Prototype of pedestrian-to-vehicle communication system for the prevention of pedestrian accidents using both 3G wireless and WLAN communication

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***Abstract*— For the realization of a safe road traffic environment a wireless communication system which makes an information network between pedestrians and vehicles has been needed. A prototype of pedestrian-to-vehicle communication system was developed by using a cellular phone and a car navigation system equipped with GPS and wireless communication function. By interoperation of 3G wireless network and wireless LAN, it was possible to communicate in a wide area and with little delay time in a local area. The system can exchange the necessary information between pedestrians and vehicles, inform of the location of the ones that have an accident risk, and give an alarm by employing the developed algorithm for estimating the collision risk between each pedestrian and vehicle. The effectiveness of the system was shown by simulation of traffic situations.**

***Keywords*—safety, P2P communication, 3G wireless, GPS, cellular phone**

I. INTRODUCTION

Wireless information network systems have been built and utilized for supporting activities in various fields. In the traffic field, ITS has been promoted for the purpose of realizing a safer and more comfortable road traffic environment [1][2]. The reason is that traffic safety measures have become important in Japan for a high incidence of traffic accidents. One of measures to improve the traffic environment is to make an information network among roads, vehicles, and pedestrians. Therefore, a road-to-vehicle communication system and an inter-vehicle communication system have been studied and developed [3][4]. On the other hand, a pedestrian-to-vehicle communication system is just beginning to be developed.

The ratio of pedestrian accidents in Japan is high compared with other advanced countries. In addition, over 30% of road accident fatalities in 2005 are occupied in walking [5]. So, the safety measures against pedestrian accidents have been required strongly. One of the principal measures for preventing accidents is to make each of pedestrians and drivers find the others and recognize the risk correctly. A technique for recognizing pedestrians with cameras and sensors which are installed in vehicles and roads has been put to practical use partly [6]. But, the applied area is limited and it is difficult for a driver to recognize pedestrians from out of sight with enough time for avoidance of an accident. A pedestrian-to-vehicle communication system which uses 5.8GHz band based on DSRC has been also studied. But, pedestrians must have a dedicated device in which a wireless module of DSRC is built. And, the practical area within which it can communicate is not enough wide. In Japan cellular phones and car navigation systems are widely used. The number of cellular subscribers grew to above 100 million. Cellular phones are particularly taken with users all the time and location-based services such as routing assistance and location check for safety have spread gradually.

This research aims to develop a pedestrian-to-vehicle communication system for contributing to the prevention of pedestrian accidents occurred in residential districts where there is not heavy traffic and sensors have not been installed on the roads. In this paper we describe the developed communication system prototype and the algorithm for estimating the collision risk between pedestrians and vehicles. We used cellular phones and car navigation systems with location measurement function and wireless communication function. The system makes each of pedestrians and vehicles recognize the others who have the risk against the one. It is particularly useful around intersections at which pedestrians are out of sight of a driver. Therefore, we focused on intersections as a traffic situation to be covered by the system and simulated.

II. MEASUREMENT EXPERIMENTATION

A. Communication delay of WLAN and FOMA

Terminals can widely send and receive information via 3G mobile networks. But, they have communication delay. FOMA provided as 3G service in Japan has at least 400ms of delay to a server and back. When a vehicle comes close to a pedestrian, it is desirable to communicate without delay of more than 200ms so as to exchange nearly real-time location information between a pedestrian and a vehicle. WLAN (IEEE802.11b) is one of communication methods which have little delay time. A lot of PC and mobile terminals have the function of WLAN. WLAN is thought to meet the system requirements by being introduced as P2P communication method in conjunction with FOMA which has more delay but wide-area network. And so,

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the communication delay of WLAN and FOMA was evaluated on the roads.

B. Measurement method and result

A vehicle moved from the point of 100m to the intersection at about 5 km/h, exchanging information with a pedestrian standing at the point of 20m in the left turn direction via FOMA. When the vehicle came close to the pedestrian, it began to exchange information via both FOMA and WLAN. Fig.1 shows the delay time measured. 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 vehicle and a pedestrian. The result shows that WLAN could be an adequate method for P2P communication.

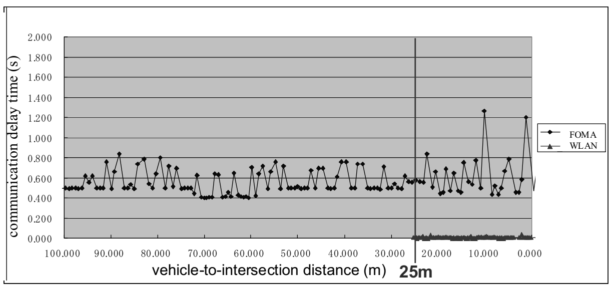

Figure 1. Communication delay time of FOMA and WLAN

III. Pedestrian-to-Vehicle Communication System Prototype

A. Basic configuration and function

A pedestrian-to-vehicle communication system which uses cellular phones and wireless communication to improve the safety of pedestrians was developed. It obtains the information of pedestrians and vehicles and alerts drivers and pedestrians to coming risks. Fig.2 is the outline of the system configuration. The system is composed of cellular phones, car navigation systems, and a server. Laptops with the digital map installed are used as car navigation systems. A cellular phone and a car navigation system have modules of GPS, FOMA, and WLAN (Fig.3). They send the information of latitude, longitude, velocity, direction of movement, and time based on GPS data to the server with each identification number (ID) via FOMA one or more times per second. Fig.4 shows the information flow of a car navigation system. The server receives their information, judges the collision risk between each pedestrian and vehicle and the need for caution, and sends the estimation results and the needed information to the pedestrian and the vehicle (Fig.5, Table.1). The server also issues an instruction of P2P communication to the terminals which are judged as the highest risk pair. The cellular phone and the car navigation system begin to communicate directly via WLAN by receiving the instruction and exchange each other's latest information.

The car navigation system displays the vehicle oneself in the center of the digital map. The icons of pedestrians, which change color depending on the collision risk, are displayed on the map with the velocity and the direction of movement while pedestrians go into the risk area of the driver (Fig.6). The car navigation system and the cellular phones also give sounds for calling for attention and warning.

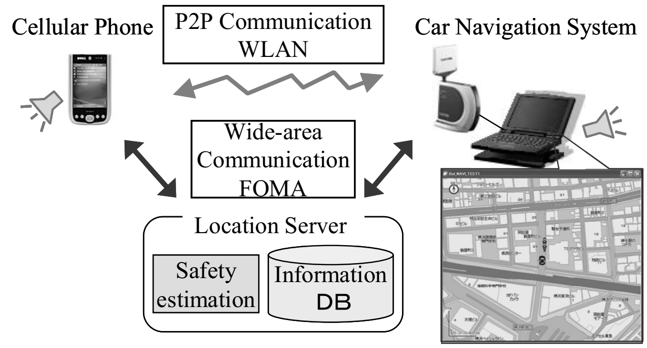

Figure 2. Outline of pedestrian-to-vehicle communication system

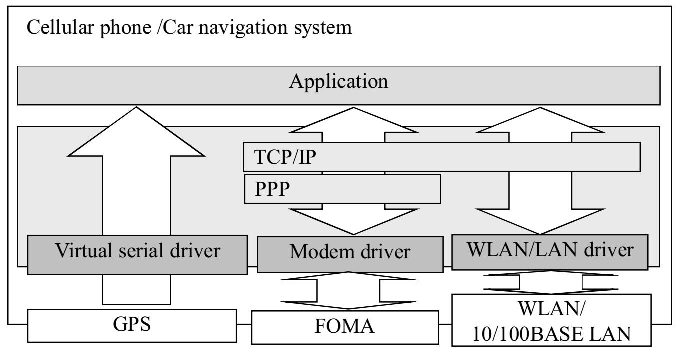

Figure 3. Software configuration of terminals

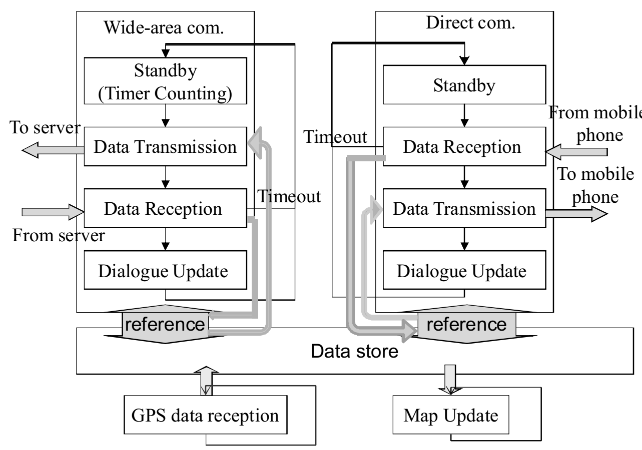

Figure 4. Information flow of car navigation system

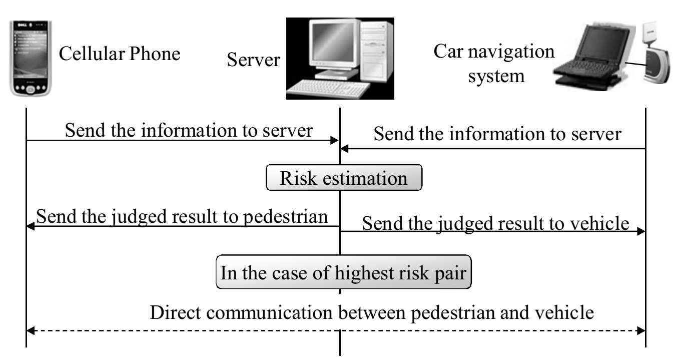

Figure 5. Information flow of pedestrian-to-vehicle communication

TABLE 1. EXAMPLE OF RESPONSE MESSAGE BETWEEN SERVER AND TERMINAL

Enter:ID=09011112222&N=3444.4170&E=13534.3582&D=359&V=13.1234 Highrisk:ID=09011112222&N=3444.4180&E=13534.3583&D=359&V=18.1234 Direct:ID=09011112222&N=3444.4180&E=13534.3583&IP=192.168.11.2&D=359&V=18.1234

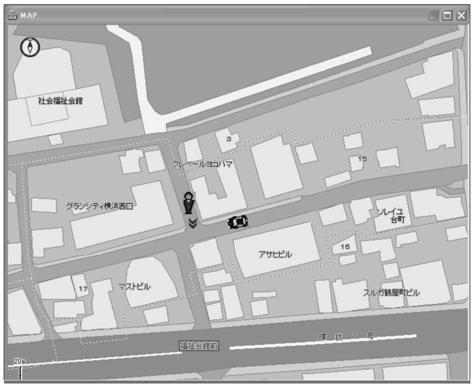

Figure 6. Example of a screen display

B. *Information processing of server*

1) Data management

Fig.7 shows the software configuration of the server. In the database (DB) of the server, individual information, intersection information, and road information have been stored in advance. The server also manages the information send by pedestrians and vehicles with each ID. The flow of information processing is shown in Fig.8. First, the following points are estimated based on the information.

- The terminal is vehicle, pedestrian, or cycle?
- The terminal is in an area of intersections or not?
- The time of GPS data is available or not?

The risk estimation is performed if the time of GPS data is available. Then, the server stores the location, the time and date, the direction of entering and leaving intersections, the traffic situation, and the collision risk level with ID in DB of history information in order to study each track and high-risk spots of traffic accidents. The estimation results are sent to the pedestrian and the vehicle

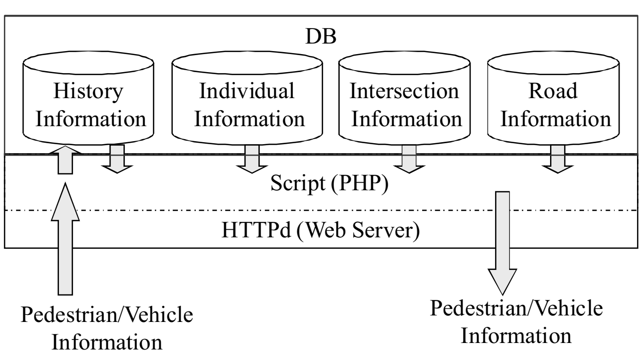

Figure 7. Software configuration of the server

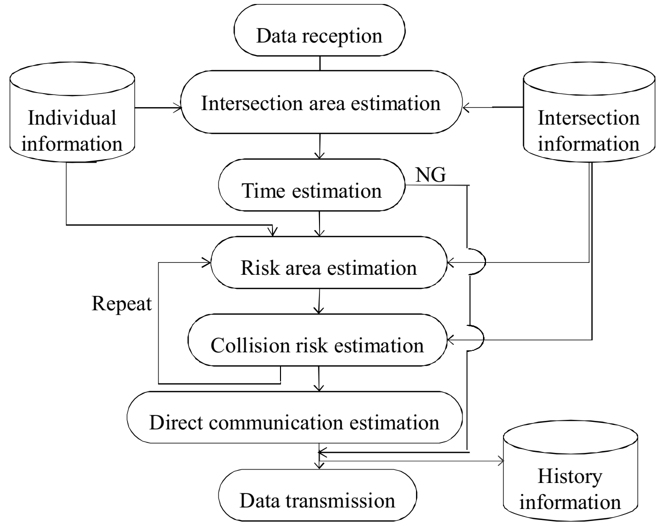

Figure 8. Flow of information processing

2) Risk estimation algorithm

The risk is estimated between vehicle and pedestrian/cycle. The risk estimation is divided into 4 phases. First, whether the risk area of a vehicle overlaps with that around a pedestrian or not is judged. Each risk area is set around one as shown in Fig.9. The size of a vehicle's risk area changes depending on the location and velocity of the vehicle. When a vehicle goes into an intersection area, the risk area of the vehicle changes to cover the out-of-sight area. Secondly, in the case of overlapping, the collision risk between the pedestrian and the vehicle is judged from the estimated time to collision and distance of closest approach based on the location, the speed, the direction of movement, and the road information. In the areas of intersections, pedestrians and vehicles do not move in a regular way and sometimes turn right or left. Therefore, the time to reach the intersection is reflected to the method of estimation in the areas, which is different from that on straight roads. Thirdly, the level of risk is estimated by judging whether the collision risk exceeds the threshold or not. Forth, one of each pair for connecting with WLAN and communicating directly is judged from the collision risk and the estimated time to collision.

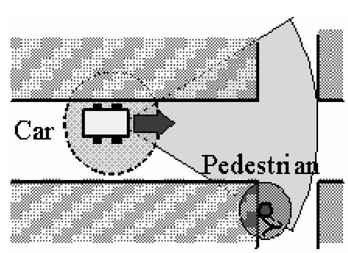

Figure 9. Risk areas of a vehicle and a pedestrian

IV. Evaluation of System

A. Simulation

1) Evaluation of traffic situation

A case of traffic accidents which actually took place was simulated. At T intersection without a traffic light a vehicle going straight hit a pedestrian walking across the street from the right side at night (Fig.10). The driver couldn't notice the pedestrian(A) because it was dark and he had been paying attention to another pedestrian(B) who was walking ahead of the pedestrian(A). Fig.11 shows the change of the collision risk against the distance between the vehicle and the pedestrian(A). The graph draws a comparison with the case that an alarm was given 6 seconds before the estimated collision and the driver could find the pedestrian approaching after attention and recognition time of 3 seconds and brake after reaction time of a second. It indicates that the risk drops to a lower level and the vehicle could stop 5m back from the pedestrian.

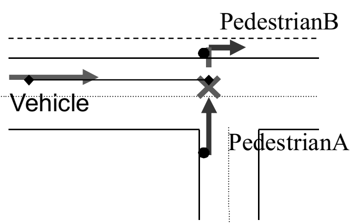

Figure 10. Traffic situation

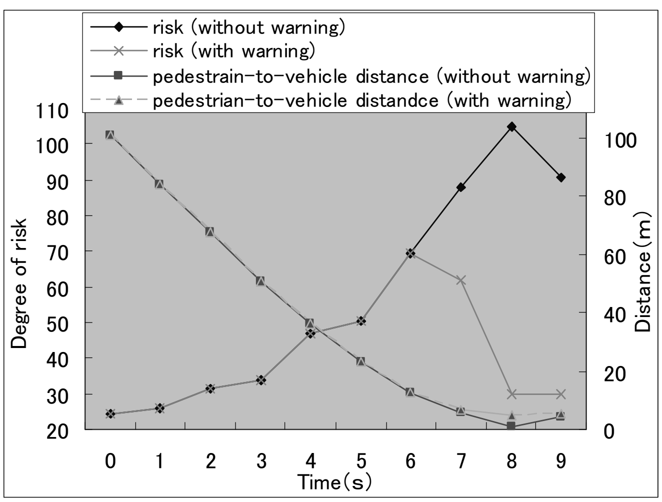

Figure 11. Collision risk and distance between pedestrian and vehicle at T intersection

2) Consideration

It takes about 6 seconds from the point of 100m away to the intersection when a vehicle runs at 60km/h. Maximum vehicle deceleration on dry pavement is generally about $8m/s^2$. It can make a stop within 3.1 seconds including reaction time in slowing down at $8m/s^2$. And so, it can be said to be possible for the driver to brake, slow down the vehicle, and avoid the collision by using the developed system because the system can make the driver aware of the pedestrian more than 6 seconds before the estimated collision.

B. Experiment

1) Evaluation of system on a road

The developed car navigation system was installed in a vehicle. As GPS device WBT-201 (Wintec), which was set to get GPS data every 200ms, was used. When the driver ran on the road and went through blind intersections, two pedestrians with the cellular phone in which the developed application was installed went toward the vehicle from a non-line-of sight road. Without the system the driver could not notice the pedestrians until the vehicle approached the intersection because the pedestrians were out of sight of the driver. On the other hand, when the application was run, the system could make the driver aware of the pedestrians with enough time and alert the driver based on more right location information via WLAN in approaching to the pedestrians. The driver could slow down and pay more attention to the pedestrians on the road by recognizing the pedestrians approaching in advance.

V. Conclusion

A prototype of pedestrian-to-vehicle communication system for the prevention of pedestrian accidents was developed by using both FOMA and WLAN. It doesn't require additional infrastructure. By using two communication methods and the developed algorithm for estimating the collision risk and the need for caution, the system could exchange information between pedestrians and vehicles with enough time and distance to avoid the collision. Additionally we will improve the algorithm for judging the best timing of warning which depends on the traffic situation because of making more appropriate notification.

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References

[1] S. Hirai, H. Hatakenaka, I. Yamazaki, "Road Traffic Safety Enhancement through ITS", Information and Environment Forum, 20074376, Mar.2007
[2] H. Nakamura, K. Osaku, T. Goto, R. Sagawa, T. Hashimoto, "Advanced wireless technology and VMC concept for mobile image services", Proc. of the 24th annual conference of the robotics society of Japan, 3M21, Sep.2006.
[3] M. Fujise, "ITS communication system by millimeter wave –making a car safer and more comfortable-", Journal of electronics, information and communication engineers, Vol.87, No.9, pp.744-749, 2004.
[4] Y. Shiraki, T. Oyama, S. Nakabayashi, K. Tokuda, "Development of an inter-vehicle communication system", Oki technical review 187, Vol.68, No.3, pp.24-25, Jul.2001.
[5] http://www.npa.go.jp/toukei/koutuu1/01home/age2.htm National Police Agency, 2005. [Nov 02, 2007]
[6] S. Hirai, H. Hatakenaka, I. Yamazaki, "An action to traffic accident reduction by AHS", Proc. of the 14th Asia Pacific automotive engineering conference, APAC-14, Aug.2007.