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(54) **AUTOMATIC INSPECTION SYSTEM AND AUTOMATIC INSPECTION METHOD**

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(57) **ABSTRACT**

An automatic inspection system, which includes a wireless slave device having a reading device that acquires a physical quantity to be inspected and a wireless master device that receives measurement data of the physical quantity from the wireless slave device, is provided with a data collection device that collects the measurement data from the wireless slave device via the wireless master device in a constant cycle and detects a time zone in which the measurement data is non-acquirable by the reading device based on a result of the collection. The wireless master device performs control to avoid the wireless slave device from re-acquisition of the measurement data in the non-acquirable time zone based on a result of the detection of the non-acquirable time zone.

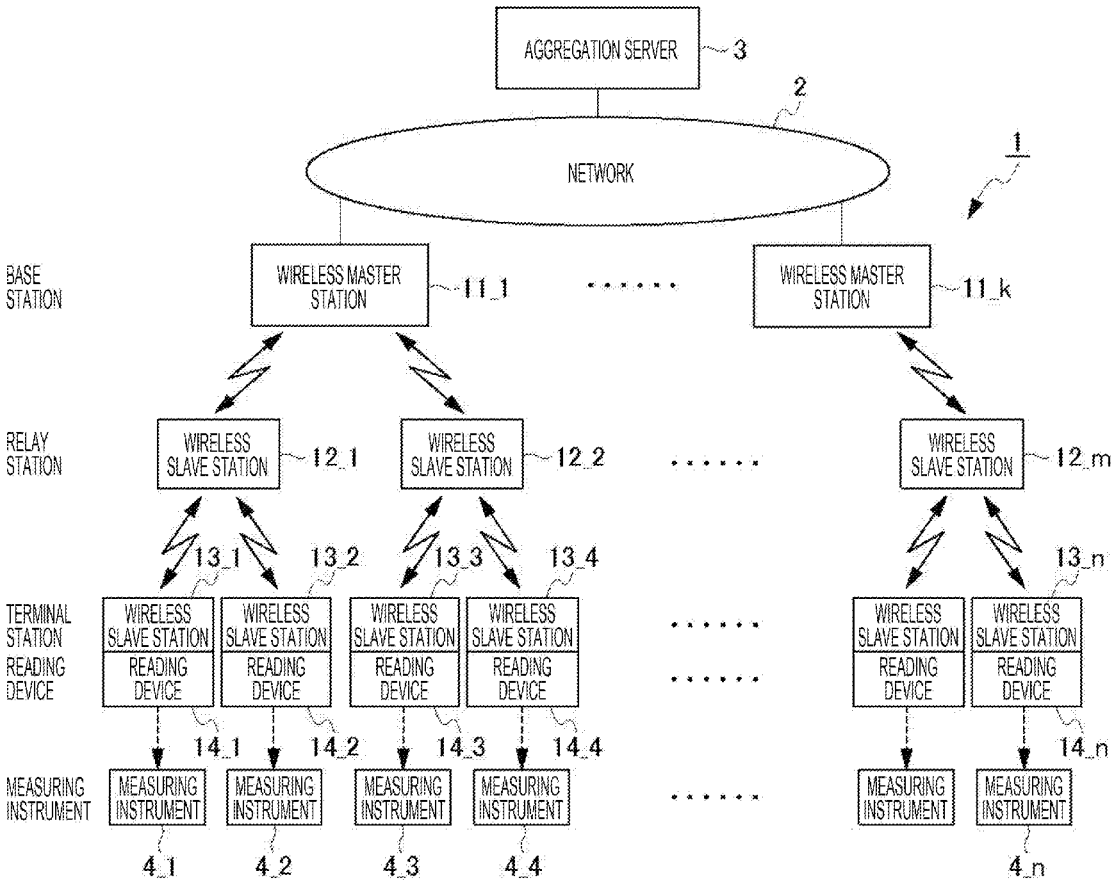


FIG. 1

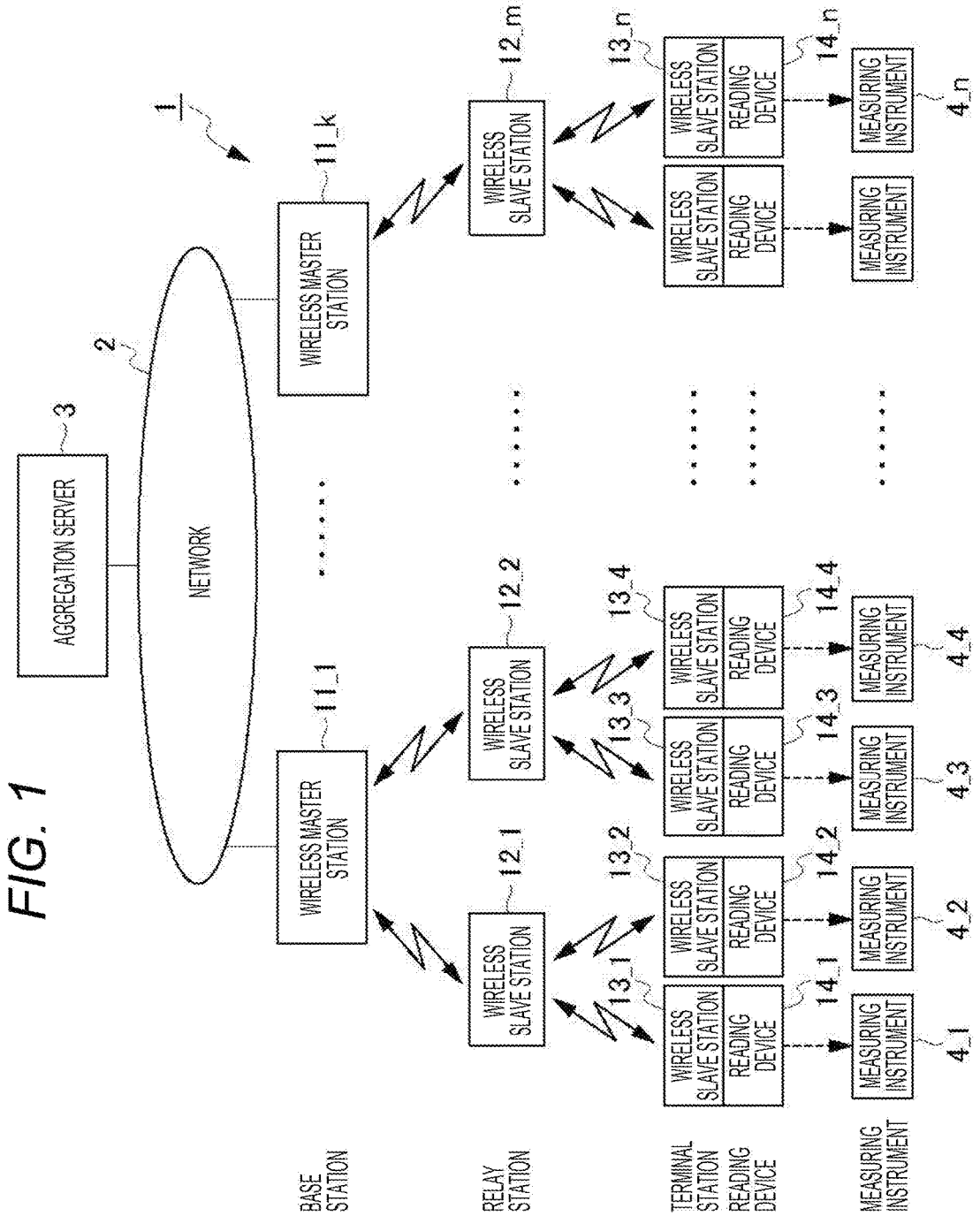

1
2
3
AGGREGATION SERVER
NETWORK
WIRELESS MASTER STATION
11_1
11_k
WIRELESS SLAVE STATION
12_1
12_2
12_m
13_1
13_2
13_3
13_4
13_n
READING DEVICE
14_1
14_2
14_3
14_4
14_n
MEASURING INSTRUMENT
4_1
4_2
4_3
4_4
4_n
BASE STATION
RELAY STATION
TERMINAL STATION
READING DEVICE
MEASURING INSTRUMENT

FIG. 2

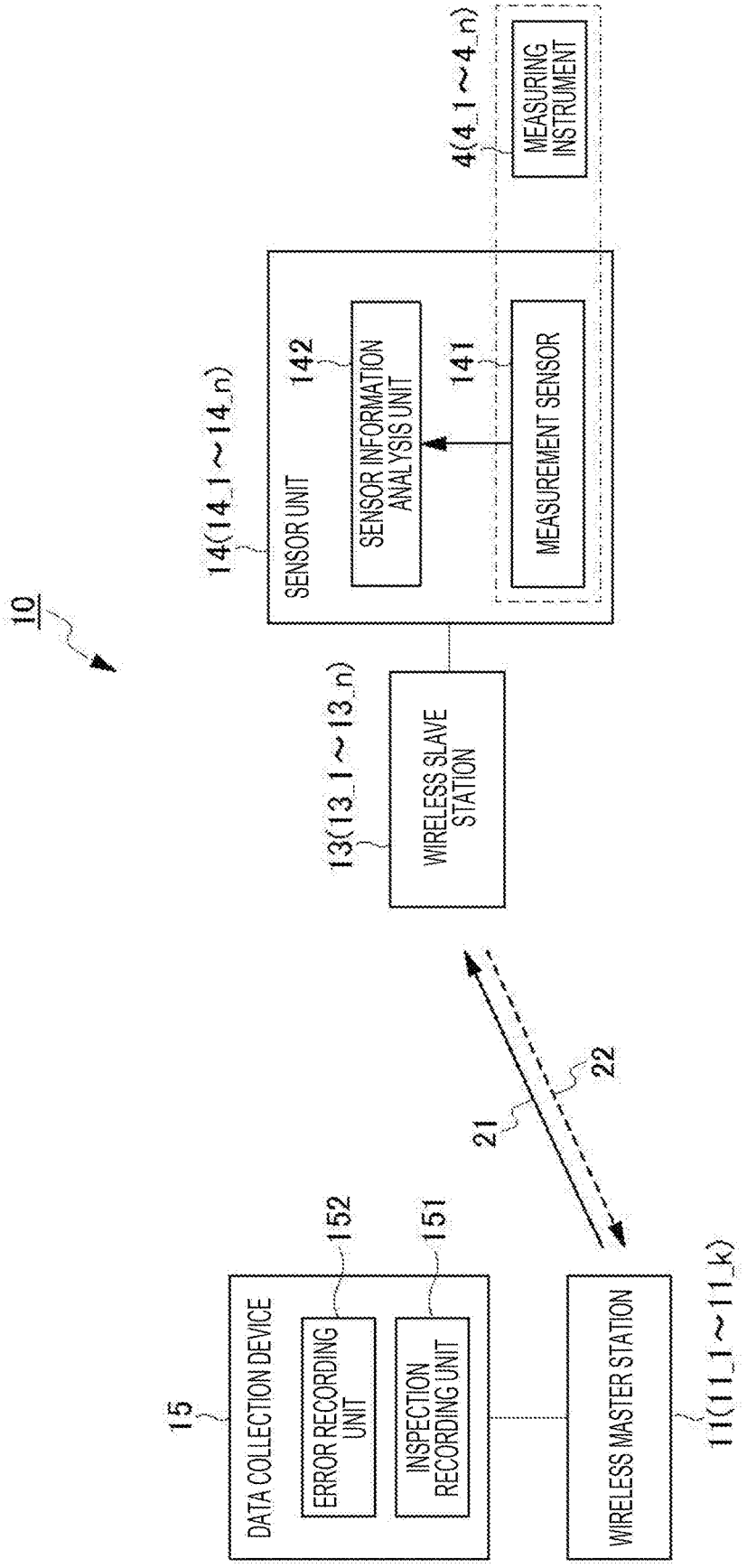

10
14(14_1~14_n)
SENSOR UNIT
142
SENSOR INFORMATION ANALYSIS UNIT
141
MEASUREMENT SENSOR
4(4_1~4_n)
MEASURING INSTRUMENT
13(13_1~13_n)
WIRELESS SLAVE STATION
21
22
15
DATA COLLECTION DEVICE
152
ERROR RECORDING UNIT
151
INSPECTION RECORDING UNIT
WIRELESS MASTER STATION
11(11_1~11_k)

FIG. 3

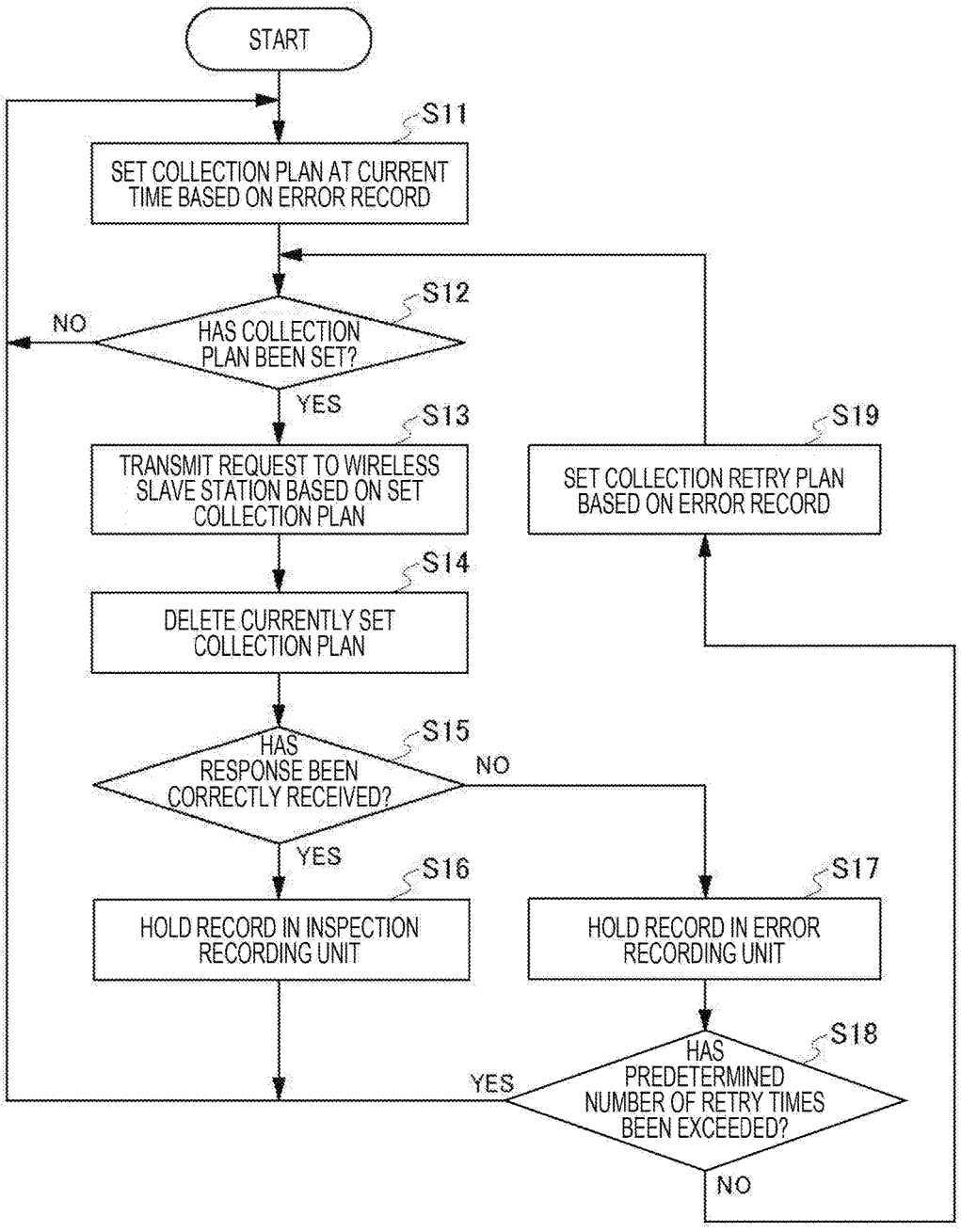

START
S11
SET COLLECTION PLAN AT CURRENT TIME BASED ON ERROR RECORD
S12
HAS COLLECTION PLAN BEEN SET?
NO
YES
S13
TRANSMIT REQUEST TO WIRELESS SLAVE STATION BASED ON SET COLLECTION PLAN
S14
DELETE CURRENTLY SET COLLECTION PLAN
S15
HAS RESPONSE BEEN CORRECTLY RECEIVED?
NO
YES
S16
HOLD RECORD IN INSPECTION RECORDING UNIT
S17
HOLD RECORD IN ERROR RECORDING UNIT
S18
HAS PREDETERMINED NUMBER OF RETRY TIMES BEEN EXCEEDED?
YES
NO
S19
SET COLLECTION RETRY PLAN BASED ON ERROR RECORD

FIG. 4

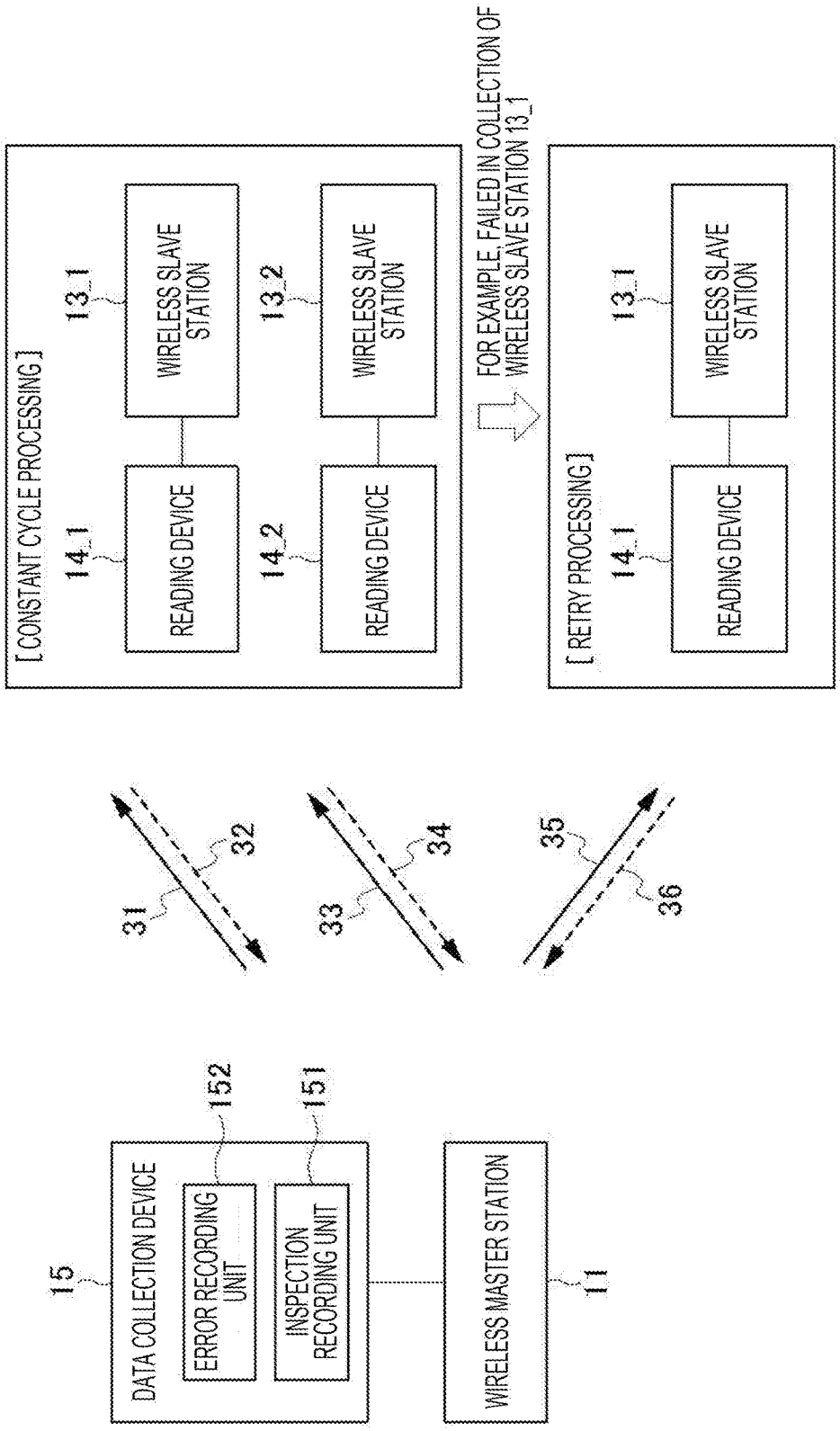

[CONSTANT CYCLE PROCESSING]
13_1
WIRELESS SLAVE STATION
13_2
WIRELESS SLAVE STATION
14_1
READING DEVICE
14_2
READING DEVICE
FOR EXAMPLE, FAILED IN COLLECTION OF WIRELESS SLAVE STATION 13_1
[RETRY PROCESSING]
13_1
WIRELESS SLAVE STATION
14_1
READING DEVICE
31
32
33
34
35
36
15
DATA COLLECTION DEVICE
ERROR RECORDING UNIT
152
INSPECTION RECORDING UNIT
151
WIRELESS MASTER STATION
11

FIG. 5A

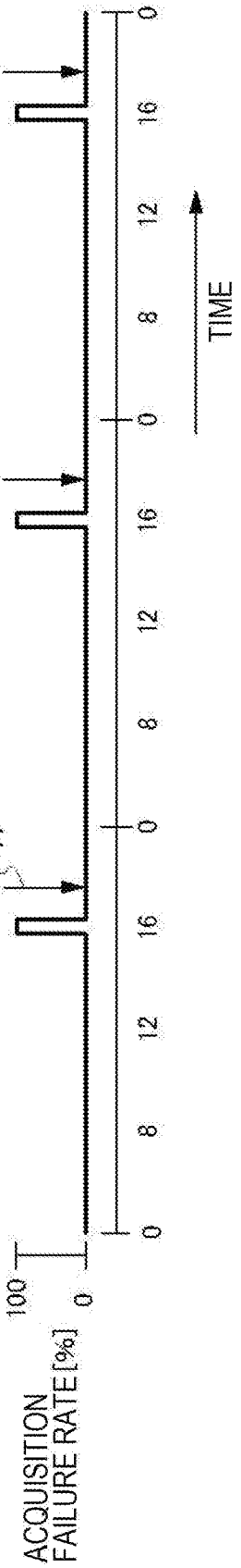

41
100
0
ACQUISITION FAILURE RATE [%]
0
8
12
16
0
8
12
16
0
8
12
16
0
TIME

FIG. 5B

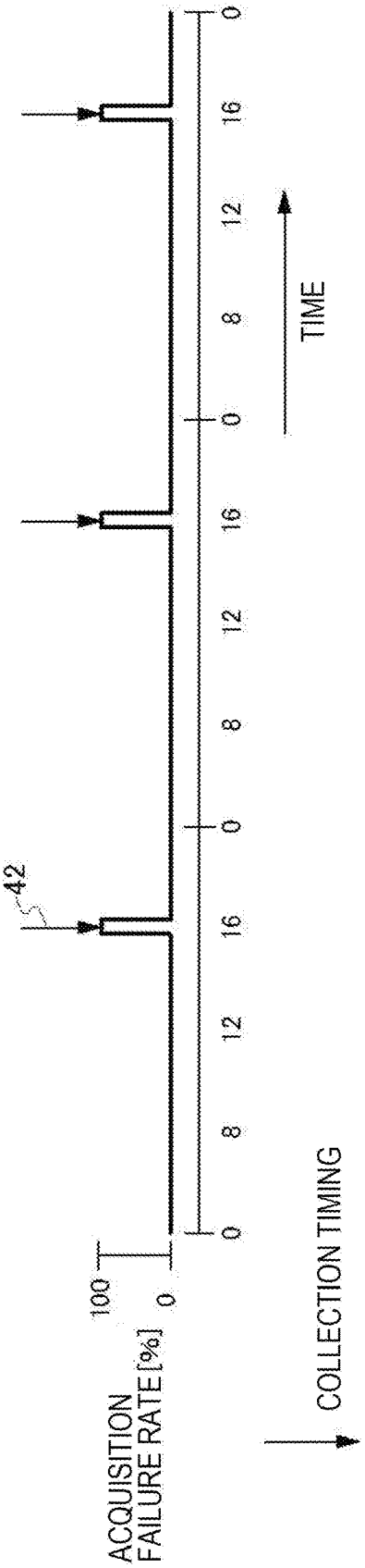

42
100
0
ACQUISITION FAILURE RATE [%]
0
8
12
16
0
8
12
16
0
8
12
16
0
TIME
COLLECTION TIMING

FIG. 6

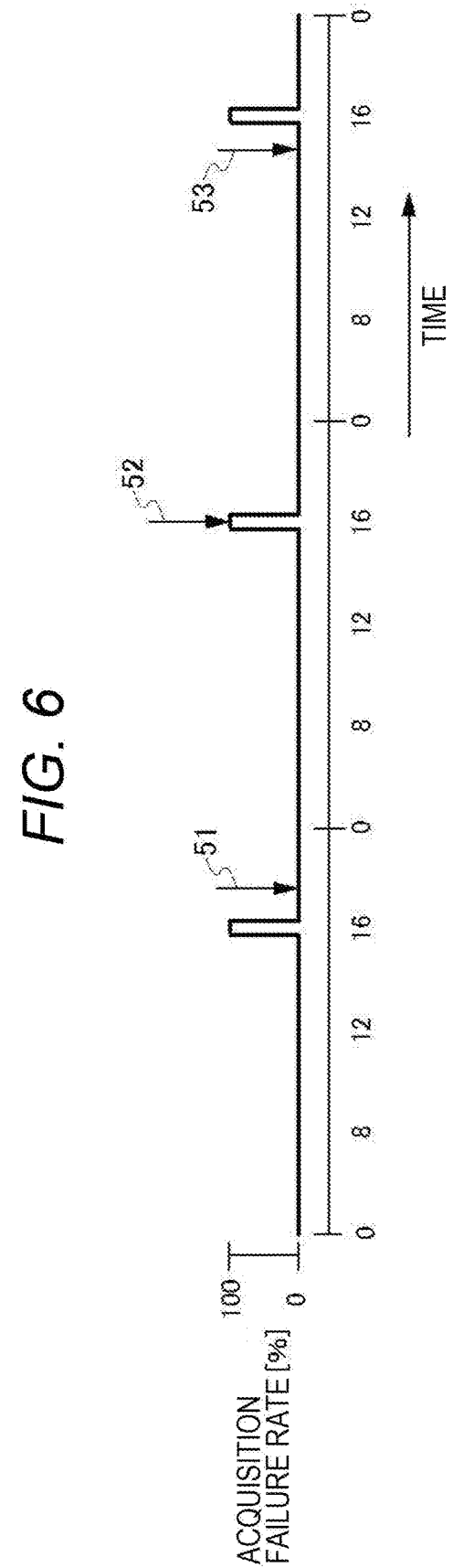

ACQUISITION FAILURE RATE [%]
100
0
0
8
12
16
0
8
12
16
0
8
12
16
0
51
52
53
TIME

FIG. 7

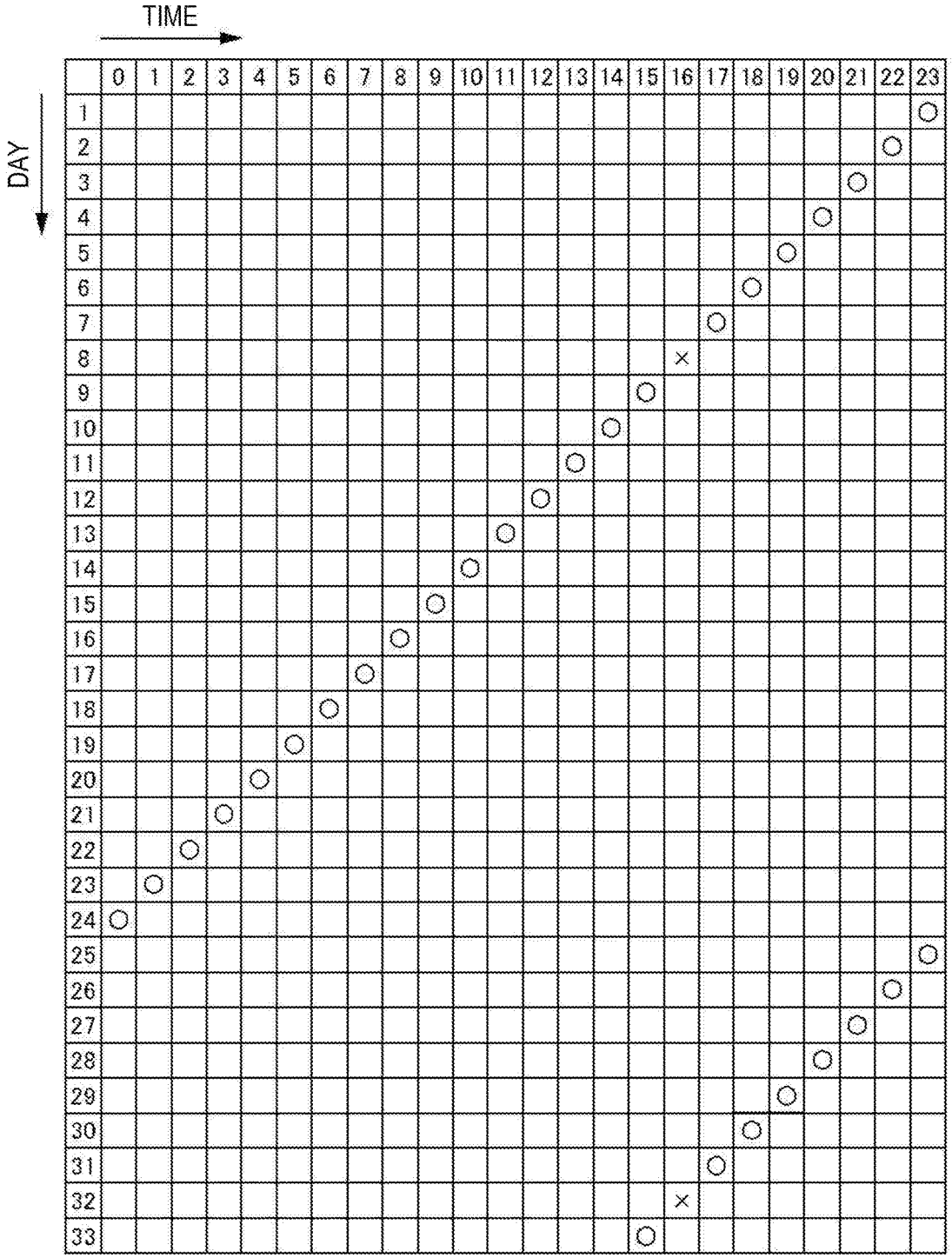

TIME
DAY
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33

FIG. 8

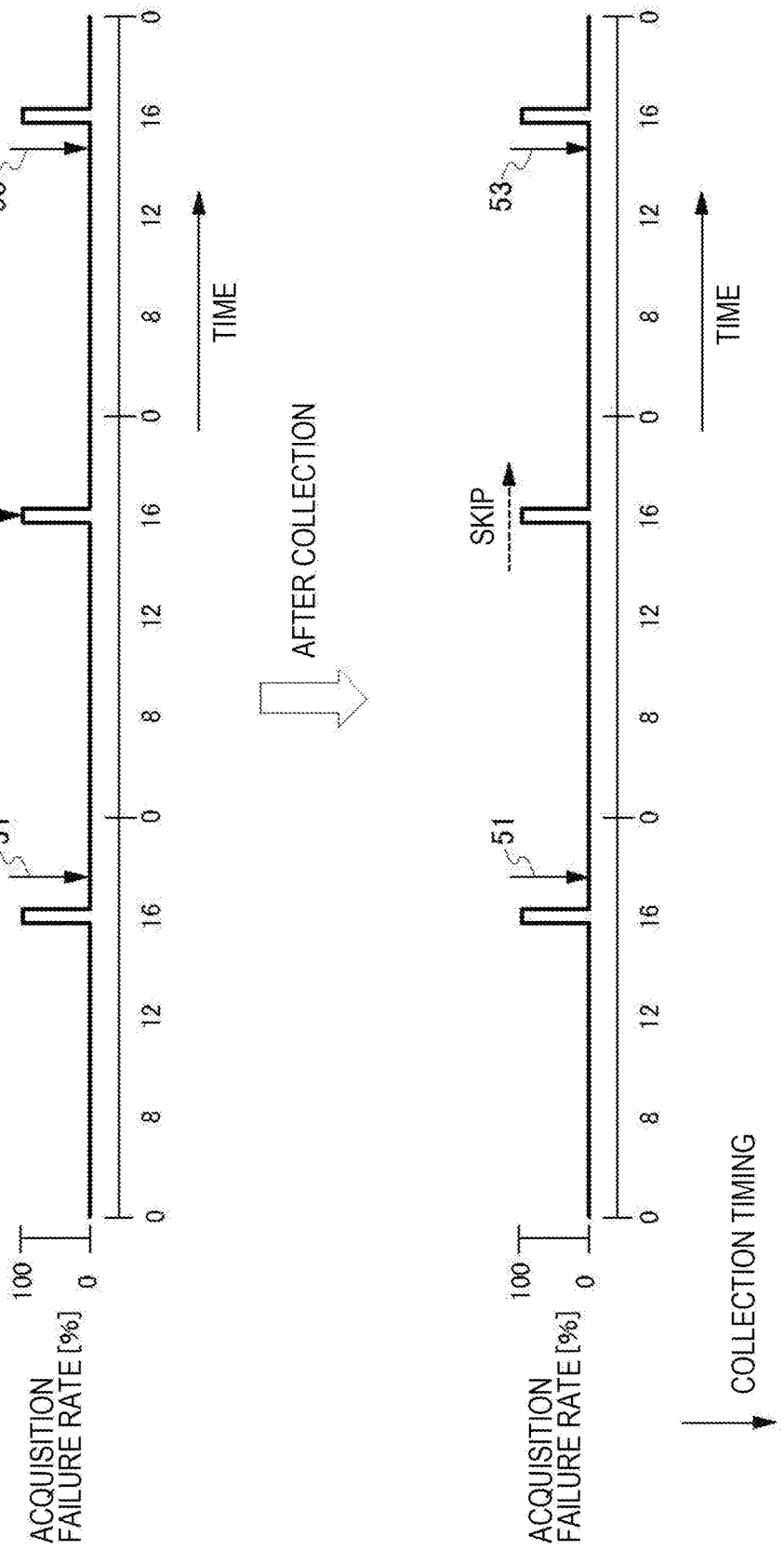

ACQUISITION FAILURE RATE [%]
100
0
0
8
12
16
0
8
12
16
0
51
52
53
TIME
AFTER COLLECTION
SKIP
COLLECTION TIMING

FIG. 9

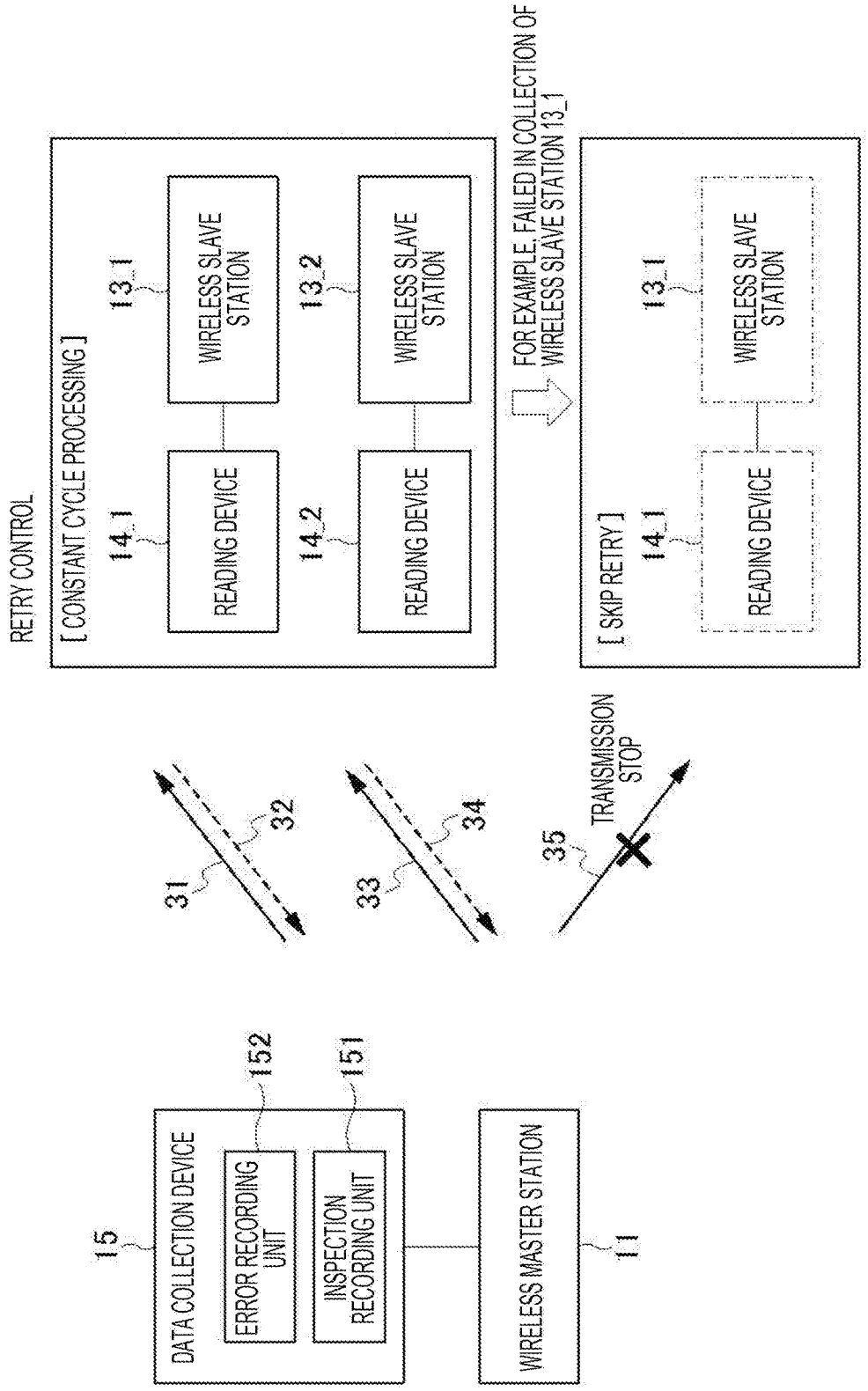

RETRY CONTROL
[CONSTANT CYCLE PROCESSING]
13_1
WIRELESS SLAVE STATION
13_2
WIRELESS SLAVE STATION
14_1
READING DEVICE
14_2
READING DEVICE
FOR EXAMPLE, FAILED IN COLLECTION OF WIRELESS SLAVE STATION 13_1
[SKIP RETRY]
13_1
WIRELESS SLAVE STATION
14_1
READING DEVICE
31
32
33
34
35
TRANSMISSION STOP
15
DATA COLLECTION DEVICE
ERROR RECORDING UNIT
152
INSPECTION RECORDING UNIT
151
WIRELESS MASTER STATION
11

FIG. 10

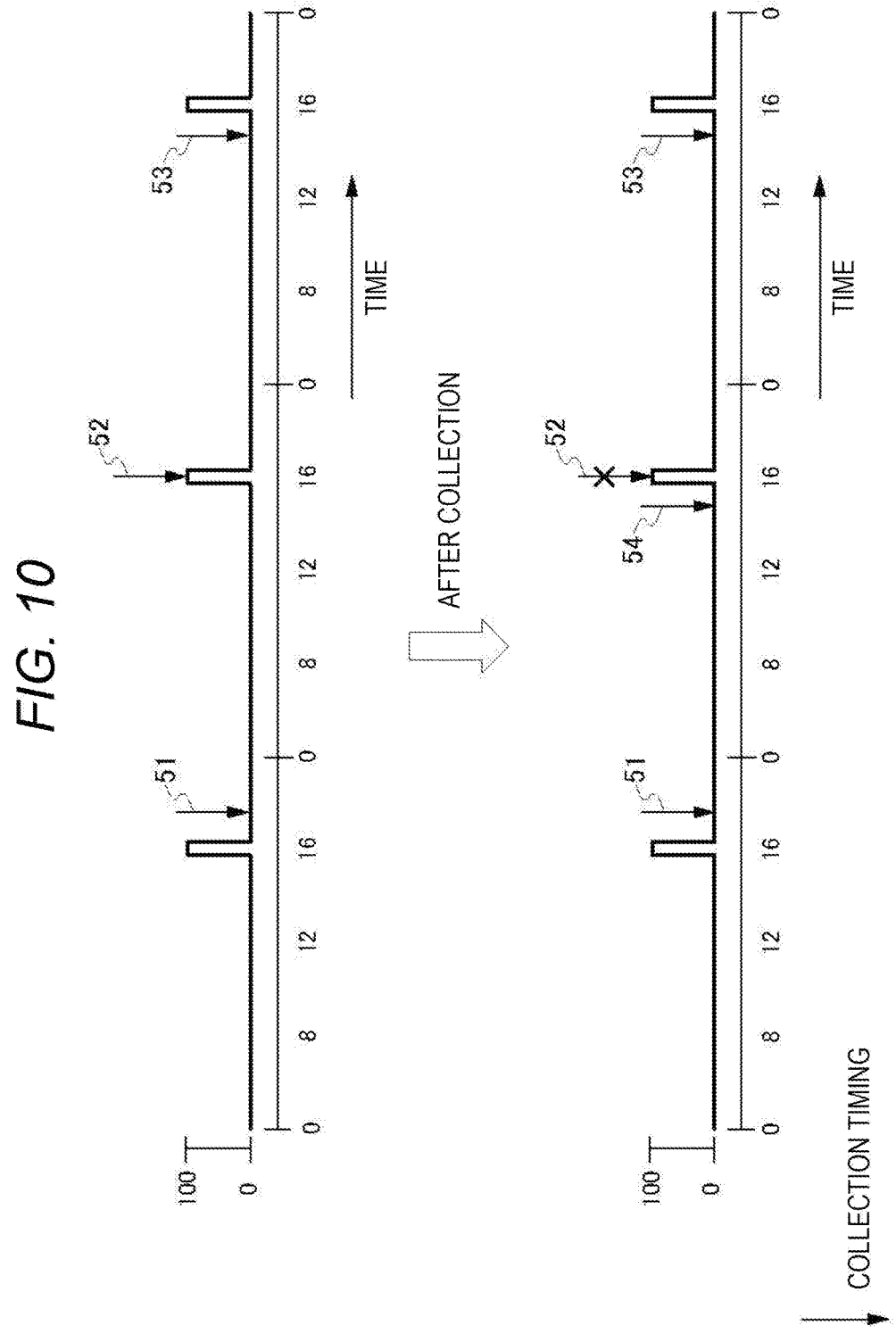
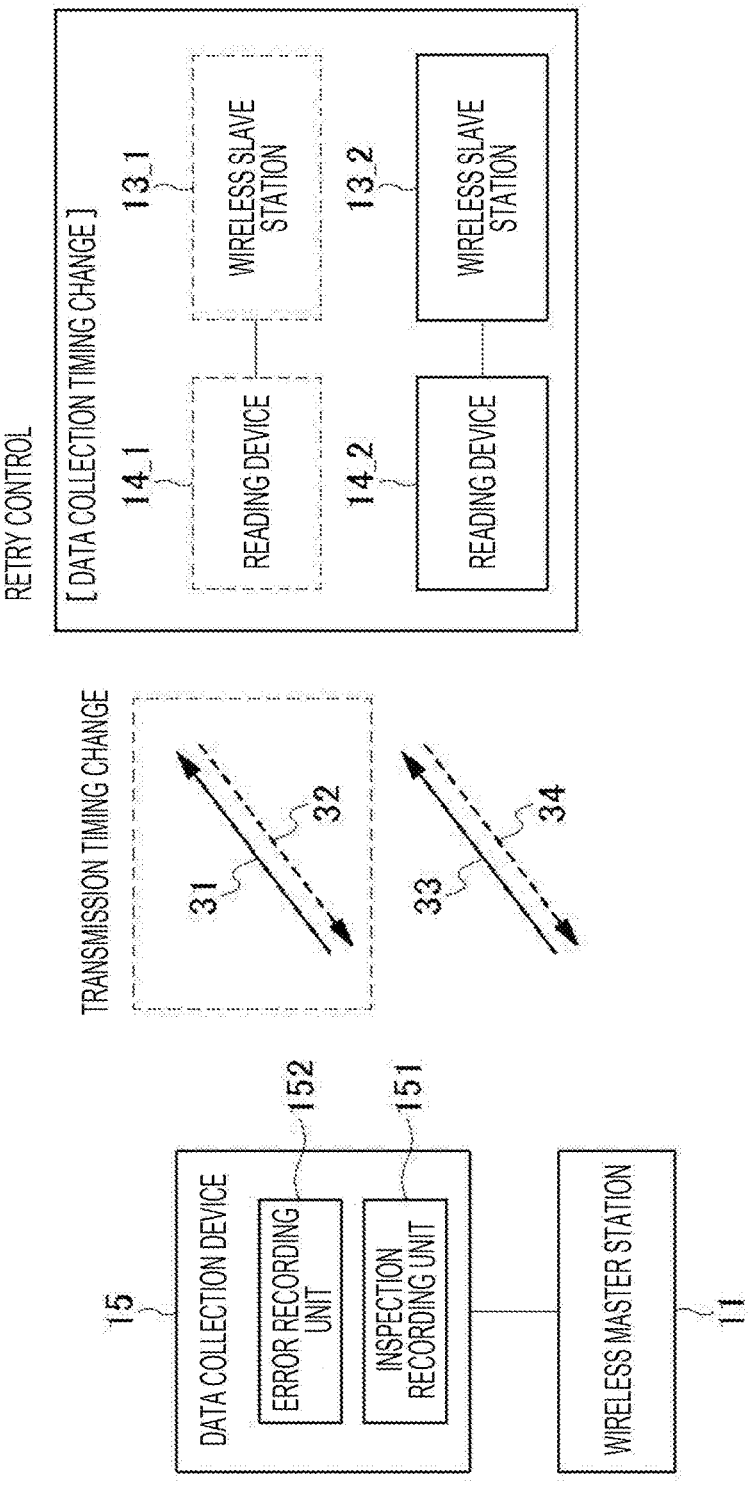

100
0
0
8
12
16
0
51
52
53
TIME
AFTER COLLECTION
54
COLLECTION TIMING

FIG. 11


RETRY CONTROL
[DATA COLLECTION TIMING CHANGE]
13_1
WIRELESS SLAVE STATION
13_2
WIRELESS SLAVE STATION
14_1
READING DEVICE
14_2
READING DEVICE
TRANSMISSION TIMING CHANGE
31
32
33
34
15
DATA COLLECTION DEVICE
152
ERROR RECORDING UNIT
151
INSPECTION RECORDING UNIT
WIRELESS MASTER STATION
11

AUTOMATIC INSPECTION SYSTEM AND AUTOMATIC INSPECTION METHOD

TECHNICAL FIELD

[0001] The present invention relates to an automatic inspection system and an automatic inspection method.

BACKGROUND ART

[0002] On-site facilities such as power plants and plants are provided with a large number of measuring instruments (for example, needle-type meters) that measure physical quantities such as the amount of water flowing through a pipe. These measuring instruments have been used for facility inspections performed by human visual observation in a cycle of about several times a day or more frequently. In maintenance and inspection work, however, problems have arisen such as aging of inspection workers and securing of personnel.

[0003] From this viewpoint, a system, which images a display unit of a measuring instrument with a camera and transmits such captured image data via a wireless network, is developed to obtain automation of inspection work (see, for example, PTL 1). PTL 1 states that "it relates to a meter reading method by image processing suitable for accurately reading positions of pointers of meters in the image processing using a monitor television camera".

[0004] Further, there is a technique of suppressing an increase in communication time in a wireless meter reading system using a wireless communication network by performing retry (re-transmission) of communication in a wireless master station when communication between a portable master device and a wireless slave station (wireless slave device) fails (see, for example, PTL 2). PTL 2 states that "the portable master device transmits a batch meter reading request telegram to the wireless slave stations, and receives response telegrams for the batch meter reading request telegram from the respective wireless slave stations. The portable master device determines and classifies each failure cause when the communication fails for each of the wireless slave stations from which the response telegram has not been received, and performs retry (re-transmission) by batch communication for each classification".

CITATION LIST

Patent Literature

[0005] PTL 1: JP H07-198331 A

[0006] PTL 2: JP 2009-282627 A

SUMMARY OF INVENTION

Technical Problem

[0007] PTL 1 discloses a technique of reading a meter pointer position of a flowmeter or the like by image analysis. PTL 2 discloses the technique of suppressing the increase in communication time caused by the retry of communication. In the conventional techniques described in PTL 1 and PTL 2, however, there is no consideration on reduction of an energy loss based on actual operation in situations where the measurement may be possible or impossible in a reading device that measures a physical quantity, that is, low power consumption of a network.

[0008] An object of the present invention is to provide an automatic inspection system and an automatic inspection method capable of realizing reduction in power consumption of a network when performing communication between a wireless master station and a wireless slave station using a wireless network.

Solution to Problem

[0009] In order to achieve the above object, an automatic inspection system of the present invention is an automatic inspection system using a wireless network which includes a wireless slave device having a reading device that acquires a physical quantity to be inspected, and a wireless master device that receives measurement data of the physical quantity acquired by the reading device from the wireless slave device by wireless communication.

[0010] Further, the automatic inspection system includes a data collection device that collects the measurement data from the wireless slave device via the wireless master device in a constant cycle and detects a time zone in which the measurement data is non-acquirable by the reading device based on a result of the collection. The wireless master device is characterized by performing control to avoid the wireless slave device from re-acquisition of the measurement data in the non-acquirable time zone based on a result of the detection of the non-acquirable time zone.

[0011] Further, an automatic inspection method of the present invention is an automatic inspection method using a wireless network which includes a wireless slave device having a reading device that acquires a physical quantity to be inspected, and a wireless master device that receives measurement data of the physical quantity acquired by the reading device from the wireless slave device by wireless communication.

[0012] Further, the automatic inspection method is characterized by: collecting the measurement data from the wireless slave device via the wireless master device in a constant cycle and detecting a time zone in which the measurement data is non-acquirable by the reading device based on a result of the collection; and avoiding the wireless slave device from re-acquisition of the measurement data in the non-acquirable time zone by the wireless master device based on a result of the detection of the non-acquirable time zone.

Advantageous Effects of Invention

[0013] According to the present invention, it is possible to suppress an energy loss caused by re-acquisition by avoiding the re-acquisition of the measurement data in the non-acquirable time zone, and thus, it is possible to realize low power consumption of the network.

BRIEF DESCRIPTION OF DRAWINGS

[0014] FIG. **1** is an example of a system configuration diagram illustrating an outline of a basic configuration of a multi-hop wireless network.

[0015] FIG. **2** is an example of a block diagram illustrating a configuration of a main part of an automatic inspection system according to an embodiment of the present invention.

[0016] FIG. **3** is an example of a flowchart illustrating flow of data collection processing in a data collection device in

the automatic inspection system according to the embodiment of the present invention.

[0017] FIG. **4** is an example of an operation explanatory diagram for describing an inspection operation of the automatic inspection system according to the embodiment of the present invention.

[0018] FIG. **5** is an example of a timing chart for describing an operation in a case where a collection schedule is data collection in a 24-hour cycle (constant cycle collection).

[0019] FIG. **6** is an example of a timing chart for describing an operation of the automatic inspection system according to Example 1.

[0020] FIG. **7** is an example of an explanatory diagram of a method for specifying a time zone in which measurement data is non-acquirable.

[0021] FIG. **8** is an example of a timing chart for describing an operation of an automatic inspection system according to Example 2.

[0022] FIG. **9** is an example of an operation explanatory diagram of the automatic inspection system according to Example 2.

[0023] FIG. **10** is an example of a timing chart for describing an operation of an automatic inspection system according to Example 3.

[0024] FIG. **11** is an example of an operation explanatory diagram of the automatic inspection system according to Example 3.

DESCRIPTION OF EMBODIMENTS

[0025] Hereinafter, modes for carrying out the present invention (hereinafter referred to as "embodiments") will be described in detail with reference to the drawings. The present invention is not limited to the embodiments. Incidentally, the same reference numerals will be used for the same elements or elements having the same functions in the following description and drawings, and redundant descriptions will be omitted.

[0026] In the present invention, a multi-hop wireless network (a sensor wireless network using multi-hopping) is preferably used as a wireless network including a wireless slave station and a wireless master station to obtain automation of an inspection of a measuring instrument that measures a physical quantity to be inspected. The multi-hop wireless network is a wireless network in which a plurality of wireless terminals transmits data via other neighboring wireless terminals by a so-called bucket relay system. Examples of the measuring instrument that measures the physical quantity to be inspected includes meters (for example, needle-type meters) such as a flow meter, a wattmeter, an ammeter, a manometer, and a thermometer.

[0027] [Multi-Hop Wireless Network]

[0028] Here, an outline of a basic configuration of the multi-hop wireless network will be described with reference to FIG. **1**. FIG. **1** is an example of a system configuration diagram illustrating the overview of the basic configuration of the multi-hop wireless network.

[0029] A multi-hop wireless network **1** according to this example includes k wireless master stations **11_1** to **11_*k*** (hereinafter referred to as a "wireless master station **11**" as a representative in some cases) as base stations. These wireless master stations **11_1** to **11_*k*** are connected to an aggregation server **3** via a network **2**. A connection form of the wireless master stations **11_1** to **11_*k*** with respect to the network **2** is not particularly limited, and may be a wired connection or a wireless connection.

[0030] The wireless master stations **11_1** to **11_*k*** are provided with M wireless slave stations **12_1** to **12_*m*** (hereinafter referred to as a "wireless slave station **12**" as a representative in some cases) as relay stations. Further, n wireless slave stations **13_1** to **13_*n*** (hereinafter referred to as a "wireless slave station **13**" as a representative in some cases) are provided as terminal stations (slave stations at a terminal layer of a hierarchy). That is, when the wireless master stations **11_1** to **11_*k*** communicate with the wireless slave stations **13_1** to **13_*n*** at the terminal layer of the hierarchy, the wireless slave stations **12_1** to **12_*m*** located in the middle thereof function as relay stations. For example, when a certain wireless master station **11_1** communicates with a certain wireless slave station **13_2**, a wireless slave station located in the middle of the multi-hop wireless network **1** (the wireless slave station **12_1** in this example) serves as a relay station to perform the communication.

[0031] Further, in an automatic inspection system using the multi-hop wireless network **1**, the terminal wireless slave stations **13_1** to **13_*n*** are provided with reading devices **14_1** to **14_*n*** (hereinafter referred to as a "reading device **14**" as a representative in some cases), respectively, that acquire measurement values of measuring instruments **4_1** to **4_*n*** (hereinafter referred to as a "measuring instrument **4**" as representative in some cases) which measure physical quantities to be inspected. As the measuring instruments **4_1** to **4_*n***, meters such as a flow meter that measures a flow rate of water, a liquid, or the like and wattmeter that measures the amount of electric power can be exemplified.

[0032] As the reading devices **14_1** to **14_*n***, for example, cameras using a solid-state imaging device, such as a charge coupled device (CCD) image sensor and a complementary metal oxide semiconductor (CMOS) image sensor, as an imaging device can be used. In this case, the reading devices **14_1** to **14_*n*** read the measurement values of the measuring instruments **4_1** to **4_*n*** from images of the measuring instruments **4_1** to **4_*n*** captured by the cameras. However, the reading devices **14_1** to **14-*n*** are not limited to the cameras. For example, any device, which is capable of measuring a physical quantity to be inspected, such as a meter that converts the physical quantity to be inspected into an electrical signal such as a current and a voltage and measures the electrical signal in conjunction with the measuring instruments **4_1** to **4_*n***, may be used.

[0033] The terminal wireless slave stations **13_1** to **13_*n*** transmit measurement results of the measuring instruments **4_1** to **4_*n*** acquired by the reading devices **14_1** to **14_*n*** to the wireless master stations **11_1** to **11_*k*** via the wireless slave stations **12_1** to **12_*m*** which are relay stations located in the middle of the multi-hop wireless network **1**.

[0034] In this example, a hierarchical structure of two layers of the relay station and the terminal station has been exemplified as the wireless slave stations, the invention is not limited to the two layers but may be a hierarchical structure of three or more layers. Further, when the wireless master stations communicates with the wireless slave stations in the terminal layer of the hierarchy, the plurality of wireless slave stations located in the middle of the multi-hop wireless network **1** functions as the relay stations as described above. At this time, not only the wireless slave stations at the terminal layer of the hierarchy, which is a

communication counterparts, but also the plurality of wireless slave stations in the middle thereof is activated to consume electric power.

[0035] The multi-hop wireless network **1** described above has an advantage that a communication range that can be covered by one data collecting station (the wireless master station or the aggregation server **3**) can be expanded by sequentially moving data between wireless terminals. Further, it is possible to eliminate a dead zone of wireless waves by setting up a multi-hop relay route so as to avoid an area with a bad wireless environment, and thus, there is also an advantage that it is possible to contribute to high reliability of data transmission.

[0036] In the multi-hop wireless network **1**, there is a case where the wireless slave station **13** and the reading device **14** are installed in a place where it is difficult to supply power from the outside. In such a case, a self-sustaining power source such as a battery is used as a power source of the wireless slave station **13** and the reading device **14**. This is because cost is required for electric facilities in order to wire a feeder over a long distance or install an outlet when a commercial power source is used as a power source of the wireless slave station **13** installed in the place where power supply is difficult, thereby increasing the cost of the multi-hop wireless network **1**.

[0037] In this manner, there is a demand for low power consumption in the multi-hop wireless network **1**, particularly the multi-hop wireless network **1** using the self-sustaining power source as the power source of the wireless slave station **13** and the reading device **14** in order to operate the wireless slave station **13** and the reading device **14** over a long time with the self-sustaining power source such as the battery. However, the reduction of the power consumption of the multi-hop wireless network **1** is not a technical problem limited only when the wireless terminal is operated by the self-sustaining power source.

[0038] Meanwhile, when the wireless master stations **11** communicates with the terminal wireless slave stations **13** in the multi-hop wireless network **1**, a communication operation is performed by hopping (transfer by reception and transmission in the unit of a packet) of the plurality of wireless slave stations **13**. Therefore, in order to suppress the power consumption of the wireless slave station **13**, particularly, it is preferable (advantageous) that a frequency of communication with the terminal wireless slave station **13** having many hops (the number of relay stations to reach the wireless master station **11**) be low.

[0039] Meanwhile, when data is transmitted between the wireless master station **11** and the wireless slave station **13** via the multi-hop wireless network **1**, there is a case where acquisition of a measurement value of the measuring instrument **4** by the reading device **14** fails in a certain wireless slave station **13**. As an example, when the reading device **14** acquires the measurement value of the measuring instrument **4** by imaging using the camera, there is a case where acquisition of the measurement value of the measuring instrument **4** by the reading device **14** fails under an environment where it is difficult to capture an appropriate image due to influence, for example, condensation, rain, reflection by the setting sun, or the like.

[0040] In this manner, when the acquisition of the measurement value of the measuring instrument **4** by the reading device **14** fails, re-attempt (re-acquisition/retry) of acquiring a measurement value is performed. When this retry is performed, the reading device **14** re-acquires (re-measures) a measurement value. Therefore, in order to reduce the energy loss of the self-sustaining power source, it is preferable advantageous) that the number of retries for re-acquiring the measurement value of the measuring instrument **4** be small.

[0041] Further, when the acquisition of the measurement value of the measuring instrument **4** by the reading device **14** fails due to any factor (for example, reflection by the setting sun), there is a low possibility that the factor is immediately eliminated. Therefore, if the wireless master station **11** immediately issues a retry request to the wireless slave station **13**, two-way communication is newly generated including the wireless slave station **12** that also operates as the relay station, and thus, an increase in the energy loss spreads throughout the entire wireless network. In addition, retry caused by an acquisition error of a measurement value frequently occurs, and the energy loss caused by the reading device **14** increases.

[0042] Meanwhile, the terminal wireless slave station **13** is normally placed in a sleep state which is a power saving mode, and is activated only when data is transferred or when the reading device **14** operates to acquire a measurement value of the measuring instrument **4**. However, if the retry caused by the measurement value acquisition error frequently occurs, activation and stop are repeated for each retry in the wireless slave station **13**, and thus, power is consumed by the corresponding amount. In other words, the activation and stop are repeated for each retry during a period in which the wireless slave station **13** is originally in the sleep state and power is not consumed so that the period in which the wireless slave station **13** is in the sleep state becomes shorter and the power consumption increases.

Embodiment of Present Invention

[0043] As described above, there is the demand for low power consumption in the multi-hop wireless network **1** which is an example of the wireless network, particularly the multi-hop wireless network **1** using the self-sustaining power source, such as the battery, as the power source for the wireless slave station **13** and the reading device **14**. Therefore, in the embodiment of the present invention, the retry (re-acquisition) accompanying the acquisition error of measurement data (the measurement value) by the reading device **14** is avoided in a time zone in which measurement data is non-acquirable and the energy loss due to the retry is reduced, thereby realizing the low power consumption of the network.

[0044] Hereinafter, a detailed description will be given regarding the embodiment of the present invention which realizes the low power consumption of the multi-hop wireless network **1** by avoiding the re-acquisition (retry) accompanying the acquisition error in the time zone in which measurement data is non-acquirable in the automatic inspection system which automatically inspects the measuring instruments **4_1** to **4_*n*** using the multi-hop wireless network **1**.

[0045] FIG. **2** is an example of a block diagram illustrating a configuration of a main part of the automatic inspection system according to the embodiment of the present invention. In the present embodiment, a needle-type meter, which measures a physical quantity by a needle and a dial (scale

board), can be used as the measuring instrument **4** (**4_1** to **4_*n***). However, the invention is not limited to the needle-type meter.

[0046] FIG. **2** schematically illustrates a system configuration in the case of performing communication between the wireless master station **11** (**11_1** to **11_*k***), which is a certain base station, and the wireless slave station **13** (**13_1** to **13_*n***) which is a certain terminal station. Further, the relay stations (wireless slave stations **12_1** to **12_*m*** in FIG. **1**) interposed between the wireless master station **11** and the wireless slave station **13** are not illustrated for ease of understanding.

[0047] As illustrated in FIG. **2**, an automatic inspection system **10** according to the present embodiment is configured such that the wireless master station **11** includes a data collection device **15** in addition to the fact that the wireless slave station **13** includes the reading device **14**. A connection form of the data collection device **15** with respect to the wireless master station **11** is not particularly limited, and may be a wired connection or a wireless connection. Similarly, a connection form of the reading device **14** with respect to the wireless slave station **13** is not particularly limited, and may be a wired connection or a wireless connection.

[0048] Incidentally, a case where the data collection device **15** is arranged at a position of the wireless master station **11** is exemplified here, but the invention is not limited thereto. That is, the data collection device **15** may be arranged at the position of the wireless master station **11** when a user collects data at the position of the wireless master station **11**, or the data collection device **15** may be arranged at a position of the aggregation server **3** when the user collects data at the position of the aggregation server **3** illustrated in FIG. **1**.

[0049] In FIG. **2**, the solid line arrow indicates a request for data transmission transmitted from the wireless master station **11** to the wireless slave station **13**, and the broken line arrow indicates a response **22** transmitted from the wireless slave station **13** to the wireless master station **11** in response to the request **21** from the wireless master station **11**. This response **22** also includes a cause of an acquisition error of a measurement value of the measuring instrument **4** by the reading device **14**.

[0050] The reading device **14** is a device that reads (acquires) the measurement value of the measuring instrument **4** such as a flow meter, a wattmeter, an ammeter, a manometer, and a thermometer. The reading device **14** is configured as an electronic circuit device which has hardware resources such as a microprocessor, a memory, an input/output unit, and a battery (none of which are illustrated). The reading device **14** includes, for example, a measurement sensor **141** and a sensor information analysis unit **142**.

[0051] The measurement sensor **141** is configured using, for example, an image sensor, outputs image data obtained by capturing the measuring instrument **4**, and supplies the image data to the sensor information analysis unit **142**. However, the measurement sensor **141** is not limited to the image sensor, but may be of any kind (type) as long as it is configured to be capable of reading a physical quantity to be inspected. The sensor information analysis unit **142** reads the measurement value of the measuring instrument **4** by analyzing (performing data analysis) the image data supplied from the measurement sensor **141**.

[0052] The wireless slave station **13** transmits the measurement value of the measuring instrument **4** read by the reading device **14** to the wireless master station **11** as measurement data and transmits the response **22** indicating a data analysis result in the sensor information analysis unit **142** to the wireless master station **11**. The response from the wireless slave station **13** to the wireless master station **11** includes a response that there is no failure in data analysis by the sensor information analysis unit **142**, a response that data analysis has failed, or a response that a measurement value has not been received from the measurement sensor **141**.

[0053] The data collection device **15** is configured as a computer or a dedicated electronic circuit device which includes, for example, hardware resources such as a microprocessor, a memory, an auxiliary storage device, an input/output unit (none of which are illustrated) and software resources such as an operating system and a computer program. The data collection device **15** includes, for example, an inspection recording unit **151** and an error recording unit **152**.

[0054] The data collection device **15** saves the response that there is no failure in data analysis in the inspection recording unit **151**, and saves the response that the data analysis has failed or the response that the measurement value has not been received from the measurement sensor **141** in the error recording unit **152**.

[0055] Hereinafter, a process of collecting data in the data collection device **15** will be described with reference to a flowchart of FIG. **3**. FIG. **3** is an example of the flowchart illustrating flow of data collection processing in the data collection device **15**. Incidentally, this processing is loop processing to wait for the next constant cycle processing.

[0056] Here, a data collection processing function in the data collection device **15** will be described by exemplifying a case where the function is realized as a microprocessor interprets and executes a program that realizes the function. In this case, a series of processes to be described hereinafter will be executed under control performed by the microprocessor.

[0057] The microprocessor sets a collection plan at a current time based on accumulated data in the error recording unit **152**, that is, an error record (Step S**11**), and then, determines whether the collection plan has been set (Step S**12**). Here, when the collection plan has not been set (NO in S**12**), the microprocessor returns to Step S**11** and waits until setting of a collection plan of the next time is performed.

[0058] When the collection plan has been set (YES in S**12**), the microprocessor transmits a data collection request (the request **21** in FIG. **2**) to the wireless slave station **13** via the wireless master station **11** based on the set collection plan (Step S**13**). Next, the microprocessor deletes the currently set collection plan (Step S**14**), and then, determines whether a response (the response **22** in FIG. **2**) from the wireless slave station **13** has been correctly received (Step S**15**).

[0059] If the response has been correctly received (YES in S**15**), the microprocessor saves a record of the data collection in the inspection recording unit **151** (Step S**16**), and then, the processing returns to Step S**11**. If the response has not been correctly received (NO in S**15**), the microprocessor saves a data collection result in the error recording unit **152** (Step S**17**). Next, the microprocessor determines whether a request for re-acquisition (retry) of data collection to the

wireless slave station **13** that has failed in data collection exceeds a predetermined number of times of retry (Step S**18**).

[0060] Further, if the predetermined number of times of retry has been exceeded (YES in S**18**), the microprocessor returns to Step S**11** and waits for the next constant cycle processing. On the other hand, if the predetermined number of times of retry has not been exceeded (NO in S**18**), the microprocessor sets a data collection retry plan based on the accumulated data in the error recording unit **152** (Step S**19**), and then, proceeds to Step S**12** and transmits again a data collection request to the wireless slave station **13** from which the response **22** of FIG. **2** has not been correctly received.

[0061] As described above, the re-acquisition (retry) of measurement data by the reading device **14** is not performed in a system in response to a case where the response from the wireless slave station **13** (response **22** in FIG. **2**) has failed in terms of time in the data collection processing in the data collection device **15**. As a result, it is possible to suppress the power consumption of the multi-hop wireless network **1** and the automatic inspection system **10** according to this embodiment.

[0062] Next, an inspection operation of the automatic inspection system **10** according to the present embodiment having the above configuration will be described with reference to FIG. **4**. FIG. **4** is an example of an operation explanatory diagram for describing the inspection operation of the automatic inspection system **10** according to the present embodiment. Here, as an example, a description will be given by exemplifying a case where two wireless slave stations **13_1** and **13_2** are set as targets of data collection processing in a constant cycle and data analysis (data acquisition) by the sensor information analysis unit **142** fails on the wireless slave station **13_1** side.

[0063] The data collection device **15** instructs the wireless master station **11** to collect data of a measurement value of the measuring instrument **4** to be measured and inspected, acquired by the reading device **14**, in accordance with a collection schedule set in advance. When receiving this instruction, the wireless master station **11** transmits a request **31** of data transmission to the wireless slave station **13_1**. When receiving the request **31**, the wireless slave station **13_1** activates the reading device **14_1** and attempts to acquire measurement data of the measuring instrument **4** obtained by sensing by the measurement sensor **141**. At this time, since the data analysis in the sensor information analysis unit **142** has failed, the wireless slave station **13_1** stops the reading device **14_1**, and then, transmits a response **32** indicating that the data analysis has failed to the wireless master station **11**.

[0064] Next, the wireless master station **11** transmits a request **33** of data transmission to the wireless slave station **13_2** when receiving the data collection instruction from the data collection device **15**. When receiving this request **33**, the wireless slave station **13_2** activates the reading device **14_2** and acquires the measurement data of the measuring instrument **4** obtained by sensing by the measurement sensor **141**. Further, the wireless slave station **13_2** stops the reading device **14_2**, and then, transmits a response **34** including the measurement data to the wireless master station **11**.

[0065] When receiving the response **32** from the wireless slave station **13_1** and the response **34** from the wireless slave station **13_2**, the wireless master station **11** supplies (transmits) reception results thereof to the data collection device **15**. Then, the data collection device **15** saves the response **34** that there is no failure in data analysis (data acquisition), received from the wireless slave station **13_2**, in the inspection recording unit **151** and saves the response **32** that the data analysis has failed, received from the wireless slave station **13_1**, in the error recording unit **152**.

[0066] Further, the data collection device **15** instructs re-acquisition (retry) of measurement data to the wireless master station **11** so as to re-perform (re-attempt) the acquisition of measurement data with respect to the wireless slave station **13_1** from which data collection has been failed. When receiving this instruction, the wireless master station **11** transmits a request **35** of data transmission to the wireless slave station **13_1** from which previous data collection has been failed. When receiving this request **35**, the wireless slave station **13_1** activates the reading device **14_1** and acquires measurement data of the measuring instrument **4**.

[0067] Further, the wireless slave station **13_1** stops the reading device **14_1**, and then, transmits a response **36** including the measurement data to the wireless master station **11**. When receiving the response **36** from the wireless slave station **13_1**, the wireless master station **11** supplies a reception result thereof to the data collection device **15**. Then, the data collection device **15** saves the response **36** that data acquisition has been successful by the current retry, received from the wireless slave station **13_1**, in the inspection recording unit **151**.

[0068] Meanwhile, if retry caused by an acquisition error of measurement data frequently occurs, the power consumption of the multi-hop wireless network **1** increases since the activation and stop are repeated for each retry in the wireless slave station **13** as described above. Therefore, it is preferable to avoid the retry (re-acquisition of measurement data) in a time zone in which measurement data is non-acquirable from the viewpoint of achieving reduction of the power consumption of the multi-hop wireless network **1**.

[0069] Here, a case where a collection schedule is data collection in a constant cycle (constant cycle collection) will be described with reference to FIG. **5**. FIG. **5** is an example of a timing chart for describing an operation when the collection schedule is data collection in a constant cycle. In FIG. **5**, the downward arrow (**1**) in the drawing indicates a collection timing of measurement data. The collection timing referred to herein includes not only an instantaneous timing but also a timing at which retry is repeatedly executed in a constant cycle within a certain period of time. The same description also applies to the following Examples.

[0070] In this example, the data collection device **15** instructs the wireless master station **11** to collect data in accordance with a collection schedule of a 24-hour cycle as an example. Further, the time at which acquisition of measurement data fails is set to, for example, 16 o'clock. In the case of this example, an acquisition failure rate is 100[%] in the time zone of 16 o'clock as illustrated in FIGS. **5**A and **5**B. A time zone about 16 o'clock is a time zone in which the reading device **14** is likely to fail to acquire a measurement value of the measuring instrument **4** due to influence of, for example, reflection on the setting sun.

[0071] In the case of the data collection in a constant cycle, it is possible to consider data collection at a collection timing **41** (see FIG. **5**A) in which acquisition of measurement data is always successful and at a collection timing **42**

(see FIG. **5**B) in which acquisition of measurement data always fails. In the collection timing **41** where acquisition of measurement data is always successful, it is difficult to detect (discover) the time in which data collection fails in one day. Further, in the collection timing **42** in which acquisition of measurement data always fails, it is conceivable that acquisition of the measurement data is successful sometime by repeating retry in the constant cycle.

[0072] However, if retry caused by data collection failure frequently occurs until acquisition of measurement data is successful, communication by the multi-hop wireless network **1** and an energy loss by the reading device **14** increase. Thus, it is desirable not to re-acquire measurement data from the wireless slave station **13** from which acquisition of measurement data has been failed, in consideration of an energy loss of an autonomous power source particularly in a system using a self-sustaining power source, such as a battery, as a power source for the wireless slave station **13** and the reading device **14**.

[0073] However, a measurement target is not monitored if the retry of acquisition of measurement data is not performed due to presence of the timing in which data collection always fails. Therefore, in the present embodiment, the retry (re-acquisition of measurement data) caused by an acquisition error of measurement data (a measurement value) by the reading device **14** is avoided in a time zone in which measurement data is non-acquirable in order to monitor the measurement target. Hereinafter, Examples for avoiding retry in the time zone in which measurement data is non-acquirable will be specifically described.

Example 1

[0074] Example 1 is an example in the case of data collection in which a collection schedule is a cycle different from the 24-hour cycle. FIG. **6** is an example of a timing chart for describing an operation of an automatic inspection system according to Example 1.

[0075] In Example 1, as an example, the data collection device **15** instructs the wireless master station **11** to collect data in accordance with a collection schedule in a constant cycle of 23 hours. Further, the time at which acquisition of measurement data fails is set to, for example, 16 o'clock for the reason described above.

[0076] In the case of Example 1, it is conceivable that collection timings **51** and **53** at which acquisition of measurement data is always successful and a collection timing **52** at which acquisition of measurement data always fails are mixedly present, for example, during data collection cycles for three days. In such a case, it is possible to detect (discover) a time zone in which acquisition of measurement data fails in one day, that is, a time zone in which measurement data is non-acquirable by continuing the data collection.

[0077] Therefore, data collection is continued in a cycle different from the 24-hour cycle (in this example, 23-hour cycle) in Example 1 to find the time zone in which acquisition of measurement data fails. Further, it is configured to skip (avoid) re-acquisition of measurement data only in the time zone (time zone in which measurement data is non-acquirable) in which acquisition of measurement data fails. As a result, it is possible to reduce the energy loss of the autonomous power source caused by acquisition of measurement data and retry. Further, the data collection timing is always different from the previous collection timing, and thus, an acquisition failure rate is averaged as compared with the constant cycle collection at a fixed time according to the 24-hour cycle. As a result, it is possible to grasp that a cause in the case where the constant cycle collection fails continuously a plurality of times does not depend on a temporal change.

[0078] Here, a method for specifying (detecting) the time zone in which measurement data is non-acquirable will be described with reference to FIG. **7**. FIG. **7** is an example of an explanatory diagram of the method for specifying the time zone in which measurement data is non-acquirable. In this example, the time at which measurement data acquisition fails is set to, for example, 16 o'clock.

[0079] When data collection is continued in a cycle (in this example, 23-hour cycle) different from the 24-hour cycle, it is possible to grasp the time zone in which acquisition of measurement data fails, in the example of FIG. **7**, a time zone with a mark x (that is, the time zone at 16 o'clock). Further, when performing acquisition of measurement data and retry thereafter, the acquisition of measurement data is skipped only the time zone in which acquisition of measurement data fails, in the example of Example 1, a time zone in the collection timing **52** illustrated in FIG. **6**. As a result, it is possible to suppress the increase in the energy loss caused by data collection failure.

Example 2

[0080] Example 2 is an example of avoiding (stopping) retry in a time zone in which measurement data is non-acquirable, with respect to the wireless slave station **13** from which data collection has failed. FIG. **8** is an example of a timing chart for describing an operation of an automatic inspection system according to Example 2.

[0081] In Example 2, it is possible to consider a case where data collection has failed despite repetition of retry in a constant cycle in the collection timing **52** in which data collection always fails. The data collection device **15** determines that the possibility of successfully acquiring measurement data is low until any cause (for example, influence such as reflection by the setting sun) is removed even when retry is performed more than a plurality of times based on accumulated data in the error recording unit **152**.

[0082] In this manner, the data collection device **15** skips and does not execute retry in the collection timing **52** in which data collection always fails (that is, the time zone in which measurement data is non-acquirable) with respect to the wireless slave station **13** from which acquisition of measurement data has failed and which has been determined that the possibility of successfully collecting data is low until the cause of the failure is removed, As a result, it is possible to reduce the energy loss caused by the data collection failure in the wireless slave station **13** from which acquisition of measurement data has failed.

[0083] A description will be given regarding the above-described retry control process in the time zone in which measurement failure frequently occurs (that is, the time zone during which measurement data is non-acquirable) based on the collected information with reference to FIG. **9**. FIG. **9** is an example of an operation explanatory diagram of the automatic inspection system according to Example 2.

[0084] As a specific example, the data collection device **15** determines that data collection failure frequently occurs in the wireless slave station **13_1** at a data collection timing of a current constant cycle (the collection timing illustrated in

FIG. **8**). Then, the data collection device **15** saves the response **34** of the wireless slave station **13_2** that there is no failure in acquisition of measurement data, in the inspection recording unit **151** and saves the response **32** of the wireless slave station **13_1** that acquisition of measurement data has failed, in the error recording unit **152**.

[0085] Further, the data collection device **15** refers to the accumulated data in the error recording unit **152**, stops transmitting the data transmission request **35** to the wireless slave station **13_1** if data collection failure frequently occurs at the data collection timing of the current constant cycle so as not to perform retry of the acquisition of measurement data with respect to the wireless slave station **13_1**. As a result, the retry with respect to the wireless slave station **13_1** is skipped, and thus, it is possible to reduce the energy loss caused by the data collection failure in the wireless slave station **13** from which acquisition of measurement data has failed.

Example 3

[0086] Example 3 is an example in which a data collection plan is changed for the wireless slave station **13** that has failed in data collection. FIG. **10** is an example of a timing chart for describing an operation of an automatic inspection system according to Example 3.

[0087] It is considered that a case where acquisition of measurement data in a constant cycle is likely to fail in the data collection device **15** at the collection timing **52** in which data collection always fails based on the accumulated data in the error recording unit **152**. In this case, it is conceivable that acquisition of measurement data fails until any cause (for example, the influence such as reflection by the setting sun) is removed even if the acquisition of measurement data in the constant cycle is performed.

[0088] Therefore, the data collection device **15** changes a data collection plan and acquires measurement data when it is anticipated that acquisition of measurement data in a constant cycle will fail. Specifically, the plan is changed to a collection timing **54** earlier by one hour than the collection timing **52** in which the data collection always fails (the plan is advanced by one hour). As a result, it is possible to reduce the possibility of failing to acquire measurement data in the wireless slave station **13** from which acquisition of measurement data has failed, and thus, it is possible to reduce the energy loss caused by the data collection failure.

[0089] A description will be given regarding the above-described retry control process in the time zone in which measurement failure frequently occurs (that is, the time zone during which measurement data is non-acquirable) based on the collected information with reference to FIG. **11**. FIG. **11** is an explanatory diagram of an operation of the automatic inspection system according to the Example 3.

[0090] As a specific example, the data collection device **15** determines that data collection failure frequently occurs in the wireless slave station **13_1** at a data collection timing of a current constant cycle (the collection timing illustrated in FIG. **10**). Then, the data collection device **15** refers to the accumulated data in the error recording unit **152**, and changes the data collection plan in the constant cycle with respect to the wireless slave station **13_1** if data collection failure frequently occurs at the data collection timing of the current constant cycle.

[0091] Due to this change of data collection plan, the data collection device **15** instructs the wireless master station **11** to collect data from the wireless slave station **13_1** in accordance with a collection schedule based on the changed data collection plan. When receiving this instruction, the wireless master station **11** transmits a request **31** of data transmission to the wireless slave station **13_1**. As a result, a transmission timing of the request **31** from the wireless master station **11** to the wireless slave station **13_1** is changed along with the change of the data collection plan.

[0092] In this manner, the data collection plan is changed with respect to the wireless slave station **13_1** for which the failure in acquisition of measurement data frequently occurs to perform acquisition of measurement data at the collection timing **54**, which is different from and earlier by, for example, one hour than the original collection timing **52**, so that it is possible to reduce the energy loss caused by the data collection failure.

[0093] [Modifications]

[0094] Incidentally, the present invention is not limited to the above-described respective Examples, and includes various modifications. For example, the above-described respective Examples have been described in detail in order to describe the present invention in an easily understandable manner, and are not necessarily limited to one including the entire configuration that has been described above. Further, one means of a certain Example can be substituted by configurations of another Example, and further, to a configuration of a certain Example, a configuration of another Example can be added. Further, with respect to one means of configurations of each Example, addition, deletion, or substitution of other configurations can be made.

REFERENCE SIGNS LIST

[0095] **1** multi-hop wireless network

[0096] **2** network

[0097] **3** aggregation server

[0098] **4**(**4_1** to **4_*n***) measuring instrument

[0099] **10** automatic inspection system

[0100] **11**(**11_1** to **11_*k***) wireless master station (base station)

[0101] **12**(**12_1** to **12_*m***) wireless slave station (relay station)

[0102] **13**(**13_1** to **13_*n***) wireless slave station (terminal station)

[0103] **14**(**14_1** to **14_*n***) reading device

[0104] **15** data collection device

1. An automatic inspection system using a wireless network which includes a wireless slave device having a reading device that acquires a physical quantity to be inspected and a wireless master device that receives measurement data of the physical quantity acquired by the reading device from the wireless slave device by wireless communication,

the automatic inspection system comprising a data collection device that collects the measurement data from the wireless slave device via the wireless master device in a constant cycle and detects a time zone in which the measurement data is non-acquirable by the reading device based on a result of the collection,

wherein the wireless master device performs control to avoid the wireless slave device from re-acquisition of the measurement data in the non-acquirable time zone based on a result of the detection of the non-acquirable time zone.

2. The automatic inspection system according to claim 1, wherein

the data collection device sets a cycle different from a 24-hour cycle as the constant cycle and continues to collect the measurement data in the cycle so as to specify a time zone in which the measurement data is non-acquirable, and

the wireless master device performs control to skip re-acquisition of the measurement data in the non-acquirable time zone specified by the data collection device with respect to the wireless slave device that has failed in collecting the measurement data.

3. The automatic inspection system according to claim 1, wherein

the wireless master device performs control so as not to perform re-acquisition of the measurement data in the non-acquirable time zone with respect to the wireless slave device that has performed re-acquisition of the measurement data more than a predetermined number of times.

4. The automatic inspection system according to claim 1, wherein

the wireless master device performs control so as to perform re-acquisition of the measurement data at a timing that avoids the time zone in which the measurement data is non-acquirable with respect to the wireless slave device that has failed in collecting the measurement data.

5. An automatic inspection method using a wireless network which includes a wireless slave device having a reading device that acquires a physical quantity to be inspected and a wireless master device that receives measurement data of the physical quantity acquired by the reading device from the wireless slave device by wireless communication,

the automatic inspection method comprising:

collecting the measurement data from the wireless slave device via the wireless master device in a constant cycle and detecting a time zone in which the measurement data is non-acquirable by the reading device based on a result of the collection; and

avoiding the wireless slave device from re-acquisition of the measurement data in the non-acquirable time zone by the wireless master device based on a result of the detection of the non-acquirable time zone.

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