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The Designing of a Wireless Integrated Building Infrastructure Automation System †

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Abstract: An IoT-based wireless centralized monitoring system has been proposed which is an effective way to monitor and control building systems. The system will serve the purpose of replacing an old and expensive PLC-based and wire-based management system. The system here uses several nodes of networks which are connected through wireless mesh and sending data to the centralized edge computing device (raspberry pi) through MQTT protocol. Then, the edge will update the data on the cloud using Firebase to generate a library and update the data on the cloud on a real-time basis and through the cloud, which will then allow us to monitor and control the system through the website which can be used easily and remotely on any browsing device.

Keywords: IoT; Firebase; MQTT

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1. Introduction

The Internet of Things (IoT) provides an opportunity for home appliances, wearable devices, and software applications to exchange data and interact with one another. It encompasses a vast network of interconnected devices, objects, and services that can connect, share information, and communicate seamlessly. Usage of this in existing building management systems could lead to a new era of advancement. The previously wired and PLC-based systems are hard to configure; long connections provide inaccurate values and loss of connection due to damaging of the wired network decreases reliability. Cost is another factor which restricts the use of these systems. Moreover, the present building management systems do not include major features like an electrical protection system, gas leakage detection, and lux level control. The proposed system contains all such features. It includes wireless transferring of data within the system to ensure reliability. This wireless data transmission is achieved through the implementation of an IoT-based wireless device. The system focuses on the management of a smaller load which decreases energy consumption to a great extent. It consists of a wireless mesh network, consisting of several nodes. Each node is an esp-8266 acting as a controller of the system connected to it. Each node sends data wirelessly through the mesh network to a bridge which is esp-32, chosen due to its larger memory and processing capacity. This bridge then sends the data through MQTT protocol to the main microprocessor [1], i.e., Raspberry pi. This main processor is called the Central Agent, responsible for managing the system [2]. To each node are connected different sensors to provide input values required for the controlling of lights, the fire suppression system, electrical load, motors, and ACs. This easy configuration of the system makes it user-friendly. electrical protection system integration with the building management system is a new feature which has not been included in any previous such system.

2. Literature Review

In [3], the study proposed a system capable of managing different systems such air conditioners, lightning, heaters, and safety systems like the fire system. The system used Arduino UNO as the main microcontroller taking data from the sensor and transferring it to the central agent, which is another Arduino UNO, using RF modules. The mode presented was wireless. Here the RF module has been used for wireless signal transmission, but it is not very reliable compared to other IEEE wireless communication modules. In [4], the system proposed is a building automation system which is based on Arduino hardware and the Android software. Different sensors are included in the system. The MIT App Invertor2 software has been used to develop Android blocks for the controlling Arduino components and the sensors. A demonstration model has also been developed and shown in the paper. Animation of building environment is conducted in the model so as to make the functions more understandable. It is more useful for educational and teaching purposes. In [5], the AT89C52 module is deployed for controlling and automation. The automation system has been designed for IQRA University. It mainly focuses on the switching and controlling of power input/output and is also concerned with security. In [2], the system proposed is a building management system. It deploys the ESP8266 module for controlling and automation. In this system, wired technology is used. Sensors send data to the esp8266 and this data is processed in esp8266 and updated on the Blynk app. The issue with ESP8266 as the Central Agent is that it has little memory and hence not feasible to deploy for larger buildings. In [6], the paper presents a building management system. In the project, the data from the temperature sensor and pressure sensor is sent to the Central Agent, which is Raspberry pi, using the Zigbee protocol. Zigbee is a smart solution for wireless technology but its cost makes it unfeasible to use in larger buildings. The Table 1 shows comparison between the proposed and the similar systems. Novel systems appended with the novel wireless mesh architecture makes the proposed system a success in comparison with other existing automation systems.

Table 1. System Comparison.

Characteristics	Proposed System	S.H.JASIM et al. [2]	Moiz Ahmed et al. [7]
Wireless	Yes	No	Yes
Humidity & Temperature Monitoring	Yes	Yes	Yes
Fire Detection & Alarm	Yes	Yes	No
AC Controlling	Yes	No	No
Motor Controlling	Yes	No	No
Power Monitoring	Yes	Yes	No
Electrical System & Earth Fault Protection	Yes	Yes	No
Cost Effective	Yes	No	No

3. Methodology

3.1. System Architecture

The system architecture in Figure 1 shows the interconnected nodes forming a mesh topology. Data from the sensors connected to each node are sent to the Central Agent through bridges. The Central Agent transfers the data to Firebase, where it is stored, and a web server displays it. The block diagram depicted in Figure 2 illustrates the complete data transfer in the system in a step-by-step manner. The integrated system ensures reliable and sustainable operation.

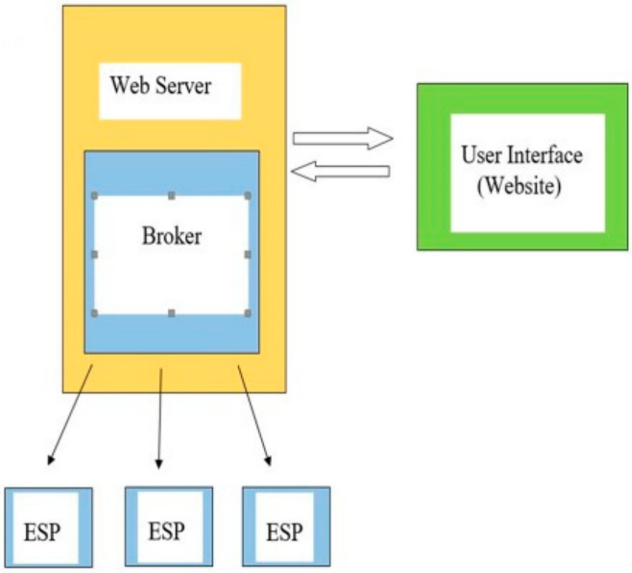

Figure 1. System Architecture.

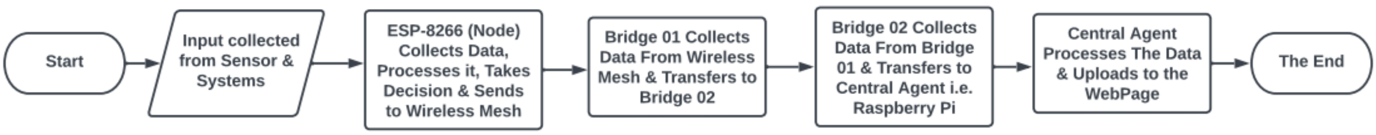

Figure 2. Data Transmission Block Diagram.

3.2. Overall Setup

3.2.1. Node A

Collects and controls data from subsystems including cooling control, temperature and humidity sensing, gas detection, and fire detection.

3.2.2. Node B

Dedicated to the water level control system, processes and transmits water height data.

3.2.3. Node C

Dedicated to the electrical power protection system, includes power monitoring, electrical power protection relay, and earth fault relay.

3.2.4. Bridge 1

Collects data from the mesh nodes and transfers it to Bridge 2.

3.2.5. Bridge 2

Acts as a bridge between the mesh network and the Central Agent (Raspberry Pi), gathers data from Bridge 1 and transmits it using MQTT protocol.

3.2.6. Central Agent (Raspberry Pi)

Receives data from the nodes via Bridge 2 and sends it to Firebase for hosting on the project website.

3.3. Mesh Network Formation

The mesh network is formed using the ESP8266 module. Node MCU collects data from sensors and sends it to the Central Agent through various paths. The painless mesh library, along with other libraries, is used for network formation and data transmission.

3.4. Sub-Systems

3.4.1. Electrical Power Monitoring

Measures voltage and current input to the building using the Pzem-004t device.

3.4.2. Electrical Power Protection System

This sub-system is designed to protect the building from any damage if any fault occurs. It includes the designing of a relay which is capable of detecting over-current faults, over and under voltage faults and earth faults. However, the earth fault system is considered separately. The protection system is smart enough to select the best characteristic curve for calculating the operating time of relay depending on the fault severity. It uses a PHxPTOC standard which is used for over-current protection. Since the protection is to be provided to single phase, if the current starts to move above the limit defined then PHxPTOC will be enabled and thus will clear the fault. A different application requires a plethora of steps which will be using different current levels and time delays. In PHxPTOC, there are three protection stages:

1. PHLPTOC: a low fault protection stage. In this case, the definite time characteristic curve is used.
2. PHHPTOC: a high fault protection stage. In this case, the IDMT characteristic curve is used which calculates the time delay based on the fault current magnitude.
3. PHIPTOC: a very high fault protection stage. In this case, the relay does not add any intentional time delay and clears the fault as soon as possible [8].

3.4.3. Earth Leakage Protection System

Designed to protect the building and individuals from harm due to earth leakage faults. It incorporates a relay capable of detecting earth leakage currents. The system employs different protection stages based on fault severity, including low earth leakage protection, high earth leakage protection, and very high earth leakage protection. The relay promptly clears the fault to mitigate risks.

3.4.4. Smoke and Gas Detector

For human safety, a gas detection system is prudent. In confined spaces, point detectors are preferred in critical areas, e.g., in offices and residential buildings, only sensors are used [7,9–11]. For gas detection, the MQ-2 sensor has been used. It is smoke-sensitive and also sensitive to the following gases • Butane • Propane • LPG • Methane • Hydrogen • Alcohol. The output of this sensor is in parts per million [2], based on ppm value it becomes easy to determine the presence of a gas type and this can be implemented as well.

3.4.5. Fire Detection System

For human safety, a fire detection system is prudent. In confined spaces, point detectors are preferred. For fire detection, a flame sensor is used which has a good range for fire detection. Once it senses the fire, it gives a signal using the LED attached to it. It has a capability to detect wire or light sources with a wavelength in the range of 760 nm to 1100 nm [12,13]. The system consists of an • IR sensor • LED indication • OPAMP • and a potentiometer. It is connected to node A's ESP8266. Real-time voltage output is provided by the thermal resistance of its analog output [1,13]. Just when fire is detected, i.e., the temperature increases to a set point, a high output signal is sent, which is digital output.

3.4.6. Temperature and Humidity Monitoring

Measures temperature and humidity using DHT21 sensor. With the increase in temperature from a set point, the air conditioner will turn on and the room will be cooled, maintaining the temperature.

3.4.7. Water Supply Control System

It is used for the continuous supply of water to the building. It includes a sensor for determining the height of the water in the main tank. If the height of the water is below the specified height, then the water motor starts and starts feeding water to the tank, thus making sure there is a continuous water supply. An IR sensor is used to obtain the water level.

3.4.8. LUX intensity Controlling System

In this system, the LUX intensity is measured and used to determine whether lightning is required, and if required then how much. It is used to curb the energy consumption by a significant amount.

3.5. User Friendly GUI

For webserver development, the cloud server has been used. The data are saved at the Central Agent. From this Central Agent the data goes to the Firebase. The Firebase is used to host a website. Figures 2 and 3 show the data transfer between the Central Agent and the Firebase and how it hosts the website.

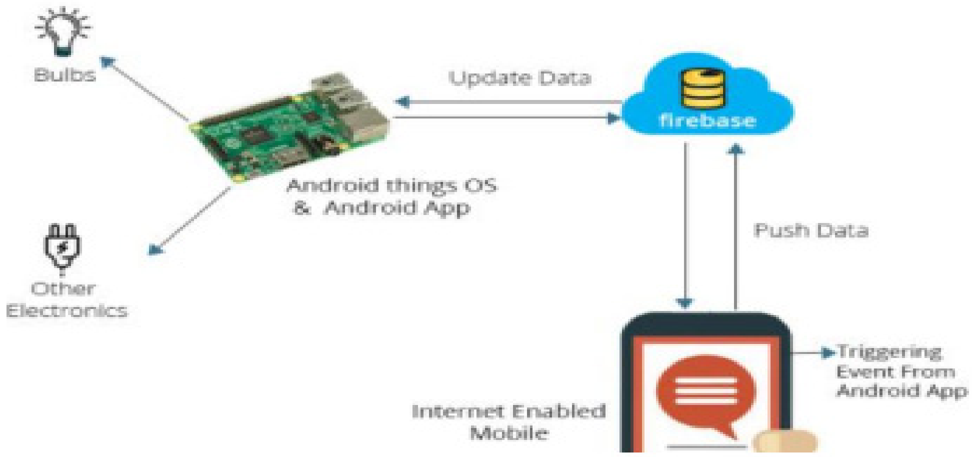

Figure 3. Data flow between Central Processor and Firebase.

4. Result

The proposed system provided the desirable outcome. The wireless transmission of data from the nodes to the main webserver was achieved. The integration of the electrical protection system with the building management system has been achieved for the first time. It was able to protect the building against any form of electrical fault, in case of any fault generated the protection system was able to isolate the faulty area, thus preventing total power failure and enhancing the system's reliability. These results were shown on the main webpage as well, as depicted in Figure 4. The fire alarm system was able to detect smoke and gas, and when exposed to these elements, the quick response of the system alarmed the users. Moreover, the temperature control system efficiently managed the temperature through the controlling of air conditioners, thus maintaining a steady-state temperature. Additionally, the water management system was tested with a jar of water, just as water level would drop below 3 inches, it would start the motor for the refilling of the tank. Another smart feature worked well, which was lux intensity control; with the day light, it turned off the lights while just as the lux level decreased, it successfully turned the lights on.

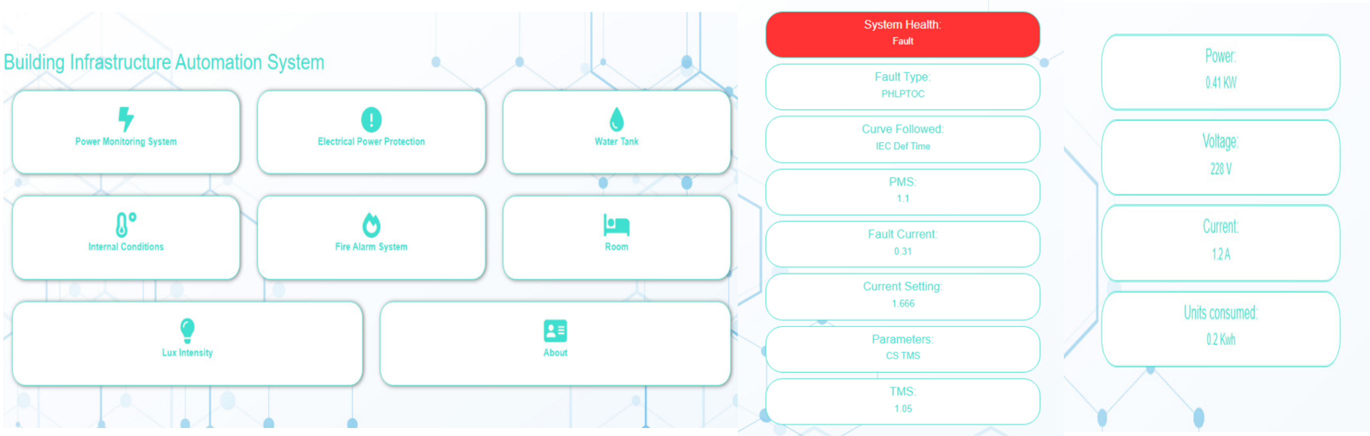

Figure 4. User-Friendly Webpage.

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