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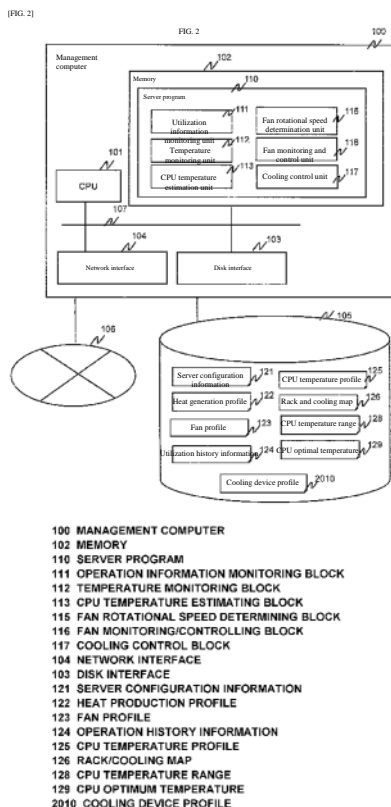
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[continuation sheet]

(54) Title: PHYSICAL COMPUTER, METHOD FOR CONTROLLING COOLING DEVICE, AND SERVER SYSTEM

(54) Title of the invention: Physical computer, method for controlling cooling device, and server system



(57) Abstract: Cooling control for reducing the overall power consumption of a system is determined. A method for controlling a management computer connected to a server device having a processor and a fan and a cooling device is characterized in that the temperature and operating rate of the processor, the rotational speed of the fan, and the temperature of the air sent into the server are acquired from the server, the temperature of the processor after a predetermined time elapse is estimated by calculation on the basis of the temperature and operating rate of the processor, the rotational speed of the fan, and the temperature of the sent air, the target rotational speed of the fan at which the estimated temperature after the time elapse is below a first predetermined value is determined if the estimated temperature is above the first predetermined value, and the server device is instructed to change the rotational speed to the target one.

(57) Abstract: Cooling control for reducing overall power consumption of a system is determined. A control method of a management computer which is connected to a server device having a processor and a fan and to a cooling device, the control method being characterized in that the temperature and utilization rate of the processor, the rotational speed of the fan, and the intake air temperature at the server are acquired from the server, the estimated temperature of the processor after a predetermined time period elapses is calculated on the basis of the temperature and utilization rate of the processor, the rotational speed of the fan, and the intake air temperature, and if the estimated temperature is not less than a first predetermined value, a target rotational speed of the fan at which the estimated temperature after said time period elapses will be not greater than said predetermined value is determined, and the server device is instructed to set said target rotational speed.

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## Specification

### Physical computer, method for controlling cooling device, and server system

#### Technical Field

[0001] The present invention relates to a physical computer and cooling device control method, particularly to a method for controlling the output of fans in physical computers and cooling devices according to CPU utilization rate.

#### Background Art

[0002] Due to performance improvement of processors and the emergence of high-density IT (Information Technology) equipment such as blade servers, the increase in power consumption of IT systems has become a major problem. To address this problem, while development of technologies to reduce power consumption such as low-power processors and high-efficiency cooling systems is proceeding, there are limits to power savings at the individual device level, and efforts encompassing the entire computer room including IT systems and cooling devices are necessary to obtain greater power savings effects.

[0003] The current cooling of IT systems will be described. Components such as CPUs and memory generate heat accompanying increases in server utilization rate. The server comprises cooling fans and detects the temperature inside the server enclosure, and when the temperature exceeds a fixed threshold value, air flow is generated to cool the heat-generating components. The heat is evacuated outside the enclosure by this air flow. Regarding the control of these cooling fans, an invention that controls fans based on temperature and temperature change of heat-generating components to optimize cooling is disclosed in Patent Document 1. An invention that controls fans based on the temperature and temperature change of heat-generating components to optimize cooling is furthermore disclosed in Patent Document 2.

[0004] Moreover, cooling devices are installed in a computer room where servers are installed to cool the heat generated by the equipment, and such devices determine their output based on temperature from fixed sensors to maintain a constant temperature in the room. However, it is difficult to make the temperature uniform in a computer room due to variations in heat emitted by IT equipment and the arrangement of the equipment. Regarding the control of these cooling devices, an invention that monitors air flow in a machine room and performs ventilation according to air flow is disclosed in Patent Document 3.

[0005] When there are large temperature variations in the computer room, equipment in areas of heat accumulation may become unstable in operation due to CPU thermal runaway, or the CPU temperature control circuit may activate, forcibly reducing processing performance or shutting down. To avoid malfunctions due to forced shutdown, an invention is disclosed in Patent Document 4 that controls heat dissipation through hibernation when temperature exceeds a fixed value to avoid failures and shutdown.

[0006] Additionally, a method is disclosed in Patent Document 5 that predicts temperature after a certain period of time elapses based on the current processing details of the CPU, CPU temperature characteristics, and user instructions input from the outside, and transfers CPU processing to another CPU if the predicted temperature exceeds a reference value.

[0007] Patent Document 1: Japanese Unexamined Patent Application Publication 2002-268775

Patent Document 2: Japanese Unexamined Patent Application Publication 2008-84173

Patent Document 3: Japanese Unexamined Patent Application Publication 2006-208000

Patent Document 4: Japanese Unexamined Patent Application Publication 2008-158787

Patent Document 5: Japanese Unexamined Patent Application Publication 2007-241376

## **Disclosure of the Invention**

### **Problem to be Solved by the Invention**

[0008] In the future, rather than cooling the entire computer room uniformly with large-scale cooling devices to eliminate temperature deviations, cooling devices that can control temperature locally will become important. For example, directional cooling devices and rack-level cooling devices that mount on the rear surface of racks are already being shipped. Additionally, for equipment that performs cooling using cold air from beneath the floor, control of opening and closing of floor grating plates (perforated tiles) changes ventilation points from beneath the floor to concentrate cooling on high-temperature locations.

[0009] Furthermore, there is a delay between when the utilization rate of heat-generating components increases and heat is generated and when that heat is detected by temperature sensors. There is also further delay from when temperature rise is

detected and fan and air conditioning output increases until actual cooling effects appear. Therefore, when burst loads occur, even if fan output increases, temperature temporarily rises before settling at a temperature allowing subsequent stable operation. However, when a CPU's own temperature rises, its leakage current increases exponentially, requiring more power for cooling.

[0010] As a result, when cooling capacity is insufficient, operation may become unstable due to CPU thermal runaway, or the CPU temperature control circuit may activate, forcibly reducing processing performance or shutting down. Even if forced shutdown is avoided through hibernation, processing must be interrupted.

[0011] Additionally, even if a server's cooling fans increase rotational speed, if there is insufficient air flow at the server rear surface, heat may spread to surrounding equipment rather than being carried to exhaust vents, potentially leading to temperature rise and failures in other equipment. Since current cooling devices adjust output based on temperature information measured at a single point, air conditioning will not engage until heat generated at one server circulates around to that measurement point, allowing such situations to occur.

### **Means for Solving the Problem**

[0012] To achieve the aforesaid object, the control method of the present invention is a control method of a management computer which is connected to a server device having a processor and a fan and to a cooling device, the control method being characterized in that the temperature and utilization rate of the processor, the rotational speed of the fan, and the intake air temperature at the server are acquired from the server, the estimated temperature of the processor after a predetermined time period elapses is calculated on the basis of the temperature and utilization rate of the processor, the rotational speed of the fan, and the intake air temperature, and if the estimated temperature is not less than a first predetermined value, a target rotational speed of the fan at which the estimated temperature after said time period elapses will be not greater than said predetermined value is determined, and the server device is instructed to set said target rotational speed.

[0013] Furthermore, the server system of the present invention is a server system characterized in that it comprises the server device, which has a processor and a fan, and measures the temperature and utilization rate of the processor, the rotational speed of the fan, and the intake air temperature; and a management computer which is connected to the server device and to the cooling device and which calculates the

estimated temperature of the processor after a predetermined time period elapses on the basis of the temperature and utilization rate of the processor, the rotational speed of the fan, and the intake air temperature, and determines a target rotational speed of the fan at which the estimated temperature after said time period elapses will be not greater than said predetermined value if the estimated temperature is not less than a first predetermined value.

### **Effect of the Invention**

[0014] According to the present invention, by cooling CPUs in advance and maintaining optimal temperature, power consumption due to leakage current can be minimized and cooling efficiency can be increased.

### **Brief Description of the Drawings**

[0015] [FIG. 1] is an example of a system configuration diagram showing the system configuration of a first embodiment example of the present invention.  
[FIG. 2] is an example of a configuration diagram showing the hardware configuration of the power savings control server of the first embodiment example of the present invention.  
[FIG. 3] is an example of a configuration diagram showing the hardware configuration of the physical computer that is the managed object of the first embodiment example of the present invention.  
[FIG. 4] (a) is an example of an interior configuration diagram of the computer room of the first embodiment example of the present invention; (b) is an example of a cross-sectional view of essential parts, showing the relationship between motors and air outlets installed in the computer room floor.  
[FIG. 5] is an example of a configuration diagram showing the server configuration information of the first embodiment example of the present invention.  
[FIG. 6] is an example of a configuration diagram showing the rack and cooling map of the first embodiment example of the present invention.  
[FIG. 7] is an example of a configuration diagram showing utilization information and power consumption information in the first embodiment example of the present invention.  
[FIG. 8] is an example of a configuration diagram showing the heat generation profile in the first embodiment example of the present invention.  
[FIG. 9] is an example of a configuration diagram showing the CPU temperature profile in the first embodiment example of the present invention.  
[FIG. 10] is an example of a configuration diagram showing the fan profile in the first embodiment example of the present invention.  
[FIG. 11] is an example of a flowchart showing the power savings control flow in the first embodiment example of the present invention.

[FIG. 12] is an example of a flowchart showing the CPU temperature estimation flow in the first embodiment example of the present invention.

[FIG. 13] is an example of a flowchart showing the fan rotational speed determination flow in the first embodiment example of the present invention.

[FIG. 14] is an example of a system configuration diagram showing the system configuration of a second embodiment example of the present invention.

[FIG. 15] is an example of a configuration diagram showing the job execution schedule and server/job map of the second embodiment example of the present invention.

[FIG. 16] is an example of a flowchart showing the power savings control flow in the second embodiment example of the present invention.

[FIG. 17] is an example of a system configuration diagram showing the system configuration of a third embodiment example of the present invention.

[FIG. 18] is an example of a configuration diagram showing the cooling control rules of the third embodiment example of the present invention.

[FIG. 19] is an example of a flowchart showing the power savings control flow in the third embodiment example of the present invention.

[FIG. 20] is an example of the cooling device profile of the first embodiment example of the present invention.

[FIG. 21] is an example of a flowchart of the cooling device unit of the first embodiment example of the present invention.

### **Description of Reference Symbols**

[0016] 110...power savings control server, 111...utilization information monitoring unit, 112...temperature monitoring unit, 113...CPU temperature estimation unit, 114...cooling control determination unit, 115...fan rotational speed determination unit, 116...fan monitoring and control unit, 117...cooling control unit, 121...server configuration information, 122...heat generation profile, 123...fan profile, 124...server utilization history, 125...CPU temperature profile, 126...rack and cooling map, 127...cooling profile, 200...physical computer, 223...measurement agent

### **[Best mode for carrying out the invention]**

[0017] Several embodiments of the present invention will be described below using the drawings.

### **Embodiment Example 1**

[0018] FIG. 1 shows the system configuration of an embodiment example of the present invention. The system configuration of the present embodiment example is an information processing system or storage systems or the like. For example, the system may be configured to comprise one management computer 100, one or more physical computers 200, one or more storage devices 230, a cooling device 151 that cools the computer room where the management computer 100, the physical computers 200, and the storage devices 230 are installed, and a cooling device control unit 150 that controls the cooling device 151. The management computer 100, physical computers 200, and cooling device 151 are connected via a management network 225. Additionally, the physical computers 200 and storage devices 230 are connected via, for example, a fiber channel network 226. Here, the cooling device control unit 150 may be stored as a program in the memory of a physical computer to perform centralized control of the cooling device 151. Also, the cooling device control unit 151 may be stored as a program in the memory within the management computer.

[0019] FIG. 2 shows the management computer 100 in an embodiment example of the present invention.

[0020] An overview of the operation of the management computer 100 will be presented. Detailed description will be provided with reference to the drawings below. The management computer 100 manages the physical computer 200, the storage device 230, and the cooling device control unit 150. It exchanges information with multiple physical computers 200 and detects the utilization status of the multiple physical computers 200. According to the detected utilization status of the multiple physical computers 200, it individually controls the cooling device 151 through the cooling device control function 151. Additionally, according to the detected utilization status of the multiple physical computers 200, it controls the fan rotational speed and cooling devices of the multiple physical computers 200.

[0021] The management computer 100 comprises a central processing unit (CPU) 101, a storage device 105 such as a hard disk device or flash memory, a memory 102, a bus 107, a network interface 104, and a disk interface 103.

[0022] The server program 110 is stored in the memory 102. The server program includes a utilization information monitoring unit 111, temperature monitoring unit 112, CPU temperature estimation unit 113, fan rotational speed determination unit 115, fan

monitoring and control unit 116, and cooling control unit 117. These programs are initially stored in the magnetic disk 105, and are executed by the CPU 101 after being transferred to the memory 102 as necessary. The utilization information and power monitoring unit 111 collects utilization information and power consumption information from the physical computers 200. The temperature monitoring unit 112 acquires the intake air temperature, CPU temperature, and exhaust temperature of the physical computers. The fan monitoring and control unit 116 acquires information about the fan rotational speed and issues instructions to modify the fan rotational speed. The CPU temperature estimation unit 113 estimates the temperature of the CPU built into the physical computer after a certain period of time. The fan rotational speed determination unit 115 determines the fan rotational speed needed to lower the CPU temperature to a target value after a certain period of time. The cooling control determination unit 114 acquires the rack and cooling map 126 and determines the output of the cooling device 151. The cooling control unit 117 issues instructions to control the output of the cooling device 151.

[0023] The utilization information history 124, server configuration information 121, heat generation profile 122, fan profile 123, CPU temperature profile 125, cooling device profile 127, CPU temperature range 128, optimal CPU temperature 129, rack and cooling map 126, and cooling device profile 2010 are stored in the storage device 105.

[0024] FIG. 3 shows the hardware configuration of the physical computer 200 in an embodiment example of the present invention.

[0025] The physical computer 200 comprises a central processing unit (CPU) 201, memory 202, storage devices such as a hard disk device and flash memory 205, a bus 207, network interface 204, disk interface 203, fan 208, and BMC (Baseboard Management Controller) 207.

[0026] The BMC 207 performs monitoring of the server intake air temperature, exhaust temperature, and CPU temperature, and monitoring and control of the fan rotational speed and power supply control.

[0027] An OS 222, a measurement agent program 223 that collects utilization information of this physical computer, and a business task service program 224 are stored in the memory 202. These programs are first stored in the magnetic disk 205, and after being transferred to the memory 202 as needed, they are executed by the CPU 201. It should

be noted that these programs may be stored in the magnetic disk 205 by being read from a portable storage medium, or by being downloaded from other computers or storage devices via a network connected to the respective devices.

[0028] Furthermore, while the various types of processing of the server program 110 of the management computer are implemented by executing each program on the CPU, these can also be implemented in hardware by creating integrated circuits as processing units that perform the various types of processing, such as a measurement agent determination unit, a measurement unit, etc.

[0029] The measurement agent 223 is a software program that runs on the computer 200 and collects utilization information such as CPU utilization rate, memory utilization rate, and network interface utilization rate of the device on which the program runs, and records the information as measurement counters. The utilization information and power monitoring unit 111 of the server program 110 of the management computer sends utilization information collection requests to the measurement agent 223 using SNMP (Simple Network Management Protocol). The measurement agent 223 receives this utilization information collection request and sends the value of the measurement counter specified by the object ID (Identification) in the request to the utilization information and power monitoring unit 111. The server program 110 receives these measurement counter values and records them as utilization information, enabling centralized management of utilization information for multiple managed objects.

[0030] FIG. 4 is a diagram showing the equipment layout of a computer room 400 where the physical computer 200, the storage device 230, and the cooling device 151 are installed in an embodiment example of the present invention.

[0031] In the computer room 400, there are arranged four racks 401a, 401b, 401c, 401d, and cooling devices 151a, 151b. Each rack 401 and the cooling devices 151a, 151b are fixed to the floor. Multiple air outlets 431-435 are installed in the floor. The air outlets 431-435 have a configuration where, as shown for example in FIG. 4 (b), a motor 440 is fixed in place, and a shutter plate 442 that opens and closes each air outlet according to the rotational drive of the motor 440 is fixed to a rotary shaft 441.

- [0032] The rack 401a houses the physical computer 200 and the storage device 230. Racks 401b-401c similarly house physical computers 200 and storage devices 230 (not illustrated).
- [0033] The cooling devices 151a, 151b are installed on the side surfaces of the computer room 400 and are configured as components of the cooling device 151 to maintain a constant temperature in the computer room 400. These cooling devices 151a, 151b send cold air to the underfloor, and the cold air blows out from the air outlets (perforated tiles) 431 to remove the heat evacuated by each of the servers. In this process, according to instructions from the management computer 100, control is performed to open some air outlets and close other air outlets among the air outlets 431-435. For example, when servers housed in racks 401a, 401d have high utilization rates while servers housed in racks 401b, 401c are in an idle state, as control for the cooling device 151, control is performed such that the rotational drive of the motor 440 closes air outlet 433 among air outlets 431-435, while other air outlets 431, 432, 434, 435 are opened.
- [0034] Additionally, when servers housed in racks 401b, 401c have high utilization rates while servers housed in racks 401a, 401d are in an idle state, as control for the cooling device 151, control is performed such that the rotational drive of the motor 440 closes air outlets 431, 435 among air outlets 431-435, while other air outlets 432, 433, 434 are opened.
- [0035] The cooling device in the present embodiment example is a common computer room air conditioner (CRAC), but is not limited to this. The cooling equipment may be a liquid cooling system where liquid coolant passes through pipes and circulates through each rack to remove the heat evacuated by each server. In the liquid cooling system, valves are installed before the pipes connecting to each rack, and cooling output adjustment is performed by opening and closing the valves, similar to the air outlets. Furthermore, the cooling equipment may be an exterior air cooling device that takes in cold air from outside and removes heat evacuated by each server by sending cold air from beneath the floor, similar to the computer room cooling device.

- [0036] FIG. 5 shows the server configuration information 121 in an embodiment example of the present invention.
- [0037] The server configuration information 121 is composed of a rack and physical computer map 500 (FIG. 5 (a)) showing the correspondence relationship between racks installed in the computer room 400 and physical computers stored in the racks, and a physical computer list 510 (FIG. 5 (b)).
- [0038] The rack and physical computer map 500 (FIG. 5 (a)) comprises rack IDs 501, which are identifiers for the racks, and physical computer IDs 502, which are identifiers for the physical computers 200 stored in each rack.
- [0039] The physical computer list 510 (FIG. 5 (b)) comprises one or more records composed of a physical computer ID 511, chassis number 512, component identifier (item) 513, and component value 514 of the physical computer 200, and represents the processing capacity of the physical computer 200. The physical computer ID 501 section stores identifiers for each physical computer. The chassis number 512 exists to identify the chassis that houses the blade server when the physical computer is a blade server. When it is a non-modular type server such as a 1U server, "-" is recorded. Blade servers share fans and power supplies among multiple servers, and may have a management processor that manages server configuration and power ON/OFF. When the managed physical computer is a blade server, CPU temperature and rotational speed of shared fans can be obtained by connecting to this management processor rather than to individual servers. The IP address and port number required to connect to the management processor, although not illustrated, are assumed to be managed as server configuration information.
- [0040] The server configuration information 121 is determined by the designer of the managed system during system build and is frequently managed through documents or software. The physical computer configuration information may be prepared based on such managed configuration information or may be prepared from dynamically collected information.

- [0041] FIG. 6 shows the rack and cooling device map 126 in an embodiment example of the present invention.
- [0042] The rack and cooling device map 126 comprises one or more records composed of a rack identifier 601, a cooling device 151 identifier 602, the air outlet 603 positioned at the front surface of the rack, and the air outlet 604 positioned at the rear surface of the rack. Each record indicates the correspondence between the rack, the cooling device 151 cooling each rack, and the identification numbers of the air outlets performing ventilation and air exchange for the rack.
- [0043] FIG. 7 shows the utilization information 710 (FIG. 7 (a)) and power information 720 (FIG. 7 (b)) in an embodiment example of the present invention.
- [0044] The utilization information 710 (FIG. 7 (a)) shows the resource usage status of a physical computer 200. As an example, it consists of one or more records comprising the measurement date 711, measurement day of week 712, measurement time 713, and CPU utilization rate 714. The unit for CPU utilization rate is %. The utilization information shown here can be obtained using WMI (Windows Management Interface) for Windows (registered trademark) or the 'top' command for Linux.
- [0045] The power information 720 (FIG. 7 (b)) shows the power consumption status of each physical computer 200 and consists of one or more records comprising the measurement date 721, measurement day of week 722, measurement time 723, power consumption 724 of the physical computer, and power consumption 726 of the chassis. It should be noted that when the physical computer 200 is a blade server, the power consumption of multiple physical computers and the chassis power consumption are managed in a single table. On the other hand, when the physical computer 200 is not a blade server, only the power consumption of a single physical computer is managed.
- [0046] FIG. 8 shows the heat generation profile 122 in an embodiment example of the present invention.

- [0047] The heat generation profile 122 consists of one or more records comprising CPU utilization rate 801 and heat generation 802. Here, utilization rate 811 refers to the CPU utilization rate, and heat generation 802 refers to the CPU heat generation. In other words, each record represents the heat generation corresponding to the CPU utilization rate of the physical computer 200.
- [0048] The heat generation profile 122 differs for each type of CPU provided in the physical computer 200. There are various methods for acquiring the heat generation profile. For example, it can be obtained from a history by recording past CPU utilization rates and heat generation history. Additionally, the relationship between utilization rate and heat generation can be measured by executing processing with the CPU in advance. Furthermore, the relationship between utilization rate and heat generation provided by the CPU vendor can be recorded.
- [0049] FIG. 9 shows the CPU temperature profile 125 (FIG. 9 (a)), CPU temperature range 128 (FIG. 9 (b)), optimal CPU temperature 129 (FIG. 9 (c)), the relationship between temperature rise and power consumption due to leakage current, and the relationship between temperature rise and fan power consumption (FIG. 9 (d)) in an embodiment example of the present invention.
- [0050] The CPU temperature profile 125 (FIG. 9 (a)) consists of one or more records comprising the CPU heat generation 901 and CPU temperature change 902 per certain period of time. In other words, each record represents the amount of temperature change after a certain period of time, corresponding to the CPU heat generation.
- [0051] In general, the temperature change of an object is the value obtained by dividing the amount of heat supplied from outside by the heat capacity, but the ease with which heat is conducted differs depending on the properties of the object. That is, even when supplied the same amount of heat, the final temperature reached and the speed of temperature change differ depending on the material and structure of the CPU. Therefore, the CPU temperature profile is a table determined for each CPU type.
- [0052] As mentioned above, the CPU temperature profile 125 differs for each type of CPU provided in the physical computer 200. There are various methods for obtaining the CPU temperature profile. For example, it can be obtained from a history by recording past heat generation and temperature change history of the CPU. Additionally, the relationship between heat generation and temperature change can be measured by executing processing with the CPU in advance. Furthermore, the relationship between heat generation and temperature change provided by the CPU vendor can be recorded.

- [0053] The CPU temperature range 128 (FIG. 9 (b)) consists of an upper limit value 911 and lower limit value 912, and shows the temperature range within which the CPU can safely operate. Normally, the upper limit and lower limit of temperature for normal operation are determined by the manufacturer/vendor of the CPU. And in many servers, when the CPU temperature exceeds this range due to room temperature rise or fan failure, a program that monitors the server hardware status issues a warning to outside the server.
- [0054] The optimal CPU temperature 129 is the temperature that minimizes the total sum of power consumption due to CPU leakage current and power consumed by the fan that cools the CPU. The optimal CPU temperature 129 consists of one or more records comprising the intake air temperature 921 and optimal CPU temperature 922, as this varies with the intake air temperature.
- [0055] The optimal CPU temperature 129 will be explained. Due to semiconductor miniaturization, a minute amount of electric current (leakage current) flows in the CPU even in the OFF state, and this leakage current has the characteristic of increasing exponentially when temperature rises. Therefore, even in idle state, when the CPU's own temperature rises, power consumption also increases exponentially. To suppress CPU power consumption due to this leakage current, it is better not to increase CPU temperature, but power for cooling is required to maintain the temperature. Generally, fan power consumption is proportional to the fan's wind speed and power consumption, and is inversely proportional to the square of CPU temperature rise. Therefore, as shown in FIG. 9 (d), keeping the temperature low suppresses leakage current but increases fan power consumption, while allowing temperature rise increases leakage current but allows fan power consumption to be kept low, creating a trade-off relationship. The optimal CPU temperature 129 is the temperature that minimizes the total sum of power consumption due to leakage current and fan power consumption, and it can be measured by the administrator or may be published by the server vendor.
- [0056] FIG. 10 shows the fan profile 123 in an embodiment example of the present invention.

[0057] The fan profile 123 consists of one or more records comprising the rotational speed 1001 of the fan of the physical computer 200 and the CPU temperature change 1002 that can be achieved per certain period of time by cooling the CPU through fan air flow. Furthermore, the CPU cooling efficiency using a fan varies with the intake air temperature. Therefore, the CPU temperature change that can be achieved per certain period of time with a fan differs depending on the intake air temperature. The fan profile in the present embodiment example shows cases for intake air temperatures of 21°C, 22°C, 23°C (1003) but is not limited to these.

[0058] Also, the relationship between server CPUs and fans is not necessarily one-to-one. For example, in blade servers where multiple servers are housed in a single enclosure, multiple servers may be cooled by a shared fan. Even in such cases, the fans are configured to cool each CPU uniformly, and the fan profile 123 can be defined as described above.

[0059] FIG. 20 shows the cooling device profile 2010 and cooling control pattern 2010 in an embodiment example of the present invention.

[0060] The cooling control profile 2010 is divided by individual cooling device and consists of one or more records comprising the output level 2011 of the cooling device, the intake air temperature change 2012 for each cooling target rack at that output level, and the power consumption 2013.

[0061] The cooling control pattern 2020 represents the combination of outputs from multiple cooling devices and power consumption, and consists of one or more records comprising a combination number 2021, the output 2022 of each cooling device, and the power consumption amount 2023 of the cooling devices as a whole at that time.

[0062] The information shown in FIG. 5 through FIG. 10 is described by the administrator in a definition file. However, this information may be inputted through a GUI (Graphical User Interface) instead of a definition file, or may be obtained from other servers via a network.

- [0063] Next, the control of the physical computers and cooling devices by the management computer in an embodiment example of the present invention will be explained using the drawings.
- [0064] FIG. 11 shows the control flow of physical computers and cooling devices by the management computer in an embodiment example of the present invention.
- [0065] First, the utilization information monitoring unit 111 of the server program 110 of the physical computer reads out the server configuration information 121 from the storage device 105 (S1101). The program then determines which physical computers 200 are to be managed, and the utilization information monitoring unit 111 collects utilization information and power consumption from these physical computers 200 (S1102) and stores this in the server utilization history 124.
- [0066] Then, the CPU temperature estimation unit 113 estimates the CPU temperature of each physical computer 200 after a certain period of time elapses based on the stored utilization history and the heat generation profile 122 and CPU temperature profile 125 stored in the storage device (S1103). This estimation process will be explained using FIG. 12.
- [0067] FIG. 12 shows the CPU temperature estimation flow in an embodiment example of the present invention. This processing is performed by the CPU temperature estimation unit.
- [0068] The CPU temperature estimation unit 113 references the server utilization history 124 and obtains the CPU utilization rate 714 of the physical computer 200 that is the object of this processing (S1201).
- [0069] Then, it determines the amount of heat generated relative to CPU utilization rate by referencing the heat generation profile 122 (S1202). At this time, the CPU type of the physical computer 200 is first determined by referencing the server list 510 of the server configuration information 121, and the CPU temperature profile corresponding to the CPU type is used.
- [0070] Next, the CPU temperature change corresponding to the generated amount of heat is determined by referencing the CPU temperature profile 125 (S1203). Specifically, the CPU temperature estimation unit 113 obtains the current CPU temperature and server device intake air temperature using the temperature monitoring unit, and obtains the current fan rotational speed using the fan monitoring and control unit 116. Then, by referencing the fan profile 123, it determines the CPU temperature change (cooling effect) if the current fan rotational speed is maintained from the current time until after a certain period of time elapses (S1204). The fan monitoring and control unit 116 connects to the BMC 207 through SSH (Secure Shell) or the like, executes commands to obtain the fan rotational speed, and obtains the fan rotational speed value.

- [0071] Finally, the CPU temperature change corresponding to the generated amount of heat is added to the current CPU temperature, the temperature change due to the fan is subtracted, and the result is set as the CPU temperature after a certain period of time elapses (S1205).
- [0072] Once the estimated value of the CPU temperature after a certain period of time elapses has been calculated, it is verified whether the estimated temperature after a certain period of time elapses exceeds the established threshold value (S1104). If it exceeds the established threshold value (in case of Y), the temperature monitoring unit obtains the intake air temperature at the physical computer, and the fan rotational speed determination unit 115 references the obtained intake air temperature and the fan profile 123 to calculate the fan rotational speed needed to reduce the CPU temperature after a certain period of time elapses to within the upper limit value (S1105).
- [0073] An example of determining the fan rotational speed is shown in FIG. 13. That is, FIG. 13 shows the fan rotational speed determination flow in an embodiment example of the present invention.
- [0074] When the estimated value of the CPU temperature exceeds the threshold value, the fan rotational speed determination unit 115 determines the difference between the estimated CPU temperature after a certain period of time elapses and the CPU temperature threshold value, and sets this as the CPU temperature change amount to be implemented (S1301).
- [0075] Then, it determines the fan rotational speed needed to achieve the required CPU temperature change amount after a certain period of time elapses by referencing the current intake air temperature at the physical computer obtained when estimating the CPU temperature after a certain period of time elapses and the fan profile 123 (S1302).
- [0076] If the threshold value is not exceeded, the system waits for a certain period of time to elapse (S1108) and returns to monitoring the utilization information, temperature and rotational speed (S1102). Here, the threshold value may be the upper limit value of the CPU temperature range 128. Also, the threshold value may be a value obtained by subtracting a fixed value from the upper limit value. By setting the threshold value as a value obtained by subtracting a fixed value from the upper limit value, operation can be maintained below the upper limit value even if there is a sudden rise in utilization.
- [0077] In the present embodiment example, the decision about whether to control the fan rotational speed was made based on whether the threshold value after a certain period of time elapses is exceeded, but the invention is not limited to this. As another embodiment, the temperature monitoring unit 112 obtains the intake air temperature, and determines the optimal CPU temperature 129, which is the value that minimizes the total of CPU leakage current and fan power consumption, from the obtained intake

air temperature. Then, the determination 1104 may be made based on whether the value is within the range between a value obtained by subtracting a fixed temperature from the optimal CPU temperature and a value obtained by adding a fixed temperature to the optimal CPU temperature.

[0078] Next, the server program 110 verifies whether the physical computer 200 can modify the fan rotational speed to the calculated rotational speed (S1106). For example, the program verifies whether the fan rotational speed determined in process 1105 exceeds the maximum value. If modification is possible (S1106: Y), the fan monitoring and control unit 116 issues instructions to the physical computer 200 to modify the fan rotational speed (S1107). Then, the system waits for a certain period of time to elapse (S1108) and returns to monitoring the utilization information, temperature and rotational speed (S1102).

[0079] If the fan of the physical computer 200 cannot achieve the fan rotational speed determined by the fan rotational speed determination unit 115 (S1106: N), the cooling control unit 117 lowers the intake air temperature of the physical computer 200 by modifying the output of the cooling equipment 151a, 151b installed in the computer room 400 (S1520). This processing will be explained using FIG. 21.

[0080] FIG. 21 illustrates a cooling control flow in an embodiment example of the present invention.

[0081] The cooling control unit 117 references the fan profile 123 to determine a target intake air temperature that achieves the required amount of CPU temperature change (S2101). Here, the fan rotational speed is set to the maximum value achievable. That is, with 5000 RPM being the maximum value as shown in FIG. 10, when the CPU temperature change is set to  $-3.0^{\circ}\text{C}$ , the target intake air temperature is determined to be  $21^{\circ}\text{C}$ .

[0082] Then, the difference between the current intake air temperature and the target intake air temperature is determined and set as the intake air temperature change target value (S2102).

[0083] Next, the cooling control unit 117 references the server configuration information 121 to identify the rack that houses the physical computer 200 to be controlled. Then, it references the rack and cooling map 126 to identify the cooling equipment responsible for cooling the identified rack. There may be multiple identified racks. Then, the cooling control unit 117 issues instructions to modify the output of this cooling device according to the aforementioned difference.

- [0084] Specifically, the method for determining the cooling device output references the cooling device profile 2010 to select an output level where the rack temperature change amount is not less than the intake air temperature change target value.
- [0085] However, in cases like the present embodiment example where multiple cooling devices cool the same rack, the power consumption of the entire computer room differs depending on which cooling device's output is modified. Therefore, to bring the intake air temperature of the managed rack to the target intake air temperature, a cooling control pattern list 2030 is created that lists combinations of possible outputs for the cooling equipment 151a and cooling equipment 151b (S2103).
- [0086] Then, the combination where the sum of power consumption of cooling equipment 151a and cooling equipment 151b becomes minimal is selected (S2104).
- [0087] For example, the combinations include patterns such as setting the cooling equipment 151a to level 1 and cooling equipment 151a to level 3, setting both outputs to level 2, or setting cooling equipment 151a to level 3 and cooling equipment 151b to level 1. Here, since the power consumption of the cooling device relative to the temperature change, i.e. the temperature to which it can cool, differs depending on the device characteristics and distance from the rack, the power consumption differs for each pattern. Then, the output of the cooling equipment 151a, 151b is modified to lower the intake air temperature of the physical computer 200 (S2105). The system then waits for a certain period of time to elapse (S1108), and returns to monitoring the utilization information, temperature and rotational speed (S1102).
- [0088] The physical computer profile 124 in the present embodiment example focuses only on the CPU as the main heat-generating component, but the heat generation profile may also be information based on the utilization rates of components other than just the CPU.
- [0089] Additionally, while the present embodiment example described a case where the IT device is a server, the IT device may also be a storage device or network equipment. When the IT device is a storage device, since the heat generation of the device varies not only with CPU utilization rate but also with IOPS (Input/Output Per Second) which indicates the number of data input/output operations to the device, the heat generation can be estimated based on the controller's CPU utilization rate and IOPS. Similarly, when the IT device is network equipment, the heat generation can be estimated based on the port utilization rate.

[0090] As described above, by configuring the power savings control server 110 with the utilization information monitoring unit 111 that collects utilization information and power consumption information of the physical computer 200, the temperature monitoring unit 112 that collects the intake air temperature, CPU temperature, and exhaust temperature of the managed server, the fan monitoring and control unit 116 that monitors the fan rotational speed of the managed server and modifies the rotational speed of the fan, the CPU temperature estimation unit 113 that reads the heat generation profile 122 and CPU temperature profile 125 and estimates the temperature of the CPU built into the managed server after a certain period of time, the fan rotational speed determination unit 115 that reads the fan profile 123 and determines the fan rotational speed to lower the CPU temperature to a target value after a certain period of time, the cooling control determination unit 114 that accepts input from the cooling device profile 127 and rack and cooling map 126 and determines the output of the cooling device 151, and the cooling control unit 117 that issues instructions for control of the cooling device 151, the CPU can be cooled in advance to maintain optimal temperature, minimizing power consumption due to leakage current and improving cooling efficiency. Additionally, by coordinating control of the server fans and air conditioning, even in cases where CPU temperature cannot be kept within the rated range through fan control alone, thermal failures can be avoided by keeping the CPU temperature within the rated range through adjusting the air conditioning in advance to lower the intake air temperature.

[0091] While in the present embodiment example the BMC in the server device controls the fans according to instructions from the management computer, it should be noted that the invention is not limited hereto, and the server program 110 may also be stored in the memory of the physical computer, with the utilization information history 124, server configuration information 121, heat generation profile 122, fan profile 123, CPU temperature profile 125, cooling device profile 127, CPU temperature range 128, optimal CPU temperature 129, rack and cooling map 126, and cooling device profile 2010 being stored in the storage device, to perform the fan control and air conditioning unit control of the present embodiment example within the physical computer.

## Embodiment Example 2

- [0092] A second embodiment of the present invention will be described below based on the drawings. For components identical to those in the first embodiment example, drawings and descriptions will be omitted as appropriate.
- [0093] The system configuration of this embodiment example of the present invention is the same as in FIG. 1. Additionally, the physical computer is the same as in FIG. 3.
- [0094] FIG. 14 shows the management computer in this embodiment example of the present invention. The difference from the management computer of Embodiment Example 1 is that here, the management computer does not maintain utilization history information 124, but maintains a job execution schedule 132 and server/job map 131. Description will be omitted for the server configuration information 121, heat generation profile 122, fan profile 123, CPU temperature profile 125, rack and cooling map 126, CPU temperature range 128, and optimal CPU temperature 129 that were already described in Embodiment Example 1.
- [0095] A brief description of the operation of the management computer will be presented. Detailed description will be provided below using the drawings. The server program 110 determines the CPU utilization rate for a certain period of time from the job execution schedule (load fluctuation) of the business tasks executed by the managed server, estimates the CPU temperature after a certain period of time from the CPU utilization rate and the heat generation corresponding to utilization rates determined for each CPU type, and upon confirming that the CPU temperature will exceed the upper limit value of the temperature range for stable CPU operation, the server program controls the fan rotational speed of the managed server and, if necessary, the output of the cooling device.
- [0096] FIG. 15 shows a configuration diagram showing the server/job map 131 (FIG. 15 (a)) and the job execution schedule 132 (FIG. 15 (b)) in an embodiment example of the present invention.
- [0097] The server/job map 131 (FIG. 15 (a)) consists of one or more records comprising the physical computer ID 1401, which is the identifier of the physical computer, and the business task type 1402 which shows the type of business task. Each record shows which business tasks are performed on which physical computer.

- [0098] The job execution schedule 132 (FIG. 15 (b)) consists of one or more records comprising, for each physical computer, the date 1411, day of week 1412, start time 1413, end time 1414, job ID 1415, and average CPU utilization rate 1416. Each record shows the average value of CPU utilization rate generated by business tasks by day of the week and time of day. The server's CPU utilization rate is predicted based on batch job execution schedules, temporal fluctuations in business task requests, or server on/off schedules. The job execution schedule 132 is determined on the basis of batch job execution schedules, temporal fluctuations in business task requests, server on/off schedules, and the server utilization history when performing equivalent processing.
- [0099] FIG. 16 is a flowchart showing the control flow of the second embodiment example of the present invention. First, the utilization information monitoring unit 111 of the server program 110 obtains the server configuration information 121 (S1601) and obtains information about the physical computers 200 it manages. Then, it obtains the job execution schedule information for the managed physical computers.
- [0100] Next, the server program 110 verifies the job execution schedule and confirms whether the end time of the job being executed by the physical computer 200 has been reached (S1603). Then, when it is the job end time (S1603: Y), the program references the server/job map 131 to identify the next job to be executed by the physical computer 200, and references the job execution schedule 132 corresponding to the job to obtain the start and end times and average CPU utilization rate of the job to be executed by that physical computer 200 (S1604).
- [0101] Then, the CPU temperature estimation unit 113 estimates the CPU temperature of each physical computer 200 after a certain period of time elapses based on the average CPU utilization rate, the heat generation profile 122, and the CPU temperature profile 125 (S1604). The temperature estimation process is identical to that in the first embodiment example.
- [0102] Here, for example, if the average CPU utilization rate for the load period about to begin is 0, power consumption can be reduced by lowering the fan rotational speed or stopping the fan.

[0103] Also, the processing in processing 1606 is the same as in Embodiment Example 1.

[0104] In the present embodiment example, the jobs to be executed and the CPU utilization rate needed to process those jobs are obtained from the job execution schedule. However, the invention is not limited to this, and, for example, data such as previously processed jobs and CPU utilization rates may be stored, and the CPU utilization rate at a certain time may be predicted and obtained based on the stored data.

### **Embodiment Example 3**

[0105] A third embodiment of the present invention will be described below based on the drawings. For components identical to those in the first embodiment example, drawings and descriptions will be omitted as appropriate.

[0106] The system configuration of the embodiment example of the present invention is the same as in FIG. 1. Additionally, the physical computer is the same as in FIG. 3.

[0107] FIG. 17 shows the management computer in an embodiment example of the present invention. The difference from the management computer in Embodiment Example 1 is that the server program maintains a rule determination unit 133, and the storage device maintains cooling control rules. Description will be omitted for the server configuration information 121, heat generation profile 122, fan profile 123, utilization history information 124, CPU temperature profile 125, rack and cooling map 126, CPU temperature range 128, and optimal CPU temperature 129 already explained in Embodiment Example 1.

[0108] FIG. 18 shows a configuration diagram of the cooling control rule 131 in the third embodiment example of the present invention.

[0109] The cooling control rule 131 consists of a rule 1010 and an action 1020, and the rule 1010 consists of one or more records comprising an evaluation item 1011 and a threshold value 1012. Each record represents one condition, and the condition is satisfied when the value of the evaluation item becomes not less than the threshold value, and when conditions expressed in all records are satisfied, the control specified in the action 1020 is performed. Also, the control specified in the action 1020 may be performed when the condition for one item is satisfied.

- [0110] The cooling control rules are conditions that can determine when abnormal temperature rise has started, and are defined in advance by the computer room administrator.
- [0111] For example, the cooling control rule 131 shown in FIG. 18 assumes that heat accumulation occurs at the rear surface of the rack where exhaust from the physical computers 200 exits when the CPU temperature of all physical computers 200 stored in a rack exceeds 60°C, and the exhaust temperature exceeds 40°C, and the fan rotational speed exceeds 10,000 revolutions/second. Then, action 1020 is performed to evacuate this heat. An instruction is issued to maximize the output of the cooling device 151 that cools that rack and to open the grating plate of the air outlet positioned at the rear surface of that rack to 100%.
- [0112] In addition to the above, it is also effective to determine that the amount of heat generated from the group of physical computers stored in that rack exceeds a certain value when the total sum of power consumption of the physical computers 200 stored in the same rack exceeds a certain value based on the power information in FIG. 5 (b), and to increase the output of the cooling device that cools that rack by one level.
- [0113] Also, it is effective to consider that heat accumulation has occurred at the front surface of the rack when the intake air temperature of all physical computers 200 stored in the same rack exceeds a certain threshold value, and maximize the output of the cooling device 151 that cools that rack and open the grating plate of the air outlet positioned at the front surface of that rack to 100%.
- [0114] FIG. 19 shows a flowchart showing the control flow of the third embodiment example of the present invention.
- [0115] First, the utilization information monitoring unit 111 of the power savings control server 110 obtains the server configuration information 121 (S1901).
- [0116] Then, after obtaining information about the physical computers 200 to be managed, the utilization information monitoring unit 111 collects utilization information and power consumption from these physical computers 200 and stores this in the server utilization history 124. The temperature monitoring unit 112 collects the current CPU temperature and exhaust temperature. The fan monitoring and control unit 116 collects the fan rotational speed (S1902).

- [0117] Next, the rule determination unit 133 compares the values of each item in rule 1010 of the cooling control rule 131 with the threshold value 1012 for the physical computers 200 stored in each rack based on the collected information (S1903). When the values of all items are not less than the threshold value 1012 and rule 1010 is satisfied (S1904: Y), the rack and cooling map 126 is referenced to identify the cooling device 151 that cools that rack and the air outlet positioned at the rear surface of that rack, and the cooling control specified in action 1020 is performed (S1905). Then, after waiting for a certain period of time to elapse (S1906), the system returns to monitoring utilization information, etc. (S1902).
- [0118] According to the present embodiment example, sensor installation costs can be reduced compared to the method of installing a large number of sensors in the vicinity of the managed equipment to detect temperature increase.

## Scope of claims

- [1] A control method using a management computer which is connected to a server device having a processor and a fan and to a cooling device, the control method being characterized in that:
- the temperature and utilization rate of the processor, the rotational speed of the fan, and the intake air temperature at the server are acquired from the server;
  - the estimated temperature of the processor after a predetermined time period elapses is calculated on the basis of the temperature and utilization rate of the processor, the rotational speed of the fan, and the intake air temperature;
  - if the estimated temperature is not less than a first predetermined value, a target rotational speed of the fan at which the estimated temperature after said time period elapses will be not greater than said predetermined value is determined; and
  - the server device is instructed to set said target rotational speed.
- [2] The control method according to claim 1, characterized in that:
- the management computer has a memory which stores a utilization information monitoring unit, a fan monitoring unit, a fan control unit, a temperature estimation unit, and a cooling control unit;
  - the utilization information monitoring unit acquires the utilization rate of the processor from the server;
  - the fan monitoring unit acquires the rotational speed of the fan;
  - the temperature estimation unit acquires the intake air temperature and the temperature of the processor, calculates an increased temperature of the processor on the basis of the temperature and the utilization rate of the processor, calculates a cooled temperature on the basis of the rotational speed of the fan and the intake air temperature, and subtracts the cooling temperature from the increased temperature to calculate the estimated temperature;
  - the fan control unit issues an instruction to the server to change the fan to the target rotational speed;
  - in the event that the estimated temperature after said time period elapses does not become not greater than said predetermined value even when the rotational speed of the fan is set to maximum, the cooling control unit determines the target intake air temperature at which the estimated temperature will become not greater than said predetermined value after said time period elapses when the rotational speed of the fan

is at a rated value, determines an output of the cooling device for achieving said target intake air temperature, and issues an instruction to the cooling device to change to said output.

- [3] The control method according to claim 1, characterized in that:  
the output of the cooling device is increased in the event that the estimated temperature does not become not greater than said predetermined value after said time period elapses even when the rotational speed of the fan is set to maximum.
- [4] The control method according to claim 3, characterized in that:  
when increasing the output of the cooling device,  
the target intake air temperature at which the estimated temperature will become not greater than said predetermined value after said time period elapses when the rotational speed of the fan is at a rated value is determined, and  
the output of the cooling device for achieving said target intake air temperature is determined.
- [5] The control method according to claim 4, characterized in that:  
when there are multiple cooling devices, multiple combinations of outputs of the multiple cooling devices are calculated;  
the power consumption by the multiple cooling devices is calculated for each of the multiple combinations;  
a combination is selected from the multiple combinations based on the power consumption; and  
the outputs of the multiple cooling devices are determined according to the selected combination.
- [6] The control method according to claim 1, characterized in that:  
when calculating the estimated temperature, an increased temperature of the processor is calculated from the temperature and utilization rate of the processor, a cooled temperature is calculated from the rotational speed of the fan and the intake air temperature, and the estimated temperature is calculated by subtracting the cooled temperature from the increased temperature.
- [7] The control method according to claim 6, characterized in that:  
the type of the processor of the server device is recognized; and  
when calculating the increased temperature, it is calculated using the relationship between utilization rate and heat generation corresponding to the type of the

processor.

- [8] The control method according to claim 1, characterized in that:  
when the estimated temperature is not less than a first predetermined value and not greater than the second predetermined value, the target rotational speed of the fan at which the estimated temperature after said time period elapses will be not greater than said predetermined value is determined; and  
the first predetermined value is a value obtained by adding a first temperature to the optimal processor temperature, and the second predetermined value is a value obtained by subtracting a second temperature from the optimal processor temperature.
- [9] The control method according to claim 9, characterized in that:  
the optimal processor temperature is calculated based on the power consumption of the processor and the power consumption of the fan.
- [10] A control method using a management computer connected to a server device having a processor and a fan and to a cooling device, the control method being characterized in that:  
the temperature of the processor, the rotational speed of the fan, and the intake air temperature at the server are acquired from the server;  
job-related information concerning jobs executed by the processor is acquired from the server;  
utilization rate is acquired from the job-related information;  
the estimated temperature of the processor after a predetermined time period elapses is calculated on the basis of the temperature and utilization rate of the processor, the rotational speed of the fan, and the intake air temperature;  
if the estimated temperature is not less than a first predetermined value, a target rotational speed of the fan at which the estimated temperature after said time period elapses will be not greater than said predetermined value is determined; and  
the server device is instructed to set said target rotational speed.
- [11] A server system characterized in that it comprises:  
the server device, which has a processor and a fan, and measures the temperature and utilization rate of the processor, the rotational speed of the fan, and the intake air temperature; and  
a management computer which is connected to the server device and to the cooling device, and which calculates the estimated temperature of the processor after a

predetermined time period elapses on the basis of the temperature and utilization rate of the processor, the rotational speed of the fan, and the intake air temperature, and determines a target rotational speed of the fan at which the estimated temperature after said time period elapses will be not greater than said predetermined value if the estimated temperature is not less than a first predetermined value.

- [12] The server system according to claim 11, characterized in that:  
the system further comprises a cooling device; and  
the management computer issues an instruction to increase the output of the cooling device in the event that the estimated temperature does not become not greater than said predetermined value after said time period elapses even when the rotational speed of the fan is set to maximum.
- [13] The server system according to claim 12, characterized in that:  
the management computer determines the target intake air temperature at which the estimated temperature will become not greater than said predetermined value after said time period elapses when the rotational speed of the fan is at a rated value, and determines the output of the cooling device for achieving said target intake air temperature.
- [14] The server system according to claim 11, characterized in that:  
when calculating the estimated temperature, the management computer calculates an increased temperature of the processor from the temperature and utilization rate of the processor, calculates a cooled temperature from the rotational speed of the fan and the intake air temperature, and calculates the estimated temperature by subtracting the cooled temperature from the increased temperature.
- [15] The server system according to claim 14, characterized in that:  
the management computer recognizes the type of the processor of the server device, and when calculating the increased temperature, calculates it using the relationship between utilization rate and heat generation corresponding to the type of the processor.

[FIG. 1]

FIG. 1

