Adaptive Model IoT for Monitoring in Data Centers

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ABSTRACT Currently, the temperature and humidity are important factors for the correct operation and security of electronic devices in a data center. According to the specifications of the International Computer Room Experts Association (ICREA) and the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), the temperature must oscillate between 64.4°F and 80°F equal to 18°C and 27°C. The humidity and non-condensing range must oscillate between 40% Relative Humidity (RH), 5.5°C (41.9°F) of Dew Point (DP) to 60% RH, 15°C (59°F) of DP. Considering the mentioned data, a technique, and a method, was developed for real-time measurements based on the fusion of embedded sensors and systems; with connectivity to the communication network in generation of a dedicated database, for information processing; with open software and hardware resources for temperature and humidity monitoring in a data center; located in a region of humid tropical climate, in the south-southeast of Mexico, specifically in the TECNM-Villahermosa. Presents itself the sensor fusion and embedded systems integrate the Internet of Things, to acquire and analyze data in real-time; as well as its communication system, mobile application and web Page developed for a boss of the data center to have in real-time the data generated from the analysis of the sensor network implemented. Graphs of the behavior of the information and the analysis of the data are presented; complying with the cited standards and associations.

INDEX TERMS Internet of Things, data center, ICREA, ASHRAE, TIERS I-IV, sensors, standards.

I. INTRODUCTION

A data center is a facility that hosts a set of electronic equipment (servers, routers, switches, and firewalls, as well as supporting components like backup equipment, fire suppression facilities, and air conditioning) in which all the important information from the organizations is stored and circulated, important data of sensor network of vehicles, agriculture, health, computer science, electronics, and others. Due to its characteristics, it is capable to allow the client's services continuity, regardless of the sector he/she works on. To achieve this, it is necessary to keep restricted access to the physical location of the equipment, maintain the correct temperature and humidity and have the required energy availability for the correct data processing at any time [1], avoiding

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abrupt changes in temperature and humidity specifically, to meet standards that a data center must meet to be certified ICREA [2] and ASHRAE [3].

The temperature and humidity are important factors that determine the correct functioning and integrity of the servers in a data center. If the temperature is too high can cause damage to the hardware and too low temperature can take a lot of electrical power resulting in waste of electricity [4]. On the other hand, high or little humidity contributes to potential problems such as: static electrical discharge, corrosion of metal components and water damage to equipment. Therefore it is important to keep the temperature and humidity aligned with the International Standards [5].

The ASHRAE established the environment thermal guidelines in which it is recommended that the temperature of a data center is 64.4°F to 80°F equals to 18°C to 27°C and non-condensing range must oscillate between 40% RH, that

is to say, 5.5°C (41.9°F) of DP to 60% RH, 15°C (59°F) of DP [6]. In order to maintain the temperature and humidity in the correct range the continuous monitoring of these variables [7] is required through electronic sensing devices and automatic or even manual regulation of the refrigeration systems. In this work, the regulation of the refrigeration systems is done manually, for a first stage of the project.

There are currently different studies that propose several measures to avoid the excessive energy consumption in cooling centers [8] and minimize the corrosion of electronic equipment [9] using ecological conditioning systems in combination with the external environment and low-cost of devices Internet of Things (IoT) [10]. However, there is not enough information to determine where to specifically locate the temperature and humidity monitoring sensors in the level 1 DataCenters (DC 1TIER I) [11] and in regions with a high level of humidity; dictated by DATA CENTER STANDARDS (TIERS I-IV) [12].

This document focuses on the application of the Internet of Things (IoT) to obtain, analyze climatic variables and mode of transmission in a data center type I and II, through electronic devices and integrated systems that integrate the IoT, to identify implementation strategies in the optimal monitoring system in compliance with the ICREA, ASHRA and TIERs standards [2], [3], [12]–[14]. The technological application was carried out in the data center of TECNM-Villahermosa, located in the State of Tabasco, Mexico and with around 6000 students and teachers. The data center maintains a tactically centralized telecommunications and server infrastructure that stores and manages all important institute information; with the obtaining and analysis of the information of the sensors placed inside the data center according to ICREA, we recorded the fluctuations of temperature and humidity (instrumented variables) and analysis of the data simple statistical method was used for data analysis, which consists of the stages: collection (measurement), count (computation), presentation, description and analysis; in compliance with the standards to obtain short-term certification. The application of the IoT, embedded systems, and the analysis of the data in real time obtained will support the data center administrators to the instrumentation and compliance with the standards.

In the first stage, the sensors capture the environmental values of temperature and humidity of the data center, in seven different points, strategically located after analysis of the hot and cold aisles. These values are concentrated on the Arduino board through the control software and sent every 10 seconds to the web service, responsible for storing them in a database. For the second stage, data storage began as of August 24, 2017 and continues to date counting a total of 1,414,086 records. In the presentation stage, the data collected is displayed in histograms, radial graphs and line graphs. In the description stage, the line graphs show the behavior of temperature and humidity with respect to time. The temperature values are compared with the upper limits that include the optimum value and the upper and lower
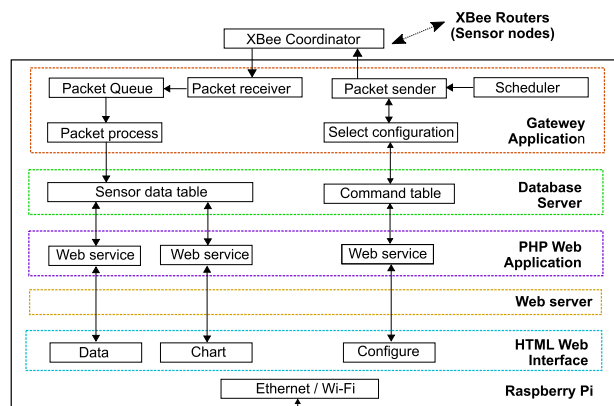

FIGURE 1. Block diagram of the base station.

value allowed by ASHRAE and by the manufacturer of the electronic components. In the analysis stage, the behavior of the study variables was analyzed and using the simple statistical method, we used the following functions: maximum value, minimum value, average, standard deviation, standard deviation, mode, among others.

The paper is organized in the following sections: the related work is mention in section II; section III explains the methodology used during the research and it describes the characteristics of the data center, standards of certification, previous studies and the importance of air conditioning; section IV presents the analyses and discusses the achieved results from the performed tests in the data center and section V present the conclusion.

II. RELATED WORK

The term IoT was coined by Kevin Ashton in 1999, the basic idea of IoT is "the pervasive presence around us of a variety of things or objects which, through unique addressing schemes, are able to interact with each other and cooperate with their neighbors to reach common goals" [15], [16].

In 2014, Sheikh Ferdoush and Xinrong Li [13] presented a design to manage a wireless sensor network with Raspberry Pi for environmental monitoring applications, in which they implement sensor network nodes using Arduino and Digi Xbee models, for wireless communication and network multi-production, used the ZigBee commercially available module, XBee Pro S2B from Digi11. The internal communication range of the XBee module is 90 meters, while the outdoor range is almost 2 miles. In the initial development, they used only one type of sensor; the sensor they used is a low-cost humidity and temperature sensor RHT03. For the base station, a single-size low power card was used the Raspberry Pi Model B, the CPU on the board is an ARM processor with 700 MHz clock speed. The CPU performance can be compared with a 300 MHz Pentium II processor and the GPU performance is similar to that of an original Xbox, it is compatible with a number of operating systems, including a distribution based on Debian Linux, Raspbian. The functional
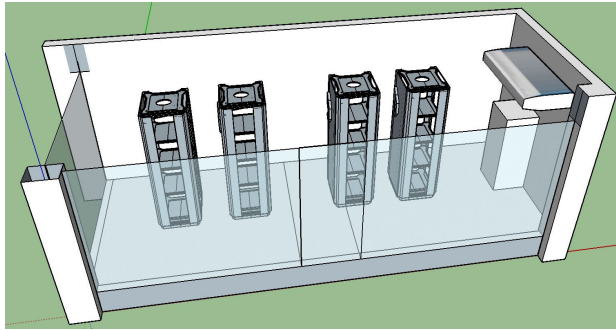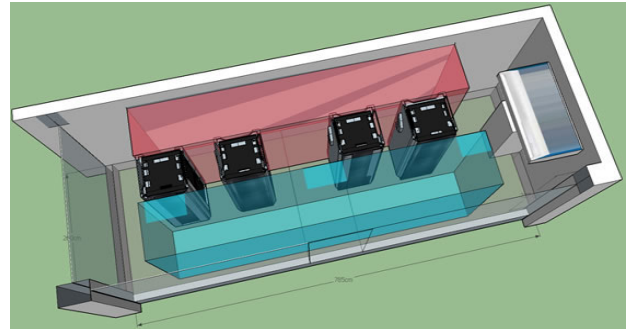
FIGURE 2. Data center distribution.

FIGURE 3. Hot aisle/cold aisle data center.

building blocks of the base station, including the application of gateway, database, and web application, are shown in Figure 1. The system has a number of attractive features, including low cost, compact, scalable, easy to customise, easy to implement and easy to maintain. As a result, it has significantly reduced the complexity of the sensor network system development Wireless.

In [5] it is monitored in real time the efficient energy and thermal management of a data center, a Wireless Sensor Network (WSN) was established in the data center to facilitate remote real-time data monitoring. Through the application of various metrics that have been developed by the IT community, this monitoring network provided the opportunity to identify performance problems that could be addressed in the redesign to improve energy efficiency and management thermal data center. As a result, the measurement and analysis of energy efficiency and thermal management metrics for the data center suggest the potential to improve performance through a change in the cooling system and the strategies of hot / cold aisle containment. It was observed that the IT racks were over cooled during more than 25% of the monitoring period. The air delivered to the shelves was often below the metrics recommended by ASHRAE for temperature, humidity ratio and often outside both limits for relative humidity. The value of the heat supply indices and return (16% and 74%, respectively) showed an inadequate separation of aisles hot/cold, therefore, hot/cold aisle containment and flow management of air can improve the overall efficiency of the data center. They detected that the cooling excessive racks raises the cooling load and decreases power efficiency, which increases the value of the efficiency of energy use.

In [17] the authors propose an ASIP model (Arduino Service Interface Programming), a new model that provides an abstraction layer of "Services" to easily add new capabilities to microcontrollers and provide support for network cards using a variety of strategies, including socket connections, bridge devices, publication-subscription messaging based on the MQTT protocol, discovery services, among others. It allows open-source implementations of code that runs on Arduino cards and client libraries in Java, Python, Racket and Erlang. ASIP allows the rapid development of
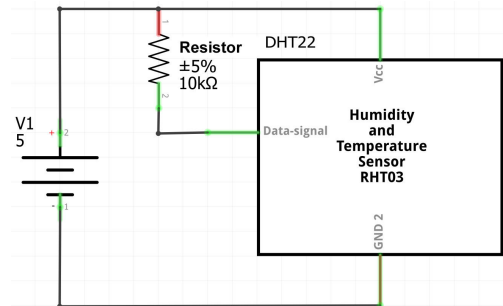

FIGURE 4. Endpoint sensor network.

non-trivial applications. In this investigation an infrastructure is presented that includes: a software architecture to manage microcontrollers as clients in a high-level language; a language for messages of exchange in a variety of channels between microcontrollers and customers; to network communication architecture that can be in serial links (USB), TCP sockets and MQTT messaging post / subscribe.

Throughout the statements made, companies have seen the potential of the Internet of Things [17] for use in optimising the production of your products originating a new paradigm of business competition called the Industrial Internet of things (IIoT). The IIoT is a concept based on its principle that the IoT but that connects the machines in the factories, which communicate and exchange information with autonomy. This ecosystem consists of many layers of hardware and software; the first established by many sensors that collect data related to processes; then these data are sent as massive data to the cloud computing or intranet using various half. Transferred data can be analysed using programs of analysis and optimisation, and use them to make efficient the different types of tasks that they make up production and service to improve the use of resources [14].

The implementation of an adaptive model supported on embedded hardware systems and software, which allows analysing the variables of climate behavior in data centers of Level I and II data, using IoT to ensure optimal operation. The working hypothesis is implementing an adaptive model of electronic components in the IoT context, we can monitor, control (manually) and optimize calefaction system behavior,
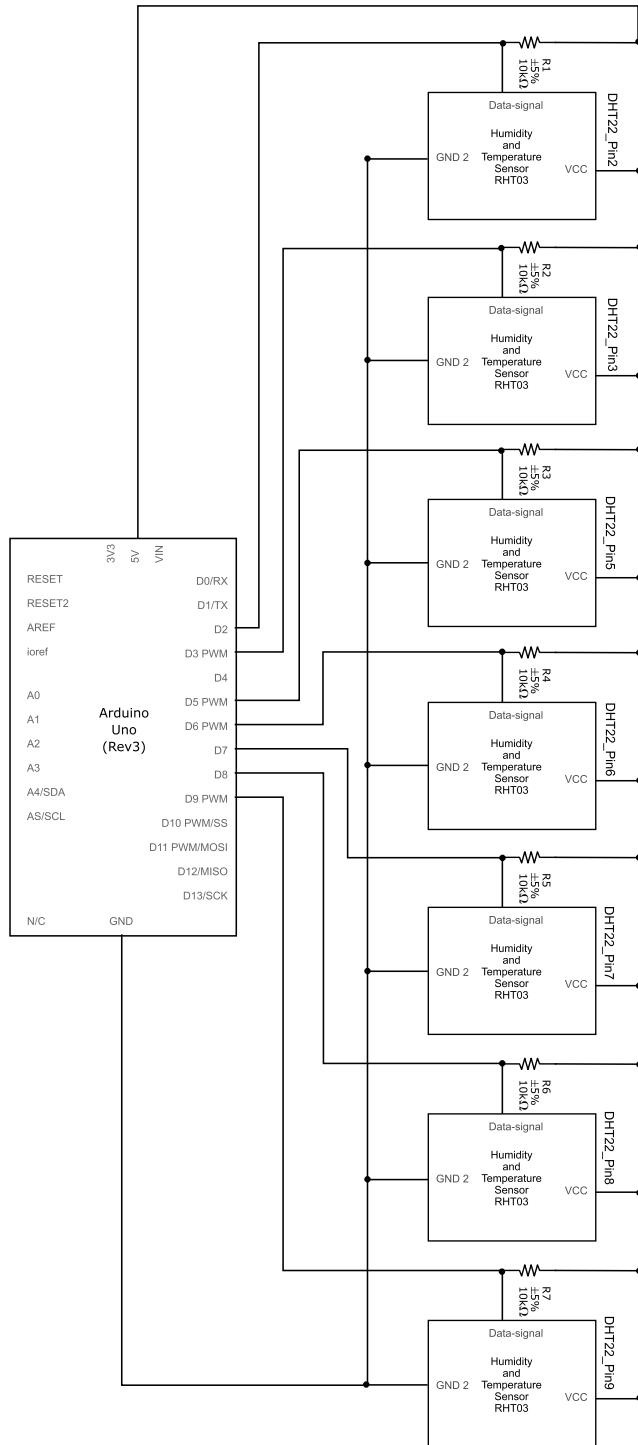
FIGURE 5. Endpoint sensor network.

applied in data centers of Level I and II data to ensure better operation.

In summary, IoT was implemented based on adaptive models, applied in data centers, which continuously monitors the temperature and humidity behavior, which results in significant benefits to the institution, organizations and consequently to its customers, achieving greater productivity and
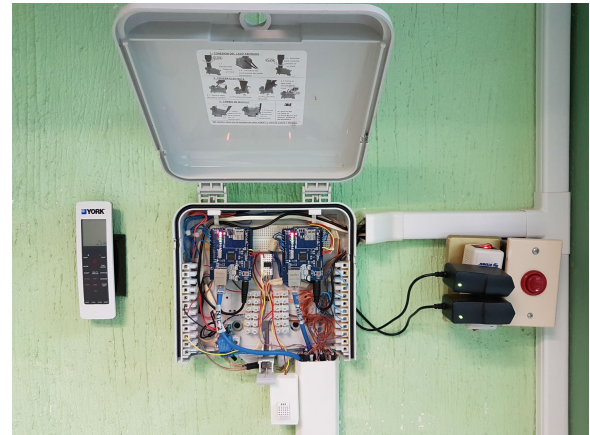

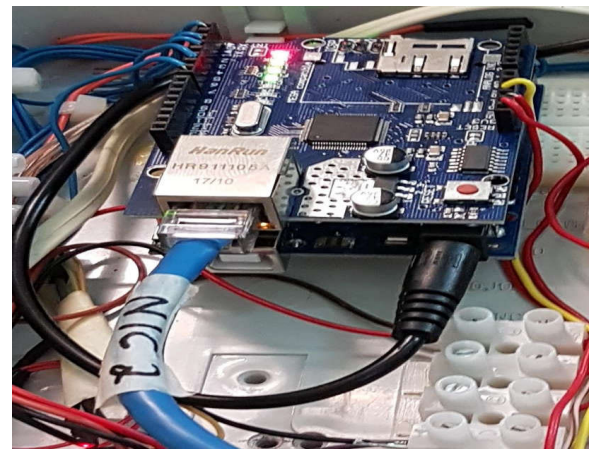**FIGURE 6.** Central of sensors.

FIGURE 7. Ethernet shield card.

avoiding losses by reducing failures in computer equipment, which will contribute to the saving of energy supplies and the preservation of natural resources.

III. METHODOLOGY OF DESIGN
A. STRUCTURAL AND DIMENSIONAL OF DATA CENTER
The data center of TECNM-Villahermosa has 25.75 feet front, 8.53 feet depth and 7.44 feet height; the total area es 219.69 square feet and the total volume is 1636.12 cubic feet.

To identify the work area, a 3D graphic representation of the data center was made using Sketch Up Pro software as shown in Figure 2, to observe the distribution of each existing element within the data center; such as racks, servers, raised the floor, dropped the roof, air conditioning, among other elements. In summary, the data center has 4 server cabinets, an air conditioner of 6000 BTUs, 1 electrical power compartment, separation from the outside with insulated glass panels, a fallen ceiling and a raised floor.

In a typical data center, IT (Information Technology) equipment is organized into rows, with a cold aisle infront, where cold air enters the equipment racks, and a hot aisle in
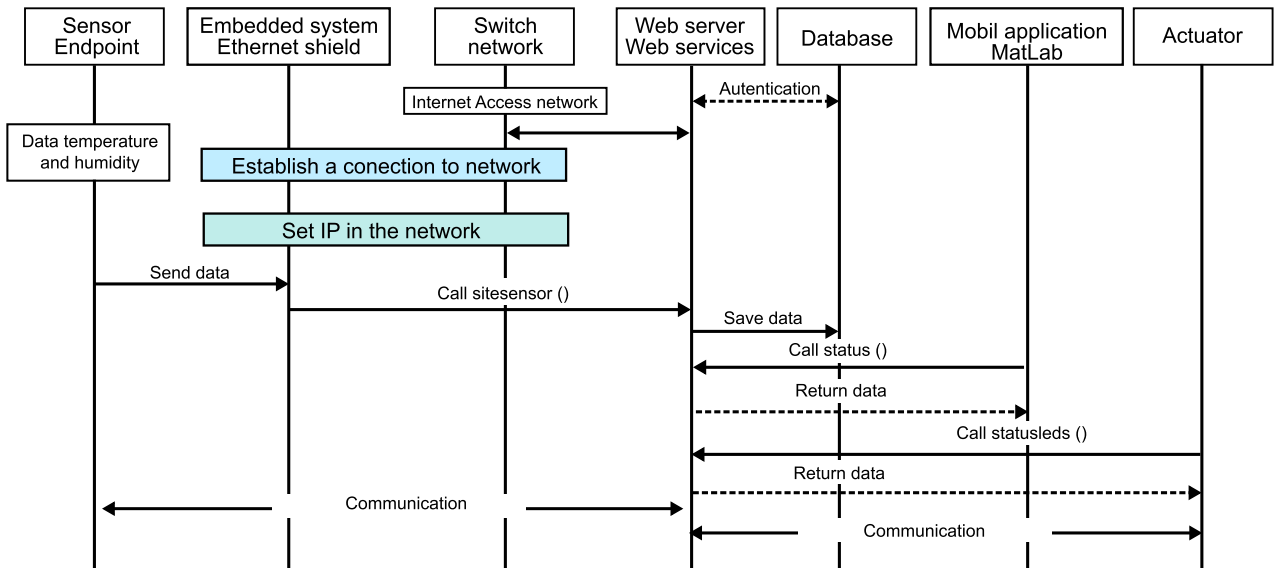
FIGURE 8. IoT scheme.

TABLE 1. Dependent and independent variables.

Dependent	Independent
Temperature, humidity, number and precision of sensor, transmission medium, distance between connected devices.	Temperature variation, room heating, rusting of the equipment, data accuracy, data lost.

TABLE 2. Experimental design of temperature and humidity.

Name of the test	IoTSoftTeam_A1
Purpose	Analyse the effect of temperature and humidity variation on data transmission media and types of sensor
Design	An experiment is performed in which they were placed: a first group of seven sensors of the same model for 48 hours and a second group of seven different model sensors for 48 hours; all the data generated from the sensors are guided to the embedded System Arduino, which is responsible for sending them to the database, in which it is consulted by a graphical user interface in Matlab to graph the temperatures and humidity in real-time.
Stimulus	During the experiment, there will be changes in the transmission medium and location of the sensors for at least four hours.
Previous test	Prior to the experiment, temperature and humidity samples will be taken at the locations established with a professional measuring instrument. This activity will establish a standard measure for comparison.
Evaluation	At the end of the experiment, the tests will be compared using the statistical technique of average, maximum and minimum applied to all the samples from a group, by time and by sensor.
Test scenario	Within the TECNM-Villa data center, the computer center is located on the first floor of the building.

back, where hot airis exhausted [18]. Figure 3 shows the cold (blue) and hot (red) areas of the data center

B. ELECTRONIC DIAGRAM

The embedded system integrates a network shield that is connected through an Unshielded Twisted Pair (UTP) to the computer network where the sensing data travel. As a protection measure, each Endpoint sensor has a resistance of a $10K\Omega$ joined between the data pin and the positive pin as observe in Figure 4, this circuit is the base cell of each sensor node of the IoT system within the data center.

The electronic schematic diagram for measuring the temperature and humidity in a data center can be seen in Figure 5. It is formed by a network of seven DHT22 sensors that constitute the components for obtaining temperature and humidity data known as point sensors final. This network is interconnected through the shielded cable (as a means of physical transmission) to the embedded system, and this by network cable (RJ45) to the database for real-time data backup and processing [19], [20].

To centralize the interconnections of the wiring of each endpoint sensors, from the embedded and energy board, a 19.68 inches tall by 13.77 inches wide NEMA box was used with the characteristic of opening and closing one of the covers to hide the components, which is represented in

a 3D design and worked as a concentrator [21] as observed in Figure 6.

C. SENSOR TESTS

Various types of sensors can be used to provide advance warnings that indicate problems caused by temperature and humidity. Although the specific quantity and type of sensors may vary according to budget, the risk of threats and the commercial cost of vulnerability, there is a minimum group and
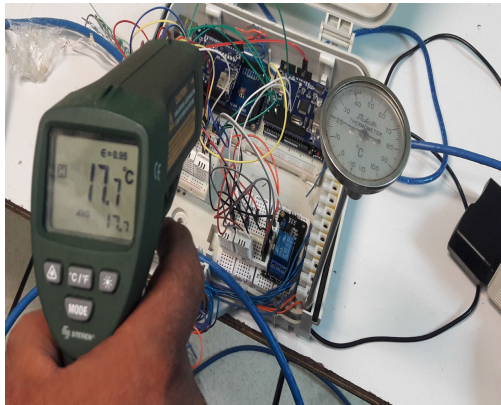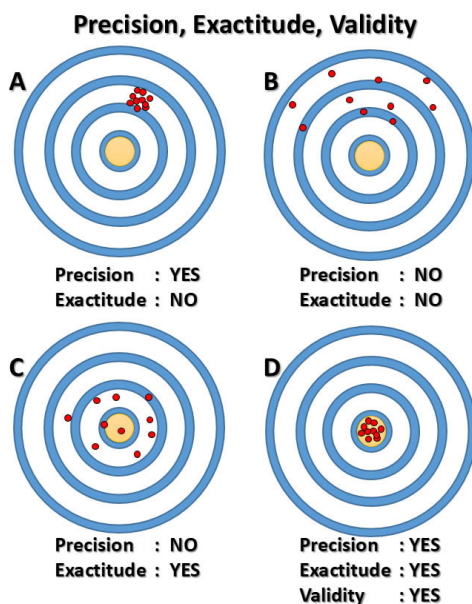
FIGURE 9. Professional infrared thermometer.

FIGURE 10. Precision, exactitude and validity.

FIGURE 11. Location of the sensors site 1.

FIGURE 12. Aisles cold and hot sensors location.

essential sensor that is reasonable for most data centers [22]. In addition to the essential sensors detailed in ASHRAE TC9.9, there are other sensors that can be considered optional according to the specific configuration of the room, the level of threats and availability requirements. The IEEE/ASHRAE guide for the ventilation and thermal management of stationary battery installations details the sensors additional and provides guidelines on best practices.

With the network of sensors installed in the Data Center, the next step is the collection and analysis of the data received. Instead of sending all sensor data directly to a central collection point, it is generally best to configure the aggregation distributed throughout the data center, with alert and notification functions in each of them. This not only eliminates the risk of single points of failure generated by the use of a single central aggregation point but also offers support for monitoring by point of use of remote servers and telecommunications rooms. The collecting devices communicate via
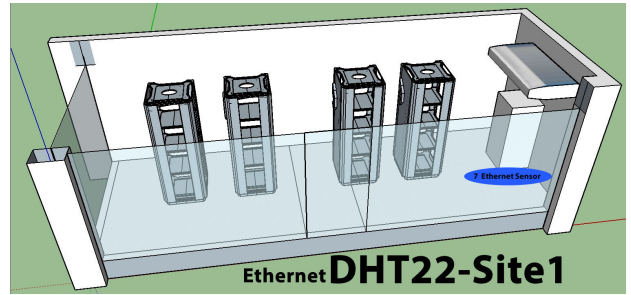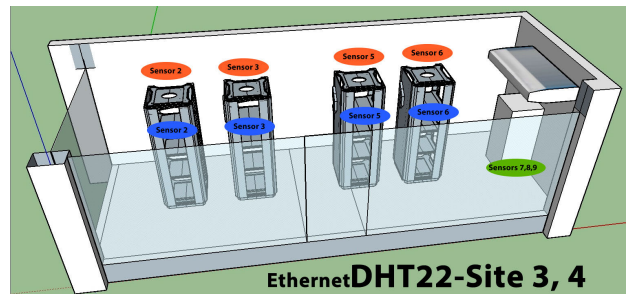
wireless communication to the hub card and through the IP network to the central monitoring system or Data Base, as shown in Figure 6.

To ensure the precision degree of resolution of the samples and the suitable means of data transfer, tests were made using the following sensor models: LM35, DHT11 and DHT22; and the following wired and wireless transmission devices: Bluetooth module HC05, WiFi (ESP8286) and Ethernet Shield in embedded Arduino Uno with shield cable [23], as shown in Figure 7.

Considering the dimensions of the data center, the communication and data transmission tests were carried out up to a distance of 49.21 feet, obtaining good results, achieving transmission without loss of data, concluding that the transmission medium is not a limiting variable. The means of data transport implemented is wireless transfer, subject to unexpected changes due to factors such as transmission interference, additional power supplies in interconnected devices; and the costs are increased by adding a controller for each measuring device with wireless communication [24].

The next phase covered the identification of the dependent and independent variables for their study (see Table 1). Table 2 lists the experimental design to analyse the variation of temperature and humidity. One of the experimental tests consists of evaluating the variable of temperature, which is independent regarding the number of the sensors, precision, and distance between the devices, and the temperature variation, room heating, data accuracy and data lost according to the scheme shown in Table 2. The second experimental test consisted of analysing the effect of humidity variation on data
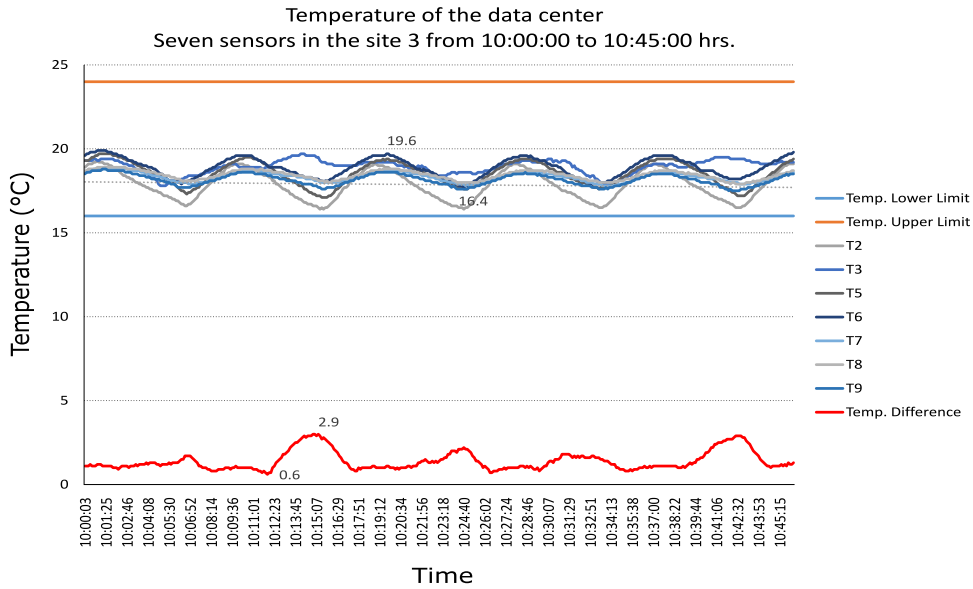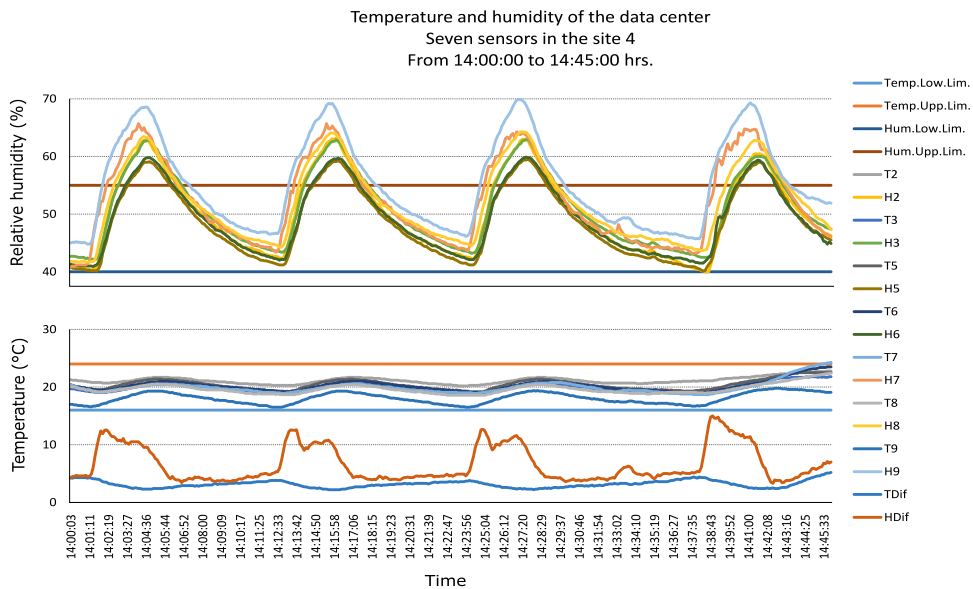
FIGURE 13. Temperature site 3.

FIGURE 14. Temperatures and humidity, site 4.

transmission medium and types of sensors according to the scheme shown in Table 2.

D. INTERNET OF THINGS APPLICATION (IoT)

The integration process of the IoT shown in Figure 8 consists in each sensor sending the obtained temperature and humidity data to the embedded system; this one calls the ''site sensor'' web service and send the values that will be saved in the database; during this process the web server establishes authentication with the database to record the sent values. From this moment, the mobile application, Matlab and the actuators can request the data through the web services

''status'' and ''status LED's'' to be presented in their respective interfaces [25], [26].

The design of system incorporates a shield-type Ethernet card, set in the embedded system Arduino Uno, to which an Unshielded Twisted Pair (UTP) is connected and has the functionality in its firmware to write an IP to communicate through the TCP/IP protocol with other network devices [27] as shown in Figure 7. The embedded system programming was structured in a modular way as indicates:

1) Sensors DHT22 initialization.
2) MAC address and IP assignment of the Ethernet shield card.

TABLE 3. Concentrate of Obtained Data.

Hour	T1	H1	T2	H2	T3	H3	T4	H4	T5	H5	T6	H6	T7	H7	Temperature Lower limit	Upper limit	Humidity Lower limit	Upper limit	TMin	TMax	TDif	HMin	HMax	HDif
00:00:04	22.8	36.1	21.5	40.4	25.4	31.5	23.4	36.2	19.9	42.2	22.5	37.5	17.5	47.4	16	24	40	55	17.5	25.4	7.9	31.5	47.4	15.9
00:00:10	22.8	35.9	21.4	40.1	25.4	31.5	23.4	36.1	19.9	42.1	22.5	37.3	17.5	47.3	16	24	40	55	17.5	25.4	7.9	31.5	47.3	15.8
00:00:17	22.8	35.8	21.5	40	25.4	31.3	23.4	36	19.9	42.1	22.5	37.2	17.5	47.3	16	24	40	55	17.5	25.4	7.9	31.3	47.3	16
00:00:24	22.8	35.7	21.4	39.8	25.4	31.3	23.4	35.9	19.9	42	22.5	37	17.5	47.3	16	24	40	55	17.5	25.4	7.9	31.3	47.3	16
00:00:31	22.7	35.5	21.4	39.5	25.4	31.1	23.4	35.8	19.9	41.8	22.6	36.9	17.4	47.4	16	24	40	55	17.4	25.4	8	31.1	47.4	16.3
00:00:38	22.7	35.3	21.4	39.4	25.4	31	23.4	35.6	19.9	41.7	22.6	36.6	17.4	47.2	16	24	40	55	17.4	25.4	8	31	47.2	16.2
00:00:45	22.7	35.2	21.4	39.3	25.4	30.8	23.4	35.4	20	41.6	22.6	36.4	17.4	47.3	16	24	40	55	17.4	25.4	8	30.8	47.3	16.5
00:00:51	22.7	35.1	21.4	39.2	25.4	30.7	23.4	35.1	20	41.5	22.6	36.2	17.3	46.9	16	24	40	55	17.3	25.4	8.1	30.7	46.9	16.2
00:00:58	22.7	35	21.4	39	25.4	30.5	23.3	34.8	20	41.2	22.7	36	17.3	47	16	24	40	55	17.3	25.4	8.1	30.5	47	16.5
00:01:05	22.6	34.8	21.4	38.9	25.4	30.4	23.3	34.7	20.1	41	22.7	35.9	17.3	46.8	16	24	40	55	17.3	25.4	8.1	30.4	46.8	16.4
00:01:12	22.6	34.8	21.4	38.8	25.4	30.3	23.3	34.5	20.2	40.7	22.7	35.7	17.3	46.7	16	24	40	55	17.3	25.4	8.1	30.3	46.7	16.4
00:01:19	22.6	34.7	21.4	38.7	25.4	30.2	23.3	34.4	20.2	40.4	22.7	35.5	17.2	46.9	16	24	40	55	17.2	25.4	8.2	30.2	46.9	16.7
00:01:26	22.6	34.6	21.4	38.5	25.4	30.1	23.2	34.4	20.2	40.1	22.8	35.4	17.2	47.8	16	24	40	55	17.2	25.4	8.2	30.1	47.8	17.7
00:01:32	22.6	34.6	21.3	38.3	25.4	30.1	23.2	34.5	20.3	40	22.8	35.2	17.2	48.5	16	24	40	55	17.2	25.4	8.2	30.1	48.5	18.4
00:01:39	22.6	34.6	21.3	38.2	25.4	30.3	23.2	34.7	20.3	40.9	22.8	35.2	17.2	49.8	16	24	40	55	17.2	25.4	8.2	30.3	49.8	19.5

3) Function that receives temperature and humidity of the endpoint sensors.
4) Function of data sending to the web service.
5) Loop cycle function.
6) Data reading.
7) Sending information to the communication center for sending to the database.
8) Visualization of data in mobile and web interface.

IV. RESULTS

To obtain the appropriate values in the temperature and humidity monitoring of a data center, seven basic magnitudes were studied: length, mass, time, electric current, thermodynamic temperature, amount of substance and luminous intensity; as well as precision measurements, exactitude, and validity.

To establish the reliability of the readings provided by the sensors, they were compared during the measurement process, using a Rochester dial thermometer and an HER-425 digital infrared thermometer, as shown in Figure 9.

The validity of the measurement results depends largely on the properties metrological instrument, determined during calibration. The Figure 10a shows that there is precision, but not accuracy, because the data obtained are close to each other, although far from the reference magnitude (the center); Figure 10b determines that there is no precision or accuracy, because the data obtained are separated from each other and far from the magnitude of reference; Figure 10c, indicates that there is no precision but accuracy, because the data obtained are separated from each other and close to the magnitude reference; Figure 10d, specifies that there are precision, accuracy and validity, because data obtained are close to each other and within the reference magnitude, thus determining the validity of the results [28].

Figure 11 shows the first test in the location of the sensor network in the data center with Ethernet communication with the Database.

In Site 3 and 4 sensors were located to measure the temperature of cold aisles (blue marks) and in hot aisles (orange marks) as shown in Figure 12; comparisons were made with three reference sensors (green mark) and it was observed
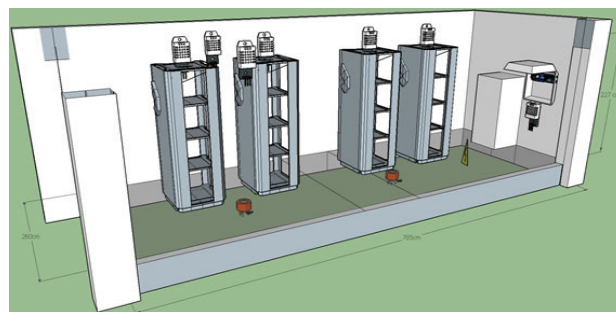

FIGURE 15. Sensors final location: Site 5.

that the temperature trend in the cold and hot aisle is valid, considering that the values obtained from all sensors in both aisles they are within the upper and lower limits as shown in Figure 13. The bottom line shows the difference between maximum temperatures and minimum obtained by the sensors at the same time.

Figure 14 shows the tendency of humidity at the same time with respect to at the temperature, while the temperature remains valid, the humidity has a lot of accuracy, but it lacks precision.

In site 5 the temperature and humidity sensors were placed correctly in compliance with the afore mentioned norms and standards as shown in Figure 15.

Table 3 shows the temperature ($T°C$) and humidity (H% RH) obtained from each sensor located in Site 5 in a given time interval; It also presents: the lower temperature limit (TTL), upper-temperature limit (TUL), lower humidity (HLL), Upper humidity limit (HUL), minimum temperature sensed (Tmin), maximum temperature sensed (Tmax), difference temperature (TDif), minimum humidity sensed (Hmin), maximum humidity sensed (Hmax) and the difference humidity (HDif). The obtained results from Site 5 are shown in Figure 16.

In summary, the results obtained from the measurements by the sensors implemented in the data center Sites we have to:

1) Six of the seven temperature sensors implemented in the data center are within the optimum range, as established by the standard. only the sensor placed in the hot
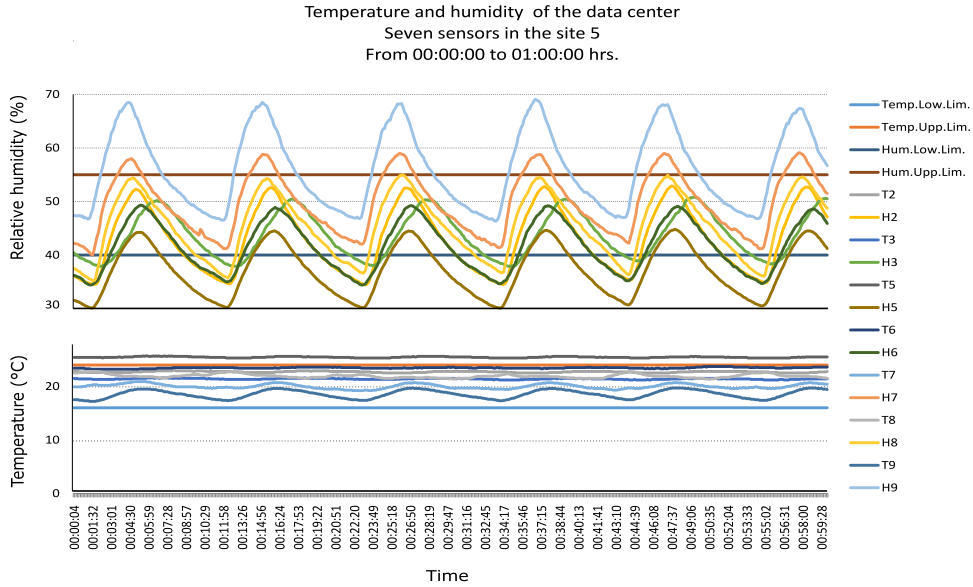
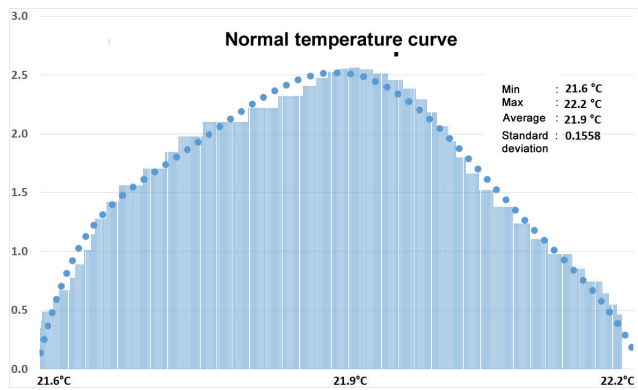**FIGURE 16.** Temperatures and humidity of site 5.

FIGURE 17. Site 5, normal temperature curve.
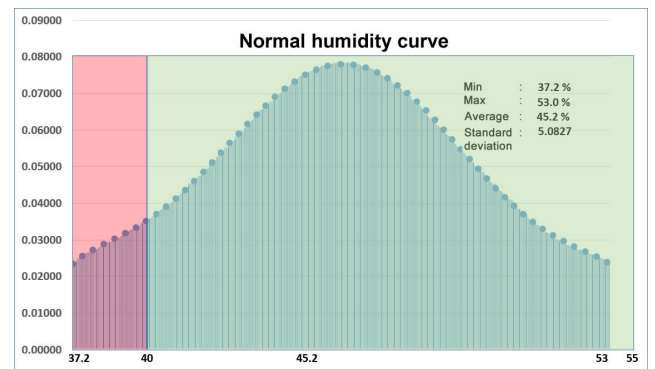

FIGURE 18. Site 5, normal humidity curve.

aisle exceeds the upper limit; however, it is necessary to be able to maintain the humidity ranges, since as the temperature increases, the humidity decreases [29].

2) Five of the seven data center humidity sensors are within the optimal range, the cold aisle sensor is above the upper limit and the hot aisle sensor is below the lower limit.

3) It is possible to raise the temperature, decrease the humidity and vice versa, making the values obtained in the cabinets conform to the optimal operating ranges.

4) In the validation phase, it was obtained that the data center needs a dehumidifier to act in accordance with the regulation and adjustment to optimum range values.

5) The normal temperature curve of the entire system, Figure 17, shows that the values they are in the optimum operating range, since the minimum value is 21.6°C, the maximum value is (22.2°C) and the average of (21.9°C), that is to say, 100% validity.

6) The normal humidity curve of the entire system, Figure 18, shows that the majority of the values are in the optimum operating range, since the maximum value it is 53%, the average of 45.2%; however, the minimum value is 37.2%, being 40% recommended.

7) It is possible to optimize the relative humidity of the entire system, reducing the temperature until the relative humidity is close to the upper limit. The normal curve of relative humidity in Figure 19 shows that most of the values are found in the optimum operating range, since the maximum value is 55%, the 47.1% average and the minimum value is 39.2%, of the 525 samples only 32 are outside the range, that is, 94% validity is achieved.

A. METHOD AND DATA ANALYSIS

The temperature and humidity data obtained are analyzed in real-time from a graphical user interface, designed in Matlab as shown in Figure 20.
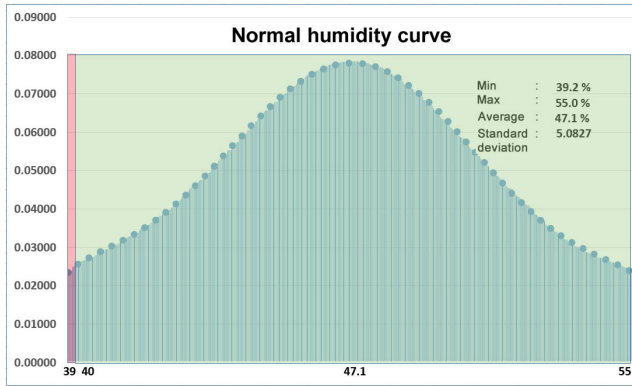
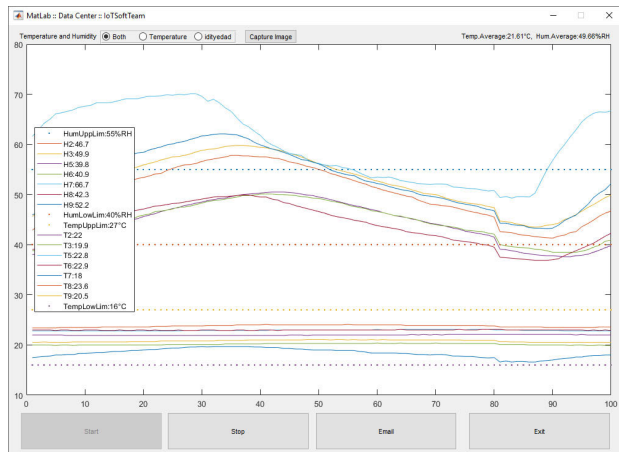**FIGURE 19.** Normal humidity curve optimized, site 5.

FIGURE 20. Real time analysis.

FIGURE 21. Visual and audible actuator.

FIGURE 22. Mobil application.

To confirm the operation of the IoT scheme a hardware interface with 4 LEDs and a speaker was designed. LEDs work as a visual alarm and change color: GREEN switches on when temperatures are within the regulation ranges; BLUE switches on when any of the temperatures is below the lower limit accepted; RED switches on when the temperature levels surpass the range: ORANGE switches on when any temperature is reading the maximum value permitted. The speaker works as an audible alarm and depending on the LEDs warning level, emits different sounds [30], [31]. The alarms alert the data center administrator to take preventive measures, as shown in Figure 21.

To have the portable IoT scheme, a mobile application was designed, as shown in Figure 22, which shows the "status" of the web service, the icons in the application change color between black, green, orange and red; and displays an alert message that becomes a visual alarm for the user. The icons used in the mobile application are seen in Figure 22 and take the following states when receiving a web service event: Black - Offline, Blue - Cold, Green - Normal, Orange - Alarm, Red - Critical.

In order to maintain constant and timely monitoring, from anywhere in the world of temperature, relative humidity, smoke and voltage, we proceeded to design and implement
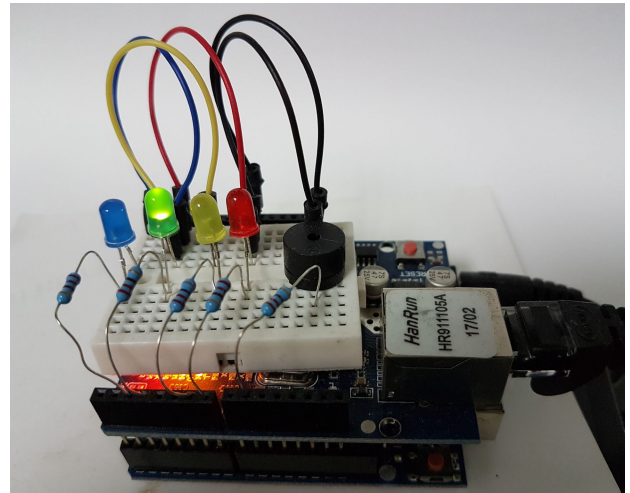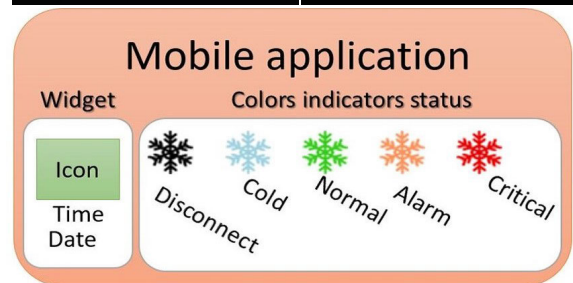
a Web Page (visit the web page http://sensores. itvillahermosa.edu.mx/), that shows both current values such as historical per second, minute, hour and day of the data stored (see Figure 23). With this interface you can observe over time, the variations of the behavior of the physical variables that are being analyzed. The temperature ratio vs. Humidity vs. Dew Point vs. Actuators; other sections included in the web interface are: temperature history, history dew point, temperature history and dew point, temperature history and humidity, humidity and dew point history and
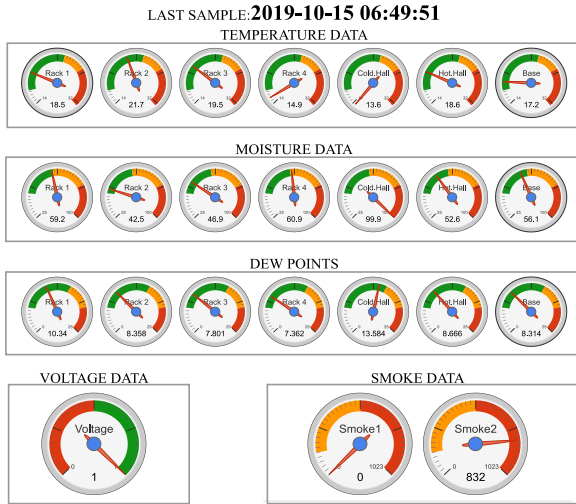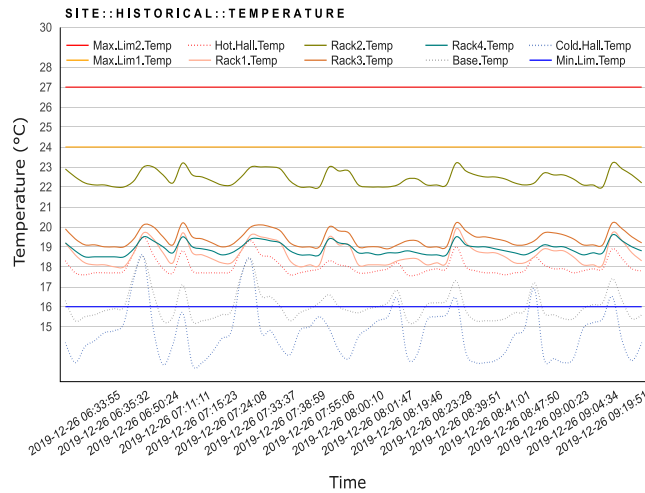
FIGURE 23. Web monitoring interface of the CPD.

FIGURE 24. Temperature decrease from 22°C to 18°C.

FIGURE 25. Dew point decrease vs temperature.

actuator history. We conclude with all the hardware and software implemented and developed, we comply with the proposed hypothesis of being able to certify the data center in reference to the aforementioned standards. This tool has allowed us to observe that with the simple opening of the doors of the cabinets, you can direct the laminar flow of the air conditioner, to modify the values of the physical variables.

The physical variables of temperature and RH directly affect another indispensable physical variable to obtain the values and determine if they conform to the norm. The mathematical expression for the calculation of DP under normal pressure conditions (1 atmosphere of pressure) is:

$$Pr = \sqrt[8]{H/100} * (112 + 0.9 * T) + (0.1 * T) - 112 \quad (1)$$

where:

- Pr = Dew Point
- T = Temperature in degrees Celsius
- H = Relative humidity (expressed as a percentage)

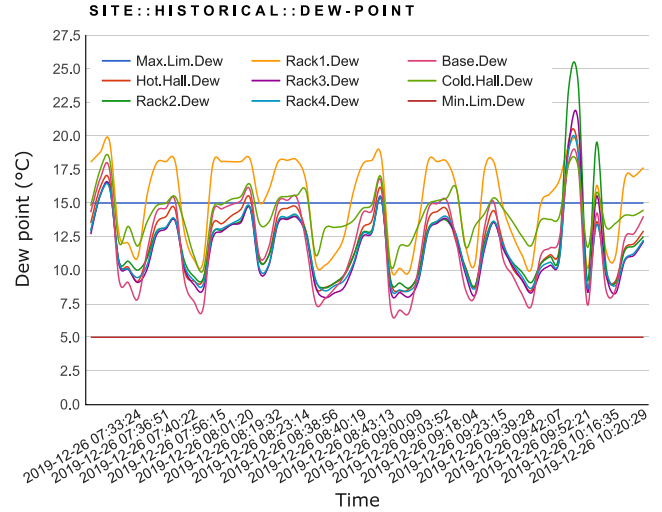Dew point or frost temperature is used to express the water vapor content in a gas or in the environment. Since the dew point temperature depends of gas pressure, the correct way to express a measurement result in dew point temperature, must include the value of the pressure at which it is measured.

The ratio of dew temperature change as a function of pressure is approximately (0.19°C/kPa (kilo pascal)) If the variation of the atmospheric pressure, on an average day it is 500 Pa (Pascal), then this pressure change would produce a change of (0.1°C). Such a change is relevant if consider dew point temperature can be measured with an uncertainty of up to ±(0.05°C).

There are applications, for example in the industry of natural gas, where the moisture content is measure at certain temperature and pressure conditions and later its value is required to others conditions (base temperature conditions and pressure) set by the buyer.

Another application where you need to calculate the dew point temperature at different values of pressure is the design of generation systems of humidity, which require initial conditions (dew point temperature and pressure), and subsequently know its value through a calculation, to other pressure values.

In figures 24 and 25, the effect of the temperature change on the Point of Dew is observed. As the Temperature value decreases the Point of Dew to be within the limits recommended by the standard.

V. CONCLUSION AND FUTURE WORK
In this work, it is presented a basic, adaptable and low-cost IOT system for monitoring in real time the temperature and humidity of a data center of level I or II, the data acquisition that are obtained can be displayed on the website in graphical form. When the temperature or humidity exceeds the limits established by the standards, the systems send notification to a mobile application. From the monitoring results, it is possible to manually control the temperature in the data center.

We also presented an analysis of the location of sensors. The results allowed identifying the appropriate location to

place the temperature and humidity monitoring sensors in a data center, such as: cold and hot aisles, upper and lower parts of the cabinets or racks, nearby places of the central connection and near the refrigeration equipment.

From the measurements obtained, the final average temperature range was 18.097°C - 21.224°C, which was found within the ASHRAE standard. On the other hand, the average humidity range 48.82%-55.71% RH is within the range rule. The development monitoring system allowed to observe that in certain periods of time the values of humidity exceed the ranges of the norm, therefore it is recommended that the institution acquire a team dehumidifier or implement a cooling system suitable for the data center.

Among the advantages with the account of our developed IOT system, the low cost feature is one of the most important factors, this is due to the commercial systems affected a greater monetary investment; Our system is easy and economical to implement in the level I and II data center. The architecture of our system is structured in layers; in which the ease of integration and modification by the user stands out, implementing the system in other scenarios. The ability to implement web services software for sending and receiving the data generated by the sensors, which can be installed on any conventional computer, these in turn, are consumed by the control cards that act as a gateway, which connect all the endpoints through a shielded cable means. This mode allows the user to access the data source from any other tool to generate reports and perform analytics. The sensor devices, cards and media used in the system, due to their characteristics, are easy to obtain and configure. This system allows adapting a wired communication medium to avoid data loss and maintain continuous service. Commercial systems implement the capacity of software and services in a proprietary manner, that is, it cannot be modified by the user, our model allows users to use and adapt web services freely.

For future work we propose:

1) Legislation and current requirements for the installation and operation of data center.
2) Monitoring of environmental variables in spaces for knowledge construction (laboratories, workshops, classrooms, data centers, among others).
3) Using artificial neural networks to predict temperature and humidity in data center.
4) Machine Learning algorithms for clustering data center variables.
5) Station for monitoring physicochemical variables in water bodies.
6) Internet of things in industry 4.0.
7) Design of protocols and open standards on the Internet of things.

PATENTS
As a result of the development of the project, the trademark was registered with the Mexican Institute of Industrial Property, Divisional Division of Administrative Processing of Trademarks. Departmental Coordination of Reception and Control of Documents. With name: SoftTeam, with File Number 1993481.

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