said to be not high. The location accuracy of a portable GPS receiver was measured in a residential district where there are few high buildings to investigate it in a daily living area. Table.3 shows the specifications of the GPS receiver.

The result showed that the accuracy of uncorrected data was 1~6m in the whole route and was especially 1~3m at the residential street of 4~5m in width (Fig.7). Recently, the sensitivity of GPS modules has been increased. It is thought to become possible to use GPS location information of cellular phones for identifying pedestrians' positions in the near future.

Table.3 Specifications of GPS receiver

Reception channel		20
Sensitivity (dBm)		-159
Update frequency (Hz)		1
Location accuracy	2DRMS	10m (GPS) 5m (DGPS SBAS)
Speed accuracy		0.1m/s

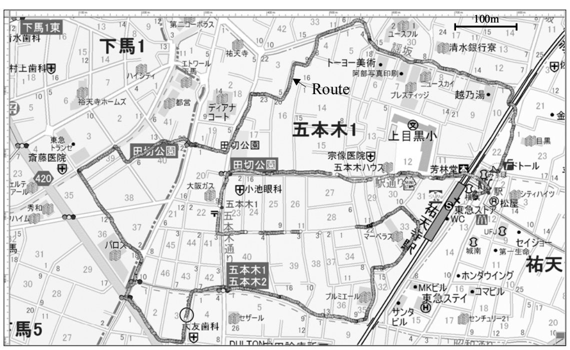

Fig.7 Location measurement result by GPS

4. Pedestrian-to-vehicle communication system prototype for pedestrian safety

4.1. Basic configuration of pedestrian-to-vehicle communication system

We designed and developed a pedestrian-to-vehicle communication experiment system for pedestrian safety which obtains the location information of each terminal and alerts drivers and pedestrians to coming risks. Fig.8 is the outline of the system configuration. The system is composed of cellular phones, car navigation systems, and a server. In the developed system, a note PC was used as a substitute for a car navigation system. A cellular phone and a car navigation system have modules of GPS, FOMA, and WLAN and send the location and time information of GPS to the server with each identification(ID) number via FOMA (Fig.9, Fig.10). The server manages their information obtained and judges the collision risk between a pedestrian and a vehicle from the location, the speed, and the direction of movement. When a pedestrian enters within the area around a vehicle where caution is needed, the server informs the pedestrian and the vehicle of each other's location information. The position is displayed on the digital map of the car navigation system and on the screen window of the cellular phone. At the same time, the server issues an instruction of direct communication to the terminals which have been judged as the highest risk pair (Table.4). The cellular phone and the car navigation system begin to communicate directly via WLAN by receiving the instruction and exchange each other's location information and so on. It alerts the driver with lighting on the display. An audio warning can be also given. The server records the location, the time, and the collision risk level with ID number in order to study high-risk intersections, pedestrians, and vehicles that are likely to have a possibility of an accident.

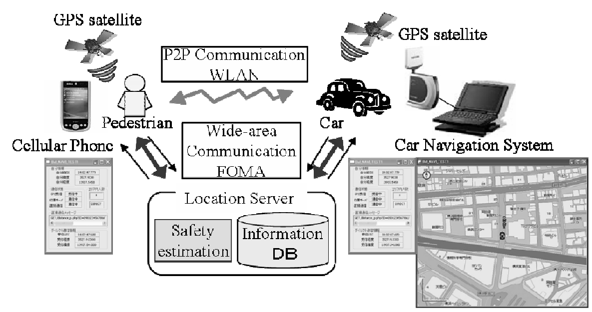

Fig.8 Outline of pedestrian-to-vehicle communication system

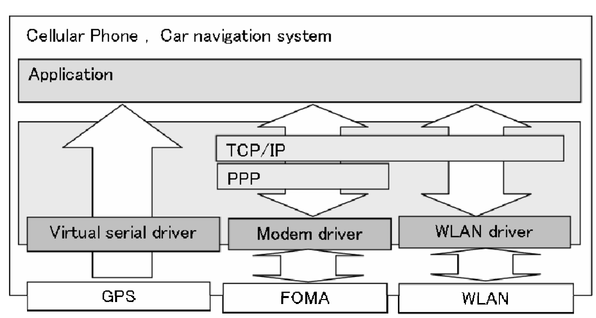

Fig.9 Software configuration of terminals

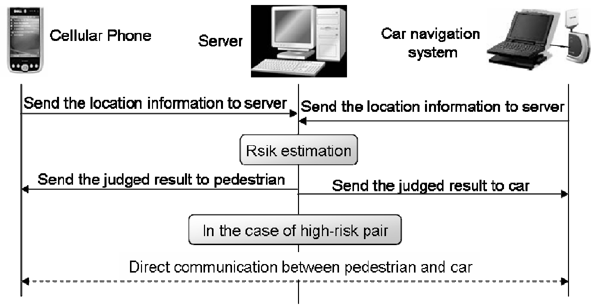

Fig.10 Information flow of pedestrian-to-vehicle communication

Table.4 Example of response message between server and terminal (a,b, and c represent numeric characters)

Enter: ID=090aaaabbbb&N=3444.4170&E=13534.3582 Direct:ID=090aaaabbbb&N=3444.4170&E=13534.3582 &IP=192.168.cc.c

4.2. Experiments with the developed system

4.2.1. Communication delay

The function of location notification by two communication methods was verified at an intersection surrounded with buildings by using the developed system. Fig.11 shows the shape of the intersection and S/N distribution of WLAN when an access point was located on about 100m away from the center of the intersection. A vehicle with a car navigation system moved from the point of 100m to the intersection at about 5 km/h and a pedestrian with a cellular phone stood still at the points of 10m and 20m on the near side of left turn direction. As a result, it was possible to communicate the location information directly via WLAN from the point of more than 90m and to display the latest position by getting the information not only via FOMA but also via WLAN. The result indicates that the communication delay time of WLAN is less than that of FOMA. Fig.12 shows the delay time measured in the case of setting the range of a risk area to 75m and 25m respectively. The delay time of FOMA was about 400~900ms and occasionally more than 1000ms. On the other hand, that of WLAN was about 20ms regardless of the distance between a pedestrian and a vehicle.

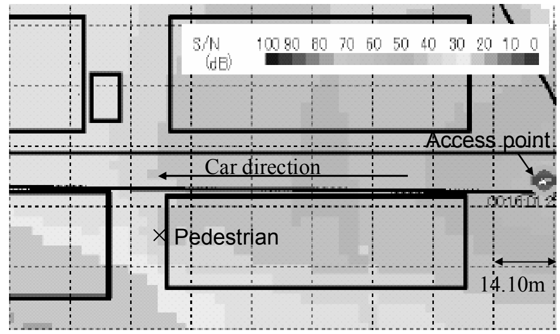

Fig.11 WLAN S/N distribution at an intersection

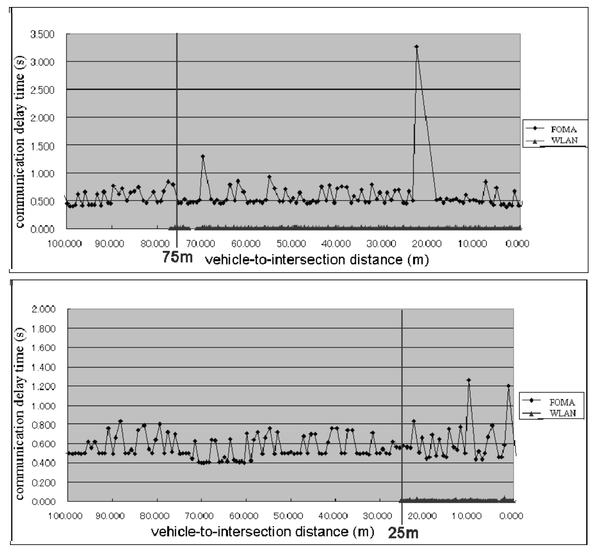

Fig.12 Delay time of wide-area communication and P2P communication
(above: risk area of 75m, bottom: risk area of 25m)

4.2.2. Communication-enabled distance

In the same way as 4.2.1, communication-enabled distance was measured at the different positions of a pedestrian. A vehicle with a car navigation system moved from the point of 100m to the center of the intersection at about 5 km/h and a pedestrian with a cellular phone stood at the points of 5m, 10m, and every meter of 20~25m. As a result, it was possible to communicate from the point of more than 90m away from the intersection when the pedestrian stood within 20m of the intersection. But, the communication-enabled distance took a sudden drop from over 20m as shown in Fig.13.

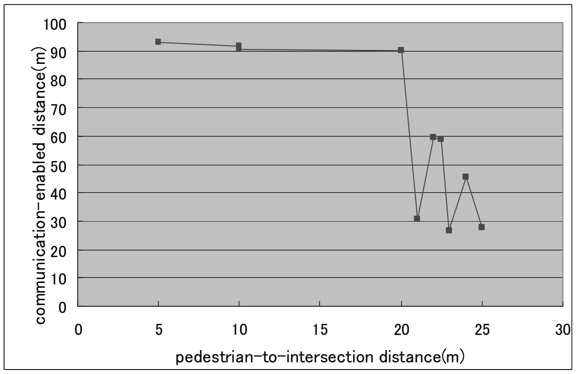

Fig.13 Communication-enabled distance by position of pedestrian

4.2.3. Consideration

It takes about 9.0s for a car to run from the point of 100m to the intersection at 40km/h. And, it takes about 15.4s for a pedestrian to go 20m at 1.3m/s which is the average speed of walking. Therefore, it is considered to be enough if communication via WLAN is started when a vehicle and a pedestrian enter within 100m and 20m of an intersection respectively. As a result, it can be said that it is possible to call for attentions of pedestrians and drivers based on location information via FOMA and inform them of more right location information via WLAN in approaching an intersection. However, both methods are needed because a good communication environment is not necessarily secured at all of the intersections continuously.

5. Conclusion

A prototype system for the prevention of pedestrian accidents which makes the information network between pedestrians and vehicles without additional infrastructure was proposed and developed. At some blind intersections where the propagation property is worse than at straight roads, the potential for WLAN to serve as P2P communication method was verified. Consequently, it was possible to exchange information between a cellular phone and a car navigation system and make each of a pedestrian and a driver find the other from out of sight by using both FOMA and WLAN.

This system needs the accuracy of location information. In urban areas of Japan which are surrounded with high buildings, it is difficult to display the correct position of pedestrians because the location accuracy of GPS measurement is low. However, in residential areas, the accuracy of a latest model of potable GPS receiver is not low. We aim at using the system in residential roads which are not busy but have high traffic accident risks for blind spots.

6. Acknowledgment

This research was supported by CREST, JST. We would like to thank Prof. T. Sato, Prof. H. Yamato and Prof. H. Hosaka of The Univ. of Tokyo for their advices on this project.

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