Adaptive Array Antenna Control Methods with Delay Tolerant Networking for the Winter Road Surveillance System

Noriki Uchida[1]*, Kenta Ito[2], Tomoyuki Ishida[3], and Yoshitaka Shibata[2]
[1]Fukuoka Institute of Technology, Fukuoka, Fukuoka 8110193 Japan
n-uchida@fit.ac.jp
[2]Iwate Prefectural University, Takizawa, Iwate 0200693 Japan
g236n001@s.iwate-pu.ac.jp, shibata@iwate-pu.ac.jp
[3]Ibaraki University, Hitachi, Ibaraki 3168511 Japan
ishida@mx.ibaraki.ac.jp

Abstract

It is considered that the road condition in the winter is one of the significant issues for the safety driving by tourists or residents. However, there are many difficulties of the V2V networks such as the transmission range of wireless networks and the noises from the automobile's bodies. Thus, this paper introduces the Adaptive Array Antenna (AAA) controls for the Vehicle-to-Vehicle (V2V) networks based Delay Tolerant Networking (DTN) in the road surveillance system. In the proposed system, the vehicles equip the AAA control systems with the IEEE802.11a/b/g based DTN, and the wireless directions are controlled by the visual recognitions with Kalman filter algorithm to make the longer and stable wireless connections for the efficiency of the DTN. The porotype system is introduced in this paper, and the results are discussed for the future studies.

Keywords: Delay Tolerant Networking, Adaptive Array Antenna, Vehicle-to-Vehicle Wireless Networks, Road Surveillance System

1 Introduction

It is considered that the road condition in the winter is one of the significant issues for the safety driving by tourists or residents. In fact, the National Institute for Land and Infrastructure Management (NILIM) in Japan reported that the 91 percent of the winter typed traffic accidents was caused by the slip on the frozen roads [7]. Therefore, there are some popular web-based services that local governments provide the winter road's information such as [2]. In the systems, there are some sensors such as thermometers and cameras at the traffic lights or the utility poles, and the information is provided through the internet.

However, in the case of such current systems, there are some considerable subjects for the safety driving during the winter. First of all, the observed values are limited to the certain points along the roads, and it is hard to recognize the whole road conditions. Especially, in the mountain areas, there are dangerous frozen roads caused by shadows by the trees and frozen points by the winds, and so it is difficult to imagine the dangerous points for the strangers such as tourists who do not have previous knowledge about the roads. Secondly, although the road conditions in the local areas are more serious than that of the urban areas, the communication networks such as LTE or 3G are not provided in many areas. Besides, many sightseeing spots such as a hot spa or a ski place are located in the mountain areas, and it is hard to receive the real-time information through the Internet.

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*Corresponding author: Department of Information and Communication Engineering, Fukuoka Institute of Technology, 3-30-1 Wajiro-higashi, Higashi-ku, Fukuoka, 811-0295 Japan

Therefore, we are now working the vehicle-to-vehicle (V2V) based Delay Tolerant Networking (DTN) [4] for road surveillance system in the mountain areas during the winter. In the system, the automobiles equip the sensor of Quasi Electrostatic Field (QEF) [12] [11] sensors on the wheels, and it measures the degrees of slippery on the roads by freezing conditions. Then, the observed data is transmitted to other automobiles through the WiFi based DTN.

However, there are many difficulties of the V2V networks such as the transmission range of wireless networks and the noises from the automobile's bodies. Moreover, the automobiles are always moving along the roads, and there are many obstacles such as trees or hills in the mountain areas. Thus, this paper mainly introduces the Adaptive Array Antenna (AAA) controls for the V2V based DTN routing in the road surveillance system. The AAA [6] [9] is known as to increase the performance of wireless connections by the radio directions, and the proposed methods control the directions in order to improve the DTN routing. In details, the vehicles equip the AAA control systems with IEEE802.11a/b/g in the proposed system, and the radio direction is controlled by the visual recognitions with Kalman filter algorithm. By using the prediction of the target nodes, the directional antenna can be controlled for the proper directions in the way of the automobile's movements. This paper discusses the methods of the AAA controls with the prediction algorithm, and the prototype system is introduced. Then, the experimental data are discussed for the effectiveness of the proposed systems and the future studies.

In the followings, the road surveillance system by V2V networks and the DTN networks is explained in section 2, and the previous studies the DTN and the proposed DTN methods are discussed in section 3. Then, the proposed AAA control methods for the DTN routing are introduced in section 4. Finally, section 5 deals with the prototype system and experimental reports, and the conclusions and future studies are discussed in section 6.

2 Road Surveillance System

It is considered that the current road surveillance systems usually consist of the sensors such cameras or thermometers at the traffic lights or the utility poles along roads, network equipment for the data transmission and remote controls, and web servers to provide the road information for the users. This system is useful for the residents or tourists if they are driving to the mountain areas during the winter since they can recognize whether the road is supposed to be frozen or not. However, the current system can provide only limited points since the sensors are settled at the traffic lights or the utility poles. Besides, the weather conditions in the mountains are easy to change, and the user needs some previous knowledge to see the dangerous points for the driving.

Therefore, we are now researching about the road surveillance system in the snowy mountain areas with the V2V based DTN networks as shown in Figure 1.

In the system, the automobiles equip the QEF sensors on the wheels, and it measures the degrees of slippery on the roads by freezing conditions. In the present, the prototype QEF sensors are evaluated in the field experiments whether it is possible to grasp the degree of slippery in every minute. Then, the observed text data is transmitted to other automobiles or fixed wireless stations through the WiFi based DTN, and the data are shared by the internet through the wireless fixed station as shown in Figure 1. Thus, the users can receive almost real-time road information from the oncoming automobiles, and it is considered to measure whole road conditions by the proposed surveillance system.

However, according to the field experiments and the previous studies such as [16] [13], there are some subjects about the DTN communication by using automobiles. Not only the delivery rate or the latency of the DTN, but also the wireless connection is hard to establish to share the observed road conditions.

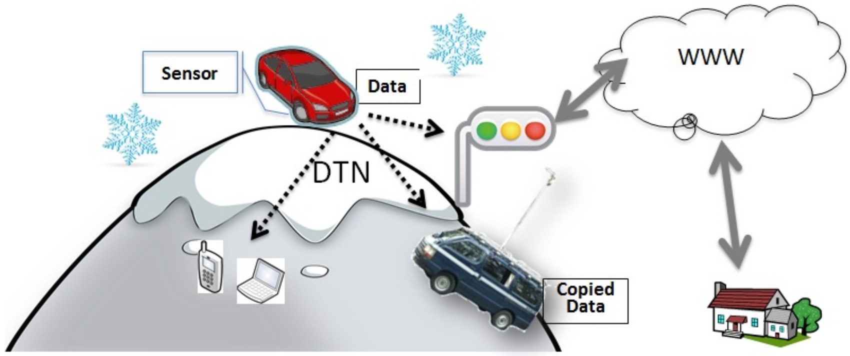

Figure 1: The Proposed Road Surveillance System with the V2V based DTN

3 Delay Tolerant Networking

The DTN is generally explained as "store-carry-forward" typed protocol for the purposes of the poor network connectivity [7]. As shown in Figure 2, the source automobile stores the data if the target automobile is out of the transmittable wireless range. Then, the source automobile carries the data until the target automobile move closer to the target automobile. If the target automobile is in the transmittable wireless range, the data is duplicated to the target automobile.

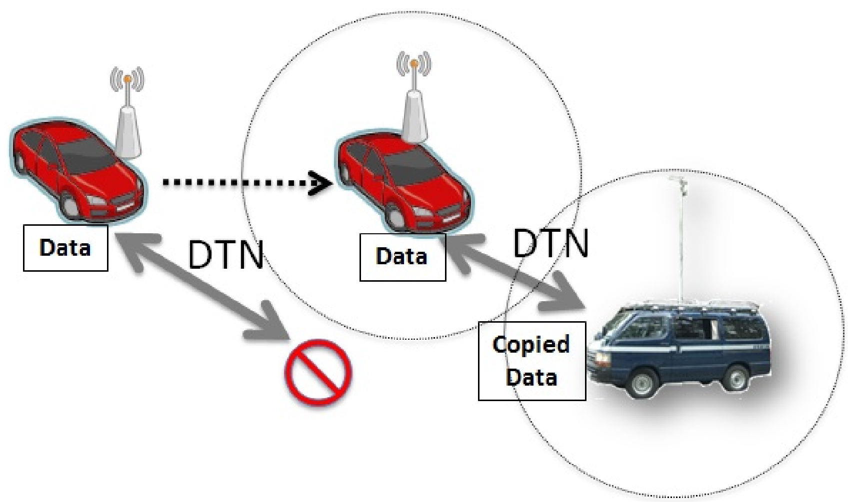

Figure 2: DTN Routing under V2V Networks

However, the previous researches such as [14] [8] pointed out that the efficiency of the DTN is depending upon the various factors such as the hardware resources, the data's queuing order, and the node's movement other than the network resources, and the various alternative approaches such as Spray and Wait [10] and MaxProp [3] in order to improve the efficiency of the DTN routing have been discussed until now. The authors [14] [8] also indicated that the delivery rate and the latency of the DTN is mainly depending on the ratio transmitting range from their experiments because the recent devices such as smartphones or note PCs have enough resources including HDD storages or RAM memory.

Therefore, this paper introduces the AAA controls with the Kalman Filter algorithm into the DTN routing in order to make the stable and longer radio connections for V2V networks. To realize the proposed AAA controls, the enhanced Media Coordinate System [5] (EMCS) for the DTN is proposed in the paper. Although the previous architecture of the DTN routings is mainly based on the higher layers such as the bundle layers and custody transfer (CT), the proposed MCS for the DTN is constructed with three layers and four planes in Figure 3.

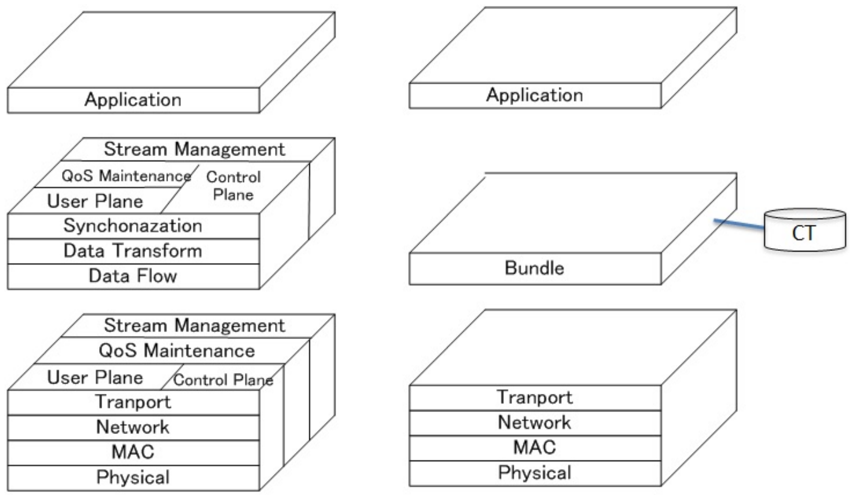

Figure 3: DTN Architectures

In the right of Figure 3, the bundle layer is located between the application and transport layers, and it mainly works as the storing or sending the cached data from/to the custody transfer (CT). However, the proposed EMCS architecture [15] will be able to control the data transmission with the various ways such as sending the data by the observed values or the calculated values. The following Table 1 shows each functions of each layer and plate in the EMCS.

Table 1: Functions of Layers and Planes of the EMCS

Synchronization Layer	It performs inter/intra message synchronizations in between DTN messages.
Data Transform Layer	It gives additional data of data priority for messages.
Media Flow Layer	It performs the AAA controls for the DTN.
Stream Management Plane	The most suitable QoS parameter values on each protocol values on each protocol layer are determined according to the user's QoS requirements and the target movement of the AAA controls.
QoS Maintenance Plane	It observes the User Plane and send/receive QoS parameters about data transmission..
User Plane	It performs message data transmission
Control Plane	It performs the negotiation and the AAA controls for the DTN.

4 Proposed Methods

This paper proposed the DTN with the AAA control systems for the sake of the longer wireless range and the predictions of the target nodes. Besides, in the proposed surveillance system, it is necessary to consider about the future location of the movement or the avoidance from the obstacles such as trees or buildings as shown in Figure 4.

Figure 4: Subjects in V2V Networks

The networks are consists of the V2V networks and V2X (X stands for the buildings and traffic lights) networks. The each network is connected by the DTN networks with the AAA beam-forming controls. Also, these vehicles equip wireless network devices, cameras, and the AAA systems. Therefore, if there are network disconnections between each node, the data connections are quickly recovered by the Kalman Filter algorithm which provides the future location of the automobile.

The AAA is the antenna arrays with smart signal processing methods used to identify spatial wireless signals [17] . It calculates beam-forming vectors in order to track and locate the antenna beam on the target nodes. Although the widely used MU-MIMO (Multi-User Multi-Input Multi-Output) algorithm such as IEEE802.11ac gains the peak data rate among the multiple wireless targets, the AAA generally uses the Beam Forming algorithm to determine the angle of the target nodes. Therefore, especially, the AAA makes the wireless range longer, and it is considered to make the active connections of the V2V networks for such as ITS (Intelligent Transport System).

Figure 5 and 6 shows the method of beam forming that consisted of phased array antennas. Both excitation amplitude and phase of each antenna's element are able to control the radio direction precisely in the AAA [17] . For example, in Figure 6, when the antenna distance (d) is known, the path distance (x) is decided by the phase difference of each element antenna. Then, the angle of the beam direction (θ)

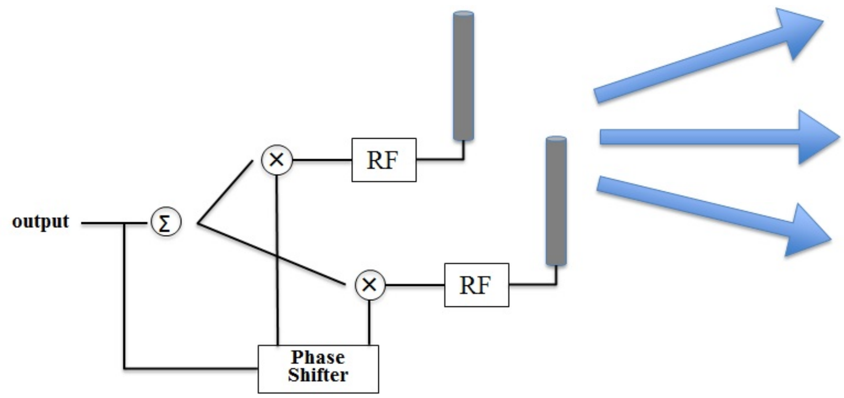

Figure 5: Subjects in V2V Networks

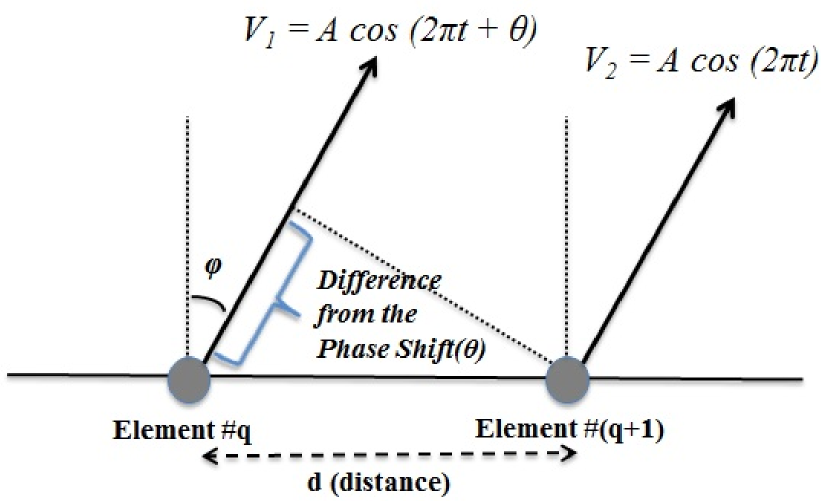

Figure 6: Subjects in V2V Networks

can be calculated with these parameters. The AAA generally applies the algorithm of the DOA (Direction of Arrival) Estimation such as estimation of signal parameters via rotational invariance techniques (ESPRIT) algorithms or Matrix Pencil method. However, this algorithm takes a longer period to calculate, and the assumed V2V networks need the prediction of the movements or the avoidance from the obstacles. Therefore, in the proposed method, the Kalman Filter is introduced for the more precious the directional controls. The Kalman filter [1] [18] is one of the estimation algorithms that widely used for the pattern recognition or weather forecast. It mainly consists of two phases such as "Time Update" and "Measurement Update" for the calculation of the predicted values in Figure 7 .

In the Time Update phase, the specific equations for the time updates are presented below in formula (1) and (2).

$$\hat{x}_k^- = A\hat{x}_{k-1} + Bu_{k-1} \tag{1}$$

$$P_k^- = AP_{k-1}A^T + Q \tag{2}$$

In these equations, x_k is the estimate of the signal x, and u_k is a zero-mean (statistically) white (spectrally) random "noise" process with autocorrelation. A and B are matrixes which are numerical

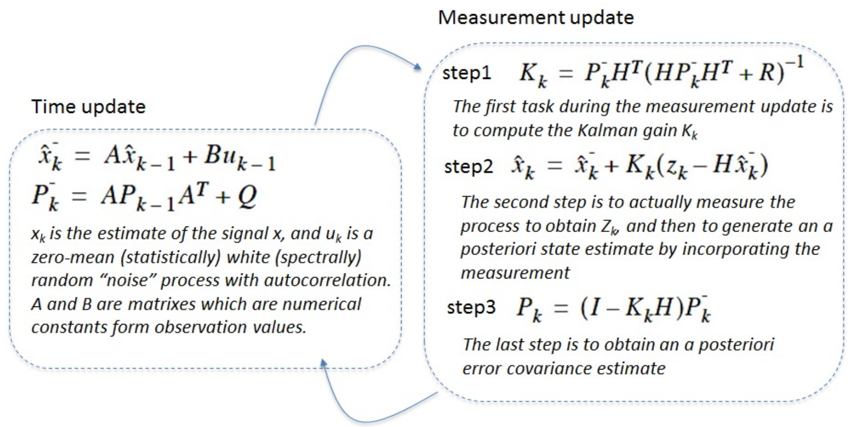

Figure 7: Phases of the Kalman Filter

constants form observation values. Also, the Measurement Update takes the following equations.

$$K_k = P_k^- H_T \left(H P_k^- H_T + R\right)^{-1} \tag{3}$$

$$\hat{x}_k = \hat{x_k^-} + K_k\left(z_k - H\hat{x_k^-}\right) \tag{4}$$

$$P_k = \left(I - K_k H\right) P_k^- \tag{5}$$

The first task during the measurement update is to compute the Kalman gain K_k by equation (3). The second step is to measure the process to obtain Z_k, and then to generate an a posteriori state estimate by incorporating the measurement as in equation (4). The last step is to obtain an a posteriori error covariance estimate via equation (5).

After each time and measurement update pair, the process is repeated with the previous a posteriori estimates used to project or predict the new a priori estimates. This recursive nature is one of the very appealing features of the Kalman filter - it makes practical implementations much more feasible than (for example) an implementation of a Wiener filter which is designed to operate on all of the data directly for each estimate. The Kalman filter instead recursively conditions the current estimate on all of the past measurements.

In the proposed method, the AAA direction control with the Kalman filter based DOA estimation is introduced in the Media Flow Layer, and the calculated values are feedback through the control plane.

5 Experiments

In order to evaluate the proposed methods, the prototype system is under working in the research. First of all, the blueprint of the prototype AAA is shown in Figure 8.

The two patch antenna's elements are connected to the phase shifter to control the wireless directions, and the following Table 2 shows the specification of the phase shifter with the given voltages.

Then, the Figure 9. shows the simulation results of the beam-forming angle in the proposed AAA system. The vertical line presents the dBi values.

According to the results, it is supposed that the 10V difference of the shifters makes the 23 degree's rotation of the wireless signal, and that the prototype system is able to control the wireless directions for the V2V networks. Moreover, the following Figure 10 shows the system configurations of the visual

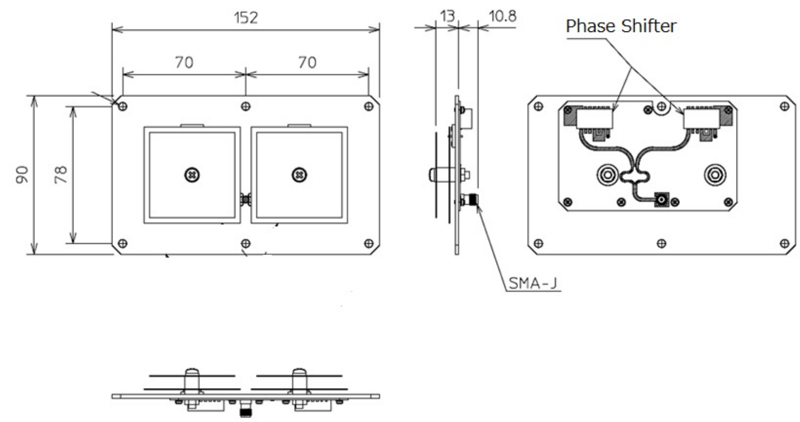

Figure 8: Blueprint of the AAA Prototype System

Table 2: Specification of The Phase Shifter

Control Voltage (V)	Phase Shift (degree)
0.0	0.00.
1.0	4.22.
2.0	8.68
3.0	14.29
4.0	22.27
5.0	33.71
6.0	48.52
7.0	65.24
8.0	82.32
9.0	99.06
10.0	115.49
11.0	135.24
12.0	148.56
13.0	165.52
14.0	183.15
15.0	3201.15

recognition in the prototype system. Unlike the common visual recognition for the calculation of the distance between the automobiles by using two cameras, the prototype system is now evaluating the correlation between the pixels and the distance as shown in Figure 10.

In the prototype system, the observed pixel area (S_n) is calculated by the height (h_n) times width (w_n), and the results are used for the estimation of the distance (d) as shown. Also, the center point (x_n, y_n) of the observed area is used for the estimation of the angle (θ). Finally, these observed pixel values are applied to the calculation of the Kalman Filter, and the results are used for the predicted location to controls the AAA's directions. Figure 11 is the screen of the implemented system.

The application is implemented by the Ubuntu 16.04, OpenCV, and Java, and we are now evaluating the system in the field experiments.

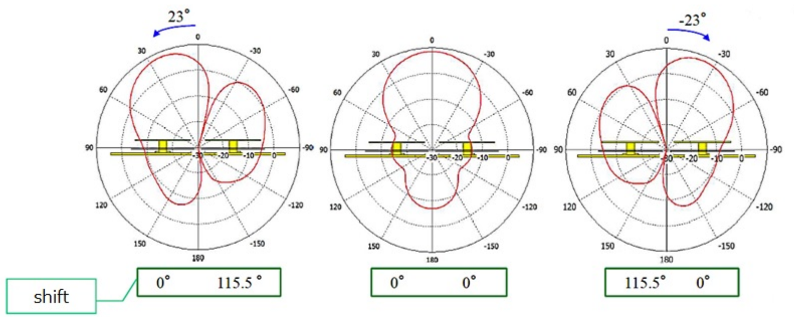

Figure 9: Results of the Beam-forming Simulation

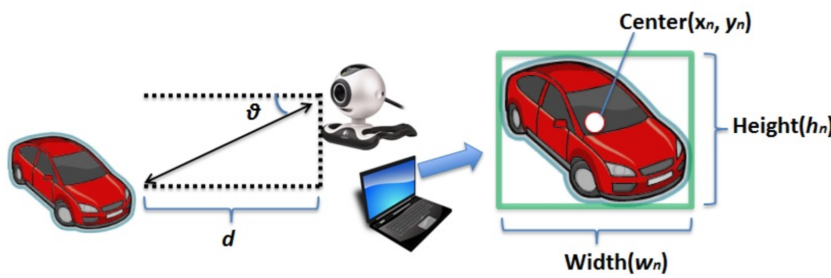

Figure 10: Visual Recognition of the Prototype System

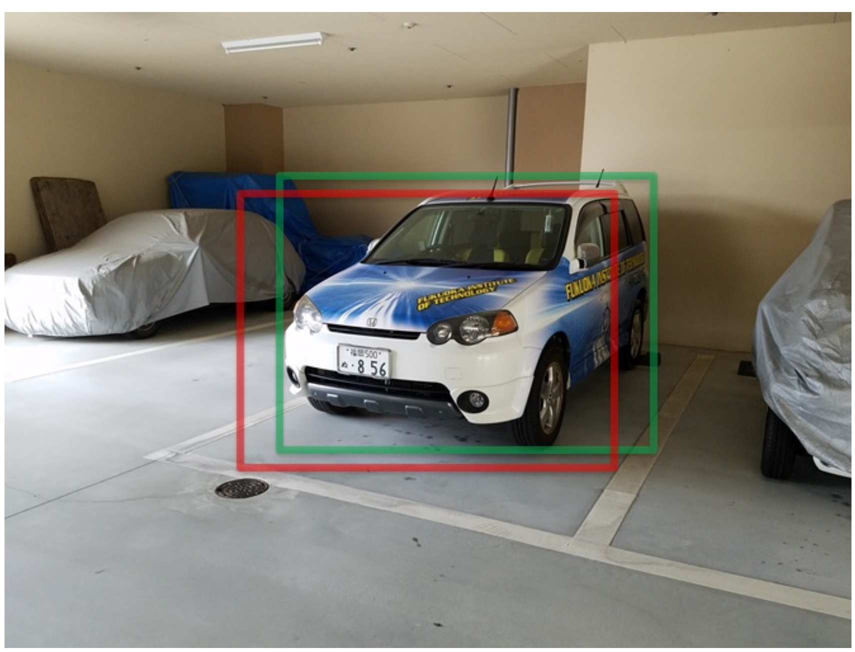

Figure 11: Screen Shot of the Prototype System

6 Conclusion and Future Study

It is considered that the road condition in the winter is one of the significant issues for the safety driving by tourists or residents. Therefore, we are now working the V2V based DTN for the road surveillance system in the mountain areas during the winter. However, there are many difficulties of the V2V networks such as the transmission range of wireless networks and the noises from the automobile's bodies. Thus, this paper introduces the AAA control method for the V2V based DTN routing in the road surveillance system. In the proposed system, the vehicles equip the AAA systems with IEEE802.11a/b/g based the DTN method, and the wireless directions are controlled by the visual recognitions with Kalman filter algorithm. Therefore, the proposed system is able to control the wireless directions as predicting the future location by the movement along the roads or the avoidance from the obstacles such as trees or buildings. The porotype system is introduced in this paper, and the results indicate that the proposed system is able to control the wireless direction effectively, and the 20 V difference between the antenna elements make about 23 degrees of the wireless signal. Also, the visual recognition is explained by the correlation between the distance of the target automobile and the pixel area of the captured image in the system. Now we are planning the additional implementations of the prototype system, and specific algorisms to controls the AAA including multi-target models. Also, we are working on the field experiments for the efficiency of the proposed methods.

Acknowledgments

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Author Biography

Noriki Uchida received the B.S. degrees from University of Tennessee in 1994, M.S. degrees in Software and Information science from Iwate Prefectural University in 2003, and Ph.D. degree degrees in the same University in 2011. From 2011 to 2014, he was an associate professor in the Saitama Institute of Technology, and he is currently an associate professor in the Fukuoka Institute of Technology. His research interests include Cognitive Wireless Networks, QoS, and Heterogeneous Network. He is a member of IEEE, Information Processing Society of Japan (IPSJ), and Institute of Electronic and Communication Engineering in Japan (IEICE).

Kenta Ito received his BS and MS from Iwate Prefectural University, Japan. Currently, he is a Ph.D. student at Iwate Prefectural University, Japan. His research interests include ITS, Disaster Information Network. He is the recipient of the Best Paper Award from the 29th International Conference on Advanced Information Networking and Applications Workshops (WAINA2015). He is a student member of IEEE and Information Processing Society of Japan (IPSJ).

Tomoyuki Ishida received the B.S. and M.S. degrees in Software and Information science from Iwate Prefectural University in 2004 and 2006, and Ph.D. degrees in the same University in 2010. Currently he is an assistant professor in the Ibaraki University. His research interests include Web Geographic Information System for local governments, Disaster Management System, Safety Confirmation System, Regional Disaster Prevention Planning, Virtual Reality and Tele-Immersion. He is a member of IEEE, Virtual Reality Society of Japan (VRSJ), Information Processing Society of Japan (IPSJ) and Visualization Society of Japan (VSJ).

Yoshitaka Shibata received his Ph.D. in Computer Science from the University of California, Los Angeles (UCLA), U.S.A. in 1985. From 1985 to 1989, he was a research member in Bell Communication Research, U.S.A., where he was working in the area of high-speed information network and protocol design for multimedia information services. Since 1998, he is working for Iwate Prefectural University, Japan as an executive director of Media Center and a professor of Faculty of Software and Information Science in the same university. He is a member of IEEE, ACM, Information Processing Society of Japan (IPSJ) and Institute of Electronic and Communication Engineering in Japan (IEICE).