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Virtual Remote Control System Using Embedded Systems with Internet of Things

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ABSTRACT

There is a great deal of inconvenience in controlling digital set up boxes and the constraint of being in a physical space with the setup boxes for satellite televisions. The ways the users consume home entertainments have changed over time. Users prefer to constantly choose more comfortable ways to control their set up boxes. With over 51 million households with setup boxes in Africa, and this number is to increase, there are many instances where the decoders are to be controlled from another location where a modulated signal has been passed to. This has created a quest for virtual remote control. This study proposes a virtual remote control system with cost-effective and cheap solution for regulating a setup box from another location over a modulated signal. We propose a virtual remote system integrated with embedded system and Internet of Things (IoT) for the control of the setup boxes from various locations. The system combines an advanced virtual remote which control setup boxes via WIFI Connection using WebSocket technology and over the internet with smartphones and android devices. The proposed system has two main components. The first main part is ESP32, which controls and manages input of Wi-Fi module. The other main component is Wi-Fi module and through a Wi-Fi module a web server can be added to the module which will help in controlling of devices over Internet. The result shows that the server running on the Esp32 can manage many hardware interface modules as long as it exists on Wi-Fi network coverage.

1. INTRODUCTION

The rapid development in technology in recent years has significantly contributed to improving daily living, creating a variety of applications in spheres such as environment, health, military and security, etc. This is gradually becoming a sustainable alternative to traditional systems. This can be traced back to the deployment of ICs and the emergence of several wireless communication standards such as Bluetooth, ZigBee and Wi-Fi which provides a reliability of the system for long-term applications (Bengherbia et al., 2017).

Entertainment is the norm to relax and enjoy off work activities carried out after a given schedule. Entertainment ranges from sports, movies, cartoons, music, and much more. Scientists have continued to model how information and entertainment can be passed down via informatic devices. Television and Satellite communication systems now ease dissemination of vital information and relaxation.

The Internet of Things (IoT) uses the Web to interconnect devices. It has applications in smart homes, automobiles, farming, wellbeing care, energy-saving, shrewd city, shrewd network, and

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transportation. IoT utilizes exertion computing gadgets that have less vitality and impact on the environment. It is anticipated that by 2025, 70 billion gadgets will be associated to the web. Presently, IoT uses sensors, actuators, and controllers that are both accessible at cheaper costs and smaller sizes. The component required (i.e. ESP32) to form an IoT framework for this study is very much accessible for utilization. It is also the cheapest Wi-Fi microcontroller, with full TCP/IP stack

The ESP32 microcontrollers interface to Wi-Fi and do basic TCP/IP connecting with AT commands (ATtention commands) which helps to return the local IP address. The virtual remote control can be controlled through the Web. Indeed, on the off chance that the remote does not know the Infrared code of a few gadgets, it is conceivable to function as they learn the IR code of their Infrared farther, (Samantha et al., 2017). The domestic gadgets are as a rule utilized with infrared LEDs to send their command to turn temperature control on and off. A producer utilizes a particular convention that is diverse from other gadgets. There are numerous endeavours to control domestic machines utilizing distinctive strategies (Balducci et al., 2018; Goodridge et al., 2017; Xu et al., 2019).

The Internet of things (IoT) is a field in calculation (computer, engineering, or related specialization) which is one of numerous sought-later and presto-growing technological advancements in moment's world. According to recent exploration and findings, the future of IoT is seen to have the eventuality to be measureless.

2. LITERATURE REVIEW

2.1. Satellite Entertainment

A satellite is an electronic device made up of antennas and transponders that receive and retransmit signals, the solar panels that provide power, and the propulsion system, which includes the rockets that propel the satellite. There are various types of satellites namely communication, remote sensing, global positioning, navigation, geostationary, drone, and ground satellites amongst others. The communication satellite, which involves the satellite television service, is the focus of this study.

Bitrus (2013) Communication satellite (or ComSAT) is an artificial satellite in space for telecommunications. He added that a communication medium uses satellites as the major links between the terminals, for its efficiency in transmission, which earth stations or terminals are said to be the ends of satellite links. Communications usually take place via terminals to the terrestrial network. In his conclusion, he agreed that satellite technology has made the world a global village given information processing and dissemination.

Automation plays an important role in industrial systems. To speed up processes, most industries now control their processes and operations remotely via their integration of informatics. Satellite communications have recently entered a crucial phase of their evolution mainly motivated by the explosive growth of various internet-based applications and services, which have triggered an ever-increasing demand for broadband high-speed, heterogeneous and ultra-reliable with low-latency. SatCom (Satellite Communications) has various contributions to humankind in terms of system aspects, air interface, medium access control techniques, and networking (Goodridge et al., 2017).

2.2. IoT Consumers

There are numerous real applications of Internet of Things (Alade et al., 2017) from consumer to enterprise, to manufacturing and industrial. IoT applications span numerous verticals, including automotive, telecom, and energy. In the consumer segment, for example, smart homes that are equipped with smart thermostats, smart appliances, and connected heating, lighting, and electronic devices can be controlled remotely via computers and smartphones.

Wearable devices with software and

sensors collect and analyse user data, sending messages to other technologies about the users to make users' lives easier and more comfortable. Wearable devices are also used for public safety (e.g. by improving the first responders' response time at emergencies by providing optimized routes to a location or by tracking construction workers' or firefighters' vital signs at life-threatening sites).

In healthcare, IoT offers many benefits, including the ability to monitor patients more closely using an analysis of the data that is generated. Hospitals use IoTs to complete tasks such as inventory management for both pharmaceuticals and medical instruments.

Smart buildings can, for instance, reduce energy costs using sensors that detect how many occupants are in a room. The temperature can adjust automatically - for example, turning the air conditioner on if sensors detect a conference room is full or turning the heat down if, everyone in the office has gone home.

In farming, IoT-smart systems can help monitor, for instance, light, temperature, humidity, and soil moisture of crop fields using connected sensors. IoT is also instrumental in automating irrigation systems.

In a smart city, IoT sensors are deployed as smart streetlights and smart meters, can help alleviate traffic, conserve energy, monitor and address environmental concerns, and improve sanitation.

2.3 Smart Remote Control Technology

We review a range of different techs/apps such as WiFi, infrared, Bluetooth-based remote-controls with smart home automation and wearable devices, its challenges and opportunities.

Thabit & Mohammed (2016) dealt with temperature. The paper presented the temperature measurement and monitoring for a proposed service or industrial application with a multi-sensor/ multi-actuator system. The PIC18F450 with 40 pins was used as the main control unit. The system displays the temperature using 7 segments of LEDs because they offer better readability concerning LCD. Thermistors are used as temperature sensors due to their suitable characteristics. The Proteus software is used to aid the development of the system in terms of editing, simulation, and Printed Circuit Board (PCB) layout production. An IR remote control with 38 kHz carrier frequency subsystem is integrated with the temperature control system to perform temperature settings replacing the use of a keypad.

Wang and Wang (2017) discussed the use of smart remote-control systems for health monitoring, with a focus on the use of wireless communication technologies and mobile devices. The authors review a range of different systems and applications, including infrared, Bluetooth, Zigbee, and Wi-Fi-based remote-controls, as well as smart home automation systems and wearable devices.

Ramesh et al (2017) built an automated system via IR technology. It is cost-effective, reliable, durable and dependable as well as user-friendly. Similarly, Reddy and Sukumar (2017) proposed the Bluetooth design circuit for IoT, Wi-Fi and Bluetooth technologies are controlling home appliances by using universal remote-controller using ARM board. The circuit is designed with less complexity, security will be provided in the controlling and with low power by taking advantage of the concept of multiple data fusion technique. The interface to carry out the automation is friendly and cost-effective. The proposed system fulfilled its purpose. It is not far-fetched that wireless technology makes a good impact on our daily lives and in this case smart systems (embedded systems and IoT).

Kim and Lee (2018) examined the use of smart remote-control technologies for energy management, with a focus on the use of wireless communication technologies and mobile devices. The authors review a range of different systems and applications, including infrared, Bluetooth, Zigbee, and Wi-Fi-based remote controls, as well as smart home automation systems and wearable devices.

Al-Saggaf (2019) notes smart remote uses wireless comms and mobile devices with a range of different systems and applications, including infrared, Bluetooth, Zigbee, and Wi-Fi-based remote-control, and smart home automation and wearable devices. They also examined challenges and opportunities for future development in this field.

Li and Chen (2020) examines the use of smart remote-control technologies for intelligent transportation systems, with a focus on the use of wireless communication technologies and mobile devices. The authors review a range of different systems and applications, including infrared, Bluetooth, Zigbee, and Wi-Fi-based remote-controls, as well as smart home automation systems and wearable devices. They also discuss the challenges and opportunities for future development in this field.

Udeani and Eze (2020) proposed system which illustrates the On and Off functionality makes use of IoT and an embedded System approach. Using the application of wireless technology, it is observed that the smart system developed by the authors is worth it as it helps in the switching on and off of electric gadgets in an efficient and less burdensome way. Thus, their proposed project as stated by the authors can be used to control several appliances, thereby achieving a simple low-cost home automation system. In view of their conclusion, they stated that the remote-controlled electrical socket prototype was achieved and constructed. The system is capable of being controlled from a phone, laptop, or an internet-enabled device from a remote location. The system was constructed using Esp8266 Wi-Fi, transistors, and Solid-state relays. This system aims to reduce the number of fire outbreaks and shocks caused by the overuse of electricity. On that note, the system can be used to remotely switch on or off an electric socket when not in use or when the user is not in proximity to physical access.

Smart home systems help to better our daily lives, as the authors, Dar and Jamwal (Reeve et al., 2022) built a smart system to automate our homes. However, the system built requires huge cost to get the appliances and tools needed to develop and design the system (Ang et al., 2019; Mao et al., 2018; Sandhya et al., 2023).

Bhagat et al., (2023) built a controller-based system for electrical appliances. Their proposed system made use of Bluetooth connectivity. However, the Bluetooth connectivity should be of a wide bandwidth for fast connection within a distant range for the automated home. Furthermore, building such a system requires a developer with experience in building embedded systems.

2.3 Study Motivation

The study thus is motivated by:

1. **Physical Damage**: As the remote control is built to be physical, it is easily prone or open to accidents as cases such as sitting on the remote unknowingly as well as mistakenly dropping it on the floor can cause damage, and in turn lead to extra cost for repair or possibly a replacement.
2. **The buttons don't respond or work overtime**: Due to overuse of the remote control, the buttons become soft and the target being pressed/clicked might not respond/work at all.
3. **Slow Responsiveness**: Button-made remote control can over time slow down in terms of responsiveness. This might be due to the case above and where battery becomes overused over time, leading to a replacement which in turn leads to additional/extra cost.

This study proposes an IoT-based virtual remote that can help cover the shortcomings of the physically made remote control. Here, the smart virtual remote is installed on a smart Android mobile phone, which can be used to control/tune the channels the individual desires. To this end, this study aspires to build/develop a smart virtual remote for satellite Television service using the mighty Internet of Things. As part of the contributions of this paper, the proposed system showcases the integration of IoT technologies with device control, highlighting the potential of IoT in transforming traditional device control mechanisms. In addition, the user interface design of the web application provides a user-friendly and intuitive platform for controlling devices remotely. The design principles and best practices employed can contribute to the development of user-centric interfaces in the IoT domain.

3. *MATERIALS AND METHODS*

3.1. The Proposed IoT-Virtual Remote

The proposed system seeks to enhance the existing design through several key upgrades to the hardware and networking components. The microcontroller will be upgraded to an ESP32, a more advanced chip with increased memory (520KB SRAM), processing power (240MHz), integrated WiFi, and dual-core capability. This provides greater flexibility for implementing more complex remote-control features beyond basic TV functions, like advanced menus, program guides, DVR controls, etc (Ang et al., 2019; Bartoletti & Pompianu, 2017; Dela Cruz et al., 2014; Eissa (SIEEE), 2015).

Two-way IR communication will be enabled using an IR transmitter along with the existing IR LEDs. The IR transmitter will allow sending control signals from the ESP32 to the cable box, while the IR LEDs continue to send signals from the ESP32 based on the smartphone app inputs. This two-way IR signal is essential for supporting interactive cable TV feats like video on demand, voice commands, search, and parental controls (Abdallah et al., 2020; Al-Turjman et al., 2019; Mao et al., 2018).

The network protocol is upgraded from WiFi to WebSocket – to enable fast, real-time, bidirectional communication on wifi between the mobile app and the ESP32. This allows lower latency control inputs for a smoother user experience. WebSocket also support multiple simultaneous connections, allowing for future multi-user capacity where multiple smartphones could control the same cable box (Kim et al., 2020; Nallaperuma et al., 2019; Naveen kumar et al., 2017).

These planned upgrades, together with the microcontroller processing and memory, IR transmit capability, and WebSocket networking optimize the performance, responsiveness, and functionality of virtual cable TV remote system. It addresses key limitations of the existing design using iterative prototyping to enable incremental developing and validating of enhancements to meet the expanded requirements for an advanced IoT-based cable remote control system (Alakbarov & Hashimov, 2018; Datta et al., 2021; Joshi et al., 2021; Pradeepa & Parveen, 2020).

3.2 Analysis of the Existing System.

The system developed in the paper "Smart-Phone Application as TV Remote Controller" by Zivkov et al., (2012) represents a well-thought-out and effective solution for utilizing smartphones as remote controllers for digital TV receivers. The system's design choices demonstrate a keen understanding of the challenges and opportunities in the field of remote-control technology. The authors' decision to create a bespoke communication protocol underscores their commitment to delivering an optimal user experience. By addressing the specific requirements of discovery and command transmission, they ensure that the system is tailored precisely to its intended purpose.

The extension of the TV software showcases a thoughtful approach to integration, emphasizing minimal disruption while maximizing functionality. This design preserves the conventional IR remote's operation, allowing users to switch seamlessly between traditional and smartphone-based control methods. Furthermore, the system's memory efficiency, with a negligible increase in memory footprint, highlights the authors' dedication to maintaining the TV's performance standards. The development of smartphone applications for both iOS and Android platforms is a testament to the system's accessibility, catering to a wide user base. The user-friendly GUI module and robust communication module exemplify the system's holistic approach to ensuring an intuitive and reliable interface for users (Zivkov et al., 2012). The data flow of the existing system is shown in Figure 1.

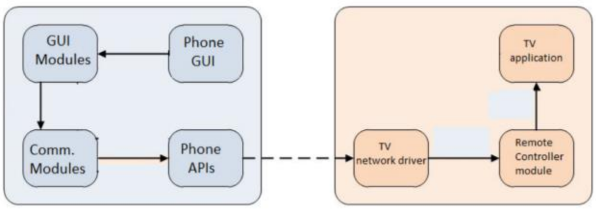

Figure 1: Data Flow of existing system (Zivkov et al., 2012)

3.3 Analysis of the Proposed System

The proposed system aims to significantly enhance the existing design through several key upgrades to the hardware and networking components. The microcontroller will be upgraded to an ESP32, a more advanced chip with increased memory (520KB SRAM), processing power (240MHz), integrated WiFi, and dual-core capability. This provides greater flexibility for implementing more complex remote-control features beyond basic TV functions, like advanced menus, program guides, DVR controls, etc.

Two-way IR communication will be enabled using an IR transmitter along with the existing IR LEDs. The IR transmitter will allow sending control signals from the ESP32 to the cable box, while the IR LEDs continue to send signals from the ESP32 based on the smartphone app inputs. This two-way IR signalling is essential for supporting interactive cable TV features like video on demand, voice commands, search, and parental controls.

The networking protocol will also be upgraded from WiFi to WebSocket. WebSocket enable fast, real-time, bidirectional communication over WiFi between the mobile app and the ESP32. This allows lower latency control inputs for a smoother user experience. WebSocket also support multiple simultaneous connections, allowing for future multi-user capacity where multiple smartphones could control the same cable box. Together, these planned upgrades to the microcontroller processing and memory, IR transmit capability, and WebSocket networking optimize the performance, responsiveness, and functionality of the virtual cable TV remote system. They address key limitations of the existing design. The iterative prototyping methodology will facilitate incrementally developing and validating these enhancements to meet the expanded requirements for an advanced IoT-based cable remote control system. Figure 2 shows the architecture of the proposed system while Figure 3 shows the dataflow of the proposed system.

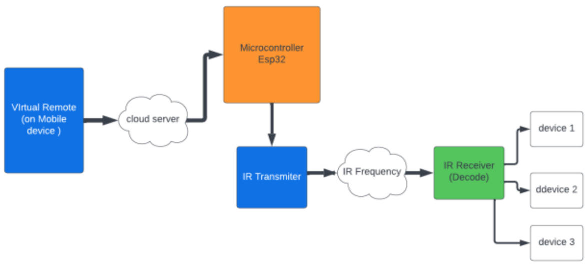

Figure 2: Architecture of the proposed system

3.3.2.2 Flow of Data of Proposed System

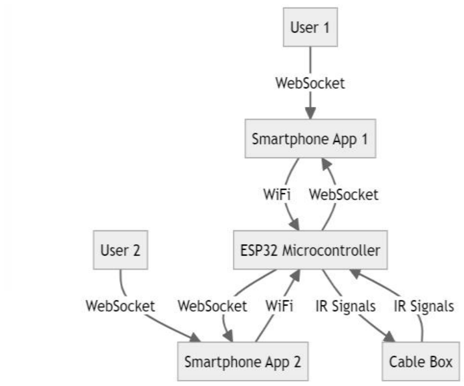

Figure 3: Dataflow of the Proposed System

4. RESULT FINDINGS & DISCUSSION

4.1. Result Findings and Discussion

Figure 4 shows the Blynk platform used to test the metrics for the proposed system.

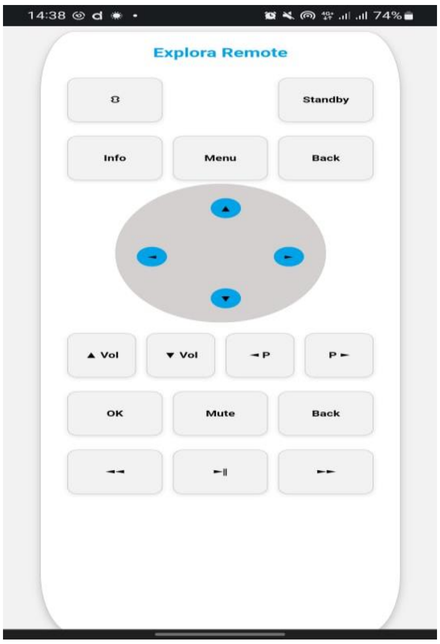

Figure 4. The virtual remote control

It involves both hardware and software (Chevalier et al., 2003; Tarafdar & Zhang, 2005), and the input design of the IoT remote-control system involves capturing user commands through the web interface and transmitting them to the ESP32 microcontroller for further processing. The PHP web interface provides a user-friendly and intuitive interface where users can easily interact with the virtual remote-control system. The following input components are considered in the design:

1. **Input Design** acquires data via ultrasonic sensor, ESP32-microcontroller and other sensors. It then lets the user input via the web app interface to set threshold feats or parameters via the following:
   Web Interface: The web interface acts as the primary user interface for the Satellite IoT remote-control system. Users can access the web interface through a web browser on their devices, enabling them to control various devices remotely. The interface presents a visually appealing and organized layout, displaying a list of available devices and corresponding functions for control.
   Function Selection: Once a device is selected, users can choose specific functions associated with the selected device. For instance, if a television is chosen, functions such as power on/off, volume control, channel selection, and input source selection can be accessed. The function selection feature offers users granular control over their devices, replicating the capabilities of a physical remote control.
   Command Transmission: After users select a device/function, corresponding command is transmitted from the web interface to the ESP32 microcontroller for further processing. The microcontroller acts as the bridge between the web interface and the physical devices. It receives the command and performs the necessary translation and encoding to convert it into an infrared (IR) signal.
2. **Output Design** provide meaningful data to the users via the web app. The output design of the remote-control system involves transmit the translated IR signals to the targeted devices for control. The ESP32 microcontroller plays a central role in processing the received commands and transmitting them through IR transmitters. The following output components are considered in the de-

sign:**ESP32-Controller** receives commands from the web interface and performs the necessary processing. It acts as a control hub of the system, managing translation and transmission of commands to the targeted devices. It communicates with an IR transmitter to convert the commands into appropriate IR signals.IR Transmitters is used to send the translated commands as IR signals. These transmitters emit the corresponding IR codes that are recognized by the targeted devices. Emitting appropriate IR, system effectively mimics the functionality of traditional remote-controls.Device Control: The transmitted IR is received by the targeted devices, such as televisions or air conditioners. These devices interpret the received IR signals as commands and perform the desired functions accordingly. For example, if a user selects the volume-up function, the IR signal will be received by the television, causing an increase in volume (Buhalis & Amaranggana, 2015; Ju et al., 2020; Suleiman & Reza, 2019; Xu et al., 2019; Zhang et al., 2015).

4.2 Algorithm

Algorithm is crucial for converting all IR codes from the IR sensor reader into useful data (i.e From actual establishing a local connection to executing the IR corresponding code,)

Step-1: Initialization involves setting up the necessary components of the system. It connects to the Wi-Fi network to enable communication between the interface and the ESP32. Also, the IR transmitters and receivers are initialized to establish the communication link with the targeted devices. Lastly, connection to the database is established to store command history and other relevant data (Dwivedi et al., 2019; Kapadia & Vaghela, 2016).

Step-2: Main Loop is responsible for continuously listening for user commands through the web interface and executing the corresponding actions; (a) to listen for commands: System awaits input from the web interface, where users select a device and function they want to control remotely, (b) Translating the user command: Once the user command is received, the system maps the selected device and function to appropriate IR code. It ensures that the transmitted IR signal corresponds to the desired action, (c) Transmit signal: System translated IR via appropriate IR transmitter so as to mimic various functions of physical remote control by emitting necessary IR codes recognized by the device, and lastly, (d) Update command history: The system updates the command history in the database. This step involves storing information such as the user command, the selected device and function, and a timestamp. It enables the system to keep track of user interactions and provides a historical record of executed commands.

Step-3: Termination: Device ends if and when the system is shut down or encounters an error condition that requires termination. The actual implementation may involve additional considerations such as error handling, input validation, and security measures to ensure system's reliability and robustness.

The performance table is shown in Table 1.

Table 1: Performance Table

Performance Metric	**Evaluation Method**	**Benchmark/ Requirement**	**Result/ Measurement**	**Pass/ Fail**
Response Time	User interaction	< 2 seconds	1.5 seconds	Pass

Transmission Reliability	Command transmission	> 95% success rate	98% success rate	Pass
Concurrent Device Control	Simultaneous operations	Smooth and no conflicts	No conflicts	Pass
Database Performance	Data retrieval/storage	< 500 ms for queries	Avg. 400 ms	Pass
System Scalability	Increased load testing	Stable performance	Stable performance	Pass
Error Handling and Stability	Exceptional scenarios	Graceful error handling	Proper error handling and stability maintained	Pass

3.4 Comparison of the Existing System with the Proposed System

The proposed system incorporates several key improvements over the existing design to enhance the performance, capabilities, and user experience:

1. Upgraded Microcontroller: The ESP32 provides more memory, faster processing, integrated WiFi, and advanced features for more flexible and responsive control.
2. Lower Latency: WebSocket protocol reduces latency for more real-time control feedback.
3. Multi-User Support: WebSocket allows multiple simultaneous user connections to the system.
4. Expanded Remote Features: More advanced remote capabilities are supported due to the ESP32's increased resources.
5. Broad Device Compatibility: Improved IR learning and storage supports controlling a wider range of devices.
6. Enhanced UI/UX: Agile user-centered design results in a more intuitive, user-friendly interface.

By upgrading both the hardware and software elements, the proposed system aims to create a significantly more responsive, customizable, and full-featured virtual remote-control solution compared to existing designs. The improvements Pie chart ratio is illustrated in Figure 5 to show an increase efficiency and usability by 10%.

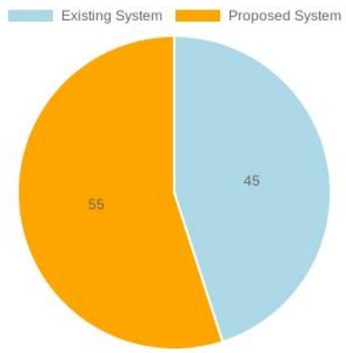

Figure 5: Pie chart of total matrices

This pie chart provides a simple visual comparison of the overall capabilities of the two systems. The proposed system is shown to have more overall capabilities based on its technological improvements.

Some of the key capabilities to be captured in this comparison include: multi-way communication, advanced remote-control features, higher bandwidth, lower latency and multi-user support.

5. CONCLUSION

The virtual remote control has demonstrated a practical, cost-effective and cheap solution for managing and controlling setup boxes. We have successfully also integrated IoTs, web-access control, button interaction integration, and ESP32-controller to create a comprehensive virtual remote control system. Its many benefits over traditional remotes includes better user experience, security, system efficiency, and user convenience. Overall, the Satellite IoT remote-control system contributes to the field of IoT and home automation by showcasing the integration of IoT technologies with device control, providing insights into user interface design, database management practices, security considerations, system integration, and testing methodologies. The Satellite IoT remote-control system demonstrates the potential of IoT technologies in transforming device control and enhancing the overall user experience.

Conflict of Interest

The authors declare that there is no conflict of interest.

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