Temperature, Humidity, and Power Outage Monitoring System of Pamapersada Nusantara's Server Racks

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Abstract — Data center is a vital location that must be managed. The room contains central devices that are essential for operational continuity of the information system. Like the PT Pamapersada Nusantara data center, this room needs to be maintained according to standards. One thing that needs to be maintained is temperature, humidity, and electricity because they have a direct impact on IT equipment and can be potentially fatal if they are not in standard conditions. Meanwhile, the data center being researched uses manual checks for temperature, humidity, and electrical power supply. The problem is the inconsistency of the administrator in documenting these parameters and the lack of responsiveness of repairs if an anomaly occurs in the parameter value, because the data is not real time. This research aims to build a monitoring system for monitoring temperature, humidity, and power outage at the PT Pamapersada Nusantara data center which provides direct notifications to administrators. Current similar studies generally do not include the sensor location factor which is essential. The sensor installation is not randomly placed in the room, nor in the hot aisle or in the cold aisle, but in the server rack so that the temperature and humidity truly represent the surroundings of the device as ASHRAE recommend. Referring to ASHRAE, the standard temperature is 18° C - 27° C while the humidity is 20% - 60%. This research starts from a needs analysis through a survey, followed by equipment design, equipment testing by comparing with manual measuring tools. ESP8266 and DHT22 sensors are used, telegram as system output in the form of notifications. Notifications are sent when the temperature and humidity values are not in standard conditions, they are sent every day at 07.00 and 15.00, and they are sent if there is 5% increasing or decreasing values. The results show that the system successfully sends a notification on telegram when the conditions are met. Tests using comparisons with other measuring instruments also show a deviation of values below 2%. Measurements on the server rack show varying value depending on the occupancy of the rack and its position against the air conditioner.

Keywords— Data center, IoT, telegram, temperature and humidity monitoring.

1. Introduction

Server room / data center is a vital room for information systems management in an institution. The data center contains a collection of IT devices that serve the information transaction needs of the institution. Among them, such as servers, storage, and network devices such as routers, switches and firewalls. They are devices that require high performance to support information system operations. These devices require special treatment regarding the surrounding environment (such as temperature, humidity, voltage, etc.) which must be maintained to maximize the performance of these devices.

Data center is divided into 4 tiers. The data center is divided based on aspects of building architecture, electrical aspects, telecommunications aspects and mechanical aspects[1]. TIA-942 is one of the standards used to design data centers[2]. This standard also covers the flow of hot air and cold air in a data center. This hot and cold airflow is designed to maintain the optimal data center temperature for the performance of the servers/devices inside.

ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers) recommends for data center temperature to be at 18°C - 27°C for class A1 and room humidity to be in the range of 20% - 60%[3]. It is important to maintain this temperature and humidity so that the performance of servers and other devices can run optimally. The temperature must also be monitored to ensure there is no overheating that could cause a fire. ASHRAE also recommends that monitoring for temperature and humidity should be placed in the rack, because it is in the rack that there are devices to be monitored.

Recently, a fire broke out in the Cyber 1 Jakarta data center, which was December 2, 2021. According to digital economy researcher at the Institute for Development of Economics and Finance (Indef) Nailul Huda, published in ekonomi.bisnis.com on December 3, 2021. The fire is detrimental to those who have equipment in the building in the number of hundreds of billions of rupiah. Of course, this is a number that is expensive because the losses in the data center are not only damage to devices but also transaction losses that occur due to system downtime. For this reason, it is important to monitor temperature and humidity in the data center to not only maintain server performance but also mitigate the impact of fires.

PT Pamapersada Nusantara jobsite SMMS (Suprabari Mapanindo Mineral Sekako), on the other hand, needs to also manage its data center. The company strives to maintain the server room at the recommended temperature and humidity levels. It has one data center whose room size is 24 square meters with three racks in it. Two racks contain network devices, and one rack contains servers. There are

also three UPS (Uninterruptible Power Supply) and has three air conditioners. IT admin monitors the temperature and humidity of the data center manually, using temperature and humidity measuring instruments and records them every day at 7:00 AM and 03:00 PM. This measuring instrument is installed near the entrance door. The three racks are lined up in a row while the air conditioner is next to the shelf, leading to the door. The level of occupancy of the racks also varies, one network rack contains 20% of the rack capacity, another network rack contains 90% of the rack capacity, while the server rack contains 60% of the capacity.

Meanwhile, data center electricity is supplied by power plant from other jobsites and relies on UPS as a backup. There are two UPS, one as backup for computers and user devices in each room, and one UPS as dedicated backup for server racks. Sometimes when an outage occurs, the UPS cannot meet the needs of the data center and only lasts for 30 minutes. If it exceeds 30 minutes, the server and network will shut down, and it will take a long time to restart until all services are running normally, at least it will take one hour for all services to run normally.

Table 1
Manual Check Temperature and Humidity using AMT-116

Day	Temperature (°C)	Humidity (%)
1	16,1	50,5
2	16,1	55,2
3	16,0	56,2
4	17,2	53,7
5	NA	NA
6	16,2	54,4
7	16,5	51,3
8	NA	NA
9	17,1	50,9
10	17,4	53,8

The problem is that IT admin is not consistent in manually monitoring temperature and humidity using AMT-116 tool as mentioned at Table 1, there is no temperature and humidity data in day 5 and 8 due to lack of checking. Not to mention, at off day the temperature and humidity of the data center are not monitored. Following-up to abnormal temperature and humidity values also cannot be done immediately because temperature checks are carried out twice a day. So, if there is a sudden increase in temperature, the IT admin cannot immediately make repairs. The IT admin also doesn't know when the power supply from the power plant shuts down, so the IT admin can't predict how much longer the data center will stay alive using power backup from the UPS.

For this reason, this research is conducted to create a temperature, humidity, and electricity outage detection system that can provide updated notifications regarding room conditions so that IT admins can take follow-up actions as soon as possible.

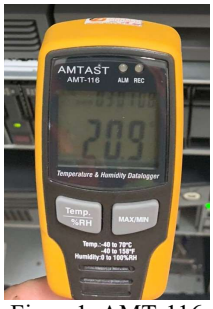

Figure1. AMT-116

Figure 1 shows the current tool used by IT admin to monitor temperature and humidity. AMT-116 is a measurement tool that save the result in a data log form. The lack of this device is that data cannot be transmitted and managed. It can only give a warning for a certain value of measurement through buzzer which can only be heard in certain radius.

In terms of building a temperature and humidity detection system, there are several previous studies. A study built a similar system with the purpose of monitoring temperature and humidity using the ESP8266 and the DHT22 sensor, data sent to web server and accessed needed to monitor the values[4]. Study [4] uses only one sensor sent to web server, then IT admin can only view the data of temperature and humidity by actively check the web. Meanwhile, in [5] a similar system is also built whose output in the form of temperature and humidity data that can be accessed via the web and short message service notifications.

The same system is also built in [6] but it uses a DHT11 sensor as a temperature detector and outputs data that is stored in the cloud, namely ThingSpeak, which can be accessed via the internet. System built in [7] is also developing temperature and humidity monitoring but using a DHT11 sensor and an output in the form of a cloud platform, namely Ubidots, and it also provides short message service and email notifications when the temperature and humidity exceed the specified level. This research using notification model to give reminder toward IT admin so that data can be quickly known, and action can be quickly done.

While research in [8] also developed the same system aiming to monitor temperature and humidity using a telegram as its output. Meanwhile, in [9] the same system has implemented the same using the ESP8266 and the DHT22 sensor and the output is a telegram notification and runs the actuator to regulate the room air conditioner temperature.

From the literature review above, only a few apply the notification model. It is when the temperature and humidity exceed a certain value, the system automatically send reminder toward the admin. Most of them use monitoring by actively viewing the dashboard/web related to the most actual temperature and humidity like in [4], [5], [6]. This type of monitoring is not reliable in terms of real monitoring. Because when there is sudden spike of value, admin will not know.

Sensor placement is also not discussed on previous studies. They're focusing on how to build system and give

output but less focusing on how to generate valid value of environment reading by sensor. As ASHRAE recommends on [3] that sensor placement is important to give validation toward actual environment condition of the devices. So, they recommend to place sensor inside the rack.

Meanwhile, this study uses notification to telegram as system output. Notification is automatically sent when the data center temperature and humidity are not at the ASHRAE recommended level, which is a maximum temperature of 27°C and a maximum humidity of 60%. The location of the sensor also becomes a concern, the sensors are placed in every rack, and they are not placed in cold aisle or hot aisle. Thus, position of the sensor will greatly affect the validity of the temperature and humidity of the devices. So that sensors really represent the temperature and humidity that is right around the device. Electricity status would also become concern of system because it can affect to data center performance. Thus, notification of power outage would be built in this system.

2. Method

2.1. System Designing

System planning to be built in this study is based on needs of PT Pamapersada Nusantara data center. Specifically, method being used in this study will be shown as figure below.

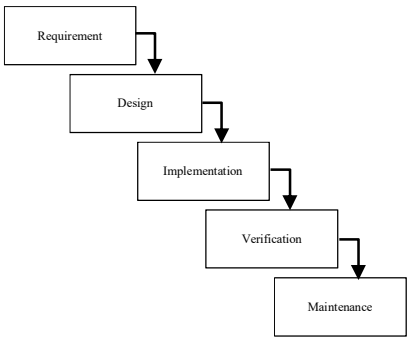

Figure 2. Waterfall model

As shown at figure 2 the method of this study uses waterfall model. It is initiated by collecting requirement needed from current condition. The needs for this server room include measuring the temperature and humidity at three points of the rack, measuring the input voltage up which is used as a monitoring of the electrical conditions that supply the server room. The needs also include the ability of system to give direct information toward IT admin if there is anomaly value of temperature, humidity, and power shortage.

There are three conditions of reading temperature and humidity that will trigger system to send notifications, including:

1. When the temperature and humidity exceed the specified upper and lower limits (lower limit: 18°C, upper limit: 27°C)

2. At 07.00 AM, and 3.00 PM as mandatory for audit purpose

3. When there is 5% of increasing or decreasing of temperature and humidity value

In terms of data center power outage monitoring, a notification will be sent when power plant failed to power up data center, so that IT admin knows when remaining backup from ups last and turn off, then IT admin can take immediate corrective action.

This study uses three sensors of DHT22, and one of AC voltage sensor, namely ZMPT101b. there are three sensors for each rack to read temperature and humidity specifically. That's because each rack has a different number of devices contained so it is potentially to have different temperature and humidity conditions. Not to mention, the occupancy of each rack is also varying as mentioned above, there are 60%, 90%, and 20% of rack capacity. Racks distance toward air conditioner is also different one to another that can affect temperature and humidity in each rack. And one AC voltage sensor connected directly to power outlet coming from power plant.

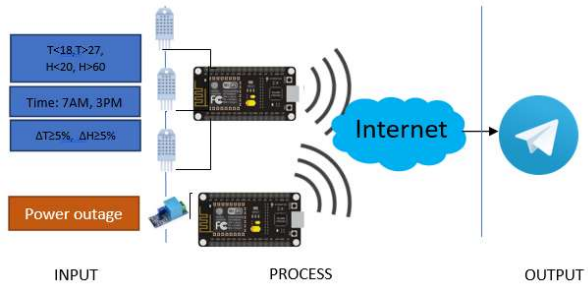

Figure 3. Design system diagram

As seen in figure 2 above, the system uses DHT22 as a temperature and humidity sensor. The sensors are connected to the ESP8266 via cable. System also uses AC sensor voltage module to detect power outage from power plant through electricity terminal inside the data center. Two ESP8266 as NodeMCUs are connected to the internet via an accessible access point in data center area. Thus, the ESP8266 can send telegram messages to the telegram bot that has been created. There are four triggers when the ESP8266 sends a telegram message, they are temperature or humidity value, time, and power outage. When the temperature and/or humidity exceed the specified level (temperature and/or humidity) then the ESP8266 will send a message to the telegram bot that the temperature or humidity has touched the maximum limit. At 7 AM and 3 PM, regular temperature and humidity updates will be sent to telegram. When there is 5% increasing or decreasing of temperature and humidity value system will also send a notification.

When there is power outage from power plant, ESP8266 will also send notification.

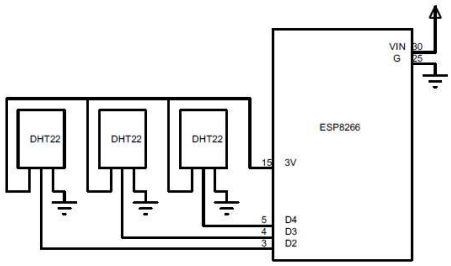

Figure 4. schematic diagram for temperature and humidity

Figure 4 shows the wiring and schematic diagram used for temperature and humidity monitoring. It is used three DHT22s, output of these sensors are connected to D2, D3, and D4 of NodeMCU. They are sharing same vcc (3volt) and ground.

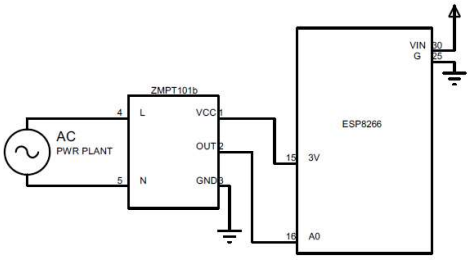

Figure 5. schematic diagram for power outage

While figure 5 shows the schematic diagram for power outage monitoring. It uses ZMPT101b as sensor, and AC power plant voltage as its input. Output of this sensor are connected to A0 NodeMCU, and VCC is supplied by 3volt form NodeMCU. While this device circuit uses UPS, so when there is outage from power plant, this device can still run and give a notification

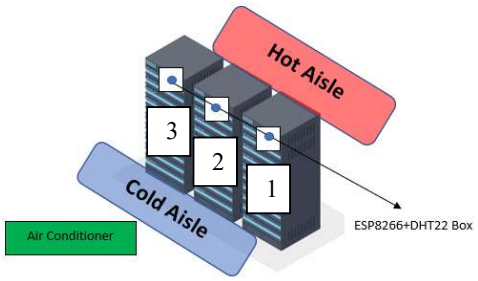

Figure 6. Sensors' placement

Figure 6 shows the location of the ESP8266 and DHT22 circuit boxes. According to ASHRAE recommendations [3], the sensor is placed in the server rack so that it is not part of the cold aisle or hot aisle, this location represents the temperature and humidity right around the server device. By this method, valid temperature and humidity gained that verify the actual condition of servers' or devices' temperature and humidity. Rack no 1 is server rack whose 60% occupancy, rack no 2 and 3 are network rack, whose 90%, 20% occupancy respectively.

2.2. Coding Configuration

Arduino coding is made referring to flowchart below

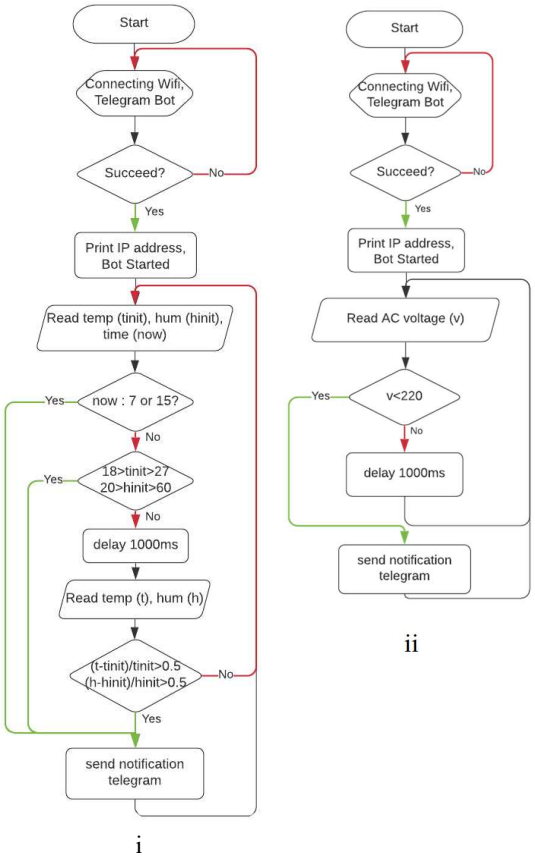

Figure 7. Program flowchart

From the figure 7 above, there are two flowcharts. The (i) flowchart shows steps for temperature and humidity and the (ii) shows steps for power outage. The first step in the system is to connect to Wi-Fi, then connect the telegram bot, then read the input. The inputs are the time taken from the NTP (Network Time Protocol) server or reading the temperature and humidity values from the DHT22 sensor. Furthermore, the input reading will be sent to the telegram bot if it meets the requirements, namely for the time the message containing the temperature and humidity values of the server room will be sent every 7 AM and 3 PM, while for the second condition the message will be sent if the temperature exceeds 27°C and or the humidity exceeds 60%.

The steps to code as flowchart above are:

1. Input libraries: Telegram, DHT, NTP, Wi-Fi, ZMPT101b
2. Initialization of variables
3. Setup function: interrupt script, Wi-Fi connection, dht.begin(), NTPClient.begin(), telegram bot begin, and set up for ZMPT101b pin.
4. detectsTemp() function: as an interrupt function which is given a condition if the temperature and humidity exceed the limit
5. Loop function: send serial monitor per second update temperature, humidity, and voltage read and send them to telegram as message

For the sake of data verification, this study uses comparation between data sent by DHT22 and data taken by manual sensors (AMT-116). They are compared for 10 last temperature and humidity data from DHT22 and from AMT-116. Then deviation between these devices can be obtained and discussed more.

3. Result and discussion

Through system implementation, this study gains some results as follow

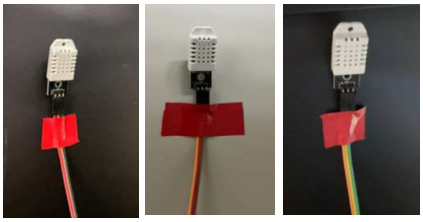

Figure 8. Sensors installed inside racks

Figure 8 shows installation sensors inside every racks, the installation located in the middle of the rack.

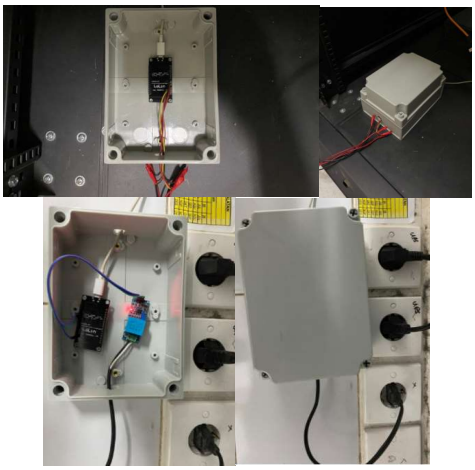

Figure 9. Installation of ESP8266

Figure 9 shows the installation of two nodeMCU ESP8266 for temperature, humidity and for the power outage sensor. Power outage sensor is connected to power terminal from power plant.

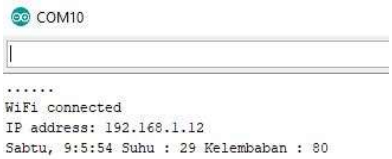

Figure 10. Initial serial monitor result

Figure 10 shows at the beginning of the circuit is supplied with power. It indicates that the device is successfully connected to wifi as evidenced by the obtained ip address, then the device begins to read the time and also the temperature and humidity.

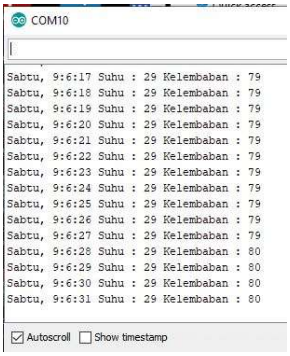

Figure 11. Serial monitor results

In Figure 11, it is shown that temperature and humidity are updated successfully on the serial monitor every one second.

Figure 12. Routine update telegram notification

Figure 12 shows the system has succeeded in sending routine updates to the telegram bot, while figure 13 below shows the system has succeeded in providing telegram notifications when the temperature exceeds the threshold and the humidity exceeds the maximum threshold.

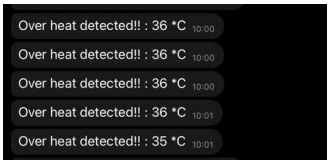

Figure 13. Overheat and high humidity telegram alert

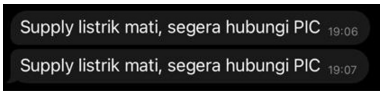

Figure 14. Power outage telegram notification

Figure 14 shows the notification given when power outage happened to data center. An automatic message sent every minute until the outage has finished. The time once this message once sent, IT admin can predict when the server should be shut down.

To verify the measuring instrument built in this study, following table shows reading comparation between manual tools and this study's tool (AMT-116 and DHT22).

Table 2
Rack 1 Results comparation

	AMT-116		DHT22		Deviation	
No	**T(°C)**	**H(%)**	**T(°C)**	**H(%)**	**T (%)**	**H (%)**
1	19,2	50,8	19	51	1,04	0,39
2	18,7	48,6	18	49	3,74	0,82
3	16,9	50,1	17	49	0,59	2,20
4	17,3	46,8	18	47	4,05	0,43
5	16,5	53,7	17	52	3,03	3,17
6	18,7	49,4	19	51	1,60	3,24
7	17,6	50,6	18	51	2,27	0,79
8	18,9	51,2	19	51	0,53	0,39
9	20,0	50,4	20	50	0,00	0,79
10	17,1	51,7	17	50	0,58	3,29
avg	**18,09**	**50,33**	**18,2**	**50,1**	**1,74**	**1,55**

Table 3
Rack 2 Results comparation

	AMT-116		DHT22		Deviation	
No	**T(°C)**	**H(%)**	**T(°C)**	**H(%)**	**T (%)**	**H (%)**
1	20,3	51,7	20	52	1,48	0,58
2	20,9	51,3	21	51	0,48	0,58
3	19,7	52,4	19	50	3,55	4,58
4	18,4	50,3	18	51	2,17	1,39
5	17,6	50,9	17	50	3,41	1,77
6	18,8	50,0	19	50	1,06	0,00
7	18,0	51,2	18	50	0,00	2,34
8	17,1	51,6	17	51	0,58	1,16
9	21,2	49,3	21	49	0,94	0,61
10	20,2	48,7	20	49	0,99	0,62
avg	**19,22**	**50,74**	**19**	**50,3**	**1,47**	**1,36**

Table 4
Rack 3 Results comparation

	AMT-116		DHT22		Deviation	
No	**T(°C)**	**H(%)**	**T(°C)**	**H(%)**	**T (%)**	**H (%)**
1	16,3	55,1	16	52	1,84	5,63
2	16,7	55,7	17	55	1,80	1,26
3	16,2	54,8	16	54	1,23	1,46
4	17,8	58,0	17	57	4,49	1,72
5	17,1	56,9	17	57	0,58	0,18
6	16,8	56,3	17	57	1,19	1,24
7	18,2	57,1	18	55	1,10	3,68
8	17,5	56,4	17	56	2,86	0,71
9	16,4	53,9	17	55	3,66	2,04
10	17,0	55,9	17	56	0,00	0,18
avg	**17**	**56,01**	**16,9**	**55,4**	**1,88**	**1,81**

Table 2, 3, and 4 show ten data of temperature and humidity reading from AMT-116 compared to DHT22. Average deviation of all data is less than 2% which means that system has generated valid data compared to manual one. It means that this study succeeds to create a valid tool to measure temperature and humidity among the racks in data center of PT Pamapersada Nusantara.

Average temperature of rack 1 is 18,2 compared to rack 2 is 19, and rack 3 is 16,9. This varying value makes sense regarding to occupancy of the racks itself. Rack number 3 is network rack whose 20% of occupancy, it has the least temperature. Followed by rack number 1, that is server rack whose 60% of occupancy, ranks 2 as the least temperature. And rack 2, that is network rack, whose 90% of occupancy, as the highest temperature. So, the occupancy of rack can affect the temperature inside. That's because devices running inside the rack generate heat.

While highest humidity goes to rack 3, whose 20% of occupancy, and the least goes to rack 1, whose 60% of occupancy. These values are considerably high and becomes warning toward IT to considerate using proper cooling system in this data center.

4. Conclusion

The following conclusion from this study are:

- Study has succeeded in making a temperature, humidity and power outage detection system in the server room with ESP8266 and DHT22
- The system successfully send telegram message containing:
  - Update temperature and humidity at 7 AM and 3 PM
  - Message notification of temperature and or humidity exceeding the threshold
  - Message notification if there is 5% increasing or decreasing values
  - Message notification if there is no AC voltage detected (power outage from power plant)
- The system outputs data are valid whose less 2% deviation compared to manual sensor
- Rack number 3 whose 20% of occupancy is the least temperature among other two. Rack occupancy affect the temperature inside
- Rack number 3 is also the highest humidity. Current level of humidity in this data center is considerably high and admin IT needs to considerate using proper cooling system.

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