Wide-Area Vehicle Position Management System that Utilizes Mobile Phone (OBVIOUS)

● Masato Maruoka ● Masataka Mizuno ● Shigehiko Kagotani

● Yoshikazu Chujo ● Hirotake Susami

Abstract

In Japan, mobile phones have become so popular that roughly one out of every two persons use one, and the technologies involving it's application is one of the most advanced in the world. Position detection accuracy that utilizes GPS (Global Positioning System) drastically improved in May of 2000 when the U.S. Department of Defense, which controlled and utilized the system, disabled Selective Availability (SA) following a declaration by the U.S. President.

We have designed, developed and started the sale last fall of a system named OBVIOUS, which detects the locations of mobile stations using GPS, and enables data communications with the office through the packet communication network of digital mobile phones. This system makes it possible to easily verify on a PC screen the location, direction of travel, and operating conditions of mobile stations nearly anywhere in Japan.

This product was developed based on several fundamental technologies including navigation systems; mobile station positioning and display technologies of GPS-AVM (the taxi dispatching system); and the mobile phone control technologies for the MONET system, supplied to the Toyota Motor Corporation.

1.Introduction

By the end of February 2001, the number of mobile phone contracts had risen sharply to approximately 59 million. The service area had also expanded, covering over 99% of the population, making mobile phones a means of communications that could be used anywhere in Japan. Data communications services such as NTT DoCoMo's "i-mode" are in use everywhere (about half of mobile phones are under contract) thanks to the benefit of packet communications that are suitable for small-volume frequent-use communications.

Using the limited transmission area of the Personal Handyphone System (PHS), the "Imadoko Service," which tracks the location of a child or older person, for example, has started up and earned a good reputation. Services such as these that make use of information on the positions of people and vehicles are expected to further develop and expand in the future.

With the Intelligent Transport System, whose market size is expected to total approximately 60 trillion yen in 2015, "commercial vehicle efficiency" will be listed among the fields of development. As a user service, "commercial vehicle operating control assistance" is expected to increase transport efficiency and improve the environment.

It was in these circumstances that our company developed OBVIOUS, a multi purpose Wide-Area Vehicle Position Control System which makes inexpensive, wide-area communications possible by utilizing mobile phone packet communications. This system, sales of which began in October 2000, will be introduced in this report.

2.Overview of system

2.1 Aim and materialization method

The system was made to incorporate the items listed below.

(1) Wide-area communications covering all of Japan
Enables data communications between mobile stations and offices through packet (tagged packet) communications, making use of digital mobile phones (hereinafter referred to as mobile phones).
During the introduction period, a line use contract between the telecommunications company and customer is required.

(2) Planning for low cost
- Uses GPS to detect positions of mobile stations.
- Uses software to execute data communications modem processing.
- Packages office applications software.
- Utilizes widely used regional map databases.

(3) Safety
- Equipped with enlarged control buttons on in-car terminal.
- Transmits kana characters with accent symbols to mobile stations; and on mobile station side, provides voice notification via speech synthesis.
- Provides hands-free calling.

2.2 Overall functions

The overall configuration of the system is shown in Figure 1.

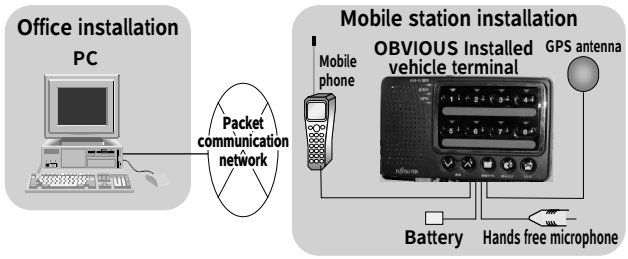

Fig.1 Overall configuration of OBVIOUS system

① Displays mobile station positions and operating status (hereinafter referred to as movement) on map screen of personal computer in office.
② On mobile station side, transmits eight movement buttons and two sets of ON/OFF sensor input status to office.
③ After accented kana characters are transmitted from the office, they are read aloud at the mobile station using speech synthesis.

2.3 Features

① Since public communications infrastructure (packet communication via mobile phones) is used, the system can be used nationwide.
② Since the position and movement of each mobile station can be monitored, instructions can be provided in a timely manner.

2.4 Application example

Figure 2 shows an example of the system being used for waterworks construction and maintenance.

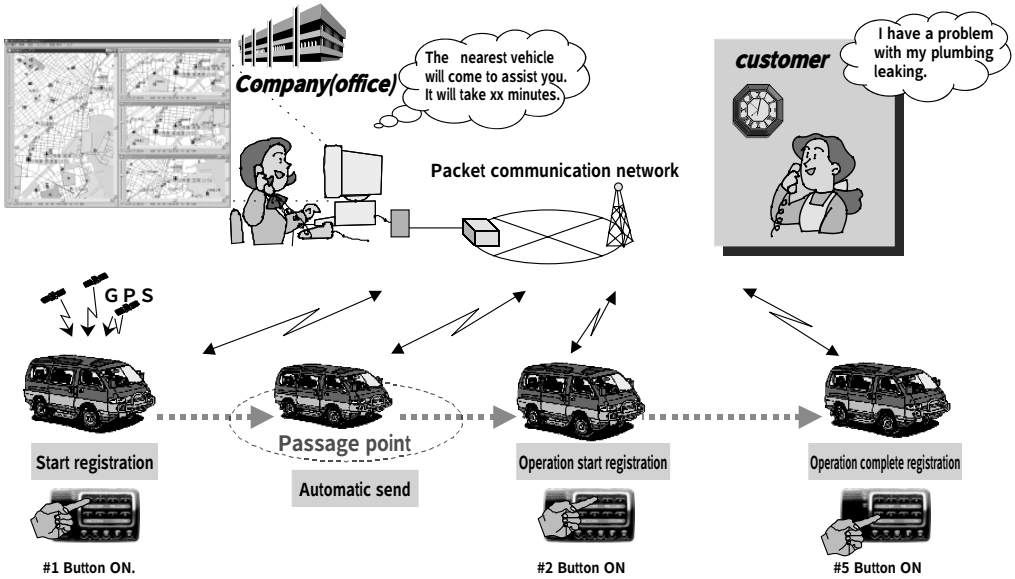

Fig.2 Example of application

When movement buttons #1 thru #8 are operated at the mobile station according to the operating status, the mobile station's position and movement can be monitored at the office.

As a result, quick action can be taken in response to a customer's inquiry, sudden work request, or other event.

2.5 Effect of introduction

① Improvement of customer service
Can take quick action in response to inquiries and sudden requests.

② Improvement in efficiency of mobile station control service
Related to operating instructions that are in line with the operating status. Furthermore, since results such as the movement time and operating time can be accumulated, the information can be utilized to reexamine the time required.

③ Can print daily reports (optional).

3. In-car terminal

3.1 Overview of in-car terminal

(1) Overview

Table 1 Specifications of the OBVIOUS in-car unit

CPU	SH-3 (SH-7709A)
OS	μITRON
Supply Voltage	DC +13.2V
Mobile phone	NTT DoCoMo : DoPa compatible phone Note1) DoPa Mobile-Ark Note 2) KDDI : PacketOne compatible phone Note 3)

Table 1 shows the equipment specifications of the OBVIOUS in-car terminal, while Figure 3 shows the configuration.

The major functions of the OBVIOUS in-car terminal include mobile phone packet communications support, GPS positioning, speech synthesis, and hands-free calling.

Packet communications includes support for NTT DoCoMo's PDC packet communication system (DoPa) and KDDI's cdmaOne (Note 4) packet communication systems (PacketOne), and is achieved through HDLC protocol-managed ASIC (Figure 3: Communications ASIC) and software modem (both newly developed).

A detailed explanation will be provided in the next section.

To reduce the development cost of this product, the existing ASIC (Figure 3: Port ASIC) was applied to the expansion of the parallel and serial ports. This ASIC was developed for in-car terminals that are used for new operations. The CPU (SH-3) used with this product had various problems; for instance, there were differences in the bus timing and source voltage, and there was no support for standby operations. Thus, packet communications

Note 1: DoPa: Registered trademark of NTT DoCoMo
Note 2: DoPa Mobile-Ark: Registered trademark of NTT DoCoMo
Note 3: PacketOne: Registered trademark of DDI
Note 4: cdmaOne: Registered trademark of DDI

support was given to the communications ASIC, and bus interface functions (bus timing conversion, voltage conversion, and standby control) were provided for the port ASIC. The configuration is such that access is provided to the port ASIC via the communications ASIC (Figure 3).

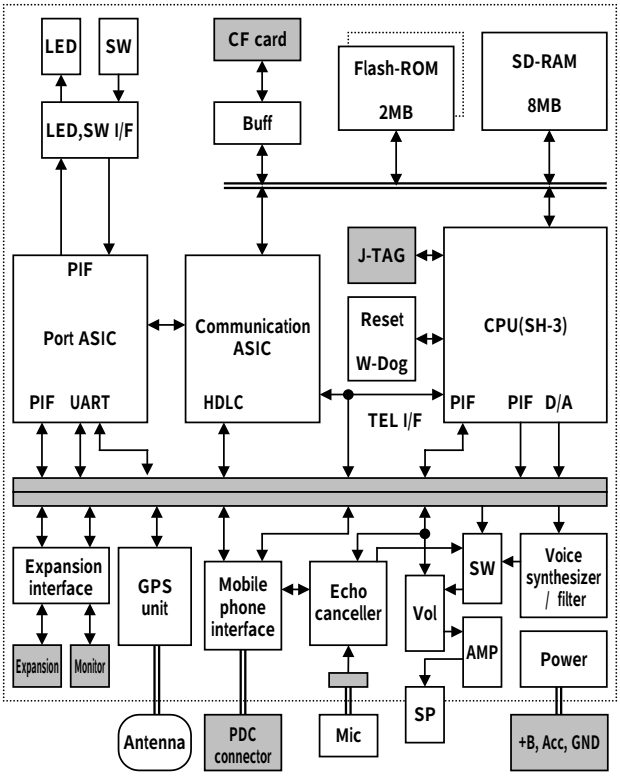

Fig.3 Block diagram of OBVIOUS in-car unit

Speech synthesis obtained production level performance with 8-bit PCM (11-kHz sampling) and 3-kHz fifth-order LPF.

With regard to hands-free calling, a digital signal processor (DSP) system and switching system were compared and examined from the perspective of cost and performance; then the DSP system was adopted for use based on its practicality (Table 2).

Table 2 Comparison of hands-free systems

Method	Feature	Cost
D S P	Simultaneous communication through the echo canceller.	Expensive
Switching	Automatic switching oftransmitting and receiving level comparison.	Inexpensive

With priority given to cost, a resin-formed solid construction was adopted (see photograph at beginning). The printed circuit board was given a double-board structure; and for compactness, an 8-layer printed circuit board was adopted for the CPU unit.

(2) Functions

① Transmission of movements

hrough packet communications, mobile station information (movement) is transmitted to a computer at the office. Transmitted information includes the following:

- Status of mobile station as preset by button operation
- Coordinates (latitude and longitude) positioned by GPS
- Direction of mobile station movement
- Time of operation (time obtained by GPS)
- Mobile station information that was input from external terminal (Can be used for door opening/closing and cargo room temperature sensors, for instance.)

The aforementioned movements are transmitted when the following events occur:

- When buttons are operated
- When change in status of external input is detected
- When certain time has passed (example: 20 minutes)
- When certain distance has been traveled (example: linear distance of 10 km or more)
- When polling from office computer is received
- When passing point has been arrived at or departed※

When a vehicle is underground, in a tunnel, or in the mountains, preventing packet communication when a transmission event has occurred (outside of a packet zone), up to ten units of transmission contents will be stored by the in-car terminal and will be transmitted in a batch when communication becomes possible.

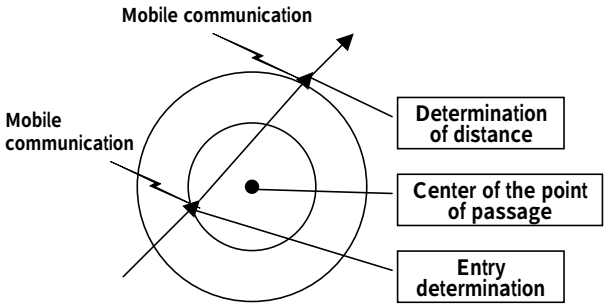

Fig.4 Transit points

※ Passing point: Transit point (area) information is marked with double circles on an office computer map ahead of time, and is transmitted/registered to each in-car terminal. The in-car terminal determines the

acceptability of the hysteretic characteristics using double circles, and transmits the vehicle's movements when a given area has been sufficiently entered and when the area has been completely departed (Figure 4). The in-car terminal can store up to 250 items of passing point information.

② Speech synthesis

When a message with accent symbols is received from the office, it is read aloud through speech synthesis. The latest five messages can be stored and then read aloud by operation of the message playback switch. Messages can be received in either secret mode or normal mode. In secret mode, a message is not read when received; rather, a buzzer sounds and a message lamp blinks, informing the user that there is an unread message. Speech synthesis is also used for error messages and guidance related to the operation of the in-car terminal itself.

③ Hands-free calling

Hands-free calling is possible through the use of a speaker and microphone. To support transmission operations, buttons #1 thru #8 are linked to the mobile phone's abbreviated numbers 101 thru 108; and using a two-touch operation consisting of "Abbreviated dialing" and "1," a call can be made to the telephone number that is stored for the mobile phone's "Abbreviated 101."

3.2 Packet communications

3.2.1 HDLC ASIC development and its functions

It is necessary to materialize the High-level Data Link Control (HDLC) that has been adopted for mobile phone packet communications. To reduce CPU Loads however, an application-specific integrated circuit (ASIC) was developed.

Figure 5 shows a block diagram, while Figure 6 shows the communications data format. The major functions of this ASIC are listed below.

① Automatic insertion and detection of starting and ending flags

When starting and ending flags are automatically inserted, data such as that shown in Figure 6 will be transmitted as a single frame; and when such flags are automatically detected during reception, a single frame of data will be received.

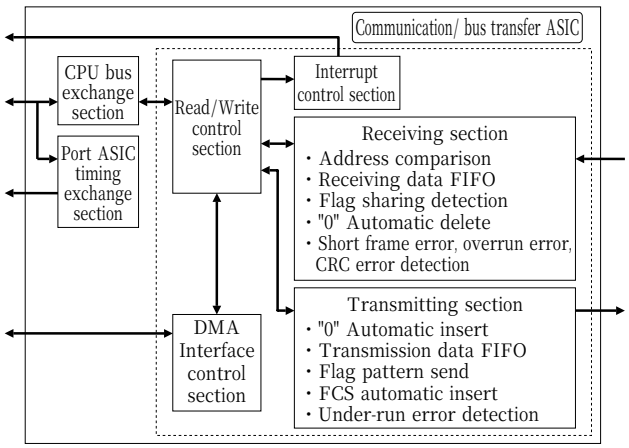

Fig.5 Internal layout of ASIC

Start flag (0111 1110)	Address field 1 byte	Information field n bytes	Frame check sequence 2 bytes	End flag (0111 1110)

Fig.6 Transmit/Receive data format

② Address comparison

As shown in Figure 6, communications data has one-byte address fields. Data will be received if the one byte of address field data match with either of the two preset types of addresses.

③ DMA transfer of transmitted and received data

Transmitted data FIFO is built in with four levels, while received data FIFO is built in with four levels. Through direct memory access (DMA) transfer, the CPU load is reduced and continuous transmission and reception are supported.

④ Sharing of starting and ending flags

During the continuous reception of reception frame data, normally, ending flags and starting flags will be continuous. As shown in Figure 7, a 1-bit logic "0" will be shared by the starting flag and ending flag. This shared bit will be recognized, and continuous frame reception will be executed.

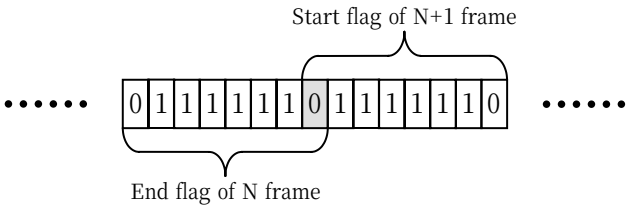

Fig.7 Sharing of flag "0" bit

⑤ Automatic insertion and deletion of "0"

When a continuous 5-bit logic "1" is detected among the transmission frame data, a 1-bit logic "0" will

automatically be inserted afterward. And when a continuous 5-bit logic "1" is detected among the reception frame data, the 1-bit logic "0" will automatically be deleted afterward.

⑥ Flag pattern and FCS automatic transmission
If, under clear-to-send conditions, no data needs to be transmitted, a logic "1" or flag pattern (01111110) will be transmitted; moreover, a cyclic redundancy check (CRC) operation of the data between the starting flag and ending flag will be performed, and an FCS will automatically be transmitted.

⑦ Detection of errors
Underrun errors will be detected during transmission, and short frame errors, overrun errors, and CRC errors will be detected during reception. Corresponding interruptions can then be requested.

3.2.2 Development of software modem

(1) What is a Software modem ?

When data communications are carried out by personal computer using a mobile phone, a special data communications interface card, which acts as the interface with the mobile phone, is connected to the PC. Communication becomes possible when the card is recognized by the PC as a modem device.

A software modem is a driver/server-level program that provides dial-up and hands-free functions by preparing a special application program interface (API) for the application. Installed in place of a data communications interface card, the software modem performs the card's call control and communications control functions with software on the CPU. Figure 8 shows the relationship between the software modem and application, as well as the functions performed by each.

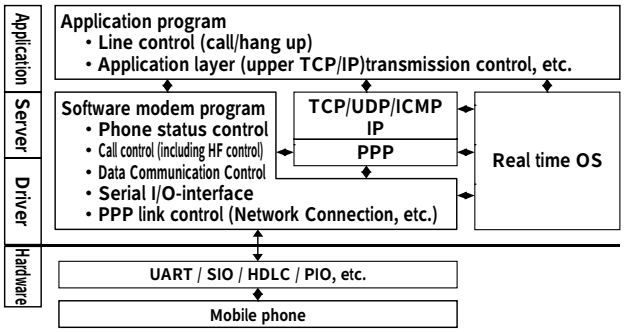

Fig.8 Relationship and functions of software modem and application

To enable DoPa to be used with the OBVIOUS system, a software modem was developed by applying software modem technology that was established with MONET (PDC circuit switching system, cdmaOne circuit switching system, and cdmaOne packet switching system) and by adding communications functions of the PDC packet switching system.

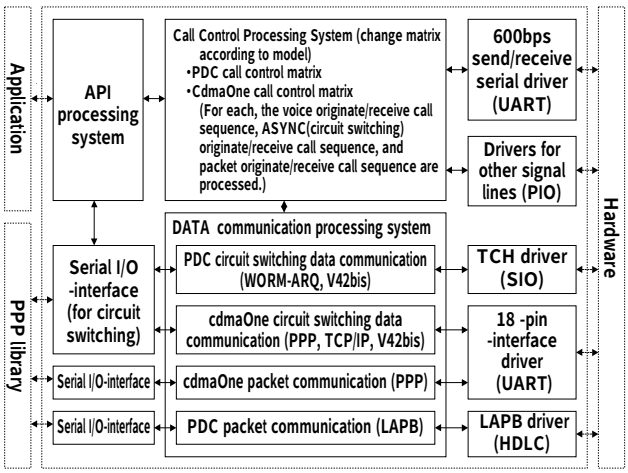

Fig.9 General view of the block diagram within the software modem

The connection between the mobile phone and data communications interface equipment is specified to be a 16-pin IF connector (or 18-pin IF connector for cdmaOne). Each piece of equipment is equipped with serial communications lines that are separated by call control system and data communications system. Broadly speaking, as shown in Figure 9, the recently developed OBVIOUS software modem consists of two processing systems; and the processing of each communication protocol is divided between the processing systems.

(2) PDC-P (PDC packet) communications control

With PDC-P, the datalink layer protocol of the data communications line between the mobile phone and data communications interface equipment is Link Access Procedure Balanced (LAPB). It is specified by X.25 Layer 2 specifications and applied to ISDN B channel packet exchange as well.

The LAPB frame configuration is the HDLC frame format. The unnumbered (U), supervisory (S), and information (I) frames are defined according to the format of the control field included in the frame.

PDC-P communications control flows in this manner. First, the packet call origination sequence is

processed in the call control line. Then after the connection in the wireless zone is completed, the LAPB link setup (SABM-UA) will begin with the unnumbered (U) frame on the data communications line.

After the LAPB link has been established, the transmission/reception packet (PPP frame) of the higher layer is stored in the information (I) frame, and exchanges take place between each node. Also, flow control and retransmission control (for error correction) are executed between the nodes by combining transmission/reception sequence numbers and supervisory (S) frames.

Figure 10 shows the data flow and contents of layer processing that occur during PDC-P communications with a software modem. As with other communication protocol modules, a serial I/O interface is installed for LAPB tasks.

(3) Performance

The throughput with file transfer protocol (FTP) was measured, and the performance of the software modem was evaluated. The results of throughput measurements according to method of communication are shown in Table 3.

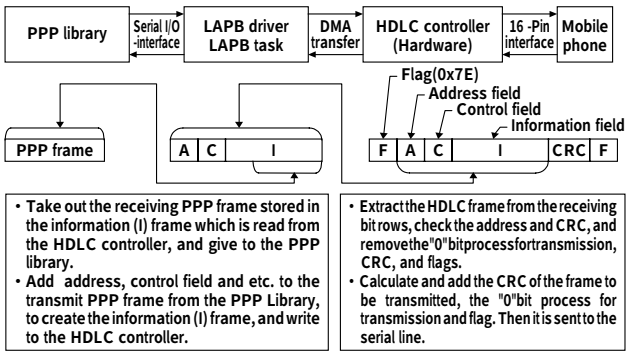

Fig.10 Data flow and processing for PDC-P communications

Table 3 Results of throughput measurements according to communication protocol

Measurement method : FTP file transfer (upload/download)
Transfer file : PN pattern file (size: 100kbytes)
FTP server : PDC packet communications-are in the company test server. Others are at www3.dion.ne.jp

Method of communication / Transfer direction	Upload	Download
PDC circuit switch	1.706 (1.664)	1.619 (1.572)
PDC packet switch	0.917 (0.883)	1.033 (0.902)
cdmaOne circuit switch	4.770 (2.696)	4.123 (2.673)
cdmaOne packet switch	1.613 (1.570)	7.710 (6.666)

Figures in kbytes/sec (1kbyte=1024byte)

Note: Values within the ( ) in the table are measured values with a PC and a retail data communication interface card.

If TCP/IP and PPP overhead are taken into account, the wireless zone communications speed is likely to be achieved with all communication protocols.

4. Office

(1) Overview

Table 4 shows the system requirements of packaged software.

Table 4 PC System Requirement for Packaged Software

Configuration	Outline
PC	Dos/V (IBM compatible) PC
(CPU)	Intel Pentium III over 500MHz Note 5)
(Main Memory)	Over 256 MB
(Hard disk)	Over 20 GB
(OS)	Microsoft Windows NT 4.0 Note 6)
(Magneto-Optical Disk)	Over 230MB
Mapdata	Zenrin wide area map data (residential map is optional)
Mapdisplaysoftware	Kernel ActiveMap is- Note 7)

Information received from the mobile station is accumulated, and the position and movement of the mobile station appear on the screen of the personal computer. Also, the current position and movement of a mobile station in use can be displayed by polling. (a mobile station position request command) Mobile station markers, movement, and times appear on a map on the computer screen (Figures 11 and 12).

(2) Functions

Figure 5 shows a list of packaged software functions. Here is a supplementary explanation of the items that appear in the aforementioned table.

① Home position registration

The home position is established in order to quickly update the location and magnification of the map display. The center position and display magnification are stored as one set.

② Passing point registration

This is a mobile station detection area registration (designation by latitude, longitude, and double circle radius). Notification of entry and departure can be selected and indicated.

Note 5: Pentium: Registered trademark of Intel Corporation

Note 6: Windows NT: Registered trademark of Microsoft Corporation (U.S.)

Note 7: ActiveMap is: Registered trademark of Kernel Concept

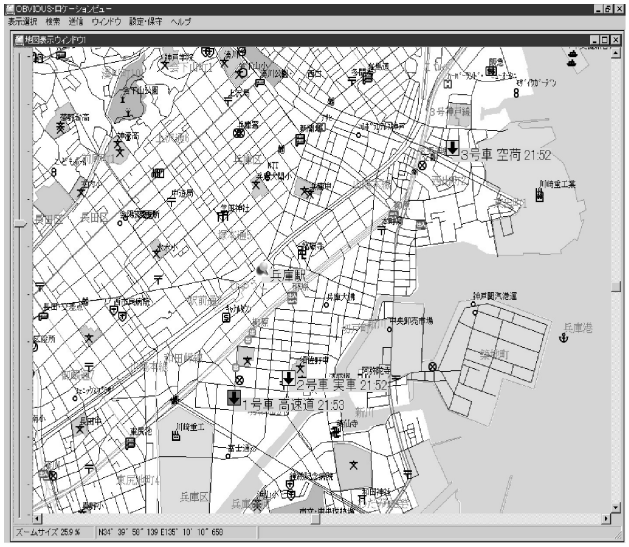

Fig.11 PC display screen example

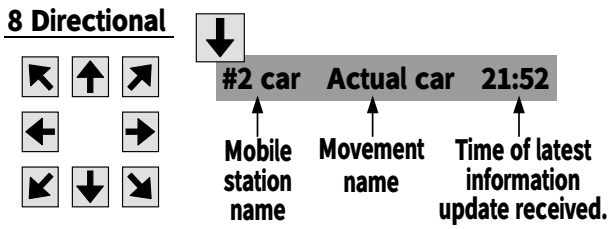

Fig.12 Mobile station markers and display contents

Table 5 Functions of packaged software in office

Major item	Middle item	Feature contents
Map display feature	Map selection	Japan, all area- city maps and residential maps (residential maps are optional)
		Zoom in/out by display multiplier control.
		Can display up to 4 screens simultaneously.
		Home position (Total 20 locations)
	Map display control	Specified vehicle center display
		Points of passage, user landmark center display
		Drag movement/ scroll movement
		Drive route history display
	Map search	Map display from latitude / longitude entry
		Map display from address/ postal code, target building search
		Map display from home name search(when using residential map)
Registration feature	Vehicle registration	Max 500 vehicles, max 25 Groups
	Point of passage	Max 2500 locations (100 locations × 25 Groups)
Communication features	Packet communication	1 selected vehicle, multiple vehicles, group selection, all vehicles selection,
	Audio message	Kana data send with accent markings, (listing available of vehicles that were not reachable) fixed messages(20 types), free message.
	E-mail	E-mail sent is indicated with upper level voice message.
File management	Operation record	The record of operation received from the mobile station is output as a CSV file.
	Data save	Storage/ save / delete of operational record (MDB, CSV) information.
Continuous form print out	Daily report print out	Specify date and time range/ dynamics, and print for each vehicle.
Other	Hardcopy	Output a hardcopy of the display screen.

③ User landmark registration

Symbol marks can be displayed as landmarks on the map.

④ Display of mobile stations whose service is completed

When the movement button defined as "Complete" (one of buttons #1 thru #8) is pressed and its signal received from the mobile station, the station will disappear from the screen display.

This is because when several terminated mobile stations are located together in the same parking garage, the markers displayed on the screen would stack up and be difficult to see.

⑤ File control

As operation results accumulate, available space on the hard disk gradually diminishes. For this reason, after a designated period of time has passed, the information is stored on a magneto-optical (MO) disk and then deleted from the hard disk in order to maintain space.

⑥ Voice messages

Kana characters with accent symbols can be transmitted to mobile stations that are currently in motion. Fixed messages that are used frequently can be selected and transmitted from a menu if they are recorded ahead of time. Free message transmission is also possible.

Fig.13 Image diagram of voice message transmission

⑦ E- mail transmission

A mobile station that is in motion can transmit e-mail, via the provider with whom the customer has a contract, to a mobile phone that is utilized for packet transmission.

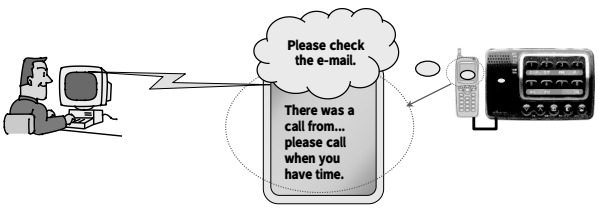

Fig.14 Image diagram of E-mail transmission

On the mobile station side, the user will be notified by voice message ("Please check your e-mail"). After the completion of packet communication with the office through "Hook" button operation from the in-car terminal, incoming mail can be read via the mobile phone. Limits are placed on the time that it takes to operate the "Hook" button and receive mail. When the specified time passes, packet communication with the office begins again.

(3) Configuration

Figure 15 shows the hierarchical structure that is involved in executing packet communication with a mobile station and in displaying maps. Communication with an external packet communications network is accomplished by TCP/IP. Two-way communication is executed inside the personal computer via the socket API (application program interface). Communications middleware consists of control of communication with mobile stations, movement control via information obtained through communication, movement access library for controlling access to MDB, and master maintenance. And with the development of an OCX interface (separate product), software vendors can now develop other user applications with a minimal amount of work by using in-car terminals. Figure 16 summarizes the flow of information, including that of the mobile station.

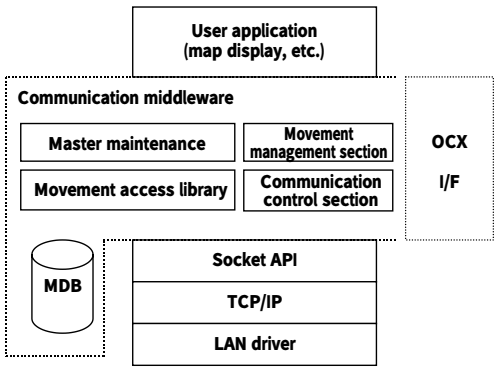

Fig.15 Layer structure diagram

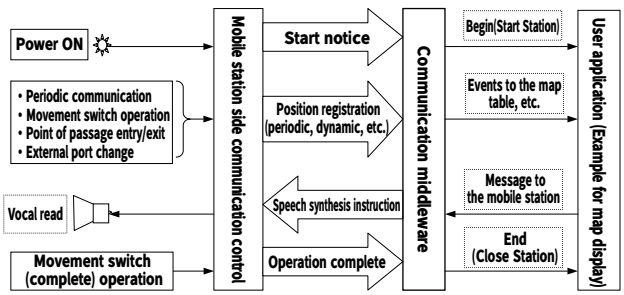

Fig.16 Information linkage diagram

5. Future developments

Since sales began, there have been a large number of inquiries about the system; moreover, companies are using the system in various ways. This has given us a new realization of the size of the position information business (position commerce).

To further broaden usage in the future, we are planning to expand the system's functions. For instance, to create an application for compact flash cards, we plan to expand the functions in order to collect detailed performance information. This will be accomplished by sequentially recording the operation results, including mobile station position information, and then batch-processing the information via a personal computer in the office after operation is completed.

In closing we wish to express our deep gratitude to those members of Zenrin Co., Ltd., Kernel Concept, Inc.and the various communications companies who provided us with guidance during the development of this product.

References

Keishima et al:Development of Radio Module, Fujitsu Ten Technical Report, Vol. 18, No. 1 (2000)

Kitani et al:In-Car Terminal for New Operations, Fujitsu Ten Technical Report, Vol. 17, No. 2 (1999)

Kamai et al:MONET-compatible In-Car Information Terminal, Fujitsu Ten Technical Report, Vol. 16, No. 1 (1998)

Profiles of Writers

Masato Maruoka

Joined the company in 1986. Since that time, has engaged in development of communications equipment. Currently in the SD2 Project Manager of System R & D Department at Engineering Division 3, A.V.C. Products Group.

Shigehiko Kagotani

Joined the company in 1995. Since that time, has engaged in development of digital applications equipment software. Currently in the SD2 Project of System R & D Department at Engineering Division 3, A.V.C. Products Group.

Hirotake Susami

Joined the company in 1995. Since that time, has engaged in design and development of digital ICs. Currently in the L2 Project at LSI Research & Development Department.

Masataka Mizuno

Joined the company in 1974. Since that time, has engaged in development of audio equipment and communications systems software. Currently in the Planning Section of Engineering Division 3 at A.V.C. Products Group.

Yoshikazu Chujo

Joined the company in 1982. Since that time, has engaged in development of communications equipment. Currently in the TE Project of Engineering Department at Engineering Division 3, A.V.C. Products Group.