

DESCRIPTION

TITLE OF INVENTION

AREA SETTING DEVICE, AREA SETTING SYSTEM, AREA SETTING METHOD, AND COMPUTER PROGRAM

TECHNICAL FIELD

[0001]

The present invention relates to an area setting device, an area setting system, an area setting method, and a computer program.

This application claims priority on Japanese Patent Application No. 2016-211832 filed on October 28, 2016, the entire contents of which are incorporated herein by reference.

BACKGROUND ART

[0002]

In recent years, intelligent transport systems (ITS) based on roadside-to-vehicle communication and vehicle-to-vehicle communication have been studied (refer to Non-Patent Literature 1, for example).

The roadside-to-vehicle communication is a communication between a roadside communication device and an on-vehicle communication device (mobile communication device), and the vehicle-to-vehicle communication is a communication between on-vehicle communication devices (mobile communication devices).

CITATION LIST

[PATENT LITERATURE]

[0003]

PATENT LITERATURE 1: Japanese Laid-Open Patent Publication No. 08-2285

SUMMARY OF INVENTION**[SOLUTION TO PROBLEM]**

[0004]

An area setting device according to one embodiment includes: a reception unit configured to receive radio signals transmitted from a plurality of on-vehicle communication devices traveling on a road; a first calculation section configured to calculate a plurality of coverage areas in which the reception unit can receive the radio signals, for the plurality of the on-vehicle communication devices, respectively, on the basis of pieces of vehicle information, of the plurality of the on-vehicle communication devices, included in reception signals received by the reception unit; a second calculation section configured to calculate, on the basis of the plurality of coverage areas, a reliability area that is determined corresponding to reception reliability indicating a probability that the radio signals are received by the reception unit; and an area setting section configured to set, on the basis of the reliability area, a specific area for specifying control information to be used for control of a traffic signal unit installed on the road, from among the pieces of vehicle information.

[0005]

An area setting system according to one embodiment includes: a roadside communication device capable of receiving radio signals transmitted from a plurality of on-vehicle communication devices traveling on a road; a first calculation section configured to calculate a plurality of coverage areas in which the roadside communication device can receive the radio signals, for the plurality of the on-vehicle communication devices, respectively, on the basis of pieces of vehicle information, of the plurality of the on-vehicle communication devices, included in reception signals obtained when the roadside communication device receives the

radio signals; a second calculation section configured to calculate, on the basis of the plurality of coverage areas, a reliability area that is determined corresponding to reception reliability indicating a probability that the radio signals are received by the roadside communication device; and an area setting section configured to set, on the basis of the reliability area, a specific area for specifying control information to be used for control of a traffic signal unit installed on the road, from among the pieces of vehicle information.

[0006]

An area setting method according to one embodiment is a method for setting a specific area for specifying control information to be used for control of a traffic signal unit installed on a road, from among pieces of vehicle information of a plurality of on-vehicle communication devices traveling on the road, the pieces of vehicle information being included in reception signals of a reception unit configured to receive radio signals from the plurality of the on-vehicle communication devices. The method includes: a first calculation step of calculating a plurality of coverage areas in which the reception unit can receive the radio signals, for the plurality of the on-vehicle communication devices, respectively, on the basis of the pieces of vehicle information; a second calculation step of calculating, on the basis of the plurality of coverage areas, a reliability area that is determined corresponding to reception reliability indicating a probability that the radio signals are received by the reception unit; and an area setting step of setting the specific area on the basis of the reliability area.

[0007]

A computer program according to one embodiment is a computer program for causing a computer to execute a process for setting a specific area for specifying control information to be used for control of a traffic signal unit installed on a road, from among pieces of vehicle information of a plurality of on-vehicle communication devices traveling on the road, the pieces of vehicle information being included in reception signals of a reception unit

configured to receive radio signals from the plurality of the on-vehicle communication devices. The computer program causes the computer to execute: a first calculation step of calculating a plurality of coverage areas in which the reception unit can receive the radio signals, for the plurality of the on-vehicle communication devices, respectively, on the basis of the pieces of vehicle information; a second calculation step of calculating, on the basis of the plurality of coverage areas, a reliability area that is determined corresponding to reception reliability indicating a probability that the radio signals are received by the reception unit; and an area setting step of setting the specific area on the basis of the reliability area.

[0008]

An area setting device according to one embodiment includes: a reception unit configured to receive radio signals transmitted from a plurality of on-vehicle communication devices traveling on a road; a first calculation section configured to calculate a plurality of coverage areas in which the reception unit can receive the radio signals, for the plurality of the on-vehicle communication devices, respectively, on the basis of pieces of vehicle information, of the plurality of the on-vehicle communication devices, included in reception signals received by the reception unit; and an area setting section configured to set, on the basis of the plurality of coverage areas, a specific area for specifying control information to be used for control of a traffic signal unit installed on the road, from among the pieces of vehicle information.

BRIEF DESCRIPTION OF DRAWINGS

[0009]

[FIG. 1] FIG. 1 is a perspective view schematically showing an overall structure of an intelligent transport system (ITS) according to an embodiment.

[FIG. 2] FIG. 2 is a diagram showing examples of a radio frame used in a wireless communication system of the present embodiment, transmission-inhibited periods of

respective communication devices, and the like.

[FIG. 3] FIG. 3 is a block diagram showing the structures of a roadside communication device, an on-vehicle communication device, a central apparatus, and a traffic signal controller according to the present embodiment.

[FIG. 4] FIG. 4 is an enlarged view of a part, of FIG. 1, around an intersection.

[FIG. 5] FIG. 5 is a flowchart showing an example of a coverage area calculation process.

[FIG. 6] FIG. 6 is a diagram showing an example of reception conditions of vehicle information transmitted from on-vehicle communication devices on a road.

[FIG. 7] FIG. 7 is a diagram showing an example of a coverage area table.

[FIG. 8] FIG. 8 is a flowchart showing an example of a side-road vehicle determination process in FIG. 6.

[FIG. 9] FIG. 9 is a flowchart showing an example of a reliability area calculation process.

[FIG. 10] FIG. 10 is a diagram showing an example of cumulative frequency distribution regarding coverage area end distances.

[FIG. 11] FIG. 11 is an explanatory diagram showing a process of obtaining a queue length, which is performed by a queue length calculation section.

[FIG. 12] FIG. 12 is an explanatory diagram showing a traffic volume calculation process performed by an actuated control processing section.

[FIG. 13] FIG. 13 is a block diagram showing the structures of a roadside communication device, an on-vehicle communication device, a central apparatus, and a traffic signal controller according to another embodiment.

[FIG. 14] FIG. 14 is a diagram showing an example of a case where a roadside communication device is installed at a position distant from an intersection at which a traffic

signal unit is installed.

DESCRIPTION OF EMBODIMENTS

[0010]

[Problems to be solved by the disclosure]

In the system described above, a roadside communication device is installed at each of predetermined points on roads, and performs wireless transmission to on-vehicle communication devices to execute serves such as provision of information, thereby performing safe driving support.

On the other hand, each on-vehicle communication device provides, to another on-vehicle communication device, vehicle information thereof such as positional information and speed information through vehicle-to-vehicle communication, as well as the services provided from the roadside communication device, and obtains vehicle information of the other on-vehicle communication device, thereby performing safe driving support.

[0011]

The roadside communication device is able to receive a radio signal transmitted from each on-vehicle communication device, and obtain vehicle information, of the on-vehicle communication device, included in the received radio signal.

It is considered that vehicle information, of an on-vehicle communication device, which is included in a radio signal transmitted from the on-vehicle communication device and received by the roadside communication device, is used for control of a traffic signal unit.

[0012]

However, a coverage area in which the roadside communication device can receive a radio signal from an on-vehicle communication device may vary depending on transmission path environment between the roadside communication device and the on-vehicle

communication device, change of each device due to aging, or the like, and depending on difference in transmission powers due to individual differences of on-vehicle communication devices.

[0013]

In controlling a traffic signal unit, for example, the following information may be needed: information regarding traffic around the traffic signal unit; and vehicle information regarding vehicles corresponding to a predetermined percentage of vehicles that pass through a predetermined point at a predetermined distance upstream of the traffic signal unit.

However, if the coverage area varies among different on-vehicle communication devices, a situation may occur where the roadside communication device can receive a radio signal from one on-vehicle communication device to obtain vehicle information thereof, but cannot receive a radio signal from another on-vehicle communication device positioned at the same point, and cannot obtain vehicle information thereof.

[0014]

As described above, if the coverage area varies among different on-vehicle communication devices, radio signals from the on-vehicle communication devices cannot be received at the predetermined position with a certain probability and therefore vehicle information cannot be stably obtained, which may interfere with appropriate use of the obtained vehicle information for control of the traffic signal unit.

That is, even if all the vehicle information obtained from the respective on-vehicle communication devices is attempted to be used, since the coverage area varies among the on-vehicle communication devices, the vehicle information may not be appropriately used as information for controlling the traffic signal unit.

Therefore, it is desired to set an area for specifying information that can be appropriately used as information for controlling the traffic signal unit, from among the obtained

vehicle information.

[0015]

The present disclosure has been made in view of the above situation, and it is an object of the present disclosure to provide a technique for setting an area for specifying information that can be appropriately used as information for controlling a traffic signal unit.

[0016]

[Effect of present disclosure]

According to the present disclosure, it is possible to set an area for specifying information that can be appropriately used for control of a traffic signal unit.

[0017]

[Description of embodiment]

First, contents of embodiments of the present invention are listed and described.

(1) An area setting device according to one embodiment includes: a reception unit configured to receive radio signals transmitted from a plurality of on-vehicle communication devices traveling on a road; first calculation section configured to calculate a plurality of coverage areas in which the reception unit can receive the radio signals, for the plurality of the on-vehicle communication devices, respectively, on the basis of pieces of vehicle information, of the plurality of the on-vehicle communication devices, included in reception signals received by the reception unit; a second calculation section configured to calculate, on the basis of the plurality of coverage areas, a reliability area that is determined corresponding to reception reliability indicating a probability that the radio signals are received by the reception unit; and an area setting section configured to set, on the basis of the reliability area, a specific area for specifying control information to be used for control of a traffic signal unit installed on the road, from among the pieces of vehicle information.

[0018]

According to the above structure, the specific area can be set on the basis of the reliability area having reception reliability according to control of the traffic signal unit.

Therefore, even if variation occurs among the plurality of coverage areas, the specific area allows vehicle information, which is received with a certain reception probability according to control of the traffic signal unit and is appropriately usable as control information for the traffic signal unit, to be specified from among the pieces of vehicle information received by the reception unit.

Thus, according to the present embodiment, the specific area can be set as an area that can specify vehicle information appropriately usable as control information for the traffic signal unit.

[0019]

(2) In the area setting section, the reliability area preferably corresponds to reception reliability necessary for control of the traffic signal unit. In this case, the specific area can be set as an area that can specify vehicle information more appropriately usable as control information for the traffic signal unit.

[0020]

(3) The second calculation section may calculate a plurality of the reliability areas corresponding to a plurality of the reception reliability, and the area setting section may select a reliability area having reception reliability necessary for control of the traffic signal unit, from among the plurality of the reliability areas. In this case, setting of the specific area is facilitated.

[0021]

(4) In the area setting device, the traffic signal unit is preferably installed at an intersection, and the first calculation section, the second calculation section, and the area setting section preferably perform, for each of paths at the intersection, calculation of the coverage area,

calculation of the reliability area, and setting of the specific area, respectively.

In this case, a specific area can be set for each of the paths at the intersection.

[0022]

(5) In the area setting device, the control information may be used for obtaining a queue length at the traffic signal unit.

(6) The control information may be used for actuated control of the traffic signal unit.

[0023]

(7) In the area setting device, the first calculation section may determine, on the basis of the vehicle information included in each reception signal, whether or not the reception signal is a reception signal from an inflow on-vehicle communication device that enters the road from a crossing path that crosses the road. Upon determining that the reception signal is a reception signal from an inflow on-vehicle communication device, the first calculation section may suspend calculation of the coverage area for the reception signal.

In this case, the inflow on-vehicle communication device that enters from the crossing path can be excluded when setting the specific area.

[0024]

(8) An area setting system according to one embodiment includes: a roadside communication device capable of receiving radio signals transmitted from a plurality of on-vehicle communication devices traveling on a road; a first calculation section configured to calculate a plurality of coverage areas in which the roadside communication device can receive the radio signals, for the plurality of the on-vehicle communication devices, respectively, on the basis of pieces of vehicle information, of the plurality of the on-vehicle communication devices, included in reception signals obtained when the roadside communication device receives the radio signals; a second calculation section configured to calculate, on the basis of the plurality of

coverage areas, a reliability area that is determined corresponding to reception reliability indicating a probability that the radio signals are received by the roadside communication device; and an area setting section configured to set, on the basis of the reliability area, a specific area for specifying control information to be used for control of a traffic signal unit installed on the road, from among the pieces of vehicle information.

[0025]

(9) An area setting method according to one embodiment is a method for setting a specific area for specifying control information to be used for control of a traffic signal unit installed on the road, from among pieces of vehicle information of a plurality of on-vehicle communication devices traveling on the road, the pieces of vehicle information being included in reception signals of a reception unit configured to receive radio signals from the plurality of the on-vehicle communication devices. The method includes: a first calculation step of calculating a plurality of coverage areas in which the reception unit can receive the radio signals, for the plurality of the on-vehicle communication devices, respectively, on the basis of the pieces of vehicle information; a second calculation step of calculating, on the basis of the plurality of coverage areas, a reliability area that is determined corresponding to reception reliability indicating a probability that the radio signals are received by the reception unit; and an area setting step of setting the specific area on the basis of the reliability area.

[0026]

(10) A computer program according to one embodiment is a computer program for causing a computer to execute a process for setting a specific area for specifying control information to be used for control of a traffic signal unit installed on a road, from among pieces of vehicle information of a plurality of on-vehicle communication devices traveling on the road, the pieces of vehicle information being included in reception signals of a reception unit configured to receive radio signals from the plurality of the on-vehicle communication devices.

The computer program causing the computer to execute: a first calculation step of calculating a plurality of coverage areas in which the reception unit can receive the radio signals, for the plurality of the on-vehicle communication devices, respectively, on the basis of the pieces of vehicle information; a second calculation step of calculating, on the basis of the plurality of coverage areas, a reliability area that is determined corresponding to reception reliability indicating a probability that the radio signals are received by the reception unit; and an area setting step of setting the specific area on the basis of the reliability area.

[0027]

(11) An area setting device according to one embodiment includes: a reception unit configured to receive radio signals transmitted from a plurality of on-vehicle communication devices traveling on a road; a first calculation section configured to calculate a plurality of coverage areas in which the reception unit can receive the radio signals, for the plurality of the on-vehicle communication devices, respectively, on the basis of pieces of vehicle information, of the plurality of the on-vehicle communication devices, included in reception signals received by the reception unit; and an area setting section configured to set, on the basis of the plurality of coverage areas, a specific area for specifying control information to be used for control of a traffic signal unit installed on the road, from among the pieces of vehicle information.

[0028]

[Details of embodiments]

Hereinafter, preferable embodiments will be described with reference to the drawings.

At least some parts of the embodiments described below may be combined together as desired.

[Overall structure of system]

FIG. 1 is a perspective view schematically showing an overall structure of an

intelligent transport system (ITS) according to an embodiment. In this embodiment, as an example of a road structure, a grid-pattern structure is assumed in which a plurality of roads in a north-to-south direction and a plurality of roads in an east-to-west direction intersect with each other.

As shown in FIG. 1, the intelligent transport system of the present embodiment includes: traffic signal units 1; traffic signal controllers 10; roadside communication devices 2; on-vehicle communication devices (mobile communication devices) 3; a central apparatus 4; vehicles 5 each being equipped with an on-vehicle communication device 3; and roadside detectors 6 each including a vehicle detector or a monitor camera or the like.

[0029]

A traffic signal unit 1, a traffic signal controller 10, and a roadside communication device 2 are installed at each of a plurality of intersections J1 to J12, and are connected to a router 8 via a cable communication line 7 such as a telephone line. This router 8 is connected to the central apparatus 4 in a traffic control center.

The central apparatus 4 establishes a LAN (Local Area Network) with the traffic signal units 1, the traffic signal controllers 10, and the roadside communication devices 2 in an area that the central apparatus 4 covers. Therefore, bidirectional communication can be performed between the central apparatus 4 and each traffic signal controller 10, between the central apparatus 4 and each roadside communication device 2, and between each traffic signal controller 10 and each roadside communication device 2.

The central apparatus 4 may be installed not in the traffic control center but on a road.

[0030]

The roadside detectors 6 are installed at various points on roads within the area that the central apparatus 4 covers, for the purpose of, for example, counting the number of

vehicles that enter or exit each intersection. Each roadside detector 6 is composed of, for example, a vehicle detector that detects a vehicle 5 traveling directly below the vehicle detector by means of an ultrasonic wave, or a monitor camera that time-sequentially photographs the traffic situation of the road. Detected information or image data obtained by the roadside detector 6 is transmitted to the central apparatus 4 via the communication line 7.

In FIG. 1, for the purpose of simplification, only one signal light unit is rendered at each intersection. However, at an actual intersection, at least four signal light units are installed for inbound and outbound lanes of roads that intersect with each other.

[0031]

In the intelligent transport system, a plurality of roadside communication devices 2 installed at the plurality of intersections, respectively, which are components of a wireless communication system, are able to perform wireless communication (roadside-to-vehicle communication) with on-vehicle communication devices 3 of vehicles traveling therearound.

Further, each roadside communication device 2 is able to perform wireless communication (roadside-to-roadside communication) with another roadside communication device 2 positioned within a predetermined reachable range of a transmission wave thereof.

Each of the on-vehicle communication devices 3, which are also components of the wireless communication system, performs wireless communication (vehicle-to-roadside communication) with each roadside communication device 2 by a carrier sensing method, and is able to perform wireless communication (vehicle-to-vehicle communication) with another on-vehicle communication device 3.

[0032]

The roadside-to-roadside communication is a communication performed between the roadside communication devices 2, and is performed when one roadside communication device 2 transmits a communication packet toward another roadside communication device 2.

The roadside-to-vehicle communication is a communication performed between each roadside communication device 2 and the on-vehicle communication devices 3, and is performed when the roadside communication device 2 broadcasts a communication packet (roadside-to-vehicle communication information) toward the on-vehicle communication devices 3.

The vehicle-to-vehicle communication is a communication performed between the on-vehicle communication devices 3, and is performed when each on-vehicle communication device 3 transmits a communication packet (vehicle-to-vehicle communication information) by the carrier sensing method.

The vehicle-to-roadside communication is a communication performed between each on-vehicle communication device 3 and each roadside communication device 2, and is performed when the on-vehicle communication device 3 transmits a communication packet (vehicle-to-roadside communication information) toward the roadside communication device 2 by the carrier sensing method.

[0033]

In this system, in order to realize coexistence of the respective communications such as the roadside-to-vehicle communication, the vehicle-to-vehicle communication, and the roadside-to-roadside communication performed between the roadside communication devices, a multi-access method based on Time Division Multiple Access (TDMA) is adopted, in which a time period for performing communication is divided to provide time slots to be exclusively used by each of the roadside communication devices for transmission.

[0034]

In the multi-access method based on TDMA, usually, a transmission time slot is periodically set for each of the roadside communication devices. Each roadside communication device performs transmission by using the transmission time slot that is periodically set for the

roadside communication device, and at other times, performs reception of transmission signals from other roadside communication devices or the on-vehicle communication devices.

[0035]

FIG. 2 is a diagram showing examples of a radio frame used in this wireless communication system, transmission-inhibited periods of the respective communication devices, and the like. In FIG. 2, (a) shows the radio frame used in this wireless communication system.

As shown in (a) of FIG. 2, the length (frame length) of the radio frame (super frame) in the time axis direction is set to 100 milliseconds. A plurality of radio frames are arrayed in the time axis direction. That is, 10 radio frames are arranged in one second.

[0036]

One radio frame includes a plurality of time slots 12.

The time slots 12 are communication time slots (roadside device communication periods) assigned to the roadside communication devices 2. A roadside communication device 2 whose transmission period is assigned to any of the time slots 12 sets, in the assigned time slot 12, the transmission period during which the roadside communication device 2 performs wireless transmission. At most, 16 time slots 12 can be set within one radio frame (100 milliseconds).

[0037]

Each time slot 12 is appended with a slot number (roadside-to-vehicle communication period number) n ($= 1$ to 16). The slot number n allows each roadside communication device 2 to recognize which time slot 12 is assigned thereto.

The time periods other than the time slots 12 assigned to the roadside communication devices 2 are time periods opened for carrier sensing type wireless transmission performed by the on-vehicle communication devices 3. Therefore, in the time periods other than the time slots 12 assigned to the roadside communication devices 2, wireless transmission by the roadside communication devices 2 is not performed.

[0038]

Among the plurality of time slots 12 included in the radio frame, one or a plurality of time slots 12 are assigned to each roadside communication device 2. The roadside communication device 2 is inhibited to perform transmission in the time periods other than the time slot 12 assigned thereto.

In FIG. 2, (b) shows examples of a transmission period and transmission-inhibited periods for the roadside communication device 2, which are set according to the radio frame. In FIG. 2, (b) shows the transmission-inhibited periods in a case where one time slot 12 having $n = 4$ is assigned to the roadside communication device 2. The roadside communication device 2 performs wireless transmission in a time period (transmission period) other than the transmission-inhibited periods.

[0039]

The plurality of time slots 12 are assigned to the respective roadside communication devices 2 so that interference does not occur between adjacent roadside communication devices 2.

Each roadside communication device 2 performs wireless transmission in a transmission period that depends on the assigned time slot 12.

The roadside communication device 2 packetizes application data generated by an application thereof, and transmits the packet in which the application data is stored, by using the time slot 12 (transmission period) assigned thereto.

[0040]

The roadside communication device 2, during the transmission-inhibited periods, intercepts radio signals of vehicle-to-vehicle communication, and receives roadside-to-vehicle communication packets and roadside-to-roadside communication packets transmitted from other roadside communication devices 2.

[0041]

In FIG. 2, (c) shows an example of transmission-inhibited periods of the on-vehicle communication devices 3. In FIG. 2, (c) shows the transmission-inhibited periods in a case where all the time slots 12 are assigned to any of the roadside communication devices 2.

As described above, the time periods other than the time slots 12 assigned to the roadside communication devices 2 are assigned for carrier sensing type wireless transmission performed by the on-vehicle communication devices 3. That is, when all the time slots 12 are assigned to the roadside communication devices 2 as shown in (c) of FIG. 2, the time periods corresponding to the respective time slots 12 are the transmission-inhibited periods.

The on-vehicle communication devices 3 perform carrier sensing type wireless transmission in the time periods other than the transmission-inhibited periods.

[0042]

Each on-vehicle communication device 3 attempts to perform wireless transmission at least one time during a time period corresponding to one radio frame. Therefore, if no collision occurs, each on-vehicle communication device 3 performs wireless transmission at least one time during one radio frame (100 milliseconds).

[0043]

As described above, the time periods other than the time slots 12 assigned to the roadside communication devices 2 are assigned as the time periods for wireless transmission of the on-vehicle communication devices 3. Therefore, if there is a time slot 12, among the time slots 12, that is not assigned to any of the roadside communication devices 2 and is not used, the time period corresponding to this time slot 12 is assigned for wireless transmission of the on-vehicle communication devices 3.

[0044]

[Structures of respective devices]

FIG. 3 is a block diagram showing the structures of the roadside communication device 2, the on-vehicle communication device 3, the central apparatus 4, and the traffic signal controller 10 of the present embodiment.

As shown in FIG. 3, the roadside communication device 2 includes: a wireless communication unit 16 for wireless communication, to which an antenna 15 is connected; a wired communication unit 17 configured to perform wired communication via a communication line 7; and a processing unit 18 configured to perform communication control and various kinds of processes.

The processing unit 18 has a function of controlling the wireless communication unit 16 and the wired communication unit 17 to perform processes regarding wireless communication and wired communication. Thus, the processing unit 18 performs roadside-to-vehicle communication and roadside-to-roadside communication, and performs wired communication with the central apparatus 4 and the traffic signal controller 10 via the communication line 7.

[0045]

The processing unit 18 is provided with a first calculation section 21, a second calculation section 22, an area setting section 23, and a specification section 24, as function sections performing a process of obtaining a coverage area, a reliability area, and a specific area which are described later, and a process of specifying information to be used for control of the traffic signal unit 1, from among pieces of vehicle information obtained from the on-vehicle communication devices 3. These functions will be described later in detail.

[0046]

The on-vehicle communication device 3 includes: a wireless communication unit 28, for wireless communication, to which an antenna 27 is connected; and a processing unit 29.

The processing unit 29 has a function of controlling the wireless communication

unit 28 to perform a process regarding wireless communication. Thus, the processing unit 29 performs vehicle-to-vehicle communication and roadside-to-vehicle communication.

The processing unit 29 includes a transmission section 30 configured to store, in a communication packet, vehicle information of the on-vehicle communication device 3, such as vehicle ID, positional information, vehicle speed information, and heading information, and causes the wireless communication unit 28 to wirelessly transmit the communication packet.

[0047]

The vehicle ID is identification information for identifying the on-vehicle communication device 3 (vehicle 5).

The positional information is information indicating the position of the on-vehicle communication device 3 when the communication packet is generated. The positional information is expressed by a latitude and a longitude.

The vehicle speed information is information indicating the speed of the vehicle 5 when the communication packet is generated. The heading information is information indicating the heading direction of the vehicle 5 when the communication packet is generated.

[0048]

The central apparatus 4 includes: a wired communication unit 35 configured to perform wired communication via the communication line 7; and a processing unit 36 configured to perform communication control and various kinds of processes.

The processing unit 36 has a function of controlling the wired communication unit 35 to perform a process regarding wired communication. Thus, the processing unit 36 performs wired communication, via the communication line 7, with the roadside communication device 2 and the traffic signal controller 10.

[0049]

The processing unit 36 includes a queue length calculation section 41 and an

actuated control processing section 42 as function sections performing processes regarding control of the traffic signal unit 1. These functions will be described later in detail.

[0050]

The traffic signal controller 10 includes: a wired communication unit 46 configured to perform wired communication via the communication line 7; and a processing unit 47 configured to perform communication control and various kinds of processes.

The processing unit 47 has a function of controlling the wired communication unit 46 to perform a process regarding wired communication. Thus, the processing unit 47 performs wired communication, via the communication line 7, with the roadside communication device 2 and the traffic signal controller 10.

The traffic signal unit 1 is connected to the wired communication unit 46, and the traffic signal controller 10 controls the traffic signal unit 1.

[0051]

The processing unit 47 includes a signal controller 48 as a function section for controlling the traffic signal unit 1. These functions will be described later in detail.

[0052]

Regarding the processing units 18, 29, 36, and 47, a part or the entirety of the function of each processing unit may be configured as a hardware circuit, or may be implemented by a computer program. Each of the processing units 18, 29, 36, and 47 includes a computer when a part or the entirety of the function thereof is implemented by a computer program, and the computer program for implementing each function is stored in a storage unit (not shown).

[0053]

[Specific area and coverage area]

FIG. 4 is an enlarged view of a part, of FIG. 1, around an intersection.

As shown in FIG. 4, the roadside communication device 2 is mounted to a post 1a of the traffic signal unit 1. The traffic signal controller 10 is installed near the intersection Ji.

[0054]

The roadside communication device 2 transmits a communication packet for roadside-to-vehicle communication toward the periphery of the intersection at which the roadside communication device 2 is installed, thereby performing services such as provision of information to the on-vehicle communication devices 3 positioned around the intersection.

[0055]

Further, the roadside communication device 2 can intercept a radio signal caused by vehicle-to-vehicle communication as described above, and has a function of obtaining vehicle information included in a communication packet received from an on-vehicle communication device 3.

In the system of the present embodiment, the traffic signal unit 1 is controlled by using the vehicle information included in the communication packet that is transmitted from the on-vehicle communication device 3 and obtained by the roadside communication device 2.

[0056]

The roadside communication device 2 receives a plurality of communication packets from the on-vehicle communication devices 3, specifies vehicle information to be used for control of the traffic signal unit 1 from among a plurality of pieces of vehicle information obtained from the plurality of communication packets, and provides the specified vehicle information to the central apparatus 4 as control information.

Based on the control information specified by the roadside communication device 2, the central apparatus 4 generates information necessary for control of the traffic signal unit 1, and provides a control command to the traffic signal controller 10, thereby controlling the traffic signal controller 10.

[0057]

In order to specify the control information from among the plurality of pieces of vehicle information, the roadside communication device 2 sets a specific area on each of the paths (roads) extending from the intersection Ji.

The vehicle information included in the communication packet that is transmitted from the on-vehicle communication device 3 and received by the roadside communication device 2, includes the aforementioned vehicle ID, positional information, vehicle speed information, and heading information.

The roadside communication device 2 refers to the positional information included in the vehicle information. When the positional information is within the specific area, the roadside communication device 2 specifies the vehicle information as control information, whereas when the positional information is outside the specific area, the roadside communication device 2 does not specify the vehicle information as control information.

[0058]

The roadside communication device 2 specifies, as control information, the vehicle information whose positional information is within the specific area, and provides the vehicle information to the central apparatus 4.

Regarding the specific area, reception reliability thereof (described later) is set to a value necessary for control of the traffic signal unit 1.

[0059]

In order to set the specific area, the roadside communication device 2 calculates an area (coverage area) in which the roadside communication device 2 can receive a radio signal caused by vehicle-to-vehicle communication, transmitted from an on-vehicle communication device 3.

The roadside communication device 2 calculates the coverage area on the basis of

positional information that is included, as vehicle information, in a communication packet from the on-vehicle communication device 3.

The roadside communication device 2 obtains the coverage area as a distance up to an upstream-side end of the area (coverage area end distance) when the position of a stop line of the intersection Ji is a reference position.

[0060]

The end of the coverage area is influenced by: transmission path environment that varies due to a building or the like between the roadside communication device 2 and the on-vehicle communication device 3; change of each device due to aging; or the like. The end of the coverage area is also influenced by, for example, difference in transmission powers due to individual differences of the on-vehicle communication devices.

Hence, the end of the coverage area may vary among different on-vehicle communication devices 3. Therefore, the roadside communication device 2 of the present embodiment calculates a plurality of coverage areas (coverage area end distances) for the plurality of on-vehicle communication devices 3, respectively.

[0061]

Further, in order to set the specific area, the roadside communication device 2 calculates a reliability area (described later) on the basis of the coverage area end distances of the plurality of on-vehicle communication devices 3. The reliability area is determined corresponding to reception reliability indicating a probability that each on-vehicle communication device 3 receives a transmitted communication packet.

[0062]

Although the following description is made for only one of the respective paths (roads) extending from the intersection Ji, similar processing is performed on other paths.

[0063]

[Calculation of coverage area]

Calculation of a coverage area (coverage area end distance) is executed by the first calculation section 21 (FIG. 3) of the roadside communication device 2. The first calculation section 21 calculates a coverage area at any time.

The first calculation section 21 calculates a coverage area for each on-vehicle communication device 3. The processing unit 18 includes a table (coverage area table) having, registered therein, a vehicle ID of each on-vehicle communication device 3 for which calculation of a coverage area has been done, and the result of the calculation.

Every time the first calculation section 21 calculates a coverage area, the first calculation section 21 registers the corresponding vehicle ID and the calculation result in this table.

[0064]

FIG. 5 is a flowchart showing an example of a coverage area calculation process.

First, the first calculation section 21 of the roadside communication device 2 receives a communication packet transmitted from an on-vehicle communication device 3, and determines whether or not the roadside communication device 2 has obtained vehicle information (step S2).

The first calculation section 21 repeats the determination in step S2 until determining that the roadside communication device 2 has obtained vehicle information.

[0065]

Upon determining that the roadside communication device 2 has obtained vehicle information, the first calculation section 21 refers to a vehicle ID included in the obtained vehicle information, and determines whether or not the vehicle ID of the obtained vehicle information is registered in the coverage area table (step S4).

[0066]

Upon determining that the vehicle ID of the obtained vehicle information is registered, the first calculation section 21 returns to step S2. Thus, redundant calculation of a coverage area of the same on-vehicle communication device 3 is avoided.

[0067]

Upon determining in step S4 that the vehicle ID of the obtained vehicle information is not registered, the first calculation section 21 performs, for a predetermined time period, reception of communication packets from on-vehicle communication devices 3 and obtainment of vehicle information (step S6). The first calculation section 21 of the present embodiment performs obtainment of vehicle information for one second that is the predetermined time period.

[0068]

Next, the first calculation section 21 determines whether or not at least eight pieces (predetermined number) of vehicle information (communication packets) having the same vehicle ID as that of the vehicle information obtained in step S4 have been received within one second (predetermined time period) (step S8).

[0069]

Depending on whether or not at least the predetermined number of pieces of vehicle information having the same vehicle ID have been obtained (received) within the predetermined time period, the first calculation section 21 calculates a coverage area of the on-vehicle communication device 3 having the vehicle ID.

FIG. 6 is a diagram showing an example of reception conditions of vehicle information transmitted from on-vehicle communication devices 3 on a road.

[0070]

In FIG. 6, an upper view shows: a road R1 which is a path extending from an intersection Ji at which a traffic signal unit 1 and a roadside communication device 2 are

installed; and vehicles 5 (on-vehicle communication devices 3) traveling on the road R1.

In FIG. 6, a lower view shows reception conditions of vehicle information transmitted from the on-vehicle communication devices 3 when the respective on-vehicle communication devices 3 advance toward the roadside communication device 2 and the traffic signal unit 1. Each of many circle marks continuously arranged indicates a position, on the road R1, at which each on-vehicle communication device 3 transmits a communication packet (vehicle information). Positions, in the lower view of FIG. 6, along the left-right direction in the sheet of FIG. 6 correspond to positions on the road R1, in the upper view of FIG. 6, along the left-right direction in the sheet of FIG. 6.

Among the circle marks, each solid circle mark indicates that the vehicle information is received by the roadside communication device 2, and each hollow circle mark indicates that the vehicle information is not received by the roadside communication device 2.

[0071]

First, a description is given of vehicle information transmitted from an on-vehicle communication device 3A advancing on the road R1 toward the traffic signal unit 1, in FIG. 6.

As described above, each on-vehicle communication device 3 transmits a communication packet at every 100 milliseconds in principle. Therefore, the respective circle marks in FIG. 6 indicate the positions at which each on-vehicle communication device 3 transmits the communication packet at the intervals of 100 milliseconds.

[0072]

It is assumed that the on-vehicle communication device 3A approaches the roadside communication device 2 and a communication packet therefrom is first received by the roadside communication device 2 at a position P1. However, at the position P1, the distance to the roadside communication device 2 is still long, and the communication packet is not necessarily received by the roadside communication device 2, resulting in an unstable reception

condition in which the communication packet is received or not received.

After passing through the position P1, the on-vehicle communication device 3 is approaching the roadside communication device 2, but the unstable reception condition still continues. However, when and after the on-vehicle communication device 3 passes through a position P2, the communication packet comes to be continuously received by the roadside communication device 2. Therefore, in an area from the position P2 to the intersection Ji, the communication packet is substantially surely received by the roadside communication device 2.

In the present embodiment, an area in which the communication packet is substantially surely received by the roadside communication device 2, such as the area from the intersection to the position P2, is regarded as a coverage area of the on-vehicle communication device 3A, and the position P2 and its vicinity is regarded as an end of the coverage area.

[0073]

In FIG. 6, the same applies to the on-vehicle communication device 3B. It is assumed that a communication packet transmitted from the on-vehicle communication device 3B is first received by the roadside communication device 2 at a position P3, and when and after the on-vehicle communication device 3B passes through a position P4, the communication packet comes to be continuously received by the roadside communication device 2.

In this case, an area in which the communication packet is substantially surely received by the roadside communication device 2, such as the area from the intersection to the position P3, is regarded as a coverage area of the on-vehicle communication device 3B, and the position P4 and its vicinity is regarded as an end of the coverage area.

[0074]

As shown in FIG. 6, the on-vehicle communication device 3A and the on-vehicle communication device 3B have different positions of the ends of the coverage areas. Such a difference in the position of the end of the coverage area between different on-vehicle

communication devices 3 is caused by a difference in transmission power or the like between the on-vehicle communication devices 3.

[0075]

Each on-vehicle communication device 3 transmits a communication packet at every 100 milliseconds in principle, as described above. Therefore, each on-vehicle communication device 3 transmits a communication packet 10 times within one second that is the predetermined time period.

If the roadside communication device 2 has received 10 communication packets from an on-vehicle communication device 3 within one second, it can be determined that this on-vehicle communication device 3 is positioned in the coverage area. If the roadside communication device 2 has receives less than 10 communication packets from an on-vehicle communication device 3, it can be determined that this on-vehicle communication device 3 is positioned between the position P1 and the position P2.

If the number of communication packets, from an on-vehicle communication device 3, received by the roadside communication device 2 within one second is closer to 10 that is the maximum number, it can be determined that the possibility of this on-vehicle communication device 3 being positioned near the position P2 is relatively high.

[0076]

Therefore, the first calculation section 21 of the roadside communication device 2 of the present embodiment determines that the on-vehicle communication device 3 is positioned near the position P2 when receiving and obtaining 8 or more communication packets within one second, and calculates a coverage area on the basis of the position of the on-vehicle communication device 3 at that time.

In other words, the first calculation section 21 determines that the on-vehicle communication device 3 is positioned near the position P2 when receiving 80% or more of the

maximum number of communication packets transmitted within the predetermined time period, and calculates a coverage area on the basis of the position of the on-vehicle communication device 3 at that time.

[0077]

Referring back to FIG. 5, in step S8, the first calculation section 21 determines whether or not 8 or more pieces of vehicle information (communication packets) having the same vehicle ID as the vehicle ID (hereinafter referred to as target vehicle ID) of the vehicle information obtained in step S4, have been received and obtained within one second (step S8).

Upon determining that 8 or more communication packets having the target vehicle ID have not been received within one second, the first calculation section 21 returns to step S2. In this case, the first calculation section 21 determines that the on-vehicle communication device 3 having the target vehicle ID has not yet arrived at the end of the coverage area, and executes step S2 again.

[0078]

Upon determining in step S8 that 8 or more communication packets having the target vehicle ID have been received within one second, the first calculation section 21 proceeds to step S10, and performs side-road vehicle determination.

In the side-road vehicle determination in step S10, the first calculation section 21 determines whether the on-vehicle communication device 3 having the target vehicle ID travels on the road R1 toward the intersection Ji, or travels on a side road R2 that crosses the road R1, or enters the road R1 from the side road R2 and travels toward the traffic signal unit 1. The method of this determination will be described later.

A vehicle equipped with an on-vehicle communication device 3 which enters the road R1 from the side road R2 and travels on the road R1 toward the traffic signal unit 1, and a vehicle equipped with an on-vehicle communication device 3 which travels on the side road R2,

are referred to as side-road vehicles.

[0079]

After performing the side-road vehicle determination in step S10, the first calculation section 21 proceeds to step S12, and determines whether or not, as the result of the side-road vehicle determination, the on-vehicle communication device 3 having the target vehicle ID has been determined to be a side-road vehicle (step S12).

[0080]

When the on-vehicle communication device 3 having the target vehicle ID has not been determined to be a side-road vehicle, the first calculation section 21 proceeds to step S14. In step S14, the first calculation section 21 refers to positional information included in vehicle information that has been first received within one second (predetermined time period) among pieces of vehicle information having the target vehicle ID that have been received within the predetermined time period, and calculates a coverage area end distance by using this positional information as an end of a coverage area.

The first calculation section 21 registers the calculated coverage area end distance in the coverage area table (step S14), ends the process, and returns to step S2.

[0081]

That is, the first calculation section 21 regards, as an end of a coverage area, the positional information included in the first communication packet within one second when 8 or more communication packets having the target vehicle ID have been received within one second, and calculates, as a coverage area end distance, a distance from the end of the coverage area to the position of the stop line of the intersection J.

[0082]

FIG. 7 is a diagram showing an example of the coverage area table.

In FIG. 7, the coverage area table has a region in which target vehicle IDs are

registered, a region in which date and time information indicating date and time of calculation is registered, and a region in which calculated coverage area end distances are registered.

The date and time information is information indicating the date and time when the first calculation section 21 calculated each coverage area end distance.

[0083]

In the coverage area table, each calculated coverage area end distance can be registered in association with the vehicle ID of the on-vehicle communication device 3 as a transmission source of the vehicle information used for the calculation, and with the date and time information.

The first calculation section 21 registers the coverage area end distance calculated for each on-vehicle communication device 3, together with the vehicle ID and the date and time information.

[0084]

As described above, the first calculation section 21 calculates the coverage area end distance.

[0085]

Referring back to FIG. 5, in step S12, when, as the result of the side-road vehicle determination, the on-vehicle communication device 3 having the target vehicle ID has been determined to be a side-road vehicle, the first calculation section 21 proceeds to step S16. In step S16, the first calculation section 21 registers only the target vehicle ID in the coverage area table (step S16), ends the process, and returns to step S2.

[0086]

There is a possibility that a coverage area end distance obtained for a side-road vehicle is not a coverage area end distance on the road R1.

In FIG. 6, the on-vehicle communication device 3C as a side-road vehicle,

approaching the road R1, enters the road R1 from the side road R2. Therefore, as shown in FIG. 6, when the on-vehicle communication device 3C travels on the side road R2, positional information included in a communication packet transmitted from the on-vehicle communication device 3C appears from a position P10 toward a position P11, that is, the positional information does not represent a position on the road R1. In the lower view of FIG. 6, the up-down direction in the sheet of FIG. 6 corresponds to a direction in which the side road R2, which crosses the road R1 shown in the upper view of FIG. 6, extends.

Therefore, a coverage area end distance is not calculated for an on-vehicle communication device 3 that enters the road R1 from the side road R2 and travels on the road R1 toward the traffic signal unit 1, and an on-vehicle communication device 3 that travels on the side road R2.

[0087]

FIG. 8 is a flowchart showing an example of a side-road vehicle determination process in FIG. 6.

When proceeding to the side-road vehicle determination process, the first calculation section 21 first obtains positional information and heading information included in the vehicle information corresponding to the target vehicle ID (step S20).

[0088]

After obtaining positional information and heading information of each of a plurality of pieces of vehicle information regarding the target vehicle ID, which have been received within the predetermined time period, the first calculation section 21 proceeds to step S22, and averages the positions indicated by the respective pieces of positional information, and determines whether or not the average position is in the road R1 (step S22).

[0089]

Upon determining in step S22 that the average position is in the target road R1, the

first calculation section 21 proceeds to step S24, and averages the headings indicated by the respective pieces of heading information, and determines whether or not the average heading faces the direction toward the target intersection J as viewed from the average position (step S24).

[0090]

Upon determining in step S24 that the average heading faces the direction toward the target intersection Ji, the first calculation section 21 proceeds to step S26, and determines that the on-vehicle communication device 3 having the target vehicle ID is not a side-road vehicle (step S26).

[0091]

On the other hand, upon determining in step S22 that the average position is not in the target road R1, or upon determining in step S24 that the average heading does not face the direction toward the target intersection Ji, the first calculation section 21 proceeds to step S28, and determines that the on-vehicle communication device 3 having the target vehicle ID is a side-road vehicle (step S28).

[0092]

When the average position is not in the target road R1, it can be determined that the on-vehicle communication device 3 having the target vehicle ID is traveling or traveled on the side road R2 at present or in the past. Therefore, in this case, it can be determined that the on-vehicle communication device 3 having the target vehicle ID is a side-road vehicle positioned on the side road.

When the average heading does not face the direction toward the target intersection Ji as viewed from the average position, even if the average position is in the road R1, it can be determined that the on-vehicle communication device 3 having the target vehicle ID is a side-road vehicle that enters the road R1 from the side road.

[0093]

According to the side-road vehicle determination process described above, the first calculation section 21 can determine whether the on-vehicle communication device 3 having the target vehicle ID is a side-road vehicle, or not a side-road vehicle but a vehicle that travels on the road R1 toward the traffic signal unit 1.

[0094]

[Calculation of reliability area]

As described above, in order to set the specific area, the roadside communication device 2 calculates a reliability area, which is determined corresponding to reception reliability indicating a probability that each on-vehicle communication device 3 receives a transmitted communication packet, on the basis of the area ends of the plurality of coverage areas calculated by the first calculation section 21.

Calculation of a reliability area is executed by the second calculation section 22 (FIG. 3) of the roadside communication device 2.

The second calculation section 22 performs calculation of a reliability area intermittently at predetermined intervals, for example.

[0095]

FIG. 9 is a flowchart showing an example of a reliability area calculation process.

The second calculation section 22 of the roadside communication device 2 first refers to the coverage area table, and obtains coverage area end distances that have been calculated during a predetermined time period in the past (e.g., the most recent 15 minutes) (step S32).

[0096]

Next, the second calculation section 22 obtains cumulative frequency distribution regarding the coverage area end distances, in accordance with classes set at intervals of 50 meters (step S34).

[0097]

FIG. 10 is a diagram showing an example of cumulative frequency distribution regarding coverage area end distances. The cumulative frequency distribution shown in FIG. 10 is obtained on the basis of 20 coverage area end distances corresponding to the number of all data registered in the coverage area table shown in FIG. 7.

[0098]

In FIG. 10, the horizontal axis indicates the coverage area end distances (meters) at the respective classes (intervals of 50 meters). The vertical axis indicates the cumulative frequency distribution of the 20 coverage area end distances registered as data in the coverage area table.

[0099]

In FIG. 10, for example, a class represented as “600” indicates a zone in which the coverage area end distance is longer than 600 meters and not longer than 650 meters. The cumulative frequency at this class “600” is “1”. The reason is as follows. In the coverage area table shown in FIG. 7, only one coverage area end distance, “610 meters” corresponding to vehicle ID “17”, exists as data corresponding to the zone in which the coverage area end distance is longer than 600 meters and not longer than 650 meters.

[0100]

Likewise, a class “550” indicates a zone in which the coverage area end distance is longer than 550 meters and not longer than 600 meters. The cumulative frequency at this class “550” is “2”. The reason is as follows. In the coverage area table shown in FIG. 7, only one coverage area end distance, “600 meters” corresponding to vehicle ID “4”, exists as data corresponding to the zone in which the coverage area end distance is longer than 550 meters and not longer than 600 meters. Therefore, by adding the cumulative frequency “1” at the class “600”, the cumulative frequency at the class “550” becomes “2”.

[0101]

A class “500” indicates a zone in which the coverage area end distance is longer than 500 meters and not longer than 550 meters. Also for the other classes, cumulative frequencies are obtained in a similar manner to that described above.

[0102]

Referring back to FIG. 9, after obtaining the cumulative frequency distribution in step S34, the second calculation section 22 proceeds to step S36, and calculates reception reliability and a reliability area corresponding to the reception reliability, on the basis of the cumulative frequency distribution (step S36).

[0103]

The second calculation section 22 obtains, as reception reliability, for each class, the percentage of the cumulative frequency relative to the number of all data in the class, and obtains, as a reliability area, an area determined by the class corresponding to each reception reliability.

[0104]

With reference to FIG. 10, for example, at the classes from “0” to “200”, the cumulative frequency is “20”. Therefore, for each of the classes from “0” to “200”, the percentage of the cumulative frequency relative to the number of all data, i.e., 20, is 100%.

Therefore, in this case, the second calculation section 22 sets reception reliability of an area corresponding to the class “200” to 100%, and sets this area as a reliability area having reception reliability of 100%.

[0105]

The second calculation section 22 obtains the reliability area as a distance up to an upstream-side end of the area (area end distance) when the position of the stop line of the intersection Ji is a reference position.

The class “200” indicates a zone in which the coverage area end distance is longer than 200 meters and not longer than 250 meters. That is, the class “200” indicates that the distance to the position of the upstream-side coverage area end, with the position of the stop line of the intersection Ji being a reference position, is longer than 200 meters and not longer than 250 meters.

On the basis of the coverage area end distance indicated by the class “200”, the second calculation section 22 calculates a distance to an end of a reliability area (reliability area end distance) having reception reliability of 100%, as 200 meters.

[0106]

Meanwhile, the cumulative frequency at a class “250” is “18”. Therefore, for the class “250”, the percentage of the cumulative frequency relative to the number of all data, i.e., 20, is 90%.

In this case, the second calculation section 22 sets reception reliability of an area corresponding to the class “250” to 90%, and sets this area as a reliability area having reception reliability of 90%.

On the basis of the coverage area end distance indicated by the class “250”, the second calculation section 22 calculates a distance to an end of a reliability area having reception reliability of 90%, as 250 meters.

[0107]

Likewise, the cumulative frequency at a class “300” is “15”, and the second calculation section 22 sets an area corresponding to the class “300”, as a reliability area (area end distance of 300 meters) having reception reliability of 75%.

The cumulative frequency at a class “350” is “10”, and the second calculation section 22 sets an area corresponding to the class “350”, as a reliability area (area end distance of 350 meters) having reception reliability of 50%.

[0108]

As described above, the reception reliability is the percentage of the cumulative frequency at each class relative to the number of all data, i.e., 20, and indicates reception probability that a communication packet from an on-vehicle communication device 3 positioned in an area (reliability area) corresponding to a target class is received by the roadside communication device 2.

[0109]

As described above, the second calculation section 22 obtains reception reliability for each class, and obtains, as a reliability area, an area that is determined based on a class corresponding to each reception reliability. That is, the second calculation section 22 obtains a plurality of reliability areas having different reception reliabilities.

[0110]

In the above-description, reception reliability is obtained for each class, and an area that is determined based on a class corresponding to each reception reliability is obtained as a reliability area. However, an intermediate value of reception reliabilities of adjacent classes may be obtained.

In FIG. 10, regarding the reception reliabilities of the respective reliability areas, the highest reception reliability is 100% and the second highest reception reliability is 90%. However, for example, a reliability area having reception reliability of 95% may be complementarily obtained.

[0111]

[Setting of specific area]

The area setting section 23 (FIG. 3) set a specific area on the basis of the reliability area calculated by the second calculation section 22.

The specific area is an area that is set on each path for the purpose of specifying

control information to be used for control of the traffic signal unit 1, from among a plurality of pieces of vehicle information.

[0112]

The area setting section 23 selects a reliability area having reception reliability necessary for control of the traffic signal unit 1, from among a plurality of reliability areas calculated by the second calculation section 22.

[0113]

In this system, as processes regarding control of the traffic signal unit 1, a process of obtaining a queue length on the road R1, and an actuated control process for the traffic signal unit 1 are performed.

It is assumed that the process of obtaining a queue length requires reception reliability of 75%, and the actuated control process for the traffic signal unit 1 requires reception reliability not lower than 95%.

[0114]

In this case, the area setting section 23 selects a reliability area (area end distance of 300 meters) having reception reliability of 75%, and sets the selected reliability area having reception reliability of 75%, as a specific area having reception reliability of 75%. In addition, the area setting section 23 selects a reliability area (area end distance of 200 meters) having reception reliability of 100%, and sets the selected reliability area having reception reliability of 100%, as a specific area having reception reliability of 100%.

[0115]

As described above, the processing unit 18 of the roadside communication device 2 of the present embodiment includes: the first calculation section 21 configured to calculate a plurality of coverage areas in which the wireless communication unit 16 can receive radio signals, for a plurality of on-vehicle communication devices 3 advancing toward the traffic signal

unit 1, respectively, on the basis of pieces of vehicle information, of the plurality of the on-vehicle communication devices 3, included in reception signals of the wireless communication unit 16 (reception unit) that receives communication packets from the plurality of on-vehicle communication devices 3; the second calculation section 22 configured to calculate, on the basis of the plurality of coverage areas, a reliability area that is determined corresponding to reception reliability indicating the probability that the radio signal is received by the wireless communication unit 16; and the area setting section 23 configured to set, on the basis of the reliability area, a specific area for specifying, from the vehicle information, control information used for control of the traffic signal unit 1. Thus, the processing unit 18 configures an area setting device for specifying control information to be used for control of the traffic signal unit 1. [0116]

According to the roadside communication device 2 of the present embodiment, the specific area can be set on the basis of the reliability area having reception reliability according to control of the traffic signal unit 1. Therefore, even if variation occurs among the plurality of coverage areas, the specific area allows vehicle information, which is received with a certain reception probability according to control of the traffic signal unit 1 and is appropriately usable as control information, to be specified from among a plurality of pieces of vehicle information received by the roadside communication device 2.

The reliability area, which is used by the area setting section 23 for setting of the specific area, corresponds to the reception reliability necessary for control of the traffic signal unit 1. Therefore, the specific area can be set as an area that can specify, from among the plurality of pieces of vehicle information, vehicle information appropriately usable as control information for the traffic signal unit 1.

[0117]

The second calculation section 22 of the present embodiment calculates a plurality

of reliability areas corresponding to a plurality of reception reliabilities, and the area setting section 23 selects a reliability area having reception reliability necessary for control of the traffic signal unit 1 from among the plurality of reliability areas. Therefore, setting of the specific area is facilitated.

[0118]

The first calculation section 21, the second calculation section 22, and the area setting section 23 perform, for each of the paths at the intersection Ji, calculation of a coverage area, calculation of a reliability area, and setting of a specific area, respectively. Therefore, a specific area can be set for each of the respective paths.

[0119]

In the present embodiment, the first calculation section 21 determines, on the basis of vehicle information of a communication packet, whether or not this communication packet is a communication packet that is transmitted from a side-road vehicle (inflow on-vehicle communication device) that enters the road R1 from the side road R2 (cross link) crossing the road R1 on which on-vehicle communication devices 3 travel, and advances toward the traffic signal unit 1. Upon determining that this communication packet is a communication packet from the side-road vehicle, the first calculation section 21 registers only the vehicle ID in the coverage area table, and suspends calculation of a coverage area end distance.

In this case, the side-road vehicle that enters from the cross link can be excluded when setting a specific area.

That is, since a coverage area end distance is not calculated for a side-road vehicle, calculation of a coverage area end distance can be accurately performed. In addition, since a side-road vehicle is excluded when setting a specific area, the specific area can be set more appropriately.

[0120]

[Specification of control information]

The specification section 24 (FIG. 3), by using a specific area set by the area setting section 23, specifies control information to be used for control of the traffic signal unit 1 from among pieces of vehicle information included in communication packets received from on-vehicle communication devices 3. The specification section 24 may perform specification of control information at any time or in response to requests from the queue length calculation section 41 and the actuated control processing section 42.

[0121]

The specification section 24 refers to positional information included in the vehicle information received and obtained by the roadside communication device 2. The specification section 24 specifies the vehicle information as control information when the positional information is in the specific area, and does not specify the vehicle information as control information when the positional information is outside the specific area.

[0122]

Therefore, the specification section 24 can specify, as control information, vehicle information that is received and obtained with certain reception reliability.

The specification section 24 of the present embodiment specifies control information for both a specific area having reception reliability of 75% and a specific area having reception reliability of 100%.

[0123]

The specification section 24 specifies control information from among pieces of vehicle information of on-vehicle communication devices 3 that are obtained by the roadside communication device 2 at any time, and provides the specified control information to the central apparatus 4.

[0124]

[Control of traffic signal unit]

As described above, the system of the present embodiment performs, as processes regarding control of the traffic signal unit 1, a process of obtaining a queue length on the road R1, and an actuated control process for the traffic signal unit 1.

[0125]

The specification section 24 of the roadside communication device 2 specifies control information to be used for control of the traffic signal unit 1, from among pieces of vehicle information, and provides the specified control information to the central apparatus 4 (FIG. 3) via the communication line 7.

[0126]

The central apparatus 4 provides the control information provided from the specification section 24 of the roadside communication device 2, to the queue length calculation section 41 (FIG. 3) and the actuated control processing section 42 (FIG. 3).

The queue length calculation section 41 has a function of performing a process of obtaining a queue length, on the road R1, caused by the traffic signal unit 1.

The queue length calculation section 41 obtains a queue length by using the control information specified in the specific area having reception reliability of 75%.

[0127]

The actuated control processing section 42 has a function of calculating a traffic volume on the upstream side of the traffic signal unit 1, and performing an actuated control process for the traffic signal unit 1 on the basis of the calculated traffic volume.

The actuated control processing section 42 performs calculation of a traffic volume by using the control information specified in the specific area having reception reliability of 100%.

[0128]

The queue length calculation section 41 and the actuated control processing section 42 each generate information necessary for control of the traffic signal unit 1, and each generate a control command for the traffic signal unit 1 from the generated information.

The queue length calculation section 41 and the actuated control processing section 42 each provide the generated control command to the traffic signal controller 10 via the communication line 7.

[0129]

The traffic signal controller 10 provides, to the signal controller 48, the control command provided from the queue length calculation section 41 or the actuated control processing section 42 of the central apparatus 4.

The signal controller 48 has a function of controlling the light color of the traffic signal unit 1. The signal controller 48 controls the light color on the basis of the control command provided from the queue length calculation section 41 or the actuated control processing section 42 of the central apparatus 4.

[0130]

FIG. 11 is an explanatory diagram showing a process of obtaining a queue length, which is performed by the queue length calculation section 41.

FIG. 11 shows a case where a plurality of on-vehicle communication devices 3 wait for the signal light to change at the stop line of the traffic signal unit 1.

[0131]

With the control information provided from the specification section 24 of the roadside communication device 2, the queue length calculation section 41 can approximately grasp the existence of on-vehicle communication devices 3 waiting for the signal light to change, in the specific area having reception reliability of 75%.

Therefore, when the queue length caused by the traffic signal unit 1 falls into the

specific area having reception reliability of 75%, the queue length calculation section 41 can obtain the queue length on the basis of the positional information included in the control information.

[0132]

Meanwhile, if the queue length caused by the traffic signal unit 1 extends to the outside of the specific area, the queue length calculation section 41 cannot obtain the queue length with just the positional information included in the control information.

Therefore, the queue length calculation section 41 has a function of measuring a time when each on-vehicle communication device 3, which approaches the specific area after the light color of the traffic signal unit 1 changes from red to green, enters the specific area, thereby estimating a queue length that extended to the outside of the specific area when the light color of the traffic signal unit 1 was red.

[0133]

The queue length calculation section 41 obtains a time interval $t(t_0)$ from a timing when the light color of the traffic signal unit 1 has changed from red to green to a timing when the first on-vehicle communication device 3D positioned outside the specific area has entered the specific area.

Further, the queue length calculation section 41 obtains a time interval $t(t_1)$ from a timing when the on-vehicle communication device 3D has passed to a timing when an on-vehicle communication device 3 just behind the on-vehicle communication device 3D has entered the specific area.

[0134]

As described above, the queue length calculation section 41 obtains the time interval t of the timings to enter the specific area, of the on-vehicle communication devices 3 that sequentially enter the specific area after the light color of the traffic signal unit 1 has changed

from red to green. The queue length calculation section 41 obtains the elapsed time t on the basis of the control information provided from the specification section 24 of the roadside communication device 2.

[0135]

The queue length calculation section 41 determines whether or not the time interval t is larger than a preset threshold value, thereby determining whether or not each on-vehicle communication device 3 outside the specific area is a vehicle that formed the queue when the light color of the traffic signal unit 1 was red.

[0136]

When the time interval t is larger than the threshold value, the queue length calculation section 41 determines that the on-vehicle communication device 3 corresponding to the timing is a vehicle that did not form the queue when the light color of the traffic signal unit 1 was red. On the other hand, when the time interval t is not larger than the threshold value, the queue length calculation section 41 determines that the on-vehicle communication device 3 corresponding to the timing is a vehicle that formed the queue when the light color of the traffic signal unit 1 was red.

[0137]

The threshold value is set as follows. That is, when vehicles, forming a queue, start to move with the light color of the traffic signal unit 1 being changed to green, the time intervals between the respective vehicles forming the queue are measured, and the threshold value is set on the basis of the result of the measurement.

[0138]

In FIG. 11, assuming that the on-vehicle communication devices 3D to 3E form a queue outside the specific area, there is no great difference among the time intervals t_0 to t_5 between the respective on-vehicle communication devices 3 from the on-vehicle communication

device 3D to the on-vehicle communication device 3E.

On the other hand, as shown in FIG. 11, the time interval t_6 between the on-vehicle communication device 3E and an on-vehicle communication device 3F that did not form the queue outside the specific area tends to be increased as compared with the time intervals t_0 to t_5 between the on-vehicle communication devices 3 that formed the queue outside the specific area.

[0139]

Therefore, the queue length calculation section 41 evaluates the time intervals t on the basis of the aforementioned threshold value, thereby determining whether or not each on-vehicle communication device 3 outside the specific area is a vehicle that formed the queue when the light color of the traffic signal unit 1 was red.

[0140]

By evaluating the time intervals t , the queue length calculation section 41 can specify the number of the on-vehicle communication devices 3 of the vehicles that formed the queue outside the specific area when the light color of the traffic signal unit 1 was red.

For example, it is preset that one vehicle corresponds to a queue length of 7 meters. Then, by specifying the number of the on-vehicle communication devices 3 that formed the queue outside the specific area when the light color of the traffic signal unit 1 was red, the queue length calculation section 41 can estimate the queue length corresponding to the number of the on-vehicle communication devices 3.

[0141]

As described above, the queue length calculation section 41 can obtain the entire queue length at the traffic signal unit 1 while estimating the queue length that extended to the outside of the specific area when the light color of the traffic signal unit 1 was red.

[0142]

FIG. 12 is an explanatory diagram showing a traffic volume calculation process performed by the actuated control processing section 42.

The actuated control processing section 42 can calculate the traffic volume on the upstream side of the traffic signal unit 1 by processing all the control information provided from the specification section 24 of the roadside communication device 2.

[0143]

Meanwhile, as shown in FIG. 12, the actuated control processing section 42 can also calculate the traffic volume on the upstream side of the traffic signal unit 1 by providing an imaginary sensitive area A in the specific area, and counting the on-vehicle communication devices 3 that pass through the sensitive area A.

In this case, since the actuated control processing section 42 need not process all the control information provided from the specification section 24 of the roadside communication device 2, the processing amount thereof can be reduced.

[0144]

In the control of the traffic signal unit shown in FIG. 11 and FIG. 12, information regarding the on-vehicle communication devices 3 on the upstream side of the traffic signal unit 1, advancing toward the traffic signal unit 1, are used. However, the system of the present embodiment can be also applied to control of a traffic signal unit based on information regarding on-vehicle communication devices 3 on the downstream side of the traffic signal unit 1, advancing in a direction away from the traffic signal unit 1.

The reason is as follows. In this system, since a specific area is obtained for each path, vehicle information from the on-vehicle communication devices 3 on the downstream side of the traffic signal unit 1, advancing in the direction away from the traffic signal unit 1, can also be obtained as control information, in addition to the vehicle information from the upstream-side on-vehicle communication devices 3.

[0145]

[Other embodiments]

FIG. 13 is a block diagram showing the structures of the roadside communication device 2, the on-vehicle communication device 3, the central apparatus 4, and the traffic signal controller 10 according to another embodiment.

The system shown in FIG. 13 is different from the system of the above embodiment in that the central apparatus 4 includes a first calculation section 21, a second calculation section 22, and an area setting section 23.

In FIG. 13, the processing unit 36 of the central apparatus 4 configures an area setting device including the first calculation section 21, the second calculation section 22, and the area setting section 23.

[0146]

In this case, the roadside communication device 2 provides obtained vehicle information of the on-vehicle communication device 3 to the central apparatus 4.

The central apparatus 4 calculates a coverage area and a reliability area by using the vehicle information provided from the roadside communication device 2, and sets a specific area.

Information indicating the specific area that is set by the area setting section 23 is provided from the central apparatus 4 to the specification section 24 of the roadside communication device 2.

The specification section 24 provides control information specified based on the specific area, to the queue length calculation section 41 and the actuated control processing section 42 of the central apparatus 4.

According to this structure, processing load of the roadside communication device 2 which is needed to be mounted to the traffic signal unit 1 or installed on the road can be

reduced.

[0147]

[Others]

In the above embodiment, an exemplary case has been described in which the second calculation section 22 is configured to calculate a plurality of reliability areas corresponding to a plurality of reception reliabilities, and the area setting section 23 is configured to select a reliability area having reception reliability necessary for control of the traffic signal unit 1, from among the plurality of reliability areas. However, the second calculation section 22 may calculate only a reliability area having reception reliability necessary for control of the traffic signal unit 1, and the area setting section 23 may set a specific area on the basis of the reliability area.

In this case, since the second calculation section 22 only needs to calculate a reliability area having reception reliability necessary for control of the traffic signal unit 1, processing load thereof is reduced.

[0148]

In the above embodiment, an exemplary case has been described in which the first calculation section 21 performs calculation of a coverage area at any time. However, for example, the first calculation section 21 may perform the calculation intermittently at predetermined intervals. Alternatively, the first calculation section 21 may set, in advance, date and time on which calculation of a coverage area is executed and a time period during which the calculation is executed, and may perform the calculation according to the setting.

[0149]

In the above embodiment, an exemplary case has been described in which the predetermined time period, during which the first calculation section 21 receives communication packets from on-vehicle communication devices 3 in step S6 (FIG. 5), is set to one second.

However, the present invention is not limited thereto. The predetermined time period can be set to a period during which a sufficient number of communication packets for determination of the reception condition of communication packets from the on-vehicle communication devices 3 can be received. That is, the predetermined time period can be set as appropriate in accordance with the transmission intervals of the communication packets from the on-vehicle communication devices 3.

[0150]

Further, an exemplary case has been described in which the first calculation section 21 is configured to determine whether or not 80% (8) or more communication packets relative to the maximum number (10) of communication packets transmitted during the aforementioned predetermined time period (one second) have been received, in order to determine whether or not an on-vehicle communication device 3 has arrived at the end of the coverage area, in step S8 (FIG. 5). However, the criterion may be set to a lower percentage as long as it is possible to determine whether or not the on-vehicle communication device 3 has arrived at the end of the coverage area.

Further, the criterion may be set to a higher percentage if necessary.

[0151]

In the above embodiment, an exemplary case has been described in which the second calculation section 22 performs calculation of a reliability area intermittently at predetermined intervals. However, the second calculation section 22 may perform calculation of a reliability area at any time. Alternatively, the second calculation section 22 may set, in advance, date and time on which calculation of a reliability area is executed and a time period during which the calculation is executed, and may perform the calculation according to the setting.

[0152]

Further, an exemplary case has been described in which, in step S32 (FIG. 9), the second calculation section 22 refers to the coverage area table and obtains the coverage area end distances that have been calculated within the most recent 15 minutes. However, the coverage area end distances that have been calculated within a time period longer or shorter than 15 minutes may be obtained according to need.

Alternatively, the second calculation section 22 may obtain, from the coverage area table, the coverage area end distances that were obtained, in the past, in the same time zone and on the same day of week as the present time, to calculate a reliability area. Since the traffic volume on a road depends on the time of day and/or the day of week, not only the most recent information but also the coverage area end distances obtained in the same time zone and on the same day of week in the past can be adopted. In this case, cumulative frequency distribution can be obtained by using more data.

[0153]

In the above embodiment, an exemplary case has been described in which the area setting section 23 selects a reliability area having reception reliability necessary for control of the traffic signal unit 1 from among a plurality of reliability areas, and sets the selected reliability area as a specific area. However, the area setting section 23 may set a specific area within the range of the selected reliability area.

[0154]

In the above embodiment, an exemplary case has been described in which a coverage area is obtained on the basis of the reception condition of communication packets (vehicle information) from each on-vehicle communication device 3 advancing toward the traffic signal unit 1 and the roadside communication device 2, and further, a reliability area and a specific area are obtained. However, a coverage area may be obtained on the basis of the reception condition of communication packets from each on-vehicle communication device 3

traveling in the direction away from the roadside communication device 2, and then a reliability area and a specific area may be obtained. Also in this case, the first calculation section 21 can obtain a coverage area end distance in a similar manner to that of the above embodiment.

Further, the first calculation section 21 can obtain a reliability area and a specific area from the obtained coverage area end distance in a similar manner to that of the above embodiment.

[0155]

FIG. 14 is a diagram showing an example of a case where a roadside communication device is installed at a position distant from an intersection at which a traffic signal unit is installed. Although, in the above embodiment, the roadside communication device 2 is installed near the traffic signal controller 1, the roadside communication device 2 may be installed at a position distant from the intersection Ji at which the traffic signal unit 1 is installed, as shown in FIG. 14, for example. FIG. 14 shows a case where the roadside communication device 2 is installed at a position distant from the intersection Ji and along the road R1 which is one of the paths at the intersection Ji.

Also in this case, a reliability area and a specific area can be obtained in a similar manner to that of the above embodiment, although the coverage area end distance on the road R1 may become longer than the coverage area end distance on the road R2 which is one of the paths at the intersection Ji.

[0156]

In the above embodiment, an exemplary case has been described in which time division multiplexing is adopted to realize coexistence of roadside-to-vehicle communication and vehicle-to-vehicle communication performed by the roadside communication device 2 and the on-vehicle communication device 3. However, the present invention is not limited thereto, and other methods, for example, frequency division multiplexing, may be adopted.

[0157]

It is noted that the embodiment disclosed herein is merely illustrative in all aspects and should not be recognized as being restrictive.

The scope of the present invention is defined by the scope of the claims rather than by the meaning described above, and is intended to include meaning equivalent to the scope of the claims and all modifications within the scope.

REFERENCE SIGNS LIST

[0158]

- 1 traffic signal unit
- 1a post
- 2 roadside communication device
- 3, 3A, 3B, 3C, 3D, 3E, 3F on-vehicle communication device
- 4 central apparatus
- 5 vehicle
- 6 roadside detector
- 7 communication line
- 8 router
- 10 traffic signal controller
- 12 time slot
- 15 antenna
- 16 wireless communication unit
- 17 wired communication unit
- 18 processing unit
- 21 first calculation section
- 22 second calculation section

23	area setting section
24	specification section
27	antenna
28	wireless communication unit
29	processing unit
30	transmission section
35	wired communication unit
36	processing unit
41	queue length calculation section
42	actuated control processing section
46	wired communication unit
47	processing unit
48	signal controller
R1	road
R2	side road
J1 to J12	intersection

CLAIMS

1. An area setting device comprising:
 - a reception unit configured to receive radio signals transmitted from a plurality of on-vehicle communication devices traveling on a road;
 - a first calculation section configured to calculate a plurality of coverage areas in which the reception unit can receive the radio signals, for the plurality of the on-vehicle communication devices, respectively, on the basis of pieces of vehicle information, of the plurality of the on-vehicle communication devices, included in reception signals received by the reception unit;
 - a second calculation section configured to calculate, on the basis of the plurality of coverage areas, a reliability area that is determined corresponding to reception reliability indicating a probability that the radio signals are received by the reception unit; and
 - an area setting section configured to set, on the basis of the reliability area, a specific area for specifying control information to be used for control of a traffic signal unit installed on the road, from among the pieces of vehicle information.
2. The area setting device according to claim 1, wherein the reliability area corresponds to reception reliability necessary for control of the traffic signal unit.
3. The area setting device according to claim 2, wherein
 - the second calculation section calculates a plurality of the reliability areas corresponding to a plurality of the reception reliability, and
 - the area setting section selects a reliability area having reception reliability necessary for control of the traffic signal unit, from among the plurality of the reliability areas.

4. The area setting device according to any one of claims 1 to 3, wherein the traffic signal unit is installed at an intersection, and the first calculation section, the second calculation section, and the area setting section perform, for each of paths at the intersection, calculation of the coverage area, calculation of the reliability area, and setting of the specific area, respectively.
5. The area setting device according to any one of claims 1 to 4, wherein the control information is used for obtaining a queue length at the traffic signal unit.
6. The area setting device according to any one of claims 1 to 4, wherein the control information is used for actuated control of the traffic signal unit.
7. The area setting device according to any one of claims 1 to 6, wherein the first calculation section determines, on the basis of the vehicle information included in each reception signal, whether or not the reception signal is a reception signal from an inflow on-vehicle communication device that enters the road from a crossing path that crosses the road, and upon determining that the reception signal is a reception signal from the inflow on-vehicle communication device, the first calculation section suspends calculation of the coverage area for the reception signal.
8. An area setting system comprising:
a roadside communication device capable of receiving radio signals transmitted from a plurality of on-vehicle communication devices traveling on a road;
a first calculation section configured to calculate a plurality of coverage areas in

which the roadside communication device can receive the radio signals, for the plurality of the on-vehicle communication devices, respectively, on the basis of pieces of vehicle information, of the plurality of the on-vehicle communication devices, included in reception signals obtained when the roadside communication device receives the radio signals;

a second calculation section configured to calculate, on the basis of the plurality of coverage areas, a reliability area that is determined corresponding to reception reliability indicating a probability that the radio signals are received by the roadside communication device; and

an area setting section configured to set, on the basis of the reliability area, a specific area for specifying control information to be used for control of a traffic signal unit installed on the road, from among the pieces of vehicle information.

9. A method for setting a specific area for specifying control information to be used for control of a traffic signal unit installed on a road, from among pieces of vehicle information of a plurality of on-vehicle communication devices traveling on the road, the pieces of vehicle information being included in reception signals of a reception unit configured to receive radio signals from the plurality of the on-vehicle communication devices, the method comprising:

a first calculation step of calculating a plurality of coverage areas in which the reception unit can receive the radio signals, for the plurality of the on-vehicle communication devices, respectively, on the basis of the pieces of vehicle information;

a second calculation step of calculating, on the basis of the plurality of coverage areas, a reliability area that is determined corresponding to reception reliability indicating a probability that the radio signals are received by the reception unit; and

an area setting step of setting the specific area on the basis of the reliability area.

10. A computer program for causing a computer to execute a process for setting a specific area for specifying control information to be used for control of a traffic signal unit installed on a road, from among pieces of vehicle information of a plurality of on-vehicle communication devices traveling on the road, the pieces of vehicle information being included in reception signals of a reception unit configured to receive radio signals from the plurality of the on-vehicle communication devices,

the computer program causing the computer to execute:

a first calculation step of calculating a plurality of coverage areas in which the reception unit can receive the radio signals, for the plurality of the on-vehicle communication devices, respectively, on the basis of the pieces of vehicle information;

a second calculation step of calculating, on the basis of the plurality of coverage areas, a reliability area that is determined corresponding to reception reliability indicating a probability that the radio signals are received by the reception unit; and

an area setting step of setting the specific area on the basis of the reliability area.

11. An area setting device comprising:

a reception unit configured to receive radio signals transmitted from a plurality of on-vehicle communication devices traveling on a road;

a first calculation section configured to calculate a plurality of coverage areas in which the reception unit can receive the radio signals, for the plurality of the on-vehicle communication devices, respectively, on the basis of pieces of vehicle information, of the plurality of the on-vehicle communication devices, included in reception signals received by the reception unit; and

an area setting section configured to set, on the basis of the plurality of coverage areas, a specific area for specifying control information to be used for control of a traffic signal

unit installed on the road, from among the pieces of vehicle information.