An IoT-Based Approach to Real-Time Conditioning and Control in a Server Room

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***Abstract*— Server room provides the needed lodging for computer network infrastructures which support data transfer and storage. Beyond network attacks and failure in connectivity, the safety of the data depends mainly on the protection of such infrastructures from breakdown as a result of environmental effects. This paper presents an implementation of an Internet-of-Thing (IoT) based system for conditioning and controlling the environmental factors in real time. A model is proposed which relates the heat index which is the major factor of negative influence in the server room, to the air temperature and humidity within the area. The hardware and software units of the system were designed and implemented to condition the server room by monitoring power outage, heat, water leakage, smoke, flame and light-out; and initiate a real-time corrective measure to keep them within the respective set thresholds. The implemented real-time control measures include: setting-off air-conditioning system whenever the heat threshold is exceeded, turning off the perimeter water supply whenever there is water-leak within the room, tripping off the system and triggering the alarm system for smoke or fire detection. Data and notifications are sent to the internet cloud, administrator's personal computer and mobile phone. The data are relayed through developed user interface platforms.**

***Keywords*—Server room, real-time, conditioning, control, IoT**

I. INTRODUCTION

Smooth business and organization's operations depend on the equipment and computer network infrastructures being housed in a server room. The major focus of administrators has been on ensuring security against network attacks and failure in connectivity, while neglecting the recurring dangers from environmental factors [1]. The effect of environmental threats on computer hardware contributes 25% of downtime in world information processing. Downtime in business transactions contributes to organizational and personal image damage, loss of customers and lower revenue. The key contributing factor to the downtime by hardware failure is heat. Temperature and humidity are however the constituent parameters which determine heat index, and should therefore be well monitored and controlled. Other factors that can also be monitored for effective conditioning of a server room include illumination, sound, vibration, water leakage, power outage, intrusion, smoke and fire[2-4].

A typical server room can be densely populated with hardware each containing infrastructure equipment generating its heat [4].

Very high heat and sudden temperature increase consequently increases humidity, while rapid temperature drop condenses moist-air water on the devices; thereby leading to higher cost in equipment replacement. Persistent high humidity level leads to condensation and fungus development, in which circuit boards experience corrosion, short-circuits and damage. Conversely, a recurring low humidity causes plastic part breakdown and electrostatic discharge which occasionally affects hardware quality and functionalities. According to a report by the University of Texas, Dallas, a standard server room should maintain its temperature between 18 – 27 ^{0}C, and its humidity between 38% and 48%. Also, other possible environmental and human factors should be well monitored and controlled [5].

The existing measures in the monitoring process of server rooms, as being documented by most literatures [1, 4, 6] are laced with inherent weaknesses. The proposed system approach in [1] was neither validated nor implemented, while the measures in [4, 6] were associated with partial coverage of threats, unpredictability, lack of real-time monitoring and control due to process and responsibility gaps, and track loss due to frequent environmental changes. A real time effective monitoring and control of the heat and other environmental parameters are therefore standard requirements for an efficient server room to avoid downtimes and failures [7-8].

Recent innovations in the applications of internet of things (IoT) devices have extended the framework of real-time solutions to various problems. Although available resources for IoT may often be limited, its devices provide a large variety of services [9 -15]. Integrating the sensing, communication, and control capabilities of the autonomous devices with the internet yields more robust research solutions. This paper develops an internet of things (IoT) based approach for effective conditioning and control of a server room. The objectives of the system are to monitor the many environmental parameters of negative influence in the server room within tolerable thresholds, and initiate a real-time corrective measure to keep them within the thresholds.

II. MATERIAL AND METHODS

The system consists of three homogenous and two heterogeneous sensing nodes, one coordinating node which also acts as a sensing node, a GPRS/GSM module for interfacing with internet and a smart device, an alarm system, an air-conditioning system and controller, a perimeter water control value, and a personal computer. The method designs and implements the hardware for the entire environmental parameters to be monitored and controlled.

A. Hardware Design

The hardware part of the system were designed by selecting devices with best comparative advantages in implementation. The architecture for the system is as shown in Fig 2.

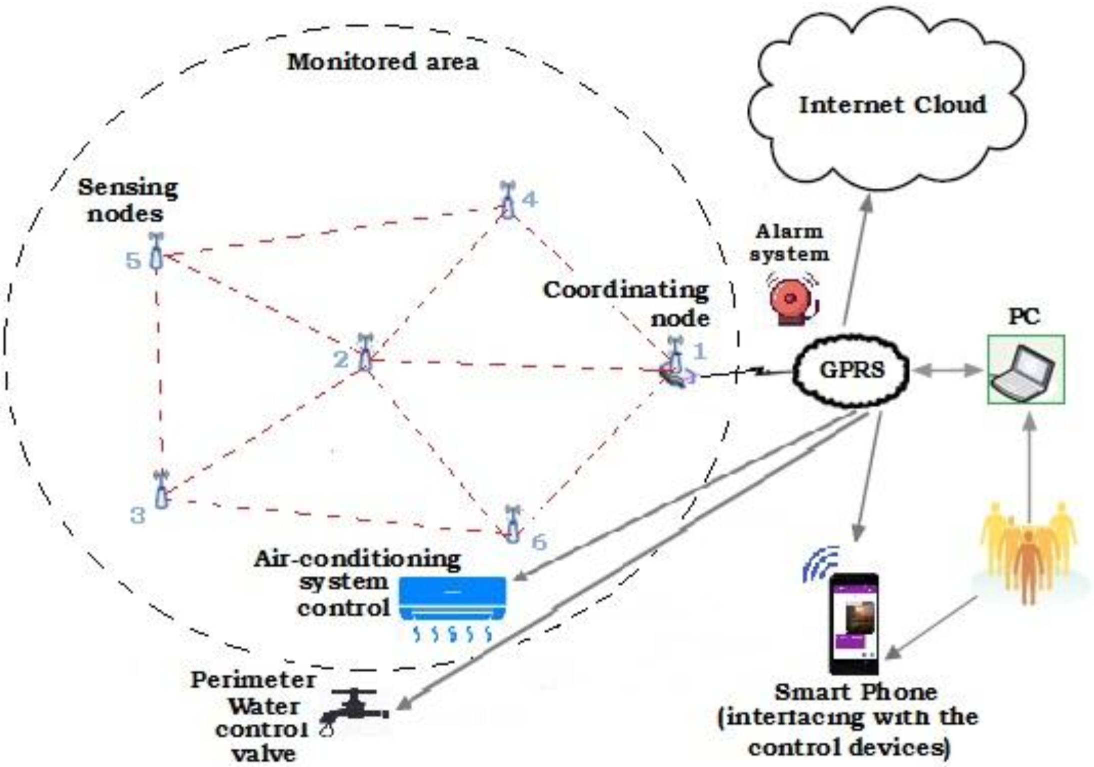


Fig.2. The System Architecture

1) Sensing Nodes: The transceiver, microcontroller, antenna and power source in the sensing nodes are the same, while the sensors relatively differentiate the homogenous nodes from the heterogenous nodes. The general block diagram for the sensing node is as shown in Fig 3(a). In all the nodes, a Digimesh 2.4GHz Xbee with a PCB antenna was designated for the transceiver communication. Arduino Uno and Nano were mixed-selected for the microcontroller unit, while each sensing node is power by a rechargeable Lithium enabled battery source. Each homogenous nodes (2, 3, 4) is designed with a Grove DHT22 Temperature/Humidity sensor to track the variation in the temperature and humidity, hence the heat index values at three different locations within the server room at each time. Node 5 was designed with MQ5 smoke sensor, Flame senor, and a Grove-GL5528 Light sensor to detect any smoke, and/or possible fire outbreak, and the illumination level for light-out condition of the server room in real time. Node 6 is designed with a Grove water sensor for detecting water leakage within the server room. The water sensor discovers the possibility of water leakage using its printed circuit board traces. The sensor has coated traces for sensor and ground signals. A 1MΩ pull-up resistor pulls the sensor line value always high, except when a drop of water shorts the two traces (sensor and ground). Some features of the Grove water sensor include high sensitivity and low power

2) Coordinating Node: The coordinating node is designed to have all the common components of the sensing nodes and a ACS712 current sensor. The block diagram for the coordinating node is as shown in Fig 3(b). The node is powered through DC regulated power source, in which the current sensor monitor its input for possibe power outage into the server room. Also, the node incorporates the GSM/GPRS module for interfacing with the internet webpage and the mobile device through short message service (sms). The node sets up the entire network and receive data from the sensing nodes and coordinates the all the interconnections among the nodes, controller unit, the GUI, and the internet.

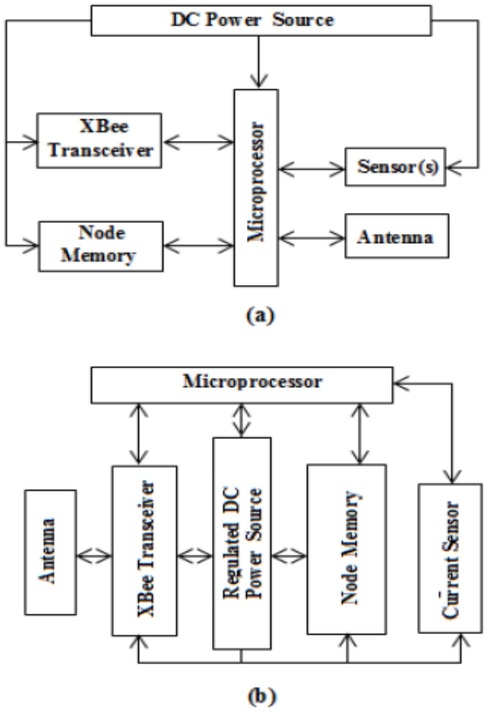


Fig.3. Block Diagram of the Nodes: (a) Sensing Node, (b) Coordinating Node

3) *Smart Device:* The system is designed with a smart phone being incorporated for remote data display and system control commands. The smart device interfaces with the controllers of the airconditioning system and the water valve through text messages and the user interface application installed on the phone.

4) *Control and Indication Devices:* The server room is being conditioned by using controller devices and measures to maintain the parameters that are being monitored within set thresholds. The water valve controls the main water supply around or through the server room, while the alarm system is the gage for smoke, fire, light-out, and power outage within the server room. The airconditioning system regulates the atmospheric heat and moisture within the server room. The air-conditioning system is notably supplied separately from the power supplying the server room, in order to ensure constant conditioning. Also, the server room is installed with an un-interrupted power supply (UPS) to extend the working period of the server room in case of short-duration power outage. The illustaration of the multiphysics approach combining this interfaces of electric currents (electromagnetic heating), heat transfer (nonisothermal flow) and the laminar flow is as shown in Fig 4.

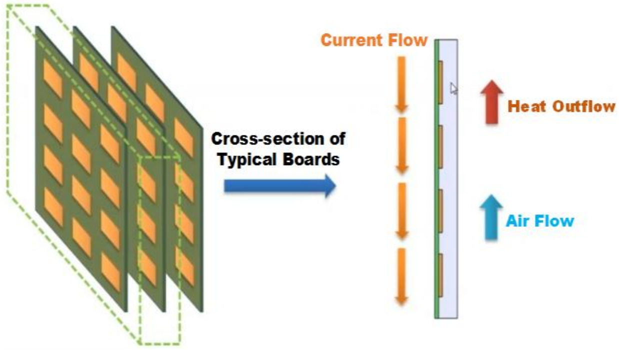


Fig.4. Cooling Model for the Hardware Boards

B. Software Design

The software design include setting up the entire network from the coordinating node, integrating the sensing nodes to the network, integrating the different controllers from the coordinator, designing the graphical user interface (GUI) for data display and records in real-time on the personal computer, and designing the user interface application (UIApp) for mobile device and internet cloud. The flowchart that itemizes the different software design for the system is as shown in Fig 5.

The algorithm that activate the nodes were implemented in C through the Arduino development environment (IDE). The GUI and UIApp were implemented using LabVIEW.

III. RESULT AND DISCUSSION

The designed units of the system were implemented, deployed and tested. The resulting system is presented in this section.

A. The Resulting Nodes

The implemented six nodes are as shown in Fig 6. Node 6 is shown in Fig 6(a) as a representative of the two heterogeneous nodes, while node 3 is shown in Fig 6(b) as one of the homogeneous nodes. The coordinating node and node 1 is as shown in Fig 6(c).

B. The Deployed System

The developed system was deployed in a server room with a standard rack as shown in Fig 7. The installed air-conditioning system and the perimeter water supply valve were connected through control units being interfaced with the coordinating node via the GPRS module.

C. User Interface and Resulting Data

The detailed parameters of the monitored factors and the status with respect to the effect on the condition of the server room are displayed or logged for the users in three modes: graphical user interface, mobile application window and the internet cloud. The GUI displaying the data for two conditions are as shown in Fig 8-9. The green indicators shows desired condition, while the red indicators shows undesired results. Also, the temperature and humidity values measured in real-time was displayed on the graphs. The data are extracted and interpreted in Table I.

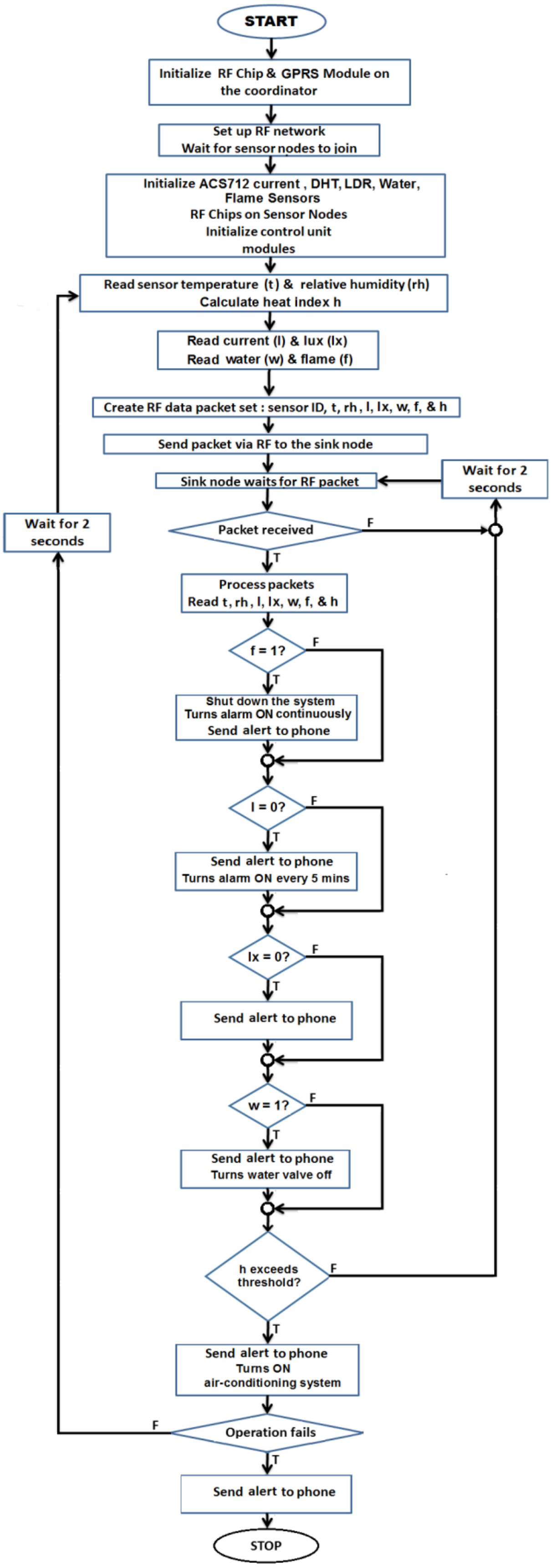
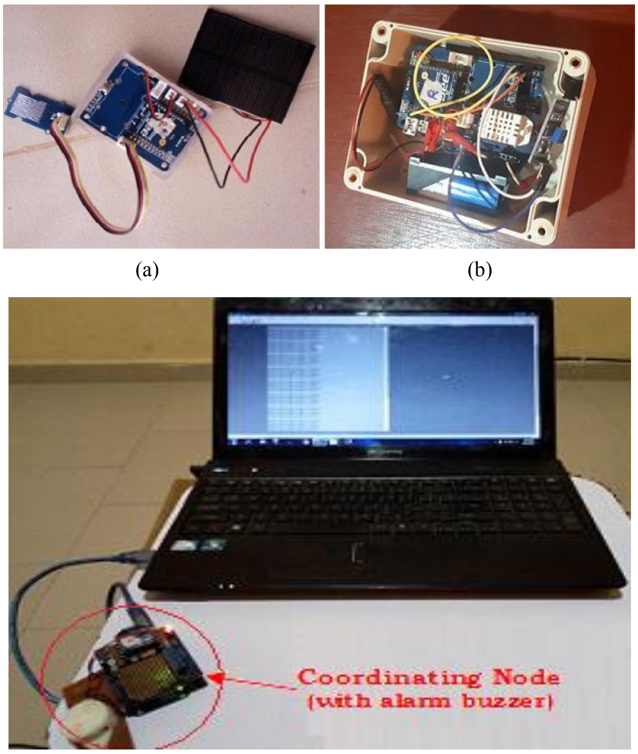


Fig.5. The Flowchart of the System Software Unit



(a) (b)

(c)

Fig.6. The Nodes: (a) Heterogeneous node 6, (b) Homogenous node 2, (c) Coordinating node, Alarm, and a PC

Fig. 7. The Server Room with the Deployed Air-conditioning Control Unit

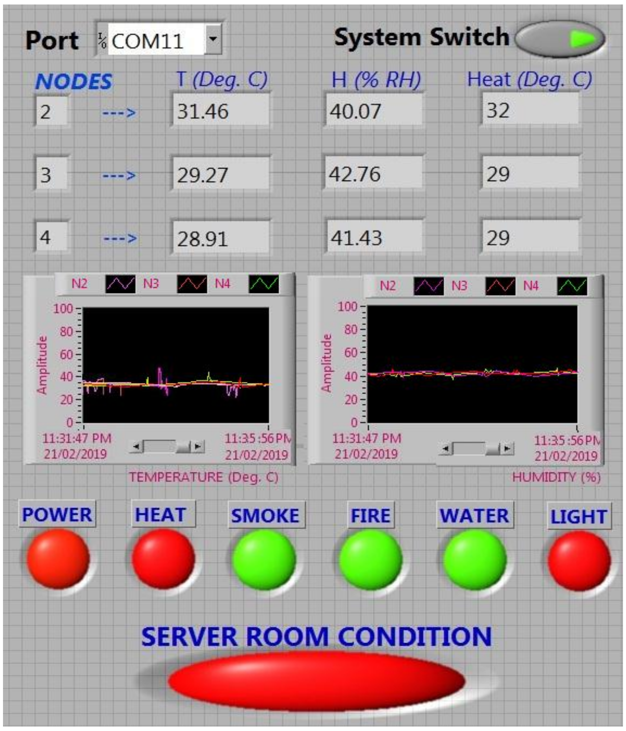


Fig.8. Graphical User Interface (GUI) indicating undesirable condition

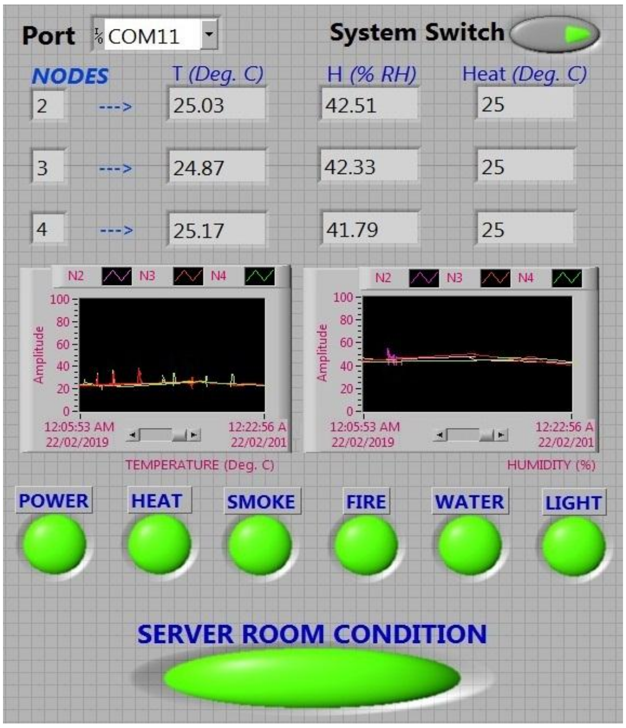


Fig.9. Graphical User Interface (GUI) indicating good condition

TABLE I. THE RESULTING DATA

Undesirable Condition in the Server Room 11:31pm on 21st February, 2019				**System Response (with messages to mobile Phone and Cloud**
Node	***Parameter***	***Value/Level***	***Threshold/ Target***	
1	Power (current)	OFF	ON	Alarm ON (repeated every 5 minutes)
2	Heat	32	27	Airconditining system activated
3	Heat	29	27	
4	Heat	29	27	
5	Smoke	OFF	OFF	-
	Fire	OFF	OFF	-
	Light	OFF	ON	Alarm ON once
6	Water-Leakage	OFF	OFF	-
Desirable Condition in the Server Room 12:05 on 22nd February, 2019				
1	Power (current)	ON	ON	-
2	Heat	25	27	-
3	Heat	25	27	-
4	Heat	25	27	-
5	Smoke	OFF	OFF	-
	Fire	OFF	OFF	
	Light	ON	ON	
6	Water-Leakage	OFF	OFF	-

At 11:31pm on 21st February, 2019, there was a power outage (as detected by node 1) which consequently resulted in light out (as detected by node 5) and increased convective heat transfer above the threshold of 27^{0}C (as detected by node 2, 3, 4) within the server room. Our system triggered the alarm system accordingly, activated the air-conditioning system, and relayed the parameters on the user interface as shown in Fig 8.

At 12:05am on 22nd February, 2019, the heat index has been conditioned to an average of 25^{0}C which was within the acceptable good server room condition. Also, power has been restored, leading to the lighting condition in the server room normalized as shown in as shown in Fig 9.

IV. CONCLUSION

An IoT system that effectively monitor and control environmental effects on a server room in real time has been developed. This study adopted a distributed approach in the design and implementation of the multi-factor conditioning system. Resourceful autonomous sensing and wireless communication devices were integrated together to build six different nodes, consisting of three homogenous sensing nodes, two heterogeneous sensing nodes, and one coordinating node which also has a sensing capability. The nodes cooperatively monitor power outage, heat condition, water leakage, smoke or fire outbreak, and light out within the monitored server room.

The control and conditioning units within the system architecture include the air-conditioning unit, water valve control unit, and alarm system. The data and conditioning status within the system are relayed to the administrator and end users through graphical user interface on PC, mobile application window, and internet cloud. The resulting data from the deployed system during two distinct conditioning periods indicate very effective control and reliable system for server rooms conditioning

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