

Title of Invention: ONBOARD UNIT, TOLL COLLECTION SYSTEM, TOLL
COLLECTION METHOD, AND PROGRAM

Technical Field

 $[0001]$

The present disclosure relates to an onboard unit, a toll collection system, a toll collection method, and a program.

Background Art

[0002]

On current toll roads, the toll fee is calculated based on a toll table distributed from a center server. There is a case where a discount is applied to a toll fee. For example, Patent Document 1 describes an automatic toll collection system that discounts a toll fee of a toll road depending on the time of day.

Citation List

Patent Literature

[0003]

Patent Document 1: JP 2009-199347 A

Summary of Invention

Technical Problem

[0004]

From the viewpoint of reducing the environmental load and from the viewpoint of fairness of the road maintenance cost, it is desirable to vary the billing amount according to the number of occupants and the axle load. However, it is difficult to detect and measure a state of the vehicle such as the number of occupants and the axle load of a traveling vehicle from the outside. Furthermore, the state of the vehicle such as the number of occupants and the axle load can be changed at a rest area, for example. There has been a demand for development of a technique for varying the billing amount according to the state of the vehicle that can possibly change.

[0005]

An object of the present disclosure is to provide an onboard unit, a toll collection system, a toll collection method, and a program that can implement billing processing according to the states of individual vehicles.

Solution to Problem

[0006]

According to one aspect of the present disclosure, an onboard unit includes a vehicle information acquisition unit configured to acquire
5 information on a vehicle including a state of the vehicle whose state can change on a toll road.

[0007]

According to one aspect of the present disclosure, a toll collection system includes: the onboard unit described above; an exit communication
10 control unit installed at an exit tollgate on the toll road; and a higher-level server configured to transmit/receive information to/from the exit communication control unit, in which the exit communication control unit transmits, to the higher-level server, a toll fee to be calculated based on a state of the vehicle, and the higher-level server performs payment processing on the
15 toll fee from the exit communication control unit.

[0008]

According to one aspect of the present disclosure, a toll collection method includes: acquiring, by an onboard unit mounted on a vehicle, information on the vehicle including a state of the vehicle whose state can
20 change on a toll road; transmitting, by an exit communication control unit installed at an exit tollgate on the toll road, a toll fee to be calculated based on a state of the vehicle to a higher-level server; and performing, by the higher-level server, payment processing on the toll fee from the exit communication control unit.

[0009]

According to one aspect of the present disclosure, a program causes an onboard unit to execute acquiring information on a vehicle including a state of the vehicle whose state can change on a toll road.

Advantageous Effects of Invention

[0010]

According to the above aspect, it is possible to implement billing processing according to the states of individual vehicles.

Brief Description of Drawings

[0011]

FIG. 1 is a view illustrating an overall configuration of a toll collection system according to a first embodiment.

FIG. 2 is a view illustrating an overall functional configuration of the toll collection system according to the first embodiment.

FIG. 3 is a view illustrating a functional configuration of an exit communication control unit according to the first embodiment.

5 FIG. 4 is a first chart diagram illustrating an example of processing of the toll collection system according to the first embodiment.

FIG. 5 is a first flowchart illustrating an example of processing of an onboard unit according to the first embodiment.

10 FIG. 6 is a second flowchart illustrating an example of processing of the onboard unit according to the first embodiment.

FIG. 7 is a third flowchart illustrating an example of processing of the onboard unit according to the first embodiment.

FIG. 8 is a fourth flowchart illustrating an example of processing of the onboard unit according to the first embodiment.

15 FIG. 9 is a fifth flowchart illustrating an example of processing of the onboard unit according to the first embodiment.

FIG. 10 is a sixth flowchart illustrating an example of processing of the onboard unit according to the first embodiment.

20 FIG. 11 is a view illustrating an example of a table of a travel distance ratio according to the first embodiment.

FIG. 12 is a schematic block diagram illustrating a configuration of a computer according to the first embodiment.

FIG. 13 is a view illustrating an overall functional configuration of the toll collection system according to another embodiment.

25

Description of Embodiments

[0012]

First Embodiment

30 Embodiments will be described in detail hereinafter with reference to the drawings.

[0013]

Overall Configuration

35 FIG. 1 is a view illustrating an overall configuration of a toll collection system 100 according to the first embodiment. FIG. 2 is a view illustrating an overall functional configuration of the toll collection system 100 according to the first embodiment. As illustrated in FIGS. 1 and 2, the toll collection system 100 is a system that performs billing processing for a vehicle 1 traveling on a toll road (e.g., expressway). Hereinafter, for simplified description, the toll

collection system 100 will be described with an example of a case where the vehicle 1 enters a toll road from one entrance tollgate and exits the toll road from one exit tollgate. The toll collection system 100 includes the vehicle 1, a roadside antenna 20, a communication control unit 30, an interface unit 9, and a higher-level server 40.

[0014]

The vehicle 1 includes all vehicles 1 traveling on a toll road. The vehicle 1 includes, for example, a passenger car, a bus, a transportation truck, and a trailer. In the present embodiment, a case where the vehicle 1 is a lift axle vehicle will be described as an example. The vehicle 1 includes an onboard unit 10, an onboard sensor 15, a lift axle control unit 7, and a vehicle control unit 8. The onboard sensor 15 is mounted on the vehicle 1. The onboard sensor 15 is equipment that acquires and supplies, to the onboard unit 10, information on the vehicle 1 including a state (e.g., the number of occupants, the axle load, the number of axles, and the like described later) of the vehicle 1 and a travel distance of the vehicle 1. The onboard sensor 15 includes, for example, a seating sensor 2, an odometer 3, a speedometer 4, an axle load sensor 5, and a lift 6, which will be described later. In the present embodiment, the odometer 3 also functions as a sensor that detects the total travel distance (cumulative travel distance), and the speedometer 4 also functions as a sensor that detects the speed of the vehicle 1. The lift 6 of the vehicle 1 includes, for example, a lifting sensor. Therefore, the lift 6 also functions as a sensor that detects the axle load of the vehicle 1. Hence, in the present embodiment, the odometer 3, the speedometer 4, and the lift 6 are all treated as a type of the onboard sensor 15. Note that the onboard sensor 15 may include sensors other than the seating sensor 2, the odometer 3, the speedometer 4, the axle load sensor 5, and the lift 6.

[0015]

The onboard unit 10 is mounted on the vehicle 1. The onboard unit 10 performs processing of automatically paying a toll fee of the vehicle 1 for a toll road by an automatic toll collection system (also called an "electronic toll collection system". In Japan, it is also called an electronic toll collection (ETC) (registered trademark) system). The functional configuration of the onboard unit 10 will be described later.

[0016]

The seating sensor 2 is mounted on the vehicle 1. The seating sensor 2 detects presence/absence of occupancy of each seat and also detects

presence/absence of wearing of a seat belt. The seating sensor 2 detects the number of occupants in the vehicle 1 from seating and wearing of a seat belt.
[0017]

5 The odometer 3 is mounted on the vehicle 1. The odometer 3 measures a total travel distance of the vehicle 1. The total travel distance means a cumulative value of the travel distance of the vehicle 1, that is, a cumulative travel distance. The odometer 3 is also referred to as a travel distance meter or a cumulative travel distance meter.
[0018]

10 The speedometer 4 is mounted on the vehicle 1. The speedometer 4 measures a travel speed of the vehicle 1.
[0019]

The axle load sensor 5 is mounted on the vehicle 1. The axle load sensor 5 measures an axle load. The axle load is the weight applied to each axle. The
15 axle load sensor 5 is mounted on a vehicle body (e.g., a suspension of the axle).
[0020]

The lift 6 is mounted on the vehicle 1. The lift 6 is a device that can lift up and lift down the axle. The lift 6 raises the axle using, for example, an air suspension, thereby preventing the tires connected to the axle from being in
20 contact with ground.
[0021]

The lift axle control unit 7 acquires axle load information from the axle load sensor 5. The lift axle control unit 7 acquires a lift state of each axle from the lift 6. Here, the lift state means how many axles are lifted up among the
25 axles that can be lifted up. The lift axle control unit 7 acquires, from the lift state, the number of axles of the vehicle 1, whose connected wheels are in contact with ground (hereinafter, simply referred to as "the number of axles").
[0022]

The vehicle control unit 8 is connected to the onboard unit 10 by a
30 communication protocol such as a controller area network (CAN). The vehicle control unit 8 controls equipment constituting the vehicle 1. The vehicle control unit 8 acquires information on the vehicle 1 from equipment such as the onboard sensor 15 mounted on the vehicle 1. Specifically, the vehicle control unit 8 acquires the number of occupants in the vehicle 1 from the seating sensor
35 2. The vehicle control unit 8 acquires the total travel distance measured by the odometer 3. The vehicle control unit 8 also acquires speed information from the speedometer 4. The vehicle control unit 8 acquires axle load information, a lift state, and the number of axles from the lift axle control unit 7. The vehicle

control unit 8 acquires various types of information on the vehicle 1 in this manner, and periodically (e.g., every 1 sec) transmits the information to the onboard unit 10. Note that the period in which the vehicle control unit 8 transmits information to the onboard unit 10 can be changed as appropriate.

5 [0023]

A plurality of the roadside antennas 20 are installed at intervals on the roadside of the toll road. The roadside antenna 20 performs communication (e.g., DSRC communication) with the onboard unit 10. The roadside antennas 20 are installed at, for example, entrance tollgates, exit tollgates, free flow (F/F), off-road facilities, and the like. Hereinafter, the roadside antenna 20 installed at the entrance tollgate is referred to as an entrance roadside antenna 21, and the roadside antenna 20 installed at the exit tollgate is referred to as an exit roadside antenna 22. The roadside antenna 20 through which the vehicle 1 can pass from the entrance tollgate to the exit tollgate is referred to as an intermediate roadside antenna 23. The intermediate roadside antenna 23 is installed at a notification point such as free flow (F/F), an off-road facility, or the like. The notification point includes, for example, a roadside communication device provided at a branching point of a toll road or the like, a free flow billing point, and a connection point of a toll road having a different toll system. Note that the off-road facility mentioned here means a facility in which the vehicle 1 is stopped and occupants can get on and off or cargo can be loaded and unloaded. Examples of an off-road facility include rest areas. The onboard unit 10 can cooperate (transmit/receive), with (to/from) the roadside antenna 20, information (e.g., information regarding the state of the vehicle such as the number of occupants, the number of axles, and the axle load acquired by a method described later) acquired at an entrance tollgate, an exit tollgate, free flow (F/F), and an off-road facility.

[0024]

A plurality of the communication control units 30 are installed at intervals on the roadside of the toll road. In the illustrated example, the communication control unit 30 is installed for each roadside antenna 20. The communication control unit 30 communicates with the roadside antenna 20 via the interface unit 9. The communication control units 30 are installed at, for example, entrance tollgates, exit tollgates, free flow (F/F), off-road facilities, and the like. Hereinafter, the communication control unit 30 installed at the entrance tollgate is referred to as an entrance communication control unit 31, and the communication control unit 30 installed at the exit tollgate is referred to as an exit communication control unit 32.

[0025]

The entrance communication control unit 30 is also referred to as, for example, an entrance tollgate server. The entrance communication control unit 31 communicates with the onboard unit 10 of the vehicle 1 via the entrance roadside antenna 21, and performs processing related to collection of the toll fee. The entrance communication control unit 31 transmits entrance information to the vehicle 1 arriving at the entrance tollgate. The entrance information includes, for example, identification information on the entrance tollgate where the vehicle 1 has entered, and date and time when the vehicle 1 arrived at the entrance tollgate (processing execution date and time). The entrance information transmitted to the onboard unit 10 is recorded in an IC card (also called an ETC card in Japan) inserted into the onboard unit 10, for example.

[0026]

The exit communication control unit 32 is also referred to as, for example, an exit tollgate server. The exit communication control unit 32 communicates with the onboard unit 10 of the vehicle 1 via the exit roadside antenna 22, and performs processing related to collection of the toll fee. The onboard unit 10 transmits the entrance information recorded in the IC card and the vehicle type information registered in the onboard unit 10 to the exit communication control unit 32 via the exit roadside antenna 22, and the exit communication control unit 32 calculates the toll fee to be billed to the vehicle 1 with reference to toll information distributed from the higher-level server 40 described later, for example, together with the exit information. This toll information includes, for example, a toll table for each vehicle type serving as a base of calculation of the toll fee, and a discount rate and a surcharge rate for each state of the vehicle 1. The exit information includes, for example, identification information on the exit tollgate where the vehicle 1 has entered, and date and time when the vehicle 1 arrived at the exit tollgate (processing execution date and time). Furthermore, the exit communication control unit 32 transmits information on the calculated toll fee to the higher-level server 40 and the onboard unit 10. The onboard unit 10 notifies the occupant of the amount of the toll fee to be billed (billing amount). The functional configuration of the exit communication control unit 32 will be described later.

[0027]

The communication control unit 30 through which the vehicle 1 can pass from the entrance tollgate to the exit tollgate is referred to as an intermediate communication control unit 33. The intermediate communication control unit 33 is installed at a notification point of a toll road such as free flow (F/F), an

off-road facility, or the like. The intermediate communication control unit 33 is also referred to as, for example, a roadside device or a lane server. The intermediate communication control unit 33 communicates with the onboard unit 10 of the vehicle 1 via the intermediate roadside antenna 23 together with the intermediate roadside antenna 23, and can transmit/receive information such as toll information, for example, to/from the onboard unit 10.

[0028]

The higher-level server 40 is provided to be able to transmit/receive information to/from each communication control unit 30. The higher-level server 40 transmits toll information to, for example, the exit communication control unit 32. The exit communication control unit 32 calculates the toll fee with reference to the toll table included in the toll information, and transmits the toll fee to the higher-level server 40 together with the IC card information acquired from the onboard unit 10. The higher-level server 40 performs payment processing on the toll fee to the credit company associated with the IC card information. The functional configuration of the higher-level server 40 will be described later.

[0029]

Functional Configuration of Onboard Unit

As illustrated in FIG. 2, the onboard unit 10 includes a vehicle information acquisition unit 101, a speed determination unit 102, a state change determination unit 103, a recording unit 104, a travel distance ratio calculation unit 105, an onboard unit information transmission unit 106, a billing information acquisition unit 107, a notification unit 108, and a communication determination unit 109.

[0030]

The vehicle information acquisition unit 101 sequentially acquires information on the vehicle 1 including the state of the vehicle 1 whose state can change on the toll road from the onboard sensor 15 (e.g., the seating sensor 2, the odometer 3, the speedometer 4, the axle load sensor 5, the lift 6, and the like described above). The vehicle information acquisition unit 101 acquires the travel distance of the vehicle 1 for each state of the vehicle 1. The state of the vehicle 1 acquired here includes, for example, the number of occupants, the axle load, and the number of axles. The vehicle information acquisition unit 101 acquires the number of occupants in the vehicle 1 as a state of the vehicle 1 from the seating sensor 2 via the vehicle control unit 8. The vehicle information acquisition unit 101 acquires the axle load of the vehicle 1 as a state of the vehicle 1 from the axle load sensor 5 via the vehicle control unit 8 and the lift

axle control unit 7. The vehicle information acquisition unit 101 acquires the number of axles of the vehicle 1 as a state of the vehicle 1 from the lift 6 via the vehicle control unit 8 and the lift axle control unit 7. In the present embodiment, the vehicle information acquisition unit 101 acquires the travel distance of the vehicle 1 from the odometer 3, and acquires the speed information on the vehicle 1 from the speedometer 4.

[0031]

The speed determination unit 102 determines whether or not the speed of the vehicle 1 is 0, for example, before the vehicle information acquisition unit 101 acquires the axle load. Regarding the "axle load", even if measured while the vehicle 1 is traveling, the "axle load" becomes a dynamic load and thus constantly varies. Therefore, the axle load during traveling is information with low accuracy. As described in detail later, the speed determination unit 102 determines whether or not the speed is 0, and acquires the axle load only when the speed is 0, whereby only the axle load with high accuracy is acquired.

[0032]

The state change determination unit 103 determines whether or not the state (e.g., the number of occupants, the number of axles, the axle load, and the like) of the vehicle 1 acquired by the vehicle information acquisition unit 101 has changed.

[0033]

The recording unit 104 records the state and the travel distance of the vehicle 1 acquired by the vehicle information acquisition unit 101. When the state change determination unit 103 determines that the state of the vehicle 1 has changed, the recording unit 104 updates the information related to the state of the vehicle 1, and records the travel distance of the section where the vehicle 1 has traveled in the state of the vehicle 1 before the update.

[0034]

The travel distance ratio calculation unit 105 calculates the travel distance ratio for each state of the vehicle 1 based on the travel distance acquired for each state of the vehicle 1 at the exit tollgate on the toll road. For example, the travel distance ratio calculation unit 105 calculates a travel distance ratio for each number of occupants in the vehicle 1. The travel distance ratio calculation unit 105 calculates a travel distance ratio for each axle load of the vehicle 1. The travel distance ratio calculation unit 105 calculates a travel distance ratio for each number of axles of the vehicle 1.

[0035]

The onboard unit information transmission unit 106 transmits information necessary for toll collection to the roadside antenna 20. The onboard unit information transmission unit 106 transmits information to the communication control unit 30 and the higher-level server 40 via the roadside antenna 20. In the present embodiment, the onboard unit information transmission unit 106 transmits the travel distance ratio for each state of the vehicle 1 calculated by the travel distance ratio calculation unit 105, for example.

[0036]

The billing information acquisition unit 107 acquires information on the toll fee to be billed to the vehicle 1 calculated by the exit communication control unit 32.

[0037]

The notification unit 108 notifies the occupant of the vehicle 1 of the toll fee to be billed to the vehicle 1.

[0038]

The communication determination unit 109 determines whether or not the onboard unit 10 and the roadside antenna 20 (e.g., the entrance roadside antenna 21 and the exit roadside antenna 22) have communicated with each other.

[0039]

Functional Configuration of Exit Communication Control Unit

As illustrated in FIG. 3, the exit communication control unit 32 includes an exit acquisition unit 301, a toll fee calculation unit 302, and an exit transmission unit 303.

[0040]

The exit acquisition unit 301 acquires information to be transmitted from the onboard unit 10 or the higher-level server 40. For example, the exit acquisition unit 301 acquires, from the onboard unit 10, IC card information on the onboard unit 10 and the travel distance ratio for each state of the vehicle 1 having been calculated. For example, toll information to be transmitted from the higher-level server 40 is acquired.

[0041]

The toll fee calculation unit 302 calculates the toll fee based on the toll information to be transmitted from the higher-level server 40 and the travel distance ratio for each state of the vehicle 1 calculated by the travel distance ratio calculation unit 105.

[0042]

The exit transmission unit 303 transmits information to the onboard unit 10 and the higher-level server 40. For example, the exit transmission unit 303 transmits the toll fee calculated by the toll fee calculation unit 302 to the onboard unit 10 and the higher-level server 40.

5 [0043]

Functional Configuration of Higher-Level Server

As illustrated in FIG. 2, the higher-level server 40 includes a higher-level server acquisition unit 401, a toll information transmission unit 402, and a payment processing unit 403.

10 [0044]

The higher-level server acquisition unit 401 acquires information from the onboard unit 10, the roadside antenna 20, and the communication control unit 30. For example, the higher-level server acquisition unit 401 acquires the toll fee to be transmitted from the exit communication control unit 32 and the IC card information on the onboard unit 10.

15

[0045]

The toll information transmission unit 402 transmits the toll information to, for example, the exit communication control unit 32.

[0046]

20

The payment processing unit 403 performs payment processing on the toll fee to the credit company associated with the acquired IC card information.

[0047]

Processing Example 1 of Toll Collection System

FIG. 4 is a first chart diagram illustrating an example of the processing of the toll collection system 100 according to the first embodiment. Here, the flow of processing of the toll collection system 100 will be described with reference to FIG. 4. The flow of processing will be described, as an example, with a case where the state of the vehicle 1 (e.g., information such as the number of occupants, the axle load, and the number of axles described above) changes when the vehicle 1 is activated and starts traveling, enters a toll road from one entrance tollgate, and travels to one exit tollgate.

30

[0048]

Until the vehicle 1 is activated and enters the entrance tollgate, the onboard unit 10 acquires an initial state of the vehicle 1 at the time of entering the entrance tollgate (step S101). Hereinafter, the flow of processing in step S101 for acquiring each initial state (the initial number of occupants, the initial axle load, the initial number of axles) of the vehicle 1 will be described in

35

detail for each of the number of occupants, the axle load, and the number of axles.

[0049]

Processing Example 1 of Onboard Unit

5 FIG. 5 is the first flowchart illustrating an example of the processing of the onboard unit 10 according to the first embodiment. Here, the flow of processing in which the onboard unit 10 acquires the initial number of occupants at the time of entering the entrance tollgate will be described with reference to FIG. 5.

10 [0050]

First, at the time of activation of the vehicle 1, the vehicle information acquisition unit 101 acquires the initial number of occupants from the seating sensor 2 (step S201). The acquired initial number of occupants is recorded in the recording unit 104.

15 [0051]

Thereafter, the vehicle information acquisition unit 101 starts acquisition of the number of occupants (step S202) from the seating sensor 2 at a predetermined period (e.g., every 1 sec, and this period can be appropriately changed). Subsequently, the state change determination unit 103 determines whether or not the number of occupants has changed from the initial number of occupants (step S203). When the number of occupants has not changed (step S203; NO), the communication determination unit 109 determines whether or not communication was performed between the onboard unit 10 and the entrance roadside antenna 21 (step S204). When the communication was performed between the onboard unit 10 and the entrance roadside antenna 21 (step S204; YES), the processing flow ends. When no communication was performed between the onboard unit 10 and the entrance roadside antenna 21 (step S204; NO), the process returns to step S202, and the vehicle information acquisition unit 101 acquires the number of occupants again.

30 [0052]

When it is determined in step S203 that the number of occupants has changed (step S203; YES), the recording unit 104 sets the number of occupants acquired in step S202 to the initial number of occupants and updates the initial number of occupants (step S205). Thereafter, the communication determination in step S204 described above is performed. When the communication was performed between the onboard unit 10 and the entrance roadside antenna 21 (step S204; YES), the processing flow ends. When no communication was performed between the onboard unit 10 and the entrance roadside antenna 21

(step S204; NO), the process returns to step S202, and the vehicle information acquisition unit 101 acquires the number of occupants again.

[0053]

In this manner, the initial number of occupants is acquired and, when the
 5 number of occupants is changed before entering the entrance tollgate, the initial number of occupants is updated.

[0054]

Processing Example 2 of Onboard Unit

FIG. 6 is the second flowchart illustrating an example of the processing
 10 of the onboard unit 10 according to the first embodiment. Here, the flow of processing in which the onboard unit 10 acquires the initial axle load at the time of entering the entrance tollgate will be described with reference to FIG. 6.

[0055]

15 First, at the time of activation of the vehicle 1, the vehicle information acquisition unit 101 acquires the initial axle load from the axle load sensor 5 (step S301). The acquired initial axle load is recorded in the recording unit 104. Thereafter, when the vehicle 1 starts traveling, the vehicle information acquisition unit 101 starts acquisition of the speed of the vehicle 1 (step S302)
 20 at a predetermined period (e.g., every 1 sec, and this period can be appropriately changed). The vehicle information acquisition unit 101 acquires the speed of the vehicle 1 from the speedometer 4. Thereafter, the speed determination unit 102 determines whether or not the speed of the vehicle 1 is 0 (step S303). When the speed of the vehicle 1 is not 0 (step S303; NO), the
 25 communication determination unit 109 determines whether or not communication was performed between the onboard unit 10 and the entrance roadside antenna 21 (step S304). When the communication was performed between the onboard unit 10 and the entrance roadside antenna 21 (step S304; YES), the processing flow ends. When no communication was performed
 30 between the onboard unit 10 and the entrance roadside antenna 21 (step S304; NO), the process returns to step S302, and the vehicle information acquisition unit 101 acquires the speed of the vehicle 1 again.

[0056]

When it is determined in step S303 that the speed of the vehicle 1 is 0
 35 (step S303; YES), the vehicle information acquisition unit 101 acquires the axle load from the axle load sensor 5 (step S305). Thereafter, the state change determination unit 103 determines whether or not the axle load has changed from the initial axle load (step S306). When the axle load has not changed (step

S306; NO), the communication determination in step S304 described above is performed. When the communication was performed between the onboard unit 10 and the entrance roadside antenna 21 (step S304; YES), the processing flow ends. When no communication was performed between the onboard unit 10 and the entrance roadside antenna 21 (step S304; NO), the process returns to step S302, and the vehicle information acquisition unit 101 acquires the speed of the vehicle 1 again.

[0057]

When it is determined in step S303 that the axle load has changed (step S306; YES), the recording unit 104 sets the axle load acquired in step S305 to the initial axle load, and updates the initial axle load (step S307). Thereafter, the communication determination in step S304 described above is performed. When the communication was performed between the onboard unit 10 and the entrance roadside antenna 21 (step S304; YES), the processing flow ends.

When no communication was performed between the onboard unit 10 and the entrance roadside antenna 21 (step S304; NO), the process returns to step S302, and the vehicle information acquisition unit 101 acquires the speed of the vehicle 1 again.

[0058]

In this manner, the initial axle load is acquired and, when the axle load is changed before entering the entrance tollgate, the initial axle load is updated.

[0059]

Processing Example 3 of Onboard Unit

FIG. 7 is the third flowchart illustrating an example of the processing of the onboard unit 10 according to the first embodiment. Here, the flow of processing in which the onboard unit 10 acquires the initial number of axles at the time of entering the entrance tollgate will be described with reference to FIG. 7.

[0060]

First, at the time of activation of the vehicle 1, the vehicle information acquisition unit 101 acquires the initial number of axles from the lift 6 (step S401). The acquired initial number of axles is recorded in the recording unit 104.

[0061]

Thereafter, the vehicle information acquisition unit 101 starts acquisition of the number of axles (step S402) from the lift 6 at a predetermined period (e.g., every 1 sec, and this period can be appropriately changed). Subsequently, the state change determination unit 103 determines

whether or not the number of axles has changed from the initial number of axles (step S403). When the number of axles has not changed (step S403; NO), the communication determination unit 109 determines whether or not communication was performed between the onboard unit 10 and the entrance roadside antenna 21 (step S404). When the communication was performed between the onboard unit 10 and the entrance roadside antenna 21 (step S404; YES), the processing flow ends. When no communication was performed between the onboard unit 10 and the entrance roadside antenna 21 (step S404; NO), the process returns to step S402, and the vehicle information acquisition unit 101 acquires the number of axles again.

[0062]

When it is determined in step S403 that the number of axles has changed (step S403; YES), the recording unit 104 sets the number of axles acquired in step S402 to the initial number of axles and updates the initial number of axles (step S405). Thereafter, the communication determination in step S404 described above is performed. When the communication was performed between the onboard unit 10 and the entrance roadside antenna 21 (step S404; YES), the processing flow ends. When no communication was performed between the onboard unit 10 and the entrance roadside antenna 21 (step S404; NO), the process returns to step S402, and the vehicle information acquisition unit 101 acquires the number of axles again.

[0063]

In this manner, the initial number of axles is acquired and, when the number of axles is changed before entering the entrance tollgate, the initial number of axles is updated.

[0064]

The initial state (the initial number of occupants, the initial axle load, and the initial number of axles) of the vehicle is acquired by the above-described processing flow. Returning to the flow of FIG. 4, thereafter, when the vehicle 1 enters the entrance tollgate, a vehicle detector at the entrance tollgate detects the vehicle 1, and communication is performed between the entrance roadside antenna 21 and the onboard unit 10 (step S102). Thereafter, the entrance communication control unit 31 transmits the entrance information to the onboard unit 10 (step S103). The transmitted entrance information is recorded in the IC card of the onboard unit 10, for example.

[0065]

When the communication between the entrance roadside antenna 21 and the onboard unit 10 is confirmed, the vehicle information acquisition unit 101

acquires, from the odometer 3, the initial value of the total travel distance at the time of entering the entrance tollgate (step S104). The acquired initial value of the total travel distance is recorded in the recording unit 104.

[0066]

5 After passing through the entrance tollgate, the vehicle 1 travels on the toll road. Thereafter, the onboard unit 10 continuously monitors the state of the vehicle 1 until the vehicle 1 reaches the exit tollgate. When the state of the vehicle 1 changes, the travel distance for each state is obtained by the onboard unit 10.

10 [0067]

For example, before the vehicle 1 reaches the exit tollgate, the vehicle information acquisition unit 101 sequentially acquires the state of the vehicle 1 whose state can change on the toll road from the onboard sensor 15 (e.g., the seating sensor 2, the axle load sensor 5, the lift 6, and the like), and acquires the travel distance of the vehicle 1 for each state of the vehicle 1 (step S105). Specifically, in step S105, the vehicle information acquisition unit 101 sequentially acquires the number of occupants as a state of the vehicle 1 from the seating sensor 2, and acquires the travel distance of the vehicle 1 for each number of occupants. In step S105, the vehicle information acquisition unit 101 sequentially acquires the axle load as a state of the vehicle 1 from the axle load sensor 5, and acquires the travel distance of the vehicle 1 for each axle load. In step S105, the vehicle information acquisition unit 101 sequentially acquires the number of axles as a state of the vehicle 1 from the lift 6, and acquires the travel distance of the vehicle 1 for each number of axles. Hereinafter, the flow of the processing in step S105 of acquiring the state of the vehicle 1 (the number of occupants, the axle load, and the number of axles) and the travel distance associated with the state of the vehicle 1 will be described in detail for each of the number of occupants, the axle load, and the number of axles.

[0068]

30 Processing Example 4 of Onboard Unit

FIG. 8 is the fourth flowchart illustrating an example of the processing of the onboard unit 10 according to the first embodiment. Here, the flow of processing in which the onboard unit 10 acquires the number of occupants in the vehicle 1 and the travel distance associated with the number of occupants will be described with reference to FIG. 8.

[0069]

First, after the vehicle 1 enters the entrance tollgate, the recording unit 104 sets the initial number of occupants to the first number of occupants, and

sets the initial value of the total travel distance to the first total travel distance (step S501).

[0070]

Thereafter, the vehicle information acquisition unit 101 starts
 5 acquisition of the number of occupants (step S502) from the seating sensor 2 at a predetermined period (e.g., every 1 sec, and this period can be appropriately changed). Subsequently, the state change determination unit 103 determines whether or not the number of occupants has changed from the first number of occupants (step S503). When the number of occupants has not changed (step
 10 S503; NO), the communication determination unit 109 determines whether or not communication was performed between the onboard unit 10 and the exit roadside antenna 22 (step S504). When the communication was performed between the onboard unit 10 and the exit roadside antenna 22 (step S504; YES), the processing flow ends. When no communication was performed between the
 15 onboard unit 10 and the exit roadside antenna 22 (step S504; NO), the process returns to step S502, and the vehicle information acquisition unit 101 acquires the number of occupants again.

[0071]

When it is determined in step S503 that the number of occupants has
 20 changed (step S503; YES), the vehicle information acquisition unit 101 acquires the total travel distance from the odometer 3 (step S505). The number of occupants acquired in step S502 and the total travel distance acquired in step S505 are recorded in the recording unit 104. Thereafter, the recording unit 104 sets the number of occupants acquired in step S505 to the second number of
 25 occupants, and sets the total travel distance acquired in step S505 to the second total travel distance (step S506).

[0072]

Subsequently, the vehicle information acquisition unit 101 acquires the travel distance in the section acquired with the first number of occupants before
 30 the change (travel distance associated with the first number of occupants before the change) (step S507). In step S507, by subtracting the first total travel distance from the second total travel distance, the travel distance in the section acquired with the first number of occupants before the change (travel distance associated with the first number of occupants before the change) is calculated.
 35 The travel distance acquired in step S507 is recorded in the recording unit 104 together with the associated number of occupants.

[0073]

Thereafter, the recording unit 104 updates the first number of occupants and the first total travel distance to changed values (step S508). That is, in step S508, the recording unit 104 sets the number of occupants (second number of occupants) acquired in step S502 to the first number of occupants, and sets the total travel distance (second total travel distance) acquired in step S505 to the first total travel distance. Thereafter, the communication determination in step S504 described above is performed. When the communication was performed between the onboard unit 10 and the exit roadside antenna 22 (step S504; YES), the processing flow ends. When no communication was performed between the onboard unit 10 and the exit roadside antenna 22 (step S504; NO), the process returns to step S502, and the vehicle information acquisition unit 101 acquires the speed of the vehicle 1 again.

[0074]

In this manner, the travel distance the vehicle 1 has traveled with each number of occupants (travel distance associated with each number of occupants) is acquired and cumulatively recorded.

[0075]

Processing Example 5 of Onboard Unit

FIG. 9 is the fifth flowchart illustrating an example of the processing of the onboard unit 10 according to the first embodiment. Here, the flow of processing in which the onboard unit 10 acquires the axle load of the vehicle 1 and the travel distance associated with the axle load will be described with reference to FIG. 9.

[0076]

First, after the vehicle 1 enters the entrance tollgate, the recording unit 104 sets the initial axle load to the first axle load, and sets the initial value of the total travel distance to the first total travel distance (step S601). Thereafter, the vehicle information acquisition unit 101 starts acquisition of the speed of the vehicle 1 (step S602) at a predetermined period (e.g., every 1 sec, and this period can be appropriately changed). The vehicle information acquisition unit 101 acquires the speed of the vehicle 1 from the speedometer 4. Thereafter, the speed determination unit 102 determines whether or not the speed of the vehicle 1 is 0 (step S603). When the speed of the vehicle 1 is not 0 (step S603; NO), the communication determination unit 109 determines whether or not communication was performed between the onboard unit 10 and the exit roadside antenna 22 (step S604). When the communication was performed between the onboard unit 10 and the exit roadside antenna 22 (step S604; YES), the processing flow ends. When no communication was performed between the

onboard unit 10 and the exit roadside antenna 22 (step S604; NO), the process returns to step S602, and the vehicle information acquisition unit 101 acquires the speed of the vehicle 1 again.

[0077]

5 When it is determined in step S603 that the speed of the vehicle 1 is 0 (step S603; YES), the vehicle information acquisition unit 101 acquires the axle load from the axle load sensor 5 (step S605). Thereafter, the state change determination unit 103 determines whether or not the axle load has changed from the first axle load (step S606). When the axle load has not changed (step 10 S606; NO), the communication determination in step S604 described above is performed. When the communication was performed between the onboard unit 10 and the exit roadside antenna 22 (step S604; YES), the processing flow ends. When no communication was performed between the onboard unit 10 and the exit roadside antenna 22 (step S604; NO), the process returns to step S602, 15 and the vehicle information acquisition unit 101 acquires the speed of the vehicle 1 again.

[0078]

 When it is determined in step S606 that the axle load has changed (step S606; YES), the vehicle information acquisition unit 101 acquires the total 20 travel distance from the odometer 3 (step S607). The axle load acquired in step S605 and the total travel distance acquired in step S607 are recorded in the recording unit 104. Thereafter, the recording unit 104 sets the axle load acquired in step S605 to the second axle load, and sets the total travel distance acquired in step S607 to the second total travel distance (step S608).

25 [0079]

 Subsequently, the vehicle information acquisition unit 101 acquires the travel distance in the section acquired with the first axle load before the change (travel distance associated with the first axle load before the change) (step S609). In step S609, by subtracting the first total travel distance from the 30 second total travel distance, the travel distance in the section acquired with the first axle load before the change (travel distance associated with the first axle load before the change) is calculated. The travel distance acquired in step S609 is recorded in the recording unit 104 together with the associated axle load.

[0080]

35 Thereafter, the recording unit 104 updates the first axle load and the first total travel distance to changed values (step S610). That is, in step S610, the recording unit 104 sets the axle load (second axle load) acquired in step S605 to the first axle load, and sets the total travel distance (second total travel

distance) acquired in step S607 to the first total travel distance. Thereafter, the communication determination in step S604 described above is performed.

When the communication was performed between the onboard unit 10 and the exit roadside antenna 22 (step S604; YES), the processing flow ends. When no communication was performed between the onboard unit 10 and the exit roadside antenna 22 (step S604; NO), the process returns to step S602, and the vehicle information acquisition unit 101 acquires the speed of the vehicle 1 again.

[0081]

In this manner, the travel distance the vehicle 1 has traveled with each axle load (travel distance associated with each axle load) is acquired and cumulatively recorded.

[0082]

Processing Example 6 of Onboard Unit

FIG. 10 is the sixth flowchart illustrating an example of the processing of the onboard unit 10 according to the first embodiment. Here, the flow of processing in which the onboard unit 10 acquires the number of axles of the vehicle 1 and the travel distance associated with the number of axles will be described with reference to FIG. 10.

[0083]

First, after the vehicle 1 enters the entrance tollgate, the recording unit 104 sets the initial number of axles to the first number of axles, and sets the initial value of the total travel distance to the first total travel distance (step S701).

[0084]

Thereafter, the vehicle information acquisition unit 101 starts acquisition of the number of axles (step S702) from the lift 6 at a predetermined period (e.g., every 1 sec, and this period can be appropriately changed). Subsequently, the state change determination unit 103 determines whether or not the number of axles has changed from the first number of axles (step S703). When the number of axles has not changed (step S703; NO), the communication determination unit 109 determines whether or not communication was performed between the onboard unit 10 and the exit roadside antenna 22 (step S704). When the communication was performed between the onboard unit 10 and the exit roadside antenna 22 (step S704; YES), the processing flow ends. When no communication was performed between the onboard unit 10 and the exit roadside antenna 22 (step S704; NO), the process

returns to step S702, and the vehicle information acquisition unit 101 acquires the number of axles again.

[0085]

When it is determined in step S703 that the number of axles has changed
 5 (step S703; YES), the vehicle information acquisition unit 101 acquires the total travel distance from the odometer 3 (step S705). The number of axles acquired in step S702 and the total travel distance acquired in step S705 are recorded in the recording unit 104. Thereafter, the recording unit 104 sets the number of axles acquired in step S705 to the second number of axles, and sets
 10 the total travel distance acquired in step S705 to the second total travel distance (step S706).

[0086]

Subsequently, the vehicle information acquisition unit 101 acquires the travel distance in the section acquired with the first number of axles before the
 15 change (travel distance associated with the first number of axles before the change) (step S707). In step S707, by subtracting the first total travel distance from the second total travel distance, the travel distance in the section acquired with the first number of axles before the change (travel distance associated with the first number of axles before the change) is calculated. The travel distance
 20 acquired in step S707 is recorded in the recording unit 104 together with the associated number of axles.

[0087]

Thereafter, the recording unit 104 updates the first number of axles and the first total travel distance to changed values (step S708). That is, in step
 25 S708, the recording unit 104 sets the number of axles (second number of axles) acquired in step S702 to the first number of axles, and sets the total travel distance (second total travel distance) acquired in step S705 to the first total travel distance. Thereafter, the communication determination in step S704 described above is performed. When the communication was performed
 30 between the onboard unit 10 and the exit roadside antenna 22 (step S704; YES), the processing flow ends. When no communication was performed between the onboard unit 10 and the exit roadside antenna 22 (step S704; NO), the process returns to step S702, and the vehicle information acquisition unit 101 acquires the speed of the vehicle 1 again.

35 [0088]

In this manner, the travel distance the vehicle 1 has traveled with each number of axles (travel distance associated with each number of axles) is acquired and cumulatively recorded.

[0089]

By the above-described processing flow, the state of the vehicle 1 (the number of occupants, the axle load, and the number of axles) and the travel distance associated with the state of the vehicle 1 are cumulatively acquired
5 until the vehicle passes through the exit tollgate.

[0090]

Here, returning to the flow of FIG. 4, until the vehicle 1 reaches the exit tollgate, the toll information transmission unit 402 of the higher-level server 40 transmits the toll information to the exit communication control unit 32 in
10 advance, and the exit acquisition unit 301 of the exit communication control unit 32 acquires the toll information to be transmitted (step S106). This toll information includes, for example, a toll table for each vehicle type serving as a base of calculation of the toll fee, and a discount rate and a surcharge rate for each state of the vehicle 1.

15 [0091]

Thereafter, when the vehicle 1 enters the exit tollgate, a vehicle detector at the exit tollgate detects the vehicle 1, and communication is performed between the exit roadside antenna 22 and the onboard unit 10 (step S107). When the communication between the exit roadside antenna 22 and the onboard
20 unit 10 is confirmed, the vehicle information acquisition unit 101 acquires, from the odometer 3, the final value of the total travel distance at the time of entering the exit tollgate (step S108). The acquired initial value of the total travel distance is recorded in the recording unit 104. Thereafter, furthermore, by subtracting the initial value of the total travel distance acquired at the
25 entrance tollgate from the final value of the total travel distance acquired at the exit tollgate, the vehicle information acquisition unit 101 acquires the travel distance of the entire section from the entrance tollgate to the exit tollgate (step S109).

[0092]

30 Thereafter, the travel distance ratio calculation unit 105 of the onboard unit 10 calculates the travel distance ratio for each state of the vehicle 1 based on the travel distance acquired for each state of the vehicle 1 (the number of occupants, the axle load, and the number of axles) (step S110). Specifically, in step S110, the travel distance ratio calculation unit 105 calculates the travel
35 distance ratio of each number of occupants in the vehicle 1. In step S110, the travel distance ratio calculation unit 105 calculates the travel distance ratio of each axle load of the vehicle 1. In step S110, the travel distance ratio

calculation unit 105 calculates the travel distance ratio of each number of axles of the vehicle 1.

[0093]

By step S110, the information illustrated in FIG. 11, for example, is
 5 acquired. FIG. 11 is a view illustrating an example of a table of the travel distance ratio according to the first embodiment. FIG. 11 summarizes the travel distance ratio of each number of occupants, the travel distance ratio of each axle load, and the travel distance ratio of each number of axles when the vehicle 1 travels a total travel distance of 10 km on a toll road from an entrance
 10 tollgate (a point where the total travel distance of the vehicle 1 is 1000 km) to an exit tollgate (a point where the total travel distance of the vehicle 1 is 1010 km). In the example of FIG. 11, the number of occupants is changed at an intermediate point (a point 5 km from the entrance tollgate), and the travel distance ratio when the number of occupants is 1 is 50%, and the travel
 15 distance ratio when the number of occupants is 2 is 50%. In the example of FIG. 11, one axle is lifted up at a point 6 km from the entrance tollgate, and the number of axles is changed from 4 to 3. Therefore, the travel distance ratio when the axle load is 5 tons or less is 60%, the travel distance ratio when the axle load is 5 tons or more and 10 tons or less is 40%, the travel distance ratio
 20 when the number of axles is 4 is 60%, and the travel distance ratio when the number of axles is 3 is 40%.

[0094]

After step S110, the onboard unit information transmission unit 106 of the onboard unit 10 transmits information to the exit communication control
 25 unit 32, and the exit acquisition unit 301 of the exit communication control unit 32 acquires the transmitted information (step S111). The information from the onboard unit 10 acquired in step S317 includes entrance information, IC card information, vehicle type information on the vehicle 1, and the travel distance ratio for each state of the vehicle 1.

30 [0095]

After Step S111, the toll fee calculation unit 302 of the exit communication control unit 32 calculates the toll fee based on the travel distance ratio for each state of the vehicle 1 (the number of occupants, the axle load, and the number of axles) calculated by the travel distance ratio
 35 calculation unit 105 (Step S112).

[0096]

Here, due to the number of axles, vehicle type information on the vehicle varies. For example, when the number of axles of a vehicle such as a

trailer or a truck varies due to a lift-up function, the vehicle type varies. When the vehicle type varies, the toll table to be applied also changes. Therefore, the number of axles is used for selection of the toll table to be applied. Note that the travel distance ratio acquired in association with the number of axles is also considered for selection of the toll table based on the number of axles. For example, in the example of FIG. 11, the travel distance ratio when the number of axles is 3 is 40%, and the travel distance ratio when the number of axles is 4 is 60%. Therefore, the toll table of the first vehicle type (e.g., a large vehicle) associated with the case where the number of axles is 3 is applied to 40% of the travel distance, and the toll table of the second vehicle type (e.g., an extra large vehicle) associated with the case where the number of axles is 4 is applied to 60% of the travel distance.

[0097]

The toll fee calculation unit 302 calculates the base toll based on the toll table selected based on the number of axles and the travel distance ratio applied with the toll table. The information on the number of occupants and the axle load is used to select a surcharge rate or a discount rate of the base toll.

[0098]

The following pattern is conceivable as a way of varying depending on the number of occupants. In a case where the vehicle 1 is a passenger car, the environmental load is reduced as more people are on one vehicle. Therefore, when the vehicle 1 is a passenger car, the larger the number of occupants is, the more the toll fee is discounted. When the vehicle 1 is a service bus or the like, the larger the number of occupants is, the larger the profit is, and the larger the load applied on the road is. Therefore, when the vehicle 1 is a service bus or the like, the larger the number of occupants is, the more the toll fee is surcharged. Note that the travel distance ratio acquired in association with the number of occupants is also taken into consideration for toll fee surcharge/discount based on the number of occupants. For example, in the example of FIG. 11, the travel distance ratio when the number of occupants is 1 is 50%, and the travel distance ratio when the number of occupants is 2 is 50%. Therefore, 50% of the travel distance is applied with the surcharge rate and the discount rate for a case where the number of occupants is 1, and 50% of the travel distance is applied with the surcharge rate and the discount rate for a case where the number of occupants is 2.

[0099]

The larger the axle load is, the larger the load applied on the road is. Therefore, the larger the axle load is, the more the toll fee is surcharged. Note

that the travel distance ratio acquired in association with the axle load is also taken into consideration for toll fee surcharge/discount based on the axle load. For example, in the example of FIG. 11, the travel distance ratio for the axle load of 5 tons or less is 60%, and the travel distance ratio for the axle load of 5 tons or more and 10 tons or less is 40%. Therefore, 60% of the travel distance is applied with the surcharge rate and the discount rate for a case where the axle load is 5 tons or less, and 40% of the travel distance is applied with the surcharge rate and the discount rate for a case where the axle load is 5 tons or more and 10 tons or less.

10 [0100]

The toll fee calculation unit 302 calculates the toll fee by performing surcharge/discount calculation corresponding to the travel distance ratios of the number of occupants and the axle load with respect to the base toll.

[0101]

15 Thereafter, the exit transmission unit 303 of the exit communication control unit 32 transmits the toll fee calculated by the toll fee calculation unit 302 to the higher-level server 40 and the onboard unit 10 (step S113). The higher-level server acquisition unit 401 of the higher-level server 40 acquires the IC card information acquired from the onboard unit 10 together with the toll fee, and the payment processing unit 403 of the higher-level server 40 performs the payment processing on the acquired toll fee (step S114). In step S114, the payment processing unit 403 performs the payment processing on the toll fee to the credit company associated with the IC card information acquired from the onboard unit 10.

25 [0102]

When the billing information acquisition unit 107 of the onboard unit 10 acquires the toll fee, the notification unit 108 of the onboard unit 10 notifies the occupant of the vehicle 1 of the toll fee to be billed to the vehicle 1 (step S115). Through the above procedure, toll collection (billing processing) is completed.

30

[0103]

Computer Configuration

FIG. 12 is a schematic block diagram illustrating the configuration of the computer according to the first embodiment. A computer 900 includes a processor 901, a main storage device 902, an auxiliary storage device 903, and an interface 904. The onboard unit 10, the lift axle control unit 7, the vehicle control unit 8, the communication control unit 30, and the higher-level server 40 described above are mounted on different computers 900. Then, the

35

operation of each processing unit described above is stored in the auxiliary storage device 903 in the form of a program. The processor 901 reads the program from the auxiliary storage device 903 to deploy it in the main storage device 902, and executes the above processing in accordance with the program.

- 5 The processor 901 secures, in the main storage device 902, a storage area used in the above processing in accordance with the program.

[0104]

The program may be for implementing some of the functions to be exerted by the computer 900. For example, the program may exert the function
 10 by a combination with another program already stored in the auxiliary storage device 903 or a combination with another program mounted on another device. Note that in other embodiments, the computer may include a custom large scale integrated circuit (LSI) such as a programmable logic device (PLD) in addition to or in place of the above configuration. Examples of the PLD include a
 15 programmable array logic (PAL), a generic array logic (GAL), a complex programmable logic device (CPLD), and a field programmable gate array (FPGA). In this case, some or all of the functions implemented by the processor may be implemented by the integrated circuit.

[0105]

- 20 Examples of the auxiliary storage device 903 include a hard disk drive (HDD), a solid state drive (SSD), a magnetic disk, a magneto-optical disk, a compact disc read only memory (CD-ROM), a digital versatile disc read only memory (DVD-ROM), and a semiconductor memory. The auxiliary storage device 903 may be an internal medium directly connected to a bus of the
 25 computer 900 or may be an external medium (an external storage device 910) connected to the computer 900 via the interface 904 or a communication line. In a case where this program is distributed to the computer 900 via the communication line, the computer 900 having received the distribution may deploy the program in the main storage device 902 and execute the above
 30 processing. In at least one embodiment, the auxiliary storage device 903 is a non-transitory tangible storage medium.

[0106]

Operational Effects

- 35 As described above, the onboard unit 10 includes the vehicle information acquisition unit 101 that acquires information on the vehicle 1 including the state of the vehicle 1 whose state can change on the toll road.

[0107]

In the known technique, when the state (e.g., the number of occupants, the axle load, and the number of axles) of the vehicle 1 varies during traveling on the toll road, variable billing corresponding to the change in the state of the vehicle 1 has not been performed. On the other hand, in the present
 5 embodiment, the onboard unit 10 can acquire the state of the vehicle 1. This enables the toll fee to be calculated based on the change in the state of the vehicle 1. Therefore, it is possible to carry out variable billing (dynamic billing) of varying the toll fee according to the change in the state of the vehicle 1. Hence, it is possible to implement the billing processing according to
 10 the states of individual vehicles 1.

[0108]

The vehicle information acquisition unit 101 acquires the state of the vehicle 1 from the onboard sensor 15 mounted on the vehicle 1.

[0109]

15 This enables the onboard unit 10 to acquire information on the vehicle 1 including the state of the vehicle 1 from the onboard sensor 15 mounted on the vehicle 1. This enables the onboard unit 10 to acquire information on the vehicle 1 without transmitting/receiving information to/from external equipment.

20 [0110]

The vehicle information acquisition unit 101 acquires the number of occupants in the vehicle 1 as a state of the vehicle 1 from the seating sensor 2, which is a type of the onboard sensor 15.

[0111]

25 This enables the onboard unit 10 to acquire the number of occupants in the vehicle 1 from the seating sensor 2 mounted on the vehicle 1. This enables the toll fee to be calculated based on the change in the number of occupants, and therefore variable billing according to the change in the number of occupants can be carried out.

30 [0112]

The vehicle information acquisition unit 101 acquires the axle load of the vehicle 1 as a state of the vehicle 1 from the axle load sensor 5 that is a type of the onboard sensor 15.

[0113]

35 This enables the onboard unit 10 to acquire the axle load of the vehicle 1 from the axle load sensor 5 mounted on the vehicle 1. This enables the toll fee to be calculated based on the change in the axle load, and therefore variable billing according to the change in the axle load can be carried out.

[0114]

The vehicle 1 is a lift axle vehicle including the lift 6 that can lift up and lift down an axle, and the vehicle information acquisition unit 101 acquires the number of axles of the vehicle 1, whose connected wheels are in contact with ground, as the state of the vehicle 1 from the lift 6 that is a type of the onboard sensor 15.

[0115]

This enables the onboard unit 10 to acquire the number of axles of the vehicle 1, whose wheels are in contact with ground, from the lift 6 mounted on the vehicle 1 when the vehicle 1 is a lift axle vehicle. This enables the toll fee to be calculated based on the change in the number of axles, and therefore variable billing according to the change in the number of axles can be carried out. In the present embodiment, since the number of axles is directly detected from the lift 6 without using a method by image processing or the like, complicated processing for detecting the number of axles is unnecessary. Hence, an increase in cost for detection of the number of axles is suppressed.

[0116]

The vehicle information acquisition unit 101 acquires, for each state of the vehicle 1, a travel distance of the vehicle 1 as information on the vehicle 1 from the odometer 3 mounted on the vehicle 1, which is a type of the onboard sensor 15, and the onboard unit 10 further includes the travel distance ratio calculation unit 105 that calculates a travel distance ratio for each state of the vehicle 1 based on a travel distance acquired for each state of the vehicle 1 at an exit tollgate on the toll road.

[0117]

This enables the toll fee to be calculated based on the change in the state of the vehicle 1 and the travel distance ratio for each state of the vehicle 1. Therefore, it is possible to carry out variable billing (dynamic billing) of varying the toll fee according to the change in the state of the vehicle 1 and the travel distance ratio for each state. Hence, it is possible to implement the billing processing according to the change in the state of each vehicle 1 and the travel distance ratio for each state. The onboard unit 10 can acquire the travel distance from the odometer 3 mounted on the vehicle 1. Hence, the onboard unit 10 can acquire the travel distance without using GNSS positioning or the like.

[0118]

The toll collection system 100 includes: the onboard unit 10 described above; the exit communication control unit 32 installed at the exit tollgate; and

the higher-level server 40 that can transmit/receive information to/from the exit communication control unit 32, in which the exit communication control unit 32 transmits, to the higher-level server 40, the toll fee to be calculated based on the state of the vehicle 1, and the higher-level server 40 performs payment processing on the toll fee from the exit communication control unit 32.

[0119]

The exit communication control unit 32 may calculate the maximum base toll calculated in no consideration of the change in the state of the vehicle 1, and calculate the toll so as to discount the maximum base toll.

[0120]

This makes it easy to incorporate the toll collection system 100 of the present embodiment into an existing toll collection system (ETC system). If the onboard unit 10 is not operated, no discount can be received, and the maximum toll fee will be billed. Therefore, the onboard unit 10 will be less likely to be illegally stopped, and the toll collection system 100 of the present embodiment will become widespread.

[0121]

Other Embodiments

While one embodiment has been described in detail with reference to the drawings, the specific configuration is not limited to that described above, and various design changes and the like can be made. That is, in other embodiments, the order of the above-described processing may be appropriately changed. Parts of processing may be executed in parallel.

[0122]

For example, as illustrated in FIG. 13, the onboard unit 10 may be provided with the toll fee calculation unit 302 in place of the exit communication control unit 32. That is, the onboard unit 10 side may calculate the toll fee based on the travel distance ratio for each state of the vehicle 1 calculated by the travel distance ratio calculation unit 105. In this case, the onboard unit 10 acquires the toll information transmitted from the higher-level server 40, and the toll fee calculation unit 302 calculates the toll fee based on the toll information acquired from the higher-level server 40 and the travel distance ratio for each state of the vehicle 1. Thereafter, the onboard unit information transmission unit 106 of the onboard unit 10 transmits the calculated toll fee to the exit communication control unit 32, and the exit communication control unit 32 transmits the toll information to the higher-level server 40 to perform payment processing.

[0123]

The higher-level server 40 or the communication control unit 30 may have a violation determination function of determining whether or not lift-up/lift-down of the axle has been operated in order to lower the toll fee than a regular price based on the number of axles acquired by the onboard unit 10 and information associated with the number of axles (information on the travel distance ratio and at what time point the number of axles was changed) at the entrance tollgate or the exit tollgate, for example.

[0124]

In the embodiments described above, a case where the discount/surcharge calculation is performed on the base toll based on the travel distance ratio for each state of the vehicle 1 has been described, but the calculation is not limited to this. At the exit tollgate, the maximum base toll may be billed as the toll fee, and point reward may be performed based on the travel distance ratio for each state of the vehicle 1 as postprocessing.

[0125]

Note that in the embodiments described above, a case where the travel distance ratio for each state of the vehicle 1 is calculated to perform the surcharge/discount calculation of the toll fee based on the travel distance ratio has been described, but the calculation is not limited to this. Without calculating the travel distance ratio for each state of the vehicle 1, the surcharge/discount calculation may be performed based on each state of the vehicle 1 directly acquired by the onboard unit 10 from the vehicle 1.

[0126]

Supplementary Notes

The above-described embodiments are understood as follows, for example.

[0127]

(1) According to a first aspect, the onboard unit 10 includes the vehicle information acquisition unit 101 configured to acquire information on the vehicle 1 including a state of the vehicle 1 whose state can change on the toll road.

[0128]

In the known technique, when the state (e.g., the number of occupants, the axle load, and the number of axles) of the vehicle 1 varies during traveling on the toll road, variable billing corresponding to the change in the state of the vehicle 1 has not been performed. On the other hand, in the present aspect, the onboard unit 10 can acquire the state of the vehicle 1. This enables the toll fee to be calculated based on the change in the state of the vehicle 1. Therefore, it

is possible to carry out variable billing (dynamic billing) of varying the toll fee according to the change in the state of the vehicle 1. Hence, it is possible to implement the billing processing according to the states of individual vehicles 1.

5 Note that the calculation of the toll fee may be performed by an upstream unit (e.g., the exit communication control unit 32 of the above-described embodiments) of the onboard unit 10 or may be performed on the onboard unit 10 side.

[0129]

10 (2) According to a second aspect, in the onboard unit 10 according to the first aspect, the vehicle information acquisition unit 101 acquires information on the vehicle 1 including a state of the vehicle 1 from the onboard sensor 15 mounted on the vehicle 1.

[0130]

15 This enables the onboard unit 10 to acquire information on the vehicle 1 including the state of the vehicle 1 from the onboard sensor 15 mounted on the vehicle 1. This enables the onboard unit 10 to acquire information on the vehicle 1 without transmitting/receiving information to/from external equipment.

20 [0131]

(3) According to a third aspect, in the onboard unit 10 according to the second aspect, the vehicle information acquisition unit 101 acquires the number of occupants in the vehicle 1 as a state of the vehicle 1 from the seating sensor 2 that is a type of the onboard sensor 15.

25 [0132]

This enables the onboard unit 10 to acquire the number of occupants in the vehicle 1 from the seating sensor 2 mounted on the vehicle 1. This enables the toll fee to be calculated based on the change in the number of occupants, and therefore variable billing according to the change in the number of
30 occupants can be carried out.

[0133]

(4) According to a fourth aspect, in the onboard unit 10 according to the second or third aspect, the vehicle information acquisition unit 101 acquires an axle load of the vehicle 1 as a state of the vehicle 1 from the axle load sensor 5
35 that is a type of the onboard sensor 15.

[0134]

This enables the onboard unit 10 to acquire the axle load of the vehicle 1 from the axle load sensor 5 mounted on the vehicle 1. This enables the toll fee

to be calculated based on the change in the axle load, and therefore variable billing according to the change in the axle load can be carried out.

[0135]

(5) According to a fifth aspect, in the onboard unit 10 according to any one of the second to fourth aspects, the vehicle 1 is a lift axle vehicle including the lift 6 configured to lift up and lift down an axle, and the vehicle information acquisition unit 101 acquires the number of axles of the vehicle 1, whose connected wheels are in contact with ground, as the state of the vehicle 1 from the lift 6 that is a type of the onboard sensor 15.

10 [0136]

This enables the onboard unit 10 to acquire the number of axles of the vehicle 1, whose wheels are in contact with ground, from the lift 6 mounted on the vehicle 1 when the vehicle 1 is a lift axle vehicle. This enables the toll fee to be calculated based on the change in the number of axles, and therefore variable billing according to the change in the number of axles can be carried out. In the present aspect, since the number of axles is directly detected from the lift 6 without using a method by image processing or the like, complicated processing for detecting the number of axles is unnecessary. Hence, an increase in cost for detection of the number of axles is suppressed.

20 [0137]

(6) According to a sixth aspect, in the onboard unit 10 according to any one of the second to fifth aspects, the vehicle information acquisition unit 101 acquires, for each state of the vehicle 1, a travel distance of the vehicle 1 as information on the vehicle 1 from the odometer 3 that is a type of the onboard sensor 15, and the onboard unit 10 further includes the travel distance ratio calculation unit 105 configured to calculate a travel distance ratio for each state of the vehicle 1 based on a travel distance acquired for each state of the vehicle 1 at an exit tollgate on the toll road.

[0138]

30 This enables the toll fee to be calculated based on the change in the state of the vehicle 1 and the travel distance ratio for each state of the vehicle 1. Therefore, it is possible to carry out variable billing (dynamic billing) of varying the toll fee according to the change in the state of the vehicle 1 and the travel distance ratio for each state. Hence, it is possible to implement the billing processing according to the change in the state of each vehicle 1 and the travel distance ratio for each state. The onboard unit 10 can acquire the travel distance from the odometer 3 mounted on the vehicle 1. Hence, the onboard

35

unit 10 can acquire the travel distance without using GNSS positioning or the like.

[0139]

(7) According to a seventh aspect, the toll collection system 100 includes: the onboard unit 10 according to any one of the first to sixth aspects; the exit communication control unit 32 installed at the exit tollgate; and the higher-level server 40 configured to transmit/receive information to/from the exit communication control unit 32, in which the exit communication control unit 32 transmits, to the higher-level server 40, a toll fee to be calculated based on a state of the vehicle 1, and the higher-level server 40 performs payment processing on the toll fee from the exit communication control unit 32.

[0140]

(8) According to an eighth aspect, the toll collection method includes: acquiring, by the onboard unit 10 mounted on the vehicle 1, information on the vehicle 1 including a state of the vehicle 1 whose state can change on a toll road; transmitting, by the exit communication control unit 32 installed at an exit tollgate on the toll road, a toll fee to be calculated based on a travel distance ratio for each state of the vehicle 1 to the higher-level server 40; and performing, by the higher-level server 40, payment processing on the toll fee from the exit communication control unit 32.

[0141]

(9) According to a ninth aspect, the program causes the onboard unit 10 to execute acquiring information on the vehicle 1 including the state of the vehicle 1 whose state can change on the toll road.

25

Reference Signs List

[0142]

100 Toll collection system

1 Vehicle

30 10 Onboard unit

101 Vehicle information acquisition unit

105 Travel distance ratio calculation unit

15 Onboard sensor

2 Seating sensor

35 3 Odometer

5 Axle load sensor

6 Lift

8 Vehicle control unit

32 Exit communication control unit

40 Higher-level server

Claims

[Claim 1]

An onboard unit comprising a vehicle information acquisition unit configured to acquire information on a vehicle including a state of the vehicle whose state can change on a toll road.

[Claim 2]

The onboard unit according to claim 1, wherein
the vehicle information acquisition unit acquires information on the vehicle including a state of the vehicle from an onboard sensor mounted on the vehicle.

[Claim 3]

The onboard unit according to claim 2, wherein
the vehicle information acquisition unit acquires the number of occupants in the vehicle as a state of the vehicle from a seating sensor that is a type of the onboard sensor.

[Claim 4]

The onboard unit according to claim 2, wherein
the vehicle information acquisition unit acquires an axle load of the vehicle as a state of the vehicle from an axle load sensor that is a type of the onboard sensor.

[Claim 5]

The onboard unit according to claim 2, wherein
the vehicle is a lift axle vehicle including a lift configured to lift up and lift down an axle, and
the vehicle information acquisition unit acquires the number of axles of the vehicle, whose connected wheels are in contact with ground, as a state of the vehicle from the lift that is a type of the onboard sensor.

[Claim 6]

The onboard unit according to any one of claims 2 to 5, wherein
the vehicle information acquisition unit acquires, for each state of the vehicle, a travel distance of the vehicle as information on the vehicle from an odometer that is a type of the onboard sensor, and

the onboard unit further comprises a travel distance ratio calculation unit configured to calculate a travel distance ratio for each state of the vehicle based on a travel distance acquired for each state of the vehicle at an exit tollgate on the toll road.

[Claim 7]

A toll collection system comprising:

the onboard unit according to any one of claims 1 to 5;

an exit communication control unit installed at an exit tollgate on the toll road; and

a higher-level server configured to transmit/receive information to/from the exit communication control unit, wherein

the exit communication control unit transmits, to the higher-level server, a toll fee to be calculated based on a state of the vehicle, and

the higher-level server performs payment processing on the toll fee from the exit communication control unit.

[Claim 8]

A toll collection method comprising:

acquiring, by an onboard unit mounted on a vehicle, information on the vehicle including a state of the vehicle whose state can change on a toll road;

transmitting, by an exit communication control unit installed at an exit tollgate on the toll road, a toll fee to be calculated based on a state of the vehicle to a higher-level server; and

performing, by the higher-level server, payment processing on the toll fee from the exit communication control unit.

[Claim 9]

A program that causes an onboard unit to execute acquiring information on a vehicle including a state of the vehicle whose state can change on a toll road.