

COMMUNICATION SYSTEM, BASE STATION, MEASUREMENT METHOD, AND
PROGRAM

Field of the Invention

5 [0001]

The present invention relates to a communication system, a base station, a measurement method, and a program.

Priority is claimed on Japanese Patent Application No. 2020-016553, filed February 3, 2020, the content of which is incorporated herein by reference.

10

Description of Related Art

[0002]

Conventionally, there are technologies for receiving radio waves transmitted from a transmitter of beacons or the like installed indoors and estimating a position of a receiver on the basis of an intensity of the received radio waves (received radio wave intensity). For example, in Patent Document 1, a technology for building a model acquiring an indoor radio wave intensity distribution using a radial basis function from a relation between an indoor position measured in advance and a radio wave intensity and estimating the position of a receiver using the built model is disclosed.

20 [Citation List]

[Patent Literature]

[0003]

[Patent Document 1]

Japanese Unexamined Patent Application, First Publication No. 2019-144120

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SUMMARY OF THE INVENTION

[Technical Problem]

[0004]

However, in a case in which the technology of Patent Document 1 is applied
5 outdoors, there is room for improvement. For example, there are obstacles in outdoors
such as buildings, vehicles, and the like, and a radio wave intensity distribution changes
over time. Thus it is difficult to build a model that is able to acquire a radio wave
intensity distribution with high accuracy. In addition, measurement of radio wave
intensities of various outdoor positions in advance takes much effort, which is not
10 realistic.

In addition, a position detection method using Global Positioning System (GPS)
signals can also be employed outdoors. However, position detection using GPS requires
consumption of much electric power. For this reason, in the case of a terminal in which
a battery of a large capacity cannot be mounted, it is difficult to use position detection
15 using GPS.

[0005]

The present invention is in view of such situations and provides a
communication system, a base station, a measurement method, and a program capable of
estimating a position of a mobile body using a method of receiving radio waves
20 transmitted from an outdoor mobile body with no effort.

[Solution to Problem]

[0006]

In order to achieve the object described above, according to a first aspect of the
present invention, there is provided a communication system that includes a terminal
25 device and a base station connected to the terminal device to be able to communicate in

two ways with each other, and that estimates a position of the terminal device, the communication system including: a communication control unit that controls communication between the base station and the terminal device; a measurement unit that measures a signal arrival time required for a signal transmitted from the base station to arrive at the terminal device; and a position estimating unit that estimates the position of the terminal device on the basis of the signal arrival time measured by the measurement unit.

[0007]

A base station according to a second aspect of the present invention is a base station connected to a terminal device to be able to communicate in two ways with each other in a communication system estimating a position of the terminal device, the base station including: a base station communication control unit that controls communication with the terminal device; and a measurement unit that measures a signal arrival time required for a signal transmitted from the base station to arrive at the terminal device on the basis of a transmission time of a transmission instruction signal transmitted from the base station to the terminal device and a reception time at which the base station receives a child signal that is a response to the transmission instruction signal from the terminal device.

[0008]

A measurement method according to a third aspect of the present invention is a measurement method of measuring a signal arrival time required for a signal transmitted from a base station to arrive at a terminal device, in the base station connected to the terminal device to be able to communicate in two ways with each other, among a communication system estimating a position of the terminal device, the measurement method including: controlling communication with the terminal device by using a base

station communication control unit; and measuring the signal arrival time by using a measurement unit, on the basis of a transmission time of a transmission instruction signal transmitted from the base station to the terminal device and a reception time at which the base station receives a child signal that is a response to the transmission instruction signal from the terminal device.

[0009]

A program according to a fourth aspect of the present invention is a program used for measuring a signal arrival time required for a signal transmitted from a base station to arrive at a terminal device, in the base station connected to the terminal device to be able to communicate in two ways with each other, among a communication system estimating a position of the terminal device, the program used for executing: a base station communication control means that controls communication with the terminal device; and a measurement means that measures the signal arrival time, on the basis of a transmission time of a transmission instruction signal transmitted from the base station to the terminal device, and a reception time at which the base station receives a child signal that is a response to the transmission instruction signal from the terminal device.

[Advantageous Effects of Invention]

[0010]

According to the present invention, a position of a mobile body can be estimated using a method of receiving radio waves transmitted from a mobile body present outdoors with no effort.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011]

Fig. 1 is a block diagram illustrating an example of the configuration of a

position estimating system according to a first embodiment.

Fig. 2 is a diagram illustrating a process of the position estimating system according to the first embodiment estimating a position.

Fig. 3 is a block diagram illustrating an example of the configuration of a server apparatus according to the first embodiment.

Fig. 4 is a block diagram illustrating an example of the configuration of a base station according to the first embodiment.

Fig. 5 is a block diagram illustrating an example of the configuration of a terminal tag according to the first embodiment.

Fig. 6 is a diagram illustrating an example of the configuration of transmission time information according to the first embodiment.

Fig. 7 is a diagram illustrating an example of the configuration of reception time information according to the first embodiment.

Fig. 8 is a diagram illustrating an example of the configuration of processing time information according to the first embodiment.

Fig. 9 is a diagram illustrating an example of the configuration of re-transmission number information according to the first embodiment.

Fig. 10 is a diagram illustrating an example of the configuration of a format of a signal used for position estimation according to the first embodiment.

Fig. 11 is a sequence diagram illustrating the flow of a process performed by the position estimating system according to the first embodiment.

Fig. 12 is a block diagram illustrating an example of the configuration of a terminal tag according to a Modified Example of the first embodiment.

Fig. 13 is a sequence diagram illustrating the flow of a process performed by a position estimating system according to a Modified Example of the first embodiment.

Fig. 14 is a sequence diagram illustrating the flow of the process performed by the position estimating system according to the Modified Example of the first embodiment.

Fig. 15 is a block diagram illustrating an example of the configuration of a position estimating system according to a second embodiment.

Fig. 16 is a block diagram illustrating an example of the configuration of a repeater according to the second embodiment.

Fig. 17 is a diagram illustrating an example of the configuration of first relay information according to the second embodiment.

Fig. 18 is a diagram illustrating an example of the configuration of second relay information according to the second embodiment.

Fig. 19 is a sequence diagram illustrating the flow of a process performed by the position estimating system according to the second embodiment.

DETAILED DESCRIPTION OF THE INVENTION

[0012]

Hereinafter, embodiments of the present invention will be described in detail with reference to the drawings.

[0013]

A first embodiment will be described.

Fig. 1 is a block diagram illustrating an example of the configuration of a position estimating system 1 according to the first embodiment. The position estimating system 1 is a system that estimates a position of a terminal tag 30 that moves while mounted in a mobile object such as a vehicle or the like. The position estimating system 1, for example, includes a server apparatus 10, a plurality of base stations 20

(base stations 20-1, 20-2, 20-3, ...), and a terminal tag 30. The position estimating system 1 is one example of a “communication system.” The terminal tag 30 is one example of a “terminal device.”

[0014]

5 The server apparatus 10 and the base station 20 are connected to be able to communicate in two ways with each other. The base station 20 and the terminal tag 30 are connected to be able to communicate with each other in two ways. In addition, the position estimating system 1 may include a plurality of server apparatuses 10 or may include a plurality of terminal tags 30. The number of base stations 20 included in the
10 position estimating system 1 may be only one. In addition, one of a plurality of base stations 20 may have the function of the server apparatus 10. In this case, the plurality of base stations 20 are composed of one master base station and a plurality of other slave base stations. Each of the slave base stations may be connected to the master base station to be able to communicate therewith.

15 [0015]

 The position estimating system 1 is a system that estimates a position of the terminal tag 30. For example, the position estimating system 1 is applied to physical distribution management. In this physical distribution management, the terminal tag 30 is
20 is attached to a product that is a target for the management, or the terminal tag 30 is mounted in a vehicle delivering the product. In accordance with this, the terminal tag 30 moves together with the product. By estimating the position of the terminal tag 30 that moves, the position estimating system 1 manages the position of the product being delivered.

[0016]

25 The terminal tag 30 is a device that has a communication function of

communicating with various sensors that monitor a monitoring target. For example, in a case in which a monitoring target is physical distribution, the various sensors described here are a temperature sensor that measures a temperature of a product of which temperature management is necessary, an illuminance sensor that detects opening of the product, and the like. The communication function included in the terminal tag 30 performs communication between the terminal tag 30 and the base station 20.

[0017]

As communication between the base station 20 and the terminal tag 30, an arbitrary communication scheme may be employed as long as at least two-way communication is enabled. For example, as the communication scheme, Sigfox (registered trademark), LoRa (registered trademark), ZETA (registered trademark), or the like of a low power wide area (LPWA) standard is used. LPWA has a feature of power consumption being suppressed to be lower than that of an existing communication network, for example, such as Long Term Evolution (LTE) or the like by suppressing a communication speed. In addition, LPWA has a feature of a communication distance being longer than that of short-range radio communication such as Bluetooth (registered trademark), for example, at about several tens of km to 100 km. In order to increase the communication distance, a repeater may be disposed between the base station 20 and the terminal tag 30.

[0018]

In this embodiment, the terminal tag 30 is used only for estimation of a position. For this reason, the terminal tag 30 may have at least a communication function and may not include any sensor. It is preferable that the terminal tag 30 have a battery or the like built therein and be a so-called radio tag (cordless tag) from an aspect of moving while attached to a product or the like. In addition, it is preferable that the terminal tag 30 be

a tag of a small size, a thin type, and a light weight so as not to interfere with conveyance of a product.

[0019]

In two-way communication between the base station 20 and the terminal tag 30,
5 one communication scheme and the other communication scheme may be the same communication scheme or be communication schemes different from each other. For example, a communication scheme in a direction for transmission of information from the terminal tag 30 to the base station 20 may be set as a communication scheme to which the LPWA standard is applied, and a communication scheme in a direction for
10 reception of information from the terminal tag 30 to the base station 20 may be set as a communication scheme of a standard other than the LPWA standard. In addition, in a case in which ZETA is applied, multi-channel communication using an ultra-narrow band (UNB) acquired by dividing a communication band into a plurality of bands is performed. In this case, a band of a channel used for communication may be fixed to
15 the same band each time or may be operated such that the band is changed without being fixed each time.

[0020]

The base station 20 may communicate with the terminal tag 30 and, for example, collect sensor information such as a temperature, luminance, and the like measured by
20 sensors of the terminal tag 30.

[0021]

The base station 20 according to this embodiment communicates with the terminal tag 30 and measures a signal arrival time of a signal used for communication. The signal arrival time is a time until a signal transmitted from the base station 20 arrives
25 at the terminal tag 30. The base station 20 communicates with the server apparatus 10

and notifies the server apparatus 10 of the measured signal arrival time. A method for the base station 20 to measure a signal arrival time will be described in detail below.

[0022]

The server apparatus 10 communicates with the base stations 20. The server
5 apparatus 10 estimates a position of the terminal tag 30 using signal arrival times each measured by the base station 20. The position of the terminal tag 30 is estimated by applying the principle of triangulation to the signal arrival times (see Fig. 2).

The server apparatus 10 notifies an external apparatus such as a position search application server, which is not illustrated in the drawing, of the estimated position of the
10 terminal tag 30. In this case, the server apparatus 10 is connected to the position search application server through a communication network such as the Internet. The position search application server is an application that provides a service of searching for a position of a product being delivered. For example, the position search application server accepts a request indicating a search for a position of a product from a user
15 terminal in which this application is installed. The position search application server makes the position estimating system 1 estimate a position of the terminal tag 30 that is attached to a product, which is a search target, on the basis of a request from the user terminal. The position search application server also notifies the user terminal of the position estimated by the position estimating system 1 as a search result.

20 [0023]

A method for the server apparatus 10 to estimate a position of the terminal tag 30 will be described with reference to Fig. 2. Fig. 2 is a diagram illustrating a process of the position estimating system 1 according to the first embodiment estimating a position. For example, the server apparatus 10 (not illustrated in Fig. 2) makes the base
25 stations 20 communicate with the same terminal tag 30 at almost the same times and

measure respective signal arrival times. The server apparatus 10 extracts candidates for the position of the terminal tag 30 on the basis of the signal arrival times of the base stations 20.

[0024]

5 For example, the server apparatus 10 calculates signal arrival distances from a relation with a velocity of signals (the velocity of light) on the basis of each of the signal arrival times of the base stations 20. A signal arrival distance is a distance of transmission until a signal transmitted from the base station 20 arrives at the terminal tag 30 and has the same meaning as a distance from the base station 20 to the terminal tag 30. The server apparatus 10 sets the position on a circumference of which radius is each signal arrival distance, and of which center is each base station 20, as a candidate for a position of the terminal tag 30.

[0025]

15 In the example illustrated in Fig. 2, a signal arrival time measured by the base station 20-1 is 0.2 seconds, and a position on a circumference R1 is a candidate for the position of the terminal tag 30. A signal arrival time measured by the base station 20-2 is 0.1 seconds, and a position on a circumference R2 is a candidate for the position of the terminal tag 30. A signal arrival time measured by the base station 20-3 is 0.5 seconds, and a position on a circumference R3 is a candidate for the position of the terminal tag 30.

20 The server apparatus 10 estimates a position at which the candidates for the positions of the terminal tag 30 extracted on the basis of the signal arrival distances measured by a plurality of the base stations 20 intersect each other, as the position of the terminal tag 30. In this example, a point at which the circumferences R1 to R3 intersect
25 each other is the estimated position of the terminal tag 30.

[0026]

In the description presented above, a case in which the server apparatus 10 estimates the position of the terminal tag 30 on the basis of signal arrival times measured by three base stations 20 has been described as an example. However, the configuration
5 is not limited thereto.

The server apparatus 10 may estimate the position of the terminal tag 30 on the basis of signal arrival times measured by four or more base stations 20. The server apparatus 10 may estimate the position of the terminal tag 30 on the basis of one or two signal arrival times. In such a case, for example, the server apparatus 10 superimposes
10 the candidates for the position of the terminal tag 30 extracted on the basis of the one or more signal arrival distances measured by the base stations 20 on a road map of the vicinity of the positions that are the candidates. The server apparatus 10 estimates a position at which the candidates for the position of the terminal tag 30 extracted on the basis of the one or more signal arrival distances and a traveling route of a vehicle or the
15 like in which the terminal tag 30 is mounted intersect each other as the position of the terminal tag 30.

[0027]

In a case in which the position of the terminal tag 30 is estimated on the basis of one signal arrival time, the server apparatus 10 can be omitted. In such a case, the
20 function of a position estimating unit 13, which is to be described below, included in the server apparatus 10 may be included in the base station 20.

[0028]

In addition, in the position estimating system 1, there is a premise that times used inside devices of the base stations 20 are synchronized with each other
25 (synchronization in time). Hereinafter, a case in which the server apparatus 10

synchronizes times of the base stations 20 by notifying the base stations 20 of a signal used for synchronization of the times (time information) will be described as an example. However, the method is not limited thereto, and the base stations 20 may be synchronized in time with each other using an arbitrary method. For example, the synchronization in time may be performed by causing each of the base stations 20 to receive a Global Positioning System (GPS) signal or receive radio waves of a radio wave clock.

[0029]

In addition, in the base station 20, measurement accuracy of a time may be arbitrarily determined in accordance with accuracy of an estimated position of the terminal tag 30, the processing capability of the base station 20, and the like.

For example, in a case in which the position is desired to be estimated on the order of kilometers (Km), the measurement accuracy is designed such that a time is able to be measured on the order of milliseconds. Alternatively, in a case in which the position is desired to be estimated on the order of meters (m), the measurement accuracy is designed such that a time is able to be measured on the order of nanoseconds. In a case in which it is difficult to measure a time on the order of nanoseconds due to the processing capability of the base station 20, the accuracy of an estimated position is lowered within an allowed range, and the time is measured on an order that can be processed by the base station 20 (for example, the order of 100 nanoseconds).

[0030]

Fig. 3 is a block diagram illustrating an example of the configuration of the server apparatus 10 according to the first embodiment. For example, the server apparatus 10 includes a communication unit 11, a signal arrival time acquiring unit 12, a position estimating unit 13, a GPS information acquiring unit 14, a time synchronization unit 15, a control unit 17, and a storage unit 18.

[0031]

The communication unit 11 communicates with each of the base stations 20 and receives information representing a signal arrival time.

The signal arrival time acquiring unit 12 acquires the information representing a
5 signal arrival time measured by each of the base stations 20 through the communication unit 11.

The position estimating unit 13 estimates a position of the terminal tag 30 on the basis of the signal arrival times acquired by the signal arrival time acquiring unit 12.

The GPS information acquiring unit 14, for example, is a GPS reception module
10 and acquires information of a time transmitted by the GPS (hereinafter referred to as GPS time information).

[0032]

The time synchronization unit 15 synchronizes an internal apparatus time of the server apparatus 10 with GPS time information using the GPS time information acquired
15 by the GPS information acquiring unit 14. In addition, the time synchronization unit 15 generates time information using the GPS time information acquired by the GPS information acquiring unit 14. The time information is information that is used for synchronizing each of the base stations 20 in time. The time synchronization unit 15 notifies each of the base stations 20 of the generated time information through the
20 communication unit 11.

[0033]

The control unit 17 integrally controls the server apparatus 10. For example, the control unit 17 makes the signal arrival time acquiring unit 12 output signal arrival times received by the communication unit 11.

25 For example, the processes performed by the signal arrival time acquiring unit

12, the position estimating unit 13, the GPS information acquiring unit 14, the time synchronization unit 15, and the control unit 17 are realized by causing a central processing unit (CPU) included in the server apparatus 10 as hardware to execute a program.

5 [0034]

The storage unit 18 is configured using a storage medium, for example, a hard disk drive (HDD), a flash memory, an electrically erasable programmable read only memory (EEPROM), a random access read/write memory (RAM), a read only memory (ROM), or an arbitrary combination of such storage media. The storage unit 18 stores
10 programs used for performing various processes of the server apparatus 10 and temporary data used at the time of performing various processes.

[0035]

Fig. 4 is a block diagram illustrating an example of the configuration of the base station 20 according to the first embodiment. For example, the base station 20 includes
15 a communication unit 21, a base station communication control unit 22, a storage control unit 23, a signal arrival time calculating unit 24, a time information acquiring unit 25, a time synchronization unit 26, and a control unit 27. The base station 20 may further include a storage unit 28. The signal arrival time calculating unit 24 is one example of a “measurement unit.”

20 [0036]

The communication unit 21 communicates with the server apparatus 10 and the terminal tag 30. The communication unit 21 receives time information from the server apparatus 10. The communication unit 21 receives a signal sent from the terminal tag 30. In addition, the communication unit 21 transmits the signal sent from the terminal
25 tag 30 to the server apparatus 10.

[0037]

The base station communication control unit 22 controls communication between the base station 20 and the terminal tag 30. The base station communication control unit 22 performs control such that a transmission instruction signal is sent to the terminal tag 30 at a time set in advance. The transmission instruction signal is a signal instructing the terminal tag 30 to transmit a signal. The time set in advance, for example, is a time at which an instruction is given from the server apparatus 10. In this case, the server apparatus 10 synchronizes the base stations 20 in time and instructs the base stations 20 to notify the same terminal tag 30 of transmission instruction signals at the same time. In accordance with this, even when the terminal tag 30 is moving, each of the base stations 20 can receive a child signal (a response to a transmission instruction signal) from the terminal tag 30 located at almost the same position. Thus, a signal arrival time between the terminal tag 30 located at almost the same position and each base station 20 can be measured, and the position of the terminal tag 30 can be identified.

15 [0038]

The storage control unit 23 stores information used for measurement of a signal arrival time in the storage unit 28. The information used for measurement of a signal arrival time is a transmission time and a reception time. The transmission time is a time at which the base station 20 transmits a transmission instruction signal to the terminal tag 30. The reception time is a time at which a child signal (a response to a transmission instruction signal transmitted at the transmission time) is received from the terminal tag 30.

When a transmission instruction signal is transmitted by the communication unit 21, the storage control unit 23 sets the time thereof as a transmission time and causes the transmission time to be stored in the transmission time information 280 of the storage

unit 28. The transmission time information 280 is information in which identification information of a transmission instruction signal and a transmission time are associated with each other. When the storage control unit 23 receives a child signal (a response to a transmission instruction signal transmitted at a transmission time) from the terminal tag 30, the storage control unit 23 sets the time thereof as a reception time and causes the time to be stored in reception time information 281 of the storage unit 28. The reception time information 281 is information in which identification information of the child signal and the reception time are associated with each other.

In addition, the base station communication control unit 22 and the storage control unit 23 of the base station 20 are configured to control communication between the terminal tag 30 and the base station 20, and each thereof can be regarded as one example of a “communication control unit.”

[0039]

The signal arrival time calculating unit 24 calculates a signal arrival time. The signal arrival time calculating unit 24 calculates a signal arrival time using the transmission time information 280, the reception time information 281, and processing time information 282. The processing time information 282 is information in which signal processing performed by the terminal tag 30 and a time required for the processing are associated with each other. The signal arrival time calculating unit 24 extracts a transmission time of a specific transmission instruction signal from the transmission time information 280. The signal arrival time calculating unit 24 extracts a reception time of a child signal corresponding to a response to the transmission instruction signal extracted from the transmission time information 280. The signal arrival time calculating unit 24 calculates a difference between the transmission time and the reception time that have been extracted and sets a time of the calculated difference as a signal reciprocation

processing time.

[0040]

In the signal reciprocation processing time, a time required for various kinds of signal processing is included in addition to a time required for reciprocation of a signal.

5 The time required for reciprocation of a signal is a sum of a time required for a transmission instruction signal from the base station 20 to arrive at the terminal tag 30 and a time required for a child signal from the terminal tag 30 to arrive at the base station 20. 1/2 of this time required for reciprocation of a signal corresponds to a signal arrival time.

10 The time required for various kinds of signal processing is a total sum of times required for a process of demodulating a transmission instruction signal, a process of determining to make a response on the basis of a result of the demodulation, a process of generating a response signal, a process of modulating the generated signal, and the like. In this embodiment, such a time required for various kinds of signal processing in the
15 terminal tag 30 is stored in association with the signal processing in the storage unit 28 in advance as the processing time information 282.

[0041]

The signal arrival time calculating unit 24 calculates a time required for reciprocation of a signal by subtracting the time required for such signal processing from
20 the signal reciprocation processing time. The signal arrival time calculating unit 24 calculates a signal arrival time by multiplying the time required for reciprocation of a signal by 1/2.

[0042]

The time information acquiring unit 25 acquires time information sent from the
25 server apparatus 10 through the communication unit 21. The time information is a

signal used for synchronizing the base stations 20 in time. The time information acquiring unit 25 outputs the acquired time information to the time synchronization unit 26. The time synchronization unit 26 adjusts a time of a timer operating inside the base station 20 on the basis of the time information and synchronizes the timer with a time represented in the time information.

[0043]

The control unit 27 integrally controls the base stations 20. The control unit 27 outputs time information received by the communication unit 21 to the time information acquiring unit 25. In a case in which sensor information is included in a child signal received by the communication unit 21, the control unit 27 extracts the sensor information and stores the extracted sensor information in the storage unit 28.

[0044]

The processes of the base station communication control unit 22, the storage control unit 23, the signal arrival time calculating unit 24, the time information acquiring unit 25, the time synchronization unit 26, and the control unit 27 are realized by causing a CPU, which is included in the base station 20 as hardware, to execute a program.

[0045]

The storage unit 28 is configured using a storage medium, for example, an HDD, a flash memory, an EEPROM, a RAM, a ROM, or an arbitrary combination of such storage media. The storage unit 28 stores programs used for performing various processes of the base station 20 and temporary data used at the time of performing various processes. The storage unit 28 stores the transmission time information 280, the reception time information 281, and the processing time information 282. In addition, in a case in which sensor information is included in a child signal, the storage unit 28 stores the sensor information.

[0046]

Fig. 5 is a block diagram illustrating an example of the configuration of the terminal tag 30 according to the first embodiment. For example, the terminal tag 30 includes a sensor unit 300 and a communication module 310. The sensor unit 300 represents various sensors, for example, a temperature sensor, an illuminance sensor, and the like. In addition, in a case in which only position estimation is performed using the terminal tag 30, the terminal tag 30 may not include the sensor unit 300. The communication module 310 includes a communication unit 31, a terminal communication control unit 32, a sensor information acquiring unit 33, a transmission signal generating unit 34, a control unit 37, and a storage unit 38.

[0047]

The communication unit 31 communicates with the base station 20. The communication unit 31 transmits a child signal to the base station 20. The communication unit 31 receives a transmission instruction signal from the base station 20.

The terminal communication control unit 32 controls communication between the terminal tag 30 and the base station 20. The terminal communication control unit 32 performs control such that a child signal is transmitted to the base station 20. The child signal is a signal that represents a response to a transmission instruction signal sent from the base station 20. In addition, the terminal communication control unit 32 of the terminal tag 30 is configured to control communication between the terminal tag 30 and the base station 20 and can also be regarded as one example of a “communication control unit.”

[0048]

The terminal communication control unit 32 determines whether or not

transmission of a signal transmitted to the base station 20 is successful. In a case in which ACK (answer back) for a signal transmitted to the base station 20 has been returned (received) from the base station 20 that is a notification destination, the terminal communication control unit 32 determines that the transmission is successful. In a case
5 in which ACK for a signal transmitted to the base station 20 has not been returned from the base station 20 that is a notification destination within a predetermined period, the terminal communication control unit 32 determines that the transmission is unsuccessful.
[0049]

In a case in which transmission was unsuccessful, the terminal communication
10 control unit 32 performs control such that the signal of which transmission was unsuccessful is re-transmitted to the base station 20 that is a transmission source. In a case in which a signal has been retransmitted, the terminal communication control unit 32 stores the number of re-transmissions of the signal (re-transmission number) as re-transmission number information 380 of the storage unit 38. The re-transmission
15 number information 380 is information in which the number of re-transmissions and identification information of a re-transmitted signal are associated with each other.
[0050]

The sensor information acquiring unit 33, for example, is connected to the sensor unit 300 through an input/output (IO) port that is an IO port connected to the
20 sensor unit 300, thereby acquiring information (sensor information) measured by the sensor unit 300. The sensor information acquiring unit 33 makes the storage unit 38 store the acquired sensor information.
[0051]

The transmission signal generating unit 34 generates signals to be transmitted to
25 the base station 20. For example, the signals to be transmitted to the base station are a

child signal that is a response to a transmission instruction signal, a signal used for notifying of sensor information, and the like. In a case in which a child signal is to be generated, the transmission signal generating unit 34 generates a child signal with information required for calculating a signal arrival time included therein. For example, the information required for calculating a signal arrival time is signal type information indicating that a child signal is a response to a transmission instruction signal, identification information of the corresponding transmission instruction signal, the re-transmission number information 380, and the like.

[0052]

10 The transmission signal generating unit 34 generates a signal including the sensor information stored in the storage unit 38, for notifying of the sensor information. The transmission signal generating unit 34 may generate a signal for notifying of sensor information at the time of acquisition of the sensor information, or may generate one signal (a signal for notifying of sensor information) to be sent by integrating sensor information acquired during a predetermined period.

[0053]

 The transmission signal generating unit 34 may generate a child signal with sensor information included therein or may generate a child signal without sensor information. By generating a child signal with sensor information included therein, a response to a transmission instruction and sensor information can be sent together, and efficient communication can be performed. By generating a child signal without sensor information, the data volume used for communication performed each time is suppressed, and thus the amount of communication can be reduced.

[0054]

25 The control unit 37 integrally controls the terminal tag 30. The control unit 37

outputs a signal generated by the transmission signal generating unit 34 to the communication unit 31.

The processes performed by the terminal communication control unit 32, the sensor information acquiring unit 33, the transmission signal generating unit 34, and the control unit 37 are realized by causing a CPU, which is included in the terminal tag 30 as hardware, to execute a program.

[0055]

The storage unit 38 is configured using a storage medium, for example, an HDD, a flash memory, an EEPROM, a RAM, a ROM, or an arbitrary combination of such storage media. The storage unit 38 stores programs used for performing various processes of the terminal tag 30 and temporary data used at the time of performing various processes. The storage unit 38 stores re-transmission number information 380. The storage unit 38 may store sensor information and the like.

[0056]

Fig. 6 is a diagram illustrating an example of the configuration of transmission time information 280 according to the first embodiment. The transmission time information 280 includes items of a signal ID, a communication destination terminal ID, a signal type, a transmission date, a transmission time, and the like.

The signal ID is identification information used for uniquely identifying a signal transmitted by the base station 20. The communication destination terminal ID is identification information of a device that is a notification destination of a signal identified by a signal ID. The signal type is a type of signal identified by a signal ID. The transmission date is a date on which a signal identified by the signal ID is transmitted. The transmission time is a time at which a signal identified by the signal ID is transmitted. In this example, a signal identified by a signal ID (Tx0001)

represents that a notification destination is the terminal tag 30, a signal type is a transmission instruction signal, and a transmission date is yy/mm/dd (year/month/day).
[0057]

Fig. 7 is a diagram illustrating an example of the configuration of reception time information 281 according to the first embodiment. The reception time information 281 includes items of a signal ID, a transmission source terminal ID, a signal type, a reception date, a reception time, a response source signal ID, a re-transmission number, and the like.

The signal ID is identification information used for uniquely identifying a signal received by the base station 20. The transmission source terminal ID is identification information of a device that is a notification source of a signal identified by a signal ID. The signal type is a type of a signal identified by a signal ID. The reception date is a date on which a signal identified by a signal ID was received. The reception time is a time at which a signal identified by a signal ID was received. The response source signal ID is identification information of a signal that is a source of a response in a case in which a signal identified by a signal ID is a response signal. The re-transmission number is the number of re-transmissions of a signal identified by a signal ID.

In this example, a signal identified by a signal ID (Rx0001) represents that the transmission source is the terminal tag 30, the signal type is a child signal, the reception date is yy/mm/dd (year/month/day), the signal is a response to a transmission instruction signal identified by a signal ID (Tx0001), and the re-transmission number is 0 (zero).
[0058]

Fig. 8 is a diagram illustrating an example of the configuration of processing time information 282 according to the first embodiment. The processing time information 282 includes items of a processing ID, a processing terminal ID, a processing

type, a signal processing time, details, and the like.

The processing ID is identification information used for uniquely identifying processing. The processing terminal ID is identification information used for identifying a device performing processing identified by a processing ID. The processing type is a type of processing identified by a processing ID. The details are details of processing identified by a processing ID and, for example, includes items of processing items, a processing time, and the like. The processing items are items of processing performing for a response. The processing time is a time required for processing represented in the processing items.

The example shows times required for a demodulation process and a modulation process in a case in which the terminal tag 30 makes a response using a child signal in which sensor information is absent. In addition, the example shows a time required for a process of acquiring sensor information in a case in which the terminal tag 30 makes a response using a child signal in which sensor information is present. Furthermore, the example shows a time required for a process of determining whether re-transmission is performed in a case in which the terminal tag 30 re-transmits a child signal.

[0059]

Fig. 9 is a diagram illustrating an example of the configuration of re-transmission number information 380 according to the first embodiment. The re-transmission number information 380 includes items of a signal ID, a communication destination device ID, a signal type, a re-transmission number, and the like.

The signal ID is identification information used for uniquely identifying a signal transmitted by the terminal tag 30. The communication destination device ID is identification information of a device that is a transmission destination of a signal identified by a signal ID. The signal type is a type of signal identified by a signal ID.

The re-transmission number is the number of re-transmissions of a signal identified by a signal ID to a device that is a transmission destination.

In this example, it is represented that a child signal identified by a signal ID (Tx1001) has been transmitted to a base station 20-1 for the re-transmission number of 0 (zero). In addition, it is represented that a child signal identified by a signal ID (Tx1002) has been transmitted to a base station 20-2 for the re-transmission number of 2. [0060]

Fig. 10 is a diagram illustrating an example of the configuration of a format of a signal SG used for communication of the position estimating system 1 according to the first embodiment. For example, the signal SG is a transmission instruction signal, a child signal without sensor information, a child signal with sensor information, a signal used for notifying of sensor information, or the like.

For example, the signal SG is composed of a header HD, a data section DA, and a footer FT.

The header HD is information that is attached to the start of the signal SG and, for example, is composed of a notification source ID, a notification destination ID, a signal type, and the like. The notification source ID is identification information of a device that is a notification source. The notification destination ID is identification information of a device that is a notification destination.

The data section DA is information representing details to be notified and, in the example illustrated in Fig. 10, is information acquired by combining information that is formed as a block for each predetermined data length like notification details 1 to notification details K.

The footer FT is information attached to the end of a signal and, for example, is a cyclic redundancy code (CRC) used for error detection.

[0061]

For example, in a case in which the signal SG is a transmission instruction signal, the header HD includes information that the notification source is the base station 20, the notification destination is the terminal tag 30, and the signal type is a transmission instruction signal. The data section DA includes information for an instruction to reply a child signal as a response, information whether or not sensor information is included in a child signal, and the like. The footer FT includes, for example, a CRC bit generated from a bit string of the data section DA.

[0062]

For example, in a case in which the signal SG is a child signal, the header HD includes information indicating that the notification source is the terminal tag 30, the notification destination is the base station 20, and the signal type is the child signal. In the data section DA, for example, a block of notification details 1 includes information regarding a child signal as a response of a certain transmission instruction, information whether or not sensor information is included, and the like. In a case in which sensor information is included, the sensor information is represented in a block after the notification details 1. The footer FT includes, for example, a CRC bit generated from a bit string of the data section DA is represented.

[0063]

In a case in which sensor information is not included, the data section DA is composed of only the block of the notification details 1. In a case in which sensor information is included, the data section DA includes a block connected after the notification details 1. In other words, between a case in which sensor information is not included and a case in which sensor information is included, the amount of information of the entire signal is different, and the amount of information can be suppressed more in

the case in which sensor information is not included than in the case in which sensor information is included.

[0064]

Fig. 11 is a sequence diagram illustrating the flow of a process performed by the position estimating system 1 according to the first embodiment. Here, as processes performed by the position estimating system 1, the flow of a process (reference sign S100) performing time synchronization and a process (reference sign S200) performing estimation of a position will be described. The processes may be performed at respective timings or may be performed with being interlinked to each other.

10 [0065]

First, the process (reference sign S100) performing time synchronization will be described.

The server apparatus 10 receives GPS information (Step S10). For example, the server apparatus 10 receives signals transmitted from GPS satellites as GPS information. The GPS information may be signals that are able to perform synchronization in time. The GPS information may be signals representing times transmitted from a radio wave clock or may be signals representing regular timings output from a quartz oscillator or the like. The server apparatus 10 generates time information based on the received GPS signals and notifies the base station 20 of the generated time information.

The base station 20 performs time synchronization by adjusting a time that is used inside the base station 20 on the basis of the time information received from the server apparatus 10 (Step S11).

[0066]

25 Next, the process (reference sign S200) of estimating a position will be

described.

The base station 20 notifies the terminal tag 30 of a transmission instruction signal at a predetermined time set in advance (Step S20). The base station 20 stores a transmission time at which the transmission instruction signal has been transmitted (Step
5 S21).

When the transmission instruction signal is received from the base station 20, the terminal tag 30 generates a child signal as a response thereto (Step S22). The terminal tag 30 transmits the generated child signal to the base station 20 (Step S23).

When the child signal is received from the terminal tag 30, the base station 20
10 stores a reception time at which the child signal has been received (Step S24). The base station 20 calculates a signal arrival time using the transmission time stored in S21 and the reception time stored in Step S24 (Step S25).

The base station 20 notifies the server apparatus 10 of the calculated signal arrival time. The server apparatus 10 estimates a position of the terminal tag 30 using
15 the signal arrival time received from the base station 20 (Step S26).

[0067]

As described above, the position estimating system 1 (one example of a “communication system”) according to the first embodiment is a system that includes the terminal tag 30 (one example of a “terminal device”) and the base stations 20. The
20 position estimating system 1 includes the terminal communication control unit 32 (one example of a “communication control unit”), the base station communication control unit 22 (one example of a “communication control unit”), the signal arrival time calculating unit 24 (one example of a “measurement unit”), and the position estimating unit 13.

The terminal communication control unit 32 and the base station communication control
25 unit 22 control communication between the base station 20 and the terminal tag 30. The

signal arrival time calculating unit 24 measures a signal arrival time required for a signal transmitted from the base station 20 to be received by the terminal tag 30. The position estimating unit 13 estimates a position of the terminal tag 30 on the basis of the signal arrival time measured by the signal arrival time calculating unit 24.

5 In this way, the position estimating system 1 according to the first embodiment can estimate the position of the terminal tag 30 by calculating a signal arrival distance from a relation between the speed of a signal and a signal arrival time, using a method in which a signal transmitted from the base station 20 is received by an outdoor mobile body (the terminal tag 30). Thus, the position of the mobile body can be estimated with
10 high accuracy with no efforts for measuring reception radio wave intensities in an area in advance.

[0068]

 In addition, in the position estimating system 1 according to the first embodiment, the communication control unit may include the base station
15 communication control unit 22, the terminal communication control unit 32, and the storage control unit 23. The base station communication control unit 22 is configured to transmit a transmission instruction signal from the base station 20 to the terminal tag 30. The terminal communication control unit 32 is configured to transmit a child signal that is a response to the transmission instruction signal from the terminal tag 30 that has
20 received the transmission instruction signal, to the base station 20. The storage control unit 23 makes the storage unit 28 store a transmission time at which the transmission instruction signal was transmitted from the base station 20 to the terminal tag 30, and a reception time at which a child signal from the terminal tag 30 was received by the base station 20.

25 The signal arrival time calculating unit 24 (one example of a “measurement

unit”) may calculate a signal arrival time using the transmission time and the reception time stored in the storage unit 28.

In this way, in the position estimating system 1 according to the first embodiment, the base station 20 transmits a signal, and a signal arrival time can be calculated on the basis of a time that a response to this transmitted signal is received by the base station 20. In this way, the signal arrival time can be calculated using only the base station 20 without the terminal tag 30 measuring a reception time. Thus, high-accuracy time synchronization does not need to be performed for the terminal tag 30.

[0069]

In addition, in the position estimating system 1 according to the first embodiment, a child signal (one example of “a signal transmitted from the terminal tag 30 to the base station 20) may be either a child signal not including sensor information (one example of “small data”) or a child signal including sensor information (arbitrary measurement information measured by a terminal device”).

In this way, in the position estimating system 1 according to the first embodiment, it is possible to select whether or not to give priority to the transmission efficiency of data in accordance with the use of the system, and a communication load can be inhibited by suppressing a data volume for each time.

[0070]

In addition, in the position estimating system 1 according to the first embodiment, the position estimating unit 13 may estimate the position of the terminal tag 30 on the basis of signal arrival times of at least three or more base stations 20.

In this way, the position estimating system 1 according to the first embodiment can estimate the position of the terminal tag 30 with high accuracy using the principle of triangulation.

[0071]

In addition, the position estimating system 1 according to the first embodiment includes the terminal communication control unit 32 (the communication control unit) that determines whether or not transmission of a child signal (one example of “a signal
5 transmitted from the terminal tag 30 to the base station 20”) has failed, in a case in which transmission of the child signal has failed, the terminal communication control unit 32 is configured to re-transmit this child signal, and store re-transmission number information 380 representing the number of re-transmissions, and information representing the re-transmission number may be included in the re-transmitted child signal.

10 In this way, in the position estimating system 1 according to the first embodiment, even in a case in which a child signal is re-transmitted, a signal arrival time can be calculated with a time required for the re-transmission process taken into account.

[0072]

(Modified Example 1 of first embodiment)

15 Modified Example 1 of the first embodiment will be described. In this Modified Example, the base station 20 and the terminal tag 30 are synchronized in time with each other, which is different from the first embodiment described above. In this Modified Example, the base station 20 notifies the terminal tag 30 of time information. The time information has the same details as the time information notified from the
20 server apparatus 10 to the base station 20 in the first embodiment. The terminal tag 30 synchronizes a time used for the process inside the device of the terminal tag 30 with a time represented in the time information on the basis of the time information received from the base station 20.

[0073]

25 Fig. 12 is a block diagram illustrating an example of the configuration of the

terminal tag 30 according to Modified Example 1 of the first embodiment. For example, the terminal tag 30 according to this Modified Example includes a time information acquiring unit 35 and a time synchronization unit 36. The time information acquiring unit 35 acquires time information notified from the base station 20 through the communication unit 31. The functions of the time information acquiring unit 35 and the time synchronization unit 36 are similar to those of the time information acquiring unit 25 and the time synchronization unit 26, and thus a description thereof will be omitted.

[0074]

Fig. 13 is a sequence diagram illustrating the flow of a process performed by a position estimating system 1 according to Modified Example 1 of the first embodiment. Here, as processes performed by the position estimating system 1, the flow of a process (reference sign S100#) performing time synchronization and a process (reference sign S300) performing estimation of a position will be described. The processes may be performed at respective timings or may be performed with being interlinked to each other.

[0075]

First, the process (reference sign S100#) performing time synchronization will be described.

Processes represented in Steps S10 and S11 are similar to the processes represented in Steps S10 and S11 illustrated in Fig. 11, and thus description thereof will be omitted. The base station 20 generates time information on the basis of GPS information received from the server apparatus 10 and notifies the terminal tag 30 of the generated time information. The terminal tag 30 performs time synchronization by adjusting a time that is used inside the terminal tag 30 on the basis of the time information received from the base station 20 (Step S12).

[0076]

Next, the process (reference sign S300) of estimating a position will be described.

The base station 20 instructs the terminal tag 30 on a planned transmission time
5 at which the terminal tag 30 transmits a child signal (Step S30).

The terminal tag 30 generates a child signal at an arbitrary timing (Step S32).
The terminal tag 30 transmits the generated child signal to the base station 20 at the
instructed time (Step S33).

When the child signal is received from the terminal tag 30, the base station 20
10 stores a reception time at which the child signal has been received (Step S34). The base
station 20 calculates a signal arrival time using the planned transmission time instructed
in Step S30 and the reception time stored in Step S34 (Step S35).

A process represented in Step S36 is similar to that of Step S26 illustrated in Fig.
11.

15 [0077]

Fig. 14 is a sequence diagram illustrating the flow of the process performed by
the position estimating system 1 according to the Modified Example of the first
embodiment. Here, as a process performed by the position estimating system 1, the
flow of a process (reference sign S400) of estimating a position will be described. A
20 process (reference sign S100#) of performing time synchronization is similar to the
process (reference sign S100#) illustrated in Fig. 13, and thus a description thereof will
be omitted. The processes may be performed at respective timings or may be performed
with being interlinked to each other.

[0078]

25 The base station 20 notifies the terminal tag 30 of a transmission instruction

signal (Step S40).

The terminal tag 30 generates a child signal as a response to the transmission instruction signal (Step S42). Here, the terminal tag 30 generates a child signal in which information representing a transmission time is included. The terminal tag 30
 5 transmits the child signal at the transmission time represented in the child signal (Step S43).

Processes represented in Steps S44 to S46 are similar to those of Steps S34 to S36 illustrated in Fig. 13.

[0079]

10 In the description presented above, although a case in which the base station 20 notifies the terminal tag 30 of a signal (the time information) used for synchronization of time, and the base station 20 and the terminal tag 30 are synchronized in time with each other has been described as an example, the configuration is not limited thereto. In this Modified Example, the base station 20 and the terminal tag 30 may be synchronized in
 15 time with each other using an arbitrary method. For example, by attaching a sensor receiving radio waves of a radio wave clock to each of the base station 20 and the terminal tag 30, time synchronization may be performed.

[0080]

As above, as described in Modified Example 1 of the first embodiment, the
 20 position estimating system 1 may include the time synchronization unit 26 and the time synchronization unit 36 that synchronize times of the terminal tag 30 and the base station 20, and the time synchronization unit 26 and the time synchronization unit 36 synchronize the times of the terminal tag 30 and the base station 20.

In addition, the communication control unit may include the terminal
 25 communication control unit 32 and the storage control unit 23. The terminal

communication control unit 32 is configured to transmit a child signal from the terminal tag 30 to the base station 20 at a planned transmission time (one example of “a first timing determined in advance”) instructed from the base station 20. The storage control unit 23 stores a reception time at which a child signal has been received from the terminal tag 30 in the storage unit 28 using the base station 20.

In addition, the signal arrival time calculating unit 24 (one example of a “measurement unit”) may calculate a signal arrival time using the planned transmission time and the reception time stored in the storage unit 28.

In this way, in the position estimating system 1 according to Modified Example 1 of the first embodiment, a child signal is transmitted from the terminal tag 30 to the base station 20 at a first timing determined in advance. In other words, in a time from the planned transmission time (the first timing) to the reception time, a time required for signal processing such as generation of a child signal and the like is not included. Thus, the signal arrival time calculating unit 24 can easily calculate a signal arrival time.

[0081]

In addition, as described in Modified Example 1 of the first embodiment, the position estimating system 1 may include the time synchronization unit 26 and the time synchronization unit 36 that synchronize the times of the terminal tag 30 and the base station 20. The time synchronization unit 26 and the time synchronization unit 36 synchronize the times of the terminal tag 30 and the base station 20.

In addition, the communication control unit may include the terminal communication control unit 32 and the storage control unit 23. The terminal communication control unit 32 is configured to transmit a child signal including information representing a transmission time (one example of a “second timing”) from the terminal tag 30 to the base station 20. The storage control unit 23 stores a reception

time at which the child signal has been received from the terminal tag 30 in the storage unit 28 using the base station 20.

In addition, the signal arrival time calculating unit 24 (one example of a “measurement unit”) may calculate a signal arrival time using the transmission time represented in the child signal and the reception time stored in the storage unit 28.

In this way, in the position estimating system 1 according to Modified Example 1 of the first embodiment, the second timing that is the transmission time from the terminal tag 30 to the base station 20 is included in the child signal. In other words, in a time from the transmission time (the second timing) to the reception time, a time required for signal processing such as generation of a child signal and the like is not included. Thus, an effect similar to the effect described above is acquired. In addition, the position of the terminal tag 30 can be estimated at an arbitrary timing at which a signal is notified from the terminal tag 30 to the base station 20.

[0082]

15 (Modified Example 2 of first embodiment)

Modified Example 2 of the first embodiment will be described. In this Modified Example, the position estimating system 1 estimates the position of the terminal tag 30 using both a signal arrival time and a reception radio wave intensity, which is different from the first embodiment.

20 [0083]

In this Modified Example, each of the base stations 20 includes a functional unit (referred to as a received radio wave intensity measuring unit) that measures a received radio wave intensity. The received radio wave intensity measuring unit measures a received radio wave intensity of a signal notified from the terminal tag 30. For example, the received radio wave intensity measuring unit measures a received radio

wave intensity in accordance with magnitude of amplitude of a radio wave received by a reception antenna of the base station 20. The received radio wave intensity measuring unit transmits the measured received radio wave intensity to the server apparatus 10.

The position estimating unit 13 of the server apparatus 10 estimates a distance
5 from the base station 20 to the terminal tag 30 using the received radio wave intensity acquired from the received radio wave intensity measuring unit. The position estimating unit 13 estimates a distance to the terminal tag 30, for example, by referring to a table or the like stored in advance on the basis of the acquired received radio wave intensity. The table described here is information representing a correspondence
10 relation between a received radio wave intensity and a distance.

The position estimating unit 13 calculates a distance from each base station 20 to the terminal tag 30 using a received radio wave intensity acquired from each base station 20. The position estimating unit 13 estimates the position of the terminal tag 30 on the basis of the calculated distance from each base station 20 to the terminal tag 30.

15 The position estimating unit 13 determines the position of the terminal tag 30 using the position (hereinafter referred to as a first estimated position) of the terminal tag 30 estimated on the basis of the signal arrival time and the position (hereinafter referred to as a second estimated position) of the terminal tag 30 estimated on the basis of the received radio wave intensity. For example, the position estimating unit 13 sets a
20 representative value of the first estimated position and the second estimated position as the position of the terminal tag 30. The representative value is a value calculated using the first estimated position and the second estimated position and, for example, is a simple average value, a weighted average value, a maximum value, a minimum value, or the like.

25 [0084]

In this way, the received radio wave intensity measuring unit (one example of a “measurement unit”) measures a radio wave intensity of a signal received by the base station 20, and the position estimating unit 13 may estimate the position of the terminal tag 30 (the terminal device) on the basis of the signal arrival time and the radio wave intensity measured by the measurement unit.

In this way, in Modified Example 2 of the position estimating system 1, the position estimating unit 13 estimates the position of the terminal tag 30 using both a signal arrival time and a received radio wave intensity. For this reason, by using the received radio wave intensity together, Modified Example 2 of the position estimating system 1 can estimate the position of the terminal tag 30 with high accuracy compared to a case in which only the signal arrival time is used.

[0085]

As a Modified Example, the position estimating system 1 may include an estimated position checking unit in the server apparatus 10 (or the base station 20) that is connected to the base station 20 to be able to communicate therewith.

The estimated position checking unit checks certainty of estimation of the position of the terminal tag 30 (the position of the terminal tag 30 estimated by the position estimating unit 13). For example, the estimated position checking unit maintains information representing an estimated position of the nearest terminal tag 30 (hereinafter referred to as estimated position information), information about a mobile object (a vehicle, a freight train, a motor cycle, or the like) in which the terminal tag 30 is mounted (hereinafter mobile object information), and estimated arrival distance information for each mobile object.

The estimated arrival distance information is information representing a distance that the mobile object is estimated to arrive at a predetermined time. For example, the

estimated arrival distance information is calculated on the basis of an average speed of the mobile object, nearest estimated position information, and an elapsed time. The elapsed time is a difference of a time interval between a time at which the nearest estimated position information is acquired and a time at which a distance is estimated.

- 5 The estimated arrival distance information corresponds to a radius of a circular area representing a movement range of a mobile object and the terminal tag 30 that is mounted in the mobile object.

[0086]

- When the latest estimated position information of the terminal tag 30 is
- 10 calculated, the estimated position checking unit checks certainty of position estimation on the basis of the estimated arrival distance information and the latest estimated position information.

- In a case in which a difference between a movement distance calculated on the basis of the estimated latest position of the terminal tag 30 and a distance based on the
- 15 estimated arrival distance information is larger than a predetermined threshold, the estimated position checking unit determines that the estimation of the position includes error, such that position estimation using the position estimating unit 13 may not be correct and a high possibility of error being present. On the other hand, in a case in which the difference between the movement distance of the terminal tag 30 and the
- 20 distance based on the estimated arrival distance information is smaller than a predetermined threshold, the estimated position checking unit determines that the estimation of the position is not an erroneous estimation, such that the position estimation using the position estimating unit 13 may be correct.

[0087]

- 25 In a case in which it is determined that there is error in the position estimation

using the position estimating unit 13, for example, the estimated position checking unit may perform re-position estimation. In addition, in a case in which it is determined that there is error in the position estimation using the position estimating unit 13, for example, the estimated position checking unit may perform repetitive position estimation until the accuracy of the position estimation reaches a predetermined criterion.

[0088]

In a case in which re-position estimation is performed, the server apparatus 10 (or the base station 20) may instruct the terminal tag 30 to transmit a signal immediately after it is determined that there is error in the position estimation, or may instruct the terminal tag 30 to transmit a signal after a predetermined time elapses. In this case, it is assumed that the terminal tag 30 is moving during a predetermined time. Thus, there is a higher possibility that communication become normal, because the server apparatus 10 (or the base station 20) performs re-transmission instruction after elapse of a predetermined time and a communication environment with the terminal tag 30 changes.

[0089]

(Second embodiment)

A second embodiment will be described. In this embodiment, communication between a base station 20 and a terminal tag 30 is performed through a repeater, which is different from the first embodiment described above.

[0090]

Fig. 15 is a diagram illustrating an example of the configuration of a position estimating system 1 according to the second embodiment. The position estimating system 1 includes repeaters 40. The repeater 40 relays communication between the base station 20 and the terminal tag 30. For example, the repeater 40 is provided between the base station 20 and the terminal tag 30. The repeater 40 receives a signal

transmitted from the base station 20 toward the terminal tag 30 and transmits the received signal to the terminal tag 30. The repeater 40 receives a signal transmitted from the terminal tag 30 toward the base station 20 and transmits the received signal to the base station 20.

5 [0091]

Fig. 16 is a block diagram illustrating an example of the configuration of a repeater according to the second embodiment. For example, the repeater 40 includes a repeater communication unit 41, a repeater storage unit 42, and a repeater control unit 43. The repeater communication unit 41 communicates with the base stations 20 and the terminal tag 30. The repeater storage unit 42 is configured using a storage medium, for example, an HDD, a flash memory, an EEPROM, a RAM, a ROM, or an arbitrary combination of such storage media. The repeater storage unit stores programs used for performing various processes of the repeater and temporary data used at the time of performing various processes. The repeater storage unit 42 stores first relay information 420 and second relay information 421.

10
15

[0092]

Fig. 17 is a diagram illustrating an example of the configuration of the first relay information according to the second embodiment. As illustrated in Fig. 17, the first relay information 420, for example, includes items of a repeater ID, a signal type, a relay flag, a repeater transmission time, and the like. The repeater ID is identification information used for uniquely identifying a repeater relaying a transmission instruction signal. The relay flag is information representing whether or not a transmission instruction signal has been transmitted (relayed) by a repeater. For example, when the relay flag is "1," it is information representing that a transmission instruction signal has been relayed, and, when the relay flag is "0 (zero)," it is information representing that a

20
25

transmission instruction signal has not been relayed. The repeater transmission time is information representing a time at which a transmission instruction signal is to be transmitted to the terminal tag 30 by a repeater.

[0093]

5 Fig. 18 is a diagram illustrating an example of the configuration of the second relay information according to the second embodiment. For example, the second relay information 421 includes items of a repeater ID, a signal type, a relay flag, a repeater reception time, and the like. The repeater ID and the relay flag are respectively similar to the repeater ID and the relay flag of the first relay information. The repeater
10 reception time is information representing a time at which a child signal has been received by the repeater.

[0094]

Referring back to Fig. 16, the repeater control unit 43 controls the repeater 40. A process performed by the repeater control unit 43 is realized by causing a CPU
15 included in the repeater 40 as hardware to execute a program.

[0095]

The repeater control unit 43 receives a transmission instruction signal transmitted from the base station 20 through the repeater communication unit. The repeater control unit 43 adds the first relay information 420 to the received transmission
20 instruction signal. For example, the repeater control unit 43 adds the first relay information 420 to the data section DA in the format of the signal SG illustrated in Fig. 10. The repeater control unit 43 transmits the transmission instruction signal to which the first relay information 420 has been added, to the terminal tag 30.

[0096]

25 The terminal tag 30 receives the transmission instruction signal to which the first

relay information 420 has been added. In this case, the terminal tag 30 adds the first relay information 420 to a child signal as a response to the transmission instruction signal. The terminal tag 30 transmits the child signal to which the first relay information has been added, to the base station 20.

5 [0097]

The repeater control unit 43 receives a child signal transmitted by the terminal tag 30 through the repeater communication unit 41. The repeater control unit 43 generates the second relay information 421 and makes the repeater storage unit 42 store a time at which the child signal has been received as the repeater reception time of the second relay information 421.

[0098]

The repeater control unit 43 adds the second relay information 421 to the received child signal. The repeater control unit 43, for example, acquires the second relay information 421 by referring to the repeater storage unit 42. The repeater control unit 43, for example, adds the second relay information 421 to the data section DA in the format of the signal SG illustrated in Fig. 10. The repeater 40 transmits the child signal to which the second relay information 421 has been added, to the base station 20.

[0099]

The base station 20 receives a child signal. The base station 20 determines whether or not relay information (at least one of the first relay information 420 and the second relay information 421) has been added to the received child signal. In a case in which the relay information has been added to the child signal, the base station 20 does not perform calculation of a signal reciprocation processing time using the transmission time information 280 and the reception time information 281.

25 [0100]

In a case in which the relay information is added to the child signal, it represents that at least one of the transmission instruction signal and the child signal is notified through the repeater. In this case, at least one of the transmission instruction signal and the child signal is transmitted through the repeater. For this reason, the base station 20 does not perform calculation of a signal reciprocity processing time using the transmission time information 280 and the reception time information 281, which is premised that the transmission instruction signal or the child signal is directly transmitted.

[0101]

In a case in which the relay information is added to the child signal, the base station 20 calculates a signal reciprocity processing time in accordance with the added relay information. In this case, the relay information may take details as below.

(1) One piece of the first relay information 420 and one piece of the second relay information 421 are included therein.

(2) Numbers of pieces in the first relay information 420 and the second relay information 421 included therein are different.

[0102]

In case of (1), it is indicated that a transmission instruction signal has been relayed by one repeater, and a child signal has been relayed by one repeater in the relay information. In this case, the base station 20 determines whether or not a repeater (hereinafter referred to as a first transmission signal repeater) that has relayed the transmission instruction signal and a repeater (hereinafter referred to as a first reception signal repeater) that has relayed the child signal are the same repeater. In a case in which a repeater ID included in the first relay information 420 and a repeater ID included in the second relay information 421 coincide with each other, the base station 20

determines that the first transmission signal repeater and the first reception signal repeater are the same repeater. In a case in which the first transmission signal repeater and the first reception signal repeater are the same repeater, the base station 20 calculates a time required for transmission of a signal between the repeater and the terminal tag 30 as a signal reciprocation processing time. Similarly to the first embodiment, the base station 20 calculates a signal reciprocation processing time with the repeater transmission time represented in the first relay information 420 set as the transmission time information 280 and the repeater reception time represented in the second relay information 421 set as the reception time information 281.

10 [0103]

In case of (2), it is indicated that a transmission instruction signal has been relayed by one or a plurality of repeaters, and a child signal has been relayed by one or a plurality of repeaters in the relay information.

[0104]

15 In this case, the base station 20 identifies a repeater (hereinafter referred to as a second transmission signal repeater) that has directly transmitted the transmission instruction signal to the terminal tag 30. In a case in which number of first relay information included in the child signal is one, the base station 20 sets a repeater corresponding to the repeater ID represented in the first relay information as a second transmission signal repeater. In a case in which a plurality of pieces of first relay information are included in the child signal, the base station 20 extracts one first relay information in which a latest time is represented as the repeater transmission time among the plurality of pieces of first relay information. The base station 20 sets a repeater corresponding to a repeater ID represented in the one extracted first relay information as
25 a second transmission signal repeater.

[0105]

The base station 20 identifies a repeater (hereinafter referred to as a second reception signal repeater) that has directly received the child signal from the terminal tag 30. In a case in which number of second relay information included in the child signal is one, the base station 20 sets a repeater corresponding to the repeater ID represented in the second relay information as a second reception signal repeater. In a case in which a plurality of pieces of second relay information are included in the child signal, the base station 20 extracts one second relay information in which a latest time is represented as the repeater reception time among the plurality of pieces of second relay information.

10 The base station 20 sets a repeater corresponding to a repeater ID represented in the one extracted second relay information as a second reception signal repeater.

[0106]

The base station 20 determines whether or not the second transmission signal repeater and the second reception signal repeater are the same repeater. In a case in which a repeater ID corresponding to the second transmission signal repeater and a repeater ID corresponding to the second reception signal repeater coincide with each other, the base station 20 determines that the second transmission signal repeater and the second reception signal repeater are the same repeater. In a case in which the second transmission signal repeater and the second reception signal repeater are the same

20 repeater, the base station 20 calculates a time required for transmission of a signal between the repeater and the terminal tag 30 as a signal reciprocation processing time. Similarly to the first embodiment, the base station 20 calculates a signal reciprocation processing time with the repeater transmission time represented in the first relay information 420 set as the transmission time information 280 and the repeater reception

25 time represented in the second relay information 421 set as the reception time

information 281. The first relay information 420 described here is first relay information associated with the second transmission signal repeater. The second relay information described here is second relay information associated with the second reception signal repeater.

5 [0107]

In addition, in case of (1), in a case in which the first transmission signal repeater and the first reception signal repeater are not the same repeater, calculation of a signal reciprocity processing time is not performed. Furthermore, in case of (2), in a case in which the second transmission signal repeater and the second reception signal
 10 repeater are not the same repeater, calculation of a signal reciprocity processing time is not performed. The reason for this is that signal delivery paths of transmission instruction signal and the child signal are different from each other.

[0108]

In a case in which the signal reciprocity processing time is calculated, the base
 15 station 20 calculates a signal arrival time on the basis of the signal reciprocity processing time. In addition, in a case in which the calculated signal arrival time is notified to the server apparatus 10, the base station 20 notifies the server apparatus 10 of information representing a repeater 40 through which the signal has been passed, for example, a repeater ID of the repeater 40 that has relayed the signal.

20 [0109]

Fig. 19 is a sequence diagram illustrating the flow of a process performed by the position estimating system 1 according to the second embodiment.

The base station 20 notifies of a transmission instruction signal (Step S50).
 The base station 20 stores a transmission time at which the transmission instruction
 25 signal has been transmitted (Step S51).

When receiving the transmission instruction signal from the base station 20, the repeater 40 adds the first relay information 420 to the received transmission instruction signal (Step S52). The repeater 40 transmits the transmission instruction signal to which the first relay information 420 has been added, to the terminal tag 30 (Step S53).

5 When receiving the transmission instruction signal, the terminal tag 30 generates a child signal as a response thereto (Step S54). In this case, the terminal tag 30 adds the first relay information 420 added to the transmission instruction signal, to the child signal. The terminal tag 30 transmits the generated child signal to the base station 20 (Step S55).

10 When receiving the child signal from the terminal tag 30, the repeater 40 adds the second relay information 421 to the received child signal (Step S56). The repeater 40 transmits the child signal to the base station 20 (Step S57). In this case, the first relay information 420 and the second relay information 421 are added to the child signal transmitted from the repeater 40 to the base station 20.

15 When receiving the child signal from the repeater 40, the base station 20 stores a reception time at which the child signal has been received (Step S58). The base station 20 calculates a signal arrival time (Step S59). The base station 20 calculates the signal arrival time using the repeater transmission time added to the first relay information 420 and the repeater reception time added to the second relay information 421. The base
20 station 20 transmits the calculated signal arrival time to the server apparatus 10.

[0110]

As described above, the position estimating system 1 according to the second embodiment further includes the repeater 40. The repeater 40 relays communication between the base station 20 and the terminal tag 30. The repeater 40 includes the
25 repeater communication unit 41 and the repeater control unit 43. The repeater

communication unit 41 communicates with the base station 20 and the terminal tag 30.

When receiving a transmission instruction signal, the repeater control unit 43 transmits a signal (first signal) acquired by adding the first relay information 420 to the received transmission instruction signal, to the terminal tag 30. The first relay information 420 is

5 information including a repeater transmission time representing a time at which the transmission instruction signal is transmitted from the repeater 40. In a case in which the first relay information 420 is included in the transmission instruction signal, the terminal tag 30 transmits the child signal to which the first relay information 420 has been added, to the base station 20. In a case in which the child signal has been received,
10 the repeater control unit 43 makes the repeater storage unit 42 store a repeater reception time representing a time at which the child signal has been received. The repeater control unit 43 transmits a signal (second signal) acquired by adding the second relay information 421 to the child signal, to the base station 20. The second relay information 421 is information that includes the repeater reception time representing a time at which
15 the repeater 40 has received the child signal. In a case in which the child signal (second signal) has been received, the base station 20 determines whether or not the first relay information 420 and the second relay information 421 are added to the received child signal (second signal). In a case in which the first relay information 420 and the second relay information 421 are added to the child signal (second signal), the base station 20
20 calculates a time required for reciprocation of a signal between the terminal tag 30 and the repeater 40 as a signal reciprocation processing time using the repeater transmission time represented in the first relay information 420 and the repeater reception time represented in the second relay information 421.

[0111]

25 In this way, in the position estimating system 1 according to the second

embodiment, in a case in which signals (the transmission instruction signal and the child signal) are relayed, relay information is added thereto. For this reason, it can be identified whether or not a signal has been relayed by the repeater 40, and a method for calculating a signal reciprocation processing time can be changed in accordance with relay/no-relay of the signal through the repeater 40. Thus, also in a case in which a signal is relayed by the repeater 40, a signal reciprocation processing time can be calculated with high accuracy.

[0112]

(Modified Example of second embodiment)

A Modified Example of the second embodiment will be described. In this Modified Example, the server apparatus 10 includes a determination unit, which is different from the second embodiment described above. The determination unit determines whether or not the signal arrival time calculated in a case in which a signal passes through the repeater 40 is to be used in a case in which the position of the terminal tag 30 is estimated.

[0113]

The base station 20 calculates a signal arrival time using the signal arrival time calculating unit 24 and notifies the server apparatus 10 of the calculated signal arrival time. In this case, the base station 20 adds route information to information representing a signal arrival time. The route information is information representing a delivery path (route) of signals corresponding to the signal arrival time. The signals corresponding to the signal arrival time are a transmission instruction signal and a child signal that is a response thereto (hereinafter referred to as a child signal and the like). The route information is information indicating whether a child signal and the like are directly delivered or are delivered through the repeater 40. In a case in which no relay

information is included in the child signal, the base station 20 sets information indicating direct delivery in the route information. In a case in which relay information is included in the child signal, the base station 20 sets information indicating passage through the repeater 40 in the route information. In a case in which the information indicating
5 passage through the repeater 40 is set in the route information, the base station 20 notifies the server apparatus 10 of information representing a repeater 40 through which the signal has passed, for example, a repeater ID of the repeater 40 that has relayed the signal.

[0114]

10 The determination unit of the server apparatus 10 determines whether or not the signal arrival time is used as information for estimating the position of the terminal tag 30, on the basis of the route information. For example, in a case in which direct delivery is indicated in the route information, the determination unit of the server apparatus 10 determines that the signal arrival time is used as information for estimating
15 the position of the terminal tag 30. On the other hand, in a case in which delivery through the repeater 40 is indicated in the route information, the determination unit of the server apparatus 10 determines that the signal arrival time is not used as information for estimating the position of the terminal tag 30.

[0115]

20 For example, the determination unit of the server apparatus 10 determines whether a signal that has passed through the repeater 40 is used for estimation of the position or not, in accordance with accuracy and the like required for position estimation of the terminal tag 30. In a case in which passage through the repeater 40 is performed, a time lag occurs in accordance with a processing time required for signal processing and
25 the like in the repeater 40, and there is a possibility of error included the signal arrival

time being increased. In such a case, when a signal that has passed through the repeater 40 is used for estimation of the position of the terminal tag 30, there is a possibility of accuracy of the estimation being decreased. For this reason, the determination unit of the server apparatus 10 determines whether or not the signal arrival time is used as information for estimating the position of the terminal tag 30 on the basis of the route information. In this way, signals used for estimation of the position can be selected in accordance with passage/no passage through the repeater 40. Thus, in a case in which the position of the terminal tag 30 is estimated, the server apparatus 10 can control the accuracy of estimation.

10 [0116]

As described above, in the position estimating system 1 according to the Modified Example of the second embodiment, the server apparatus 10 further includes the determination unit. The base station 20 transmits information representing the signal arrival time to which the route information has been added, to the server apparatus 10. The route information is information representing a delivery path of a child signal corresponding to the signal arrival time. For example, the route information is information indicating whether a signal is directed delivered between the base station 20 and the terminal tag 30 without passing through the repeater 40 or is delivered through the repeater 40. The determination unit of the server apparatus 10 determines whether or not the signal arrival time is used as information for estimating the position of the terminal tag 30 on the basis of the route information. In this way, in the position estimating system 1 according to the Modified Example of the second embodiment, a signal arrival time can be selected in accordance with required accuracy. For example, in a case in which the accuracy of position estimation is desired to be improved, only signals that do not pass through the repeater 40 and are directed delivered from the base

station 20 to the terminal tag 30 can be used. On the other hand, in a case in which the accuracy is not required much, the position can be estimated using signals that have passed through the repeater 40 for proper use.

[0117]

5 In addition, in the first embodiment and the second embodiment described above, a case in which the base station 20 calculates a signal arrival time using the signal arrival time calculating unit 24 has been described as an example. However, the configuration is not limited thereto. The server apparatus 10 may calculate a signal arrival time. In that case, each of the base stations 20 transmits information used in a
10 case in which a signal arrival time is calculated, for example, a time at which the transmission instruction signal has been transmitted, a time at which a child signal has been received, and the like, to the server apparatus 10. The server apparatus 10 includes a functional unit that performs a process equivalent to the signal arrival time calculating unit 24. This functional unit calculates a signal arrival time on the basis of information
15 received from each of the base stations 20. In accordance with the server apparatus 10 calculating a signal arrival time, compared to a case in which a signal arrival time is calculated in each of the base stations 20, the processing load in the base station 20 can be decreased. Thus, a high capability is not required for the base station 20, and accordingly, the equipment of the base station 20 can be simplified.

20 [0118]

A computer program used for realizing some of or all of the functions of the position estimating system 1 according to at least one of the embodiments described above may be recorded on a computer-readable recording medium, and a computer system may be caused to read and execute the program recorded on this recording
25 medium to perform the process. The “computer system” described here includes an OS

and hardware such as peripherals thereof.

In addition, the “computer system” also includes a WWW system having a home page provision environment (or a display environment). The “computer-readable recording medium” represents portable medium such as a flexible disk, a magneto-optical disk, a ROM, a CD-ROM, or the like and a storage device such as a hard disk built into a computer system or the like. In addition, the “computer-readable recording medium” may include a medium storing a program for a predetermined time such as an internal volatile memory (a RAM) of a computer system serving as a server or a client in a case in which the program is transmitted through a network such as the Internet or a communication line such as a telephone line.

[0119]

Furthermore, the program described above may be transmitted from a computer system storing the program in a storage device or the like to another computer system through a transmission medium or using transmission waves in a transmission medium. Here, the “transmission medium” transmitting the program represents a medium having a function of transmitting information such as a network (communication network) including the Internet and the like or a communication line including a telephone line. In addition, the program described above may be used for realizing some of the functions described above. Furthermore, the program described above may be a program realizing the functions described above by being combined with a program recorded in the computer system in advance, a so-called differential file (differential program).

[0120]

As above, although the embodiments of the present invention have been described in detail with reference to the drawings, a specific configuration is not limited to these embodiments, and a design and the like in the range not departing from the

concept of the present invention are included therein as well.

[Reference Signs List]

[0121]

- 1 Position estimating system (communication system)
- 5 10 Server apparatus
- 11 Communication unit
- 12 Signal arrival time acquiring unit
- 13 Position estimating unit
- 14 GPS information acquiring unit
- 10 15 Time synchronization unit
- 17 Control unit
- 18 Storage unit
- 20 Base station
- 21 Communication unit
- 15 22 Base station communication control unit (communication control unit)
- 23 Storage control unit
- 24 Signal arrival time calculating unit (measurement unit)
- 25 Time information acquiring unit
- 26 Time synchronization unit
- 20 27 Control unit
- 28 Storage unit
- 280 Transmission time information
- 281 Reception time information
- 282 Processing time information
- 25 30 Terminal tag (terminal device)

- 31 Communication unit
- 32 Terminal communication control unit (communication control unit)
- 33 Sensor information acquiring unit
- 34 Transmission signal generating unit
- 5 35 Time information acquiring unit
- 36 Time synchronization unit
- 37 Control unit
- 38 Storage unit

[CLAIMS]

What is claimed is:

1. A communication system that includes a terminal device and a base station
connected to the terminal device to be able to communicate in two ways with each other,
5 and that estimates a position of the terminal device, the communication system
comprising:
 - a communication control unit that controls communication between the base
station and the terminal device;
 - a measurement unit that measures a signal arrival time required for a signal
10 transmitted from the base station to arrive at the terminal device; and
 - a position estimating unit that estimates the position of the terminal device on
the basis of the signal arrival time measured by the measurement unit.
2. The communication system according to claim 1,
15 wherein the communication control unit includes:
 - a base station communication control unit configured to transmit a
transmission instruction signal from the base station to the terminal device;
 - a terminal communication control unit configured to transmit a child
signal that is a response to the transmission instruction signal, from the terminal device
20 that has received the transmission instruction signal, to the base station; and
 - a storage control unit that makes a storage unit store a transmission time
at which the transmission instruction signal is transmitted from the base station to the
terminal device, and a reception time at which the child signal from the terminal device is
received by the base station, and
- 25 wherein the measurement unit calculates the signal arrival time using the

transmission time and the reception time stored in the storage unit.

3. The communication system according to claim 1, further comprising:

a time synchronization unit configured to synchronize the terminal device and

5 the base station in time,

wherein the communication control unit includes:

a terminal communication control unit configured to transmit a child
signal from the terminal device to the base station at a first timing determined in advance;
and

10 a storage control unit that makes a storage unit store a reception time at
which the child signal from the terminal device is received by the base station, and

wherein the measurement unit calculates the signal arrival time using the first
timing and the reception time stored in the storage unit.

15 4. The communication system according to claim 1, further comprising:

a time synchronization unit configured to synchronize the terminal device and

the base station in time,

wherein the communication control unit includes:

a terminal communication control unit configured to transmit a child
20 signal that is transmitted from the terminal device, and that includes information
representing a second timing that is a time at which the child signal is transmitted from
the terminal device to the base station; and

a storage control unit that makes a storage unit store a reception time at
which the child signal from the terminal device is received by the base station, and

25 wherein the measurement unit calculates the signal arrival time using the

information representing the second timing included in the child signal and the reception time stored in the storage unit.

5. The communication system according to any one of claims 1 to 4, wherein the
5 position estimating unit estimates the position of the terminal device on the basis of the signal arrival time of each of at least three or more base stations including the base station.
6. The communication system according to any one of claims 1 to 5,
10 wherein the measurement unit measures a radio wave intensity of a signal received by the base station, and
wherein the position estimating unit estimates the position of the terminal device on the basis of the signal arrival time and the radio wave intensity measured by the measurement unit.
15
7. The communication system according to any one of claims 1 to 6, further comprising:
a server apparatus that is connected to the base station to be able to communicate with each other,
20 wherein the server apparatus includes the position estimating unit.
8. The communication system according to any one of claims 1 to 7,
wherein the communication control unit includes a terminal communication control unit that determines whether or not transmission of a signal transmitted from the
25 terminal device to the base station has failed and,

in a case in which the transmission of the signal has failed, the terminal communication control unit controls re-transmission of the signal, and stores re-transmission number information representing a re-transmission number that is the number of re-transmissions of the signal, and

5 wherein the information representing the re-transmission number is included in the signal to be re-transmitted.

9. The communication system according to claim 2, further comprising:

 a repeater that relays communication between the base station and the terminal
10 device,

 wherein the repeater includes:

 a repeater communication unit that receives the transmission instruction signal and the child signal; and

 a repeater control unit that transmits a first signal acquired by adding
15 first relay information to the transmission instruction signal received by the repeater communication unit, to the terminal device and, and that transmits a second signal acquired by adding second relay information to the child signal received by the repeater communication unit, to the base station,

 wherein the first relay information includes a repeater transmission time
20 representing a time at which the first signal is transmitted to the terminal device by the repeater,

 wherein the second relay information includes a repeater reception time representing a time which the child signal is received by the repeater,

 wherein, when receiving the transmission instruction signal, the terminal device,
25 in a case in which the first relay information is added in the received transmission

instruction signal, generates the child signal to which the first relay information is added as the child signal corresponding to the transmission instruction signal, and transmits the generated child signal to the base station, and

wherein, in a case in which the first relay information and the second relay
5 information are included in the received second signal, the measurement unit calculates a time required for a signal transmitted from the repeater to arrive at the terminal device as the signal arrival time, using the repeater transmission time represented in the first relay information and the repeater reception time represented in the second relay information.

10 10. The communication system according to claim 9, further comprising:

a determination unit that determines whether or not the signal arrival time is to be used at the time of estimating the position of the terminal device, on the basis of route information for the signal arrival time measured by the measurement unit,

wherein the route information is information representing a delivery path of a
15 signal corresponding to the signal arrival time.

11. A base station connected to a terminal device to be able to communicate in two ways with each other in a communication system estimating a position of the terminal device, the base station comprising:

20 a base station communication control unit that controls communication with the terminal device; and

a measurement unit that measures a signal arrival time required for a signal transmitted from the base station to arrive at the terminal device, on the basis of a transmission time of a transmission instruction signal transmitted from the base station to
25 the terminal device and a reception time at which the base station receives a child signal

that is a response to the transmission instruction signal from the terminal device.

12. A measurement method of measuring a signal arrival time required for a signal transmitted from a base station to arrive at a terminal device, in the base station

5 connected to the terminal device to be able to communicate in two ways with each other, among a communication system estimating a position of the terminal device, the measurement method comprising:

controlling communication with the terminal device by using a base station communication control unit; and

10 measuring the signal arrival time by using a measurement unit, on the basis of a transmission time of a transmission instruction signal transmitted from the base station to the terminal device, and a reception time at which the base station receives a child signal that is a response to the transmission instruction signal from the terminal device.

15 13. A program used for measuring a signal arrival time required for a signal transmitted from a base station to arrive at a terminal device, in the base station connected to the terminal device to be able to communicate in two ways with each other, among a communication system estimating a position of the terminal device, the program used for executing:

20 a base station communication control means that controls communication with the terminal device; and

a measurement means that measures the signal arrival time, on the basis of a transmission time of a transmission instruction signal transmitted from the base station to the terminal device, and a reception time at which the base station receives a child signal

25 that is a response to the transmission instruction signal from the terminal device.