Development of MODEL-2013 as GPS-AVM system

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Abstract

We at FUJITSU TEN have developed GPS-AVM (Automatic Vehicle Monitoring) systems for taxies applied with a wireless system for business. In line with the decision of full digitalization in 2016 of the wireless system for business, we have strengthened competitiveness of our products by releasing a digital wireless device adopting a $\pi/4$ QPSK modulation system in 2003 and releasing another digital wireless device adopting a 4-FSK modulation system in 2012 as a low-priced version.

In these days, a new communication system using a mobile phone network draws attention as an alternative system to the conventional wireless systems due to the reduction in facility investment in accordance with the decrease of income in taxi business, and due to the extension of taxi service area such as for pick-up and drop-off service at airport. This time, we decided the incorporation of the mobile phone network into our GPS-AVM systems so as to further strengthen the competitiveness of our products.

1 Introduction

An AVM system (Automatic Vehicle Monitoring System) is the computer management system in which the computer installed in a center controls the operation conditions such as locations and behavior of business-use vehicles. The AVM system we at FUJITSU TEN developed is a "taxi dispatching system" specialized for operation in taxi companies.

We started the development of the system centering on a mobile communication technology by use of an analog wireless system. Since then, we have kept the development, for example, the development and delivery in 1981 of "semi-automatic AVM system" in which a driver reports his/her own location by the unit of predetermined area, the achievement in 1994 of "GPS-AVM system" which adopts GPS for obtaining vehicle locations, the achievement in 1996 of "automatic taxi dispatching system" which links with a customer management system[(i)], and the release in 1997 of "CTI (Computer Telephony Integration)-linked GPS-AVM system" which links with a number display function for telephone.

In line with the transition from analog wireless systems to digital wireless systems, made by mainly Ministry of Internal Affairs and Communications due to stringency of frequency band, we have been providing the products adapted to the needs of the times so as to meet market needs, by releasing the industry's first digital wireless device adopting a $\pi/4$ QPSK (Quadrature Phase Shift Keying) modulation system in 2003, and the low-priced digital wireless device adopting a 4-FSK (Frequency Shift Keying) modulation system in 2012.

As for the recent trends in taxi business, the full digitalization in June 2016 of the business-use wireless systems is determined. However, it is necessary to renew the equipment of conventional wireless systems so as to adapt to the transition from analog systems to digital systems. Due to the necessity of high cost for introduction, the full digitalization is not progressing as planned. In accordance with the introduction of a long-distance discount system and with the change of service area, such as a pick-up/drop-off airport service at a fix rate, there is a growing demand for the extension of communication area. Therefore, we have developed an IP (Internet Protocol) wireless device as a new means of communication. This paper describes the problems to apply the IP wireless device to the AVM system, and their solutions.

2 Function and Configuration of AVM System

2.1 Function

First, the functions common in every wireless system are described. The GPS-AVM system for taxi is the vehicle management system for selecting a vehicle for the most efficient dispatching upon the reception of an order from a customer for taxi dispatch via telephone, smartphone, etc.

Here, the flow from the reception of an order to completion in the AVM system is explained based on **Fig. 1**. Each of the following numbers corresponds to the number shown in **Fig. 1**.

(1) Upon the reception of an order via telephone, a telephone number is obtained from a number display service.
(2) Previously registered database is searched for the information corresponding to the telephone number, and the found customer information [name, location (longitude and latitude), address, name of building, route, etc.] is displayed on a screen[(ii)].
(3) A server automatically searches for and decides the most suitable vehicle for dispatch based on the customer information indicated in Step (2) and respective vehicle information[(iii)].
(4) The server sends the instruction data for vehicle dispatch (address, name of building, name, route, etc.) indicated in Step (2) to the vehicle decided by the server in Step (3).
(5) The data are sent to the vehicle via a base station wireless device.

＊(i) System for managing registered information on customer's name, address, use history, etc. based on telephone number.
＊(ii) When applicable data are not in the database, the data are entered on the screen for new entry.
＊(iii) The location information obtained from GPS and navigation systems, and the behavior information (unoccupied, occupied, rest, etc.) transmitted from external devices are collected at a predetermined timing.

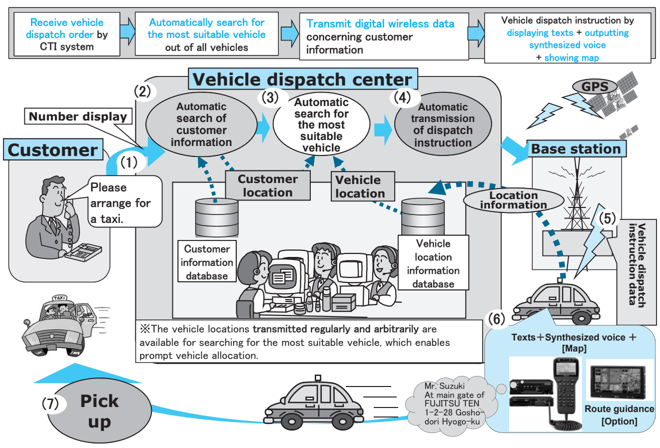


Fig.1 Functional explanation

(6) In the vehicle that received vehicle dispatch instruction, the dispatch instruction is displayed as text on a display, output by means of synthesized voice, given as route guidance on a navigation system, or other means to inform a driver.

(7) The vehicle that received the vehicle dispatch instruction moves to pick up the customer, and arrives at the customer. This is the end of a series of vehicle dispatch processing.

2.2 Configuration

The AVM system consists of the following three components.

●Vehicle dispatch center: Server and computers set in vehicle dispatch room

●Base station: Wireless apparatus set in operating room

●Mobile station: In-vehicle wireless device and ECU installed in vehicle

The description below is based on Fig. 2.

In the example, the equipment of the center consists of one server and two client personal computers. Each of the personal computers is equipped with an exclusive board to provide telephone functions, and thus the computer connected to a telephone switchboard is capable of receiving orders via telephone.

The equipment of the base station consists of wireless installation such as a wireless device and an antenna, a wireless console for dealing with telephone calls and other devices. Fig. 2 shows the simplest example where one base station wireless device is installed in a vehicle dispatch center. However, some taxi companies may install a plurality of base station devices in a plurality of locations in their taxi service areas in accordance with their business scales and location conditions.

The equipment of the mobile station in each vehicle consists of a wireless device, an ECU and a handy terminal. Optionally, the equipment may link with a navigation system and/or a drive recorder.

3 Difference between IP Wireless Device and Conventional Wireless Device

First, it is necessary to understand the advantages and the disadvantages of application of an IP wireless device to the AVM system. The description below is about the characteristics of the IP wireless device.

3.1 What is an IP Wireless Device

An IP wireless device is the device to make wireless communication by use of an IP (Internet Protocol) communication system over a mobile phone network, unlike the conventional wireless device using a digital wireless network for wireless communication.

3.2 Advantage

3.2.1 Wider Communication Area

The conventional wireless device is capable of communicating only in a certain range(iv) from an installed base station, while the IP wireless device is capable of communicating in the area where mobile phones are available. That is, the communication area is the whole country, in effect, and the device is capable of keeping collection of vehicle information anywhere.

3.2.2 Smaller Insensitive Area

The radio waves used by the IP wireless device are hardly affected by buildings and land shapes. Thus, the IP wireless device is capable of communicating almost anywhere, even in the places where the conventional wireless device is not capable of communicating, such as behind a building and in tunnel.

Fig. 3 shows the communication area where we actually conducted a vehicle running test with regard to the cases relevant to Section 3.2.1 and Section 3.2.2.

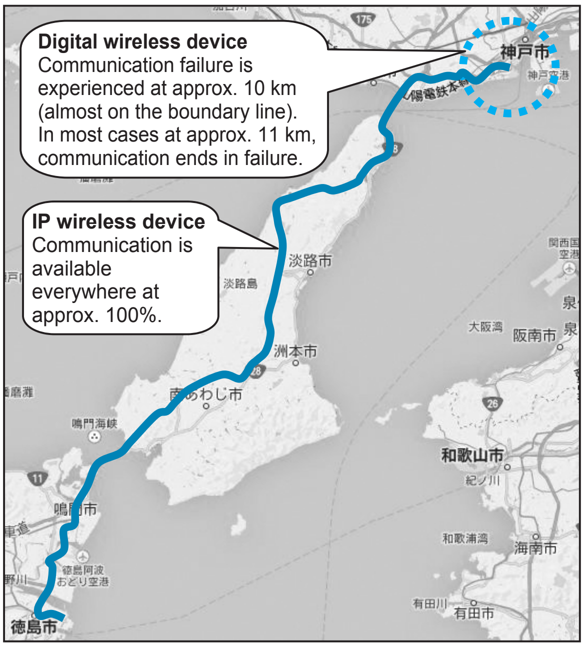


Fig.3 Running test

＊(iv) Approximately 30 km at maximum (in the case of the base station being set at TOKYO Skytree)

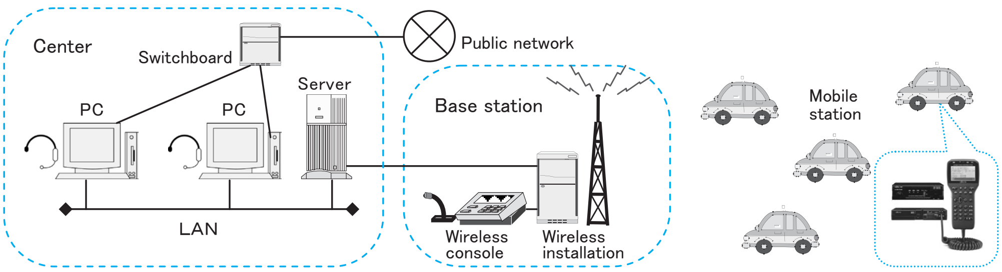


Fig.2 AVM system block diagram

The circle on the figure represents the wireless communication area for evaluation set at FUJITSU TEN, and the line represents the route we actually conducted the vehicle running test by use of the IP wireless device. The result shows that the IP wireless device is capable of communicating even across the prefecture border, and further in the tunnel to Akashi-Kaikyo Bridge.

3.2.3 No Interference

The conventional wireless device, receiving all of the signals having the same frequency, may receive data from another company's vehicle.

On the other hand, the IP wireless device makes communication based on the unique IP address[v] assigned for each wireless device, which becomes free from interference even the same frequency used.

3.2.4 Lower Initial Costs

Initial costs for use of the conventional wireless devices are expensive, including the costs for establishing original communication infrastructure, application fee for a license, and land rent for a base station, in addition to the costs for communication devices.

On the other hand, the initial costs for use of the IP wireless devices are less than those for conventional wireless devices by approx. 2 million or 3 million yen at lowest depending on a system size. This is because using the IP wireless devices requires neither the application fee for the license nor the land rent for the base station.

3.2.5 Broader Market

To use the conventional wireless device, a license for wireless communication has to be obtained, and the staffing of radio operators has to be considered, which narrows the market.

On the other hand, to use the IP wireless device, the application for and the obtaining of the license are not necessary, which provides us the chance to make proposals to the business enterprises that have not used the wireless devices.

3.3 Disadvantage

3.3.1 Generation of Running Cost

To use the IP wireless device, monthly communication fee is necessary the same as a mobile phone. That is, a running cost is generated. Thus, for the taxi company having a large number of vehicles, monthly costs become expensive. Since the usage fee is based on a meter-rate charging system, the usage fee may be more expensive than assumed fee depending on usage conditions. In addition, even for the device with no usage, the monthly basic fee is charged. Accordingly, it is difficult to prepare stand-by wireless devices that incur running cost.

In the infrastructure based on the conventional system, every taxi company has to establish a dedicated communication network between the taxi company and a mobile phone carrier. Accordingly, estimated service cost was expensive.

3.3.2 Multiple Address Processing Unavailable

The conventional wireless device is capable of performing multiple-address broadcasting to all of the vehicles using the same frequency by one time transmission. However, the IP wireless device basically makes one-to-one communication, and the multiple address broadcasting is not available.

3.3.3 Occasional Interruption of Voice

In the case of the IP wireless device, as the communication speed in the mobile phone network is not constant, the voices arrived late may be occasionally interrupted, or some part of the voices may be lost.

3.3.4 Difficulty in Dealing with Failure

The conventional wireless device uses original infrastructure, while the IP wireless device uses the infrastructure of the mobile phone carrier. Therefore, it may take time to specify and investigate the cause of a failure.

3.4 Summary

Table 1 shows the difference between the conventional wireless device and the IP wireless device.

Table 1 Comparison of wireless devices

Issue	Wireless network (45 type)	Mobile phone network
Infrastructure	Originally installed	Mobile phone (public) network
Communication area	Limited	Anywhere in Japan in effect
Insensitive area	Spot behind building or the like	Almost nowhere
Applicable devices for communication	Every wireless device using the same frequency	Individual wireless devices
Initial costs	Expensive	Low
Usage fee	Unnecessary (excluding land rent, etc.)	Necessary (charged based on meter-rate system)
Frequency adjustment	Necessary	Unnecessary
Indication of service area	When downstream data are received	Based on information from communication module
Indication of out of service area	When downstream data are unavailable for 30 sec.	
Prevention of erroneous reception	Judged based on 9 bit scramble	Free from voice interference because of one-to-one communication
Voice interference	As voice interference causes noises, judgment based on base-specific color code is necessary.	
Synchronization processing	Reception and transmission in synchronism with base station	Reception and transmission with UDP without synchronization processing
Prioritizing operation	Transmission is given priority.	Reception is given priority.
CH switching	Available	Unavailable

*(v) IP address is determined by the SIM (Subscriber Identity Module) that is built in the wireless device and provided by a mobile phone carrier. FUJITSU TEN's IP wireless device adopts a chip-type SIM (not exchangeable) due to its reliability.

4 Challenges toward Application to AVM System

Based on the result of the comparison described so far, we decided to address the following challenges so as to reduce the disadvantages of the IP wireless device to the minimum while taking its advantages, and to provide the same functions provided by the conventional wireless device.

4.1 Reduction of Running Cost

Since using the IP wireless device incurs the running cost that has not been required conventionally, the important challenge is to reduce the running cost. To reduce the usage fee, we addressed the following issues for reducing a data communication volume as much as possible.

4.1.1 Revision of Communication Format

In the format specified for the wireless network, reserve areas shall be prepared to ensure extensibility, and zero-filling shall be implemented to match digits in consideration of easier analysis. While in the new format for the mobile phone network, these excess parts shall be all deleted so as to reduce the communication volume by 1-bit unit.

Fig. 4 is one example showing the change in the data that represent the positioning status obtained by GPS and correspond to a part of the location information transmitted from a vehicle. The volume of the data is reduced by 40 bits: approx. 26%, from conventional 152 bits down to 112 bits.

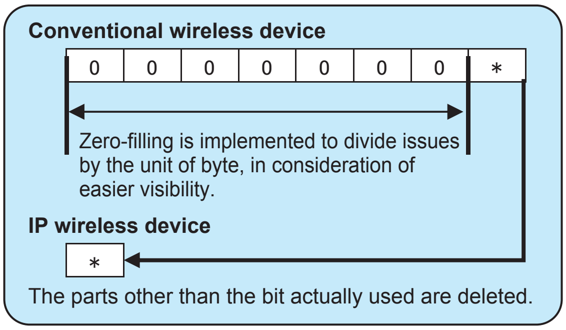


Fig.4 Format example

4.1.2 Improved Compressibility of Voice

The system of VoIP (Voice over Internet Protocol) is used for voice communication over the IP network. If a general voice codec is used, the bit rate of 8kbps is too low as compression rate. Thus, there is a concern that an excess fee will be incurred because the call time included in the monthly basic fee is too short for the AVM system to make both voice communication and data communication.

Therefore, we at FUJITSU TEN adopted the codec that uses the compressed bit rate of 2kbps while ensuring the sufficient level of quality for voice call based on the know-hows concerning the voice call used by the digital wireless device, and succeeded in providing four-times longer call time even with the same data volume.

4.1.3 Revision of Periodical Information

Conventionally, various types of information, for example, the number of vehicles by area and the busy status of vehicles, have been sent to vehicles as much as possible within the limit of traffic. However, the volume of information is reduced to the level where the reduction has no effect on operation so that unnecessary communication is reduced.

4.1.4 Restriction in Communication Setting

Conventionally, it was easy to change the setting concerning the intervals of information transmission from vehicles and periodical information. Thus, there was a concern that with erroneous setting, the communication volume would increase, and thus excess fee would be incurred. In this new system, various methods are taken to prevent unintended setting change. In an example, setting change requires file rewriting, or setting function is on the cloud or other site only accessible by engineers.

These methods have reduced the data communication volume to approximately one third of the initial estimate. This allows us to use the IP wireless device at the standard operation level of the standard conventional wireless device, within the range of monthly basic fee.

4.2 Reduction of Service Cost

Installing on the cloud a common-use server connected to a mobile phone carrier by use of a dedicated communication network reduces the service cost.

The configuration of the cloud is detailed in Section 5.

4.3 Achievement of Multiple Address Processing

A multiple address processing is not available by the IP wireless device due to the communication system. However, it is essential in taxi business to perform the processing of concurrent communication to a plurality of vehicles, for example, informing all of the vehicles of operation status as common information, and concurrently calling to all of the vehicles from a center.

This time, we established the system in which the server that stores the vehicle information of all of the taxi companies using FUJITSU TEN's IP wireless devices is installed on the cloud, and the server specifies a plurality of communication destinations to send the same data concurrently.

4.4 Reduction of Interruption of Voice

The conventional wireless network using the infrastructure entirely and originally prepared is rarely affected by external factors, and its communication rate is stable. On the other hand, since the mobile phone network used by the IP wireless devices is a public line, the network is easily affected by external factors, for example, the concentrated communication during Year-end and New Year holidays, and its communication rate varies.

If voices are replayed in real time, slower communication rate may delay the timing of the reception of the following voice, which causes the interruption of voice. In addition, in the case of reception of the following voice during replaying the delayed voice, voices may be lost. For these reasons, we adopted the system in which the voice data of a predetermined period of time are once stored in a buffer as the data to be replayed, and then replayed.

A larger buffer is capable of reducing interruption of voice but increases the delay of voice because it requires longer period of time to be filled. Therefore, we carried out several patterns of tests, and decided the optimum buffer capacity based on the test results. **Fig. 5** shows the system for replaying voice.

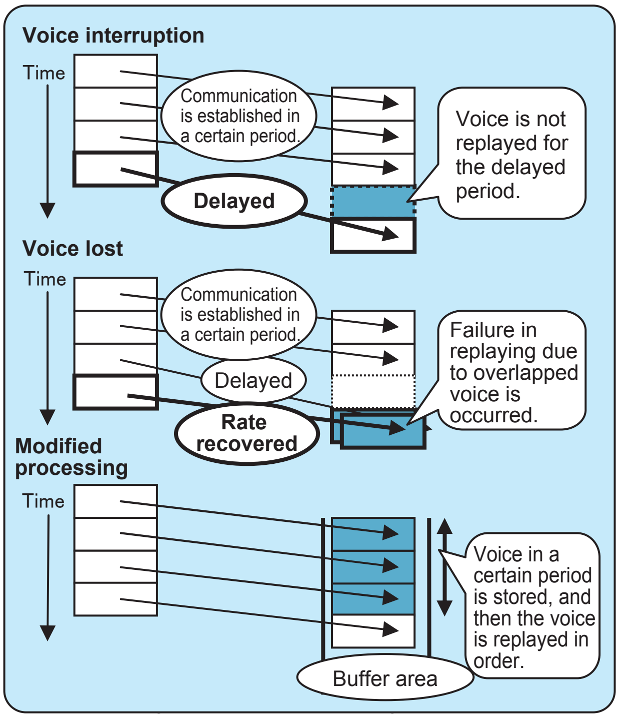


Fig.5 Voice processing

4.5 Achievement of Communication by Every Network Configuration

The IP wireless device adopts the protocol called UDP (User Datagram Protocol) in consideration of data communication rate. This protocol includes the information on the IP address and the port number of a transmission source in the header part of the format. However, in some types of network configurations, these values may be changed, and the changed values may not be available for judgment of data consistency.

Therefore, we set a new communication format that includes essential information such as the IP address of a transmission source and vehicle information as header information so that the communication format is available in every network configuration.

5 Configuration of Cloud

As described in Section 4.2, we installed a common server on the cloud, unlike the conventional AVM system. We addressed the following issues for application to the AVM system.

5.1 Overview

To restrain the service cost for using the IP wireless devices in the AVM system, we installed the server capable of controlling entire communication made by the IP wireless devices on the cloud. In case of failure, the failure affects every taxi company using the IP wireless devices through the server. We designed the cloud configuration, considering the securing of continuous system operation and the prevention and the early detection of any failure as the most important issues.

5.2 Securing of Reliability

In the cloud environment, a redundant configuration is provided with double servers and double communication devices to ensure its reliability.

Fig. 6 shows the hardware configuration.

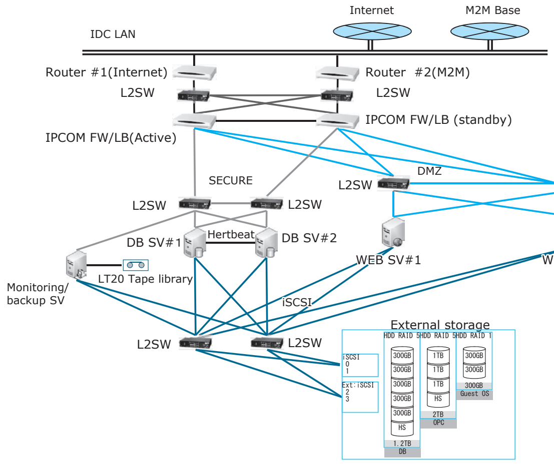


Fig.6 Hardware configuration

An external storage that is a physical recorder of database does not have a redundant hardware configuration. However, it adopts the configuration of RAID (Redundant Arrays of Independent Disks) including a hot spare, capable of keeping processing even in case of failure in disc apparatus.

The double server system is the system in which double servers are activated at all times, not switched on or off in turn for operation in case of failure. Therefore, the processing is continued as is even in case of failure occurred in one server, or during the period for maintenance.

5.3 Prevention and Early Detection of Abnormality

In this system, the servers installed on the cloud for monitoring systems continuously monitor not only the operating/non-operating states but the operating states of respective devices, and transmit alert messages in stages. Accordingly, users can notice the occurrence of failure in advance.

The servers of vehicle dispatch centers are connected to the same network, unlike the conventional servers working in stand-alone environment. Thus, in case of an abnormality occurring in the server of a vehicle dispatch center, this system is capable of transmitting the information on the abnormality via the cloud.

5.4 Reduction of Loads

As the communication transmitted from IP wireless devices goes through the cloud every time, its loads become much more than the amount conventionally assumed. We addressed the following issues so that the increased loads would not cause any delay in processing.

5.4.1 Application Configuration

The communication transmitted from the IP wireless devices is divided into data communication and voice communication each of which requires different processing. The system we developed includes the application for controlling the data communication and the application for controlling the voice communication so as to distribute the loads.

Further, the processing on the cloud is limited to the minimum processing necessary for making communication between a vehicle dispatch center and IP wireless devices.

5.4.2 Data Control Application

The data control application receives communication from IP wireless devices and a vehicle dispatch center.

When the received data correspond to the data communication, the data control application decides a data transmission destination based on its communication details and database. When the received data correspond to the voice communication, the data control application transmits the data as is to the voice control application.

There was a concern that the load on the data control application would increase because the application receives entire communication and also executes the processing for allocating the received data. To reduce the loads, the area for judging whether the received data correspond to the data communication or the voice communication is newly prepared in the header of the communication format so that the application can allocate the received data without analyzing data details.

5.4.3 Voice Control Application

The voice control application decides a voice data transmission destination based on the data received from the data control application and database.

5.4.4 Operation Summary

Fig. 7 shows the flow of the data transmitted over the mobile phone network.

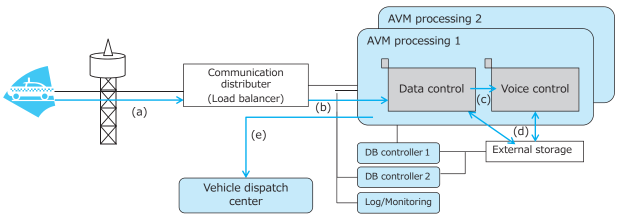


Fig.7 Operation summary

(a) The load balancer installed in the cloud environment receives the data transmitted from an IP wireless device.
(b) The load balancer decides the destination server of the received data based on the operation states and the communication conditions of the application servers.
(c) The data control application that has received data confirms the details of the data. When the data correspond to the voice data, the data control application transmits the data to the voice control application.
(d) Each of the application decides a transmission destination based on the details of the data, database and others.
(e) The data are transmitted to the vehicle dispatch center decided as an applicable transmission destination.

The data transmitted from a vehicle dispatch center are, also in the same manner, transmitted to the IP wireless device decided as an applicable transmission destination. In the case of the communication to all of the vehicles, the same data are simultaneously transmitted to the multiple transmission destinations having specified IP addresses.

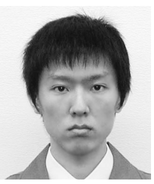
6 Conclusion

This paper described the application of the IP wireless devices to the GPS-AVM system for taxi. Since the first delivery of the system in September 2013, a plurality of taxi companies have started operating this system.

In the trend centering on the IP wireless devices, new business is now under negotiation and tried for operation in cooperation with a mobile phone carrier.

We will expand our target markets by developing the system capable of covering other business fields than taxies, and create new advantages in data utilization by applying the cloud system we developed this time.

Profiles of Writers



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