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(54) **BASE STATION, WIRELESS COMMUNICATION METHOD, AND WIRELESS COMMUNICATION PROGRAM**

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(57) **ABSTRACT**

A base station according to an embodiment includes an antenna, a wireless device, a wireless information acquisition unit, a control unit, a directivity setting unit, a directivity control unit, and a communication instruction unit. The antenna has an omni-directional array antenna. The wireless device communicates with one or more terminals in a cover area by using a wireless signal via the antenna. The wireless information acquisition unit acquires wireless information including the position of the terminal and a communication time block. On the basis of the wireless information, the control unit determines a communication execution time block, which is a time block for executing communication with the terminal, and an antenna gain of the antenna for communicating with the terminal. On the basis of the antenna gain, the directivity setting unit sets a directivity pattern of the omni-directional array antenna so as to have directivity in the direction of the terminal. On the basis of the directivity pattern, the directivity control unit controls the directivity of the omni-directional array antenna. The communication instruction unit instructs the wireless device to communicate with the terminal in the communication execution time block.

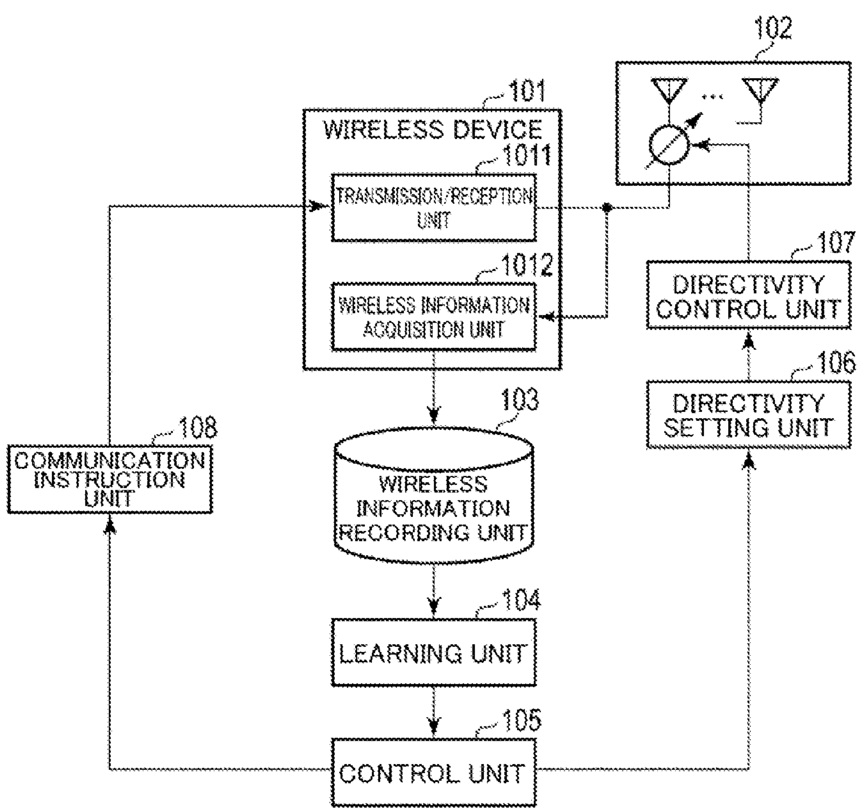


Fig. 1

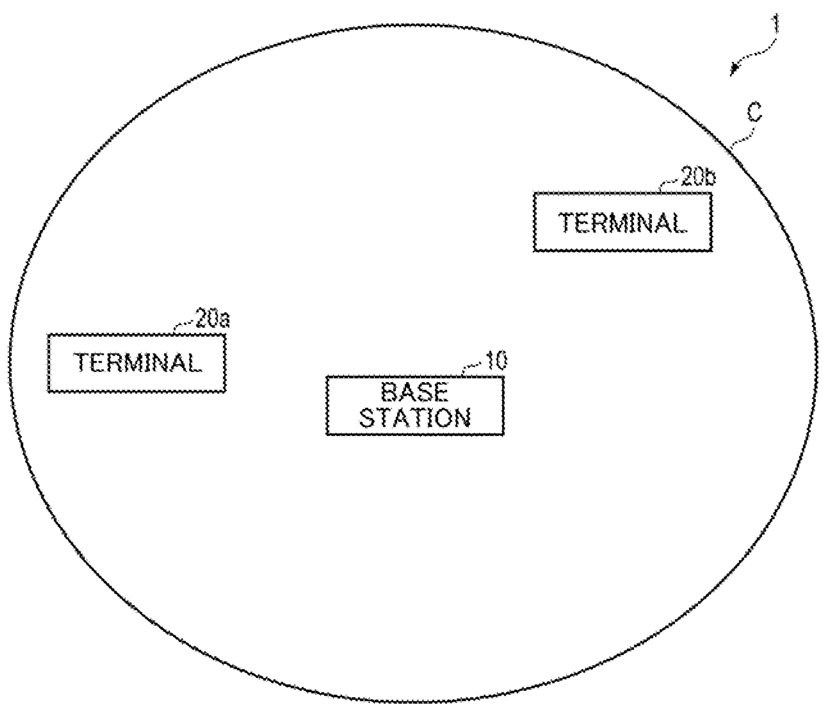


Fig. 2

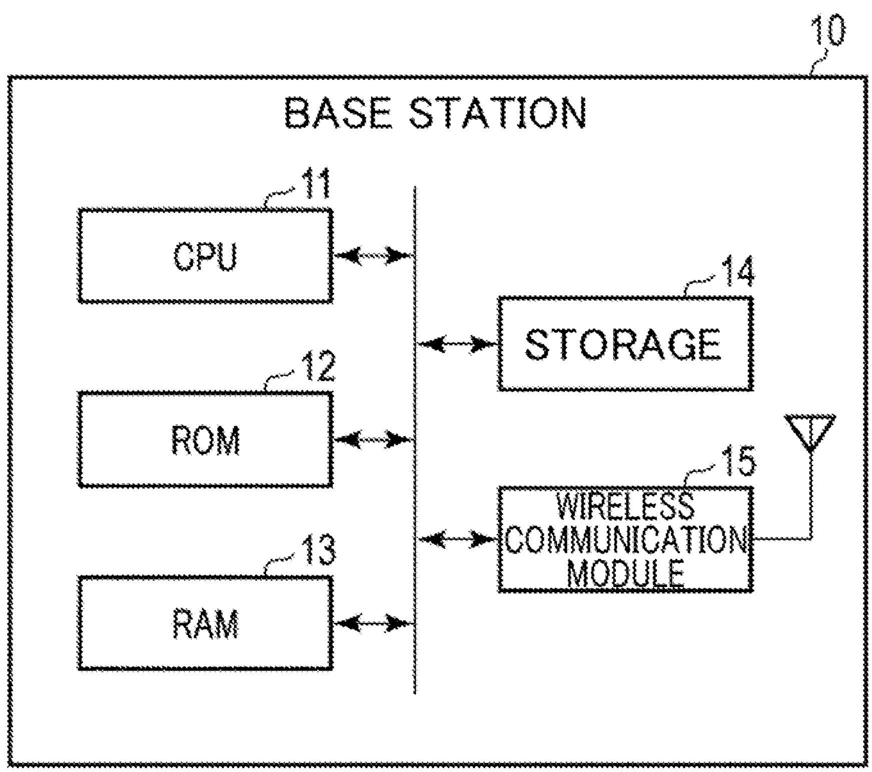

10
BASE STATION
11
CPU
12
ROM
13
RAM
14
STORAGE
15
WIRELESS COMMUNICATION MODULE

Fig. 3

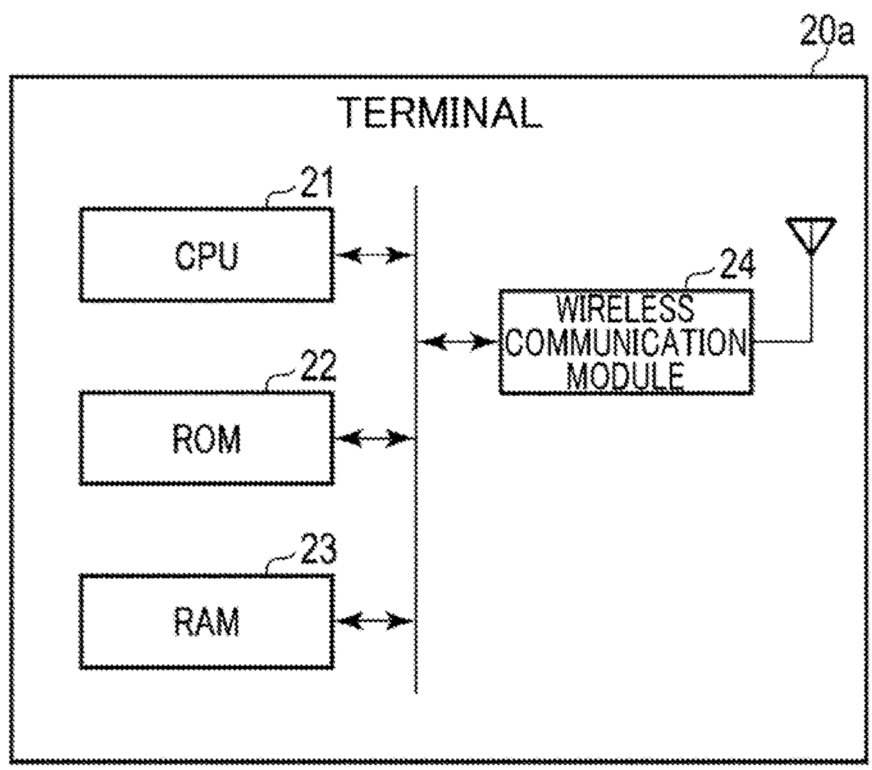

20a
TERMINAL
21
CPU
22
ROM
23
RAM
24
WIRELESS COMMUNICATION MODULE

Fig. 4

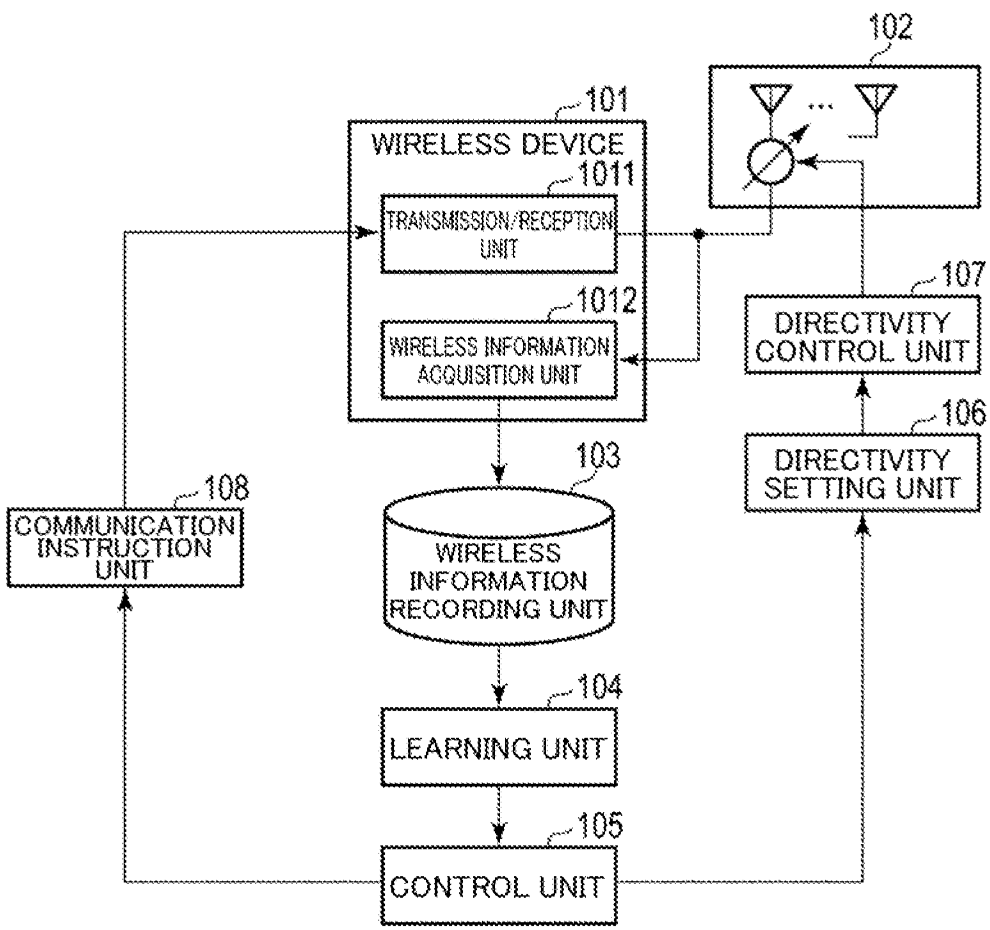

102
101
WIRELESS DEVICE
1011
TRANSMISSION/RECEPTION UNIT
1012
WIRELESS INFORMATION ACQUISITION UNIT
107
DIRECTIVITY CONTROL UNIT
106
DIRECTIVITY SETTING UNIT
103
WIRELESS INFORMATION RECORDING UNIT
108
COMMUNICATION INSTRUCTION UNIT
104
LEARNING UNIT
105
CONTROL UNIT

Fig. 5

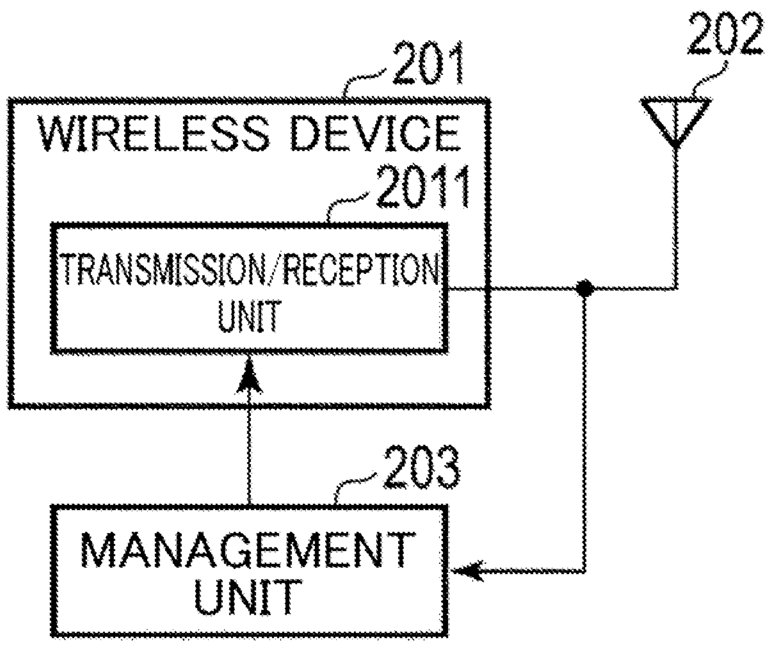

201
WIRELESS DEVICE
2011
TRANSMISSION/RECEPTION UNIT
202
203
MANAGEMENT UNIT

Fig. 6

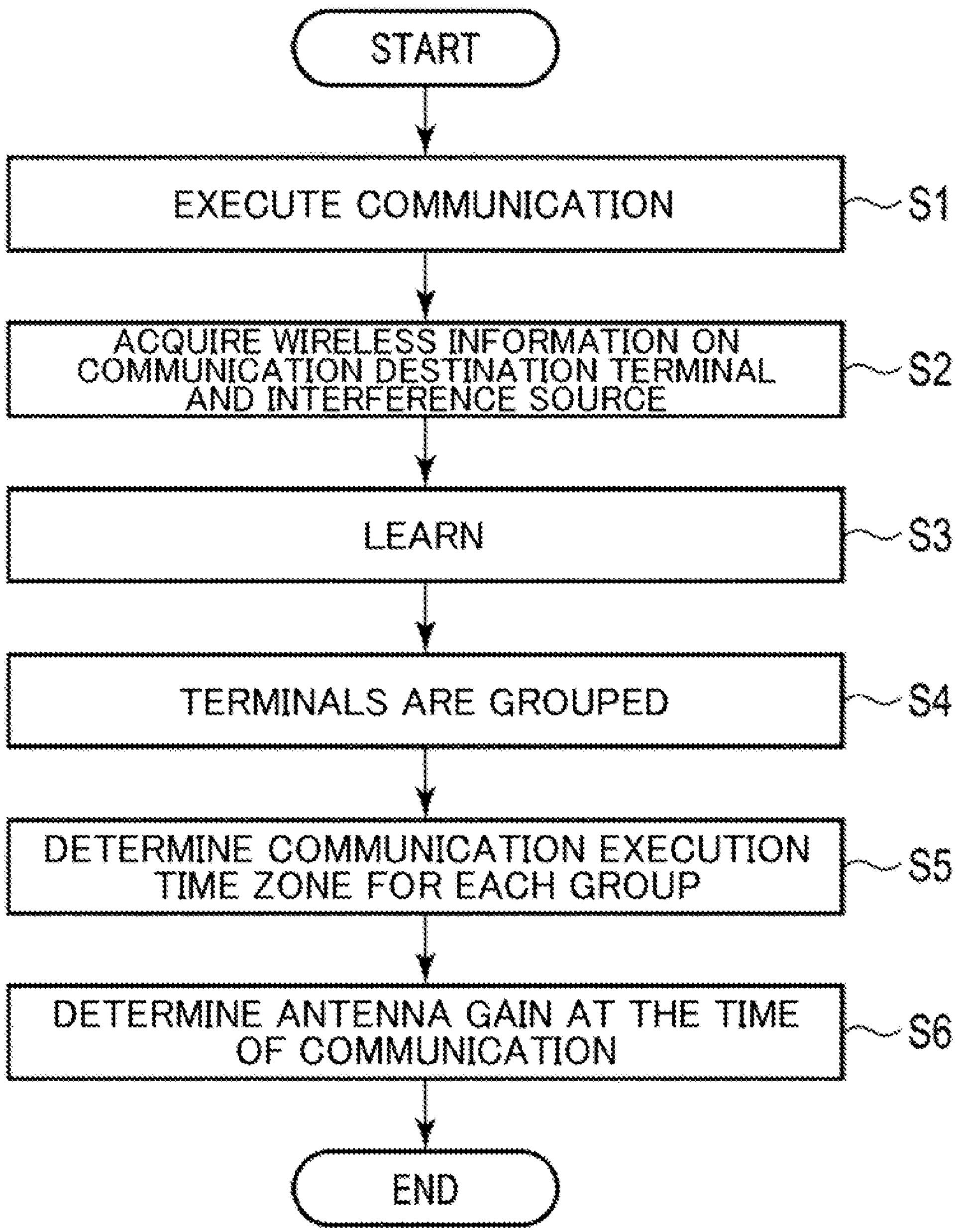

START
EXECUTE COMMUNICATION
S1
ACQUIRE WIRELESS INFORMATION ON COMMUNICATION DESTINATION TERMINAL AND INTERFERENCE SOURCE
S2
LEARN
S3
TERMINALS ARE GROUPED
S4
DETERMINE COMMUNICATION EXECUTION TIME ZONE FOR EACH GROUP
S5
DETERMINE ANTENNA GAIN AT THE TIME OF COMMUNICATION
S6
END

Fig. 7

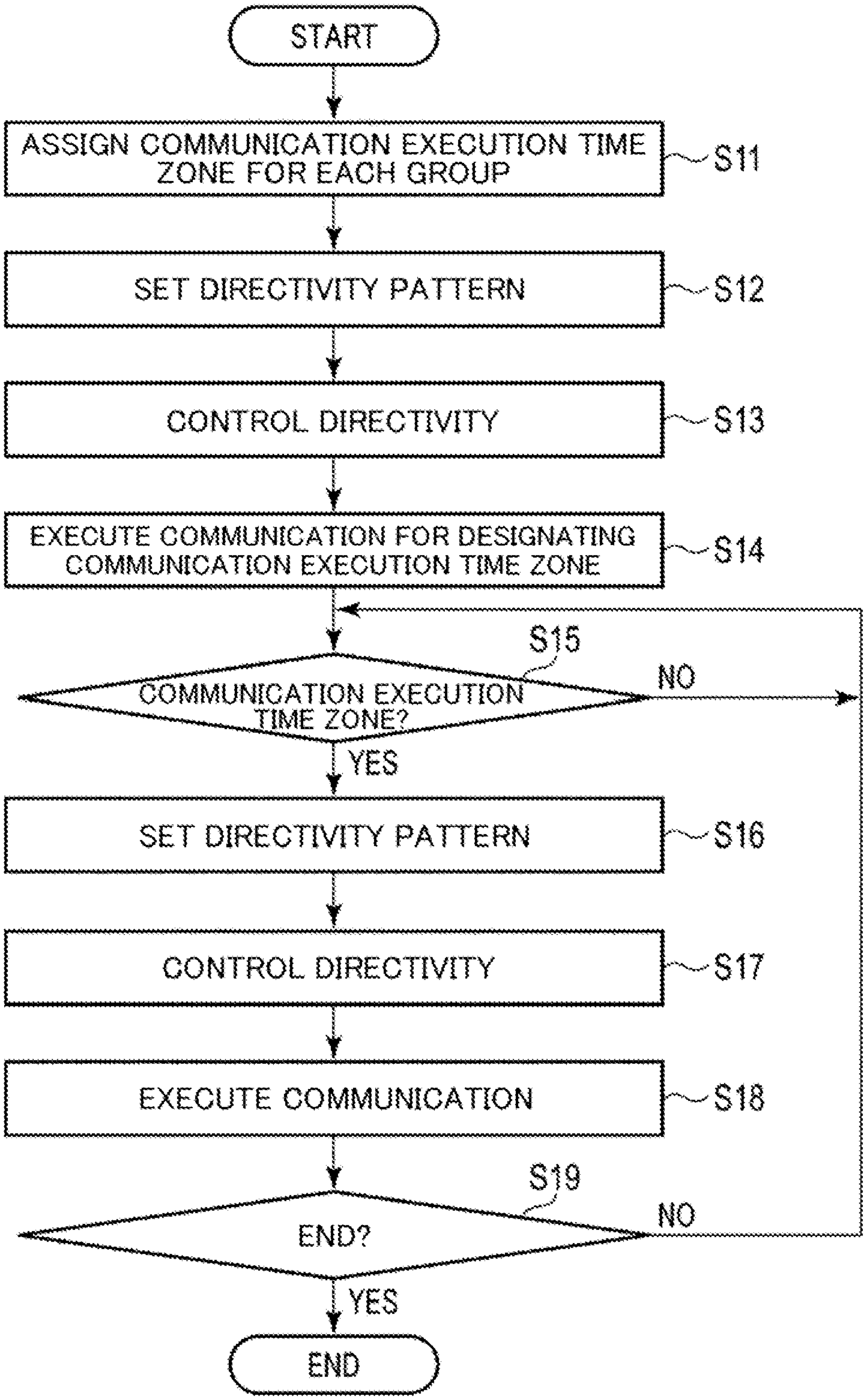
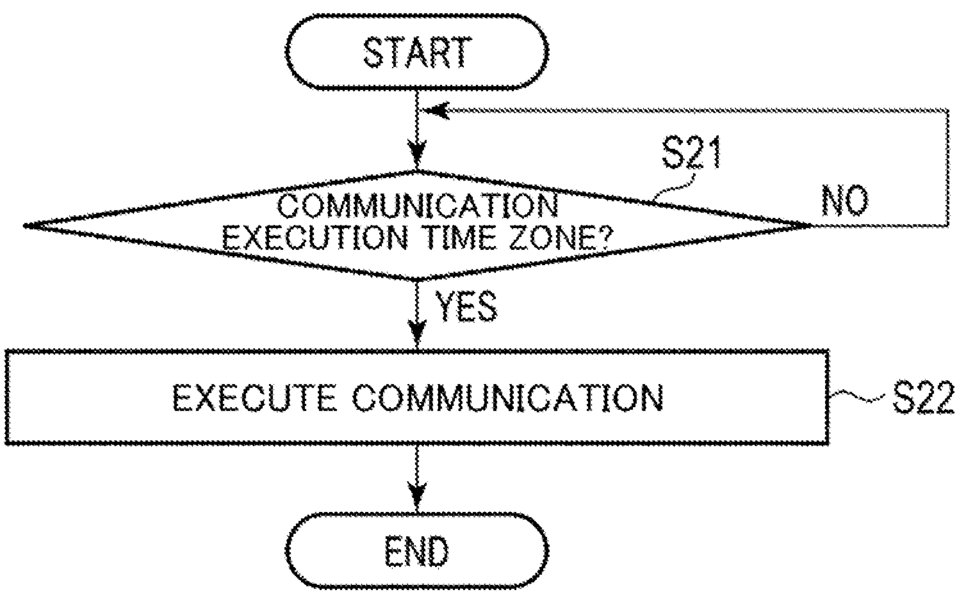

START
ASSIGN COMMUNICATION EXECUTION TIME ZONE FOR EACH GROUP
S11
SET DIRECTIVITY PATTERN
S12
CONTROL DIRECTIVITY
S13
EXECUTE COMMUNICATION FOR DESIGNATING COMMUNICATION EXECUTION TIME ZONE
S14
S15
COMMUNICATION EXECUTION TIME ZONE?
NO
YES
SET DIRECTIVITY PATTERN
S16
CONTROL DIRECTIVITY
S17
EXECUTE COMMUNICATION
S18
S19
END?
NO
YES
END

Fig. 8


START
S21
COMMUNICATION
EXECUTION TIME ZONE?
NO
YES
EXECUTE COMMUNICATION
S22
END

BASE STATION, WIRELESS COMMUNICATION METHOD, AND WIRELESS COMMUNICATION PROGRAM

TECHNICAL FIELD

[0001] An embodiment relates to a base station, a wireless communication method, and a wireless communication program.

BACKGROUND ART

[0002] A base station used for wireless LAN communication is preferably configured to be able to communicate with terminals existing in various directions. Therefore, an omni-directional antenna is often used as an antenna used in a base station.

CITATION LIST

Patent Literature

[0003] [PTL **1**] Japanese Patent Application Publication No. 2019-009658

SUMMARY OF INVENTION

Technical Problem

[0004] In the case of an omni-directional antenna, the gain is smaller than that of the directional antenna. Therefore, it is more difficult for the omni-directional antenna to transmit over a long distance as compared with a directional antennas. In addition, the omni-directional antennas is affected by interfering radio waves more easily.

[0005] An embodiment provides a base station that covers a wide area while using an omni-directional antenna and has reduced impact of interference radio waves, and a wireless communication method and a wireless communication program using such a base station.

Solution to Problem

[0006] In the embodiment, the base station includes an antenna, a wireless device, a wireless information acquisition unit, a control unit, a directivity setting unit, a directivity control unit, and a communication instruction unit. The antenna has an omni-directional array antenna. The wireless device communicates with one or more terminals in a cover area by using a wireless signal via the antenna. The wireless information acquisition unit acquires wireless information including the position of a terminal and a communication time block. On the basis of the wireless information, the control unit determines a communication execution time block, which is a time block for executing communication with the terminal, and an antenna gain of the antenna for communicating with the terminal. On the basis of the antenna gain, the directivity setting unit sets a directivity pattern of the omni-directional array antenna so as to have directivity in the direction of the terminal. On the basis of the directivity pattern, the directivity control unit controls the directivity of the omni-directional array antenna. The communication instruction unit instructs the wireless device to communicate with the terminal in the communication execution time block.

Advantageous Effects of Invention

[0007] The embodiment can a base station that covers a wide area while using an omni-directional antenna and has reduced impact of interference radio waves, and a wireless communication method and a wireless communication program using such a base station.

BRIEF DESCRIPTION OF DRAWINGS

[0008] FIG. **1** is a diagram showing an example of a configuration of a wireless system according to an embodiment.

[0009] FIG. **2** is a diagram showing an example of a configuration of a base station.

[0010] FIG. **3** is a diagram showing an example of a configuration of a terminal **20***a*.

[0011] FIG. **4** is a diagram showing an example of a functional configuration of the base station.

[0012] FIG. **5** is a diagram showing an example of a functional configuration of the terminal **20***a*.

[0013] FIG. **6** is a flowchart showing an example of a learning operation at the base station.

[0014] FIG. **7** is a flowchart showing an example of a communication operation after learning in the base station.

[0015] FIG. **8** is a flowchart showing an example of a communication operation at the terminal **20***a*.

DESCRIPTION OF EMBODIMENTS

[0016] Embodiments will be described hereinafter with reference to the drawings. FIG. **1** shows an example of a configuration of a wireless system **1** according to an embodiment. As shown in FIG. **1**, the wireless system **1** includes, for example, a base station **10** and a terminal **20***a*. The terminal **20***a* exists within a cover area C of the base station **10**. Furthermore, a terminal **20***b* which can be an interference source when the base station **10** and the terminal **20***a* communicates with each other exists in the cover area C of the base station **10**. In the following, although the interference source is the terminal **20***b*, the terminal **20***a*, too, can be an interference source when the base station **10** and the terminal **20***b* communicates with each other. That is, the following explanation can hold true even if the terminal **20***a* and the terminal **20***b* are replaced with each other.

[0017] The base station **10** is a wireless communication device used as an access point for a wireless LAN. For example, the base station **10** can wirelessly transmit, to the terminal **20***a*, data received from a server via a network, not shown. The base station **10** can also receive data wirelessly from the terminal **20***a*. Communication between the base station **10** and the terminal **20***a* is based on, for example, the IEEE 802.11 standard.

[0018] The terminal **20***a* is a terminal provided with a wireless communication device, such as a smartphone, or a tablet PC. The terminal **20***a* may be an immobile terminal provided with a wireless communication device, such as a desktop computer. The terminal **20***a* may be capable of communicating with at least the base station **10**. FIG. **1** shows only one terminal **20***a*. A plurality of terminals **20***a* may exist in the cover area C of the base station **10**.

[0019] The terminal **20***b* is a terminal provided with a wireless communication device, such as a smart phone or a tablet PC, and is, for example, a terminal handling traffic different from the terminal **20***a*. The terminal **20***b* may be an immobile terminal provided with a wireless communication device, such as a desktop computer. The terminal **20***b* may be capable of communicating with at least the base station **10**. FIG. **1** shows only one terminal **20***b*. A plurality of terminals **20***b* may exist in the cover area C of the base station **10**. In addition, in FIG. **1**, the interference source is the terminal **20***b*. On the other hand, the interference source in communication with the terminal **20***a* does not necessarily have to be a terminal. The interference source may be, for example, a base station different from the base station **10**. The interference source in the embodiment may be any interference source capable of communicating with the base station **10**.

[0020] FIG. **2** shows an example of a configuration of the base station **10**. As shown in FIG. **2**, the base station **10** includes, for example, a CPU (Central Processing Unit) **11**, a ROM (Read Only Memory) **12**, a RAM (Random Access Memory) **13**, a storage **14**, and a wireless communication module **15**. The base station **10** may be provided with a wired communication module or the like for communication connection with a server, not shown.

[0021] The CPU **11** is a circuit capable of executing various programs, and controls an overall operation of the base station **10**. An ASIC or the like may be used instead of the CPU. Also, the number of CPUs **11** is not limited to one; there may be two or more CPUs **11**. The ROM **12** is a non-volatile semiconductor memory, and holds a program, control data, and the like for controlling the base station **10**. The RAM **13** is, for example, a volatile semiconductor memory and is used as a work area of the CPU **11**. The storage **14** is a nonvolatile storage device such as a flash memory, and holds system software and the like of the base station **20**. The storage **14** also holds a learning result described hereinafter. The wireless communication module **15** is a circuit used for transmitting and receiving data by a wireless signal, and is connected to an antenna. As will be described later, the antenna in the embodiment is an omni-directional array antenna.

[0022] FIG. **3** shows an example of a configuration of the terminal **20***a*. The terminal **20***b* may or may not have the same configuration as the terminal **20***a*. The following describes a case where the terminal **20***b* has the same configuration as the terminal **20***a;* the description of the configuration of the terminal **20***b* is omitted accordingly. As shown in FIG. **3**, the terminal **20***a* includes, for example, a CPU **21**, a ROM **22**, a RAM **23**, and a wireless communication module **24**.

[0023] The CPU **21** is a circuit capable of executing various programs, and controls an overall operation of the terminal **20***a*. An ASIC or the like may be used instead of the CPU. Also, the CPU **21** is not limited to one, and may be two or more. The ROM **22** is a non-volatile semiconductor memory, and holds a program, control data, and the like for controlling the terminal **20***a*. The RAM **23** is, for example, a volatile semiconductor memory and is used as a work area of the CPU **21**. The wireless communication module **24** is a circuit used for transmitting and receiving data by a wireless signal, and is connected to an antenna. The antenna of the terminal **20***a* is not particularly limited.

[0024] The wireless system **1** executes data communication on the basis of, for example, the OSI (Open Systems Interconnection) reference model. Communication functions in the OSI reference model are divided into seven layers (first layer: physical layer, second layer: data link layer, third layer: network layer, fourth layer: transport layer, fifth layer: session layer, sixth layer: presentation layer, and seventh layer: application layer). The data link layer includes, for example, an LLC (Logical Link Control) layer and a MAC (Media Access Control) layer.

[0025] FIG. **4** shows an example of a functional configuration of the base station **10**. As shown in FIG. **4**, the base station **10** includes, for example, a wireless device **101**, an antenna **102**, a wireless information recording unit **103**, a learning unit **104**, a control unit **105**, a directivity setting unit **106**, a directivity control unit **107**, and a communication instruction unit **108**. The wireless device **101** and the antenna **102** correspond to, for example, the wireless communication module **15**. The wireless information recording unit **103** corresponds to, for example, the storage **14**. The learning unit **104**, the control unit **105**, the directivity setting unit **106**, the directivity control unit **107**, and the communication instruction unit **108** are implemented, by, for example, the CPU **11** executing a wireless communication program stored in the ROM **12**.

[0026] The wireless device **101** performs processing related to transmission/reception of wireless signals. The wireless device **101** includes a transmission/reception unit **1011** and a wireless information acquisition unit **1012**. Here, the wireless device **101** may include a plurality of wireless devices for handling wireless signals of different channels.

[0027] The transmission/reception unit **1011** transmits/receives a wireless signal according to an instruction from the communication instruction unit **108**. For example, when transmitting a wireless signal, the transmission/reception unit **1011** generates a wireless signal from data that is input from a server or the like, not shown, receives the wireless signal, and transmits the wireless signal to the terminal **20***a* via the antenna **102**. Also, when receiving the wireless signal, the transmission/reception unit **1011** restores data from the wireless signal received from the terminal **20***a* via the antenna **102**.

[0028] The wireless information acquisition unit **1012** acquires wireless information of each of the terminal **20***a,* which is a communication partner of the base station **10**, and the terminal **20***b,* which is an interference source. The wireless information includes an identifier of each terminal, a communication time block, positions of the terminals, and a traffic amount in communication. The communication time block is a time block in which communication with a corresponding terminal is performed. The communication time block is measured from, for example, the communication time from the start to the completion of communication. The positions of the terminals are the positions of the terminals in the cover area C. The positions of the terminals are measured from, for example, the reception signal strength (RSSI) of the radio wave of a wireless signal and the direction of arrival of the radio wave. The RSSI is measured from, for example, received power of a wireless signal. The direction of arrival of the radio wave is measured from, for example, a phase difference between wireless signals received by respective antenna elements constituting an omni-directional array antenna. The traffic amount is the data amount of a wireless signal transmitted within a fixed period. The traffic amount is measured from, for example, RSSI.

[0029] The antenna **102** is an antenna provided with an antenna element for transmitting and receiving wireless signals. The antenna **102** in the embodiment is an omni-directional array antenna having a plurality of omni-directional antenna elements. By controlling the amplitude and phase of each omni-directional antenna element, the antenna **102** can operate as an antenna with directivity.

[0030] Wireless information related to each of the terminals **20***a* and **20***b* acquired by the wireless information acquisition unit **1012** is recorded in the wireless information recording unit **103**. The wireless information is recorded for each terminal.

[0031] The learning unit **104** learns the correspondence relationship between the positions of the terminals **20***a* and **20***b* in the cover area C and the communication time block of each terminal on the basis of the wireless information recorded in the wireless information recording unit **103**. Here, the learning unit **104** does not necessarily have to be provided in the base station **10**. The learning unit **104** may be provided in a server or the like capable of communicating with the base station **10**.

[0032] The control unit **105** performs grouping of terminals **20***a* on the basis of a learning result of the learning unit **104**. A group of terminals **20***a* includes at least one terminal **20***a*. The control unit **105** also assigns a communication execution time block for each group of terminals **20***a* on the basis of a learning result of the learning unit **104**. The communication execution time block is a time block for communicating with the group of terminals **20***a*. Then, the control unit **105** notifies the communication instruction unit **108** of the communication execution time block. Also, the control unit **105** determines a condition for antenna gain in each direction of the antenna **102** for communicating with the group of terminals **20***a* in the communication execution time block. Then, the control unit **105** notifies the directivity setting unit **106** of the determined antenna gain condition.

[0033] The directivity setting unit **106** sets a directivity pattern satisfying the antenna gain condition notified by the control unit **105**. The directional pattern includes the amplitude and phase of each omni-directional antenna element constituting the antenna **102**.

[0034] The directivity control unit **107** controls the directivity of the antenna **102** on the basis of the directivity pattern set by the directivity setting unit **106**.

[0035] The communication instruction unit **108** instructs the transmission/reception unit **1011** of the wireless device **101** to execute communication when the communication execution time block notified by the control unit **105** comes. The communication instruction unit **108** also provides the terminal **20***a* with the communication execution time block notified by the control unit **105**. The instruction about a communication execution time block is provided to the terminal **20***a* by using the transmission/reception unit **1011**.

[0036] FIG. **5** shows an example of a functional configuration of the terminal **20***a*. As shown in FIG. **5**, the terminal **20***a* includes, for example, a wireless device **201**, an antenna **202**, and a management unit **203**. The wireless device **201** and the antenna **202** correspond to, for example, the wireless communication module **24**. The management unit **203** is implemented by, for example, the CPU **21** executing a wireless communication program stored in the ROM **22**.

[0037] The wireless device **201** performs processing related to communication by a wireless signal. Here, the wireless device **201** handles a wireless signals of the same channel as the wireless device **101**. The wireless device **201** includes a transmission/reception unit **2011**.

[0038] The transmission/reception unit **2011** transmits and receives a wireless signal according to an instruction from the management unit **203**. For example, when transmitting a wireless signal, the transmission/reception unit **2011** generates a wireless signal from input data, receives the wireless signal, and transmits the wireless signal to the base station **10** via the antenna **202**. When receiving the wireless signal, the transmission/reception unit **2011** restores data from the wireless signal received from the base station **10** via the antenna **202**.

[0039] The antenna **202** is an antenna provided with an antenna element for transmitting and receiving wireless signals. The antenna **202** is not particularly limited. For example, the antenna **202** may have a single antenna element or a plurality of antenna elements. The antenna **202** may be an omni-directional antenna or a directional antenna.

[0040] The management unit **203** manages a communication time block of the wireless device **201**. For example, when the communication execution time block is not notified from the base station **10**, the management unit **203** allows the wireless device **201** to communicate with the base station **10**. On the other hand, when the communication execution time block is notified from the base station **10**, the management unit **203** allows the wireless device **201** to communicate with the base station **10** when the communication time block comes.

[0041] Operations in the wireless system **1** are now described next. An operation of the base station **10** is described first. The operation of the base station **10** is divided into a learning operation and a communication operation. FIG. **6** is a flowchart showing an example of the learning operation performed by the base station **10**. The base station **10** learns the correspondence relationship between the positions each of the terminals **20***a* and **20***b* in the cover area C and the communication time block of the same while communicating with the terminal **20***a*, which is a communication partner, and the terminal **20***b*, which is an interference source. The base station **10** then communicates with the terminal **20***a* by using the learning result. The processing shown in FIG. **6** is periodically executed every hour, every day, every week, every month, or the like.

[0042] In step S**1**, the base station **10** performs communication with the terminal **20***a* or the terminal **20***b*. The communication may be transmission of a wireless signal including data from the base station **10**, or reception of a wireless signal including data from the terminal **20***a* or **20***b*. In addition, the communication may be transmission of a beacon signal from the base station **10**. When transmitting a beacon signal, the antenna **102** is controlled to operate as an omni-directional antenna even after the learning operation. This is because the beacon signal needs to be detected in each terminal in the cover area C. Here, a wireless signal and a beacon signal for transmitting and receiving data can be identified by a frame type recorded in a header of a MAC frame included in the wireless signal.

[0043] In step S**2**, the base station **10** acquires wireless information in the communication in step S**1**. As described above, the wireless information includes the identifiers of the terminals, the communication time block for communicating with the terminals, the positions of the terminals, and the traffic amount.

[0044] In step S**3**, the base station **10** records the wireless information, and learns the correspondence relationship between the position of each terminal in the cover area and the communication time block on the basis of the recorded wireless information. The learning method for learning the correspondence relationship between the positions of the terminals and the communication time block is not limited to a specific method. For example, various types of multi-value classification learning can be used for this learning. Here, the processing of steps S**4** to S**6** may not be performed until a certain amount of learning is performed in step S**3**.

[0045] In step S**4**, the base station **10** performs grouping of terminals **20***a* on the basis of the learning result. Specifically, the base station **10** classifies a plurality of terminals **20***a* in close proximity into one group. There may be only one terminal **20***a* included in the group. The base station **10** may classify a plurality of terminals **20***a* that are similar in position as well as communication time block and type of traffic being communicated, into one group. The number of terminals **20***a* belonging to one group may be determined by the traffic amounts of the terminals **20***a* belonging to the group. For example, the number of terminals **20***a* belonging to one group may be determined so that the total traffic amount for each group is a predetermined value. In this case, if the traffic amount of each terminal **20***a* is small, the number of terminals **20***a* belonging to one group increases. On the contrary, if the traffic amount of each terminal **20***a* is large, the number of terminals **20***a* belonging to one group decreases.

[0046] In step S**5**, the base station **10** assigns communication execution time block. Specifically, the base station **10** assigns the same communication execution time block for a group having close communication time block, on the basis of the learning result. On the other hand, when a terminal **20***b* as an interference source to the group of the terminals **20***a* exists in the same direction as the group of terminals **20***a*, the base station **10** assigns communication execution time block so that the communication execution time block varies between the group of terminals **20***a* and the terminal **20***b*. For example, when the terminal **20***b* always performs communication in the same communication time block, the base station **10** assigns a communication execution time block of each group of terminals **20***a* so as to avoid the communication time block of the terminal **20***b*. On the other hand, when the terminal **20***b* does not always perform communication in the same communication time block, the base station **10** assigns the communication execution time block of the terminal **20***b* so as to avoid the communication execution time block of each group of terminal **20***a*.

[0047] In step S**6**, the base station **10** determines an antenna gain for communication with the group of terminals **20***a* in the communication execution time block on the basis of the learning result. Specifically, the base station **10** increases the antenna gain in the direction in which the group of terminals **20***a* exists, and decreases the antenna gain in the direction in which the interference source such as the terminal **20***b* exists. Furthermore, the base station **10** may reduce the antenna gain not only in the direction in which the interference source such as the terminal **20***b* exists but also in the direction in which the group of terminals **20***a* does not exist. Here, the RSSI may also be considered when determining the antenna gain.

[0048] FIG. **7** is a flowchart showing an example of the communication operation performed by the base station **10** after learning. In step S**11**, the base station **10** assigns a communication execution time block for each group of terminals **20***a* according to the learning result.

[0049] In step S**12**, the base station **10** sets a directivity pattern. In step S**12**, a directivity pattern is set in such a manner that the antenna **102** operates as an omni-directional antenna.

[0050] In step S**13**, the base station **10** controls the directivity of the antenna **102** on the basis of the set directivity pattern.

[0051] In step S**14**, the base station **10** executes communication for notifying of a communication execution time block. For example, the base station **10** transmits a beacon signal including the communication execution time block of each group of terminals **20***a* and the communication execution time block of the terminal **20***b* which is an interference source. Since the directivity of the antenna **102** is controlled in such a manner that the antenna **102** operates as an omni-directional antenna, the beacon signal can be received by each of the terminals **20***a* and the terminal **20***b* in the cover area C. After receiving response signals from each terminal **20***a* and the terminal **20***b,* the processing moves to step S**15**. In step S**14**, the communication execution time block are not necessarily notified by the beacon signal. For example, the communication execution time block may be notified by communication of an individual wireless signal with each terminal.

[0052] In step S**15**, the base station **10** determines whether or not the communication execution time block assigned to a group of terminals **20***a* has come. In step S**15**, the processing is held up until the communication execution time block comes. The directivity pattern may be set so that the antenna **102** operates as an omni-directional antenna until the communication execution time block comes. Since the antenna **102** operates as an omni-directional antenna, the base station **10** can receive a wireless signal from each direction. When it is determined in step S**15** that the communication execution time block has come, the processing proceeds to step S**16**.

[0053] In step S**16**, the base station **10** sets a directivity pattern so as to have directivity to the direction of the group of terminals **20***a* corresponding to the current communication execution time block. In step S**16**, the directivity pattern is set so that the antenna gain in the direction of a group of terminals **20***a* performing communication in the current communication execution time block becomes high. When the terminal **20***b* exists as an interference source, the directivity pattern is set so that the antenna gain in the direction of the terminal **20***b* becomes lower.

[0054] In step S**17**, the base station **10** controls the directivity of the antenna **102** on the basis of the set directivity pattern.

[0055] In step S**18**, the base station **10** performs communication with a group of terminals **20***a*. For example, the base station **10** transmits a wireless signal to the group of terminals **20***a*. The base station **10** receives a wireless signal from the group of terminals **20***a*. After the execution of the communication, the processing then moves to step S**19**.

[0056] In step S**19**, the base station **10** determines whether to end the communication. For example, when communication with all groups of terminals **20***a* to which communication execution time block are assigned is executed, it is determined that the communication is ended. If it is determined in step S**19** that the communication is not ended, the processing returns to step S**15**. If it is determined in step S**19** that the communication is to be ended, the base station **10** ends the processing of FIG. **7**.

[0057] FIG. **8** is a flowchart showing an example of a communication operation of the terminal **20***a*. Here, it is assumed that the terminal **20***a* is notified of the communication execution time block from the base station **10**. The operation of the terminal **20***a* will be described hereinafter, but the operation of the terminal **20***b* may be performed in the same manner as the terminal **20***a*.

[0058] In step S**21**, the terminal **20***a* determines whether or not the communication execution time block notified from the base station **10** has come. In step S**21**, the processing is held up until the communication execution time block comes. The terminal **20***a* may communicate with a base station other than the base station **10** until the communication execution time block comes. When it is determined in step S**21** that the communication execution time block has come, the processing proceeds to step S**22**.

[0059] In step S**22**, the terminal **20***a* performs communication with the base station **10**. For example, the terminal **20***a* transmits a wireless signal to the base station **10**. The terminal **20***a* also receives a wireless signal from the base station **10**. After the communication is executed, the terminal **20***a* ends the processing shown in FIG. **8**.

[0060] According to the embodiment described above, the directivity of the antenna is controlled by controlling the amplitude and phase of each omni-directional antenna element of the omni-directional array antenna. Furthermore, a communication execution time block to be assigned to each terminal is determined on the basis of a correspondence relationship between the position of a terminal in the cover area of the base station and the communication time block of each terminal. Then, a beam with directivity is directed toward the terminal which is a communication partner, for each communication execution time block. Thus, although an omni-directional array antenna is used, the antenna gain is improved. Therefore, in the embodiment, long-distance transmission is possible while using an omni-directional array antenna, and as a result, the cover area of the base station **10** can be expanded. Moreover, since the antenna gain is reduced in a direction other than the terminal which is the communication partner, the impact of interference radio waves arriving from other directions is reduced.

[0061] The communication time execution zone of the terminal which is the communication partner is set so as to avoid the communication time block of the terminal which is an interference source. Thus, the impact of interference radio waves arriving from directions other than the group of communication partners is further reduced.

[0062] Terminals as communication partners are grouped according to the positions and traffic amounts thereof, and communication is performed for each group. Thus, the total traffic amount in each communication time block can be suppressed to a certain fixed value.

[0063] Here, in the embodiment, different communication execution time block are assigned to the terminal **20***a* and the terminal **20***b* in order to suppress the arrival of interference radio waves from the terminal **20***b* which is an interference source. On the other hand, the arrival of interference radio waves by the terminal **20***b* can also be suppressed by causing the terminal **20***b* to perform carrier sense during the communication execution time block of the terminal **20***a*. Assigning different communication execution time block for the terminals **20***a* and **20***b* and causing the terminal **20***b* to perform carrier sensing during the communication execution time block of the terminal **20***a* may be used together.

[0064] In the embodiment, the correspondence relationship between the positions of terminals in the cover area of the base station and the communication time block of each terminal is learned, and the communication time block assigned to each terminal and the antenna gain condition are determined based on the learning result. On the other hand, the communication time block assigned to each terminal and the antenna gain condition may be determined more simply based on various statistical values such as the average value of the positions of the terminals and the average value of the communication time block. In addition, when the terminals **20***a* are immobile terminals and the communication time block are constant, the communication time block assigned to each terminal and the antenna gain condition may be determined without obtaining the correspondence relationship.

[0065] Each processing described in the embodiment can also be stored as a program that can be executed by a CPU or the like that is a computer. The program can also be stored in a storage medium of an external storage device such as a magnetic disk, an optical disk, or a semiconductor memory, or the like, and distributed. The CPU or the like can then execute the above-described processing by reading in the program stored in the storage medium of the external storage device, and actions thereof being controlled by the program read in.

[0066] The present invention is not limited to the embodiments described above and can variously be modified at an execution stage within a scope not departing from the gist thereof. The embodiments may also be combined appropriately to be implemented, and in that case, combined effects can be obtained. In addition, the embodiments described above include various inventions, and the various inventions can be extracted by combinations selected from a plurality of disclosed constituent elements. For example, even when some of all the constituent elements disclosed in the embodiments are deleted, as long as the problems can be solved and the effects can be obtained, a configuration from which the constituent elements are deleted can be extracted as an invention.

REFERENCE SIGNS LIST

[0067] **1** Wireless system
[0068] **10** Base station
[0069] **11** CPU
[0070] **12** ROM
[0071] **13** RAM
[0072] **14** Storage
[0073] **15** Wireless communication module
[0074] **20***a*, **20***b* Terminal
[0075] **21** CPU
[0076] **22** ROM
[0077] **23** RAM
[0078] **24** Wireless communication module
[0079] **101** Wireless device
[0080] **102** Antenna
[0081] **103** Wireless information recording unit
[0082] **104** Learning unit
[0083] **105** Control unit
[0084] **106** Directivity setting unit
[0085] **107** Directivity control unit
[0086] **108** Communication instruction unit
[0087] **201** Wireless device
[0088] **202** Antenna

[0089] **203** Management unit
[0090] **1011** Transmission/reception unit
[0091] **1012** Wireless information acquisition unit
[0092] **2011** Transmission/reception unit

1. A base station, comprising: an antenna that has an omni-directional array antenna; a wireless device that communicates with one or more terminals in a cover area by a wireless signal via the antenna; a wireless information acquisition unit that acquires wireless information including a position of the terminal and a communication time block; a control unit that determines a communication execution time block, which is a time block in which communication with the terminal is executed, and an antenna gain of the antenna for communicating with the terminal, on the basis of the wireless information; a directivity setting unit that sets a directivity pattern of the omni-directional array antenna so as to have directivity in a direction of the terminal, on the basis of the antenna gain; a directivity control unit that controls directivity of the omni-directional array antenna based on the directivity pattern; and a communication instruction unit that instructs the wireless device to communicate with the terminal in the communication execution time block.

2. The base station according to claim **1**, wherein the wireless information acquisition unit further acquires, as the wireless information, a position of an interference source and a communication time block when the wireless signal is transmitted and received between the wireless device and the terminal, and the control unit determines the antenna gain so as to increase a first antenna gain with respect to the direction of the terminal and to reduce a second antenna gain with respect to a direction of the interference source, and determines the communication execution time block so as to avoid a communication time block of the interference source.

3. The base station according to claim **1**, wherein the control unit determines the antenna gain and the communication execution time block based on a correspondence relationship between a position of the terminal and a communication time block of the terminal that are learned based on the wireless information.

4. The base station according to claim **1**, wherein two or more of the terminals exist, the wireless information acquisition unit further acquires a traffic amount of communication with each of the terminals as the wireless information, and the control unit groups two or more of the terminals on the basis of a position and a traffic amount of each of the terminals and determines the antenna gain and the communication execution time block for each group of the terminals.

5. The base station according to claim **4**, wherein the control unit determines the terminal included in one group so that a total amount of the traffic amount for each group of terminals becomes a predetermined value.

6. A wireless communication method by a base station that communicates with one or more terminals in a cover area by using an antenna having an omni-directional array antenna, the wireless communication method comprising:

acquiring wireless information including a position of the terminal and a communication time block; determining a communication execution time block, which is a time block in which communication with the terminal is executed, and an antenna gain of the antenna for communicating with the terminal, on the basis of the wireless information; setting a directivity pattern of the omni-directional array antenna so as to have directivity in a direction of the terminal, on the basis of the antenna gain; controlling directivity of the omni-directional array antenna based on the directivity pattern; and communicating with the terminal in the communication execution time block.

7. A wireless communication program for causing a processor to function as the wireless information acquisition unit, the control unit, the directivity setting unit, the directivity control unit, and the communication instruction unit of the base station according to claim **1**.

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