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SMART BUILDING CONTROL THROUGH INTERNET OF THINGS/MACHINE-TO-MACHINE DEVICE MANAGEMENT VIA HETEROGENEOUS WIRELESS NETWORKS

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ABSTRACT

The increasing use of wireless communication technologies has made IoT and machine-to-machine (M2M) connections crucial to a wide range of industries. Smart buildings are an excellent example of an IoT/M2M application. Issues such as a lack of a convergent solution, high costs, restricted wireless transmission range, user-unfriendly interfaces, and the inability to integrate IoT and M2M technologies. Consequently, this article suggests a more effective method for for Machine-to-Machine (M2M) and The Internet of things smart building systems: heterogeneous wireless networks that include both WSNs and MCNs. The suggested system is a cost-effective embedded system that includes Several functional actuators, sensors, and modules for Arduino and NodeMCU, ESP32CAM boards allow for data collection and control across a variety of heterogeneous communication methods like Bluetooth, Wi-Fi, and global system for Mobile (GSM). All collected data is issued to the ThingSpeak platform, allowing the building system to be monitored via the Thing Speak webpage or the UR Smarthome app. One of the researchs most important results is that it can give the server precise information with extremely little delay, allowing users to quickly control and monitor remotely the proposed system that consists of several innovative services names indoor applications(fire detection and gas leakage detection, intrusion alarm by ultrasonic, medicine reminder by RTC module, light and fan control, smart door) and outdoor applications(garden irrigation by soil moisture and DHT11, air quality, smart parking). Our free mobile application UR Smarthome, which is a local server that controls and monitors the building from a distance, is used to plan and execute all of these services that provides remote control and monitor of the building via Bluetooth/ Cellular networks and Wi-Fi access. With its customizable features, this IoT/M2M smart building system can be tailored to the demands of its users, enhancing their quality of life and safety while using less energy. In addition, identifying and lowering risks, it assists in preventing the loss of resources and human lives.

KEYWORDS— *Converged networks, heterogeneous networks (HetNets), Internet of Things (IoT)/machine-to-machine (M2M), mobile application, mobile cellular networks (MCNs), smart building, wireless sensor networks (WSNs).*

1. INTRODUCTION

The fields of cutting-edge technologies that are expanding the fastest are the Internet of Things (IoT) and machine-to-machine (M2M), where the number of linked gadgets has now much surpassed that of humans. The Internet of Things (IoT) is defined by the International Telecommunication Union (ITU) as a worldwide infrastructure for the information society that connects real and virtual objects to enable new services. on compatible information and communication technologies,both current and developing [1]. M2M, which is developing characterized as a communication that enables devices to connect with one another across a wired or wireless commnication network without the need for human involvement, is seen as a crucial component of the Internet of Things ecosystem [2]. In an M2M system, network devices are assisted in comprehending and delivering data as well as making decisions via the use of intelligent sensors, sophisticated wireless technologies, and autonomic computing software [3]. Intelligent reflecting surfaces [4], massive MIMO [5], and ambient backscattering [6] are just a few examples of the many wireless communication technologies that have recently evolved. These technologies have significantly increased IoT/M2M technologies' potential capabilities and expanding prevalence are due to the necessity of their convergence to fulfill the ever-increasing requirement of M2M and IoT. Ambient backscatter is one of the emerging wireless communication technologies for large-scale Internet of Things/machine-to-machine

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(IoT) applications. It enables data transmission without the need for power from the IoT device, facilitating device-to-device (D2D) and even multi-hop connections. An ultra-low power consumption device can transfer data by reflecting ambient radio frequency (RF) transmitters' far-field electromagnetic (EM) waves. Large-scale IoT/M2M communications may now successfully address the battery issue that low-power devices with high throughput are facing [7], [8], and [9]. Heterogeneous networks, or HetNets, are networks that function on various wireless communication technologies, particularly mobile cellular networks (MCNs) and wireless sensor networks (WSNs). These networks have a wide range of applications in various industrial sectors, including smart cities, home automation, industry, healthcare, and agriculture[10]. Smart buildings are a new category of application that facilitates information flow throughout the building and offers advanced functionalities and services. These enable automated control, monitoring, management, and maintenance of the building's various subsystems and applications in an efficient and integrated manner, either locally or remotely [11]. Wireless network-based IoT/M2M smart building systems, whether MCN or WSN, are the subject of several research articles [1], [2], [3], [4], [5], [6], [7], [8], [9], which will be covered in depth in the related work section. When comparing the proposed system to all of these research works, it can be seen that the disadvantages of current building management systems are as follows: they do not combine IoT and M2M technologies; they rely solely on one or wo wireless communication technologies; their wireless transmission range is limited; their user interfaces are typically awkwardly designed; and they are very expensive. As a result, our strategy offers a low-cost, hybrid (local and remote) IoT/M2M-based smart building solution with an intuitive smartphone interface. The suggested system has multiple primary functions, including smart parking, smart lighting, fire and gas detection, garden irrigation , intrusion alarm, smart door, and smart lighting. Our mobile application called "URSmarthome", which via various HetNets, including cellular networks like 4G or 5G, global system for mobile (GSM) Bluetooth, WiFi, connectivity, , allows for the remote control and monitoring of all these services. Furthermore, all smart devices are connected by the suggested system and monitoring of all these services. Furthermore, all smart devices are connected by the suggested system in a convenient, safe, economical, and energy-efficient manner. This article builds on our earlier research you create a prototype IoT/M2M smart building that makes use of a variety of compatible sensors, actuators, and modules in addition to the UR Smarthome App. Apart from obtaining information from the smart building, the system also retains data in a cloud database, presents it graphically on the ThingSpeak website, and allows for remote monitoring using the URSmarthome app.

2. OBJECTIVE

Interest in heterogeneous wireless networks is rising in a number of domains, such as IoT/M2M smart building automation, which in recent years has grown at a very rapid speed. Reduced maintenance costs, less energy use, comfort, peace, entertainment, safety, security, increased productivity, more livable structures, and increased resale value are the key advantages of smart buildings.IoT and M2M technology integration techniques are lacking in most current systems, despite the Internet of Things' broad application in the deployment of smart building systems. The majority of the studies that are currently available suffer from poor user interface design, high pricing, and restricted wireless range connectivity, in addition to relying solely on one or two wireless communication technologies.

The paper suggests employing heterogeneous wireless reaching the more general scenario of smart cities, thanks to the development of IoT/M2M networks to enable adaptive control of IoT/M2M devices in smart buildings, with the aim of decreasing current smart building system functions as a local server to control the building

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applications based on heterogeneous wireless and give consumers easy and efficient control over their building by selecting the right connection WSN or MCN through a user-friendly smartphone interface via the UR Smarthome App, independent of time and place. Effective and reasonably priced components are used, along with the free UR Smarthome App, to manage, monitor, and control building conditions and devices across several HetNets. The research contribution is summed up as a design for our own mobile application UR Smarthome,which uses heterogeneous wireless networks to provide adaptive control of IoT/M2M devices in smart buildings. Consequently, the following is a list of contributions that research attempt has made:

1. Examining and evaluating relevant research on IoT/M2M wireless technologies for smart building with the presented approach.
2. Creation, execution, and design of adaptive control for IoT/M2M devices combining Arduino and NodeMCU ESP32 CAM boards with inexpensive, small-sized sensors and actuators linked to HetNets in smart building systems;
3. making use of the IoT platform ThingSpeak and intelligently managing M2M devices to enable the monitoring and control of smart building systems via our free smartphone app "UR Smarthome";
4. suggesting eight cutting-edge services for smart buildings, such as garden irrigation, smart door, smart parking, smart alarm, smart gas and fire detection, smart lighting, smart medication reminders, and IAQ monitoring;
5. verifying that the suggested system works as intended in terms of performance, adaptability, control, and automation.

2.1 Literature Survey

Centered on employing a variety of sensors to monitor temperature, fire, and gas in homes, along with an LCD panel to show the sensor values, to monitor appliances over the Internet of Things. The device promptly alerts customers of gas leaks or fires by sending a text message to their mobile phone, turning on the siren, starting the spray engine, and displaying a warning on an LCD screen. The Internet of Things (IoT) has the potential to enhance security by facilitating wireless communication between sensors and transducers through a single chip via Wi-Fi. However, this system is not without its limitations, as the number of users increases and the cost of GSM increases due to SMS charges.

A prototype home system for control and monitoring in that uses Bluetooth, RFID, and heterogeneous wireless networks A specialized graphical user interface (GUI) programmed in HTML allows the user to monitor the home security status and turn on and off the outdoor lights using a specific Internet protocol (IP) address provided by NodeMCU. The system is based on two components: an automation system built using an Arduino UNO that is responsible for reading and processing various types of sensor values; and an outdoor lighting system and security system using NodeMCU. But the apps that have been put in place are not only incredibly simple and unoriginal, but they also ignore the user's freedom to select their preferred wireless communication method.

IoT@HoMe, a portable automation system for smart homes based on the Internet of Things, was created and produced with NodeMCU serving as the Internet gateway and microcontroller. A variety of actuators manage home device functions in addition to utilizing many sensors to track different building conditions. The primary goal of this project is to develop a portable, cost-

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effective, and dependable system that can effortlessly monitor home conditions and control home appliances via the Internet from anywhere at any time. These studies are nevertheless limited in that they only consider the Internet as a means of communication, ignoring its unavailability or disruptions in some areas.

While the proposed M2M-based smart home system offers numerous advantages, it also presents several disadvantages. Firstly, reliance on wireless communication technologies such as 2G/3G/4G and Bluetooth introduces vulnerabilities to security breaches and interference. Hackers could potentially gain unauthorized access to the system, compromising the safety and privacy of the occupants. Additionally, the use of off-the-shelf components like Arduino UNO and inexpensive sensors may result in limitations regarding scalability and reliability. These components may not withstand long-term usage or meet the evolving needs of a smart home environment. Moreover, integrating various functionalities such as alarm systems, automatic doors, and environmental monitoring into a single system increases complexity, making troubleshooting and maintenance challenging for users without technical expertise. Furthermore, dependence on mobile applications for remote control implies reliance on smartphones, which could pose accessibility issues for individuals without compatible devices or reliable network connectivity. Lastly, the cost of implementing and maintaining a comprehensive M2M-based smart home solution may be prohibitive for some users, particularly in regions with limited resources or economic constraints. Thus, while M2M technologies offer promising advancements in home automation, addressing these disadvantages is crucial to ensuring widespread adoption and usability in diverse contexts.

3. METHODOLOGY

Lately, there has been a rapid rise in the size of automated environments, starting from the living room and progressing to the apartment, then buildings, and ultimately reaching the more general scenario of smart cities, thanks to the development of IoT/M2M networks. Limitations. to increase the range of connectivity.

3.1 Proposed System

The IoT/M2M smart building's planned HetNet architecture is made up of mobile-cellular networks and WSNs. Wireless local area networks (WLANs), like Wi-Fi (IEEE802.11x), which support small area connectivity, and wireless personal area networks (WPANs), like Bluetooth (IEEE802.15.1) and RFID, which support short-range connectivity for communication between personal devices, are examples of WSNs that address communication between devices within the building. On the other hand, mobile communication networks (MCNs) serve as the communication channel between devices within a building and those connected to the external network. They comprise wireless wide area networks (WWANs) that employ mobile telecommunications technologies, including 4G (LTE),3G [universal mobile telecommunications system (UMTS), and 2G (GSM).

3.1.1. Design of System Architecture:

The suggested architectural plan for an IoT/M2M smart building system based on HetNets gathers data and organizes it in accordance with the functions and services provided by a business using various pieces of recognized hardware. Smart parking, smart garden irrigation, smart doors, smart lighting, smart medication reminders, intrusion alarms are the primary services provided. These services are all set up to operate and observe the building from a distance via cellular networks, such as GSM, 4G, Bluetooth, and WiFi, and the UR Smarthome App. In addition to helping owners, operators, and facility managers increase asset performance and dependability, this IoT/M2M smart building infrastructure design also helps to stop the loss of resources and human lives brought on by unfavourable situations. In addition, the suggested system is inexpensive and energy-

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efficient, making it suitable for usage in a variety establishments on hotels, hospitals, offices and suggested proposed system design is seen in Fig.1.

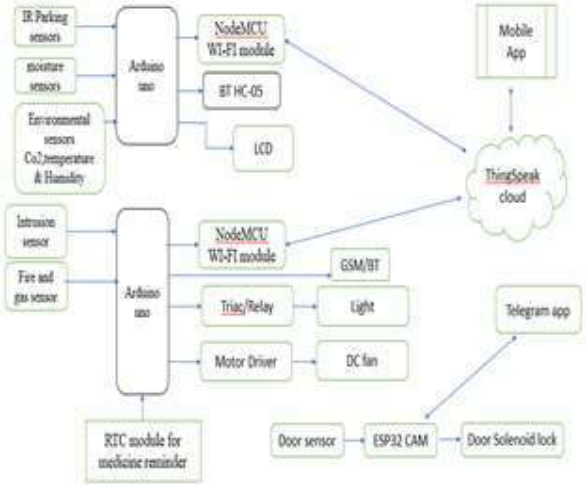

Fig.1 : Proposed System Block Diagram

3.1.2 Hardware and Software for the System

Several sensors and actuators are used in the proposed IoT/M2M smart building system, which is based on HetNets networks, to gather data and manage it in accordance with services. The Arduino microcontroller serves as the system's brain. Furthermore, for wireless communication, the NodeMCU board , ESP32 CAM and other modules like the Bluetooth HC-06, Sim800l are utilized. While the software is detailed below, the primary hardware components are mentioned below.Next, we go over the suggested system's architecture and execution.

4. Creating and deploying M2M/IOT smart building services

The simulations and real-world application of IoT/M2M smart building services are the focus of this section. Two types of primary processing units are utilized in the implementation of these services, which include NodeMCU and Arduino. The phone devices' appliances from a distance, while Arduino will be used to control the other gadgets. ESP 32 cam is used to monitor and control of the smart door application via telegram app. We go into detail about each smart application prototype in the sections that follow.

Fig. 2. Shows the various UR Smarthome App interfaces for the suggested IoT/M2M smart building.

4.1 Indoor Applications:

The indoor applications has different types of applications like as fire and gas detect-ion,smart lighting, intrusion alarm this all are implemented by using of Arduino uno, NodeMCU v3,GSM module and BT HC-05. This mention modules are used to give the data through cloud to app and app to cloud. This can be seen in Fig 3. The proposed system represents a sophisticated solution for environmental monitoring, security surveillance, and remote management. By integrating hardware components, software services, and communication technologies, the system offers a holistic approach to monitoring and managing the environment, ensuring safety, security, and efficiency in various settings such as smart homes, commercial buildings, and industrial

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facilities

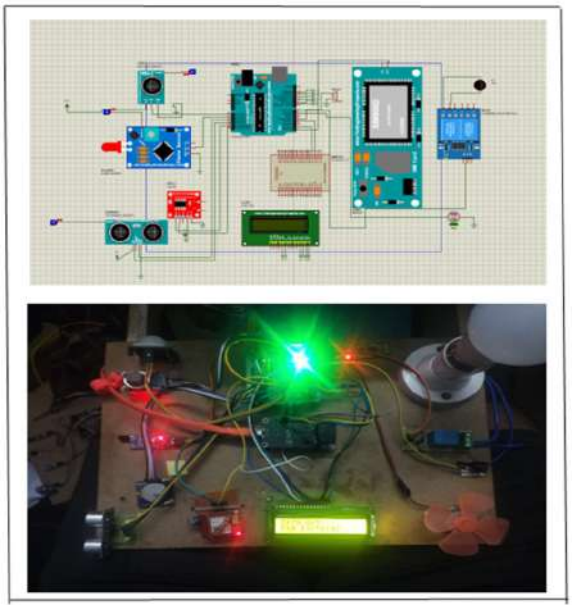

Fig. 3. Indoor Applications in Virtual and practically

Fig. 4: App interface of indoor applications

4.1.1. Systems for Intruder Alarm

People are more concerned about losing their belongings due to the rise in building robberies. Thus, the suggested service shown in Fig. 3 makes use of a GSM module, an ultrasonic sensor and a buzer to allow the building's defense against theft or attack. the ultrasonic sensor is used to record distance. When the distance is close, the GSM module sends the building owner brief messages and calls. The LCD screen displays an alarm state, buzzer sounds an alert for theft. This data can be monitored from the ThingSpeak cloud to UR Smarthome app Furthermore, as seen in Fig.4, customers can keep an eye on their building from anywhere at any time using the intrusion alarm interface in the URSmarthome app, which instantly informs users to any risk, as well as our channel on the ThingSpeak platform, which is depicted in Fig.5.

Fig.5: Intrusion alarm system monitoring on ThingSpeak

4.1.2 Intelligent Healthcare Remember

We live longer, healthier lives thanks to medicines. It can be risky, though, to take it incorrectly, to combine specific drugs, or to forget to take it at the appropriate time. These issues are resolved by the suggested IoT/M2M smart medication reminder, which notifies and reminds patients to take the recommended dosage at the appropriate time.

The GSM module, the DS3231 real-time clock module, the LCD screen, the buzzer, and the LEDs are all part of this system. To notify and remind people that it's time to take their medication, The application allows for the customization of the time slot and allows for its modification. The GSM module phones and texts the patient to remind them to take their prescription right away if they are more than 30 minutes late. The user may also remotely manage

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and control medication/pill schedules and consumption statistics by utilizing the UR Smarthome app's smart medication reminder interface, as shown in Fig. 4, which will assist them in taking their medication on time and in accordance with their treatment plan. Additionally, it enables instantaneous direct contact. The fig. 6 is shows intrusion, fire , medicine reminder by the message alerts via GSM module.

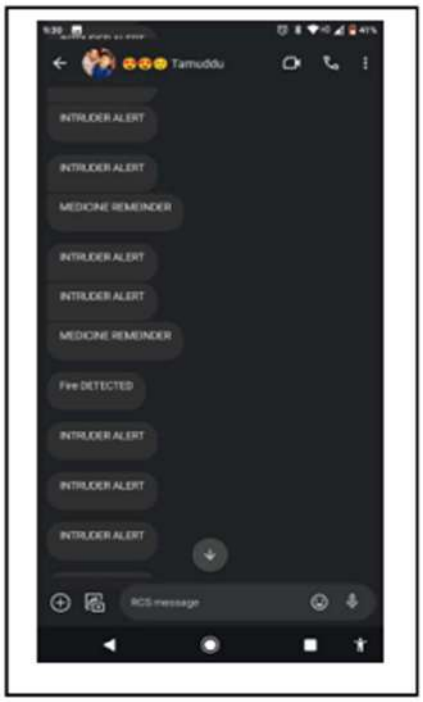

Fig.6: Intrusion, medicine reminder, fire detection messages monitoring via GSM

4.1.3 Gas and Fire Alert System

The purpose of using this suggested procedure for putting out flames and spotting gas leaks is to safeguard people and property from this can be monitored from UR Smarthome app and getting the message alerts via GSM module And as well as the data monitored via serial terminal BT via HC-05, when the fire and gas values exist from fire 0 to 1 and gas levels > 20 Then its will generate an message to presented mobile number likely we can see that interface in fig. 6 for GSM module and fig.4: is used for the fire and gas levels in App interface.

This system can be monitored through ThingSpeak cloud. These values are plotted in graph via cloud server it seen at Fig.7

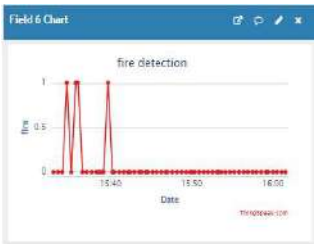

Fig.7: Fire an gas detection graph via ThingSpeak

4.2 Outdoor Applications:

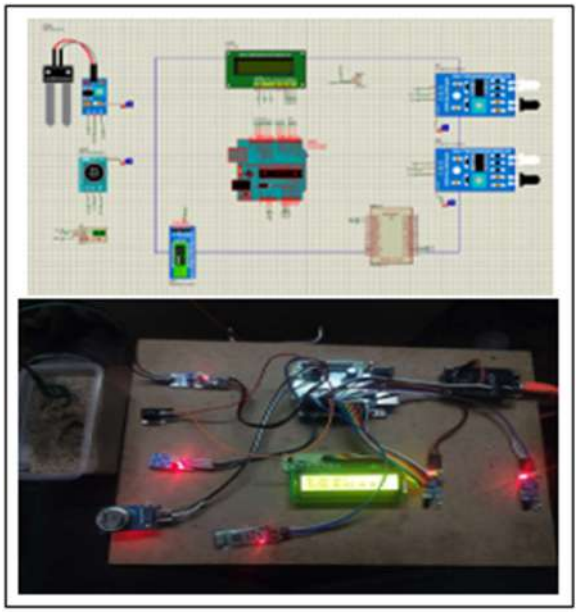

Fig. 8: Outdoor Applications in Virtual and practically.

The outdoor applications consist of different modules like gardening, temperature, humidity, parking slots alarm this all are implemented by using of Arduino uno, NodeMCUv3and BT HC-05 This mention modules are used to give the data

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through cloud to app and app to cloud. This can be seen in Fig 8.

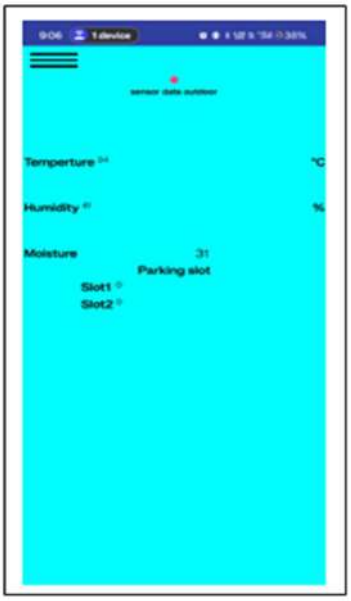

Fig.9: App interface of Outdoor applications

4.2.1 Intelligent Parking:

An IoT/M2M-based system called "smart parking" delivers data on the availability of every parking space in real time and chooses the best one. An Arduino uno microcontroller, a NodeMCUboard, infrared sensor(TCRT5000),an LCD, a buzzer components make up the system. Fig. 8 displays the suggested smart parking system prototype.

The system looks for the available parking spots using infrared sensors, determines whether any one are occupied, and updates data with cloud server every 30 seconds. As seen in Fig. 9, the UR Smarthome App's smart parking interface allows for hassle-free parking and allows you to check the availability of parking slots online from anywhere.

This all data are feed to the ThingSpeak cloud for the monitoring purpose and plots are plotted by ThingSpeak this can be seen in Fig. 10. The HC-05 is used to get the data in serial terminal BT app where monitor in certain distance around of 10 meters.

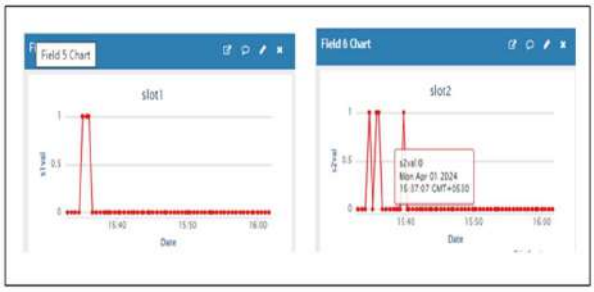

Fig. 10 Intelligent Parking graph on ThingSpeak

4.2.2 Garden Irrigation System:

The irrigation automation system for gardens that is being suggested monitors the temperature, humidity, light levels, and soil moisture of the plants with little to no operator intervention (see Fig. 8). A DHT11 sensor is used to track temperature and humidity levels in the system. A soil moisture sensor measures the percentage of soil wetness to optimize irrigation dose and prevent water waste

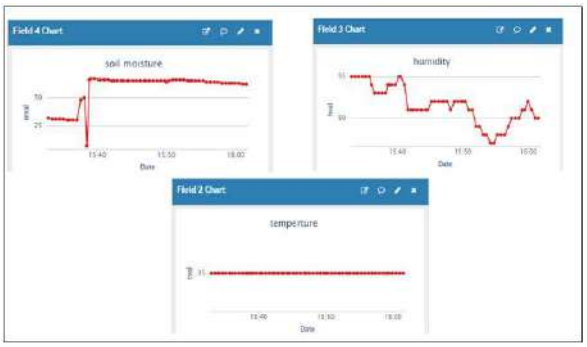

Fig.11: Garden Irrigation System graphs on ThingSpeak

Furthermore, this solution makes it easier to manage the irrigation systems and make the necessary adjustments in real-time by enabling remote control and monitoring of the garden irrigation system via the UR Smarthome app (see Fig. 9) and via our channel in ThingSpeak, which is used to view data from the proposed smart garden system remotely (see Fig. 8). Through the use of an intelligent monitoring system, this system maximizes the use of resources (water, electricity, and fertilizers) and irrigation schedule.

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4.3 Smart Door System:

The proposed system is consist of PIR se--nsor, ESP32 CAM module, solenoid lock, used an telegram bot to gather the data from ESP32 for the monitoring and controlling purpose. When the application is started from telegram bot by commanding as START it gives so some commands as 1. capture photo 2. Enable flash 3. Disable flash 4. Enable PIR 5. Disable PIR. All this are the commands interface in the telegram smart door bot. The hardware kit is sen in fig.12

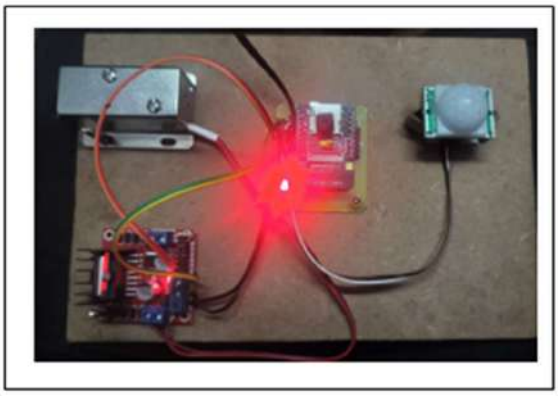

Fig. 12: Smart Door System

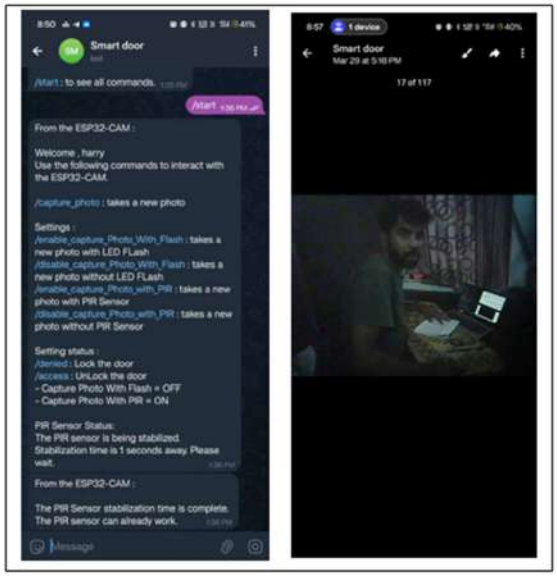

Fig. 13: Telegram Smart Door bot page interface and captured photo from ESP32CAM

When a person comes in front of PIR sensor the sensor detects a motion that motion is a trigger point to the ESP32CAM then the camera captures the person's photo and uploads it to the telegram bot account if the person is known by giving a command as access the lock will unlock within a delay of 5 seconds it will lock.

5. RESULTS AND DISCUSSION

The results of the functional testing of the prototype for the proposed IoT/M2M smart building system are discussed in this section. The system includes a number of different services and functionalities, including smart parking, garden irrigation, intrusion alarm, smart door, fire and gas detection, smart lighting, and smart medication reminder. We tested each of these services separately in Section 4, but in this section, the efficacy of the designed system is verified by testing all of its features on the final IoT/M2M smart building model, which was developed to elaborate on the performance and functionality of the suggested approach.

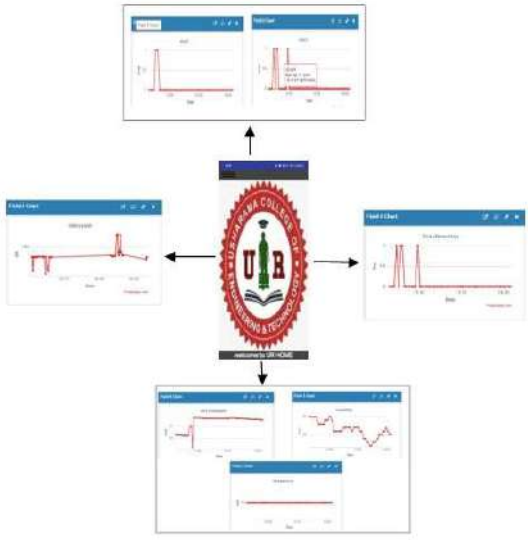

Fig. 14: Sensing results for all the Proposed System

The usage of several sensors, actuators, and shields led to a low power supply and few

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connectors. Consequently, we included the Arduino Mega board in addition to the Arduino UNO and NodeMCU to ensure flawless functionality and meet the demands of the IoT/M2M smart building. Designing and implementing an IoT/M2M smart building based on the convergence of two HetNets was our aim. WSNs functioning on Wi-Fi, Bluetooth, and MCNs (such as 4G, 5G, or GSM). Every piece of information gathered from the proposed system was transmitted to the ThingSpeak server, stored in a cloud database, and displayed across four channels. The channels are shown as real-time line graphs on the ThingSpeak website and the Raniso App. The channels receive data from the building sensors at intervals of 15 s. Figure 14.

Our efforts have yielded very satisfying results, as we were able to fulfill our aim of giving the server precise readings. Additionally, because there is extremely little latency, users can effortlessly utilize the Raniso App on their mobile phones to operate and monitor the smart building remotely from any location at any time. Using artificial intelligence to operate appliances by enabling Google Assistant voice commands is another one of this study's breakthroughs. The suggested smart building can be altered to suit the needs and tastes of the user. For instance, the user can use Google Assistant to speak commands to operate the lights, pushbuttons, Bluetooth, Wi-Fi, 4G/5G networks, or an automated system that senses input from the PIR sensor.

6. Conclusion

This paper focuses on creating a smart building paradigm for IoT and M2M based on the convergence of WSNs and networks that are mobile-cellular. The suggested system made use of open-source software (IDE, Proteus, and Telegram App and UR Smarthome) and open hardware (Arduino, NodeMCU,ESP32 Cam sensors, modules, and so on). Our research in this article demonstrates that our suggested approach provides a unique architectural design for an affordable and adaptable system that can be implemented for a range of smart IoT/M2M systems, such as smart grids, smart cities, smart retail, and so forth. For instance, the architectural design for a smart building was given in greater depth, and we recommended a number of key features and services, including smart parking, automated garden watering, intrusion alarm, smart door, fire and gas detection, smart lighting, and smart medication reminders. Through our channels on the ThingSpeak platform and our multi-platform mobile application called "UR Smarthome," which is a local server that enables remote building control via RFID, Bluetooth, and WiFi connectivity as well as cellular networks like GSM, 4G, or 5G, all of these services can be managed and observed remotely. The planned IoT/M2M smart building was created, put into practice, tested, and produced the desired outcomes. Machine learning techniques can be integrated into this smart building system to make it more sophisticated and resilient for use in future studies.

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